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International Council for the Exploration of the Sea

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Above.
Ocean climate monitoring in the iceberg infested waters of Newfoundland and Labrador in July 2002, on board the Canadian Coast Guard ship "Teleost". Image courtesy of E. Colbourne, Fisheries and Oceans, Canada

Cover image.
RV "Polarstern" in Fram Strait. Image courtesy of A. Beszczynska-Möller, AWI, Germany.

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1. INTRODUCTION

The North Atlantic region is unusual in having a relatively large number of locations at which oceanographic data have repeatedly been collected for many years or decades; the longest records go back more than a century. In this report, we provide the very latest information from the ICES Area of the North Atlantic and Nordic Seas, where the ocean is currently measured regularly. We describe the status of sea temperature and salinity during 2007, as well as the observed trends over the last decade or longer. In the first part of the report, we draw together the information from the longest time-series in order to give the best possible overview of changes in the ICES Area. Throughout the report, additional complementary datasets are provided, such as sea level pressure (SLP), air temperature, and ice cover.

This is the tenth edition of the annual *ICES Report on Ocean Climate* (previously titled the *ICES Annual Ocean Climate Status Summary*), and we have continued to develop the contents. The main focus of the report is the observed variability in the upper ocean (the upper 1000 m), and the introductory section includes operational model output from the Coriolis Centre, France, which assimilates data from the ARGO float programme and satellites. We have expanded and slightly reorganized the section, describing changes in the deeper layers of the ocean. In this edition, we include, for the first time, a long time-series from the western English Channel, courtesy of Plymouth Marine Laboratory, UK. In addition to these new datasets, we continue to update the many time-series that have been diligently reported for many years to the ICES Working Group on Oceanic Hydrography.

The data presented here represent an accumulation of knowledge collected by many individuals and institutions through decades of observations. It would be impossible to list them all, but at the end of the report, we provide a list of contacts for each dataset, including e-mail addresses for the individuals who provided the information, and the data centres at which the full archives of data are held.

More detailed analysis of the datasets that form the time-series presented in this report can be found in the annual meeting reports of the ICES Working Group on Oceanic Hydrography at www.ices.dk/iceswork/wgdetail.asp?wg=WGOH.

1.1 Highlights for 2007

The upper layers of the North Atlantic and Nordic Seas remained exceptionally warm and saline in 2007, compared with the long-term average. The largest anomalies were observed at high latitudes.

The North Sea, Baltic Sea, and Bay of Biscay had an unusually warm winter and spring as a result of a combination of stored heat from the warm autumn in 2006 and high solar radiation in 2007.

The trend in the past decade (1996–2006) has been of warming and increasing salinity in the upper ocean. Temperature and salinity have been relatively stable since 2004.

1.2 The North Atlantic atmosphere in winter 2006/2007

The Iceland Low and Azores High were both stronger than normal, and the centre of the Iceland Low was displaced towards the southern Labrador Sea.

The mean mid-latitude westerly winds were stronger than normal.

Across the mid-North Atlantic, winter surface air temperatures were generally near normal. Farther north and away from the inflow to the Nordic Seas, surface air temperature was generally more than 1°C warmer than normal.

NORTH ATLANTIC UPPER OCEAN TEMPERATURE OVERVIEW

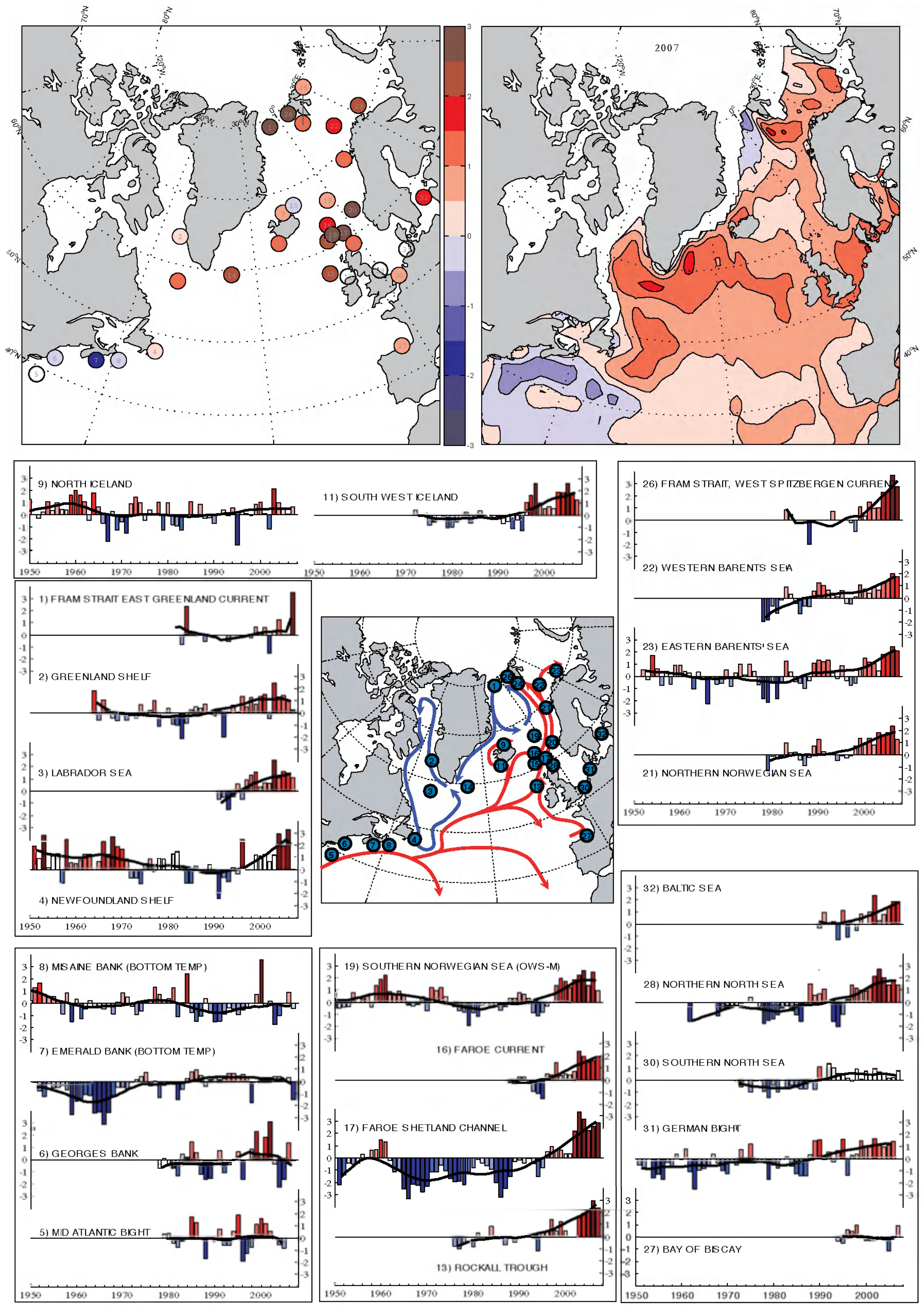


Figure 1.
Upper ocean temperature anomalies at selected locations across the North Atlantic. The anomalies are normalized with respect to the standard deviation (e.g. a value of +2 indicates 2 standard deviations above normal). The upper maps show conditions in 2007; data on the left are from in situ *observations; 2007 anomalies on the right are calculated from OISSTv2 data (see Figure 3); the lower panels show time-series of normalized anomalies at each of the selected stations (colour intervals 0.5; reds are positive/warm, and blues are negative/cool). See Figure 9 for a map showing more detail about the locations in this figure.*

NORTH ATLANTIC UPPER OCEAN SALINITY OVERVIEW

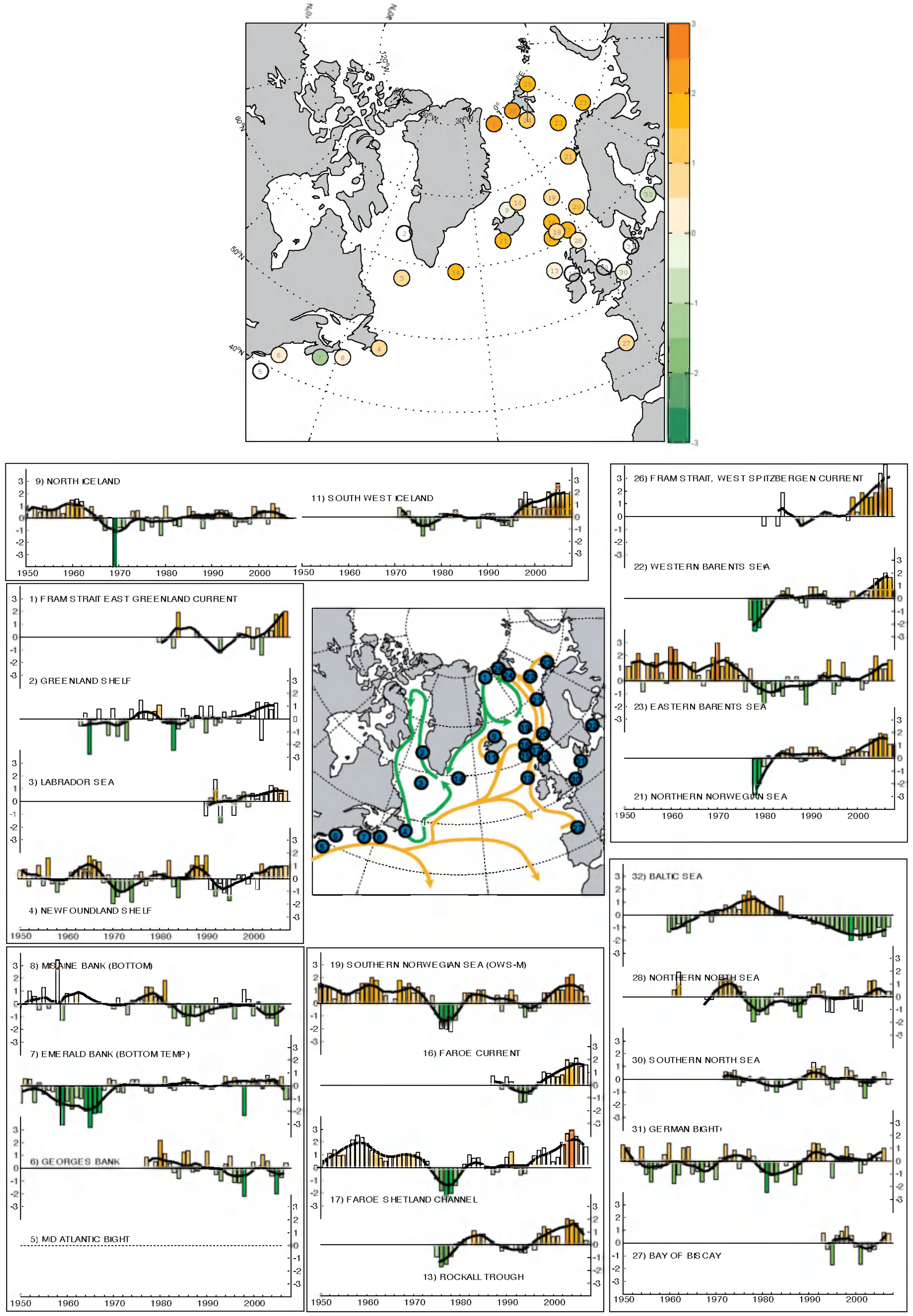


Figure 2.
Upper ocean salinity anomalies at selected locations across the North Atlantic. The anomalies are calculated relative to a long-term mean and normalized with respect to the standard deviation (e.g. a value of +2 indicates 2 standard deviations above normal). The map (upper panel) shows conditions in 2007; the lower panels show time-series of normalized anomalies at each of the selected stations (colour intervals of 0.5; orange are positive/saline, green are negative/fresh). See Figure 9 for a map showing more detail about the locations in this figure.

2. SUMMARY OF UPPER OCEAN CONDITIONS IN 2007

In this section, we summarize the conditions in the upper layers of the North Atlantic during 2007, using data from a selected set of sustained observations and additional data products (gridded sea surface temperature (SST) data and summaries from ARGO floats).

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

Sea surface temperatures across the entire North Atlantic have also been obtained from a combined satellite and *in situ* gridded dataset. Figure 3 shows the annual and seasonal SST anomaly for 2007, extracted from the Optimum Interpolation SSTv2 dataset provided by the NOAA-CIRES Climate Diagnostics Center in the US. 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 the averaging period are left blank.

Maps of temperature, salinity, and winter mixed-layer depth in the North Atlantic have been prepared using *in situ* data including the newly expanding dataset from the ARGO float programme. The upper layer temperature anomalies for 2007 compare well with those obtained using OISSTv2 data (Figure 1). These maps (Figures 4 and 5) offer a more detailed overview of conditions than can be obtained from satellite observations and provide the spatial context to compare with the *in situ* time-series.

THE UPPER LAYERS OF THE NORTH ATLANTIC AND NORDIC SEAS WERE WARMER AND MORE SALINE THAN THE LONG-TERM AVERAGE.

"SUSTAINED OBSERVATIONS" OR "TIME-SERIES" ARE REGULAR MEASUREMENTS OF OCEAN TEMPERATURE AND SALINITY MADE OVER A LONG PERIOD (10–100 YEARS). MOST MEASUREMENTS ARE MADE 1–4 TIMES A YEAR, BUT SOME ARE TAKEN MORE FREQUENTLY.

"ANOMALIES" ARE THE MATHEMATICAL DIFFERENCE BETWEEN EACH INDIVIDUAL MEASUREMENT AND THE AVERAGE VALUES OF TEMPERATURE, SALINITY, OR OTHER VARIABLES AT THAT LOCATION. POSITIVE ANOMALIES MEAN WARM OR SALINE CONDITIONS; NEGATIVE ANOMALIES MEAN COOL OR FRESH CONDITIONS.

THE "SEASONAL CYCLE" DESCRIBES THE SHORT-TERM CHANGES AT THE SURFACE OF THE OCEAN BROUGHT ABOUT BY THE PASSING OF THE SEASONS; THE OCEAN SURFACE IS COLD IN WINTER AND WARMS THROUGH SPRING AND SUMMER. THE TEMPERATURE AND SALINITY CHANGES CAUSED BY THE SEASONAL CYCLE ARE USUALLY MUCH LARGER THAN THE PROLONGED YEAR-TO-YEAR CHANGES WE DESCRIBE HERE.

Below.
Frozen lights on the RV "Polarstern" in Fram Strait. Image courtesy of A. Beszczynska-Möller, AWI, Germany.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1 (12)	-0.25	0.68	0.06	0.60	-1.52	0.32	1.22	0.04	0.04	3.50
2 (1)	1.27	0.75	1.34	1.56	-0.51	2.46	1.30	1.41	1.09	0.27
3 (2b)	1.35	1.55	0.33	0.67	0.64	2.56	1.09	1.60	1.51	1.10
4 (2)	-0.04	1.18	1.15	1.25	0.68	1.18	2.94	1.97	3.26	0.01
5 (2c)	-0.80	1.14	1.59	1.20	0.54	-0.13	-0.56	-0.83		
6 (2c)	0.86	2.29	0.47	1.84	3.11	-0.32	-2.24	-1.59	1.36	-0.11
7 (2)	-1.79	-0.22	0.22	0.11	0.09	0.37	0.36	0.11	0.30	-1.53
8 (2)	-0.03	0.75	3.55	-0.31	0.14	-1.77	-1.01	-0.02	0.88	-0.41
9 (3)	-0.11	0.84	1.02	0.07	-1.19	2.11	0.94	0.44	0.05	0.61
10 (3)	-0.34	0.08	-0.44	-0.49	-1.04	1.54	0.39	-0.16	0.14	-0.44
11 (3)	2.57	0.95	0.53	0.70	0.49	1.89	1.84	2.58	1.68	1.26
12 (4b)	1.60	1.38	1.38	0.50	1.38	1.82	2.69	2.48	2.26	
13 (5)	0.47	1.23	0.50	0.09		1.58	1.94	2.18	2.95	2.35
14 (5b)		1.37	0.26	1.24	1.04	1.11	2.72	1.58	1.22	2.01
15 (6)	1.24	-0.07	0.34	0.86	0.89	2.75	2.43	1.53	2.58	2.34
16 (6)	1.42	0.41	0.49	0.45	0.74	2.37	1.96	1.50	1.59	1.92
17 (7)	0.64	0.66	0.32	0.32	2.17	3.72	3.16	2.27	2.59	2.85
18 (7)	0.71	1.07	1.17	1.83	2.72	3.12	2.72	2.45	2.92	2.56
19 (10)	1.39	1.97	1.69	1.18	1.85	2.21	2.57	1.39	2.45	0.97
20 (10)	1.42	0.21	1.81	1.52	3.41	2.95	1.70	1.35	2.59	3.59
21 (10)	0.72	1.39	0.87	1.37	0.77	1.82	1.67	1.82	2.34	1.27
22 (11)	0.08	1.09	0.70	0.39	0.89	0.69	1.32	1.44	1.99	1.78
23 (11)	-0.57	0.64	1.47	1.16	1.03	0.48	1.79	1.86	2.39	2.10
24 (12)	-1.01	-0.21	0.12	0.13	-0.08	-0.68	0.50	1.10	2.13	1.04
25 (10)	-0.10	0.37	0.03	0.58	0.15		0.81	1.54	1.73	0.95
26 (12)	-0.93	1.07	0.34	1.45	0.95	1.03	2.29	2.33	3.71	2.74
27 (4)	1.00	0.10	-0.26	-0.27	-0.29	0.13	-0.20	-1.13	-0.17	0.92
28 (8&9)	1.15	0.95	0.89	1.16	2.11	2.71	2.02	1.43	1.80	1.41
29 (8&9)	0.19	0.74	0.60	0.49	0.69	0.84	0.68	0.17		
30 (8&9)	0.90	0.10	0.74	0.54	0.95	0.70	0.34	0.17	0.20	0.78
31 (8&9)	0.40	1.47	0.97	0.95	1.66	1.17	0.95	1.15	1.43	
32 (9b)	-0.55	0.83		0.99	2.34	0.24	0.80	1.44	1.83	1.83

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1 (12)	-0.04	0.78	-0.94	0.69	-1.40	0.42	0.51	1.78	1.69	2.01
2 (1)	0.27	0.30	0.24	1.33	-1.69	1.30	0.75	1.24		
3 (2b)	0.72	-0.41	0.61	0.17	0.63	0.54	1.20	1.02	0.60	0.80
4 (2)	0.33	-0.45	0.41	-0.87	1.15	0.54	0.95	0.99	0.91	0.99
5 (2c)										
6 (2c)	-2.26	-0.03	0.44	-0.11	1.01	0.50	-0.67	-2.02	-0.76	0.37
7 (2)	-2.34	0.37	0.53	0.25	-0.22	0.84	0.30	0.43	0.69	-1.11
8 (2)	1.15	0.36	-0.97	0.12	-0.70	-1.15	-1.16	-1.73	-0.29	0.02
9 (3)	-0.48	0.95	0.56	0.61	-0.48	1.14	0.81	0.02	-0.09	-0.09
10 (3)	-1.33	0.19	0.59	0.34	-0.12	0.29	0.35	0.18	0.70	0.69
11 (3)	1.98	1.44	0.79	0.66	0.78	2.03	1.89	2.77	1.89	1.89
12 (4b)										
13 (5)	1.41	1.25	0.66	0.67		2.07	1.93	1.69	1.27	0.32
14 (5b)		1.53	0.10	0.70	1.37	0.54	2.45	1.84	1.53	1.72
15 (6)	1.10	0.61	0.70	0.54	0.57	2.16	2.37	1.92	1.41	1.62
16 (6)	1.07	0.93	0.67	0.63	0.83	2.02	1.73	2.15	1.46	1.58
17 (7)	1.54	1.05	0.42	0.77	1.95	2.66	2.92	2.42	1.85	1.60
18 (7)	0.65	1.08	1.11	1.34	1.71	2.05	2.08	1.99	1.65	0.91
19 (10)	0.81	0.81	0.81	1.05	1.05	2.01	2.25	1.05	1.42	0.55
20 (10)	0.85	0.34	0.89	0.49	1.27	1.49	1.47	1.27	1.22	1.42
21 (10)	0.65	0.85	0.51	0.56	0.49	1.48	1.52	1.95	1.88	1.12
22 (11)	-0.10	0.56	0.16	0.06	0.34	0.72	1.55	1.51	2.00	1.64
23 (11)	0.28	-0.05	0.12	-0.72	-0.22	0.95	1.95	0.95	0.95	1.62
24 (12)	-1.02	-0.74	-0.32	0.13	0.17	-0.18	0.50	1.41	1.89	1.42
25 (10)	-0.55	0.20	-0.11	0.57	0.29		0.94	1.76	2.00	1.63
26 (12)	-0.38	1.51	0.38	1.89	1.51	1.51	1.89	3.40	4.15	2.23
27 (4)	1.26	0.58	-0.34	-1.68	-0.19	-0.70	-0.50	-0.02	0.82	0.73
28 (8&9)	0.78	0.22	-0.94	-1.09	0.05	1.24	1.27	0.66	0.03	0.40
29 (8&9)										
30 (8&9)	0.86	0.63	0.28	-0.59	-1.52	-0.56	0.16	0.12	0.53	-0.41
31 (8&9)	1.13	0.55	0.04	-0.95	-0.27	0.60	0.44	0.27	1.01	
32 (9b)	-1.44	-2.02	-1.11	-1.98	-1.48	-1.77	-1.40	-0.99	-1.69	-0.94

Tables 1 and 2.
Changes in temperature (Table 1, top) and salinity (Table 2, bottom) at selected stations in the North Atlantic region during the past decade. The index numbers on the left can be used to cross-reference each point with information in Figures 1 and 2 and Table 3. The numbers in brackets refer to detailed area descriptions later in the report. 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 are available for regions 5, 12, and 29.

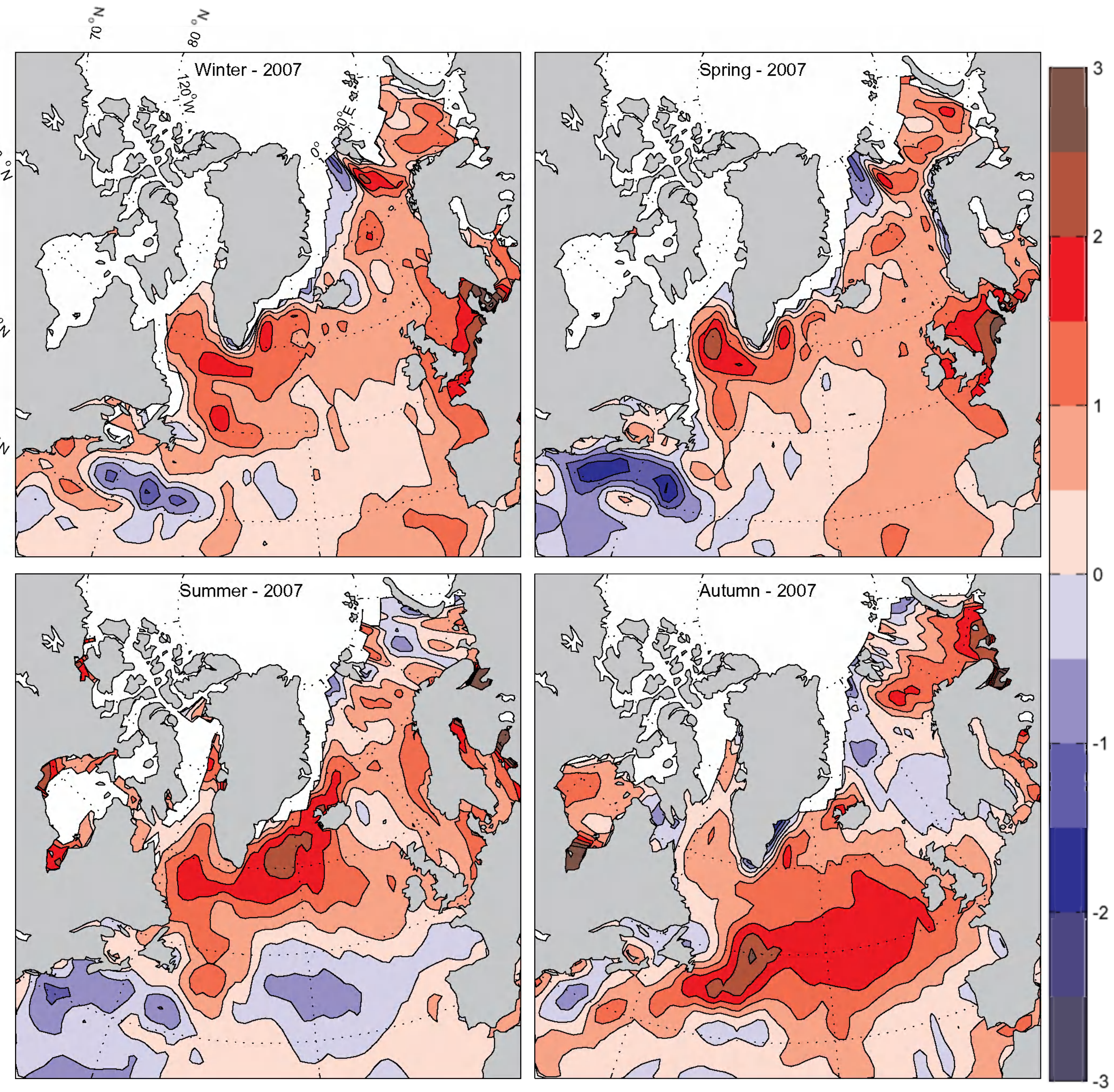


Figure 3.
Maps of seasonal sea surface temperature anomalies (°C) over the North Atlantic for 2007 from the NOAA Optimum Interpolation SSTv2 dataset provided by the NOAA-CIRES Climate Diagnostics Center, US. The colour-coded temperature scale is the same in all panels. The anomaly is calculated with respect to normal conditions for 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 the averaging period are left blank.

Table 3. *Details of the datasets included in Figures 1 and 2, and Tables 1 and 2. Blank boxes indicate areas for which information was unavailable at the time of publication.*

Index	Description	Area	Measurement depth	Long-term average	Lat	Lon	Mean *T*	Stdev *T*	Mean *S*	Stdev *S*
1	Fram Strait – East Greenland Current Section Average 3°W to shelf edge	12	50–500 m	1980–2000	78.83	-8.00	0.58	0.39	34.67	0.11
2	Station 4 – Fylla Section – Greenland Shelf	1	0–200 m	1971–2000	63.88	-53.37	2.86	1.03	33.56	0.33
3	Section AR7W – Central Labrador Sea	2b	0–150 m	1990–2000	57.73	-51.07	3.49	0.42	34.68	0.08
4	Station 27 – Newfoundland Shelf Temperature – Canada	2	0–175 m	1971–2000	47.55	-52.59	0.27	0.33	31.63	0.24
5	Oleander Section (120–400 km) – Mid-Atlantic Bight USA	2c	Surface	1978–2000	39.00	-71.50		0.86		
6	Georges Bank – Mid-Atlantic Bight USA	2c	0–30 m	1977–2000	42.00	-70.00	9.78	0.42	32.65	0.23
7	Emerald Bank – Central Scotian Shelf – Canada	2	Near Bottom	1971–2000	44.00	-63.00		1.20		0.23
8	Misaine Bank – Northeast Scotian Shelf– Canada	2	Near Bottom	1971–2000	45.00	-59.00		0.65		0.16
9	Siglunes Station 2–4 – North Iceland – Irminger Current	3	50–150 m	1971–2000	67.00	-18.00	3.34	1.09	34.82	0.19
10	Longanes Station 2–6 – Northeast Iceland – East Icelandic Current	3	0–50 m	1971–2000	67.50	-13.50	1.24	0.95	34.70	0.14
11	Selvogsbanki Station 5 – Southwest Iceland – Irminger Current	3	0–200 m	1971–2000	63.00	-22.00	7.58	047	35.15	0.05
12	Malin Head Weather Station	4b	Surface	1971–2000	55.37	-7.34	10.57	0.46		
13	Ellett Line – Rockall Trough – UK (section average)	5	0–800 m	1975–2000	56.75	-11.00	9.21	0.32	35.33	0.03
14	Central Irminger Sea – Subpolar Mode Water	5b	200–400 m	1991–2005	59.40	-36.80	3.99	0.55	34.88	0.03
15	Faroe Bank Channel – South Faroe Islands	6	Upper layer high salinity core	1988–2000	61.00	-8.00	8.23	0.32	35.24	0.04
16	Faroe Current – North Faroe Islands (Modified North Atlantic Water)	6	Upper layer high salinity core	1988–2000	63.00	-6.00	7.92	0.37	35.22	0.04
17	Faroe Shetland Channel – Shetland Shelf (North Atlantic Water)	7	Upper layer high salinity core	1971–2000	61.00	-3.00	9.57	0.15	35.36	0.03
18	Faroe Shetland Channel – Faroe Shelf (Modified North Atlantic Water)	7	Upper layer high salinity core	1971–2000	61.50	-6.00	7.87	0.22	35.22	0.04
19	Ocean Weather Station "Mike" – 50 m	10	50 m	1971–2000	66.00	-2.00	7.41	0.33	35.15	0.04
20	Southern Norwegian Sea – Svinøy Section – Atlantic Water	10	50–200 m	1978–2000	63.00	3.00	7.84	0.28	35.22	0.05
21	Central Norwegian Sea – Gimsøy Section – Atlantic Water	10	50–200 m	1978–2000	69.00	12.00	6.67	0.40	35.14	0.04
22	Fugløya–Bear Island Section – Western Barents Sea – Atlantic Inflow	11	50–200 m	1977–2006	73.00	20.00	5.35	0.52	35.06	0.04
23	Kola Section – Eastern Barents Sea	11	0–200 m	1971–2000	71.50	33.30	3.92	0.49	34.76	0.06
24	Greenland Sea Section – West of Spitsbergen 76.5°N	12	200 m	1996–2006	76.50	10.50	3.08	0.66	35.05	0.04
25	Northern Norwegian Sea – Sørkapp Section – Atlantic Water	10	50–200 m	1977–2000	76.33	10.00	3.80	0.71	35.05	0.05
26	Fram Strait – West Spitsbergen Current – Section average 5°E to shelf edge	12	50–500 m	1980–2000	78.83	8.00	2.60	0.58	34.99	0.03
27	Santander Station 6 (shelf break) – Bay of Biscay – Spain	4	5–200 m	1993–2000	43.70	-3.78	13.13	0.41	35.59	0.08
28	Fair Isle Current Water (waters entering North Sea from Atlantic)	8 & 9	0–100 m	1971–2000	59.00	-2.00	9.67	0.34	34.88	0.08
29	UK Coastal Waters – Southern Bight – North Sea	8 & 9	Surface	1971–2000	54.00	0.00				
30	Section average – Felixstowe – Rotterdam – 52°N	8 & 9	Surface	1971–2000	52.00	3.00	12.14	1.12	34.64	0.21
31	Helgoland Roads – Coastal Waters – German Bight North Sea	8 & 9	Surface	1971–2000	54.19	7.90	10.10	0.72	32.11	0.54
32	Baltic Proper – East of Gotland – Baltic Sea	9b	Surface	1971–2000 (S) 1990–2000 (T)	57.50	19.50	8.57	1.05	7.35	0.24

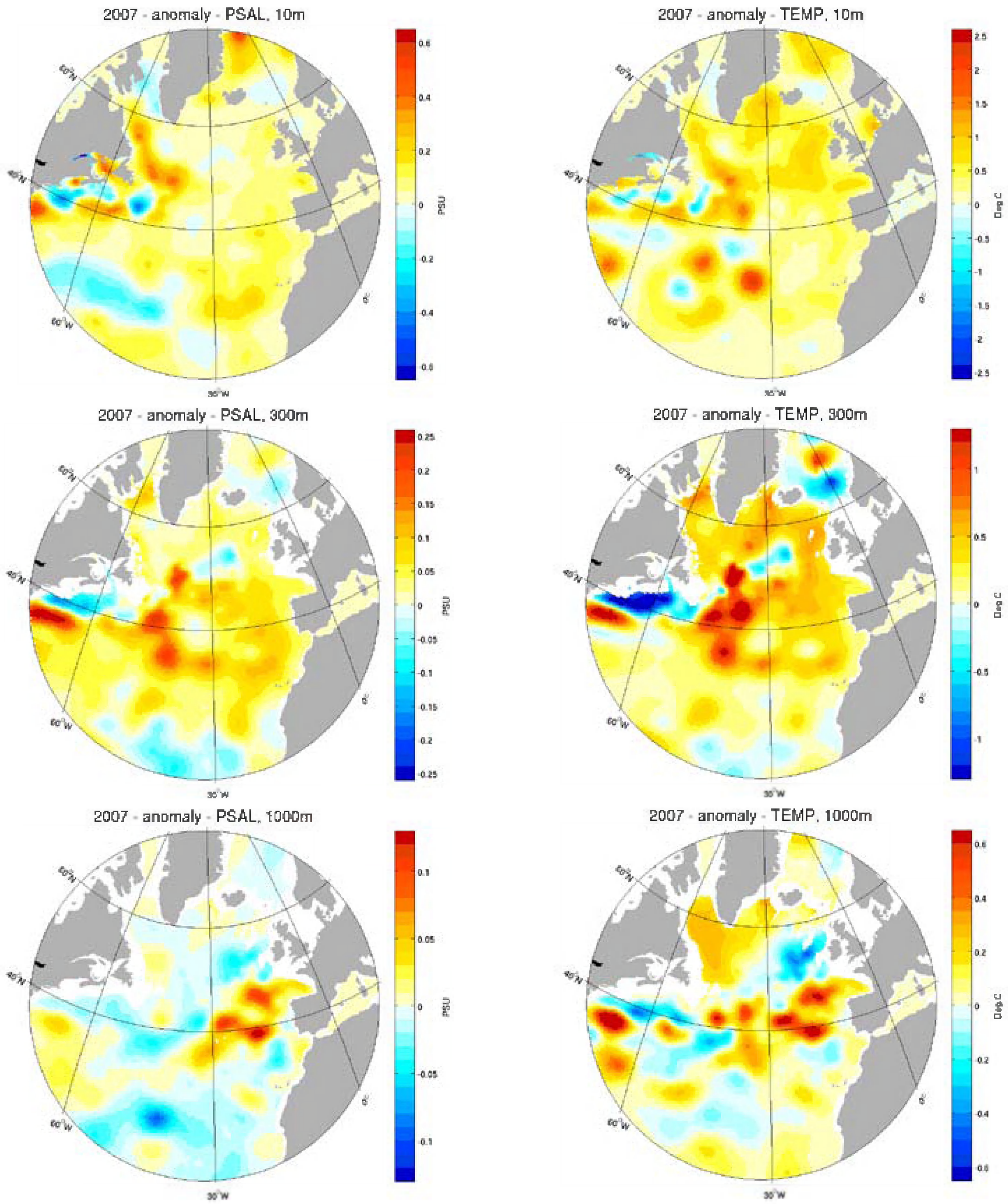


Figure 4.
Maps of North Atlantic salinity (left column) and temperature (right column) at 10 m, 300 m, and 1000 m. Anomalies are differences between 2007 data and climatology. These products are generated by the Coriolis Operational Oceanography Centre, which compiles in situ *(including Argo float temperature and salinity profiles) and satellite data into an ocean circulation model. Maps provided by Fabienne Gaillard, www.coriolis.eu.org/default.htm.*

