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Climatic Conditions Around Greenland – 1992

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Abstract

Air temperature anomalies and sea ice cover during 1992 around Greenland indicated that the early-1990s experienced similar anomalous cold environmental conditions to those experienced during the beginning of the 1970s and 1980s. Similar to the last decade, cold air masses in February centred around the town of Egedesminde area in West Greenland which contributed to the extreme cold conditions off West and South of Greenland in early-1992. In contrast to the west coast, the east coast of Greenland during 1992, under the regime of the anomalous cold air temperatures showed that the surface layer of the ocean cooled and sea ice formed to a larger extent than normal. The ice did not leave Cape Farewell before mid-August and the next winter's ice began forming off East Greenland early in October. Analysis of air temperature time-series from Nuuk/West Greenland revealed characteristic periods which contributed to the climatic variability in the area. Computer models showed that low frequency climatic variation has a period of about 108 years.

Key words: Climate, environment, Greenland, ice, salinity, temperature, water masses

Introduction

The statistical average of the day-to-day weather fluctuations in the atmosphere and oceans provide the bases for the weekly, monthly, seasonal and annual climate averages, and the variability of these from one year to another is referred to as interannual variability (Shukla, 1991). Greenland, located in the northern Northwest Atlantic Ocean, is an area where dramatic changes in climate have been experienced, both at land-based stations and at sea. Since the times of Eric the Red, who discovered Greenland in 982 AD, there have been significant fluctuations in climate which seem to be characteristic of the area (Buch, MS 1986). In more recent times, Greenland suffered from two winters with record low temperatures in 1983 and 1984 (Buch and Stein, 1989). Then, after relatively warm conditions during the mid- to late-1980s, the early-1990s again revealed considerable atmospheric cooling off. The present paper compiles the climatic conditions of the northwestern and the northeastern North Atlantic area during 1992, with focus on the climate of Greenland.

Materials and Methods

Data on the atmospheric climate of Greenland at Nuuk (64°11'N, 51°44.5'W), Egedesminde (68°42.5'N, 52°53'W) and Angmagssalik (65°36'N, 37°40'W) were collected by the Danish Meteorological Institute. Whereas the data set at Nuuk was supplied by the Danish Meteorological Institute in Copenhagen, the latter data sets were taken from Anon. (1992). Ice charts were constructed from the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce, satellite ice charts. The progression of the approximate location of the ice edge was initially prepared as a computer simulation (Stein, unpublished data, available as computer diskettes), and depicted in this paper in selected representative figures. The temperature anomaly maps for the Northwest Atlantic and for the Northeast Atlantic were also taken from Anon. (1992). These temperature anomaly maps were also prepared as computer simulations (Stein, unpublished data, available as computer diskettes). Subsurface ocean data were available from Danish measurements for the West Greenland area (Buch, pers. comm. (Buch, MS 1993)), and from German measurements for the East Greenland area. Due to technical problems with RV *Walther Herwig*, the East Greenland survey was prematurely terminated having completed only the Dohrn Bank W–E Section, the Dohrn Bank NE–SW Section and the Gauss Bank Section (Stein, MS 1982). The West Greenland survey was delayed by about 1 month to the beginning of December. Statistical analysis of the Nuuk Air Temperature time-series was achieved with the CSS Software package.

Results

Air temperature and sea ice anomaly during 1992

Northwest Atlantic. Generally, air temperatures over the Northwest Atlantic were below normal during 1992, except in a small area off Southeast Greenland where positive air temperatures prevailed (Fig. 1). On both sides of the Davis Strait, anomalies were observed in the year mean which were below -3K. The anomalies were lower than

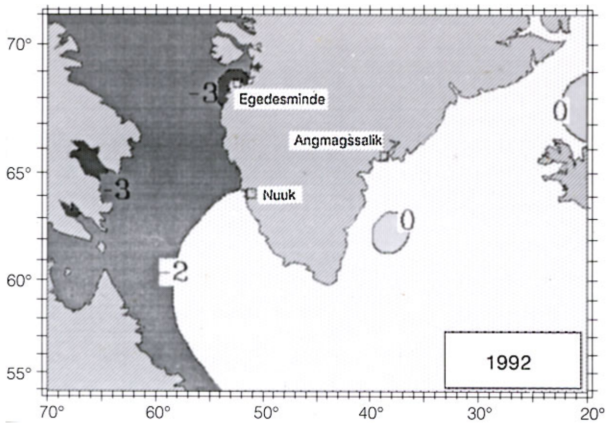

Fig. 1. Mean air temperature anomalies over the Northwest Atlantic, 1992.

those encountered during 1990 and 1991 in this region. Also the areal extent with negative anomalies, especially those of the central cold area around Labrador/Davis Strait, had increased since 1990 (Henning, 1993). Two examples which occurred in the 1992 annual series demonstrate the extreme nature of air temperature anomaly over the Northwest Atlantic during 1992. (A) February conditions revealed an extremely cold air mass centred over the town of Egedesminde (Fig. 2) with the temperature anomalies less than -10K. This air mass was observed to influence the entire Davis Strait/Labrador Sea region with only the area northeast of Iceland where positive air temperature anomalies were encountered. (B) The warmest month in the Northwest Atlantic region during 1992 was October, with positive anomalies ranging to +2K in the Irminger and Labrador Sea, as well as in the Davis Strait (Fig. 3).

