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Are Subsurface Ocean Temperatures Predictable at Fylla Bank, West Greenland?

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Abstract

The hypothesis that subsurface ocean temperatures off the shelf-break and on top of Fylla Bank are predictable from air temperature data sampled at Godthaab, West Greenland is tested. It appears that late summer air temperature conditions steer the upper ocean layer temperatures (0–200 m) that are observed in November. A general warming trend apparent in the meteorological time-series was not found in the ocean time-series due to the shortness of the time-window of the latter series.

Introduction

The hydrographic conditions off West Greenland are governed by the West Greenland Current system which is composed of two main components, the cold East Greenland Current, and the warm Irminger Current (Buch, 1982; Stein and Buch, 1985). The cold near-coastal component attains its maximal influence on the West Greenland Current in early summer (June), while the warm component has its maximal influence in late autumn (November).

Since 1950, a time-series of temperature and salinity data were regularly collected along the Fylla Bank Section. The bulk of the existing temperature and salinity data originated from the Standard Oceanographic Station 4 at 63°53′N 53°22′W (Fig. 1), and from the inshore stations 1, 2 and 3 at 64°01′N 52°19′W, 63°58′N 52°44′W and 63°55′N 53°07′W, respectively, of this section (Stein, MS 1988). During the past decades anomalous cold situations have been encountered at West Greenland and in the West Greenland Current system (Stein and Buch, 1985). Due to regional meteorological anomalies strong negative anomalies of temperature and salinity were observed at Fylla Bank Section Station 4, which peaked in 1983. Stein (1986) noted that the two coldest periods in over 20 years on Fylla Bank occurred in 1972 and 1983, at times when strong El Niño-type events occurred in two successive years in the South Pacific Ocean. He suggested that there was a linkage through large-scale atmospheric circulation.

Analysis on the short term variability in hydrographic conditions off Fylla Bank was done by Stein and Buch (MS 1985). Based on repeated CTD profiles during a 15 hr period at Station 4 of the Fylla Bank Section, they observed that due to changing wind direction, advective processes took place which led to cooling of the upper surface layer (0–30 m). This was in correlation with the theoretical value for the depth of frictional influence for a pure drift current (39 m at the station site). The influence of tidal motion was mostly expressed in the deep layers of the water column.

Stein and Messtorff (1990) showed that warm-saline and cold-diluted periods in the oceanic climate

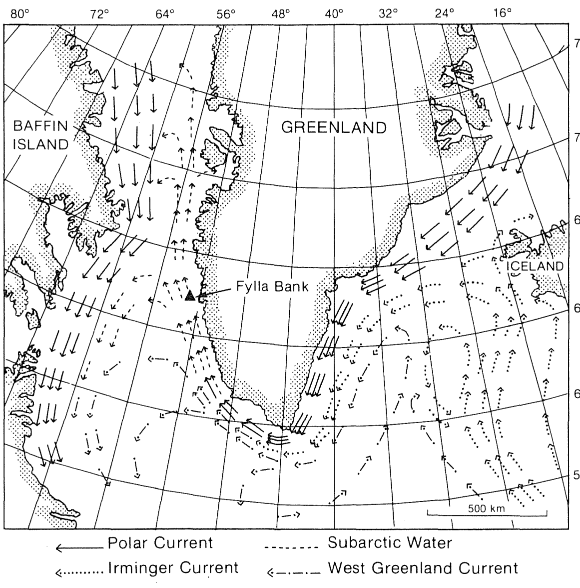

Fig. 1. Location of Fylla Bank Section Station 4 (triangle) and general sea surface circulation.

lasted for about 3 to 5 years and a similar periodicity was observed for strong cod year-classes up to 1973. In a recent paper (Sloth and Buch, MS 1988) the relationship between sea-ice distribution and concentration in the Greenland and Iceland Seas and temperatures at Fylla Bank indicated that ice-cover in December were correlated with June temperature, representing an approximately 6-month travel time from the Greenland and Iceland Seas to Fylla Bank. Using information based on the relationship, the authors predicted the next year's temperature of 1.5° to 1.7° C (for June 1988) on Fylla Bank. The subsequent measured value was close to the predicted one, but slightly higher.

