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Variability of Climate - Impact on Cod Recruitment off West Greenland?

by

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Introduction

The northern Northwest Atlantic Ocean is an area where mankind has experienced dramatic changes in climate, both at land-based stations and at sea. There is evidence for human settlement during periods of warming in Greenland, there is loss of life during extreme cold periods in this area. Since the times of Eric the Red 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)**. As the people in Greenland, the marine biota are exposed to climatic variation. Variability of the atmosphere-ocean-kryosphere environment is dependent on various parameters, like solar radiation input and backscattering, ice cover, tides, atmospheric forcing. During the past four decades oceanographic research off Greenland has brought forward our knowledge on scales of this complex system of action and reaction. It is the aim of the present paper to enumerate some of the bits and pieces of this complex scenario and to give indication on possible inter-relationships between processes and forces which form the existing picture of Greenland Waters, and to indicate the means to measure climate changes and potential relationship to cod recruitment off West Greenland.

Scales Of Variability

West Greenland Waters are a compositum of the large-scale circulation of the North Atlantic Ocean, the meso-scale co-existence of warm and cold current components of the West Greenland Current system, and small-scale events like the shifting of water mass fronts, generation of meanders and eddies. Variability in the North Atlantic circulation has recently been treated by **DICKSON et. al. (1988)**. They describe "the Great Salinity Anomaly" in the 1970'ies in the North Atlantic Ocean as largely an advective event, traceable around the Atlantic subpolar gyre for over 14 years from its origins north of Iceland in the mid-to-late 1960s until its return to the Greeland Sea in 1981-1982. The overall propagation speed around this subpolar gyre is estimated at about 3cm s^{-1}. Whereas this variability is in the range of decades, the meso-scale variabilty in West Greenland waters is visible in the semi-annual signal of the two current components, the cold East Greenland component, and the Irminger component. **BUCH (1982)**, and **STEIN and BUCH (1985)** note that the cold , near-coastal component attains its maximal influence on the West Greenland Current in early summer (June), whereas the warm component is of maximal influence in late autumn (November). On the small-scale, the influence of changing wind direction on the Ekman layer has been shown by **STEIN and BUCH (1985a)** and is discussed by the same authors in a recent paper **(STEIN and BUCH, 1991)**. They observed that due to changing wind direction advective processes took place which affected the upper 20-30m of the water column on the time-scale of less than two hours. Solar heating is acting on all three scales (Fig. 1). As shown by **BUCH (1986)** "the warm conditions in the twentieth century are extraordinary, and we must go about 1000 years back in time to find similar conditions, i.e. at the time when Eric the Red colonized Greenland." The climatic time series displayed in the paper covers the time range from 553-1975 A.D. and is based on isotop measurements on ice cores from the Greenland Icesheet **(DANSGAARD, 1985)**. It shows several positive temperature anomalies during the past 1500 years, i.e. between 700 and 800, around 1000, in the 13th century, and in the present century (Fig. 2). These large-scale fluctuations are superimposed on the variations which we observe during the past decades. Solar heating is thus acting on time-scales from hours to centuries, it influences the weather and the climate.

Climate is a question of time-windows. If we look at the time-window of the past 1500 years (Fig. 2), we observe the warmer than normal periods as mentioned above. But we also detect the "Little Ice-age" around 1700, or a similar one around 650.

If we open the time-window of the past 110 years, the thermal records indicate periods of warmer than normal conditions off West Greenland (1923-1969), and colder than normal conditions before and after this period (Fig. 3). Fig. 3, however, also reveals characteristic cold events, two of those being observed during the last 20 years. The first anomaly is part of the above mentioned "Great Salinity Anomaly" **(DICKSON et al., 1988)**, it is an advected event. The second is a local event. As analyzed by **ROSENOERN et al. (1985)**, the anomalous cold conditions found at West Greenland in the early eighties were due to a locally placed cold air mass, with the center near the city of Egedesminde, West Greenland (Fig. 4). The extremely cold conditions in the atmosphere had cooled the upper water masses in the Davis Strait, resulting in negative heat flux and negative temperature anomalies of 1 to 2° K throughout the year, as well as in formation of great amounts of ice **(STEIN and BUCH, 1985; STEIN, 1988)**. The negative heat-flux led to severe ice-formation (Fig. 5).

The air pressure or its gradient, the wind, acts on all scales. Via friction momentum is inferred to the surface layer. As a consequence turbulent mixing and vertical convection take place which are responsible for heat exchange, nutrification of the water column and the thermal part of the circulation. According to the heat distribution on the northern hemisphere, the winds, storms and hurricanes follow the "normal" path from the western to the northeastern North Atlantic, or the "anomalous" path from land to land (Figs. 6 and 7). The examples display the normal northern hemisphere winter situation (Fig. 6), and the anomalous winter situation during early 1990 when the borderline between warm and cold air masses was shifted far to the east. The Icelandic low had increased in size and a high pressure cell was situated in the western Mediterrainean Sea.

Of permanent nature are the tidal forces. For the West Greenland area **BUCH (1982)** gives maximum speeds of 30 cm/s for the 24-hr mean current. Of major influence are the semi-diurnal (M_2) tides which yield 120cm amplitudes for the Nuuk (Godthaab) region.

The Attempt to Measure Climate Changes off West Greenland

Generally, the task to measure climate changes can only be fulfilled by generations, since climate counts on time-scales larger than 30 years. Our work thus can only be a humble enlargement of the recent time-window.

