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Temperature and Salinity Anomalies Along the Flemish Cap Section in the 1970's

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Abstract

An analysis of water temperature and salinity anomalies at selected stations on the Flemish Cap section across the northern Grand Bank and Flemish Cap is presented for the 1970-79 decade. Relative to the long-term mean conditions, the analysis indicated that the water flowing through the section was colder and fresher during the early part of the decade, followed by a return to warmer and saltier water during the later years of the decade. The change seems to have occurred sometime in 1976 or 1977.

Introduction

At the June 1973 Meeting of the Standing Committee on Research and Statistics of the International Commission for the Northwest Atlantic Fisheries (ICNAF), the Canadian Oceanographic Data Centre, subsequently named the Marine Environmental Data Service (MEDS), was identified as the regional center for the processing and exchange of data for the Northwest Atlantic, as well as an analysis center for historical and climatological summaries of hydrographic data (ICNAF, 1973). Although MEDS does not have all of the physical oceanographic data collected by countries conducting research in the Northwest Atlantic, it does hold a substantial portion of the total.

The NAFO area is large and oceanographic data collections are not frequent in any one location. When the Scientific Council of NAFO recently decided to undertake a review of environmental conditions during the 1970-79 decade (NAFO, 1980), extending similar reviews for 1960-69 (ICNAF, 1972) and 1950-59 (ICNAF, 1965, 1967), it was decided for this paper to consider the analysis of hydrographic data for an area where such data were relatively plentiful. Gagnon (1977) analyzed the data holdings of MEDS for the ICNAF (now NAFO) standard oceanographic sections shown in Fig. 1 (ICNAF, 1978), and an examination of that report indicated that data were most plentiful for stations on the Flemish Cap Section. It is the analysis of water temperatures and salinities, derived from reversing thermometer and sampling bottom observations along that section, that is presented in this paper.

Data Analysis

The calculation of anomalies of a variable requires information on mean conditions over a long period of time, and such estimates of water temperature and salinity were reported by Keeley (1981a) for the Flemish Cap section (Fig. 2). The data used in calculating the means consisted of all temperature and salinity determinations at stations between 46°45'N and 47°15'N along the section, extending from 52°30'W eastward across the northern Grand Bank and the Flemish Cap to 41°30'W. The data set comprised observations at standard depths for about 3,000 stations, the earliest in 1910 and the latest in 1980, but the vast majority of the observations was taken in the past 25 years. The largest number of observations along the section was from the Flemish Pass region (Stations 7-16). Mean condition was calculated for each standard depth at each standard station in each month. Data were usually scarcest for the winter months, and, for the times and locations where the data were scarce, there was sometimes only one year in which observations were made. For both temperature and salinity, the anomaly for each depth and month was calculated as the difference between the mean observed in the 1970-79 period and the corresponding long-term mean. Thus, positive and negative anomalies indicate conditions above and below the long-term means respectively.

The anomalies and their characteristics across the Flemish Cap section are presented for only Stations 1, 7, 10, 13, 16 and 20. These six stations were chosen because they appeared to sample the oceanographic regime most effectively. The temperature anomalies are illustrated in Fig. 3 to 8 and the salinity anomalies in Fig. 9-14.

The diagrams were contoured with the use of the computer program CONMAP, described by Taylor (1976, 1977). The only notable change from the procedure was provision for flexibility of grid spacing in the horizontal direction. This was done to accommodate