On the basis of long-term records of monthly mean air temperature at Godthaab, West Greenland and on subsurface temperature data at Fylla Bank west off Godthaab from June and November the hypothesis that the trend of ocean temperature variation might be deduced from the mean air temperatures is tested.

Data and Methods

Air temperatures at Godthaab used in the present study are part of a time-series of monthly mean values sampled from 1976 onwards at the Godthaab meteorological station. For correlation with the ocean subsurface temperature data, the last 25 years covering the period from 1963 to 1987 were taken. Fylla Bank mid-June temperature data from top of the bank were sampled by the Greenland Fisheries Research Institute, Copenhagen, whereas the November temperature anomaly data originated from a data set sampled by the Institut für Seefischerei, Hamburg, and mutually completed by the Greenland Fisheries Research Institute, Copenhagen. Correlation analysis was performed for each monthly time-series.

Results and Discussion

The smoothed temperature time-series from 1963–87 of mid-June from the top of the Fylla Bank is shown in Fig. 2. It clearly demonstrates that in the past 25 years, periods of warm and cold conditions were present in the shallow waters of Fylla Bank. Anomalies, especially in the early-1970s and early-1980s emerge from the picture. The November data set (Fig. 3) outlines the anomalous cold in the early-1980s. In the period late-1960s to early-1970s, anomalous cold temperatures were indicated at Station 4, but not in the same order of magnitude as a decade late. The results of "Lag 0" correlations are shown in Fig. 4 and 5. Correlation between the two ocean temperature time-series yielded a coefficient of 0.54 at Lag 0, indicating that there was a positive interrelation between the June and November time-series. From Fig. 4 and 5 it appears that correlation between ocean and air temperature time-series yields an annual spectrum which peaks in May

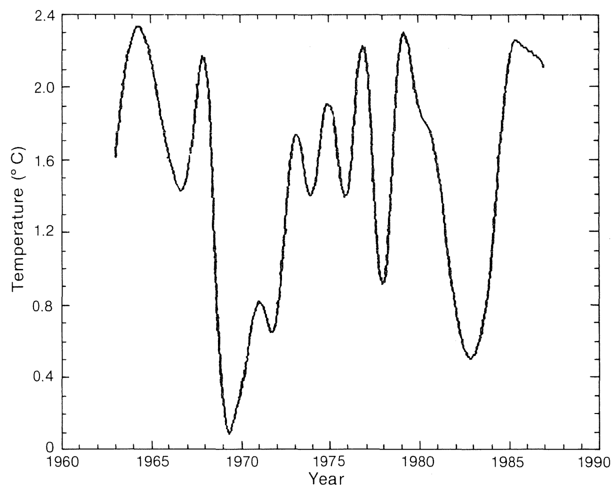

Fig. 2. Smoothed temperature time-series for mid-June 1963–87 on top of Fylla Bank.

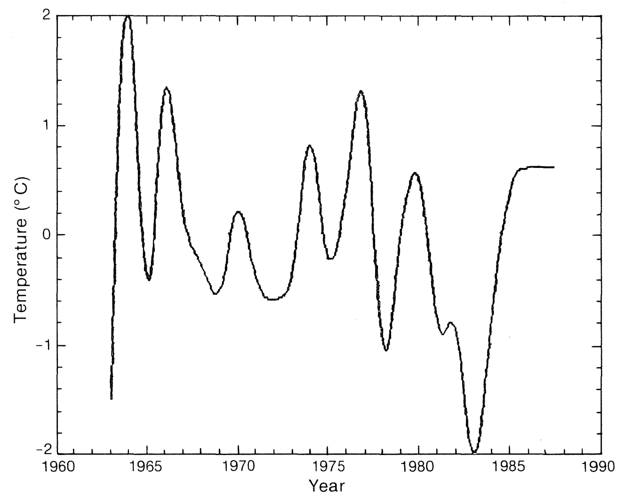

Fig. 3. Smoothed temperature anomaly time-series for November 1963–87 in the 0–200 m layer at Station 4 of Fylla Bank Section.

