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Northwest Atlantic Fisheries Organization

Serial No. N847

NAFO SCR Doc. 84/VI/59

SCIENTIFIC COUNCIL MEETING - JUNE 1984

1983: an unusual year off West Greenland?

by

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Abstract

Based on a Danish/West German time series of temperature and salinity data at the NAFO Standard Oceanographic Station 4 west off Fylla Bank the year to year variation of both parameters is discussed. By means of a stability analysis the preconditions for winter convection which might influence the strength of West Greenland cod year classes are inspected. Strong negative anomalies of temperature and salinity since 1981 which yield a maximum during 1983 are explained due to variations of the East Greenland component of the West Greenland Current system, and due to regional meteorological anomalies.

Introduction

Observations on the physical oceanographic environment of the waters off West Greenland were mostly carried out in conjunction with biological programs. The measurements of the vertical temperature and salinity profiles were partly done along Standard Sections on Standard Oceanographic Stations which are listed in ICNAF Selected Papers No. 3, 1978. The bulk of the existing temperature and salinity data originates from the Standard Section Fylla Bank especially from Standard Oceanographic Station 4 at 63° 53' N, 53° 22' W (fig. 1). This station which is located at the shelf break off West Greenland was occupied most frequently throughout the last century primarily by Danish research vessels and vessels from the USSR and the Federal Republic of Germany. Whereas a large amount of publications dealt with the summer situation on Fylla Bank (e.g. Hermann, 1967; Hermann, 1969; Hermann, 1972; Alekseev et al., 1972; Buch, 1982), less attention has been paid to the autumn conditions in this area. The Danish and the West German data available to the authors were therefore composed to enable a closer view to the autumn conditions at Fylla Bank station 4. The range of observation starts in 1963 and covers the last twenty years. Only for 1972 no data are available for station 4. Based on these data which were collected between the mid of October and the beginning of December, the present paper considers mean conditions of the physical environment and the year to year variations in the vertical structure of the water column at station 4.

General circulation off West Greenland

Since the hydrograhy of the area off West Greenland has been described in detail by the aforementioned authors, only a short description is given here: Mostly influenced by the concurrence of two different water masses, the hydrography of the region west of West Greenland depends largely on the variations of both water masses which jointly form the West Greenland Current system (fig. 1). Being composed of the polar component of the East Greenland Current and the warmer Irminger component, both water masses round Cape Farewell (fig. 1) and flow north-westward as the West Greenland Current. The East Greenland component of this current is mostly confined to the shelf area off West Greeland, whereas the Irminger component leans against the shelf break on its way to the north. The seasonal variation of the thermohaline structure is mainly influenced by the seasonal periodicity of the two currents (Buch, 1984) as well as by the discharge of icebergs, the formation of sea-ice, the wind stress and the seasonal variation of the solar radiation. Due to the major heat input during the months of June to October (Buch, 1982), a thin surface layer of 3°C to 5°C is formed which inhabits the upper 40m of the water column. During winter (January to March) the surface layer is cooled reaching temperatures below 0° C, often below -1°C. The temperature minimum occurs mostly during February. Below the surface layer the maximum temperatures are observed during autumn and the beginning of winter when temperatures above 5° C are measured in depths below 200m. This indicates the strengthened influence of the Irminger component which dominates the deep water layers between August and February.

Mean profiles at Station 4

The vertical profiles of temperature and salinity were measured at discrete depths (Nansen bottles) or sampled continously (CTD data). From these measurements standard depth data were extracted and stored in a computer file. Fig. 2 to 4 display the mean profiles of temperature (°C), salinity ($S*10^{-3}$) and density (σ_t) versus depth. The first data column to the right of the plot gives the mean values of the individual parameters T, S, σ_t, the second column indicates the variance of the mean.

a) Temperature (fig. 2)

The year to year variation of temperature is expressed most within the upper

200m of the water column. With a variance of approximately 1 the annual fluctuation is less than the mean temperatures. Below 30m water depth the variance keeps within 50% of the mean values. Temperatures above 5°C outline the upper limit of the Irminger component of the West Greenland Current which is located at about 300m depth. The temperature maximum is found at a depth of 400m with a temperature of 5.3°C. According to the aforementioned ICNAF Selected Papers No.3,1978, the depth at station 4 is 605m. Discrepancies with regard to the maximum observed depth occur during our time series. The major reason for this is subject to inaccuracies of position determination. Due to the steep slope at the station site small errors of position determination might cause large differences in the depth of the station.

b) Salinity (fig. 3)

Within a thin surface layer of about 10m thickness the salinity is less than $33.0*10^{-3}$, indicating the top layer of the diluted waters of land drainage Below 30m water depth the salinity gradient which decreases from $0.01*10^{-3}*m^{-1}$ to $0.004*10^{-3}*m^{-1}$ in the upper 200m marks the transition to the deep water layers.As shown in the vertical temperature profile the upper boundary of the warm water of Irminger origin is found at 300m depth. Salinities between $34.79*10^{-3}$ and $34.93*10^{-3}$ outline the domain of this warm component of the West Greenland Current.

c) Density (fig. 4)

Similar to the salinity profile the σ_t profile shows a homogeneous surface layer of 30m thickness. The upper boundary of the Irminger component emerges with σ_t values of approximately 27.50.

