Seasonal and year to year variations of West Greenland waters in recent years

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ABSTRACT

The water masses flowing along the west coast of Greenland originate partly from the East Greenland polar current and partly from the Irminger current. The hydrographic conditions in the area therefore greatly depend on the relative strength of each of these two currents. Observations from the last 3–4 decades have revealed a distinct annual perodicity as well as great year to year variations in the intensity of the two currents. Two periods with low temperatures in the surface layer have occurred during the last twenty years, both due to meteorological anomalies in the polar region. Variations in temperature and salinity of the Irminger current component seem to be closely correlated.

INTRODUCTION

Hydrographical observations in the West Greenland waters have been carried out for more than 100 years. At the beginning they were few, scattered and casual, but after World War II coherent series of temperature and salinity observations have been obtained for the summer period at fixed standard sections along the coast.

Earlier investigations were reported by Kiilerich (1943) who gave a thorough description of the hydrographic observations before World War II, Hachey et al. (1954), Hansen and Hermann (1965), Blindheim (1967), Lee (1968) who reported on the observations made during the Norwestland surveys in 1963, and Alekseev et al. (1972). In addition to these papers various reports by Hermann (1957, 1960, 1967, 1975) should be mentioned.

During the last fifteen years the hydrographic observation programme of the Greenland Fisheries and Environment Research Institute has been intensified. Measurements have been performed at the Fylla Bank section regularly throughout the year (normally 5–6 cruises per year) providing information about the annual course of temperature and salinity. The main bathymetrical features of Greenland waters are shown in Figure 1 which also includes localitites referred to in the text.

Because of the greater intensity of observations during the last fifteen years this paper will focus on this period. First a description of the annual changes in the hydrography of West Greenland is given, followed by a discussion of the year to year variations and their possible causes.

CURRENTS AND WATER MASSES

The water masses flowing northwards along the Greenland west coast originate partly from the East Greenland Current of polar origin and partly from the Irminger Current (Fig. 2a). The two meet in the area

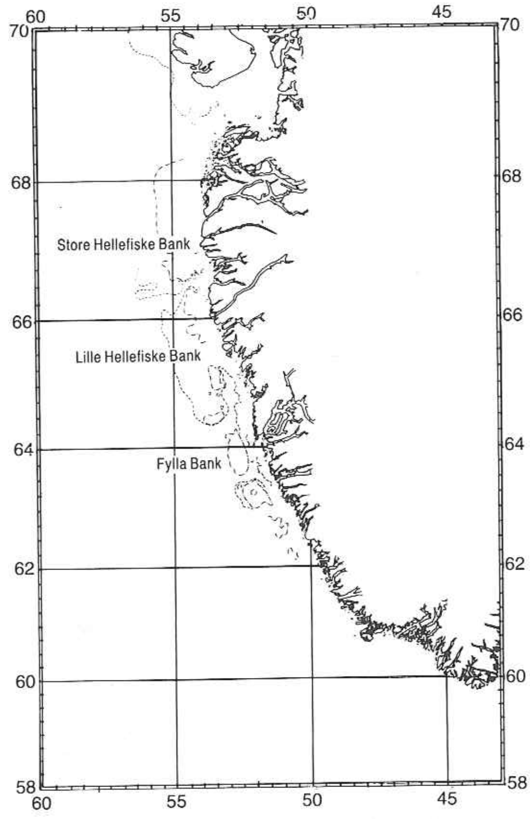


Fig. 1. Bathymetrical chart of the West Greenland area.

between Greenland and Iceland and flow southward under intense mixing, so that when rounding Kap Farvel some of the original characteristics of the two water masses are lost. The hydrographic conditions along the west coast of Greenland therefore greatly depend on the relative strength of each of the two currents and the degree of mixing between them as well as on the meteorological conditions over the West Greenland area.

It is difficult to assign definite values of temperature and salinity as characteristic for the two water masses, but for the East Greenland water temperatures range from –0.5 to 1°C, when reaching Fylla Bank in June and salinity from about 33.0 to 33.75. In the Irminger water temperatures are 3.5–4.5°C during the summer and above 5°C in November-December, while the salinity is 34.75–35.0 throughout the year.

Due to the lower density the cold East Greenland water is situated on top of and to the right of the warmer and denser Irminger water (Fig. 2b).

SEASONAL VARIATIONS

The hydrographical conditions off the west coast of Greenland throughout the year are well illustrated by the observations of temperature and salinity just west of the