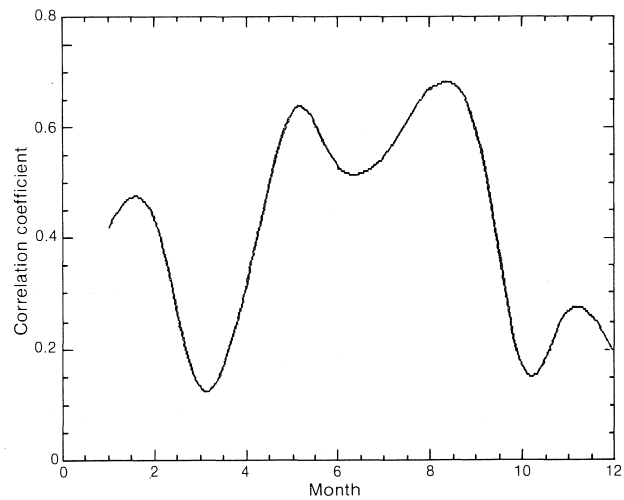

Fig. 4. Correlation spectrum at Fylla Bank for mid-June temperature *versus* Godthaab monthly mean air temperature.

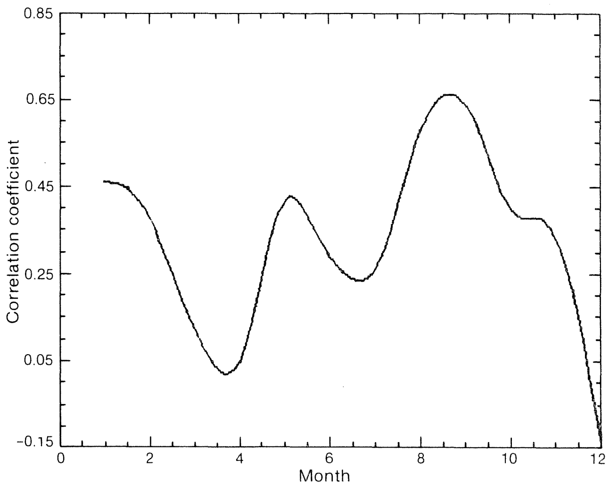

Fig. 5. Correlation spectrum at Fylla Bank for 0-200 m temperature anomaly *versus* Godthaab monthly mean air temperature.

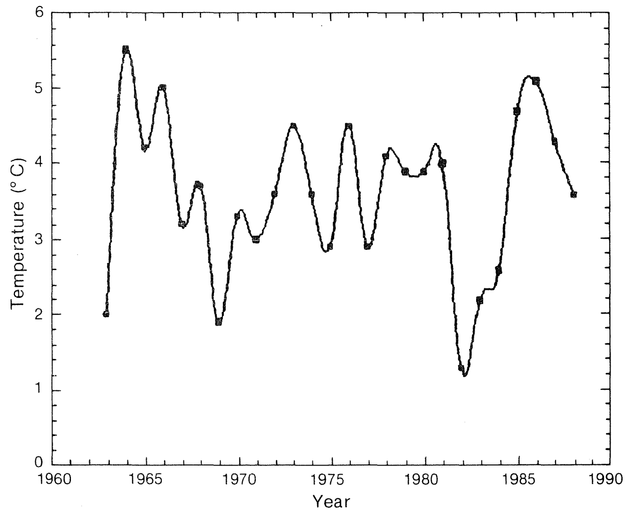

Fig. 7. Godthaab mean air temperature for September 1963-88.

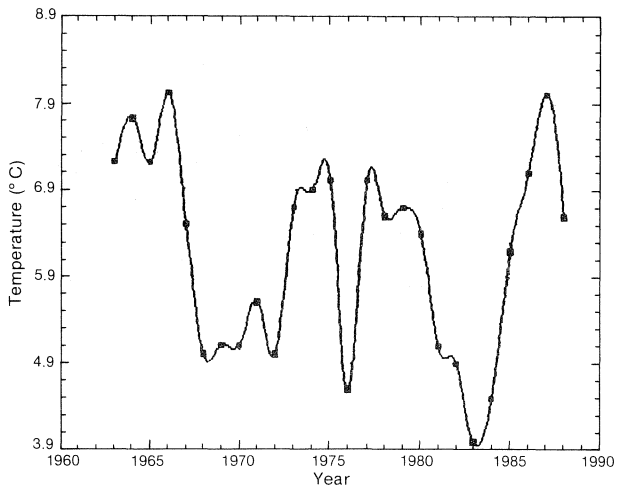

Fig. 6. Godthaab mean air temperature for August 1963-88.

