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Climatic Conditions Around Greenland - 1992

by

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Abstract

Air temperature anomalies and sea ice cover during 1992 off West Greenland indicate that the early nineties experience similar anomalous cold environmental conditions than during the beginning of the seventies and eighties. It is shown that, similar to the last decade, cold air masses centered over the town of Egedesminde contribute to the extreme conditions off West Greenland in February 1992. In contrast to the west coast, the east coast of Greenland showed different climatic conditions during 1992. Under the regime of the anomalous cold air temperatures the surface layer of the ocean is cooled and sea ice formed to a larger extent than normal. The ice left Cape Farewell not before mid August and returned off East Greenland early in October. Analysis of air temperature time series from Nuuk/West Greenland reveals characteristic periods contributing to the climatic variability in the area. Model computations show that low frequency climatic variation has a period of about 108 years. These model results also indicate that the present downward trend in the West Greenland climate will come to an end around the beginning of the next decade. Compared to the climatic outlook, based on oxygen isotope studies of the North Greenland ice sheet which reveal a faint warming peak around 2015, the low freqency model postpones this event to the middle of the next century. Refering to the shorter period variability (3.8 years), however, an intermediate warming period as observed in the mid-seventies and mid-eighties is likely to establish, e.g. during the mid-nineties.

Introduction

It is the statistical average of the day to day weather fluctuations in the atmosphere and oceans which gives rise to the weekly, monthly, seasonal and annual average climates, whose variability from one year to another is referred to as interannual variability **(SHUKLA, 1991)**. Greenland, embedded in the northern Northwest Atlantic Ocean, is an area where man has experienced dramatic changes in climate, both at land-based stations and at sea. Since the times of Eric the Red who discovered Greenland in 982, there were up's and down's in climate which seem to be characteristic of the area **(BUCH,1986)**. Even in most recent time Greenland suffered from two record-cold winters, 1983, 1984 **(BUCH and STEIN, 1989)**. After relatively warm conditions during the mid-eighties, the early nineties reveal considerable atmospheric cooling off Greenland. The present paper compiles the climatic scenarios of the northwestern and the northeastern North Atlantic during the past year, with emphasis on the climate of

Greenland. It is planned to give this climatic overview during the forthcoming NAFO Environmental Subcommittee meetings.

Data and Methods

Data on the atmospheric climate of Greenland were sampled by the Danish Meteorological Institute 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). Whereas the first data set was mutually supplied by the Danish Meteorological Institute in Copenhagen, the latter data sets are taken from **ANON. (1992)**. Ice charts were constructed from **NOAA** satellite ice charts. The approximate location of the ice edge is given in the selected figures and in the computer slide show. The temperature anomaly maps for the Northwest Atlantic and for the Northeast Atlantic were also taken from **ANON. (1992)**. Both the ice charts and the temperature anomaly maps, are available from the author on request as computer slide shows. Sub-surface ocean data are available from Danish measurements for the West Greenland area, and from German measurements for the East Greenland area.(**BUCH**, pers. comm.; **BUCH, 1993**).Due to technical problems with FRV "Walther Herwig", the East Greenland survey had to be terminated prior to schedule, the West Greenland survey was postponed about one month to the beginning of December. Thus, for the East Greenland area only three of the national Standard Oceanographic Sections could be performed (**STEIN, 1982**), the Dohrn Bank W-E Section, the Dohrn Bank NE-SW Section and the Gauß Bank Section (Fig. 9).

Statistical analysis of the Nuuk Air Temperature time series was achieved with the CSS Software package(Fig. 17).

Results

Air Temperature and Sea Ice Anomaly during 1992

Northwest Atlantic

Generally, air temperatures over the Northwest Atlantic were below normal during 1992, except a small area off Southeast Greenland where positive air temperatures prevailed (Fig. 1). On both sides of the Davis Strait year mean anomalies were observed which were below -3 K, a value which was not encountered during 1990 and 1991 in this region. Also the areal extent with negative anomalies, especially those of the central, too cold area around Labrador/Davis Strait, increased since 1990 (**HENNING, 1993**). Two examples from an annual series show the extremes of air temperature anomaly over the Northwest Atlantic during 1992: **February** conditions reveal a cold air mass centered over the town of Egedesminde (Fig. 2). Temperature anomalies were less than -10 K, influencing the entire Davis Strait/Labrador Sea region. Only northeast off Iceland positive air temperature anomalies were encountered. The warmest month in the Northwest Atlantic region during 1992 was **October,** with positive anomalies ranging from 0 K to 2 K in the Irminger and Labrador Sea, as well as in the Davis Strait (Fig. 3).