Temperature Time Series

The standard depth data of temperature of the individual years of the time series at Fylla Bank Standard Station 4 are given in fig. 5 (note the change of the depth scale below 200m). Within the upper 50m of the surface water layer six events with temperatures less than 1°C were recorded during the last twenty years. Obviously, there are two events which covered more than one year, i.e. from 1967 to 1969 and from 1982 onwards. In contrast to the cold event at the end of the sixties, the early eigthies for the the first time indicate sub-zero temperatures during autumn. Parallel to the cooling at the surface the thermal influence of the Irminger component on the deep layers decreases. Since 1981 the upper boundary of the warm component of the West Greenland Current (T>5° C) was found below 300m depth. During 1983 no 5°C-water was observed at station 4. A similar stepwise deepening of the upper temperature boundary of the Irminger component emerges in the early seventies which led to the anomalous ice year of 1972. Similar to 1983 no 5°C-water was found during autumn 1973. Ten years before, in 1963, the cooling of the surface layer was accompanied by a reduction of the Irminger influence.

Salinity Time Series

Fig. 6 displays the standard depth data of salinity between 1963 and 1983. In the surface layer five events of low salinity, less than $33 * 10^{-3}$, mark the increased inflow of the East Greenland component off West Greenland or perhaps land drainage or water from the Baffin Current. As shown for the years 1982 and 1983 the low saline water deepens its influence to the upper 75m of the water column. Whereas the thermal situation of 1971 and 1973 is characterized by temperatures above 1°C, the salinity data clearly show the existence of low saline water. Salinities larger than $34.7 * 10^{-3}$ outline the domain of the warm Irminger component of the West Greenland Current. Except for 1969, 1976 and 1979 this component was found at depths below 200m. During the last three years the depth of the $34.7 * 10^{-3}$ isohaline was found between 250m and 400m indicating more or less the mean condition as may be seen from fig. 3.

Temperature and Salinity Anomalies

The temperature anomalies (fig. 7) very clearly demonstrate the outstanding thermal situation during the last three years. Whereas positive anomalies were prevailing during the sixties (1963 excl.) and mid seventies, the cooling of the surface layer from 1981 onwards resulted in anomalies which exceeded -2° during 1983. From the salinity anomalies (fig. 8) it can be concluded that major negative anomalies occurred only in the upper water layers which cover the East Greenland component. For better understanding the approximate depth of the $34.7*10^{-3}$ isohaline has been plotted in fig. 8. With the exception of 1973, 1975 and 1980 all negative salinity anomalies are found above this line. It shows that the early seventies which were affected by anomalous ice seasons (Wolford, 1982), also excelled with a profound decrease of salinity throughout the entire water column (e.g. 1973). In contrast with that the dilution which takes place since 1981 is restricted to the depth range inhabited by the East Greenland component and its transition zone to the Irminger component.

Meteorological events

During the last two decades the hydrographical conditions along West Greenland have been influenced by two meteorological extremes. In the late sixties positive anomalies appeared over the Norwegian- and the Barents Sea (Dickson et al. 1975). The resulting pressure gradient caused a majority in northerly winds pressing large amounts of cold, relatively fresh water out of the Arctic area, i.e. the East Greenland Current was intensified. At West Greenland the result of this event was a great admission of polar drift ice, negative temperature and salinity anomalies. This however does not clearly appear in the autumn anomalies shown in fig. 7 and 8, due to the low intensity of the East Greenland Current at this part of the year (Buch, 1984). The second meteorological event, which we experience right now, is of a quiet different and more direct nature. An analysis of the possible causes and effects of this event has recently been carried out by Rosenoern et al. 1984, from which some of the main points of the meteorological analysis will be outlined here. The analysis is based on observations from the meteorological station in Godthaab. The monthly mean temperatures have since February 1982 been below normal (1931 - 1960 standard period), fig. 9. Especially the winter months January and February have been extremely cold, with the lowest temperatures registrated since regular temperature observations started in 1984, about 12°C below normal. The mean temperature for the whole year was in 1983 3.5°C below normal, which is the third coldest year ever registrated. An analysis of temperatures from other parts of the arctic region, fig. 10, shows that the extreme conditions found at West Greenland is a very locally placed cold eddy, only covering the Davis Strait, Greenland and parts of the northeastern Canada, and the center placed near the city of Egedesminde, West Greenland. The extremely cold conditions in the atmosphere has cooled the upper watermasses in the Davis Strait, resulting in negative temperature anomalies of 1 to 2° throughout the year as well as in formation of great amounts of ice, fig. 11. The last two winters have been the most severe ice winters in Greenland this century, producing great difficulties to the operations of the fishing fleet at the West Greenland fishing banks.

Stability of the Surface Layer

Supposed that the intensity of the winter convection is one of the salient preconditions for a good or a weak cod year class (Meyer, 1968), the stability of the surface water layers during autumn of the year previous to the cod year class should be indicative for good or bad environmental conditions during spawning and larval stage of cod. Since it is mainly the salinity which determines the density stratification at station 4 west off Fylla Bank, periods of strong salinity gradients should parallel weak cod year classes. As shown in fig. 6 during the first decade 1963 to 1973 events of low salinity, i.e. salinity gradients, were prevailing. For closer inspection of the stability conditions during the individual years, the mean stability of the upper 200m of the water column was calculated as well as the variance of the mean density within this layer. Whereas the latter method is a raw instrument to test stable or unstable conditions, the detailed method was performed according to Hesselberg (1918), i.e. stability

$$E = 1/\bar{\rho} * d\rho / dz$$

with $\bar{\rho}$ being the mean density of the individual water layer. From the results of the standard layers (0-10, 10-20, ... , 150-200) a mean value was computed. Both results, the variance of the mean density as well as the stability coefficient are plotted in fig.12. Additionally, fig.12 displays the estimated number of West Greenland cod (at age 3) as published by Horsted et al. (1983). The year class 1973 is marked with an E indicating that this year class represents cod of mainly East Greenland origin. With regard to the oceanographic part of this figure the data are dephased to the corresponding year classes. During the first decade high stability coefficients represent unfavourable conditions for a profound winter convection. This confirms Meyer (1968) who predicted week year classes of West Greenland cod due to increasing salinity gradients. Between 1975 and 1984 the mean stability coefficient was nearly half of that between 1964 and 1974 (dashed line in fig. 12). This might be one of the environmental reasons which led to the strong year classes 1977 and 1979. Especially during autumn 1978 the stability coefficient is very low indicating good conditions for deep reaching winter convection. For the 1981 and 1982 year classes fairly good conditions emerge from the stability analysis, whereas for the 1983 and especially for the 1984 year classes the preconditions for active winter convection are bad ($E = 6.5*10^{-6}$).

