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Environmental Overview of the Northern Atlantic Area – With Focus on Greenland

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Abstract

Air temperature anomalies and sea ice cover around Greenland during the early-1990s indicate that anomalous cold environmental conditions were experienced in the Northwest Atlantic region at the beginning of the present decade similar to conditions during the beginning of the 1970s and 1980s. It was observed that, similar to the 1980s decade, cold air masses which centered over the town of Egedesminde contributed to the extreme conditions off West Greenland during late-winter/early-spring. In contrast to the west coast, the east coast of Greenland showed different climatic conditions during 1992 and 1993. Under the regime of the anomalous cold air temperatures the surface layer of the ocean cooled and sea ice formed to a larger extent than normal. Subsurface temperature observations on Fylla Bank/West Greenland indicated a close correlation with air temperature variation. Recent XBT-measurements of the vertical thermal field (0–750 m) of the North Atlantic Ocean between Cape Farewell and the waters west off the British Isles, along 60°N, revealed no changes in the thermal properties when compared to historical observations during 1955.

Key words: Environment, ice, temperature, Greenland

Introduction

There is evidence of global climatic changes (Houghton, 1991) which are of different magnitude and sign, depending on latitude and region. Climatic models predict regional cooling, e.g. in the Arcto-Canadian and Greenland region, and they indicate warming in the Siberian region (Mikolajewicz *et al.*, 1990). As concerns the Northwest Atlantic area, time series of sea ice cover and air temperatures indicate a considerable increase in the duration and extent of sea ice and cooling trends of air temperatures on both sides of the Davis Strait/Labrador Sea (Drinkwater *et al.*, 1994). The potential impact of climatic changes on fish stocks and fisheries in the Northwest Atlantic has been discussed recently (Stein, 1991). Changes observed on decadal scales seem to be relevant in the North Atlantic area (Anon., 1992a). Among these changes, the influence of a salinity anomaly travelling along the North Atlantic circulation since the late-1960s described as the "Great Salinity Anomaly" (Dickson *et al.*, 1988), is thought to have discernable influences on recruitment of certain cod stocks (Cushing, 1990; Mertz and Myers, 1994).

The present paper collates information on decadal scales since the beginning of this century, sea-surface temperature anomalies of North Atlantic areas, air temperature and subsurface ocean temperature variation during the last forty years off West Greenland, and air temperature and sea ice anomalies of the Northwest Atlantic during the early-1990s with reference to the climatic mean of 1961–90. In a separate section, the paper gives information on thermal properties in the upper layer (0–750 m) of the North Atlantic between Cape Farewell, Greenland, and Scotland.

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 supplied by the Danish Meteorological Institute in Copenhagen, the latter data sets are taken from Anon. (1992b, 1993). The Nuuk air temperature anomaly time series as displayed in Fig. 1, was referenced to the actual climatic mean of 1961–90.

Ice charts were constructed from NOAA satellite ice charts. They give the approximate position of the ice edge for the annotated date and the anomalous ice cover is related to mean ice conditions as given in Buch and Stein (1989). The temperature anomaly maps for the Northwest Atlantic were also taken from Anon. (1992b, 1993). These temperature maps give air temperature anomalies relative to the 1961–90 climatic mean[1].

Subsurface ocean data were available from Danish observations (June temperature data from Fylla Bank/West Greenland, Buch pers. comm., Royal Danish Adm. of Nav. & Hydrography, Denmark) and from German research survey measurements (November temperature data from Fylla Bank/

[1] Both the ice charts and the temperature anomaly maps, are available from the author on request as computer slide shows.

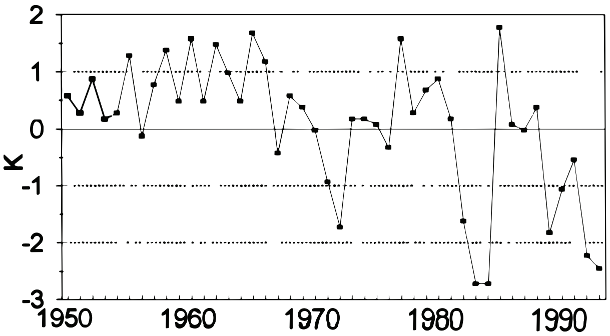

Fig. 1. Air temperature anomaly for year mean data at Nuuk, 1950–93 relative to the climatic mean of 1961–90.

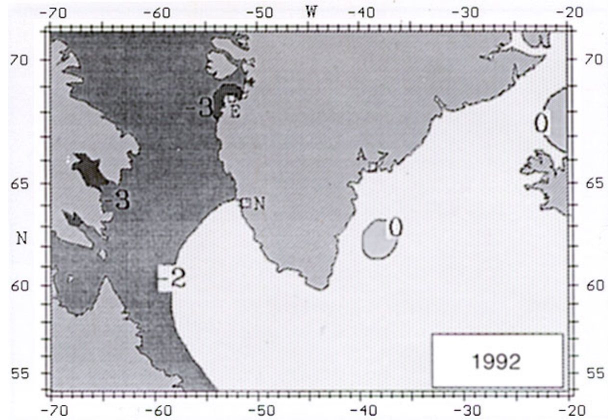

Fig. 2. Mean air temperature anomalies over the Northwest Atlantic during 1992 given relative to the climatic mean of 1961–90 (E = Egedesminde, N = Nuuk, A = Angmagssalik).

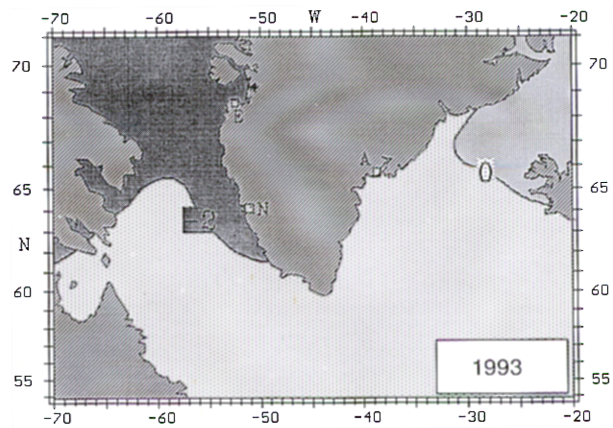

Fig. 3. Mean air temperature anomalies over the Northwest Atlantic during 1993 given relative to the climatic mean of 1961–90. (E = Egedesminde, N = Nuuk, A = Angmagssalik).