Northeast Atlantic

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

Fig. 5 displays a temperature anomaly scenario which indicates cold conditions west of about 20°W, and up to 4 K above normal conditions in the southeastern Barents Sea. Only off Spitzbergen, 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. The two extremes of the 1992 ice cover are given in Figs. 7 and 8. During February, the entire coast of Greenland was blocked with ice. The areas normally ice free during February, are 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). Off East Greenland, however, formation of new ice is already visible.

Subsurface observations off Greenland

East Greenland

Off East Greenland three of the national Standard Oceanographic Sections could be performed (Fig. 9). The **Dohrn Bank West-East Section** crosses the Irminger Current on it's way to the north off the west coast of Iceland, and the East Greenland Current on it's way south (Fig.10). As published 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, reveal the intense mixing and temporal variation in the water column. In the upper 100m of the water column a "masked" Polar Front emerges from the thermal field (Fig.10a): Covered by cold diluted water the modified North Atlantic Water meets the cold Polar Water of East

Greenland Current origin (core temperature <0.5°C). A steep thermal front marks the transition between these water masses. At depth, around 150m, the North Atlantic Water with salinities above 35 PSU (Fig. 10b) and temperatures above 5.5°C is visible at the eastern side of the section. Above the slope Artic Intermediate Water with temperatures around 1°C is found.

Orthogonal to the previous section the **Dohrn Bank NE-SW Section** maps the downstream properties in the Greenland/Iceland sill area (Fig.11). As mentioned in **STEIN (1988)** the warm water of the Irminger Current flows along the Greenlandic continental slope and into the deep Kangerdlugsuak Fjord due to the bottom topography south of Dohrn Bank (c.f. Fig. 9). This is documented in the thermohaline fields (left side of Figs.11a,b). Situated on the "nose" of the bank, the cold polar water of East Greenland origin is visible.

Downstream of the Dohrn Bank the **Gauss Bank Section** crosses the southward flowing current system influenced by the East Greenland and the Irminger Currents (Fig. 9, 12a,b). On the shelf, the warm water of Irminger Current origin is covered by cold diluted water. The off shore parts of the section indicate 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 are compared to the climatic means available from **ANON. (1992)**. On the West Greenland side the 1992 temperature curves reveal the anomalous February conditions which amounted to less than -26°C at Egedesminde, and less than -17°C at Nuuk. Except October, the entire temperature curves are below the mean (Figs. 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 enables a closer look to interannual and long-term variability of climate at West Greenland (Fig. 16). As shown by **STEIN (1992)** February air temperature conditions explain 57% of the variance of the mean annual air temperature. Spectral analysis of the February air temperature time series reveals characteristic frequencies which compose the climatic variability (Fig. 17). The first signal corresponds to the 125 year cycle, the first harmonic which is larger than the entire length of the analyzed time series (1877 to 1992). Those spectral peaks labeled 12.5, 7.7, 5.9 and 3.8 in fig. 17, indicate characteristic events like: short period variability during warming/cooling phase (3.8 years), period of cold events (normal/cold/normal/warm/normal) 5.9 years, double of 3.8 years (7.7 years), anomalous cold winters (peak/peak) 12.5 years. A 13 year running mean applied to the

Nuuk mean annual air temperature time series (Fig. 16) reveals that low-frequency warm and cold periods govern the climate off West Greenland. The amplitude of this low-frequency oscillation is -1.2 K(1888) and 1.0 K(1935). Further analysis with the mean amplitudes and periods found from the results displayed in fig. 16, yields model assumptions as follows:

Climatic Model for Thermal Variability off West Greenland

Fig. 16 gives indication for a low frequency sine curve incorporated in the thermal year-to-year variability.

$$\zeta(t) = A * \sin(2\pi/\tau + \varphi) \qquad (1)$$

describes a simple harmonic oscillation.

With: $A = -1.2$

$\tau = 108$ years (twice the warm phase from fig. 16), and

$\varphi = \pi/4$

the air temperature model (1) for the year mean anomaly at Nuuk gives reasonable results (Fig. 18). Accordingly, the warm period is from 1923 to 1976, and the present downward trend is maintained until the beginning of the next decade (2003/2004).

Discussion

The continous, **positive** temperature **anomalies** in the **European region** - mean air temperatures during 1990 and 1991 were above normal - and the continous, **negative anomalies** over **northeastern North America** and **northern North Atlantic** are obviously due to the prevailing circulation of air masses: High negative anomalies in the north and positive anomalies in the south result in a decrease of meridional exchange, i.e. blocking 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 is largest on the West Greenland side which is documented by the annual climatic curves of Egedesminde and Nuuk, which in contrast to Angmagssalik on the East Greenland, coast indicate the tremendous cooling during February. Subsurface observations made by the Royal Danish Administration of Navigation and Hydrography in June, 1992 **(BUCH, 1993)** show the following: Except for the area off Southwest Greenland which is 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 indicate a homogenous surface layer off West Greenland. These water properties are interpreted as a consequence of the atmospheric cooling in the area. At greater depths, where the water of Atlantic origin is found, the oceanographic conditions are close to normal, i.e. temperatures in the interval 3.5 to 4.5°C and salinities above 34.85 PSU (**BUCH, 1993**). The author emphasizes that Irminger Water (S>34.92 PSU) was observed in great quantities as far north as the Lille Hellefiskebanke (Sukkertoppen) Section - line along 65°06'N -, which is unusual at this time of the year. The **cold atmosphere has 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, 44m) medio June demonstrates that since 1989 the temperature conditions have been comparable to what was observed during the cold years around 1970 and 1983 **(BUCH, 1993)**.