It has been a common feeling in international working groups that Standard Station work is a useful tool to tackle the variability problem. Thus, many nations, among them the Danish, the German and the former USSR have worked since more than 40 years along internationally agreed Standard Oceanographic Stations and Section **(STEIN, 1988)**. On different scales this Standard Station work reveals changes in the physical environment. For the large and meso scale the deepwater sections are used. Inflow and outflow into/from the Labrador Sea/Davis Strait is controlled along the Cape Farewell-Seal Island Section (Fig. 8). Of interest for the West Greenland region is the right part of Figs. 8 and 9. Warmest conditions are found in the core of the West Greenland Current which coincides with highest salinities in the near-surface layers (Fig. 9). It is the amount and annual change of inflowing heat across this section line which is controlled each year when performing the profiling work at the standard stations. Further north, along the Cape Desolation Section and the Frederikshaab Section, the same method is applied to monitor the annual change of heat flowing into the Davis Strait off the West Greenland shelf break **(STEIN, 1991)**. Figs. 10a, b indicate the annual amount of change of inflowing heat (a) and salt (b) to the waters off West Greenland. Anomalies were calculated for the three layers, i.e. the near-surface layer (0-50m), the layer of seasonal variability (0-200m), and the layer where the inflowing Irminger Water is expressed most (200-300m). Qualitatively, both figures show a similar trend: cold, low saline conditions prevailed during 1983 and 1984; since 1986, thermohaline conditions at station 4 of the Cape Farewell Section are above normal with the exception of 1988. On 11 October 1988 salinity in the upper layer (0-75m) was anomalous low. this might represent diluted water of East Greenland Current origin. Changes in the Irminger layer (200-300m) are low. They range from -0.47°K to +0.33°K, and -0.146 PSU to +0.089 PSU.

The data set from the Fylla Bank site (Fig. 11) is the most comprehensive one as considers length of the time-series. The oceanographic conditions at this site are assumed to be characteristic for the middle shelf area off West Greenland. Compared to Fig. 10a, the temperature anomalies of the 0-200m layer at Fylla Bank Station 4 are in phase with Cape Farewell Station 4, indicating that the Irminger component is influencing the hydrographic conditions in the middle shelf area off West Greenland. To extract further information from these data, they are used for correlation with air temperature changes at the neigbouring Nuuk meteorological station. **STEIN and BUCH (1991)** found that August and September air temperatures yield best correlation with the November ocean data down to depths of 75m. The first step for a prognosis was done.

Relationship to Cod Recruitment off West Greenland

If we look through the time-window of the last 30 years, there are periods of warming and increasing salinities (Fig. 12). This is the case especially after "cold events" as in the early seventies and early eighties. Is cod recruitment coupled with increased inflow of Irminger water to West Greenland? In a recent paper **STEIN and MESSTORFF (1990)** discuss relationship of fluctuations in cod recruitments off West Greenland to long-term variations of the physical environment. They observe that warm/saline and cold/diluted periods in the oceanic climate lasted for about 3 to 5 years. A similar 3-5 years periodicity was observed for strong cod year-classes through 45 years up to 1973. If we add to Fig. 3 the so-called "good cod year-classes" which appeared in West Greenland waters **(SCHMIDT, 1966; 1968; 1969; 1971)**, it would appear that they were mostly living during the warm period, the period which ended 1969. When mean temperature fell below the zero-line (Fig. 13) good year classes were observed at times after cold events.
Bearing in mind the linkage between air temperature and ocean surface temperatures, it would appear that the temperature anomalies given in Fig. 10a with a positive trend, on a longer time scale might still have a downward trend.

Conclusions

Normal means for the climate of West Greenland high variability which led during the past 1500 years to warm and cold phases. There is no stable Greenland climate as outlined in Fig. 2 from the middle of the 6th century until present. Normal for the region are events which may lead to catastrophical cooling, e.g. 1983, 1984 with lethal consequences for fish. And economical consequences for fishery? Part of the events are the extreme hurricanes as observed during 1989 and 1990 (Fig. 7). They hinder fishery. Although it is not climate impact on fishery but weather impact, in the balance it counts negative for fishery.
The downward trend in the annual mean temperatures as observed since 1969 (Fig. 3), and the linkage between atmosphere and ocean, might

indicate regional cooling which takes place in the Davis Strait. This cooling might favour the decline of certain demersal fish stocks, such as the Greenland cod.

Which are the deficits? First steps are made to estimate phase-time spaces on a prognostic basis. However, at the time being correlations are not possible for fish/environment relations due to the short time-scales and the limited dimensionality of the available models.

Observations on the small-scale are underrepresented in the West Greenland region. They must be performed to better understand the dynamics of the system. The spectrum of measured parameters is unsufficient. Is it only temperature, salinity, current flow and meteorological forcing which plays a role in the survival rate of cod? Is there a chance for "clean" biological time series for correlation with physical time series? Is there a chance to eliminate the anthropogenic part in the fishery data to get time series free of fishery effects? To clearly indicate in Fig. 13 the origin of cod in the West Greenland waters, whether they result from West Greenland spawning grounds or are advected from East Greenland/Iceland waters, a dicrimination between immigrants and local, West Greenland populations would be necessary. This could clarify the problem whether climate change plays a role in the reduction of West Greenland cod stocks.

