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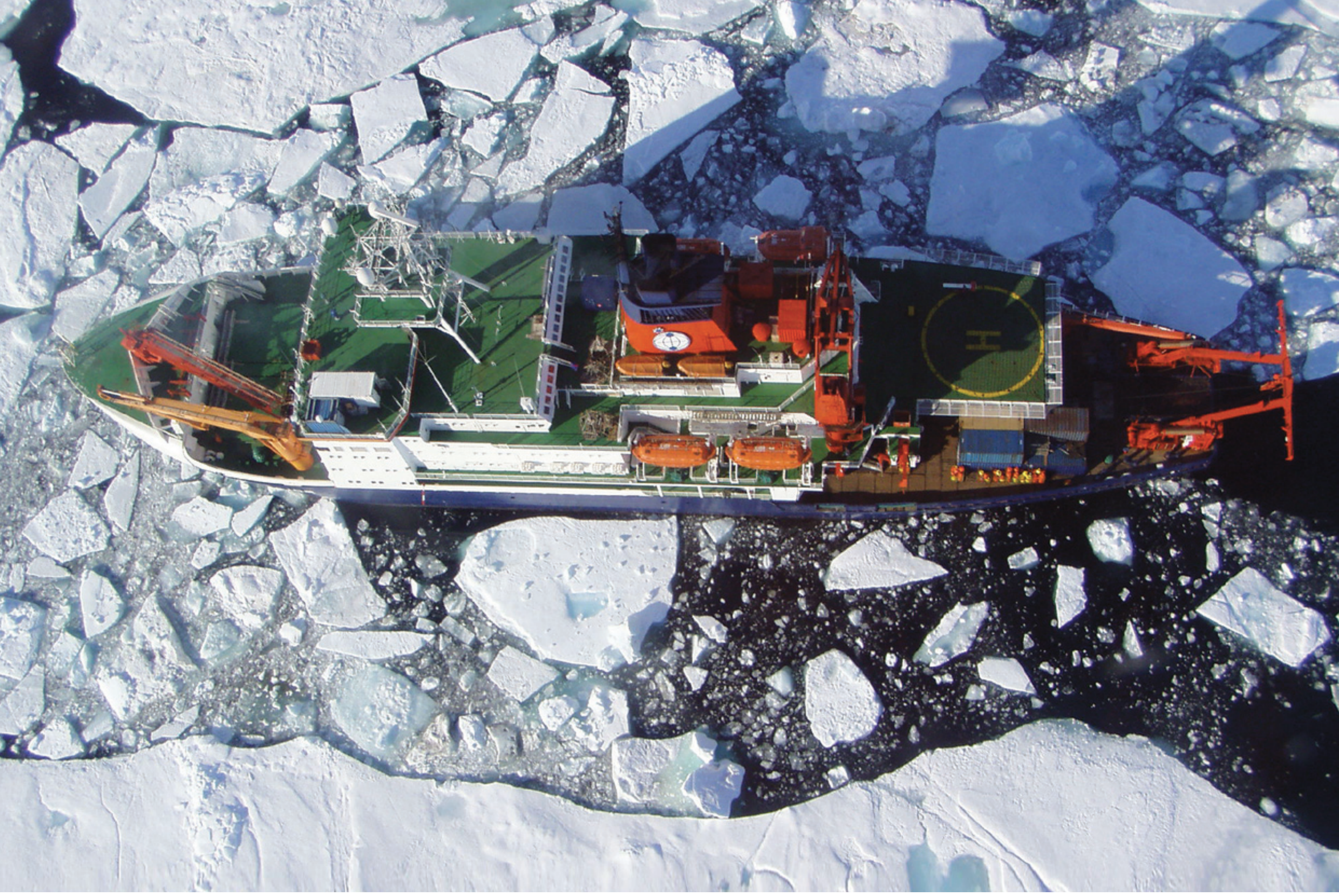

Above.
RV "Polarstern" in Fram Strait, image courtesy of A. Beszczynska-Möller, AWI, Germany.

Cover image.
RV Lance 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 2008, as well as the observed trends over the past 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, air temperature, and ice cover.

The main focus of the annual *ICES Report on Ocean Climate* is the observed variability in the upper ocean (the upper 1000 m), and the introductory section includes gridded fields constructed by optimal analysis of the Argo float data distributed by the Coriolis data centre, in France. Later in the report, there is a short section summarizing the variability of the intermediate and deep waters of the North Atlantic.

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 http://www.ices.dk/iceswork/wgdetail.asp?wg=WGOH.

1.1 Highlights of 2008

The upper layers of the North Atlantic and the Nordic Seas were warm and saline in 2008 compared with the long-term average.

In the Labrador and Irminger Seas, a cold winter led to enhanced convection and cooler intermediate waters compared with 2007.

Ice cover in the Baltic Sea was the lowest on record.

In the Nordic Seas, the shallow winter convection observed in the past two decades persisted into 2008, continuing the warming and increasing salinity of the deep water.

1.2 The North Atlantic atmosphere in winter 2007/2008

Both the Iceland Low and the Azores High were close to normal in strength, but were displaced towards the east.

Mean winds were stronger than normal across the eastern North Atlantic, northwest European continental shelf, and the Baltic, but weaker than normal in the western and southern North Atlantic.

The North Sea, Barents Sea, and Greenland Sea were more than 1°C warmer than normal. In contrast, surface air temperatures over the Labrador Sea were colder than normal.

NORTH ATLANTIC UPPER OCEAN TEMPERATURE OVERVIEW

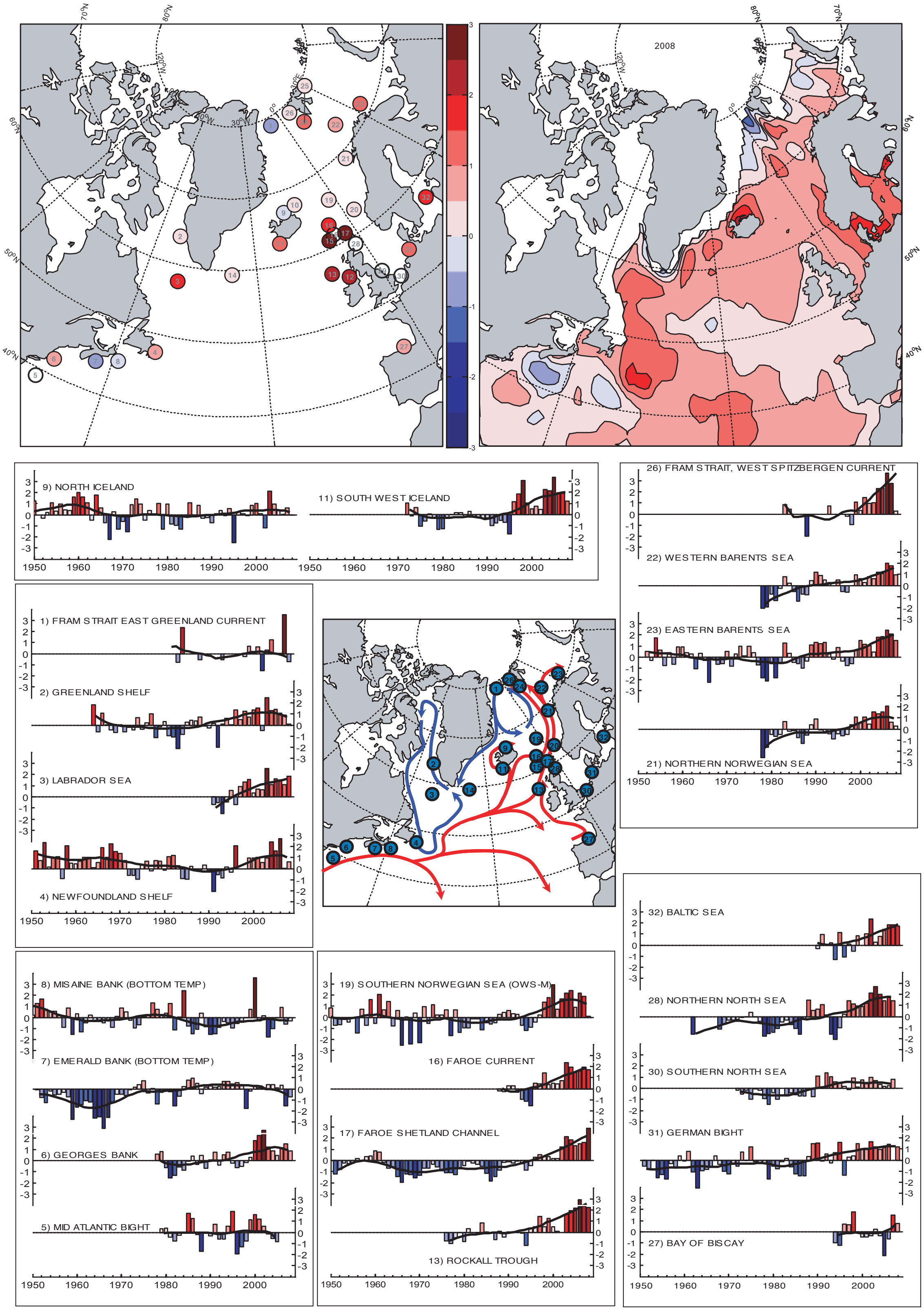


Figure 1.
Upper ocean temperature anomalies at selected locations across the North Atlantic. The anomalies are normalized with respect to the standard deviation (e.g. a value of +2 indicates 2 standard deviations above normal). Upper panels: maps of conditions in 2008; (left) data from in situ observations; (right) 2008 anomalies calculated from OISST.v2 data (see Figure 3). Lower panels: time-series of normalized anomalies at each of the selected stations. Colour intervals 0.5; reds = positive/warm; blues = negative/cool. See Figure 13 for a map showing more detail about the locations in this figure.

NORTH ATLANTIC UPPER OCEAN SALINITY OVERVIEW

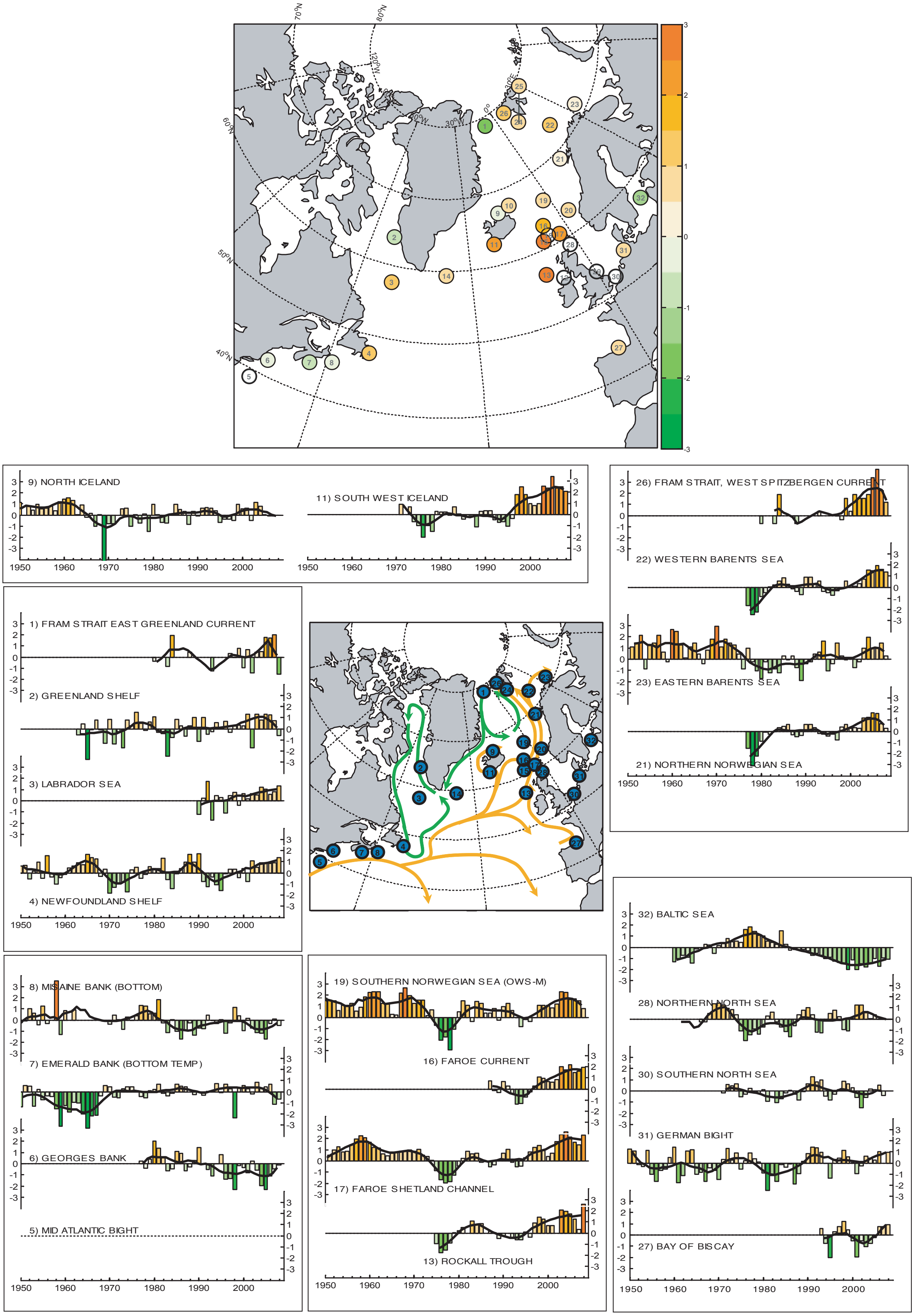


Figure 2.
Upper ocean salinity anomalies at selected locations across the North Atlantic. The anomalies are calculated relative to a long-term mean and normalized with respect to the standard deviation (e.g. a value of +2 indicates 2 standard deviations above normal). Upper panel: map of conditions in 2008. Lower panels: time-series of normalized anomalies at each of the selected stations. Colour intervals 0.5; oranges = positive/saline; greens = negative/fresh. See Figure 13 for a map showing more detail about the locations in this figure.

2. SUMMARY OF UPPER OCEAN CONDITIONS IN 2008

In this section, we summarize the conditions in the upper layers of the North Atlantic during 2008, using data from: (i) a selected set of sustained observations, (ii) gridded sea surface temperature (SST) data, and (iii) gridded vertical profiles of temperature and salinity from Argo floats.

2.1 *In situ* stations and sections

Where *in situ* section and station data are presented in the summary tables and figures, normalized anomalies have been shown 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.

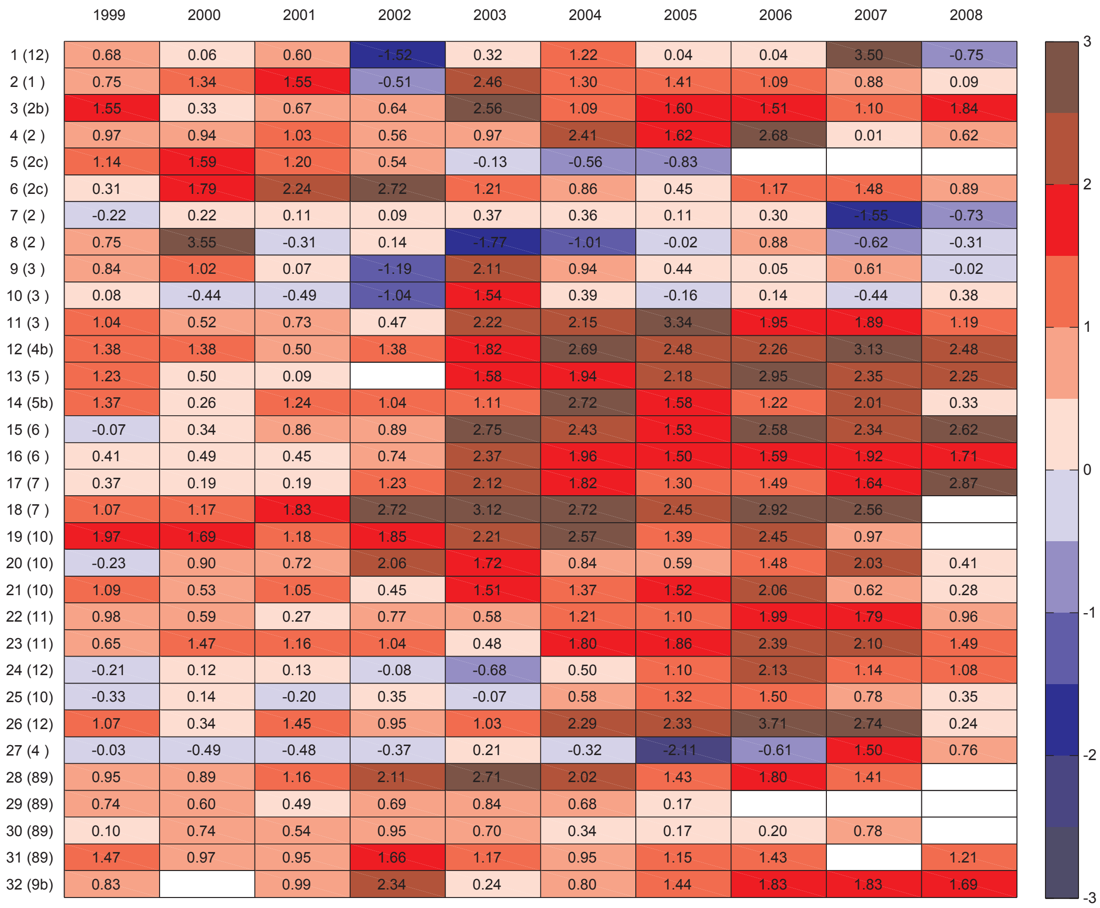
"SUSTAINED OBSERVATIONS" OR "TIME-SERIES" ARE REGULAR MEASUREMENTS OF OCEAN TEMPERATURE AND SALINITY MADE OVER A LONG PERIOD (10–100 YEARS). MOST MEASUREMENTS ARE MADE 1–4 TIMES A YEAR, BUT SOME ARE MADE MORE FREQUENTLY.

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

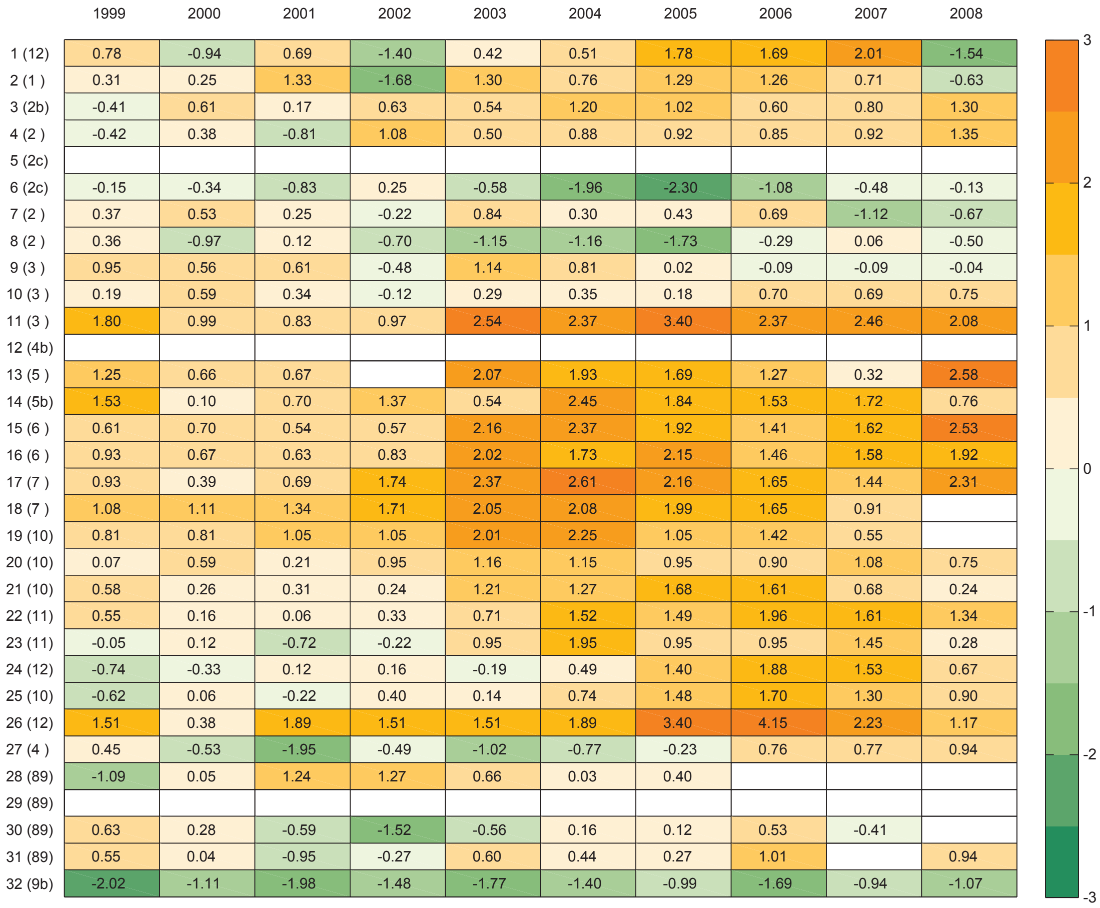
THE "SEASONAL CYCLE" DESCRIBES THE SHORT-TERM CHANGES AT THE SURFACE OF THE OCEAN BROUGHT ABOUT BY THE PASSING OF THE SEASONS; THE OCEAN SURFACE IS COLD IN WINTER AND WARMS THROUGH SPRING AND SUMMER. THE TEMPERATURE AND SALINITY CHANGES CAUSED BY THE SEASONAL CYCLE ARE USUALLY MUCH GREATER THAN THE PROLONGED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

Mooring recovery on RV Merian in Fram Strait, image courtesy of A. Beszczynska-Möller, AWI, Germany.

THE UPPER LAYERS OF THE NORTH ATLANTIC AND NORDIC SEAS WERE WARMER AND MORE SALINE THAN THE LONG-TERM AVERAGE IN 2008.



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1 (12)	0.68	0.06	0.60	-1.52	0.32	1.22	0.04	0.04	3.50	-0.75
2 (1)	0.75	1.34	1.55	-0.51	2.46	1.30	1.41	1.09	0.88	0.09
3 (2b)	1.55	0.33	0.67	0.64	2.56	1.09	1.60	1.51	1.10	1.84
4 (2)	0.97	0.94	1.03	0.56	0.97	2.41	1.62	2.68	0.01	0.62
5 (2c)	1.14	1.59	1.20	0.54	-0.13	-0.56	-0.83			
6 (2c)	0.31	1.79	2.24	2.72	1.21	0.86	0.45	1.17	1.48	0.89
7 (2)	-0.22	0.22	0.11	0.09	0.37	0.36	0.11	0.30	-1.55	-0.73
8 (2)	0.75	3.55	-0.31	0.14	-1.77	-1.01	-0.02	0.88	-0.62	-0.31
9 (3)	0.84	1.02	0.07	-1.19	2.11	0.94	0.44	0.05	0.61	-0.02
10 (3)	0.08	-0.44	-0.49	-1.04	1.54	0.39	-0.16	0.14	-0.44	0.38
11 (3)	1.04	0.52	0.73	0.47	2.22	2.15	3.34	1.95	1.89	1.19
12 (4b)	1.38	1.38	0.50	1.38	1.82	2.69	2.48	2.26	3.13	2.48
13 (5)	1.23	0.50	0.09		1.58	1.94	2.18	2.95	2.35	2.25
14 (5b)	1.37	0.26	1.24	1.04	1.11	2.72	1.58	1.22	2.01	0.33
15 (6)	-0.07	0.34	0.86	0.89	2.75	2.43	1.53	2.58	2.34	2.62
16 (6)	0.41	0.49	0.45	0.74	2.37	1.96	1.50	1.59	1.92	1.71
17 (7)	0.37	0.19	0.19	1.23	2.12	1.82	1.30	1.49	1.64	2.87
18 (7)	1.07	1.17	1.83	2.72	3.12	2.72	2.45	2.92	2.56	
19 (10)	1.97	1.69	1.18	1.85	2.21	2.57	1.39	2.45	0.97	
20 (10)	-0.23	0.90	0.72	2.06	1.72	0.84	0.59	1.48	2.03	0.41
21 (10)	1.09	0.53	1.05	0.45	1.51	1.37	1.52	2.06	0.62	0.28
22 (11)	0.98	0.59	0.27	0.77	0.58	1.21	1.10	1.99	1.79	0.96
23 (11)	0.65	1.47	1.16	1.04	0.48	1.80	1.86	2.39	2.10	1.49
24 (12)	-0.21	0.12	0.13	-0.08	-0.68	0.50	1.10	2.13	1.14	1.08
25 (10)	-0.33	0.14	-0.20	0.35	-0.07	0.58	1.32	1.50	0.78	0.35
26 (12)	1.07	0.34	1.45	0.95	1.03	2.29	2.33	3.71	2.74	0.24
27 (4)	-0.03	-0.49	-0.48	-0.37	0.21	-0.32	-2.11	-0.61	1.50	0.76
28 (89)	0.95	0.89	1.16	2.11	2.71	2.02	1.43	1.80	1.41	
29 (89)	0.74	0.60	0.49	0.69	0.84	0.68	0.17			
30 (89)	0.10	0.74	0.54	0.95	0.70	0.34	0.17	0.20	0.78	
31 (89)	1.47	0.97	0.95	1.66	1.17	0.95	1.15	1.43		1.21
32 (9b)	0.83		0.99	2.34	0.24	0.80	1.44	1.83	1.83	1.69



	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1 (12)	0.78	-0.94	0.69	-1.40	0.42	0.51	1.78	1.69	2.01	-1.54
2 (1)	0.31	0.25	1.33	-1.68	1.30	0.76	1.29	1.26	0.71	-0.63
3 (2b)	-0.41	0.61	0.17	0.63	0.54	1.20	1.02	0.60	0.80	1.30
4 (2)	-0.42	0.38	-0.81	1.08	0.50	0.88	0.92	0.85	0.92	1.35
5 (2c)										
6 (2c)	-0.15	-0.34	-0.83	0.25	-0.58	-1.96	-2.30	-1.08	-0.48	-0.13
7 (2)	0.37	0.53	0.25	-0.22	0.84	0.30	0.43	0.69	-1.12	-0.67
8 (2)	0.36	-0.97	0.12	-0.70	-1.15	-1.16	-1.73	-0.29	0.06	-0.50
9 (3)	0.95	0.56	0.61	-0.48	1.14	0.81	0.02	-0.09	-0.09	-0.04
10 (3)	0.19	0.59	0.34	-0.12	0.29	0.35	0.18	0.70	0.69	0.75
11 (3)	1.80	0.99	0.83	0.97	2.54	2.37	3.40	2.37	2.46	2.08
12 (4b)										
13 (5)	1.25	0.66	0.67		2.07	1.93	1.69	1.27	0.32	2.58
14 (5b)	1.53	0.10	0.70	1.37	0.54	2.45	1.84	1.53	1.72	0.76
15 (6)	0.61	0.70	0.54	0.57	2.16	2.37	1.92	1.41	1.62	2.53
16 (6)	0.93	0.67	0.63	0.83	2.02	1.73	2.15	1.46	1.58	1.92
17 (7)	0.93	0.39	0.69	1.74	2.37	2.61	2.16	1.65	1.44	2.31
18 (7)	1.08	1.11	1.34	1.71	2.05	2.08	1.99	1.65	0.91	
19 (10)	0.81	0.81	1.05	1.05	2.01	2.25	1.05	1.42	0.55	
20 (10)	0.07	0.59	0.21	0.95	1.16	1.15	0.95	0.90	1.08	0.75
21 (10)	0.58	0.26	0.31	0.24	1.21	1.27	1.68	1.61	0.68	0.24
22 (11)	0.55	0.16	0.06	0.33	0.71	1.52	1.49	1.96	1.61	1.34
23 (11)	-0.05	0.12	-0.72	-0.22	0.95	1.95	0.95	0.95	1.45	0.28
24 (12)	-0.74	-0.33	0.12	0.16	-0.19	0.49	1.40	1.88	1.53	0.67
25 (10)	-0.62	0.06	-0.22	0.40	0.14	0.74	1.48	1.70	1.30	0.90
26 (12)	1.51	0.38	1.89	1.51	1.51	1.89	3.40	4.15	2.23	1.17
27 (4)	0.45	-0.53	-1.95	-0.49	-1.02	-0.77	-0.23	0.76	0.77	0.94
28 (89)	-1.09	0.05	1.24	1.27	0.66	0.03	0.40			
29 (89)										
30 (89)	0.63	0.28	-0.59	-1.52	-0.56	0.16	0.12	0.53	-0.41	
31 (89)	0.55	0.04	-0.95	-0.27	0.60	0.44	0.27	1.01		0.94
32 (9b)	-2.02	-1.11	-1.98	-1.48	-1.77	-1.40	-0.99	-1.69	-0.94	-1.07

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 last decade: 1999–2008. The index numbers on the left can be used to cross-reference each point with information in Figures 1 and 2 and in Table 3. The numbers in brackets refer to detailed area descriptions featured 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 were 2 standard deviations above normal). Blank boxes indicate that data were unavailable for a particular year at the time of publication. Note that no salinity data are available for stations 5, 12, and 29. Colour intervals 0.5; red = warm; blue = cold; orange = saline; green = fresh.*

2.2 Sea surface temperature

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 seasonal SST anomalies for 2008, extracted from the Optimum Interpolation SST dataset (OISST.v2) 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 appear blank.

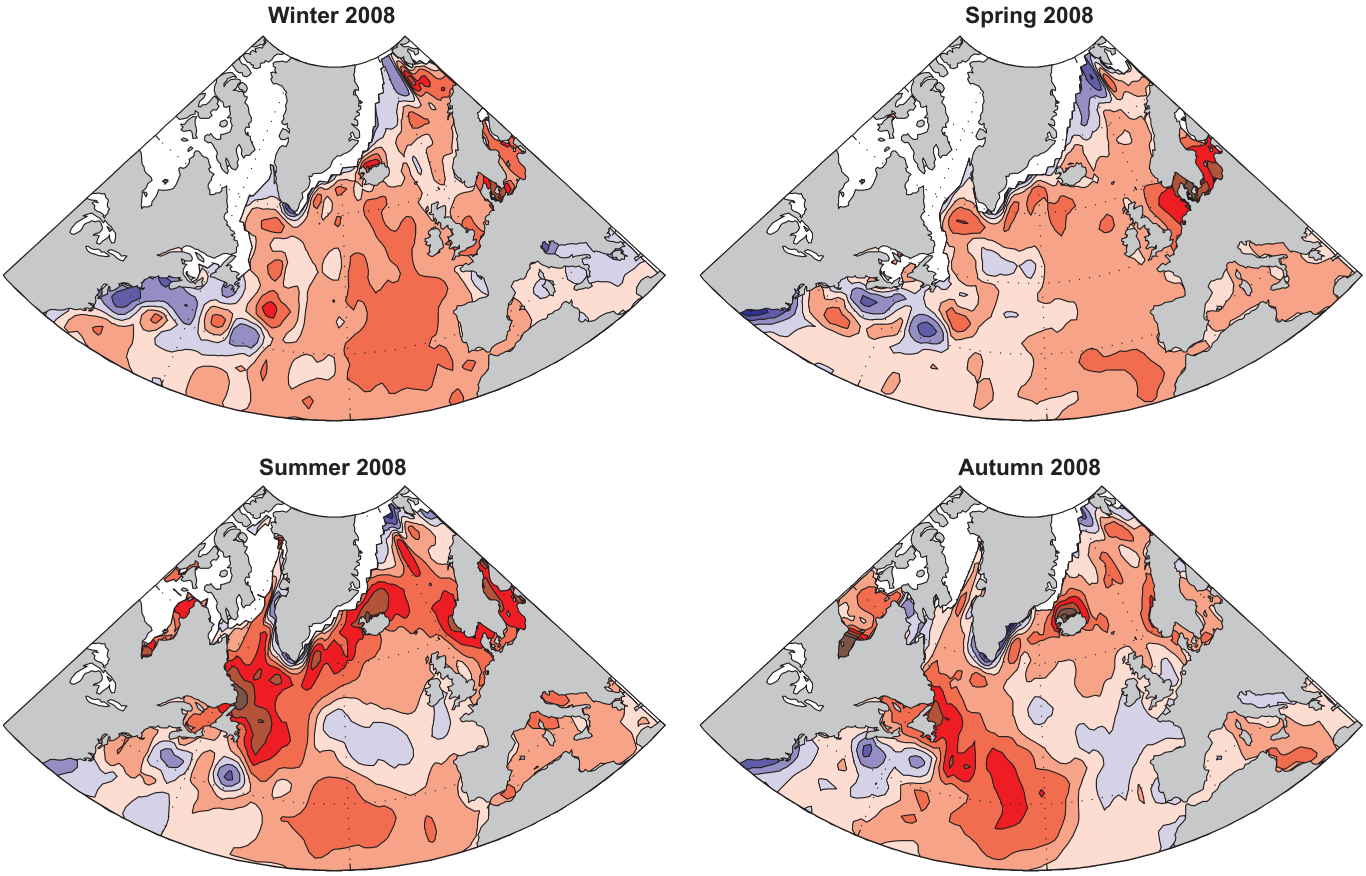


Figure 3.
Maps of seasonal sea surface temperature anomalies (°C) over the North Atlantic for 2007 from the NOAA Optimum Interpolation SSTv2 dataset provided by the NOAA-CIRES Climate Diagnostics Center, US. The colour-coded temperature scale is the same in all panels. The anomaly is calculated with 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 in Tables 1 and 2. Blank boxes indicate that no information was available for the area at the time of publication. T = temperature; S = salinity.*

Index	Description	Area	Measurement depth	Long-term average	Lat	Lon	Mean *T*, °C	S.d. *T*, °C	Mean S	S.d. 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 – Fyllas Bank Station – 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	0.34	31.63	0.26
5	Oleander Section (120–400 km) – Mid-Atlantic Bight USA	2c	Surface	1978–2000	39.00	-71.50				
6	Northwest Georges Bank – Mid-Atlantic Bight USA	2c	1–30 m	1977–2000	42.00	-70.00	9.71	0.42	32.64	0.23
7	Emerald Basin – Central Scotian Shelf – Canada	2	Near Bottom	1971–2000	44.00	-63.00		1.20		0.23
8	Misaine Bank – Northeastern 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	Langanes 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	7.64	0.37	35.15	0.04
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 – West Faroe Islands	6	Layer between 100 and 300 m depth	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	7.48	0.34	35.14	0.04
20	Southern Norwegian Sea – Svinøy Section – Atlantic Water	10	50–200 m	1977–2000	63.00	3.00	7.99	0.39	35.23	0.05
21	Central Norwegian Sea – Gimsøy Section – Atlantic Water	10	50–200 m	1977–2000	69.00	12.00	6.81	0.39	35.15	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	0.05
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	1996–2008	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	12.71	0.31	35.61	0.06
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	57.50	19.50	8.57	1.05	7.35	0.24

2.3 Argo gridded temperature and salinity fields

In this section, we present summaries of recent conditions in the North Atlantic as described by the growing data resource provided by Argo float temperature and salinity profiles. The gridded fields were generated by ISAS (*In Situ* Analysis System), an analysis tool originally designed for the synthesis of the Argo dataset and developed/maintained at LPO (Laboratoire de Physique des Océans) within the CREST-Argo project **(http://wwz.ifremer.fr/lpo/observation/crest_argo).** The version ISAS_V4.2 was used to perform the monthly analysis presented here. The datasets are the standard files prepared by Coriolis for the operational users. They contain mostly Argo profiles, but CTDs (Conductivity, Temperature and Depths), buoys, and mooring data are also included (not exceeding 5% of the total dataset). XBT (EXpendable BathyThermograph) data are not included because of concerns over the fall-rate error, and because consistent temperature and salinity fields are needed to compute density. The results are monthly gridded fields of temperature and salinity for depth levels from 0 m to 2000 m.

