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Hydrographic fluctuations off West Greenland during the years 1959-1966

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Summary

Hydrographic data from the West Greenland waters in March-April during a period of 8 years, from 1959 to 1966, were studied. The study is mainly based on sections worked off Frederikshaab and off the Dana Bank. It is shown that changes occur in temperature, salinity and also in vertical extent of the Irminger component of the West Greenland Current. Thus in 1960 and particularly in 1966 the Irminger component was well developed Such changes may be due partly to fluctuations in the main structure of the Irminger Current, but also to the extent of the convection during the different winters The depth of convection is dependent upon the salinities in the surface layer, where considerable variations from one year to the next are observed. In the years around 1960, the salinity in the surface layer was relatively high, but decreased in later years, resulting in a cold and very stable surface layer in the years 1964-1966. In the years 1959-1961 a considerably warmer surface layer was observed, with convection reaching deeper because of less stability.

Research vessels from the Institute of Marine Research, Bergen, have investigated the waters off West Greenland in March-April since 1959. The principal aim of these cruises was to study the stock of cod in the area during the spawning season, and record hydrographic factors important for the recruitment and distribution of cod.

At the meeting of the Research and Statistics Committee of the International Commission for the Northwest Atlantic Fisheries held in Madrid in 1966, it was recommended to obtain synthesis of hydrographic and meteorological fluctuations observed in the ICNAF Area during the recent years. The present paper is intended to contribute to the preparation of such a synthesis.

The material dealt with here consists mainly of observations during the period March-April, but in a few cases observations made during the first days of May are included. Since 1959, cruises to the West Greenland waters have been repeated every year, and data collected to 1966 are worked up, allowing a period of 8 years to be studied. More or less the same program has been followed every year. Usually 4 or 5 hydrographic sections have been worked seaward from the coast between Noname Bank and Lille Hellefiske Bank. Further to the north navigation has been hindered by ice, except for a narrow lane along the coast. The most northern station on each cruise was usually located off Holsteinsborg in about Lat. 66°30'N to 67°N.

From 1959 to 1962, the hydrographic stations were worked to a maximum of 2,000 m depth, but since 1963 all stations have been worked to the bottom regardless of depth.

The lengths of the sections have varied some with the time available, ice conditions and weather conditions, but generally the sections are longer in the years since 1963 than in the previous years. The station grid worked in 1966 is shown in Fig. 1.

The study of the waters of the West Greenland Current is based on the data from the sections worked off Frederikshaab and off the Dana Bank. These sections are situated south of the area where the greater portion of the West Greenland Current bends westward, and will presumably give good information about the inflow carried by this current.

In 1959 a section was worked both off Frederikshaab (Fig. 2) and off the Dana Bank. The temperature in the upper 100 m was above 0°C throughout these sections, and only close to the shore was the temperature below 0.5°C. The salinities in the same layers were below 34‰ over the inner part of the shelf, on the outer part being around 34.1‰. The Irminger component of the current exhibited salinities slightly above 34.90‰ with corresponding temperatures mainly below 4.50°C. In the section off Frederikshaab the temperature was higher than 4.50°C only in a small core between 400 and 500 m depth. Off Dana Bank the highest temperature was 4.35°C.

Figure 3 shows a section in April 1960 off Frederikshaab. The temperatures in the upper 100 m varied between 1°C at depths less than 30 m over the inner part of the shelf, and about 3°C at 100 m depth farther out on the section. The corresponding salinities varied between about 33.9‰ close to the shore and 34.5‰ at the western end of the section.

The salinity of the Irminger component exceeded 34.90‰ from 300 m downward. Off the slope relatively large water masses exhibited salinities above 34.95‰ with corresponding temperatures up to 4.72°C.

The conditions in 1961 were apparently not very different from those in 1960. Figure 4 shows the section toward the southwest from Dana Bank. In the upper layers the distribution of temperature and salinity was almost the same as in 1960. The salinities in the Atlantic component of the West Greenland Current exceeded 34.95‰ between approximately 300 and 500 m depth, but no temperatures higher than 4.43°C were observed.

In 1962 no section was worked off Frederikshaab or on Dana Bank, but according to the sections off Noname Bank and across Fylla Bank, the temperatures in the upper layer were generally lower than in the previous years. The conditions in the Irminger component showed no features much different from those in the previous years.

Figure 5 shows a section off Frederikshaab from 1963. Rather low temperatures were observed over the shelf, and salinities below 34.00‰. Off the shelf, however, the temperatures were high from the surface to 100 m depth, mostly between 2° and 3°C. The corresponding salinities were between 34.25 and 34.75‰. The Irminger component was not well developed, its mean temperature being about 4.2°C, the maximum 4.45°C. Off the slope salinities were slightly above 34.90‰ at depths greater than approximately 200 m.

A section from across Dana Bank in 1964 is illustrated in Fig. 6. The salinities in the upper layers were mainly below 34.00‰ and in the greater part of the section the corresponding temperatures were below 0°C at depths less than 50 m. The isotherm for 2°C was situated at about 100 m depth.

The temperatures of the Irminger component were considerably higher in this section. Relatively large water masses were warmer than 4.50°C with corresponding salinities around 34.90‰. Just off the slope the temperature exceeded 5.0°C between 450 and 600 m depth. The maximum temperature in this extremely warm core was 5.16°C, and the salinity 34.96‰.

The section off Dana Bank in 1965 is illustrated in Fig. 7. Over the shelf temperatures were below 0°C in the surface layer outward to about 50 nautical miles off the coast. At the western end of the section, 70 nautical miles off the coast, the temperature was about 0.8°C near the surface and 3.9°C at 100 m depth. Throughout the section the salinities of the surface layer were below 34.00‰, and over the shelf even below 33.5‰.

The highest temperatures of the Irminger component off the slope were found at relatively moderate depths, between 150 and 500 m. The temperatures exceeded 4.50°C, the maximum of 4.81°C being observed at 250 m depth. The salinity of this water was 34.90‰. Salinities exceeding 34.90‰ were encountered downward from 400 m depth, but no values higher than 34.93‰ were observed.

In 1966 (Fig. 8) subzero temperatures were observed in the upper 50 m over the shelf off Frederikshaab. The salinities were between 33.00‰ and 33.5‰. Outside the shelf area the salinities in the upper 100 m were well above 34.00‰,

and the temperatures were also high, approximately 4.4°C at station 124 about 60 nautical miles off the coast.

The Irminger component exhibited extreme conditions; the temperatures were above 4.50°C at depths between approximately 100 and 700 m at some distance from the slope. In the slope area such high temperatures were observed down to about 1000 m depth. As shown in Fig. 8 there were also great water masses with temperatures above 5.00°C. A maximum of 5.28°C were observed at 300 m depth. The corresponding salinities were also high, and the figure shows that an intermediate layer with salinities above 34.95‰ was found along the whole section between approximately 150 and 450 m depth. In this layer most of the observed salinities were slightly below 35.00‰, mostly 34.98‰. At station 123, 35.001‰ was observed at 300 m and 35.000‰ at 400 m depth.

Off Dana Bank the conditions of the Irminger component were similar to those off Frederikshaab; great water masses with temperatures above 5.00°C were observed, with corresponding salinities up to 34.99‰. In the surface layer, the temperatures were below 0°C in the greater part of the section, and the salinities were considerably below 34.00‰.

