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ON THE HYDROGRAPHIC FLUCTUATIONS IN THE LABRADOR SEA DURING THE YEARS 1959—1969

By

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ABSTRACT

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During the years 1959–1969 Norwegian fishery research vessels collected oceanographic data off West Greenland, the observational work mainly being done in April. The data reveal gradually falling temperatures in the upper layers because of increasing supply of Arctic water to the West Greenland Current during the 1960s. The reason for this seems to be the atmospheric pressure and wind conditions which also were in favour of an offshore drift of the surface waters along the West Greenland coast.

Between the surface waters of Arctic characteristics and the Irminger water below vertical convection was to a great extent prevented by a transition layer of high stability. The radiant heat loss during the winter season was, therefore, limited to the upper layers, adding to the decrease in temperature created by the growing supply of Arctic water. In waters of salinity below 34‰ in the section across the Fylla Bank the temperature fell by 1.6°C during the period.

The trend in the Irminger water was different, and the temperature in this water mass rose until 1966.

The cooling in the upper layers can be traced down to approximately 400 m depth, but it was most pronounced at 100 to 150 m depth off the edge of the shelf where the temperature fell by about 2°C. At depths below 400 m the warming effect of the Irminger water can be traced down to 1 000 to 1 200 m depth.

INTRODUCTION

In West Greenland waters where some important fish species find the poleward border of their range, these species are particularly sensitive to environmental fluctuations. This was clearly demonstrated at the beginning of the last good cod period on the West Greenland fishing banks when a marked temperature increase was observed. The longest series of oceanographic observations in the area are sea surface temperatures collected for the Danish Meteorological Institute since 1876. As shown by SMED (1965) these observations indicate a marked temperature increase in the 1920s. The warming continued until the beginning of the 1930. Since then the temperature has on an average remained above the mean for the 40 year period 1876—1915 until recently.

The biological consequences of this temperature increase is described by JENSEN (1939), the best known and most important being the northward extention and strongly increased abundance of the cod stock. The capelin in the area showed an opposite reaction as the southern limit of its range shifted northwards.

Since the beginning of the 1960s a cooling trend has been observed, and the temperature in the surface layer is now about the same as it was before 1920, and its unfavourable effect on the cod stock is already being observed. The reason for this is a general climatic deterioration over the Northwest Atlantic and the European Arctic. This hydro-meteorological fluctuation has in particular been studied by RODEWALD (1967, 1969, 1971), and he shows that since the 1950s the atmospheric pressure in the Greenland high has been above normal. This has given rise to anomaly northerly winds over the Greenland and Norwegian Seas, and consequently to a temperature decrease in this area. It has also given rise to increased transport of Polar water to the East Greenland Current, and as described by MALMBERG (1969), also to the East Icelandic Current. In the North Atlantic south of Iceland and in the Irminger Sea the anomaly pressure and wind have caused an increased supply of Atlantic water to the Irminger Current. Off West Greenland the atmospheric conditions brought about an offshore drift of the surface waters which resulted in an abnormal great lateral extent of the Arctic Component of the West Greenland Current. As reported on by BLINDHEIM (1967) this is demonstrated by observations made on Norwegian fishery research vessels which surveyed the area during the spring of the years 1959—1969. After 1969 these investigations were discontinued and the present paper is, therefore, based on the complete series of hydrographic data from these cruises.

MATERIAL AND METHODS

The hydrographic data consists of temperature and salinity observations made with Nansen casts. Most of them are collected in late March or in April, and some few in the first days of May. Mainly due to ice obstacles, the station grid varied somewhat from year to year. In general, however, the intention was to work sections perpendicular to the coast across the more important fishing banks. As an example the grid of stations worked in 1966 is shown in Fig. 1. The number of stations worked in the sections across the banks in the different years are compiled in Table 1.