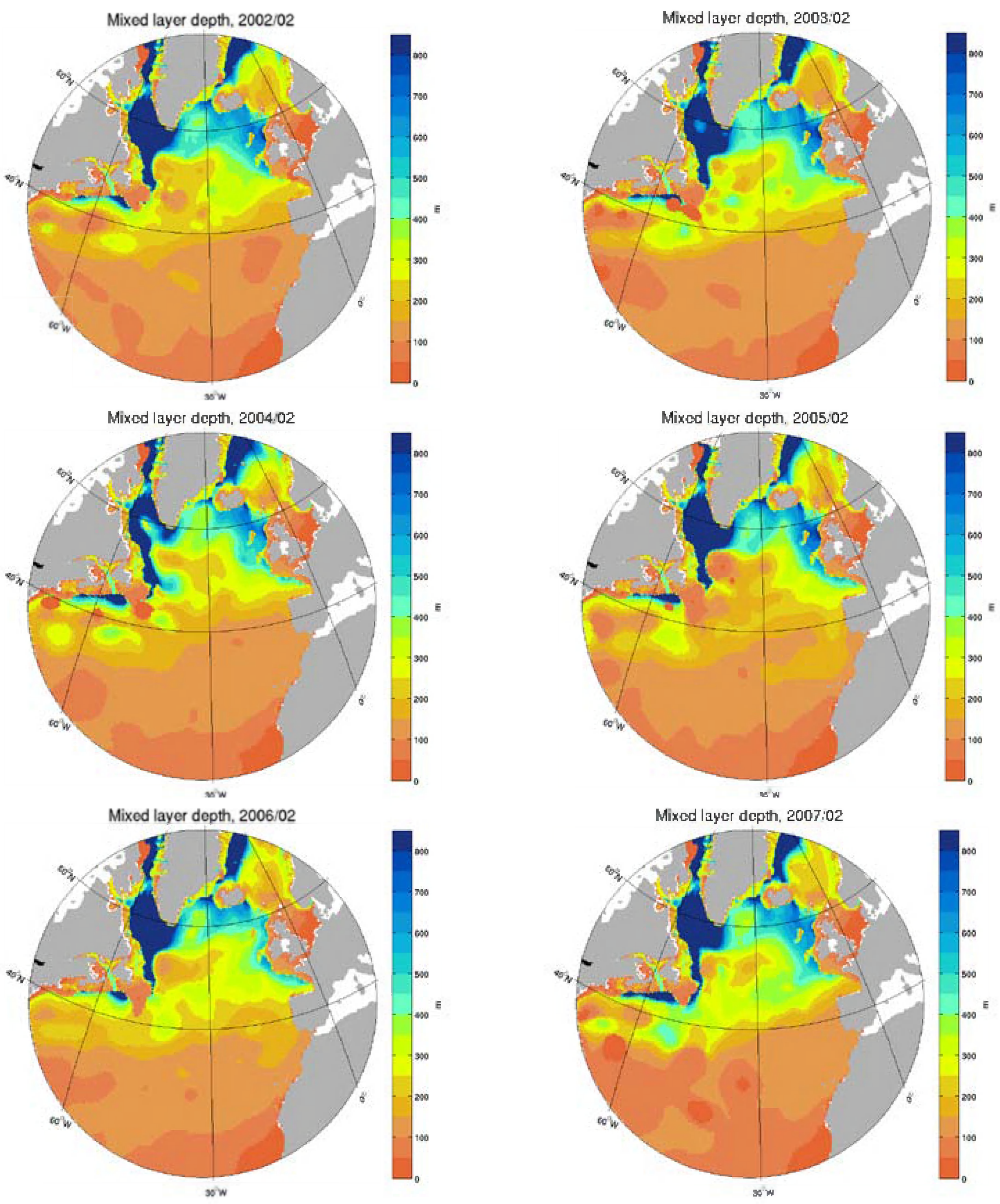


Figure 5.
Maps of North Atlantic winter (February) mixed-layer depths, 2002–2007. These products are generated by the Coriolis Operational Oceanography Centre, which compiles in situ *data (including Argo float temperature and salinity profiles) and satellite data into an ocean circulation model. Maps provided by Fabienne Gaillard, www.coriolis.eu.org/default.htm.*

3. THE NORTH ATLANTIC ATMOSPHERE

3.1 North Atlantic Oscillation

The North Atlantic Oscillation (NAO) is a pattern of atmospheric variability that has a significant impact on oceanic conditions. It affects windspeed, precipitation, evaporation, and the exchange of heat between ocean and atmosphere, and its effects are most strongly felt in winter. The NAO index is a simple device used to describe the state of the NAO. It is a measure of the strength of the sea level air pressure gradient between Iceland and the Azores. When the NAO index is positive, there is a strengthening of the Icelandic low-pressure system and the Azores high-pressure system. This produces stronger mid-latitude westerly winds, with colder and drier conditions over the western North Atlantic and warmer and wetter conditions in the eastern North Atlantic. When the NAO index is negative, there is a reduced pressure gradient, and the effects tend to be reversed.

There are several slightly different versions of the NAO index calculated by climate scientists. The Hurrell winter (DJF) NAO index is most commonly used and has particular relevance to the eastern North Atlantic. 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 then, the Hurrell NAO index has been fairly weak and a less-useful descriptor of atmospheric conditions. In winter 2007, the NAO index was strongly positive.

THE OCEAN CAN RESPOND QUICKLY TO THE STATE OF THE NAO, PARTICULARLY IN WINTER WHEN ATMOSPHERIC CONDITIONS AFFECT THE OCEAN SO INTENSELY THAT THE EFFECTS ARE FELT THROUGHOUT THE FOLLOWING YEAR. SOME REGIONS, SUCH AS THE NORTHWEST ATLANTIC AND THE NORTH SEA, ARE MORE RESPONSIVE TO THE NAO THAN OTHER REGIONS, SUCH AS THE ROCKALL TROUGH. HOWEVER, THE NAO IS NOT THE ONLY, OR EVEN THE MAIN, CONTROL ON OCEAN VARIABILITY. OVER THE ATLANTIC AS A WHOLE, THE NAO STILL ONLY ACCOUNTS FOR ONE-THIRD OF THE TOTAL VARIANCE IN WINTER SEA LEVEL PRESSURE. THE CHAOTIC NATURE OF ATMOSPHERIC CIRCULATION MEANS THAT EVEN DURING PERIODS OF STRONGLY POSITIVE OR NEGATIVE NAO WINTERS, THE ATMOSPHERIC CIRCULATION TYPICALLY EXHIBITS SIGNIFICANT LOCAL DEPARTURES FROM THE IDEALIZED NAO PATTERN.

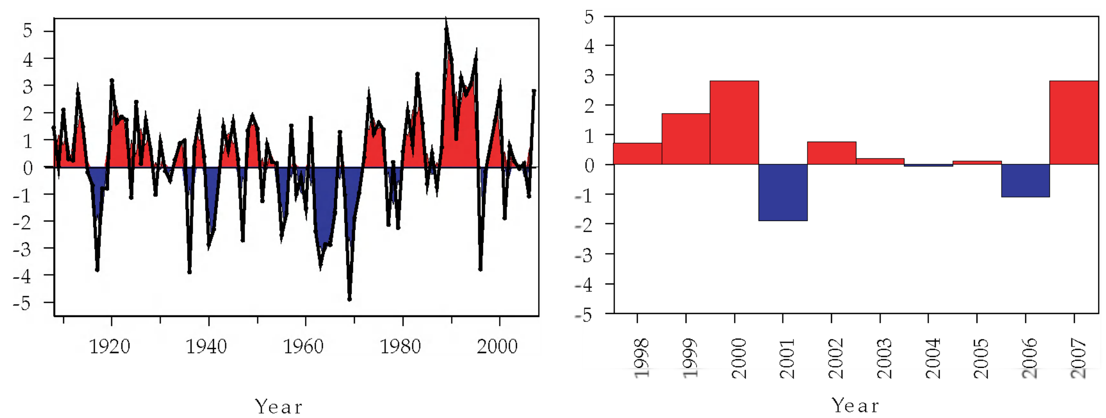


Figure 6.
The Hurrell winter (DJF) NAO index for the past 100 years with a two-year running mean applied (left panel) and the current decade (right panel). Data source: http://www.cgd.ucar.edu/cas/jhurrell/indices.html.

The NAO index is an indicator of the gradient of SLP, but maps can provide more information about the windfield. Winter conditions dominate the ocean properties in particular; therefore, Figure 7a shows maps of SLP in winter (December/ January/February/March (DJFM)). The top panel in Figure 7a shows the winter SLP averaged over 30 years, 1971–2000. The dominant features ("action centres") are the Iceland Low (the purple patch situated southwest of Iceland) and the Azores High (the orange patch west of Gibraltar).

NORTH ATLANTIC MEAN WINDS WERE MOSTLY STRONGER THAN NORMAL.

The middle panel in Figure 7a shows the mean SLP for winter 2007 (December 2006, January–March 2007), and the bottom panel shows the 2007 winter SLP anomaly – the difference between the top and middle panels. In winter 2007, both the Iceland Low and the Azores High were stronger than normal (lower pressure in the Iceland Low and higher pressure in the Azores High). Also, the centre of the Iceland Low was displaced towards the southwest and Cape Farewell. The strength of the mean surface wind averaged over the 30-year period 1971–2000 is shown in the upper panel of Figure 7b, and the lower panel shows the anomaly in winter 2007. These reanalyses show that the North Atlantic mean winds were stronger than normal, associated with the strengthening of the SLP pattern, centred on a band from Newfoundland across to the Bay of Biscay and the English Channel and into the southern Baltic.

THE FIGURES SHOW CONTOURS OF CONSTANT SEA LEVEL PRESSURE (ISOBARS). THE GEOSTROPHIC (OR "GRADIENT") WIND BLOWS PARALLEL WITH THE ISOBARS, WITH LOWER PRESSURE TO THE LEFT. THE CLOSER THE ISOBARS, THE STRONGER THE WIND.

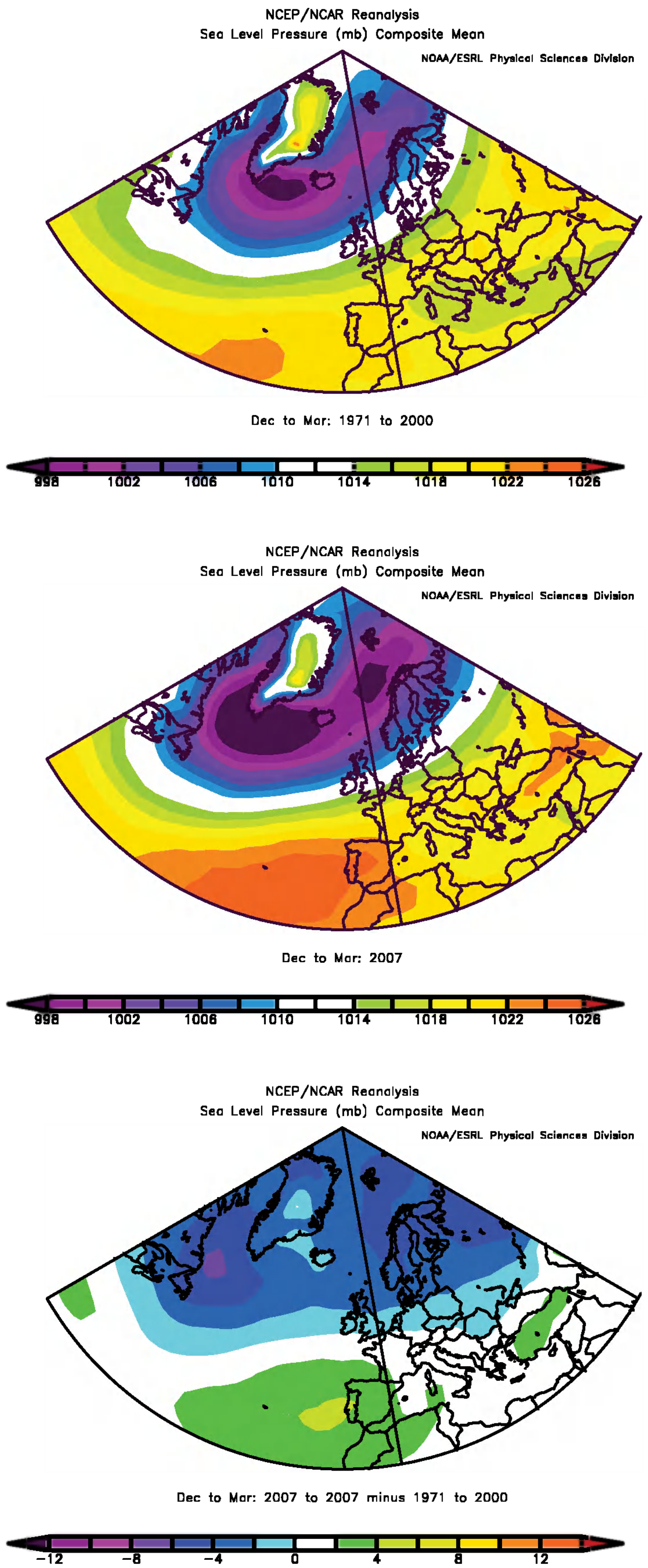


Figure 7a.
Winter (DJFM) sea level pressure (SLP) fields. The top panel shows SLP averaged over 30 years, 1971–2000. Middle panel shows mean SLP in winter 2007 (December 2006, January–March 2007). Bottom panel shows the winter 2007 SLP anomaly, the difference between the top and middle panels. Images provided by the NOAA/ESRL Physical Sciences Division, Boulder, Colorado, available at www.cdc.noaa.gov/.

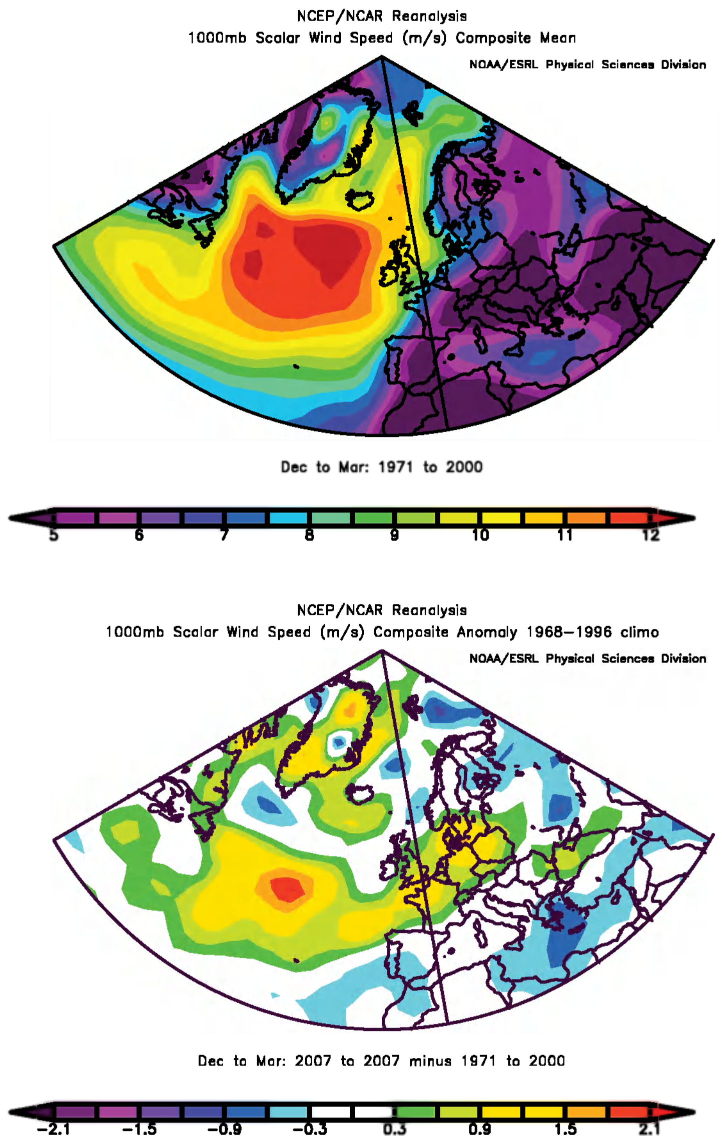


Figure 7b.
Winter (DJFM) surface windspeed. Top panel shows surface windspeed averaged over 30 years, 1971–2000. The bottom panel shows the winter 2007 anomaly in surface windspeed. Images provided by the NOAA/ESRL Physical Sciences Division, Boulder, Colorado, available at www.cdc.noaa.gov/.

Below.
View from the RV "Celtic Explorer".
Image courtesy of G. Nolan, Marine Institute, Ireland.

3.2 North Atlantic surface air temperature

North Atlantic winter mean surface air temperatures are shown in Figure 8. The 1971–2000 mean conditions (Figure 8, top panel) show warm temperatures penetrating far to the north on the east side of the North Atlantic and Nordic Seas, caused by northward movement of warm oceanic water. The middle panel in Figure 8 shows the conditions in winter (DJFM) 2007, and the bottom panel shows the difference between the two. In winter 2007, the central North Atlantic and Norwegian Sea surface air temperatures were near normal. In contrast, surface air temperatures over much of the Labrador Sea, North Sea, Barents Sea, Greenland Sea, and Irminger Basin were more than 1°C warmer than normal in 2007. The exceptions are the orange/red areas, which show warmer-than-normal conditions (by 6–10°C); this is the result of sea-ice edges retreating in the northern Labrador Sea and northeast of Svalbard. The bottom panel in Figure 8 also shows that it was a warm winter over most land areas surrounding the northern North Atlantic and its marginal seas.

SURFACE AIR TEMPERATURE OVER MUCH OF THE NORDIC SEAS AND WESTERN NORTH ATLANTIC WAS MORE THAN 1°C WARMER THAN NORMAL.

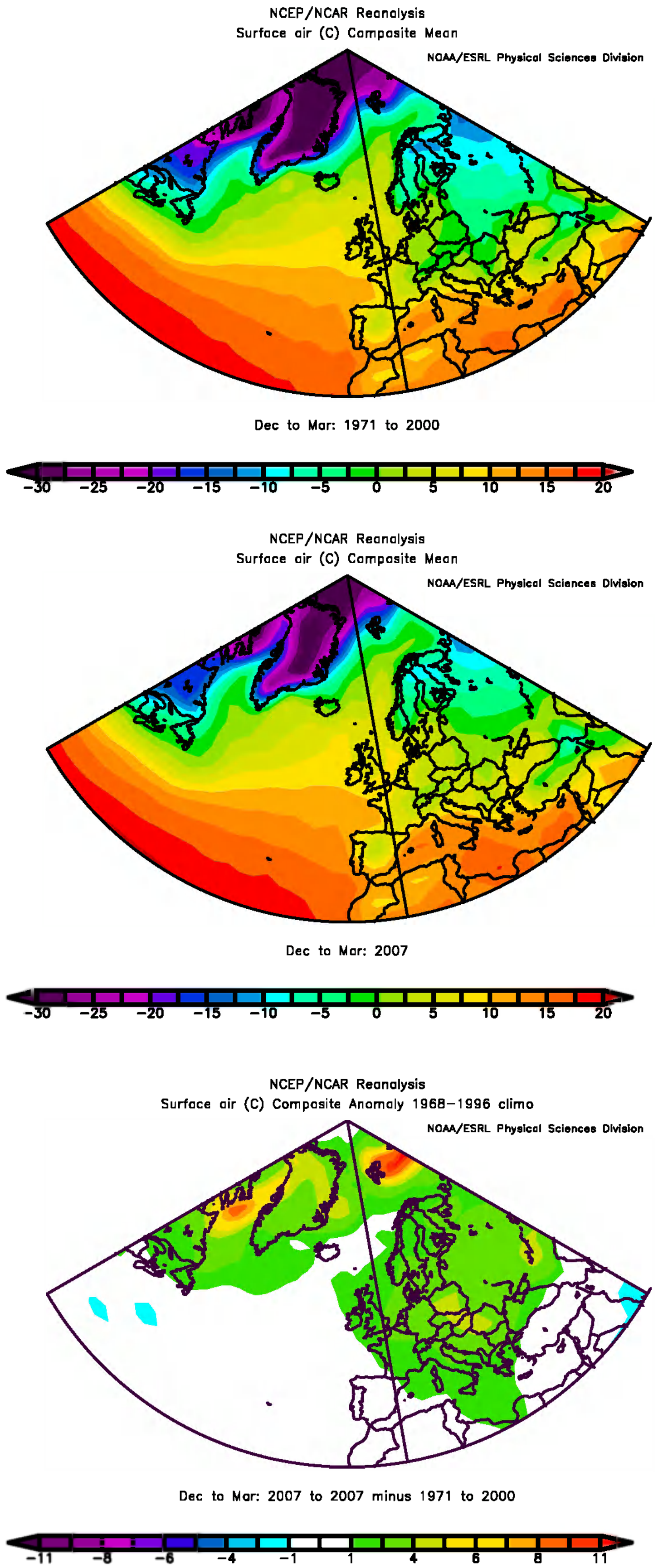


Figure 8.
Winter (DJFM) surface air temperature fields. The top panel shows surface air temperature averaged over 30 years, 1971–2000. The middle panel shows temperatures in winter 2007 (December 2006, January to March 2007). The bottom panel shows winter 2007 surface air temperature anomaly, 1971–2000, the difference between the top and middle panels. Images provided by the NOAA/ESRL Physical Sciences Division, Boulder, Colorado, available at www.cdc.noaa.gov/.

4. DETAILED AREA DESCRIPTIONS, PART 1: THE UPPER OCEAN

4.1 Introduction

In this section, we present time-series from many sustained observations in each area of the ICES Area. The general pattern of oceanic circulation in the upper layers of the North Atlantic, in relation to the areas described here, is given in Figure 9. In addition to temperature and salinity, we present other indices where they are available, such as air-temperature and sea-ice indices. The text summarizes the regional context of the sections and stations, noting any significant recent events.

Most standard sections or stations are repeated annually or more frequently. Often, the time-series presented here have been extracted from larger datasets and chosen as indicators of the conditions in a particular area. Where appropriate, data are presented as anomalies to demonstrate how the values compare with the average or "normal" conditions (usually the long-term mean of each parameter during 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.

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

In some areas, data are sampled regularly enough to allow a good description of the seasonal cycle. Where this is possible, monthly data from 2007 are presented and compared with the average seasonal conditions and statistics.

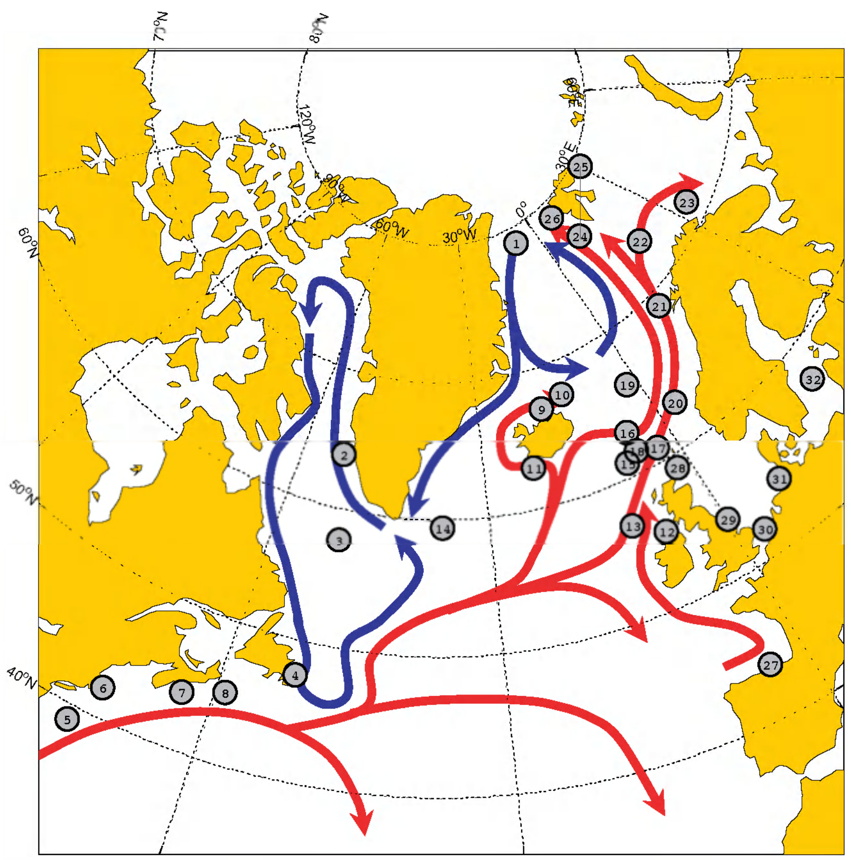


Figure 9.
Schematic of the general circulation of the upper ocean (0–1000 m) in the North Atlantic in relation to the numbered areas presented below. The blue arrows indicate the movement of the cooler waters of the Subpolar Gyre. The red arrows indicate the movement of the warmer waters of the Subtropical Gyre.

4.2 Area 1 – West Greenland

West Greenland lies at the northern boundary of the subpolar gyre and is thus subject to climatic variations within this gyre. The West Greenland Current follows the continental slope off West Greenland and travels northwards through Davis Strait. The Fyllas Bank Station 4, located on the bank slope in about 900 m of water, is governed mostly by the warm component of the West Greenland Current (below 150 m). In some years, shallow shelf water extends farther offshore, bringing colder water to Station 4 (e.g. 1983, 1992, and 2002). Located farther offshore, Cape Desolation Station 3 has a 3000-m-deep water column and samples the West Greenland Current and the deep boundary current of the Labrador Sea.

West Greenland lies within an area that normally experiences warmer conditions when the NAO index is negative. Despite a positive NAO winter 2007 index, air temperature conditions around Greenland continued to be warmer than normal; mean air temperatures at Nuuk show positive anomalies (+0.8°C).

At Fyllas Bank, the 2007 subsurface temperatures were high, similar to the warm 1960s, but lower than autumn 2003, when temperatures were 2.69°C above normal.

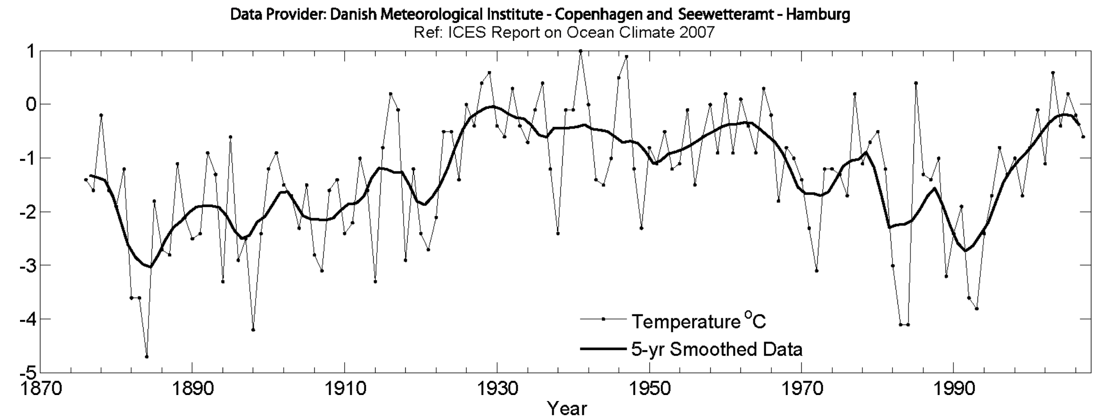


Figure 10.
Area 1 – West Greenland. Annual mean air temperature observed at Nuuk.

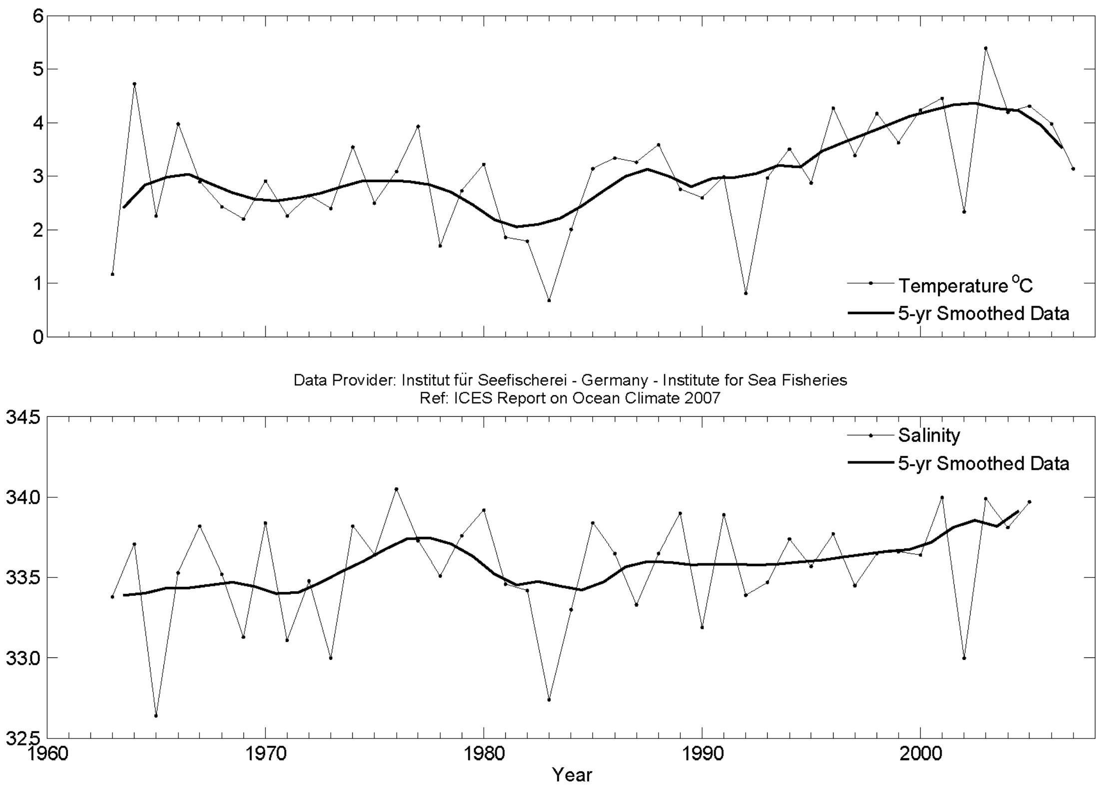


Figure 11.
Area 1 – West Greenland. Fyllas Bank Station 4 autumn temperature (upper panel) and salinity (lower panel), 0–200 m.

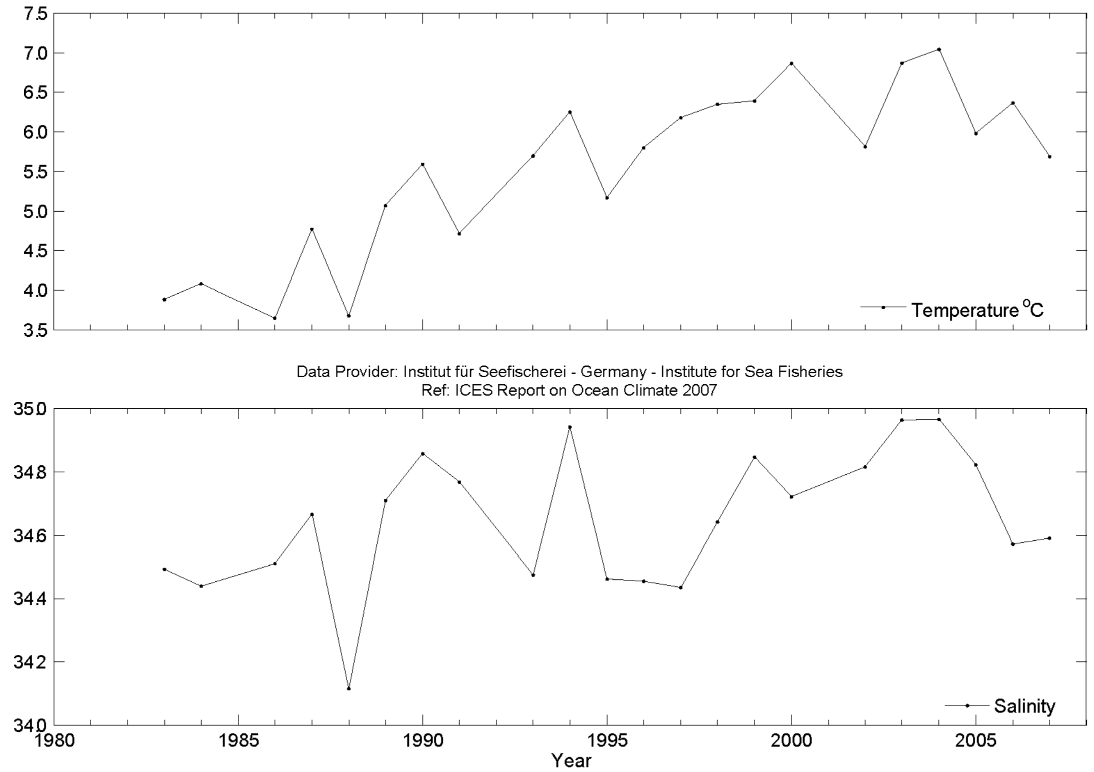


Figure 12.
Area 1 – West Greenland. Temperature (upper panel) and salinity (lower panel) at 50 m at Cape Desolation Station 3.

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

Scotian Shelf

The continental shelf off the coast of Nova Scotia is characterized by complex topography consisting of many offshore shallow banks and deep mid-shelf basins. It is separated from the southern Newfoundland Shelf by the Laurentian Channel and borders the Gulf of Maine to the southwest. Surface circulation is dominated by a general flow towards the southwest, interrupted by clockwise movement around the banks and anticlockwise movement around the basins, with the strengths varying seasonally.