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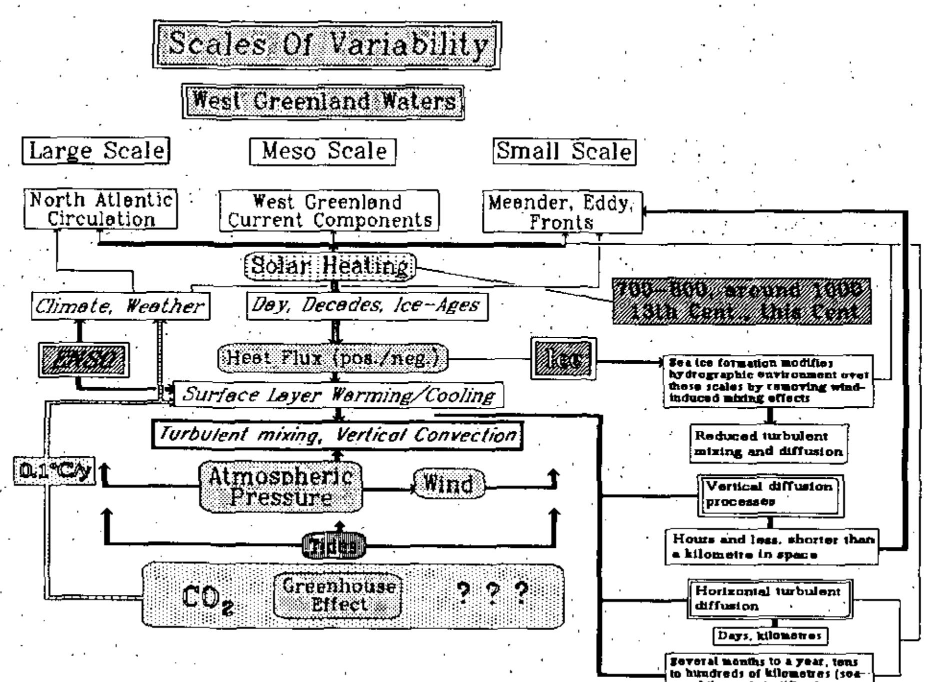

Fig. 1 Scales Of Variability in West Greenland Waters

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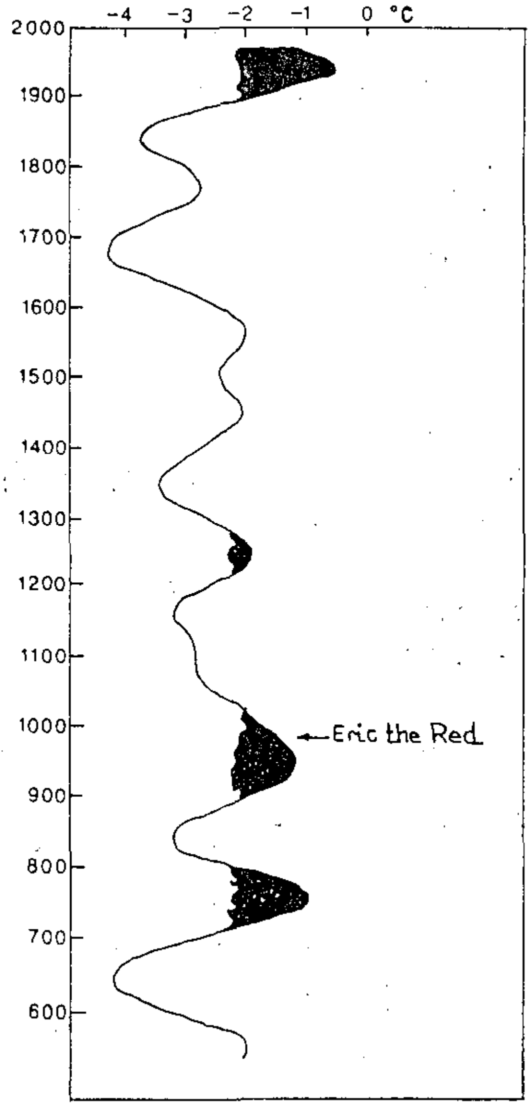

Fig. 2 Climate in Greenland from 553 - 1975, evaluated from isotop measurements on ice cores from the Greenland Icesheet. Blach areas indicate positive temperature anomalies. After DANSGAARD (1985)