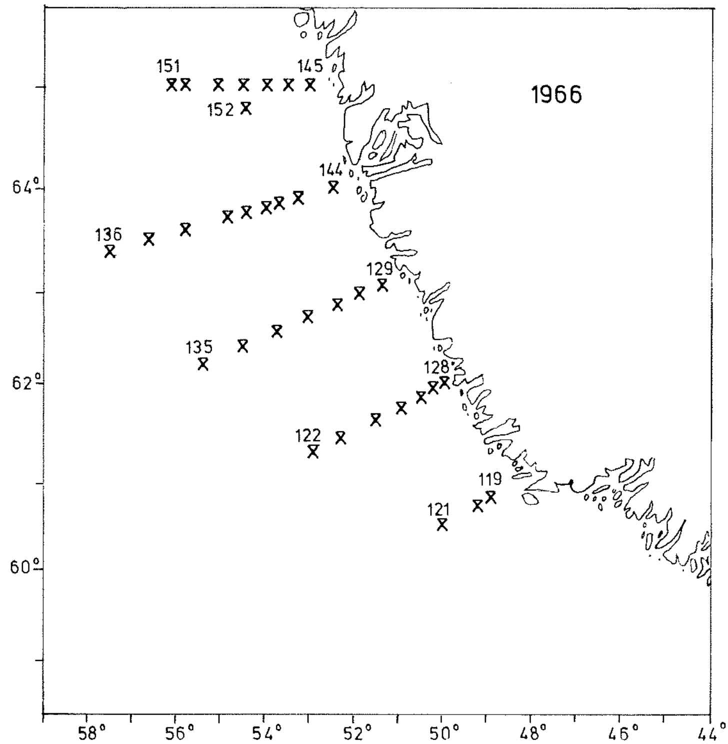

Fig. 1. Grid of stations worked in 1966.

Table 1. Number of hydrographic stations worked in the different sections across the fishing banks off West Greenland in the years 1959—1969.

Year	Fredriks-håb Bank	Danas Bank	Fyllas Bank	Lille Hellefiske Bank	Other	Total
1959 ...	4	8	8	8	10	38
1960 ...	5	5	5	5	8	28
1961 ...	7	7	7	7	25	53
1962 ...	4	0	5	5	2	16
1963 ...	6	0	9	5	7	27
1964 ...	7	6	6	5	15	39
1965 ...	6	5	9	6	9	35
1966 ...	7	7	9	7	4	34
1967 ...	7	7	5	4	6	29
1968 ...	5	7	9	7	5	33
1969 ...	0	7	8	6	4	25

