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# Variability of Oceanographic Conditions in the Hamilton Bank Area in the Autumn Period

by

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## Abstract

A structure of fields of long-term means of temperature, salinity and water density, geostrophic currents and stability were analysed based on the results of statistic processing of long-term data from Soviet oceanographic surveys on the section 8-A in October-November. Salinity was found to be of predominant importance in the distribution of density and other characteristics calculated according to density field.

Peculiarities of spatial differentiation of standard deviations of temperature and salinity were revealed, the extent of variability of the characteristics was found to be dependent on the degree of their spatial heterogeneity. Given charts of the distribution of temperature and salinity anomalies at the section in October-November of some years within 1970-1979 show the predominance of monodirectional changes in the characteristics. A possibility of studying the time structure of variability in connection with aliasing problem is discussed.


## Introduction

A spring-summer period has been in the centre of attention for a long time during investigations of the oceanographic regime in the North-West Atlantic areas, and only in recent years an opportunity appeared to describe in detail an autumn-winter state of waters. The present paper is aimed at extending and making more exact our knowledge of the autumn water regime and variability of oceanographic characteristics in one of the important NAFO Divisions.

Materials and methods

Climatic peculiarities of hydrological conditions in the Hamilton Bank area were analysed on the basis of Soviet data from deep-sea observations on temperature and salinity at the standard oceanographic section 8-A, shown in Fig.1. Water temperature was measured according to standard methods with deep-sea reversing thermometer with an accuracy of $\pm$ 0.02°C. A depth of measurements was, as a rule, controlled with unprotected reversing thermometers. Salinity of water samples taken with bathometers was determined on shore in salinity meters IMC and "Autolab", providing an accuracy of $\pm$ 0.003 $\div$ 0.005°/₀₀.

When building up a long-term series of data a problem of information homogeneity has arisen, it results from the difference in the time of observations in different years. To achieve higher homogeneity of the data series a possibly narrower time interval should be taken, but this would result in the reduction of information volume and then in less reliable statistical estimates of characteristics of oceanographic regime.As for the maximum allowable time interval,which would satisfy the principle of information homogeneity, it is hardly possible to determine it in this case as different oceanographic parameters have different structure of time variability and, besides, this structure is subject to spatial variations. In order to ensure the homogeneity of long-term data, from one hand,and statistical reliability of characteristics of oceanographic regime,from the other,a 1-month time interval - from 16 October to 16 November- has been chosen.In accordance with this a 17-year period of observations relative to 1962-1980 was taken, data for 1963 and 1978 are not included.

Statistical processing of the data, including the calculation of the arithmatical mean and standard deviation of water temperature and salinity was performed in the "Minsk - 32" computer separately for each of 137 standard depths of observations at stations of the section. Long-term means obtained were further used to determine the oceanographic characteristics as well as temperature and salinity anomalies at the section during the period from October to November 1970-1979.

Data of a 24-hour series of oceanographic observations conducted with 2-hour intervals at station F on 5-6 October 1980 during the 21-st cruise of RV "Protsion" in the Hamilton Bank area were also used in the paper(Fig.1). They were then statistically processed to obtain data for comparative estimation of variability of different time scales.

Main features of the structure of oceanographic characteristics at the section.

Fig.1 shows the distribution of long-term means of water temperature and salinity at the section in late October-early November. As it is seen in the charts, there are both common features and peculiarities in the structure of fields of the characteristics under study. A similarity of horizontal structures is most marked at the shelf margin and continental slope, where a sharp increase of characteristics off-shore is observed. This frontal zone results from the interaction of two main water types - arctic distributed at the shelf and atlantic waters with a higher heat and salt content, distributed eastward. While moving off the frontal zone the interaction of the above said water masses lessens, which results in partial loss of similarity between horizontal structures of temperature and salinity fields. Long-term means keep to change similarly along the section in layers deeper 30-50 m , and in the upper layer a comparatively smooth increase of salinity - from 32.2°/₀₀ to 32.8°/₀₀- towards the shelf margin is followed by an insignificant (up to 0.5°C) decrease of temperature.