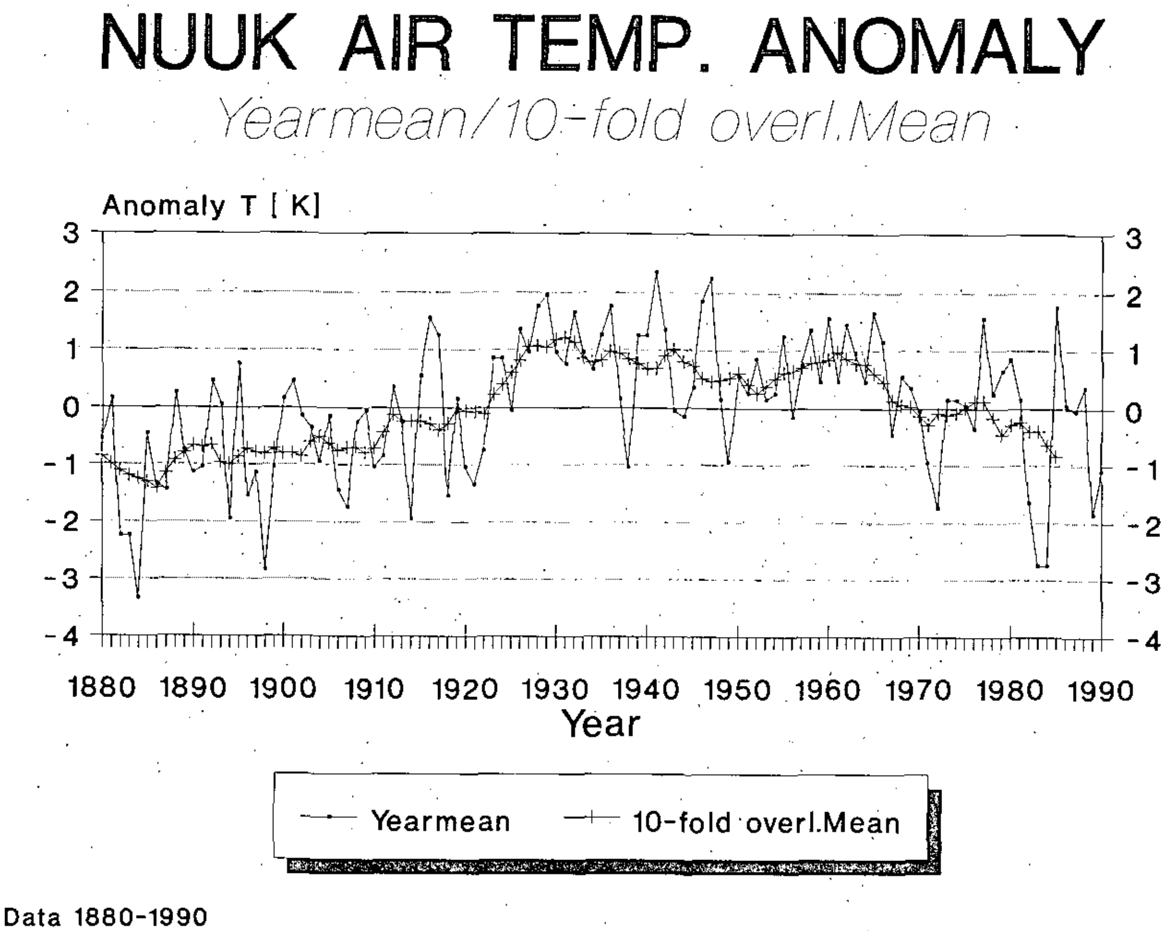

Fig. 3 Nuuk Air Temperature Anomaly, Yearmean and 10-fold overlapping mean.

Fig. 4 Anomalies of mean air temperature (°K) of January-February 1983 in the Arctic region.

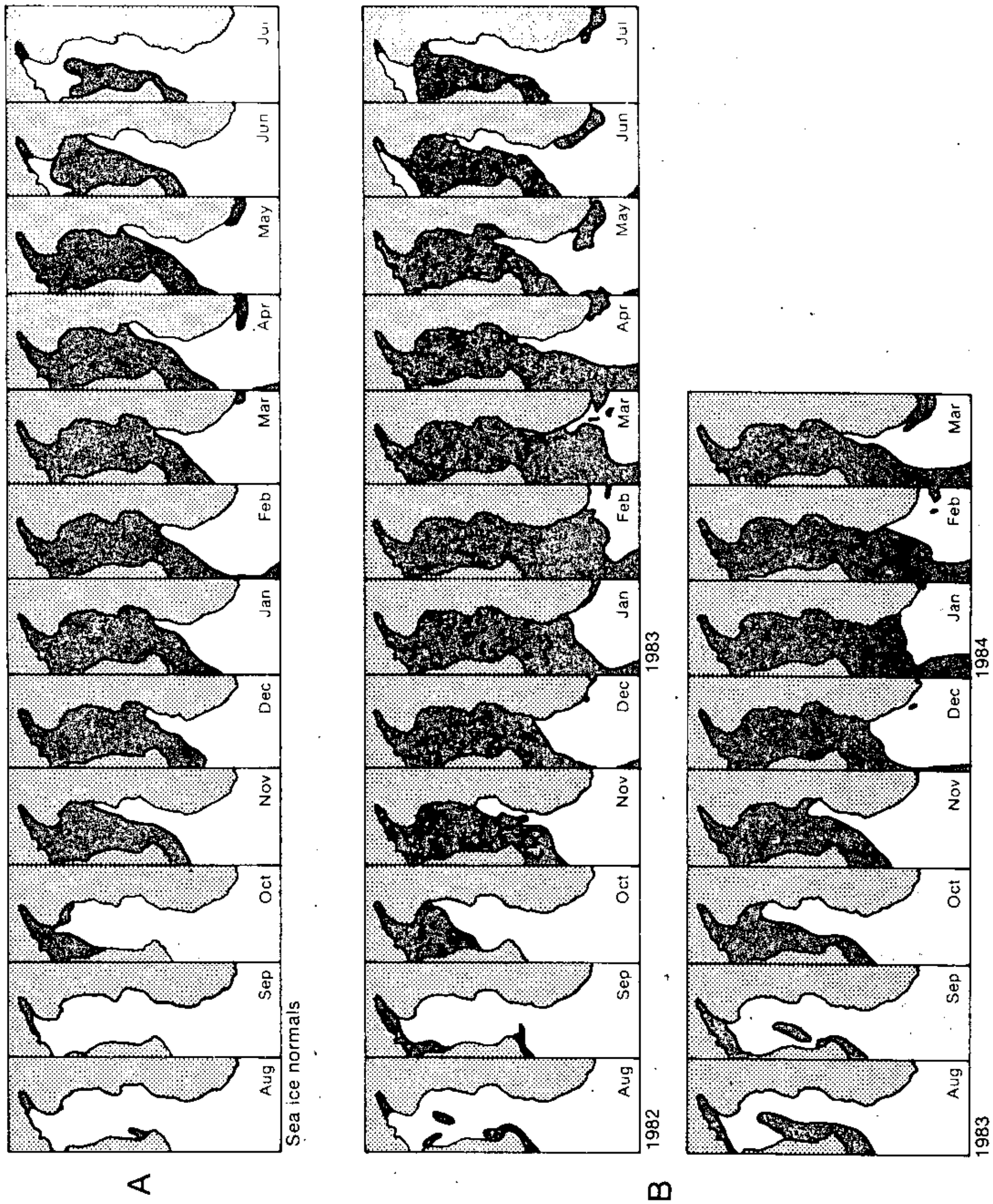

Fig. 5 Sea ice distribution in the Davis Strait. (A) normal distribution through the course of a year, (B) distribution during the period August 1982 to March 1984.

