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On the Consistency of Thermal Events in the East Greenland/ West Greenland Current System

by

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Introduction

During the past decade Greenland and Canadian waters experienced a series of anomalous cold ice winters (1983, 1984, 1985, 1991), with 1991 being the worst ice year in 30 years in the Labrador region (**NARANYANAN et al., 1992**). There is evidence that some of these anomalies are travelling along the North Atlantic Current system (**DICKSON et al., 1988**), others are due to regional effects, such as atmospheric cooling (**BUCH and STEIN, 1989**). 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. 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). Since 1963, the Institut für Seefischerei, Hamburg, occupies a set of NAFO Oceanographic Standard Stations in West Greenland waters, and since 1981 a set of national Oceanographic Standard Stations in East Greenland waters.

Part of this standard station work has been compiled to form the database for the present paper (Fig. 1). By means of these data the hypothesis is tested whether thermal events which are observed in the East Greenland Current, can be traced in the West Greenland Current system.

The Data

During the annual groundfish surveys to the waters off East and West Greenland, the Institut für Seefischerei completed CTD profiles at national oceanographic standard stations (East Greenland) and at NAFO standard stations off West Greenland (**STEIN, 1982; STEIN 1988a**). From the database standard depth data were extracted and temperature anomalies were calculated for individual depth ranges. The base period for the mean value is 1982-1989/1990 for East Greenland waters, 1963-1991 or 1981-1990 for the Fylla Bank data, and 1983-1991 for the Cape Farewell station 4. The data represent autum conditions, i.e. September/October conditions for the East Greenland sections, and October/November conditions for the West Greenland sections. The 1981 anomaly value in the East Greenland sections Discord, Bille and Mösting (figs. 2 to 4) was added to show early December conditions.

Results

a) The Hydrographic Situation off East Greenland

The Mösting, Bille and Discord Sections are chosen to demonstrate the vertical mean fields of temperature and salinity. The salinity means represent the base period 1985 to 1990 (figs. 2 to 4). The concurrence of two water masses characterizes the oceanographic conditions along the East Greenland shelf and slope region. The Irminger Current with temperatures above 6°C and core-salinities above 35 PSU intermingles with the cold, diluted East Greenland Current which is the outflow of the North Polar Sea. In a recent paper **STEIN (1988b)** describes the general oceanographic features of this region. The intense mixing leads to leaved structures in the vertical distribution of temperature and salinity (e.g. fig. 2a, b).

b) Annual Variability of Salinity

Table 1 Depth (m) of Salinity r.m.s. Deviation (with r.m.s. < 0.1 PSU)

Section	S1	S2	S3	S4	S5
Mösting	200	250	30	50	30
Bille 150	100	200	10		
Discord	----	----	100	0	

Table 1 displays the variability of salinity along the sections in terms of the r.m.s. deviation. The depth is given where the year-to-year variation is less than 0.1 PSU. Off Cape Mösting the station data S3, S4, and S5 reveal that salinity varies mostly in the wind driven surface layer. The outer positions of the Bille and Discord sections indicate little or no variability above this threshhold value. The inner stations of all sections, S1, S2, and S3 (except Mösting) yield highly variable vertical salinity fields.

c) Annual Variability of Temperature

Off East Greenland the thermal conditions along the Mösting, Bille and Discord section indicate cold events during 1983 and 1984. The 1983 event is documented at stations 2, 3 and 5 of the Mösting section (fig. 5), stations 2 and 3 of the Bille section (fig. 6), and stations 1 and 2 of the Discord section (fig. 7). Off Cape Mösting, anomalous cold conditions were found at stations 1 and 4 during 1984 (fig. 5). Off Cape Bille, stations 1 and 4 reveal a cold event during 1984 with a clear signal at the inner station 1 (fig. 6). The Discord section data enable a clear discrimination between the 1983 and 1984 events along the section, with the inner stations being anomalous cold during 1983, and the outer stations during 1984 (fig. 7). Off Cape Farewell, at station 4 of the section, the years 1983 and 1984 emerge as anomalous cold years as concerns the depth layers 0-50m, 0-200m, and 200-300m (fig. 8).The Fylla Bank section data clearly indicate anomalous low temperatures for the years 1982 to 1984 and 1989 (figs. 9, 10).