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

It would appear that one of the conclusions, presented during the ICNAF Symposium on Environmental Conditions in the Northwest Atlantic, 1960-1969 **(RODEWALD, 1972)** is 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 for a 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 sixties/early seventies is still persistent. After the cold 1992 winter and spring conditions, the downward trend continues during the 1993 winter and spring. Whether the climatic scenario of West Greenland will develop as indicated by the model will be proven in the future. 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-seventies and mid-eighties. Similar to the last two decades, these intermediate warming periods can raise mean air temperatures to above normal levels, e.g. during the mid-nineties.

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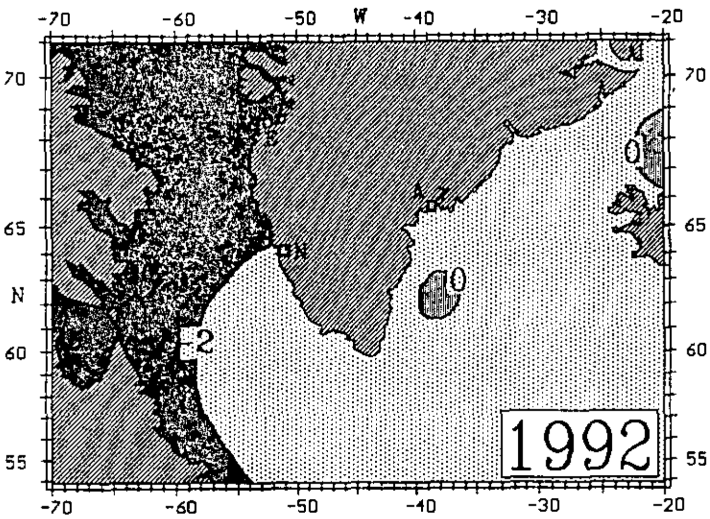

Fig. 1 Mean air temperature anomalies over the Northwest Atlantic during 1992 (E=Egedesminde, N=Nuuk, A=Angmagssalik)

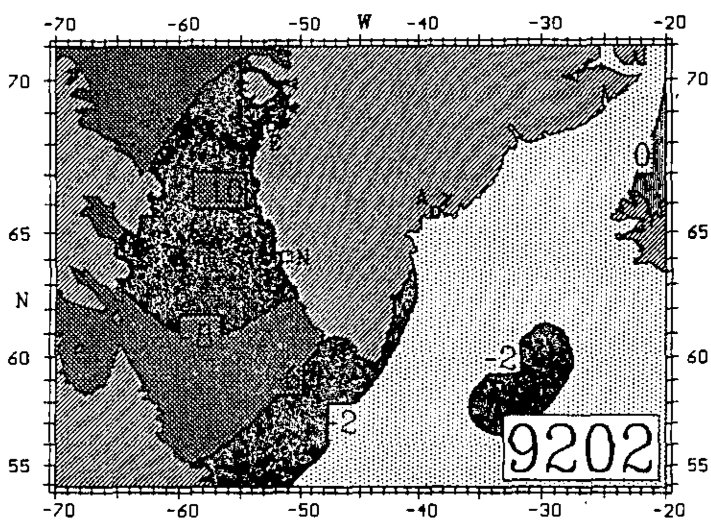

Fig. 2 Mean air temperature anomalies over the Northwest Atlantic during February, 1992 (E=Egedesminde, N=Nuuk, A=Angmagssalik)

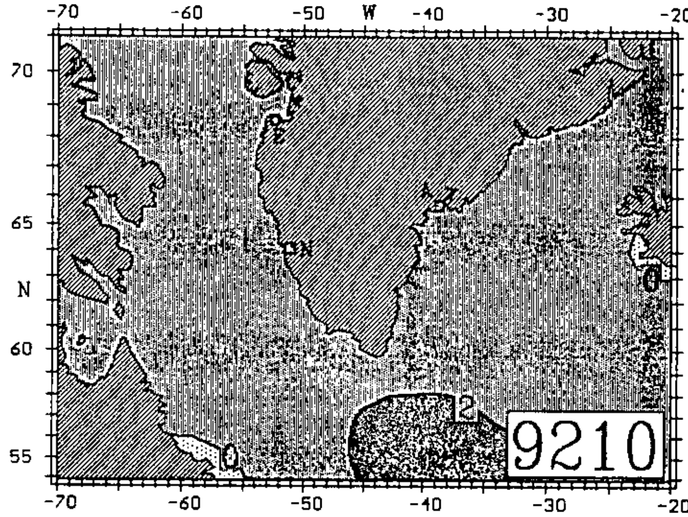

Fig. 3 Mean air temperature anomalies over the Northwest Atlantic during October, 1992 (E=Egedesminde, N=Nuuk, A=Angmagssalik)

