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Variability of Autumn Oceanographic Conditions in the Hamilton Bank Area

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Abstract

Temperature, salinity, density, geostrophic currents and stability were analyzed on the basis of a long-term series of data from USSR oceanographic surveys of Section 8-A across Hamilton Inlet Bank in October–November 1962–79. The density field was found to be controlled primarily by salinity. Spatially, the standard deviations of temperature and salinity from the long-term mean varied markedly and were related principally to the lateral gradients in the mean field. Section plots, on a year-by-year basis, of the distributions of temperature and salinity anomalies in October–November of the 1970–79 period indicated the predominance of monodirectional changes in the characteristics. Data are presented which reveal that aliasing is an important problem that severely limits discernment of real year-to-year variations from the existing data.

Introduction

The spring-summer period has been the focus of USSR attention for a long time during investigation of the oceanographic regime in the Northwest Atlantic, and only in recent years has it been possible to describe in detail the autumn-winter oceanographic conditions. This paper is aimed at extending and improving knowledge of the autumn water regime and variability of oceanographic characteristics on a section across Hamiliton Bank off southern Labrador.

Materials and Methods

Oceanographic conditions in the Hamilton Bank area were analyzed from observations of temperature and salinity along the USSR standard oceanographic Section 8-A (Fig. 1). Water temperature was measured with deep-sea reversing thermometers to an accuracy of ±0.02° C. Salinity samples, taken with bathometers, were analyzed ashore using IMC and "Autolab" salinometers to an accuracy of ±0.005. In order to insure the homegeneity of long-term data on the one hand and statistical reliability of characteristics of the oceanographic regime on the other, a 1-month time interval was chosen, from 16 October to 16 November. Data for all years of the 1962–80 period were incorporated into the analyses except 1963 and 1978.

Statistical processing of the data, including calculation of arithmetic means and standard deviations of water temperature and salinity, was performed separately for each of 137 standard depths of observations at stations on the section. The long-term means were further used to determine the October–November oceanographic anomalies for each year (except 1978) of the 1970–79 period. Additionally, a 24-hr series of oceanographic observations taken at 2-hr intervals at station F (Fig. 1) on 5–6 October 1980 by the RV *Protsion* on Hamilton Inlet Bank were processed to obtain data for a comparative estimate of variability on different time scales.

Results and Discussion

Oceanographic characteristics of the section

Figure 2 shows the distribution of long-term means of water temperature and salinity in the section

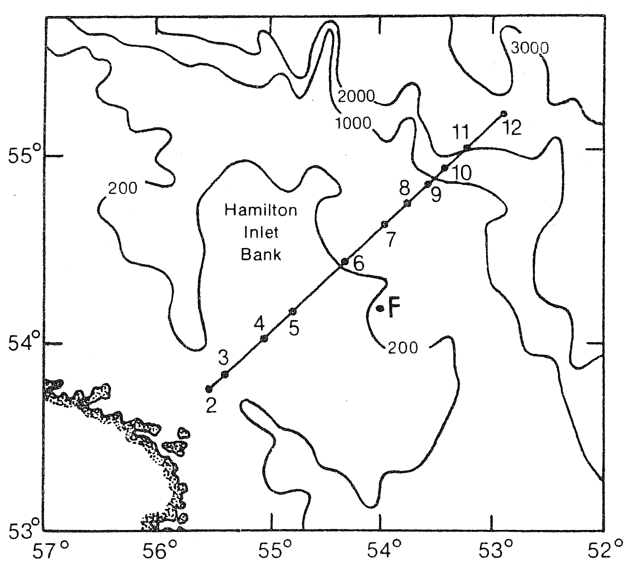

Fig. 1. Locations of oceanographic stations on USSR Section 8-A across Hamilton Bank off southern Labrador occupied during mid-October to mid-November in l962, 1964–77, and 1979–80 (mean date, 31 October).