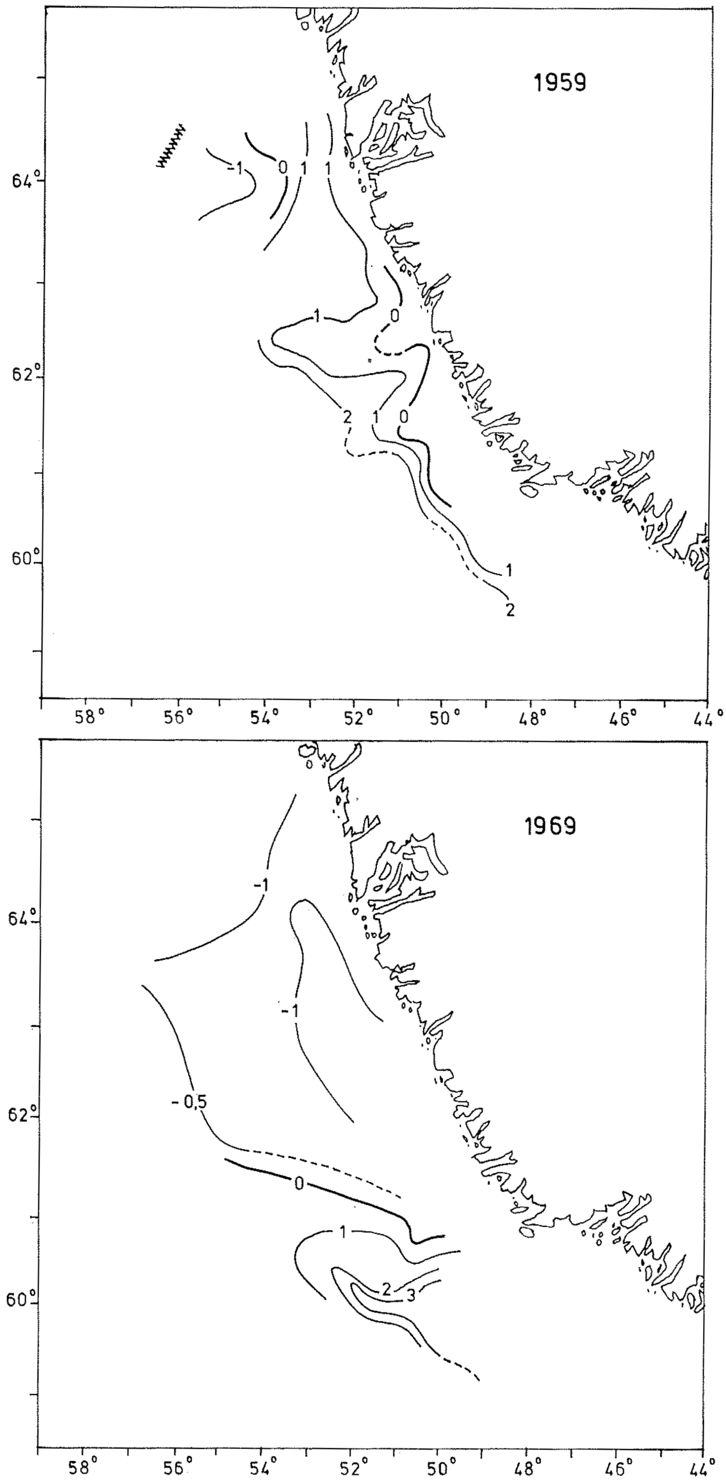

Fig. 2. Surface temperature as observed in April 1959 (top) and April 1969 (bottom).

RESULTS AND DISCUSSIONS

Fig. 2 shows the distribution of the surface temperature as observed in April 1959 and in 1969. Even though the chart for 1969 is lacking somewhat in detail, it is evident that the temperatures in the surface layer have decreased considerably during the period. In 1959 only a minor area close to the coast exhibited temperatures below 0°C while in 1969 the isotherm for 0°C was situated far from the coast, and the greater part of the survey area had sub-zero temperatures in the upper layers. By comparing similar charts for all years during the period it is seen that from 1961 the lateral extent of the Arctic Component of the West Greenland Current has increased gradually.

Sections across the Fylla Bank from 1961 and 1969 are shown in Fig. 3 and Fig. 4 respectively. They demonstrate the situation typical for the beginning and the end of the period. The increased lateral extent of the waters of Arctic and coastal origin in the West Greenland Current towards the end of the period is clearly seen. In the section from 1961 only the waters close to the coast was colder than +1°C with associated salinities about 34.1‰. In 1969 the temperature was below 0°C in the upper 52 m along the whole section, and the associated salinities had

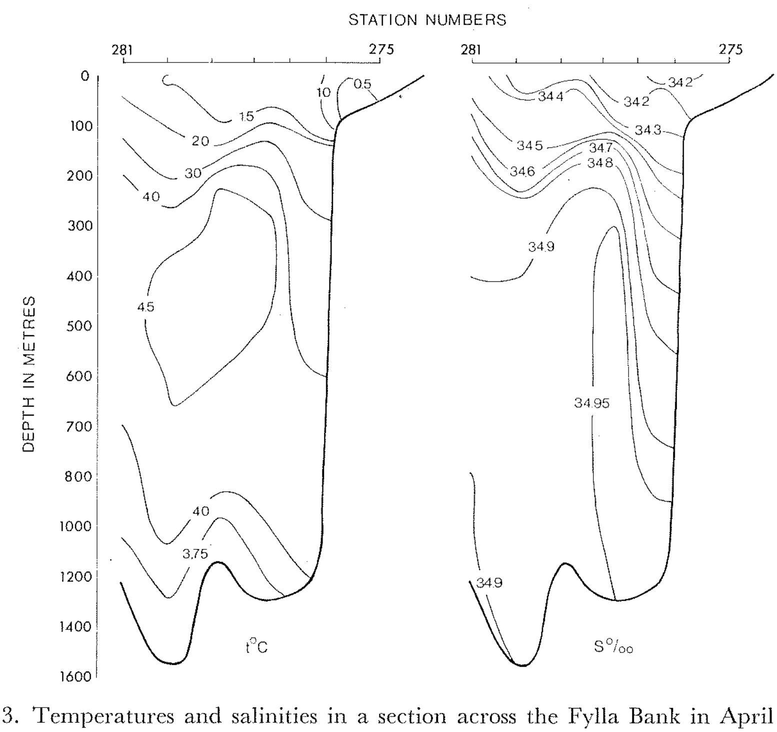

Fig. 3. Temperatures and salinities in a section across the Fylla Bank in April 1961.