The 2008 annual mean fields of temperature and salinity are presented in Figure 4 at four levels: 10, 300, 1000, and 1600 m. In Figure 5, the anomalies from reference climatology (the latest World Ocean Atlas, WOA-05) are given. Anomalies for recent years at two selected depths, 10 and 1600 m, are given in Figures 6 and 7. Finally, in Figure 8, the winter (February) mixed-layer depth is shown. Note that the mixed-layer depth (z) is defined as the depth where the temperature has decreased by 0.5°C from the temperature measured at 10 m depth ($T(z) < T(10\ m) - 0.5$). This criterion is not suitable for areas where effects of salinity are important (ice melting) or where the basic stratification is weak. Therefore, results in the Labrador Sea, around Greenland, and in the Gulf of Lion are not significant.

On average, in 2008, the North Atlantic was mostly warmer and saltier than the climatology in the near-surface layer (10 m). However, three areas tended to be cooler and fresher: the northern part of the Labrador Sea, a small area south of Newfoundland, and the area centred on 55°N–30°W. Relative to 2007, the cooling of the centre of the gyre is marked, and the freshening of the Labrador Sea extends farther south.

The cooling is even more extensive at the level of the mode waters (300 m). The only area showing a marked warming (and increased salinity) lies at 40°N along the North American shelf. At depths of 1000 and 1600 m, the Greenland Sea is warmer, and the Irminger and Labrador seas are both warmer and more saline. The signal associated with Mediterranean Water (MW) varies with depth. Near the core of the MW (at 1000 m), the water is warmer and saltier, while it is colder and fresher at its lower boundary (1600 m). Interannual change from 2007 to 2008 is low in the northern part, and a slight cooling is noted in the Labrador and Irminger seas at 1000 m. South of 45–50°N, the changes show strong spatial variability.

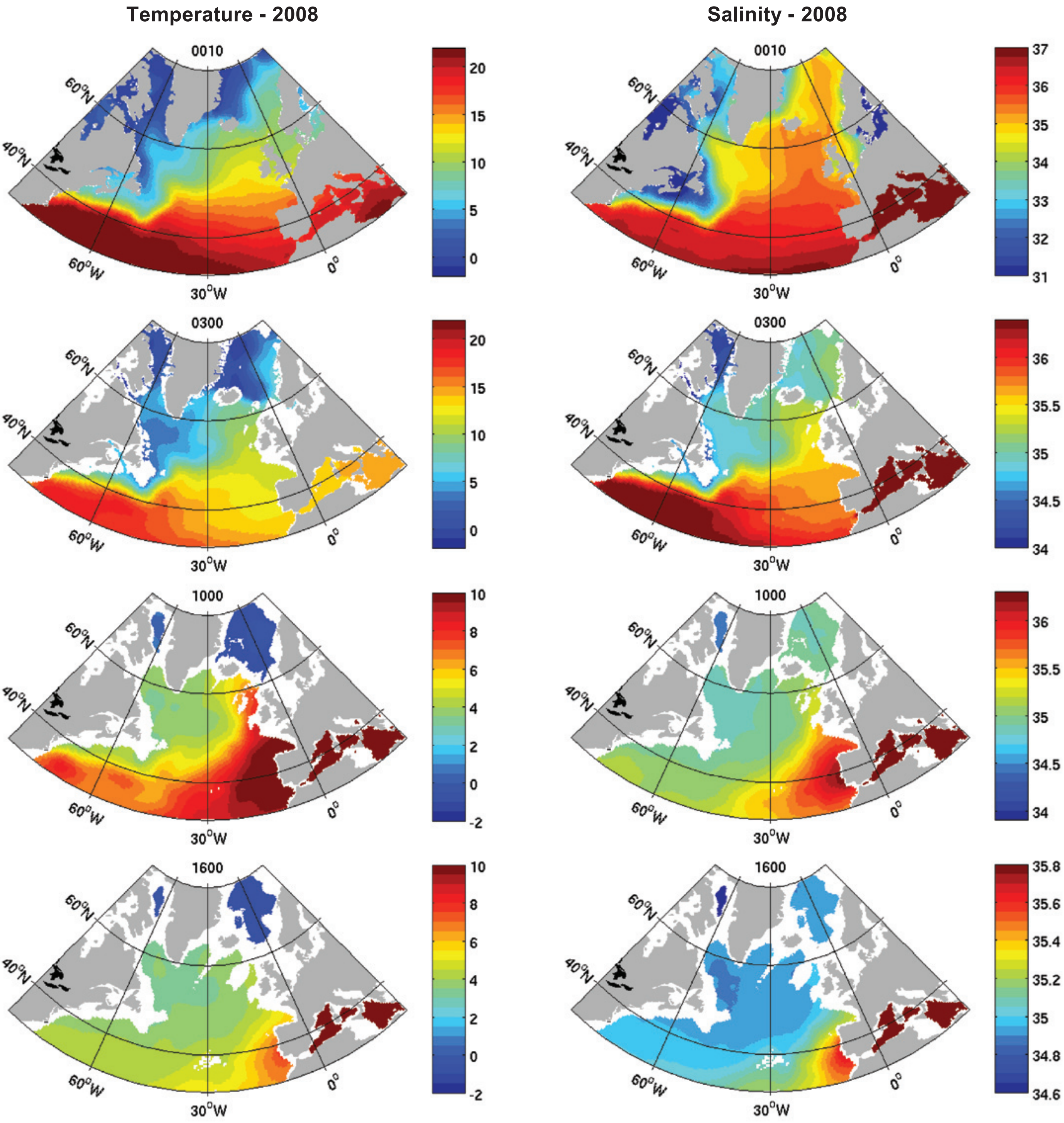


Figure 4.
Maps of 2008 annual mean temperature (left) and salinity (right) at 10, 300, 1000, and 1600 m. From ISAS monthly analysis of Argo data.

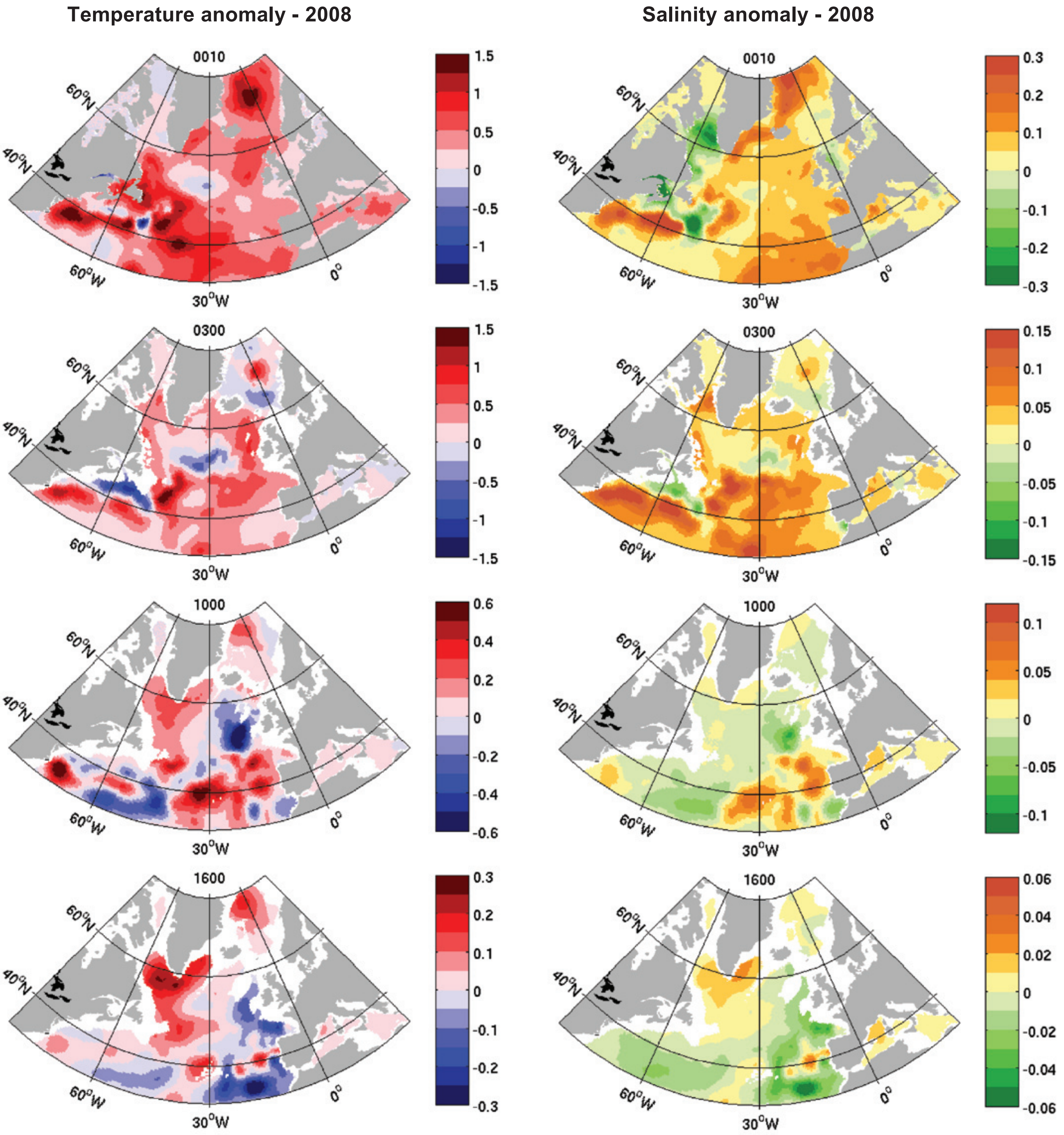


Figure 5.

Maps of 2008 annual temperature anomalies (left) and salinity anomalies (right) at 10, 300, 1000, and 1600 m. (Anomalies are the differences between the ISAS annual means (see Figure 4) and the reference climatology (WOA-05) Note different scales for each map.) From ISAS monthly analysis of Argo data.

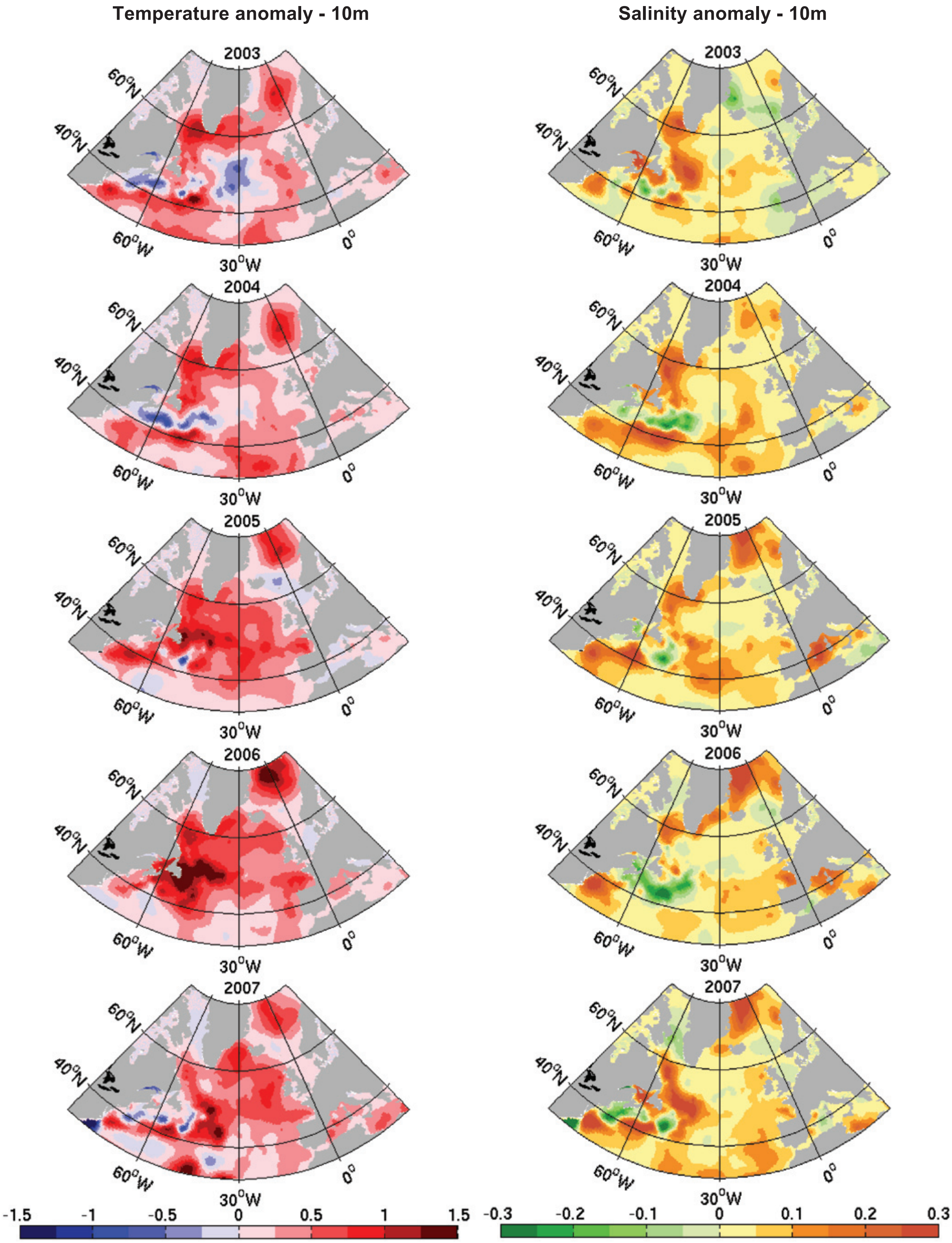


Figure 6.
Maps of annual temperature anomalies (left) and salinity anomalies (right) at 10 m for 2003–2007. From ISAS monthly analysis of Argo data. Data for 2008 are presented in Figure 5.

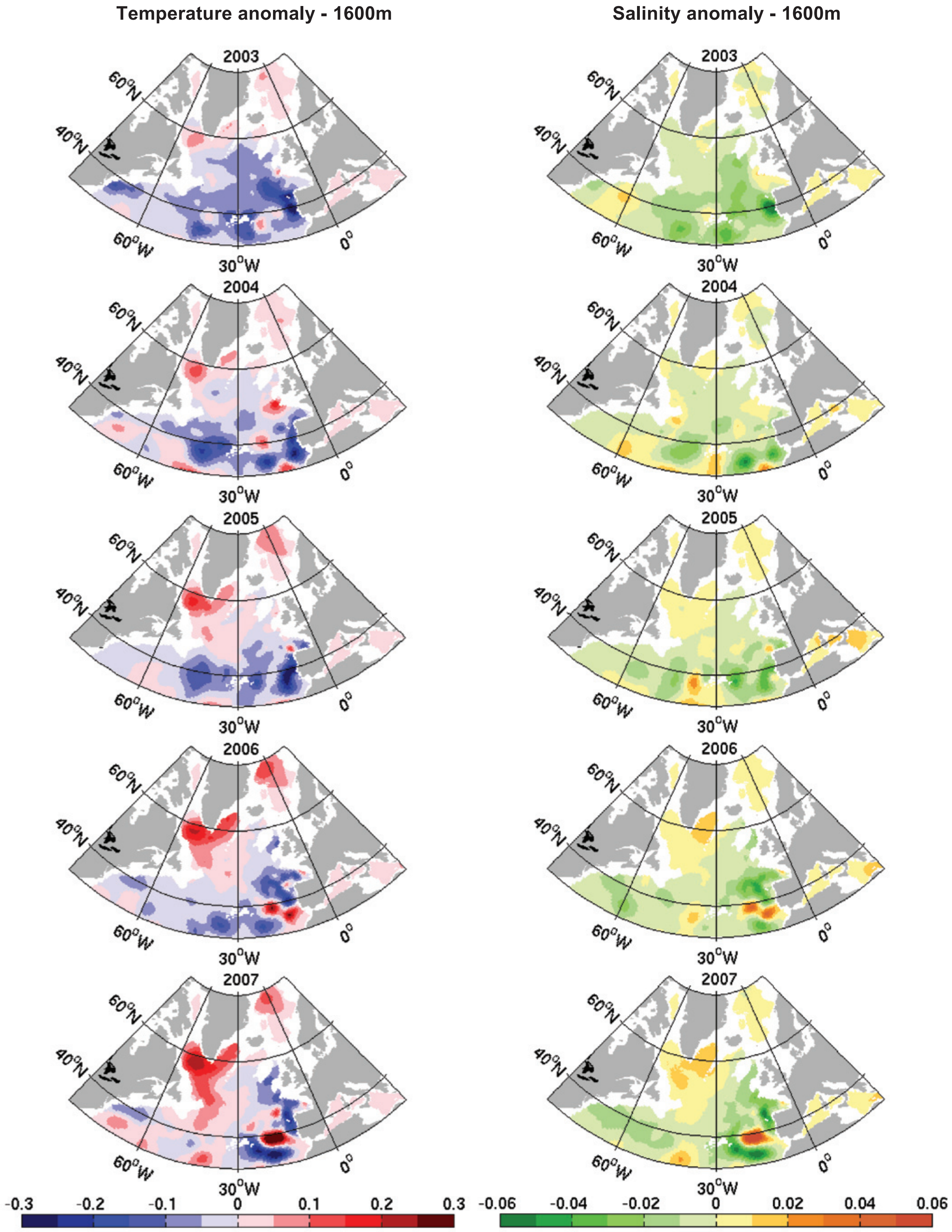


Figure 7.
Maps of annual temperature anomalies (left) and salinity anomalies (right) at 1600 m for 2003–2007. From ISAS monthly analysis of Argo data. Data for 2008 are presented in Figure 5.

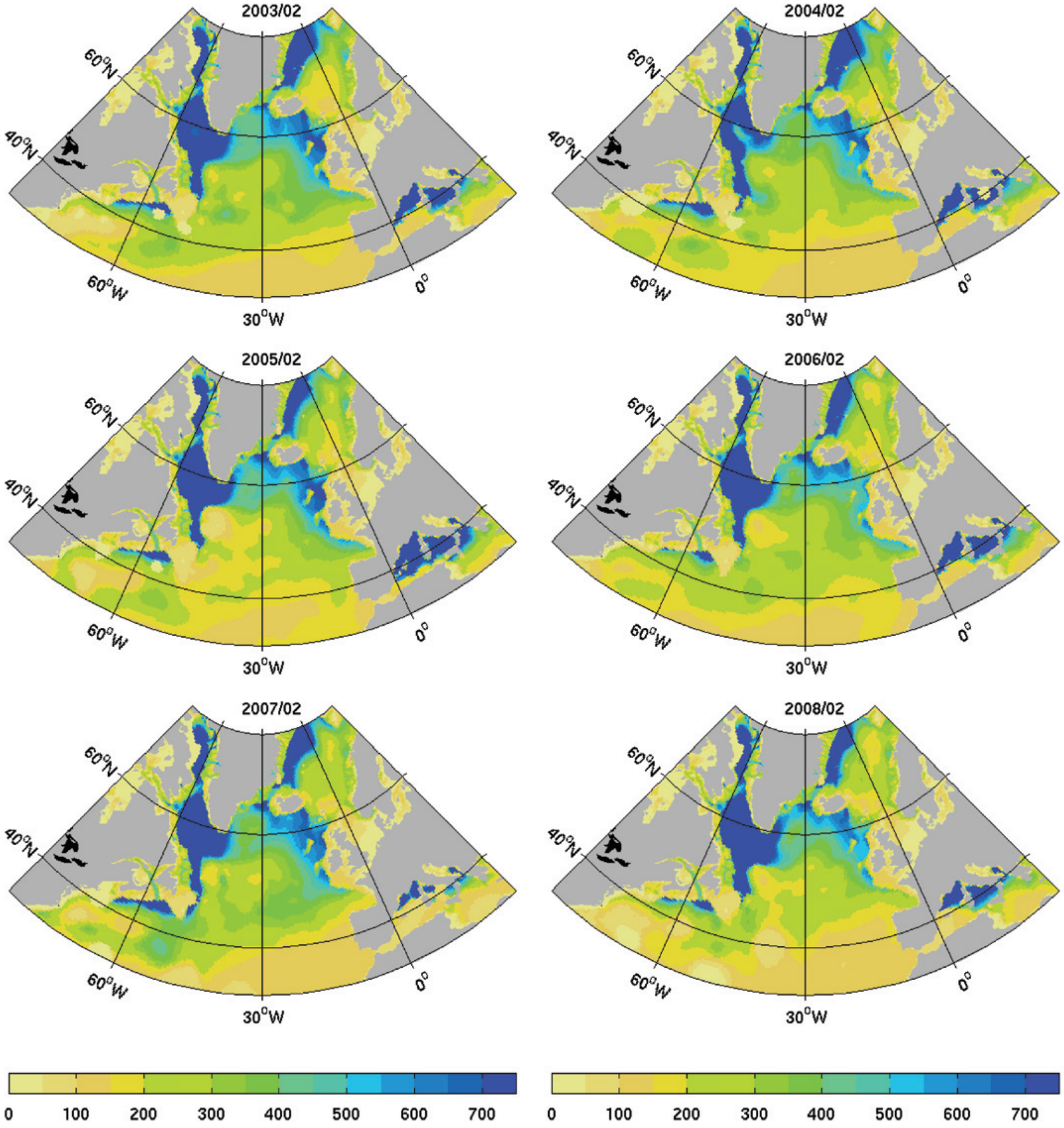


Figure 8.
Maps of North Atlantic winter (February) mixed-layer depths for 2003 – 2008. From ISAS monthly analysis of Argo data. Note that the mixed-layer depth is defined as the depth at which the temperature has decreased by more than 0.5° from the temperature at 10 m depth. This criterion is not suitable for areas where effects of salinity are important (ice melting) or where the basic stratification is weak. Therefore, results in the Labrador Sea, around Greenland, and in the Gulf of Lion are not significant.

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 (December/January/February/March [DJFM]) 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 winter of 1995/1996. Since then, the Hurrell NAO index has been fairly weak and a less useful descriptor of atmospheric conditions. In the winter of 2007/2008, the NAO index was 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.

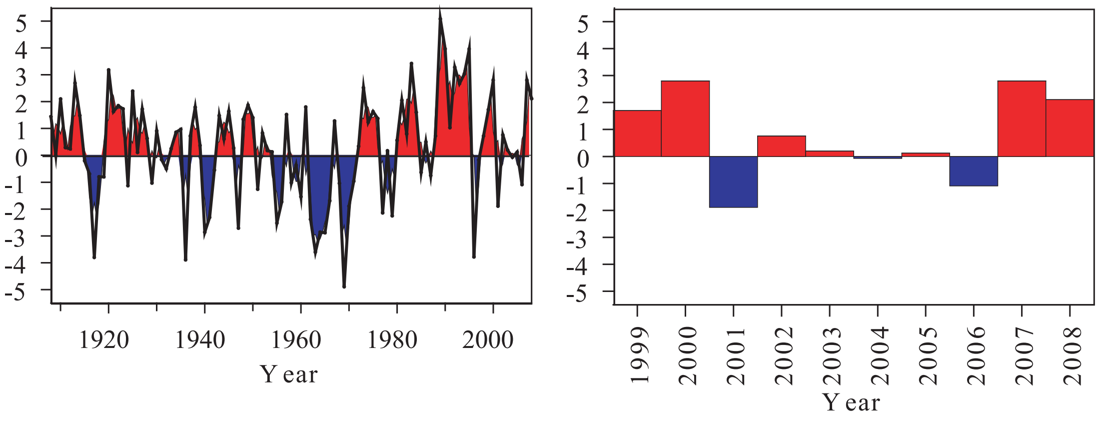


Figure 9.
The Hurrell winter (DJFM) NAO index for the past 100 years with a two-year running mean applied (left panel) and for the current decade (right panel). Data source: http://www.cgd.ucar.edu/cas/jhurrell/nao.stat.winter.html.

The NAO index is an indicator of the gradient of SLP, but maps can provide more information about the windfield. Ocean properties are particularly dominated by winter conditions, hence the inclusion of maps of SLP for winter (DJFM Figure 10). The top panel of Figure 10 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 STRONGER THAN NORMAL IN THE EAST.

The middle panel of Figure 10 shows the mean SLP for winter 2008 (December 2007, January–March 2008), and the bottom panel shows the 2008 winter SLP anomaly – the difference between the top and middle panels. In winter 2008, both the Iceland Low and the Azores High were close to normal, but were displaced towards the east. The strength of the mean surface wind averaged over the 30-year period (1971–2000) is shown in the upper panel of Figure 11, and the lower panel shows the anomaly in winter 2008. These reanalyses show that the mean winds were stronger than normal across the eastern North Atlantic, Northwest European continental shelf, and Baltic, but weaker than normal in the western and southern North Atlantic.

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.

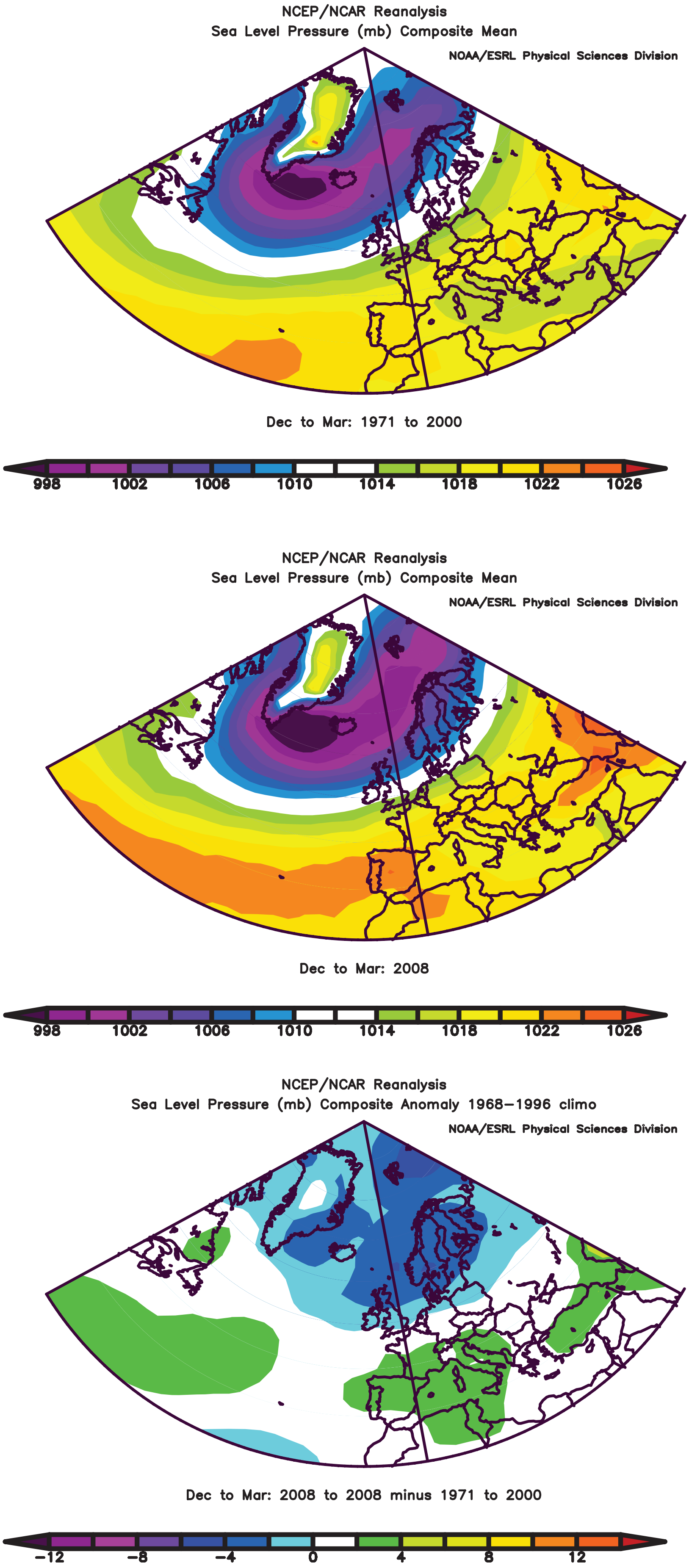


Figure 10.
Winter (DJFM) sea level pressure (SLP) fields. Top panel: SLP averaged over 30 years (1971–2000). Middle panel: mean SLP in winter 2008 (December 2007, January–March 2008). Bottom panel: winter 2008 SLP anomaly – the difference between the top and middle panels. Images provided by the NOAA/ESRL Physical Sciences Division, Boulder, Colorado (available online at http://www.cdc.noaa.gov/).

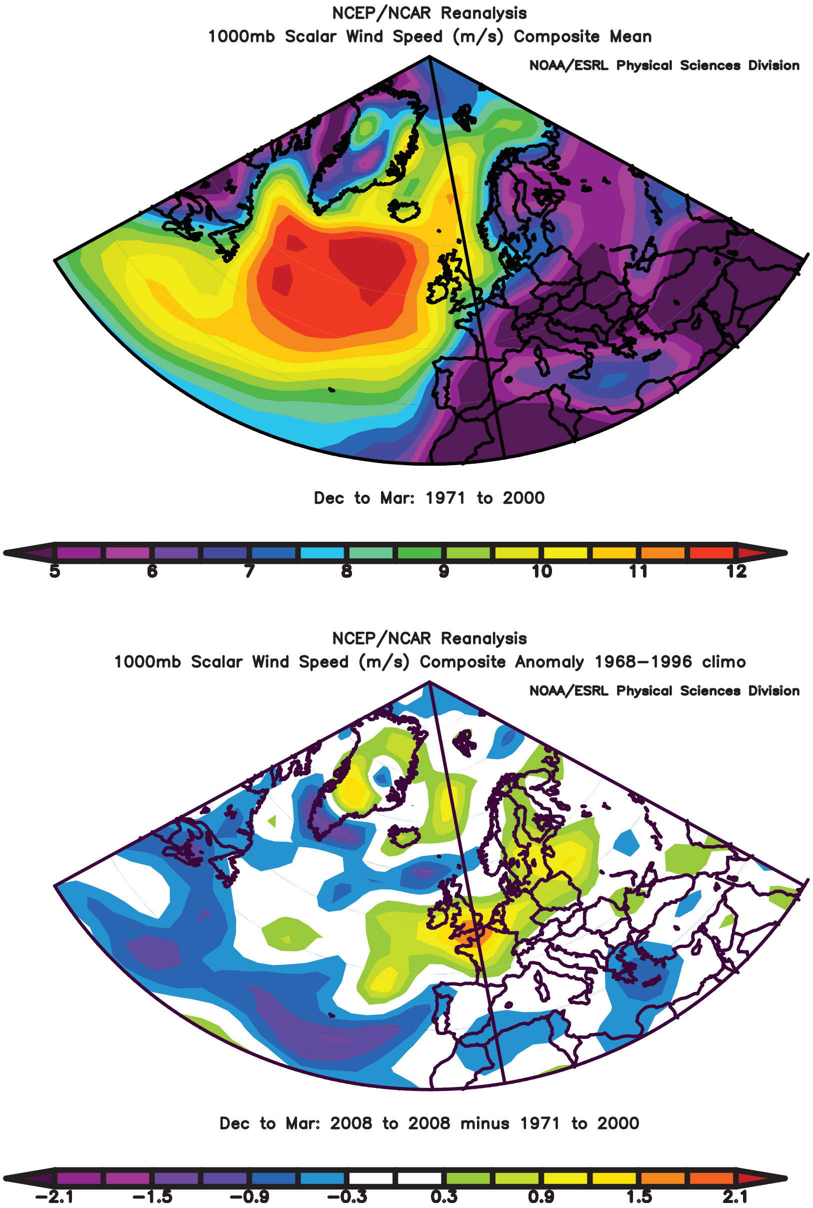


Figure 11.
Winter (DJFM) surface windspeed. Upper panel: surface windspeed averaged over 30 years (1971–2000). Lower panel: winter 2008 anomaly in surface windspeed. Images provided by the NOAA/ESRL Physical Sciences Division, Boulder, Colorado (available online at http://www.cdc.noaa.gov/).

3.2 North Atlantic surface air temperature

North Atlantic winter mean surface air temperatures are shown in Figure 12. The 1971–2000 mean conditions (Figure 12, top panel) show warm temperatures penetrating far to the north on the eastern side of the North Atlantic and the Nordic seas, caused by the northward movement of warm oceanic water. The middle panel of Figure 12 shows the conditions in winter (DJFM) 2007/2008, and the bottom panel shows the difference between the two. In winter 2007/2008, the central North Atlantic and Norwegian Sea surface air temperatures were near normal. In contrast, the surface air temperature over the Labrador Sea was significantly colder than normal, while that over the North Sea, Barents Sea, and Greenland Sea was more than 1°C warmer than normal. The exception is the orange/red area northeast of Svalbard, which shows warmer than normal conditions (by 6–10°C); this is the result of sea-ice edges retreating.

IN WINTER 2007/2008, THE SURFACE AIR TEMPERATURE OVER MUCH OF THE NORTH SEA AND BALTIC, BARENTS SEA, AND THE GREENLAND SEA WAS MORE THAN 1°C WARMER THAN NORMAL, WHILE THAT OVER THE LABRADOR SEA WAS SIGNIFICANTLY COLDER THAN NORMAL.