Estimating the similarity of spatial changes in the characteristics, we can single out some structural zones also within the vertical structure of fields under study. A mixed 10-30 m layer, where both temperature and salinity are homogeneous along the vertical, is one of the main zones. In the intermediate layer, distributed lower, an increase of salinity with the depth is followed by a decrease of temperature up to -0.2° ÷ -0.4° at the Bank and to 3.5° ÷ 3.7° east of the front. The depth,at which the above said minimum temperature is registered, serves as a lowest boundary of the intermediate layer, this depth decreases from 150-170 m in the area of the Bank to 100 m in the eastern part of the section.

In the near-bottom layer at the shelf and upper part of the continental slope when salinity keeps increasing with depth, temperature inversion is observed. And at last there is a layer in the deepwater part of the section between the depths of 600 and 1200 m, where water temperature decreases with depth, vertical distribution of salinity being homogeneous.

The field of conventional density shown in Fig.2A serves as an integral characteristic of the long-term mean thermohaline water structure. As it is seen in the figure, water density grows with depth and off-shore, the minimum density (25.8-26.0 conventional units) is registered in surface waters of the coastal zone, the maximum one - about 27.7 conventional units - in deep waters in the north-eastern part of the section. When comparing fields of characteristics (Fig. 1A, 1B, 2A) one can easily see, that spatial changes in density conform markedly only with salinity field structure. Hence it appears, salinity distribution is the main factor, which determines the distribution of water density in the area under consideration in late October - early November.

Proceeding from the concept that there is a close relationship between the density field and field of movement of water masses in the ocean it is possible on the basis of data available to estimate a long-term mean kinematic structure. Toward this end let's consider the results of calculation of geostrophic currents at the section (Fig. 2B). The section crosses the area of the Labrador Current, according to long-term mean data the movement of waters in this area has a southern (south-eastern) direction. Judging by the distribution of isotachs, the Labrador Current in the area of the section is a system of relatively rapid jets, which are separated by water areas with a slower movement of waters. The main part of the Labrador Current,located in the frontal zone at the shelf margin and continental slope consists of two jets, the maximum surface velocity being 40 $cm \cdot s^{-1}$. This part of the Current is separated from its coastal part by a comparatively vast area with a slower water transport (velocity less than 5 $cm \cdot s^{-1}$), the minimum surface velocity is registered at the peak of the Hamilton Bank.

According to calculations made on the basis of the given velocity field a discharge of water of the main part of the Labrador Current in the layer from the surface to the bottom or to the depth of 2000 m is 4.70 Sv, 68% of the total (6.88 Sv) section water discharge. These values conform well with the means (4.04 Sv and 5.51 Sv) of discharge of the Labrador Current waters in the area of the Hamilton Bank in summer during different periods, which are given in literature ( Dinsmore & Moynihan, 1972; Alekseev et al., 1972).

The above said features of the kinematic structure are representative of peculiarities of density heterogeneity both in vertical and horizontal directions. Fig. 2C made by the results of stability estimation, indicates vertical density gradients at the section. Evidently, the vertical density structure along the whole section is characterized by a stable stratification, with the maximum between the depths of 30-50 m and 75-100 m, the width of the layer and its stability are not the same within space, changes of the said parameters tend to increase along the section towards the western margin of the Bank.

An under-surface extremum of stratification results from maximum vertical gradients of temperature and salinity, which contributions to the stability are of the same sign. The ratio of salinity stability $E_S$ to the total stability E, which amounts to 85-95% (Fig.2D), indicates that the contributions have the same sign and the salinity gradient effect predominates over the effect of temperature gradients in the layer under consideration.

A fall in density heterogeneity observed when moving up and down the maximum stability layer results both from the decrease of gradients of either characteristic and temperature inversions. The location of the inversions conforms with those zones at the section where a relative contribution of the salinity gradient to stability is over 100%.