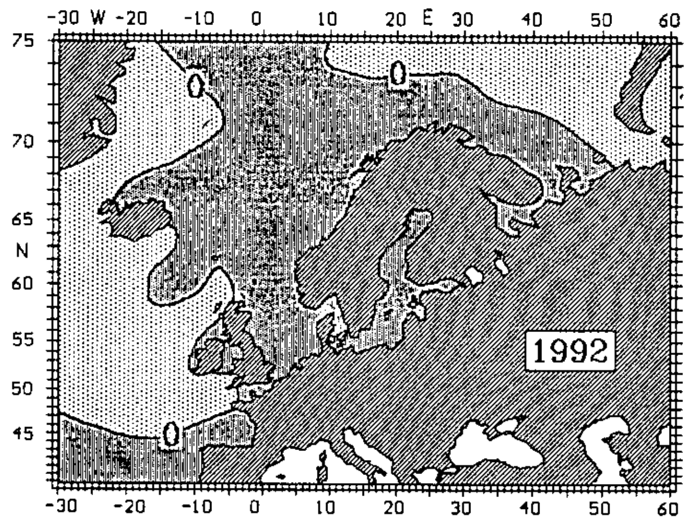

Fig. 4 Mean air temperature anomalies over the Northeast Atlantic during 1992

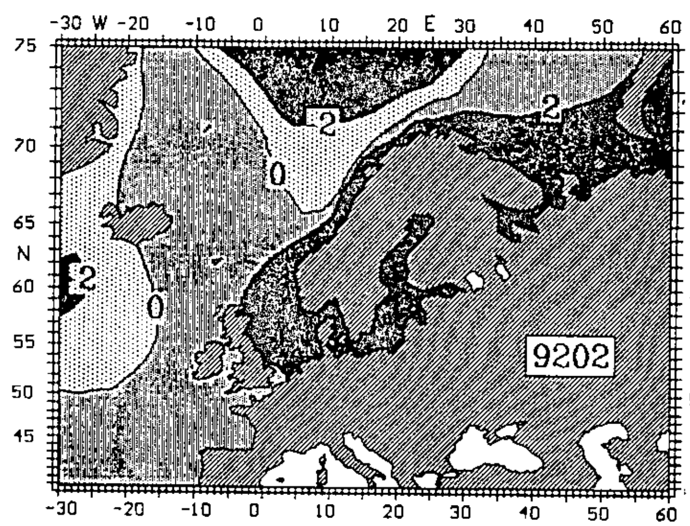

Fig. 5 Mean air temperature anomalies over the Northeast Atlantic during February, 1992

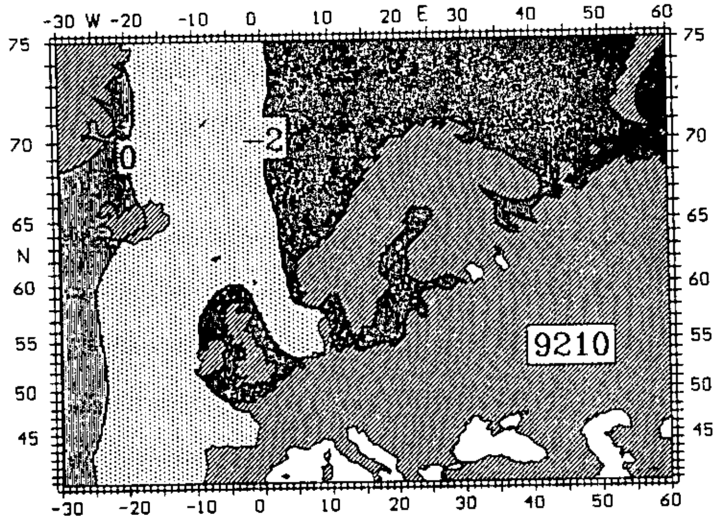

Fig. 6 Mean air temperature anomalies over the Northeast Atlantic during October, 1992