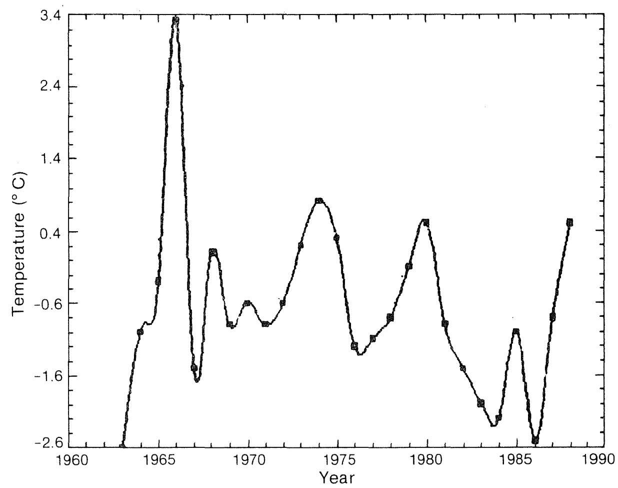

Fig. 8. Godthaab mean air temperature for October 1963-88.

and August/September for the mid-June data, and August/September for the November data. Correlation coefficients ranged from +0.19/−0.15 (December) to +0.67 (August)/+0.64 (September) indicating predominantly positive correlations between both time-series. The highest correlations were found for May (+0.63) and August (+0.67) for the mid-June data, and for August (+0.57) and September (+0.64) values for late-summer (November) data.

The correlation spectrum for the mid-June data (Fig. 4) might indicate that the air temperatures in May influence the mid-June ocean temperatures, whereas the August air temperatures are determined by the thermal history in mid-June. Based on the assumption that late-summer air temperatures are indicative of the ocean temperature conditions found in November, the time-series analysis of air temperatures was continued to the extent of the August and September data from 1963-88 (Fig. 6 and 7). The figures point at a cooling tendency which was already present in the 1987 data of September air and ocean temperatures. However, when RV *Walther Herwig* performed its annual groundfish survey off West Greenland at the end of October/ beginning of November (Fig. 8), upper ocean temperatures were anomalously warm in the 0-200 m layer (Fig. 9). In October 1988, the West Greenland area experienced a strong inflow of warm Irminger Water, which was reflected in high temperatures (Fig. 10) and salinities at Fylla Bank Section Station 4 from 75 m downwards. Therefore, it is indicated that the high ocean temperatures in October are due to advective processes and the surface layer is heated from below. The atmospheric cooling during November affected the same depth range of the upper surface layer and led to temperature anomalies as displayed in Fig. 9. However, both October and November data sets correlate in the same way with the air temperature time-series (Fig. 5)

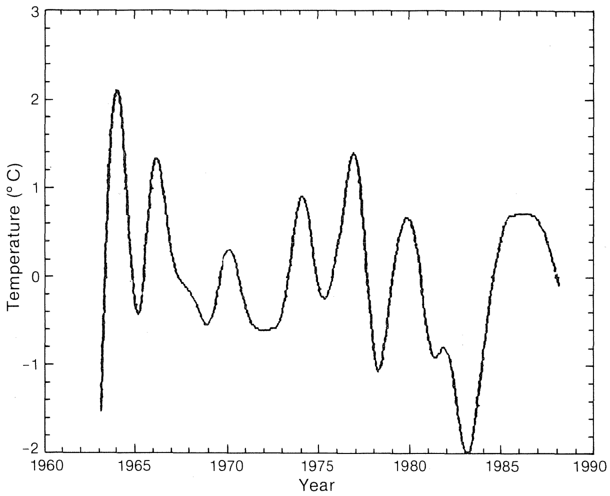

Fig. 9. Smoothed temperature anomaly time-series in the 0-200 m layer at Station 4 of Fylla Bank Section, 1963-88.