Conclusion

The time series of temperature and salinity versus depth indicate an increased cooling and dilution of the upper 300m of the water column during the last three years. A stepwise deepening of the upper temperature boundary of the Irminger component led to intensive vertical cooling of the water column and to the complete absence of 5°C-water at station 4 west off Fylla Bank. Whereas the far-reaching negative temperature anomalies might be a sign of reduced influence of the warm Irminger component off West Greenland during 1983, the salinity trend is opposite. The fact that all negative salinity anomalies since 1981 and especially during 1983 were found above the Irminger component, points at an additional factor of cooling, i.e. of meteorological origin. Besides the intensification of the East Greenland component off West Greenland which led to increasing dilution and cooling of the upper 300m, very cold air masses from Canada placed over Davis Strait seem to be additionally responsible for the far-reaching cooling of the water column at Standard Station 4. The stability analysis yields better preconditions for intensive winter convection for the cod year classes from 1975 onwards than for the previous years. In contrast with this the 1983 observations, however, indicate bad preconditions for active winter convection.

This leads to the final conclusion that 1983, within the frame of the last 20 years, was an unusual year off West Greenland.

Acknowledgements

The authors benefit from discussions with A. Schumacher. B. Schillat prepared the final version of the figures.

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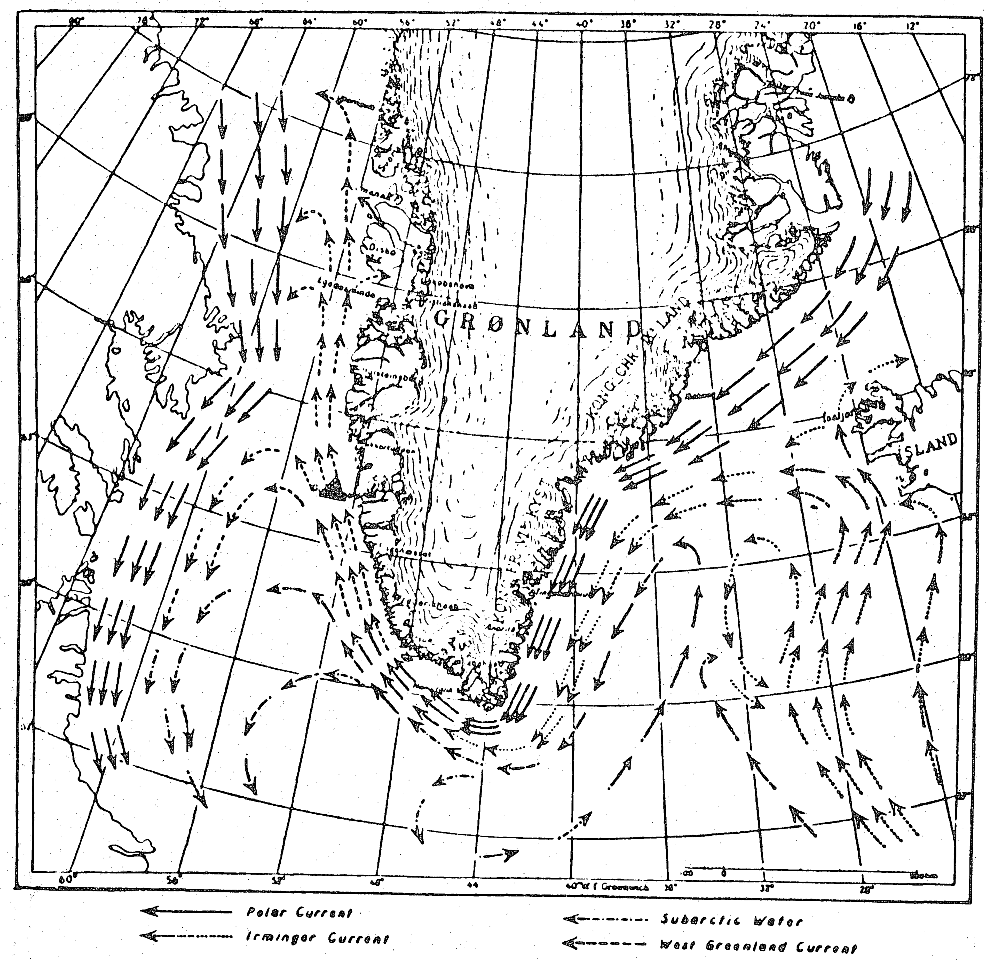


Fig. 1 Surface currents in Greenland waters
(Triangle: Oceanographic Standard Station 4 off Fylla Bank; from Hansen and Hermann: Fisken og Havet ved Gronland)