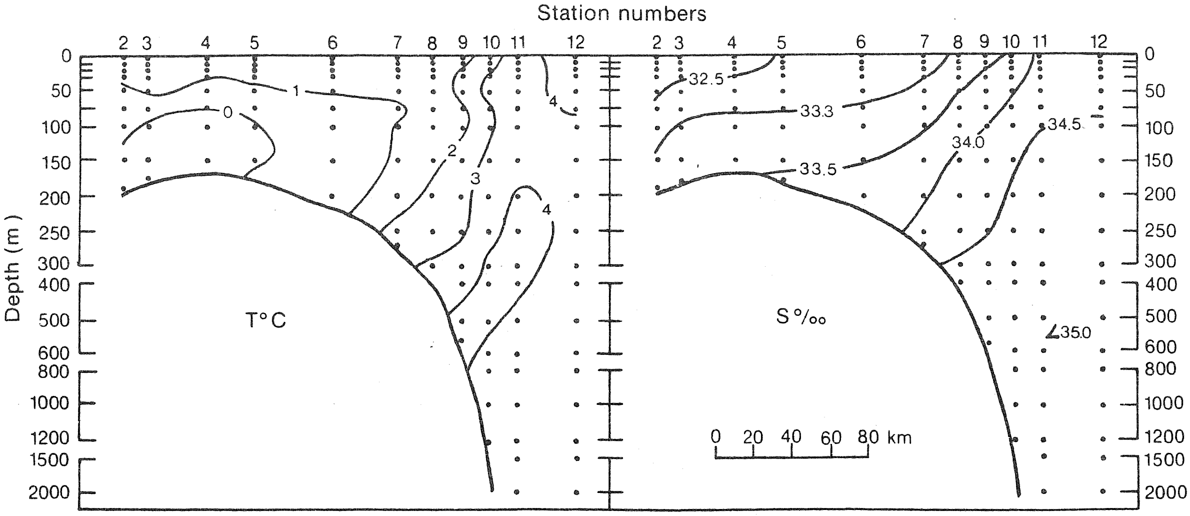

Fig. 2. Distribution of long-term mean temperature and mean salinity for the Hamilton Bank section shown in Fig. 1.

for the mid-October to mid-November period. As can be seen from the diagrams, there are both common features and peculiarities in the structure of the temperature and salinity profiles. The similarity of horizontal structure is most marked in the shelf edge and slope areas, where a sharp seaward increase in both temperature and salinity is observed. This frontal zone results from the interaction of two main water types — cold Arctic water distributed over the shelf, and Atlantic water with higher heat and salt content distributed eastward from the slope. Away from the frontal zone, the interaction of these two water masses lessens, resulting in partial loss of similarity between the horizontal structure of the temperature and salinity fields. Over the shelf, the salinity of the surface layer increases progressively from 32.2°/oo inshore to 33.0°/oo over the shelf edge, whereas the surface temperature is quite uniform.

Vertically, the temperature and salinity fields exhibit some noteworthly features. One of the main zones is a near-surface 10–30 m layer over the bank where both temperature and salinity are homogeneous (Fig. 2). Below this is a cold intermediate layer where an increase in salinity with depth is accompanied by a decrease in temperature to a minimum of -0.2° to -0.4° C near bottom (150–170 m) on the shallowest part of the bank. Considering the depth where the minimum temperature occurs as the lower boundary of the intermediate layer, this depth decreases to about 100 m over the northeastern slope of the bank where the temperature is about 3° C and the intermediate layer is less distinct. In the near-bottom layer on the shelf and the upper part of the slope, salinity increases with depth, but a temperature inversion is evident off the slope. In the deep water layer (600–1,200 m), temperature decreases slightly with depth, but salinity remains nearly constant.

The field of density (σ_t) shown in Fig. 3A, serves as an integral characteristic of the long-term mean thermohaline water structure. The minimum density (25.6-26.0) occurs in the surface water of the coastal zone and the maximum (about 27.7) in deep water in the northeastern part of the section. Comparison of the density field (Fig. 3A) with those of temperature and salinity (Fig. 2) indicates that spatial changes in density conform closely only with the salinity field structure. Hence, salinity distribution seems to be the main factor which determines the distribution of water density in the area during the autumn (October-November).

