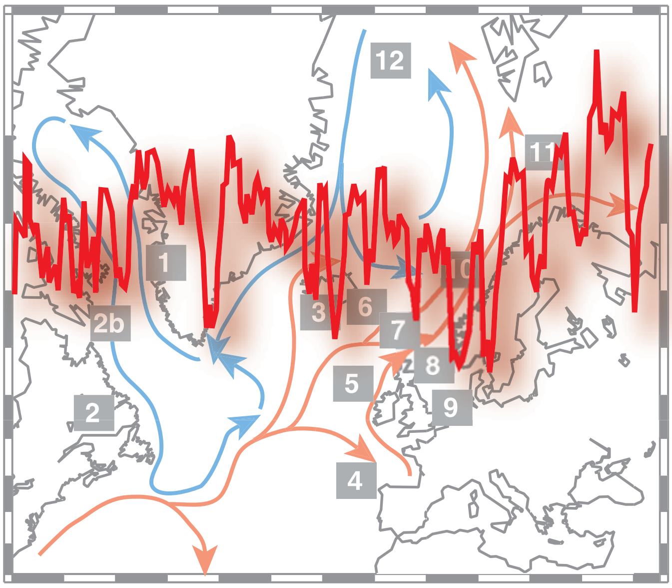
ICES COOPERATIVE RESEARCH REPORT

RAPPORT DES RECHERCHES COLLECTIVES

NO. 245

The Annual ICES Ocean Climate Status Summary 2000/2001



Prepared by the
Working Group on Oceanic Hydrography

Editors
Bill Turrell and N. Penny Holliday

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK-1261 Copenhagen K Denmark

February 2002

https://doi.org/10.17895/ices.pub.5123

ICES Cooperative Research Report No.245
ISSN 2707-7144
ISBN 978-87-7482-419-0

Table of Contents

The 2000/2001 ICES Annual Ocean Climate Status Summary

Overview

The North Atlantic Oscillation (NAO) Index continued to recover to positive values up to and including winter 2000 (winter is defined by the year of the January), though with some indication of an eastward shift in the NAO dipole pattern. The result was that most parts of the area under review showed moderate or warm conditions in 2000. Though the climatic data set for winter 2001 is not yet complete, early indications are that the NAO index has undergone a sharp return to negative conditions.

Surface temperatures off West Greenland were relatively warm during the summer of 2000 due to mild atmospheric conditions. Stronger inflows of polar water were noted.

Ocean conditions in the Northwest Atlantic cooled slightly during 2000 relative to 1999 values, but were near or above normal in most areas. Sea-ice extent also increased slightly over the light ice conditions of 1999. An increased southward transport of polar waters was noted on the Labrador shelf.

The surface waters of the Labrador Sea were observed to be slightly cooler, fresher and denser in the summer of 2000 compared to 1999. More convection and overturning took place in the Labrador Sea during the 2000 winter than in recent years, but not as intense as during the early 1990s.

In Icelandic waters, 2000 revealed in general relatively high temperatures and salinities as in the last 2-3 years, following the very cold years of 1995 and 1996, although temperatures were also cooler than 1999 in this area.

The annual mean air temperature over the southern Bay of Biscay during 2000 remained at nearly the same value as during the two preceding years. Surface waters were slightly cooler and fresher than in previous years.

Early 2000 saw a peak in the temperature of surface waters in the Rockall Trough, caused by an influx of unusually warm water into the region. By the spring of 2000 the temperature had dropped somewhat, though it remained above the long-term mean.

2000 was the sixth warmest year since 1971 in the North Sea, in terms of annual mean sea surface temperature. All months were warmer than average, except for June and July. There was evidence of a large input of freshwater from the Baltic.

Since 1996, temperatures have increased in the southern and central Norwegian Sea. In 2000 the warming continued at the southern section while a cooling occurred at the central section. In the northern Norwegian Sea the temperature since 1996 has been close to the long-term average.

The temperature in the Barents Sea decreased from 1°C above average during early winter to 0.2°C in the autumn. In the eastern Barents Sea the temperature remained high throughout the year.

A larger than normal inflow of Atlantic water results in warmer and more saline conditions in the eastern Greenland Sea.

Prognosis

There are indications that in the winter 2000/2001 the "recovering" NAO Index will have undergone a further rapid reversal to negative values. If correct we can expect warming in the NW Atlantic and cooling in the east.

The North Atlantic Oscillation (NAO) Index

Since the NAO is known to control or modify three of the main parameters which drive the circulation in the ocean area covered by this climate summary (i.e. wind speed, air/sea heat exchange and evaporation/precipitation), knowledge of its past and present behaviour forms an essential context for the interpretation of observed ocean climate change in 2000.

The NAO alternates between a "high index" pattern, characterised by strong mid-latitude westerly winds, and a "low index" pattern in which the westerly winds over the Atlantic are weakened. High index years are associated with warming in the southern North Atlantic, and NW European shelf seas and cooling in the Labrador and Nordic Seas. Low index years generally show the reverse.

When we consider the winter NAO index for the present decade, and the present decade in the context of this century (Figure 1), the 1960s were generally low-index years while the 1990s were high index years. There was a major exception to this pattern occurring between the winter preceding 1995 and the winter preceding 1996, when the index flipped from being one of its most positive values to its most negative value this century. The index rose from the extreme low, and the recovery continued during the winter preceding 2000. Thus 2000 has a positive NAO index. during winter.

However, although the simple index continued to increase back to positive values during the winters preceding 1999 and 2000, the actual pattern of the NAO over the ICES area did not recover to a "normal" distribution expected during high NAO years, but was rather displaced towards the east or northeast. This subtle change had most impact in the northwest Atlantic, where instead of a chill and strong north-westerly airflow promoting cooling there, as it did in the early 1980s and 1990s, any north-westerly airflow was mainly confined to the east of Greenland, while the Labrador Sea was occupied by light or southerly anomaly-winds.

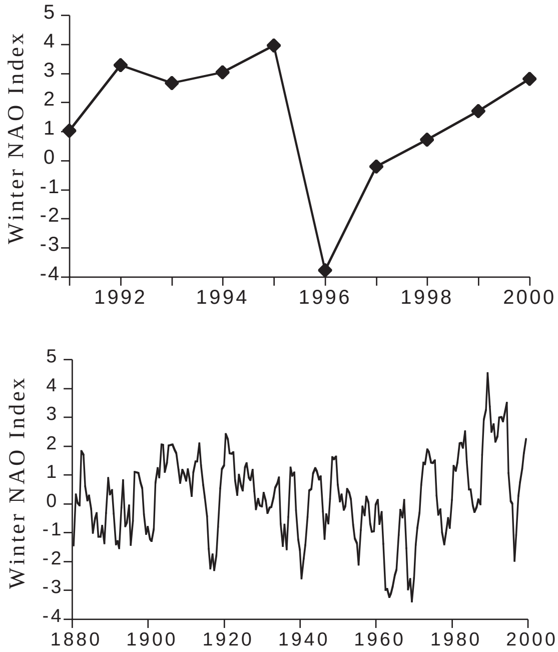


Figure 1. *The winter NAO index in terms of the present decade (upper figure) and the present century (lower figure – a 2- year running mean has been applied).*

It would appear that the winter of 2000/2001 might be exhibiting another sudden reversal similar to that seen in 1995/1996. Text Box 1 has the details. However, Text Box 2 adds a cautionary note about over-interpreting the simple NAO index.