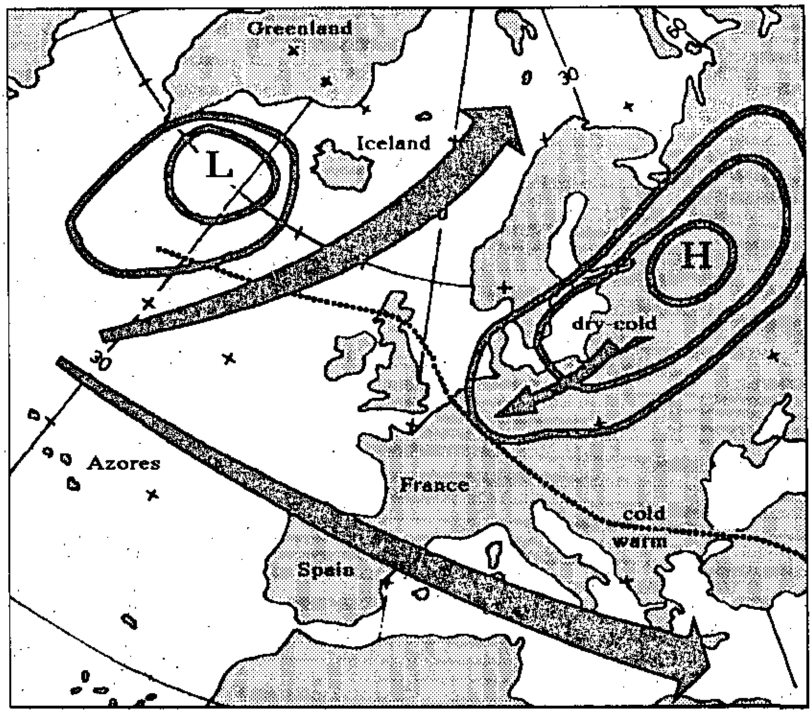

Fig. 6 Generalized air pressure distribution, bottom air temperature boundary and storm tracks during a normal winter over the North Atlantic and Europe.

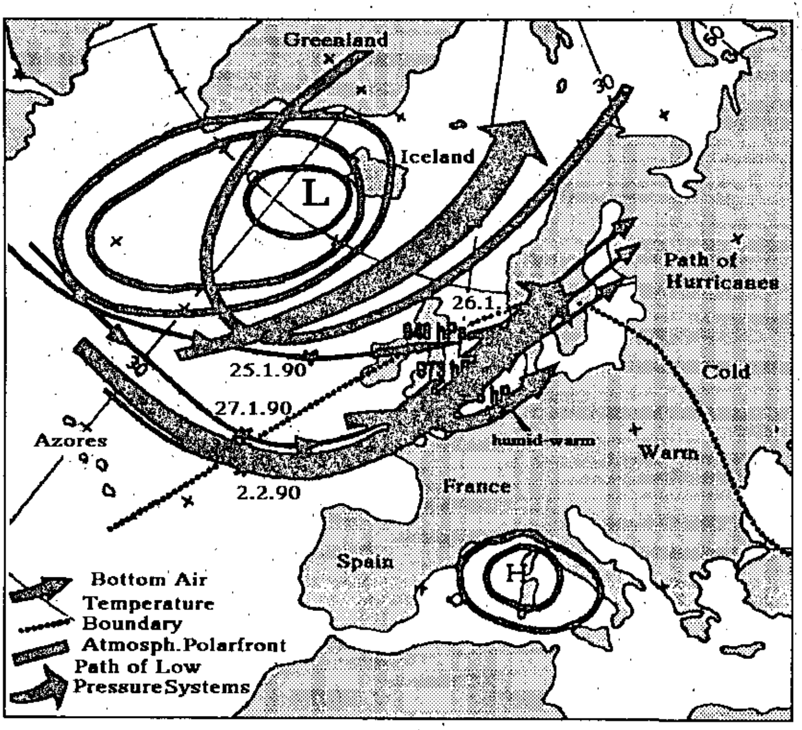

Fig. 7 Air pressure distribution, bottom air temperature boundary and storm tracks during winter 1990 over the North Atlantic and Europe.

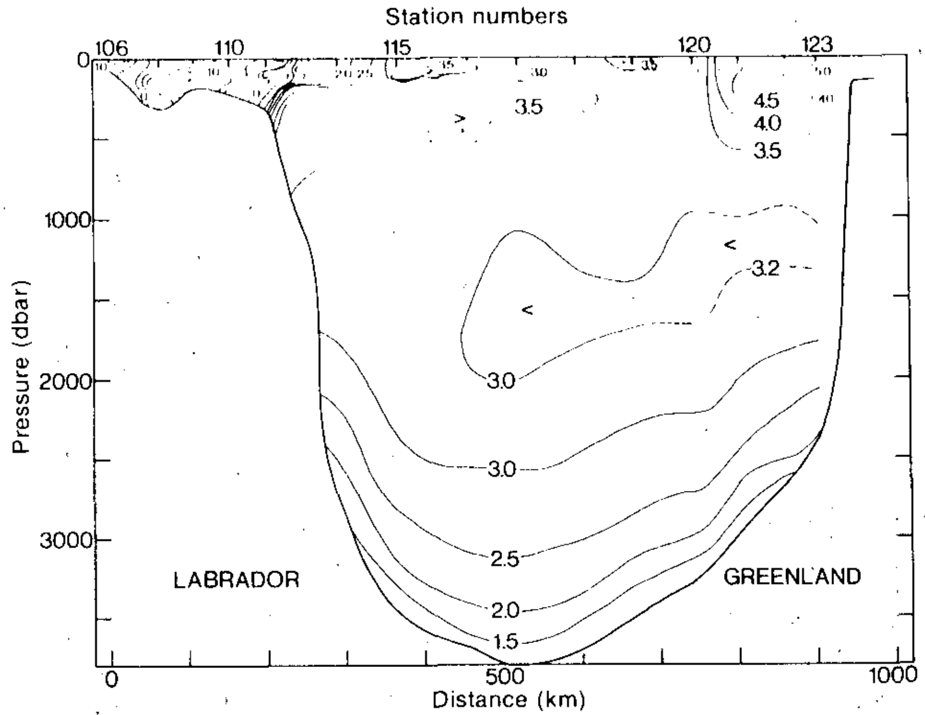

Fig. 8 Potential temperature along the Seal Island-Cape Farewell Section, 6-8 November 1984.