Proceeding from the concept that there is a close relationship between the density field and movement of water masses in the ocean, the long-term mean current pattern can be estimated. Accordingly, geostrophic currents were computed from the mean densities (Fig. 3B). The hydrographic section is perpendicular to the Labrador Current which generally flows in a southeasterly direction. From the distribution of isotachs, the Labrador Current in this area appears to be a system of high velocity jets which are separated by slower moving water masses. The main part of the current, located over the slope of the bank, consists of two jets the maximum surface velocity of one being 40 cm/sec. This component of the current is separated from the coastal component by a large mass of slow-moving water (velocity less than 5 cm/sec) over the central part of Hamilton Bank.

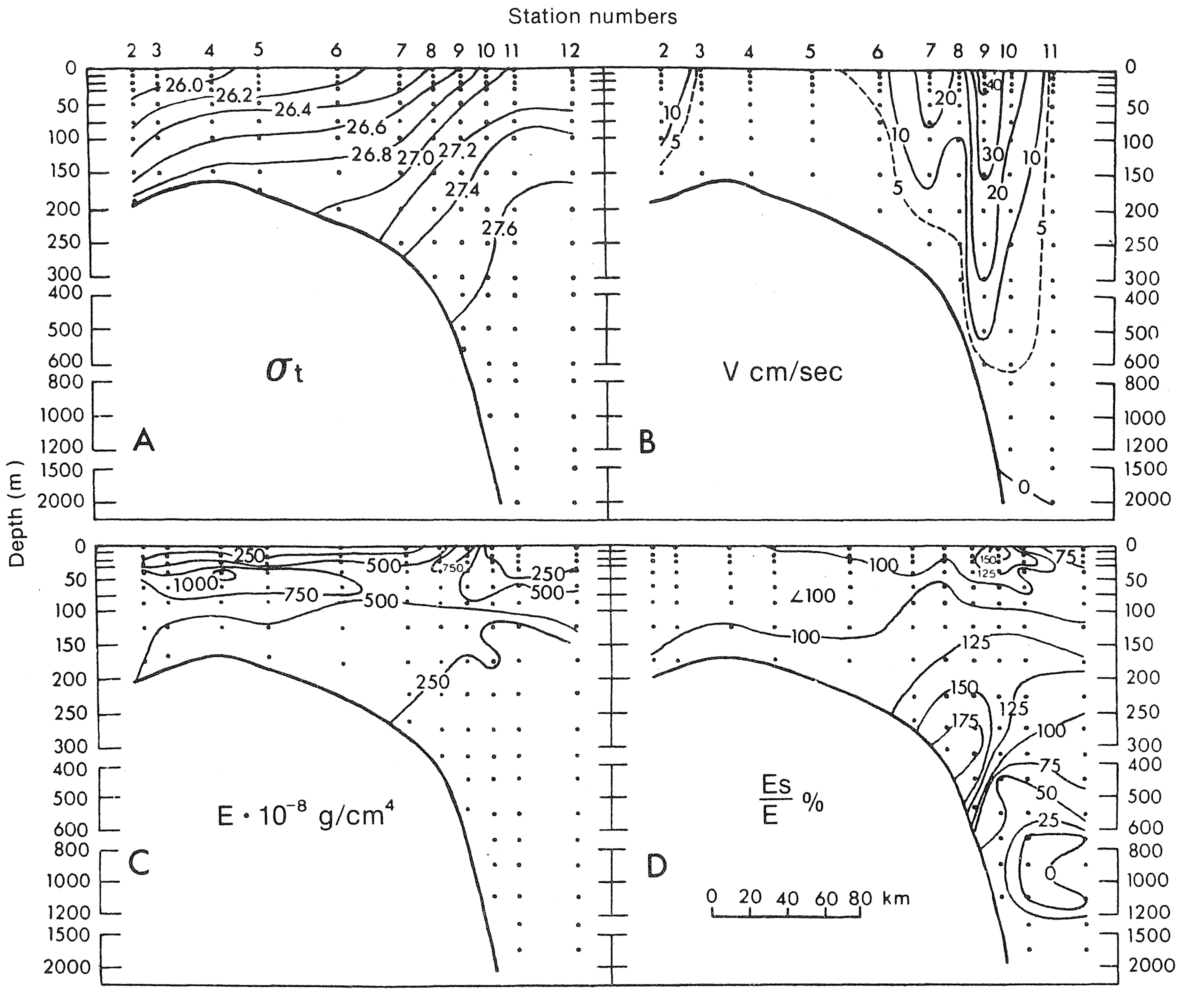

Fig. 3. Distribution of long-term mean density (**A**), velocity of geostrophic currents (**B**), stability of water layers (**C**), and contribution of salinity to stability (**D**), for the Hamilton Bank section shown in Fig. 1.