In the remainder of the ocean climate summary the regional descriptions will proceed in an anti-clockwise manner around the North Atlantic, commencing in the waters west of Greenland. This follows the main circulation pattern of the North Atlantic (Figure 2).

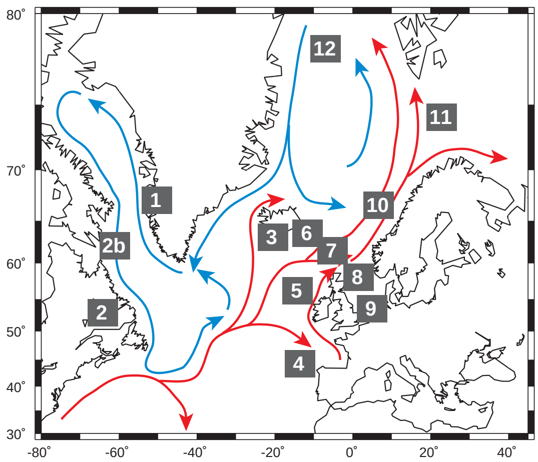


Figure 2*. Schematic illustration of the general circulation of the North Atlantic in relation to the numbered areas presented in the 2000/2001 Annual ICES Ocean Climate Status Summary. The light grey arrows indicate the cooler waters of the sub-polar gyre. The dark grey arrows show the movement of the warmer waters in the sub-tropical gyre.*

Text Box 1 – The NAO in winter 2001: early indications of a sharp return to NAO-negative conditions

Background

The characteristics of the NAO and many aspects of the ocean's response were described in the equivalent context-setting sections of previous ICES Annual Ocean Climate Summaries. Following a long period of amplification from its most extreme and persistent negative phase in the 1960s to its most extreme and persistent positive phase during the late 1980s early 1990s, the winter NAO index underwent a large and rapid decrease in winter 1995–1996, and both the 1999 and the present IAOCSS describe the recovery to more positive values since then. Though the March 2001 atmospheric pressure values are not available at the time of writing, the evidence is that the "recovering" NAO Index will be found to have undergone a further rapid reversal to negative values.

The NAO in winter 2001

Figure 3 describes the Atlantic distribution of sea level pressure anomaly in (a) December 2000, (b) January 2001, and (c) February 2001 respectively, with panel (d) showing the December to February composite (NCEP/NCAR reanalysis data from the NOAA-CIRES Climate Diagnostics Centre: www.cdc.noaa.gov/Composites). In every month, but especially in December and February, the NAO dipole pattern is configured in such a way that the more northerly (southerly) cell exhibits a positive (negative) sea level pressure anomaly, so that the composite is strongly NAO-negative. With centres over Iceland-Greenland and Azores-Biscay, it is difficult to detect any marked difference from the classical EOF-1 sea level pressure anomaly distribution.

Monthly values of the Jones Gibraltar-Iceland index (www.cru.uea.ac.uk) are listed for December 2000 and January 2001 only, as –1.41 and + 0.02 respectively, but inspection of the individual monthly maps confirms that because of the locations of Lisbon and Gibraltar in relation to the southern pressure-anomaly centre, the Gibraltar-Iceland pressure pair is likely to record a smaller pressure difference than Lisbon-Iceland.

Ocean response

The return to strongly NAO-negative conditions, however briefly it lasts, is likely to have an important bearing on the ocean and ecosystem response. This stems from the dominant role of the winter NAO in driving both, and in particular its control of all three of the factors that alter the ocean's circulation (wind speed and direction, evaporation minus precipitation, and the fluxes of sensible and latent heat). The responsiveness of the ocean is now known to be sufficiently rapid to reflect even short-term annual changes in the NAO. The large-amplitude but short-lived drop in the Index in 1996 showed that a clear response was evident in a wide range of parameters, including a basin-wide change in sea level, the northward heat transport through 48ºN, the westward shift of the sub-Arctic front in mid-Atlantic, the reversal of the precipitation regime over Europe, the ice flux through Fram Strait, and the sea temperatures and cod recruitment of the southern North Sea.

Though the NAO pattern for the full winter is not yet available and though the ocean's response has still to be worked through, this interim report is compiled both as a pointer to the sorts of environmental changes that are likely to appear in our observations. Text Box 2 adds a cautionary note about over-interpreting the simple NAO index.