Since stratification is one of the main factors of development of winter vertical circulation, the above mentioned peculiarities of stability horizontal distribution at the section may be regarded as a sign of spatial differences of winter convective mixing. Besides, in high and moderate latitudes due to convective mixing a photic layer is enriched with biogenes from deep waters, so the winter vertical circulation may be supposed to restrict the bioproductivity at the shelf of the area to a greater extent than in the near-by deepwater zone. With regard for the regularities of water structure in the Labrador Current area, the last assumption appears to be acceptable to apply at a considerable part of the Labrador and Newfoundland shelf. A study of regularities of fluctuations of the Labrador cod year classes strength (Borovkov, 1980) proves indirectly a hypothesis that the winter vertical circulation at the shelf of the mentioned areas is a factor limiting the bioproductivity.

Peculiarities of temperature and salinity variability.

A solution of some applied tasks in the sphere of oceanography is connected with the problem of variability of physical and chemical water properties. Data obtained during observations at the section permit to illustrate some aspects of the problem which are related to the variability of temperature and salinity in late autumn.

The variability of water temperature and salinity may be estimated by corresponding standard deviations, shown in Fig.3. These data are indicative of a spatial differentiation of values of year-to-year variability, which change within the following interval of standard deviations of temperature $\pm 0.14° \div \pm 1.26°$ and those of salinity $\pm 0.03°/_{oo} \div \pm 0.43°/_{oo}$. Since the maximum of standard deviations of both characteristics is located in the frontal zone and the minimum - in the zone which is below the depths of 1000 - 1500 m, a degree of their spatial heterogeneity is of decisive importance in the formation of the year-to-year variability of characteristics. This regularity is closely connected with shifts of heterogeneities, which occur under a joint influence of dynamical processes different in nature and scale. Due to overlapping of dynamic effects additional information is required to determine the significance of each, data available permit only in some cases by indirect signs to determine, what dynamic process contributes mostly to the variability of characteristics. Particularly, if to take into account, that advection of properties by currents is chiefly of isopycnic nature, then a noticeable (compare Figs. 2a and 3) orientation of zones with higher variability of temperature and salinity along isolines of water density may be regarded indicative of a predominant influence of currents variations upon shifts of the front and variability of the said characteristics in the frontal zone.

The above said peculiarity of the spatial structure of the year-to-year variability, namely, a localization of the maximum variability in the frontal zone, is also observed in the structure of anomalies field of both characteristics (Figs. 4 and 5). Besides, the given charts show a very interesting peculiarity - similarity of distribution of signs of temperature and salinity anomalies. This peculiarity as well as a conformity in occurrence of extremely*high negative anomalies of temperature (-2.48°) and those of salinity (-0.87°/₀₀) in 1972, and highest positive anomalies - 3.08° and 1.08°/₀₀,respectively, in 1977, show the predominance of monodirectional changes of both characteristics.

As for the question of time structure of variability, its solution on the basis of data available appeared to be rather problematic due to a perverting effect of fluctuations, which period is smaller than the time interval between observations at the section, i.e. due to aliasing phenomenon.

Results of statistical processing of data from a 24-hour observation series, conducted at station F in early October 1980 illustrate the effect of short-period fluctuations (Fig.6). A comparison of these results with the above given data shows that under the conditions of vertical thermohaline structure which conformed well with the long-term mean for the period from late October to early November vertical distribution of temperature and salinity at the part of the section 8-A, which is located at the western

* In relation to some data available for 1970-1979.

margin of the frontal zone, daily variability of different characteristics either reached the maximum year-to-year variability or was of the same order. Hence, it may be concluded, that data from single observations at the section with a 1-year discretion are not reliable to determine the time structure and trends in year-to-year variations of water temperature and salinity in the Hamilton Bank area. Evidently this problem could be solved after the IGOSS Programme is implemented, in accordance with it a constantly operating net of buoy oceanographic stations is to be located in ocean.

