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The North Atlantic Oscillation and the Ocean Climate of the Newfoundland Shelf

by

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Abstract

We relate 40 years of temperature and salinity data at an oceanographic station on the Newfoundland Shelf to large scale changes in wind and pressure fields, ice cover, Hudson Bay outflow, and salinity patterns from the West Greenland Shelf. Almost 50 percent of the interannual variation in the bottom (175 m) temperature of the Newfoundland Shelf was associated with the North Atlantic Oscillation. In winters with strong mid-latitude westerlies, there was a decrease in the stratification of the water column in the winter, but an increase in the following late summer and early autumn which appears to be caused by the formation and advection of ice from the the northern Labrador shelf. Interannual variation in temperature and salinity was also related to salinity fluctuations at West Greenland, which probably reflects a differential input of Arctic versus Atlantic water into the Labrador Sea. Interannual variation in Hudson Bay summer runoff was associated with salinity on the Newfoundland shelf the following spring; this indicates that Hudson Bay runoff is not primarily responsible for the seasonal variability in salinity on the Newfoundland Shelf.

1 Introduction

In this paper we examine a 40 year time series from an oceanographic station located in the inner branch of the Labrador Current at a bottom depth of 176m. Our purpose is to relate the variability of the temperature and salinity observations to large scale atmospheric forcing, Hudson Bay runoff, ice cover, and salinity of the West Greenland current. We also provide a description of the seasonal cycle at this oceanographic station.

Our study is motivated by the importance of variations in surface salinity in this region which can affect deep water formation (Lasier 1973, 1980; Brewer et al. 1983, Clarke and Gascard 1983), the importance of this station in monitoring the ocean climate (Petrie and Anderson 1983, Petrie et al. 1988) and the importance of understanding the ocean climate's effect on the distribution and survival of marine fish in the region (Sutcliffe et al. 1983).

2 Station 27

2.1 A continental shelf oceanographic station off Newfoundland.

The oceanographic station 2 km off Cape Spear (Fig. 1), known as Station 27 (176 m depth, 47°32.8′N 52°35.2′W) is the twenty-seventh station in a pattern of ocean transects established as a time-series in 1946 (Templeman 1975). The station is occupied by research vessels entering and leaving St. John's harbor, and has been sampled approximately twice monthly since 1950, providing coverage of all the seasons. Our analysis uses data up to and including 1987. *Fig. 1 near here*

Until 1959 oceanographic bottle data from Station 27 were collected at 25 m depth increments; since 1959 measurements were taken at the standard oceanographic depths (0, 10, 20, 30, 50, 75, 100, 150, and near-bottom at 175 m). After 1963 an additional level at 125 m was collected. The intended depth was not always achieved, and wire-angle and unprotected thermometer observations were utilised in assigning data to depth classes. After 1977, CTD and XBT data were also collected, and single values for the above depths were extracted from each cast.

2.1.1 Outlier Detection

About 8180 observations of temperature and salinity were available from Canadian archives. Laboratory and field sheets for about 90 percent of the data was available for checking. The following procedures were used to check for errors.

First, salinity inversions were considered as errors because the stability at temperatures typical of Station 27 is essentially a function of salinity alone. When the water was warmer than 4°C temperature was checked to make sure it decreased with depth. Density inversions were eliminated by this procedure. About 10% of the surface salinity observations were more saline than simultaneous observations at 10 m, probably due to sampling with a canvas bucket that dried between uses. *Second,* temperature-salinity plots of each station were examined for smoothness, and points departing from the expected curve were re-examined for possible errors. *Third,* residuals more than 4 standard deviations from fitted seasonal cycles by depth (see the following subsection) were removed from the analysis unless they occurred at a time when surrounding residuals were also extreme. *Fourth,* scatterplots of temperature residuals versus salinity residuals were examined and outlying points were deleted unless time-series plots suggested they might be tolerable.

If inversions and outliers could not be related to transcription errors or to mis-ordered salinity samples within a cast, the questionable data was deleted. Approximately 20 points were corrected and 356 temperature or salinity observations were removed from the analysis.

2.1.2 The *Seasonal* Cycle

Seasonal cycles at Station 27 were fitted to the edited data by a sine and cosine series. The mean and wavelengths of 1, 1/2, 1/3 and 1/4 years were fitted by linear regression (Smith 1983).

The regression model was

$$\hat{Y}_t = \overline{Y} + \sum_{i=1}^{4} [\varsigma_i \cos(2\pi i t/365.25) + \sigma_i \sin(2\pi i t/365.25)],$$

where t is the sequential day of the year. The fitted parameters are the mean $\overline{Y}$, and the coefficients ς_i and σ_i. The amplitude and phase of the i^{th} wavelength are $(\varsigma_i{}^2 + \sigma_i{}^2)^{1/2}$ and $\tan^{-1}(\sigma_i/\varsigma_i)$ respectively. Parameters for the first three wavelengths were significant for all depths; whereas parameters for the 1/4 year wavelength were significant for only 11 of the 20 regressions (α=0.05). *Fig. 2 near here*

The surface temperature maximum and surface salinity minimum occur in August to September, but the corresponding maximum and minimum at the bottom (175 m) occur in February to March (Fig. 2). There is a decrease in the amplitude of the annual cycle with depth that corresponds to this phase shift.

Huyer and Verney (1975) and Keeley (1981) determined the annual cycle at Station 27 by other techniques. The latter applied "objective analysis" to interpolate the data to a 15 day by 10 m grid in each year, and then averaged those grids over years. Comparing our regression analysis with Keeley's (1981) gridpoint estimates indicated that his technique slightly underestimated the amplitude of the seasonal cycle, and heavily smoothed the sharp summer thermocline. Specifically, the maximum and minimum of surface temperature and salinity by the harmonic analysis (with day of the year in brackets) were 13.07(236), -1.13(69), 32.38(84) and 30.97(266). The corresponding values from Keeley (1981) are 12.81(236), -0.92(84), 32.27(84), and 31.21(282). The minimum temperature -1.30°C within the Keeley (1981) grid occurred at 90 m on day 221, compared to -1.43°C at 125m on day 221 from our analysis. Some of the discrepancies may be due to the much larger region Keeley(1981) drew his data from, the increased harmonics included in our analysis, and our longer time series.

The residuals at each depth from the annual cycle regressions were time-averaged into months by linear interpolation between observations. Months in which no data were collected were treated as missing observations. We use this monthly series of seasonal residuals in the analysis below. Unless we state otherwise, all temperature and salinity estimates from Station 27 will refer to these seasonal residuals.

2.2 The Lag-Correlation of Temperature and Salinity

We now examine the relationship of surface temperature and salinity with temperature and salinity measurements at all depths, so that we can interpret later results. The lag-correlations of surface salinity and temperature at Station 27 over all depths are shown in Fig. 3 for February and June. *Fig. 3 near here*

The June surface temperature is correlated with subsequent surface temperatures on a time scale of a few months. The June surface temperature is weakly correlated with deep temperatures; however, there may be an effect on deep temperatures after a lag of 6 or 7 months. This may represent the mixing down of water from above the summer thermocline. The February surface temperature is correlated with surface temperatures in past and future winters, but are uncorrelated, or perhaps even negatively correlated, with summer temperatures. The February surface temperature appears to be correlated on a longer time scale with bottom temperatures, with the strongest correlations being after a lag of 2 or 3 months.

The February and June surface salinity are correlated with subsequent surface salinity on a time scale of a few months. The June surface salinity is weakly correlated with deep temperatures; however, there may be an effect on deep temperatures after a lag of 6 or 7 months. The February surface salinity appears to be only weakly correlated with bottom salinity, with the strongest correlations being after a lag of 2 or 3 months.

The autocorrelation of winter surface temperatures is probably caused by the storage of anomalously cold or warm water that is shielded by a shallow layer in summer. This deep water is stirred up to the surface by increased wind stress in winter (Namias and Born 1970).

The autocorrelation of the bottom salinity appears to be less than that of of bottom temperature. The January surface salinity is autocorrelated on a short time scale; the autocorrelation with the next year may even be reversed. The June surface salinity is autocorrelated on a longer time scale. Note that both of the autocorrelations disappear the following spring. We shall see below that the variation in spring salinity is largely controlled by Hudson Bay runoff from the previous summer.

3 Station 27 and Wind, Pressure Fields

3.1 Exploratory

We examined the association between atmospheric forcing and Station 27 data. We used the teleconnection method to relate the monthly Station 27 temperature and salinity to the sea level pressure in the North Atlantic. Monthly estimates of the sea level pressure from 1950 to 1980 were obtained on a 5° by 10° grid from the publication "Die Grosswetterlagen Europas", Deutscher Wetterdienst, Offenbach, via K. L. Thompson of Dalhousie University, Halifax, Canada. Residuals from the long term mean of the monthly pressures were calculated at each grid point.

The teleconnection analysis consisted of calculating the correlation between the salinity or temperature at a fixed depth at Station 27 with the sea level pressure at each of the grid points for the 30 year time series. The resulting "field" of correlation coefficients were then contoured. The most consistent result for temperature and salinity at all depths and at several time lags showed the pattern observed for the sea level pressure anomalies associate with the NAO, i.e. the correlations were positive in a region corresponding to the location of the Azores High, and negative in the region associated with the Iceland Low.

This atmospheric circulation pattern is known as North Atlantic Oscillation and we investigated it before proceeding with further analyses.

3.2 The North Atlantic Oscillation (NAO) indices

We considered two indices of the NAO. The simplest index is the difference in the winter sea level pressure between the Azores High, as measured at Ponta Delgadas, Azores, and the Iceland Low, as measured at Akureyri, or Stykkisholmur, Iceland (Rogers 1984, Moses 1987). A second index has been developed from monthly principal components analysis of northern hemisphere 700 mb height data (Barnston and Livezey 1987). For this index we used the average of the first principal component of December, January, February and March for each winter.