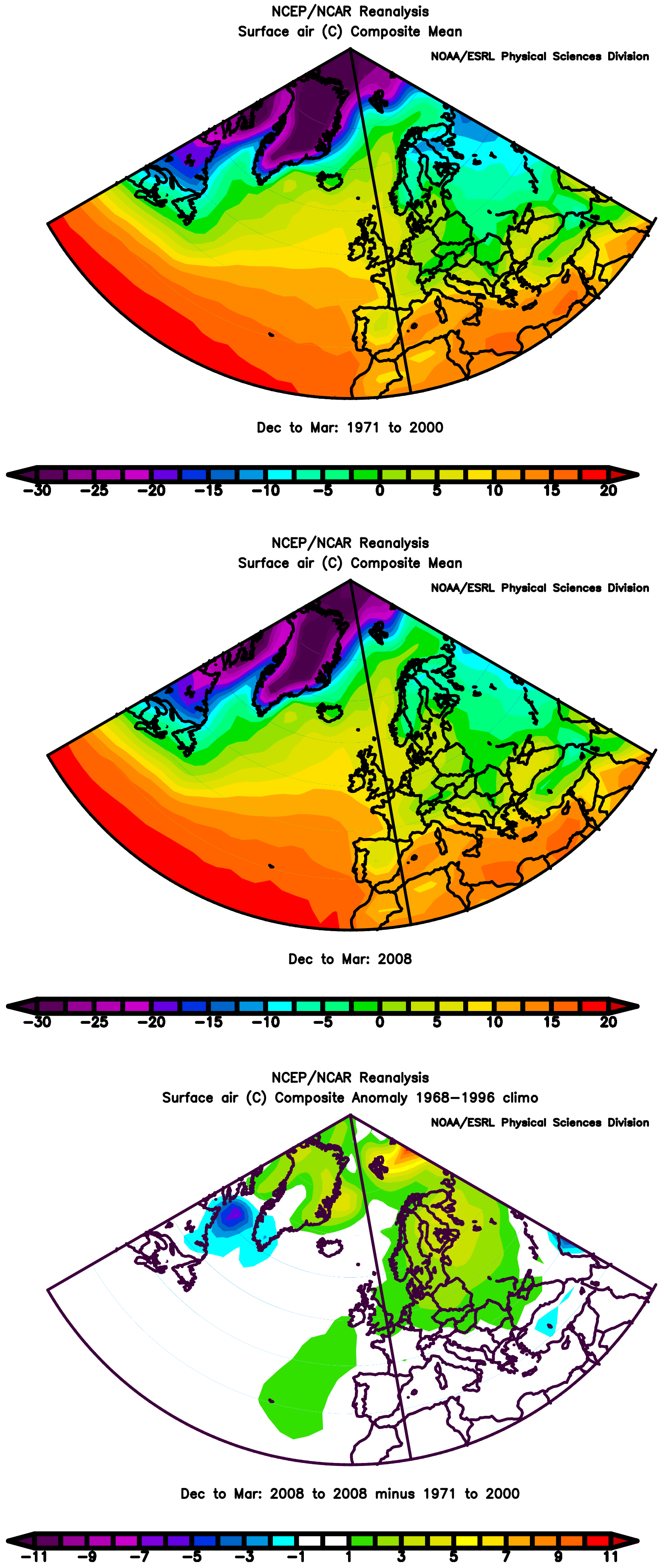


Figure 12.
Winter (DJFM) surface air temperature fields. Top panel: surface air temperature averaged over 30 years (1971–2000). Middle panel: temperatures in winter 2008 (December 2007, January to March 2008). Bottom panel: winter 2008 surface air temperature anomaly – the difference between the top and middle panels. Images provided by the NOAA/ESRL Physical Sciences Division, Boulder, Colorado (available online at http://www.cdc.noaa.gov/).

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

4.1 Introduction

In this section, we present time-series from many sustained observations in each of the ICES Areas. 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 13. 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 sampled 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 2008 are presented and compared with the average seasonal conditions and statistics.

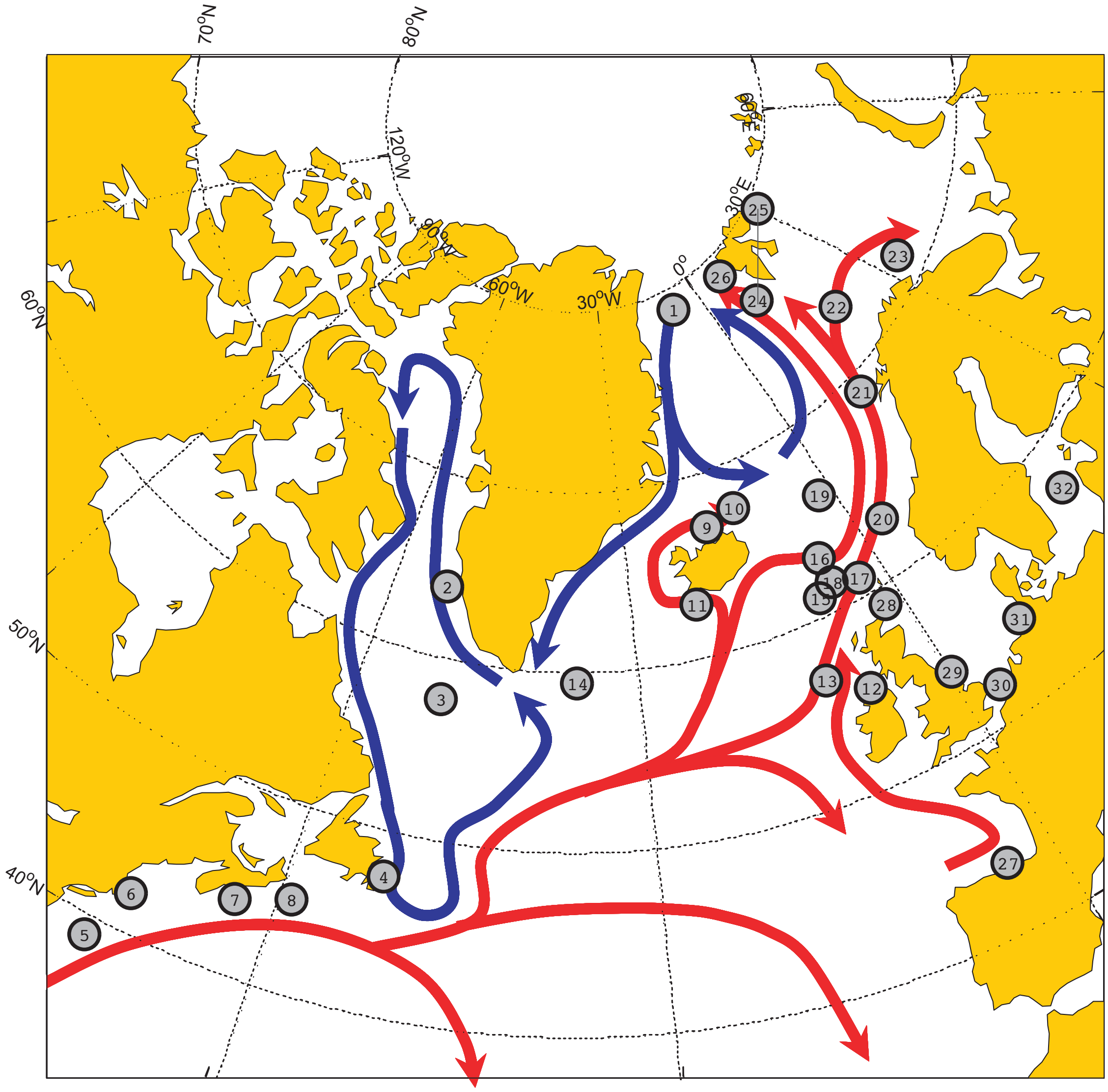


Figure 13.
Schematic of the general circulation of the upper ocean (0–1000 m) in the North Atlantic in relation to the numbered areas presented below. Blue arrows indicate the movement of the cooler waters of the Subpolar Gyre; red arrows indicate the movement of the warmer waters of the Subtropical 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. 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. in 1983, 1992, and 2002). Located farther offshore, Cape Desolation Station 3 has a water column that is 3000 m deep 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 (0.65) winter NAO index in 2008, air temperature conditions around Greenland continued to be warmer than normal; mean air temperatures at Nuuk show positive anomalies (+0.3°C).

At Fyllas Bank, the autumn 2008 subsurface temperatures were only 0.26°C above normal, which is significantly lower than in autumn 2003, when temperatures peaked at 2.69°C above normal. Gradual cooling can be seen at Fyllas Bank, continuing during autumn. The long-term mean (1963–1990) for the 0–200 m layer is 2.70°C.

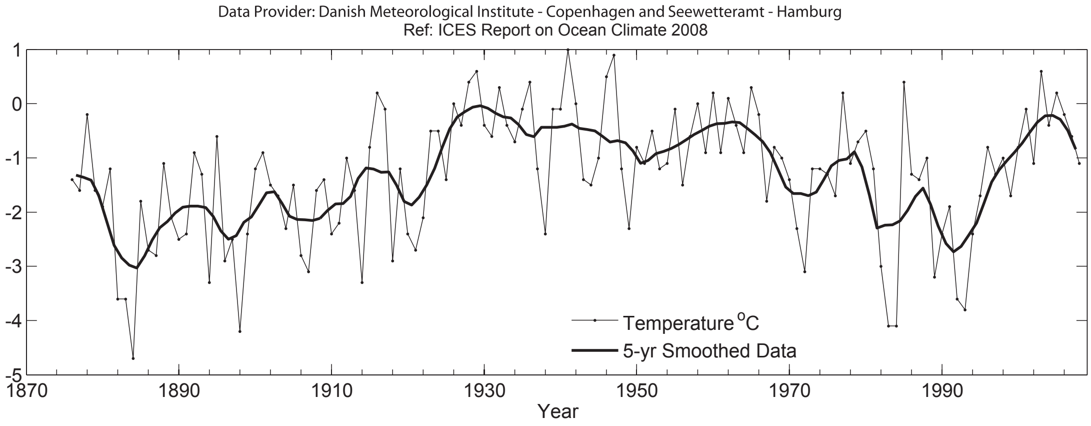

Data Provider: Danish Meteorological Institute - Copenhagen and Seewetteramt - Hamburg
Ref: ICES Report on Ocean Climate 2008

Figure 14.
Area 1 – West Greenland. Annual mean air temperature at Nuuk.

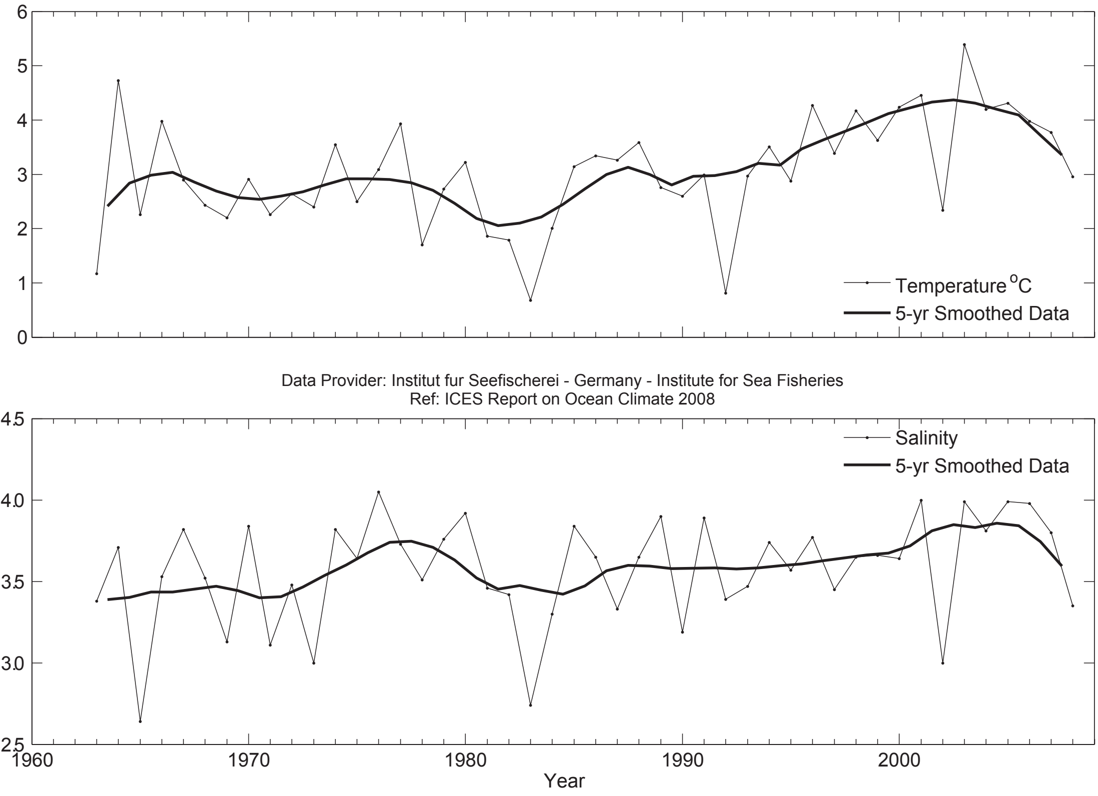
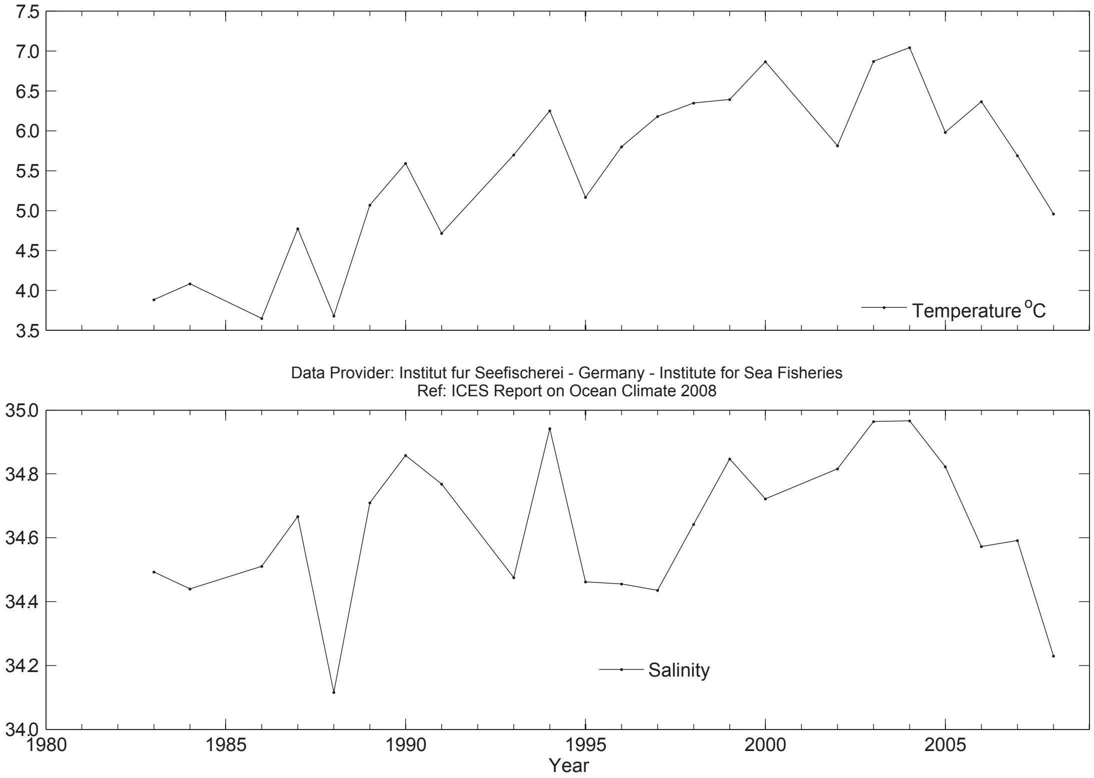

Data Provider: Institut fur Seefischerei - Germany - Institute for Sea Fisheries
Ref: ICES Report on Ocean Climate 2008

Figure 15.
West Greenland. Autumn temperature (upper panel) and salinity (lower panel) at 0–200 m at Fyllas Bank Station 4.



Data Provider: Institut fur Seefischerei - Germany - Institute for Sea Fisheries
Ref: ICES Report on Ocean Climate 2008

Figure 16.
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 FRESHWATER 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 2008, annual mean air temperatures over the Scotian Shelf, represented by Sable Island observations, were 0.5°C above the long-term mean (based on 1971–2000 mean values).

The amount of sea ice on the Scotian Shelf in 2008, as measured by the area of ice seawards of Cabot Strait between Nova Scotia and Newfoundland from January to April, was well below the long-term mean coverage of 39 000 km^2. This is substantially less than the 2003 cover which was the highest in the 40-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 average conditions in 2008. In Emerald Basin, temperatures in 2008 were below normal at 100 m.

THE AMOUNT OF SEA ICE ON THE SCOTIAN SHELF WAS WELL BELOW NORMAL IN 2008.

Figure 17.
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).

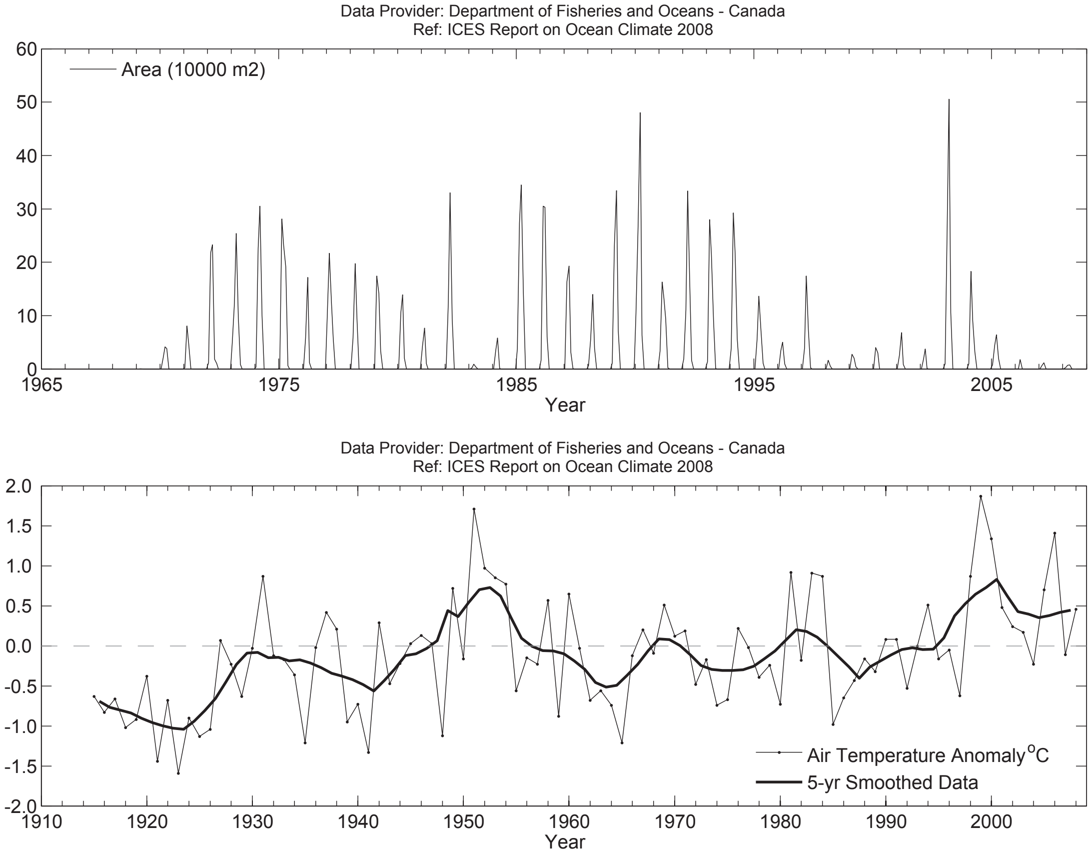
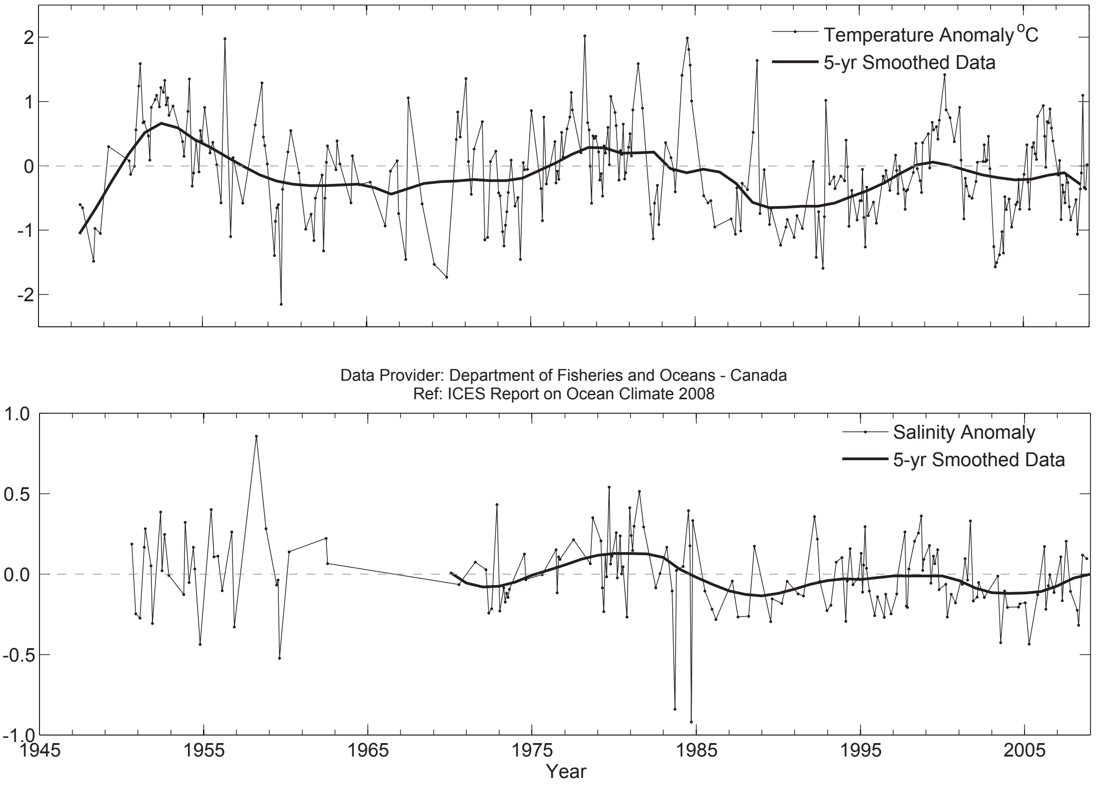


Figure 18.
Area 2 – Northwest Atlantic: Scotian Shelf. Near-bottom temperature anomalies (upper panel) and salinity anomalies (lower panel) at Misaine Bank (100 m).



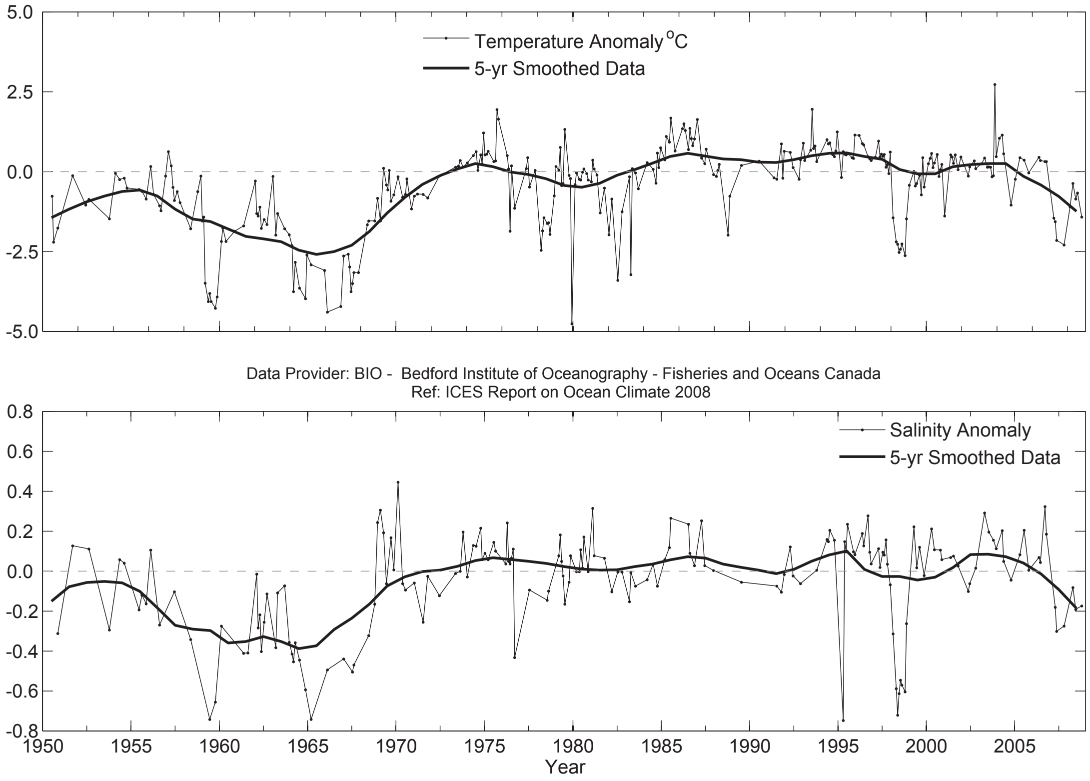


Figure 19.
Area 2 – Northwest Atlantic: Scotian Shelf. Near-bottom temperature anomalies (upper panel) and salinity anomalies (lower panel) in the central Scotian Shelf (Emerald Basin 250 m).

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 FROM THE NORTH, TOGETHER WITH SEA ICE AND ICEBERGS, 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 NAO index for 2007 and 2008 was slightly above normal (this 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 (0.8°C at Cartwright) and Newfoundland (1°C at St John's), and were significantly lower than the record highs of 2006, although higher than 2007. Sea-ice extent on the Newfoundland and Labrador Shelf was below average for the 14th consecutive year. The winter ice extent was the highest since 1997, whereas the spring extent ranked 11th lowest since 1963.

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 in 2007, and to 0.2°C above normal in 2008. Surface temperatures at Station 27 also increased from the record 2007 values to 1°C above normal, while bottom temperatures remained above normal for the 13th 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 index was well below normal, with the lowest value ever recorded in the 19th century, the volume of CIL water was at a minimum, while during the high NAO years of the early 1990s, the CIL volume reached a near-record high. During 2008, the cross-sectional area of the CIL remained below normal on the eastern Newfoundland Shelf for the 14th consecutive year, ranking 5th lowest since 1948.

In general, water temperatures on the Newfoundland and Labrador Shelf were below 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 seven years, although there has been considerable local variability as a result of melting sea ice and freshwater run-off.

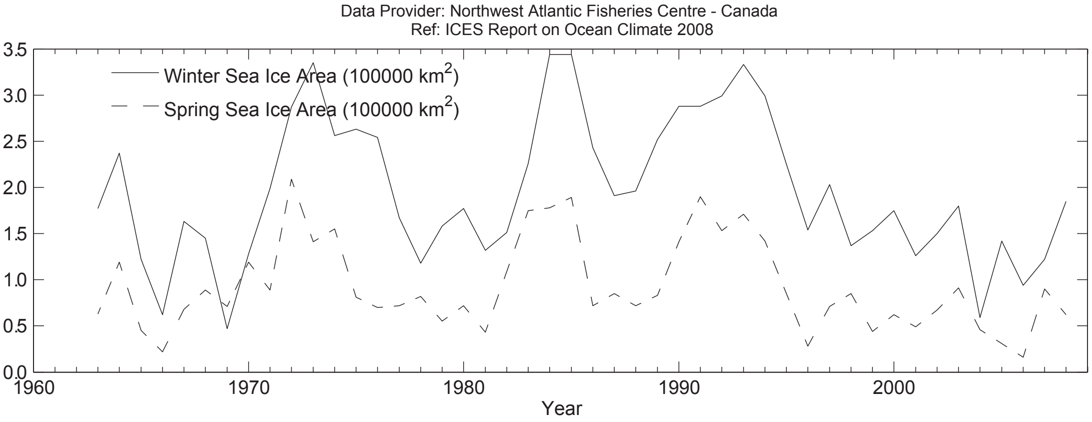

Data Provider: Northwest Atlantic Fisheries Centre - Canada
Ref: ICES Report on Ocean Climate 2008

Figure 20.
Area 2 – Northwest Atlantic: Newfoundland and Labrador Shelf. Monthly sea-ice areas off Newfoundland and Labrador between 45°N and 55°N.

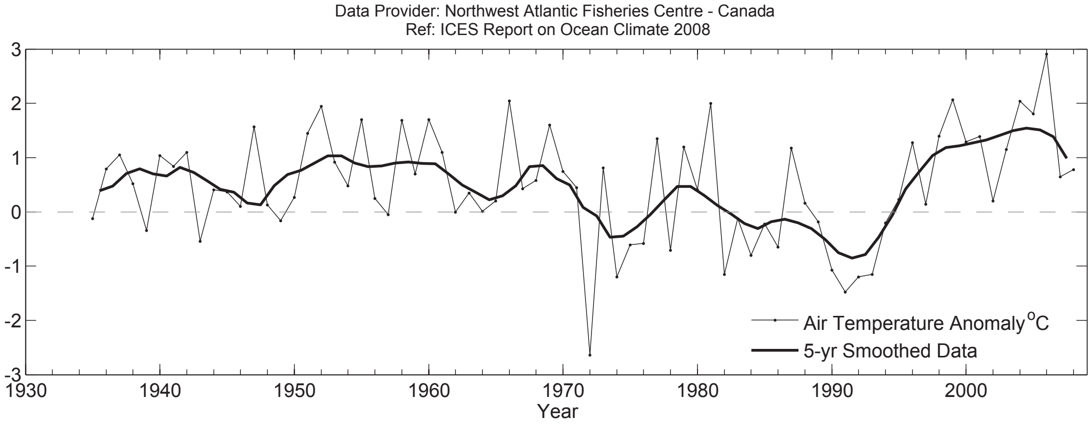
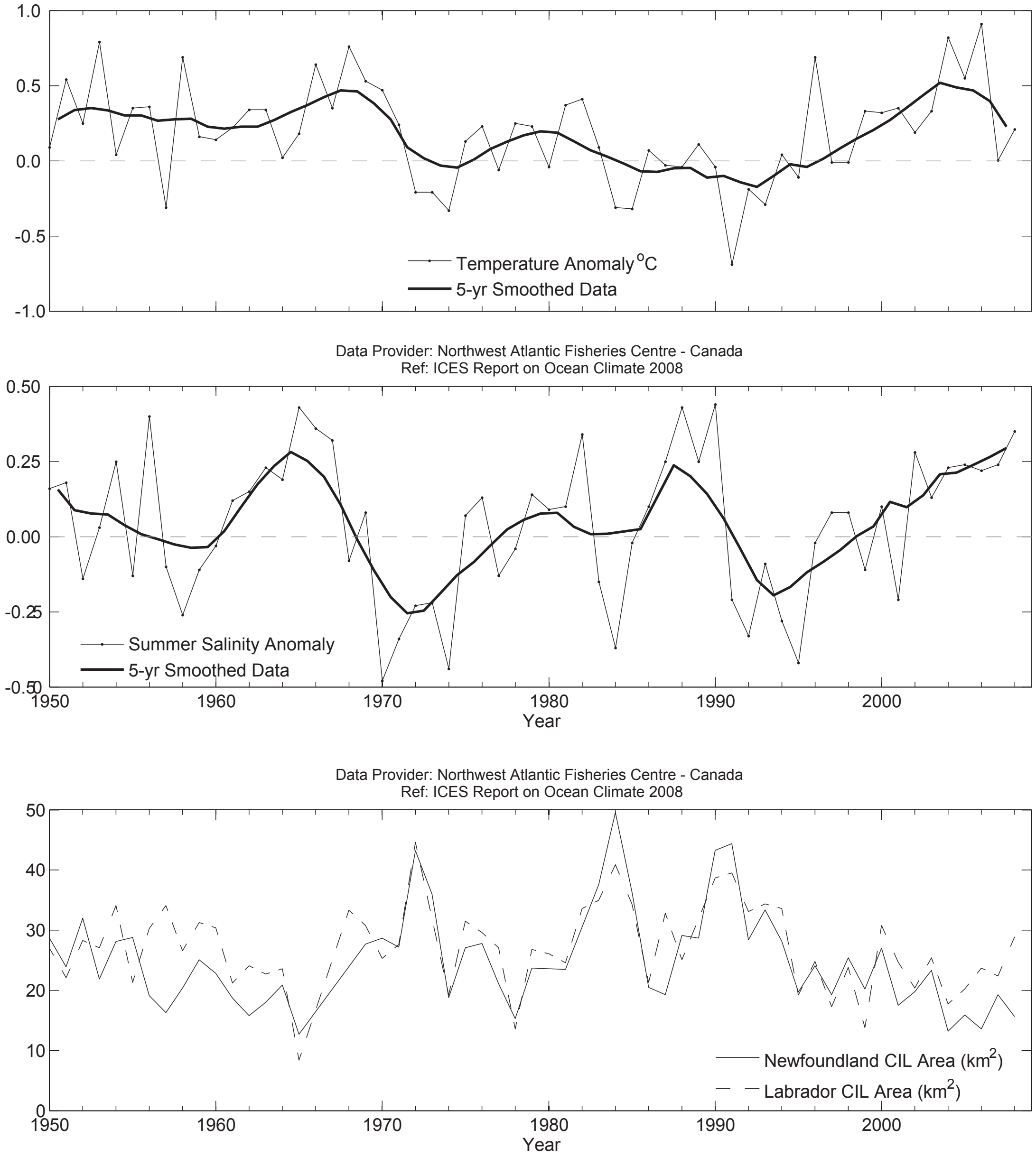

Data Provider: Northwest Atlantic Fisheries Centre - Canada
Ref: ICES Report on Ocean Climate 2008

Figure 21.
Area 2 – Northwest Atlantic: Newfoundland and Labrador Shelf. Annual air temperature anomalies at Cartwright on the Labrador coast.



Data Provider: Northwest Atlantic Fisheries Centre - Canada
Ref: ICES Report on Ocean Climate 2008

Data Provider: Northwest Atlantic Fisheries Centre - Canada
Ref: ICES Report on Ocean Climate 2008

Figure 22.
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 freshwater 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, 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. The winter of 2007/2008 was unusually cold compared with recent years, but hydrographic conditions in 2008 remained warm and saline, with both temperature and salinity showing increases relative to 2007. The 2008 annual mean SST in the west-central Labrador Sea rebounded from a slight cooling in 2007 to exceed the long-term 1971–2000 mean by 0.8°C. This was the 15th consecutive year that was warmer than normal.

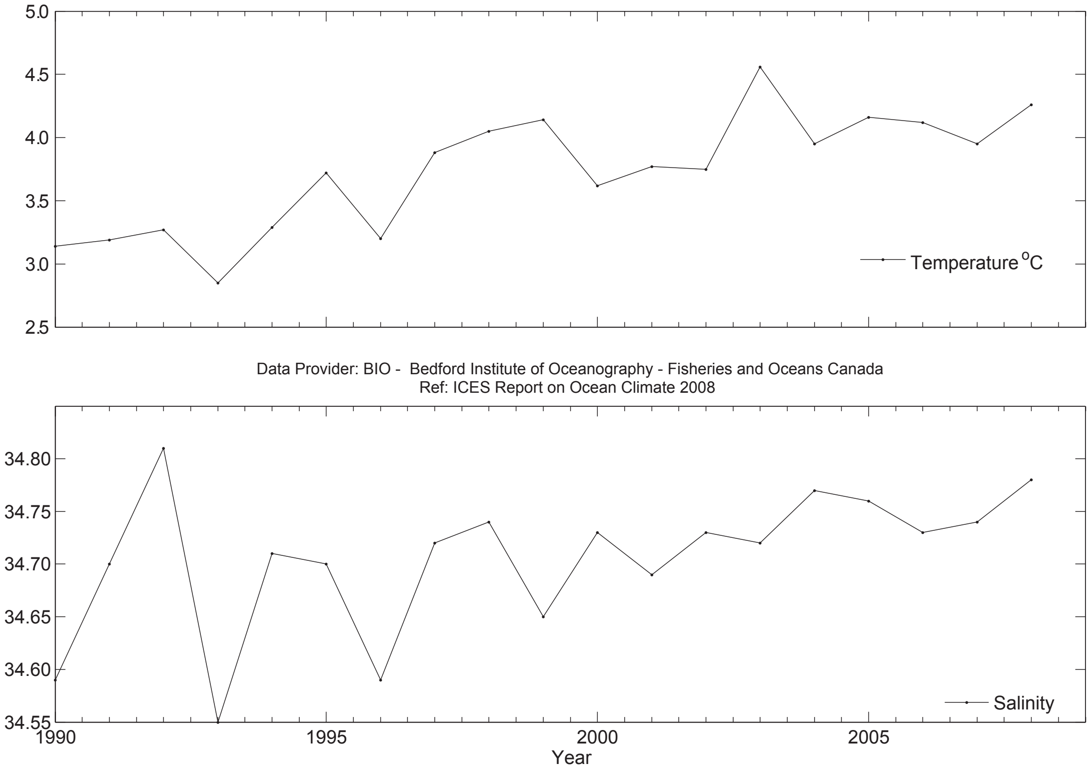


Figure 23.
Area 2b – Labrador Sea. Potential temperature (upper panel) and salinity (lower panel) at 0–150 m, from four stations in the west-central Labrador Sea (centred at 56.7°N 52.5°W). Estimates of seasonal changes based on climatology have been removed from these spring/early summer measurements.