Northeast Atlantic. For the greater part of the 1992 year, temperature conditions over the Northeast Atlantic were above normal (Fig. 4). On the western side the borderline between positive and negative air temperature anomalies was located at about 10°W, while on the eastern side air temperatures were below normal over the northeastern Barents Sea and the Spitzbergen area.

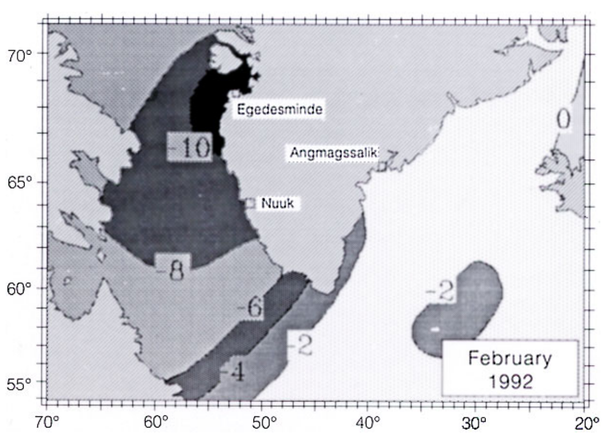

Fig. 2. Mean air temperature anomalies over the Northwest Atlantic, February, 1992.

Figure 5 displays a temperature anomaly pattern which indicates cold conditions west of about 20°W, and up to +4K above normal conditions in the southeastern Barents Sea. On the eastern side again, the area off Spitzbergen showed the February conditions were below normal. The only month during 1992 which showed colder-than-normal air temperatures over the Northeast Atlantic and warmer-than-normal air temperatures over the Northwest Atlantic was October (Fig. 6).

Ice conditions in the Northwest Atlantic

Ice cover around Greenland was anomalous during 1992. At Cape Farewell, the ice left late, and returned early off East Greenland during autumn.

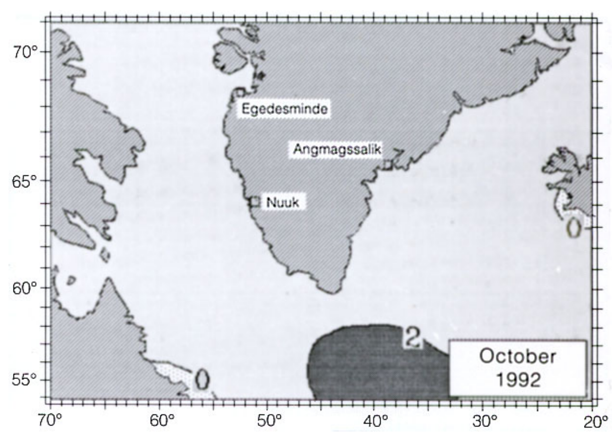

Fig. 3. Mean air temperature anomalies over the Northwest Atlantic, October, 1992.

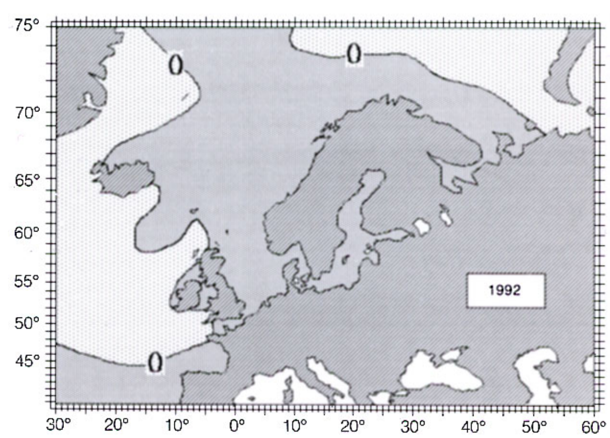

Fig. 4. Mean air temperature anomalies over the Northeast Atlantic, 1992.

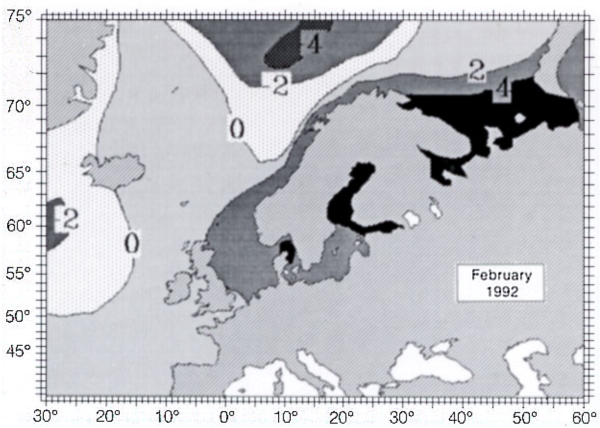

Fig. 5. Mean air temperature anomalies over the Northeast Atlantic, February, 1992.