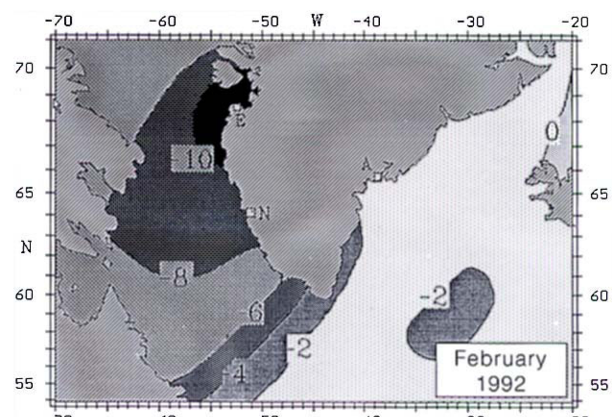

Fig. 4. Mean air temperature anomalies over the Northwest Atlantic during February 1992 given relative to the climatic mean of 1961–90. (E = Egedesminde, N = Nuuk, A = Angmagssalik).

West Greenland, and XBT-transects along 60°N across the Atlantic). These XBT (Deep Blue) probes were launched every three hours after leaving Cape Farewell, thus, about every 30 naut. miles a vertical temperature profile was obtained and transmitted via METEOSAT to the German Hydrographic Office. Data analysis and plotting of vertical sections was done there using the technique as described by Sy and Ulrich (1994). Sea surface temperature (SST) anomalies were supplied by Jens Smed (Author – institute, pers. comm.). The data were first transformed into computer readable format, smoothed by a 25-year running mean, to display anomalies for areas described by Smed (1965) for the North Atlantic area.

Results

Air temperature anomalies over the North Atlantic and Greenland

Similar to the last two decades, at the beginning of this decade anomalous low temperatures were encountered at West Greenland (Fig. 1). Although not being at record low values as during 1983 and 1984, the year mean data indicated near record low values for the years 1992 and 1993. These climatic conditions are quite in contrast to the 1950s and 1960s, when positive temperature anomalies prevailed at West Greenland.

Mean air temperature conditions for the North Atlantic west of 20°W during 1992 and 1993 are outlined in Fig. 2 and 3. In both years negative temperature anomalies were observed to the west and south of Iceland, off Labrador and Greenland. During 1992, year mean temperature anomalies were below -3K in the Egedesminde area. February and March were the coldest months in these years, with temperature anomalies below -10K (February 1992 at Egedesminde, Fig. 4) and below -8K (March 1993 at Egedesminde, Fig. 5). March 1994 air temperature anomaly distribution revealed similar conditions as during March 1993 for the West Greenland area (Fig. 6).

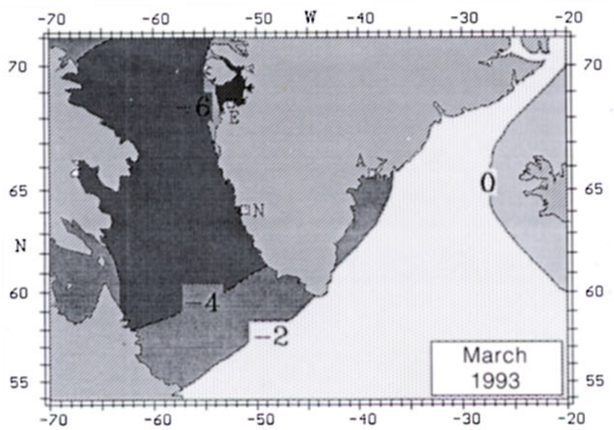

Fig. 5. Mean air temperature anomalies over the Northwest Atlantic during March 1993 given relative to the climatic mean of 1961–90. (E = Egedesminde, N = Nuuk, A = Angmagssalik).

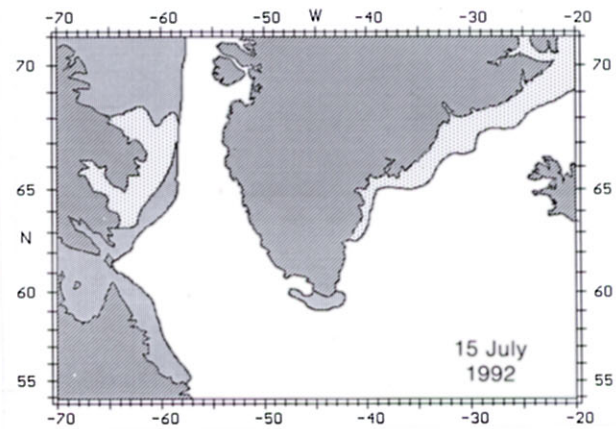

Fig. 7. Location of ice edge on 15 July 1992. The dark shaded areas denote anomalous ice cover for the given month.

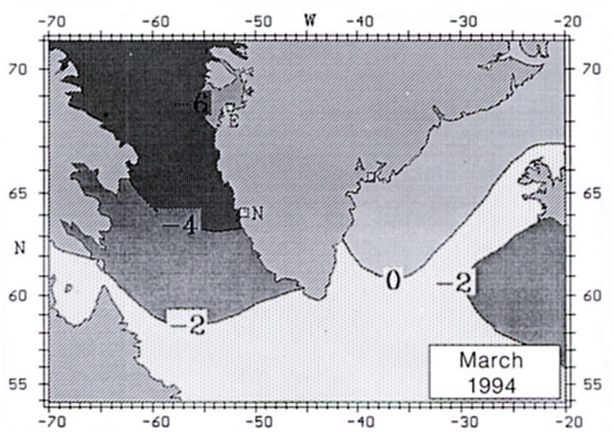

Fig. 6. Mean air temperature anomalies over the Northwest Atlantic during March 1994 given relative to the climatic mean of 1961–90. (E = Egedesminde, N = Nuuk, A = Angmagssalik).