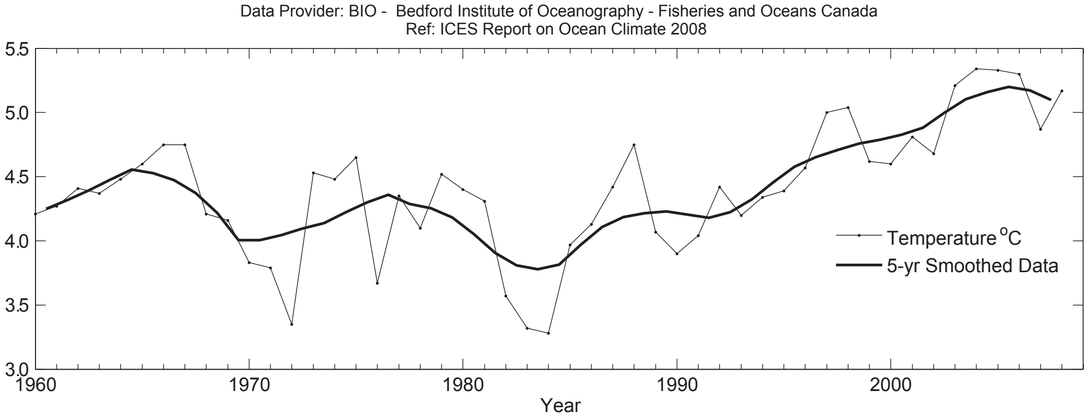


Figure 24.
Area 2b – Labrador Sea. Annual mean sea surface temperature data from the west-central Labrador Sea (56.5°N 52.5°W). Data obtained from the HadISST1.1 sea ice and sea surface temperature dataset, UK Meteorological Office, Hadley Centre.

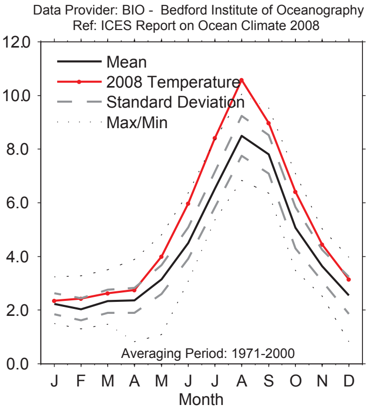


Figure 25.
Area 2b – Labrador Sea. 2008 monthly sea surface temperature data from the west-central Labrador Sea (56.5°N 52.5°W). Data obtained from the HadISST1.1sea ice and sea surface temperature dataset, UK Meteorological Office, Hadley Centre.

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 SOUTHEAST OF NEW YORK CITY TO BERMUDA AND THE OTHER TRAVERSES THE GULF OF MAINE, EAST OF BOSTON. HYDROGRAPHIC CONDITIONS THROUGHOUT THE SHELF, INCLUDING GEORGES BANK, HAVE ALSO BEEN MONITORED ANNUALLY SINCE 1977 BY BOTTOM-TRAWL SURVEYS.

Figure 27 shows surface temperature and salinity anomalies along the XBT line southeast of New York City. On the shelf (within 200 km of the coast), the waters have generally been warm and fresh since 2005, but slope waters have displayed more variability, with higher amplitude signals.

Figure 28 shows surface temperature and salinity anomalies along the XBT line through the Gulf of Maine. Conditions have been generally warm since 2006, while the salinity has remained close to the climatological average (although there is a gap in data in the latter half of 2008).

The Georges Bank surface observations (0–30 m) come from a wide region covering the Bank. Figure 29 shows temperature and salinity anomalies. The anomalies are in original units relative to the mean for 1977–2000. Since 2005, conditions on the Bank have tended to be warm with a weaker salinity signal. This is consistent with the Gulf of Maine XBT data. Figure 30 suggests that Georges Bank has returned to the state it was in during the late 1990s and early 2000s (i.e. generally warm, but close to the long-term average in salinity).

SHELF WATERS ON THE MID-ATLANTIC BIGHT HAVE BEEN WARMER THAN AVERAGE THE PAST FEW YEARS.

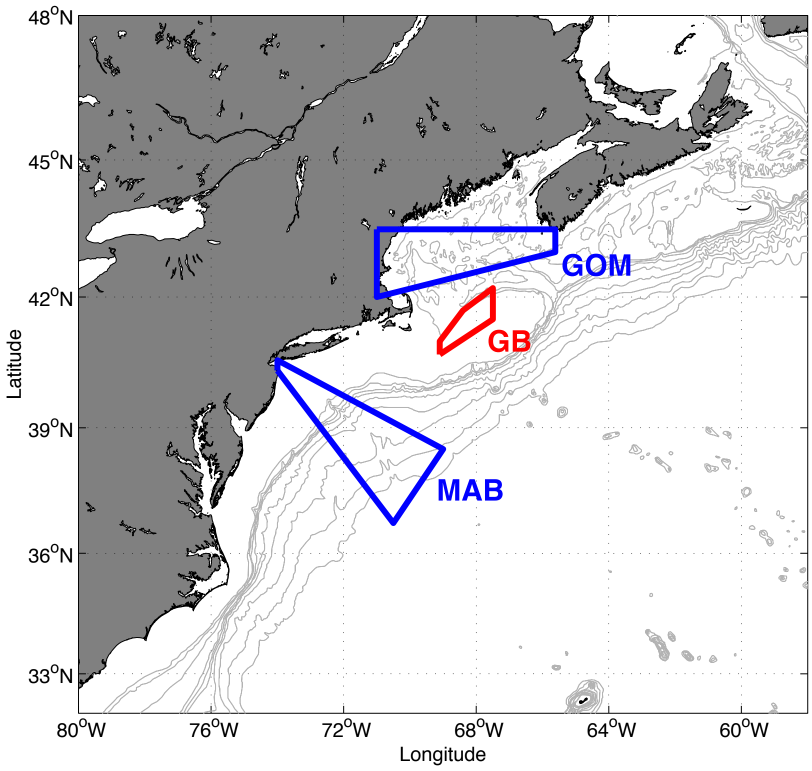


Figure 26.
Area 2c – Mid-Atlantic Bight. The three regions of ongoing time-series. GOM = Gulf of Maine (XBT measurements and surface samples); GB = Georges Bank (CTD stations); MAB = central Mid-Atlantic Bight (XBT measurements and surface samples). The isobaths shown range from 100 to 500 m by 100 m increments, and from 1000 to 4000 m by 500 m increments. Data provider: Woods Hole Oceanographic Institution, USA.

Figure 27.
Area 2c – Mid-Atlantic Bight. Temperature and salinity in the central Mid-Atlantic Bight. Top panel: surface temperature anomaly (relative to the base period of 1978–2007) from XBT measurements. The origin of the line is New York City. Bottom panel: sea surface salinity anomalies from bottle measurements. Data provider: Woods Hole Oceanographic Institution, USA.

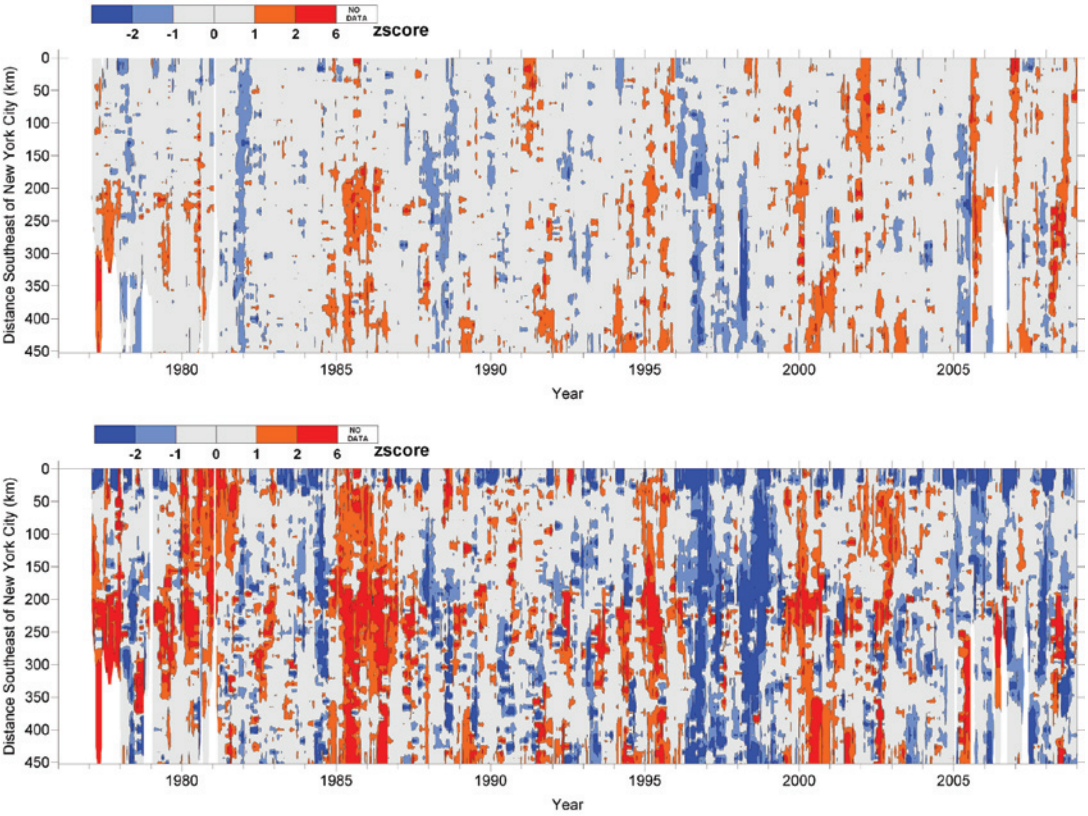
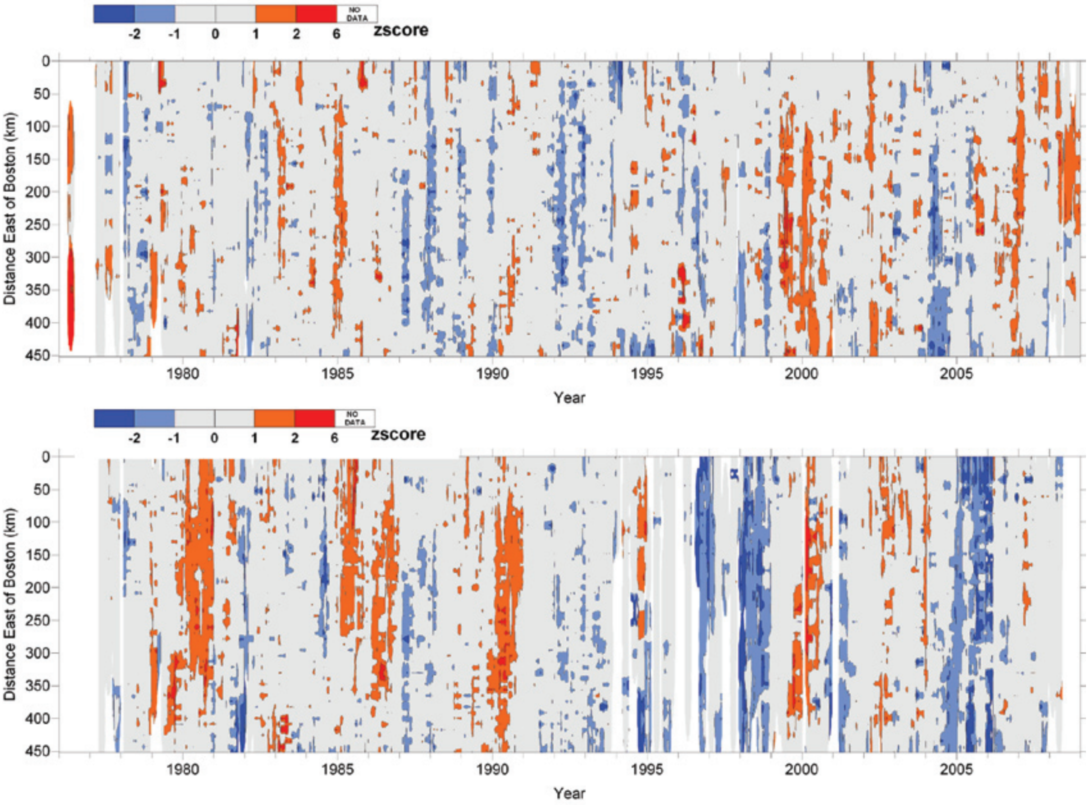


Figure 28.
Area 2c – Mid-Atlantic Bight. Temperature and salinity in the Gulf of Maine. Top panel: surface temperature anomaly (relative to the base period of 1978–2007) from XBT measurements. The origin of the line is Boston. Bottom panel: sea surface salinity anomalies from bottle measurements. Data provider: Woods Hole Oceanographic Institution, USA.



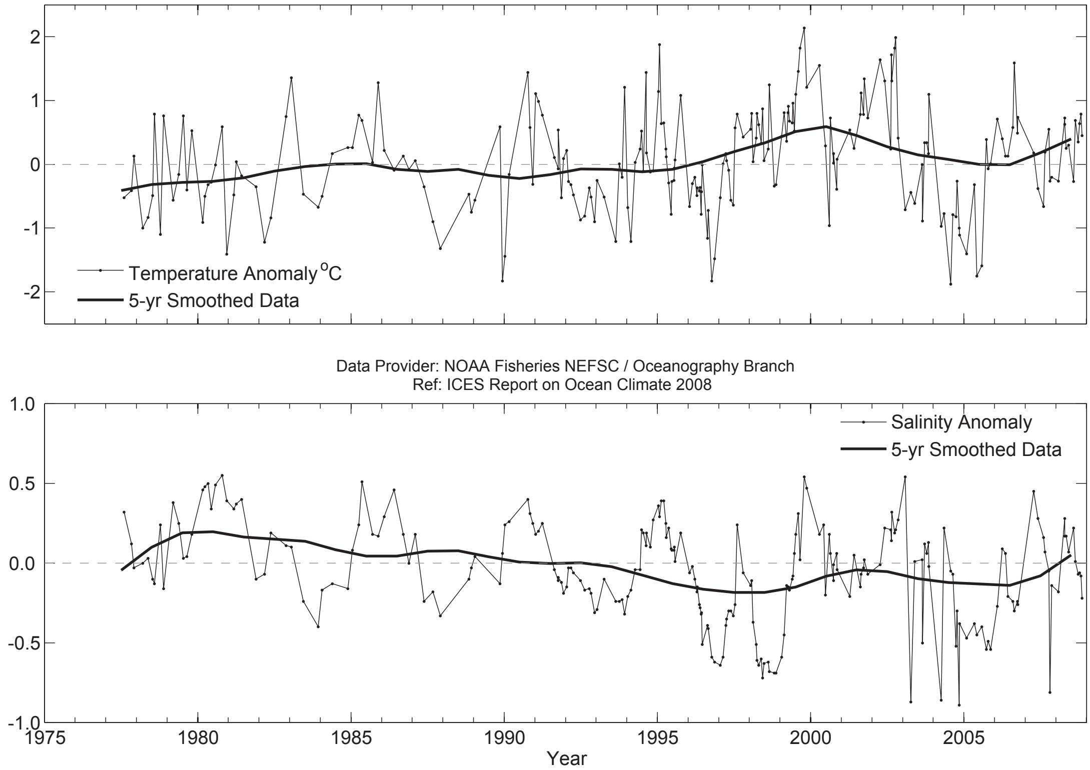


Figure 29.
Area 2c – Mid-Atlantic Bight. Time-series plots of 0–30 m averaged temperature anomaly (top panel) and salinity anomaly (bottom panel) at Georges Bank.

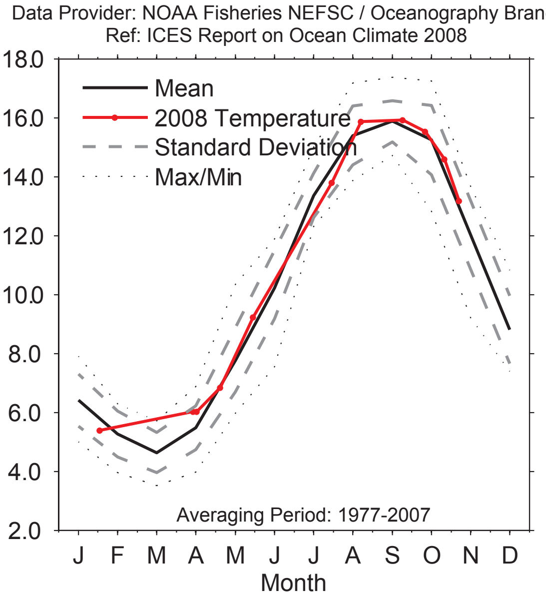


Figure 30.
Area 2c – Mid-Atlantic Bight. 2008 monthly temperatures (0–30 m) at Georges Bank.

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 to 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-pressure and Greenland high-pressure systems. 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 2008, mean air temperatures in the south (Reykjavik) and north (Akureyri) were above long-term averages. During the year, temperature and salinity levels south and west of Iceland remained high. In the north, spring and autumn temperatures and salinities of surface layers were around average. Salinity and temperature in the East Icelandic Current in spring 2008 were above average. In February 2009, temperatures and salinities were above the long-term mean in the south and west, and around or below it in the north and east.

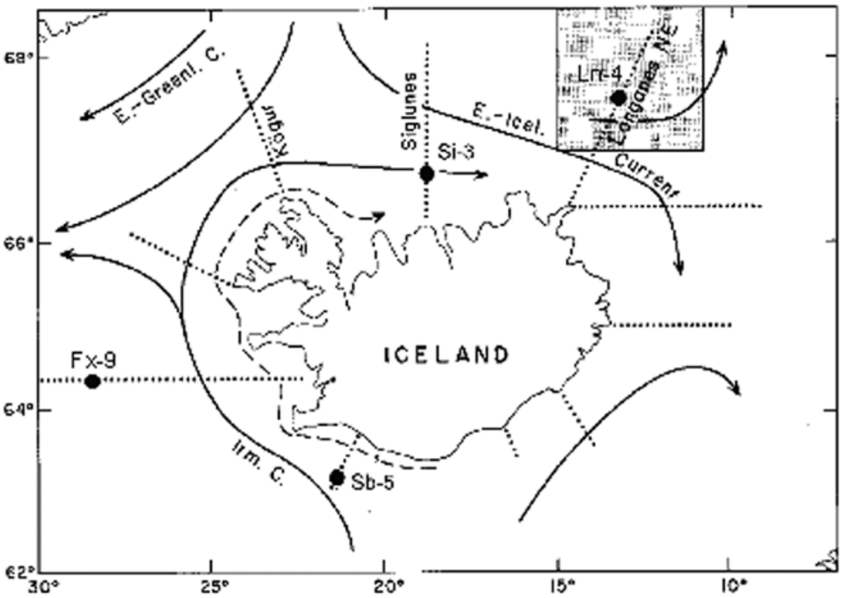


Figure 31.
Area 3 – Icelandic waters. Main currents and location of standard sections in Icelandic waters.

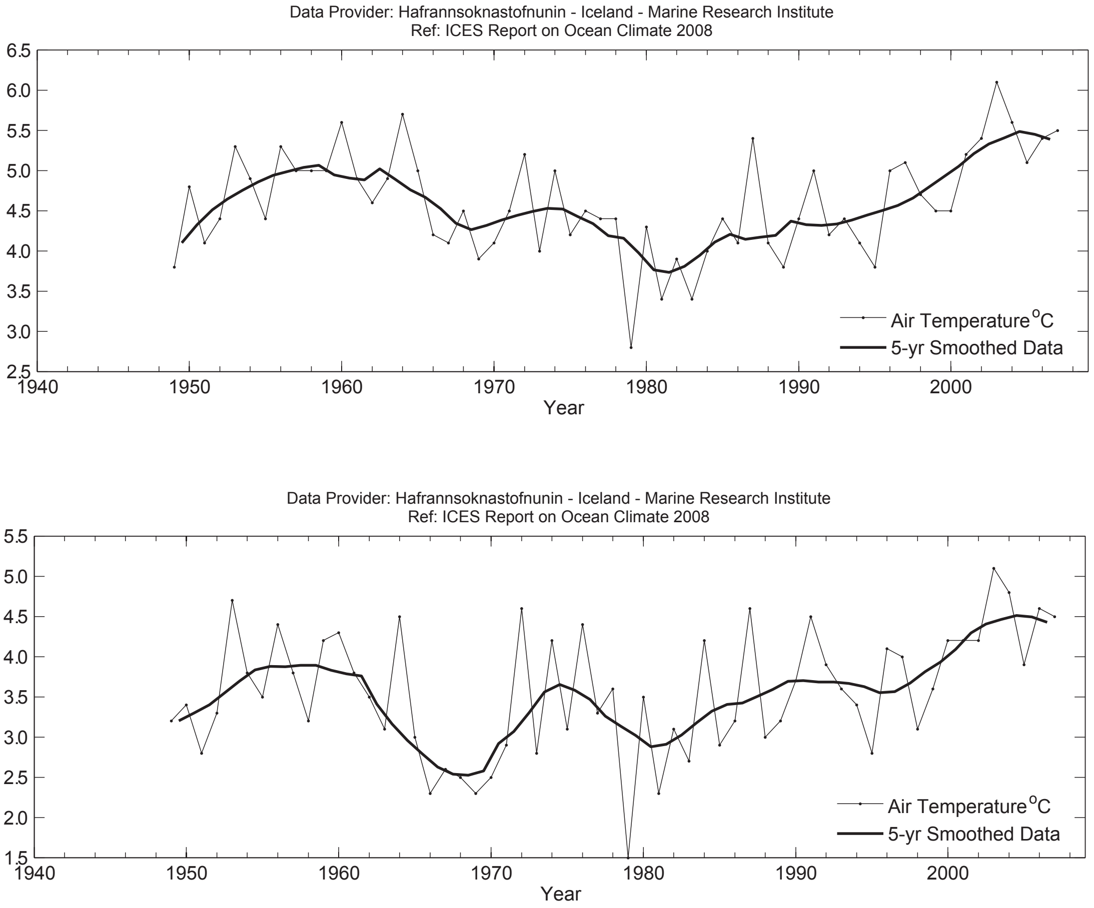


Figure 32.
Area 3 – Icelandic waters. Mean annual air temperature at Reykjavík (upper panel) and Akureyri (lower panel).

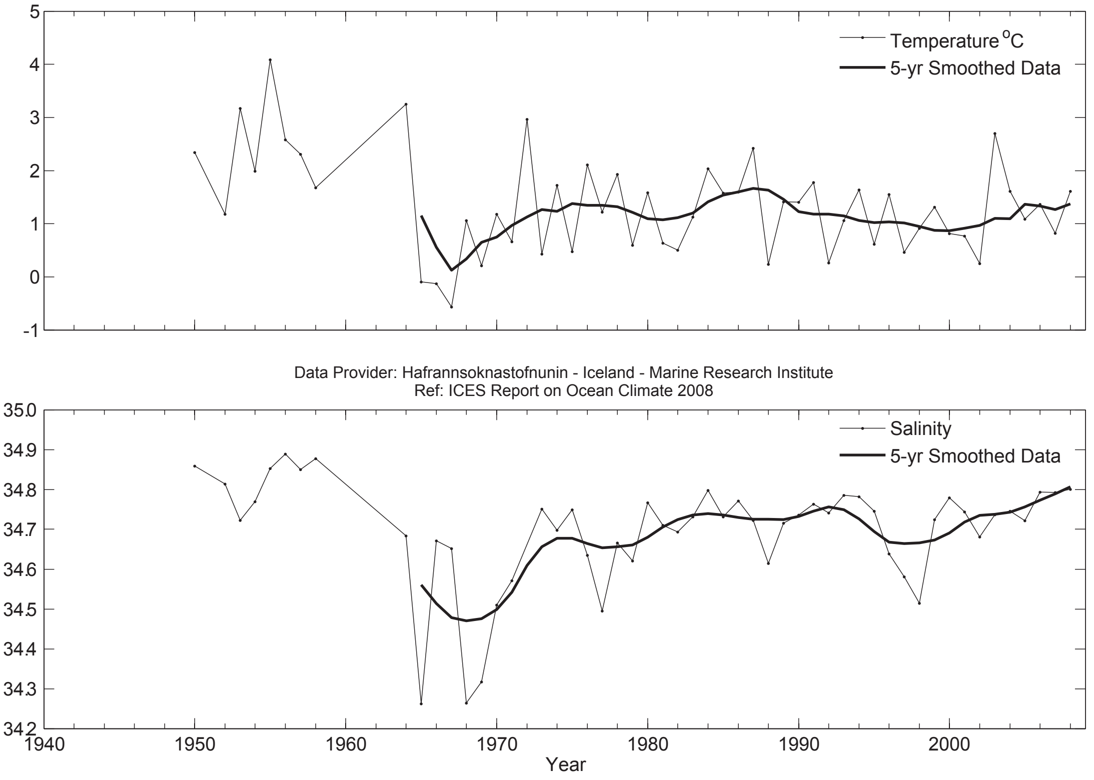


Figure 33.
Area 3 – Icelandic waters. Temperature (upper panel) and salinity (lower panel) at 50–150 m at Siglunes Stations 2–4 in North Icelandic waters.

Figure 34.

Area 3 – Icelandic waters. Temperature (upper panel) and salinity (lower panel) at 0–200 m at Selvogsbanki Station 5 in South Icelandic waters.

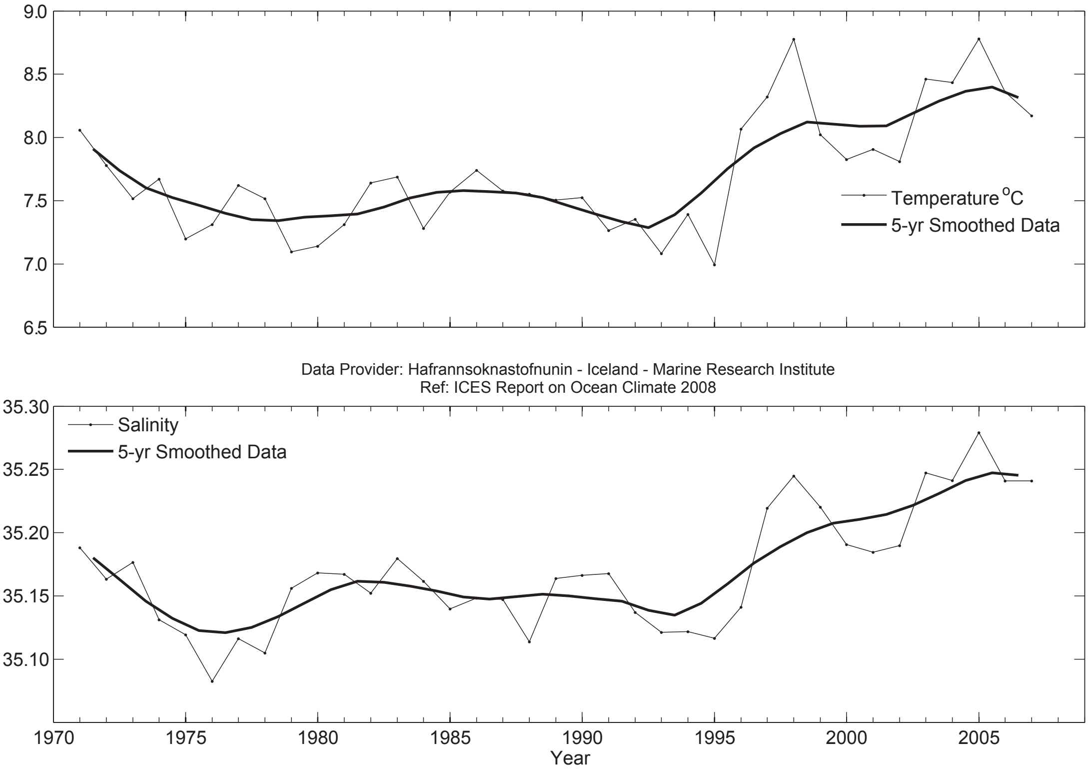
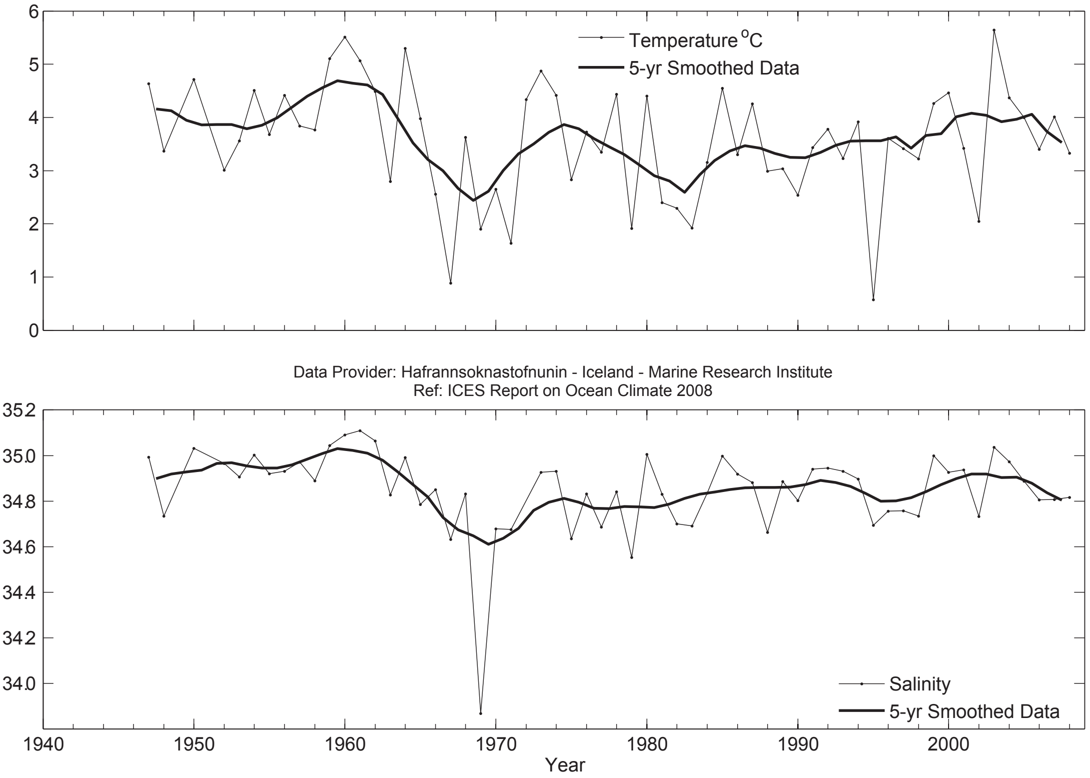


Figure 35.

Area 3 – Icelandic waters. Temperature (upper panel) and salinity (lower panel) at 0–50 m in the East Icelandic Current (Langanes Stations 2–6) since 1950.



4.7 Area 4 – Bay of Biscay and eastern Atlantic

THE BAY OF BISCAY IS LOCATED IN THE EASTERN NORTH ATLANTIC. ITS GENERAL CIRCULATION FOLLOWS THE SUBTROPICAL ANTICYCLONIC GYRE AND IS RELATIVELY WEAK. IN THE SOUTHERN PART OF THE BAY OF BISCAY, EAST-FLOWING SHELF AND SLOPE CURRENTS RELATED WITH THE IBERIAN POLEWARD CURRENT 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.

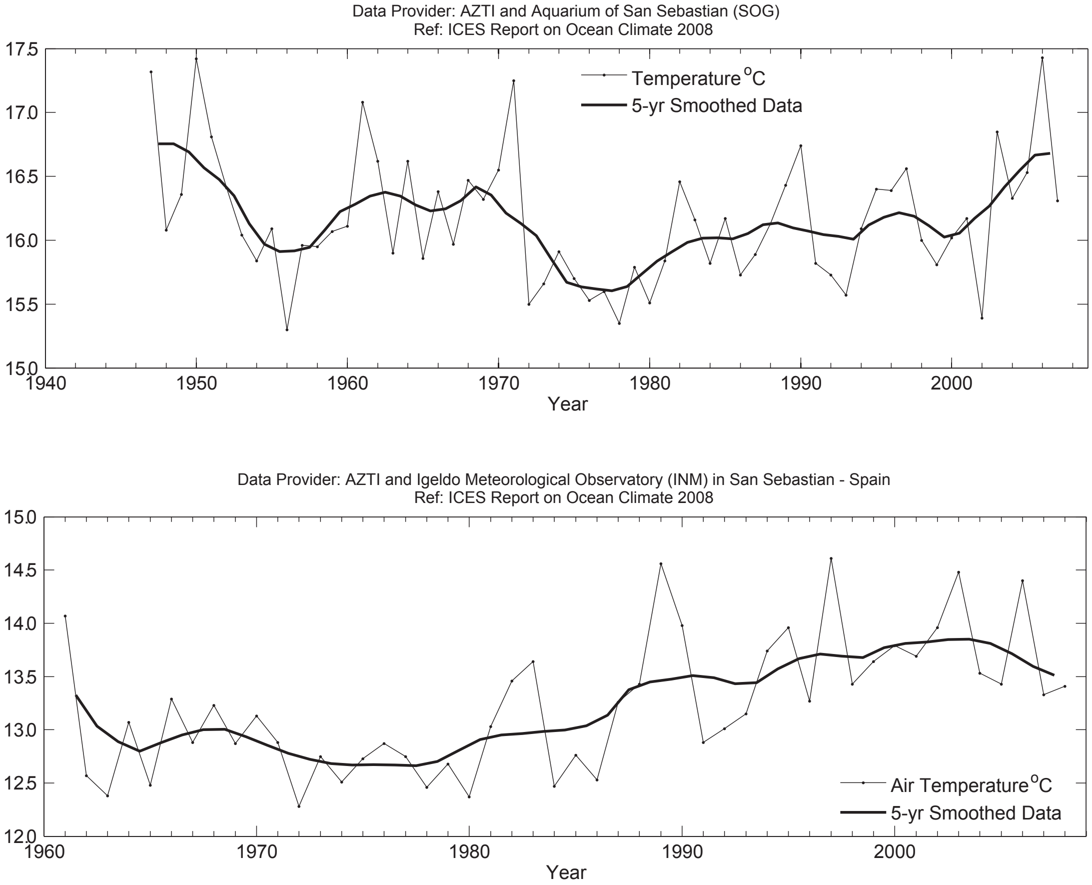
Like 2007, the year 2008 was one of contrasts in the Bay of Biscay: a mild early winter and spring, and a cold summer and autumn. Overall, the northern part of the Iberian Peninsula had average annual meteorological conditions in 2008. Annual mean air temperature over the southern Bay of Biscay during 2008 was 0.25°C higher than the average value for the 1971–2000 period, but lower (~1°C) than some recent warm years (2003 and 2006). The 2008 pattern of warm winter/cold summer also contrasts with the cold winter/warm summer pattern in 2005 and 2006. As expected, the SST reflected the warmer–colder pattern, with a high temperature in May, contrasting with the fast and deep cooling from September to December. This pattern was caused by low air temperatures in the second half of the year, related to the high frequency of cloudy and rainy days. As in 2007, a noticeable reduction in hours of sunshine and subsequent solar radiation was recorded (24% lower than the 1986–2007 average for the year and 36% lower for the June–December period).