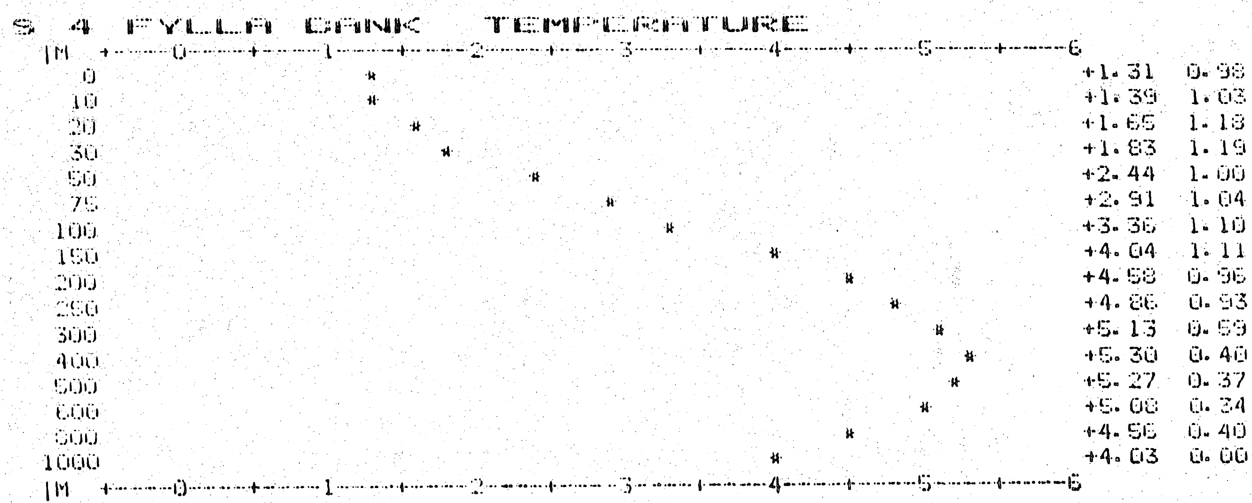


Fig. 2 Mean Temperature Profile at Station 4

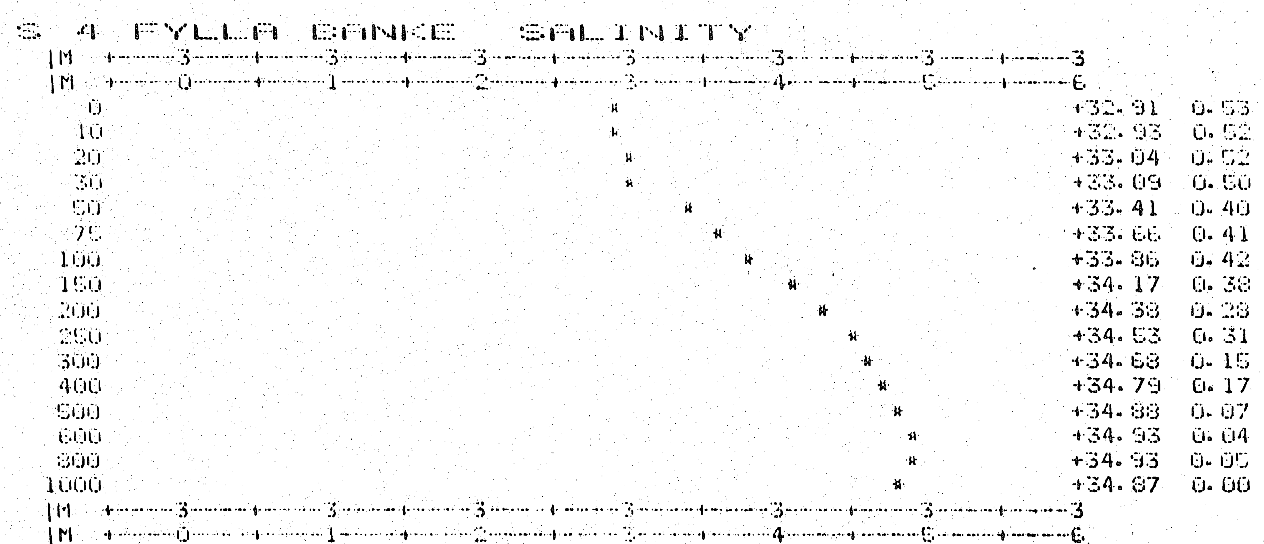


Fig. 3 Mean Salinity Profile at Station 4

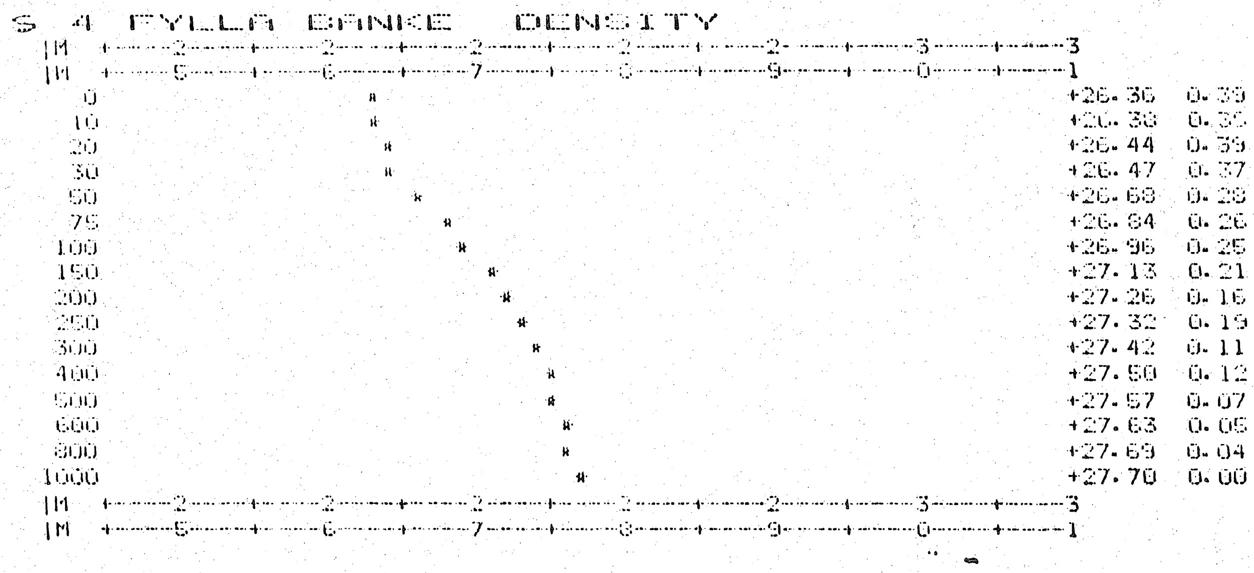


Fig. 4 Mean Density Profile at Station 4