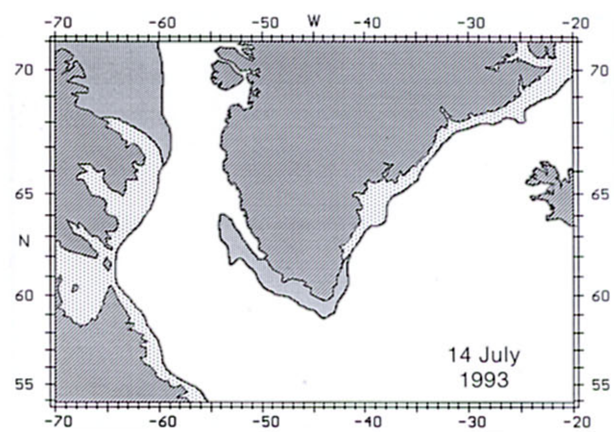

Fig. 8. Location of ice edge on 14 July 1993. The dark shaded areas denote anomalous ice cover for the given month.

Distribution of sea ice

As a consequence of the anomalous cold air temperatures around Greenland during 1992 and 1993, the distribution of sea ice in the area was also anomalous. Two examples which show the situation during mid-July are given here (Fig. 7 and 8): Ice was still present off Labrador and north of Baffin Island, as well as at Cape Farewell (July 15, 1992). A year later, a tremendous tongue of sea ice was covering the Cape Farewell area and stretched out to the northwest off West Greenland, as far as Nuuk. Also, at the western side of Davis Strait, north of Baffin Island, unusual coverage of sea ice was encountered on 14 July 1993.

Subsurface temperature distribution at Fylla Bank/West Greenland

Annual values of temperature anomaly on top of Fylla Bank (June data) and at the slope (November data) are given in Fig. 9 and 10. A 5-year running mean is superimposed on the annual curves. The data are referenced to the mean of the entire time series, whereas the data from the top of the bank are referred to the 1951–80 climatic mean. Similar to the air temperature time series of Nuuk (Fig. 1), the water temperatures on top of Fylla Bank (40 m of water column) revealed the cold events during 1969, 1970 and 1972, during 1983, and during 1991. The temperature anomaly data on the slope of the bank, at station 4 (Stein, MS 1988), represent mean anomaly values of the upper 200 m of the water column. Anomalous cold events were observed during 1972 and 1983.

Thermal properties of the North Atlantic along 60°N

During eastbound crossings of the North Atlantic, FRV "*Walther Herwig*" performed regular surveys of the upper ocean thermal field (0–750 m) since 1989. Figures 11–13 show the vertical thermal fields during October, November and December. For

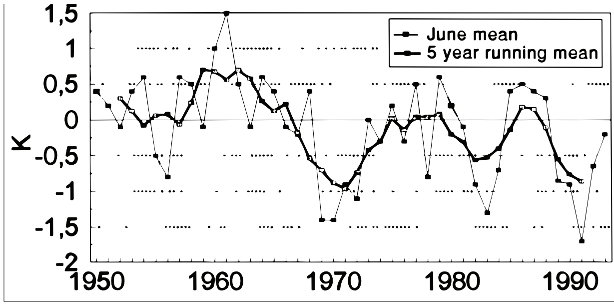

Fig. 9. Mean temperature anomaly on top of Fylla Bank (0–40 m) during June given relative to the mean of 1951–80, and 5-year running mean of the anomaly data.

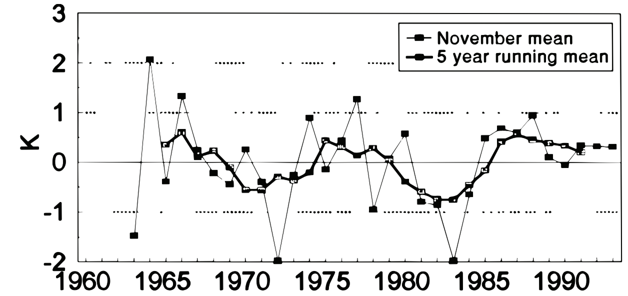

Fig. 10. Mean temperature anomaly at the slope of Fylla Bank (0–200 m) during November given relative to the mean of 1963–93, and 5-year running mean of the anomaly data.