We used both indices but the results presented are based upon the height of the 700 mb level. Unless otherwise stated, this is the time series we shall refer to as the NAO index. We repeated our analysis using the alternative index to test the robustness of our conclusions. The conclusions in all cases were duplicated.

The sign of the NAO index was set such that increased mid-latitude westerlies, i.e. large sea surface pressure differences between the Azores and Iceland, are positive. The NAO index has been normalised by subtracting the long-term mean and dividing by the standard deviation of the time series.

3.3 The NAO and Station 27

We first examined the effect of the NAO on the temperature and salinity at different depths as a function of lag (Fig. 4). Our initial conclusions from the analysis were as follows. *Fig. 4 near here*

1. When the mid-latitude westerlies are strong, there are below normal temperatures that persist for at least 5 months at the surface, and for at least a year near the bottom.
2. Salinity in the upper water column in the spring increases following a winter with strong westerlies, whereas the reverse occurs at the bottom. This is consistent with increased mixing caused by increased wind stress and convection from cooling.
3. There appears to be increased stratification in the early autumn following a winter of strong westerlies. This increased stratification is associated with increased surface temperature and decreased surface salinities. This increased stratification appears to reverse in the following winter, but appear again the following autumn (18 months after the strong westerlies), however, the relationship may not be reliable.
4. The NAO appears to have little effect on the year to year variability of the annual mean salinity, however there are important within year effects described below.

The pattern of bottom salinity and temperature compared with the NAO index is shown in Fig. 5. *Fig. 5 near here*

3.3.1 Interannual Temperature Variation

The bottom temperatures were averaged over each year and regressed against the NAO index (Fig. 6). The resulting regression was significant ($p \leq 0.0001$) and explained 44% of the variance in the bottom temperature. Multiple regression was used to determine if the NAO lagged one year also had a significant effect on the mean bottom temperature. The resulting regression showed that the effect of increased westerlies may persist for a second year in the bottom temperature, but the regression result was not significant ($p \leq 0.11$). *Fig. 6 near here*

Our hypothesis is that the decrease in Station 27 temperature associated with the NAO is caused by Arctic winds cooling the water in the Labrador Sea. This hypothesis was checked by examining the effect of local winds in the Labrador Sea. We found that bottom temperature at Station 27 was most strongly correlated with north winds in Baffin Bay and west winds near the Avalon Peninsula of Newfoundland. This is consistent with our hypothesis. It is interesting to note that the relationships were not better or worse when we used the local winds.

We suspected that the residual interannual variation in bottom temperature from the NAO regression was related to long term changes in water masses entering the region, as opposed to winter cooling. This hypothesis was tested by correlating the residuals from the temperature with NAO regression against the annual bottom salinity (Fig. 7). The two time series appear to be related ($r=0.37$, $n=35$; $p\leq0.02$, uncorrected for autocorrelation). The positive relationship indicates that in years when conditions are warmer than might be explained by the NAO, the water is also more saline than usual.

Fig. 7 near here

3.4 The NAO, Sea Ice, and Station 27

Low surface salinity in the late summer following strong mid-latitude winter westerlies is probably caused by the melting of ice extending further south than normal from the Arctic. This hypothesis was tested by regressing the NAO index against the area of ice south of 55°N from January to June from 1953-1984 using maximum likelihood linear regression with autocorrelated error (Judge et al. 1980). The ice data is derived from a data set described by Walsh and Sater (1981). See Symonds (1986) and Ikeda et al. (1988) for an analysis of the seasonal and interannual variability of ice cover in this region. The resulting regression was significant ($p\leq0.01$).

Variation in surface salinity in response to the NAO can be best explained when compared directly to the area of ice below 55°N (Fig. 8). Correlations of salinity and ice area are greatest in August-October for the surface, and greatest in January for 175 m. These times correspond to the minimum salinities in the seasonal cycles for these depths (Fig. 2), which suggests ice melt is a major contributor to the salinity seasonal cycle at Station 27.

Fig. 8 near here

The temperature correlation of Station 27 may be stronger with respect to the ice data than to the NAO index. We expect that this is because that the ice extent is a better measure of cooling than wind or pressure data in the absence of air and sea temperature estimates. The NAO is not significantly autocorrelated at a one year lag ($r=-0.005$, $n=40$), whereas bottom temperature for Station 27 ($r=0.37$, $n=41$) and the interannual variability of ice south of 55°N ($r=0.43$, $n=31$) are autocorrelated. Thus it may be that the bottom temperature of Station 27 and the amount of ice south of 55°N are "integrating" the effects of the NAO in a similar manner.

An alternative explanation is the possible effect of the NAO on precipitation in the region. Rogers (1984) found no evidence of a relationship between the NAO and precipitation in Western Greenland. We investigated the relationship between the NAO and river input into Hudson Bay using the data compiled by Prinsenberg et al. (1987) and found no significant relationship between the NAO index and Hudson Bay runoff.

Strong couplings between Greenland Sea ice and the Southern Oscillation (SO) were suggested by Johnson et al. (1985), with ice lagging the July SO index by 0 to 6 months. Rogers (1984) showed that the NAO and the SO are not directly linked statistically, and co-occurences of their extrema are due to chance. The winters of 1973 and 1983 are such co-occurences and stand out as low temperatures at Station 27.

4 Runoff from Hudson Bay

We tested the hypothesis that salinity at Station 27 is reduced by runoff from Hudson Bay. Sutcliffe et al. (1983) noted a 4 month lag between the seasonal cycle of runoff into Hudson Bay and the seasonal cycle of salinity in the upper 50 m at Station 27, and suggested that the time lag was consistent with ocean drift speeds. Prinsenberg et al. (1987) considered it possible that the peak freshwater runoff in June caused the September salinity minimum at Station 27, but they also considered it possible that the melt of the seasonal ice cover caused the salinity minimum. We used the Prinsenberg et al. (1987) time series (1963–1983) of total river runoff into Hudson Bay and Ungava Bay, without considering separate lags for individual rivers, to examine the effects on Station 27 of runoff into Hudson Bay.

Fig. 9 near here

We correlated the annual river runoff into Hudson and Ungava Bay with monthly temperature and salinity at Station 27. We have taken June as the reference for the runoff because that is the month in which runoff is maximum. There is a maximum negative correlation at 7 and 8 months lag for the surface salinity, corresponding to February and March at Station 27. The correlation of river runoff and the 175 m salinity shows a lag of 9 to 11 months, corresponding to April to June at Station 27. The difference in lag correlation between the surface and the the bottom may be caused by the greater velocity of the surface layer in the inshore component of the Labrador Current.

Temperatures at Station 27 are positively correlated with runoff, especially at 175 m. This association is probably caused by large-scale meteorological processes.

We tested our results by using a proxy for Hudson Bay runoff that covered years before 1963 The Gods River (station 04AC005, Water Survey of Canada, 1985), which drains into southwestern Hudson Bay, was found to be a good proxy to the total runoff (r=0.54, n=21). The 1963–1983 data from the Gods River was not used in correlations with Station 27, to allow an independent test of our correlation results. The Gods River annual runoff is negatively correlated with surface salinity at Station 27, at lags of 8–10 months (Fig. 10), which is consistent with our previous result. The expected correlation with bottom salinity at about 11 months is not apparent in Fig. 10. There is no consistent pattern of Gods River annual runoff with temperatures at Station 27. *Fig. 10 near her*

We conclude that Hudson Bay runoff does affect Station 27 salinity, but in contrast to the Sutcliffe et al. (1983) hypothesis, the effect of peak runoff on Station 27 salinity is in March at the surface, and April to June at the bottom. Evidence to support this conclusion comes from an 11 month long record of salinity at 40 m in Hudson Strait (Fig. 11), that shows the salinity minimum is in December. This would imply a 3 month delay between the Hudson Strait salinity minimum and the predicted effect on Station 27 (1800 km away). This results in a surface velocity consistent with the 0.2 ms^{-1} velocity in the upper 100 m of the Labrador Current estimated by Petrie and Isenor (1985). We conclude that the surface salinity minimum at Station 27 is caused by the melt of the seasonal ice cover, and is not due to river runoff into Hudson Bay. *Fig. 11 near her*

5 The West Greenland Current

The only long term monitoring of the West Greenland current has been carried out at the Fyllas Bank section, which is described by Buch and Stein (1987). Here we use data observed in July from a standard section. They calculated salinity at each station for four depth sones: less than 50 m, 50–150 m, 150–400 m, and 400–600 m. We examined salinities below 50 m, which excluded short-term noise from local surface effects, because we were interested in long-term, large-scale effects. For each depth sone and at each station, we normalised the anomalies by dividing by the standard deviation. Then we calculated the median for particular depth zones.

The strongest correlations of the Fyllas Bank residuals with Station 27 bottom salinity and temperatures were with the salinity residuals in the combined 50–150 and 150–400 m depth sone. Station 27 bottom salinity was most strongly correlated with Fyllas Bank 50-400m salinity after a lag of 15 to 21 months, although the correlation is primarily positive for two years (Fig. 12). The correlation of the Fyllas Bank 50-400m salinity with Station 27 bottom temperature appears to be delayed compared to the Station 27 salinity (Fig. 12). This would imply a circulation time of about a year and a half between these two areas. This appears longer than what is generally assumed (Buch 1984). *Fig. 12 near her*

5.1 The West Greenland Current and the NAO

Salinities above 400 m were not correlated with the NAO index. However, the salinity from 400 to 600 m of the Fyllas Bank section in July is negatively related to the NAO index ($p \leq 0.001$; see Fig. 13). That is, during winters of strong mid-latitude westerlies, the deep water of the Fyllas Bank section is fresher than usual. *Fig. 13 near her*

6 Sea Ice from the East Greenland Sea to Hudson Bay

The amount of ice and water advected from the relatively low salinity Arctic Ocean might influence the temperature and salinity in the Labrador Sea. We investigated this hypothesis by relating the temperature and salinity at Station 27 and Fyllas Bank to the area of ice from Denmark Strait, the East Greenland Sea, Baffin Bay, Hudson Bay, and the Labrador Sea. The data we used is described by Walsh and Sater (1981) and Manak and Mysak (1987). These data covered the period 1963 to 1984. The spatial resolution of the grid was about 111 km, and estimates are representative of end-of-month conditions. An updated copy of this data was provided by John Walsh.