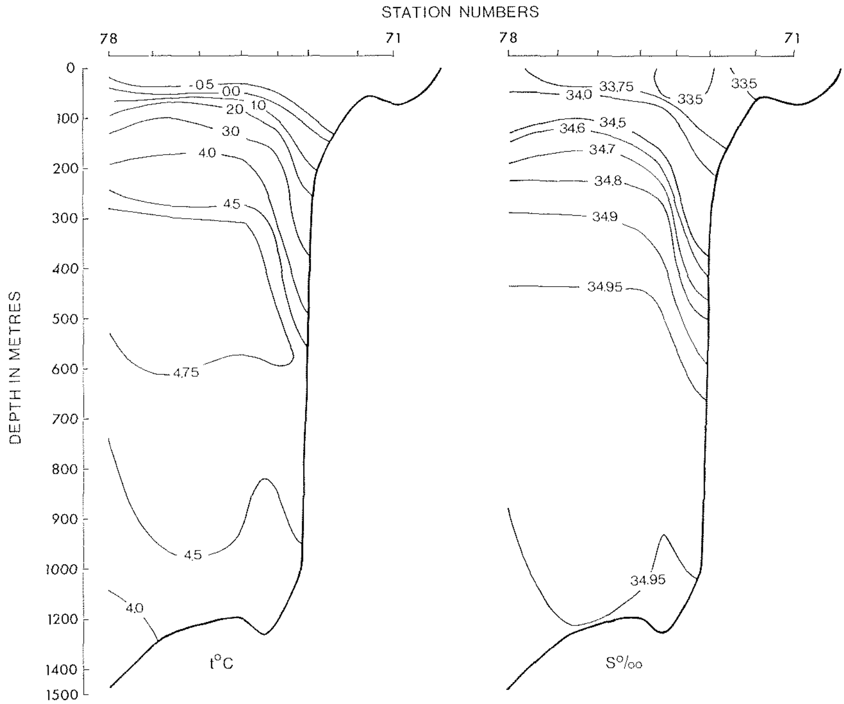

Fig. 4. Temperatures and salinities in a section across the Fylla Bank in April 1960.

decreased to between 33.5 and 33.8‰. The temperature decrease in the upper layers during the 11 year period is demonstrated by the curves in Fig. 5. The figure shows three years moving average of mean temperature and salinity in the Arctic Component of the West Greenland Current, i.e. in waters of salinity below 34.0‰. The figure shows that the temperatures have fallen gradually during the period and the difference between the mean for 1959 — 61 and 1967 — 69 amounts to 1.6°C. In the same manner the curve for the salinity shows a decrease of about 0.3‰, but during the last years of the period it shows a minor increase.

The Irminger Component of the West Greenland Current is seen in Fig. 3 and 4 as a temperature maximum at depths between about 300 and 600 m. It is shown in the figures that this water mass exhibited somewhat lower temperatures in 1961 than in 1969, the maximum being about 4.6 in 1961 and between 4.9 and 5.0°C in the end of the period. Fig. 6 which shows mean temperatures between 300 and 500 m depth in the Fylla sections, demonstrates the temperature trend in the Irminger Component more in detail. The mean feature demonstrated is a relatively cold period in the years 1961, 62 and 63 followed by an increase which culminated in 1966 when the mean temperature was 1.4°C

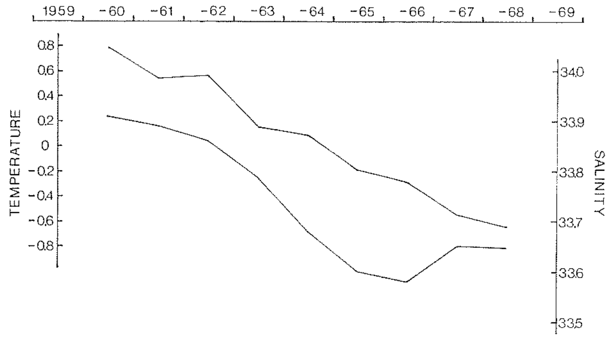

Fig. 5. Three years moving averages of temperature and salinity in waters of salinity below 34‰ in the section across the Fylla Bank.

above the mean value for 1963. During the following years the temperature decreased again to values below the overall mean for the 11 year period. A similar trend has also been observed in the other sections to the north and south of the Fylla Bank. The temperature increase until 1966 is in agreement with the trend in the July temperature which is reported on by Hermann (1967).

A trend which is closely related to the trend in the Irminger water off West Greenland is also observed in the surface layer at OWS ALFA in the Irminger Sea as described by Rodewald (1971). The fluctuations observed in the Irminger water of the West Greenland Current are, therefore, related to the conditions in the Irminger Sea. The reason is, as explained by Rodewald (1971), the distribution of the atmospheric pressure and wind field which up to the mid 1960s were in favour of greate transport than normal of Atlantic water to the Irminger Current. At the same time, however, the supply of Arctic water to the East-, and consequently to the West Greenland Current was also enlarged and contributed to its increased offshore extent in the surface layer.