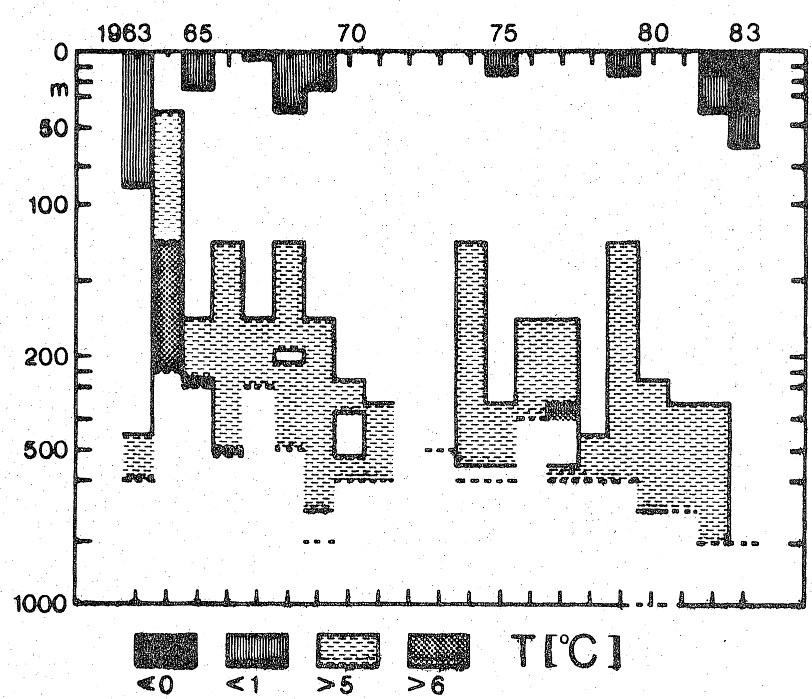


Fig. 5 Temperature/Time/Series at Station 4 (dashed line: max. obs. depth)

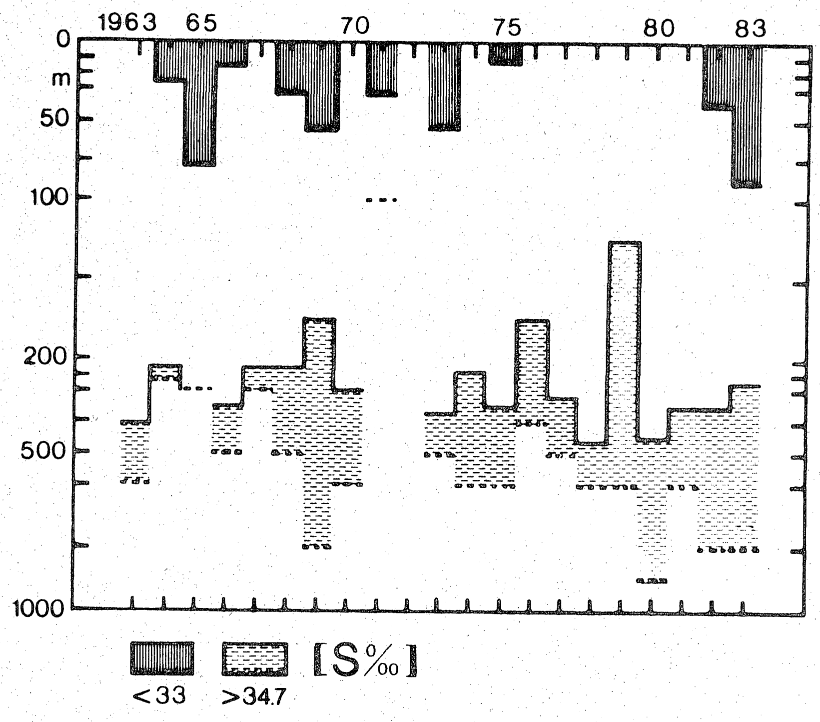


Fig. 6 Salinity/Time/Series at Station 4 (dashed line: max. obs. depth)