Annual ice anomalies in the Greenland Sea were negatively correlated with all time series of measurements of salinity at Fyllas Bank. Annual ice anomalies in the Greenland Sea were positively correlated with bottom temperatures at Station 27 the following year.

Annual ice anomalies in Hudson Bay were correlated with fresher surface water at Station 27 the following spring. This delay is consistent with the delay seen in runoff from Hudson Bay.

There was no significant correlation between ice extent from Denmark Strait, East Greenland Sea, or Hudson Bay and the NAO index. The ice cover in the East Greenland Sea may be positively related to Hudson Bay runoff ($r=0.51, n=23$; $p \leq 0.01$, uncorrected for autocorrelation). Rogers and van Loon (1979) found similar correlations between variations of atmospheric circulation and subsequent ice coverage in the region.

The NAO time series is less autocorrelated than the bottom temperature data from Station 27. One possible cause of this autocorrelation that we considered is the build-up of multi-year ice in Baffin Bay. However, this was not the case. After a winter in which the NAO index was large, i.e. strong north winds in Baffin Bay, there was more ice the following spring, but less ice than usual the following summer. The reduction of ice in the summer may be caused by increased salinity in Baffin Bay caused by salt rejection associated with ice formation and transport south, or with increased salinity caused by greater than usual vertical mixing or deep convection associated with the strong North winds.

7 Conclusions

We have shown that the North Atlantic Oscillation is associated with almost 50% of the interannual variability in bottom temperature at Station 27. It is also associated with much of the interannual variation in sea ice in the region. In winters with strong mid-latitude westerlies, there was a decrease in the stratification of the water column in the winter, but an increase in the following late summer and early autumn which appears to be caused by the formation and advection of ice from the northern Labrador shelf. Interannual variation in temperature and salinity was also related to salinity fluctuations at West Greenland, which probably reflects a differential input of Arctic versus Atlantic water into the Labrador Sea. Interannual variation in Hudson Bay summer runoff was associated with surface salinity residuals on the Newfoundland shelf the following spring; this indicates that Hudson Bay runoff is not primarily responsible for the seasonal variability in salinity on the Newfoundland Shelf.

8 Acknowledgments

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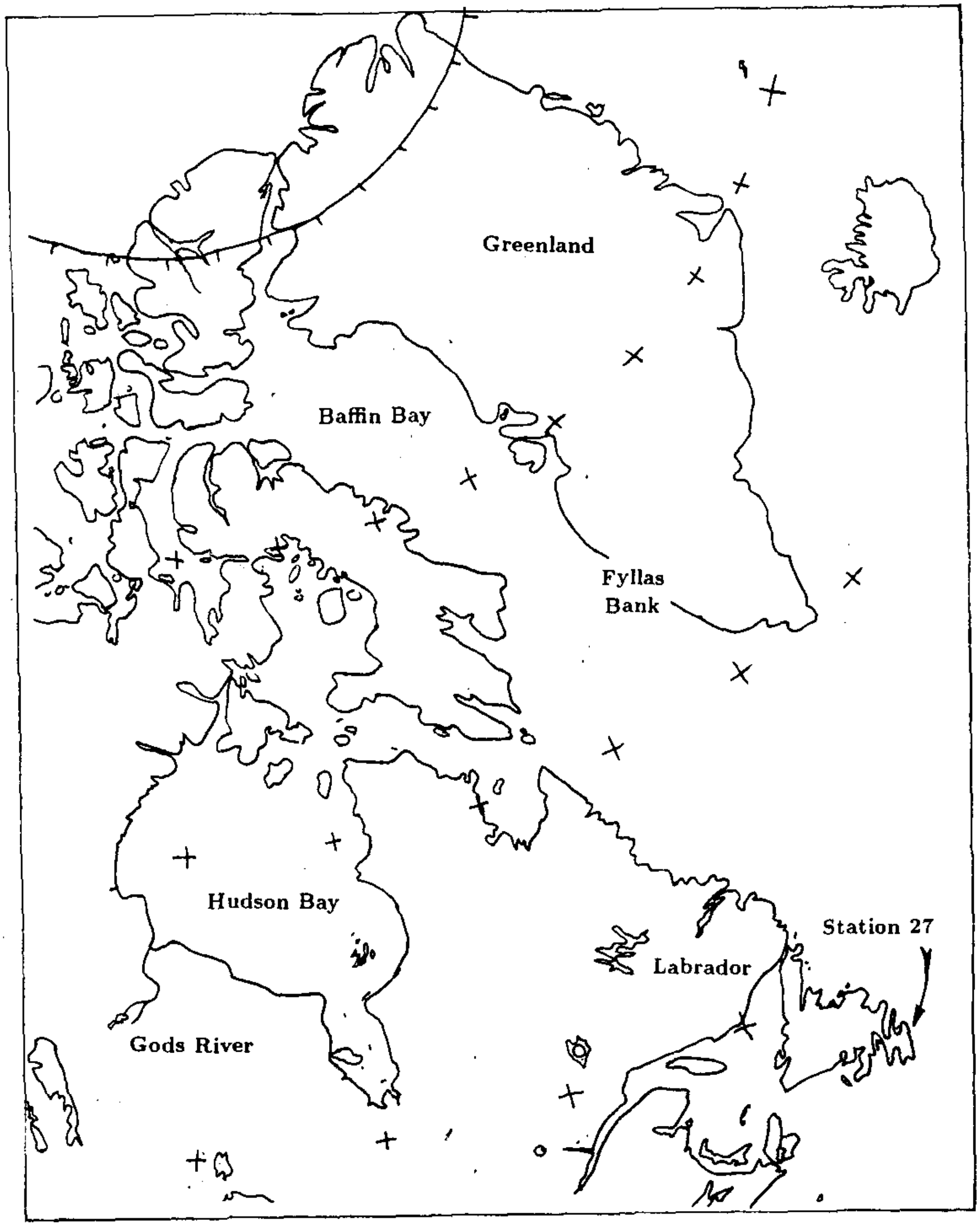


Fig. 1. Location of station 27 and other locations mentioned in the text.

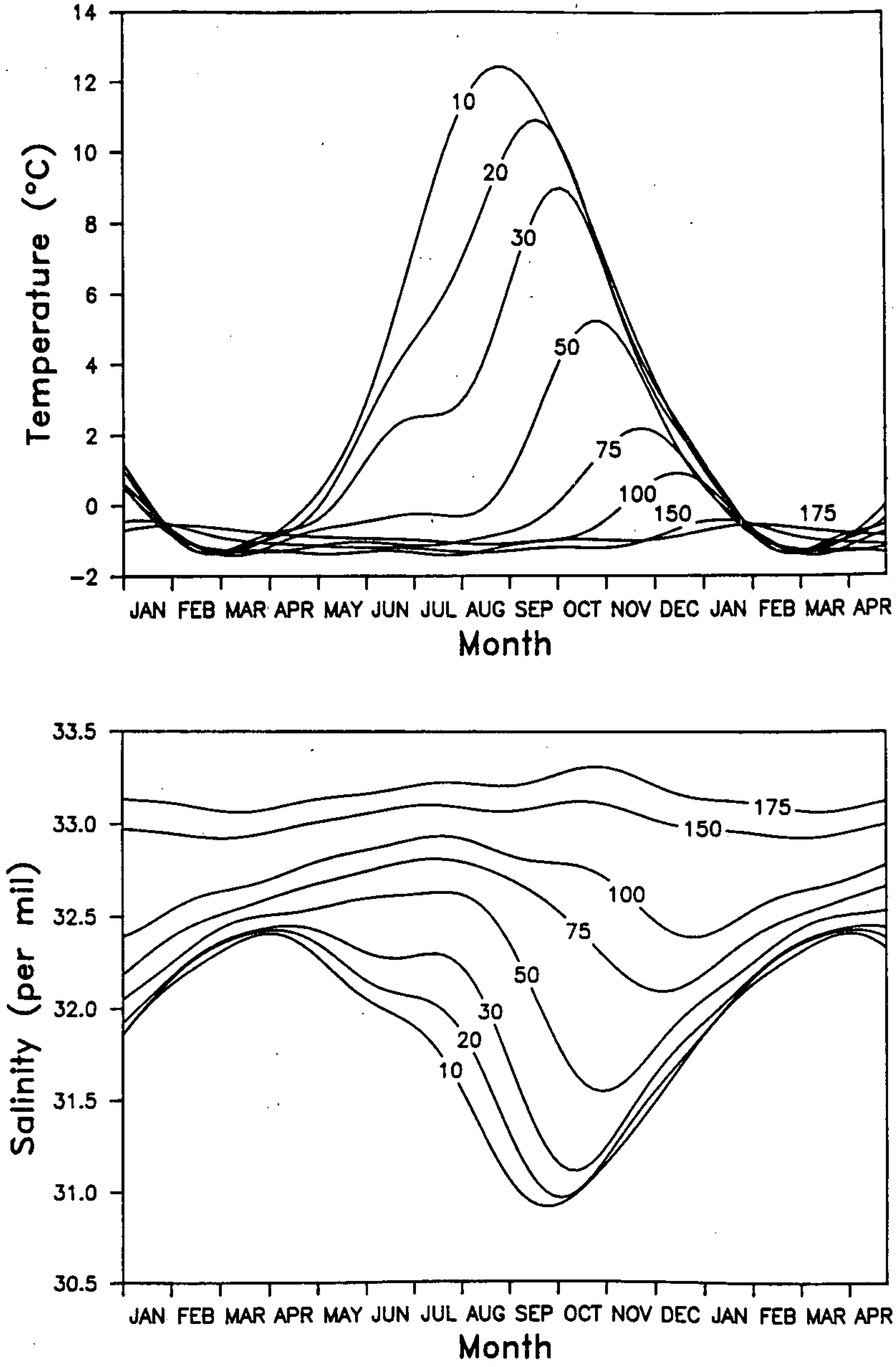


Fig. 2. The seasonal cycle of temperature and salinity at station 27 as a function of depth (in meters).