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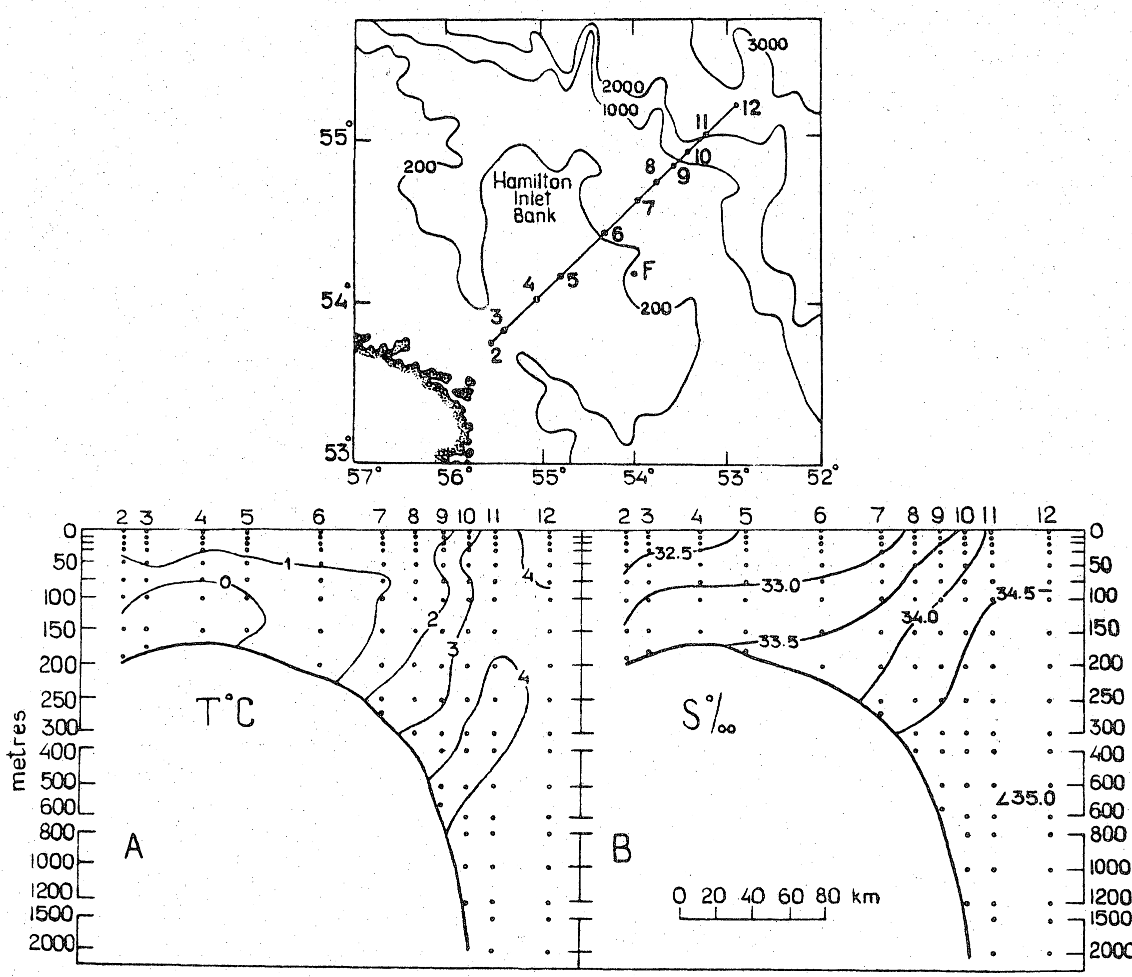


Fig. 1 Position of oceanographic stations and distribution of the long-term mean temperature (A) and salinity (B) at the section in 1962, 1964-1977, 1979-1980 16 October-16 November, mean date - 30 October-1 November.