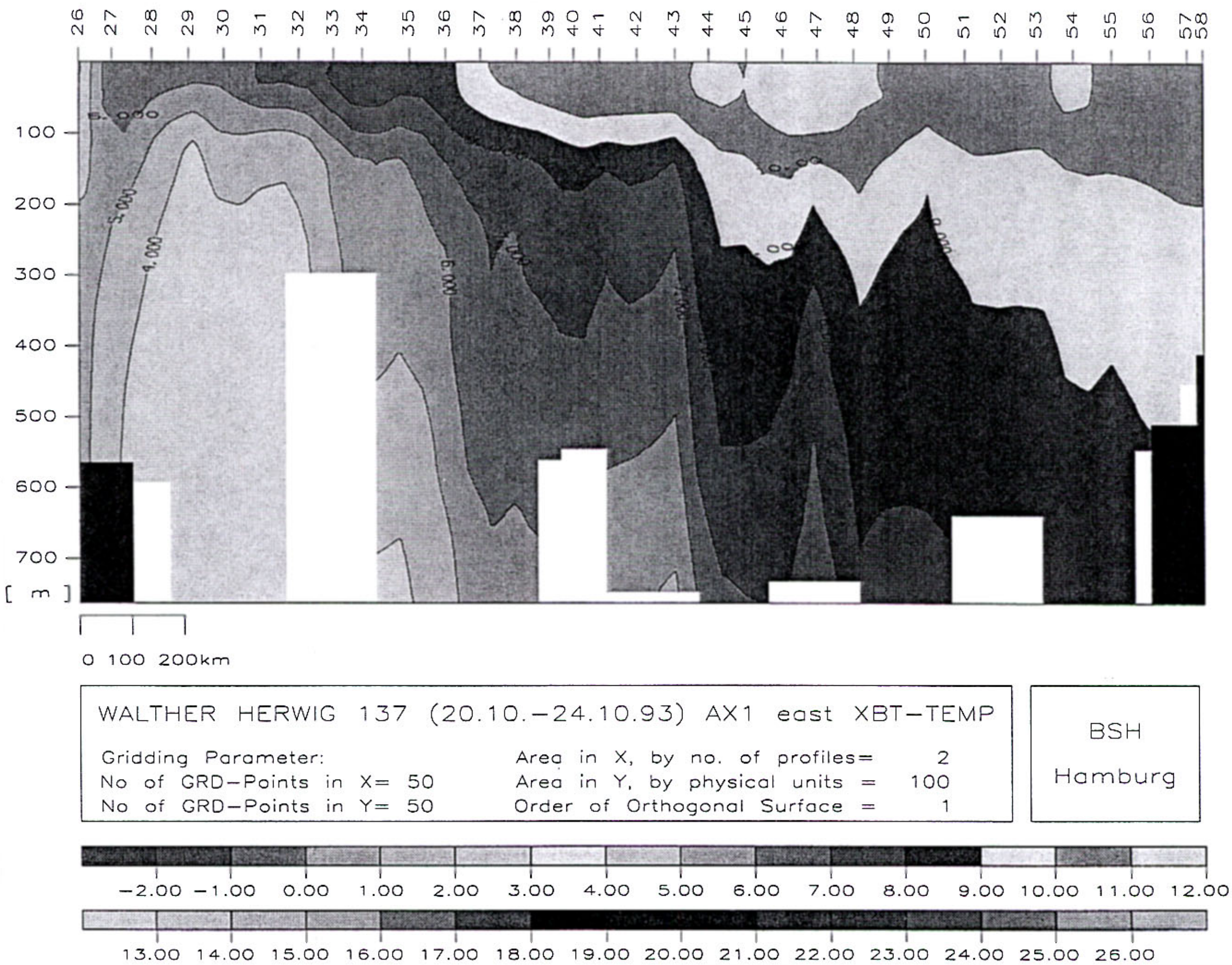

Fig. 11. Upper ocean thermal field of the North Atlantic along 60°N between Cape Farewell and the British Isles during 20–24 October 1993.

comparison results from published data are displayed in Fig. 14. These data are May/June and October observations, done by FRV "*Anton Dohrn*" in 1955 (Dietrich *et al.*, 1961). To illustrate the temporal variation of thermal properties of the North Atlantic throughout most of this century, sea-surface

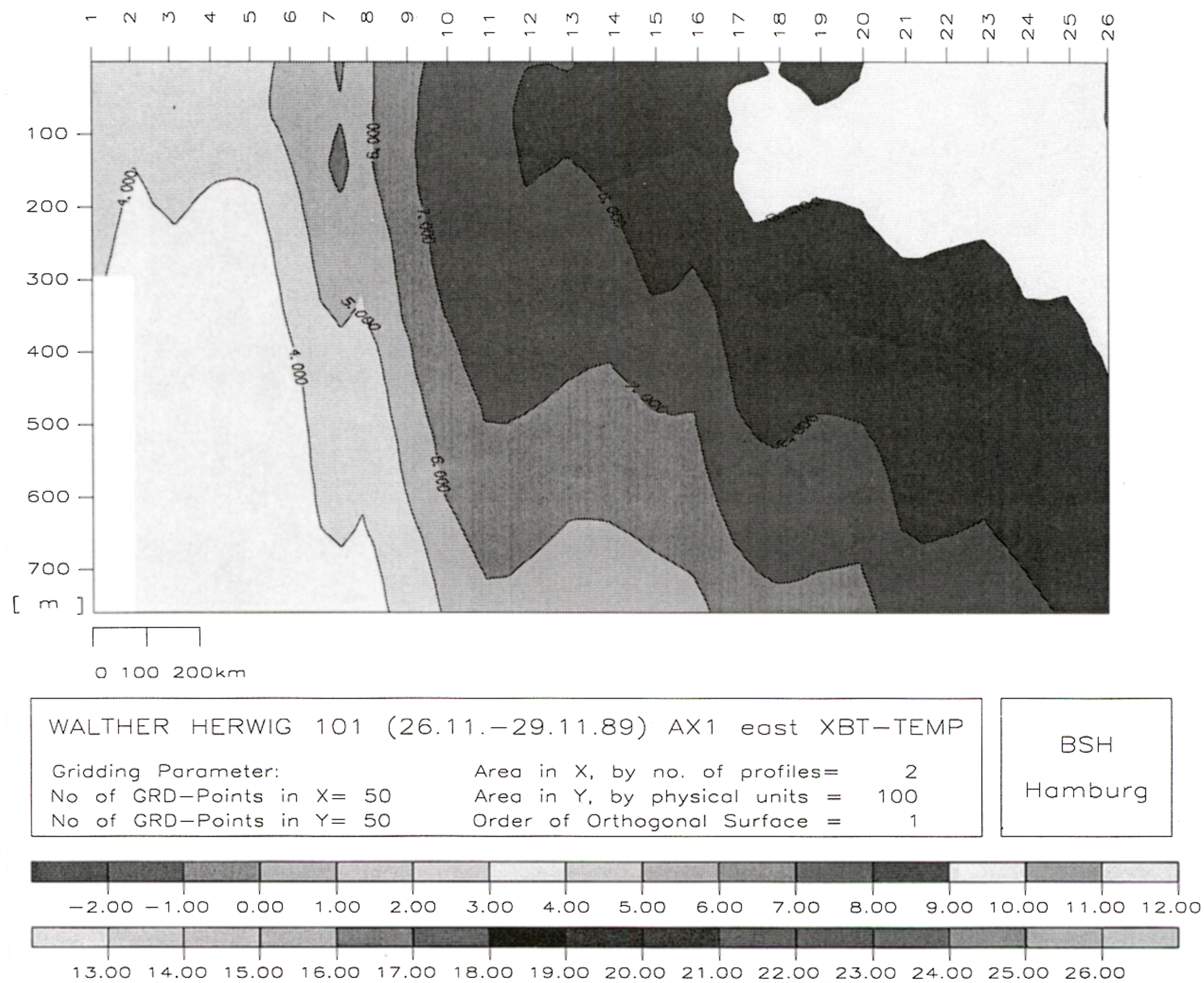

Fig. 12. Upper ocean thermal field of the North Atlantic along 60°N between Cape Farewell and the British Isles during 26–29 November 1989.

temperature anomalies from West Greenland to the west of the British Isles are given (Fig. 15) for the belt between 55°N and 60°N. Unfortunately, this time series was abandoned from 1975 onwards.