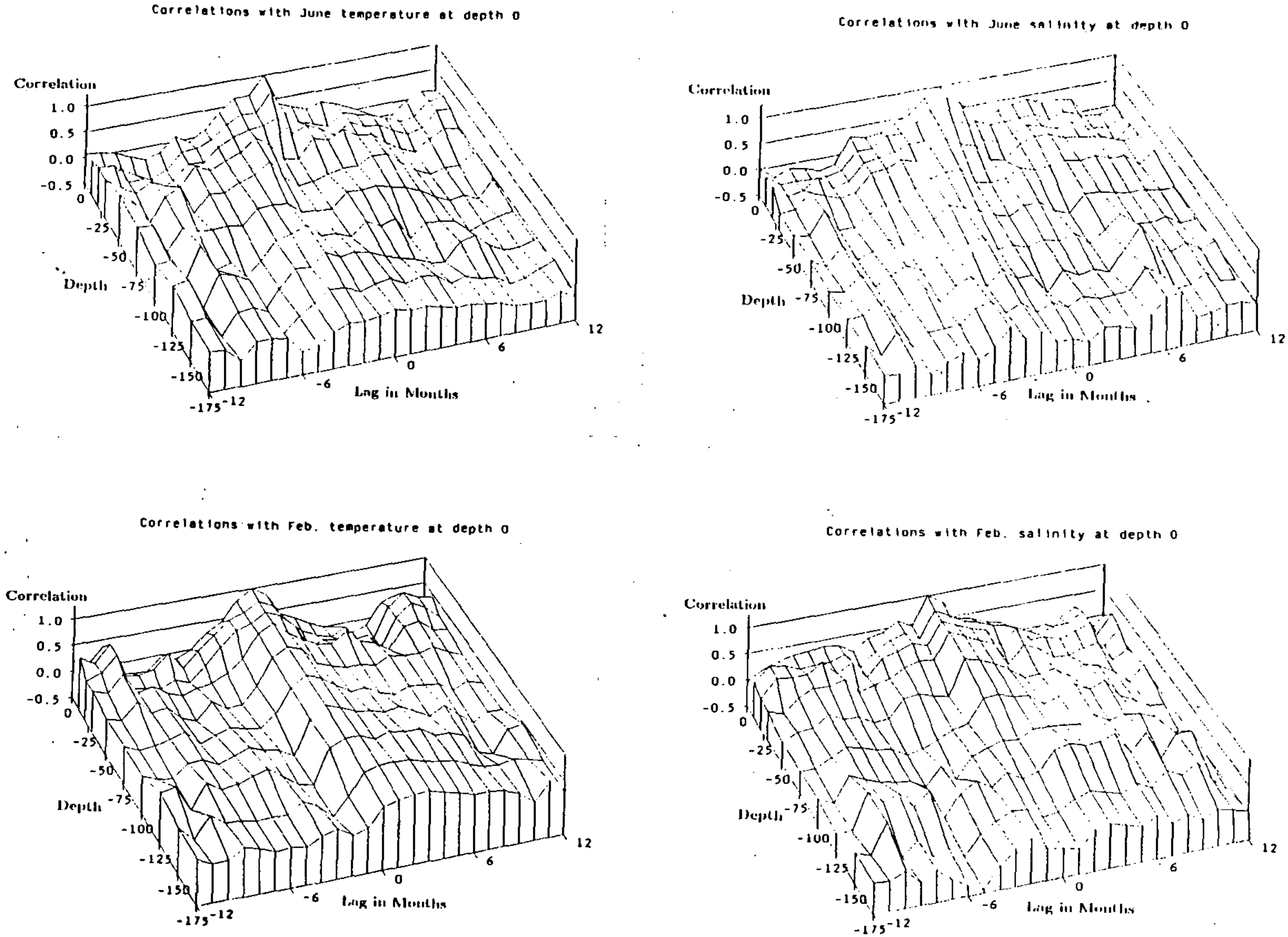


Fig. 3. The lag-correlation of Feburary and June surface temperature and salinity with temperature and salinity at all depths at station 27. The seasonal cycle has been removed from the data.

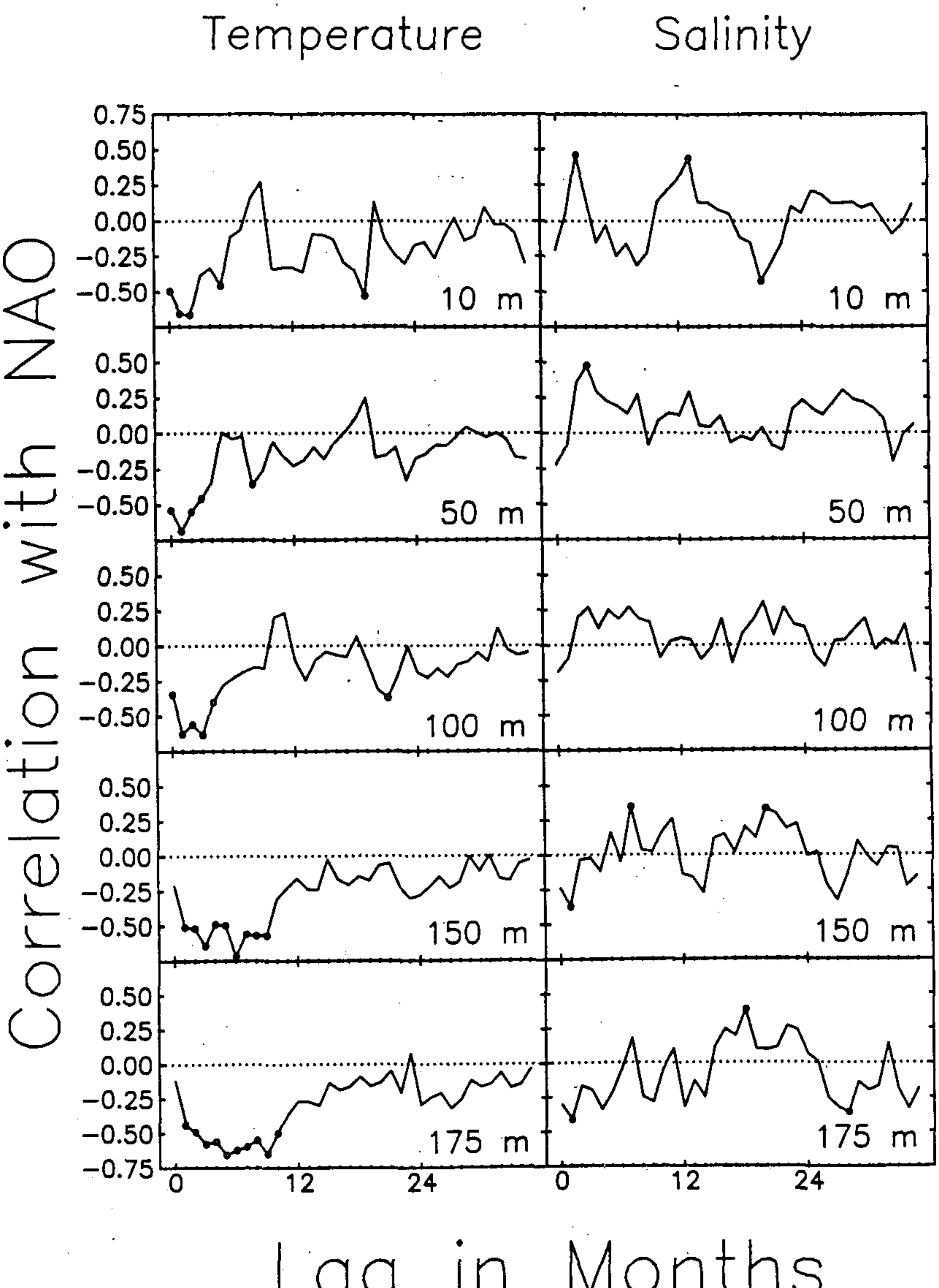


Fig. 4. The correlation of the interannual monthly temperature and salinity at station 27 with an index of the North Atlantic Oscillation. A negative correlation implies that strong westerlies are associated with low temperatures and salinities. A nominal significance of the correlation at $p < 0.05$ is denoted by (•).

Fig. 5. A comparison of the NAO index with the bottom tempearature and salinity (175m), the runoff from Hudson Bay Region, the Gods river, the normalized area of ice sourth of 55°N in the Labrador Sea, and normalized salinity at Fyllas Bank. The monthly estimates of the bottom temperature and salinity (•) are smoothed by an approximating spline function with the minimum curvature, i.e. second derivative, subject to the constraint that the sum of square deviation is less that 100. The solid line for the Fyllas Bank data connects the median of the estimates for each depth zone.