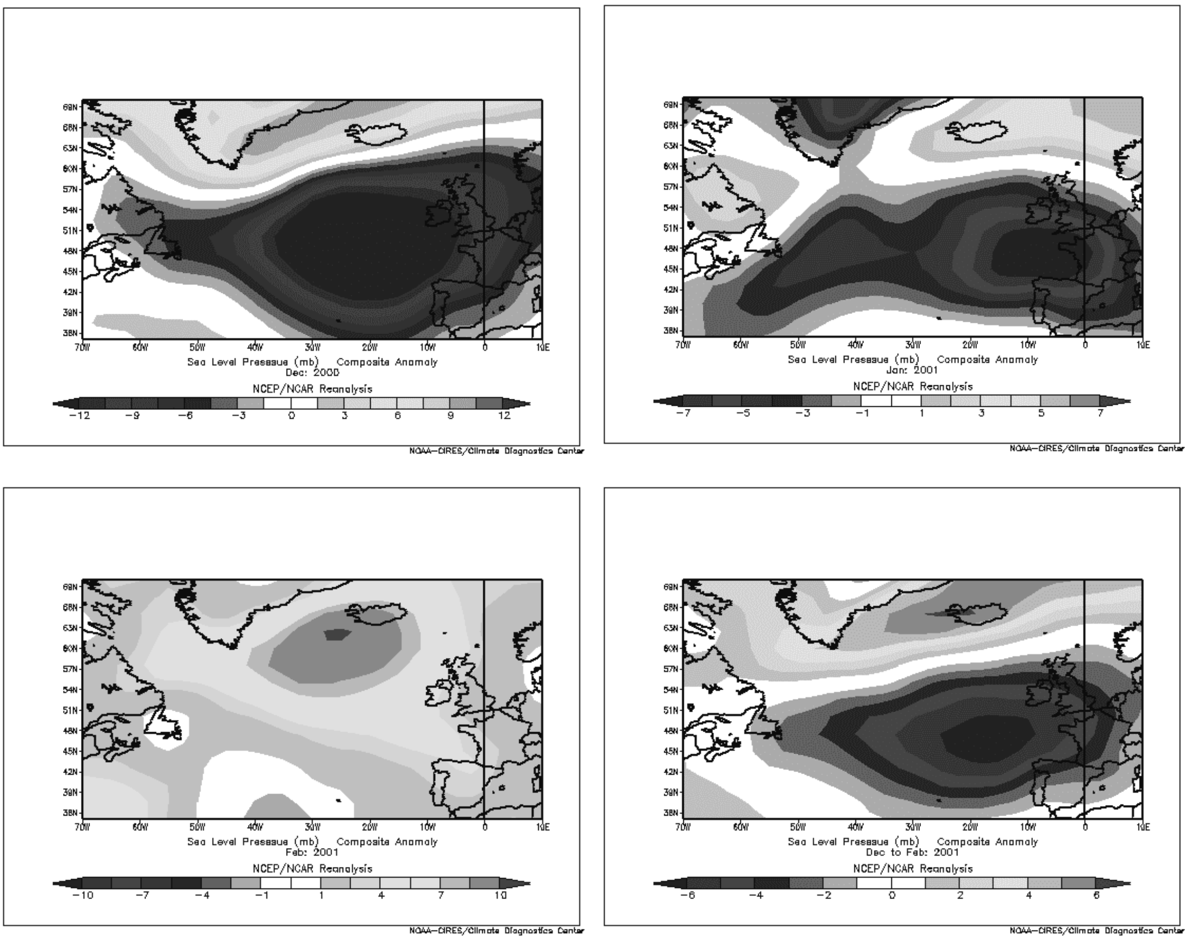


Figure 3. *The NAO in winter 2001 – The Atlantic distribution of sea level pressure anomaly in (a) December 2000, (b) January 2001, and (c) February 2001 respectively, with panel (d) showing the December to February composite (NCEP/NCAR reanalysis data from the NOAA-CIRES Climate Diagnostics Centre: www.cdc.noaa.gov/Composites).*

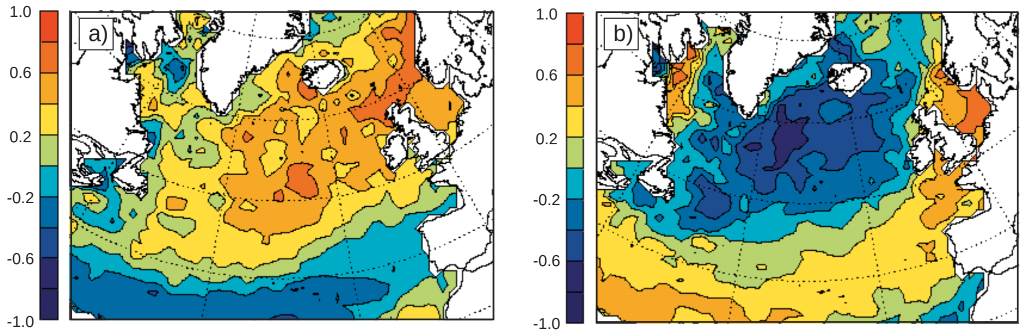


Figure 4. *The NAO in winter 2001 – Spatial distribution of the Pearson correlation coefficient between the NAO Index and (a) local winter scalar wind speed (ms^{-1}) and (b) local sea surface temperature (°C) for the period 1950 – 1995. Winter is taken as the months January to March. Kindly provided by Ben Planque, IFREMER, Nantes, pers comm.*

Text Box 2 – Is the North Atlantic Oscillation always the dominant control on Atlantic variability?

In many of the regional summaries in this, and previous editions of the ICES Annual Ocean Climate Status Summary, we describe possible associations between various parameters of Atlantic hydrography and the winter behaviour (pattern and amplitude) of the NAO. As one of the most robust recurrent modes of atmospheric behaviour on Earth, the NAO dictates much of the climate variability from the eastern seaboard of the United States to Siberia and from the Arctic to the tropical Atlantic, especially during boreal winter. Further, from the mid-1960s to the 1990s, which includes our best and most recent hydrographic record, the NAO Index has been observed to amplify slowly between one extreme state and the other in an instrumental record that extends back to at least 1865.

However, there are areas and times when the influence of the NAO will be less dominant in our long-term records. For example:

Warm period 1925–1960

During the middle decades of the century there was a notable warm period in the North Atlantic, lasting from 1925 until 1960, when the dominance of the NAO decreased temporarily, allowing a quite different set of physical controls to drive a protracted change through the northern Gyre of the North Atlantic. This regional event had some of the largest dislocations ever observed in the Atlantic ecosystem (see CM2001/C:06 for more details).

Zones of minimal correlation

Areas such as the Rockall Trough lie on the zone of minimal correlation between centres of significant correlation with the NAO, which are found to the east and west of such areas (Figure 4). In general we can expect this to be one area where the NAO bears little obvious relation to hydrographic change.

Chaotic variability

Even in an area of maximum responsiveness to the NAO, the NAO is not the only or even the main control on ocean variability. Over the Atlantic as a whole, though the NAO accounts for substantially more than any other pattern of variability, it still explains only around one-third of the total variance in winter sea level pressure, and the chaotic nature of the atmospheric circulation means that, even during periods of strongly positive or negative NAO index winters, the atmospheric circulation typically exhibits significant local departures from the idealized NAO pattern.

Finally, it is worth stressing that we do not yet know the causes of longer-term NAO behaviour, the periods when anomalous NAO-like circulation patterns persist over many consecutive winters, or the fact that the magnitude of the recent upward trend is unprecedented in the observational record. Whether such low frequency (interdecadal) NAO variability arises from interactions of the North Atlantic atmosphere with other, more slowly varying components of the climate system such as the ocean, whether the recent upward trend or eastward shift in the NAO reflect a human influence on climate, or whether the longer time scale variations in the relatively short instrumental record simply reflect finite sampling of a purely random process, are topics of considerable current interest. However, we can say that we have almost certainly not experienced the full range of possible NAO variability!

Regional Descriptions – Area 1 – West Greenland

West Greenland lies within the area which normally experiences cool conditions when the NAO index is positive. However, although the index has been positive since 1996, and in the winter 1999/2000 recovered to the level of extreme positive values experienced in the early 1980s and especially in the early 1990s, conditions around Greenland remained warm. In 2000 the annual mean air temperature in Nuuk was -0.80°C, which is about 1°C above normal (Figure 5), confirming that an anomalous NAO pattern was still influencing the area. Changes in the ocean climate in the waters off West Greenland generally follow those of the air temperatures. The relatively mild atmospheric conditions were reflected in the mean temperature on top of Fylla Bank in the middle of June (Figure 6), with the 2000 temperature value (T=2.45°C) being the fifth highest temperature observed since the start of the time series in 1950, and thereby also well above the average value of 1.67°C for the whole 50 year period.

In summary, oceanographic conditions off West Greenland during the summer 2000 were characterised by high surface temperatures due to mild atmospheric conditions and a relatively high inflow of Polar Water. Pure Irminger Water was absent during the summer of 2000 even in the Cape Farewell region, but reappeared as far north as 64°N by the autumn.

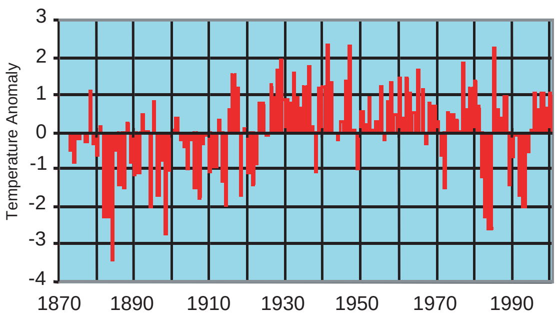


Figure 5. Area 1 – West Greenland. Anomaly in the annual mean air temperature observed at Nuuk for the period 1873 to 2000. (The anomaly is taken relative to the mean temperature for the whole period).