Discussion

The drift of ice-floats off East Greenland might be a measure for the surface current speeds in the East Greenland Current, although the influence of the surface winds on the ice-float's drift might play a role. Fig. 11 displays the track of pack ice, which was monitored with a radio beacon. The ice-float passed during 10 days from 65°N to 60°N, which represents a mean speed of 64cm/sec. After passing Cape Farewell, it began to move northwestward, but it subsequently made an anticlockwise loop south of Cape Farewell and then vanished. Along similar paths the surface waters may travel from East to West Greenland. Some current bands may succeed to find their way to the waters off West Greenland and transport "thermal information", such as cold events. On the other hand, there is quite a dramatic change in the horizontal as well as in the vertical distribution of cold and warm water masses. As emphasized by **STEIN (1988b)** there is variability on the small-scale (less than 10 nautical miles). This elucidates the width of polar and subtropical current bands which meet and mix in the area off East Greenland. The oceanographic time-series is thus unfortunately infected by meandering water mass boundaries, or even by the entrainment of water boluses **(STEIN, 1990)**. This might influence the consistency of events along an individual section. Mean temperatures for the individual stations off East Greenland are given in table 2.

Table 2 Mean Temperature (°C) of the 0-200m layer for the East Greenland Sections Mösting, Bille, Discord

Section	**S1**	**S2**	**S3**	**S4**	**S5**
Mösting	3.05	5.34	5.68	6.47	6.65
Bille 2.89	3.94	5.87	6.50		
Discord	2.35	3.25	5.88	6.43	

The inner stations of the sections are influenced by the polar component of the East Greenland Current, whereas the outer stations are under the regime of the Irminger Current. Off Cape Mösting, station 5, which is under the regime of the Irminger Current (6.65°C mean temperature for the 0-200m layer) reveals little change in the thermohaline fields troughout the years 1982-1990 (figs. 2 and 5). The standard deviation of temperature ranges from 0.34 to 0.1 in the 0-200m layer, the variability in the haline field reveals only surface near variation (1985-1990), indicating stable thermohaline conditions in the Irminger component at this site during autumn. Largest interannual variability occurs at station 1 of the Mösting section, with the r.m.s. deviation of the mean temperature being 1.55 at the surface and 0.67 at 200m depth.

Largest variability was observed at station S1 of the Bille section (fig. 6). The temperature anomalies along this section, as well as along the Cape Discord section (fig. 7) yield similar trends as off Cape Farewell (fig. 8): Cold conditions during 1983, 1984 (S1, S2 of the Discord section), and warm conditions from 1985 to 1988 at the outer stations (S3, S4). The years 1989 and 1990 indicate a downward trend off southeast Greenland, as is the case at the Cape Farewell station 4. On the West Greenland side, however, the temperature is still above normal.

Station 4 of the Cape Farewell section lies in the core of the Irminger component of the West Greenland Current **(STEIN and WEGNER, 1990; STEIN, 1992)**. The variability of temperature from 1983 onwards (no observation during 1985) very clearly indicates the cold events in 1983 and 1984, and the warm years 1986 to 1988 in the surface layer 0-50m and the 0-200m layer. Fig. 8 also reveals that warmer than normal conditions prevail in the Irminger layer (200-300m) since 1986. The warming of this layer is postponed by one year as compared to the 0-50m and 0-200m layers.

At Fylla Bank thermal conditions indicate the cold early eighties, and a warmer than normal period from 1985 to 1988. The downward trend, as observed versus the end of the eigthies, is also apparent in the middle off West Greenland. In contrast to the Cape Farewell section this trend implies, however, colder than normal years, especially 1989.