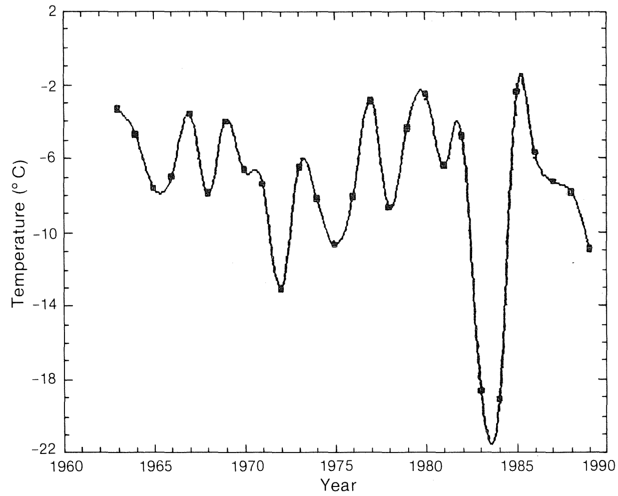

Fig. 11. Godthaab mean air temperature for January 1963-89.

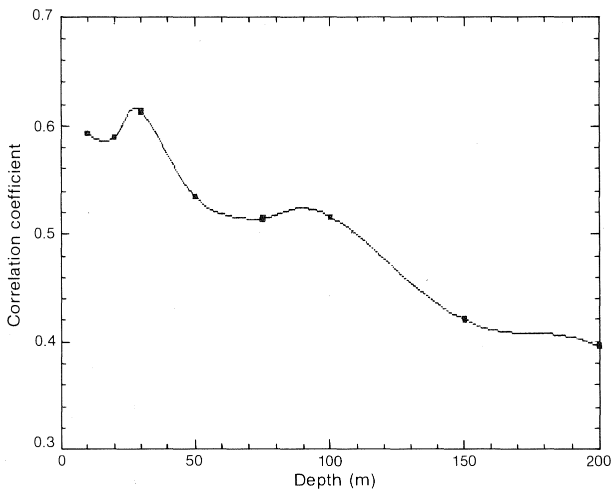

Fig. 10. Correlation spectrum at Fylla Bank for 0-200 m for the November mean air temperatures.

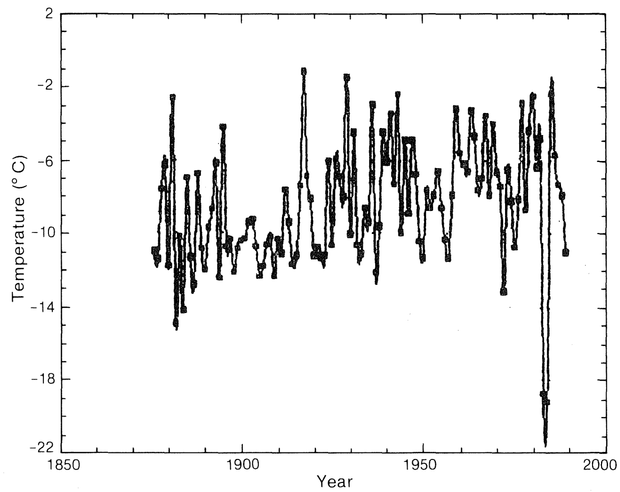

Fig. 12. Godthaab mean air temperature for January 1876-1989.

and thus confirm the predicted trend as statistically indicated from the August/September air temperatures. Air temperature in following months decreased drastically (Fig. 11). This confirms the cooling trend as postulated from the upper ocean/late summer air temperature scenario.

Are we facing a new cold epoch off West Greenland?

The January and February 1989 air temperatures suggest this trend. The entire January air temperature time-series at Godthaab (Fig. 12) from 1876 onwards indicates a continuous up and down of warm and cold winter periods. It shows the extreme cold anomaly of the early-1980s, which is unique in the course of the 114 year time-series. Additionally, the most recent trend suggests another cold winter period to come.