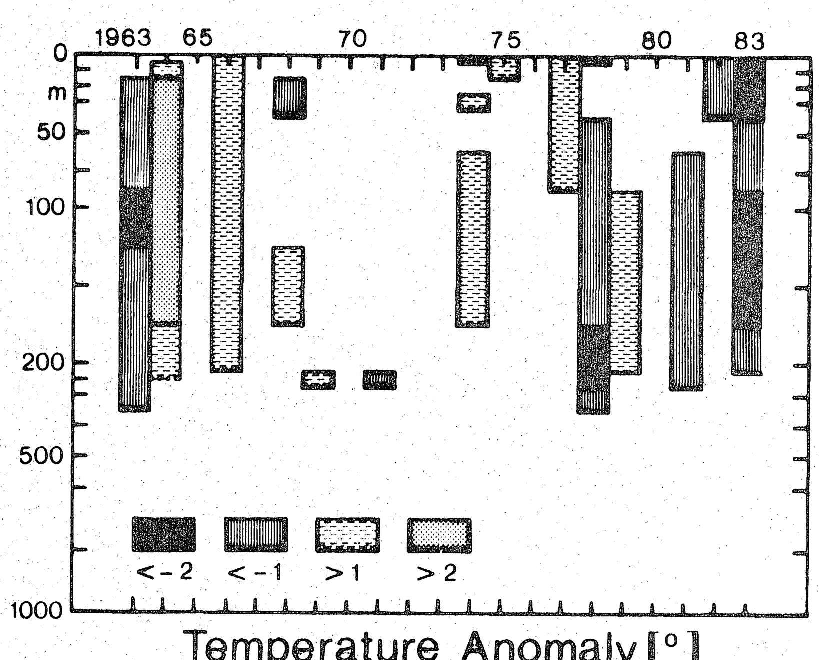


Fig. 7 Temperature Anomaly at Station 4 (dashed line: max. obs. depth)

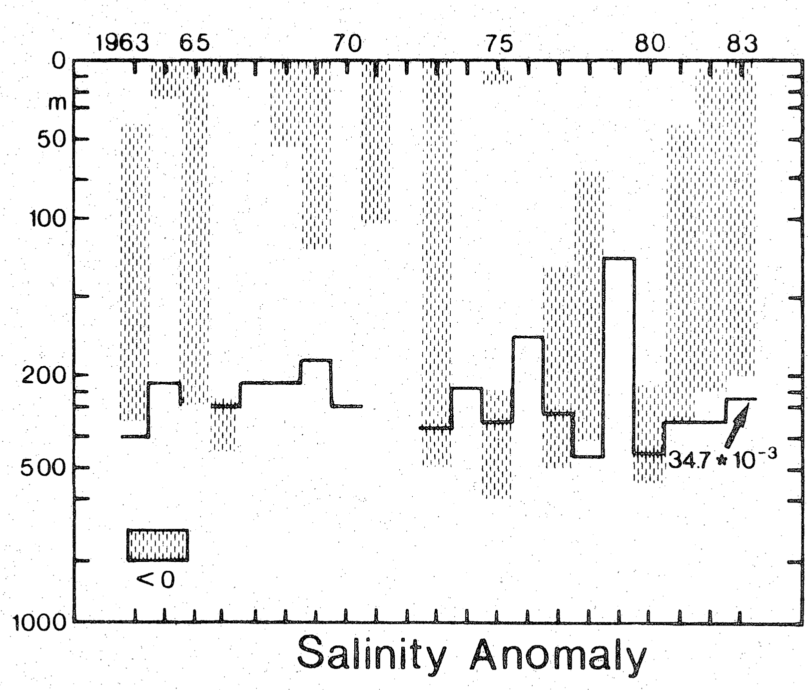


Fig. 8 Salinity Anomaly at Station 4 (dashed line: max. obs. depth)