Hydrographic conditions on the Scotian Shelf are determined by heat transfer between the ocean and atmosphere, inflow from the Gulf of St Lawrence and the Newfoundland Shelf, and exchange with offshore slope waters. Water properties have large seasonal cycles and are modified by fresh-water run-off, precipitation, and melting of sea ice. Temperature and salinity exhibit strong horizontal and vertical gradients that are modified by diffusion, mixing, currents, and shelf topography.

In 2007, annual mean air temperatures over the Scotian Shelf, represented by Sable Island observations, were normal, only 0.1°C below the long-term mean (based on 1971–2000 mean values); this is a decline of 1.5°C from 2006. West of Sable Island, the air temperature anomaly was -0.2°C over the eastern Gulf of Maine.

The amount of sea ice on the Scotian Shelf in 2007, as measured by the area of ice seawards of Cabot Strait between Nova Scotia and Newfoundland from January to April, was 18 400 km^2 below the long-term mean coverage of 39 000 km^2. This is an increase from the 2006 value of 1850 km^2, but is still substantially less than the 2003 cover which was the second highest in the 39-year record.

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 typically have bottom-water temperatures of 8–10°C. The origin of the latter is the offshore slope waters, whereas in the northeast, the water comes principally from the Gulf of St Lawrence. The interannual variability of the two water masses differs. Measurements of temperatures at 100 m at the Misaine Bank station capture the changes in the northeast. They reveal cooler-than-normal conditions in 2007 by 0.3°C, a decrease of 0.9°C from above normal conditions in 2006. In Emerald Basin, temperatures in 2007 were 1°C below normal at 100 m, a decrease of approximately 1.8°C from 2006. There was a large decrease of 2.2°C at 250 m to annual values nearly 1.9°C below normal. The water mass characteristics in 2007 for depths greater than 100 m were very similar to those in 1998 when Labrador Slope water moved into the deep inner shelf basins. In 2007, though, the deepest waters (~250 m) were about 0.2°C warmer and 0.3 saltier than in 1998.

Annual SST anomalies varied about 0.3°C over the eastern, 0.4°C over the central, and -1.5°C over the western Scotian Shelf during 2006. The Lurcher Shoal area west of Nova Scotia had an annual anomaly of -1°C and the Bay of Fundy an anomaly of 0.4°C. These are decreases of 1.4°C to 2.3°C from the above-normal values of 2006.

THE AMOUNT OF SEA ICE ON THE SCOTIAN SHELF WAS WELL BELOW NORMAL IN 2007.

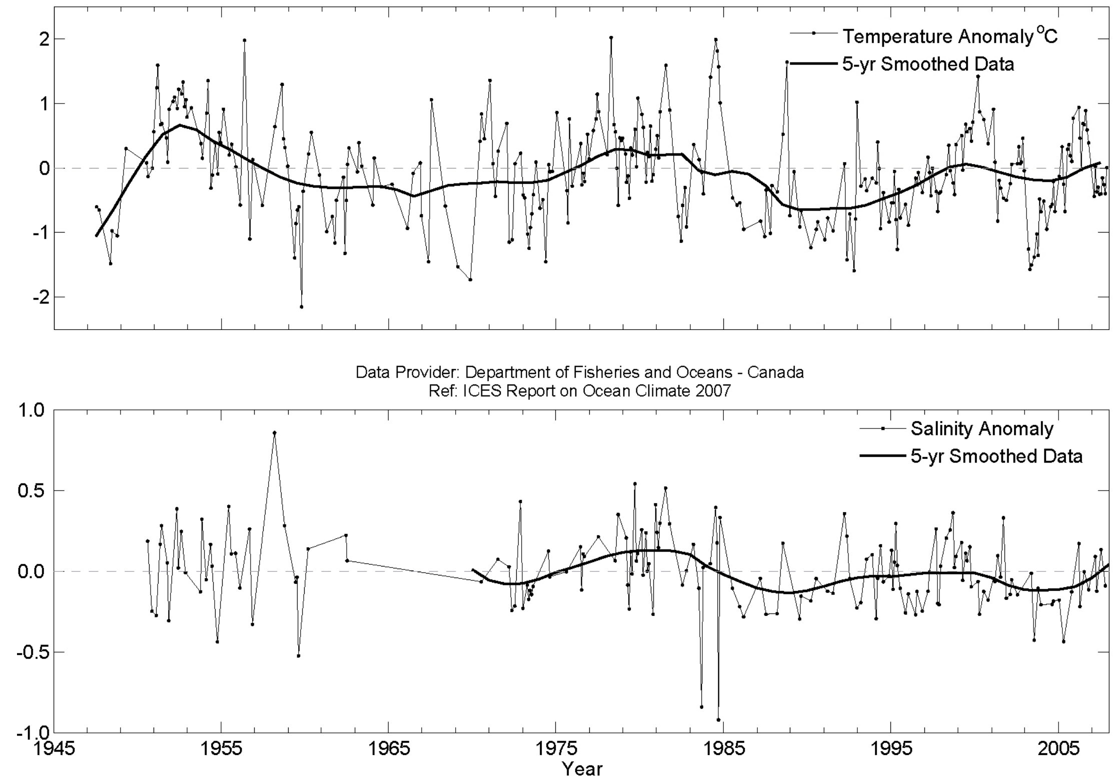


Figure 14.
Area 2 – Northwest Atlantic: Scotian Shelf. Near-bottom temperature anomalies (upper panel) and salinity anomalies (lower panel) in the northeastern Scotian Shelf (Misaine Bank, 100 m).

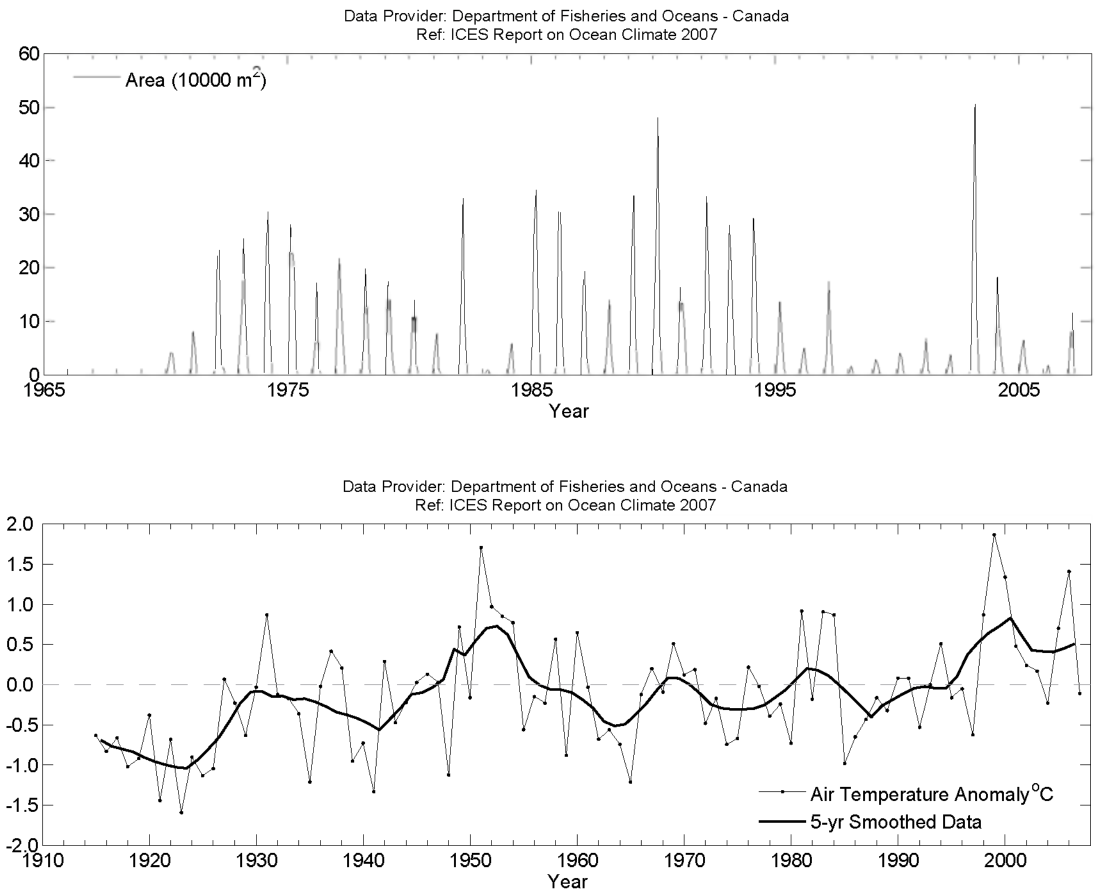


Figure 13.
Area 2 – Northwest Atlantic: Scotian Shelf. Monthly means of ice area seawards of Cabot Strait (upper panel) and filtered air temperature anomalies at Sable Island on the Scotian Shelf (lower panel).

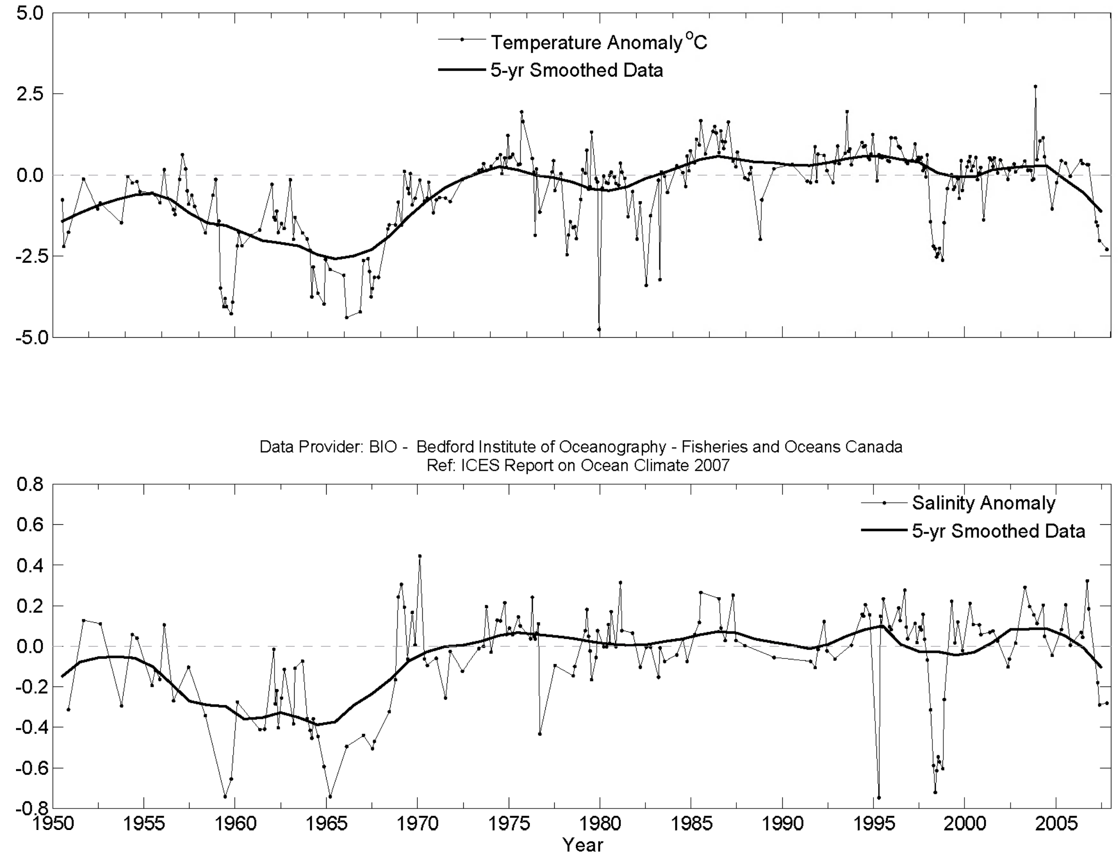


Figure 15.
Area 2 – Northwest Atlantic: Scotian Shelf. Near-bottom temperature anomalies (upper panel) and salinity anomalies (lower panel) in the central Scotian Shelf (Emerald Basin, 250 m).

Newfoundland and Labrador Shelf

THIS REGION IS SITUATED ON THE WESTERN SIDE OF THE LABRADOR SEA, STRETCHING FROM HUDSON STRAIT TO THE SOUTHERN GRAND BANK AND DOMINATED BY SHALLOW BANKS, CROSS-SHELF CHANNELS OR SADDLES, AND DEEP MARGINAL TROUGHS NEAR THE COAST. CIRCULATION IS DOMINATED BY THE SOUTH-FLOWING LABRADOR CURRENT BRINGING COLD, FRESH WATERS TOGETHER WITH SEA ICE AND ICEBERGS FROM THE NORTH TO SOUTHERN AREAS OF THE GRAND BANKS.

HYDROGRAPHIC CONDITIONS ARE DETERMINED BY THE STRENGTH OF THE WINTER ATMOSPHERIC CIRCULATION OVER THE NORTHWEST ATLANTIC (NAO), ADVECTION BY THE LABRADOR CURRENT, CROSS-SHELF EXCHANGE WITH WARMER CONTINENTAL SLOPE WATER, AND BOTTOM TOPOGRAPHY. SUPERIMPOSED ARE LARGE SEASONAL AND INTERANNUAL VARIATIONS IN SOLAR HEAT INPUT, SEA-ICE COVER, AND STORM-FORCED MIXING. THE RESULTING WATER MASS ON THE SHELF EXHIBITS LARGE ANNUAL CYCLES WITH STRONG HORIZONTAL AND VERTICAL TEMPERATURE AND SALINITY GRADIENTS.

The Rogers North Atlantic Oscillation index for 2007 was slightly above normal (the Rogers NAO index offers a better comparison with conditions in the western North Atlantic than the Hurrell winter NAO index). As a result, Arctic outflow to the Northwest Atlantic was stronger than in 2006, resulting in a broad-scale cooling throughout the Northwest Atlantic from West Greenland to Baffin Island and to Labrador and Newfoundland.

Annual air temperatures remained above normal at Labrador (0.7°C at Cartwright) and Newfoundland (0.3°C at St John's), significant decreases over the record highs of 2006. Sea-ice extent on the Newfoundland and Labrador Shelf for 2007 was below average for the 13th consecutive year; however, it increased significantly during spring, extending the ice season into June for the first time in several years.

At the standard monitoring site off eastern Newfoundland (Station 27), the depth-averaged annual water temperature decreased from the record high observed in 2006 to about normal. Surface temperatures at Station 27 also decreased from the record high observed in 2006 to just slightly above normal, whereas bottom temperatures remained above normal for the 12th consecutive year.

A robust 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 summer and autumn. 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 2007, the CIL remained below normal on the eastern Newfoundland Shelf for the 13th consecutive year.

The near-bottom thermal habitat cooled significantly in southern regions but warmed in areas north of the Grand Banks during autumn, when bottom temperatures were up to 2°C above the long-term mean in many areas.

In general, water temperatures on the Newfoundland and Labrador Shelf cooled from the record high observed in 2006, but remained above normal in most areas, continuing the warmer-than-normal conditions 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 six years, although there was considerable local variability.

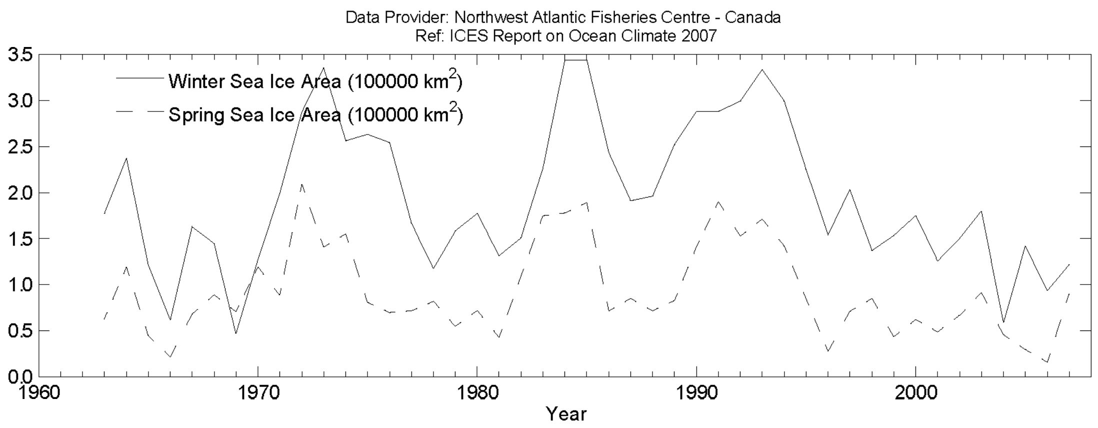


Figure 16.
Area 2 – Northwest Atlantic: Newfoundland and Labrador Shelf. Monthly sea-ice areas off Newfoundland and Labrador between 45°N and 55°N.

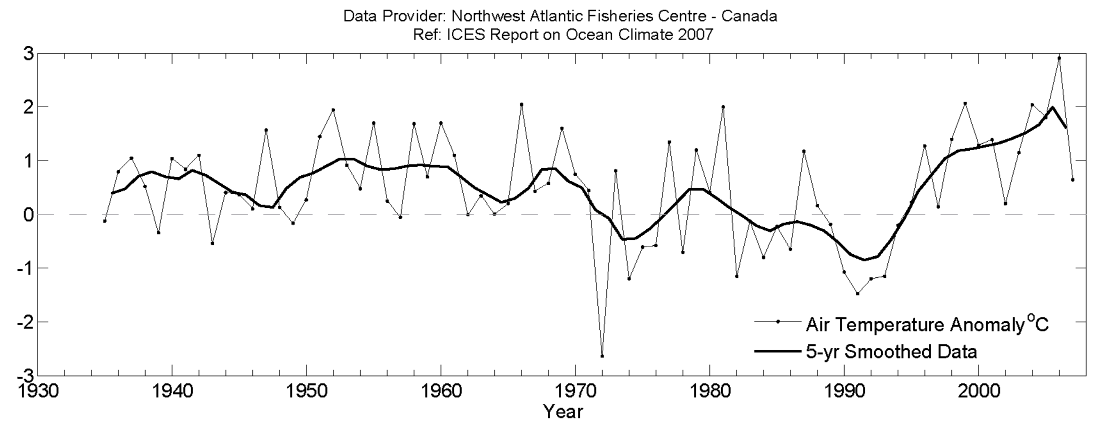


Figure 17.
Area 2 – Northwest Atlantic: Newfoundland and Labrador Shelf. Annual air temperature anomalies at Cartwright on the Labrador coast.

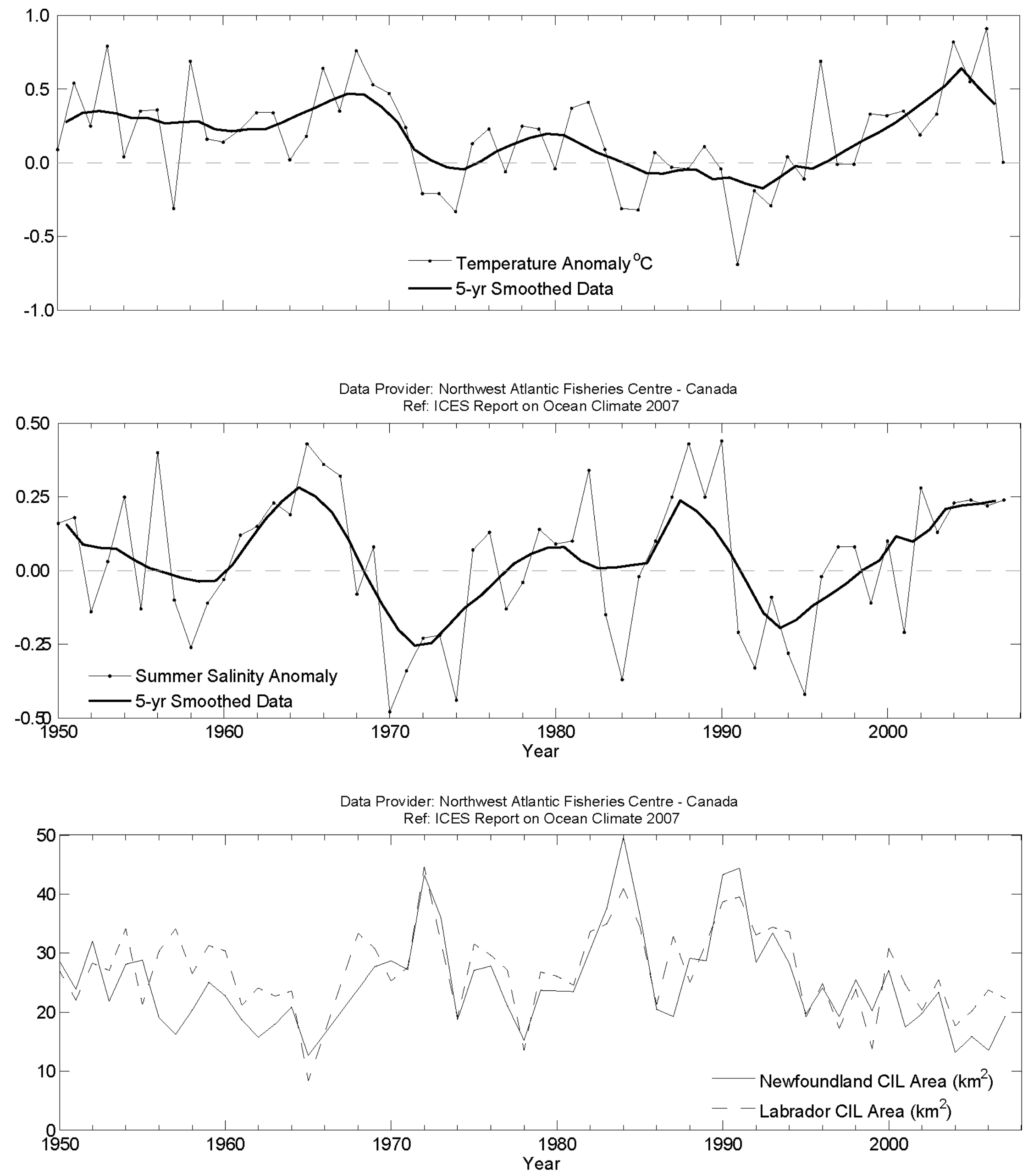


Figure 18.
Area 2 – Northwest Atlantic: Newfoundland and Labrador Shelf. Annual depth-averaged Newfoundland Shelf temperature anomalies (top panel), salinity anomalies (middle panel), and spatial extent of cold intermediate layer (CIL; bottom panel).

4.4 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 AN ANTICLOCKWISE 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 ATLANTIC WATERS ORIGINATING IN THE SUBTROPICS FLOW NORTHWARDS INTO THE LABRADOR SEA ON THE GREENLAND SIDE AND BECOME COLDER AND FRESHER AS THEY CIRCULATE.

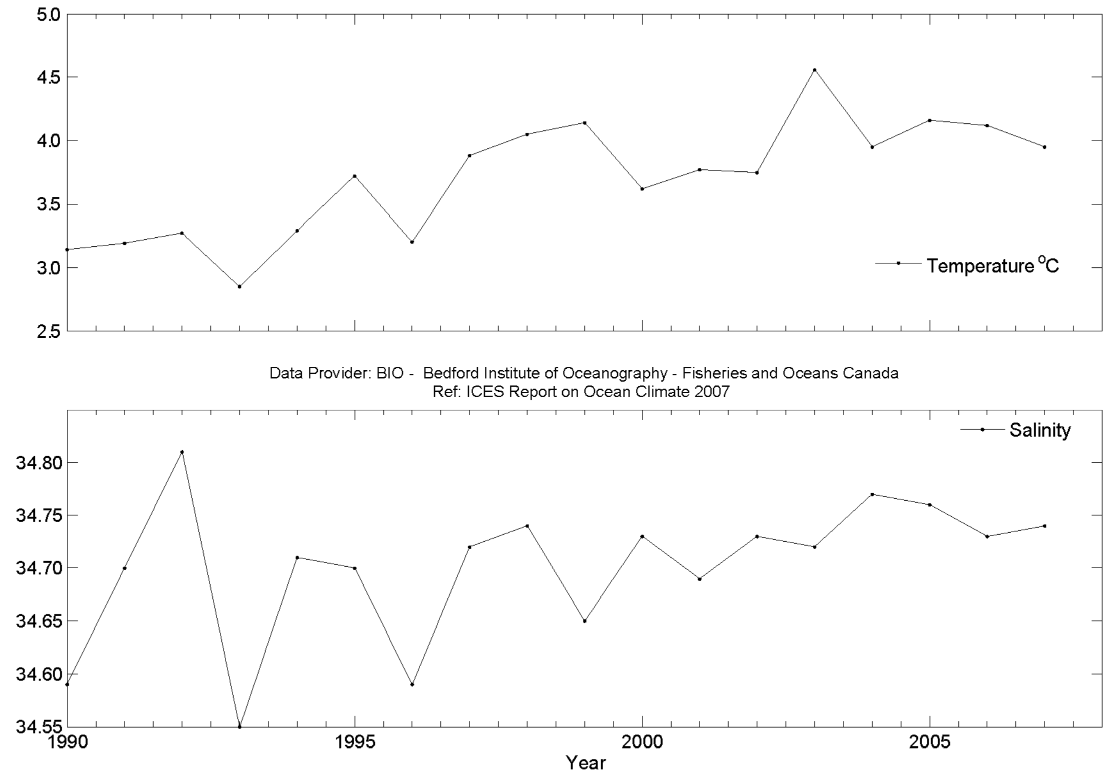
CHANGES IN LABRADOR SEA HYDROGRAPHIC CONDITIONS ON INTERANNUAL TIME-SCALES DEPEND ON THE VARIABLE INFLUENCES OF HEAT LOSS TO THE ATMOSPHERE, HEAT AND SALT GAIN FROM ATLANTIC WATERS, AND FRESH-WATER GAIN FROM MELTING ARCTIC SEA ICE. A SEQUENCE OF SEVERE WINTERS IN THE EARLY 1990S LED TO DEEP CONVECTION PEAKING IN 1993–1994 THAT FILLED THE UPPER 2 KM OF THE WATER COLUMN WITH COLD AND FRESH WATER.

CONDITIONS HAVE BEEN MILDER IN RECENT YEARS. THE UPPER LEVELS OF THE LABRADOR SEA HAVE BECOME WARMER AND MORE SALINE AS HEAT LOSSES TO THE ATMOSPHERE HAVE DECREASED AND ATLANTIC WATERS HAVE BECOME INCREASINGLY DOMINANT.

The upper 150 m of the west-central Labrador Sea has warmed by ~1°C and increased in salinity by ~0.1 since the early 1990s. Conditions in 2007 remained warm and saline, but slightly cooler than in 2005–2006.

The 2007 annual mean SST in the west-central Labrador Sea was about 0.6°C warmer than normal. Although 2007 was noticeably cooler than the previous four years, it continues a series of 14 consecutive years that have been warmer than normal.

Figure 19.
Area 2b – Labrador Sea. 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). Estimates of seasonal changes based on climatology have been removed from these spring/early summer measurements.



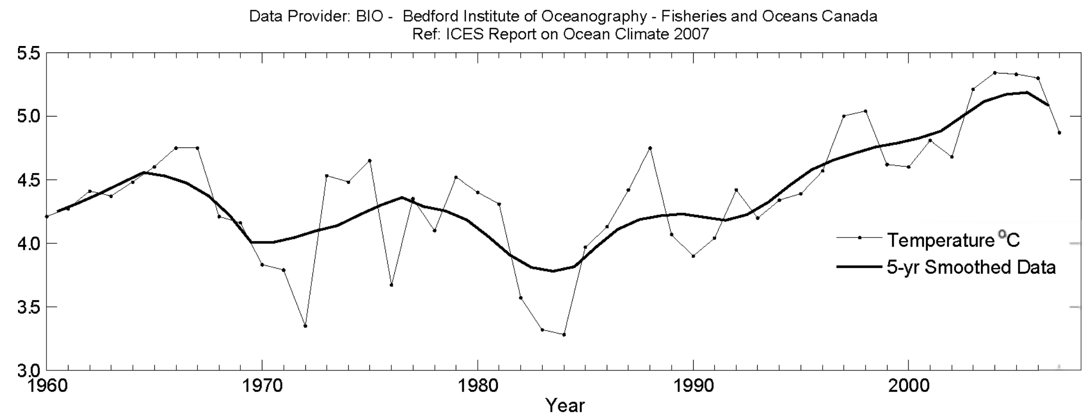


Figure 20.
Area 2b – Labrador Sea. Annual mean sea surface temperature data from the west-central Labrador Sea (56.5°N 52.5°W). Data obtained from the HadISST1.1 Global Sea Surface Temperature dataset, UK Meteorological Office, Hadley Centre.

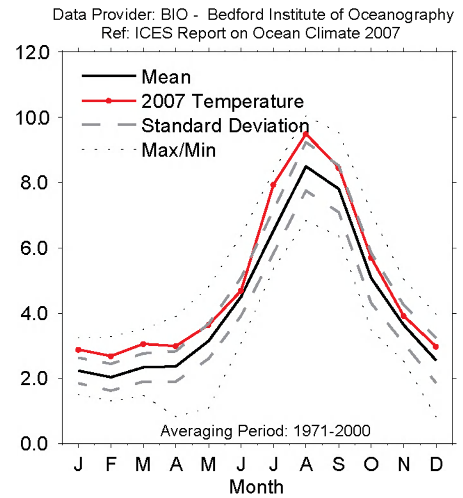


Figure 21.
Area 2b – Labrador Sea. Monthly sea surface temperature data from the west-central Labrador Sea (56.5°N 52.5°W). Data obtained from the HadISST1.1 Global Sea Surface Temperature dataset, UK Meteorological Office, Hadley Centre.

4.5 Area 2c – Mid-Atlantic Bight

THE HYDROGRAPHIC CONDITIONS IN THE WESTERN SLOPE SEA, THE MID-ATLANTIC BIGHT, AND THE GULF OF MAINE DEPEND UPON THE SUPPLY OF WATERS FROM THE LABRADOR SEA, ALONG BOTH THE SHELF AND THE CONTINENTAL SLOPE. THESE WATERS HAVE BEEN MONITORED BY REGULAR EXPENDABLE BATHYTHERMOGRAPH (XBT) AND SURFACE SALINITY OBSERVATIONS FROM COMMERCIAL AND FISHING VESSELS SINCE 1978. ONE SECTION RUNS BETWEEN NEW JERSEY AND BERMUDA AND THE OTHER TRAVERSES THE GULF OF MAINE, EAST OF BOSTON. HYDROGRAPHIC CONDITIONS ARE ALSO MONITORED ON GEORGES BANK.

The slope waters of the Mid-Atlantic Bight have remained generally fresh over the last three years, whereas there are no obvious trends in SST.

Figure 23 shows temperature anomalies from XBTs taken in the Gulf of Maine since 1978, the start of the programme, to 2007.There are no obvious trends in Gulf of Maine temperatures. Surface salinity has returned to more-average conditions over the last year.

GEORGES BANK WATERS HAVE BEEN WARMER BUT FRESHER SINCE 1990.

The Georges Bank surface observations (0–30 m) come from a wide region covering the Bank. Figure 24a shows temperature and salinity anomalies. The anomalies are in original units relative to the mean for 1978–1987. Note the continued warmer-than-normal temperatures; this is quite consistent with the XBT values. What is perhaps more surprising are the rather low surface salinities, nearly 0.5 below the average for 1978–1987. Indeed, the waters have overall been warmer and fresher since approximately 1990. More usually in the Slope Sea (offshore of the Gulf of Maine), high salinities accompany high temperatures and vice versa. There is much that is still not understood about the shelf and Slope Sea Waters.

Figure 22.
Area 2c – Mid-Atlantic Bight. Temperature and salinity from the Oleander section (New York City to Bermuda). Sea surface temperature (SST) anomalies as averaged values from 120–400 km southeast from New York City (upper panel); SST anomalies along the transect (middle panel); and sea surface salinity anomalies along the transect (lower panel).

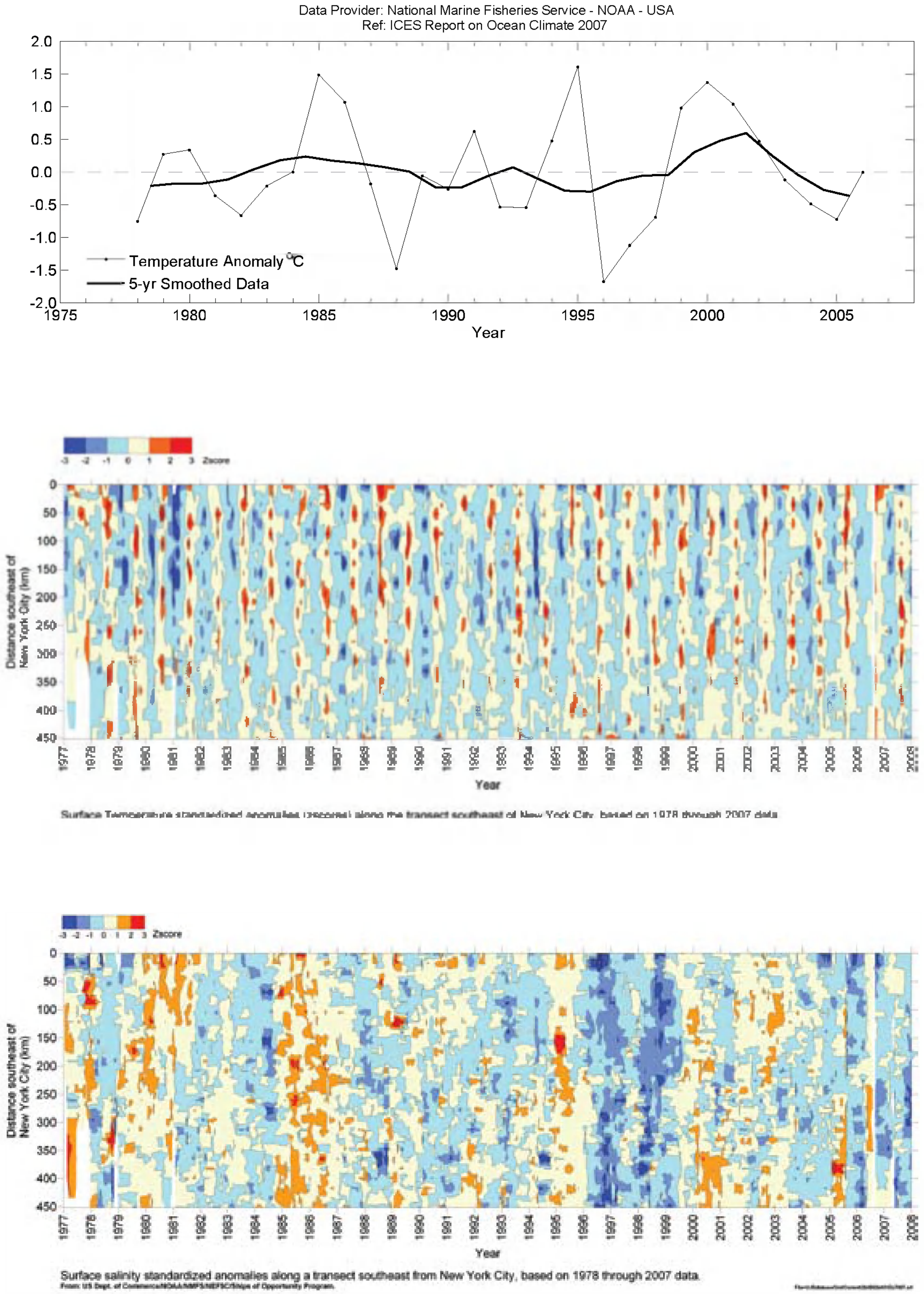


Figure 23.
Area 2c – Mid-Atlantic Bight. Temperature and salinity in the Gulf of Maine from the section east of Boston. The upper panel is a chart showing the area from which expendable bathythermographs (XBT) observations are used to construct the time-series (note the distance scale east from the longitude of Boston). SST anomalies along the transect (middle panel); sea surface salinity anomalies along the transect (lower panel).