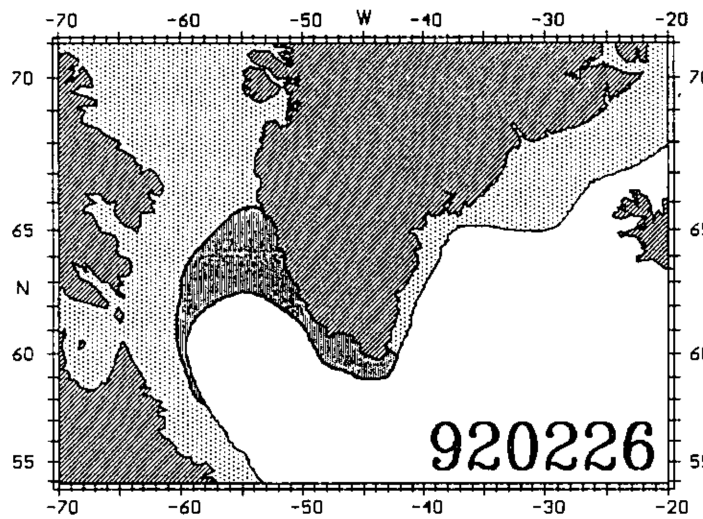

Fig. 7 Ice edge during February 26, 1992; dark shaded areas indicate anomalous extent of ice edge during the month of February

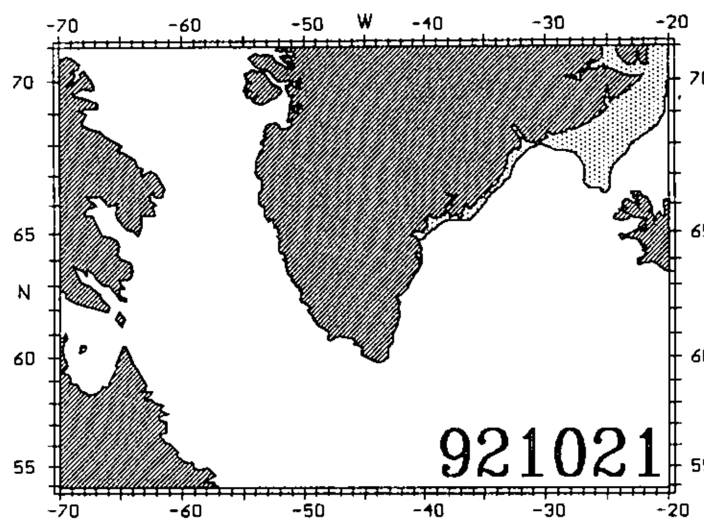

Fig. 8 Ice edge during October 10, 1992

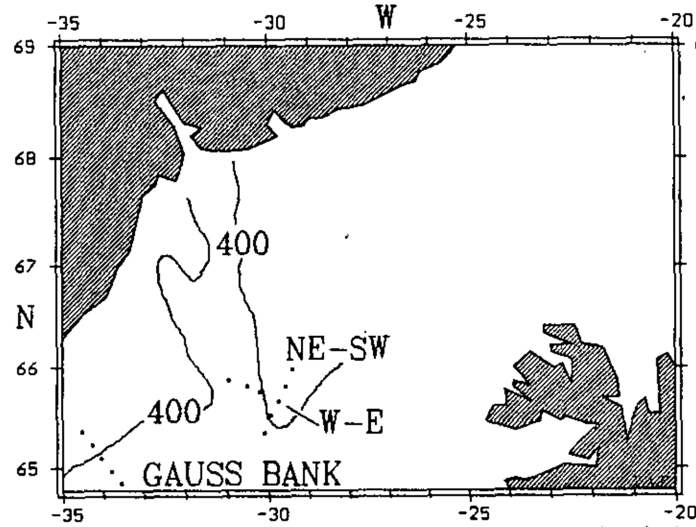

Fig. 9 Location of national Standard Oceanographic Sections in the Greenland/Iceland Ridge area; 400m bottom contour is given

