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Variations in Temperature and Salinity of West Greenland Waters, 1970-82

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Abstract

Hydrographic observations on three sections off West Greenland since the late 1960's indicated the following: distinct annual periodicity in the intensity of inflow of waters of the East Greenland Current and the Irminger Current to the West Greenland fishing banks; similarity in year-to-year variations at different sections along the coast; great influence of polar water in June-July and consequent effect on biological production of the area; correlation of temperatures and salinities of Irminger Current water offshore along the coast; and the presence, in the deep Atlantic-type water in 1976, of the major anomaly which occurred throughout the North Atlantic in the mid-1970's.

Introduction

Hydrographic observations in 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 (1939-45), coherent series of temperature and salinity observations were made in the summer at fixed standard sections along the coast. Kiilerich (1943) provided a thorough description of hydrographic data collected before World War II, and post-war observations have been reported by Hachey *et al.* (1954) and Alekseev *et al.* (1972). Lee (1968) reported on observations made during the Norwestlant Surveys in 1963.

During 1968-82, hydrography data were obtained from the Fylla Bank section fairly regularly throughout the year (normally 5-6 cruises annually). This paper will focus on hydrographic conditions during that period because of the higher intensity of observations than previously.

Annual Variation in Hydrographic Conditions

Water flowing northward along the West Greenland coast originates partly from the cold East Greenland Current and partly from the warmer Irminger Current (Fig. 1). The two currents meet in the area between Greenland and Iceland and mix intensely as they flow southward. Upon moving pass Kap Farvel, some of the original characteristics of the two water masses are lost. Therefore, hydrographic conditions along West Greenland depend greatly on the relative strengths of the two currents, the effectiveness of mixing of the water masses, and the meteorological conditions in the West Greenland area.

Hydrographic conditions off the west coast of Greenland throughout the year are well illustrated by observations of temperature and salinity at a station just west of Fylla Bank in 1974 (Fig. 2) and also by the time series of mean temperatures for different depth intervals at the same station (Fig. 3).

Cold water

The temperature of the surface layer decreases below 0° C normally in winter and below -1° C in cold winters. Due to vertical convection, a cold homogeneous upper layer with a thickness of approximately 50 m develops. Although the temperature of the atmosphere begins to increase in April and the winter cooling ceases, the upper water layer continues to remain cold with temperature below 1° C until July and its thickness actually increases to a depth of about 150 m. This is

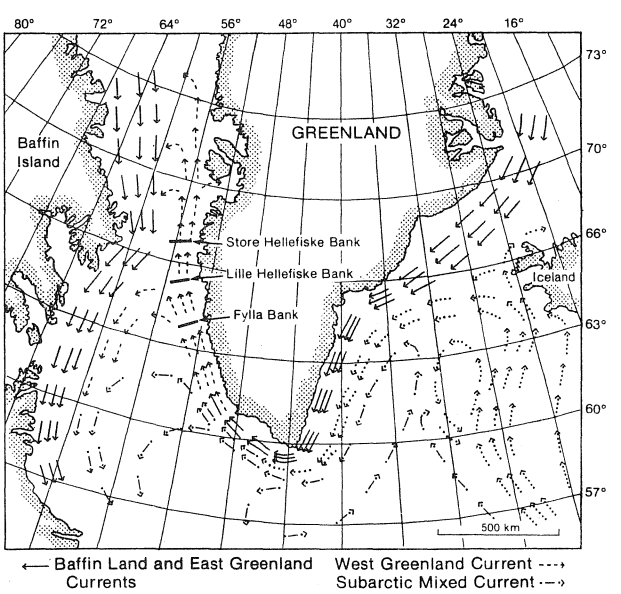

Fig. 1. The currents around Greenland (redrawn from Hackey *et al.*, 1954), and the locations of the three hydrographic sections off West Greenland.