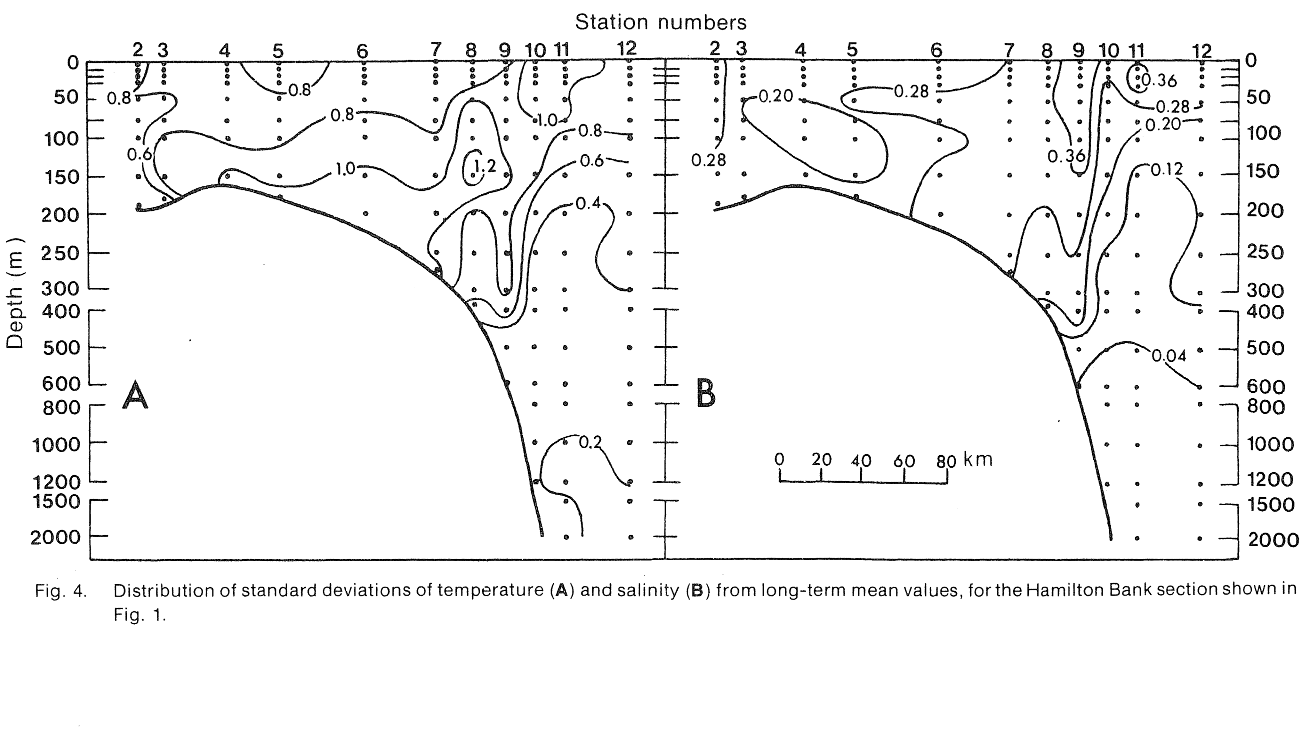

Fig. 4. Distribution of standard deviations of temperature (**A**) and salinity (**B**) from long-term mean values, for the Hamilton Bank section shown in Fig. 1.