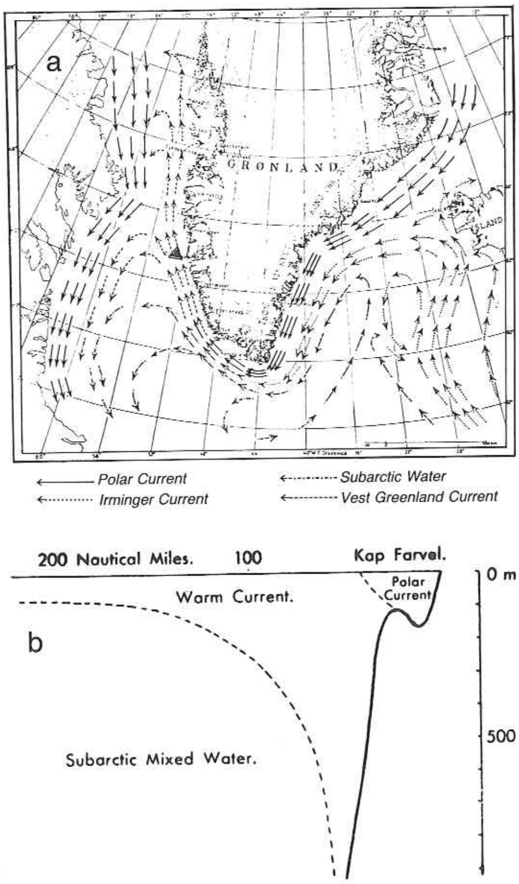


Fig. 2. a) The currents around Greenland (taken from Hachey, Hermann and Bailey 1954). The triangle indicates the position of Fylla Bank St. 4. b) Water mass distribution from Cape Farewell towards south.

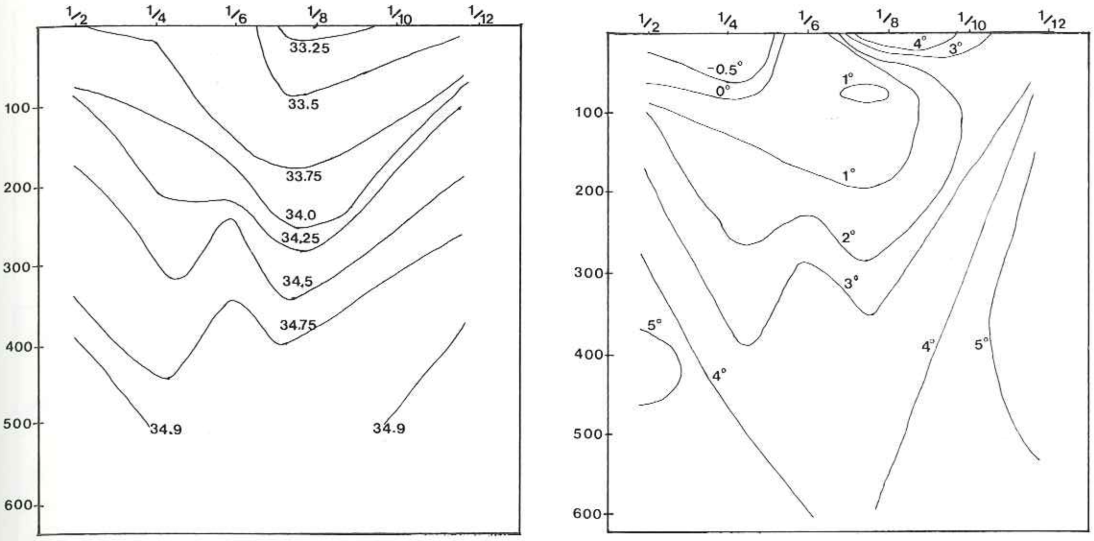


Fig. 3. Temperature and salinity distribution just west of Fylla Bank in 1974.

Fylla Bank in 1974 (Fig. 3), as well as by time series for the last 15 years of the mean temperature at different depth intervals at the same station (Fig. 4).

Cold water

During the winter the surface layer cools, reaching temperatures below –1°C. Due to vertical convection a cold, homogeneous upper layer with a thickness of approximately 50 m develops.

By April the temperature of the atmosphere begins to rise and the winter cooling stops, but as revealed in Figure 3 the upper water layer still remains cold with temperatures below 1°C until June, and it grows in thickness reaching depths of about 150 m. This is due to an intensification of the East Greenland current.

During spring and early summer the upper water layer is slowly heated by solar radiation, and over the shallow part of the banks the average temperature of the water column (0–40 m) may reach values of 2–3°C as early as by the middle of June. However, on its course along West Greenland, the polar current is subject to the action of the Coriolis force. In years with normal or strong velocities, it would then be expected that the East Greenland current component is pressed so strongly towards the outer slopes of the banks that it interferes with the heating of the surface layer near and on the banks. From the observations made across the Fylla Bank it is known that the East Greenland current component attains its greatest cooling power at this latitude in June, sometimes also at the beginning of July. In the most favorable cases the increase in temperature ceases or a small decline is observed (see for instance the temperature curves for 1977 at the depth intervals 0–50 m and 50–150 m in Fig. 4). But in unfavorable cases an enormous water stratum with negative temperatures appears, exemplified by the 1982 observations (Figs. 4 and 5). In years with the polar current having slight velocity it flows westward before reaching the banks. In such cases the temperature of the surface layer continues to rise undisturbed throughout the summer and there may even by a gain of heat from the warm water masses at greater depth (Fig. 6).