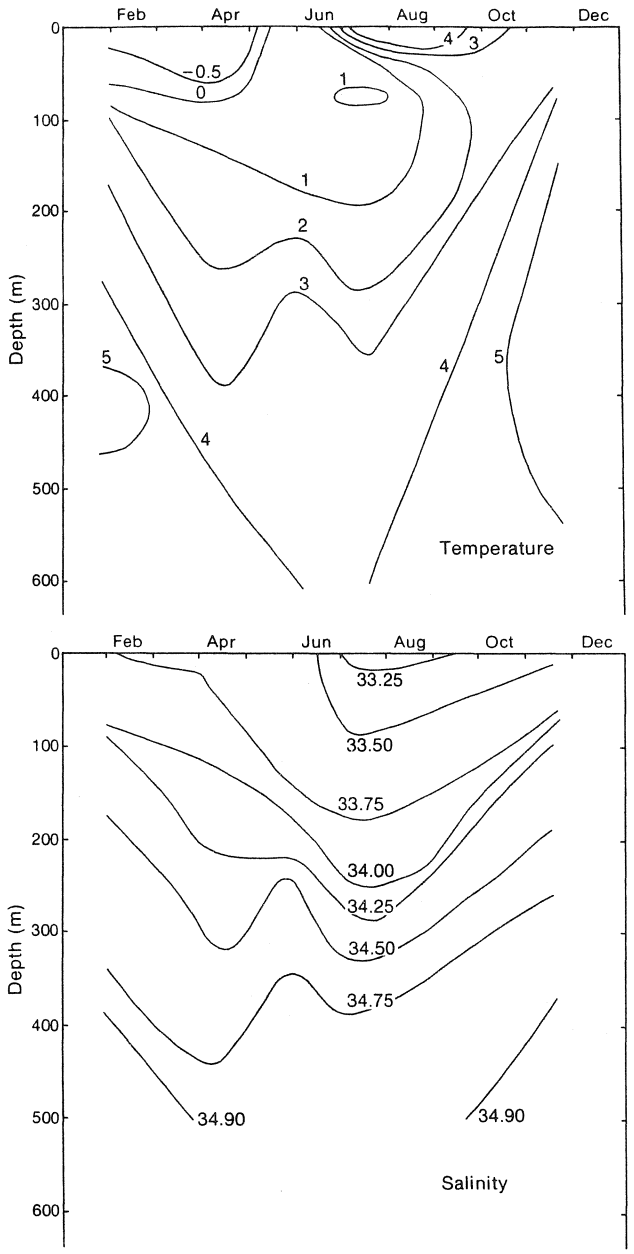

Fig. 2. Temperature and salinity profiles at Station 4 on the Fylla Bank section in 1974.

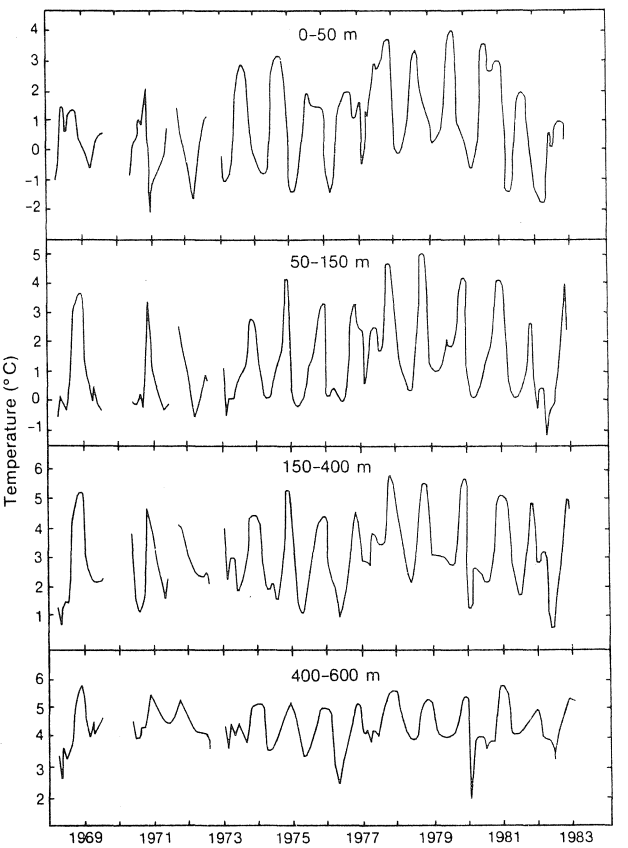

Fig. 3. Time series of mean temperatures for four depth intervals at Station 4 on the Fylla Bank section, 1968-82.

due to intensification of the cold East Greenland Current which carries drift ice of East Greenland origin or from the Polar Sea. It is difficult to indicate definite values of temperature and salinity characteristics for the polar water, but, from available observations, representative temperatures may range from -0.5° to -1.0° C and salinity values from 33.0 to 33.75.