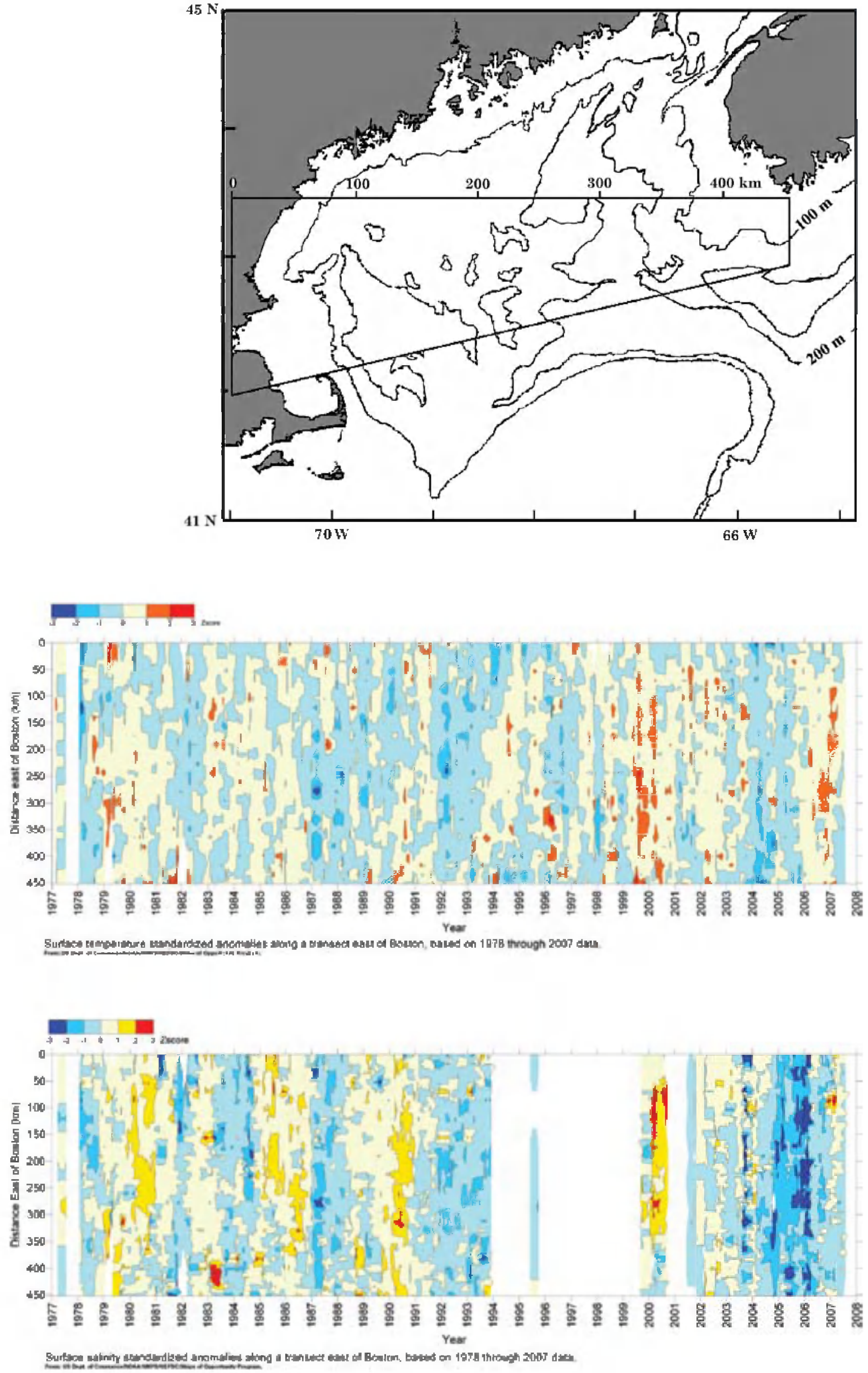
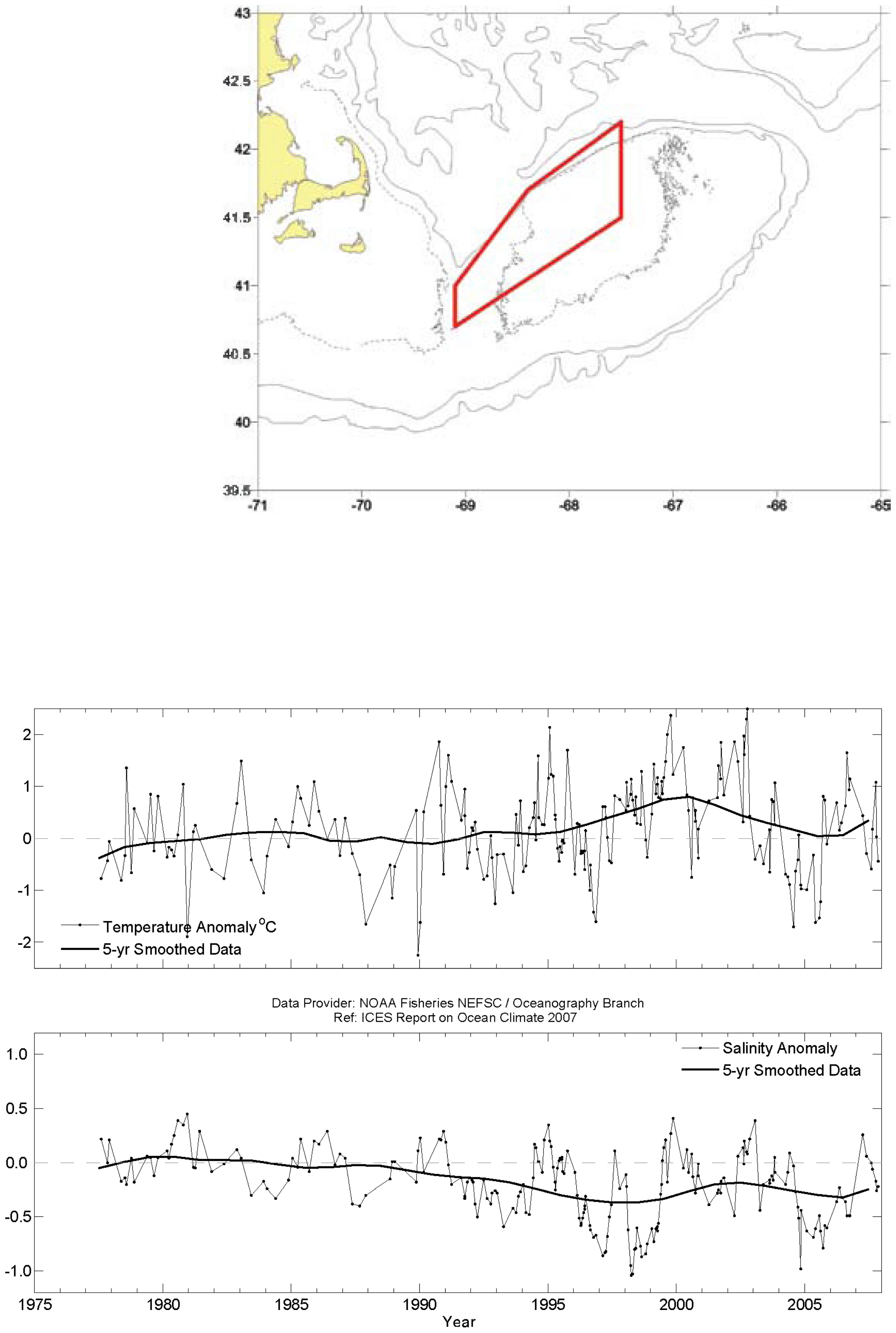


Figure 24a.
Area 2c – Mid-Atlantic Bight. The upper panel is a chart of the northwest portion of Georges Bank. The 60 m isobath (dashed) and 200 m isobath (solid) are shown. Time-series plots of 0–30 m averaged temperature anomaly (middle panel) and salinity anomaly (lower panel) at Georges Bank.



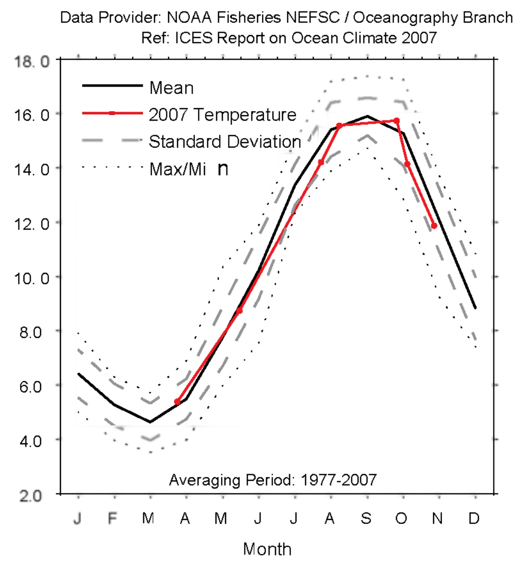


Figure 24b.
Area 2c – Mid-Atlantic Bight. Monthly surface (0–30 m) temperatures at Georges Bank.

▶ Voluntary observing ships

Many of the data presented here are collected from commercial vessels that voluntarily make ocean measurements along their journeys. The results from monthly sampling of surface and bottom temperatures for nearly three decades reveal the power of systematic or repeat sampling from merchant marine vessels. A number of vessels are now operating automated systems to sample temperature and salinity while underway. The key to success with these is to ensure that the data become available as soon as the vessel makes a port call. There is a pressing need for merchant-marine-optimized techniques to track and report data from the ocean in a timely fashion.

The section east of Boston has depended upon observations from various vessels, including those from Eimskipafelag, Caribou Seafoods, the US Coast Guard, and Hans Speck and Son. Their cooperation is greatly appreciated.

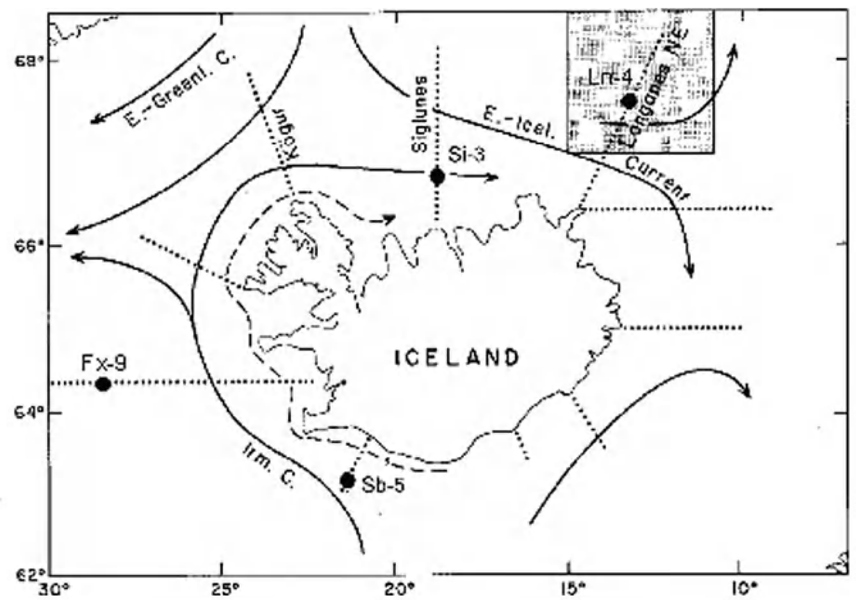
4.6 Area 3 – Icelandic Waters

ICELAND IS AT THE MEETING PLACE OF WARM AND COLD CURRENTS. THESE CONVERGE IN AN AREA OF SUBMARINE RIDGES (GREENLAND–SCOTLAND RIDGE, REYKJANES RIDGE, KOLBEINSEY RIDGE) THAT FORM NATURAL BARRIERS AGAINST THE MAIN OCEAN CURRENTS. THE WARM IRMINGER CURRENT, A BRANCH OF THE NORTH ATLANTIC CURRENT (6–8°C), FLOWS FROM THE SOUTH, AND THE COLD EAST GREENLAND AND EAST ICELANDIC CURRENTS (–1°C TO 2°C) FLOW FROM THE NORTH. DEEP 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 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 AFFECT BIOLOGICAL CONDITIONS, EXPRESSED THROUGH THE FOOD CHAIN IN THE WATERS, INCLUDING RECRUITMENT AND ABUNDANCE OF COMMERCIALLY IMPORTANT FISH STOCKS.

In 2007, mean air temperatures in the south (Reykjavik) and north (Akureyri) were above long-term averages. During the year, temperature and salinity south and west of Iceland remained high. In spring and autumn, temperatures and salinity of surface layers were around average. Temperature and salinity in February 2008 were again above long-term averages. Salinity and temperature measurements in the East Icelandic Current in spring 2007 were above average.

Figure 25.
Area 3 – Icelandic waters. Main currents and the location of standard hydrobiological sections in Icelandic waters.



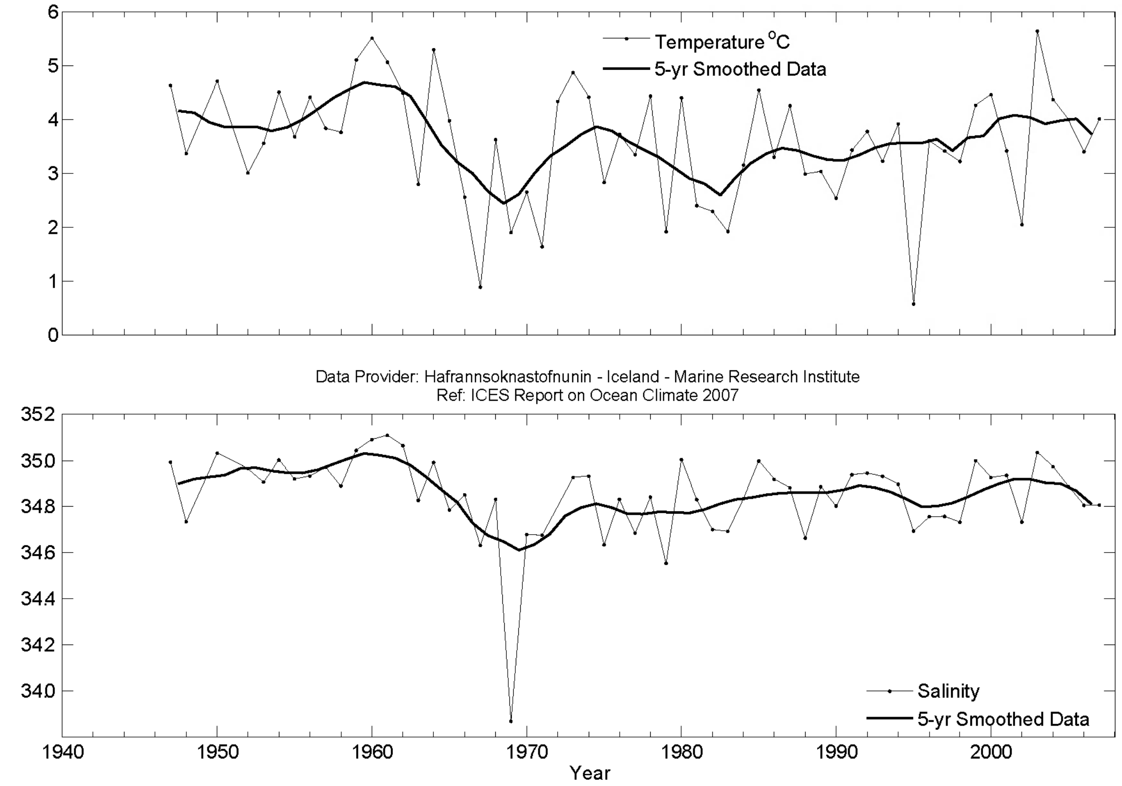
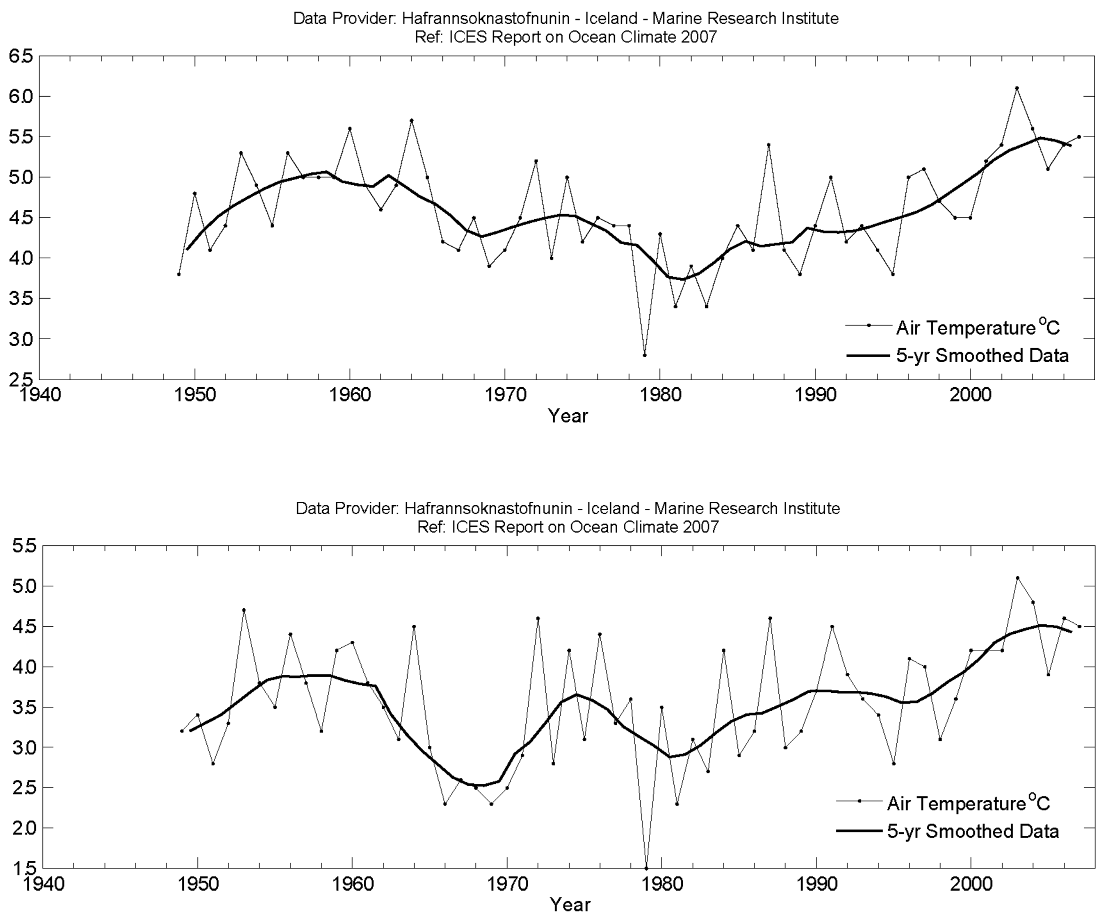


Figure 27.
Area 3 – Icelandic waters. Temperature (upper panel) and salinity (lower panel) at 50–150 m depth at Stations Si2–4 in North Icelandic waters.

Figure 26.
Area 3 – Icelandic waters. Mean annual air temperature at Reykjavík (upper panel) and Akureyri (lower panel).



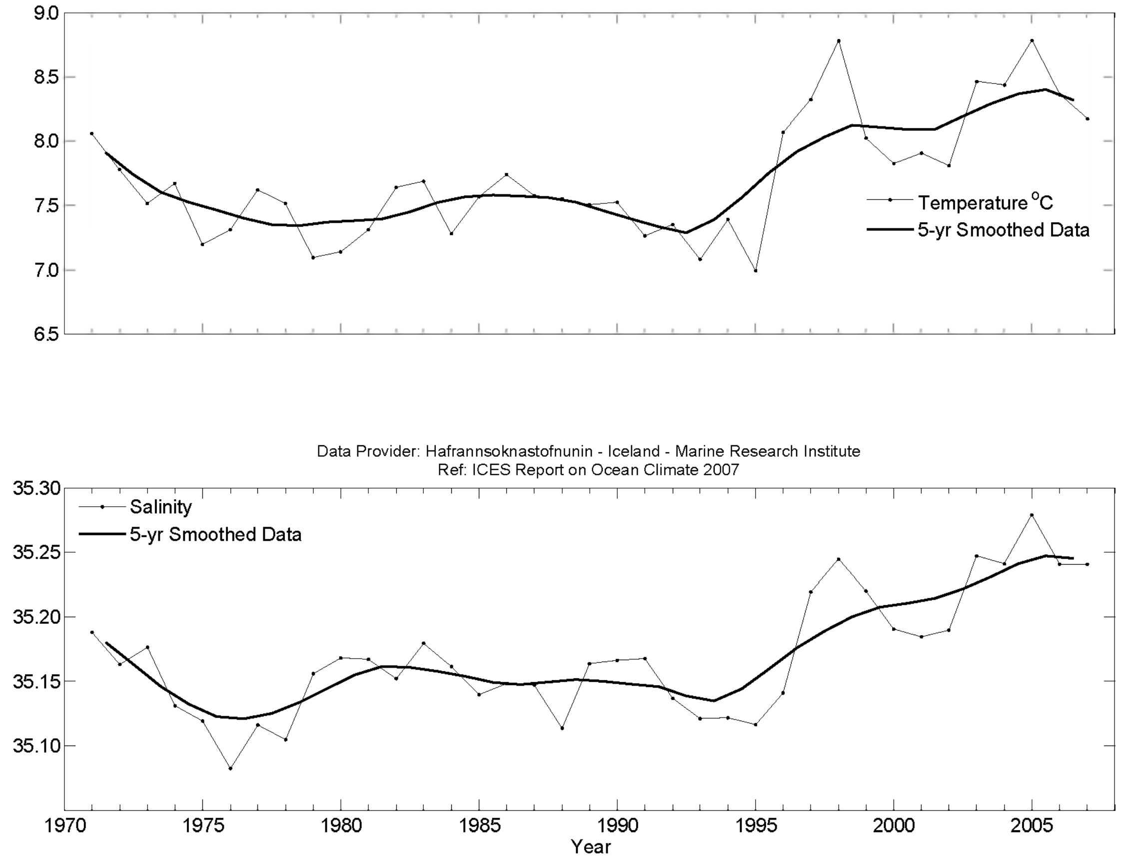


Figure 28.
Area 3 – Icelandic waters. Temperature (upper panel) and salinity (lower panel) between 0 m and 200 m at Station Sb5 in South Icelandic waters.

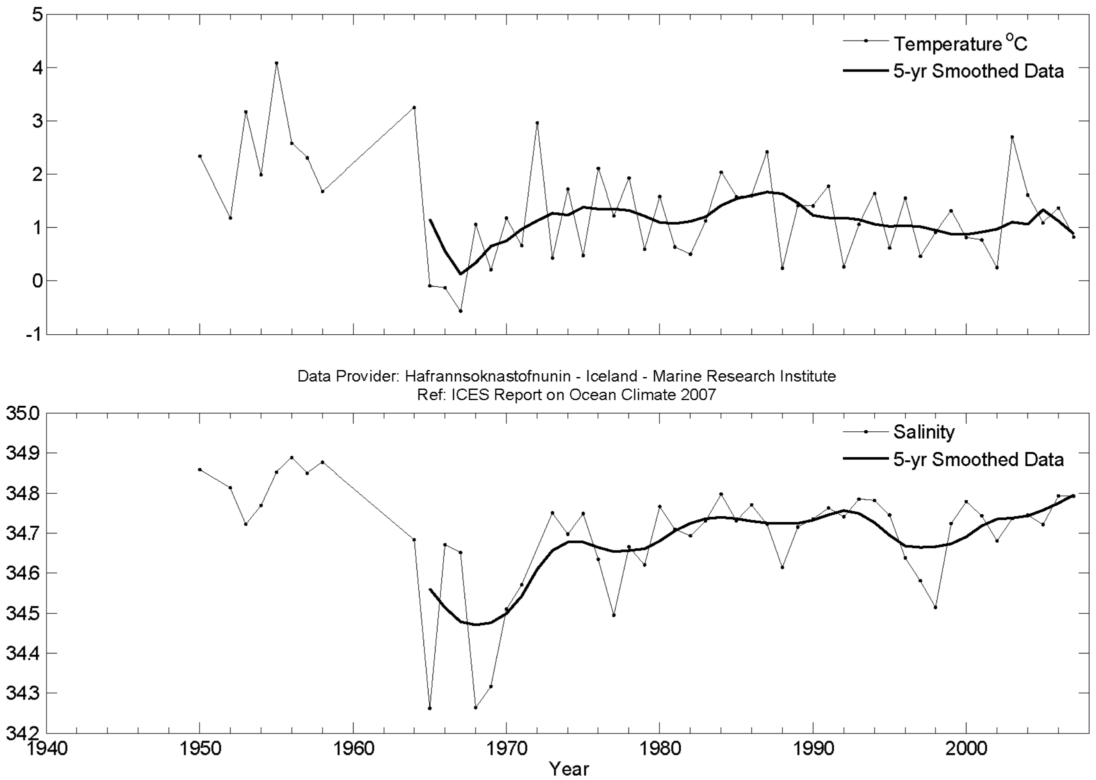


Figure 29.
Area 3 – Icelandic waters. Temperature (upper panel) and salinity (lower panel) between 0 m and 50 m in the East Icelandic Current (Stations Lna2–6).

4.7 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.

The year 2007 was one of contrasts in the Bay of Biscay: a mild winter and spring, and a cold summer and autumn. The northern part of the Iberian Peninsula had average meteorological conditions in 2007. Annual mean air temperature over the southern Bay of Biscay during 2007 was 14.6°C, an average value compared with 1961–2007, but cooler than the previous two warm decades. The 2007 pattern of warm winter and cold summer also contrasts with the cold winter and warm summer pattern in 2005 and 2006. As expected, SST reflected the warmer–colder pattern, with July showing the lowest value for this month on record. This pattern was caused by the relatively low air temperature as well as a noticeable reduction in hours of sun and the subsequent solar radiation (22% lower than the average for 1986–2007).

However, the pattern for subsurface and intermediate water differs from the air and SST pattern. The warm 2007 winter, preceded by a warm 2006 autumn, has consequences for the local intermediate waters. The strong cold anomaly present in the area from the 2005 winter, with a mixed layer reaching 300 m depth, completely disappeared in the upper part of this layer following the formation of an anomalous warm mixed layer in 2007. Therefore, the warming tendency detected in the ocean interior continues. In the North Atlantic Central Water, the warming trend continues for the whole period, and salinity has stabilized after the strong increase from 2005 to 2007. The Mediterranean Water also shows temperature and salinity increases.

This area is occasionally affected by a strong high salinity signal at the shelf and shelf break, a phenomenon typically associated with the advection of waters of subtropical origin through the Iberian Poleward Current. Between 1998 and 2001, freshening was observed in the water from 0 m to 200 m. In 2002, this trend was reversed during an event of the Iberian Poleward Current. An increase in salinity was observed in the upper 200 m in 2003–2006, and at 300–600 m in 2004–2006. The salinity increases were also, in part, the result of atmospheric forcing in the formation area of the eastern North Atlantic Central Water (lower precipitation, higher evaporation). Autumn 2006 and winter 2007 were also characterized by a strong episode of the Iberian Poleward Current, and relatively low precipitation and river discharge maintained high salinity values.

AVERAGE TEMPERATURE OF THE UPPER OCEAN REMAINS HIGH IN THE BISCAY REGION.

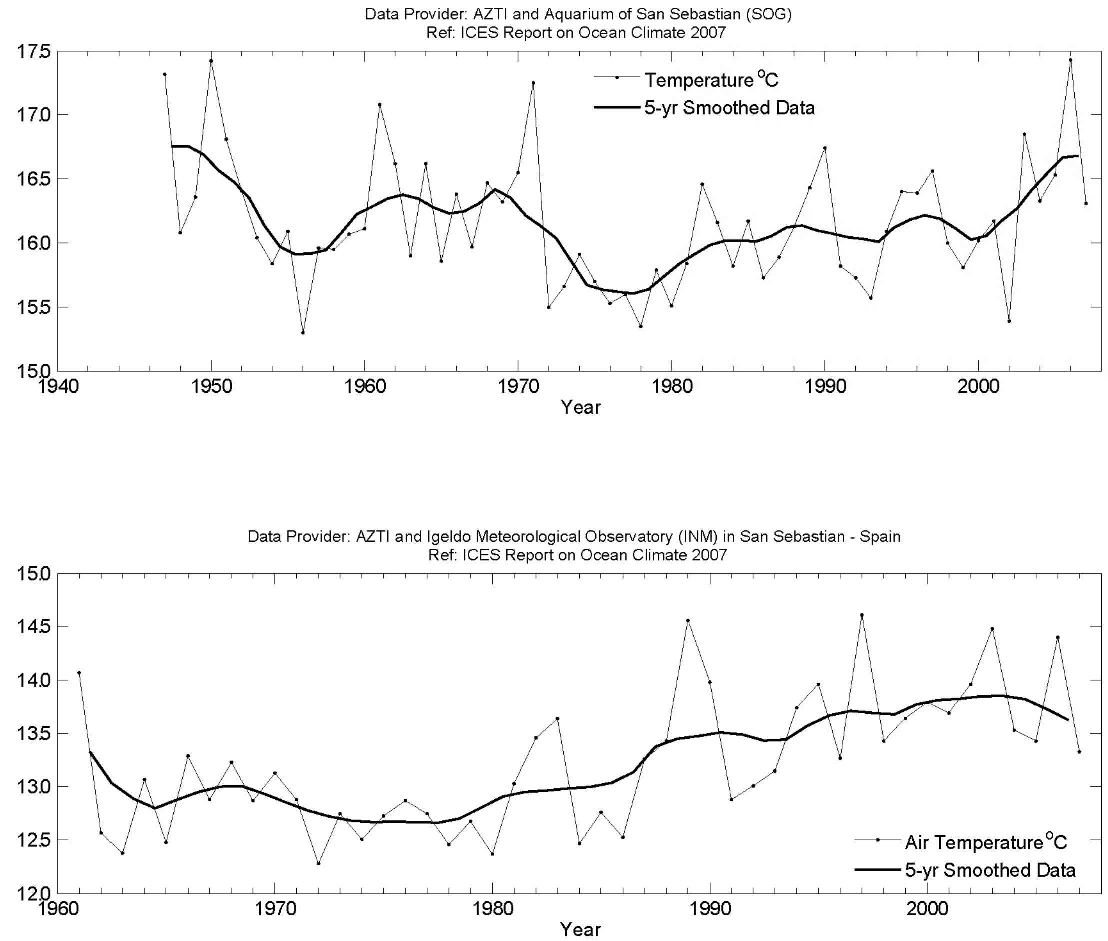


Figure 30.
Area 4 – Bay of Biscay and eastern Atlantic. SST (upper panel) and air temperature (lower panel) at San Sebastian (43°18.5′N 02°2.37′W).

Figure 31.
Area 4 – Bay of Biscay and eastern Atlantic. Potential temperature (upper panel) and salinity (lower panel) at Santander Station 6 (43°42′N 3°47′W; shelf break; 5–200 m).

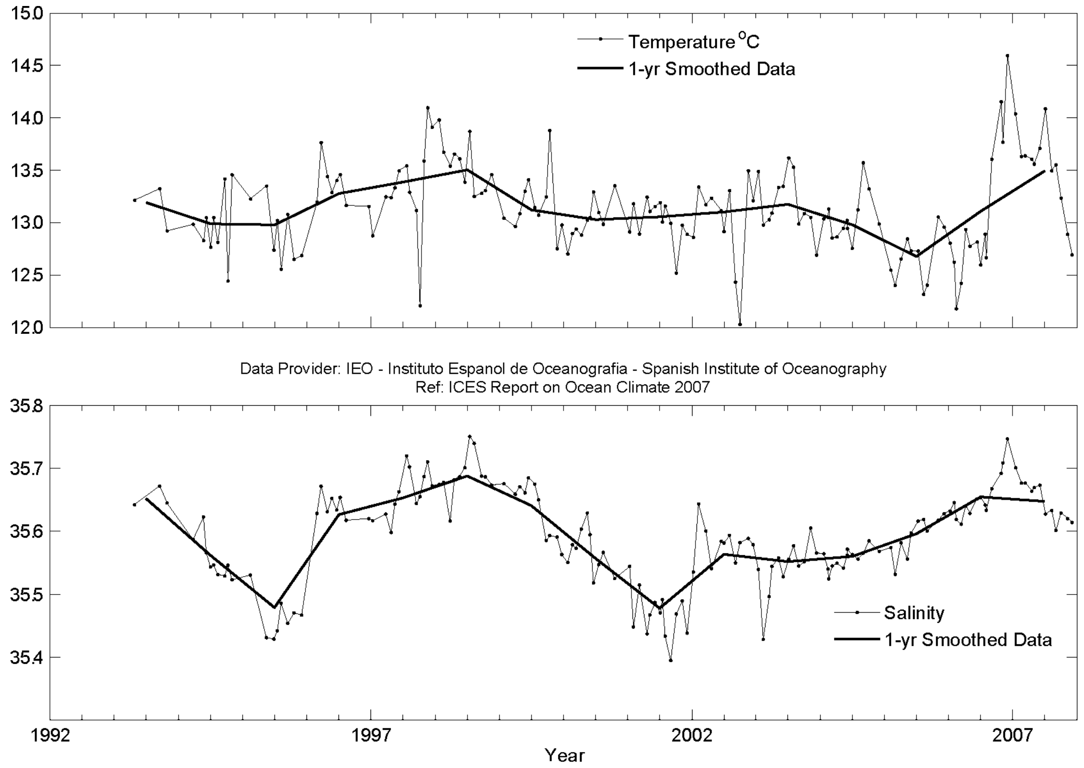
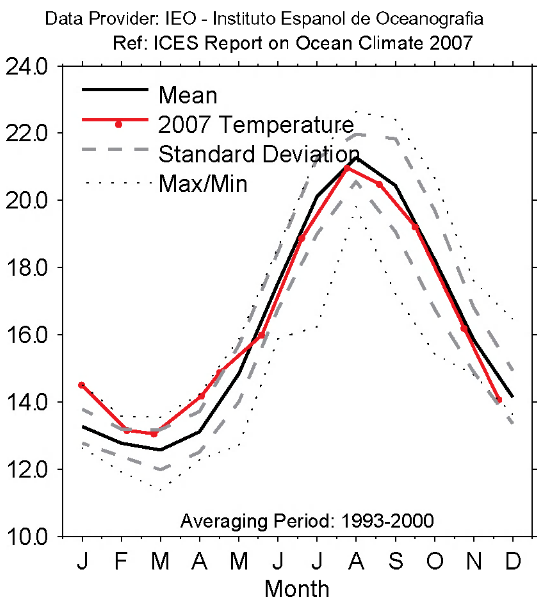


Figure 32.
Area 4 – Bay of Biscay and eastern Atlantic. Monthly surface water temperature at Santander Station 6.