A comparison of these sections for the different years reveals that there have been fluctuations in the Atlantic inflow of the West Greenland Current as well as in the conditions of the upper layers strongly influenced by the Polar component of the West Greenland Current. There is no rule that the upper layer should be warm when the Irminger component is well developed. Thus, in 1959, the waters of the upper layers were relatively warm but the temperatures and salinities of the Irminger component were rather low. The observations from 1960 revealed a warm surface layer at the same time as the Irminger component was well developed. In 1964 and particularly in 1966, however, the Irminger component was extremely well developed, but the temperatures and salinities of the upper layers were relatively low.

The temperature variations in the upper layers, indicated by the hydrographic sections, may best be illustrated by horizontal temperature charts. Such charts were therefore prepared at 4 m depth for all the 8 years, based on observations from sea surface thermographs. The charts for 1961 and 1966 are shown in Fig. 9 and 10. The years 1959, 1960 and 1961 stand out as warm years and of these 1961 shows the most extreme conditions. In this year, subzero temperatures were observed only in Julianehaab Bay and a few places very close to the coast farther to the north. North of Lat. 66°N temperatures below -1°C were observed at some distance from the coast. Temperatures above 1°C were found over the slope as far north as approximately 65°30'N. Over the Lille Hellefiske Bank the temperatures were between 0.5 and 1°C, but south of this bank the isotherm for 1°C followed the coastline at a distance of about 15 to 30 nautical miles.

The conditions in 1959 and 1960 were similar to those in 1961, even though temperatures above 1°C did not extend so far to the north in these years. In 1959 there was also more cold water along the coast than in 1961.

In 1962 no temperatures above 0°C were observed north of 66°N, and the temperatures above 1°C seemed to extend to about 63°N. This is, however, a rough approximation since all observations were made within 60 to 70 nautical miles of the coast. In the shelf area, waters with temperatures below 0°C were observed along the whole coast, its extension being about 15 to 30 nautical miles off shore. The isotherm for 0°C bent to the west and southwest at about 65°45'N.

In 1963 the conditions of the surface layer south of about 64°N were apparently not very different from those in 1962. North of this latitude, however, only subzero temperatures were observed, and compared with the preceding years this means considerable decrease. The largest temperature decrease occurred in the area of northern Fylla Bank and Lille Hellefiske Bank.

The chart for 1964 shows that temperatures above 1°C were not observed north of 62°N, and even at 60°N temperatures above 1°C were observed only in a narrow belt off the slope extending over hardly 2 degrees of longitude. This year the cold waters from the Labrador area were apparently extended farther to the east, and in 62°N, west of 54°W, the temperatures were below 0°C. Northward from this latitude only a narrow tongue of water warmer than 0°C extended toward 64°N.

In 1965 the surface temperatures were generally a little higher than in 1964. This was particularly true for the western part of the area investigated where the westerly cold waters this year did not extend so far east to influence the conditions.

Figure 10 shows that for 1966 very low temperatures were observed north of about 62°30'N. This year a relatively sharp front developed in the east-west direction, and the isotherms for 0°C and 2°C were close to each other. North of 63°N no temperatures above -0.5°C were observed, and northward from this latitude the year 1966 obviously revealed a colder surface layer than the previous years since 1959. South of 62°N, however, the temperatures were rather high at some distance from the coast.

In order to compare the temperature fluctuations in the surface layer with the climatic conditions, monthly mean temperatures from three meteorological stations have been scrutinized. These stations are: Ocean Weather Station "B" in 56°30'N, 51°00'W, Prince Christian Sound near Cape Farewell, and Egedesminde in Disko Bay. The mean temperatures are taken from monthly climate charts prepared for the Institute of Marine Research by the Meteorological Institute in Bergen. The variations of the mean temperature for the period December-March in each winter are illustrated by Fig. 11. The coldest winters occurred in the years around 1960, while the winters in the years 1963-1965 were relatively mild. Consequently there seems to be little relationship between the temperatures in the surface layer in the Davis Strait and the mean air temperature during the preceding winter. The reason for the lack of a relationship may be to some degree that the temperature observations at these meteorological stations are not representative for the area investigated, and that the wind conditions also have an influence. The latter possibility would explain the great eastward extension of the cold waters from the Labrador side in 1964, as due to a prevailing westerly wind during the previous months.

The salinity in the upper layers seems also to be of great importance since it varies considerably in the different years. Figure 12 illustrates the variations in the mean salinity for the years between 0 and 50 m depth in the sections across Fylla Bank. The year 1961 had the highest value of 34.26‰, while 1965 and 1966 only had 33.36‰ and 33.54‰ respectively. These variations in salinity influence the stability in the upper layers, and again the temperature conditions, agreeing well with the observations made in the area. It seems therefore clear that during the winter the temperature of the upper layers depends more on the stability than on the air temperature. Figure 13, with mean sigma-t curves for the sections across Fylla Bank in 1960 and 1966, demonstrates clearly that there was a more stable stratification in the upper 200 m in 1966 than in the former year. An example of an extreme condition is shown in the sigma-t curves for station 86 in 1965 and station 259 in 1961 (Fig. 14) both situated on the western slope of the Lille Hellefiske Bank. The figure demonstrates clearly that the stratification of the water masses was far less stable in 1961 when the salinities in the surface layer were high, than in 1965. Thus, low salinities in the surface layer create very stable stratification, and the convection resulting from the winter cooling will not reach deep. Thereby the loss of heat takes place only in a thin surface layer. A more saline surface layer creates less stability, thus permitting a deeper convection during winter cooling. The heat will then be drawn from a considerably thicker layer, extending down to a depth of several hundred meters. However, a smaller temperature decrease near the surface will consequently occur.

Also the high temperature in the Irminger component of the West Greenland Current in 1964 and 1966 may to some degree be explained by the lack of deep-reaching convection in these years.

It is possible that the variations of temperature in the upper layers influence the behaviour of the cod in such a way that it finds preferable temperatures at different depths in the different years, as indicated by the varying fishing depths with bottom longline on the cruises. In 1960 and 1961 the mean fishing depth was 155 and 210 m respectively, while in 1964 and 1966 it was 260 and 270 m respectively. The varying fishing depths are probably determined by the temperatures on the fishing grounds, which in 1964 and 1966 to some degree excluded the cod from the Banks at depths less than say 200 m.