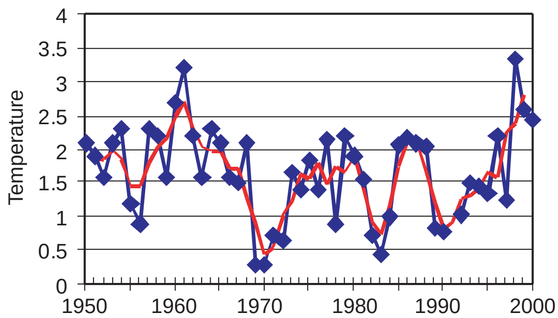


Figure 6. Area 1 – West Greenland. Time-series of mean temperature (observations and 3- year running mean) on top of Fylla Bank (0 - 40 m) in the middle of June.

Area 2 – Northwest Atlantic

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

During 2000 annual mean air temperatures cooled slightly over the record high values of 1999 in many regions of the northwest Atlantic. Maximum air temperature anomalies occurred from southern Labrador to the Scotian Shelf, where values were up to 2°C above their long-term (1961–1990) means. Seasonally, air temperatures in these areas were above normal for the majority of 2000. Air temperature in the northern-most regions warmed slightly over 1999 values.

Sea ice on the Newfoundland and Labrador Shelves during 2000 generally appeared on schedule but left early, resulting in a shorter duration of ice than normal. The ice coverage in these areas during 2000 was lower than average but increased slightly over 1999. Off eastern Newfoundland, the depth-averaged ocean temperature ranged from a record low during 1991 (high NAO index in preceding winter), a near record high in 1996 (following the reversal in the preceding winter to the near record low NAO index), and above the long-term (1961–1990) average in 1999 and 2000. Summer salinities, which were below normal during most of the early 1990s, returned to near normal values during 2000.

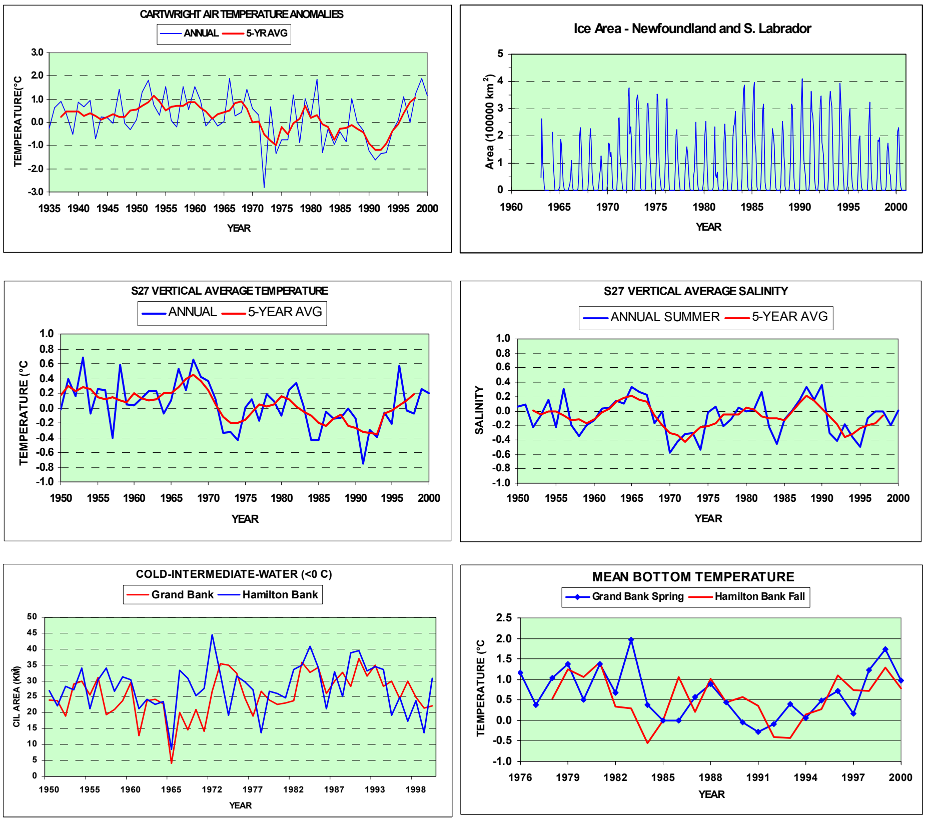


Figure 7. *Area 2 – Northwest Atlantic. Annual air temperature anomalies at Cartwright on the Labrador Coast, the sea-ice area off Newfoundland and Labrador between 45°N-55°N, the depth-averaged Station 27 annual temperature and summer salinity anomalies, the time series of cold intermediate layer (CIL) on the Grand Bank of Newfoundland and Hamilton Bank off southern Labrador, and the annual mean bottom temperatures on the Grand Bank and Hamilton Bank.*

A robust index of the general oceanic environmental conditions off the eastern Canadian continental shelf is the extent of the cold intermediate layer (CIL) of sub-zero centigrade water. This winter-cooled water remains trapped between the seasonally heated upper layer and the warmer shelf-slope water throughout the summer and autumn months. During the 1960s, when the NAO was well below normal and had the lowest value ever in this century, the volume of CIL water was at a minimum, and during the high NAO years of the early 1990s, the CIL volume reached record high values. During 2000 the CIL remained below normal in southern regions (Grand Bank), but increased to above normal on the southern Labrador Shelf.

Annual mean bottom temperature for the Grand Bank and Hamilton Bank have recently increased over the lows of the early 1990s, with average values during 1999 >1.5°C on the Grand Bank and >1°C on the southern Labrador Shelf. During 2000 mean bottom temperatures decreased over 1999 values by about 0.5°C.

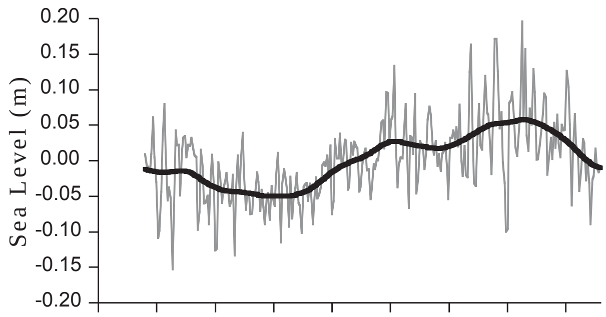
In general ocean conditions in the north-west Atlantic during 2000 cooled slightly over 1999 values but still ranged from near normal to warmer than normal over most areas.

Area 2b – The Labrador Sea

The Labrador Sea is part of the North Atlantic located between Greenland and the Labrador coast of eastern Canada. Cold, fresh waters of polar origin circle the Labrador Sea in a counter-clockwise current system that includes both the northward flowing West Greenland Current on the eastern side and the southward flowing Labrador Current on the western side.

Wintertime cooling and evaporation increase the density of surface waters in the central Labrador Sea. In some years, the wintertime density increase is so large that the surface layers overturn, a process that has been observed to penetrate to depths as great as 2000 m. The temperature, salinity, and density of Labrador Sea Water formed by these overturning processes vary from one year to another, depending on the winter conditions. The intermediate-depth Labrador Sea water mass created in this way spreads throughout the northern North Atlantic.