The pattern for subsurface and intermediate waters differs from the air and SST pattern. A strong, cold anomaly was produced in the local intermediate waters after the very cold winter of 2004/2005, followed by the formation of an anomalous warm mixed layer in 2007, as a consequence of the warm 2006 autumn and the warm 2006/2007 winter. The integration into the upper layers of the 2008 seasonal anomalies slightly reverses the warming tendency detected in the ocean interior in previous years. In the North Atlantic Central Water and Mediterranean Water, the warming trend continues.

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 (IPC). In 2008, a high-salinity signal appeared throughout the water column as a result of a strong episode of IPC advecting saltier waters than those observed in December 2006 and January 2007. The salinity increase reached the maximum of the trend started in 2003. There were high positive anomalies in precipitation and river run-off in the area, but the subsequent low-salinity signal was slight and restricted to upper layers until the autumn. At the end of the year, after strong precipitation and the start of winter mixing, some reversal of the increasing trend in salinity was observed.

THE ADVECTION OF HIGH-SALINITY WATER OVERWHELMED ABOVE-AVERAGE PRECIPITATION AND RUN-OFF.

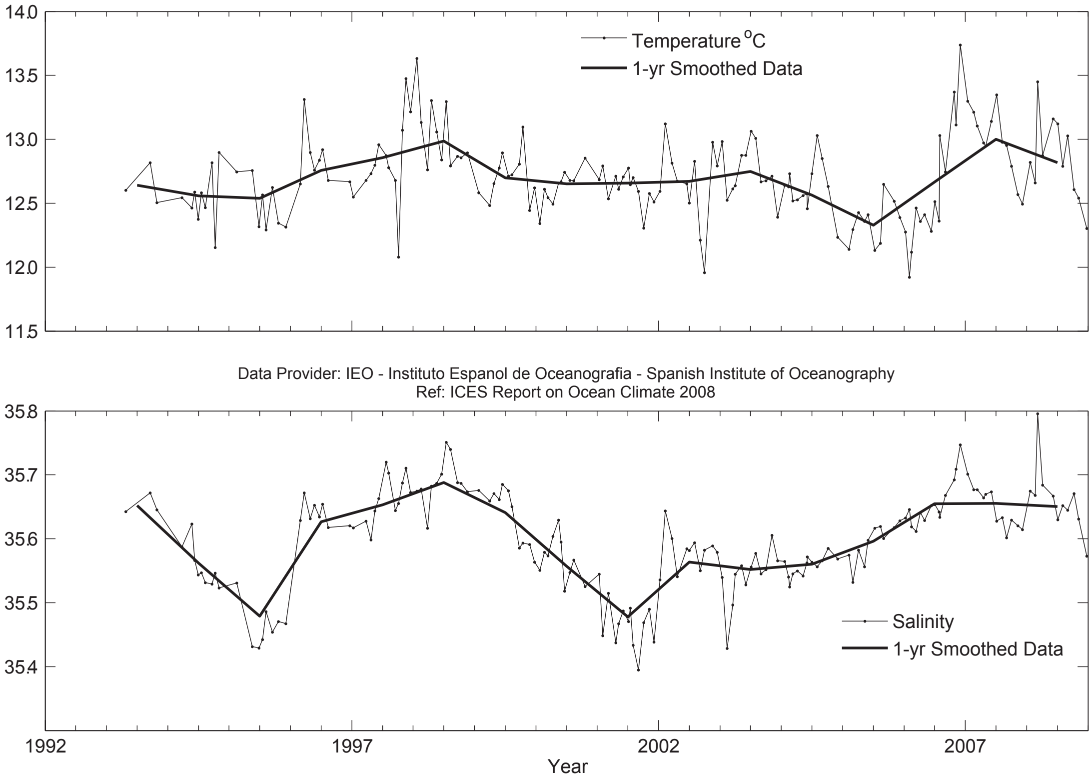
RV Polarfront, image courtesy of Margaret Yelland, National Oceanography Centre, Southampton, UK.



Data Provider: AZTI and Aquarium of San Sebastian (SOG)
Ref: ICES Report on Ocean Climate 2008

Data Provider: AZTI and Igeldo Meteorological Observatory (INM) in San Sebastian - Spain
Ref: ICES Report on Ocean Climate 2008

Figure 36 .
Area 4 – Bay of Biscay and eastern Atlantic. Sea surface temperature (upper panel) and air temperature (lower panel) at San Sebastian (43°18.5′N 02°2.37′W).



Data Provider: IEO - Instituto Espanol de Oceanografia - Spanish Institute of Oceanography
Ref: ICES Report on Ocean Climate 2008

Figure 37 .
Area 4 – Bay of Biscay and eastern Atlantic. Potential temperature (upper panel) and salinity (lower panel) at Santander Station 6 (5–300 m).

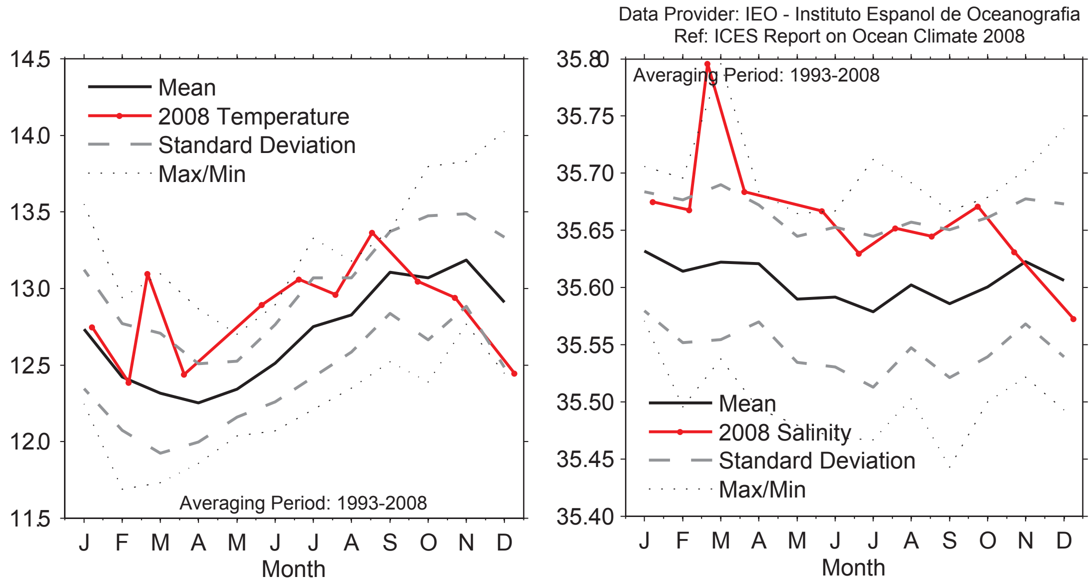


Figure 38.
Area 4 – Bay of Biscay and eastern Atlantic. 2008 monthly temperature (left panel) and salinity (right panel) at Santander Station 6 (5–300 m).

4.8 Area 4b – Northwest European continental shelf

Western English Channel

Station E1 (50.03°N 4.37°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 takes 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 in temperature. In 2008, Station E1 was sampled on 11 occasions, with no sampling occurring before April. The minimum recorded surface temperature (April) was 10.1°C, and the maximum surface temperature (July) was 15.8°C. The temperatures for the year as a whole were close to average throughout, although slightly cooler than the long-term mean in the spring and early summer. This could be partly the result of the enhanced vertical mixing caused by the windiest summer conditions for 40 years and reduced levels of insolation.

Figure 39.
Area 4b – Northwest European continental shelf. Temperature anomalies (upper panel) and salinity anomalies (lower panel) of surface water at Station E1 in the western English Channel (50.03°N 4.37°W).

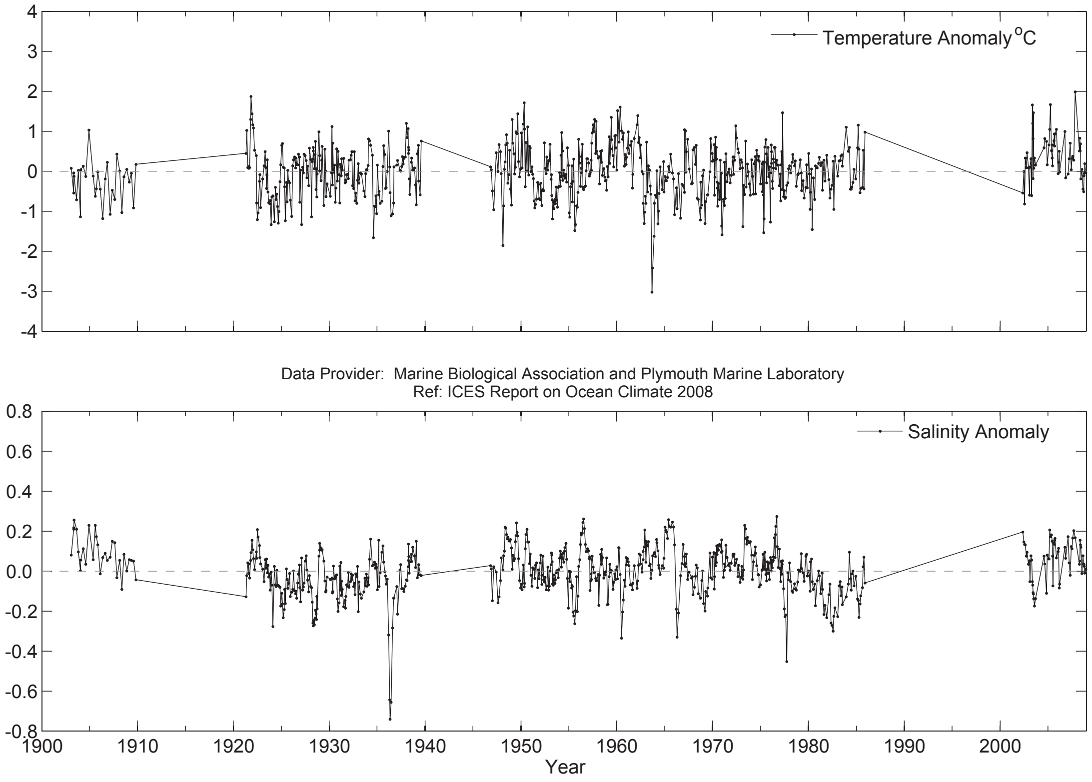
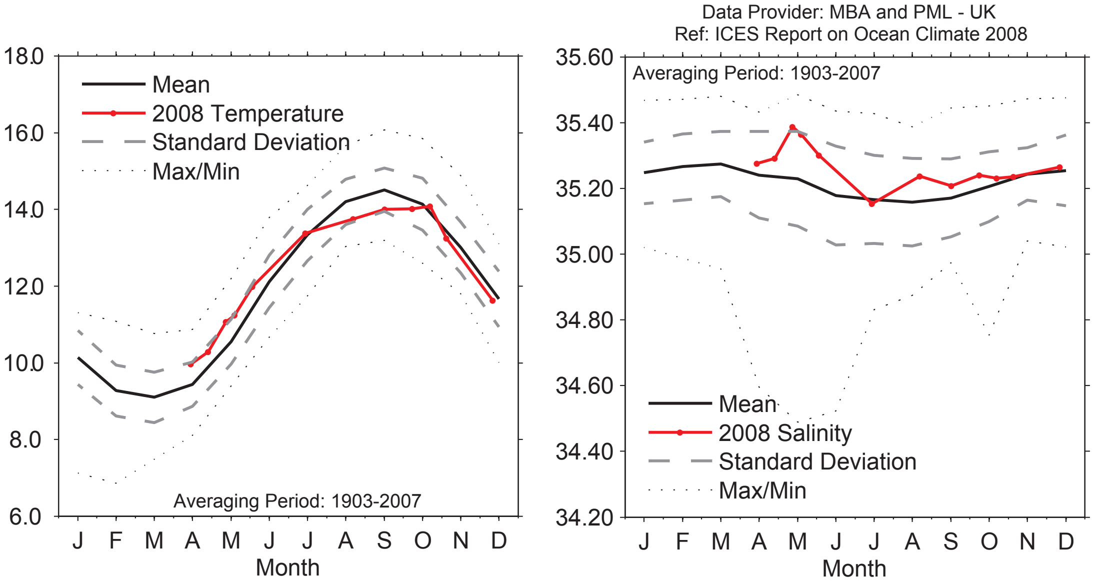


Figure 40.
Area 4b – Northwest European continental shelf. 2008 monthly temperature (left panel) and salinity (right panel) of surface water at Station E1 in the western English Channel (50.03°N 4.37°W).



North and southwest 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.

Temperatures have been increasing since the late 1980s, and those for the mid-2000s were the highest since records began in 1960. Temperatures in 2008 remained above the long-term mean in all months. Data presented here are to the end of 2008. The seasonal cycle on the Irish Shelf is illustrated by data from the M3 weather buoy, southwest of Ireland.

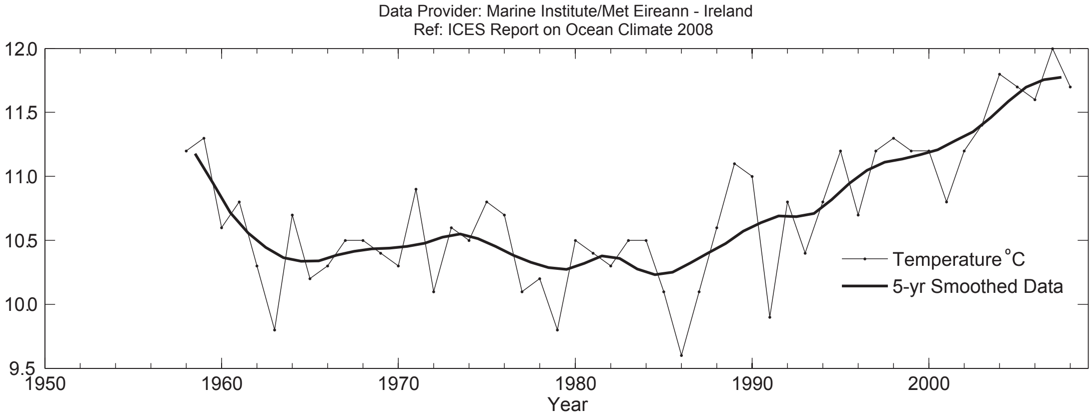


Figure 41.
Area 4b – Northwest European continental shelf. Temperature at the Malin Head coastal station (55.39°N 7.38°W).

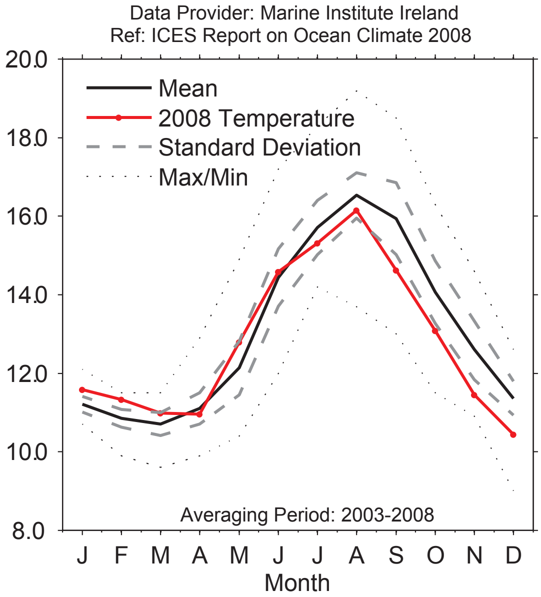
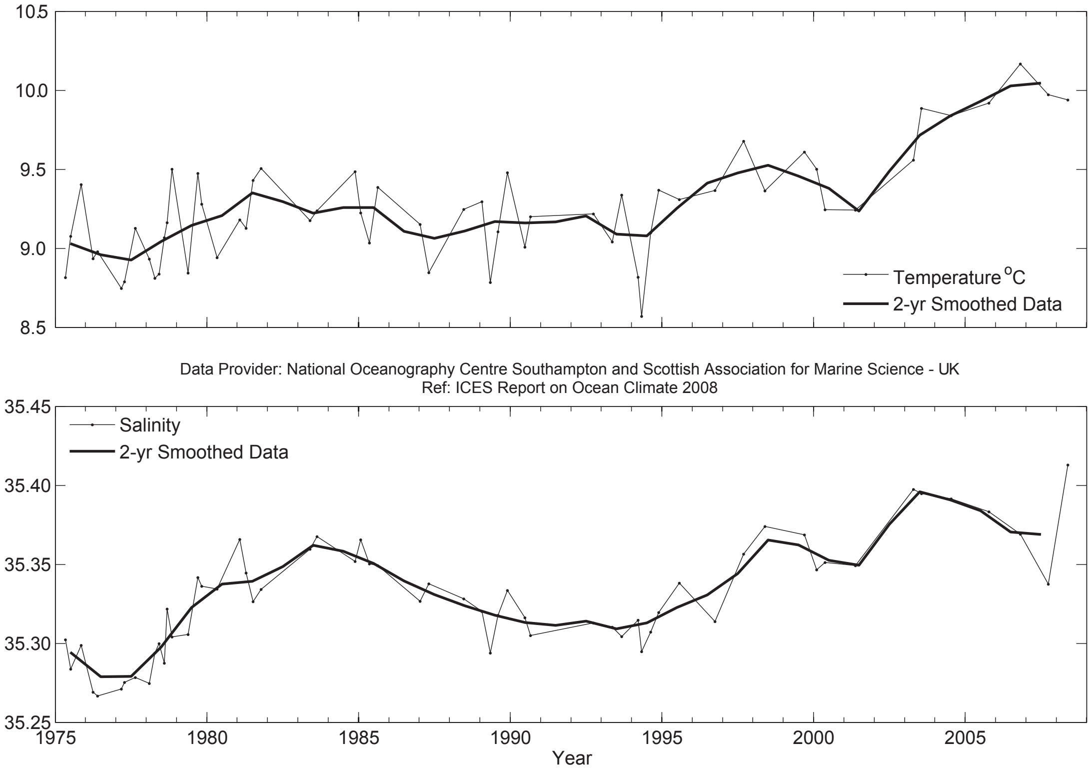


Figure 42.
Area 4b – Northwest European continental shelf. 2008 monthly temperature at the M3 Weather Buoy southwest of Ireland (51.22°N 10.55°W). No salinity data collected at this station.

4.9 Area 5 – Rockall Trough

THE ROCKALL TROUGH IS SITUATED TO THE 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 POLEWARD-MOVING EASTERN NORTH ATLANTIC WATER, WHICH IS WARMER AND SALTIER THAN WATERS OF THE ICELAND BASIN, (WHICH ALSO CONTRIBUTE TO THE NORDIC SEA INFLOW).

In 2008, the surface waters of the Rockall Trough (averaged from the surface to a depth of 800 m from the Rockall Bank to the Scottish Shelf) remained warm relative to the 1975–2000 mean value (9.21°C). However, they were cooler than in the preceding two years. The highest recorded salinity since 1975 (35.413) occurred in 2008, in contrast to the freshening trend that had begun to emerge in the observations. This value was 0.86 higher than the 1975–2000 mean. The years 2006 and 2007 were anomalously warm for their observed salinities. Since 1975, the Rockall Trough has been warming at a rate of 0.027°C year^{-1} and becoming saltier at a rate of 0.0024 units year^{-1}.



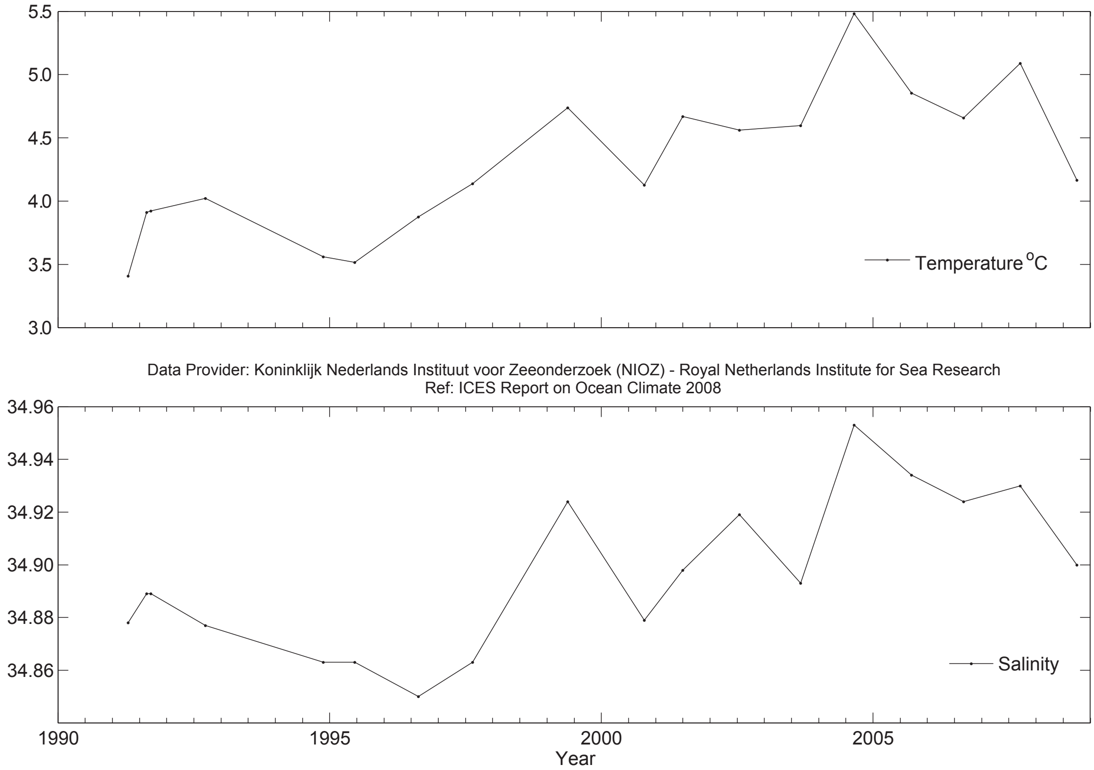
Data Provider: National Oceanography Centre Southampton and Scottish Association for Marine Science - UK
Ref: ICES Report on Ocean Climate 2008

Figure 43.
Area 5 – Rockall Trough. Temperature (upper panel) and salinity (lower panel) for the upper ocean (0–800 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 (SPMW) 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, related to a lack of convective activity. In winter 2007/2008, convection in the SPMW reached depths of at least 1000 m, resulting in a temperature decrease of nearly 1°C and a salinity decrease of 0.03 from 2007 to 2008, similar to the SPMW change observed after the cold winter of 1999/2000.



Data Provider: Koninklijk Nederlands Instituut voor Zeeonderzoek (NIOZ) - Royal Netherlands Institute for Sea Research
Ref: ICES Report on Ocean Climate 2008

Figure 44.
Area 5b – Irminger Sea. Temperature (upper panel) and salinity (lower panel) of Subpolar Mode Water (averaged over 200–400 m).

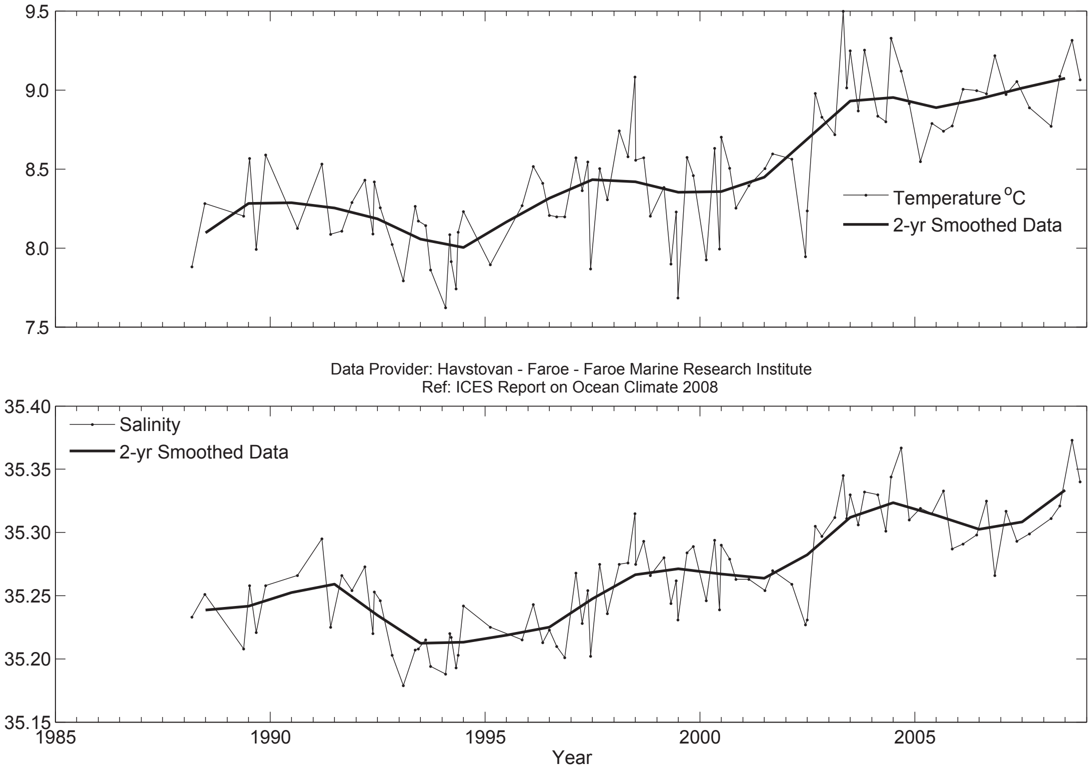
Understanding patterns of variability

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 can 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.

4.11 Area 6 – Faroe Bank Channel and Faroe Current

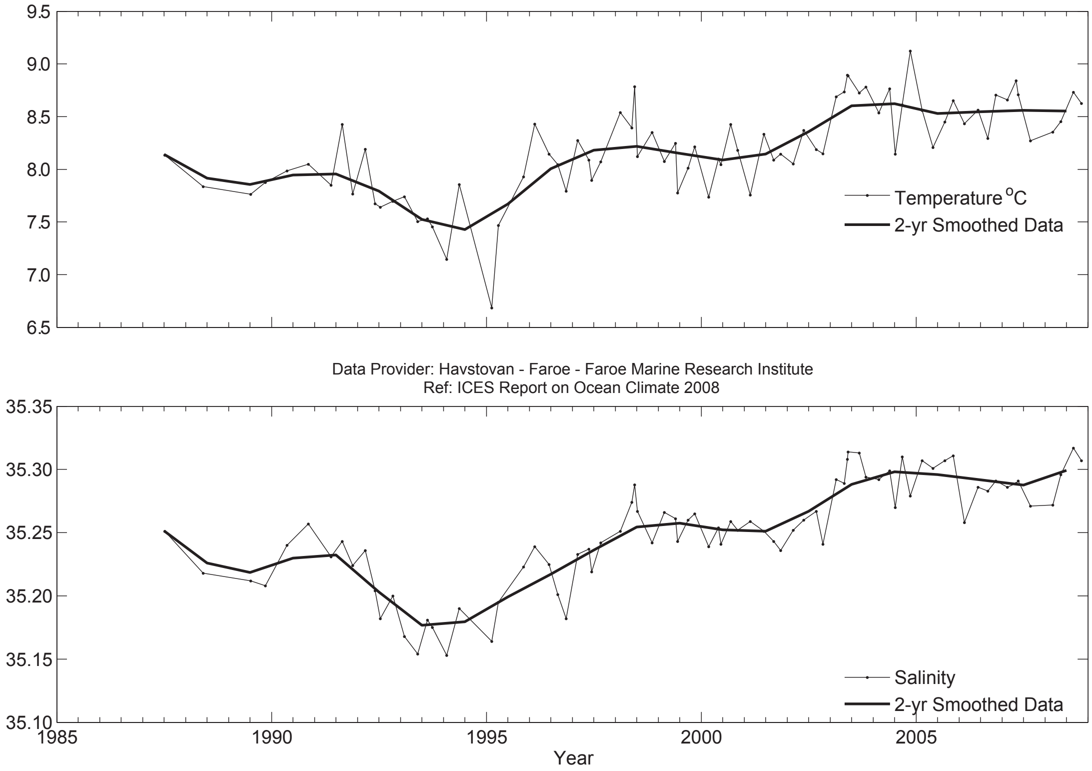
ONE BRANCH OF THE NORTH ATLANTIC CURRENT CROSSES THE GREENLAND–SCOTLAND RIDGE ON BOTH SIDES OF THE FAROES. ITS PROPERTIES ARE SAMPLED BY THE FAROE BANK CHANNEL BEFORE IT CROSSES THE RIDGE, AND BY THE FAROE CURRENT AFTER IT CROSSES THE RIDGE.

Temperature and salinity of the upper waters in the Faroe region increased from the mid-1990s until 2003–2004, after which they decreased slightly. However, they returned to their maximal values in 2008.



Data Provider: Havstovan - Faroe - Faroe Marine Research Institute
Ref: ICES Report on Ocean Climate 2008

Figure 45.
Area 7 – Faroe–Shetland Channel. Temperature anomaly (upper panel) and salinity anomaly (lower panel) in the Atlantic Water in the Slope Current.



Data Provider: Havstovan - Faroe - Faroe Marine Research Institute
Ref: ICES Report on Ocean Climate 2008

Figure 46.
Area 6 – Faroe Bank Channel and Faroe Current. Temperature (upper panel) and salinity (lower panel) in the core of the Faroe Current (maximum salinity averaged over a 50 m deep layer).

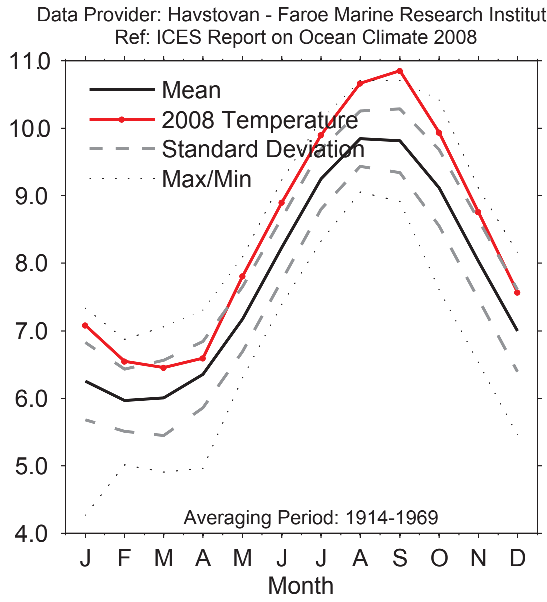


Figure 47.
Area 6 – Faroe Bank Channel and Faroe Current. 2008 monthly temperature data from the Faroe coastal station at Oyrargjogv (62.12°N 7.17°W). Note the average values were calculated from the nearby station at Mykines (69.10°N 7.66°W).

Mooring recovery on RV Merian in Fram Strait, image courtesy of A. Beszczynska-Möller, AWI, Germany.

4.12 Area 7 – Faroe–Shetland Channel

THE CONTINENTAL SLOPE CURRENT FLOWS ALONG THE EDGE OF THE NORTHWEST EUROPEAN CONTINENTAL SHELF, ORIGINATING IN THE SOUTHERN ROCKALL TROUGH. IT CARRIES WARM, SALINE ATLANTIC WATER (AW) INTO THE FAROE–SHETLAND CHANNEL. A PROPORTION OF THIS AW 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 AW AND ALSO ENTERS THE FAROE–SHETLAND CHANNEL FROM THE NORTH AFTER CIRCULATING AROUND THE FAROE ISLANDS. THIS SECOND BRANCH OF AW JOINS THE WATERS ORIGINATING IN THE SLOPE CURRENT AND ALSO ENTERS THE NORWEGIAN SEA.

The temperature and salinity of the surface waters of the Faroe–Shetland Channel have generally increased 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. There is no update for 2008.

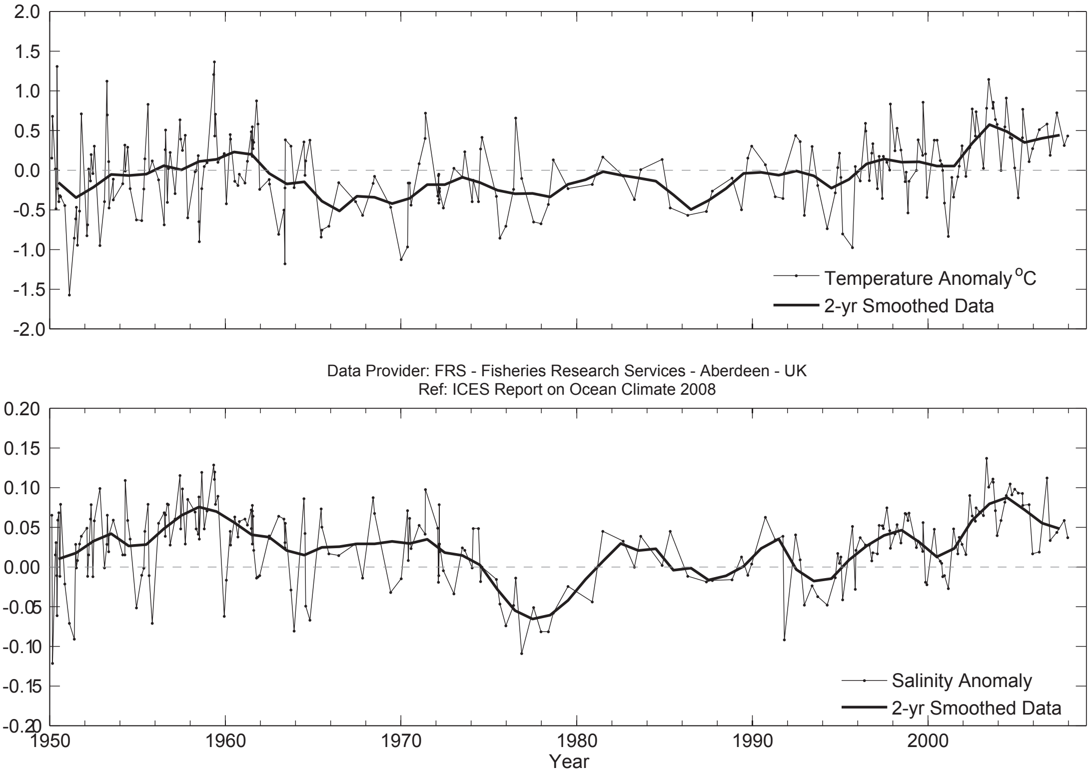
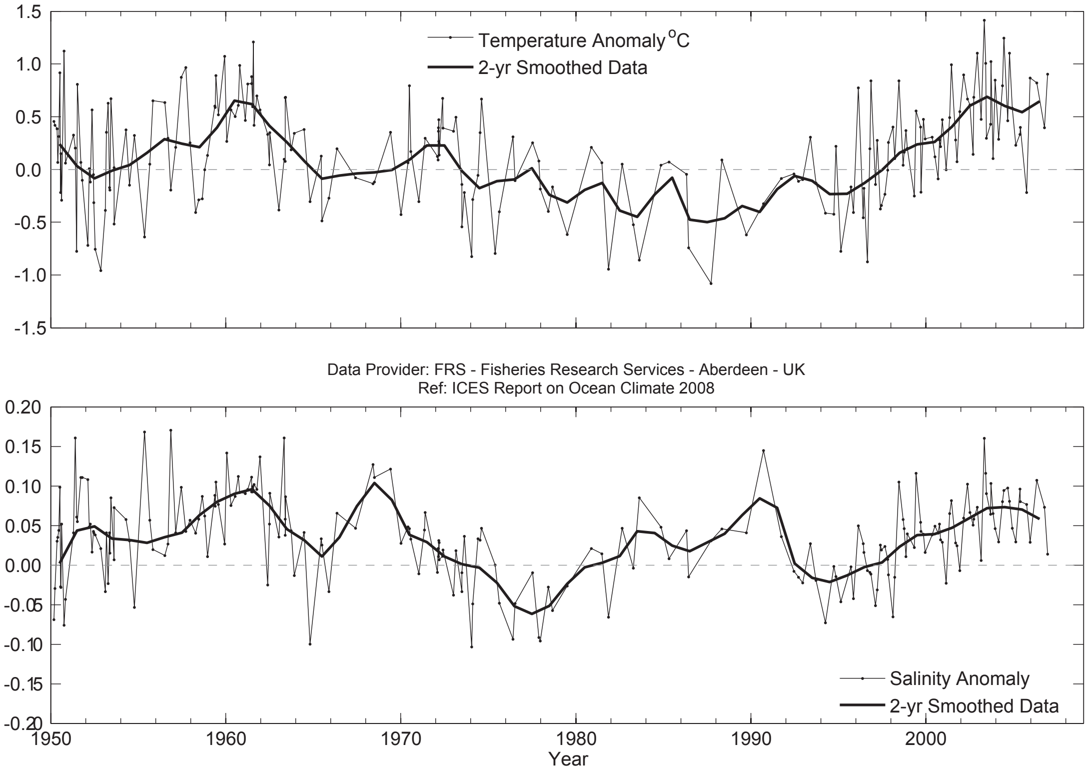


Figure 48.
Area 7 – Faroe–Shetland Channel. Temperature anomaly (upper panel) and salinity anomaly (lower panel) in the Atlantic Water in the Slope Current.