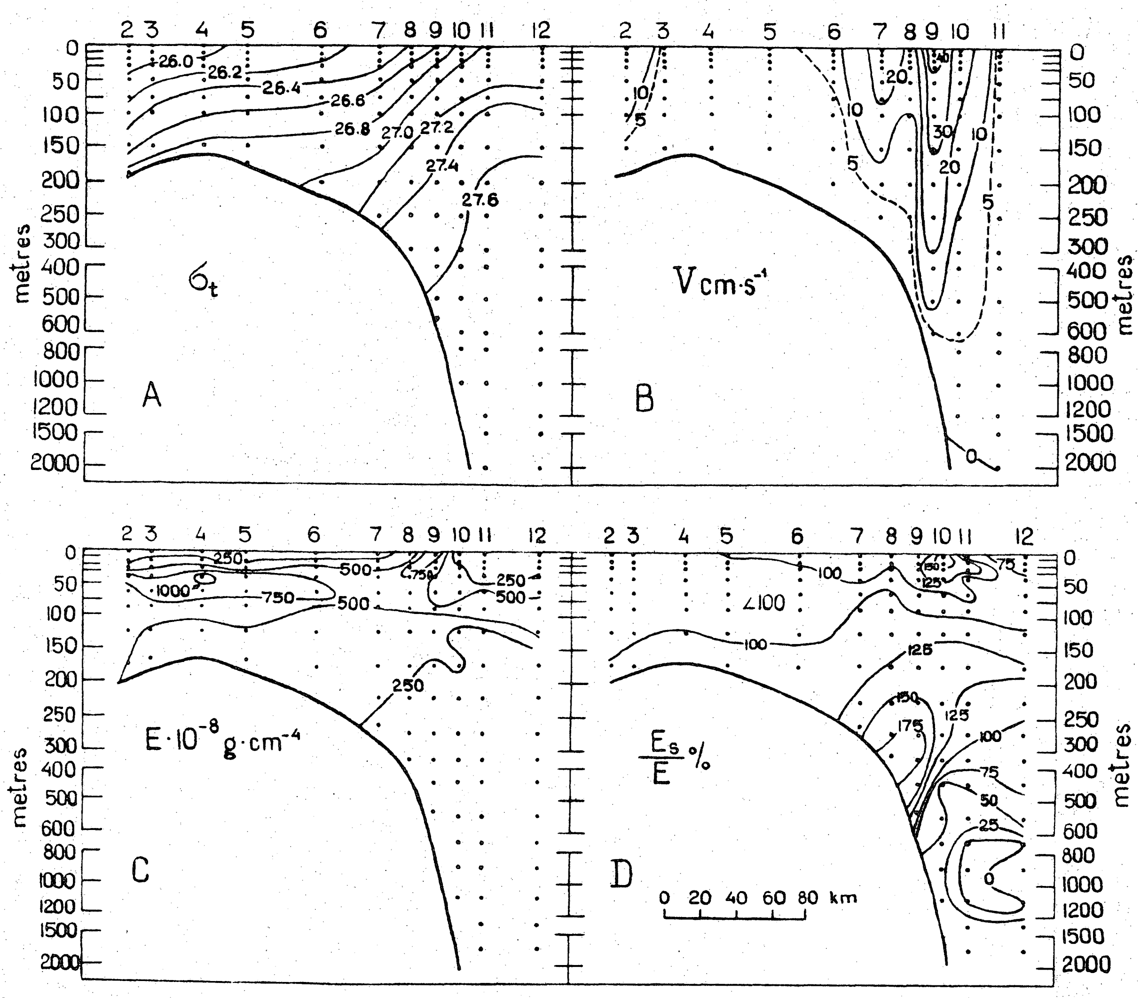


Fig. 2 Distribution of long-term means of conventional density (A), velocity of geostrophic currents (B), stability of water layers (C) and contribution of salinity to stability (D) at the section 8-A. For the average time period and mean date see Fig. 1.