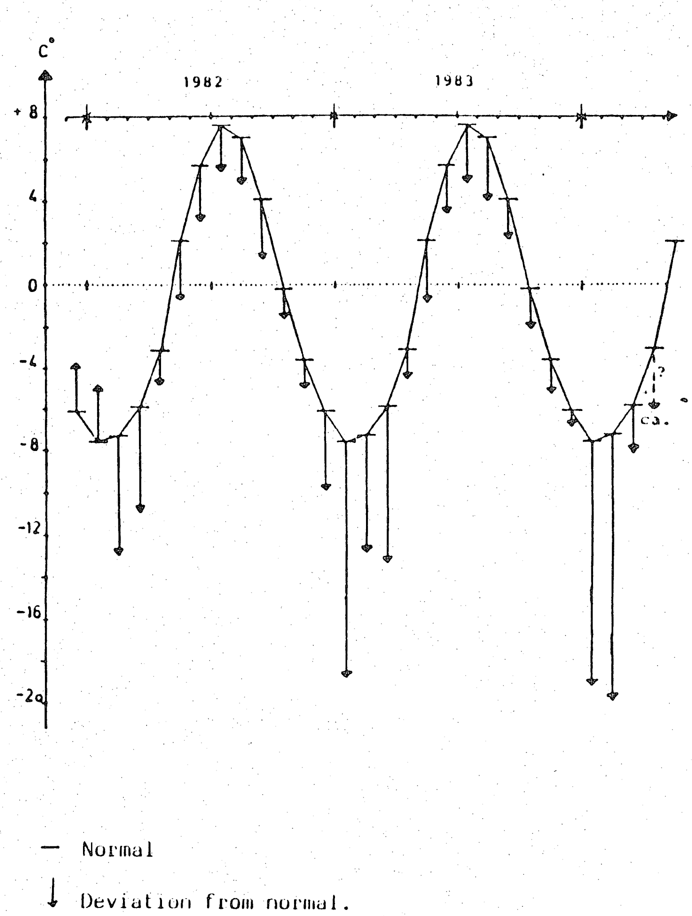


Fig. 9 Air temperature anomalies at the Godthaab station since January 1982

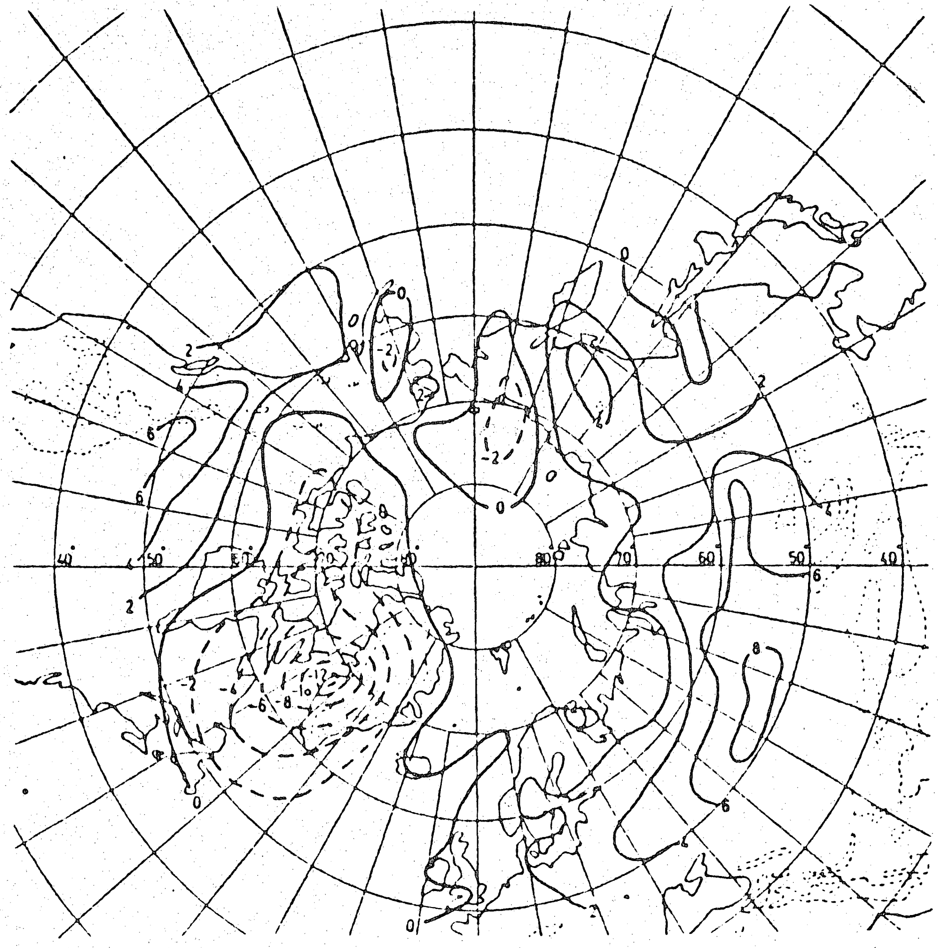
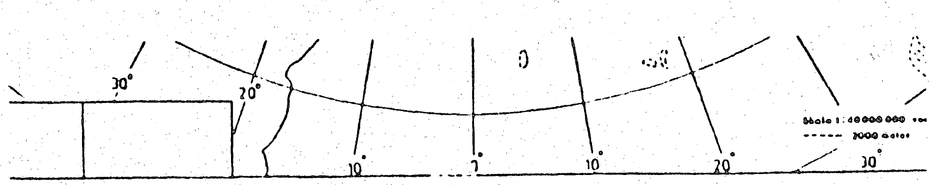


Fig. 10 Anomalies of the mean air temperature of January-February 1983 in the arctic region