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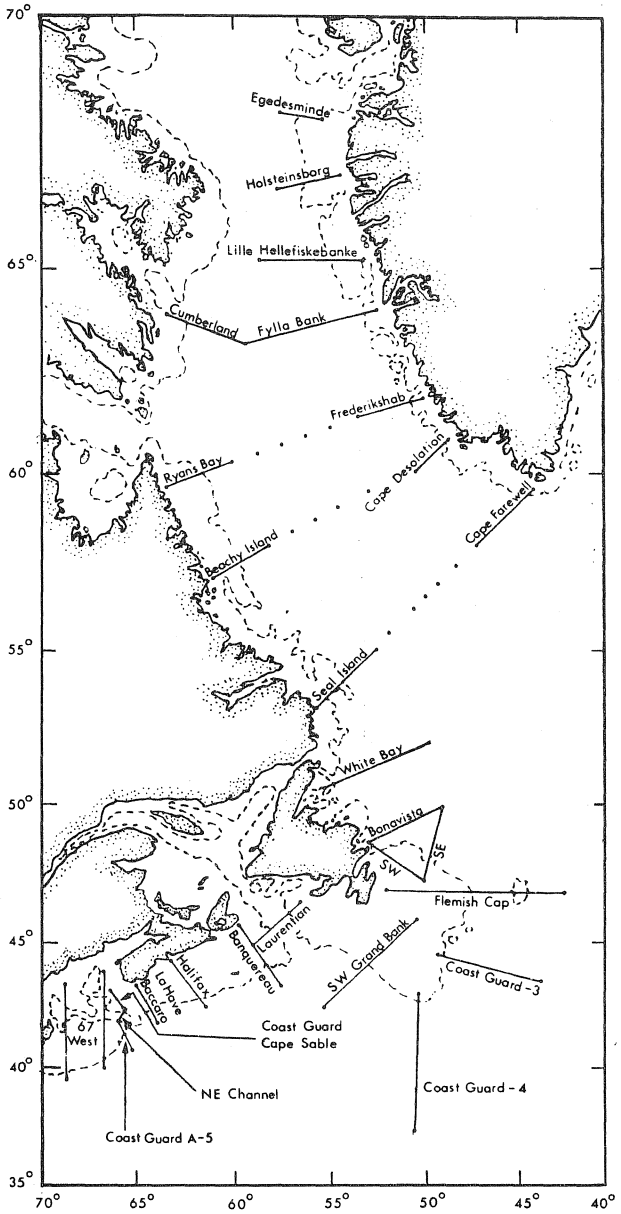

Fig. 1. Map of the Northwest Atlantic showing the standard oceanographic sections.

the pecularities of oceanographic observation programs, because stations are rarely equally spaced along a section and observatioins are not taken at regular time intervals.

Some consideration was given to using the technique of optimum interpolation (Bretherton *et al.*, 1976) to assist in contouring the data. The main feature of this technique is to determine a correlation function for the data in both horizontal and vertical directions of the grid. Station 10 was the only one with enough data to allow a reliable calculation of the temporal correlation function over selected depth ranges. The time scale of the correlation function (the time necessary

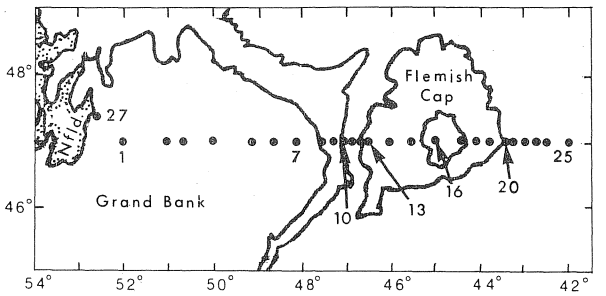

Fig. 2. Locations of stations along the Flemish Cap section.

before the correlation function drops to zero) was very short for data in the upper 50 m. This implies that the data are dominated by variations with time scales shorter than a few months. There was a gradual decrease in the variance with depth until below 150 m, where the time scale was on the order of 3 years. It is unfortunate that these results could not be checked at other stations along the section.

Results

The most obvious aspect of both the temperature and salinity patterns illustrated in Fig. 3 to 14 is the long time over which the anomalies persist. This was also inferred by the trial results from the optimum interpretation analysis. Because of the low frequency of sampling, few statements can be made about variations on time scales shorter than a few months. For occasions when data were more frequently available, the anomalies tend to persist and, in particular, maintain their positive or negative signs.

Before examining the characteristics of individual stations, it is interesting to note the apparent correlations of the temperature and salinity anomalies in Fig. 3 to 14. Lower than-normal temperatures tend to be associated with relatively fresh water and higher temperatures with saltier conditions. This correlation is apparent at Stations 13, 16 and 20, particularly so at Station 10. It appears, then, for stations in and east of the Flemish Pass, that colder water is associated with fresher conditions and warmer water with saltier conditions. However, it is difficult to assess if a correlation of any kind exists for Station 1 and 7, both on the Grand Bank. A simple test of the correlation between temperature and salinity anomalies at Station 1 showed a positive but non-significant correlation between cold and salty conditions. Overall, Stations 1 and 7 appear to exhibit inconsistent relations between temperature and salinity.