Usually the strong advance of the polar current slows down before August, where-

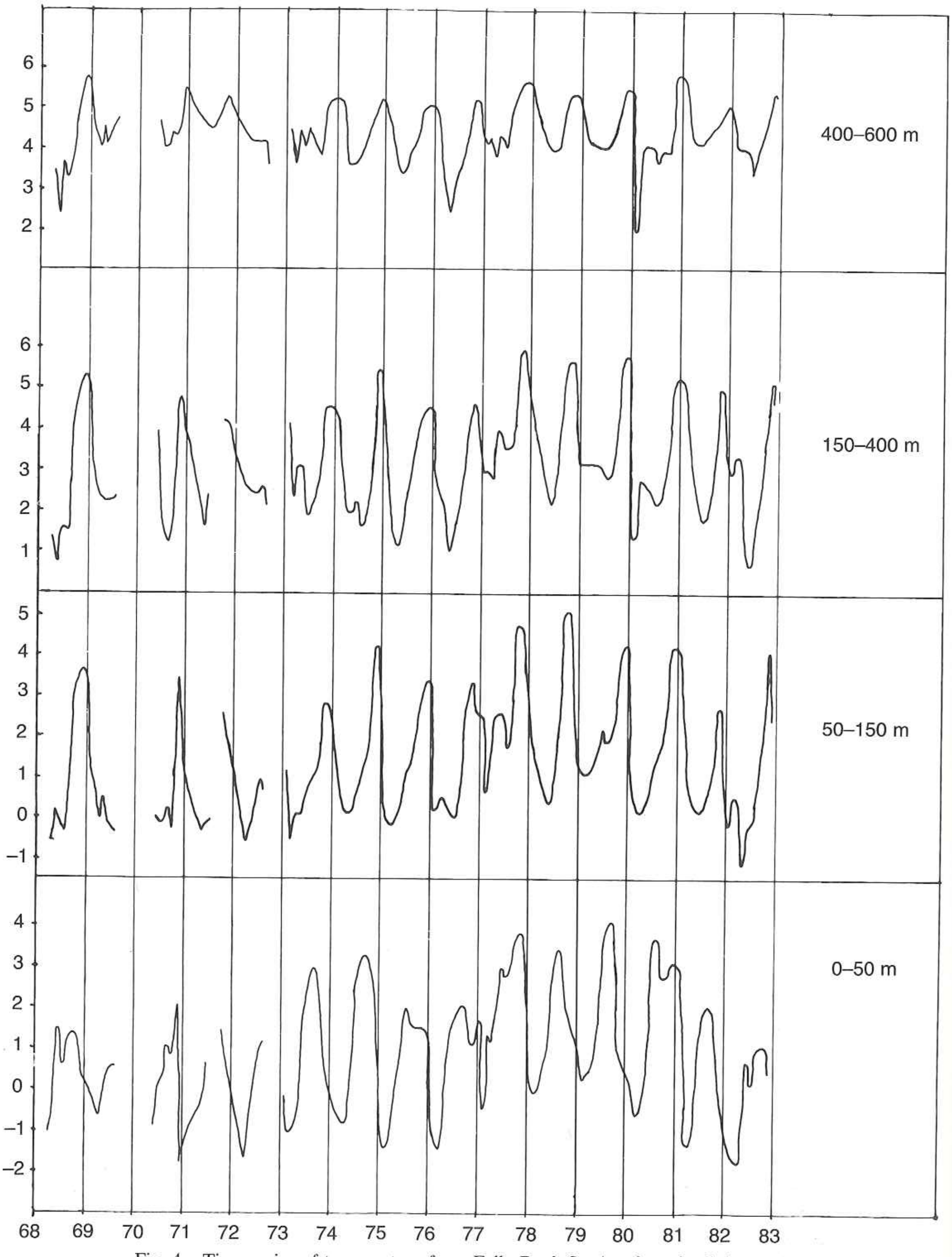
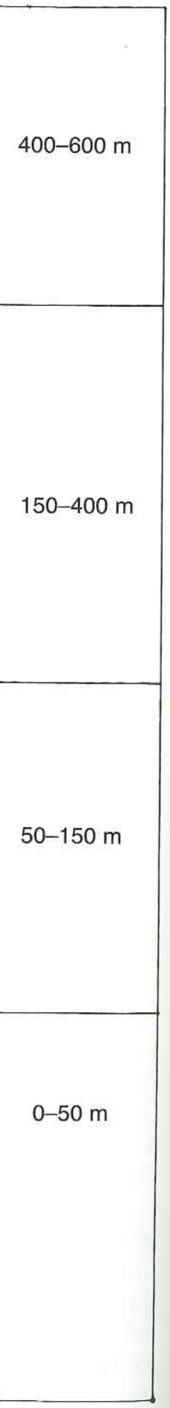


Fig. 4. Time series of temperature from Fylla Bank St. 4 at four depth intervals.