Cold winters and strong winds during the high NAO-index conditions of the first half of the 1990s gave rise to the formation of a notably dense, deep Labrador Sea water mass. Since that period, relatively warm winters have produced only shallow convection. The convection that took place in the 1999–2000 winter dominated the layer between 200 m and 1000 m. The newly-produced water mass penetrated 300 m deeper on average than during the previous winter. The upper 1000 m showed a cooling and freshening trend, up to 0.3°C cooler and 0.02 fresher in 2000 than in 1999. The associated density increase of the upper kilometre of the Labrador Sea was accompanied by a 5 cm lowering in sea level, according to TOPEX/POSEIDON altimeter measurements. Summer 2000 sea level was lower than observed since the end of the intense cooling period of the early 1990s (Figure 8).



Area 3 – Icelandic Waters

Iceland is situated at the meeting place of warm and cold currents (Figure 9), which meet in this area because of its geographical position and the location of submarine ridges (parts of the Greenland-Scotland Ridge), that form a natural barrier against the main ocean currents around the country. To the south is the warm Irminger Current, which is a branch of the North Atlantic Current (6-8°C), and to the north are the cold East Greenland and East Icelandic Currents (-1°C to 2°C). There are also deep and bottom currents in the seas around Iceland, principally the overflow of deep, cold water from the Nordic Seas and the Arctic Ocean south over the submarine ridges into the North Atlantic.

The hydrographic conditions in Icelandic waters in 2000 revealed in general relatively high temperatures and salinities as seen in the previous 2–3 years. The salinity in the warm water from the south was higher than has been observed over the last decades, and these conditions have been evident since 1997. This was further evidence of the Atlantic inflow into North Icelandic waters (Figure 10).

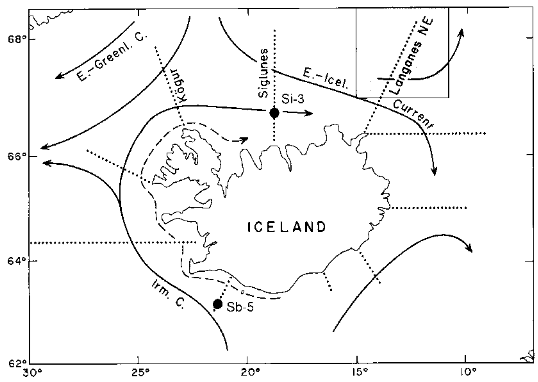


Figure 9. Area 3 – Icelandic waters. Main currents and location of standard hydro-biological sections in Icelandic waters.

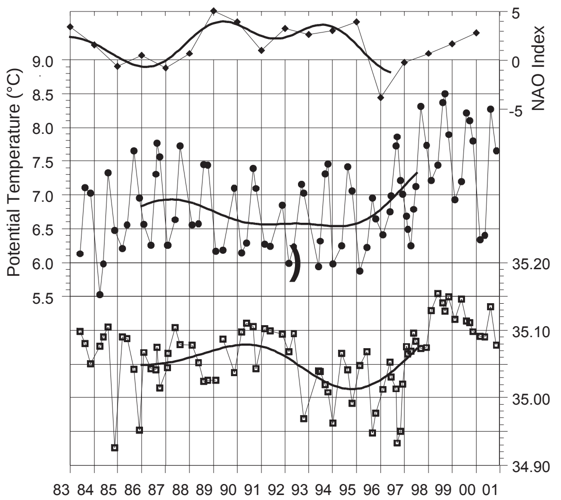


Figure 10. Area 3 – Icelandic waters. Time series of the NAO index, mean temperature and salinity of the upper 200 m for station 9 of Faxaflói section 1983–-2000: annual and 5-year Gaussian filtered values.

The cold waters north and north-east of Iceland in the East Icelandic Current were in 2000 as in 1999, relatively far offshore, and had salinities of around 34.8, which is well above a critical value which prevents overturning. These mild conditions in Icelandic waters in 2000 follow extremely cold conditions in 1995, improving in 1996 and 1997, and continuing to do so in 1998 and 1999, but showing a slight decrease in 2000.

Area 4 – Bay of Biscay and Eastern Atlantic

The Bay of Biscay is located between the eastern part of the sub-polar gyre and the sub-tropical gyre. This region may be affected by both gyres, depending on the latitude and the general circulation in the North Atlantic.

The annual mean air temperature over the southern Bay of Biscay during 2000 remained at nearly the same value as during the two preceding years, at 14.7°C, 0.3ºC over the 1961–2000 average (Figure 11).

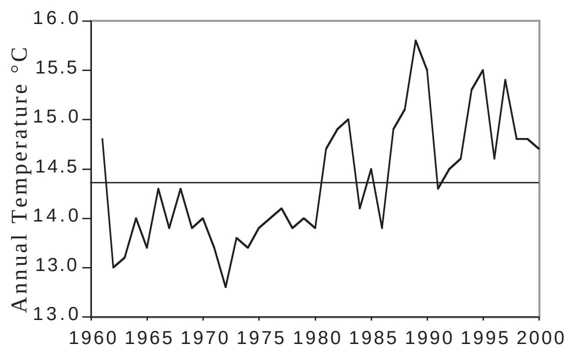


Figure 11. *Area 4 – Bay of Biscay and Eastern Atlantic. Annual mean air temperatures at Santander, northern Spain. (Data courtesy of Instituto Nacional de Meteorología).*

However, positive anomalies in the annual cycle appear in February, the whole of spring, August, September and, above all, December. During that month the air temperature was 2.9ºC higher than the historical mean. These high air temperatures reflect the pattern of sea level pressures found in December for the southern area (see Figure 3, upper left).

In terms of sea temperatures, 2000 was not a warm year. However, it had the greatest amplitude in the seasonal cycle of seawater temperature at 10 m (9.1°C) with the coldest winter of the decade, and the warmest September with temperatures 2.5ºC above the 1992–2000 mean. At this depth the 2000 annual mean was 15.6°C, which was lower than the previous year. Upper water salinity in the Bay of Biscay, which was increasing from a low salinity event in 1995, reached an apparent maximum around 1997/1998 and has decreased since then. This behaviour was also found at 200 m depth.

Area 5 – Rockall Trough

The Rockall Trough is situated west of the British Isles and separated from the Iceland Basin by the Hatton and Rockall Banks and from the Nordic Seas by the shallow (500 m) Wyville-Thomson ridge. It is one pathway by which warm North Atlantic upper water reaches the Norwegian Sea, where it is converted into cold dense overflow water as part of the thermohaline overturning in the North Atlantic. The upper water column is characterised 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. Below 1200 m the deep Labrador Sea Water is trapped by the shallowing topography to the north, which prevents through-flow but allows recirculation within the basin.

Early 2000 saw a peak in the de-seasoned upper ocean temperatures in the Rockall Trough. Thought to be caused by an influx of unusually warm water into the region, the mean temperature of the upper ocean was more than 0.5°C above the long-term mean (since 1975), with most of the warming having taken place from 1995 to 2000 (Figure 12). By May 2000 the temperature had dropped somewhat, although it remained 0.2°C above the long-term mean.