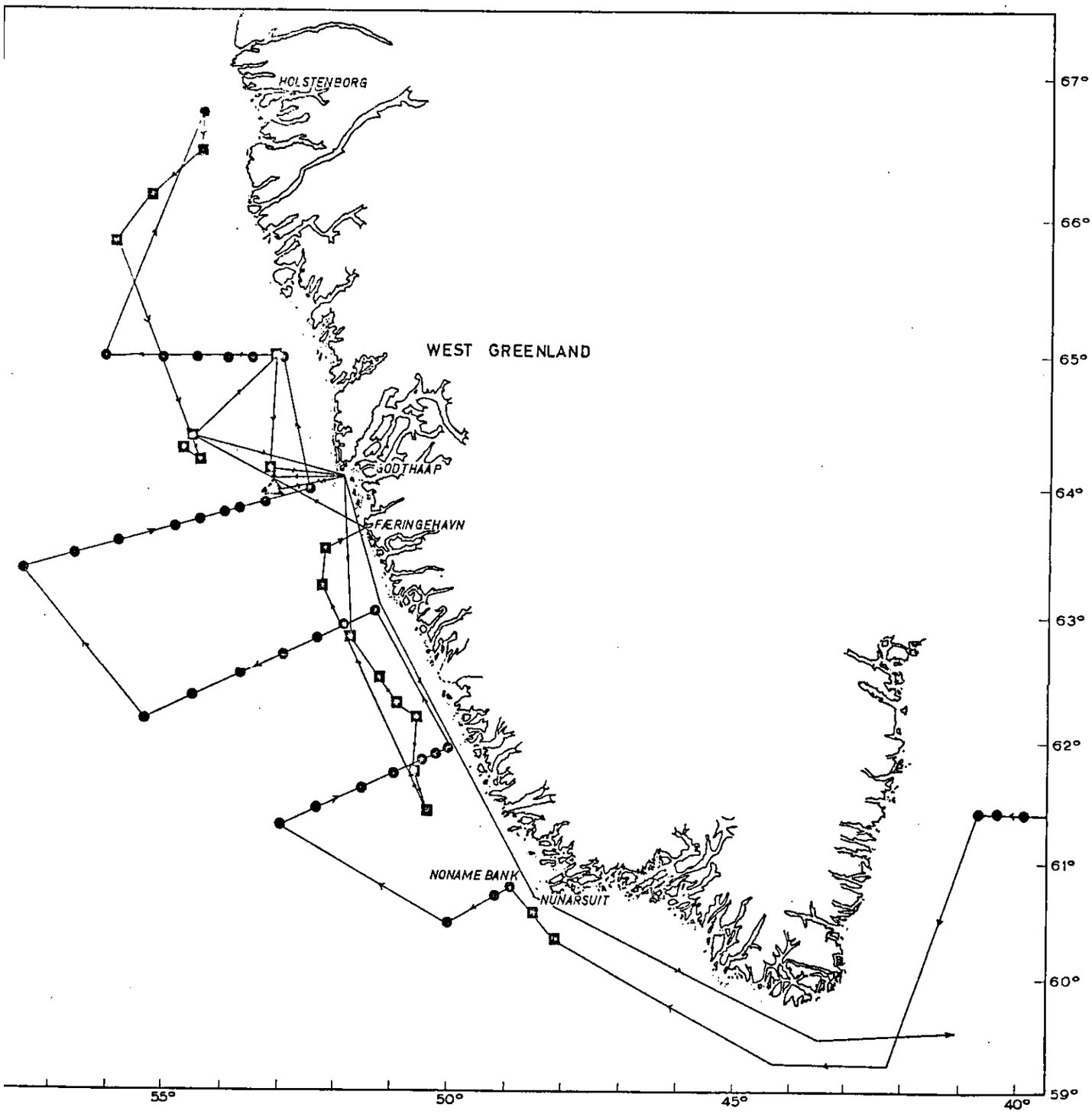

Fig. 1. Station grid for 1966.

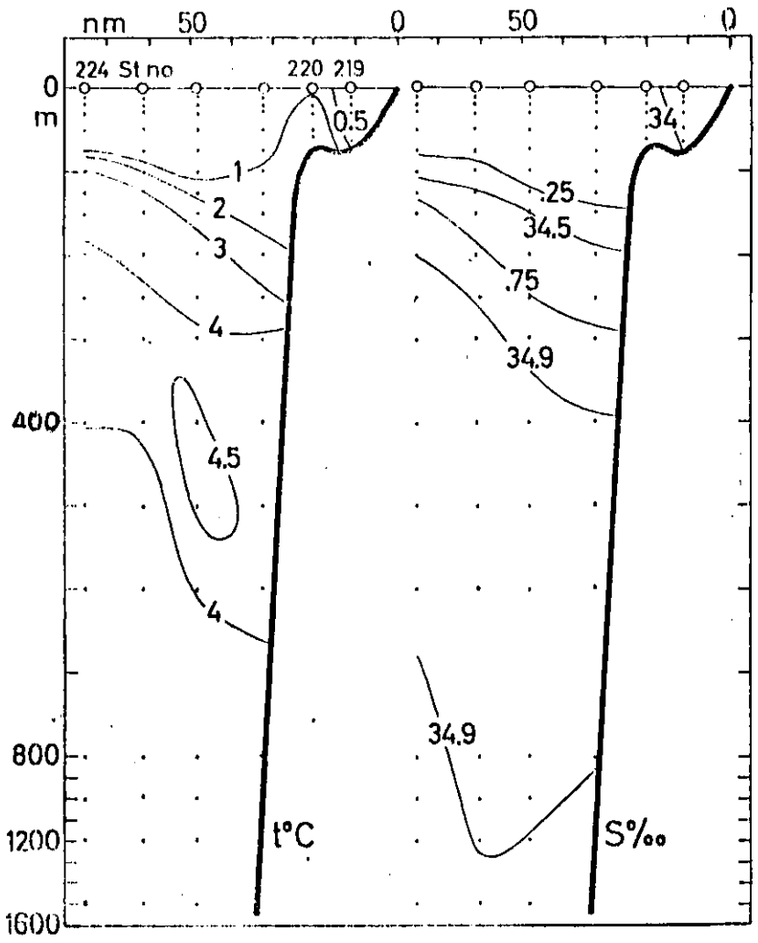

Fig. 2. Hydrographic section off Frederikshaab, 11 April 1959.

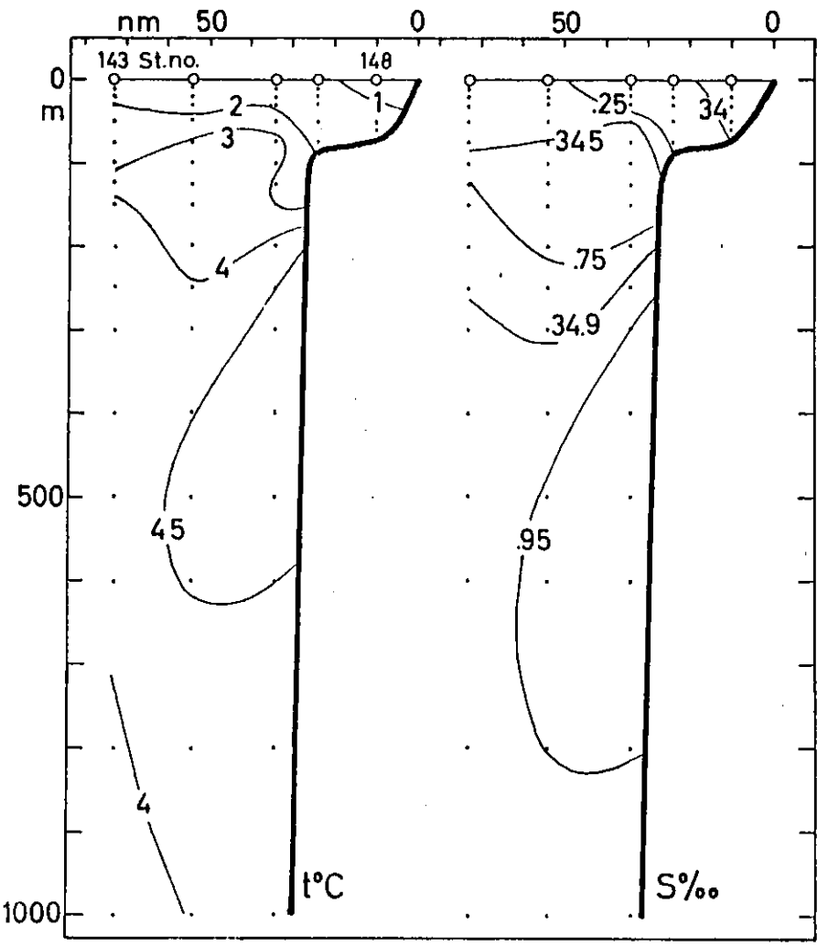

Fig. 3. Hydrographic section off Frederikshaab, 7-8 April 1960.