On the other hand it indicates that an overall warming trend prevailed in the January time-series. Using a linear model, a general warming which amounts to 0.03° C per year is observed (Fig. 13). Considering the annual spectrum of warming per year as shown in Fig. 14, the winter months of December, January and February stand out as those of the year where the warming trend is ⩾0.03° C per year. These values clearly differ from those of the rest of the year, which do not exceed 0.01° C per year. It would appear that this warming is due to the so-called "Greenhouse-Effect" which affects the cold season to a considerably larger extent (Fig. 14) than the warmer seasons. This overall warming might also be detectable in the ocean temperature time-series. However, analysis of the comparatively short ocean time-series for June reveals this general warming trend, i.e. +0.004° C per year (Fig. 15).

As for the November conditions, the time-window enables a look at a cooling trend which amounts to -0.01° C per year (Fig. 16). The problem of a reduced time-window is shown in Fig. 17 which displays the past

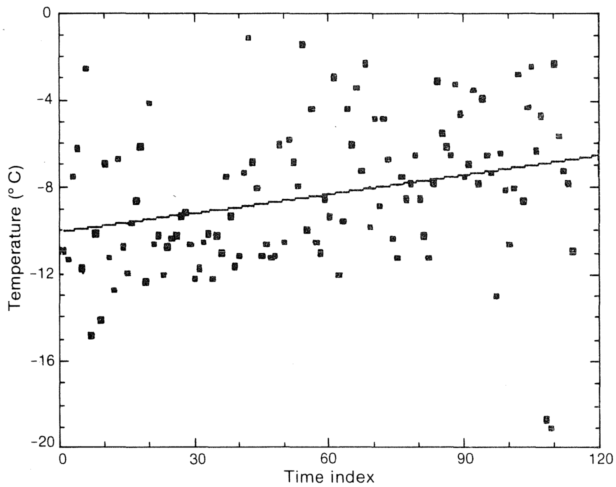

Fig. 13. Godthaab mean air temperature for January 1876-1989 based on the linear trend analysis.

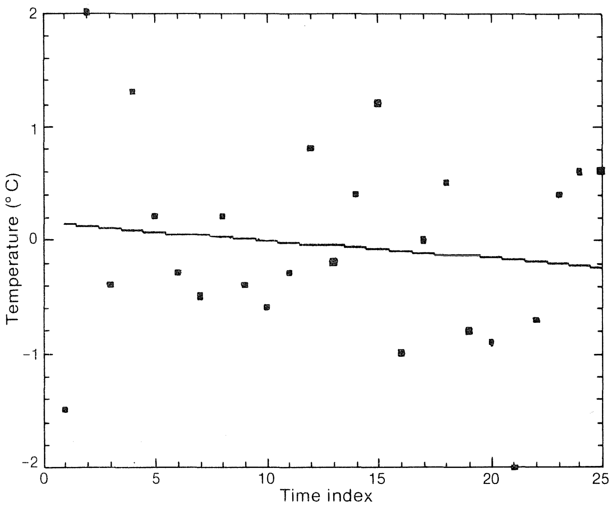

Fig. 16. Fylla Bank November temperature anomaly linear trend analysis.

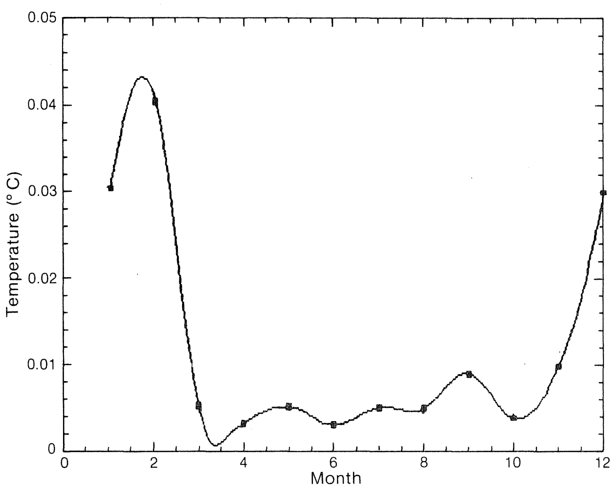

Fig. 14. Spectrum of coefficient of warming in °C per year for Godthaab mean air temperature 1876-1989.