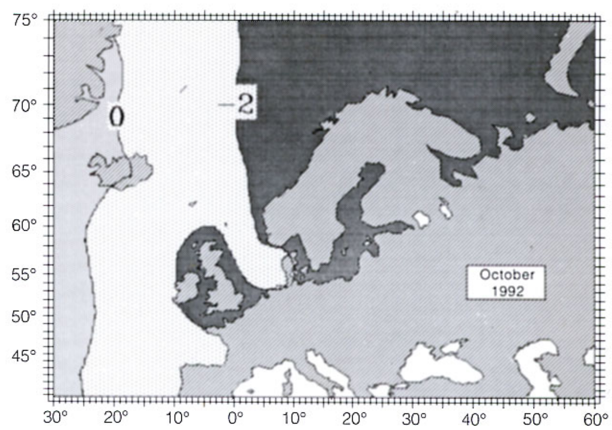

Fig. 6. Mean air temperature anomalies over the Northeast Atlantic, October, 1992.

The two extremes of the 1992 ice cover are given in Fig. 7 and 8. During February, the entire coast of Greenland was blocked with ice. The areas normally ice free during February had anomalous ice coverage as shown by the extent of the ice edge (dark shaded in Fig. 7). Ice free conditions in the Irminger and Labrador Sea and in the Davis Strait, were observed during October (Fig. 8), while off East Greenland the formation of new ice was already apparent.

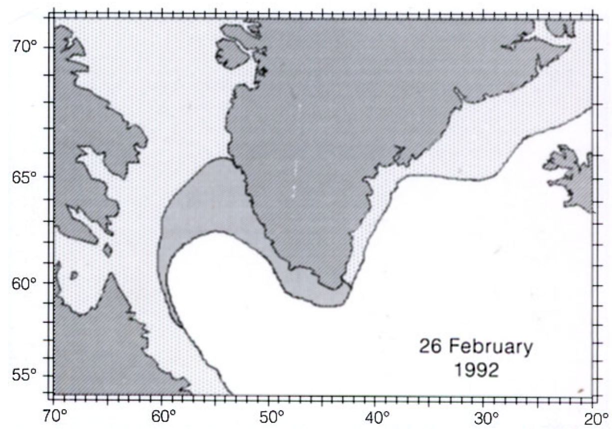

Fig. 7. Ice edge, 26 February 1992; dark shaded areas indicate anomalous extent of ice edge during the month of February.

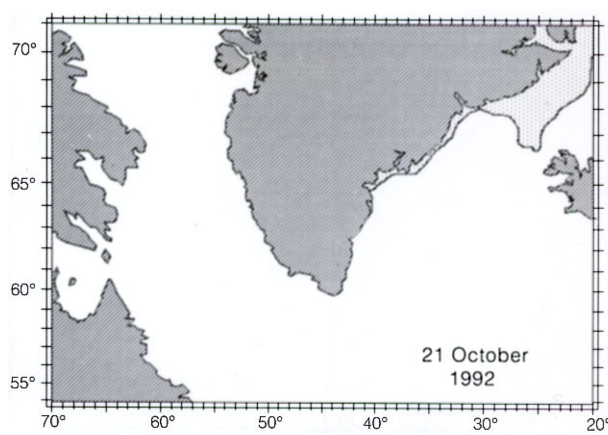

Fig. 8. Ice edge, 21 October 1992.

Subsurface observations off Greenland

East Greenland. Off East Greenland only three of the national Standard Oceanographic Sections were performed (Fig. 9). The Dohrn Bank West–East Section showed that it crosses the Irminger Current on its way to the north off the west coast of Iceland, and the East Greenland Current on its way south (Fig. 10). As reported by Stein (1988) the meso scale variability in the Dohrn Bank area is large. Changes in the water mass composition occur on spatial scales of less than 10 nautical miles. Horizontal and vertical distribution of the three main water masses found in the area, i.e. the Polar Water, the North Atlantic Water and the Arctic Intermediate Water, revealed the intense mixing and temporal variation in the water column. In the upper 100 m of the water column, a "masked" Polar Front was apparent from the thermal field (Fig. 10A), where the modified North Atlantic Water covered by cold diluted water was observed to meet the cold Polar Water of East Greenland Current origin (core temperature <0.5°C). A steep thermal front marked the transition between these water masses. At depths of around 150 m, the North Atlantic Water, with salinities above 35 PSU (Fig. 10B) and temperatures above 6°C (Fig. 10A), was visible at the eastern side of the section. Above the slope the Arctic Intermediate Water, with temperatures around 1°C, was found.