Conclusions

Bearing in mind that anomaly calculations are based on a given time-window (**STEIN, 1992**), the analysis is focussed on this selected period. In areas like Greenland this can imply that warmer than normal conditions take place in a colder than normal period if the time-window is opened wide enough. The data suggest that there is east-west consistency in the cold and warm signals as observed under East and West Greenland.

Consistency of event is high for the Bille, Discord and Cape Farewell sections, and for the Cape Farewell and Fylla Bank section. Consistency is low as concerns the Mösting, Cape Farewell and Fylla Bank sections.

Consistency of event is most expressed on the West Greenland side of the system, since the modification of the water masses is no longer under the regime of two concurrent components, the polar and subtropic parts (Polar Water and Irminger Water) which is the oceanic environment on the East Greenland shelf. The co-existence of polar and subtropic water masses on the East Greenland shelf leads to inconsistencies of events along the sections, especially documented along the Cape Mösting section.

Not covered by this paper, but emphasized in a recent paper by **BUCH and STEIN (1989)**, are regional meteorological events which may lead to negative heat flux from ocean to atmosphere, resulting in tremendous cooling and ice formation. The early eigthies anomaly was induced by this process. Since the core of cold airmasses was placed over the town of Egedesminde (Northwest Greenland), the cooling was more intense on the West Greenland side than on the East Greenland side. This might be one reason for the inconsistency of the 1983 event between the Cape Mösting temperature anomalies and the West Greenland section anomalies.

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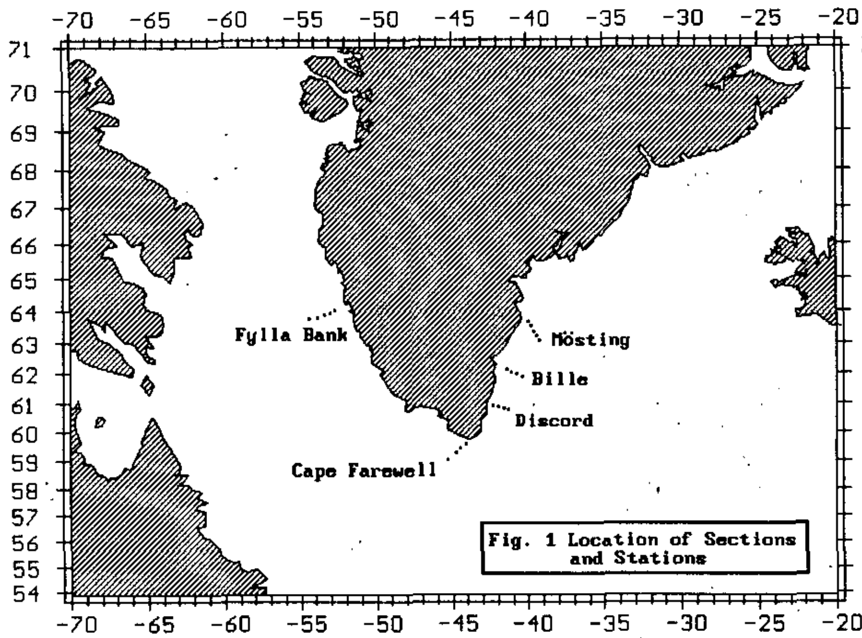