During spring and early summer, the upper water layers are slowly heated by solar radiation, and the average temperature of the water column (0-40 m) over the shallow areas of the banks may increase to 2° -3° C as early as mid-June. However, on its course along West Greenland, the polar current is subject to the action of Coriolis force, and, in years when its velocity is greater than normal, it presses against the outer slopes of the banks and thus interferes with heating of the water near and on the banks. In the Fylla Bank area, the polar current attains its greatest cooling power in June and sometimes in early July. In the most favorable situations, the increase in temperature ceases or a small decline is observed, as indicated, for example, by the temperature curves for 1977 at the depth intervals of 0-50 m and 50-150 m (Fig. 3). In unfavorable situations, a large volume of water (to a depth of 100 m) with negative temperatures appears west of Fylla Bank, as exemplified by observations in 1982 (Fig. 3 and 4A).

In years when the polar current has a low velocity, it flows westward before it reaches the banks off West Greenland. In such cases, the temperature of the surface layer continues to increase throughout the summer, and there may even be a gain in heat from the warmer water in greater depths (Fig. 4B). Usually, the strong influence of the polar current declines before August, and warm water penetrates quickly both from above and below, so that temperatures of 2° to 5° C are attained over the banks. In addition, the stability of the upper water layer is increased further by low salinity water from land drainage. Farther northward on Store

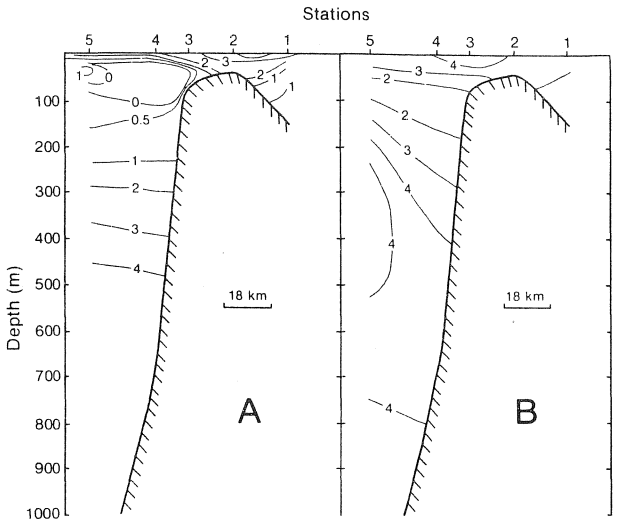

Fig. 4. Temperature profiles for the Fylla Bank section in (**A**) July 1982 and (**B**) July 1979.

Hellefiske Bank, the influence of the East Greenland Current becomes negligible. In addition to the extremely cold (-1.0° to -1.5° C) winter-cooled surface water, this area may be influenced by the cold Baffin Land Current (also of polar origin) which is found at 50–200 m and is characterized by temperatures of 0° to 1° C and salinity values around 34.0.

Warm water

Warm water of Irminger Current origin can be detected at depth off West Greenland, and it may be at or near the surface along the western border of the cold water during the spring and summer. It has a distinct annual period. During spring and early summer, the intensity of this water is significant only off the southern part of West Greenland, whereas northward in the vicinity of Fylla Bank it is found only in the deeper layer below 300–400 m. In July, the current intensifies and approaches the coast due to the effect of Coriolis force. Its border with the cold surface layer rises along the outer slopes of the banks and reaches its highest level usually in November or December (Fig. 3). On Fylla Bank, the warm current is characterized by temperatures from 3.5° to 4.5° C in early summer and above 5° C in November–December. The salinity of this water is 34.75–35.00 throughout the year.