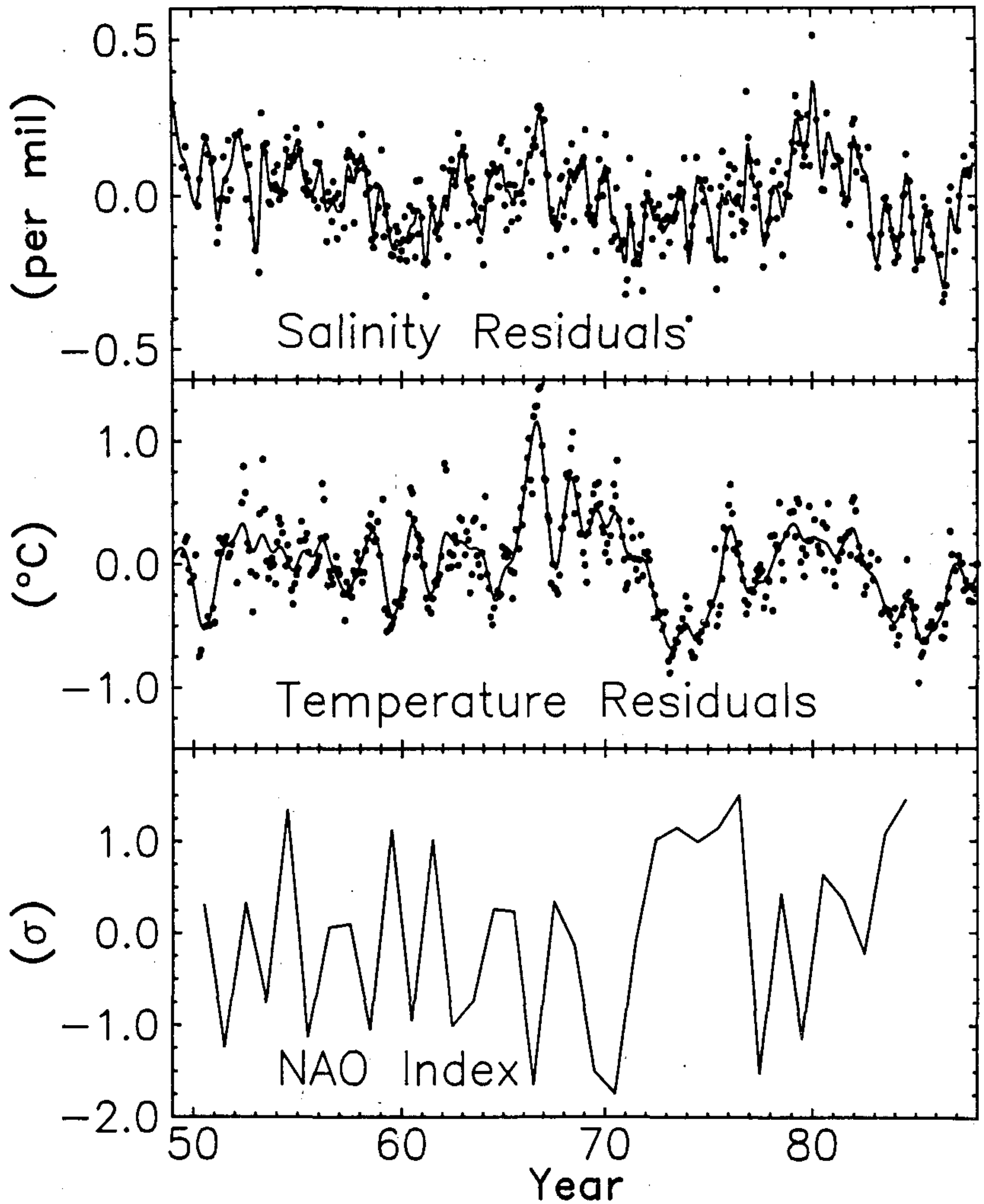
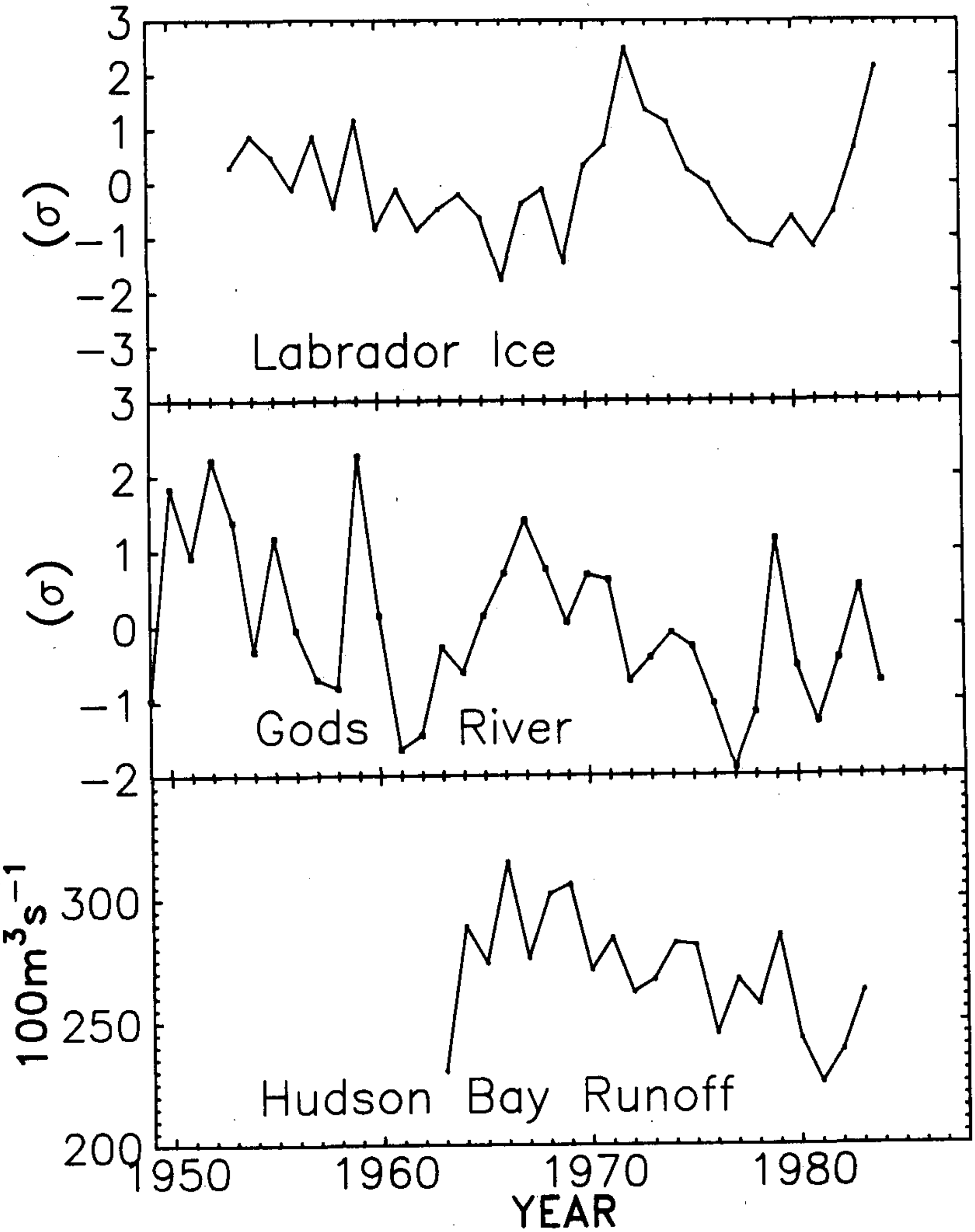
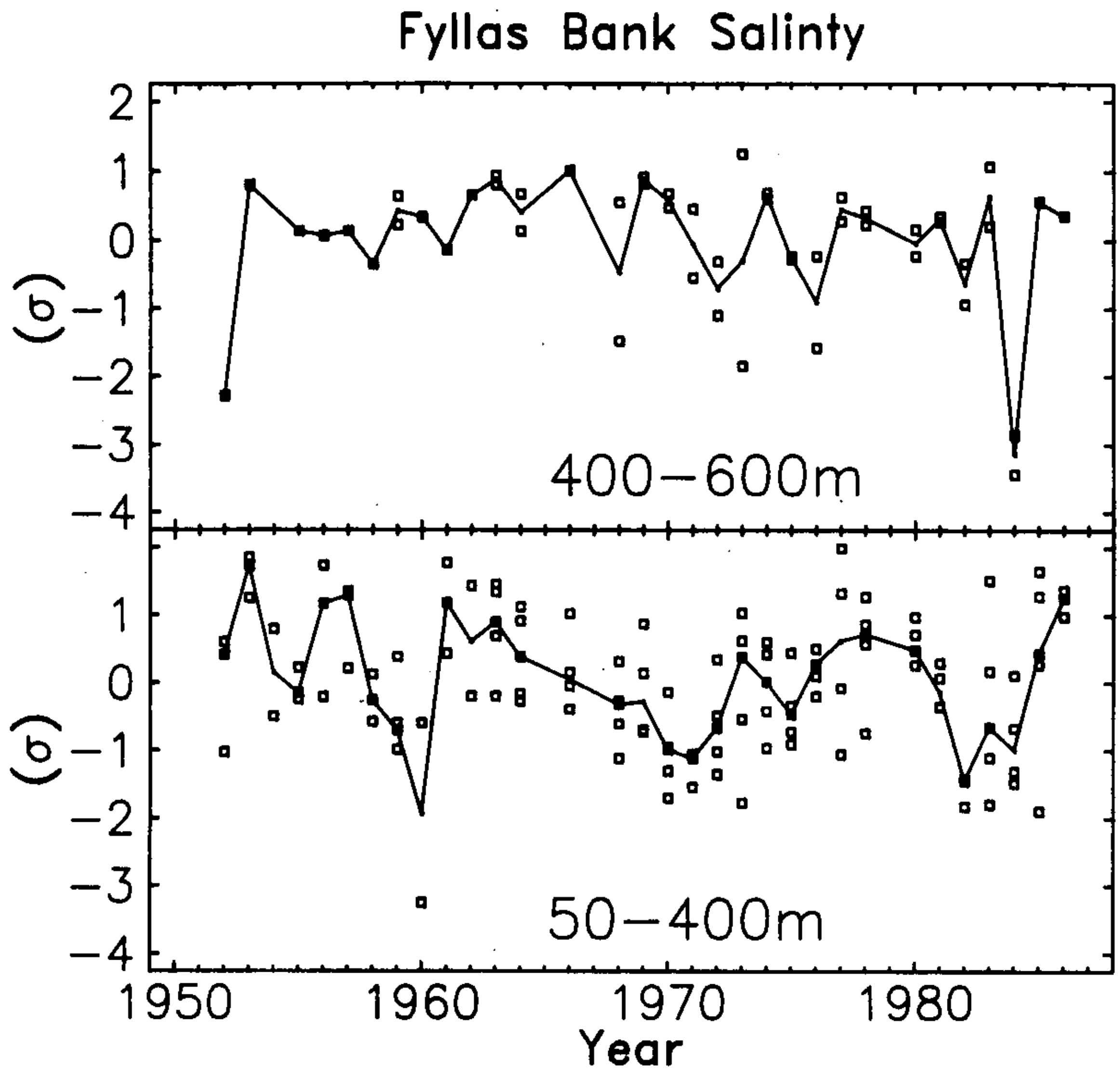