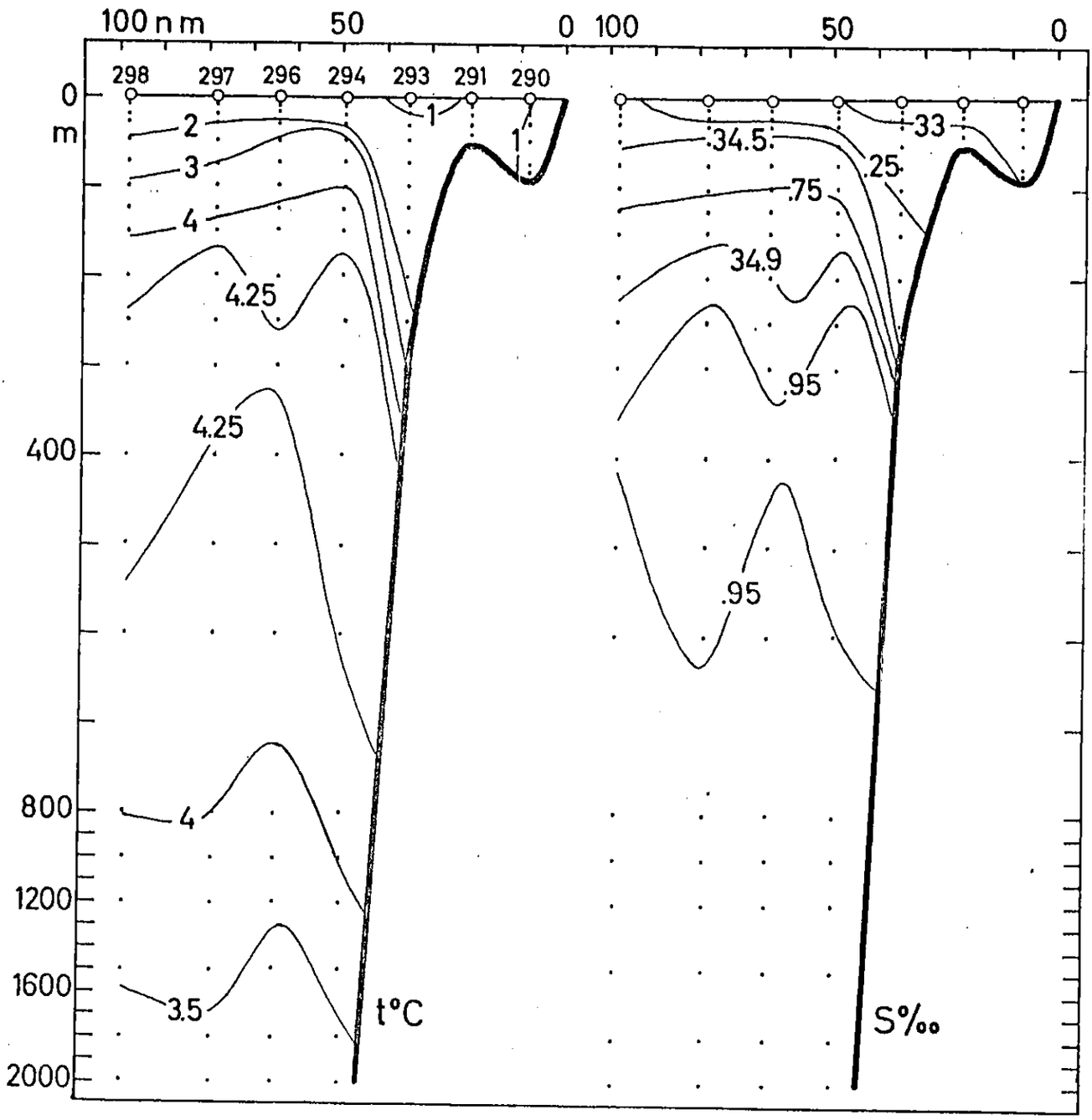

Fig. 4. Hydrographic section off Dana Bank, 3-5 April 1961.

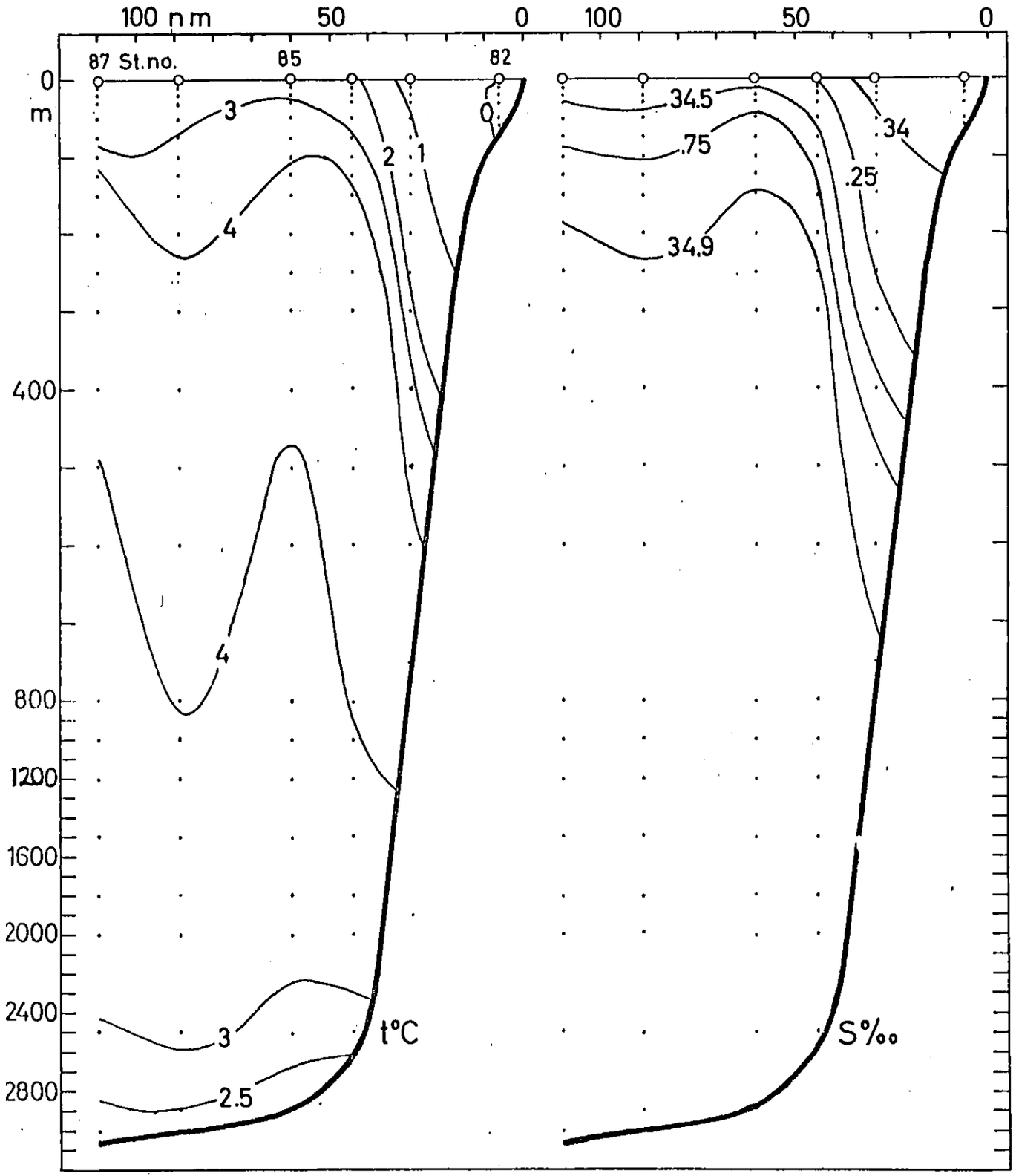

Fig. 5. Hydrographic section off Frederikshaab, 11-12 April 1963.