Fig. 1 Locatio of Sections and Stations

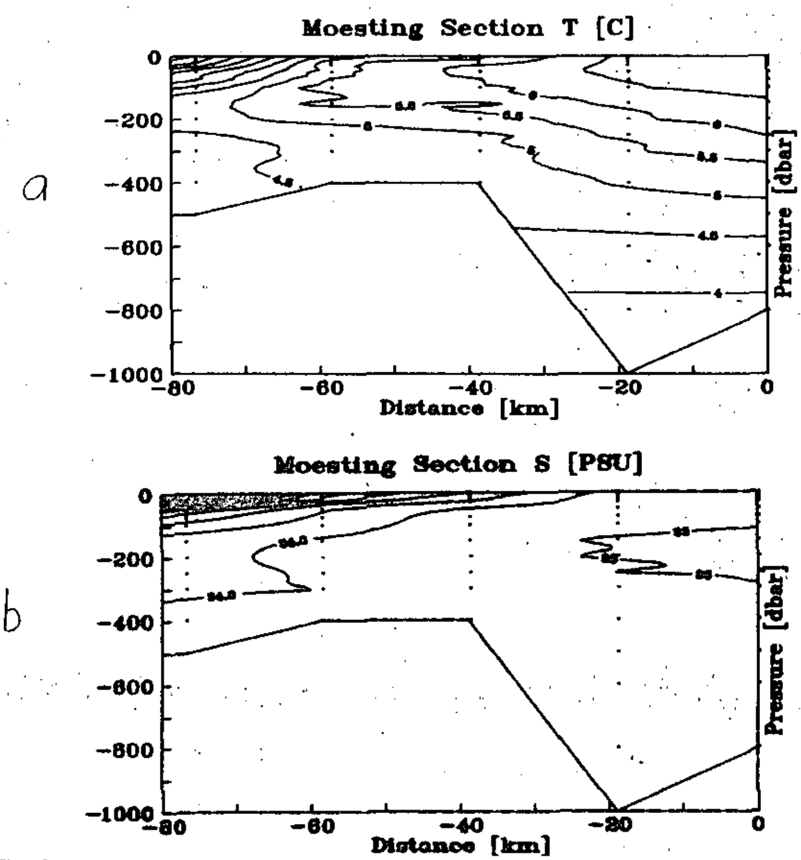


Fig. 2 Mean Vertical Distribution of Temperature (a) and Salinity (b) along the Mösting Section