Fig. 5B



3
2
1
0
-1
-2
-3
(σ)
Labrador Ice
3
2
1
0
-1
-2
(σ)
Gods River
300
250
200
100m³s⁻¹
Hudson Bay Runoff
1950
1960
1970
1980
YEAR

Fig. 5c


Fyllas Bank Salinty
2
1
0
(σ) −1
−2
−3
−4
400−600m
1
0
(σ) −1
−2
−3
−4
50−400m
1950
1960
1970
1980
Year

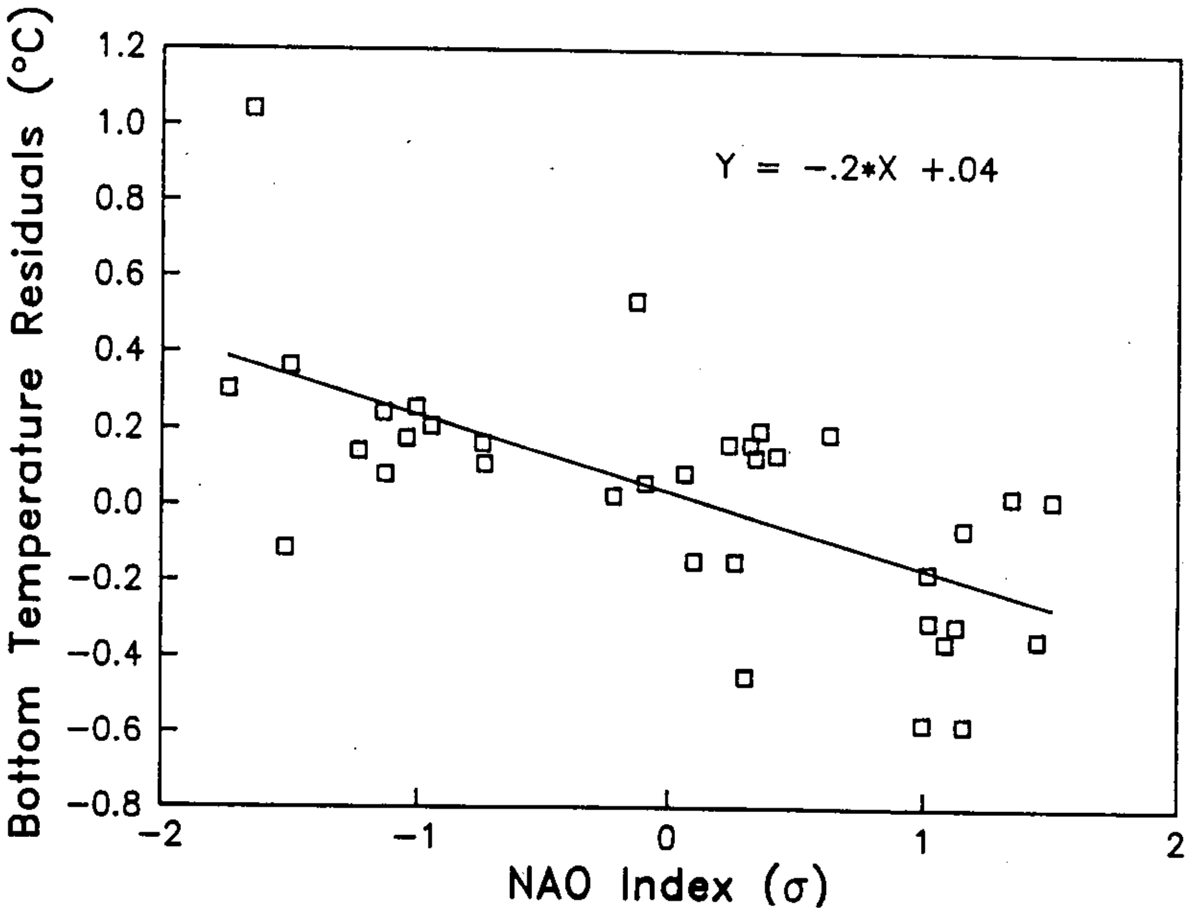


Fig. 6. The relationship between the normalised NAO index and the annual bottom temperature (175m) residuals at station 27.

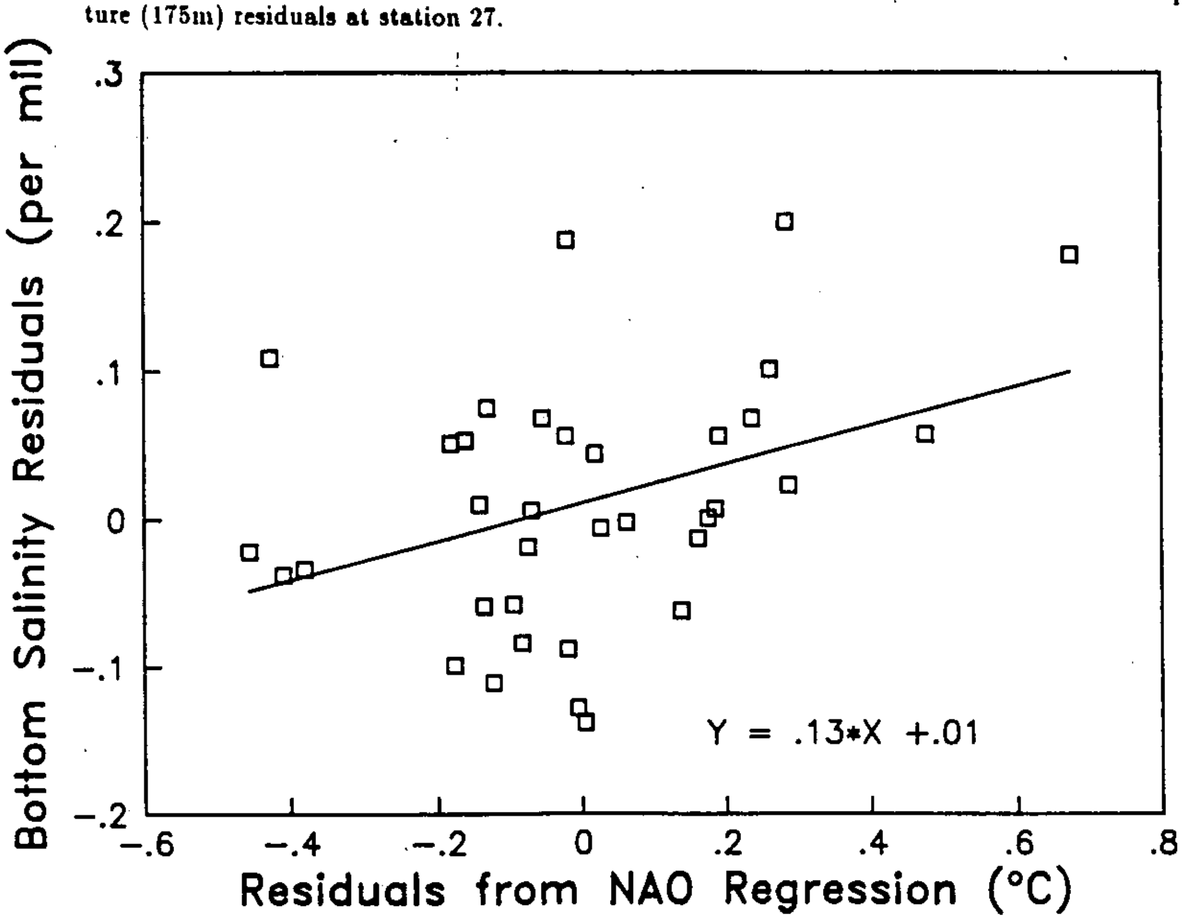


Fig. 7. The relationship between bottom salinity (175m) residuals at station 27 and the residuals from the regression of the bottom temperature and the NAO index.