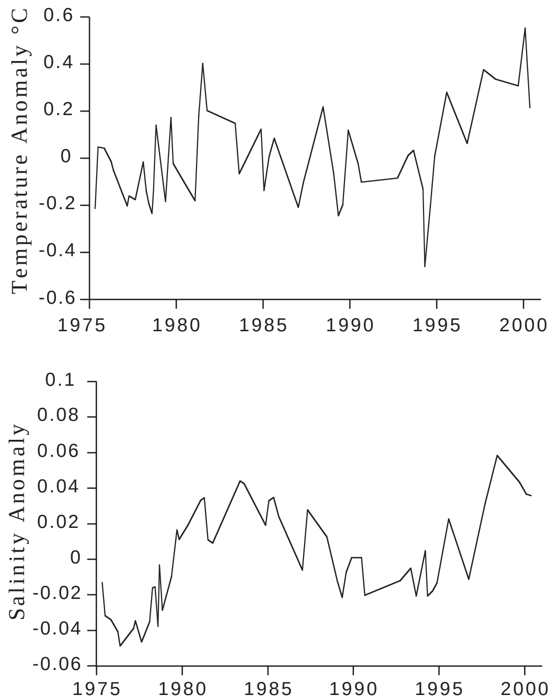


Figure 12. *Area 5 – The Rockall Trough. Salinity and temperature anomalies for the upper ocean (0-800 m) of the northern Rockall Trough (average across the section, seasonal cycle removed).*

The salinity has fallen from the peak in 1998, which reached 0.06 above the mean; nevertheless by mid-2000 it was still as high as the previous peak in 1983 (0.04 above the 25-year mean). Both temperature and salinity appear to be following a cyclical trend with a period of about 15 years.

The deep Labrador Sea Water (below 1200 m) was unchanged from the previous year; the long-term trend is of decreasing salinity (0.25 per decade) and slowly decreasing temperature (0.08°C per decade), reflecting periodic input of fresher, cooler water from outside the basin.

Area 7 – Northwest European Shelf

The northwest European shelf edge, west and north of Scotland, is dominated by the poleward flowing slope current, carrying Atlantic water towards the Norwegian Sea. This water is the principle source for water crossing onto the shelf, and into the North Sea.

The Atlantic water lying at the northwest European shelf edge has been warming since 1987 at a rate of 0.5°C/decade. Particularly high temperatures (Figure 13) were observed in the spring of 1998 but have remained fairly constant, although cooler, since then. The salinity of the Atlantic water reached a maximum in 1998, and has since been reducing.

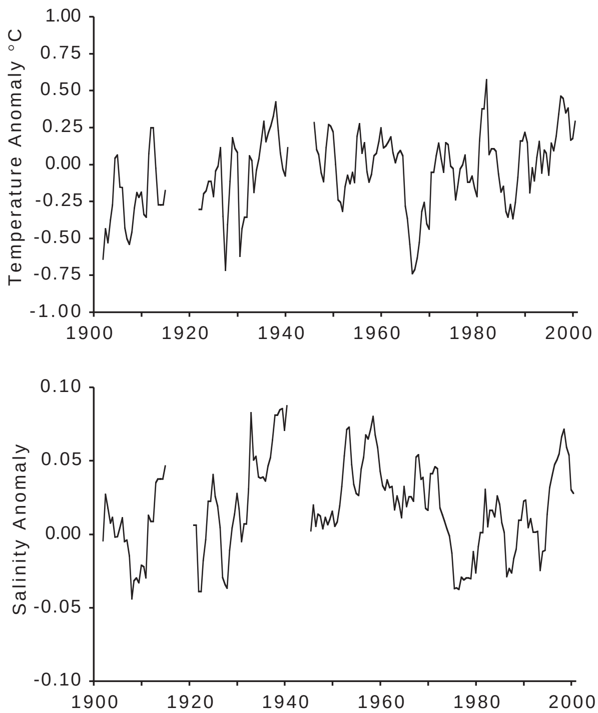


Figure 13. *Area 7 – Northwest European shelf edge. Temperature and salinity anomalies in the surface Atlantic waters lying within the slope current north of Scotland.*

Areas 8 and 9 – Northern and Southern North Sea

The oceanographic measurements made during the quarter 1 (January-March 2000) ICES International Bottom Trawl Survey (IBTS) show that North Sea conditions were again very similar to recent years. Temperature and salinity continued at high levels, especially in the northern North Sea, though not quite so high as in the record year of 1998. Overall average temperatures have been higher by up to 1°C following the late 1980s (Figure 14a).

Conditions immediately east of the entrance to the English Channel (Figure 14b) show marked interannual fluctuations in response to changes in the volume of Atlantic inflows to the North Sea through the Channel. Most of the 1990s have witnessed a fairly sustained presence of Atlantic water in this area, apart from around 1995–1996. Changes in winter atmospheric circulation patterns are the likely cause of these variations. Time–series from ten North Sea locations, including these two, can be viewed and downloaded from http://www.ices.dk/ocean/project/data/iyfsmaps/time/.

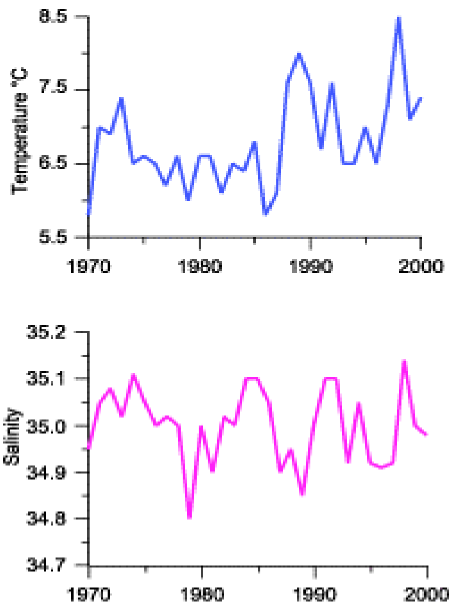


Figure 14a. *Area 8 – Time series of temperature and salinity at a location in the NW North Sea (57°30'N 0°E) during the ICES IBTS Quarter 1 Surveys.*

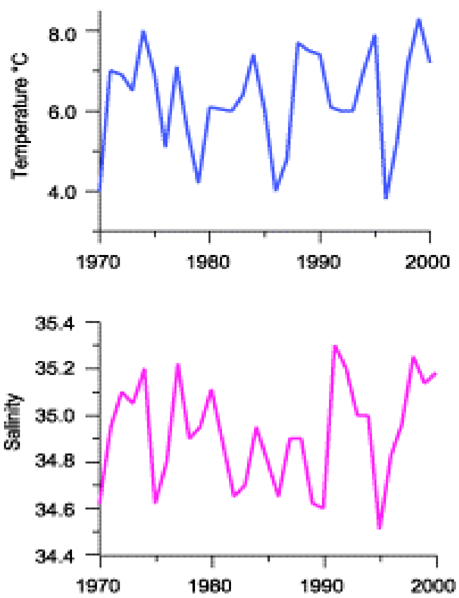


Figure 14b. Area 9 *— Time series of temperature and salinity at a location in the SE North Sea (52°30'N 3°E) during the ICES IBTS Quarter 1 Surveys.*