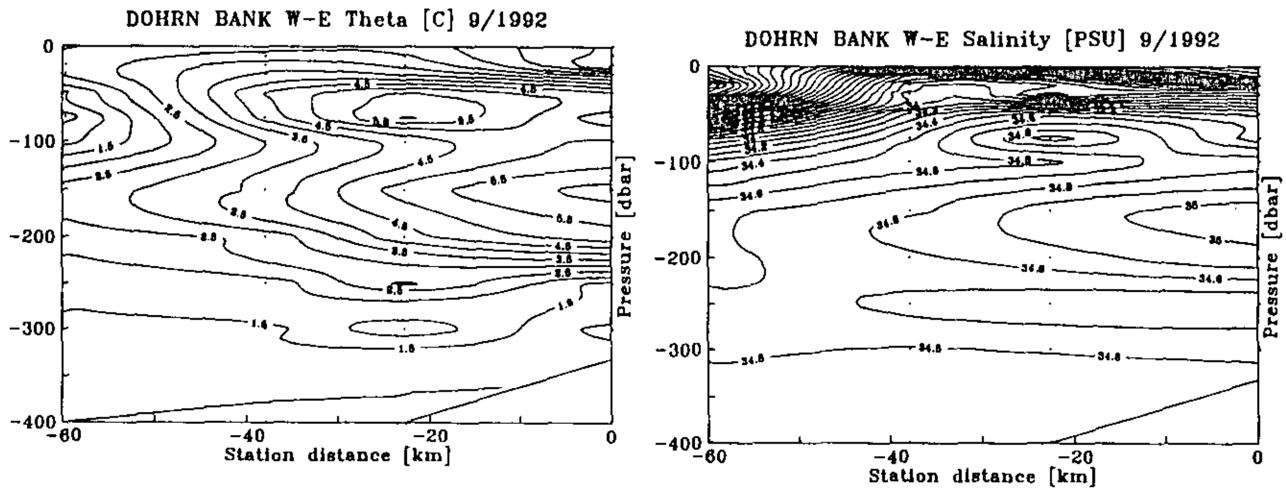

Fig. 10 Vertical distribution of temperature (a) and salinity (b) along the DOHRN BANK West-East Section during September 15 - 16, 1992

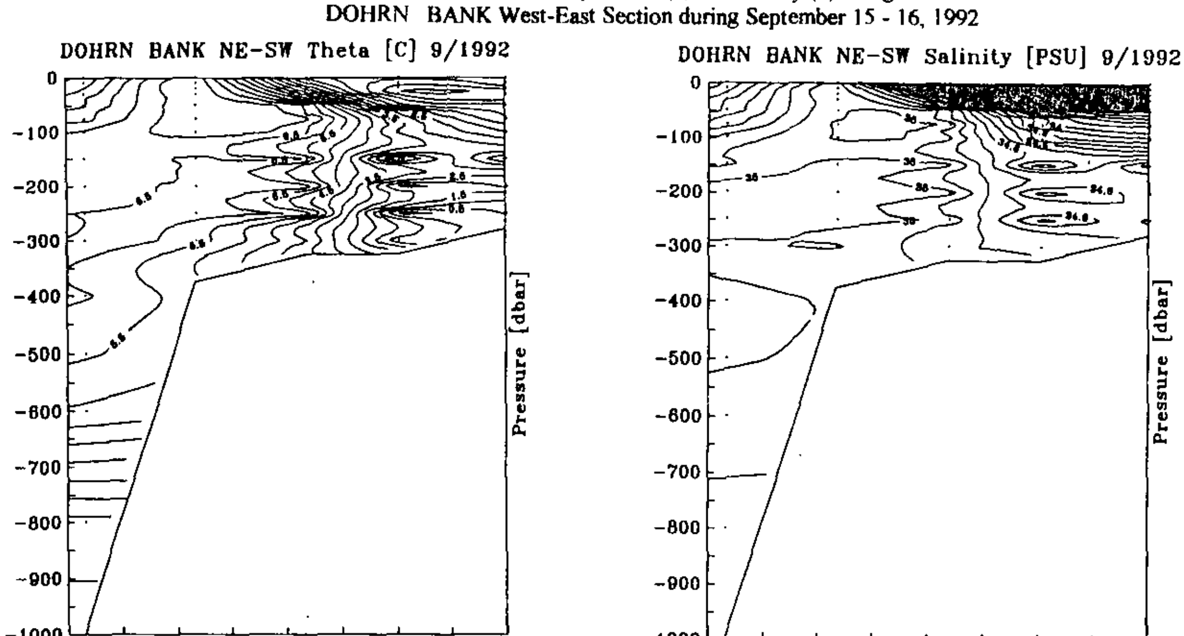

Fig. 11 Vertical distribution of temperature (a) and salinity (b) along the DOHRN BANK Northeast-Southwest Section during September 14 - 15, 1992