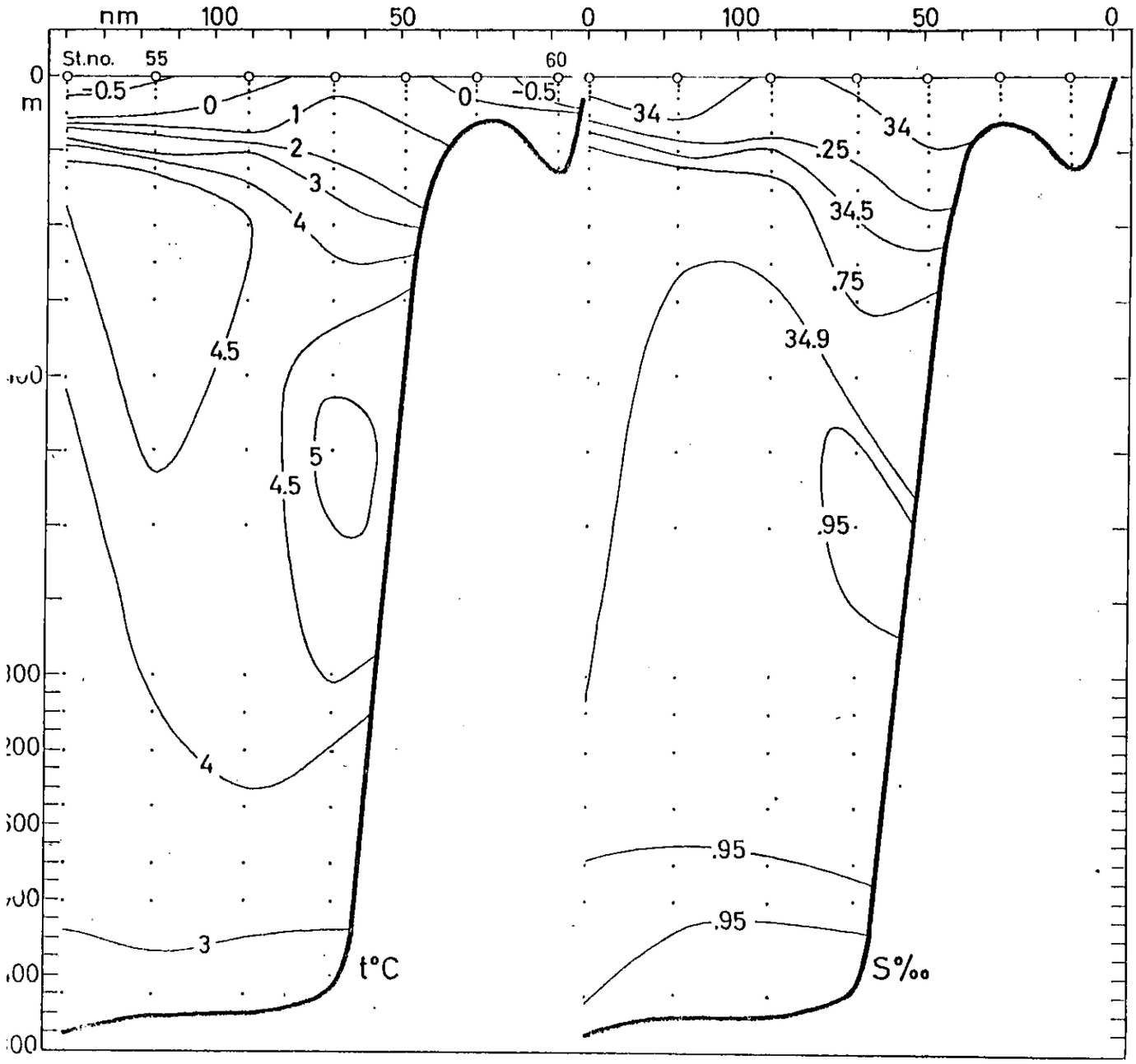

Fig. 6. Hydrographic section off Dana Bank, 14-15 April 1964.