In terms of the surface temperatures in the North Sea in 2000, the annual mean SST of 10.4°C made 2000 the sixth warmest year on the record dating from 1971. Except for June and July, North Sea SSTs exceeded climatological monthly means at all times and at all locations. The seasonal warming in June averaged only 1.4°C, which is 50% short of the usual heating rate. This caused the jump-like change from anomalously warm conditions in May to a widespread cold anomaly that grew even more intense in July, making it the fourth coldest July since 1971 (Figure 15). The mean SST of 13.4 °C remained 2.1°C behind the 2nd warmest July of 1999. While usually seasonal cooling sets in around mid-August, August 2000 was special in that a belated extreme increase in SST of 2°C occurred which exceeded the average heating rate by 200%. This again was associated with a rapid return to anomalously warm conditions. The warm anomaly strengthened during the autumn, which underlines the significance of warmer than normal autumn SSTs during the decade of the 1990s. Additional information is available at http://www.bsh.de/Oceanography/Climate/Climate.htm

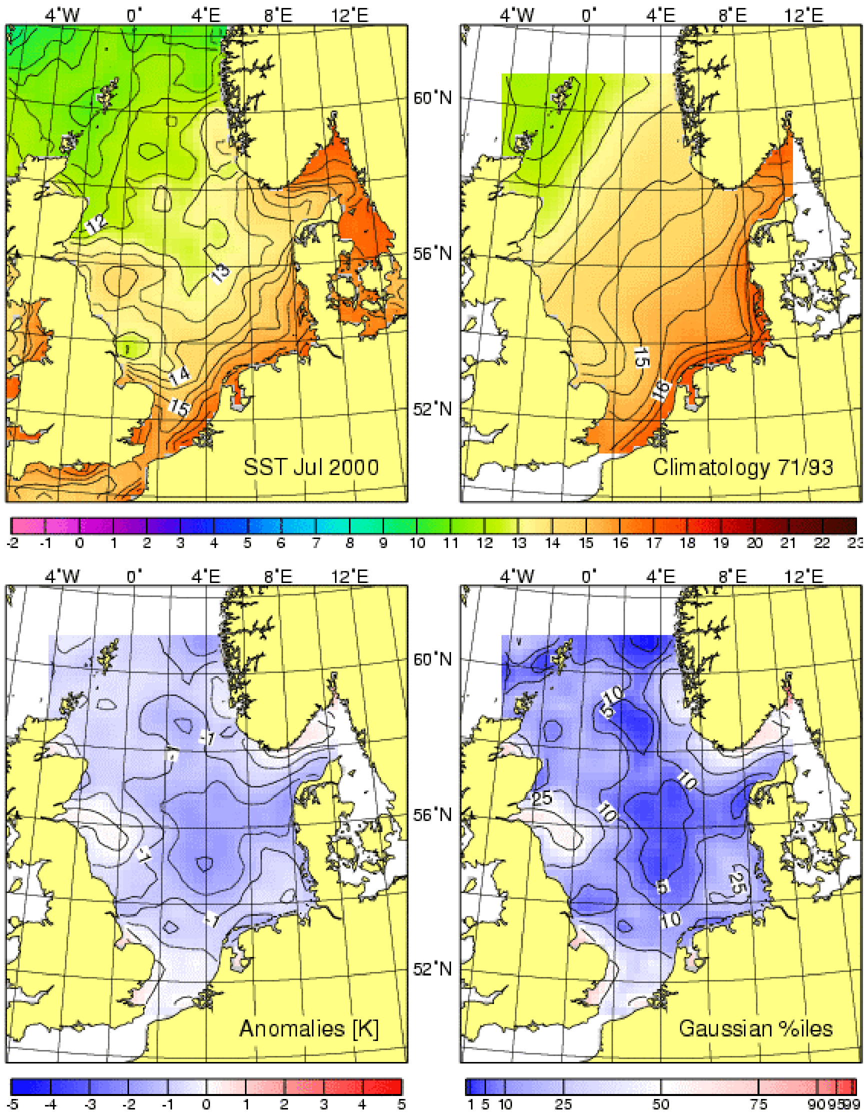


Figure 15. *Areas 8 and 9 – North Sea SSTs and SST anomalies in July 2000. Percentiles (bottom right) give the area under the unit normal distribution between infinity and the standardised anomalies. P-values below 10% suggest that the expected average occurrence of such strong or stronger cold anomalies is less than 10%.*

Area 9b – Skagerrak and Baltic

The year 2000 was characterised by large rates of precipitation, especially during the summer and late autumn. In Sweden the mean temperature over the year was one of the highest ever recorded, with an especially mild autumn. These weather conditions were also reflected in the hydrographic observations.

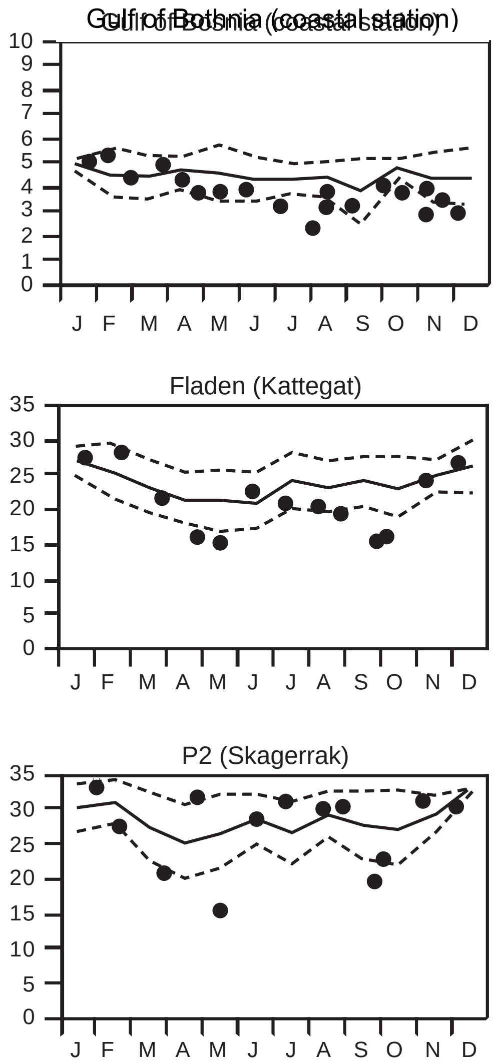


__Figure 16.__ Area 9b – Skagerrak and Baltic. Surface salinity in the Gulf of Bothnia (coastal station), Fladen (Kattegat), and Skagerrak (dots). In this figure mean values (from the period 1986–1995) are also given (black lines) as well as the associated standard deviations (dashed lines).

In the Gulf of Bothnia very low values of the surface salinity were measured at the end of July and in the autumn (Figure 16). In Kattegat and Skagerrak the lowest values of the surface salinity were found in late spring and early autumn (Figures 16b and 16c). These events followed periods of large fresh-water flux through the Øresund and the Belts.

In the Baltic Proper the tendency over the last 20–25 years has been towards decreasing values of the surface salinity, following a peak of 7.6ºC in the late 1970s (Figure 17). East of Gotland, the sea surface temperature was around 3°C above normal in December. Higher than normal surface water temperatures were observed in many areas at the end of the year.