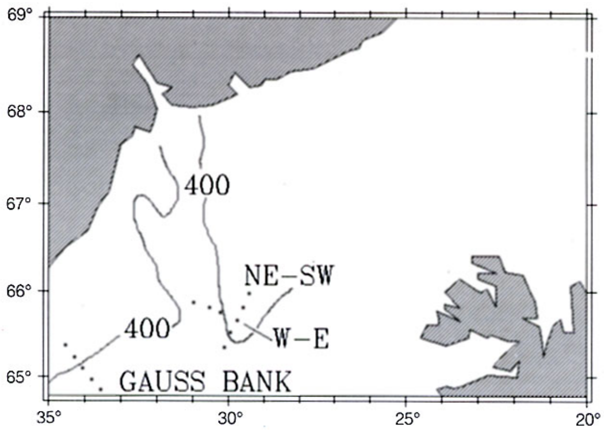

Fig. 9. Location of national Standard Oceanographic Sections in the Greenland/Iceland Ridge area; 400 m bottom contour is given.

Orthogonal to the above mentioned Dohrn Bank West–East Section, the Dohrn Bank NE–SW Section is placed to map the downstream properties in the Greenland/Iceland sill area (Fig. 11). As mentioned in Stein (1988), due to the bottom topography south of Dohrn Bank (Fig. 9), the warm water of the Irminger Current flows along the Greenlandic continental slope and into the deep Kangerdlugsuak Fjord. In the 1992 data, this was documented in the thermohaline fields (left side of Fig. 11A,B). Situated on the "Nose" of the Bank, the cold polar water of East Greenland origin was visible.

Downstream of the Dohrn Bank sections, the Gauss Bank Section is placed (Fig. 9) across the southward flowing current system influenced by the East Greenland and the Irminger Currents (Fig. 12A,B). On the shelf, the 1992 data showed that

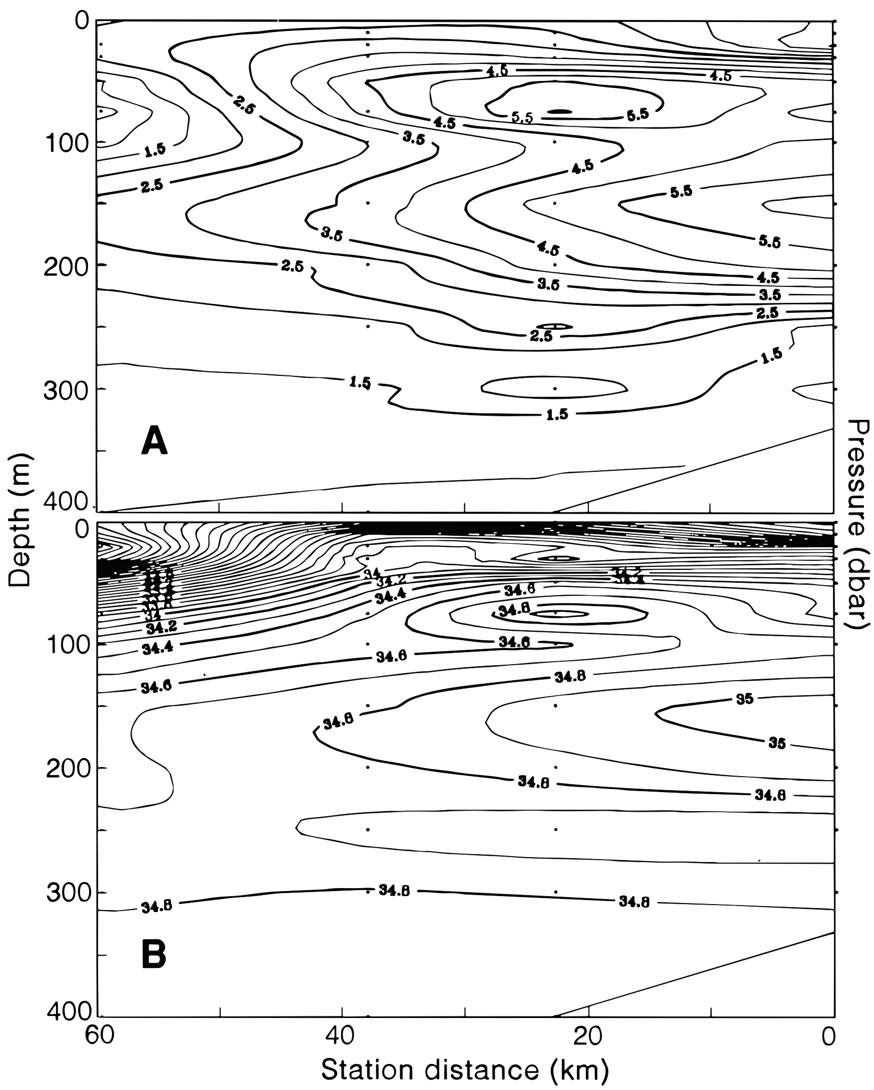

Fig. 10. Vertical distribution of (**A**) temperature (°C) and (**B**) salinity along the Dohrn Bank West–East Section, 15–16 September 1992.