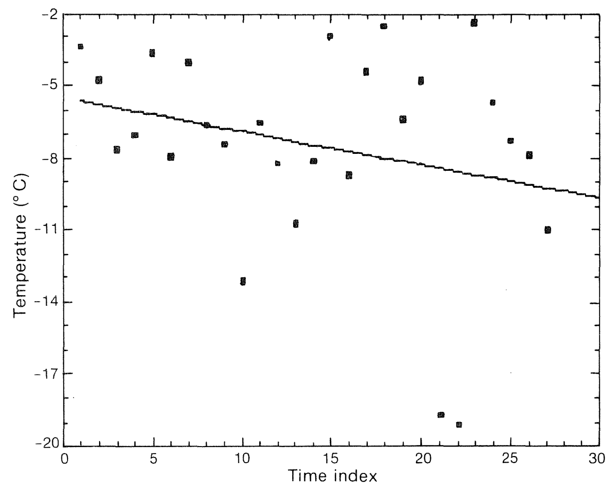

Fig. 17. Godthaab mean air temperature for January 1963-89 based on the linear trend analysis.

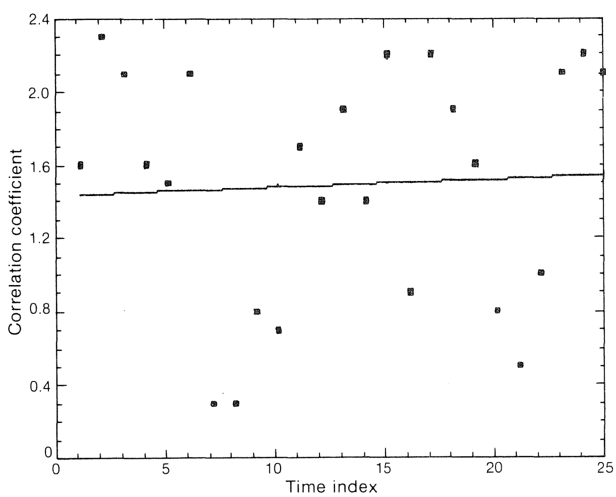

Fig. 15. Fylla Bank mid-June temperature linear trend analysis.

26 years of the January time-series at Godthaab. From these data it would appear that cooling, instead of the afore revealed warming, governs the atmospheric climate of West Greenland during winter season. Especially the anomalous cold temperatures in the early-1980s, plus the most recent thermal scenario from January 1989, determine the negative trend visible in the time-window of the past 26 years. Surface temperature data collected during January 1989 on the West Greenland fishery banks for the area between 62° 50'N and 60° 00'N (Schoene, pers. comm.), indicate a cooled surface layer which ranges from 0° C to -1° C. Air temperatures at sea were well below -5° C, mostly around -10° C. Cold air was mostly advected by strong gales from northwesterly directions. As analyzed by Buch (MS 1987), the temperature of the surface layer, as well as its interannual variations, are very much dependent on the heat exchange between ocean and

atmosphere. During the anomalously cold early-1980s, a stationary cold air mass was located at Egedesminde, West Greenland. This led to heat loss of the ocean.

The 1989 conditions may have been influenced in a similar way. Again a stationary cold air mass was situated above the Labrador Sea area, however, this time it was off Newfoundland. Off the West Greenland coast the atmospheric cooling led to formation of great amounts of sea-ice during February 1989, in areas which normally are ice free during winter.

Conclusions

Based on the present data, the analysis shows that the statistical coherence between air temperature and upper ocean temperatures are a useful tool to estimate future trends of the upper ocean climatic development. Especially the correlation analysis between the November ocean temperature anomaly curve and the air temperatures of August and September which peaks in a very defined time band, yields promising results. With the short time-frame warming/cooling effects of the wind on the upper frictional layer of the ocean (0–30 m) in mind, prediction of ocean surface layer (0–200 m) climatic development seems to be possible.

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