4.8 Area 4b – Northwest European continental shelf

Western English Channel

Station E1 (50°02′N 4°22′W) is situated in the western English Channel and is mainly influenced by North Atlantic water. The water depth is 75 m, and the station is tidally influenced by a 1.1 knot maximum surface stream at mean spring tide. The seabed is mainly sand, resulting in a low bottom stress (1–2 ergs cm^{-2} s^{-1}). The station may be described as oceanic with the development of a seasonal thermocline; stratification typically starts in early April, persists throughout summer, and is eroded by the end of October. The typical depth of the summer thermocline is around 20 m. The station is greatly affected by ambient weather.

Measurements have been taken at this station since the end of the 19th century, with data currently available since 1903. The series is unbroken, apart from the gaps for the two world wars and a hiatus in funding between 1985 and 2002. The data take the form of vertical profiles of temperature and salinity. Early measurements were taken with reversing mercury in glass thermometers and discrete salinity bottles. More recently, electronic equipment (Seabird CTD) has been utilized.

The time-series shows considerable interannual variability. AVHRR satellite sea-surface analysis for the missing 1985–2002 period shows a gradual warming of the surface waters, with increases in summer maxima and winter minima. In 2007, E1 was sampled on only eight occasions, with the minimum surface temperature (March) being 10.8°C and the maximum surface temperature (September) being 16.9°C. The winter minima is on the very warm side (typical winter conditions are around 8–10°C), a testament to the mild winter in 2007. During summer, temperatures were close to the long-term mean. During autumn, temperatures were again very warm compared with the long-term mean.

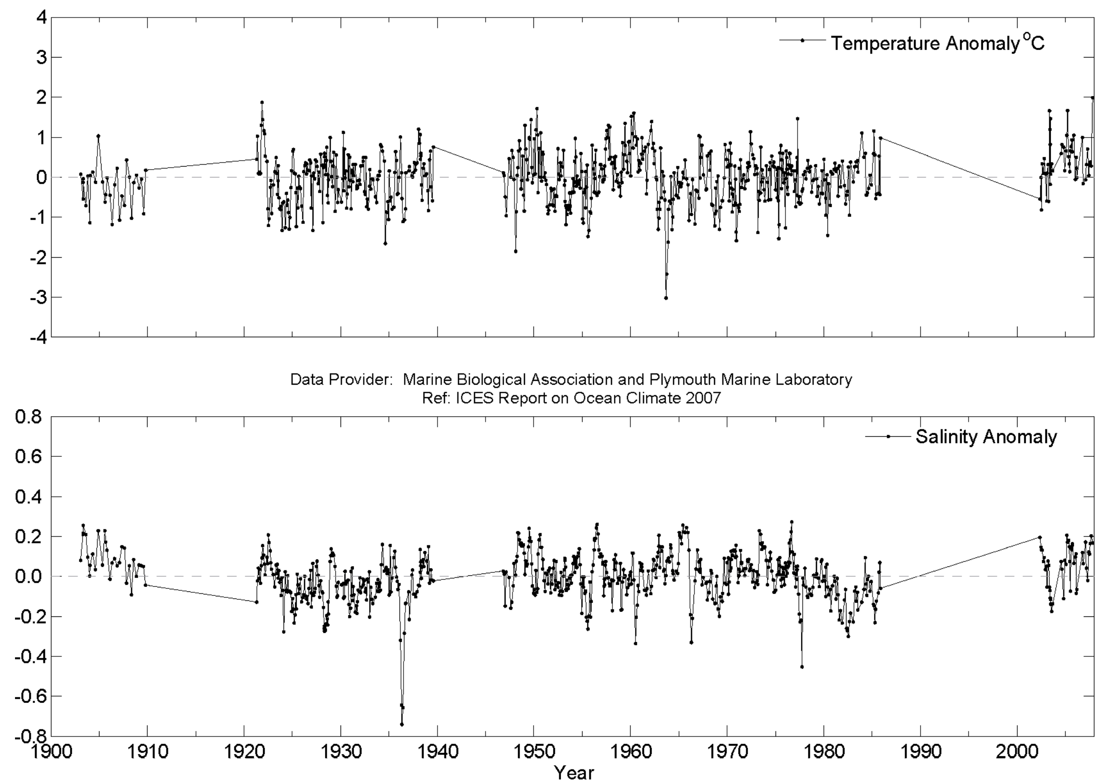


Figure 33.
Area 4b – Northwest European continental shelf. Temperature anomaly (upper panel) and salinity anomaly (lower panel) of surface water at station E1 in the western English Channel (50°02′N 4°22′W).

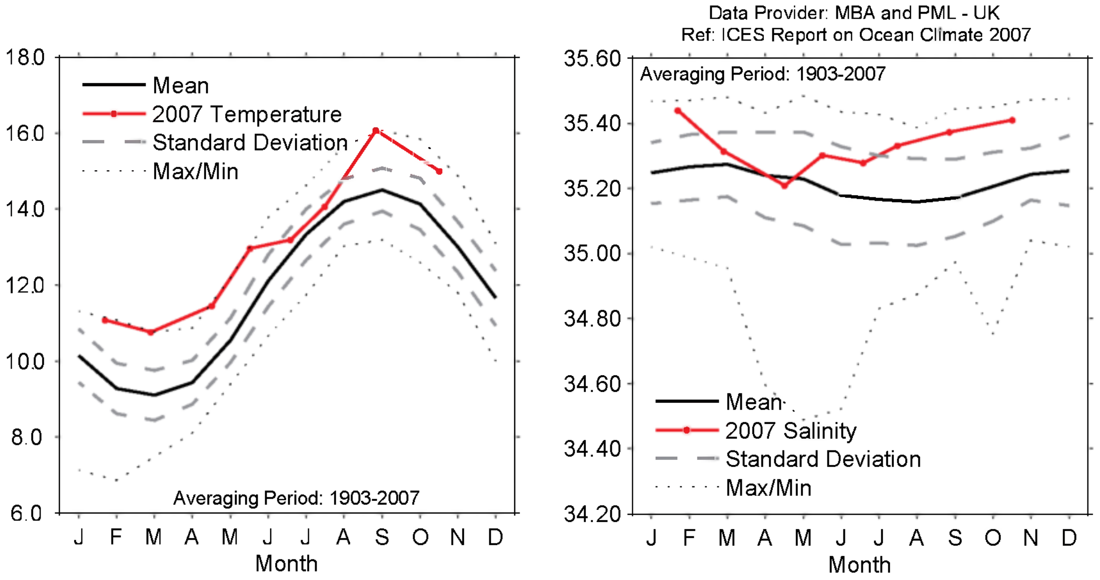


Figure 34.
Area 4b – Northwest European continental shelf. Monthly temperature (left panel) and salinity (right panel) of surface water at station E1 in the western English Channel (50°02′N 4°22′W).

North and west of Ireland

THE TIME-SERIES OF SURFACE OBSERVATIONS AT THE MALIN HEAD COASTAL STATION (THE MOST NORTHERLY POINT OF IRELAND) IS INSHORE OF COASTAL CURRENTS AND INFLUENCED BY RUN-OFF.

Since the late 1980s, temperatures have been increasing, with the mid-2000s being the highest recorded since records began in 1960. Data presented here are to 2006. The seasonal cycle on the Irish Shelf is illustrated by data from the M1 weather buoy west of Galway.

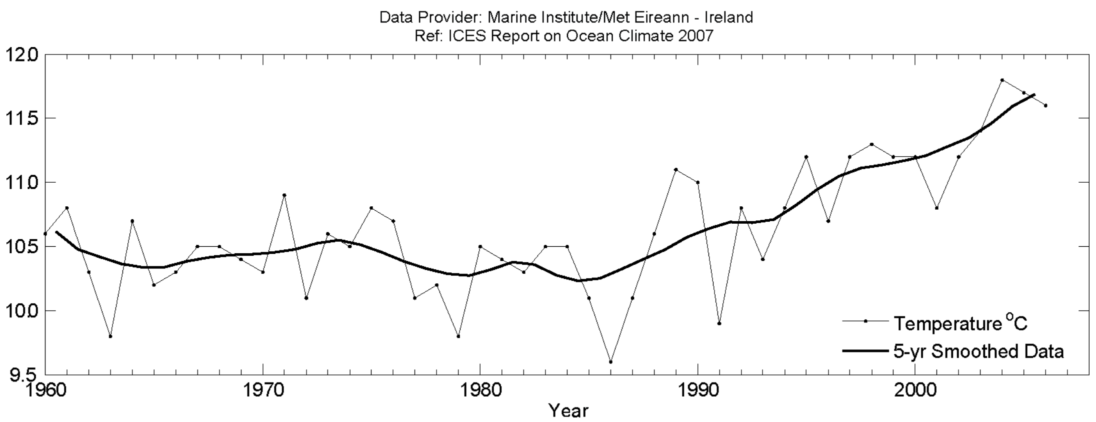


Figure 35.
Area 4b – Northwest European Continental Shelf. Temperature at the Malin Head coastal station (55.39°N 7.38°W).

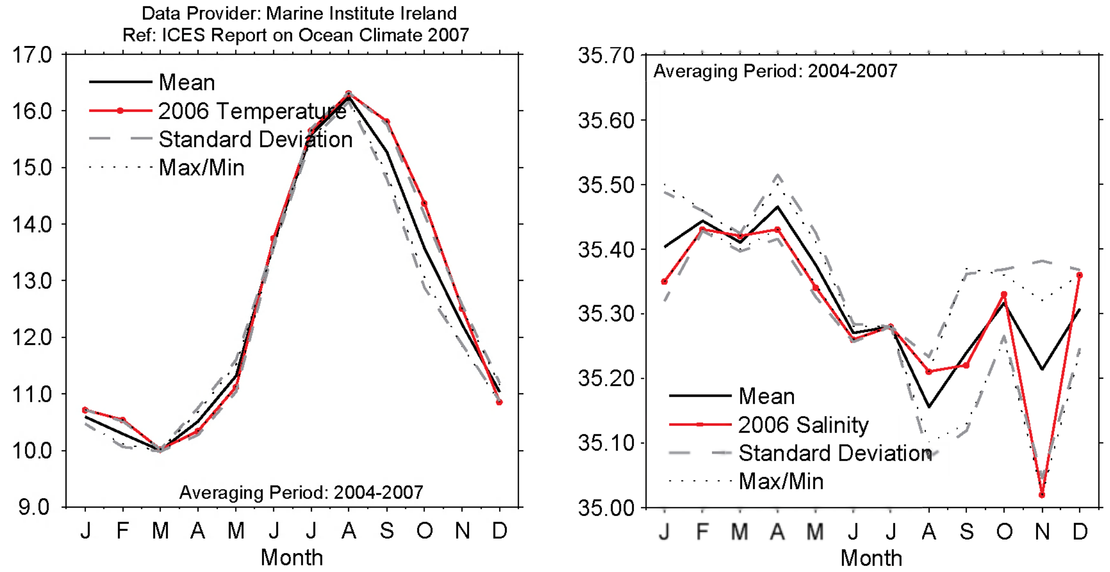


Figure 36.
Area 4b – Northwest European Continental Shelf. Monthly temperature (left panel) and salinity (right panel) at the M1 weather buoy west of Galway, Ireland.

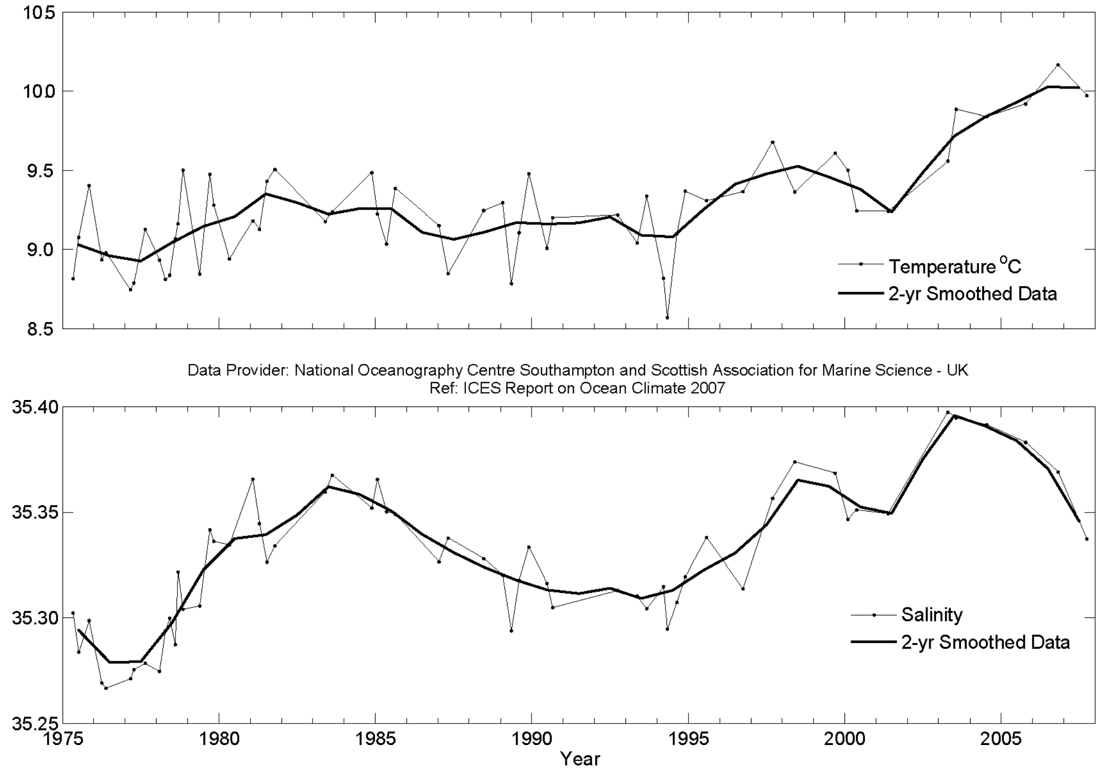
4.9 Area 5 – Rockall Trough

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 ALLOWS WARM NORTH ATLANTIC UPPER WATER TO REACH 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 POLEWARDS-MOVING EASTERN NORTH ATLANTIC WATER, WHICH IS WARMER AND SALTIER THAN WATERS OF THE ICELAND BASIN (THAT ALSO CONTRIBUTE TO THE NORDIC SEA INFLOW).

In 2007, warm conditions persisted in the upper ocean of the Rockall Trough, whereas salinity is only slightly higher than the long-term mean after decreasing from a maximum in 2003. The decrease in mean salinity is caused by incursions of fresher water, initially seen between the Anton Dohrn Seamount (11°W) and Rockall Bank (13°W), but now found across the whole section. Temperatures remained very high compared with the long-term mean; averaged from the surface to a depth of 800 m, temperature was 0.7°C above the long-term mean, 1975–2000. Salinity averaged from the surface to 800 m was 0.01 above the long-term mean, 1975–2000.

Below.
A conductivity/temperature/depth (CTD) rosette is lowered into the East Greenland Coastal current from the icebreaker RRS "James Clark Ross" in August 2004. Prior to the cast, the ship was manoeuvred to create an open water "pond" for the rosette. Image courtesy of R. Pickart, WHOI, USA.

Figure 37.
Area 5 – Rockall Trough. Temperature (upper panel) and salinity (lower panel) for the upper ocean (0–800 m).



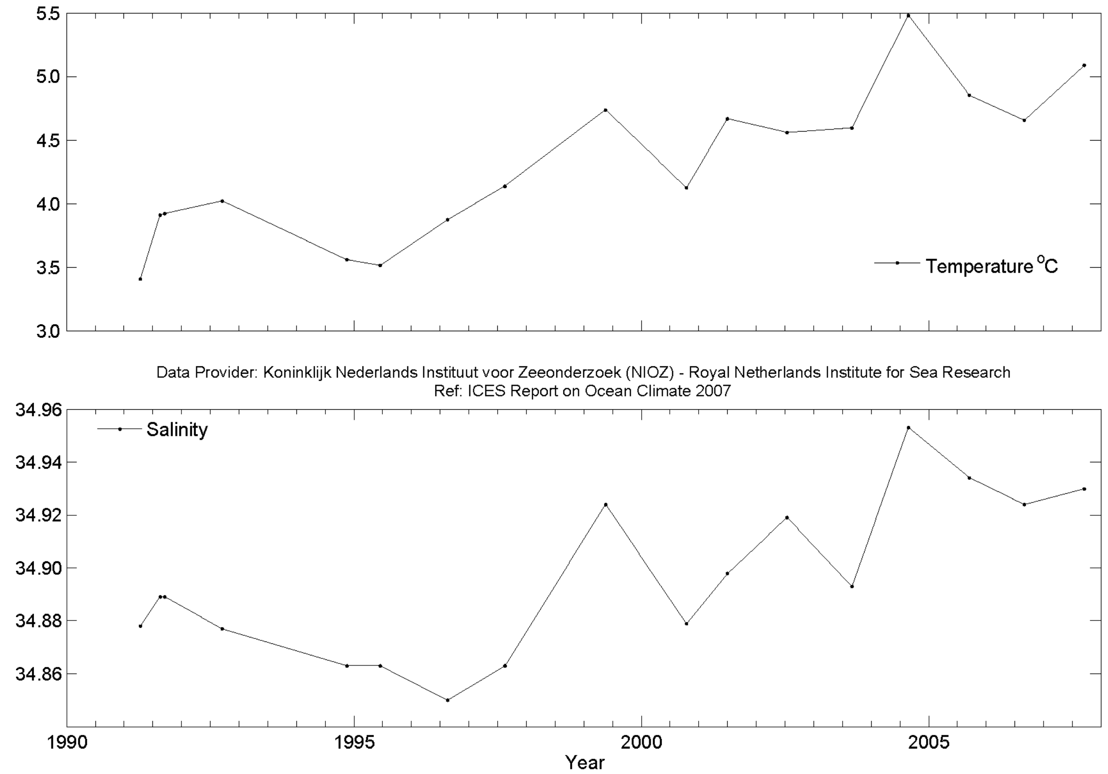


Figure 38.
Area 5b – Irminger Sea. Temperature (upper panel) and salinity (lower panel) of Subpolar Mode Water (averaged over 200–400 m).

4.10 Area 5b – Irminger Sea

THE IRMINGER SEA IS THE OCEAN BASIN BETWEEN SOUTHERN GREENLAND, THE REYKJANES RIDGE, AND ICELAND. THIS AREA FORMS PART OF THE NORTH ATLANTIC SUBARCTIC ANTICYCLONIC GYRE. BECAUSE OF THIS GYRE, THE EXCHANGE OF WATER BETWEEN THE IRMINGER SEA AND THE LABRADOR SEA IS RELATIVELY FAST.

In 2004, the Subpolar Mode Water in the centre of the Irminger Sea, in the pressure interval 200–400 dbar, reached its highest temperature and salinity since 1991. Since then, a slight cooling and freshening has occurred. Although convection that reached depths of more than 600 m in the following winters reduced temperature and salinity slightly, the temperature of the Subpolar Mode Water in 2007 was the second highest since 1991, whereas salinity in summer 2007 was still considerably higher than observed before 1998. Thus, the trend of increasing temperature and salinity that began in 1995/1996 seems to have continued during 2007.

▶ Understanding patterns of variability

The ocean at any one location varies on many time-scales from hours and days to decades, centuries, and millennia. In this report, we aim to identify variations on a time-scale of months to decades, so that when we interpret time-series that sample the ocean only a few times a year, or even once a year, we need to understand how the shorter time-scales or higher frequency changes might affect the results. A good example is the apparently erratic behaviour of the annual time-series from deep water in the Irminger Sea. A new set of daily measurements with a moored sensor system over three years (2003–2006) reveals that the erratic annual time-series is, in fact, a poor representation of variability within each year. This is known as "aliasing" and is a significant problem in interpreting long-term changes.

Below.
Mooring recovery from RV "Merian" in the ice in Fram Strait. Image courtesy of A. Beszczynska-Möller, AWI, Germany.

4.11 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. THE FAROE BANK CHANNEL SAMPLES ITS PROPERTIES BEFORE, AND THE FAROE CURRENT SAMPLES THE PROPERTIES AFTER, CROSSING THE RIDGE.

Since 1988, temperature and salinity of the upper waters have been steadily increasing. Values in 2007 were slightly down from 2004, but remained higher than average for the time-series.

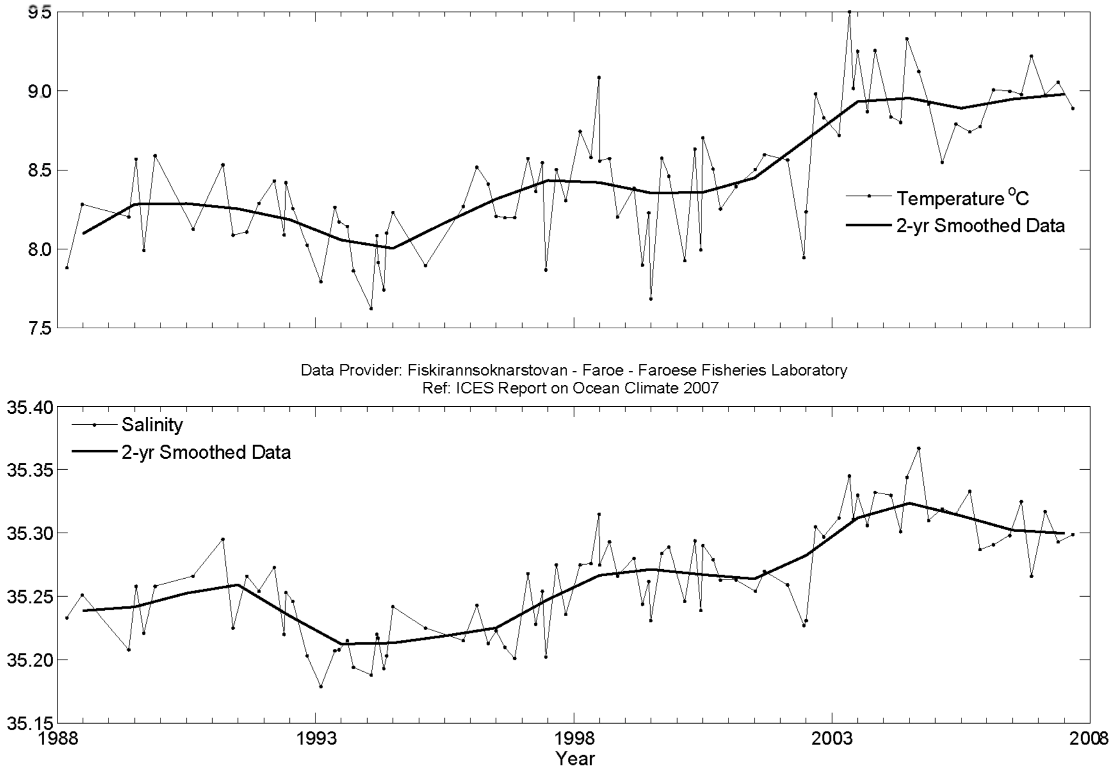


Figure 39.
Area 6 – Faroe Bank Channel. Temperature (upper panel) and salinity (lower panel) from the layer 100–300 m deep at two standard stations in the channel.

TEMPERATURE AND SALINITY OF THE UPPER WATERS HAVE BEEN STEADILY INCREASING IN THE FAROE AND SHETLAND REGIONS.

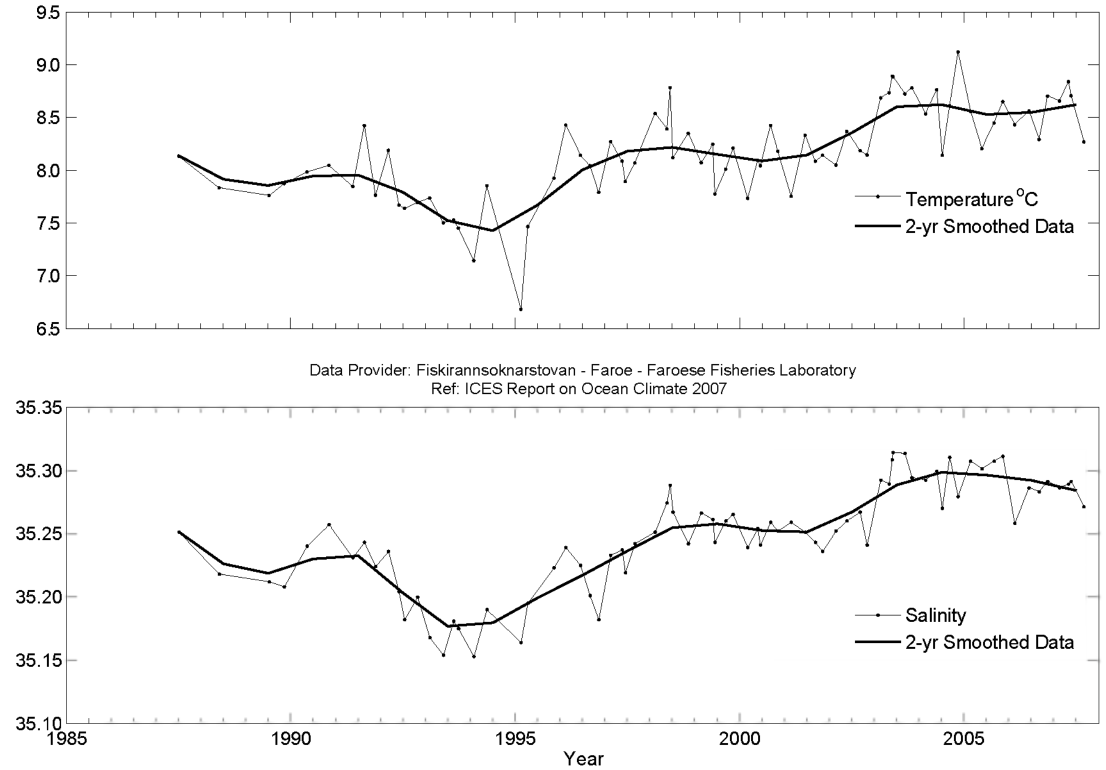


Figure 40.
Area 6 – Faroe Current. Temperature (upper panel) and salinity (lower panel) in the core of the Faroe Current (maximum salinity averaged over a layer 50 m in depth.

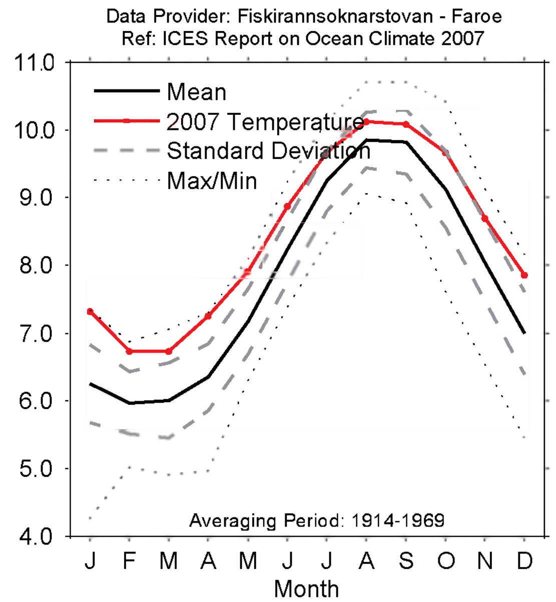


Figure 41.
Area 6 – Faroes coastal temperature. Monthly temperature data from the Faroe coastal stations Mykines (1914–1969, 69.10°N 7.66°W) and Oyrargjogv (1991 onwards, 62.12°N 7.17°W).

4.12 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 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.

The surface waters of the Faroe–Shetland Channel have generally increased in temperature and salinity over the past two decades, with record-high temperatures observed in 2003. Both temperature and salinity have declined slightly since 2003. Although salinity values were high in 2003, they have been at this level in the past.

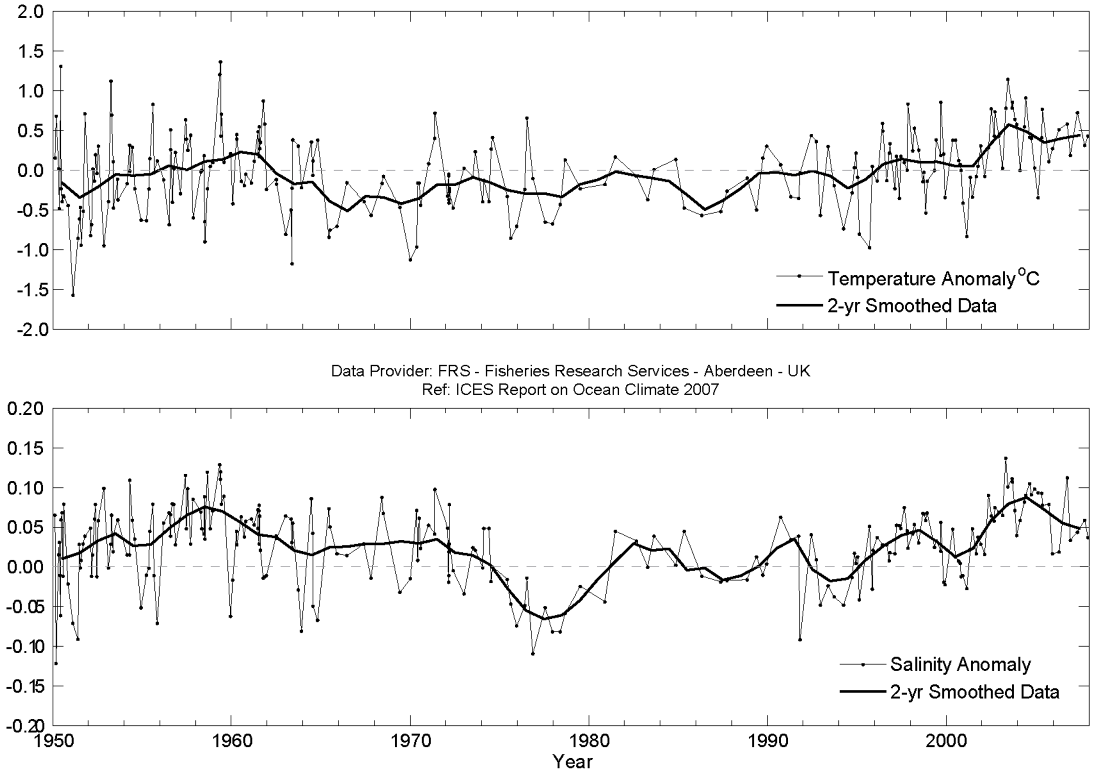


Figure 42.
Area 7 – Faroe–Shetland Channel. Temperature anomaly (upper panel) and salinity anomaly (lower panel) in the Atlantic Water in the Slope Current.

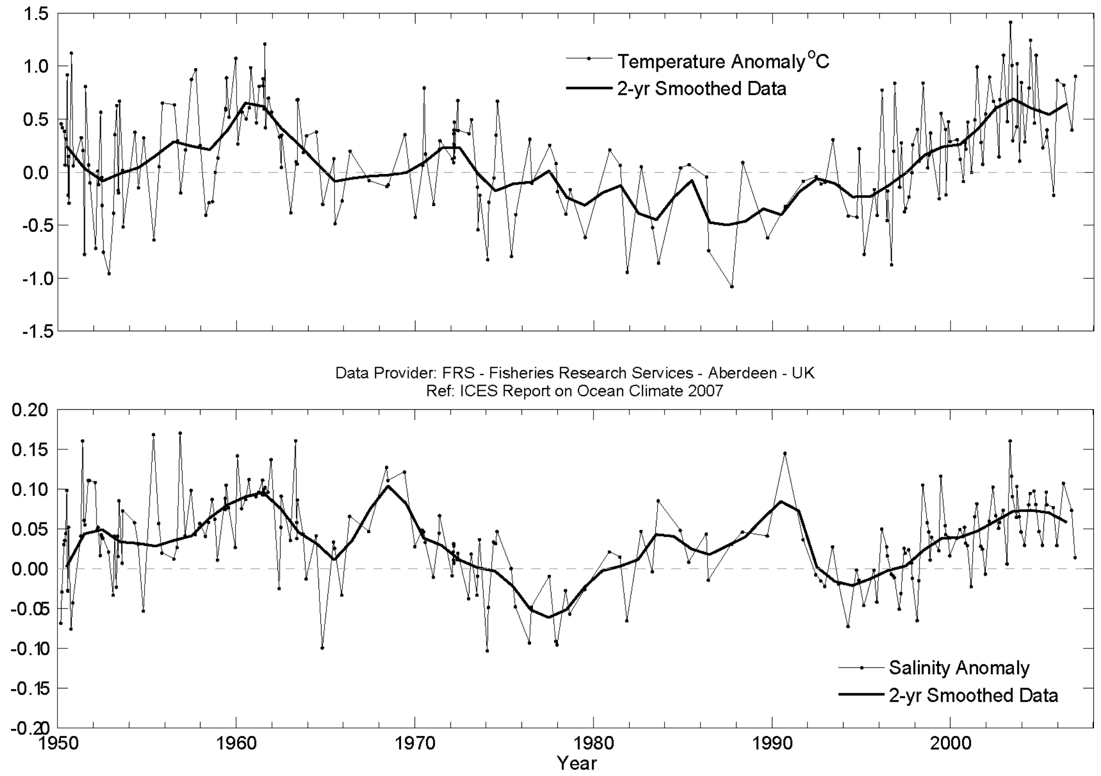


Figure 43.
Area 7 – Faroe–Shetland Channel. Temperature anomaly (upper panel) and salinity anomaly (lower panel) in the Modified Atlantic Water entering the Faroe–Shetland Channel from the north after circulating around Faroe.