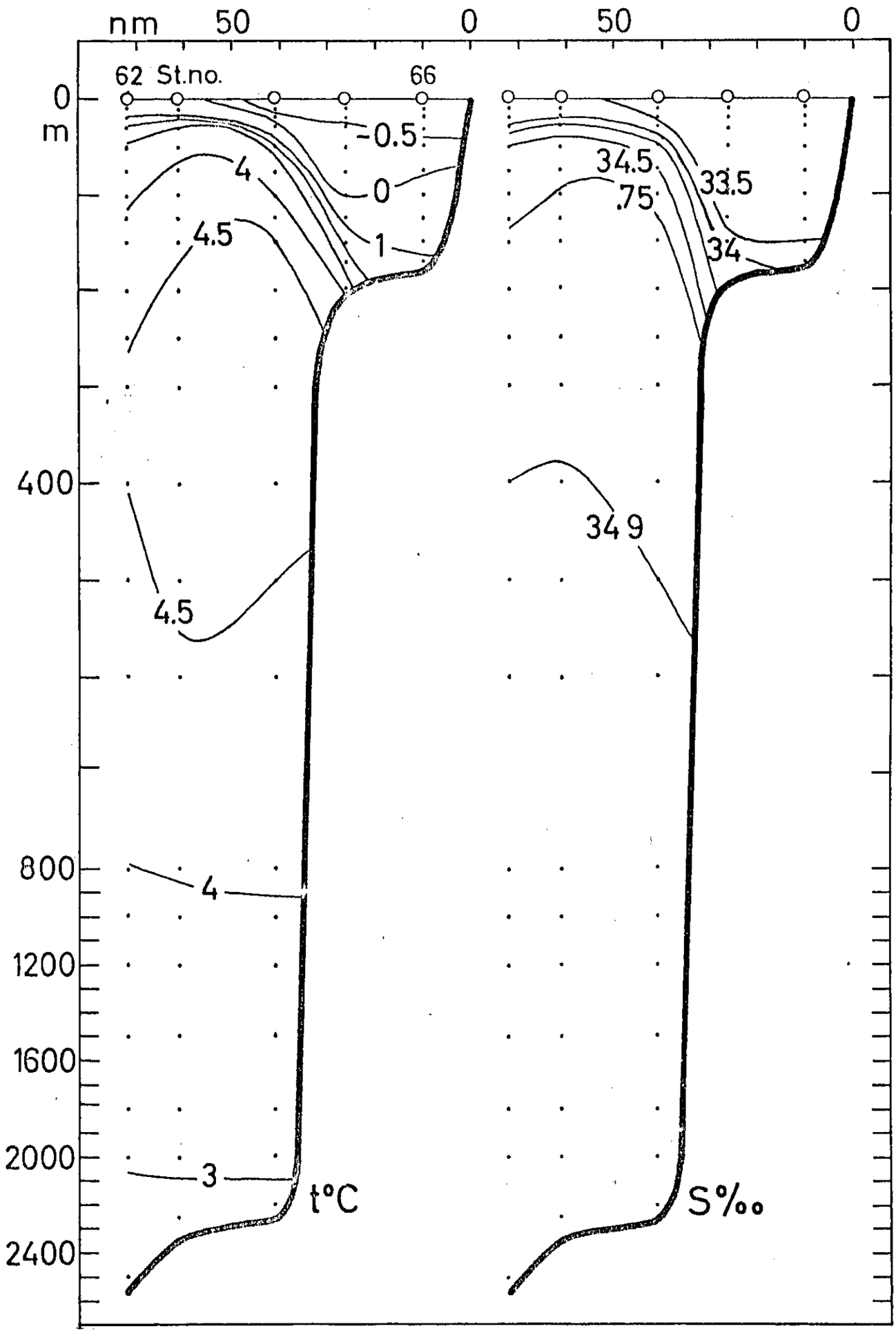

Fig. 7. Hydrographic section off Dana Bank, 10-11 April 1965.

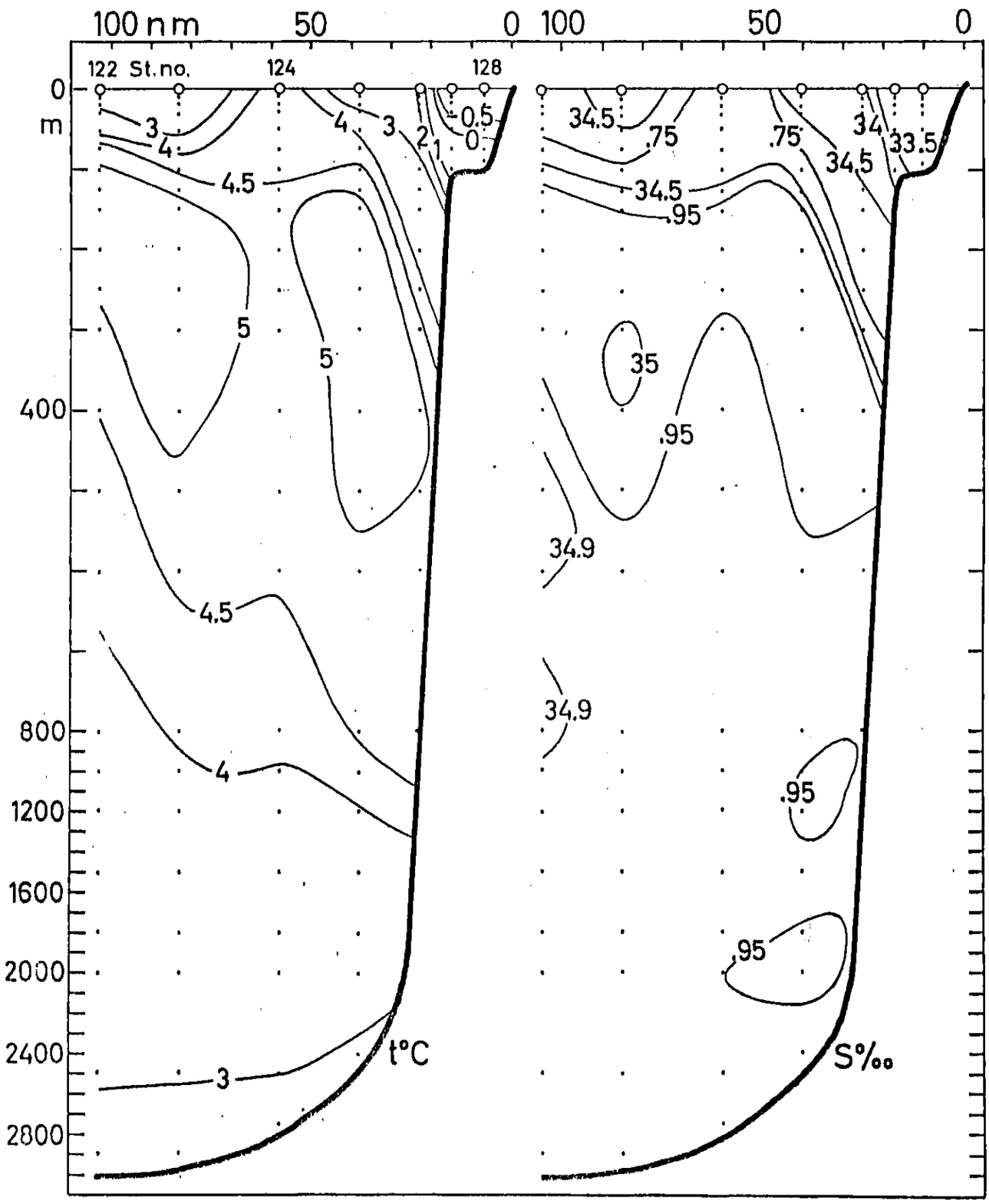

Fig. 8. Hydrographic section off Frederikshaab, 30-31 March 1966.