Discussion

After extremely cold years at the beginning of the previous two decades of the 1970s and 1980s, there was a warming or a return to normal conditions during the second half of these two decades with the exception of 1989 which was nearly 2K below the mean (Fig. 16). The early-1990s seemed to follow this trend. The climatic curve for Nuuk (Fig. 17) shows that on average March was the coldest month of the climatic mean (1961–90). During the early-1990s, February 1992 was the coldest month. The present year (1994) was near normal during January, February, but anomalously cold during March and again slightly above normal in April and May. The years two and three of the 1980s and 1990s (Fig. 16) indicated similar trends. Cooling in both years was strongest in February and March. This might reflect that there were similar meteorological conditions in those years. The air temperature anomaly maps of February 1992, March 1993 and also March 1994 indicate a cold air mass centered over the town of Egedesminde (Fig. 4, 5 and 6). As discussed by Buch and Stein (1989), a comparable meteorological situation was observed during the early-1980s, when cold arctic air masses were kept over Davis Strait for about two months. This resulted in cooling of the oceanic surface layer and led to the anomalous formation of sea ice.

A completely different situation in air temperatures at Nuuk was encountered during the 1950s and 1960s. Except for a minor negative deviation in 1956 and 1967, these decades were characterized by anomalously warm conditions (Fig. 18).

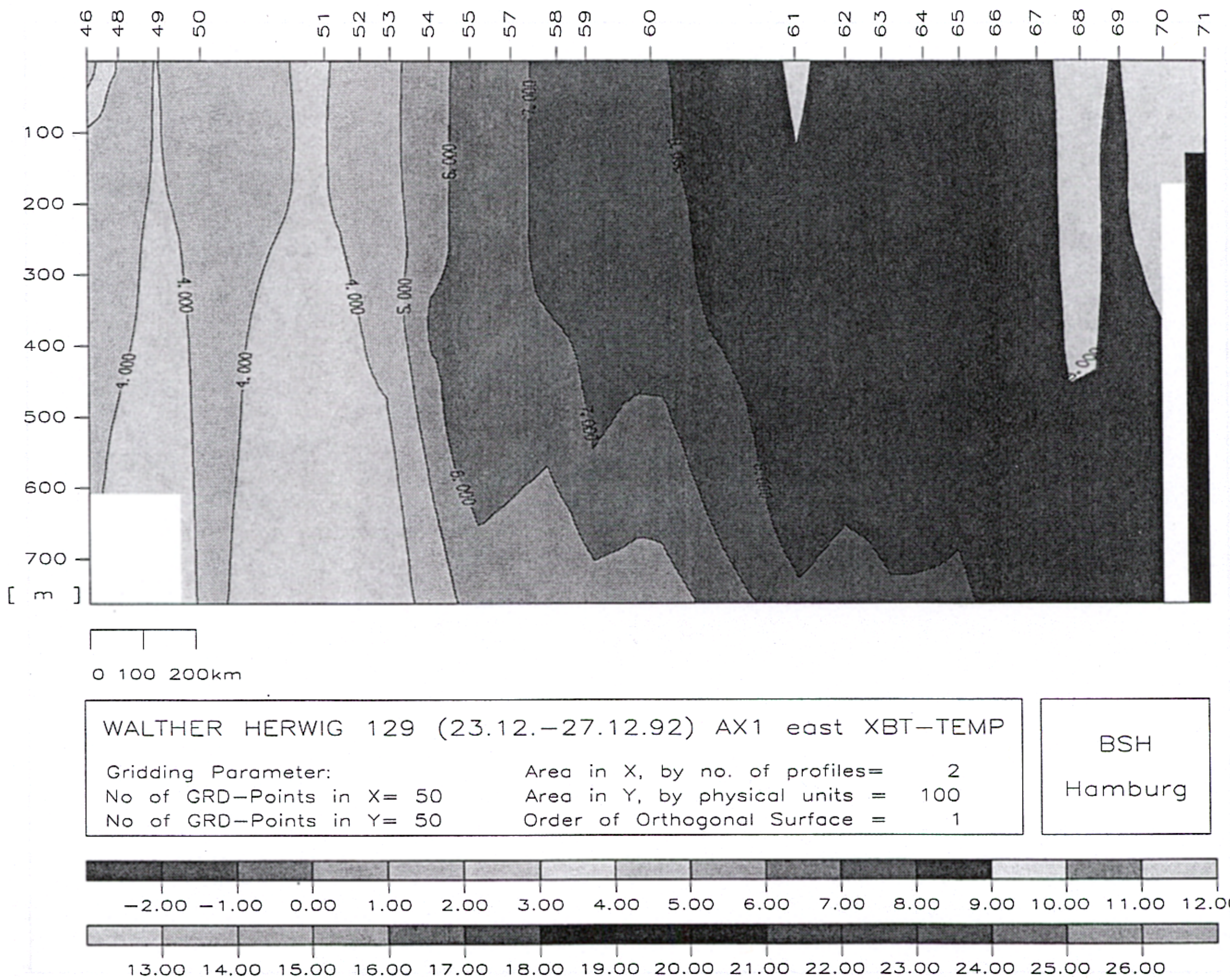

Fig. 13. Upper ocean thermal field of the North Atlantic along 60°N between Cape Farewell and the British Isles during 23–27 December 1992.

The warm conditions of the 1950s and 1960s are well reflected in the thermal conditions of the water column on top of Fylla Bank (Fig. 9). When air temperatures decreased at the end of the 1960s, the first significant drop in water temperatures was observed during the beginning of the 1970s. Warming in the middle of the 1970s and 1980s did also influence the thermal conditions on Fylla Bank. From 1989 through to the early-1990s, colder than normal ocean temperatures were observed. According to Buch (pers. comm.) during the 1993 measurements in June, the surface layer at all stations off West Greenland was dominated by the inflow of cold, relatively fresh polar water.