To begin the examination of the anomalies presented for the six stations along the Flemish Cap section, it is worthwhile to note the oceanographic regime sampled by each station. Water circulation through the

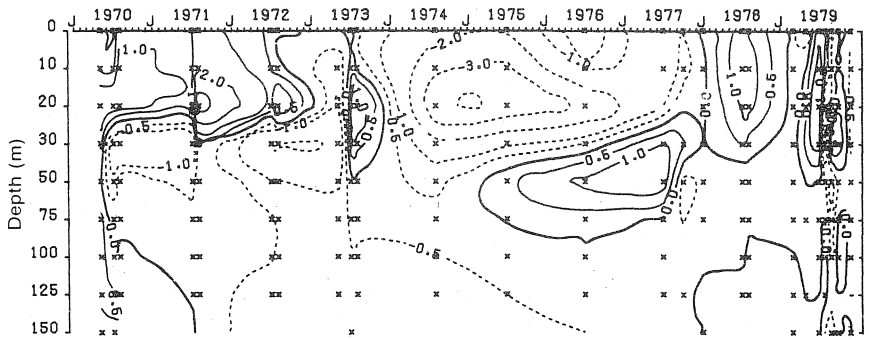

Fig. 3. Contoured potential temperature anomalies at Station 1 of the Flemish Cap section, 1970–79. (Dashed lines are negative anomalies.)

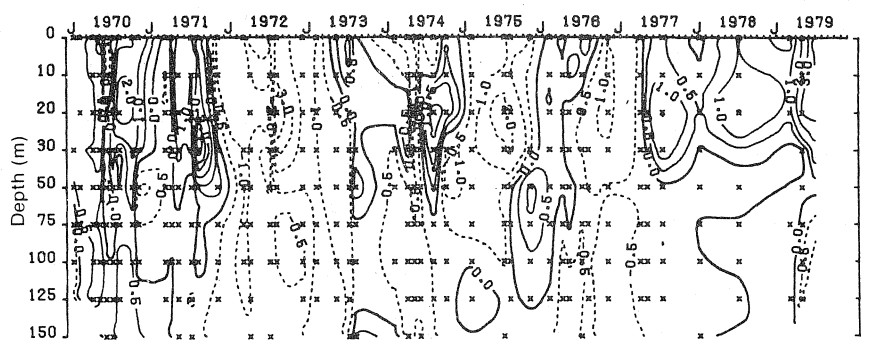

Fig. 4. Contoured potential temperature anomalies at Station 7 of the Flemish Cap section, 1970–79. (Dashed lines are negative anomalies.)

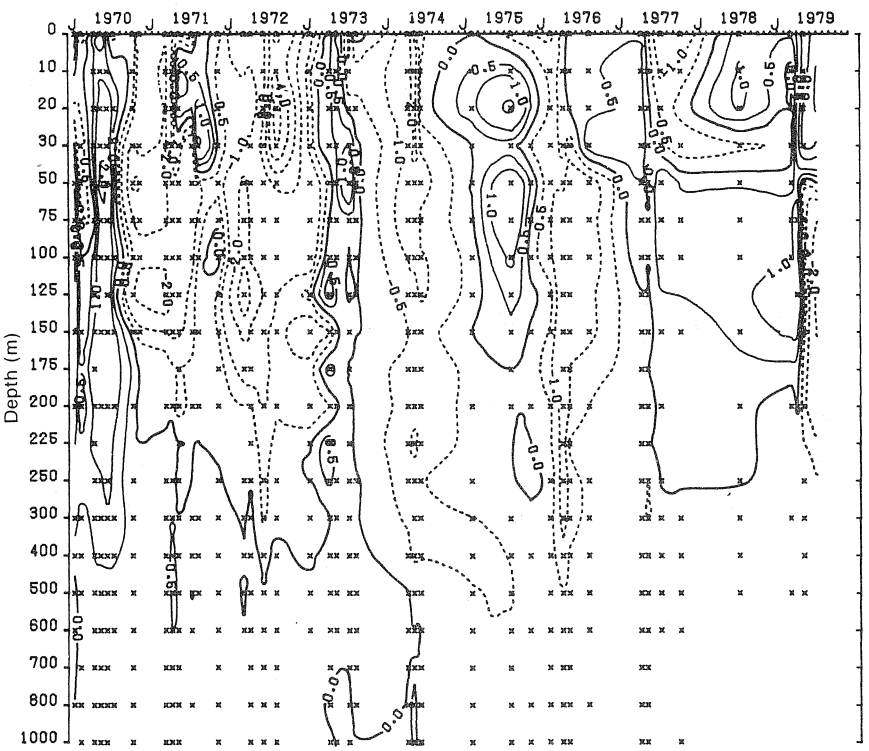

Fig. 5. Contoured potential temperature anomalies at Station 10 of the Flemish Cap section, 1970–79. (Dashed lines are negative anomalies.)