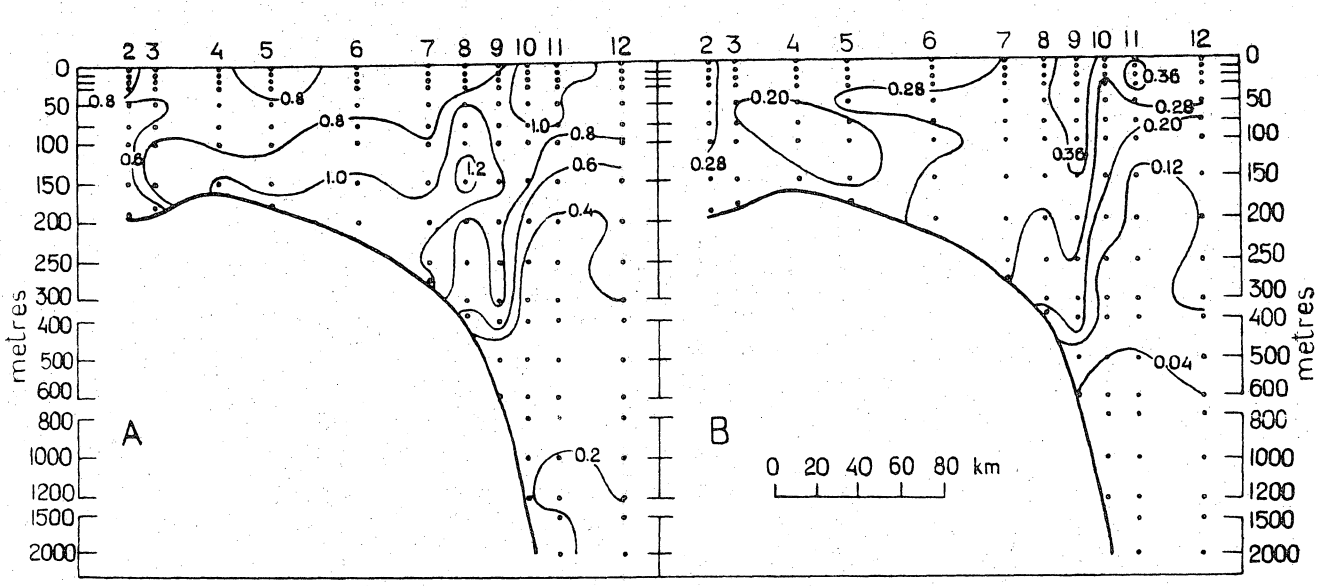


Fig. 3. Distribution of standard deviations of temperature (A) and salinity (B) from corresponding mean values. For the average time period and mean date see Fig. 1.