The decreasing salinity in the surface layer brought about a decline

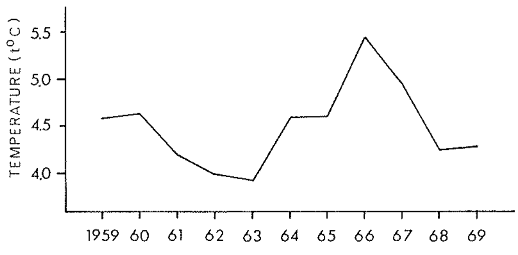

Fig. 6. Mean temperature between 300 and 500 m depth in the section across the Fylla Bank.

in density, the lowest values being observed in 1966, but densities remained low also during the rest of the period. In 1966 the mean δ_t-value in the upper 50 m of the Fylla section was 0.5 less than the value for 1960. Consequently the transition layer between the more or less Arctic waters of the surface layer and the Irminger water below became more pronounced, and the vertical exchange of heat by convection was consideraly reduced. During the winter season this resulted in an additional cooling of the surface layer because of radiant heat loss and only moderate heat supply from below. This seems also to be the reason for rising maximum temperatures in the Irminger Component from south to north. In the section across the Lille Hellefiske Bank the average maximum temperature in the Irminger water during the period was 5.11°C. This is respectively 0.22°C and 0.48°C higher than the associated averages in the sections across the Fylla and Dana Banks further south. A similar, but not so pronounced trend was also established for the salinity. This northward augmented preservation of the Irminger characteristics may be explained by a northward decrease in vertical convection during the winter season.

The vertical distribution of the temperature and salinity fluctuation is illustrated in Fig. 7. This figure shows a mean difference between the

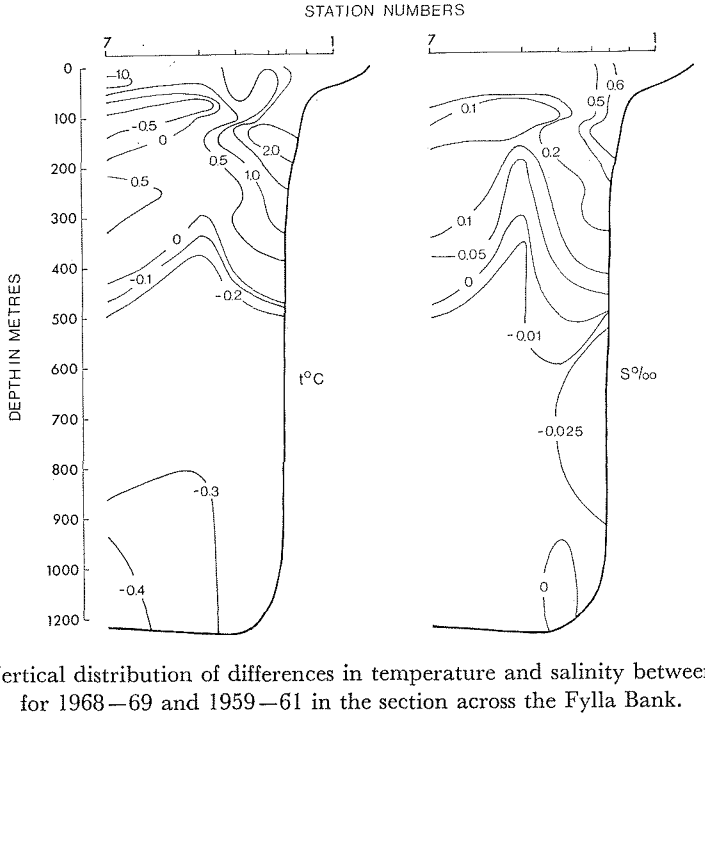

Fig. 7. Vertical distribution of differences in temperature and salinity between means for 1968—69 and 1959—61 in the section across the Fylla Bank.

beginning and the end of the period in the section across the Fylla Bank. It is based on the sections worked in 1959, 1961, 1968 and 1969. The temperature differences, t, which are depicted in the section are

$$t = \tfrac{1}{2}(t_{1968} + {}_{1969}) - \tfrac{1}{2}(t_{1959} + t_{1961}),$$

and the salinity values are worked out in the same manner. The figure indicates that the temperature has increased down to about 400 m depth, the cooling effect being most pronounced over the shelf and slope. At 150 m depth just off the edge of the shelf the difference exceeded 2.0°C, the associated difference in salinity being between 0.6 and 0.7‰. The extent of Arctic water which spread out in the upper layers during the period, is indicated by a difference of about 0.5°C and 0.2‰ above approximately 50 m depth.

In 1968 and 1969 the transport of Irminger water to the Labrador Sea was diminishing compared to the inflow in the middle of the period as indicated in Fig. 6, but still it's temperature was higher in the beginning of the period. This is shown in Fig. 7 by the core which is indicated by rising temperatures at intermediate depths. It is also seen that the effect of the Irminger water, being mixed with surrounding water masses, can be traced down to depths of 1 000 to 1 200 m.

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