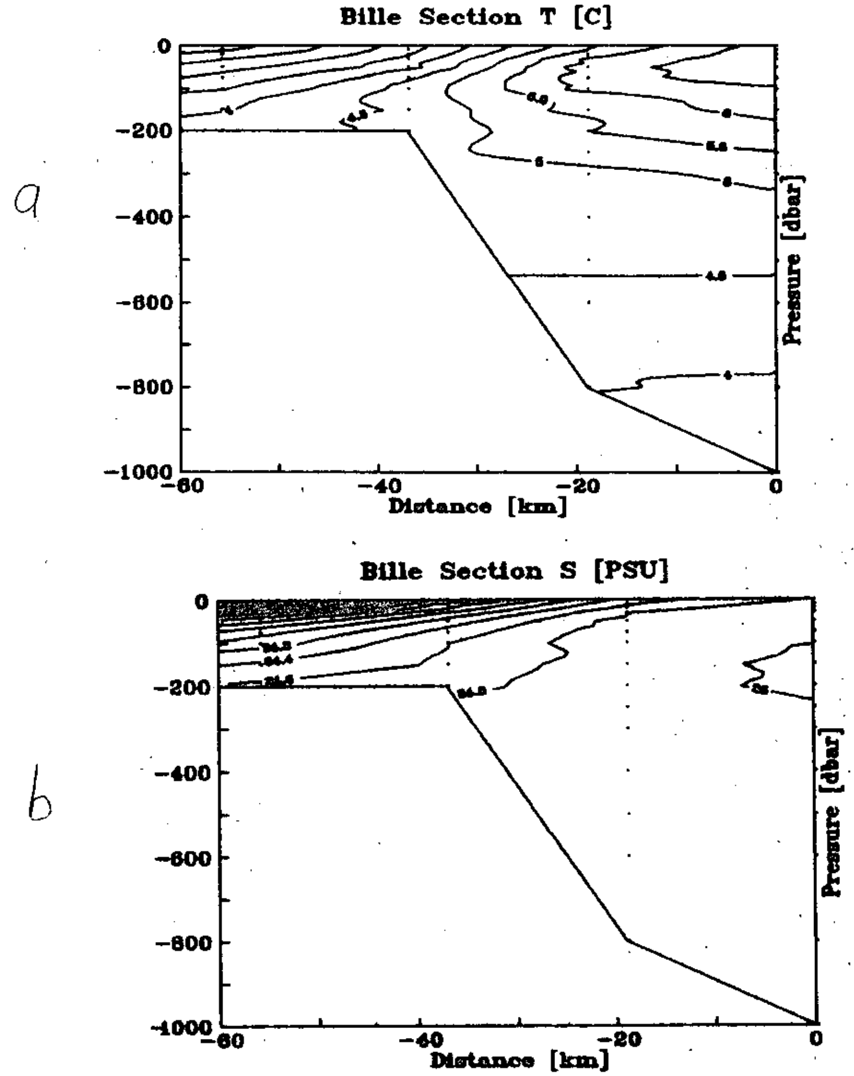


Fig. 3 Mean Vertical Distribution of Temperature (a) and Salinity (b) along the Bille Section

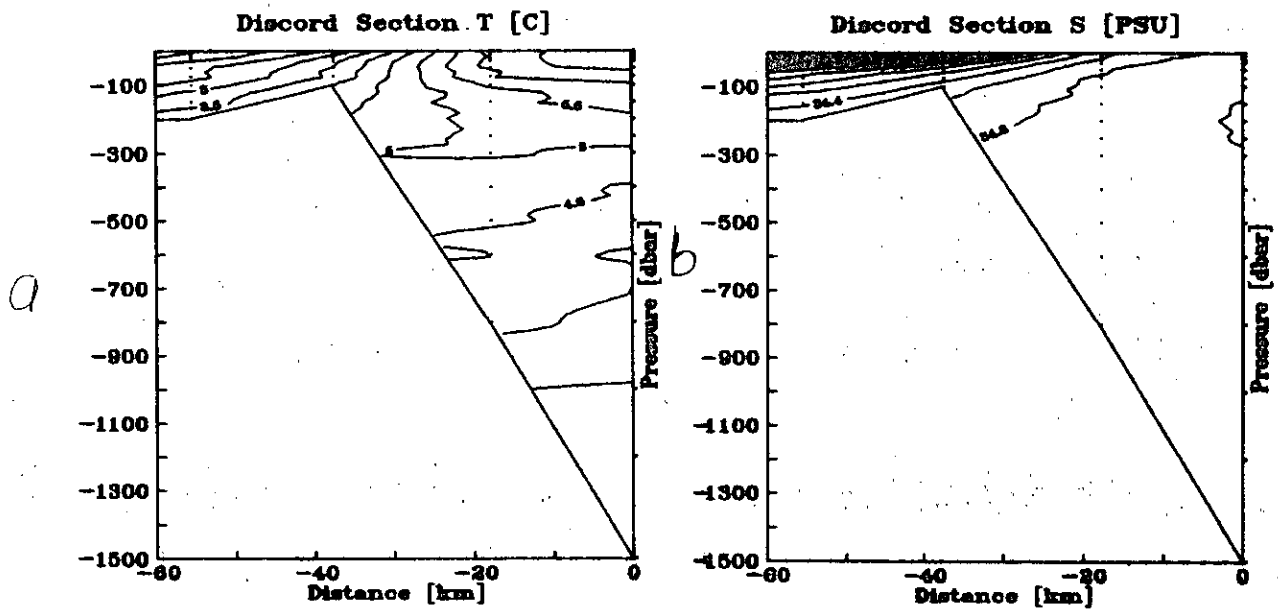


Fig. 4 Mean Vertical Distribution of Temperature (a) and Salinity (b) along the Discord Section