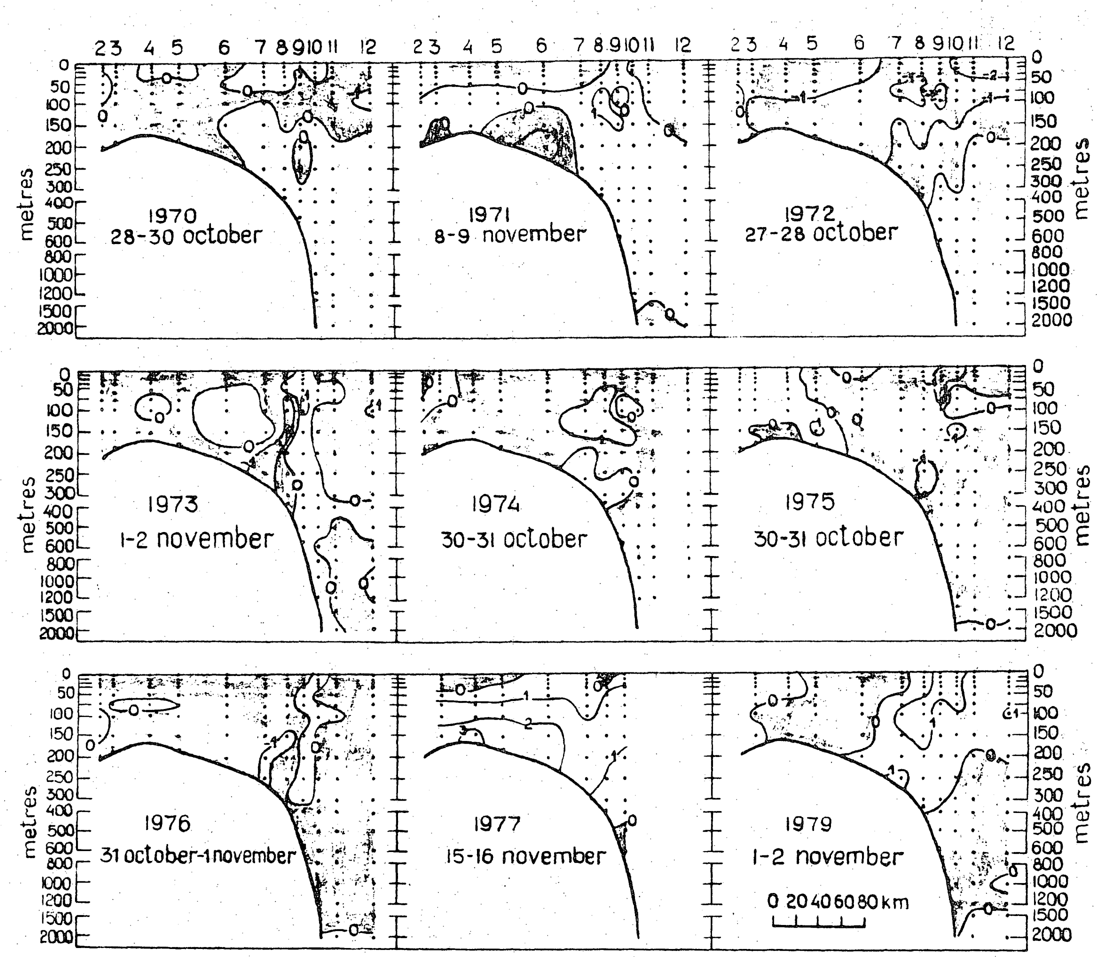


Fig. 4. Distribution of temperature anomalies at the section 8-A in October-November 1970-1977 and 1979, zones of negative anomalies are dark.