Data Provider: FRS - Fisheries Research Services - Aberdeen - UK
Ref: ICES Report on Ocean Climate 2008

Figure 49.
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 the Faeroes.

Sampling frequency

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 the Faroes.

4.13 Areas 8 and 9 – Northern and southern North Sea

NORTH SEA OCEANOGRAPHIC CONDITIONS ARE DETERMINED BY THE INFLOW OF SALINE ATLANTIC WATER (AW) 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 AW 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.

During 2008, the weekly means of area-averaged SST were slightly above the long-term means. At the beginning of 2008, the heat excess from the previous year was much less than at the beginning of 2007. The anomalies varied between +0.4 and +1.7°C. In December 2008 and January 2009, the SST matched the long-term mean (+0.1 and 0.0°C). Compared with 2007, seasonal warming started later and seasonal cooling started earlier, i.e. the 2008 vegetation period was shorter than in 2007.

The temperature distribution in the North Sea usually has a gradient, with increasing temperatures from the open northern boundary towards the inner German Bight and with isotherms running approximately SW–NE. In 2008, the near-surface isotherms were running roughly NNW–SSE, with a pronounced warming along the Norwegian and Danish coasts, although the monthly averaged SST for July 2008 had a positive anomaly of only 0.6°C.

In 2008, the bottom layer exhibited a typical gradient, with isotherms running approximately SW–NE, and with temperatures and spatial pattern comparable to 2007. The area covered by the 8°C isotherm was greater than in 2007, and temperatures close to the Dutch coast were locally about 1°C lower.

The Helgoland Roads standard station demonstrates that, since the cold winter of 1995/1996, SSTs have been above the 30-year mean (1971–2000), with positive anomalies of 0.5–1.0°C.

Compared with 2007, the salinity concentrations in the surface and bottom layers increased in the northern part of the North Sea, while the southern part became fresher. The tongue of Atlantic Water (AW) with salinity >35 in the near-surface layer reached about half a degree farther to the south. In the bottom layer, the 35.25 isohaline extended to about 58°N over the entire North Sea between the Scottish and Norwegian coasts, covering a much larger area than in the previous year. The position of the 34 isohaline at the bottom was comparable to 2007. At the surface, north of 57°N, the 34 isohaline was located about one degree farther west. The total salt content during the 2008 survey equals that of the 2007 survey (1.143×10^{12} tonnes), i.e. the increasing salinity in the northern part was compensated by the freshening in the southern North Sea.

In 2008, the monthly Elbe River run-off was slightly above the long-term mean from February to April and slightly below it from June to December. The annual averaged run-off decreased from 22 km^3 $year^{-1}$ (which corresponds to the long-term mean) to 20 km^3 $year^{-1}$.

Temperature and salinity at two positions in the northern North Sea illustrate conditions in the Atlantic inflow (Figure 51). The first (Location A) is at 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, temperatures and salinities were above average in 2008.

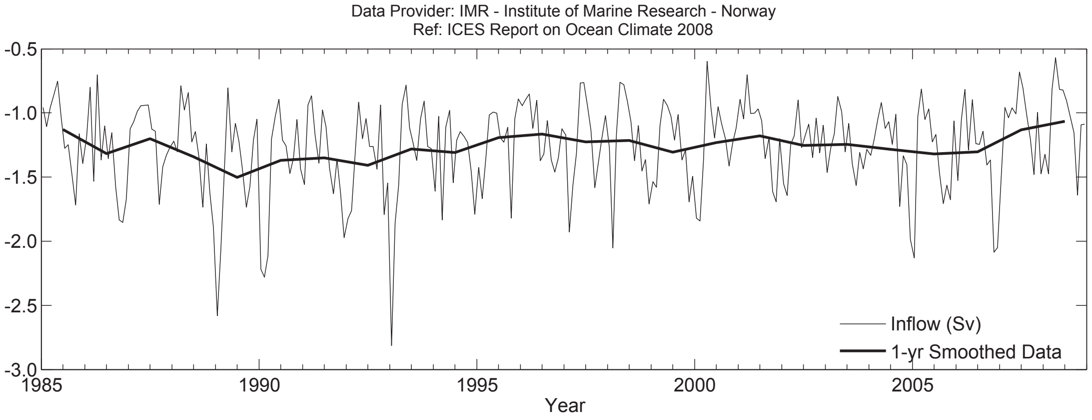
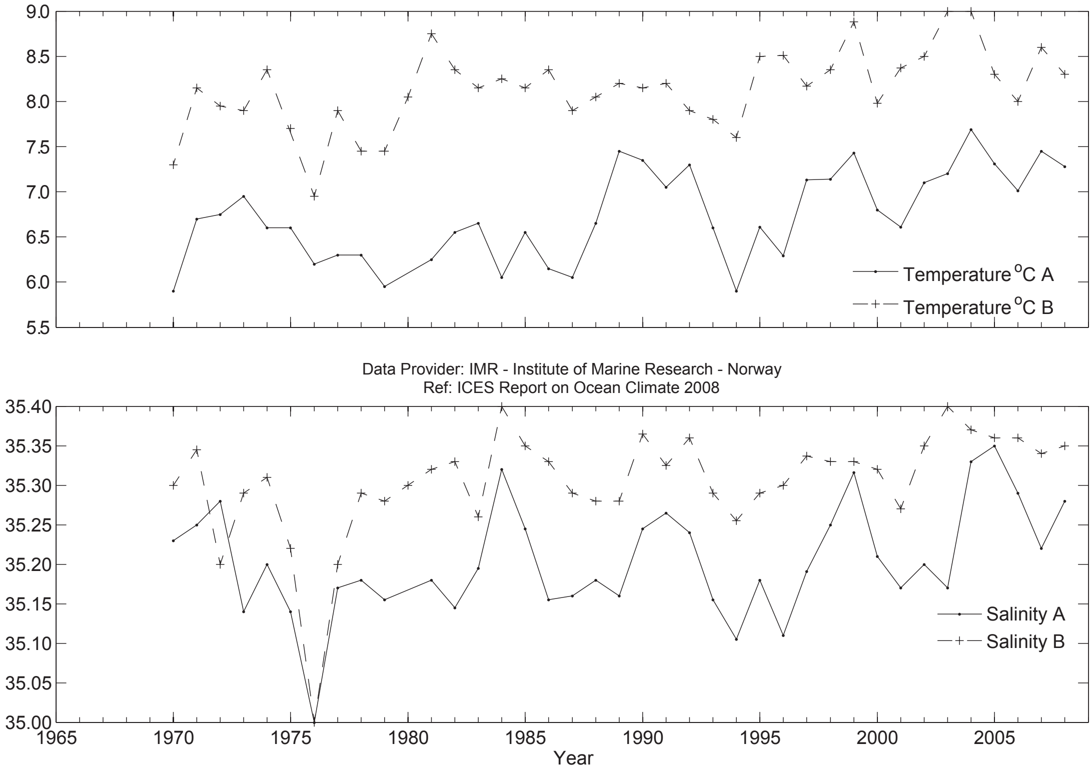


Figure 50. *Area 8 – Northern North Sea. Modelled annual mean (bold) and monthly mean volume transport of Atlantic Water into the northern and central North Sea southwards between the Orkney Islands and Utsire, Norway.*

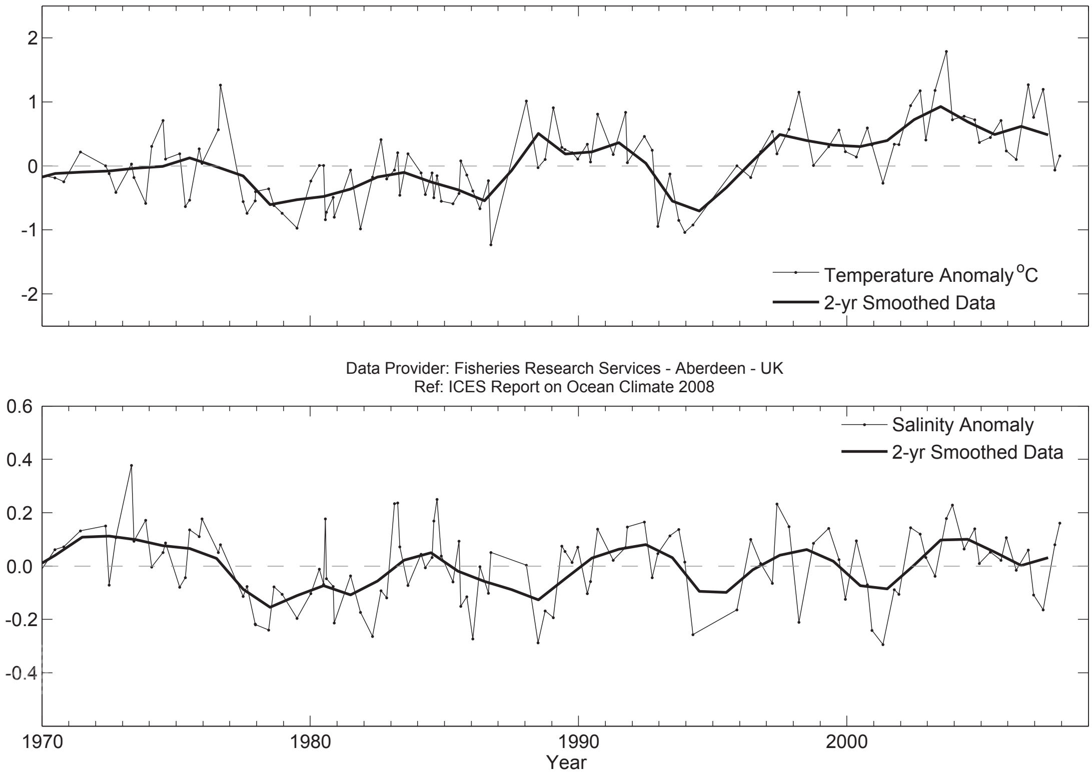
Skagerrak

In the Skagerrak, in addition to overall increased temperature, the length of the warm season has increased significantly over the past 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.



Data Provider: IMR - Institute of Marine Research - Norway
Ref: ICES Report on Ocean Climate 2008

Figure 51.
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 the summers of 1970–2007.



Data Provider: Fisheries Research Services - Aberdeen - UK
Ref: ICES Report on Ocean Climate 2008

Figure 52.
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 53.

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

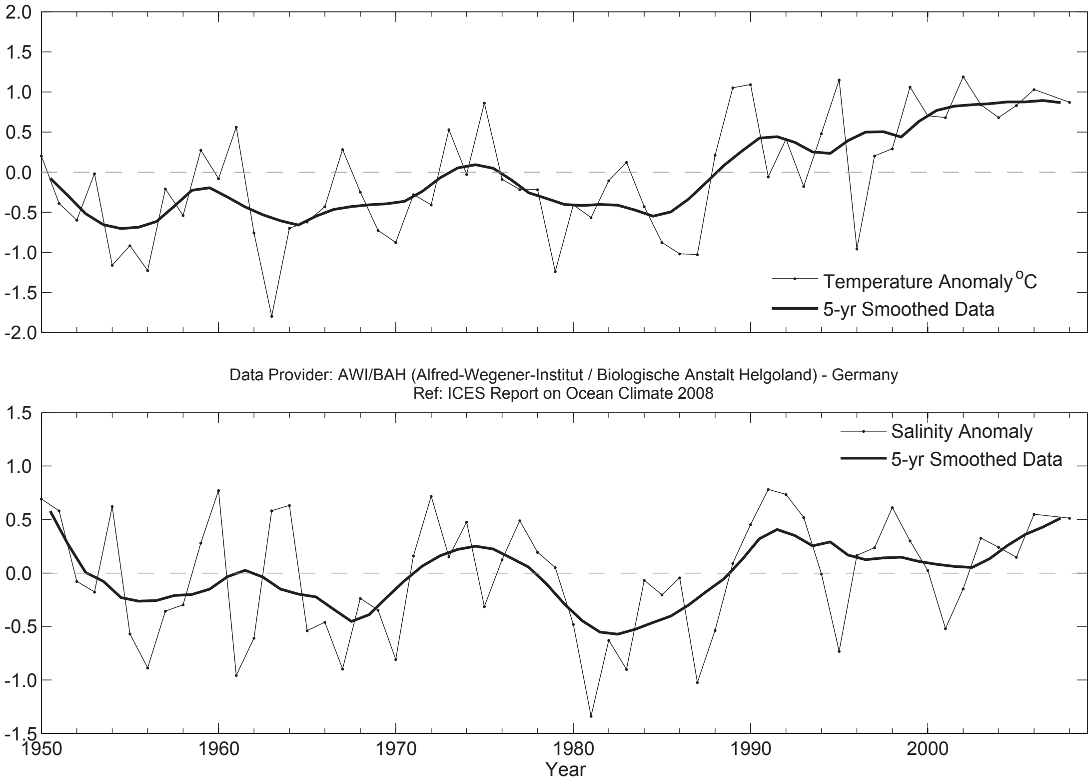
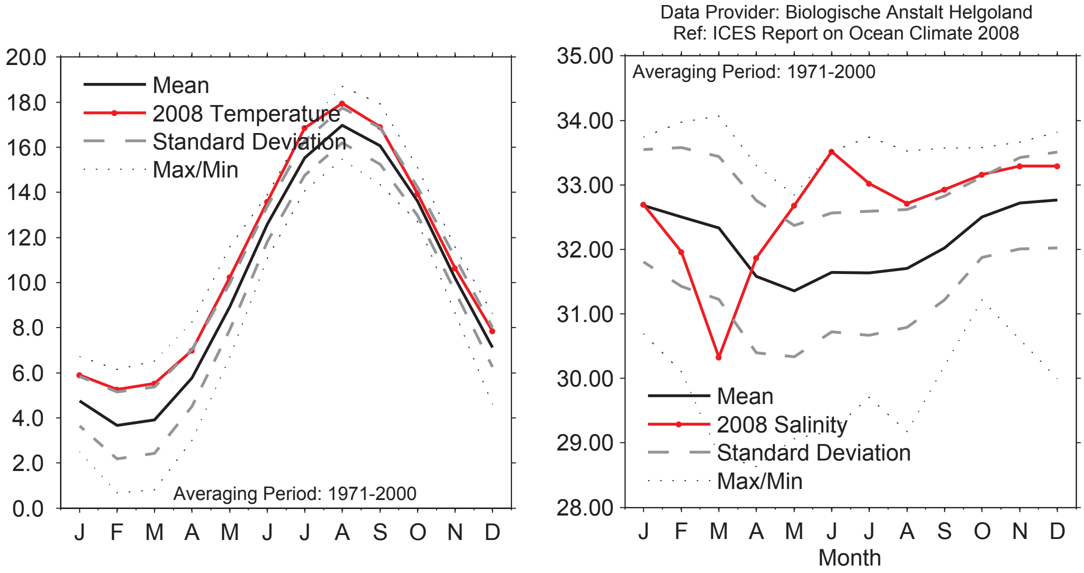
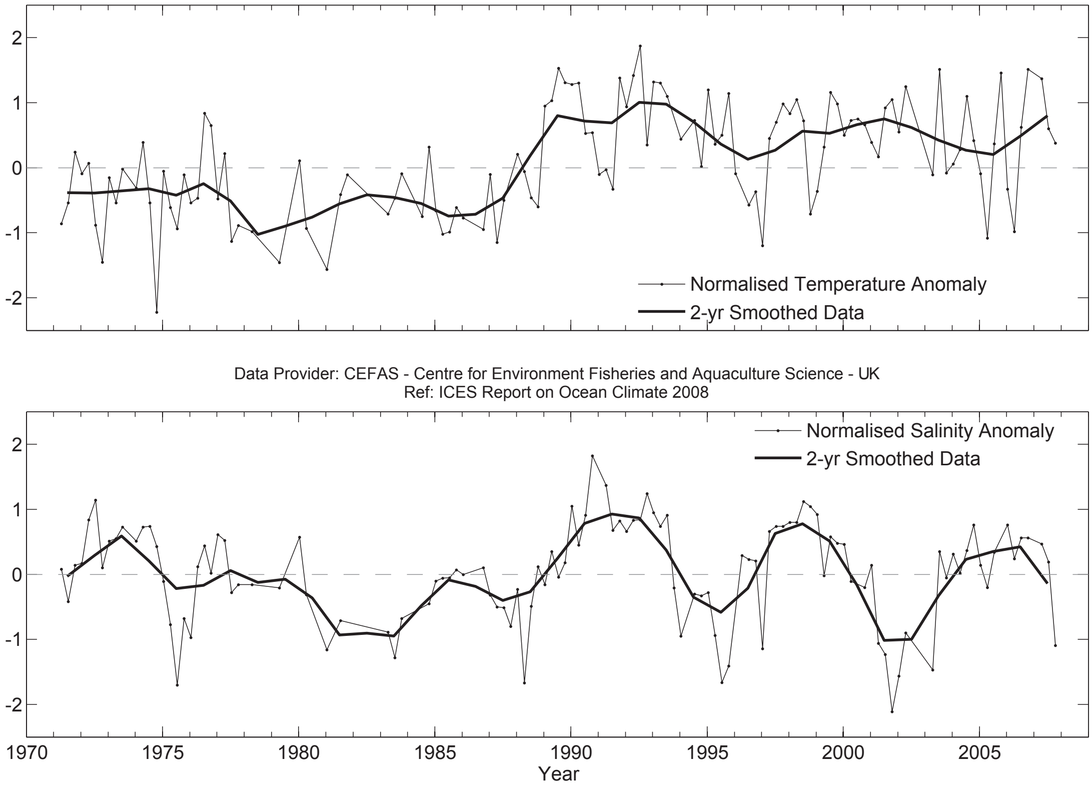


Figure 54.

Area 9 – Southern North Sea. 2008 monthly surface temperature (left panel) and salinity (right panel) at Station Helgoland Roads.





Data Provider: CEFAS - Centre for Environment Fisheries and Aquaculture Science - UK
Ref: ICES Report on Ocean Climate 2008

Figure 55.
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 by a regular ferry at six standard stations. The time-series reveals the seasonal section average (DJF, MAM, JJA, SON) of the normalized variable..

Data Provider: Bundesamt fuer Seeschifffahrt und Hydrographie
Ref: ICES Report on Ocean Climate 2008

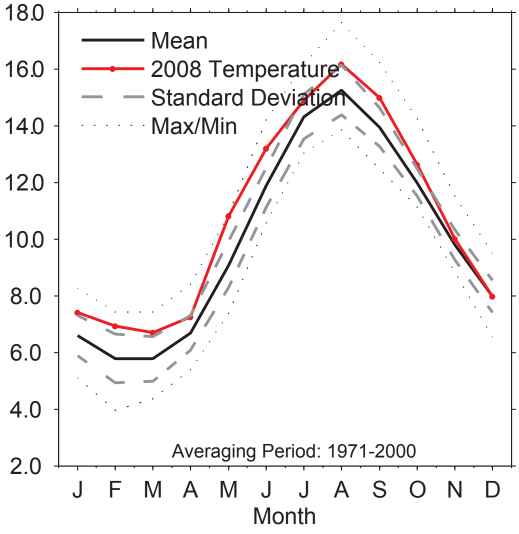


Figure 56.
Areas 8 and 9 – Northern and southern North Sea. North Sea area-averaged sea surface temperature (SST) annual cycle; 2008 monthly means based on operational weekly North Sea SST maps.

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.

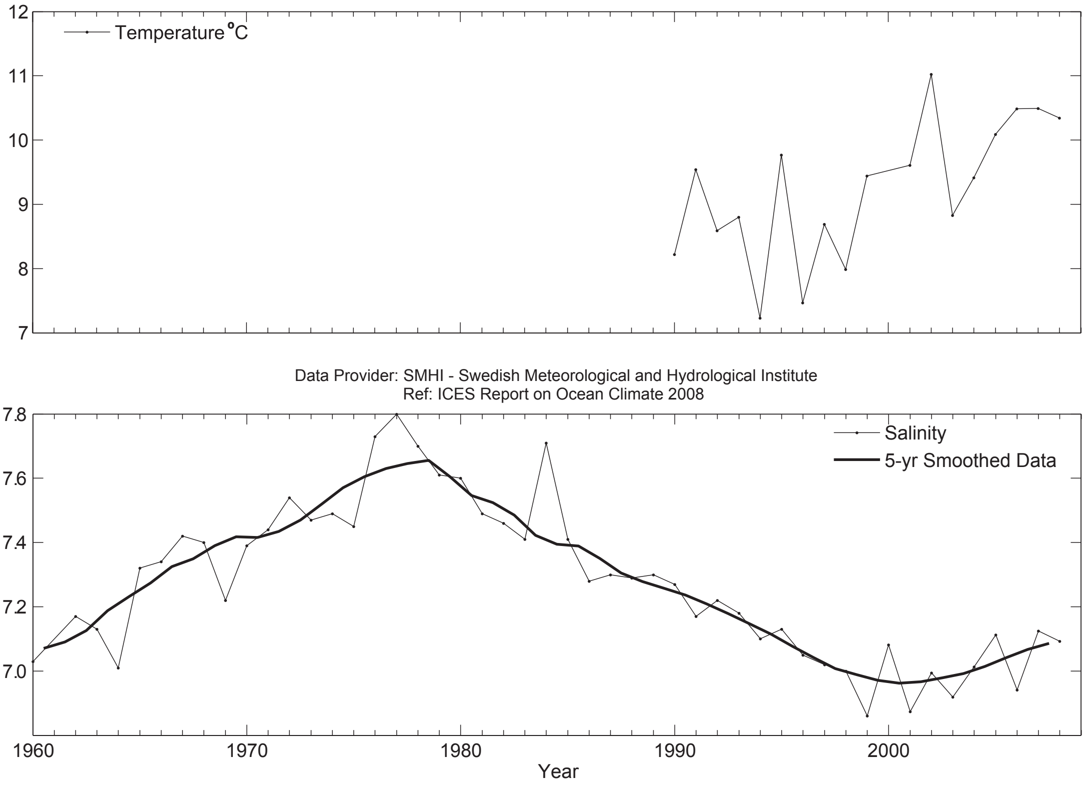
Owing to its central location relative to the Skagerrak, Kattegat, and Baltic, the weather in Sweden can be taken as representative for the area. The mean air temperature during 2008 was 1–2°C above normal in most parts of Sweden, which was higher than in 2007, but not as high as in 2006. The start of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

The SST was above normal in January and February in the whole area. Higher than normal temperatures were also observed in June and at the end of July, with the highest anomalies in Kattegat and Skagerrak. For the rest of the year, temperatures were close to normal.

There were a few minor inflow events into the Baltic during 2008, but the effect on oxygen conditions in the deep water of the Arkona and Bornholm Basins was of short duration.

The freeze-up was unusually late during winter 2007/2008, even later than in the previous ice seasons. During the first two months of 2008, there was very little ice, and the Bothnian Bay was not ice-covered until the final weeks of March. Maximum ice extent occurred on 24 March, and its value was the lowest observed in the time-series starting at 1961.

ANOTHER WARM WINTER WITH RECORD-LOW ICE COVER IN THE BALTIC SEA.



Data Provider: SMHI - Swedish Meteorological and Hydrological Institute
Ref: ICES Report on Ocean Climate 2008

Figure 57.
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.

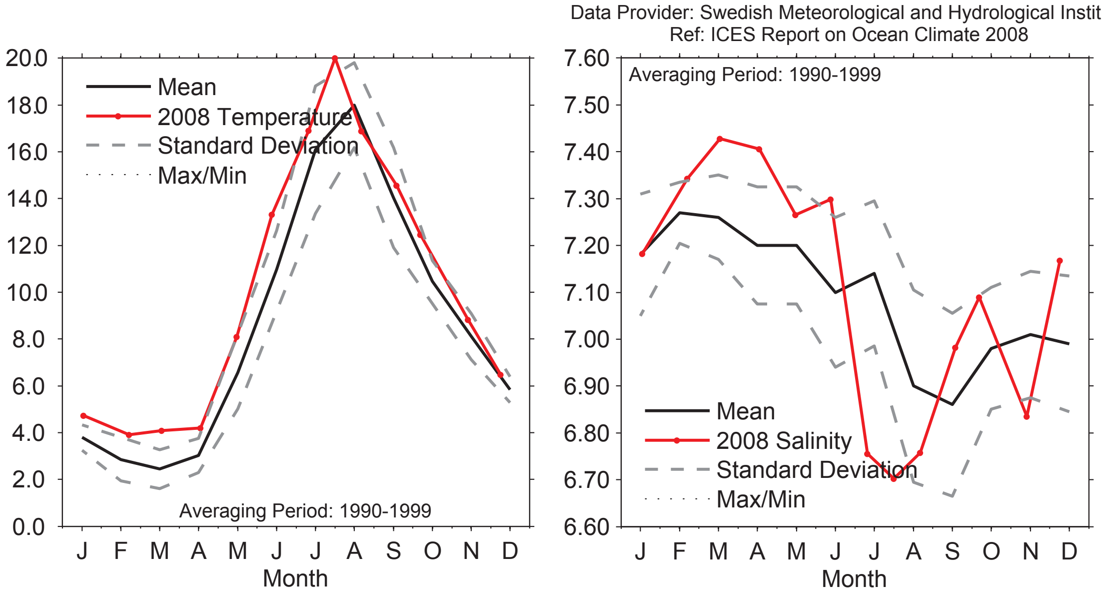


Figure 58.
Area 9b – Skagerrak, Kattegat, and the Baltic. 2008 monthly surface temperature (left panel) and salinity (right panel) at Station BY15 (east of Gotland) in the Baltic Proper.

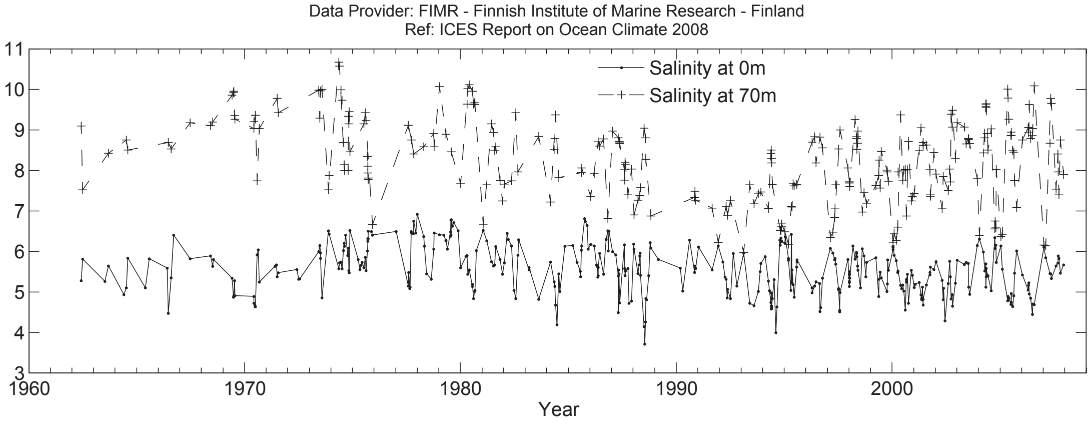


Figure 59.
Area 9b – Skagerrak, Kattegat, and the Baltic. Salinity at Station LL7 in the Gulf of Finland.

RV Aranda in the Gulf of Finland, image courtesy of Ilkka Lastumäki, Finnish Institute of Marine Research, Finland.

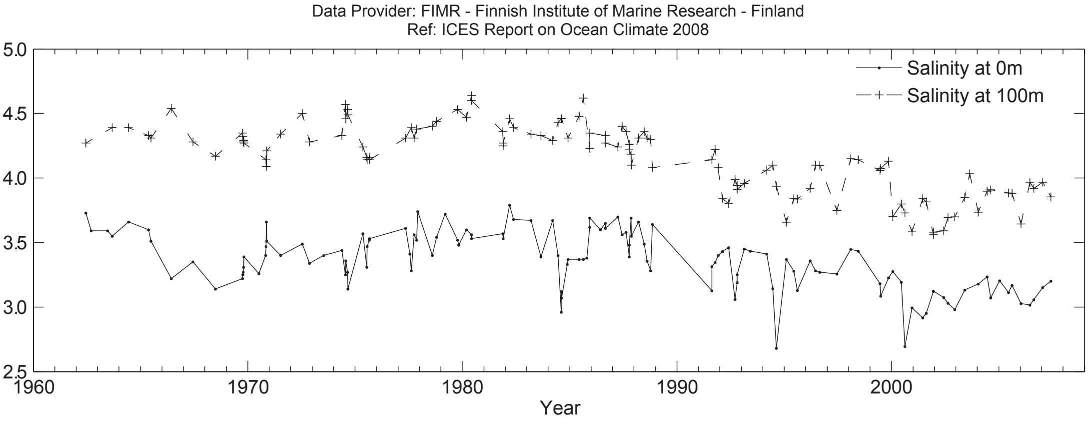


Figure 60.
Area 9b – Skagerrak, Kattegat, and the Baltic. Salinity at Station B03 in the Bothnian Bay.

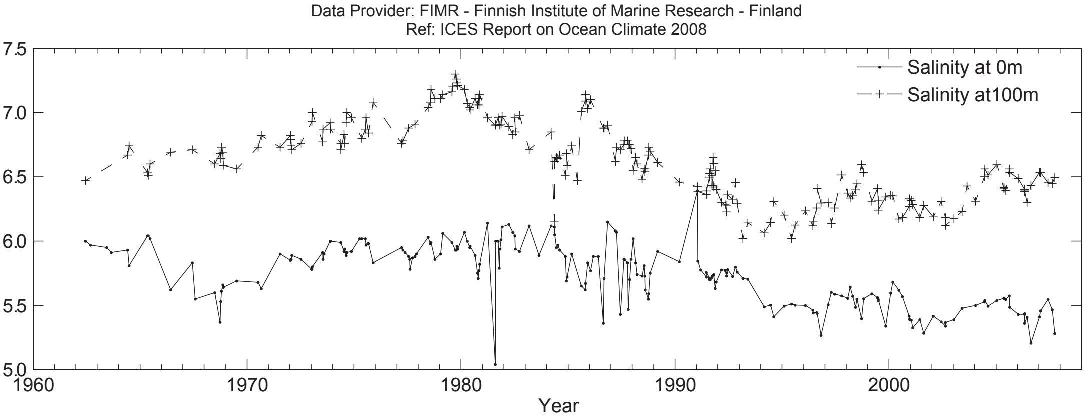


Figure 61.
Area 9b – Skagerrak, Kattegat, and the Baltic. Salinity at Station SR5 in the Bothnian Sea.

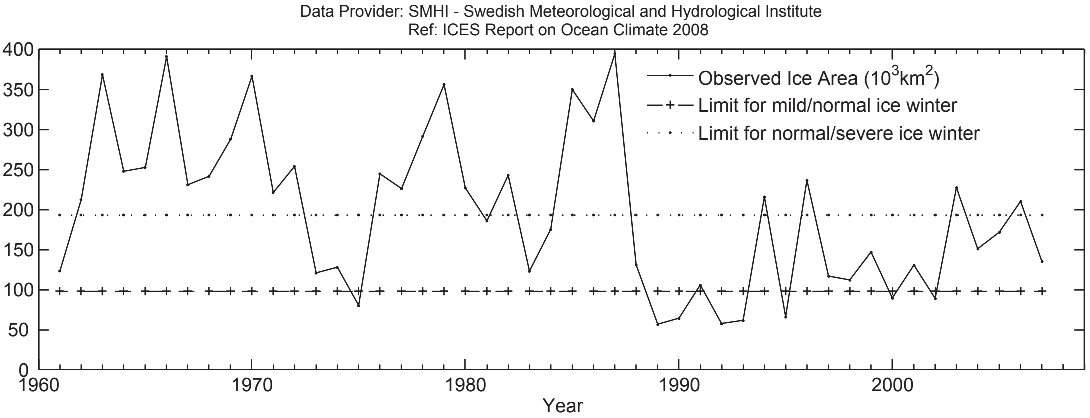


Figure 62.
Area 9b – Skagerrak, Kattegat, and the Baltic. The ice extent in the Baltic since 1961.