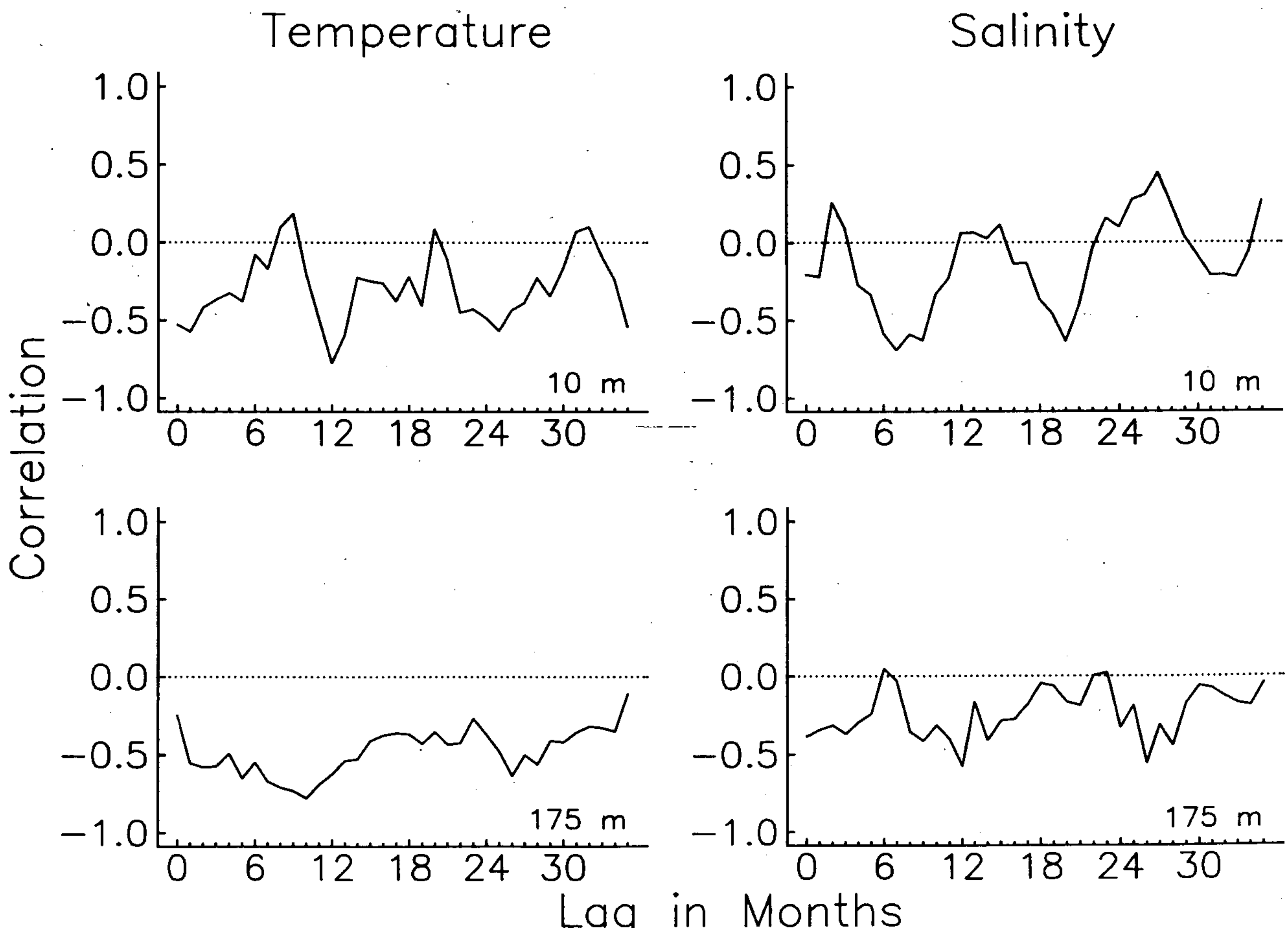


Fig. 8. The cross correlations of bottom temperature and salinity at station 27 residuals with the normalized area of ice south of 55°N. The lags are referenced to January.

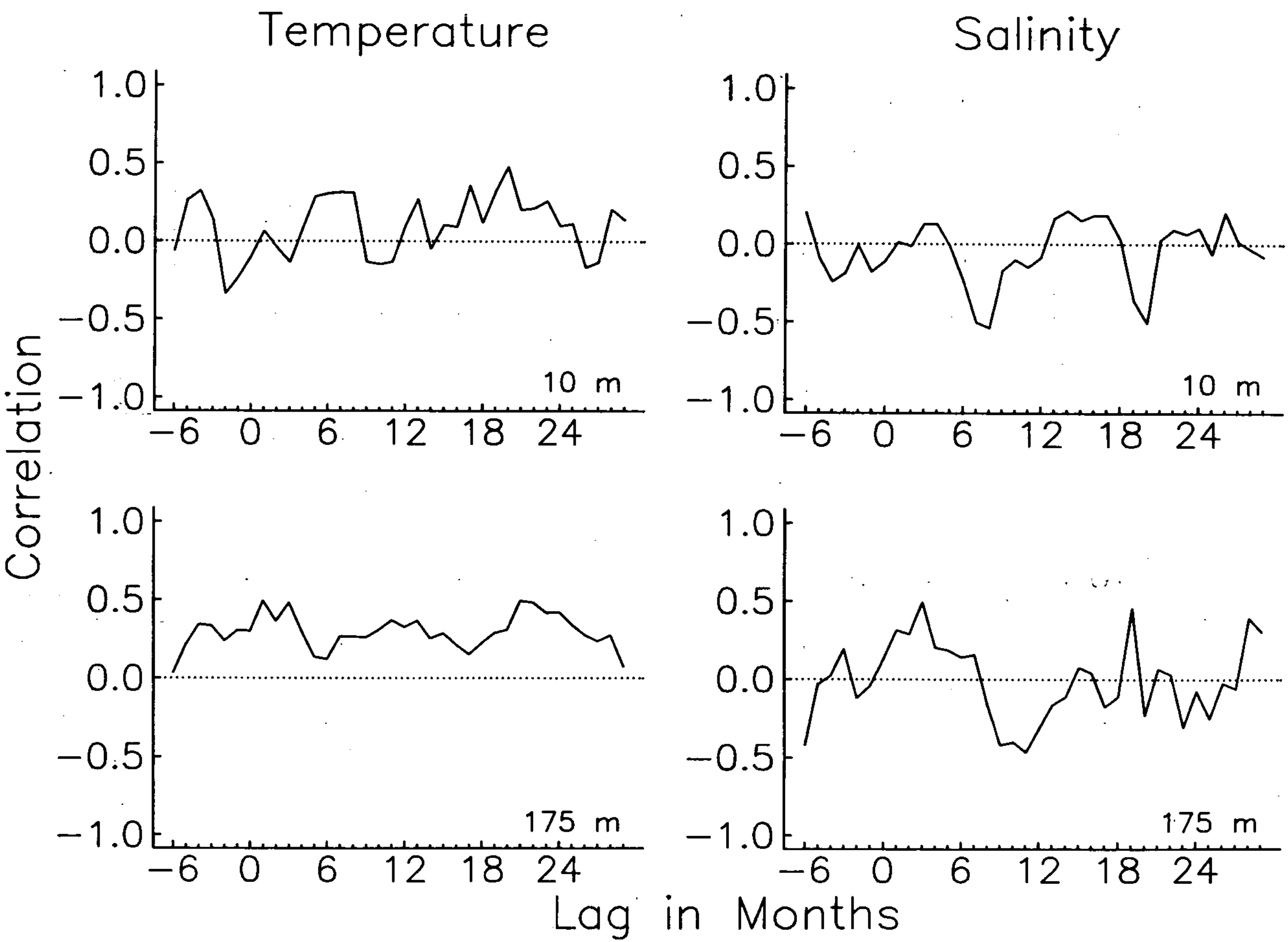


Fig. 9. The correlation of yearly runoff from Hudson Bay Region (1963-1983) with the lagged salinity and temperature residuals at station 27. The estimates of Hudson Bay runoff is maximum in June and July, so that the lag with respect to the annual mean runoff is in reference to June.