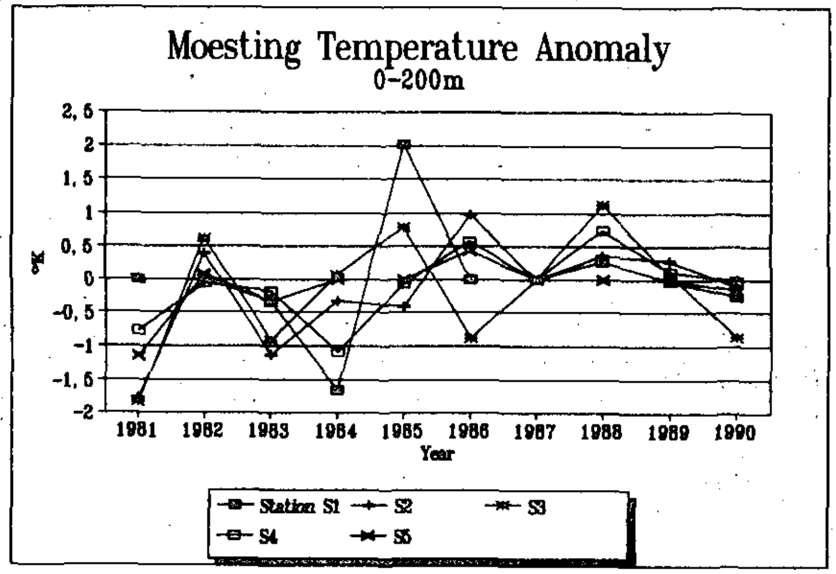


Fig. 5 Annual Variation of Temperature along the Mösting Section

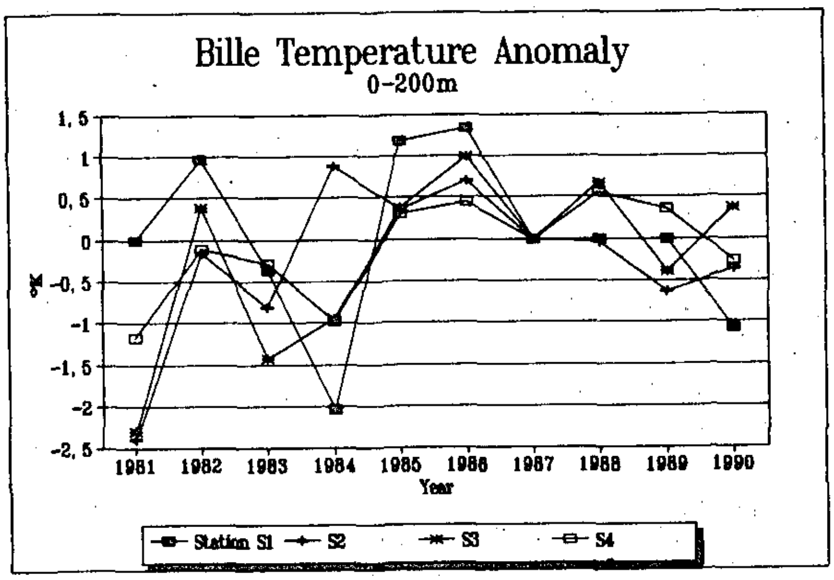


Fig. 6 Annual Variation of Temperature along the Bille Section

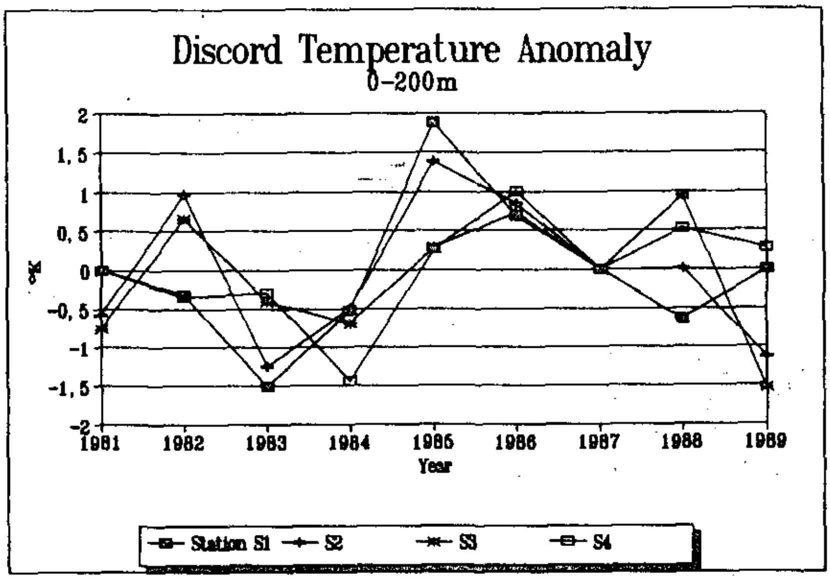