► Since 1970, the sampling frequency in the Faroe–Shetland Channel has increased and, over that period, a decadal-scale cycle of temperature and salinity has emerged in the properties of the Atlantic Water, thought to be related to wider scale changes in atmospheric and oceanic circulation. This pattern is not as clear in the Modified North Atlantic Water, which travels into the Faroe–Shetland Channel from around the north of Faroe.

4.13 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 DEMONSTRATE STRONG DIFFERENCES IN THE NORTH SEA CIRCULATION, DEPENDING ON THE STATE OF THE NAO. THE ATLANTIC WATER MIXES WITH RIVER RUN-OFF AND LOWER SALINITY BALTIC OUTFLOW ALONG THE NORWEGIAN COAST. A BALANCE OF TIDAL MIXING AND LOCAL HEATING FORCES THE DEVELOPMENT OF A SEASONAL STRATIFICATION FROM APRIL/MAY TO SEPTEMBER IN MOST PARTS OF THE NORTH SEA.

Area-averaged SSTs of the North Sea have been increasing since June 2001. Owing to very mild winter temperatures, the vegetation period (primary production) was much longer than usual in 2007.

During the first months of 2007, mean SST in the North Sea clearly exceeded the long-term mean by 1.1–1.7°C, because of warm temperatures in autumn 2006 and extraordinarily warm air temperatures during April. January and April were the warmest (both +1.7°C) since the beginning of these observations in 1971. During the second half of 2007, area-averaged monthly SST values were comparable with the climatological means (1971–1993) showing anomalies between +0.5°C and +1.0°C.

Near-surface temperatures exhibit the typical gradient with increasing values from the open northern boundary towards the inner German

Bight. The spatial pattern is comparable with 2006, but temperatures are generally about 1–2°C cooler. The monthly averaged SST for August 2007 has a positive anomaly of only +0.5°C compared with +2.2°C in 2006.

The Helgoland Roads standard station demonstrates that, since the cold winter of 1996, SSTs have been above the 30-year mean (1971–2000), with positive anomalies of 0.5–1.0°C.

A VERY WARM START TO THE YEAR IN THE NORTH SEA.

Compared with 2006, the tongue of Atlantic Water (AW) with surface salinity (S >35) is much smaller and is restricted to the northern part of the North Sea. In 2006, this tongue was much broader and expanded southwards to about 55°N. The ribbon of less saline water (S <34) generated by continental river run-off and Baltic outflow is roughly comparable with 2006 in its horizontal extension, but is regionally much deeper, as in 2006 north of 56°N. The total North Sea salt content increased from 1.138 × 10^{12} tonnes in August 2006 to 1.143 × 10^{12} tonnes in August 2007, caused by higher salinity values in the shallower southern part of the North Sea.

In 2005, 2006, and 2007, run-off from the Elbe and Weser rivers was close to the long-term mean after a minimum run-off in 2004. In 2007, the monthly Elbe River run-off was below the long-term mean between March and June. April 2007 was the warmest and most arid April since 1901, with minimum precipitation in Germany; some areas had no precipitation during April. However, there were no significant variations from the long-term mean.

Temperature and salinity at two positions in the northern North Sea illustrate conditions in the Atlantic inflow (Figure 45). The first (Location A) is at the near bottom in the northwestern part of the North Sea, and the second (Location B) is in the core of the AW at the western shelf edge of the Norwegian Trench. Measurements were taken during summer and represent the previous winter's conditions. The average temperature at Location A was 1–2°C lower than at Location B, and salinity was also slightly lower. In both locations, there were high temperatures and salinities in 2005. This was the result of the high salinity of inflowing AW and the effect of a mild winter (though the relatively cold winter and spring of 2005 led to less extreme temperatures in the deep layers than in 2004).

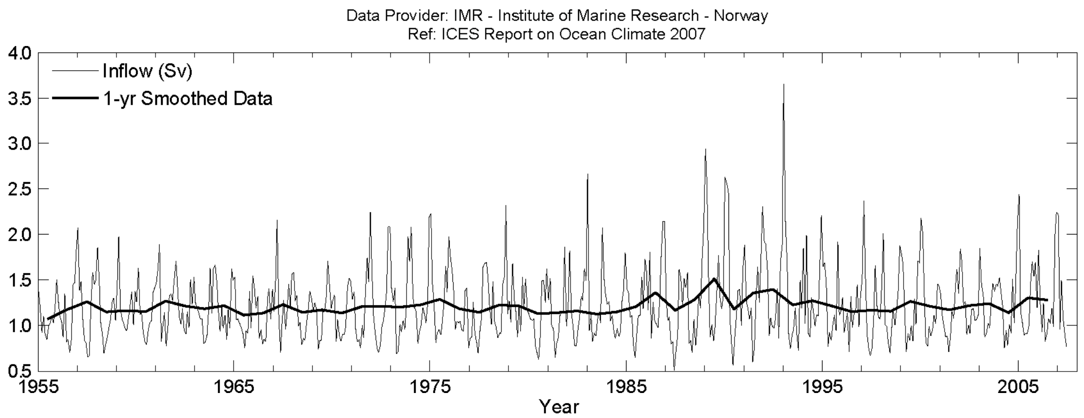


Figure 44.
Area 8 – Northern North Sea. Modelled annual mean (bold) and monthly mean volume transport of Atlantic Water into the northern and central North Sea southwards between the Orkney Islands and Utsira, Norway.

▶ In the Skagerrak, in addition to overall increased temperature, the length of the warm season has increased significantly over the last few 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 ecosystem dynamics in the North Sea and the Skagerrak.

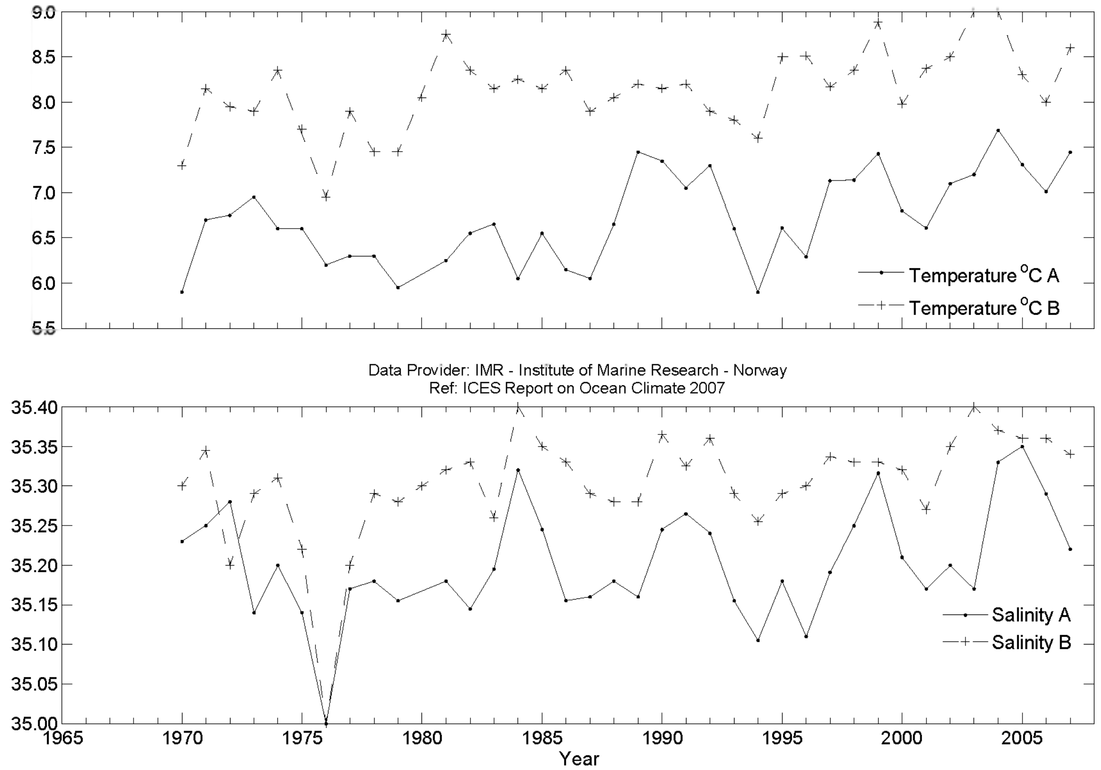


Figure 45.
Area 8 – Northern North Sea. Temperature (upper panel) and salinity (lower panel) near the seabed in the northwestern part of the North Sea (Location A) and in the core of Atlantic Water at the western shelf edge of the Norwegian Trench (Location B) during summers 1975–2007.

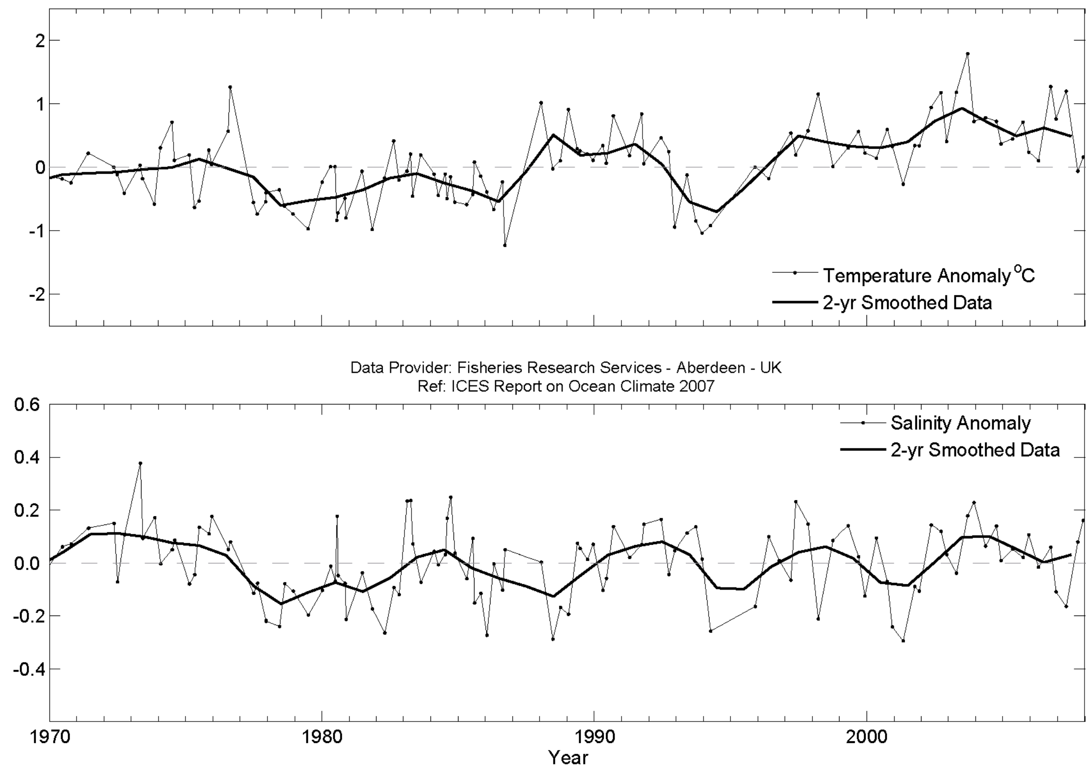


Figure 46.
Area 8 – Northern North Sea. Temperature anomaly (upper panel) and salinity anomaly (lower panel) in the Fair Isle Current entering the North Sea from the North Atlantic.

Figure 47.
Area 9 – Southern North Sea. Annual mean surface temperature anomaly (upper panel) and salinity anomaly (lower panel) at Station Helgoland Roads.

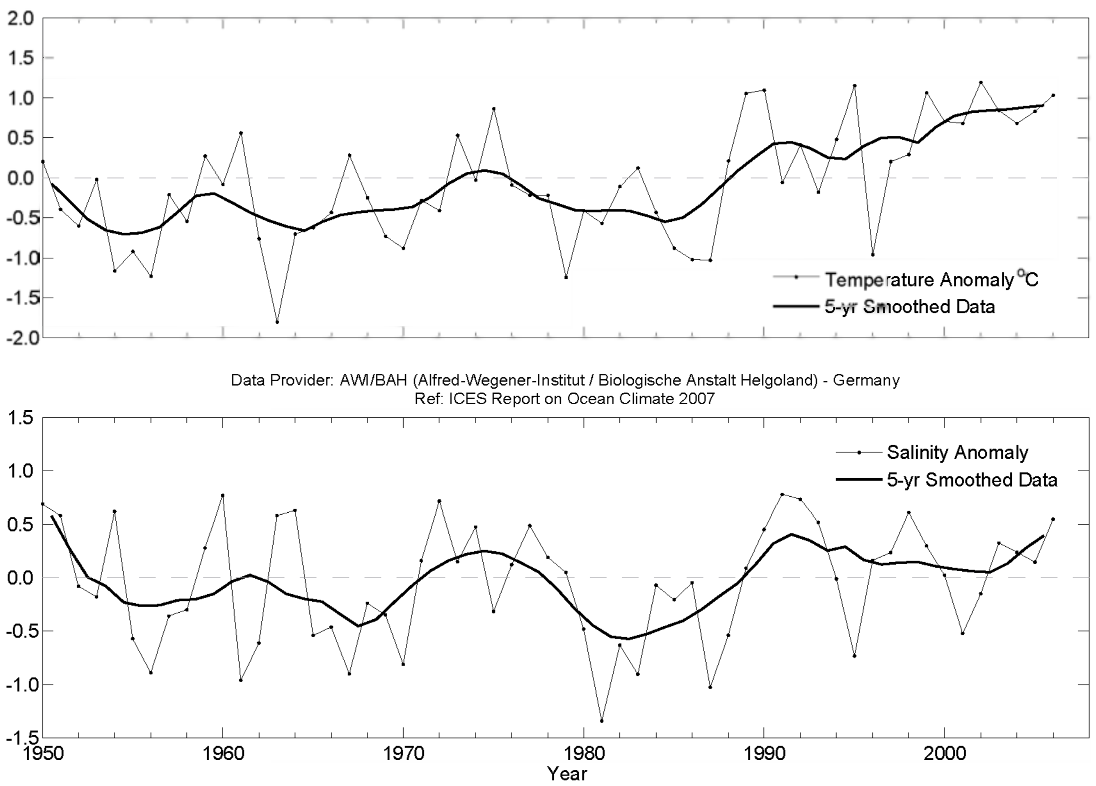
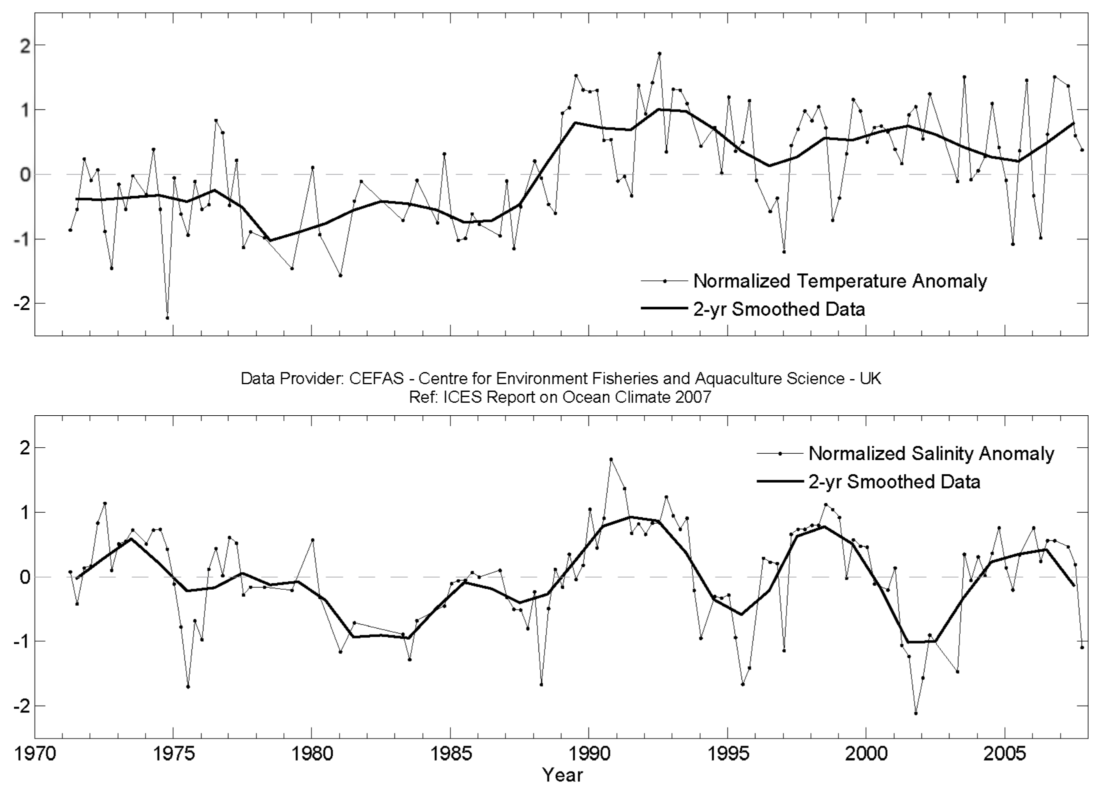


Figure 48.
Area 9 – Southern North Sea. Normalized sea surface temperature anomaly (upper panel) and salinity anomaly (lower panel) relative to 1971–2000, measured along 52°N, a regular ferry at six standard stations. The time-series reveals the seasonal section average (DJF, MAM, JJA, SON) of the normalized variable.



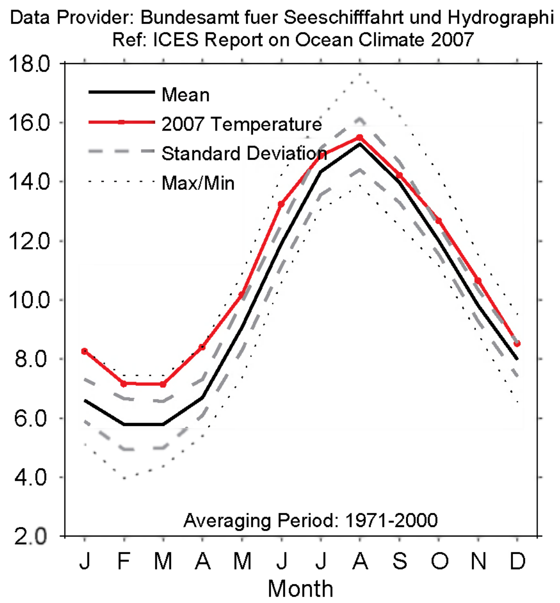


Figure 49.
Areas 8 and 9 – Northern and southern North Sea. North Sea area-averaged sea surface temperature (SST) annual cycle; monthly means based on operational weekly North Sea SST maps.

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

THE SEAS IN AREA 9B 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 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 IN THE SOUTHERN BALTIC, SMALLER INFLOWS PASS RELATIVELY QUICKLY, AND THE CONDITIONS IN THE DEEP WATER ARE VERY VARIABLE. SURFACE SALINITY IS VERY LOW IN THE BALTIC PROPER AND THE GULF OF BOTHNIA. THE LATTER AREA IS ICE COVERED DURING WINTER.

Owing to its central location relative to the Skagerrak, Kattegat, and Baltic, the weather in Sweden can be taken as representative for the area. Mean air temperature during 2007 was 1.5–2°C above normal in most parts of Sweden, but not quite as high as in 2006. January, March, and April were warmer than normal, and in June, a heat wave set in. As in the previous year, December 2007 was unusually warm. Precipitation was above normal throughout Sweden, and the fresh-water input to Skagerrak–Kattegat was large during January–March and July.

Sea surface temperature was well above normal at the beginning of the year in the whole area except Bothnian Bay. Warm weather in the first half of June also gave rise to higher-than-normal SSTs. This heating period ended in late June, earlier in the north than in the south. For the rest of the year, temperatures were close to normal.

There were a number of minor inflows of salty and oxygen-rich water to the Baltic, but none of them reached the deeper parts of the Baltic Proper where water was stagnant.

The freeze-up was late during winter 2006/2007, as in the previous ice season. In January 2007, ice cover was small, but at the end of the month and in February, cold weather in the north accelerated the ice growth. Maximum ice extent occurred early, by 23 February, and the ice winter was classified as mild.

AN UNUSUALLY WARM WINTER WITH LESS THAN NORMAL ICE EXTENT FOR THE BALTIC AREA.

Figure 50.
Area 9b – Skagerrak, Kattegat, and the Baltic. Surface temperature (upper panel) and surface salinity (lower panel) at Station BY15 (east of Gotland) in the Baltic proper.

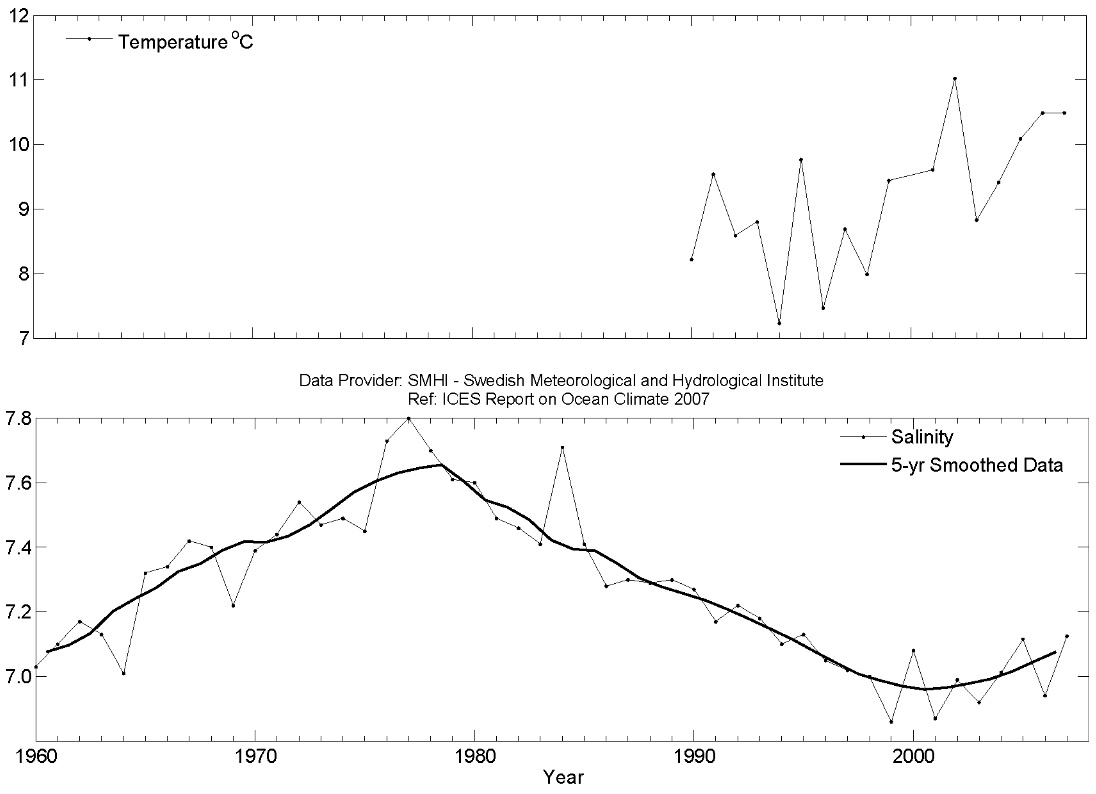


Figure 51.
Area 9b – Skagerrak, Kattegat, and the Baltic. Monthly surface temperature (left panel) and salinity (right panel) at Station BY15 (east of Gotland) in the Baltic proper.

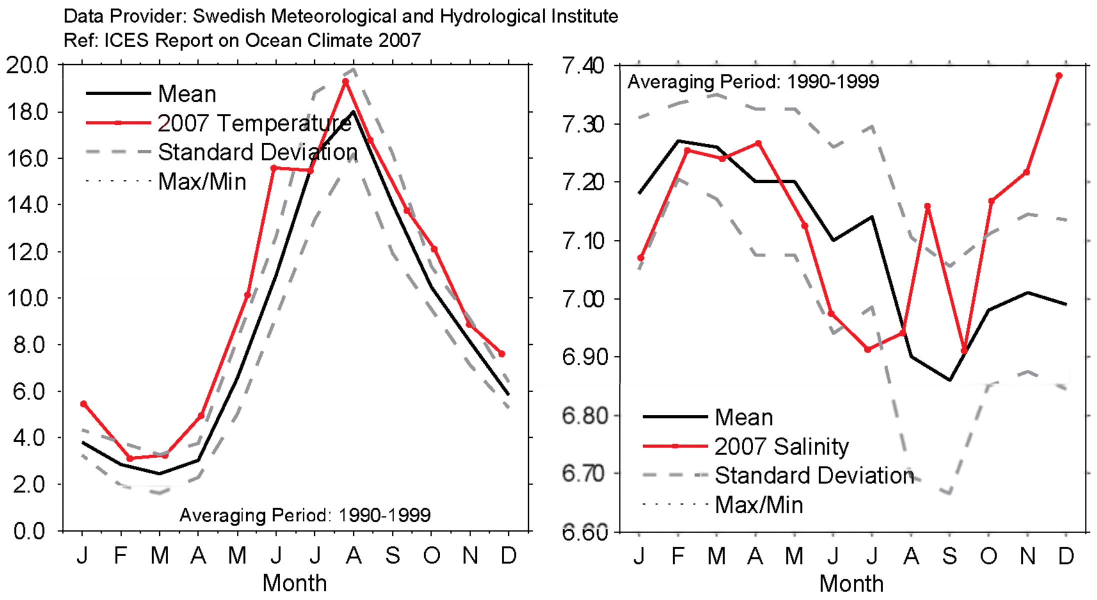


Figure 52.
Area 9b – Skagerrak, Kattegat, and the Baltic. Salinity at Station LL7 in the Gulf of Finland.

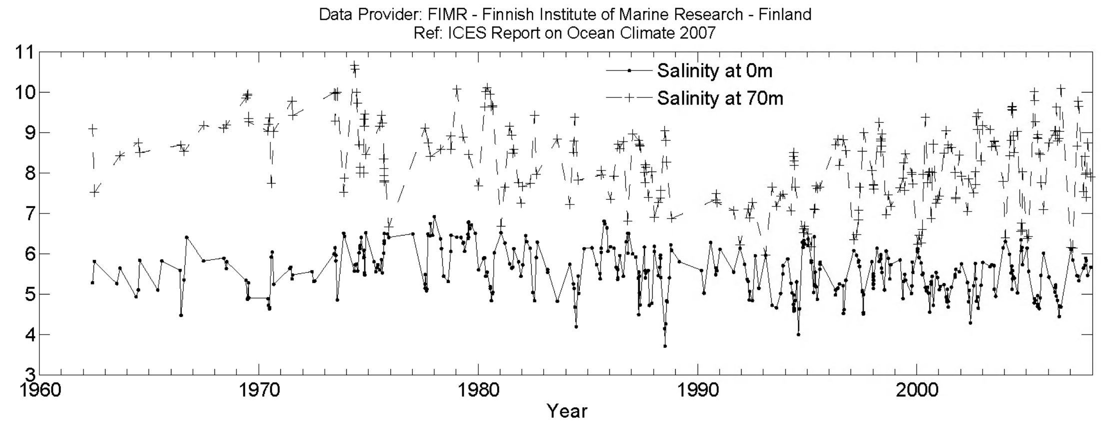


Figure 53.
Area 9b – Skagerrak, Kattegat, and the Baltic. Salinity at Station B03 in Bothnian Bay.

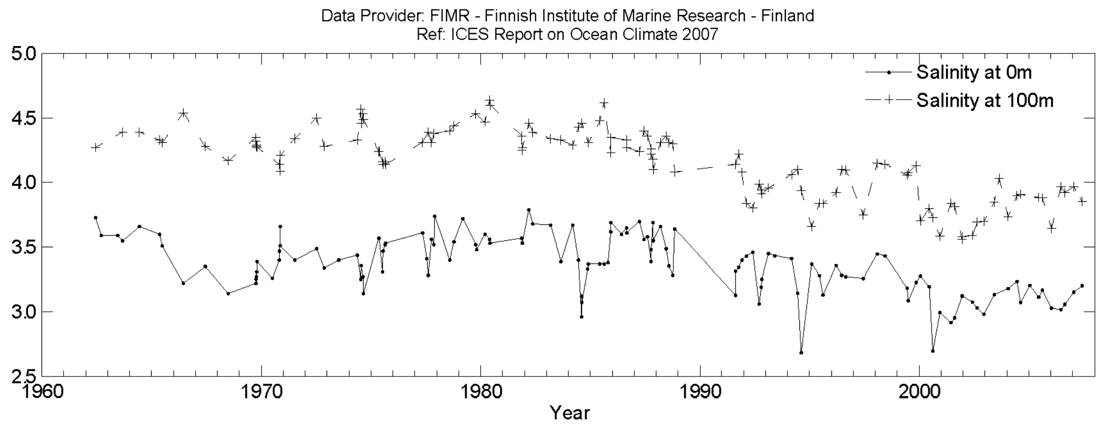


Figure 54.
Area 9b – Skagerrak, Kattegat, and the Baltic. Salinity at Station SR5 in the Bothnian Sea.

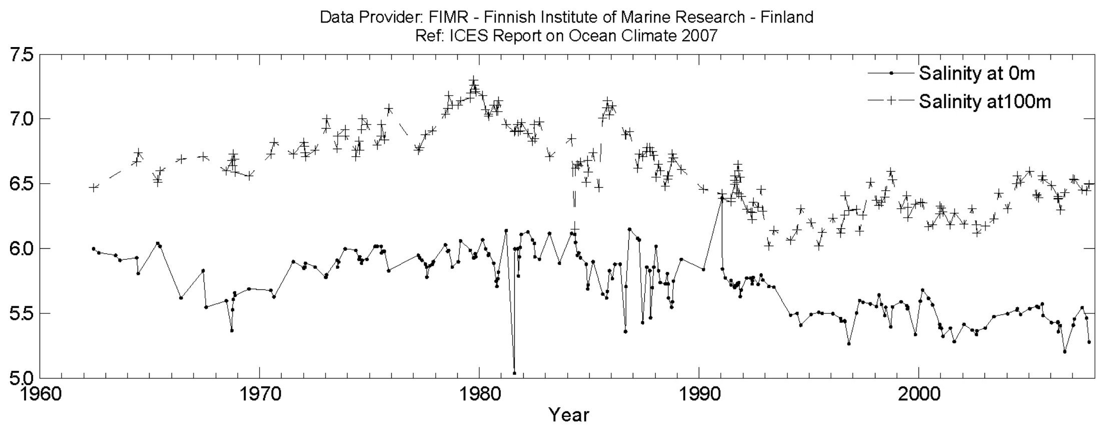
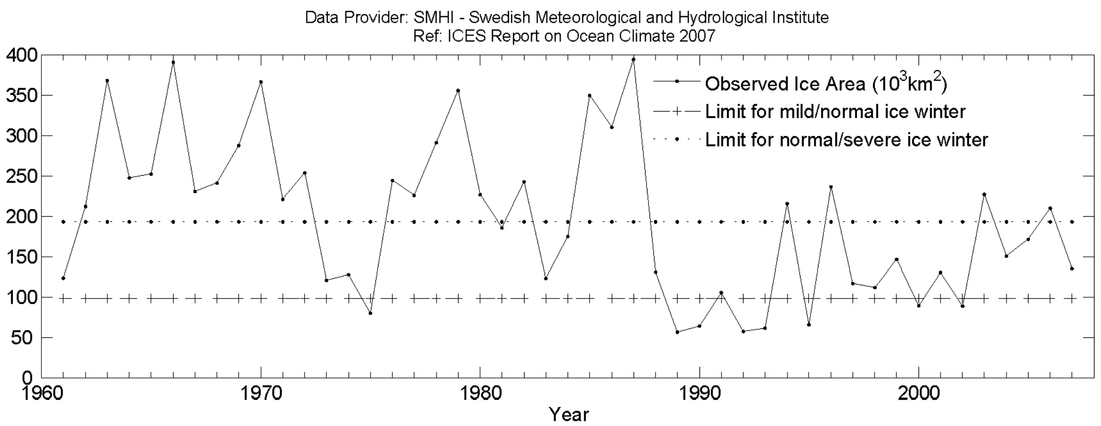


Figure 55.
Area 9b – Skagerrak, Kattegat, and the Baltic. The ice extent in the Baltic starting from 1961.



4.15 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. ATLANTIC WATER FLOWS NORTHWARDS AS THE NORWEGIAN ATLANTIC CURRENT, WHICH 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.

Three sections from south to north in the eastern Norwegian Sea show the development of temperature and salinity in the core of the AW (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 2007, temperature in the Svinøy section was the highest in the time-series. In the other sections, both temperature and salinity decreased from 2006 to 2007, but were still above the long-term mean.

In 2007, temperatures and salinities were 0.9°C, 0.4°C, and 0.6°C, and 0.05, 0.04, 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 AW in the Faroe–Shetland Channel.

Ocean Weather Station "M" located at 66°N 2°E revealed the 2007 temperature and salinity at 50 m to be above the long-term mean, although there was a slight decrease in both from 2004 values.