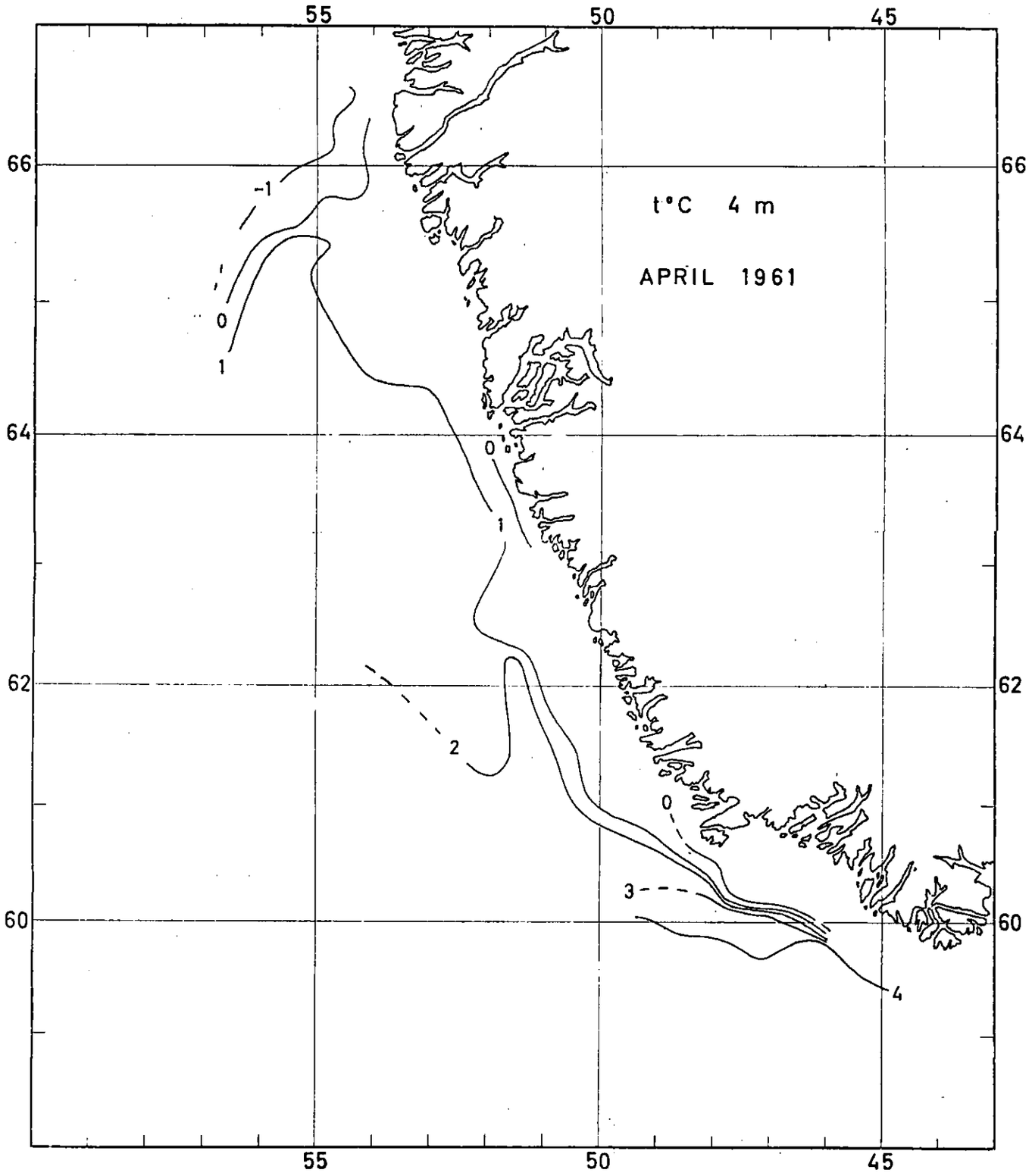

Fig. 9. Temperature distribution at 4 m depth in April 1961.

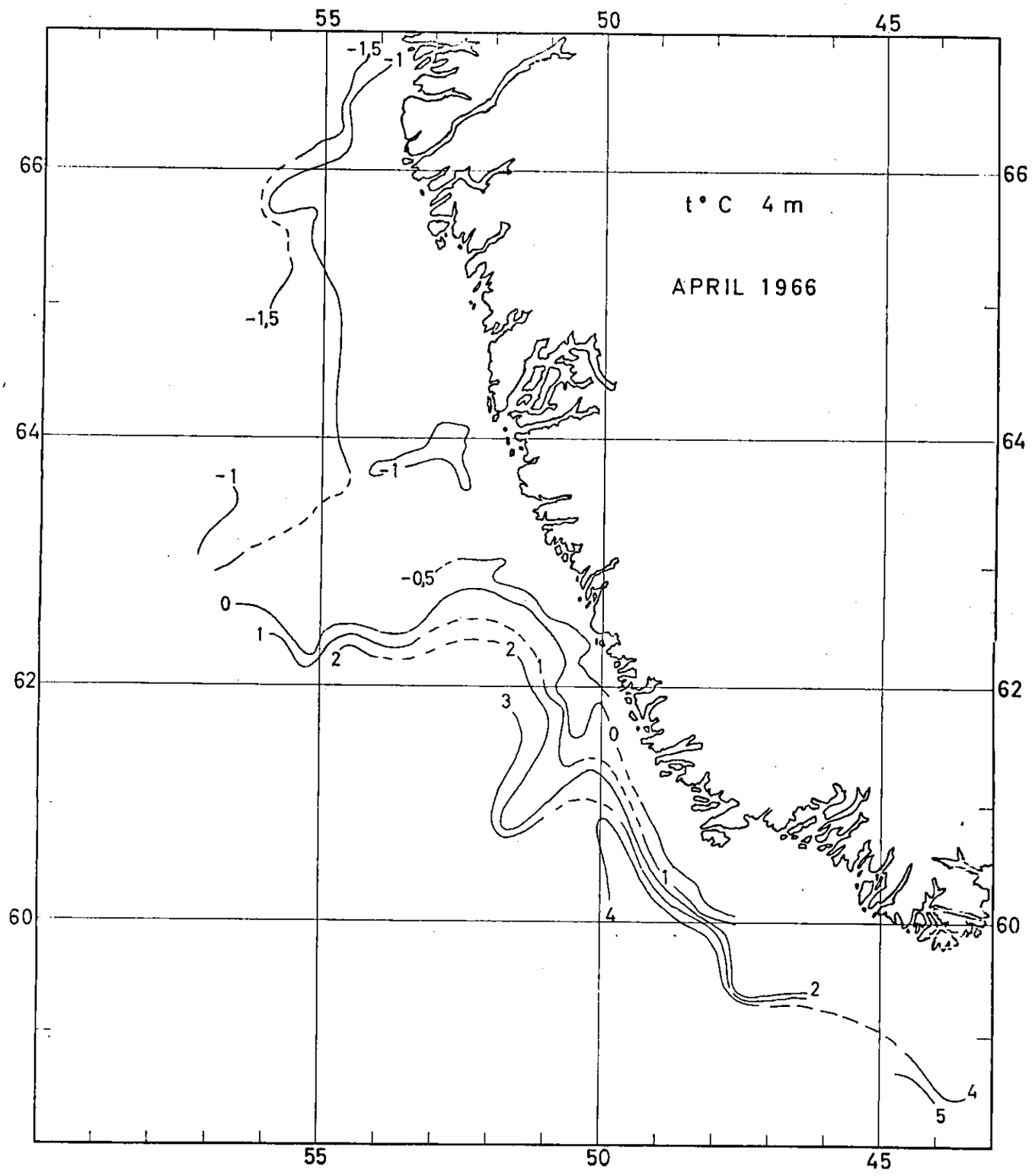

Fig. 10. Temperature distribution at 4 m depth in April 1966.

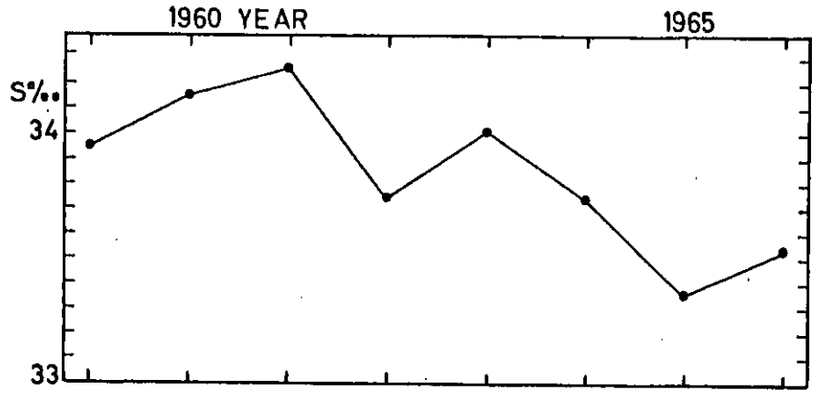

Fig. 12. Mean salinity between 0 and 50 m depth in the different sections across Fylla Bank.