section is strongly influenced by the Labrador Current. This current in the vicinity of the Grand Bank is comprised of inshore and offshore branches (Buzdalin and Elizarov, 1962; Hachey, 1961). The inshore branch can be found on the shelf in less than 200 m and consists of water with temperatures typically below 0°C. It flows southward through the Avalon Channel and over the shallow areas of the Grand Bank, and it is thus sampled by observations at Stations 1 and 7. The offshore branch of the Labrador Current, extending to greater depths but typically confined above 1,000 m, flows southward along the eastern slope of the Grand Bank (on the western side of Flemish Pass) and is sampled at Station 10. Details of the circulation eastward of Station 10 have been variously discussed (e.g. Worthington, 1962; Mann, 1967), but it is clear that Labrador

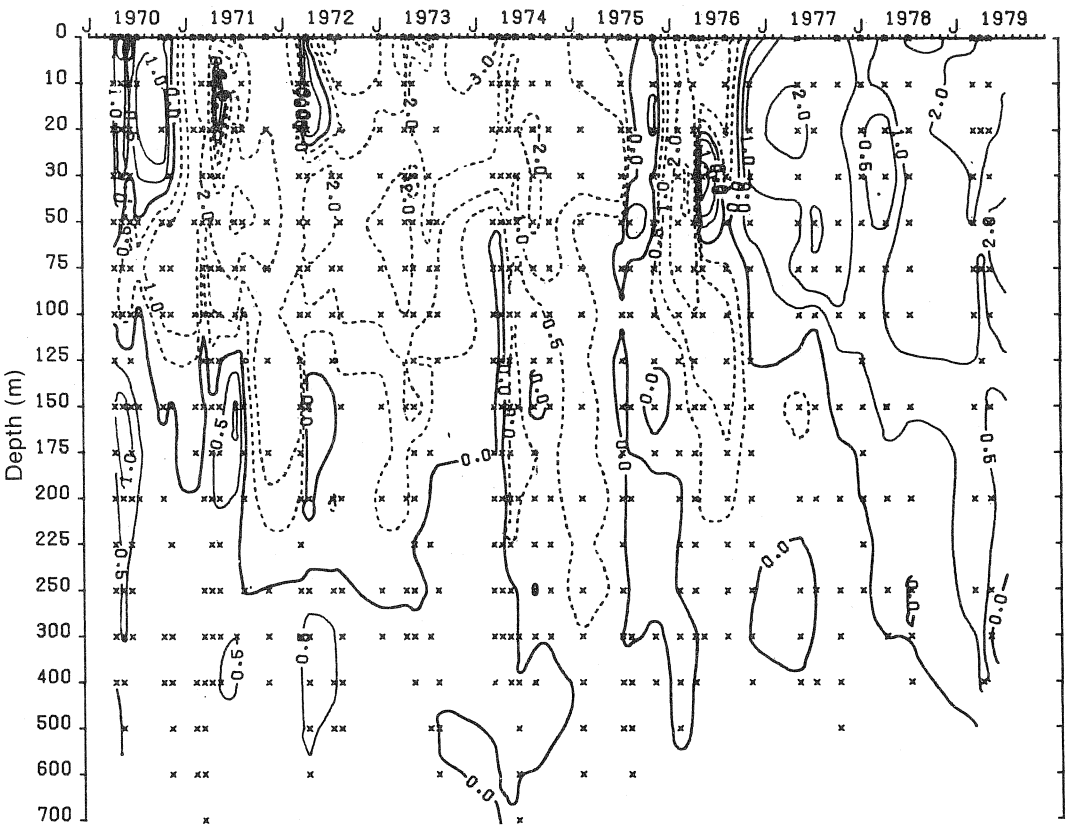

Fig. 6. Contoured potential temperature anomalies at Station 13 of the Flemish Cap section, 1970–79. (Dashed lines are negative anomalies.)