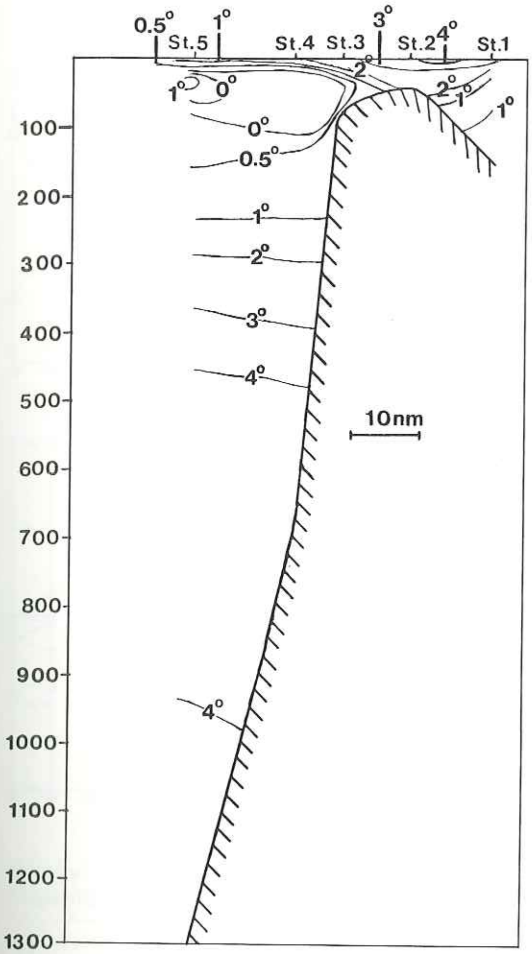


Fig. 5. Temperature distribution across Fylla Bank in July 1982.

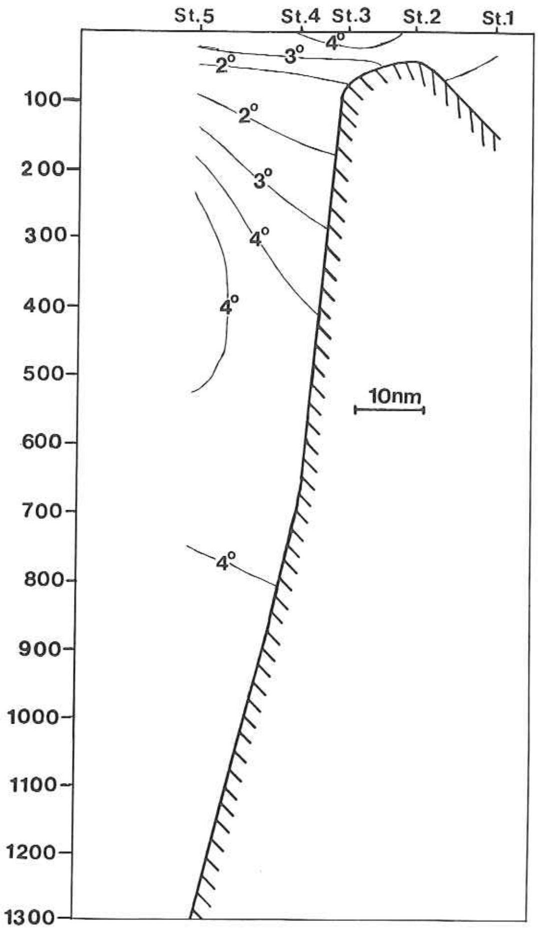


Fig. 6. Temperature distribution across Fylla Bank in July 1979.

after heat quickly is added both from above and below, so that temperatures of 2–5°C are reached on top of the banks. In addition, the stability of the upper layer is increased further due to land drainage of fresh water.

Further north at the Store Hellefiske Bank the influence of the East Greenland Current is negligible. This area may, however, be influenced by the cold Baffin Land Current, also of polar origin, in addition to the extremely cold (–1 to –1.5°C) winter cooled water. The Baffin Land Current is found at a depth of 50–200 m and characterized by temperatures of 0–1°C and a salintiy of about 34.0.

Warm water

The warm water with origin in the Irminger Current can be detected at some depth along the whole coast of West Greenland, and west of the East Greenland Current it will reach or nearly reach the surface both during spring and summer. The intensity of the warm current has a distinct annual period. During spring and first part of summer the intensity is only appreciable at the southern part of West Greenland, while further north the water movement is rather sluggish and takes only place at greater depths (300–400 m at Fylla Bank). In July the current is intensified and is deflected towards the coast due to the action of the Coriolis force. The boundary between the warm and the cold water rises along the outer slopes of the banks reaching its highest level around November-December (Fig. 4).

YEAR TO YEAR VARIATIONS

Variations in the intensities of the East Greenland Current, the Irminger Current and the time of their maximum intensity on the West Greenland banks as well as variations in the meteorological conditions, i.e. winter cooling, summer heating, storms etc., will cause year to year variations in the West Greenland hydrography.

The mean temperature of the water column above the Fylla Bank (0–40 m) in the middle of June since 1950 (Fig. 7), reveals considerable year to year changes in the temperature conditions, with temperatures varying from 0.3°C to 3°C, and two

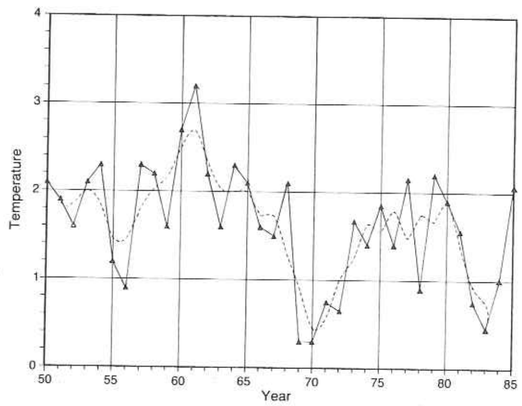


Fig. 7. Mean temperature of the upper 40 m on Fylla Bank about mid-June 1950–1985.
▲———▲ actual observations
– – – – 3 years moving average