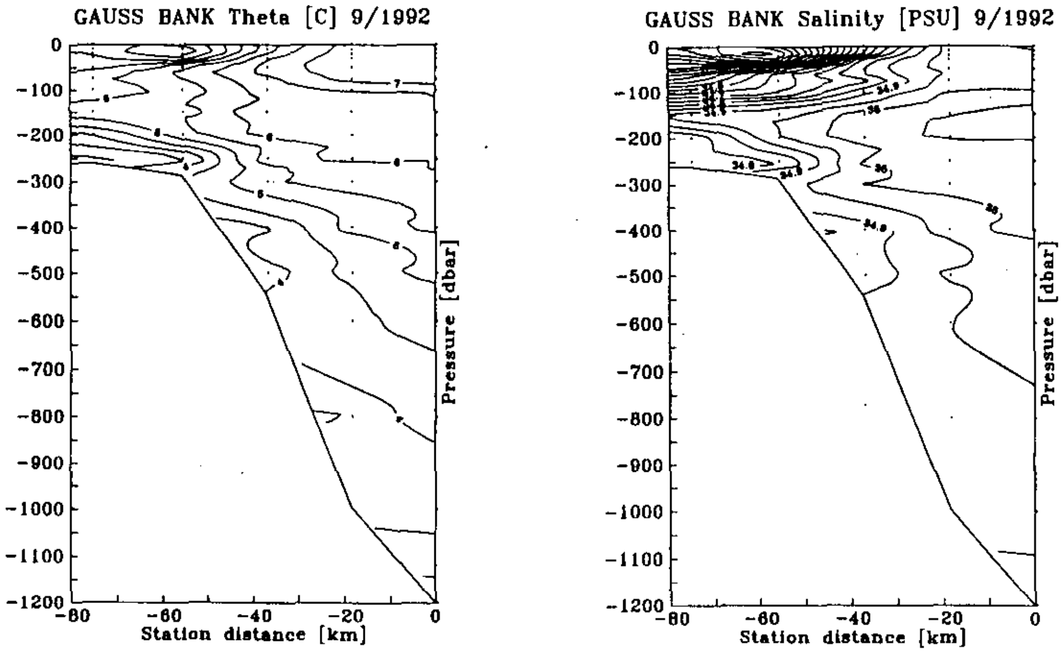

Fig. 12 Vertical distribution of temperature (a) and salinity (b) along the GAUSS BANK Section during September 19 - 20, 1992

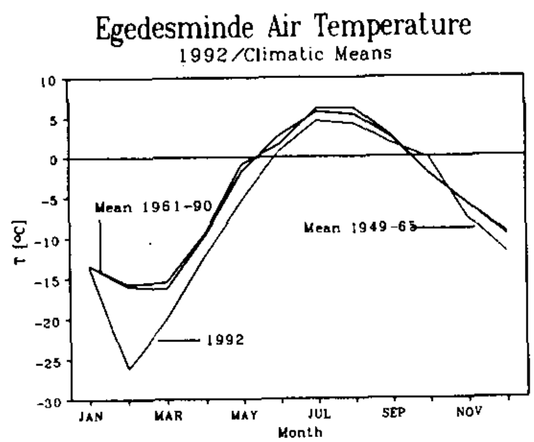

Fig. 13 Monthly mean temperature at Egedesminde during 1992 and climatic means (1949-65; 1961-90)

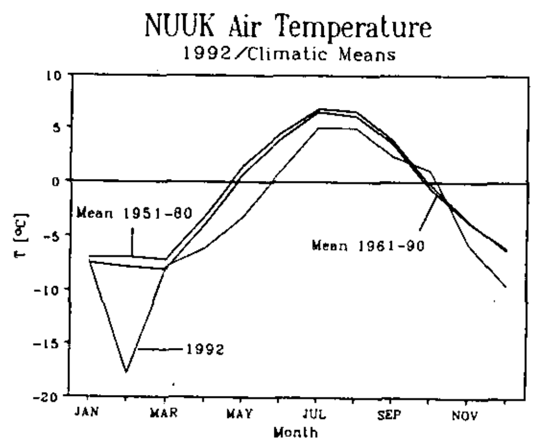

Fig. 14 Monthly mean temperature at Nuuk during 1992 and climatic means (1951-80; 1961-90)

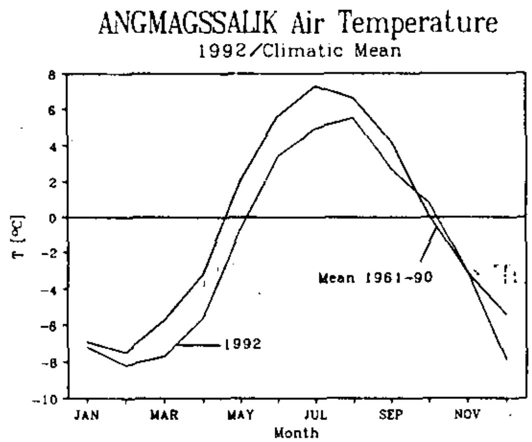

Fig. 15 Monthly mean temperature at Angmagssalik during 1992 and climatic mean(1961-90)