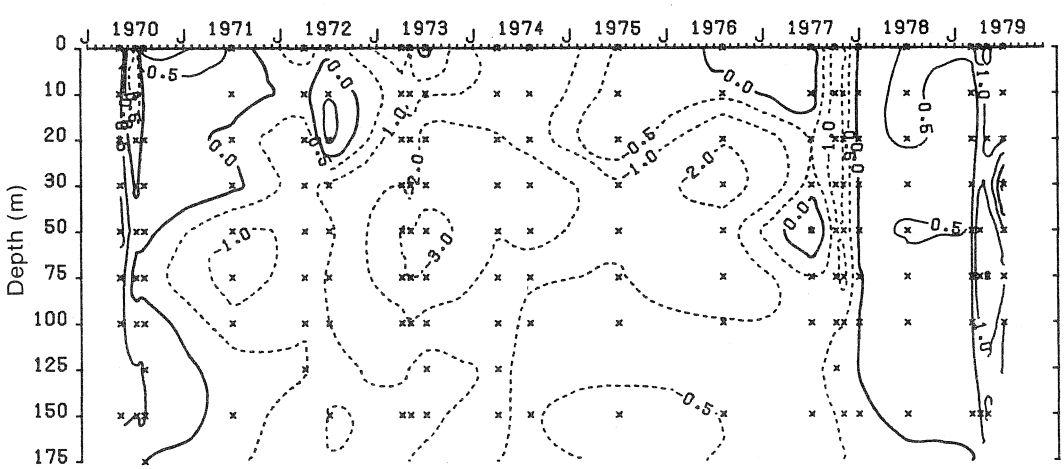

Fig. 7. Contoured potential temperature anomalies at Station 16 of the Flemish Cap section, 1970–79. (Dashed lines are negative anomalies.)

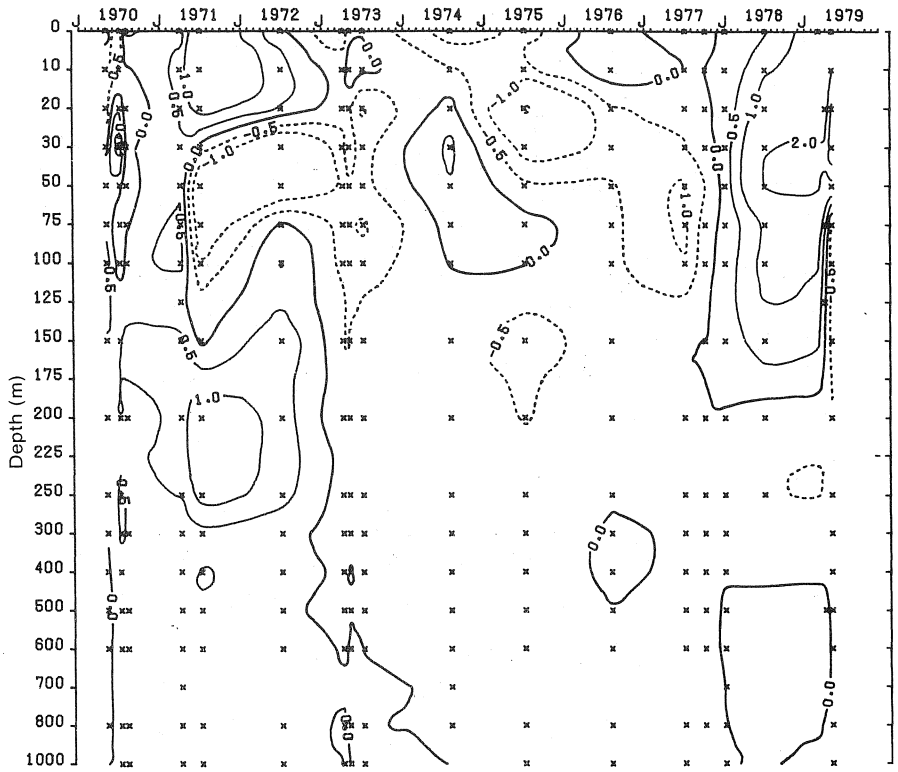

Fig. 8. Contoured potential temperature anomalies at Station 20 of the Flemish Cap section, 1970–79. (Dashed lines are negative anomalies.)

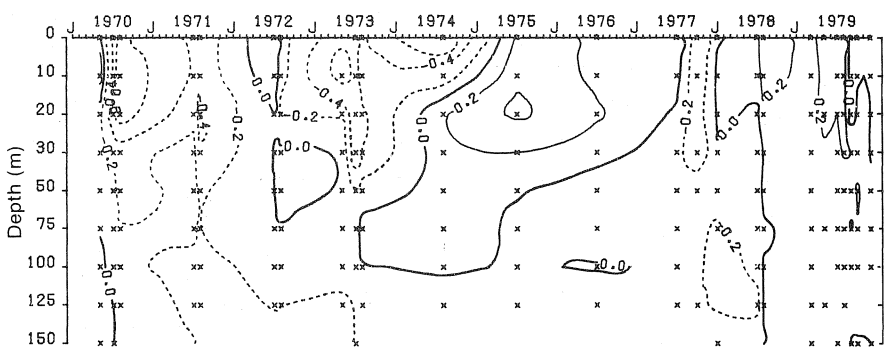

Fig. 9. Contoured salinity anomalies at Station 1 of the Flemish Cap section, 1970–79. (Dashed lines are negative anomalies.)