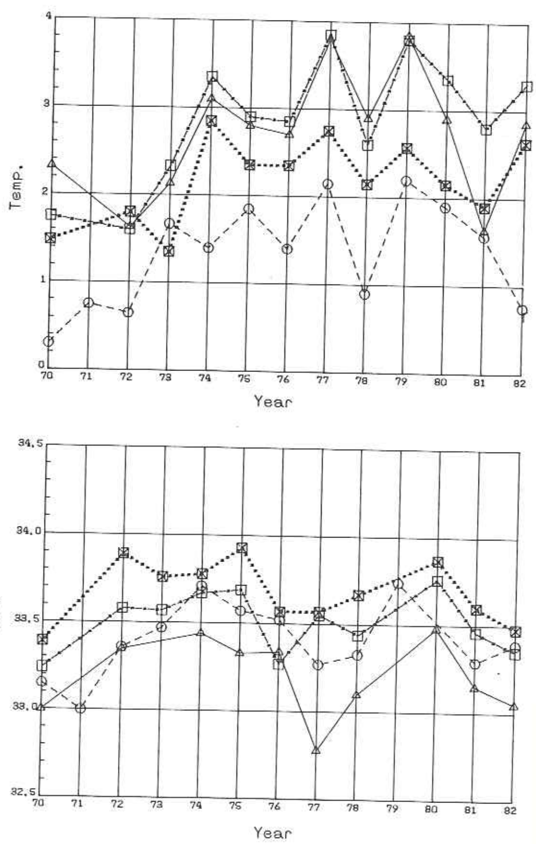


Fig. 8. Mean temperature and salinity of the upper 40 m on top of the banks in mid-June and the beginning of July.
O – – – O Fylla Bank
△———△ Fylla Bank, July
□—×—□ Lille Hellefiske Bank, July
⊠ × × × × ⊠ Store Hellefiske Bank, July

distinct cooling periods are recognized during the last two decades.

For a further study of these variations and their reasons, we will focus on the hydrographical conditions since 1970, because for this period there exist, in addition to the Fylla Bank observations (Fig. 4), almost continuous series of temperature and salinity observations at the Lille Hellefiske Bank and Store Hellefiske Bank sections from the beginning of July (Figs. 8 and 9).

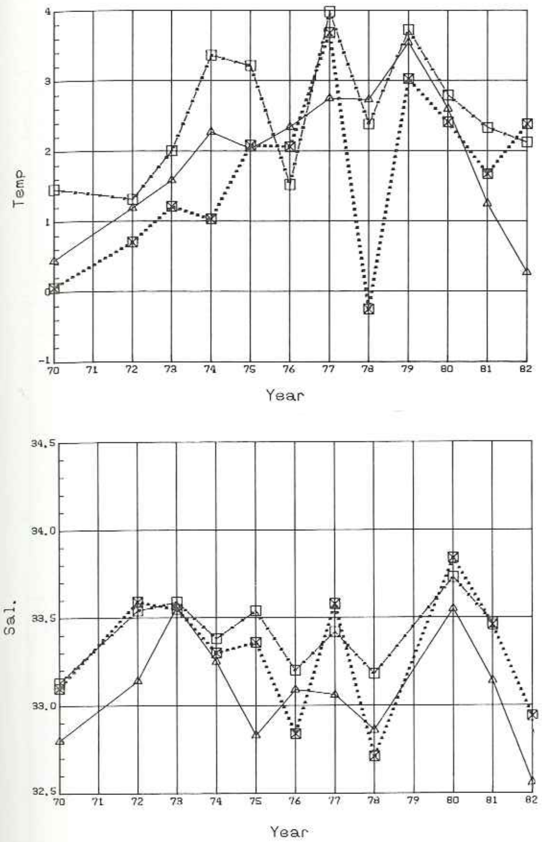


Fig. 9. Mean temperature and salinity of the upper 50 m at the beginning of July just west of the banks.
△——△ Fylla Bank St. 4
□—×—□ Lille Hellefiske Bank St. 5
⊠ ×××× ⊠ Store Hellefiske Bank St. 5

General trends

Before considering separate years the following general trends should be noted:

1) The year to year variations of temperature and salinity on top of and west of the three banks in July are very much alike, indicating that the hydrographical conditions along the West Greenland coast are governed by advective processes.

2) The temperature on top of Fylla Bank rises for most of the years by 1–2°C during the 2–3 weeks period between the June and the July observations, while the salinity decreases by 0.1–0.2 units.

3) The differences in temperature between the three banks in July, on top of as well as west of the banks, are within 0.5–1°C, with the highest temperature normally observed at the Lille Hellefiske Bank, and the lowest at the Store Hellefiske Bank.

4) The salinity increases from south to north by 0.3–0.6 units.

Upper layers

In the years 1970–72 and 1982 the mid-June temperatures on the Fylla Bank were extremely low (below 1°C), while the June temperatures were relatively high on the bank but rather low at the station west of the bank. These years are characterized also by relatively low salinities. These observations indicate that the influx of East Greenland polar water was intense during May and the first half of June, but that it weakened and was therefore deflected to the west during the second half of June, resulting in favourable conditions for solar heating of the water masses on top of the bank.