Time Series of Temperature and Salinity

General trends

Variations in intensity of the East Greenland Current and the Irminger Current and the time of their arrival to the West Greenland banks, as well as variations in meteorolgoical conditions (i.e. winter cooling, summer heating, storms, etc.), cause year-to-year variations in the West Greenland hydrographic regime.

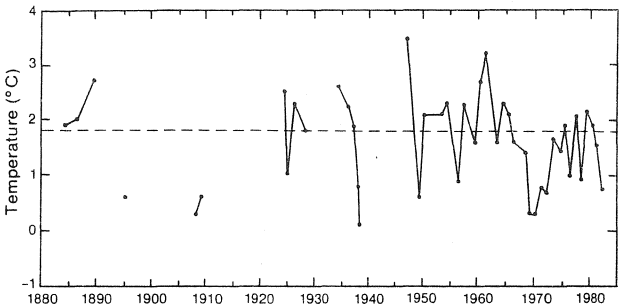

Fig. 5. Mean temperatures of the surface (0–40 m) layer on Fylla Bank about mid-June, 1883–1982, relative to 1.8°C which represents the lower limit of temperature for high survival of cod larvae.

The longest time series of water temperature observations is that for mean temperature of the upper (0–40 m) water column over Fylla Bank in mid-June (Fig. 5). This time series reveals considerable variation from the late 1800's to the early 1980's, with mean temperatures ranging from 0° C to about 3.5° C. However, attention will be focused on conditions since 1970, because, in addition to the Fylla Bank observations, there exists for this recent period an almost continuous series of temperature and salinity observations in early July for Lille Hellefiske Bank and Store Hellefiske Bank (Fig. 6 and 7). Before considering the year-to-year variations, some general trends should be noted:

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

b) In most years, the temperature on the top of Fylla Bank increases by 1° to 2° C during the 2–3 weeks between the mid-June and early July observations, whereas the salinity decreases by 0.1–0.2 units.

c) Temperature differences on the three banks are within the range of 0.5° to 1.0° C, with the highest normally occurring on Lille Hellefiske Bank and the lowest on Store Hellefiske Bank.

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

Upper water layer (0–50 m)

In 1970–72 and 1982, the mid-June temperatures on Fylla Bank were extremely low (<1° C), whereas the July temperatures were relatively high on the bank but rather low at the station west of the bank. These years were characterized also by relatively low salinities. These observations indicate that the influx of East Greenland Current water was intense during May and the first half of June, but that it weakened and was deflected westward in late June, resulting in favorable conditions for solar heating on the surface layer over

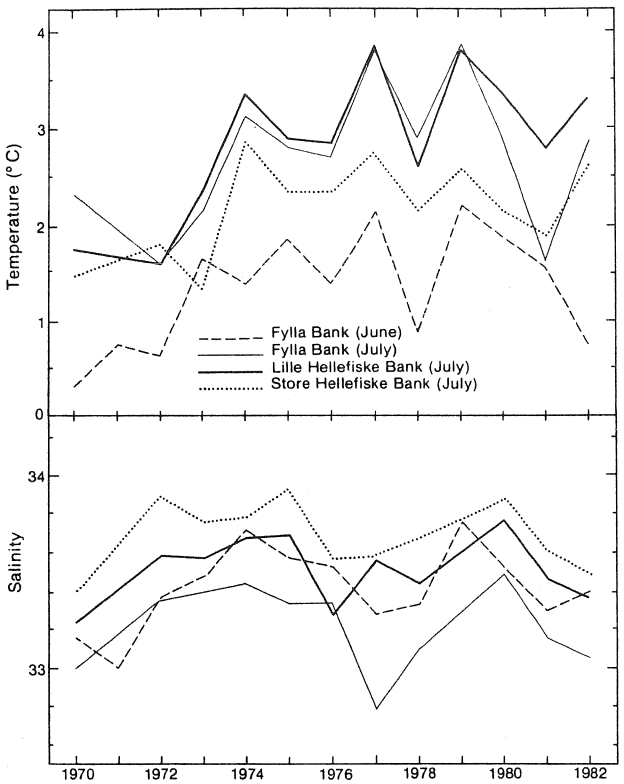

Fig. 6. Mean temperatures and salinities of the surface (0-40 m) layer on Fylla Bank, Lille Hellefiske Bank and Store Hellefiske Bank about mid-June and early July, 1970-82.