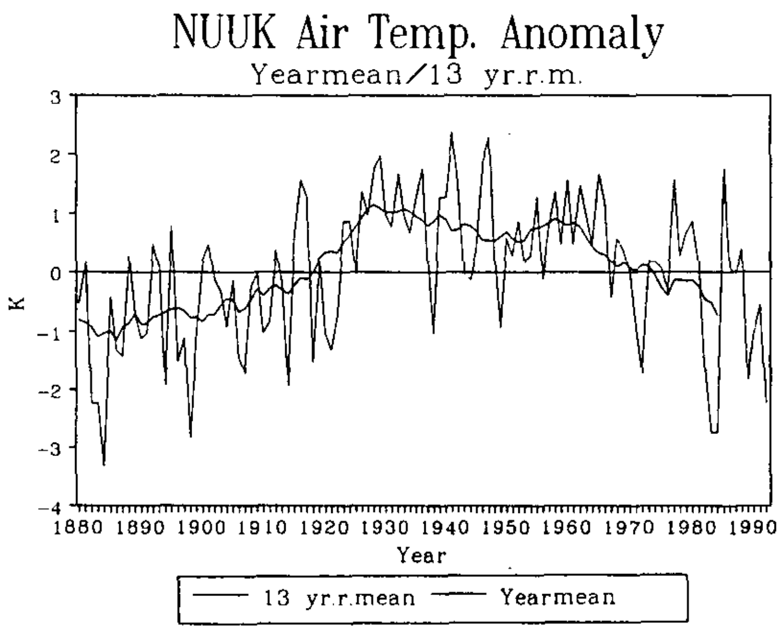

Fig. 16 Time series of annual mean air temperature anomalies at Nuuk (1880-1992) and 13 year running mean

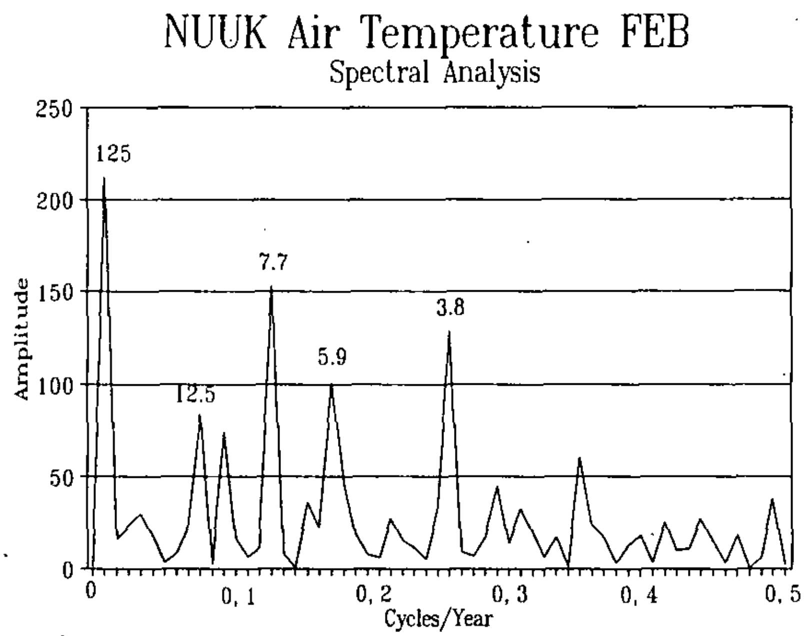

Fig. 17 Spectral analysis of annual mean air temperature anomalies at Nuuk

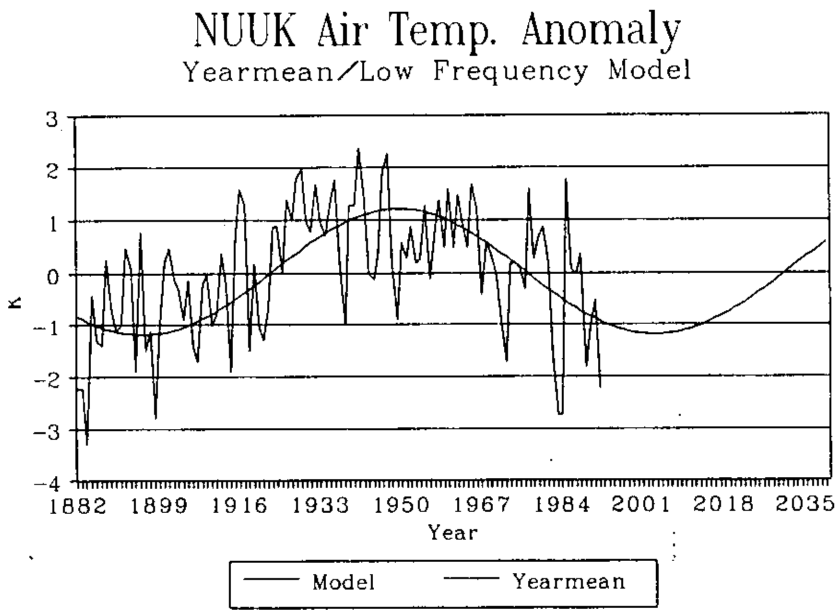

Fig. 18 Nuuk Air Temperature Anomaly: Yearmean versus Low Frequency Model