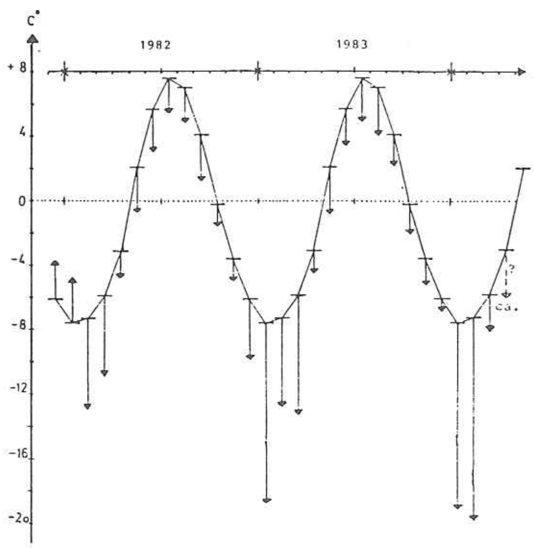


Fig. 10. Air temperature anomalies at the Godthaab Station since January 1982. (From Rosenoern et al. 1984).
—— Monthly mean temperatures based on observations during 1930–1960.
↓ Temperature anomalies

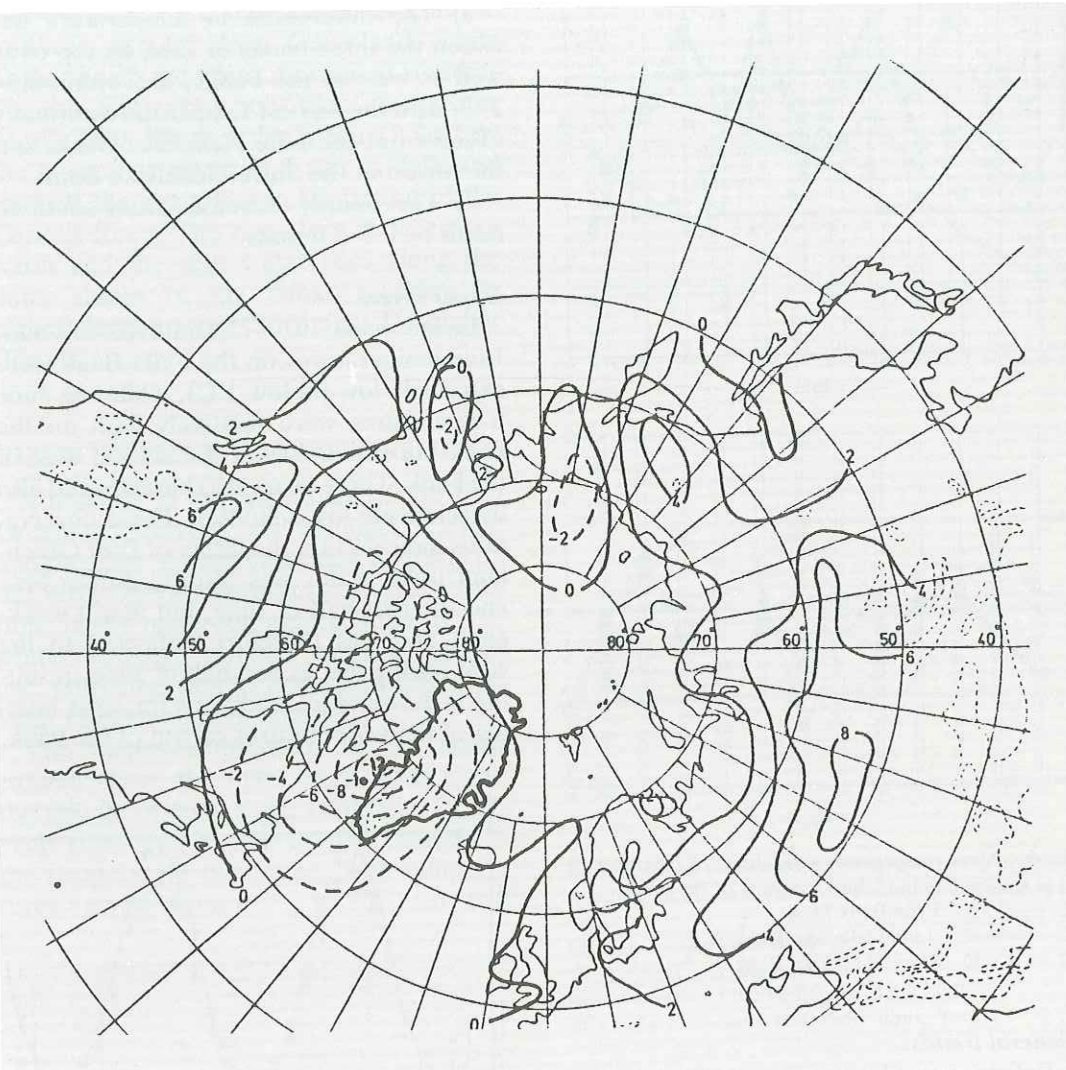


Fig. 11. Anomalies of the mean air temperature of January-February 1983 in the arctic region.