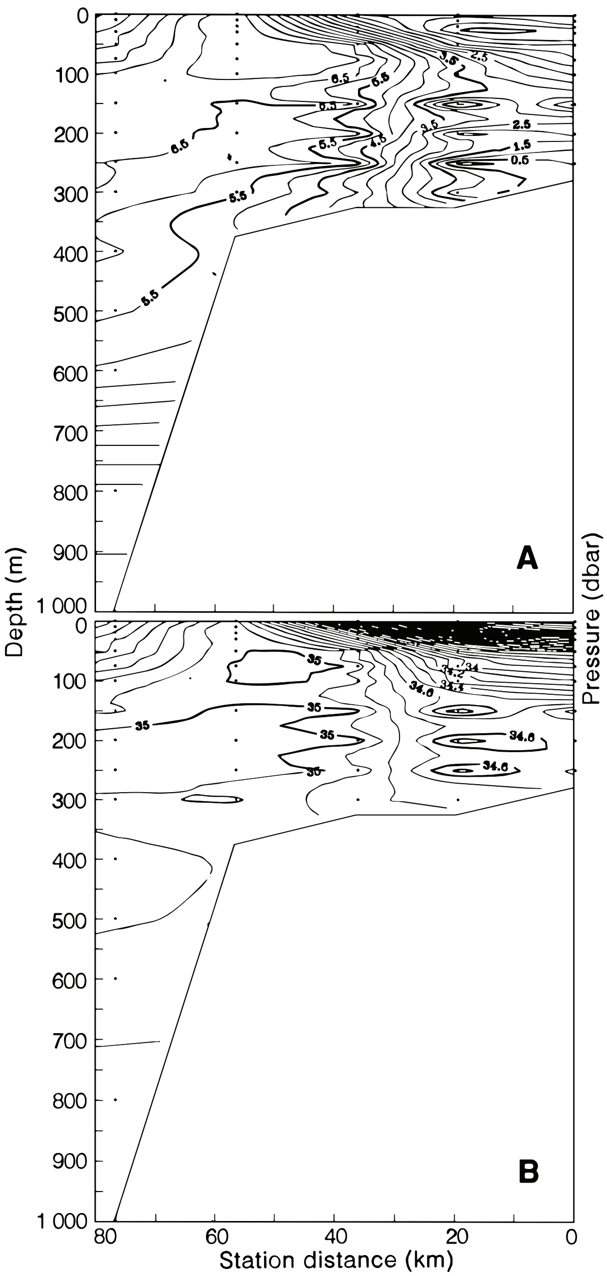

Fig. 11. Vertical distribution of (**A**) temperature (°C) and (**B**) salinity along the Dohrn Bank Northeast-Southwest Section, 14–15 September 1992.

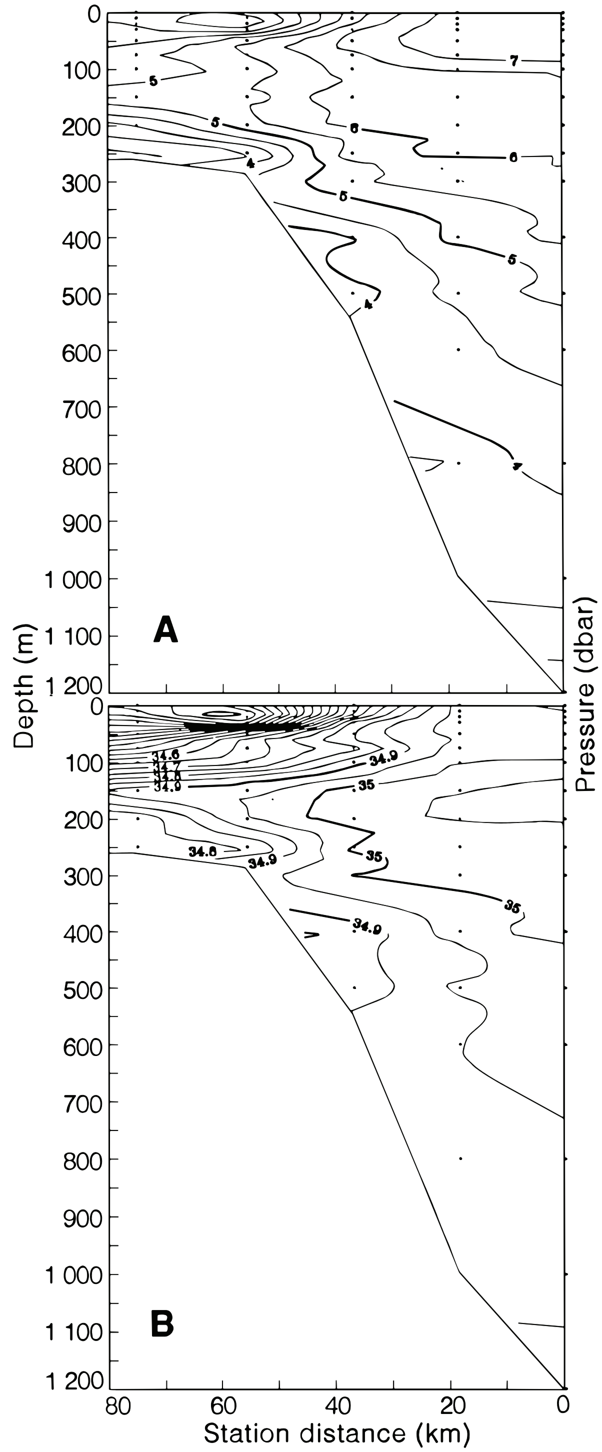

Fig. 12. Vertical distribution of (**A**) temperature (°C) and (**B**) salinity along the Gauss Bank Section, 19–20 September 1992.

the warm water of Irminger Current origin was covered by cold diluted water. The offshore parts of the section indicated the presence of North Atlantic Water with temperatures above 6°C and core salinities above 35.10 PSU.