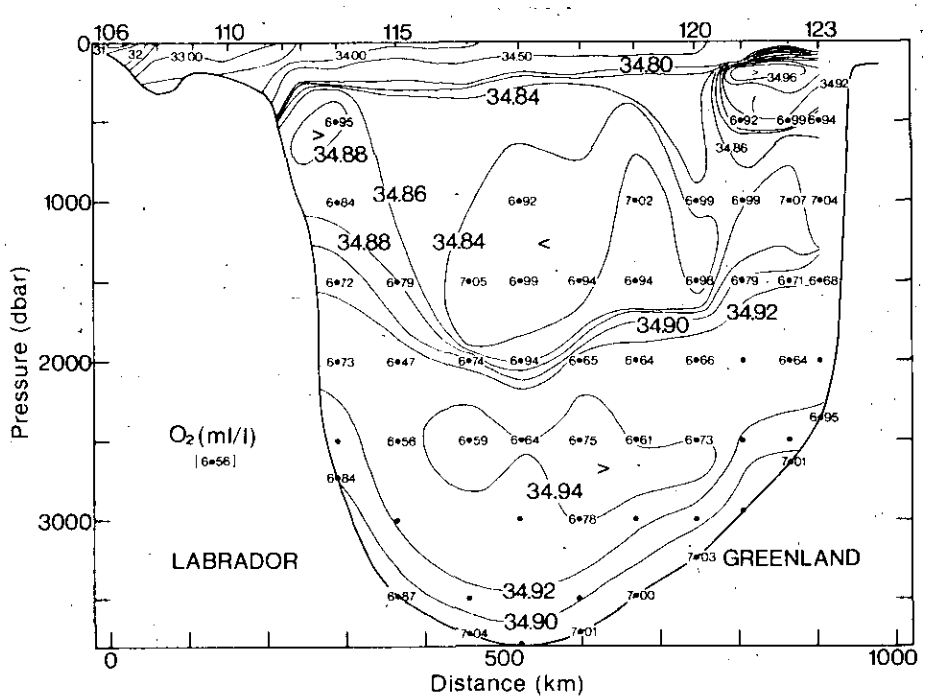

Fig. 9 Salinity and oxygen along the Seal Island-Cape Farewell Section, 6-8 November 1984 (dots indicate depths of calibration samples).