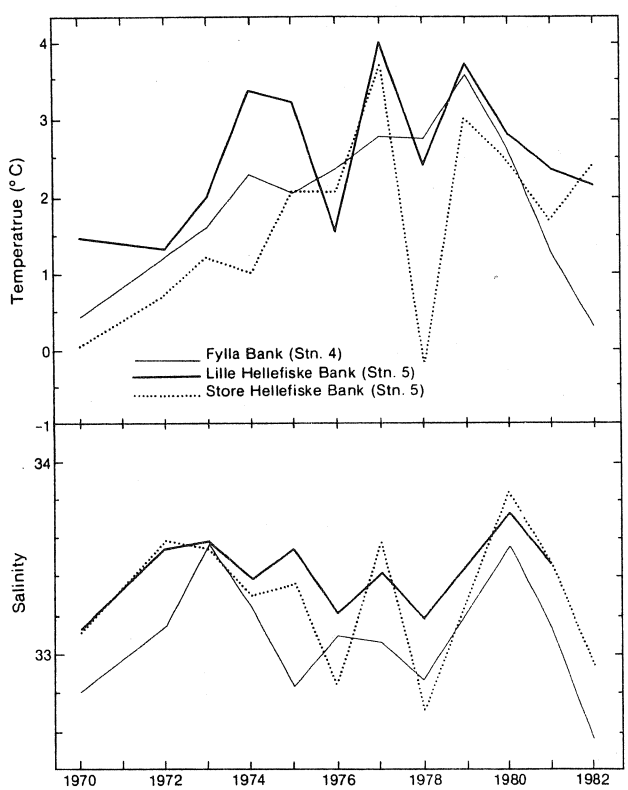

Fig. 7. Mean temperatures and salinities of the surface (0-50 m) layer at stations on the western slope of Fylla Bank, Lille Hellefiske Bank and Store Hellefiske Bank in early July, 1970-82.

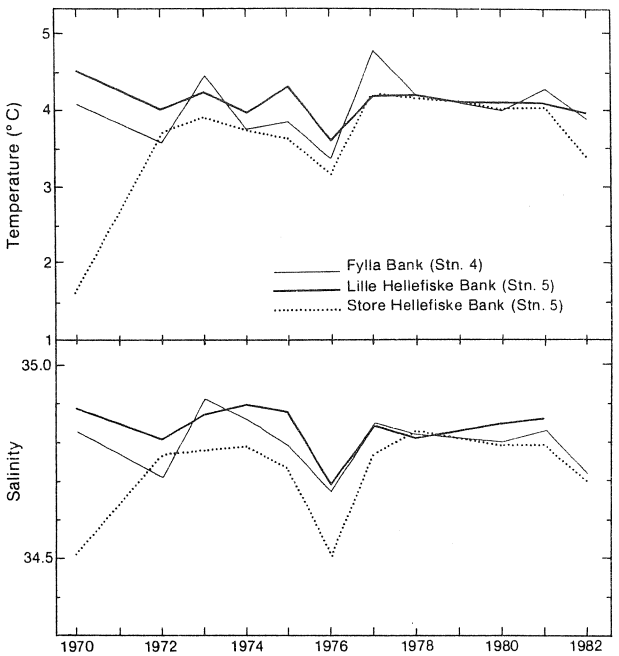

Fig. 8. Mean temperatures and salinities of deep water (400-600 m) at stations on the western slopes of Fylla Bank, Lille Hellefiske Bank and Store Hellefiske Bank in early July, 1970-82.

the bank. This interpretion is confirmed by temperature observations across Fylla Bank in July 1982 which show a thick (200 m) water layer with temperature characteristics of the East Greenland polar water west of the bank (Fig. 4A). In 1981, there was nearly no heating of the water from mid-June to early July on Fylla Bank (Fig. 6), and temperatures west of the bank in early July were low but not particularly so. This is believed to have been due to the later appearance of polar water in that year.