Air temperatures and climatic means

The annual air temperature curves of Egedesminde, Nuuk and Angmagssalik were compared to the climatic means available from Anon. (1992). On the West Greenland side, the 1992 temperature curves revealed the anomalous February conditions which amounted to less than –26°C at Egedesminde and less than –17°C at Nuuk. Except in October, the entire set of temperature curves were below the mean (Fig. 13 and 14). Off East Greenland, at Angmagssalik, thermal conditions were below normal, with the exception of October which had a mean temperature of 0.8°C (Fig. 15).

Climatic variability off West Greenland

The air temperature time-series of Nuuk enabled a closer look at interannual and long-term variability of climate at West Greenland (Fig. 16). As shown by Stein (MS 1992), the February 1992 air temperature conditions explain 57% of the variance of the mean annual air temperature. Spectral analysis of the February air temperature time-series revealed characteristic frequencies which constituted the climatic variability (Fig. 17). The first signal corresponded to the 125-year cycle, which is the entire length of the analyzed time-series (1877–92). The spectral peaks labelled 12.5, 7.7, 5.9 and 3.8 in Fig. 17 indicated characteristic events such as: the short-period variability during warming/cooling phase of 3.8 years, the period of cold events (normal/cold/normal/warm/normal) of 5.9 years, the exact double of 3.8 years (7.7 years) short period warming/cooling phase, the anomalous cold winters (peak to peak) of 12.5 years. A 13-year running mean applied to the Nuuk mean annual air temperature time-series (Fig. 16) revealed that low-frequency warm and cold periods govern the climate off West Greenland. The amplitude of this low-frequency oscillation was –1.2K(1888) and 1.0K(1935). Further analysis of the mean amplitudes and the observed periods from the results displayed in Fig. 16 resulted in the following model assumptions:

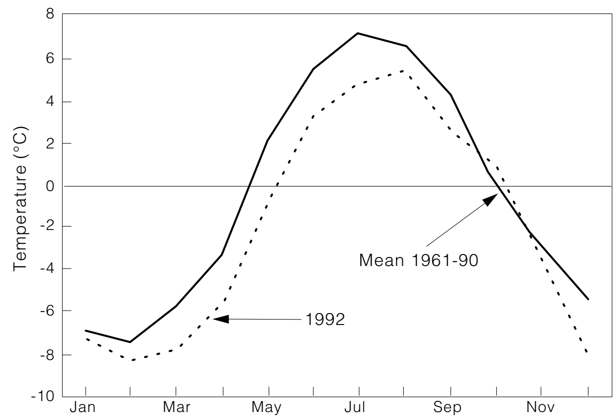

Fig. 15. Monthly mean temperature at Angmagssalik during 1992 and climatic mean (1961–90).

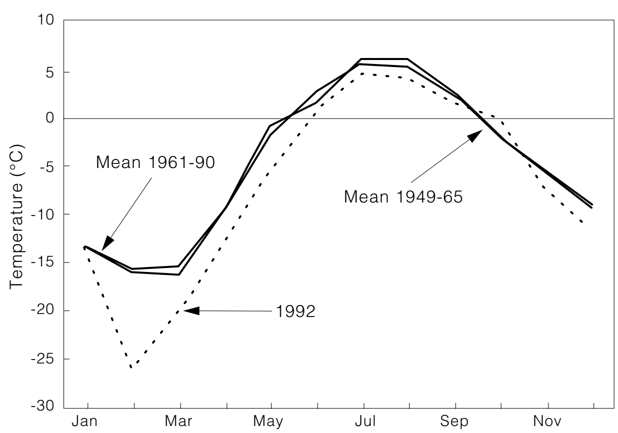

Fig. 13. Monthly mean temperature at Egedesminde during 1992 and climatic means (1949–65; 1961–90).

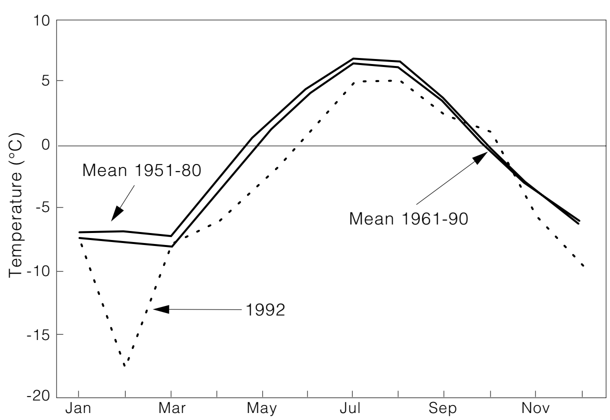

Fig. 14. Monthly mean temperature at Nuuk during 1992 and climatic means (1951–80; 1961–90).