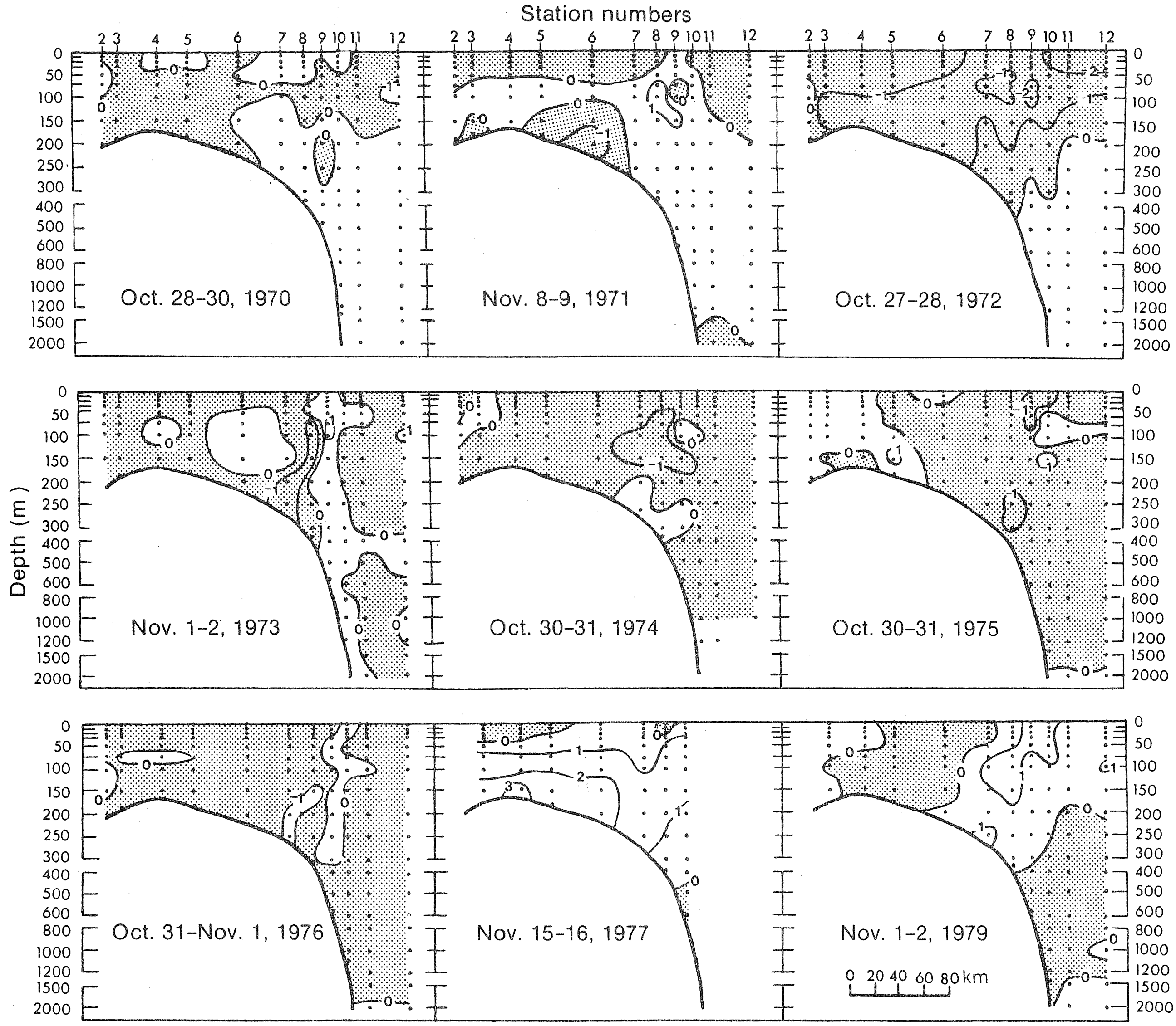

Fig. 5. Distribution of temperature anomalies for the Hamilton Bank section in October-November 1970-77 and 1979. (Zones of negative anomalies are shaded.)

The volume transport through the section was computed from the geostrophic currents, assuming no motion near bottom or at 2,000 m. For the Labrador Current, a transport of 4.70 Sv (1 Sverdrup = $10^6 m^3/sec$) was found, which represents 68% of the total (6.88 Sv) transport through the section. These values agree well with the means (4.04 and 5.51 Sv) of discharge of the Labrador Current in the vicinity of Hamilton Bank in summer, as reported by Dinsmore and Moynihan (1972) and Alekseev *et al.* (1972).