The water on and to the west of the banks was relatively warm in 1977 and 1979 (Fig. 6 and 7). A vertical temperature section across Fylla Bank in July 1979 (Fig. 4B) shows that the layer with temperature characteristics of polar water was absent, thus providing favorable conditions for solar heating. Water of Atlantic origin occurred at depths of 150-250 m.

In July 1978, it is worth noticing the extremely low temperature and salinity conditions west of Store Hellefiske Bank (Fig. 7). These may be explained by the combined influence of remanent winter-cooled water and the influx of polar water from the Baffin Land Current which carried a great amount of drift ice.

Deep layers (400-600 m)

The deep layers to the west of the three banks were dominated by Atlantic water, and the year-to-year variations in hydrographic conditions were quite similar, especially in 1977-81 (Fig. 8). The low temperature and salinity conditions near Store Hellefiske Bank in 1970 may have been due to the influence of the great outflow

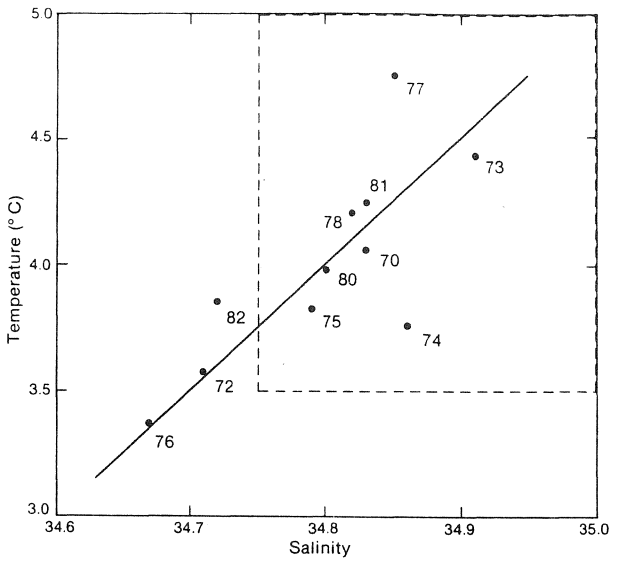

Fig. 9. Temperature-salinity (T-S) diagram for the deep water (400–600 m) west of Fylla Bank in early July, 1970–82. (Region borbored by dashed lines indicate T-S characteristics of Irminger Current water.)

of polar water from the Arctic, as was mentioned above in the description of the upper layers. In 1976, the deepwater stations west of the three banks exhibited relatively low temperatures and salinities, which may be associated with the so-called "1970's anomaly" which was observed at various places throughout the North Atlantic (Ellett, MS 1980; Martin, 1981; Malmberg and Svansson, MS 1982). The last-named authors reported minimum temperatures and salinities of the Irminger Current south of Iceland in 1976. The year-to-year variations in temperature of the 400–600 m layer seem to be well correlated with salinity variations. This is evident in Fig. 9, where the 1976 anomaly can also be clearly seen.

Conclusions

Hydrographic data, which have been collected fairly regularly throughout the year on the Fylla Bank section since 1968, reveal distinct annual periodicities in the influx of the two water masses which constitute the West Greenland Current. Polar water of East Greenland Current origin dominates during the spring and reaches its greatest intensity in June. Influx of water from the Irminger Current is quite low during the first half of the year, being found only at depths below 300–400 m, but it intensifies during the summer and autumn, reaching its peak in November–December.

Observations from three sections along the West Greenland coast show similarity in hydrographic conditions in each year as well as in year-to-year variations, thus indicating the dominance of advective processes along the coast.

Temperature conditions of the upper water layer in June and early July depend greatly on the intensity of inflow of polar water, which in turn greatly influences biological production and the survival of fish larvae in the region.

Water of Atlantic origin dominates at depths greater than 400 m, and the "1970's anomaly", which was observed throughout the North Atlantic in the mid-1970's, was also evident at West Greenland in 1976.

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