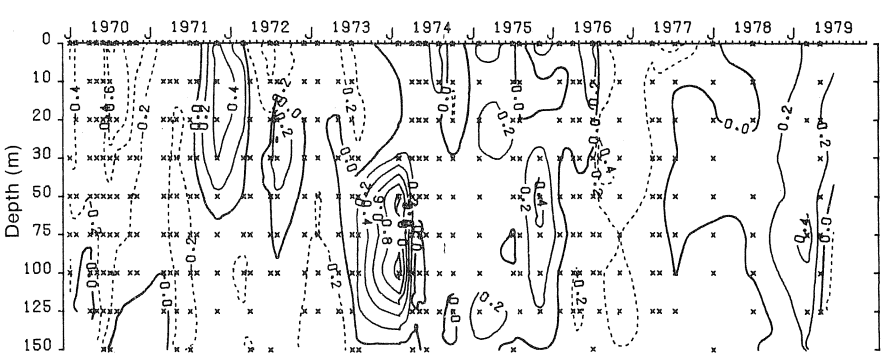

Fig. 10. Contoured salinity anomalies at Station 7 of the Flemish Cap section, 1970–79. (Dashed lines are negative anomalies.)

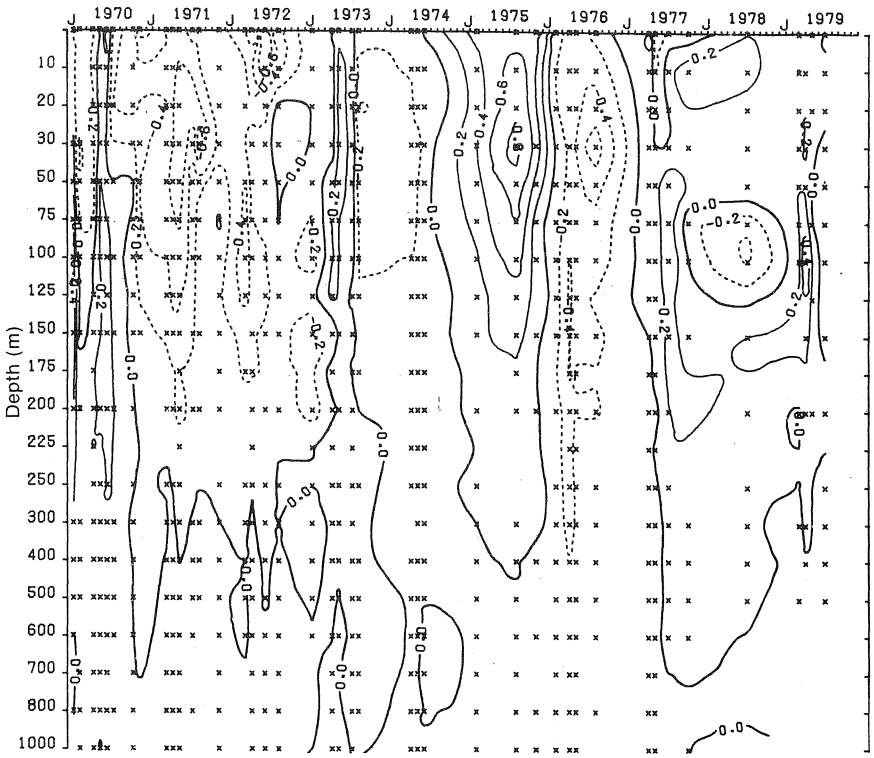

Fig. 11. Contoured salinity anomalies at Station 10 of the Flemish Cap section, 1970-79. (Dashed lines are negative anomalies.)