The SST-anomalies of the North Atlantic areas given in Fig. 15, reveal a general warming of the surface waters between 55°N and 60°N which started in the 1920s. Warming was most pronounced in area A1 (West Greenland, Fig. 15a). At the end of the 1960s, cooling of the surface waters occurred in all areas except for area N. At the same time cooling started off West Greenland in the air temperatures at Nuuk (Fig. 1), and the subsurface observations on Fylla Bank (Fig. 9). Subsurface observations on the thermal properties of these areas reveal a completely different picture. Measurements done by FRV "*Anton Dohrn*" during 1955, and by FRV "*Walther Herwig*" nearly forty years later, revealed about the same thermal conditions during October (Fig. 11 and 14). The topographic influence of the Mid-Atlantic Ridge on the distribution of water masses is similarly mapped during both observations (9–16 October 1955 and 22–25 October 1993). Doming of the isotherms to the west of the ridge (Fig. 14) shows the Irminger Sea thermal properties: a deep reaching, nearly homogenous water mass below the upper thermocline. The upper 1 000 m

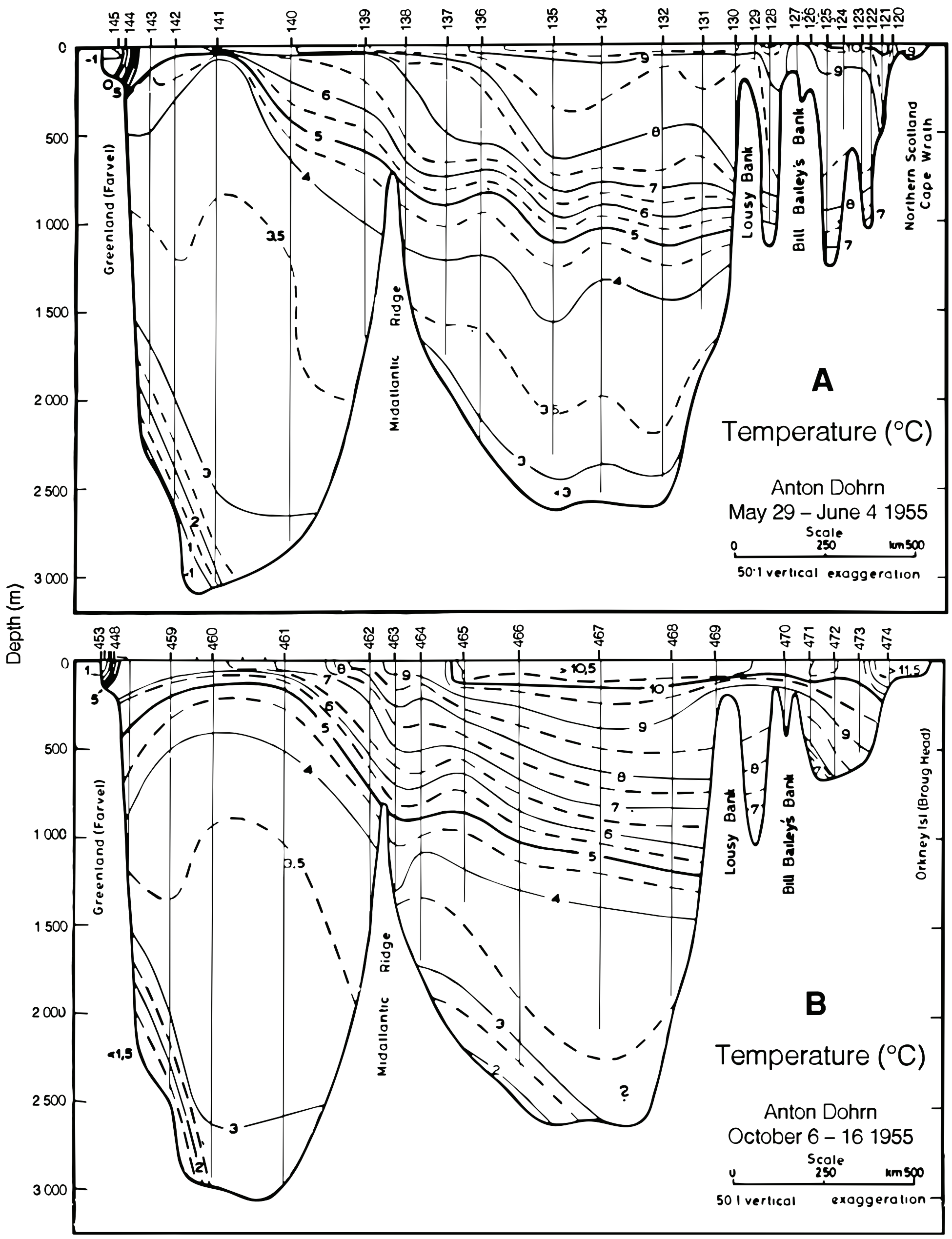

Fig. 14. Upper ocean thermal field of the North Atlantic along 60°N between Cape Farewell and the British Isles during (**A**) 29 May–4 June 1955 and (**B**) 9–16 October 1955.

of the water column east of the ridge comprise the waters of the North Atlantic Current, structured during the preceding summer. A tongue of warm summer surface water stretches to the west with temperatures being well above 10°C. Both features and the same thermal properties were found during 1989, even with the tilting isotherms above the Mid Atlantic Ridge. Figures 12 and 13 elucidate the gradual decrease of thermal structure east of the Ridge when winter is approaching. The December observations (Fig. 13) show vertical convection within the upper 750 m west off the British Isles with a nearly homogenous water mass.

The two comparable observations, made in 1955 and 1989, are too scarce to draw climatic conclusions. However, these examples express what Global Climatic models take into account: no warming in this part of the North Atlantic, but cooling in the Labrador/West Greenland area.