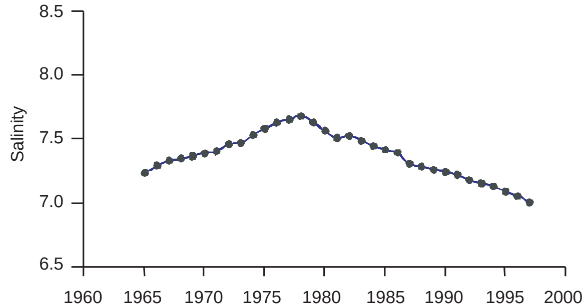


Figure 17. *Area 9b – Skagerrak and Baltic. Surface salinity east of Gotland. A 5-year running mean has been applied.*

Area 10 – Norwegian Sea

In the southern and central Norwegian Sea a warming has taken place since 1996. In 2000 the warming continued at the southern section, while a cooling occurred at the central section (Figure 18). In the northern Norwegian Sea the temperature since 1996 has been close to the long-term average but below the long-term trend.

An overall feature of the conditions over the slope in the Norwegian Sea is a trend toward higher temperatures and lower salinities. The magnitude of this trend increases northwards. The rate of warming at the northern section (76°N, Figure 18) amounts to 0.94°C since 1978, compared to 0.31°C at the southern section (63°N). The salinity trend is also strongest in the north, with decreases of 0.06 since 1981 compared to 0.02 at 63°N.

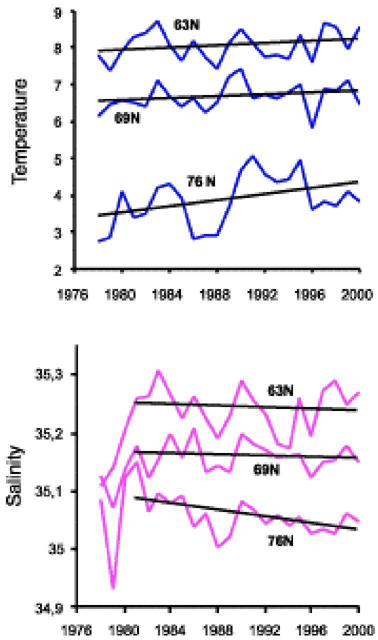


Figure 18. *Area 10 – The Norwegian Sea. Average temperature and salinity above the slope at three sections, Svinøy (approx. 63°N), Gimsøy (approx. 69°N), and Sørkapp (approx. 76°N), representing the southern, central, and northern Norwegian Sea.*

Area 11 – Barents Sea

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

After a period with high temperatures in the first half of the 1990s, the temperatures in the Barents Sea dropped to values slightly below the long-term average over the whole area in 1996 and 1997. From March 1998, the temperature in the western area increased to just above the average (Figure 19), while the temperature in the eastern areas stayed below the average during 1998 (Figure 20). From the beginning of 1999 there was a rapid temperature increase in the western Barents Sea, which also spread to the eastern part of the Barents Sea.

During 2000 the temperature decreased from almost 1°C above average to 0.2°C above average in the autumn. In the eastern Barents Sea, however, the temperature was more than 0.5°C above the long-term mean during the entire year of 2000. Early indications suggest that the status at the beginning of 2001 is the same as during autumn 2000.

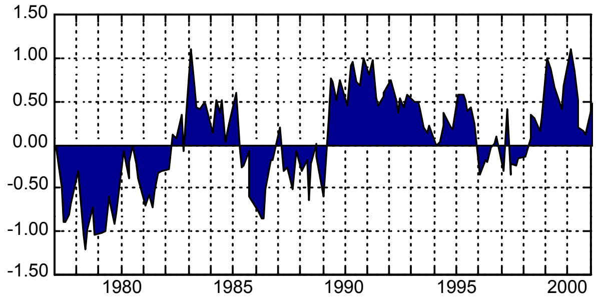


Figure 19. *Area 11 - Barents Sea. Temperature anomalies in Atlantic inflow through the section Norway- Bear Island in the western Barents Sea.*

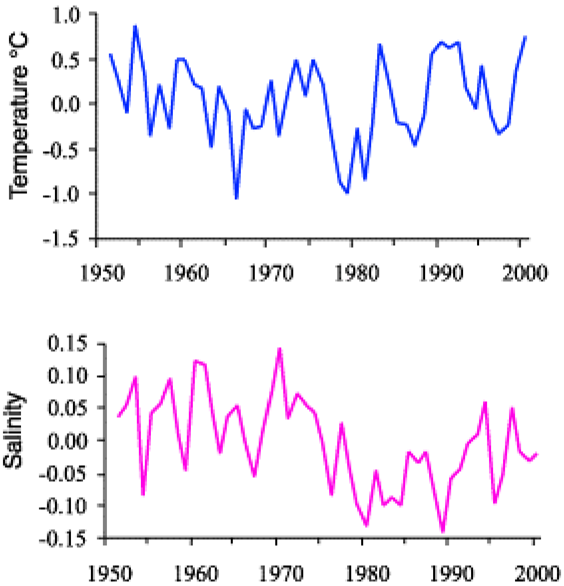


Figure 20. *Area 11 – Barents Sea. Temperature and salinity anomalies in the Kola section (0-200 m).*

Area 12 – Greenland Sea (West Spitsbergen Current)

On the eastern side of the Greenland Sea, the thickness of the Atlantic Water layer within the West Spitsbergen Current at the latitude 76°30'N in summer 2000 was larger than in previous years. Water temperature and salinity were a little higher as well (Figure 21). All values were also higher than in the period 1991–1996.

At the latitude 78°N summer 2000 values of temperature, salinity and Atlantic Water layer thickness were only slightly higher than during summer 1999, but show significant increases compared to summer 1997 when measurements first started (Figure 22).

Summer 1997 was exceptional, as observations indicate very low temperatures, salinities, and layer thickness of Atlantic Water. This could have been caused by a strong inflow of polar waters from the Storfjordrenna, but very low temperatures and salinities further north could also suggest that it could have been a more general phenomenon.

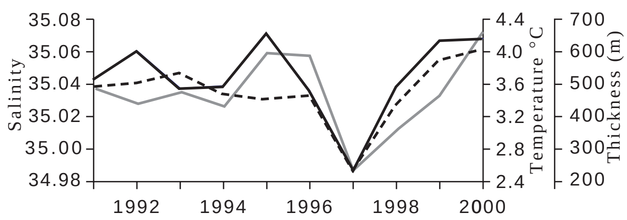


Figure 21. *Area 12 – Greenland Sea (West Spitsbergen Current). Mean salinity (dashed line), temperature (black line) and Atlantic Water layer thickness (grey line) at 76° 30'N.*

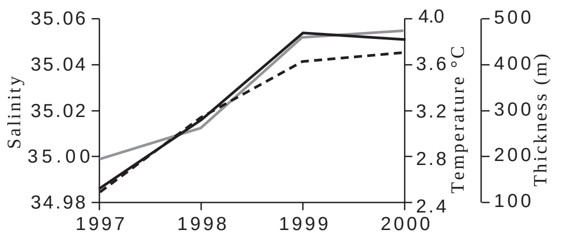


Figure 22. *Area 12 – Greenland Sea (West Spitsbergen Current). Mean salinity (dashed line), temperature (black line) and Atlantic Water layer thickness (grey line) at 78°N.*