Stability of the water column, as defined by the vertical density gradient, was computed as shown in Fig. 3C. The section is characterized by a stable stratification, with the maximum occurring over the bank between 30 and 100 m. This water layer with maximum stability is thickest and had the highest stability values in the shoreward part of the section over the western margin of Hamilton Bank.

Since density is a function of both temperature and salinity, the stability can be separated into a temperature component (E_t) and a salinity component (E_s). Maximum stratification occurs when maximum vertical gradients of temperature and salinity are of the same sign. The ratio of salinity stability (E_s) to total stability (E) is plotted in Fig. 3D. It is clear for most of the section that salinity is the principal component producing stable stratification. When the ratio E_s/E is less than 100%, vertical temperature gradients are positive, and vice versa.

Autumn and winter cooling decreases vertical stability and the water convectively overturns. In general,

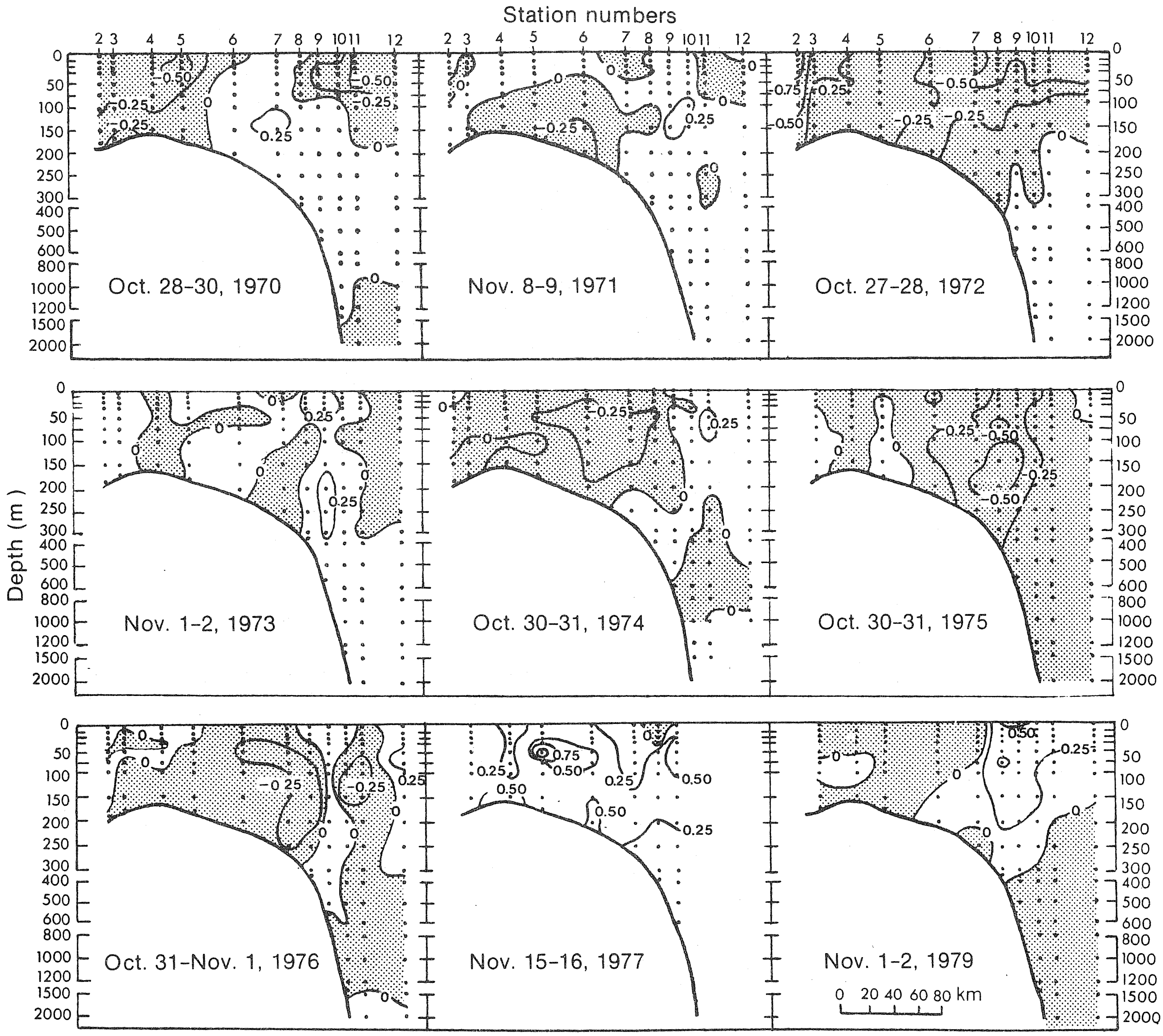

Fig. 6. Distribution of salinity anomalies for the Hamilton Bank section in October-November 1970-77 and 1979. (Zones of negative anomalies are shaded.)