Climatic Model for thermal variability off West Greenland based on Fig. 16 gives indications of a low frequency sine curve which could be incorporated in the thermal year-to-year variability as

$$\zeta(t) = A * \sin(2\pi/\tau + \varphi)$$

which describes a simple harmonic oscillation.

With: A = -1.2
τ = 108 years (twice the warm phase from Fig. 16), and
φ = $\pi / 4$

this air temperature model for the year-mean anomaly at Nuuk gave reasonable results (Fig. 18). Accordingly, it was possible to interpret that the warm period was from 1923 to 1976, and the present downward trend would be maintained until the beginning of the next decade (2003/2004).

Discussion

The data suggested the continuous positive temperature anomalies in the European region of the Atlantic, where mean air temperatures during 1990 and 1991 were above normal, and the continuous negative anomalies over northwestern and northern Atlantic area were due to the prevailing

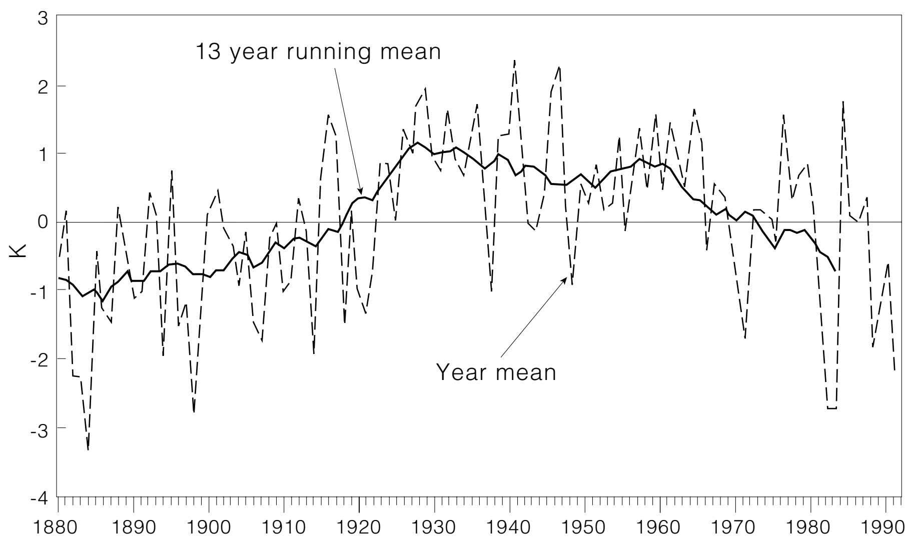

Fig. 16. Time series of annual mean air temperature anomalies at Nuuk (1880–1992) and 13 year running mean.

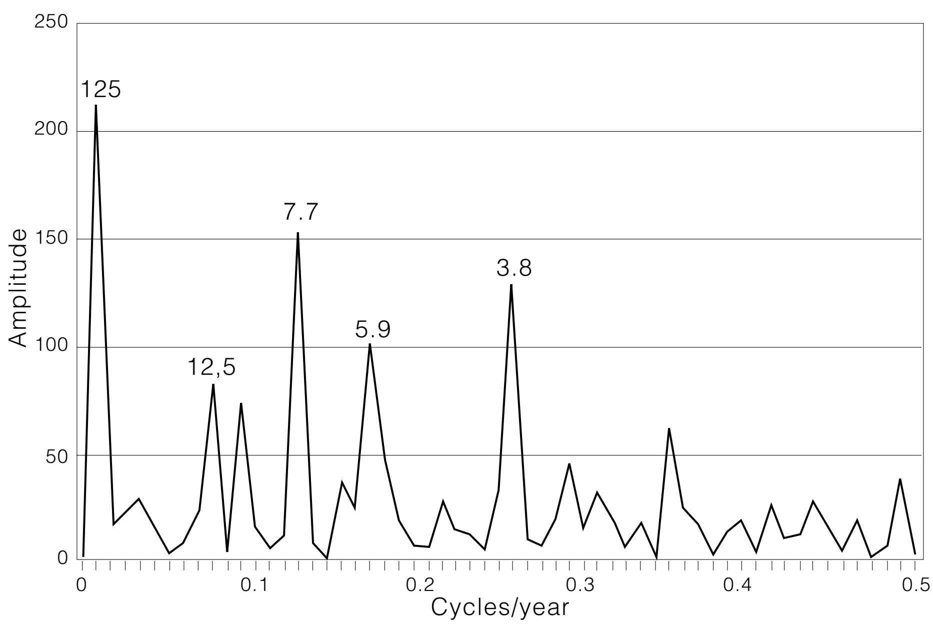

Fig. 17. Spectral analysis of annual mean air temperature anomalies at Nuuk.

circulation of air masses. The high negative anomalies in the north, and positive anomalies in the south resulted in a decrease of meridional exchange, i.e. the blocking of high pressure systems were seldom (high zonal index, Henning (1993)). The negative anomalies led to anomalous ice formation in the area around Greenland. The cooling signal was largest on the West Greenland side which is documented by the annual climatic curves of Egedesminde and Nuuk for the month of February. In contrast, the Angmagssalik area on the East Greenland coast experienced no tremendous cooling during February.