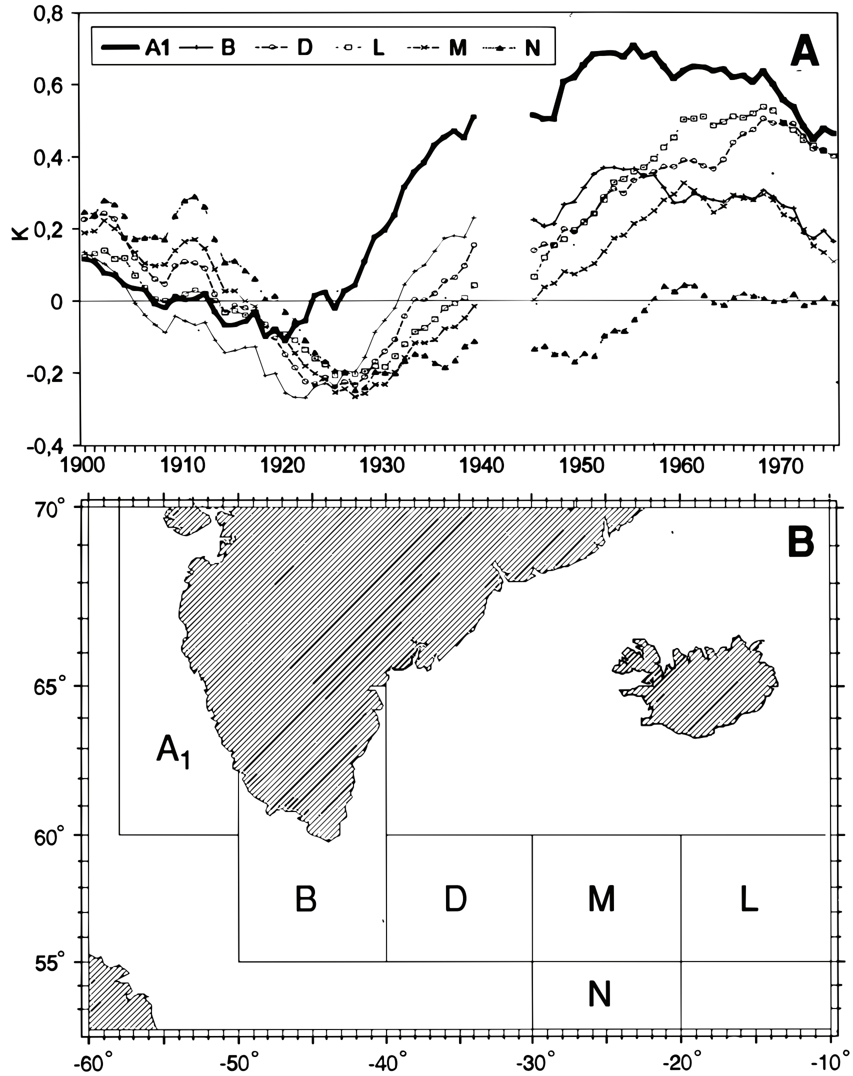

Fig. 15. (**A**) Sea-surface temperature anomalies of North Atlantic areas denoted in Fig. 15B (data are smoothed by a 25-year running mean) and (**B**) North Atlantic areas as given by Smed, 1965.

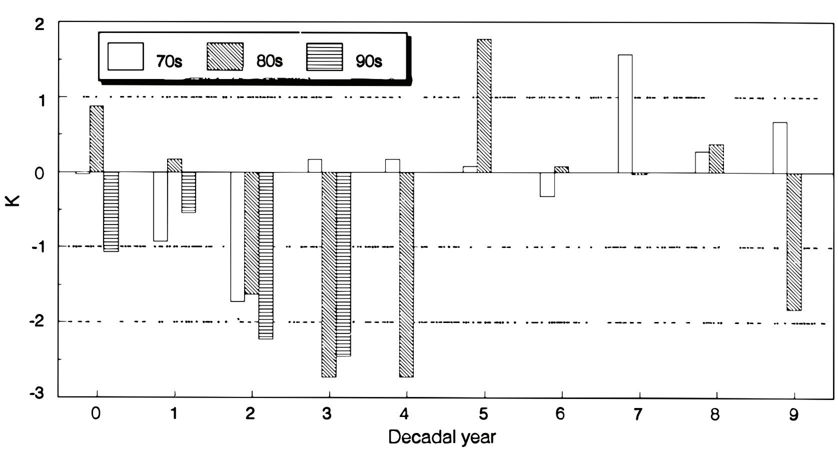

Fig. 16. Composite of decadal air temperature anomalies at Nuuk given relative to the climatic mean of 1961–90 for the decades of the 1970s, 1980s and 1990s.