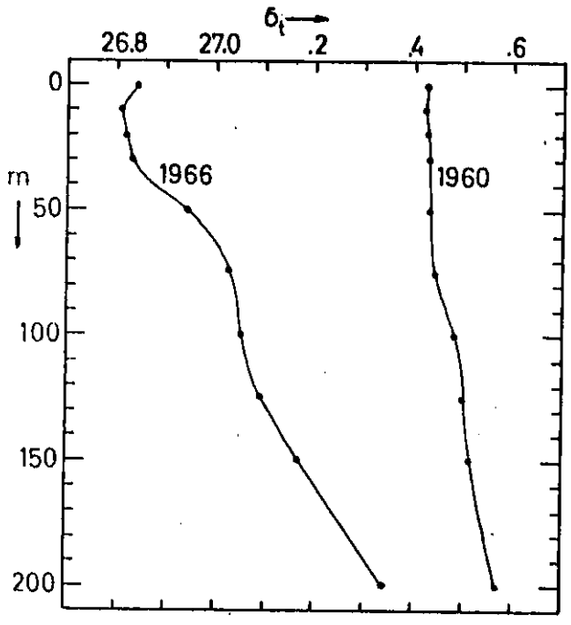

Fig. 13. Mean sigma-t curves for the sections across Fylla Bank in 1960 and 1966.

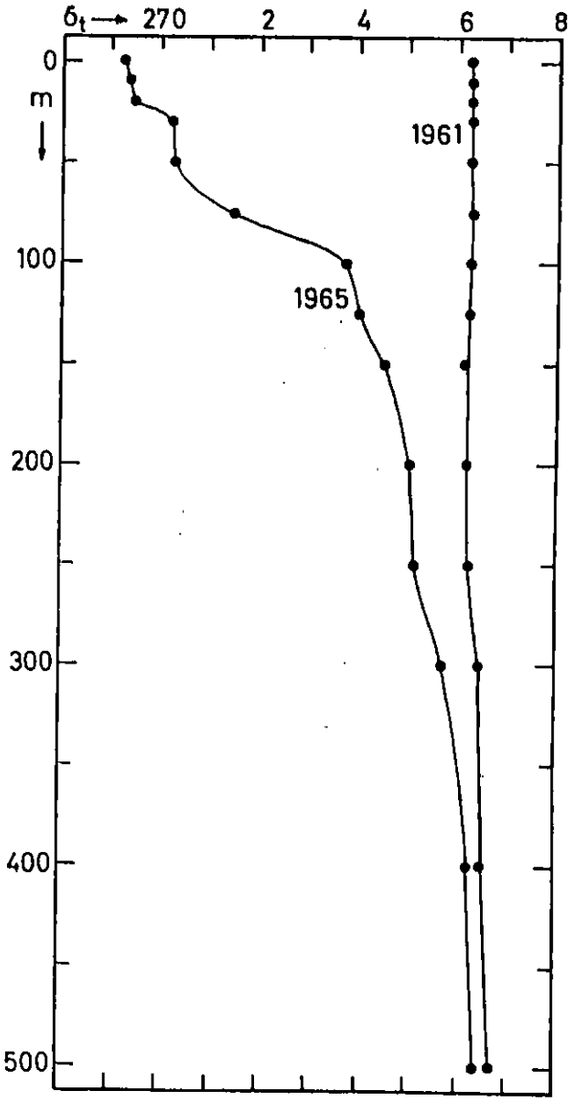

Fig. 14. Sigma-t curves for two hydrographic stations showing great difference in stability. The stations are worked over the western slope of the Lille Hellefiske Bank in 1961 and 1965.

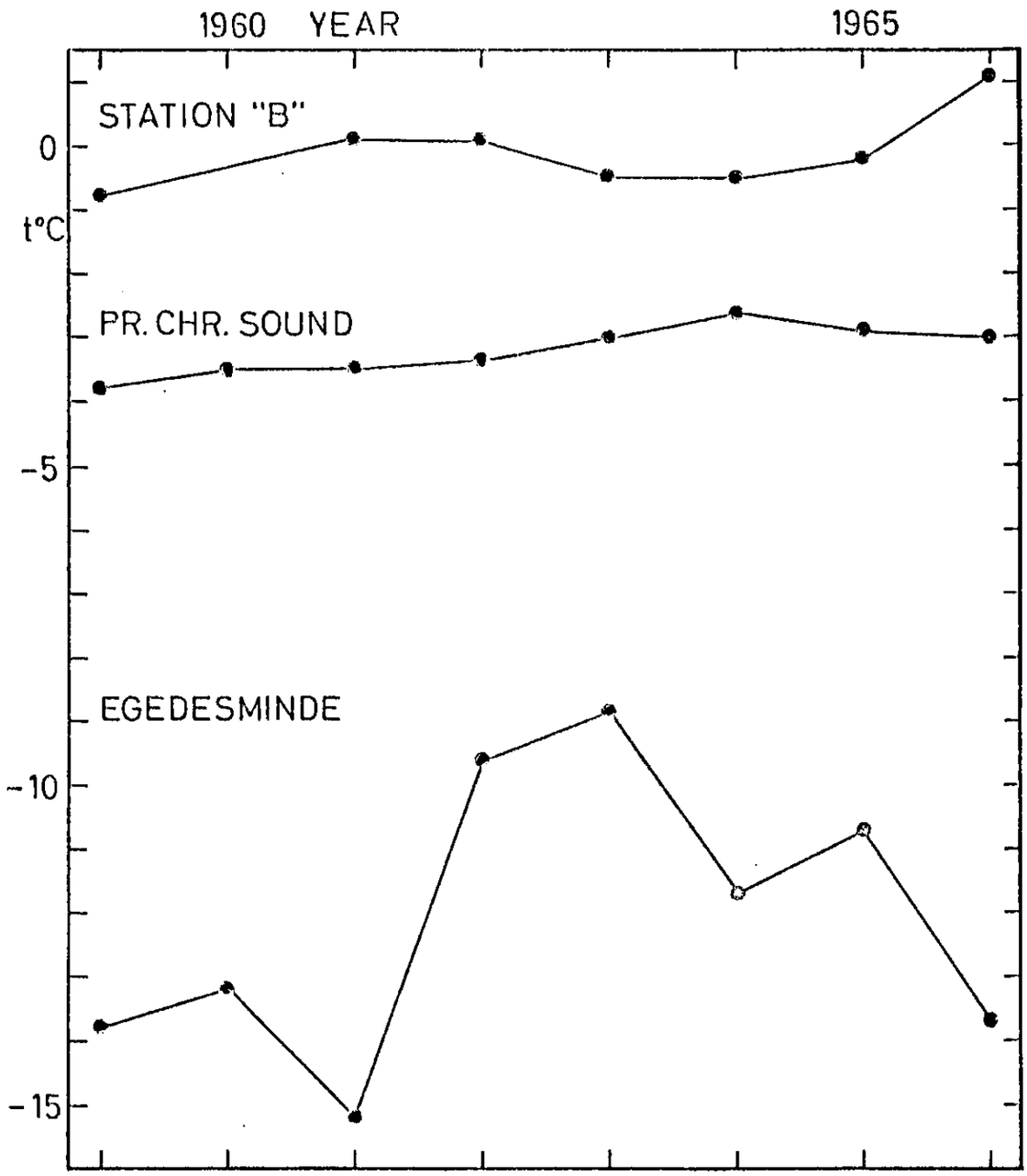

Fig. 11. Mean air temperature for the period December-March during the winters 1959-1966 at the following meteorological stations: Ocean Weather Station "B", Prince Christian Sound, and Egedesminde.