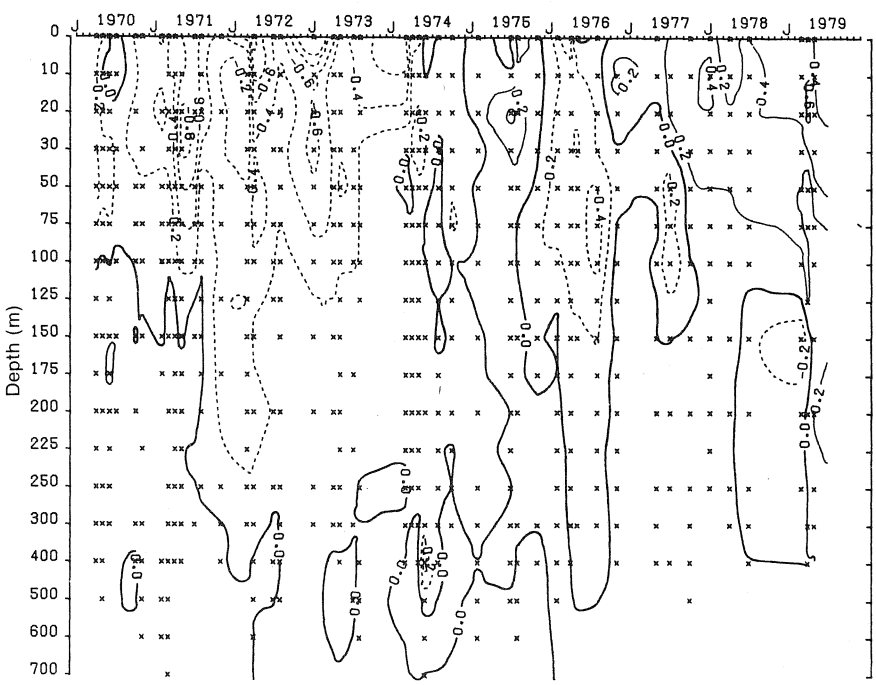

Fig. 12. Contoured salinity anomalies at Station 13 of the Flemish Cap section, 1970-79. (Dashed lines are negative anomalies.)

Current water mixes with Gulf Stream water south of Flemish Cap and a northerly flow of mixed water occurs on the eastern side of Flemish Pass (Station 13). There is apparently a weak anticyclonic flow around the Flemish Cap (Ross, MS 1980), and it is part of this flow that is sampled at Stations 13 and 20. Station 16 is situated on the shallowest part of Flemish Cap.

The 1970–79 decade began with saltier water than normal in the inshore branch of the Labrador Current, observed at Station 1 and 7. The offshore branch, sampled at Station 10, comprised warmer and saltier water, particularly below 200 m, and the northward flowing water in Flemish Pass, sampled at Station 13, exhibited similar conditions, especially below about 150 m. Both on the Flemish Cap and eastward, water conditions, especially below 100 m, were warm and salty at the start of the decade.

Conditions changed from late 1970 to late 1971. The inshore branch of the Labrador Current showed negative temperature anomalies, with extremes recorded below 30 m, particularly at Station 7, and the corresponding salinities were lower than usual. The

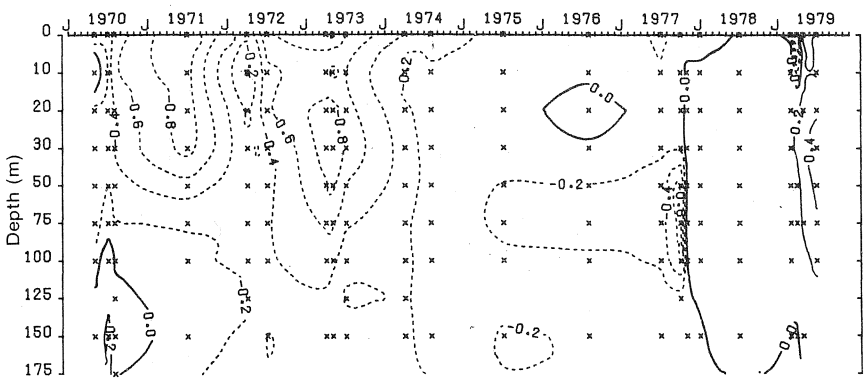

Fig. 13. Contoured salinity anomalies at Station 16 of the Flemish Cap section, 1970–79. (Dashed lines are negative anomalies.)