This interpretation is confirmed by the temperature observations across the Fylla Bank in July 1982, which show a nearly 250 m thick water layer with temperature characteristics equal to those of East Greenland polar water west of the Fylla Bank (Fig. 5). In 1981 practically no heating took place between June and July at Fylla Bank, and also the temperatures west of the bank were relatively low, without any of them being particularly low. This is believed to be due to a late appearance of the polar current that year. It may therefore be concluded that the above mentioned two cooling periods observed during the last two decades are related to great inflow of East Greenland water. Around 1970 (Fig. 7) the great intensity of the East Greenland Current was caused by positive anomalies of air pressure over Greenland together with negative

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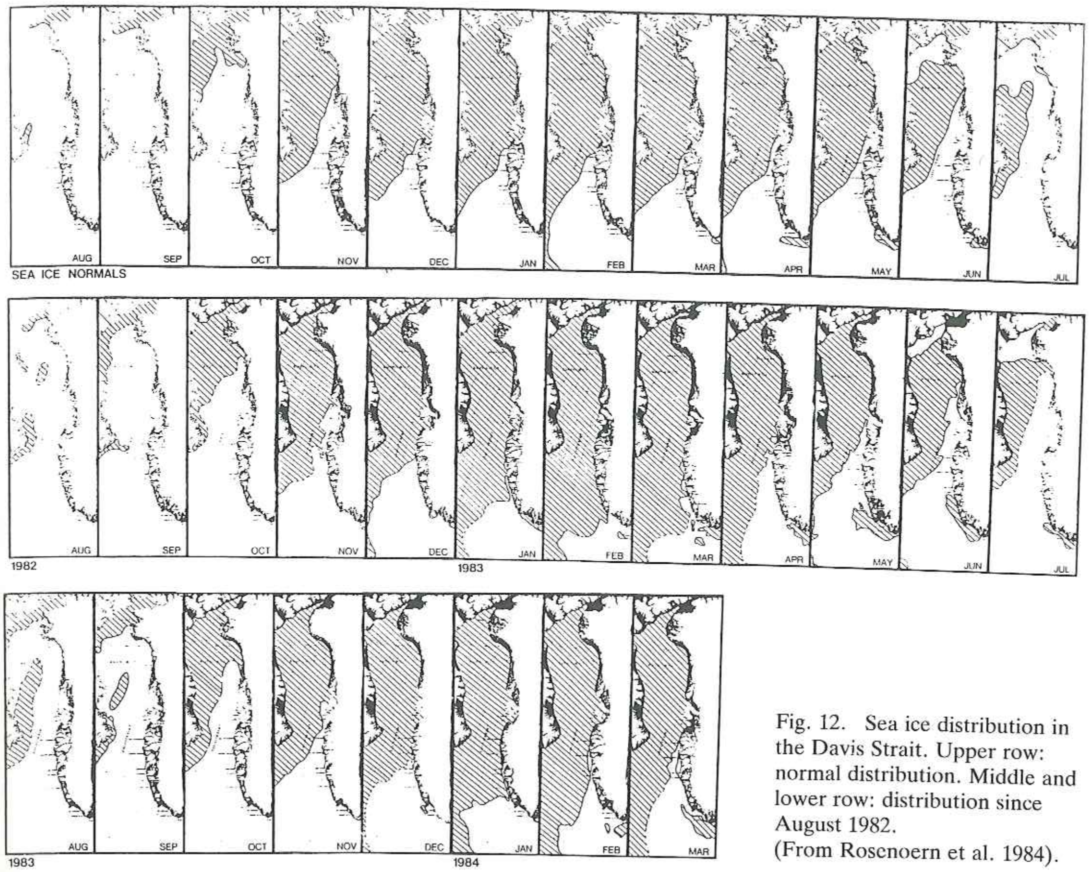

Fig. 12. Sea ice distribution in the Davis Strait. Upper row: normal distribution. Middle and lower row: distribution since August 1982.
(From Rosenoern et al. 1984).

anomalies over the Norwegian- and the Barents Seas (Dickson et al. 1975). The resulting gradient in the air pressure led to a predominance of northerly winds pressing large amounts of cold, relatively fresh water out of the Arctic Ocean.

The second cooling period which we experience right now is caused not only by inflow of East Greenland polar water, but also by extreme meteorological conditions over the Davis Strait. These have been analysed by Rosenoern et al. (1984), mainly on the basis of observations from the meteorological station in Godthaab.

Since February 1982 the monthly mean temperatures have been below the 1931–1960 normal (Fig. 10). Especially the winter months January and February have been extremely cold, with the lowest temperatures registered — about 12°C below normal — since regular temperature observations started in 1884. The mean annual temperature was 3.5°C below normal in 1983, which is the third coldest year ever registered.

An analysis of temperatures from other parts of the Arctic region (Fig. 11) shows that the extreme conditions found at West Greenland appeared as a cold eddy, only covering the Davis Strait, Greenland and parts of northeastern Canada, with the centre placed near the city of Egedesminde, West Greenland.

The extremely low temperatures of the atmosphere have led to a cooling of the upper water masses in the Davis Strait, resulting in negative temperature anomalies of 1–2°C throughout the year and the formation of great amounts of ice (Fig. 12). The last two winters in Greenland (1982–83 and 1983–84) have been the most severe ice winters of this century producing great difficulties for the operations of the fishing fleet at the West Greenland fishing banks.