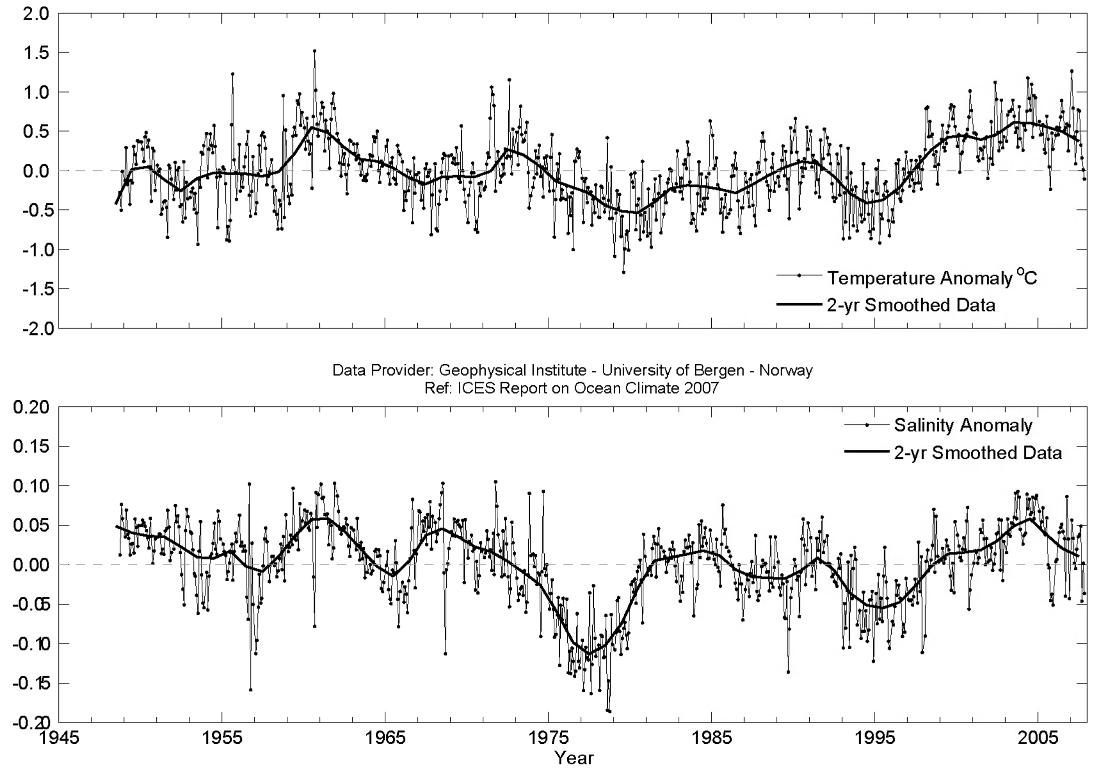


Figure 57.
Area 10 – Norwegian Sea. Temperature anomaly (upper panel) and salinity anomaly (lower panel) at 50 m at Ocean Weather Station "Mike" (66°N 2°E).

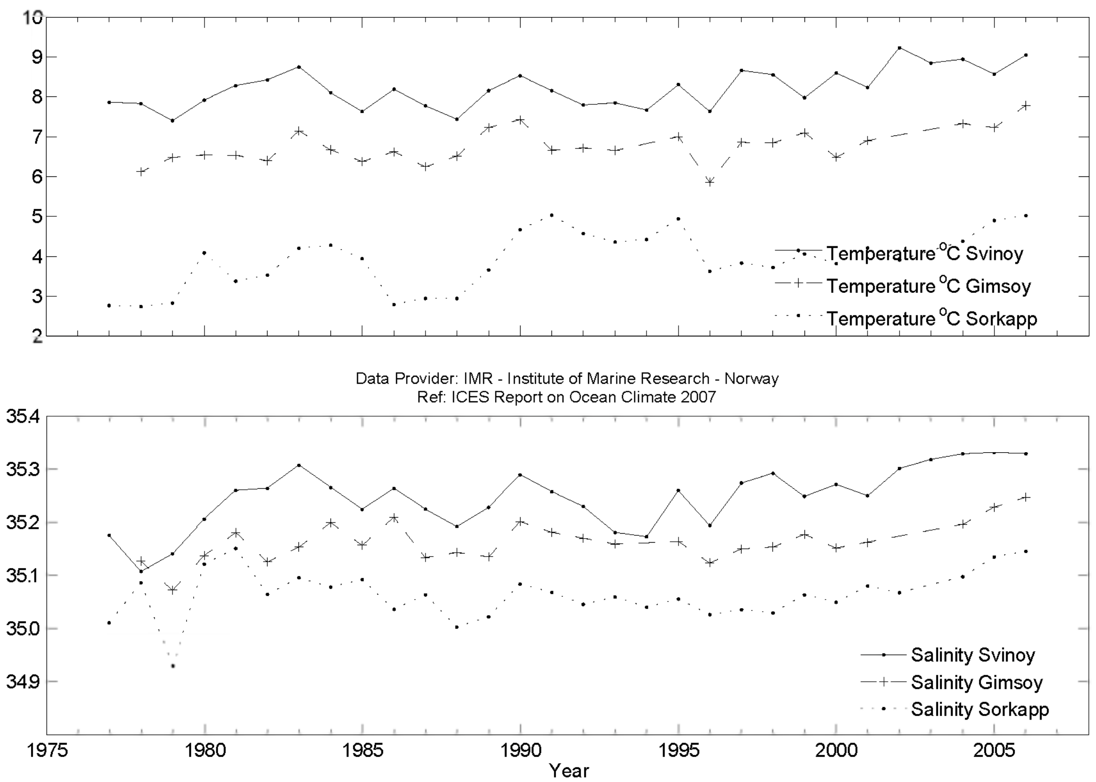


Figure 56.
Area 10 – Norwegian Sea. Average temperature (upper panel) and salinity (lower panel) above the slope at three sections, Svinøy (63°N), Gimsøy (69°N), and Sørkapp (76°N).

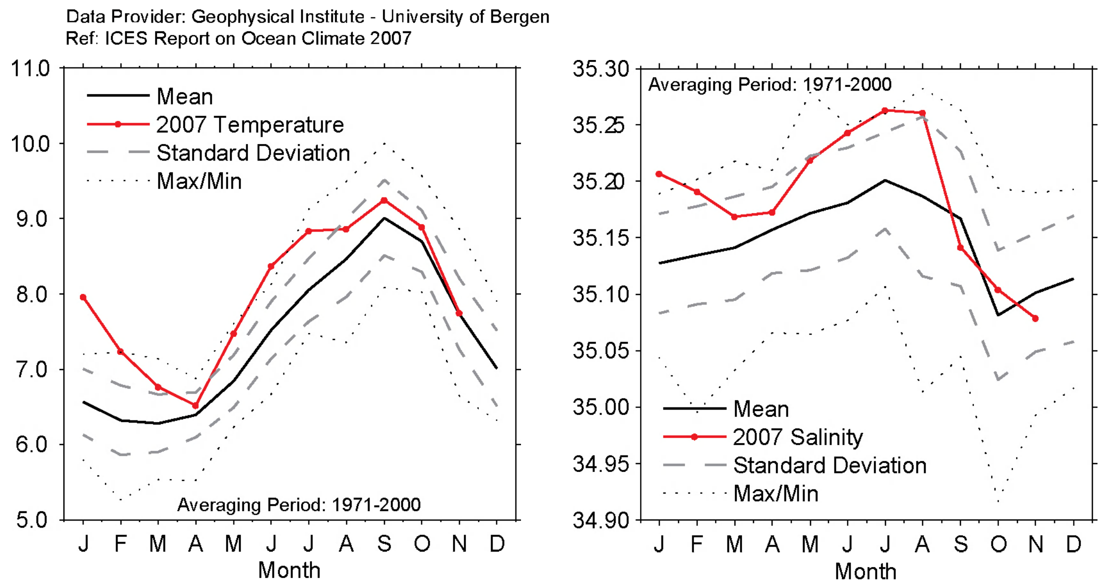


Figure 58.
Area 10 – Norwegian Sea. Monthly temperature (left panel) and salinity (right panel) at 50 m at Ocean Weather Station "Mike" (66°N 2°E).

HIGH SALINITY VALUES REFLECT SALTIER ATLANTIC WATER AT OCEAN WEATHER STATION "MIKE".

4.16 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. CONSEQUENTLY, HEAT CONTENT AND ICE COVERAGE IN THE BARENTS SEA ALSO SHOW LARGE FLUCTUATIONS.

After a period with high temperatures in the first half of the 1990s, 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, temperature in the western area increased to just above average, whereas temperature in the eastern areas remained below 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. Since then, temperature has stayed above average.

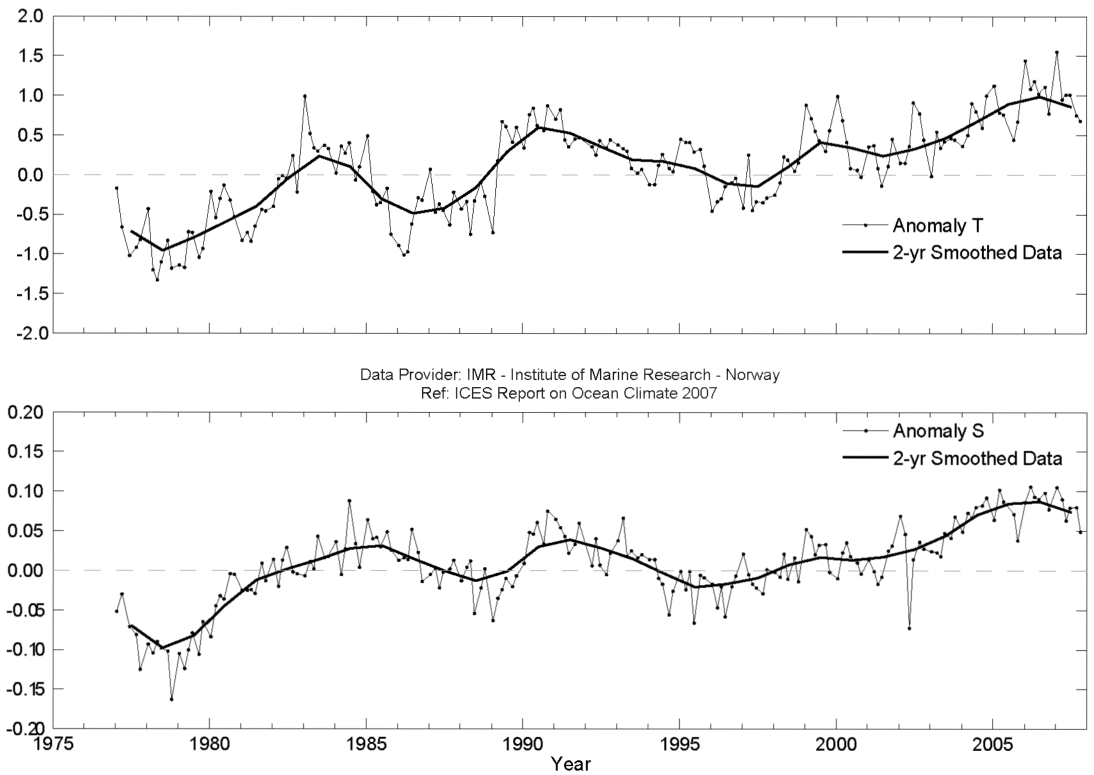
In the southern Barents Sea, water temperature anomalies in 2007 were about 1°C above the long-term means. Temperature of the Atlantic Waters varied between 0.7°C and 1.7°C higher than normal throughout the year, depending on time and place.

During the first half of the year, positive anomalies were predominantly higher than during the second half. Temperature conditions in 2007 were generally close to those in 2006, the warmest year ever observed in the Barents Sea. The total ice extent of the sea was much lower throughout the year than the long-term average, and sea ice was not observed during winter south of 76°N.

Current measurements showed that 2006 was an extreme year, with both the highest (in winter) and lowest (in spring) inflow observed. At the beginning of 2007, inflow had increased to just below the long-term mean, but then underwent another strong decrease during spring 2007. Data are only available until summer 2007, but wind conditions during autumn 2007 indicate a relatively weak inflow also in the last part of the year. Because inflow was very low in 2007 compared with earlier years, it is expected to increase in 2008.

Water temperature in the Barents Sea in 2008 is expected to be higher than the long-term mean. As inflow is expected to increase after the weak inflow in 2007, temperature will probably be as high as or even higher than in 2007.

Figure 59.
Area 11 – Barents Sea. Temperature anomaly (upper panel) and salinity anomaly (lower panel) in the Fugløya–Bear Island Section.



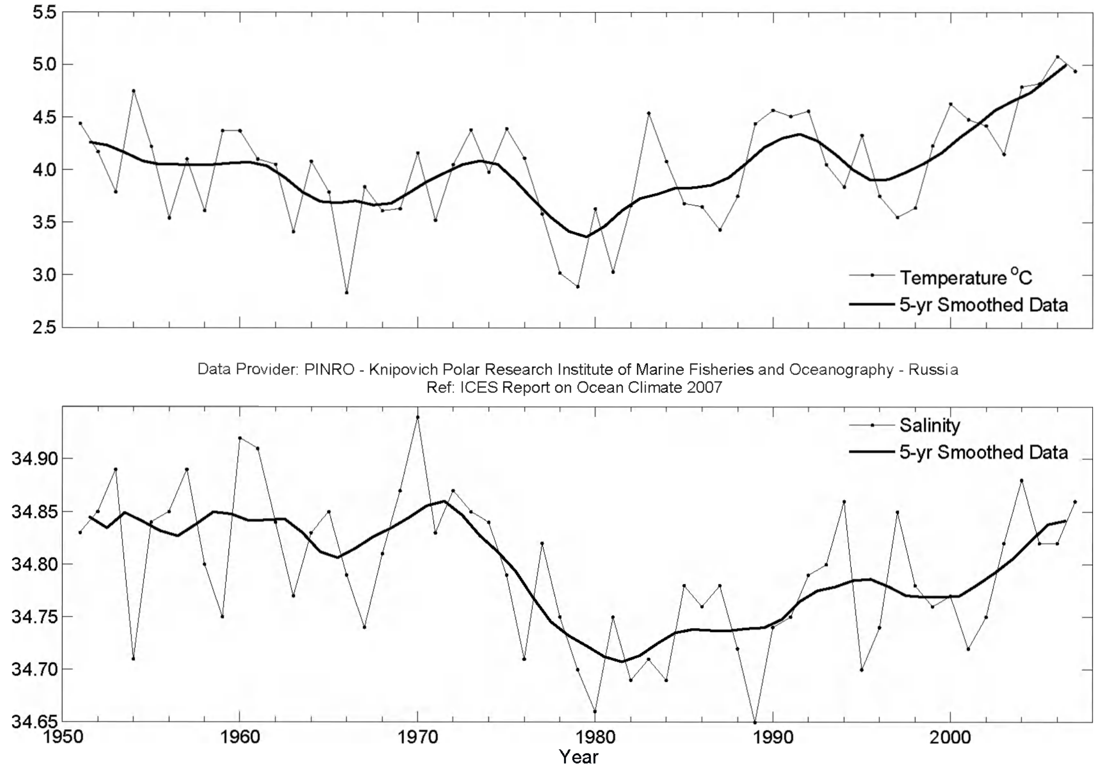


Figure 60.
Area 11 – Barents Sea. Temperature (upper panel) and salinity (lower panel) in the Kola Section (0–200 m).

4.17 Area 12 – Greenland Sea and Fram Strait

FRAM STRAIT IS THE NORTHERN BORDER OF THE NORDIC SEAS. IT IS THE DEEPEST PASSAGE CONNECTING THE ARCTIC TO THE REST OF THE WORLD OCEAN AND ONE OF THE MAIN ROUTES WHEREBY ATLANTIC WATER (AW) ENTERS THE ARCTIC (THE OTHER IS THE BARENTS SEA). ATLANTIC WATER IS CARRIED NORTHWARDS BY THE WEST SPITSBERGEN CURRENT, AND VOLUME AND HEAT FLUXES DEMONSTRATE STRONG SEASONAL AND INTERANNUAL VARIATIONS. A SIGNIFICANT PART OF THE AW ALSO RECIRCULATES WITHIN FRAM STRAIT AND RETURNS SOUTHWARDS (RETURN ATLANTIC WATER). POLAR WATER FROM THE ARCTIC OCEAN FLOWS SOUTHWARDS IN THE EAST GREENLAND CURRENT AND AFFECTS WATER MASSES IN THE NORDIC SEAS.

Although a slight decrease in AW temperature and a further drop in salinity occurred in the Greenland Sea (75°N) in 2007 relative to 2006, they were still much higher than their long-term averages. At the western boundary, the salinity of Return Atlantic Water (RAW) dropped significantly in 2007 from the record high in 2006, as did temperature, which returned to the long-term mean.

Also, in southern Fram Strait, at 76°30′N, the averaged properties of AW in the West Spitsbergen Current (WSC) were slightly lower than in 2006, but still higher than the long-term means. Both temperature and salinity trends for this period are positive (maximum temperature was 3.93°C and maximum salinity 35.11).

In northern Fram Strait at 78°50′N, three characteristic areas can be distinguished in relation to the main flows: the 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 2007, temperature and salinity from the upper layer (50–500 m) in the WSC, which had been increasing for the last three years, dropped significantly from 2006, but were still much above their long-term averages. In the AW recirculating with the RAC, temperature and salinity were close to 2006 values. Also, mean properties in the EGC remained similar to those recorded in 2006, still significantly exceeding the long-term average. Because ice conditions prevented sampling in western Fram Strait, a small increase in mean temperature in the EGC domain most likely resulted from excluding a significant part of the area occupied by cold Polar Water.

The increase in temperature and salinity, which has been observed in the RAC and EGC since 2003, is related to the westward shift of the boundary between the recirculating Atlantic and Polar Waters. The hydrographic properties of AW (defined as water mass with T >2°C and S >34.92) based on summer sections, which had revealed a clear positive trend over the previous seven years, dropped significantly in 2007. Also, the area of the cross section occupied by AW (a proxy for the amount of AW in Fram Strait), declined after five years of steady increase.

In 2007, although the westward limit of the recirculating AW was not reached, the observed AW layer thickness at the western end of the section suggested that it continued even farther west. Although thickness of the AW layer in the WSC in summer 2007 was clearly lower than in 2006, the AW layer was even thicker in the central and deep western part of Fram Strait than the previous year. The maximum AW temperature and thickness were found in late winter and early spring.

The northward flow, and consequently the volume transport, in the WSC from mooring data was very high in winter and spring (similar to extreme values from 2005), but dropped significantly in summer 2007. Accompanied by high temperatures, the increased volume flux resulted in a very high heat flux in winter, followed by a decrease in spring and extremely low values in summer. The winter-centred averages of volume and heat transport in the WSC in 2006/2007 remained similar to the previous year. In summer 2007, an extreme extent of very thick and compact sea ice as well as an enormously fast southward drift were observed in northern Fram Strait.

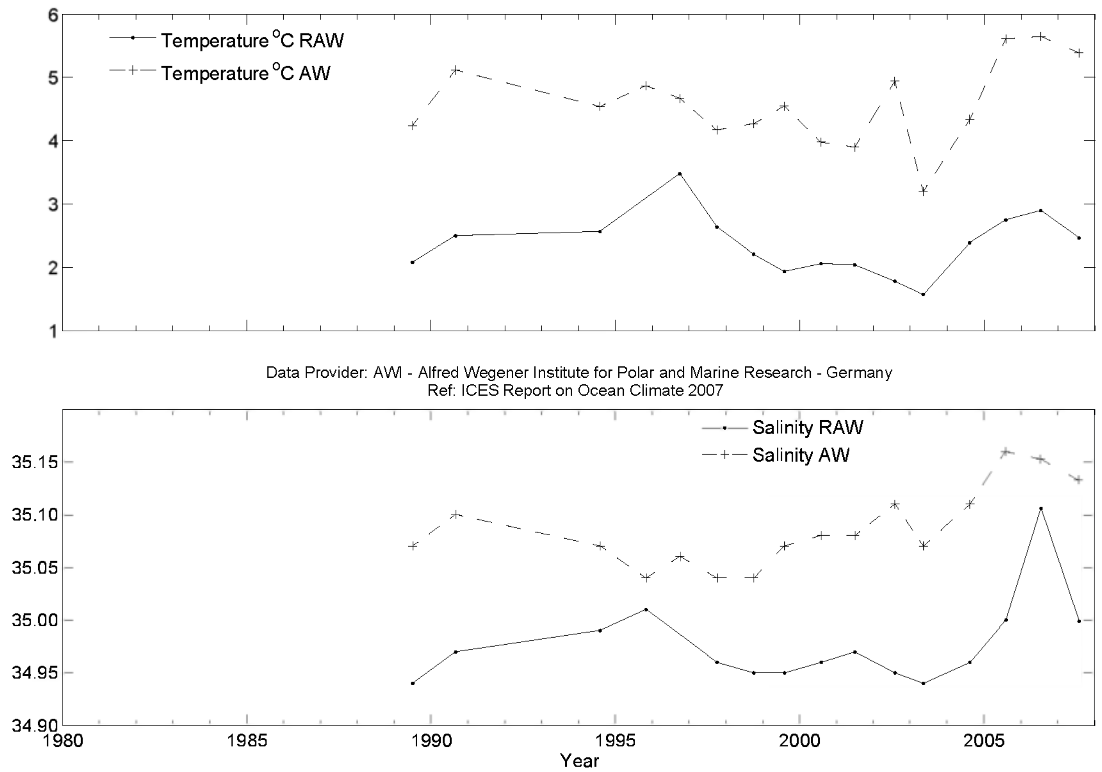


Figure 62.
Area 12 – Greenland Sea and Fram Strait. Temperature (upper panel) and salinity (lower panel) anomalies of the Atlantic Water (AW) and Return Atlantic Water (RAW) in the Greenland Sea Section at 75°N. AW properties are 50–150 m averages at 10–13°E. The RAW is characterized by temperature and salinity maxima below 50 m averaged over three stations west of 11.5°W

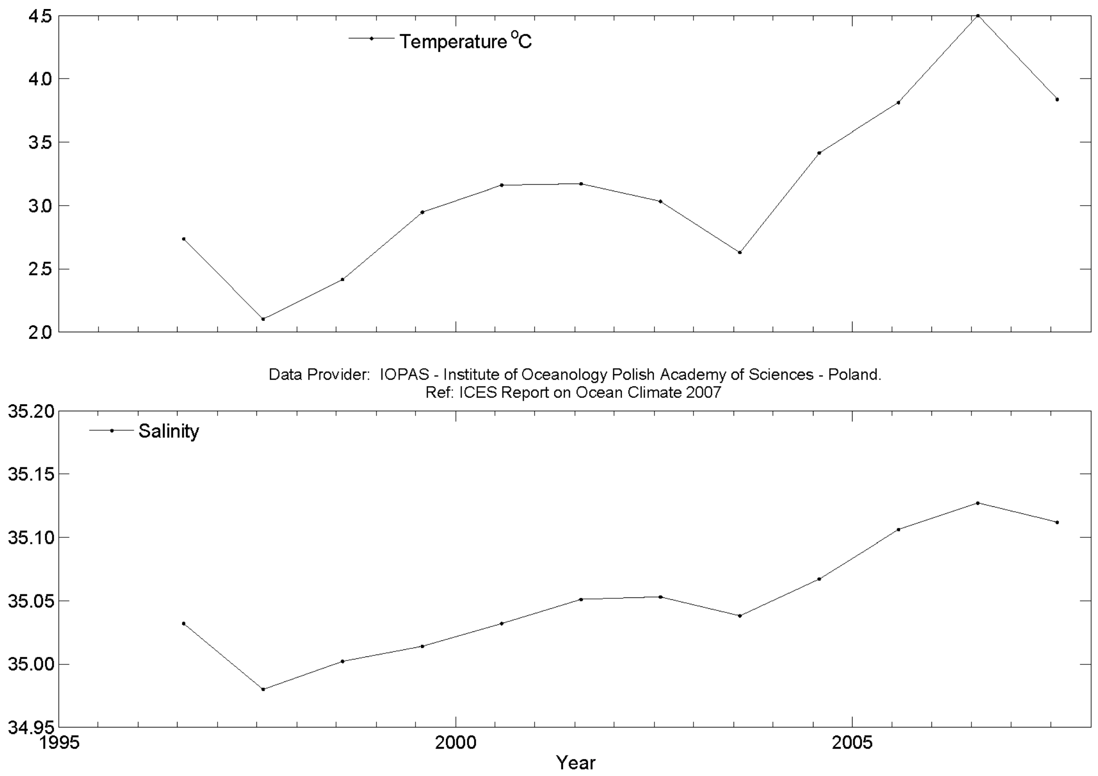


Figure 61.
Area 12 – Greenland Sea and Fram Strait. Temperature (upper panel) and salinity (lower panel) at 200 m in the Spitsbergen Section (76°30'N).

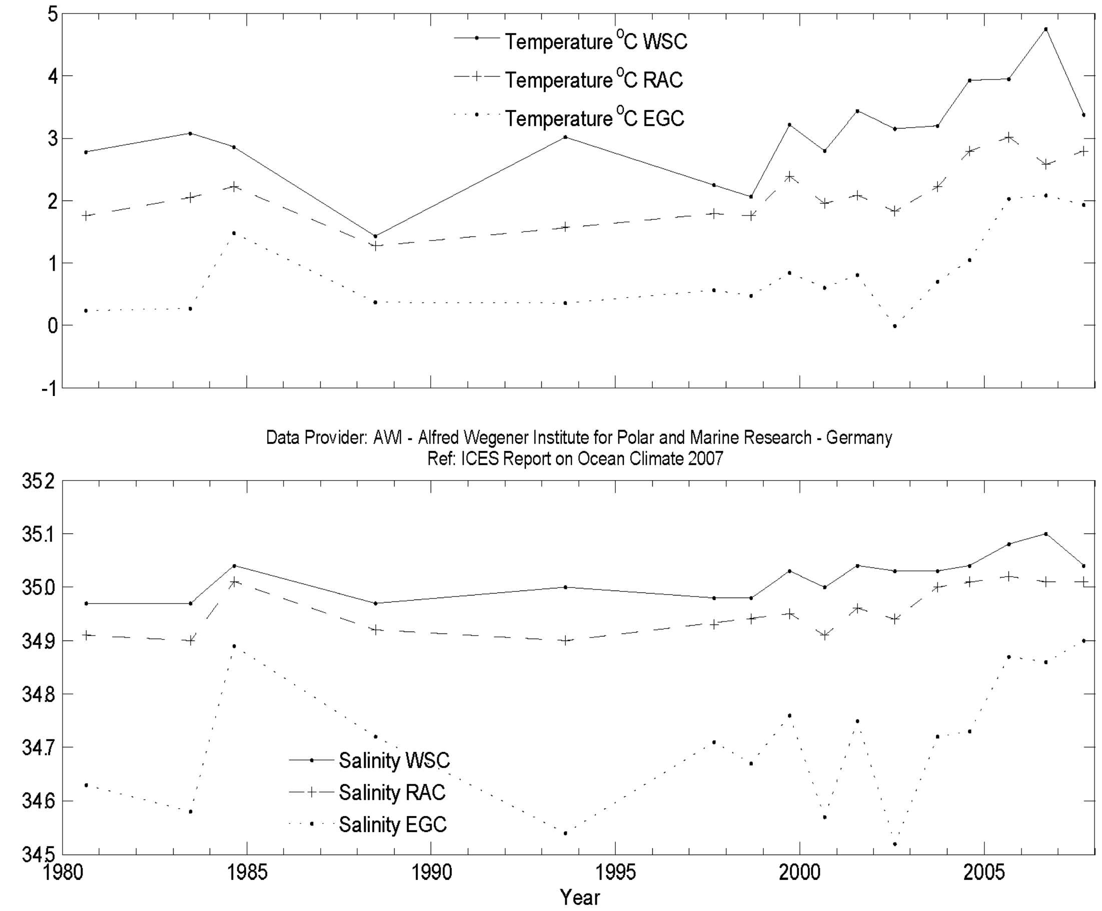


Figure 63.
Area 12 – Greenland Sea and Fram Strait. Temperature (upper panel) and salinity (lower panel) anomalies in Fram Strait (78°50'N), in the West Spitsbergen Current (WSC) between the shelf edge and 5°E, Return Atlantic Current (RAC) between 3°W and 5°E, and Polar Water in the East Greenland Current (EGC) between 3°W and the Greenland Shelf for the 50–500 m layer.

VERY THICK AND COMPACT SEA ICE WAS OBSERVED IN NORTHERN FRAM STRAIT DURING SUMMER 2007.

5. DETAILED AREA DESCRIPTIONS, PART II: THE DEEP OCEAN

5.1 Introduction

In this section, we focus on the deeper waters of the Nordic Seas and North Atlantic, typically below 1000 m. The general circulation scheme and dominant water masses are given in Figure 64.

AT THE NORTHERN BOUNDARY OF OUR REGION OF INTEREST, THE COLD AND DENSE OUTFLOW FROM THE ARCTIC OCEAN ENTERS FRAM STRAIT AND REACHES THE GREENLAND SEA. THE OUTFLOW IS A MIXTURE OF EURASIAN AND CANADIAN BASIN DEEP WATERS AND UPPER POLAR DEEP WATER. THE EURASIAN DEEP WATER FEEDS THE DENSEST WATER OF ALL NORDIC SEAS, THE GREENLAND SEA BOTTOM WATER. THE CANADIAN BASIN DEEP WATER AND UPPER POLAR DEEP WATER SUPPLY THE ARCTIC INTERMEDIATE WATER IN THE GREENLAND SEA, AND THE LATTER ALSO INCLUDES PRODUCTS OF THE WINTER CONVECTION.

THE DEEP SOUTHWARD OUTFLOW FROM THE NORTH ATLANTIC IN THE DEEP WESTERN BOUNDARY CURRENT IS FED BY THE COLD AND DENSE OVERFLOW WATERS. THE DEEPEST AND DENSEST IS THE DENMARK STRAIT OVERFLOW WATER. THIS WATER MASS ORIGINATES IN THE ARCTIC INTERMEDIATE WATER PRODUCED IN THE GREENLAND AND ICELAND SEAS BY WINTER CONVECTION AND MIXING WITH SURROUNDING WATER MASSES. THE DENMARK STRAIT OVERFLOW WATER SINKS TO THE BOTTOM AS IT PASSES THROUGH THE DENMARK STRAIT SILL, VIGOROUSLY ENTRAINING AMBIENT WATER. DOWNSTREAM, IT IS OVERLAIN BY AN INTERMEDIATE WATER MASS, THE LABRADOR SEA WATER, FORMED BY DEEP WINTER CONVECTION IN THE LABRADOR SEA. THE MIDDLE LAYER OF THE DEEP, COLD WATER EXPORT IN THE DEEP WESTERN BOUNDARY CURRENT IS SUPPLIED BY THE ICELAND SCOTLAND OVERFLOW WATER ORIGINATING IN WATER MASSES FORMED IN THE NORWEGIAN SEA (ARCTIC INTERMEDIATE WATER AND NORTH ATLANTIC DEEP WATER). PASSING THROUGH THE ICELANDIC BASIN, THE ICELAND SCOTLAND OVERFLOW WATER ALSO ENTRAINS UPPER OCEAN WATER AND LABRADOR SEA WATER. THE DEEP ANTARCTIC BOTTOM WATER ENTERS THE NORTH ATLANTIC ON THE WESTERN SIDE AND SOME AMOUNT OF THE LOWER DEEP WATER ACCOMPANIES THE INFLOW OF MEDITERRANEAN WATER ON THE EASTERN SIDE.

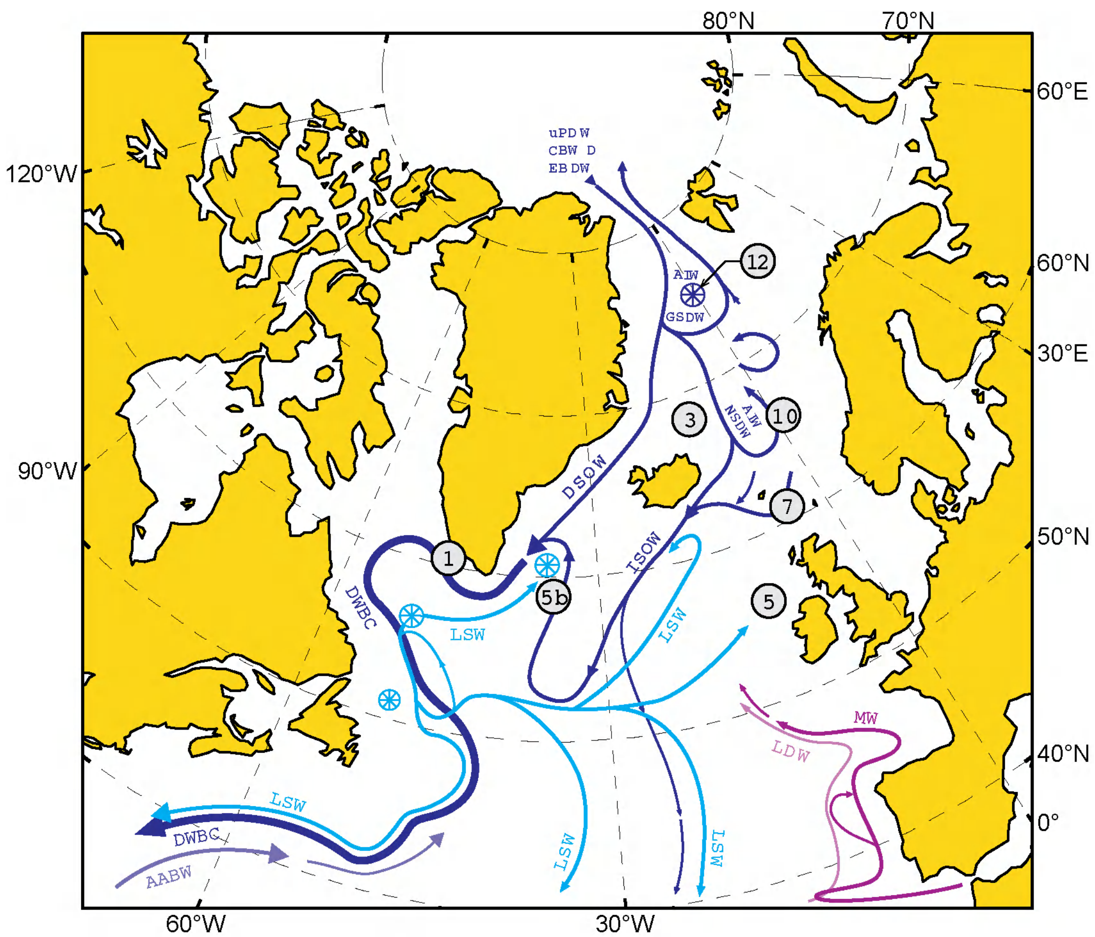


Figure 64. *Schematic circulation of the intermediate-to-deep waters in the Nordic Seas and North Atlantic. CBDW – Canadian Basin Deep Water; EBDW – Eurasian Basin Deep Water; AIW – Arctic Intermediate Water; GSDW – Greenland Sea Deep Water; NSDW – Norwegian Sea Deep Water; DSOW – Denmark Strait Overflow Water; ISOW – Iceland Scotland Overflow Water; LSW – Labrador Sea Water; DWBC – Deep Western Boundary Current; AABW – Antarctic Bottom Water; MW – Mediterranean Water; LDW – Lower Deep Water. Possible convection regions marked by circled stars.*

5.2 Nordic Seas deep waters

The deep waters of the Greenland, Iceland, and Norwegian seas are all warming. The longest time-series (the Norwegian Sea, Area 10) reveals warming from the mid-1980s; however, a slight decrease in temperature occurred in 2007. The continuous warming has been observed in the Greenland Sea deep layer at 3000 m (Area 12) and in the Iceland Sea in the depth range 1500–1800 m since the beginning of the time-series (early 1990s, Area 3). The warming rates per decade are 0.13°C (Greenland Sea), 0.06°C (Norwegian Sea), and 0.06°C (Iceland Sea). The source of the warming is the deep outflow from the Arctic Ocean, a south-going current of the Eurasian and Canadian Basin Deep Waters and upper Polar Deep Water found on the western side of Fram Strait around a depth of 2000 m. The Greenland Sea Deep Water is warming fastest owing to the most direct contact with this Arctic outflow, whereas the Iceland and Norwegian Seas are warming more slowly because they are products of mixing between their own ambient waters with Greenland Sea Deep Water and Arctic outflow water.