Subsurface observations were made by the Royal Danish Administration of Navigation and Hydrography in June, 1992 (Buch, MS 1993). Except for the area off Southwest Greenland, which was dominated by the front between the cold, relatively fresh polar water near the coast and the warm, saline Atlantic water further offshore, the remaining sections indicated a homogenous surface layer off West Greenland. These water properties were interpreted to be a consequence of the atmospheric cooling in the area. At greater depths, where the water of Atlantic origin is found, the oceanographic

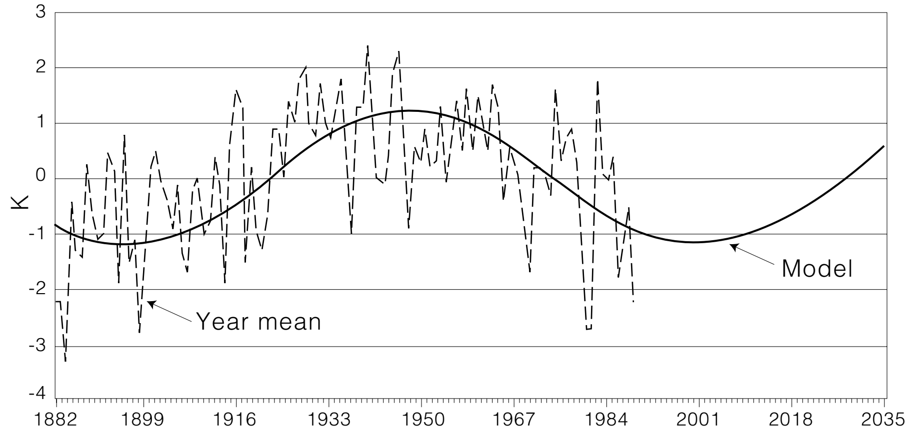

Fig. 18. Nuuk Air Temperature Anomaly: Year mean *versus* Low Frequency Model.

conditions were close to normal, i.e. temperatures in the 3.5° to 4.5°C interval and salinities above 34.85 PSU (Buch, MS 1993). It is emphasized here that Irminger Water (S>34.92 PSU) was observed in great quantities as far north as the Lille Hellefiskebanke (Sukkertoppen) Section, a line along 65°06'N, which is unusual at this time of the year. The cold atmosphere had resulted in a cooling of the oceanic surface layer along the entire West Greenland coast. The mean temperature on top Fylla Bank (Fylla Bank Section St. 2, 44 m) in mid-June demonstrated that, since 1989, the temperature conditions have been comparable to what was observed during the cold years around 1970 and 1983 (Buch, MS 1993).

Off East Greenland, comparison with data collected along the Gauss Bank Section since 1983 during September, indicated thermal anomalies at the outer station (S5) which amounted to –0.3K for the upper 200 m, and revealed about normal conditions (0.09K) for the station S4 which is the next to the west of S5. Climatic pre-conditioning, as noted above, also favoured cooling of the surface layer during entire 1992 year prior to the September observations. Station S5, however, revealed cooling down to 300 m depth, which is far beyond the seasonal variable surface layer. This indicated there was cooling of the Irminger Water mass, which started during 1989, in the upper 75 m of the water column.

It would appear that one of the conclusions, presented during the ICNAF Symposium on Environmental Conditions in the Northwest Atlantic, 1960–69, (Rodewald, 1972) was still valid:

> " the further climatic outlook, based on oxygen isotope studies of the North Greenland ice sheet, is for a continuation of the cooling trend for another one to two decades, future development may include the danger of a new 'Little Ice Age'. From the curve showing dominating periods of climatic development over the last 800 years, it would seem that 1970 is about 3 long periods of 181 years and 7 short periods of 78 years each away from 1425 which was the beginning of the 'Little Ice Age' (about 1430–1850)."

Extrapolation of the climatic curve composed from these two periods, points at further cooling. There is, however, indication of a possible faint warming peak around 2015.

Based on direct air temperature observations, the climatic time-series points at similar trends as postulated by Rodewald (1972). The decrease of air temperature in the West Greenland area since the late-1960s and early-1970s is still persistent. After the cold 1992 winter and spring conditions, the downward trend continued during the 1993 winter and spring. Bearing in mind that all elements of climatic variability are subject to stochastic fluctuations, the future will reveal whether the climatic scenario of West Greenland will develop as indicated by the model. In contrast to the climatic outlook, based on oxygen isotope studies of the North Greenland ice sheet, the low frequency model points at a warming peak around the middle of the next century. Considering the shorter period variability (3.8 years), however, there is a probability for intermediate warming periods like in the mid-1970s and mid-1980s. Similar to the last two decades, these intermediate warming periods can raise mean air temperatures to above normal levels, e.g. during the mid-1990s.

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