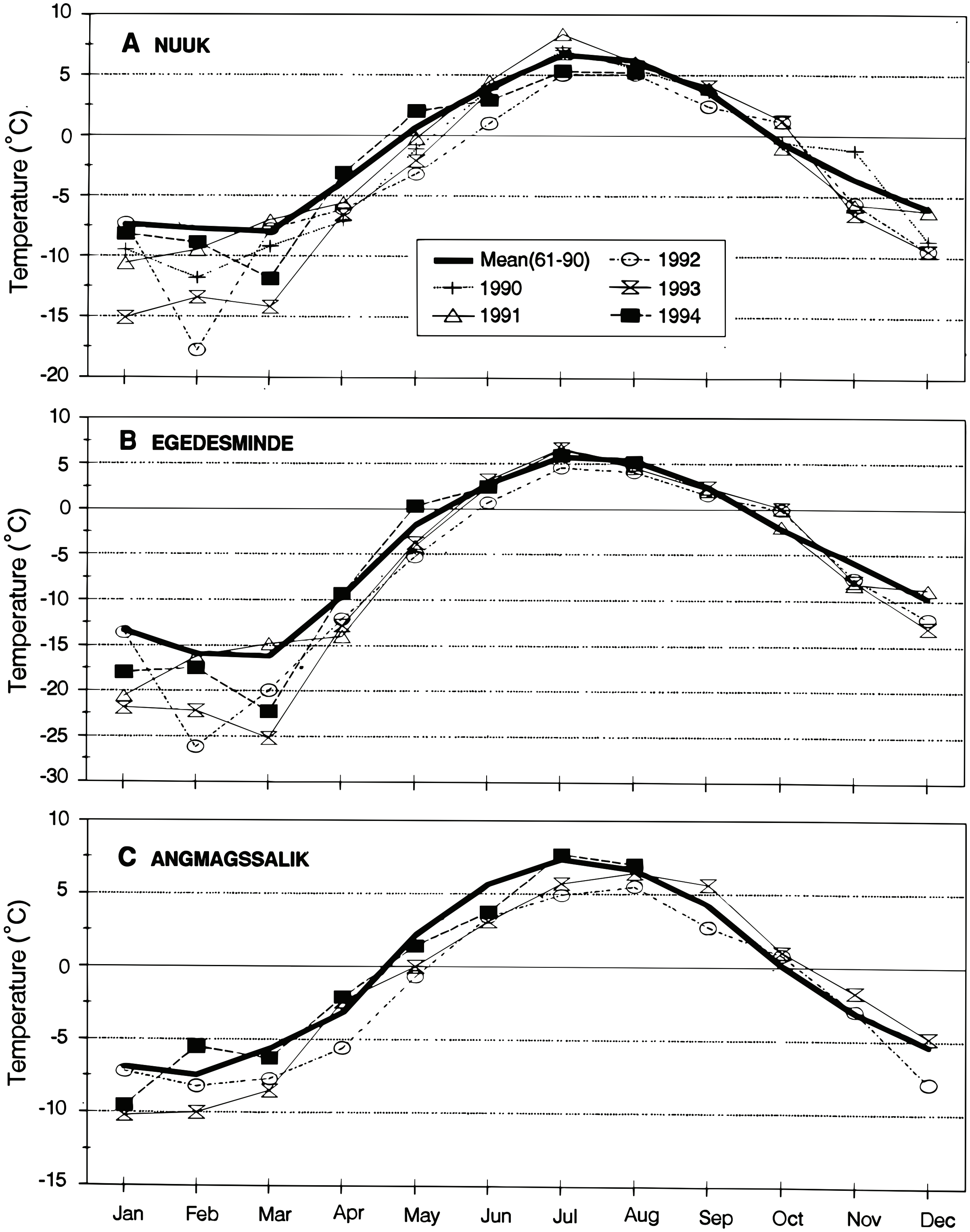

Fig. 17. Climatic mean monthly air temperature curve (1961–90) and climatic curves for the early-1990s for (**A**) Nuuk, (**B**) Egedesminde and (**C**) Angmagssalik.

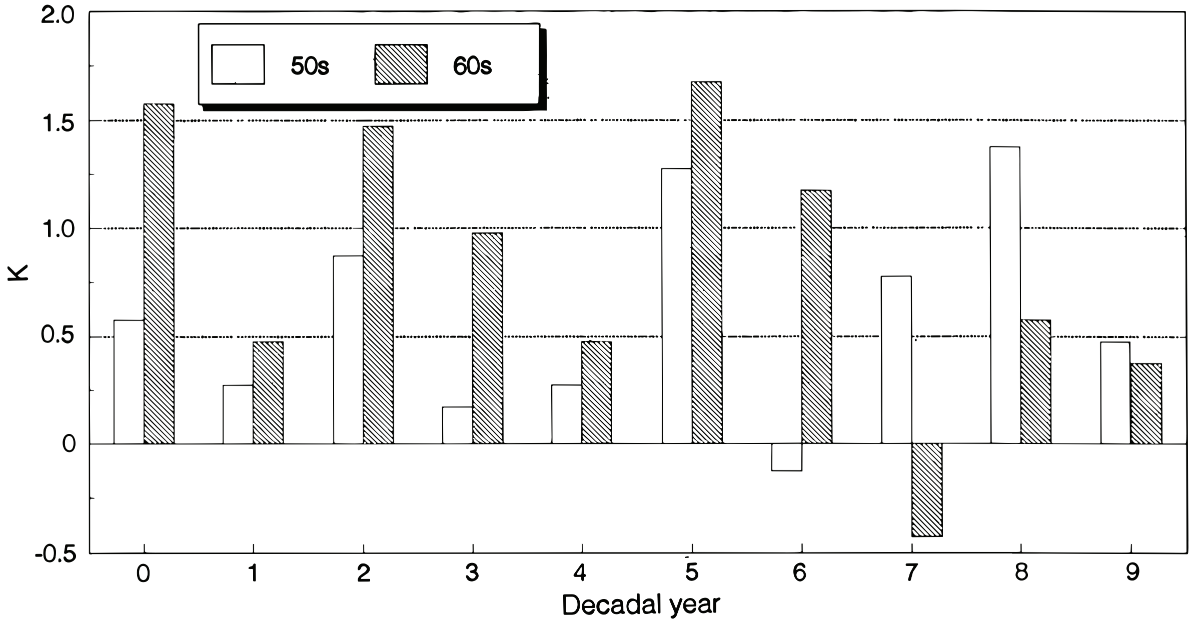

Fig. 18. Composite of decadal air temperature anomalies at Nuuk given relative to the climatic mean of 1961–90 for the decades of the 1950s and 1960s.

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Discussions

Question: When will the downward trend be stopped?

Response: If I knew, I would make a fortune out of it; we can only judge from previous climatic events and project similar behaviour into the future.

Question: SST anomalies (Fig. 15 of the paper) show eastward propagation of maximum of warming. How can this be explained, especially the lag time?

Response: This is not analyzed so far.

Comment: We are now at about the 0°C-line. There are SST data to continue the time series beyond 1975.

Question: Is the model of the Great Salinity Anomaly still valid based on more recent observations?

Response: It is a good conceptual framework but there are strong regional *in situ* modifications of T/S characteristics (e.g. cooling in Davis Strait, Egedesminde gives rise to strong impacts).

Question: The temporal pattern is similar to the survival index (NAFO SCR Doc. 94/73). Are the processes that generate the temperature anomaly on Fylla Bank more wide spread processes?

Response: Cold air masses at Egedesminde provide large scale effects.

Question: Can we compare the Smed SST-data from Area A1 with Fylla Bank data?

Response: Due to 25-year running mean given in Fig. 15, it is at present difficult to see, but based on the original data it should be possible.