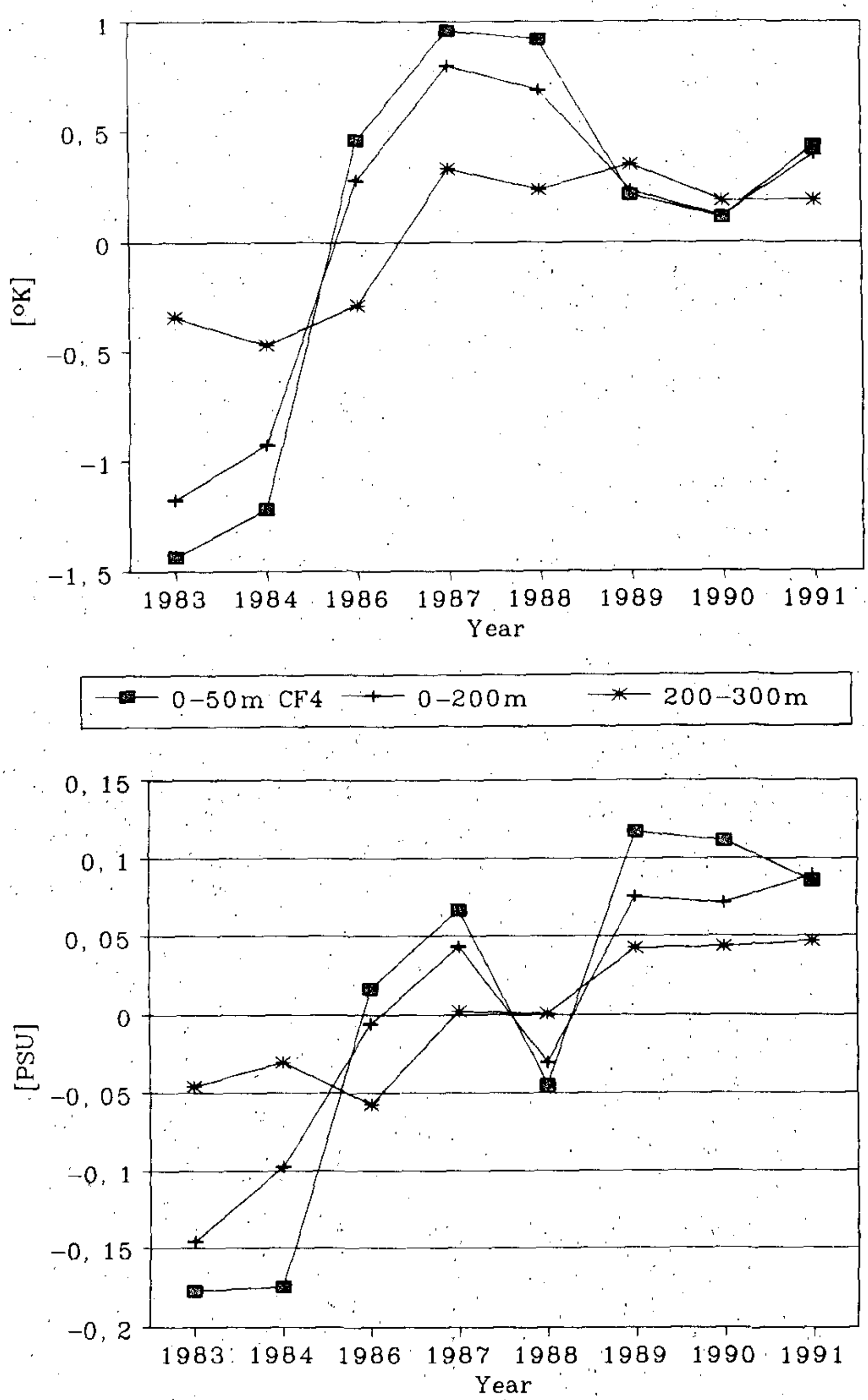

Fig. 10 Annual variability of heat (A) and salt (B) flow to the waters of West Greenland for three different water layers 0-50m, 0-200m, 200-300m.

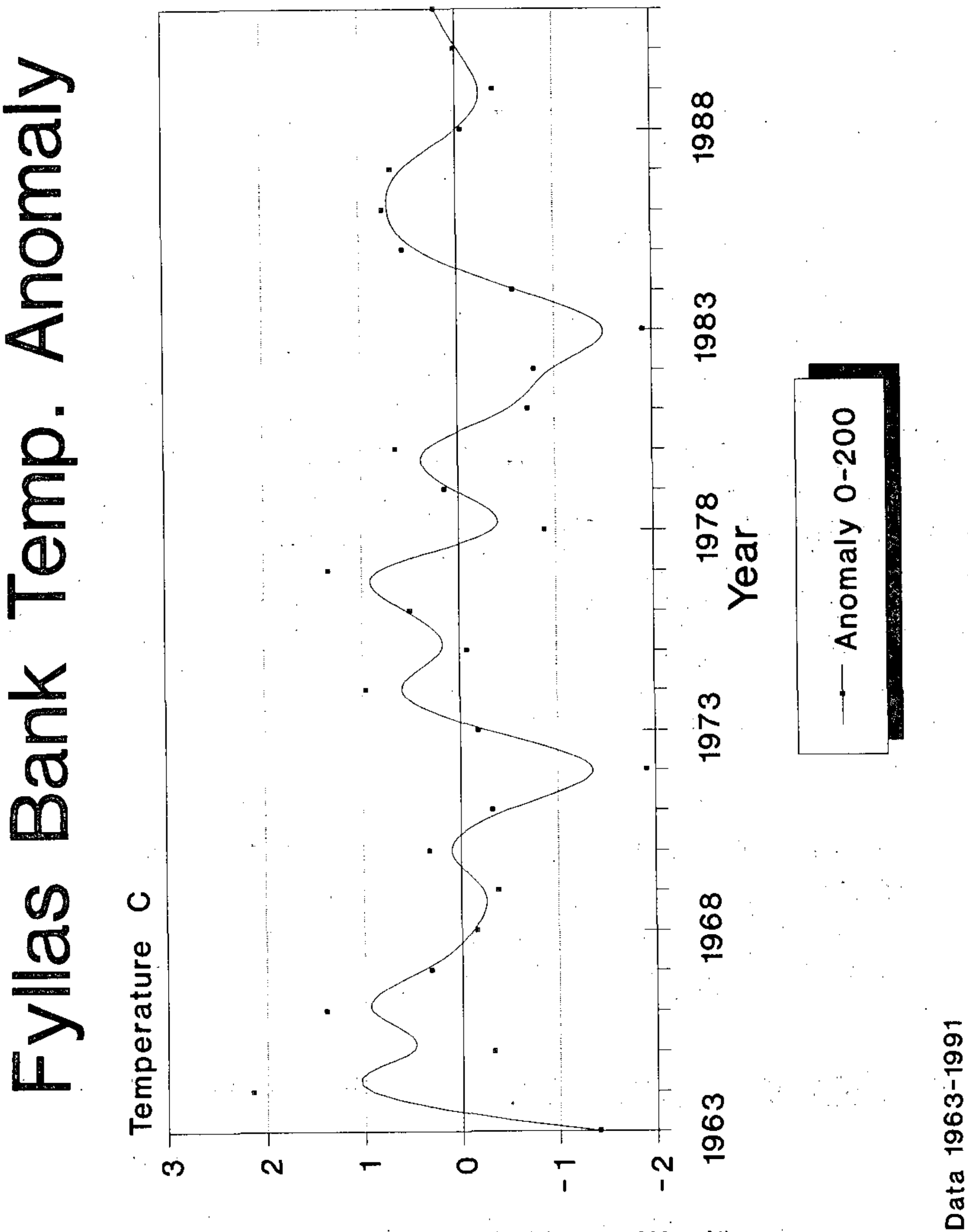

Fig. 11 Interannual variability of temperature anomaly of the upper 200m of the ocean on Fylla Bank/West Greenland between 1963 and 1991.