The doming structure in the Greenland Gyre is being replaced by a two-layered water mass arrangement, after a cessation of deep convection. Since the beginning of measurements in 1993, the winter convection depth has varied between 700 m and 1600 m, and only in small-scale convective eddies was it significantly deeper. In winter 2006/2007, the maximum convection depth was estimated to be 1200 m, similar to that observed the previous winter. The Greenland Sea Deep Water had previously included a small admixture of surface fresh water through the convective process and, therefore, had a lower salinity than the Arctic outflow waters. The observed increase in the Greenland Sea Deep Water salinity is likely an adjustment to the Arctic outflow in the continued absence of deep convection. It is not clear that there has been any corresponding salinity trend in either the Norwegian or Iceland Sea Deep Waters in recent decades. After some decrease in the early 1990s, salinity in both deep basins has remained relatively stable the last decade.

THE DEEP WATERS OF THE GREENLAND, ICELAND, AND NORWEGIAN SEAS ARE ALL WARMING.

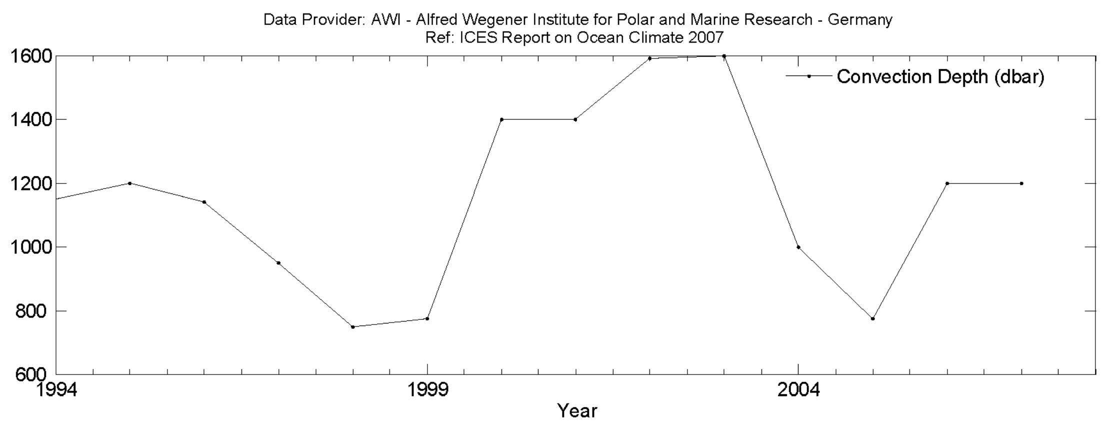


Figure 65. *Area 12 – Greenland Sea and Fram Strait. Winter convection depths in the Greenland Sea Section at 75°N.*

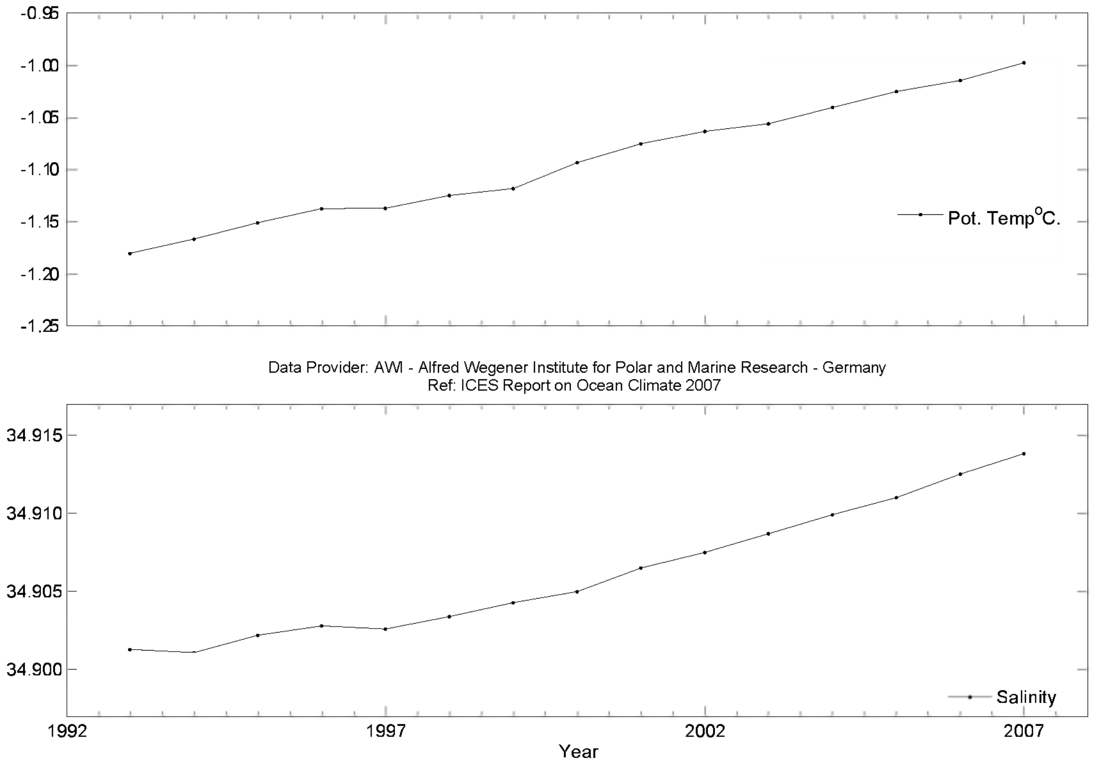


Figure 66.
Area 12 – Greenland Sea and Fram Strait. Temperature (upper panel) and salinity (lower panel) at 3000 m in the Greenland Sea Section at 75°N.

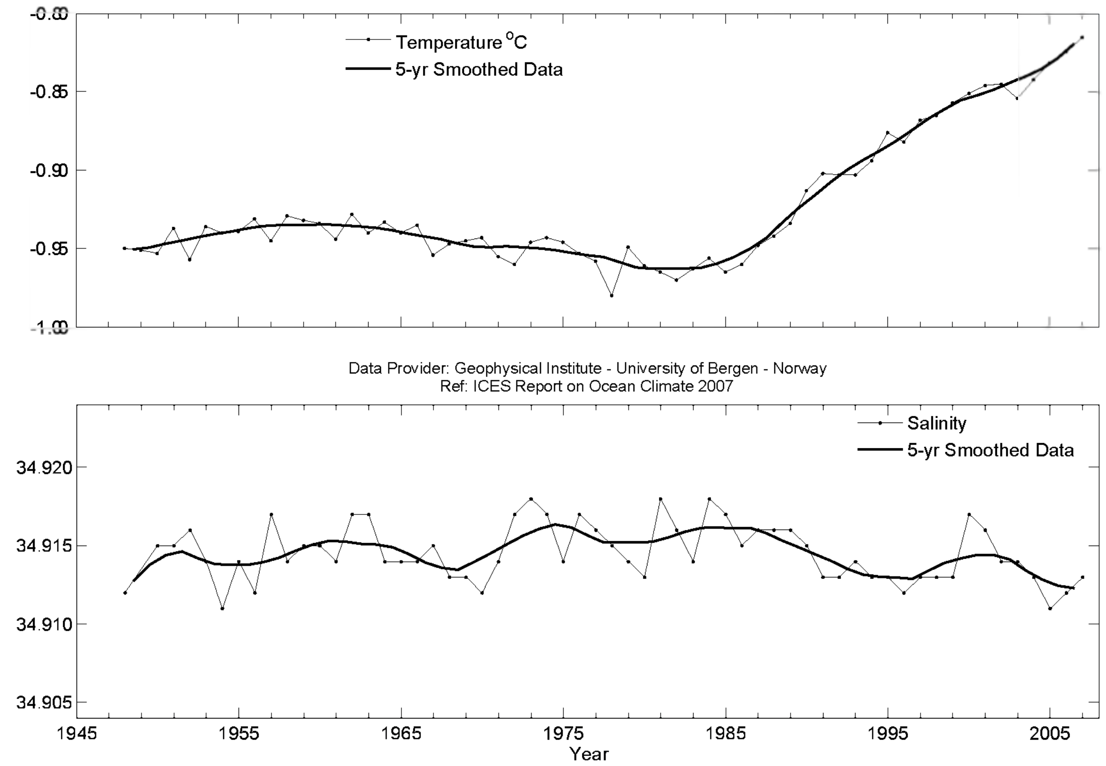


Figure 68.
Area 10 – Norwegian Sea. Temperature (upper panel) and salinity (lower panel) at 2000 m at Ocean Weather Station "Mike" (66°N 2°E).

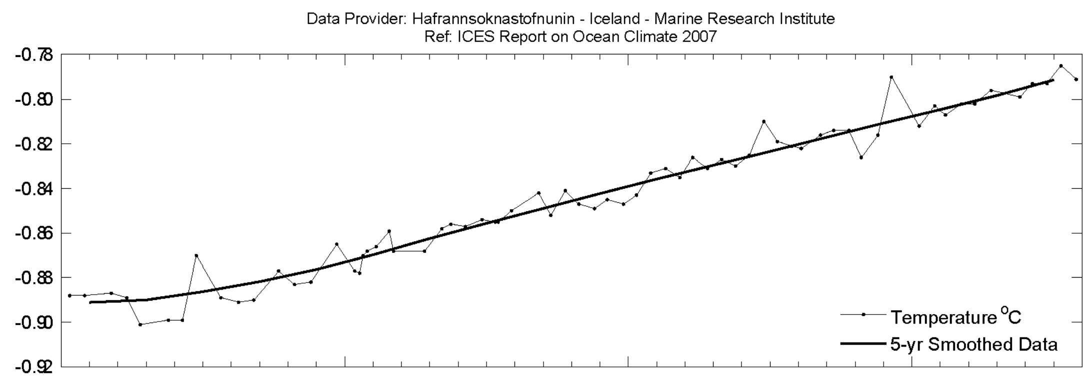


Figure 67.
Area 3 – Icelandic Waters. Temperature at 1500–1800 m in the Iceland Sea (68°N 12°40′W).

5.3 North Atlantic deep waters

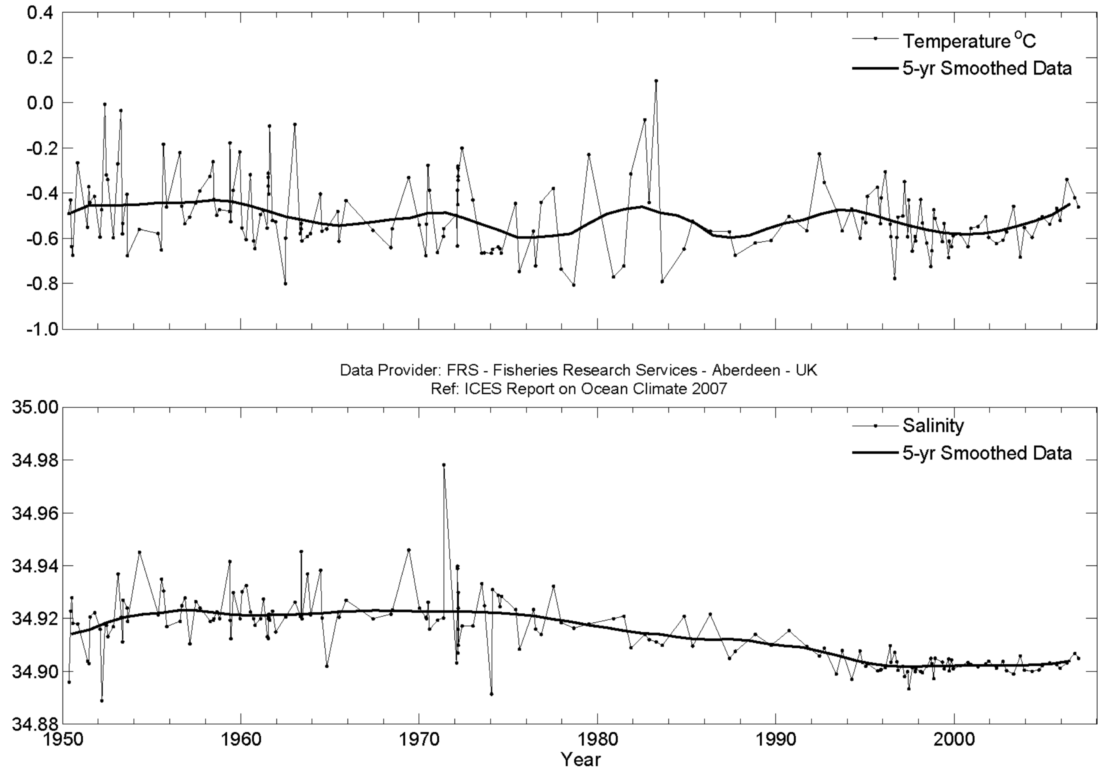
In the deep layers of the Faroe–Shetland Channel (Area 7), the properties at 800 m are the same as those of Norwegian Sea Deep Water as it passes through the Channel back into the North Atlantic. After a period of decline in the 1990s, temperature has increased since 2000, but still remains lower than the highest temperatures observed in the 1950s, 1960s, and early 1980s. The relatively stable salinity in the first period of measurements (1950 to mid-1970s) was followed by a slow decline through the next 15 years; since 1992, it has stabilized again. A slight decrease was observed in temperature and salinity from 2006 to 2007.

Salinity and potential temperature of the Denmark Strait Overflow Water near Cape Farewell (Area 5b) demonstrate considerable well-correlated interannual variations between 1991 and 2006 (correlation = 0.7). The long-term trends in salinity and temperature for the period 1991–2007 are not significant. The long-term standard deviations of temperature and salinity are 0.15°C and 0.014, respectively. In 2007 and 2006, the two highest Denmark Strait Overflow Water temperature values since 1991 were observed. Evidence from a moored temperature salinity sensor suggests that the dominant time-scale of hydrographic variability is about eight months, well less than a year.

In deep waters at the Cape Desolation station (at 2000 m, Area 1), which represents the West Greenland and Deep Western Boundary Currents, an increase in temperature and salinity was observed between 1984 and 1989, followed by a cooling and freshening trend that continued until the late 1990s. An increase in temperature (~0.3°C per decade) has been observed since 1997, and an increase in salinity (~0.05 per decade) has been observed since 1998.

THE HIGHEST TEMPERATURE IN DENMARK STRAIT OVERFLOW WATER WAS OBSERVED IN 2007.

Figure 69.
Area 7 – Faroe–Shetland Channel. Temperature (upper panel) and salinity (lower panel) at 800 m in the Faroe–Shetland Channel.



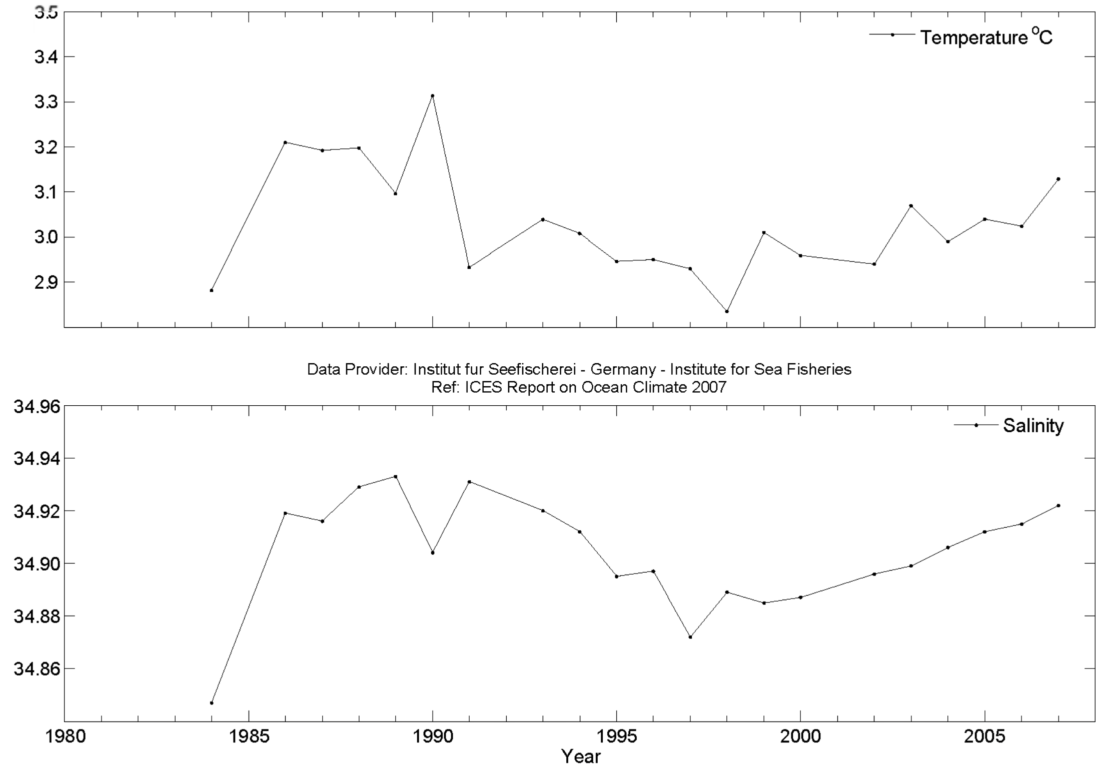
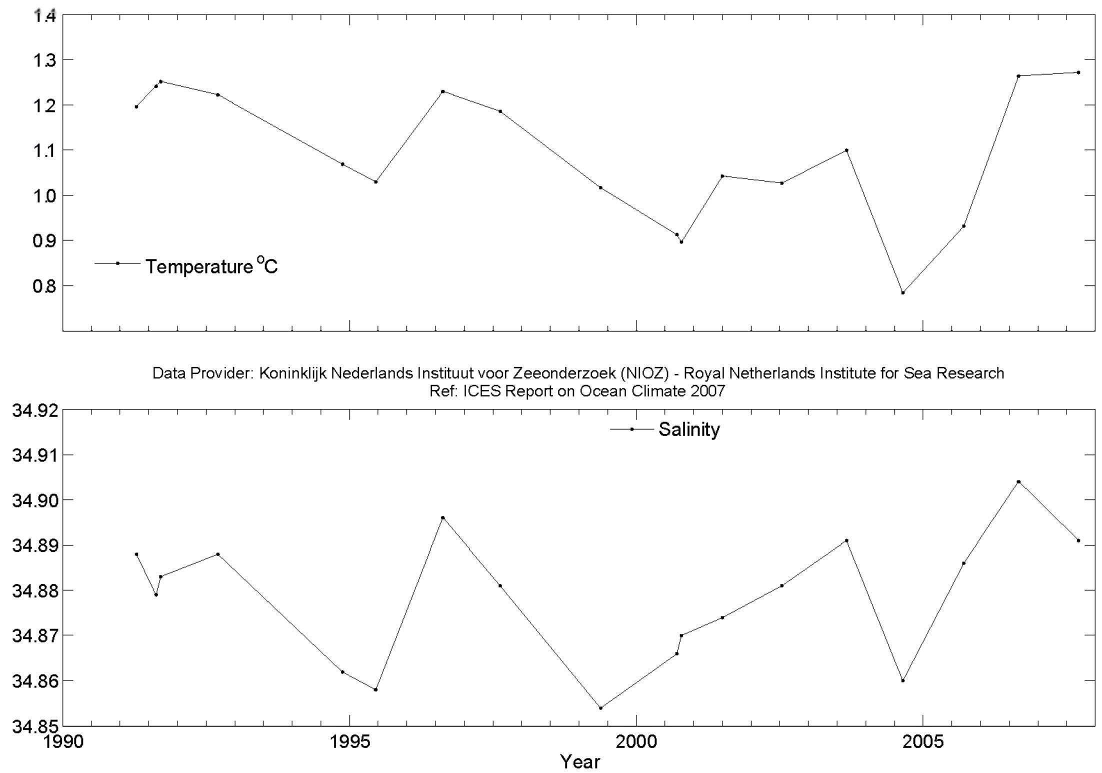


Figure 71.
Area 1 – West Greenland. Temperature (upper panel) and salinity (lower panel) at 2000 m at Cape Desolation Station 3, in the West Greenland Current.

Figure 70.
Area 5b – Irminger Sea. Temperature (upper panel) and salinity (lower panel) in Denmark Strait Overflow Water on the East Greenland Slope.



5.4 North Atlantic intermediate waters

In the central Irminger Sea (Area 5b), the cold and low-salinity core was observed between 1600 m and 2000 m in the early 1990s as a result of the deep Labrador Sea Water (LSW) formation in 1988–1995. Since 1996, a quasi-continuous increase in temperature and salinity has been observed (with one exception in 2000, when both properties dropped temporarily) as the LSW mixes with surrounding water masses. The temperature in 2007 returned to its highest value, which had been observed only once at the beginning of measurements, before the cooling period. After a levelling of the salinity between 2002 and 2005, it increased again in 2006 and declined slightly in 2007.

In the Rockall Trough (Area 5), the core of the Labrador Sea Water at 1800–2000 m is defined as the part of the water column with the lowest stratification. This deep-water mass demonstrated continued cooling, a trend that has dominated the entire time-series. The similar long-term freshening trend has also continued; in 2007, both temperature and salinity reached record-low values. In particular, temperature decreased significantly after a transient peak in 2006, and salinity was lower by 0.05 than the last-decade maximum in 2005.

Below.
RV "Lance" at the ice edge in Fram Strait. Image courtesy of A. Beszczynska-Möller, AWI, Germany.

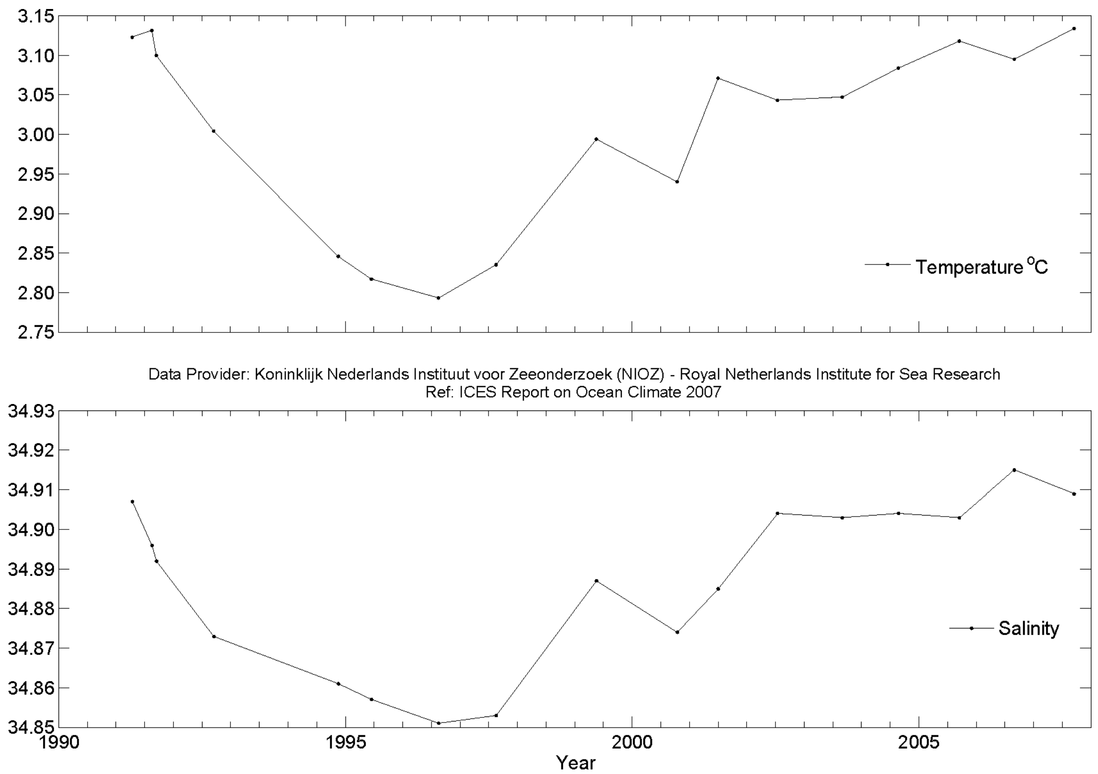


Figure 72.
Area 5b – Irminger Sea. Temperature (upper panel) and salinity (lower panel) of Labrador Sea Water (averaged over 1600–2000 m).

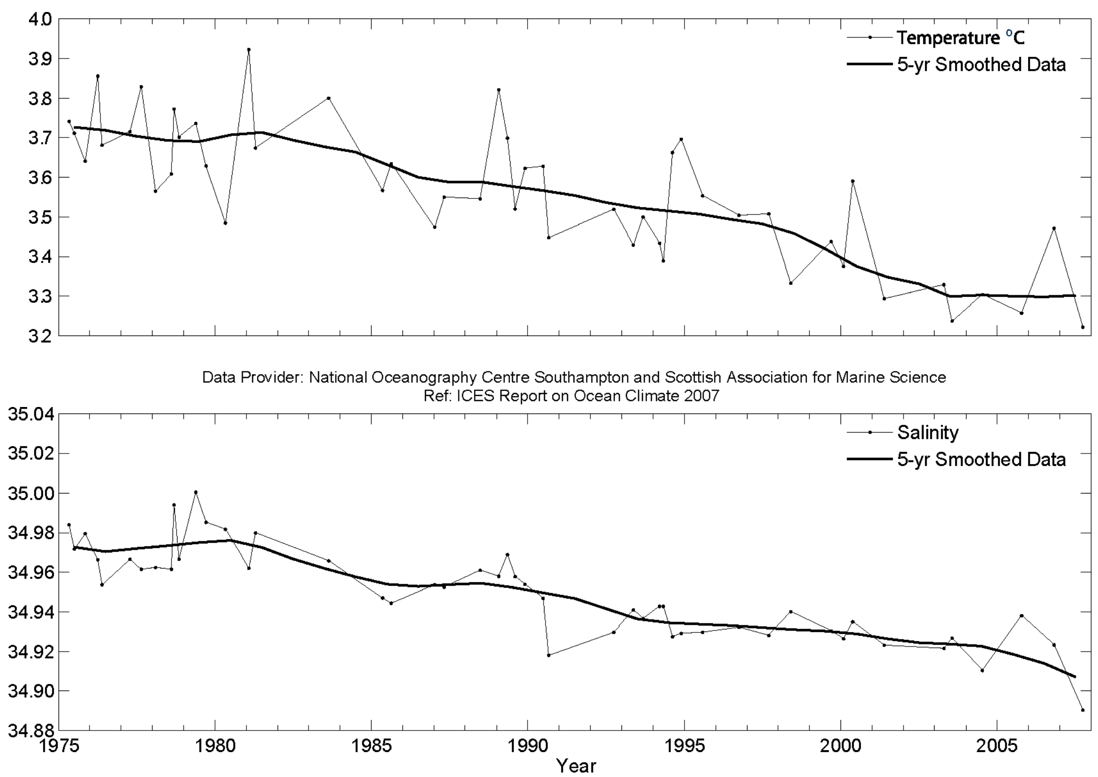


Figure 73.
Area 5 – Rockall Trough. Temperature (upper panel) and salinity (lower panel) of Labrador Sea Water (depth 1800–2000 m).

CONTACT INFORMATION

Area	Figures	Time-series	Contact	Institute
1 West Greenland	10	Nuuk Air Temperature	Manfred Stein (manfred.stein@vti.bund.de)	Danish Meteorological Institute, Copenhagen, and Seewetteramt, Hamburg
1 West Greenland	11, 12, 71	Fylla Section and Cape Desolation Section	Manfred Stein (manfred.stein@vti.bund.de)	Institut für Seefischerei (Institute for Sea Fisheries), Germany
2 Northwest Atlantic	13, 14, 15	Sable Island Air Temperature, Cabot Straight Sea Ice, Misaine Bank, Emerald Bank	Brian Petrie (PetrieB@mar.dfo-mpo.gc.ca)	BIO (Bedford Institute of Oceanography), Fisheries and Oceans Canada
2 Northwest Atlantic	16, 17, 18	Sea Ice, Cartwright Air Temperature, Station 27, CIL	Eugene Colbourne (colbourn@dfo-mpo.gc.ca)	Northwest Atlantic Fisheries Centre, Canada
2b Labrador Sea	19, 20, 21	Section AR7W	Ross Hendry (hendryr@dfo-mpo.gc.ca)	Bedford Institute of Oceanography (BIO), Department of Fisheries and Oceans Canada
2c Mid-Atlantic Bight	22	Oleander and East of Boston Section	Bob Pickart (rpickart@whoi.edu)	Woods Hole Oceanographic Institute, US
2c Mid-Atlantic Bight	23, 24	Georges Bank	Maureen Taylor (mtaylor@mercury.wh.whoi.edu)	NOAA Fisheries, NEFSC Oceanography Branch, US
3 Icelandic Waters	26, 27, 28, 29, 67	Air temperatures, Siglunes Station 2–4, Selvogsbanki Station 5, Langanes Station 2–6, Deep Data 1800 m	Hedinn Valdimarsson (hv@hafro.is)	Hafrannsoknastofnunin (Marine Research Institute), Iceland
4 Bay of Biscay	30	San Sebastian sea surface temperature and air temperature	Victor Valencia (vvalencia@pas.azti.es)	AZTI, Aquarium of San Sebastian (SOG) and Igeldo Meteorological Observatory (AEMet) in San Sebastian, Spain
4 Bay of Biscay	31, 32	Santander Station 6 (shelf break)	Alicia Lavin (alicia.lavin@st.ieo.es)	Instituto Español de Oceanografía (IEO; Spanish Institute of Oceanography), Spain
4b Northwest European Continental Shelf	33, 34	Station E1 10 m salinity Continental Shelf	Tim J. Smyth (tjsm@pml.ac.uk)	Marine Biological Association and Plymouth Marine Laboratory, UK
4b Northwest European Continental Shelf	35	Malin Head Weather Station	Glenn Nolan (Glenn.Nolan@marine.ie)	Marine Institute (Met Eireann), Ireland
4b Northwest European Continental Shelf	36	M1 Marine Weather Buoy	Sheena Fennel (Sheena.Fennell@marine.ie)	Marine Institute (Met Eireann), Ireland
5 Rockall Trough	37, 73	Ellet Line	N. Penny Holliday (nph@noc.soton.ac.uk)	National Oceanography Centre, Southampton and Scottish Association for Marine Science, UK
5b Irminger Sea	38, 70, 72	Irminger Sea	H. M. van Aken (aken@nioz.nl)	Koninklijk Nederlands Instituut voor Zeeonderzoek (NIOZ; Royal Netherlands Institute for Sea Research)
6 Faroe Bank Channel	39, 40	Faroe Bank Channel Faroe Current	Bogi Hansen (bogihan@frs.fo)	Fiskirannsoknarstovan (Faroese Fisheries Laboratory), Faroe
6 Faroe Bank Channel	41	Faroe Coastal Oyrargjogv	Karin Margretha Larsen (KarinL@frs.fo)	Fiskirannsoknarstovan (Faroese Fisheries Laboratory), Faroe
7 Faroe-Shetland Channel	42, 43, 69	Faroe-Shetland Channel	Sarah Hughes (s.hughes@marlab.ac.uk)	Fisheries Research Services (FRS), Aberdeen, UK
8&9 North Sea	44	Modelled North Sea Inflow	Morten Skogen (morten@imr.no)	Institute of Marine Research (IMR), Norway
8&9 North Sea	45	North Sea Utsira	Solfrid Hjollo (solfrid.hjollo@imr.no)	Institute of Marine Research (IMR), Norway
8&9 North Sea	46	Fair Isle Current Water	Sarah Hughes (s.hughes@marlab.ac.uk)	Fisheries Research Services (FRS), Aberdeen, UK
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8&9 North Sea	48	Section Average, Felixstowe, Rotterdam, 52°N	Stephen Dye (stephen.dye@cefas.co.uk)	Centre for Environment Fisheries and Aquaculture Science (CEFAS), UK
8&9 North Sea	49	Sea Surface Temperature North Sea Average	Peter Lowe (peter.loewe@bsh.de)	Bundesamt für Seeschifffahrt und Hydrographie, Germany
9b Baltic Sea	50, 51	Baltic Proper, East of Gotland Baltic Sea	Karin Borenas (karin.borenas@smhi.se)	Swedish Meteorological and Hydrological Institute, Sweden
9b Baltic Sea	52, 53, 54	Baltic Sea, LL7, SR5	Pekka Alenius (pekka.alenius@fimr.fi)	Finnish Institute of Marine Research (FIMR), Finland
9b Baltic Sea	55	Baltic Proper, SMHI Observed Ice Extent	Karin Borenas (karin.borenas@smhi.se)	Swedish Meteorological and Hydrological Institute, Sweden
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11 Barents Sea	59	Fugløya, Bear Island Section Western Barents Sea, Atlantic Inflow	Randi Ingvaldsen (randi.ingvaldsen@imr.no)	Institute of Marine Research (IMR), Norway
11 Barents Sea	60	Kola Section, Eastern Barents Sea	Oleg V. Titov	Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Russia
12 Greenland Sea and Fram Strait	61	Greenland Sea Section West of Spitsbergen 76.5°N	Waldemar Walczowski (walczows@iopan.gda.pl)	Institute of Oceanology, Polish Academy of Sciences (IOPAS), Poland
12 Greenland Sea and Fram Strait	62, 65, 66	Greenland Sea Section 75°N	G. Budeus (Gereon.Budeus@awi.de)	Alfred Wegener Institute for Polar and Marine Research (AWI), Germany
12 Greenland Sea and Fram Strait	63	Fram Strait, West Spitsbergen Current, Section Average 5°E to shelf edge	A. Beszczynska-Möller (abeszczynska@awi-bremerhaven.de)	Alfred Wegener Institute for Polar and Marine Research (AWI), Germany