Warm conditions on the banks and west of them were observed in 1977 and 1979. A vertical temperature section across the Fylla Bank in July 1979 (Fig. 5) shows that water masses with temperature characteristics of the polar water were absent that year, thus providing favourable conditions for solar heating. In addition, water masses of Atlantic origin dominated at depths of 150–250 m.

Finally, attention should be drawn to the extremely low temperatures and salinities west of the Store Hellefiske Bank in July 1978. These may be explained by the combined influence of remanent winter cooled water and an inflow of polar water from the Baffin Land Current carrying great amounts of drift ice.

400–600 m layer

The 400–600 m layer west of the banks is totally dominated by Atlantic water. It will be noted that the hydrographical conditions as well as the year to year variations at the three banks are very much alike, especially in the years 1977–1981 (Fig. 13).

The low temperature and salinity at the Store Hellefiske Bank in 1970 may be attributed to the influence of Baffin Bay water due to the great inflow of water from the Arctic observed that year, as had also been found for the upper layer. In 1976 the three stations showed relatively low temperatures and salinities, which may be related to the so-called "1970's anomaly" observed in various places all over the North Atlantic (Ellett 1980; Martin 1981). Malmberg and Svansson (1982) reported a minimum in temperature and salinity in the Irminger Current south of Iceland in 1976.

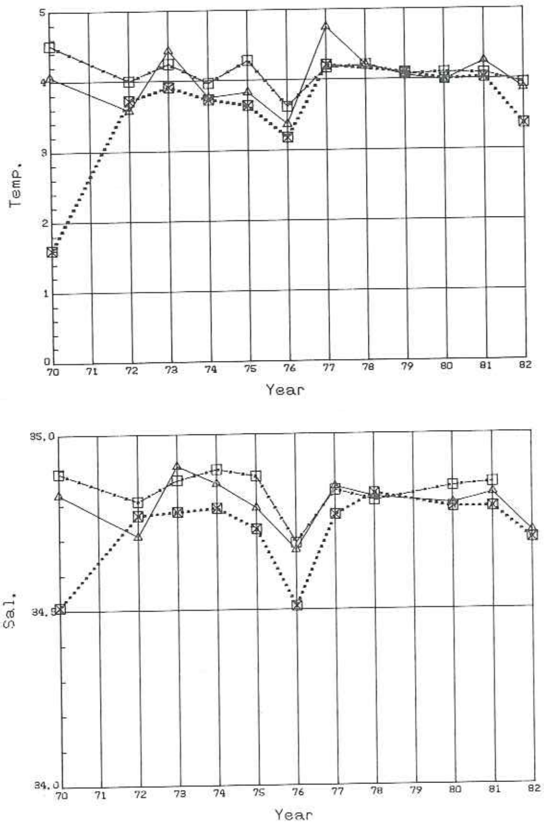

Fig. 13. Mean temperature and salinity from the 400–600 m water column just west of the banks at the beginning of July.
△———△ Fylla Bank St. 4
□——×——□ Lille Hellefiske Bank St. 5
⊠ × × × × ⊠ Store Hellefiske Bank St. 5.

The year to year variations in temperature in the 400–600 m layer seem to be closely correlated with those in salinity. This is apparent from Figure 14 where the 1976 anomaly can also be clearly seen.

CONCLUSIONS

Hydrographic surveys performed along the Fylla Bank section regularly throughout the year for the last fifteen years have shown distinct annual periodicities in the maximum intensity of the West Greenland Current. The East Greenland polar water

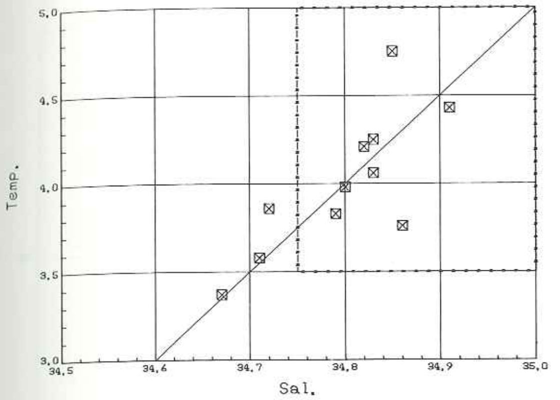

Fig. 14. Temperature-salinity diagram for the 400–600 m water column at the beginning of July since 1970. The T-S characteristics of the Irminger water are shown inside the rectangular.

dominates during the spring and reaches its greatest intensity in June. The Irminger water is advected at a low rate during the first half of the year and is found only at great depths, below 300–400 m. During the summer the current intensifies, reaching a maximum around November-December.

Observations from three sections along the West Greenland coast show great similarities in the hydrographical conditions in the individual years as well as in the year to year variations, thus indicating the dominance of the same advective processes.

The temperature conditions of the upper layer in June and the beginning of July depend largely on the intensity of the influx of polar water, a fact of utmost importance to biological production and survival of fish larvae.

Recent negative temperature anomalies are caused by the combined effect of strong inflow of East Greenland polar water and the presence of extremely cold air masses over the Davis Strait region.

Below 400 m where water of Atlantic origin dominates, a close correlation between temperature and salinity variations is observed, and the presence of the "1970's anomaly", which has been observed all over the North Atlantic, can be identified at West Greenland in 1976.

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