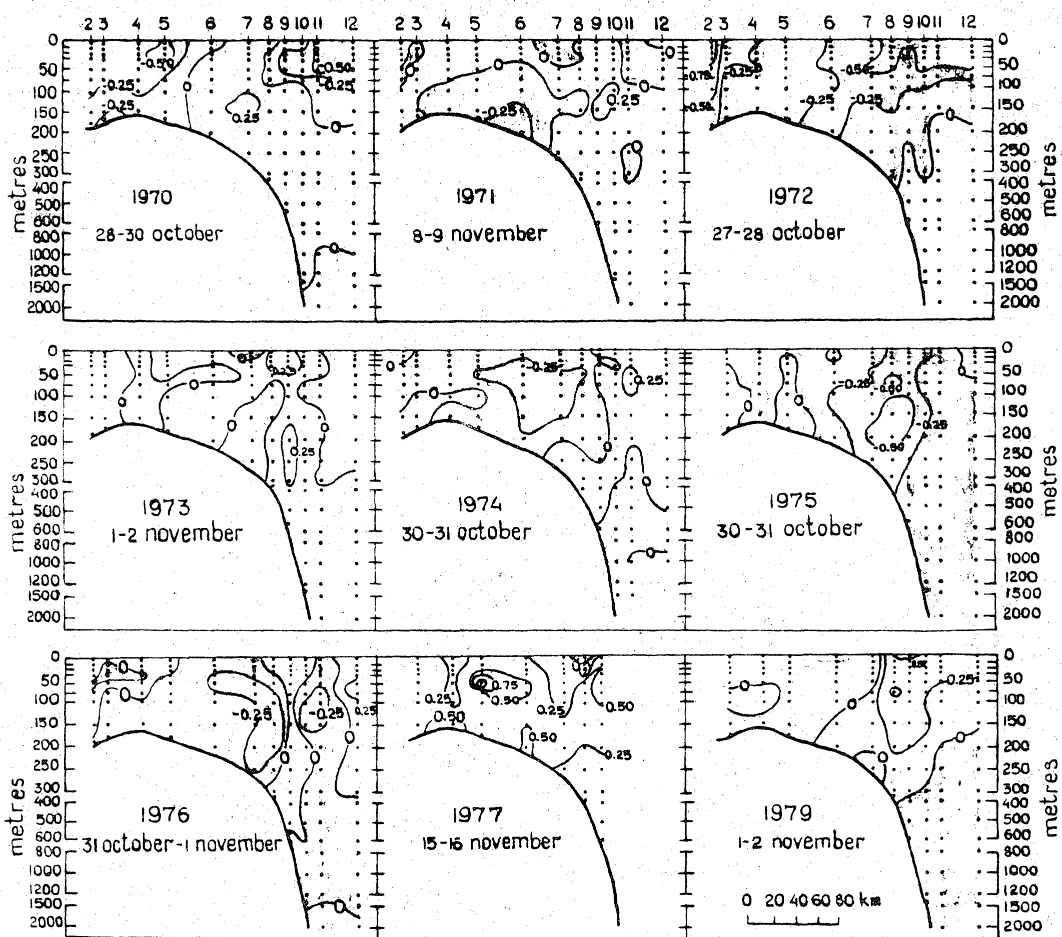

Figure 5. Distribution of salinity anomalies at the section 8-A in October-November 1970-1977 and 1979; zones of negative anomalies are dark.

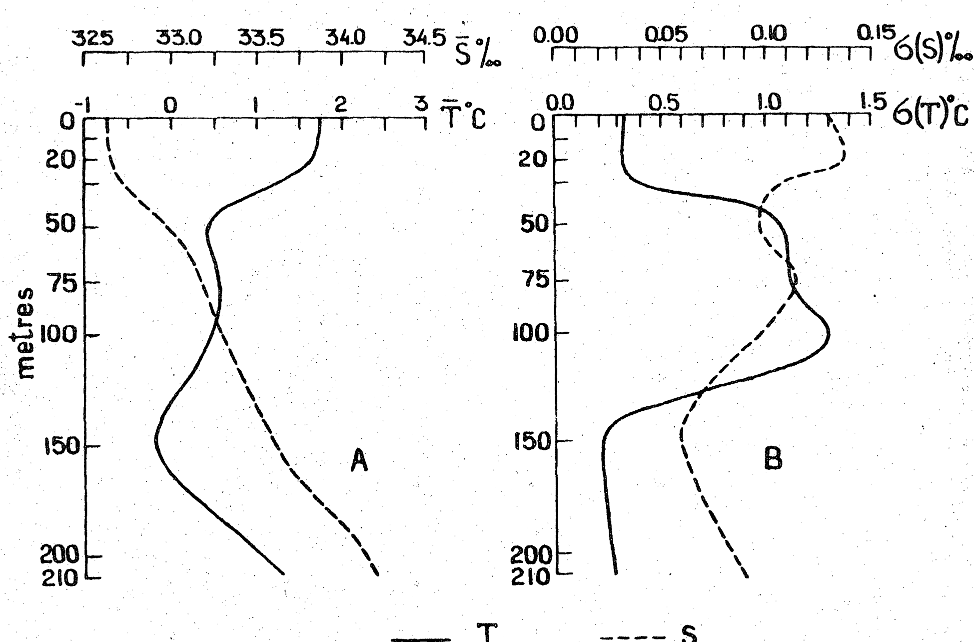

Fig. 6. Vertical profiles of average daily values (A) and standard deviations (B) of temperature and salinity at station F on 5-6 October 1980 (54°12'N, 54°00'W).