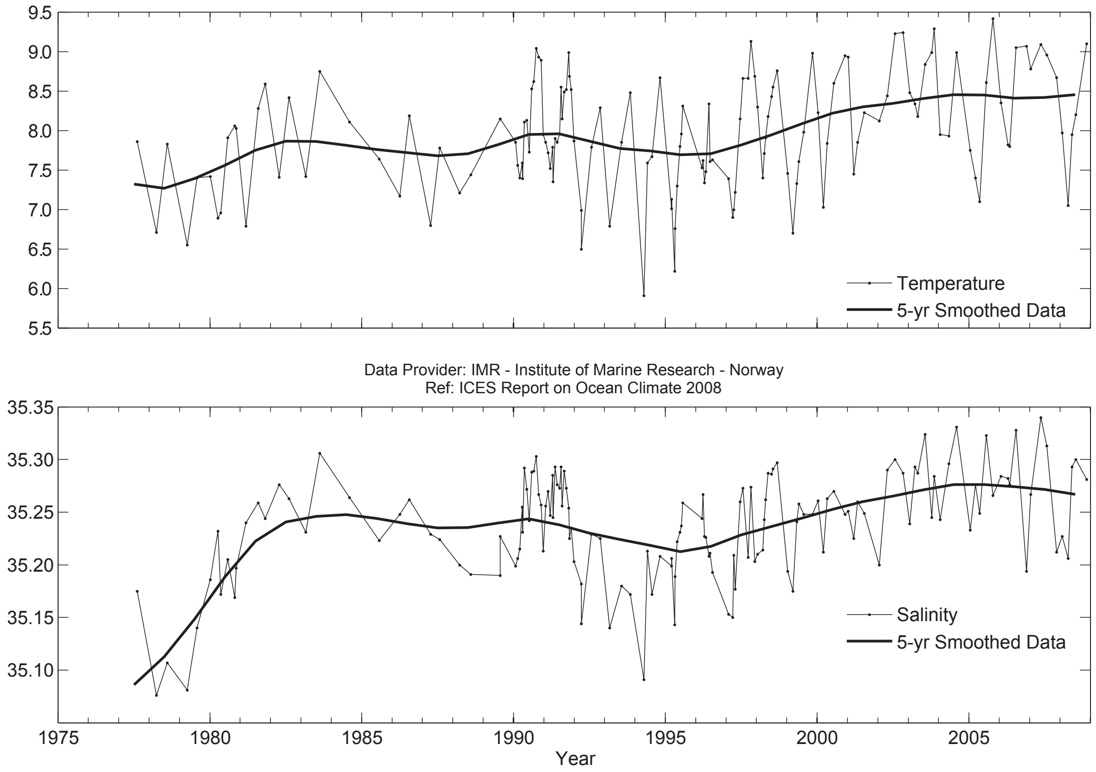
4.15 Area 10 – Norwegian Sea

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 Atlantic Water (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. However, in all three sections, both the temperature and salinity decreased from 2007 to 2008, but were still above the long-term means.

In 2008, temperature and salinity values were 0.2°C, 0.1°C, and 0.3°C, and 0.04, 0.01, and 0.05 above the long-term means for the time-series in the Svinøy, Gimsøy, and Sørkapp Sections, respectively. The high salinity values reflect saltier AW in the Faroe–Shetland Channel.

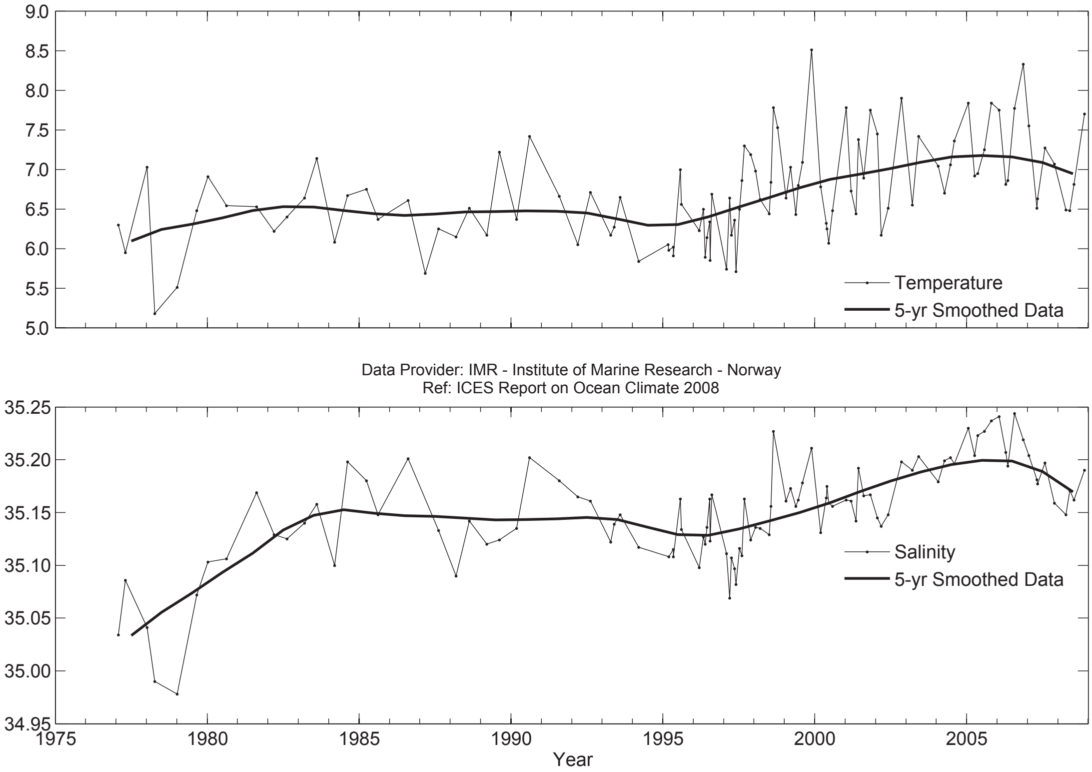
Data from Ocean Weather Station "Mike", located at 66°N 2°E, revealed the 2008 temperature and salinity at 50 m to be above the long-term mean, although both showed a slight decrease from 2004 values. Note that there were no updates of the monthly dataset in 2008.



Data Provider: IMR - Institute of Marine Research - Norway
Ref: ICES Report on Ocean Climate 2008

Figure 63.
Area 10 – Norwegian Sea. Average temperature (upper panel) and salinity (lower panel) above the slope at Svinøy Section (63°N).

Figure 64.
Area 10 – Norwegian Sea. Average temperature (upper panel) and salinity (lower panel) above the slope at Gimsøy Section (69°N).



Data Provider: IMR - Institute of Marine Research - Norway
Ref: ICES Report on Ocean Climate 2008

Figure 65.
Area 10 – Norwegian Sea. Average temperature (upper panel) and salinity (lower panel) above the slope at Sørkapp Section (76°N).

Data Provider: IMR - Institute of Marine Research - Norway
Ref: ICES Report on Ocean Climate 2008

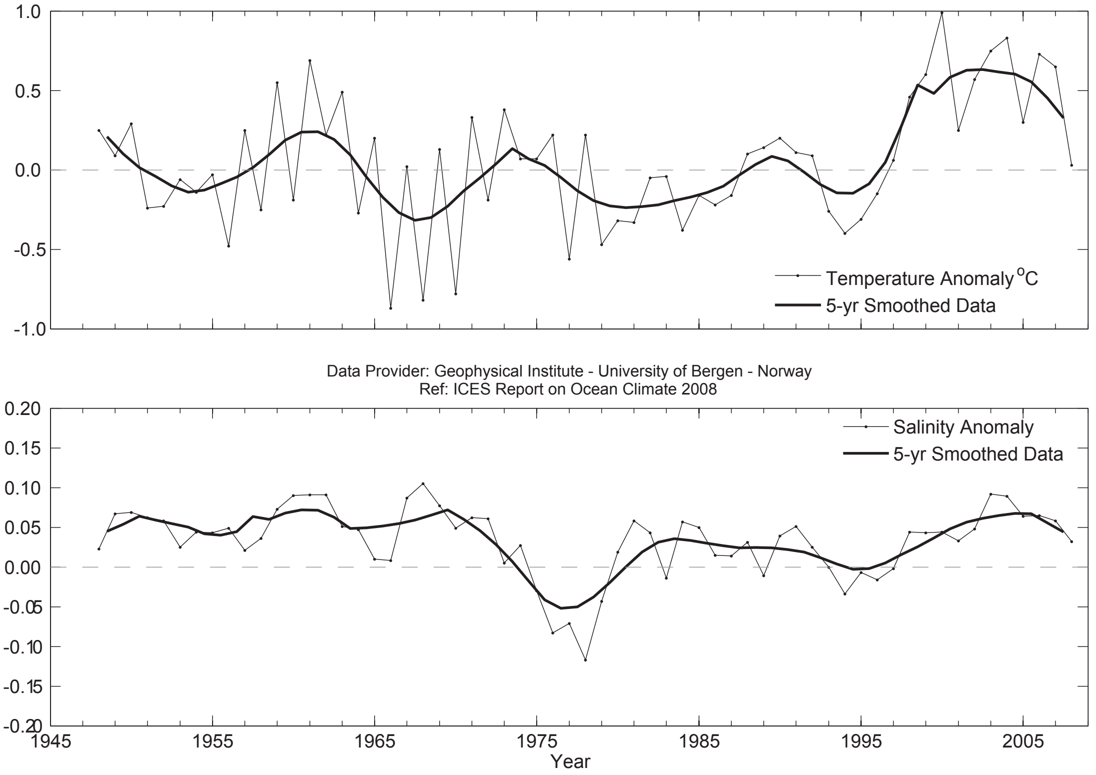


Figure 66.
Area 10 – Norwegian Sea. Temperature anomaly (upper panel) and salinity anomaly (lower panel) at 50 m at Ocean Weather Station "Mike" (66°N 2°E).

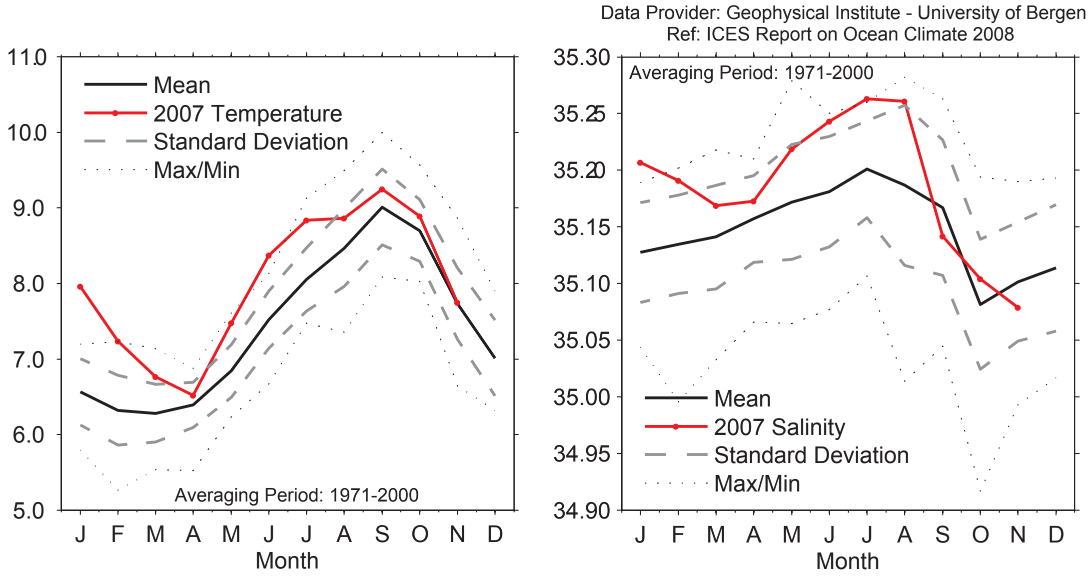


Figure 67.
Norwegian Sea. 2007 monthly temperature (left panel) and salinity (right panel) at 50 m at Ocean Weather Station "Mike" (66°N 2°E). NOTE: No updates of monthly data are available for 2008.

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, PARTICULARLY IN HEAT CONTENT AND, CONSEQUENTLY, ICE COVERAGE.

In 1996 and 1997, 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. From March 1998, the temperature in the western Barents Sea increased to just above the average, while the temperature in the eastern part remained below the average during 1998. From the beginning of 1999, there was a rapid temperature increase in the western Barents Sea that also spread to the eastern part. Since then, the temperature has remained above average.

In the southern Barents Sea, water temperature in 2008 was about 0.8°C above the long-term mean. The temperature of the Atlantic Water was 0.2–2.1ºC higher than the average throughout the year, depending on time and place. The positive anomalies gradually decreased, from 1.2–2.1°C in January–March to 0.2–0.8°C in August–September, and then increased to 0.6–1.4°C during autumn 2008. In the coastal waters in the Kola Section, negative temperature anomalies were registered in September 2008. Such cold anomalies have not been observed there in September for the past 10 years. Although it started out warmer, 2008 was, on the whole, colder than the previous two years. Throughout the year, the total extent of sea-ice was less than the long-term average, but greater than in 2007.

The volume flux into the Barents Sea varies over periods of several years, and was significantly lower during 1997–2002 than during 2003–2006. The year 2006 was special because the volume flux had both a maximum (in winter 2005/2006) and a minimum (in autumn 2006). Since then, the inflow has been low, particularly during spring and summer. The inflow in 2008 was similar to 2007: moderate during winter followed by a strong decrease in spring. In early summer 2008 (the time of the most recent data), the flux was close to the average. There was no significant trend in the observed volume flux from 1997 to summer 2008.

The water temperature in the Barents Sea in 2009 is expected to be higher than the long-term mean, but probably lower than in 2008.

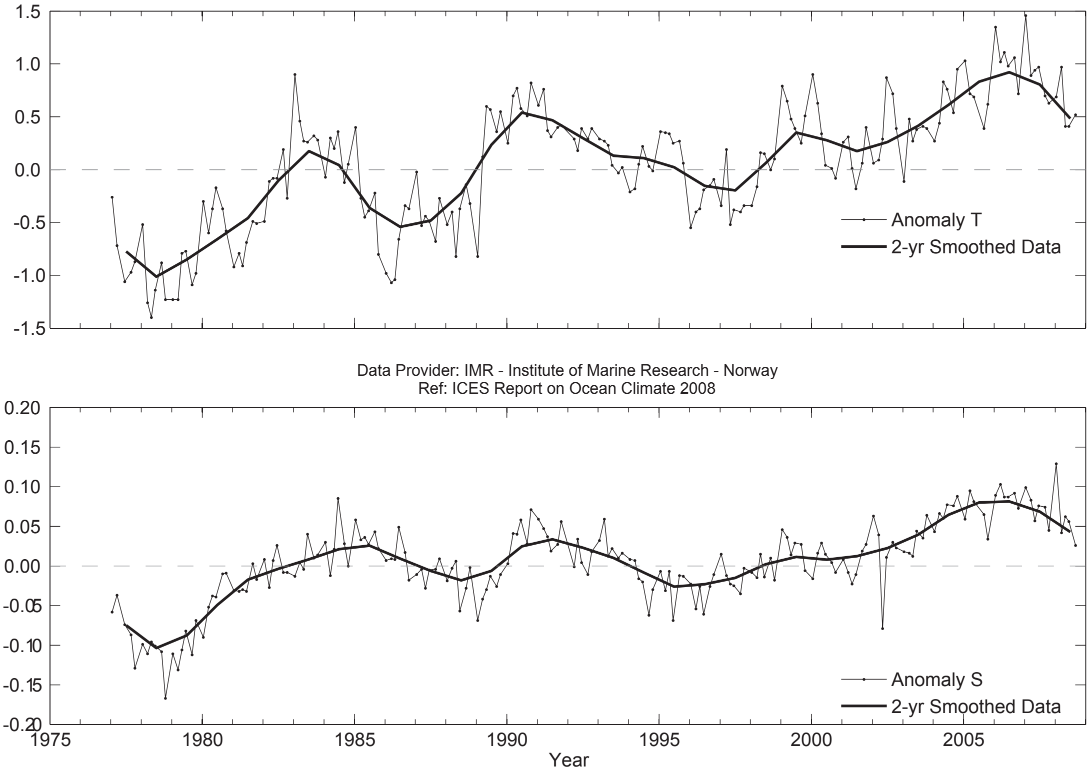
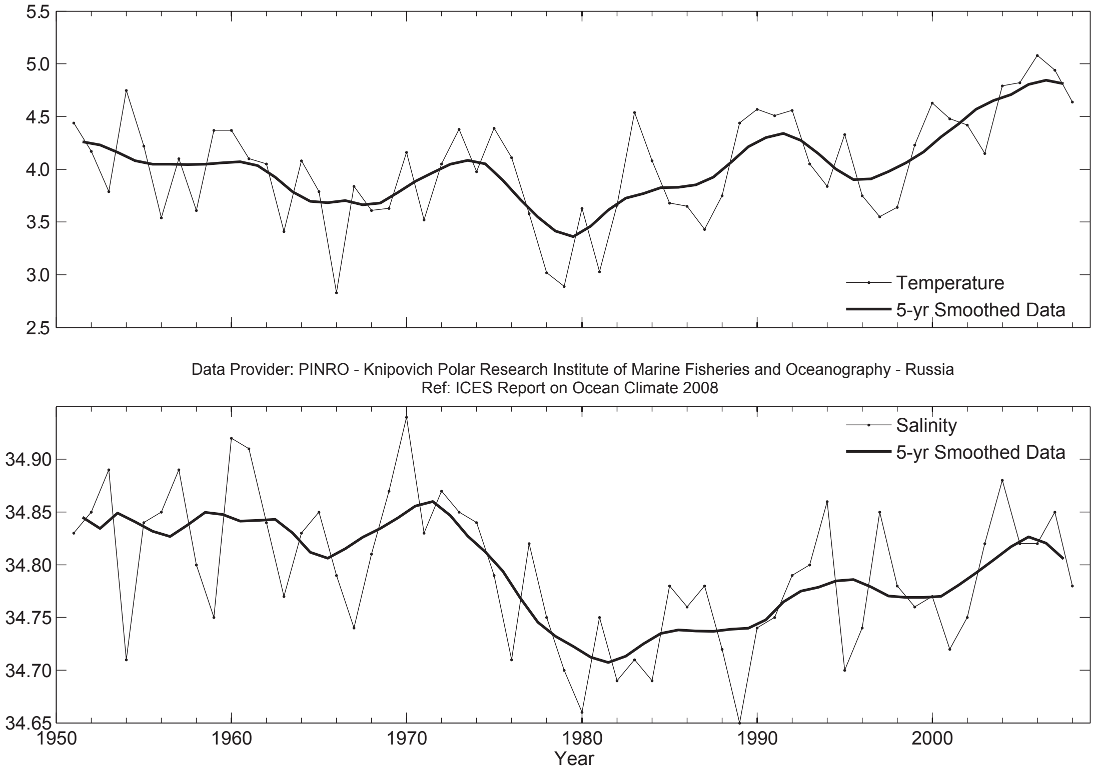


Figure 68.
Area 11 – Barents Sea. Temperature anomaly (upper panel) and salinity anomaly (lower panel) in the Fugløya – Bear Island Section.



Data Provider: PINRO - Knipovich Polar Research Institute of Marine Fisheries and Oceanography - Russia
Ref: ICES Report on Ocean Climate 2008

Figure 69.
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). THE AW 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.

In 2008, there was a decrease in Atlantic Water (AW) temperature and salinity at the eastern rim of the Greenland Sea (75°N) relative to 2007 and their values returned to the long-term averages. At the western boundary, the salinity of Return Atlantic Water (RAW) in 2008 was similar to that observed in 2007, and temperature decreased slightly. In the central basin, a warm and saline anomaly spread from the upper layer down to ca. 1500 m, and the two-layer structure was maintained in 2008. The interface between the two layers descended and showed a depression in the centre. Winter convection extended to 1700 m, but the ventilated layer remained unexpectedly warm and saline. This is because the import of warm and salty AW was not balanced by an import of cold and fresh Polar Waters. During winter convection, the increases in density occurred due to advection of salt by Atlantic waters rather than localized salt formation (which occurs during formation of sea-ice). The dominant input of AW tends to prevent ice formation and to vertically homogenize the waters ventilated by winter convection. Two essential events have resulted in far-reaching changes of the hydrographic structure in the Greenland Basin since the last phase of the classical cold-water dome structure in the 1980s. The first event was the globally unique, basin-wide rearrangement of the hydrographic structure by the establishment of the two-layer pattern in 1990/1991, which replaced the cold-water dome structure, and the second was the overwhelming input of AW since 2005.

In the southern Fram Strait, AW salinity and temperature have decreased significantly from their maxima in 2006. At the standard section along the 76.50°N latitude, mean salinity at 200 dbar, averaged between meridians 009–012ºE, decreased from 35.112 in 2007 to 35.075 in summer 2008.

Mean salinity at this section was still higher than the 13-year mean (35.053). Changes in temperature were more pronounced. Mean temperature at 200 dbar has decreased from 4.50ºC in summer 2006 and 3.84ºC in summer 2007 to 3.08ºC in summer 2008, and was lower than the 13-year mean (3.14ºC). Nevertheless, the linear trends of AW temperature and salinity were still positive.

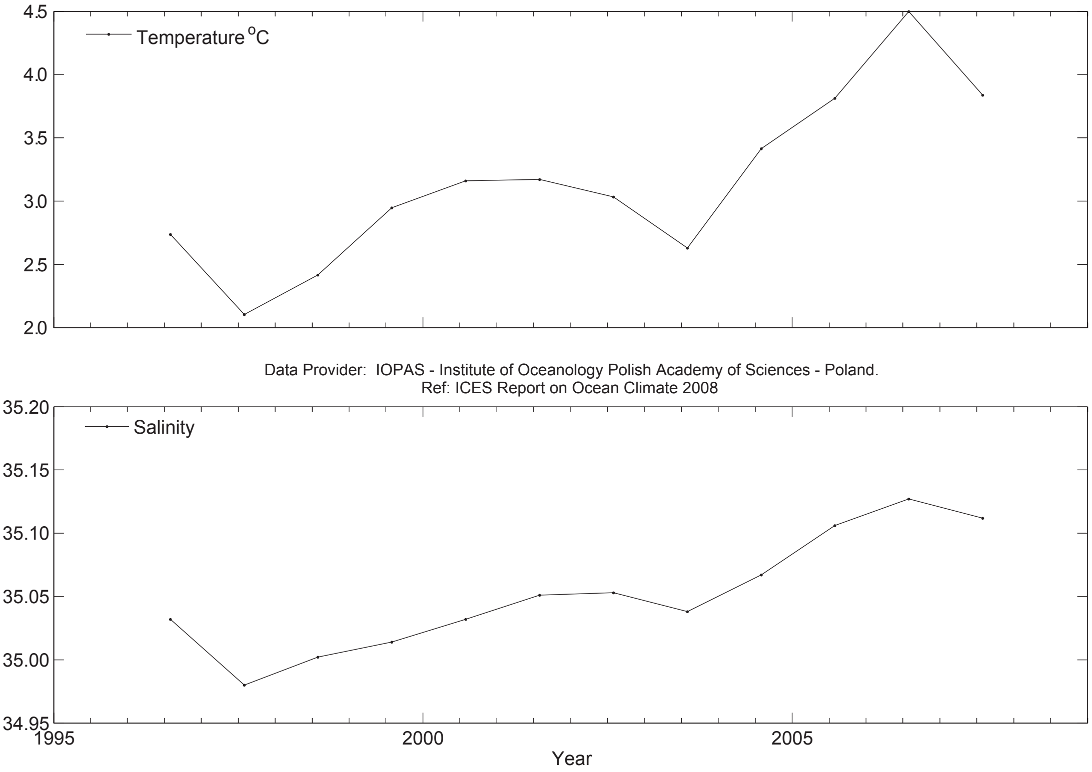
In the northern Fram Strait (78.83°N), three characteristic areas can be distinguished in relation to the main flows: the West Spitsbergen Current (WSC) between the shelf edge and 5°E, the Return Atlantic Current (RAC) between 3°W and 5°E, and the Polar Water in the East Greenland Current (EGC) between 3°W and the Greenland Shelf.

BOTH TEMPERATURE AND SALINITY DECREASED IN THE ATLANTIC WATER IN THE GREENLAND SEA AND FRAM STRAIT IN 2008.

In 2008, temperature and salinity in the upper layer (50–500 m) significantly decreased in all three domains after a period of steady increase which had lasted since 2003. Consequently, all values were close to their long-term means, except salinity in the EGC, which was much lower than average (the lowest in the observation period). Temperature in the EGC also decreased below the mean.

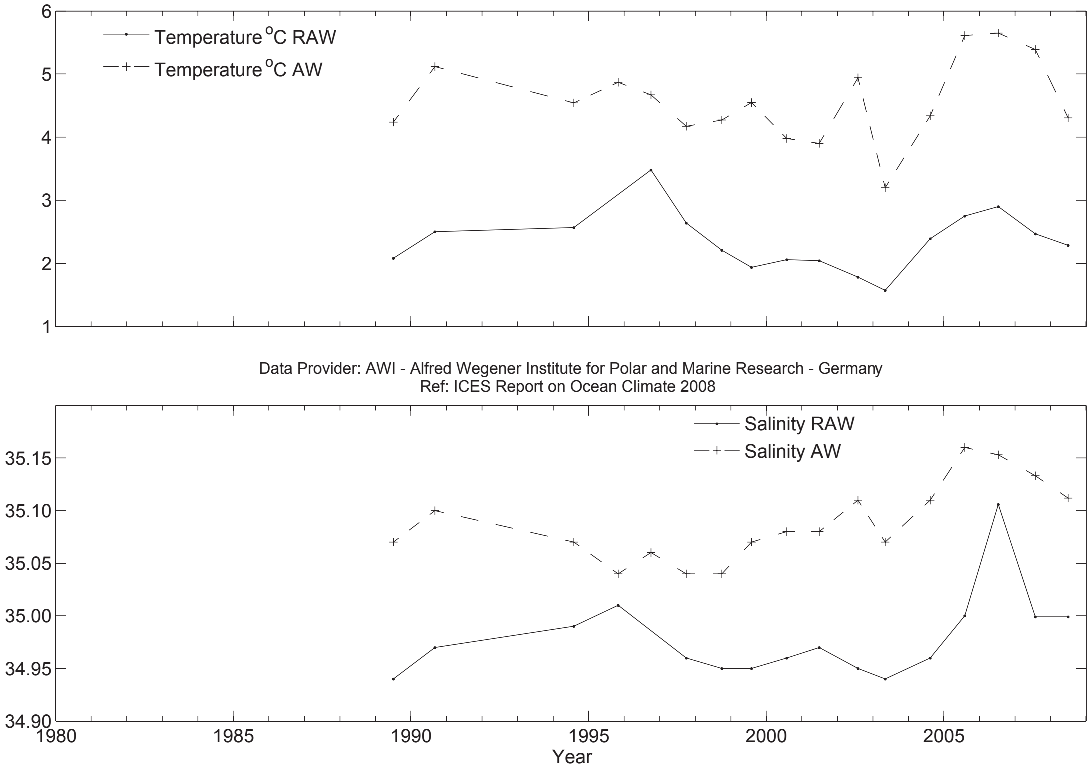
The increase in temperature and salinity observed in the RAC and EGC since 2003 was related to the westward shift of the boundary between the recirculating Atlantic and Polar Waters. In 2008, the recirculating AW still extended farther westward than in the 1990s, but was less warm and less saline than in recent years. The hydrographic properties of the AW mass (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, began to decrease in summer 2007, and this decrease has continued in 2008. The areal coverage of the AW (a proxy for the amount of AW in Fram Strait) has declined significantly in the past two years, after five years of steady increase.

The winter-centred annual mean of net transport through Fram Strait in 2007/2008 remained close to that found in 2006/2007. However, inflow of AW in 2008 was significantly lower than its peak in 2007. Together with lower temperatures of AW, it resulted in a decreased heat flux through Fram Strait to the Arctic Ocean. Relatively strong outflow was maintained in the EGC, similar to the previous year. Due to cooler AW inflow and lower oceanic heat flux into the WSC, sea-ice cover in the northern Fram Strait and north of Svalbard was greater than in the previous two years.



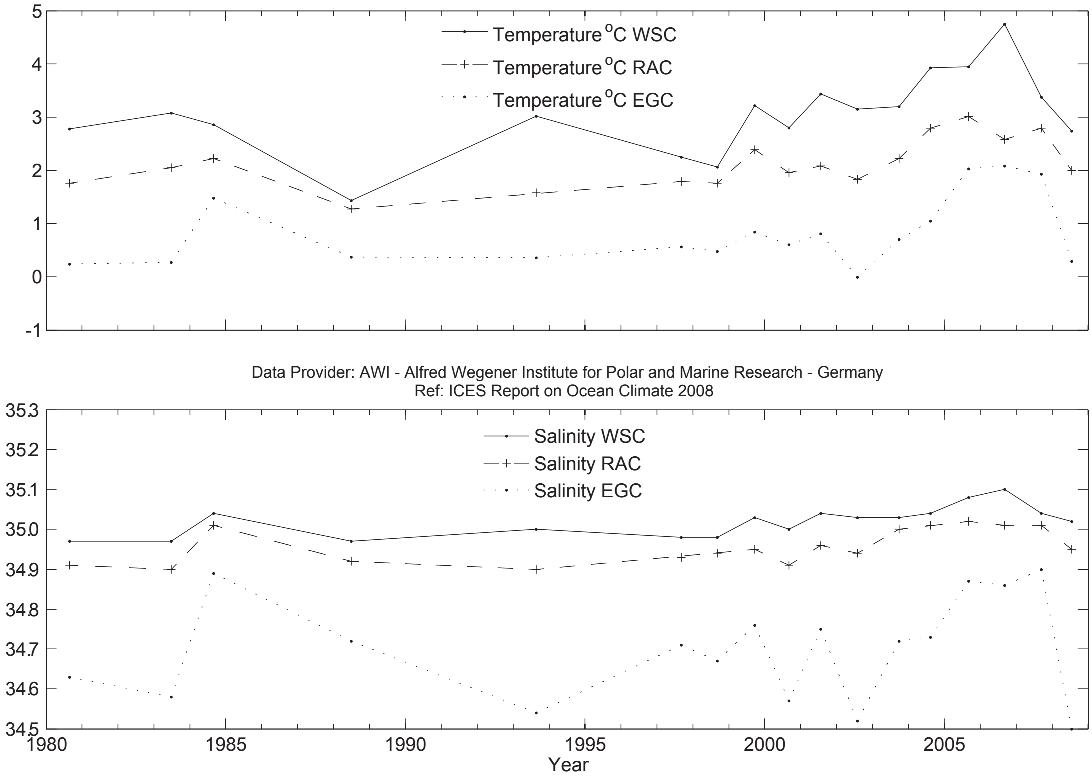
Data Provider: IOPAS - Institute of Oceanology Polish Academy of Sciences - Poland.
Ref: ICES Report on Ocean Climate 2008

Figure 70.
Area 12 – Greenland Sea and Fram Strait. Temperature (upper panel) and salinity (lower panel) at 200 m in the Spitsbergen Section (76.50°N).



Data Provider: AWI - Alfred Wegener Institute for Polar and Marine Research - Germany
Ref: ICES Report on Ocean Climate 2008

Figure 71.
Area 12 – Greenland Sea and Fram Strait. Temperature anomaly (upper panel) and salinity (lower panel) anomaly of 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.



Data Provider: AWI - Alfred Wegener Institute for Polar and Marine Research - Germany
Ref: ICES Report on Ocean Climate 2008

Figure 72.
Area 12 – Greenland Sea and Fram Strait. Temperature anomaly (upper panel) and salinity (lower panel) anomaly in Fram Strait (78.83°N) at 50–500 m: in the West Spitsbergen Current (WSC; between the shelf edge and 5°E), in the Return Atlantic Current (RAC; between 3°W and 5°E), and in the Polar Water in the East Greenland Current (EGC; between 3°W and the Greenland Shelf).

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 the North Atlantic, typically below 1000 m. The general circulation scheme and dominant water masses are given in Figure 73.

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 Basin and Canadian Basin deep waters and upper Polar Deep Water (uPDW). The Eurasian Deep Water feeds the densest water of all Nordic Seas: the Greenland Sea Bottom Water. The Canadian Basin Deep Water and uPDW supply the Arctic Intermediate Water in the Greenland Sea, and the uPDW 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 over 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 of the lower deep water accompanies the inflow of Mediterranean Water on the eastern side.

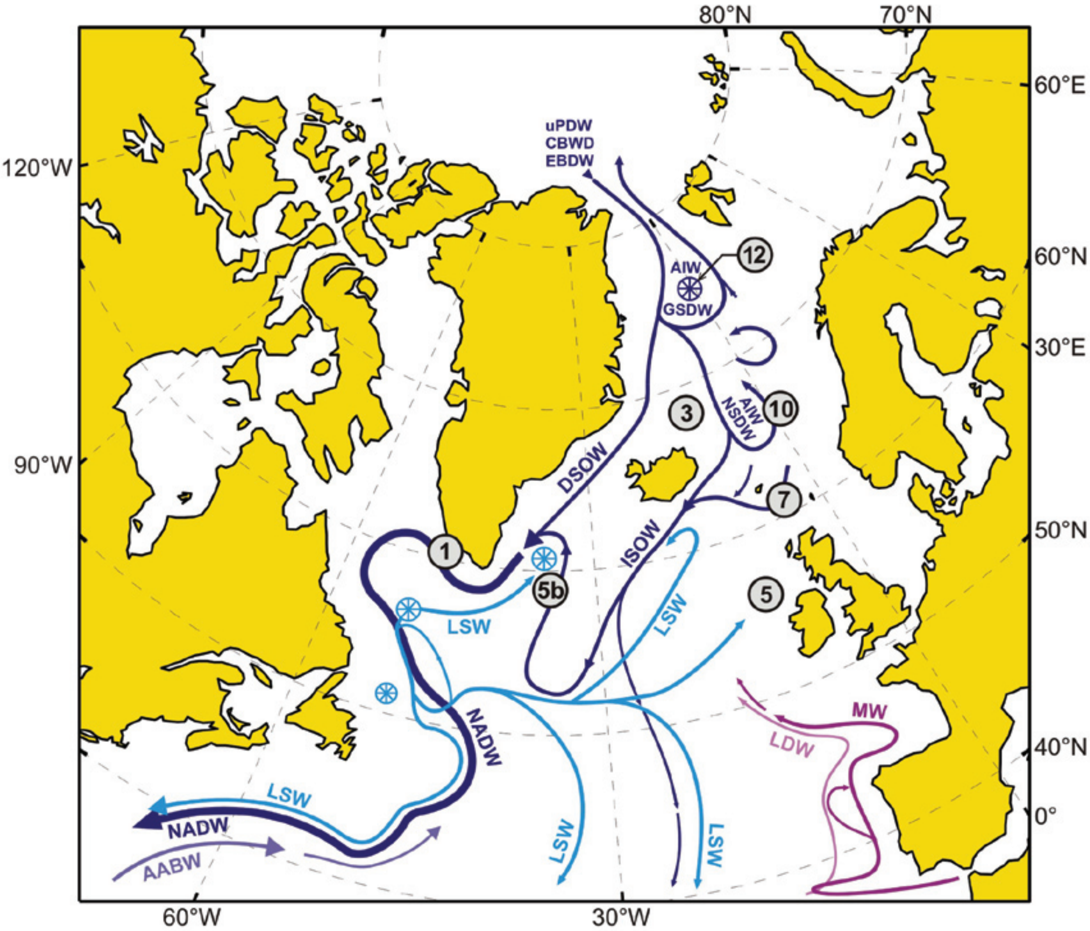


Figure 73.
Schematic circulation of the intermediate to deep waters in the Nordic Seas and North Atlantic. uPDW = upper Polar Deep Water, CBDW = Canadian Basin Deep Water; EBDW = Eurasian Basin Deep Water; AIW = Arctic Intermediate Water; GSDW = Greenland Sea Deep Water; NSDW = Norwegian Sea Deep Water; DSOW = Denmark Strait Overflow Water; ISOW = Iceland–Scotland Overflow Water; LSW = Labrador Sea Water; NADW = North Atlantic Deep Water; AABW = Antarctic Bottom Water; MW = Mediterranean Water; LDW = Lower Deep Water. Circled stars indicate possible convection regions.