the depth of the overturn is inversely related to the initial stability. Convective overturn provides a mechanism for resupplying the euphotic zone with nutrients. The higher stability of the water column over the shelf may thus inhibit nutrient resupply (and hence bioproductivity) to the greater extent than in the nearby deep-water zone. The features observed along the Hamilton Bank section may in fact be typical of much of the Labrador and Newfoundland shelf-slope area. A study of fluctuations in year-class strength of cod off Labrador (Borovkov, MS 1980) tends to support the hyopthesis that winter vertical circulation on the shelf is a factor limiting bioproductivity.

Temperature and salinity variability

Standard deviations of long-term averages of temperature and salinity, depicted in Fig. 2, are shown in Fig. 4. The standard deviations show a marked spatial variation from ±0.14° to ±1.26°C for temperature and from ±0.03 to ±0.43% for salinity. Maximum deviations are evident in the upper 150 m of the frontal zone over the shelf slope, and minimum values are found in depths of 1,000–2,000 m. The highest variability occurs in the region where the Labrador Current reaches its highest velocity and where the lateral temperature and salinity gradients are highest. Although the dynamics of the region are not well understood, it seems probable that much of the variability may be due to relatively small shifts in the position of the Labrador Current and consequent rapid adjustments in the temperature and salinity fields.

To examine the year-to-year variability in temperature and salinity during the 1970-79 decade, anomalies from the long-term means were computed (Fig. 5

and 6). Interestingly, these plots show a similarity in the distribution of signs of temperature and salinity anomalies. This peculiarity as well as the extremely high negative anomalies of temperature (-2.48) and salinity (-0.87) in 1972 and the highest positive anomalies (3.08 and 1.08 respectively) in 1977, show the predominance of monodirectional changes in both characteristics.

Whether the yearly anomalies portrayed are a reliable indication of conditions throughout the autumn is questionable, as there may be relatively large fluctuations on a much shorter time scale than a month. Repeated sampling at station F (Fig. 1) over a 24-hr period in early October 1980 shows the effect of short-period fluctuations (Fig. 7). The mean profiles of temperature and salinity are similar to the long-term means for October-November (see Station 6 in Fig. 2). However, the variability in temperature and salinity over the 24-hr period was similar to that associated with the long-term means. Therefore, it may be concluded that observations taken along the section once a year are not sufficient to reliably determine year-to-year variation in water temperature and salinity in the Hamilton Bank area. This problem could be solved by implementation of the IGOSS Program whereby oceanographic parameters are continuously monitored by a network of data-transmitting buoys.

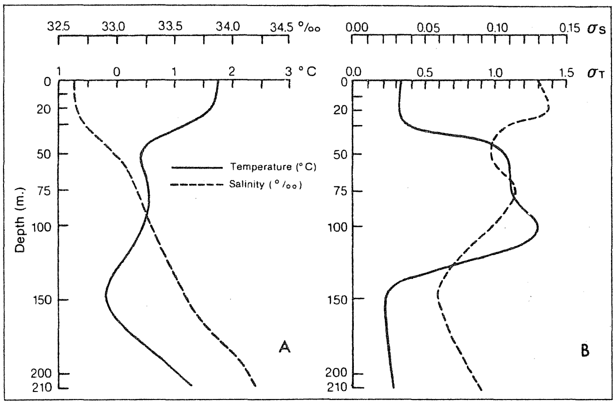

Fig. 7. Vertical profiles of average temperature and salinity (**A**) and corresponding standard deviations (**B**) at station F over a 24-hr period on 5-6 October 1980.

Acknowledgements

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