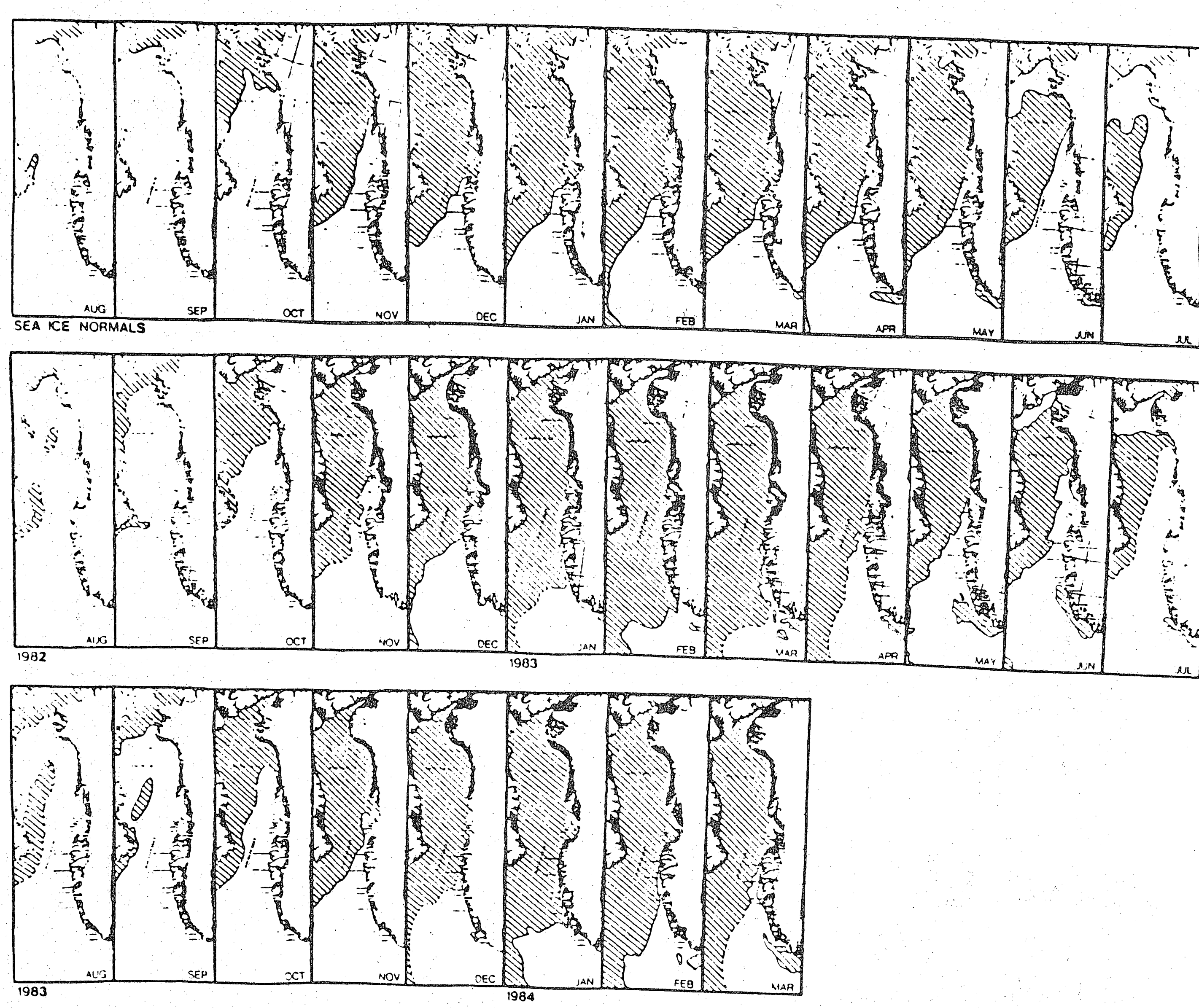


Fig. 11 Sea ice distribution in the Davis Strait. Upper row: normal distribution; middle and lower row: distribution since August 1982

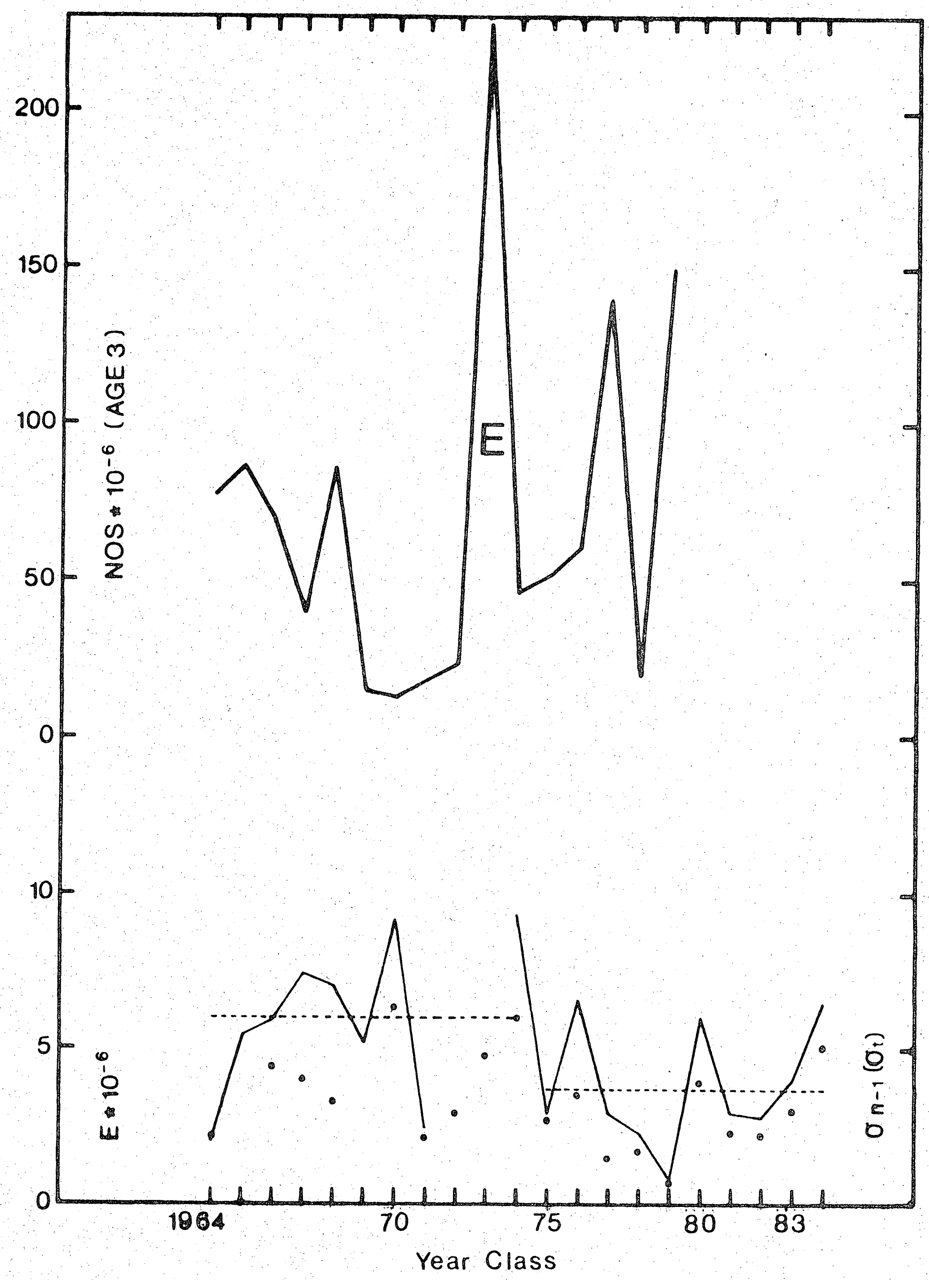


Fig. 12 Estimated year class strength of cod (above, acc. to Horsted et al., 1983); Stability of 0 - 200m water layer during autumn of previous year (below, dots represent the variance of the mean density)