Fig. 7 Annual Variation of Temperature along the Discord Section

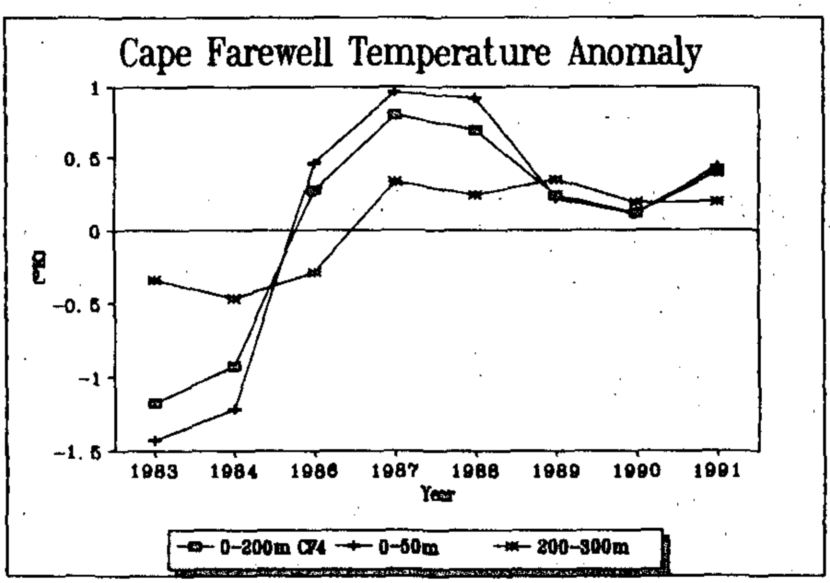
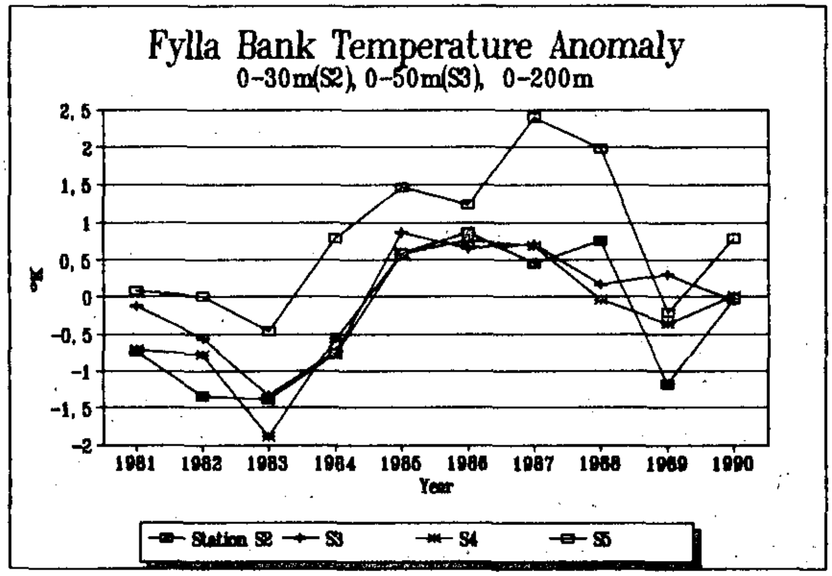


Fig. 8 Annual Variation of Temperature at the Cape Farewell Section Station 4 .