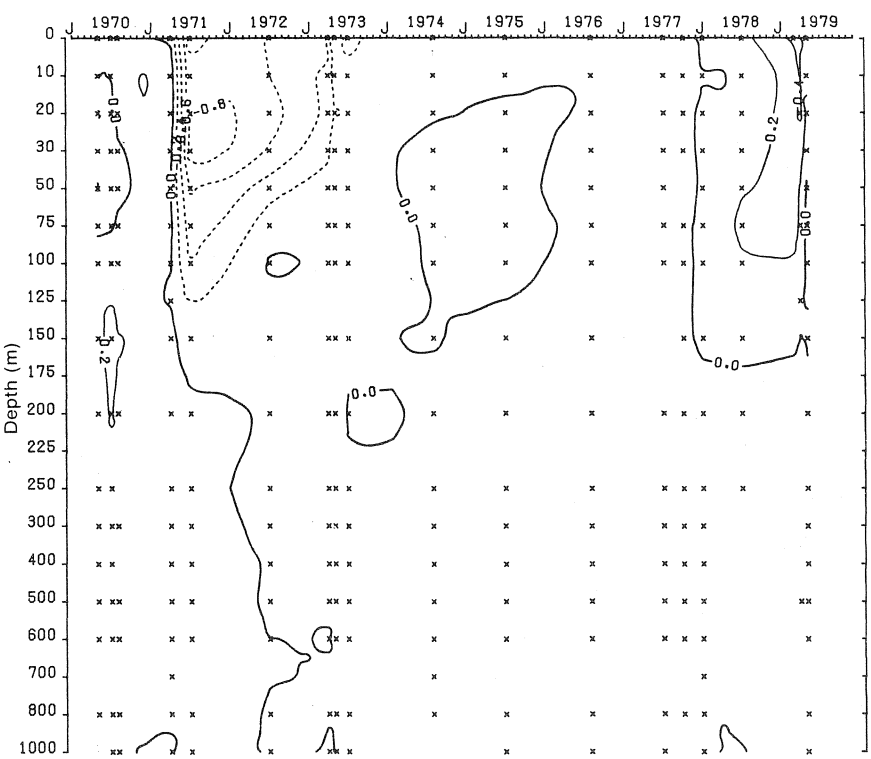

Fig. 14. Contoured salinity anomalies at Station 20 of the Flemish Cap section, 1970–79. (Dashed lines are negative anomalies.)

offshore branch, observed at Station 10, showed cold, fresh water conditions which persisted only in the upper 250 m until 1973. Deeper water was still warm and salty relative to the long-term mean. On the eastern side of Flemish Pass (Station 13), cold conditions began in late 1970 and persisted until 1975, with extreme negative temperature anomalies evident at about 50 m in 1972, 1973 and 1974. During the same period, negative salinity anomalies were evident throughout the whole water column. Similar conditions occurred on the Flemish Cap (Station 16), but the cold period extended into 1977, with extremes in the upper 50 m. Here, the water was freshest near the surface in 1971 and 1973, but a fairly abrupt return to average conditions occurred in 1974. East of Flemish Cap (Station 20), both temperature and salinity declined, so that by mid-1972 below-normal conditions prevailed throughout the water column. The extreme below-normal salinity conditions in late 1971 (Fig. 14) appears to have been associated with cold water at 30–50 m (Fig. 8).

The cold and fresh conditions of the water along the Flemish Cap section prevailed through the mid-1970's with few exceptions. The most notable exception was a brief period of warm, salty conditions throughout the water column at Station 10 in 1973 and in the upper few hundred meters in 1975. The event in 1973 shows no correspondence with events at other stations, except perhaps at Station 1. If anything, conditions at other stations were below normal in mid-1973. The warm conditions at Station 10 in 1975 appear to be reflected at Station 13, but to a lesser extent.

A change in the characteristics began in 1976 or 1977 at all stations on the section. The water in the upper 300 to 400 m became warmer and saltier than the long-term mean, and these conditions persisted into 1979 with extremes in late 1978.

Discussion

Burmakin (MS 1980) analyzed the heat content of the water in the upper 200 m along several standard sections in the Northwest Atlantic, one of which is the Flemish Cap section. Quantitative comparisons with the present analysis are difficult because of differences in presentation of the analyses, but qualitative comparisons indicate basic agreement. Burmakin's (MS 1980) general statement, that the first 5 years of the 1970–79 decade are characterized by colder water and the second 5 years by warmer water, can be further qualified to indicate that water conditions were colder and fresher in the first case and warmer and saltier in the second. In particular, there is agreement that a change to warmer conditions occurred in 1976 and 1977.

The results of the analysis for Station 1 in this paper can be compared with those presented by Keeley (1981b) for station 27, situated 5 miles off St. John's, Newfoundland. The anomalies cannot be directly compared because of the different techniques used in the calculations, but the trends are similar. Negative anomalies at Station 27 were evident in 1972 and 1973 at all depths but were most pronounced in depths greater than 100 m.

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