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 the temperature increase between 2007 and 2008 was the same as the increase over the past five years (0.016°C). Warming in the Greenland Sea was accompanied by a year-to-year increase in salinity of 0.001. In the Iceland Sea, an increase in temperature in the depth range 1500–1800 m has been found since the beginning of the time-series (early 1990s), but the temperature in 2008 remained the same as in 2007. The long-term warming rates per decade are 0.131°C (Greenland Sea), 0.06°C (Norwegian Sea), and 0.063°C (Iceland Sea). The source of the warming is the deep outflow from the Arctic Ocean, a south-flowing current of the Eurasian and Canadian Basin Deep Waters and the upper Polar Deep Water found on the western side of Fram Strait around a depth of 2000 m. The Greenland Sea Deep Water (GSDW) is warming fastest owing to its direct contact with this Arctic outflow, whereas the Iceland and Norwegian Seas are warming more slowly because they are products of the mixing of their own ambient waters with GSDW 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 and 1600 m, and has only been significantly deeper in small-scale convective eddies. In winter 2007/2008, the maximum convection depth was estimated to be 1700 m, deeper than the previous year (1200 m) and similar to the maxima observed during 2001/2002 and 2002/2003. The import of warm and salty Atlantic Water (AW) to the Greenland Sea is currently not balanced by an import of cool and fresh Polar Waters from the north. The AW, which dominated changes in the upper ocean, took over the role of former ice production as a source of salt and densification in the context of winter convection. The input of AW tends to prevent ice formation and to vertically homogenize the waters ventilated by convective processes. The GSDW formerly included a small admixture of surface freshwater through the convective process and, therefore, had a lower salinity than the Arctic outflow waters. The observed increase in the GSDW salinity may be due to an adjustment to the Arctic outflow in the continued absence of deep convection and an increased presence of AW in the upper layer. It is unclear whether there has been any corresponding salinity trend in either the Norwegian or the Iceland Sea Deep Waters in recent decades. After some decrease in the early 1990s, salinity in both deep basins has remained relatively stable for the past decade.

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

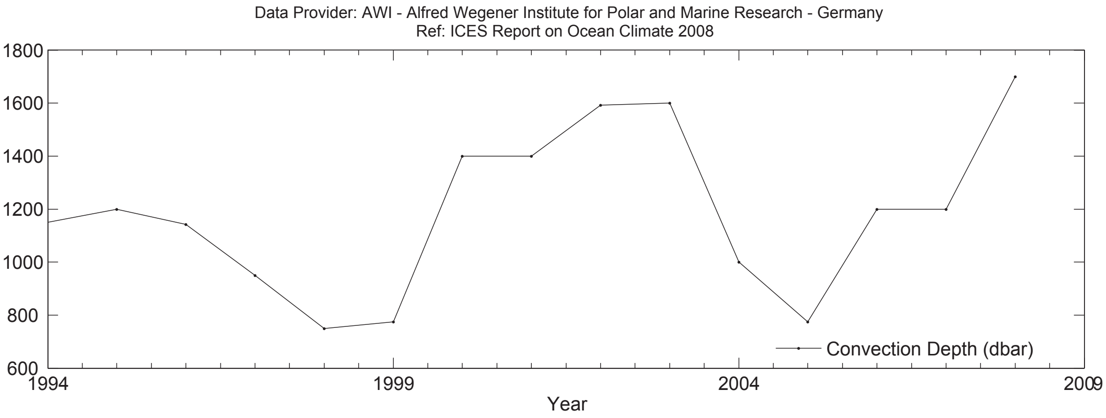
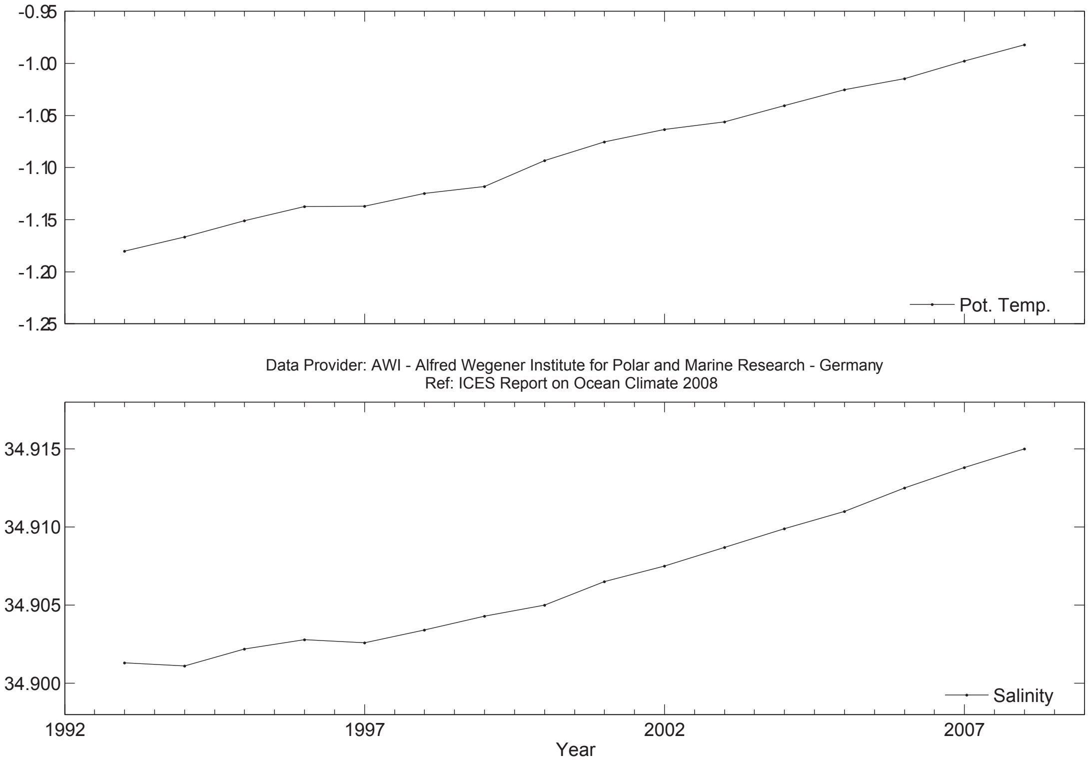


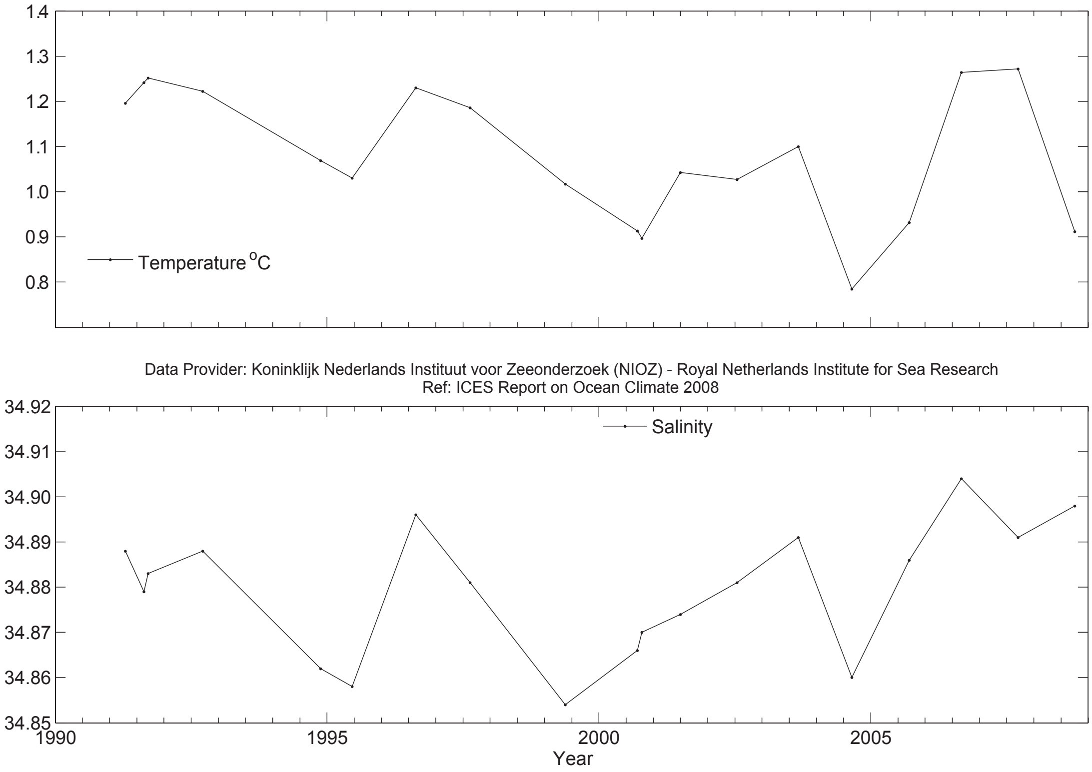
Figure 74.
Area 12 – Greenland Sea and Fram Strait. Winter convection depths in the Greenland Sea Section at 75°N.

Figure 75.
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.



Data Provider: AWI - Alfred Wegener Institute for Polar and Marine Research - Germany
Ref: ICES Report on Ocean Climate 2008

Figure 76.
Area 3 – Icelandic Waters. Temperature at 1500–1800 m in the Iceland Sea (68°N 12.67°W).



Data Provider: Koninklijk Nederlands Instituut voor Zeeonderzoek (NIOZ) - Royal Netherlands Institute for Sea Research
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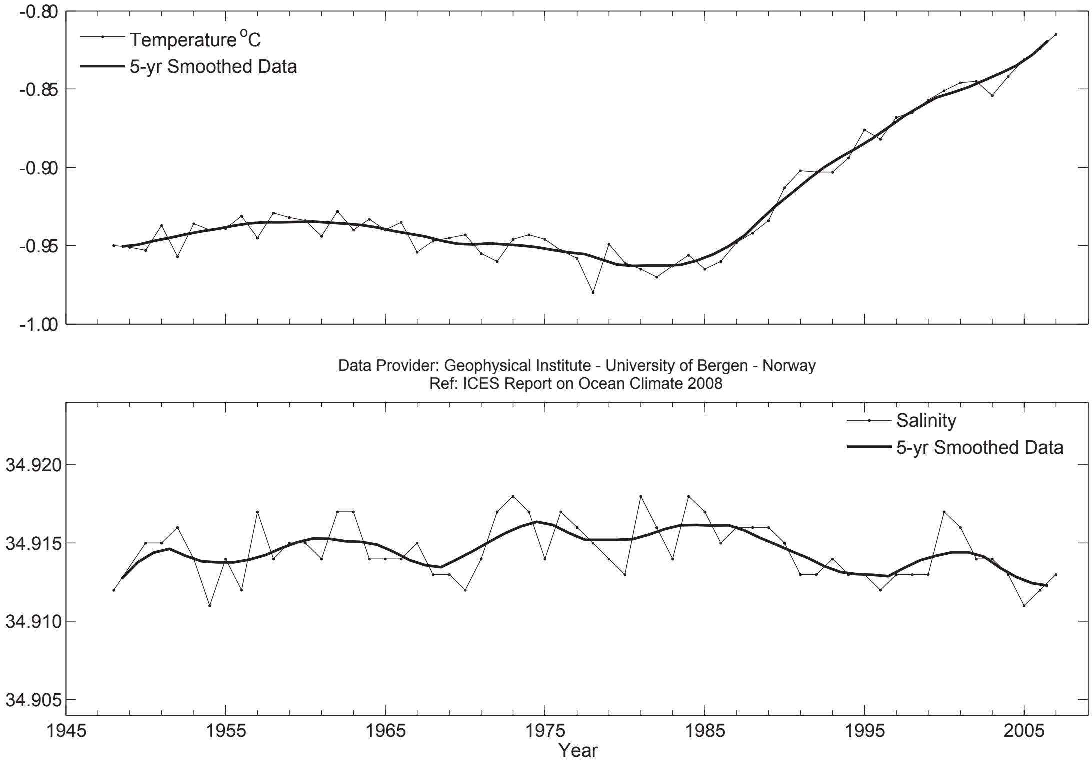

Data Provider: Geophysical Institute - University of Bergen - Norway
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Figure 77.
Area 10 – Norwegian Sea. Temperature (upper panel) and salinity (lower panel) at 2000 m at Ocean Weather Station "Mike" (66°N 2°E).

5.3 North Atlantic deep waters

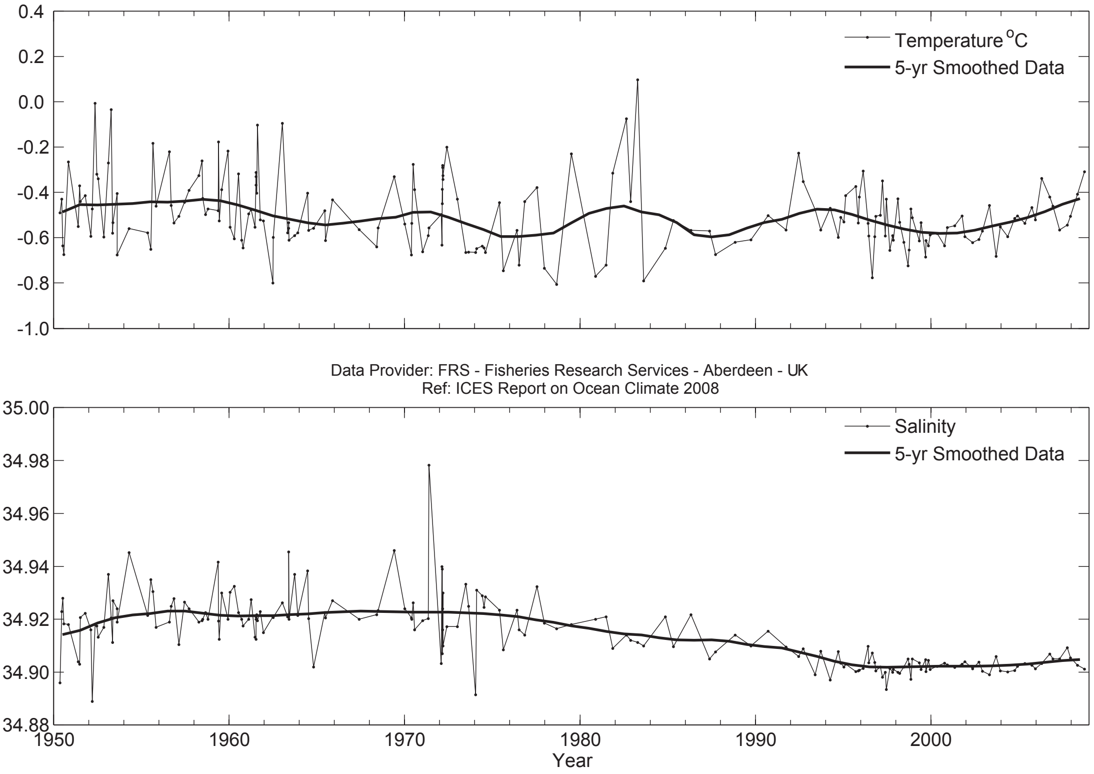
In the deep layers of the Faroe–Shetland Channel (Area 7), the properties at 800 m are the same as those of Norwegian Sea Deep Water as it passes through the channel back into the North Atlantic. After a period of decline in the 1990s, temperature has increased since 2000, but still remains lower than 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 subsequent 15 years; since 1992, it has stabilized again.

The salinity and potential temperature of the Denmark Strait Overflow Water (DSOW) near Cape Farewell demonstrated considerable well-correlated interannual variations between 1991 and 2007 (correlation = 0.7). However, from 2007 to 2008, the changes in temperature and salinity of the DSOW broke this rule. Temperature decreased and salinity increased, leading to the highest potential density of DSOW since the time-series started in 1991. The long-term trends in salinity and temperature since 1991 are not significant. The interannual variability of the DSOW is dominant. The long-term standard deviations in temperature and salinity are 0.15°C and 0.014, respectively.

In deep waters at Cape Desolation Station 3 (at 2000 m), 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. Since 1997, an increase in temperature (~0.3°C per decade) and, since 1998, an increase in salinity (~0.05 per decade) have been observed again. In 2008, temperature at 2000 m was slightly lower than in 2007, but was still the second highest observed since 1993. Salinity at 2000 m remained the same as the previous year.

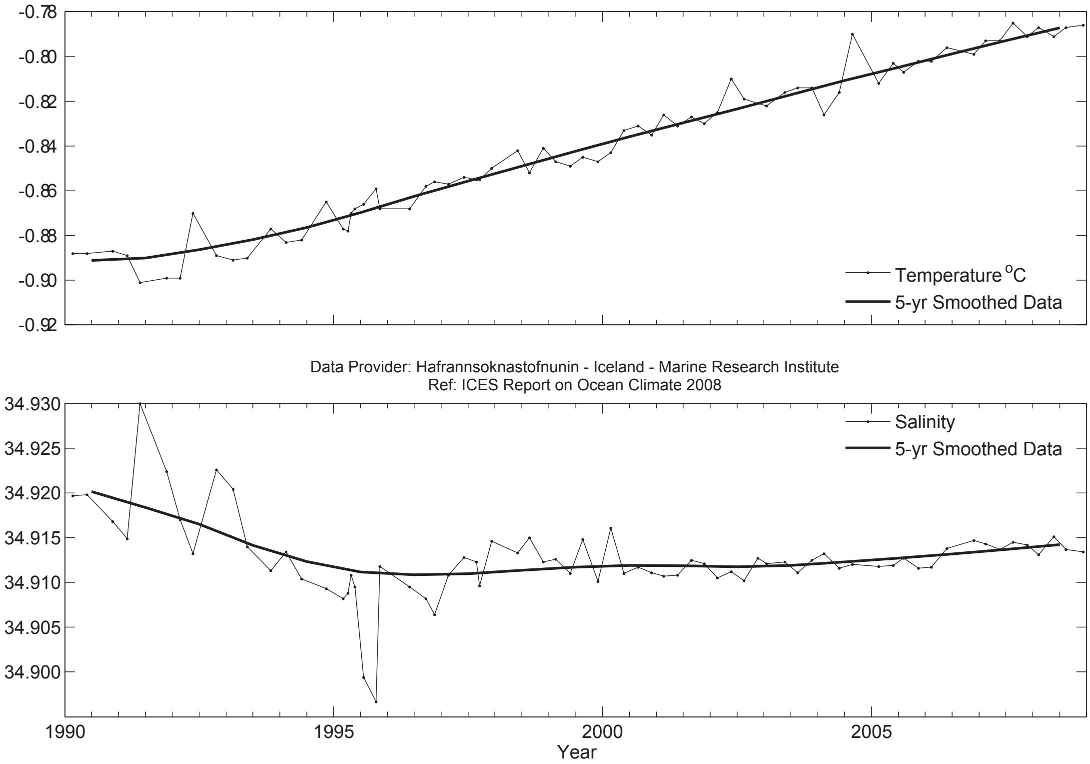
THE HIGHEST DENSITY DENMARK STRAIT OVERFLOW WATER WAS OBSERVED IN 2008.

Figure 78.
Area 7 – Faroe–Shetland Channel. Temperature (upper panel) and salinity (lower panel) at 800 m in the Faroe–Shetland Channel..



Data Provider: FRS - Fisheries Research Services - Aberdeen - UK
Ref: ICES Report on Ocean Climate 2008

Figure 79.
Area 5b – Irminger Sea. Temperature (upper panel) and salinity (lower panel) in Denmark Strait Overflow Water on the East Greenland Slope.



Data Provider: Hafrannsoknastofnunin - Iceland - Marine Research Institute
Ref: ICES Report on Ocean Climate 2008

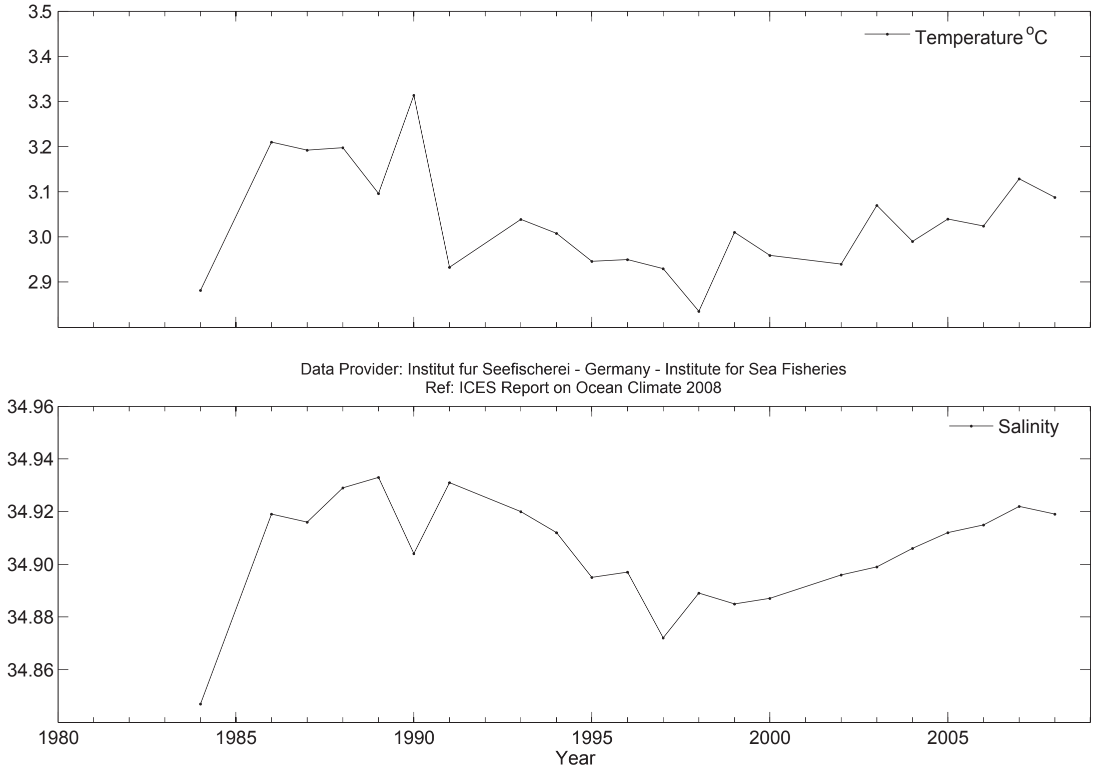


Figure 80.
Area 1 – West Greenland. Temperature (upper panel) and salinity (lower panel) at 2000 m at Cape Desolation Station 3 in the West Greenland Current.

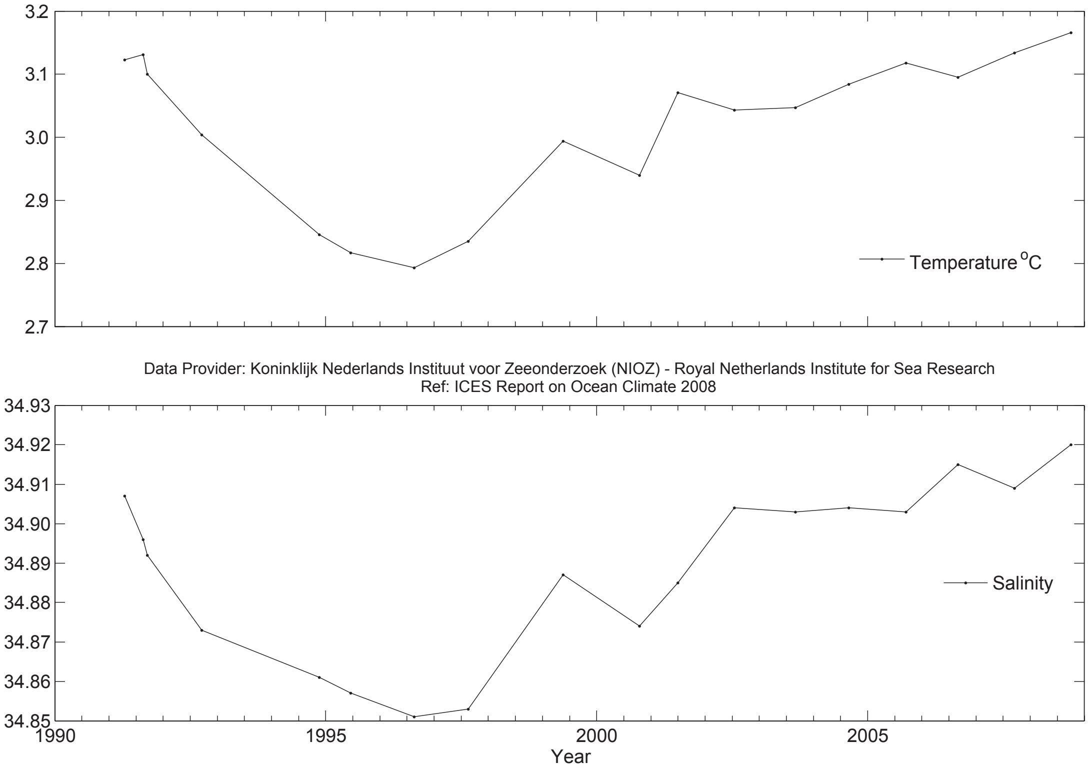
5.4 North Atlantic intermediate waters

In the central Irminger Sea (Area 5b), the cold, low-salinity core was observed between 1600 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 decreased temporarily) as the LSW mixes with surrounding water masses. After levelling in 2001–2002, overall temperature and salinity slowly increased until 2008, reaching the highest values observed since 1991.

In the Rockall Trough (Area 5), the core of the LSW at 1800–2000 m is defined as the part of the water column with the lowest stratification. The persistent cooling and freshening of this intermediate water mass continued during 2008 and was accompanied by a gradual increase in density and depth (at rates of 0.44 × 10^{-3} kg m^{-3} and 5 m $year^{-1}$, respectively). Both state variables were slightly higher than the record lows of 2007, although no significance is attributed to this.

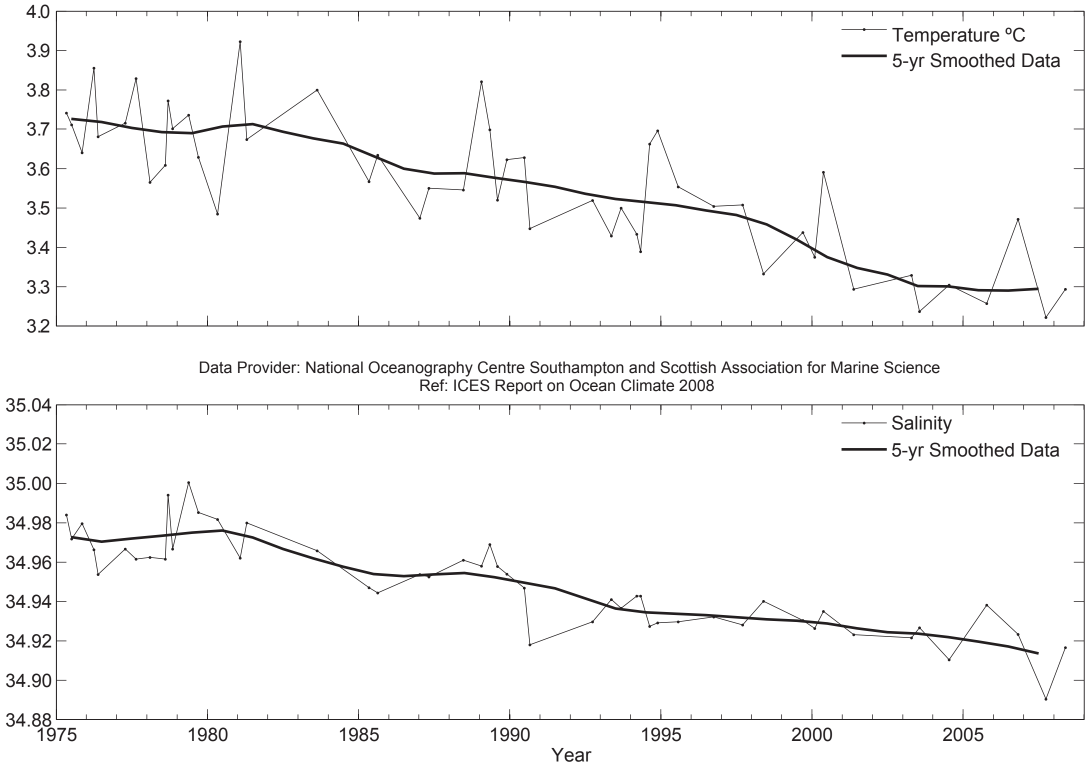
Image courtesy of H. Klein, BSH, Germany

Figure 81.
Area 5b – Irminger Sea. Temperature (upper panel) and salinity (lower panel) of Labrador Sea Water (averaged over 1600–2000 m).



Data Provider: Koninklijk Nederlands Instituut voor Zeeonderzoek (NIOZ) - Royal Netherlands Institute for Sea Research
Ref: ICES Report on Ocean Climate 2008

Figure 82.
Area 5 – Rockall Trough. Temperature (upper panel) and salinity (lower panel) of Labrador Sea Water (1800–2000 m).



Data Provider: National Oceanography Centre Southampton and Scottish Association for Marine Science
Ref: ICES Report on Ocean Climate 2008

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1 West Greenland	14	Nuuk-air temperature	Manfred Stein (manfred.stein@ish.bfa-fish.dk)	Danish Meteorological Institute (DMI), Denmark, and Seewetter-amt, Hamburg, Germany
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2 Northwest Atlantic	17, 18	Cabot Straight – sea ice, Sable Island – air temperature, Misaine Bank	Brian Petrie (PetrieB@mar.dfo-mpo.gc.ca)	Bedford Institute of Oceanography (BIO), Fisheries and Oceans, Canada
2 Northwest Atlantic	19	Emerald Basin	Brian Petrie (PetrieB@mar.dfo-mpo.gc.ca)	Bedford Institute of Oceanography (BIO), Fisheries and Oceans, Canada
2 Northwest Atlantic	20, 21, 22	Sea Ice, Cartwright – air temperature, Station 27 – CIL	Eugene Colbourne (colbourn@dfo-mpo.gc.ca)	Northwest Atlantic Fisheries Centre, Canada
2b Labrador Sea	23, 24, 25	Section AR7W	Ross Hendry (Ross.Hendry@dfo-mpo.gc.ca)	Bedford Institute of Oceanography (BIO), Fisheries and Oceans Canada
2c Mid-Atlantic Bight	26, 27, 28	Central MAB and Guf of Marine	Robert Pickart (rpickart@whoi.edu)	Woods Hole Oceanographic Institution, USA
2c Mid-Atlantic Bight	29, 30	Georges Bank	Maureen Taylor (mtaylor@mercury.wh.whoi.edu)	NOAA Fisheries, NEFSC Oceanography Branch, USA
3 Icelandic Waters	31, 32, 33, 34, 35, 76	Air temperatures, Siglunes Stations 2–4, Selvogsbanki Station 5, Langanes Stations 2–6, deep data – to 1800 m	Hedinn Valdimarsson (hv@hafro.is)	Hafrannsoknastofnunin (Marine Research Institute), Iceland
4 Bay of Biscay	36	San Sebastian – sea surface and air temperatures	Victor Valencia (vvalencia@pas.azti.es)	AZTI, Aquarium of San Sebastian (SOG) and Igeldo Meteorological Observatory (INM) in San Sebastian, Spain
4 Bay of Biscay	37, 38	Santander Station 6 (shelf break)	Alicia Lavin (alicia.lavin@st.ieo.es)	Instituto Español de Oceanografía (IEO, Spanish Institute of Oceanography), Spain
4b NW European continental shelf	39, 40	Western Channel Observatory Station E1	Tim J. Smyth (tjsm@pml.ac.uk)	Marine Biological Association (MBA) and Plymouth Marine Laboratory (PML), UK
4b NW European continental shelf	41	Malin Head Weather Station	Glenn Nolan (Glenn.Nolan@marine.ie)	Marine Institute and Met Éireann, Ireland
4b NW European	42	M3 Marine Weather Buoy continental shelf	Sheena Fennel (Sheena.Fennell@marine.ie)	Marine Institute, Ireland
5 Rockall Trough	43, 82	Ellet Line; deep data – to 2000 m	Toby Sherwin (toby.sherwin@sams.ac.uk)	National Oceanography Centre, Southampton (NOCS) and Scottish Association for Marine Science (SAMS), UK
5b Irminger Sea	44, 79, 81	Irminger Sea	H. M. van Aken (aken@nioz.nl)	Koninklijk Nederlands Instituut voor Zeeonderzoek (NIOZ, Royal Netherlands Institute for Sea Research), Netherlands
6 Faroe Bank Channel	45, 46, 47	Faroe Bank Channel Faroe Current, coastal stations	Karin Margretha Larsen (KarinL@frs.fo)	Havstovan (Faroe Marine Research Institute, FAMRI), Faroe Islands
7 Faroe-Shetland Channel	48, 49, 78	Faroe-Shetland Channel	Sarah Hughes (s.hughes@marlab.ac.uk)	Fisheries Research Services (FRS), Aberdeen, UK
8 North Sea	50	Modelled North Sea Inflow	Morten Skogen (morten@imr.no)	Institute of Marine Research (IMR), Norway
8 North Sea	51	North Sea Utsira Section Station A and B	Solfrid Hjollo (solfrid.hjollo@imr.no)	Institute of Marine Research (IMR), Norway
8 North Sea	52	Fair Isle Current Water	Sarah Hughes (s.hughes@marlab.ac.uk)	Fisheries Research Services (FRS), Aberdeen, UK
9 North Sea	53, 54	Helgoland Roads – Coastal Waters – German Bight, North Sea	Karen Wiltshire (kwiltshire@awi-bremerhaven.de)	Alfred-Wegener-Institut / Biologische Anstalt Helgoland (AWI/BAH), Germany
9 North Sea	55	Felixstowe – Rotterdam (52˚N) – section average,	Stephen Dye (stephen.dye@cefas.co.uk)	Centre for Environment Fisheries and Aquaculture Science (CEFAS), UK
8&9 North Sea	56	Sea surface temperature – North Sea average	Peter Loewe (peter.loewe@bsh.de)	Bundesamt für Seeschifffahrt und Hydrographie, (BSH, Federal Maritime and Hydrographic Agency), Hamburg, Germany
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9b Skagerrak, Kattegat and the Baltic Sea	59, 60, 61	Stations LL7, BO3 and SR5	Pekka Alenius (pekka.alenius@fimr.fi)	Finnish Institute of Marine Research (FIMR), Finland
10 Norwegian Sea	63, 64, 65	Svinøy, Gimsøy, and Sørkapp Sections	Kjell Arne Mork (kjell.arne.mork@imr.no)	Institute of Marine Research (IMR), Norway
10 Norwegian Sea	66, 67, 77	Ocean Weather Station "Mike" – 50 m and 2000 m	Svein Østerhus (Svein.Osterhus@gfi.uib.no)	Geophysical Institute, University of Bergen, Norway
11 Barents Sea	68	Fugløya – Bear Island Section, western Barents Sea – Atlantic Inflow	Randi Ingvaldsen (randi.ingvaldsen@imr.no)	Institute of Marine Research (IMR), Norway
11 Barents Sea	69	Kola Section, eastern Barents Sea	Oleg V. Titov (titov@pinro.ru)	Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Russia
12 Greenland Sea and Fram Strait	70	Spitsbergen Section (76.5˚N)	Waldemar Walczowski (walczows@iopan.gda.pl)	Institute of Oceanology, Polish Academy of Sciences (IOPAS), Poland
12 Greenland Sea and Fram Strait	71, 75	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	72	Fram Strait Section	A. Beszczynska-Möller (abeszczynska@awi-bremerhaven.de)	Alfred Wegener Institute for Polar and Marine Research (AWI), Germany
12 Greenland Sea and Fram Strait	74	Greenland Sea Section – convection depth	G. Budeus (Gereon.Budeus@awi.de)	Alfred Wegener Institute for Polar and Marine Research (AWI), Germany

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