a



b

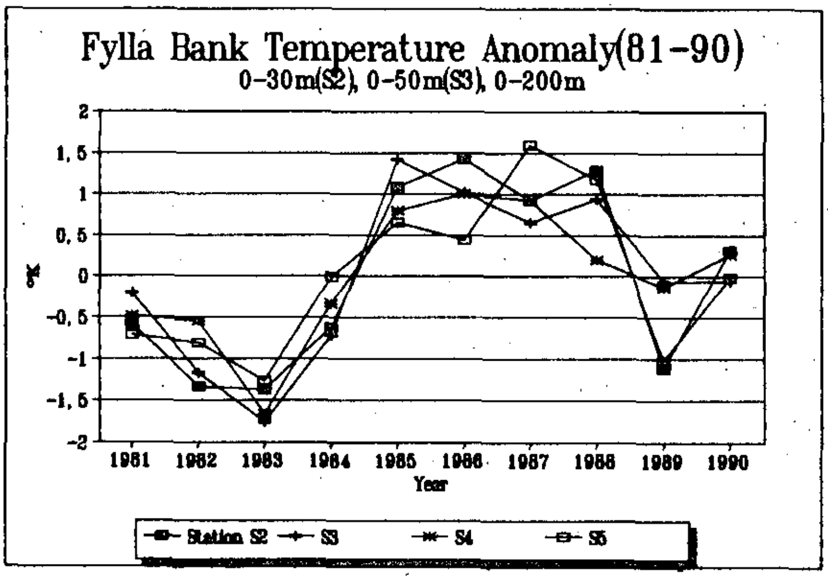


Fig. 9 Annual Variation of Temperature along the Fylla Bank Section (a) based on mean 1963-1991, (b) based on mean 1981-1990

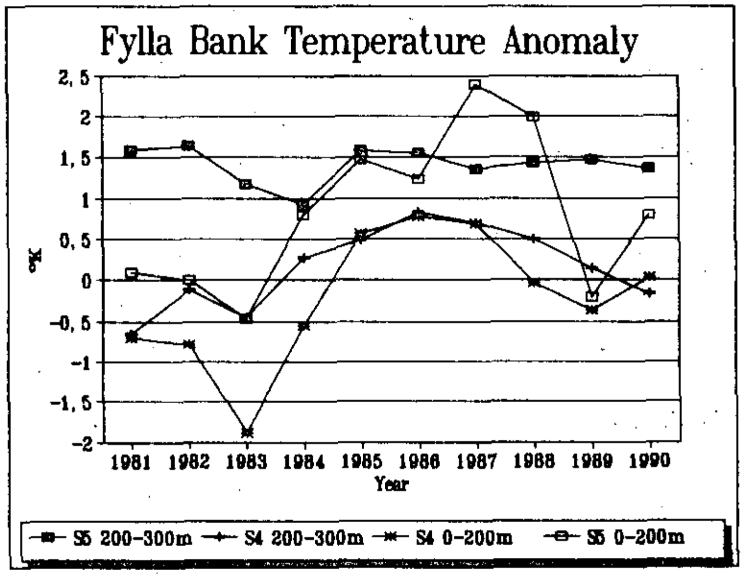


Fig. 10 Annual Variability of Temperature at stations S4 and S5 of the Fylla Bank Section with reference to the Irminger layer (200-300m)

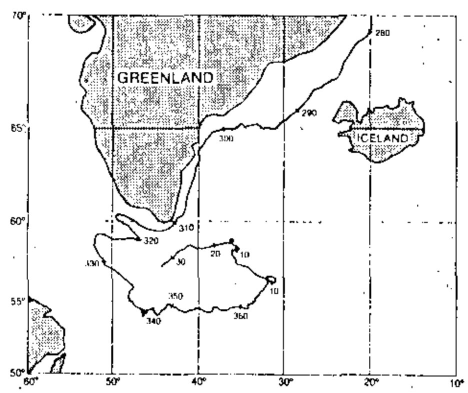


Fig. 11 Monitored track of an ice float from October 1984 (day 280) to February 1985 (day 35). (Courtesy of A. Clarke, Bedford Institute of Oceanography, Dartmouth, Nova Scotia, Canada)