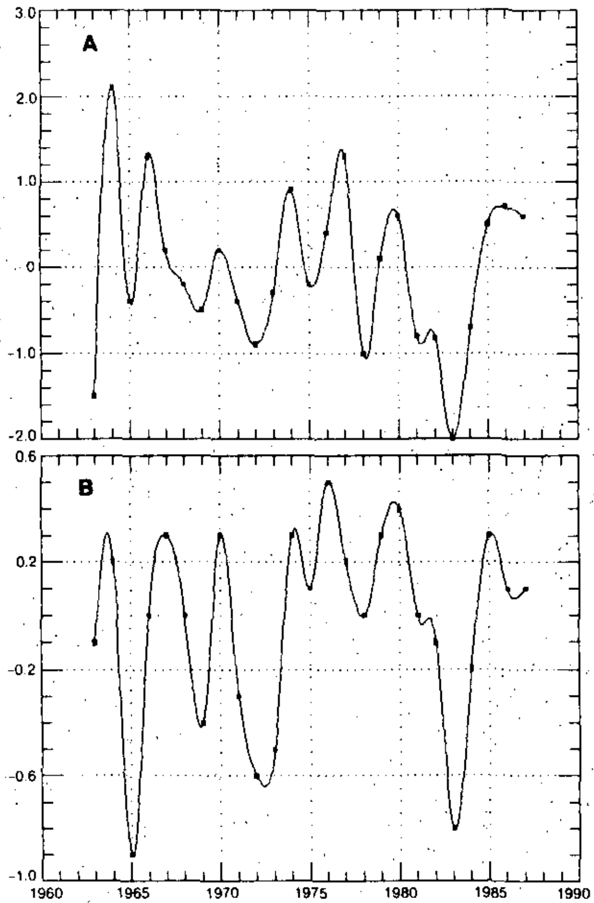

Fig. 12 (A) Mean temperature anomaly and (B) mean salinity anomaly (0-200m) from 1963 to 1987, Fylla Bank.

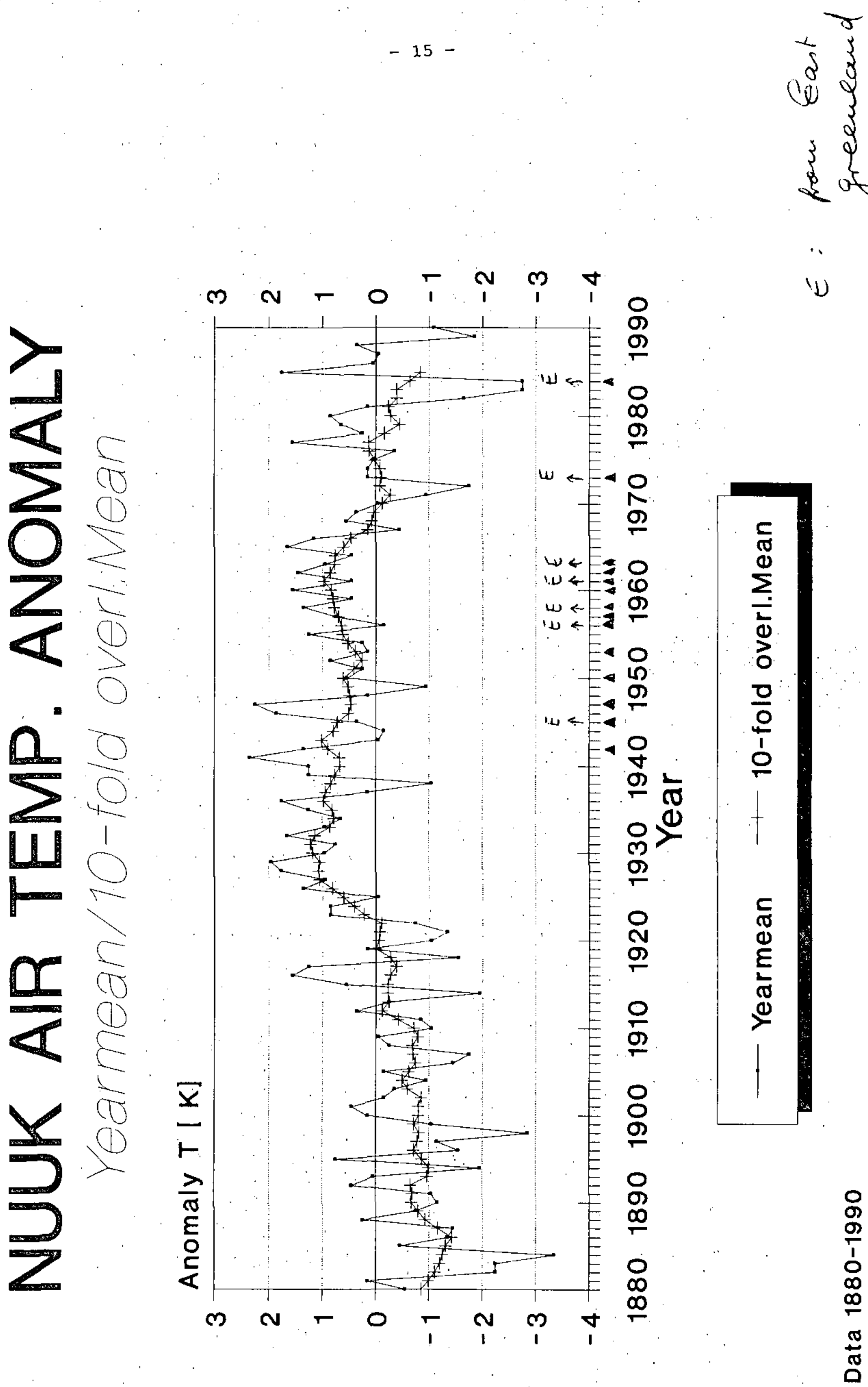

Fig. 13 Nuuk Air Temperature Anomaly. Yearmean, 10-fold overlapping mean and strong cod year-classes.