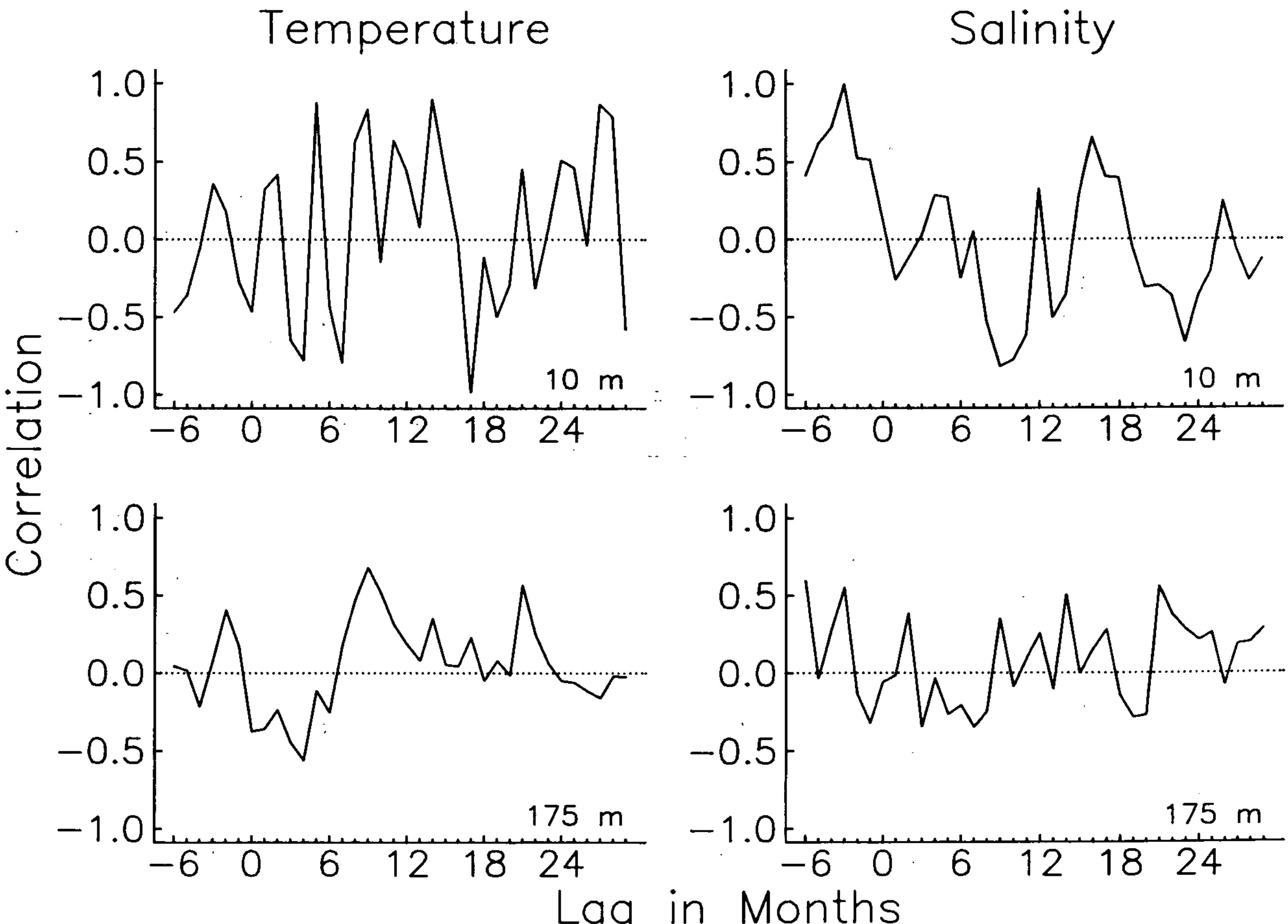


Fig. 10. The correlation of yearly runoff from runoff from the Gods River, years 1948-1962 and 1984-1985, with the lagged salinity and temperature residuals at station 27. The runoff is maximum in June and July, so that the lag with respect to the annual mean runoff is in reference

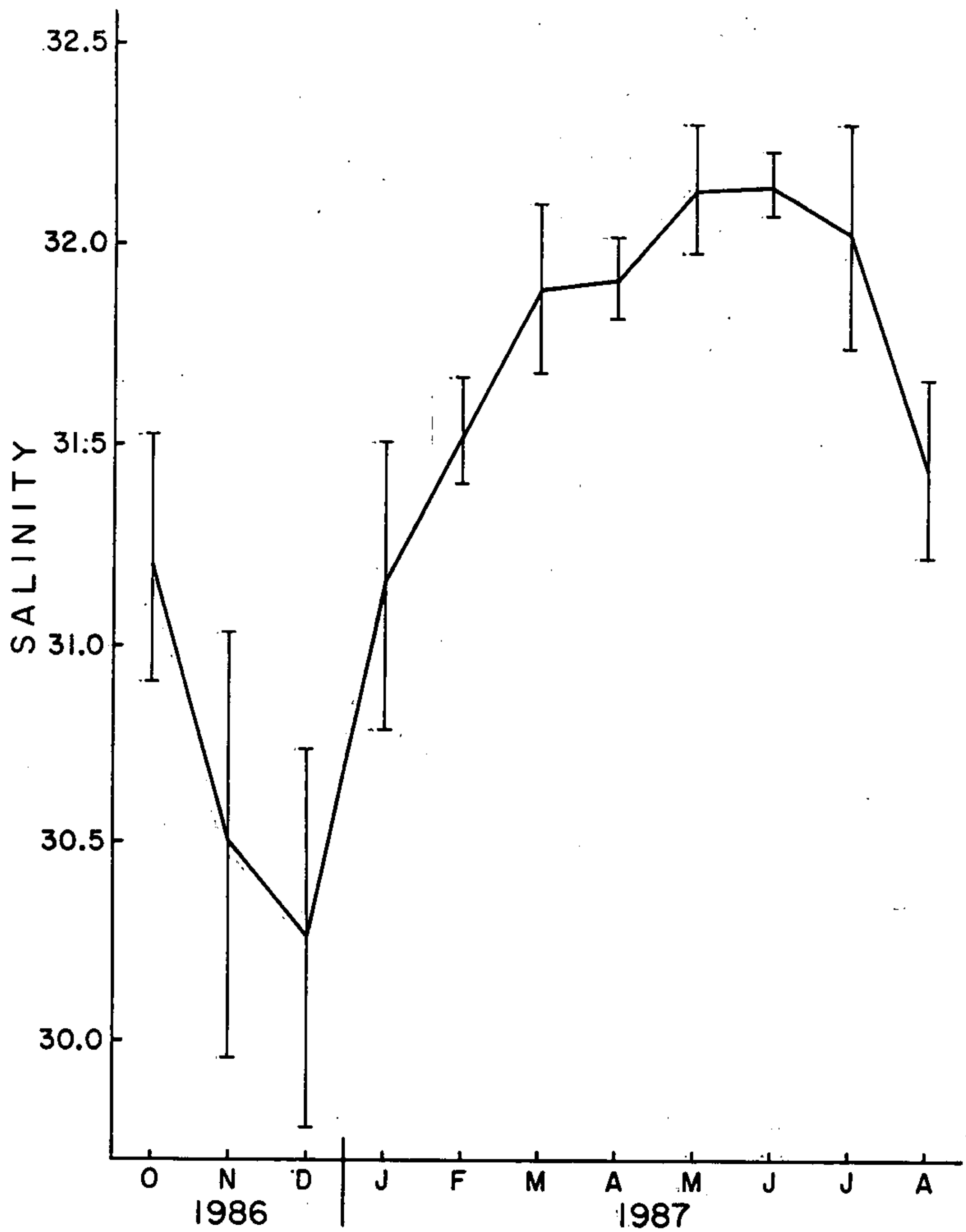


Fig. 11. Salinity in Hudson Strait measured at 40m depth.

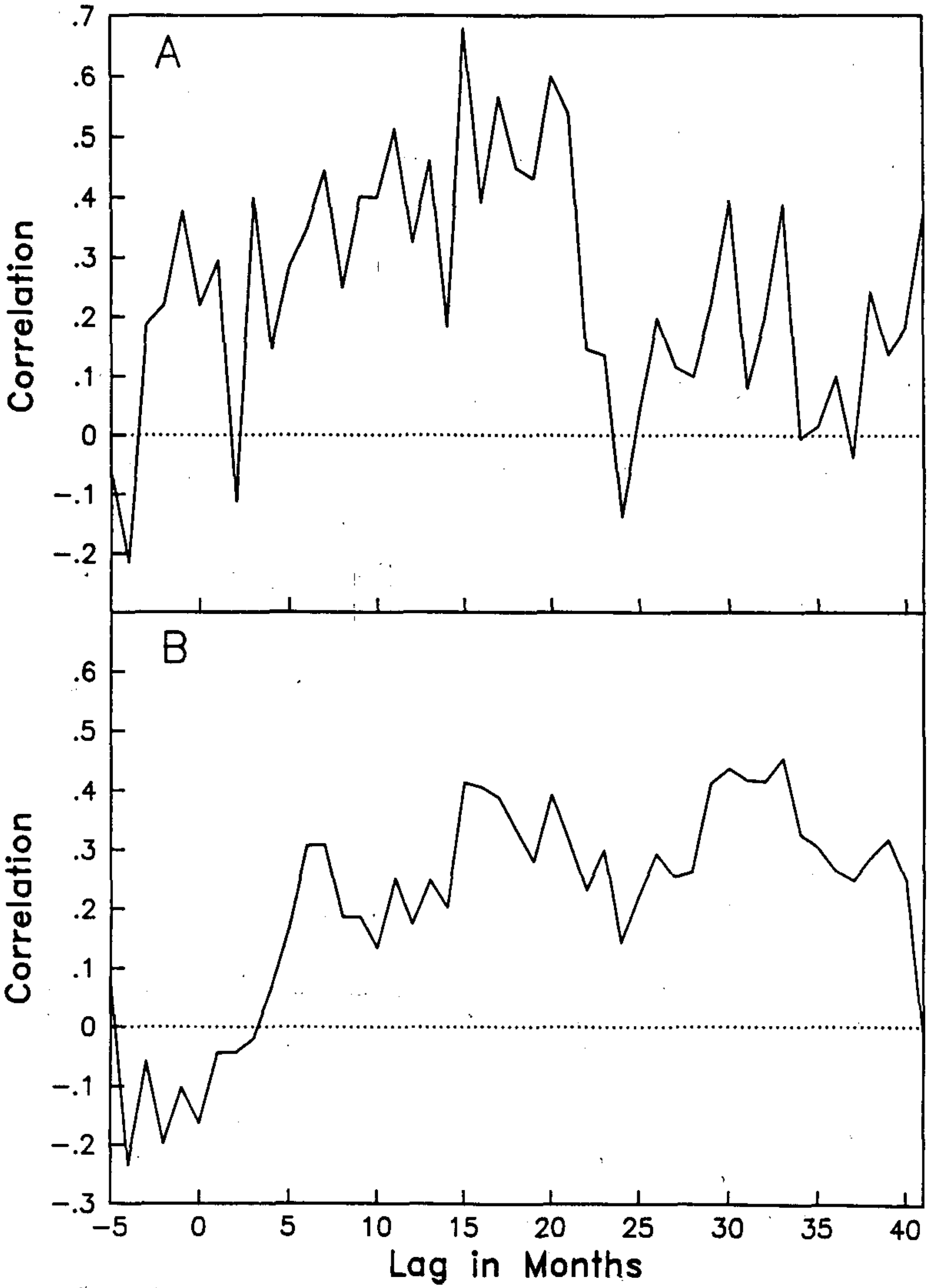


Fig. 12. The correlation of July salinity at Fyllas Bank with the lagged salinity (A) and temperature (B) residuals at station 27.

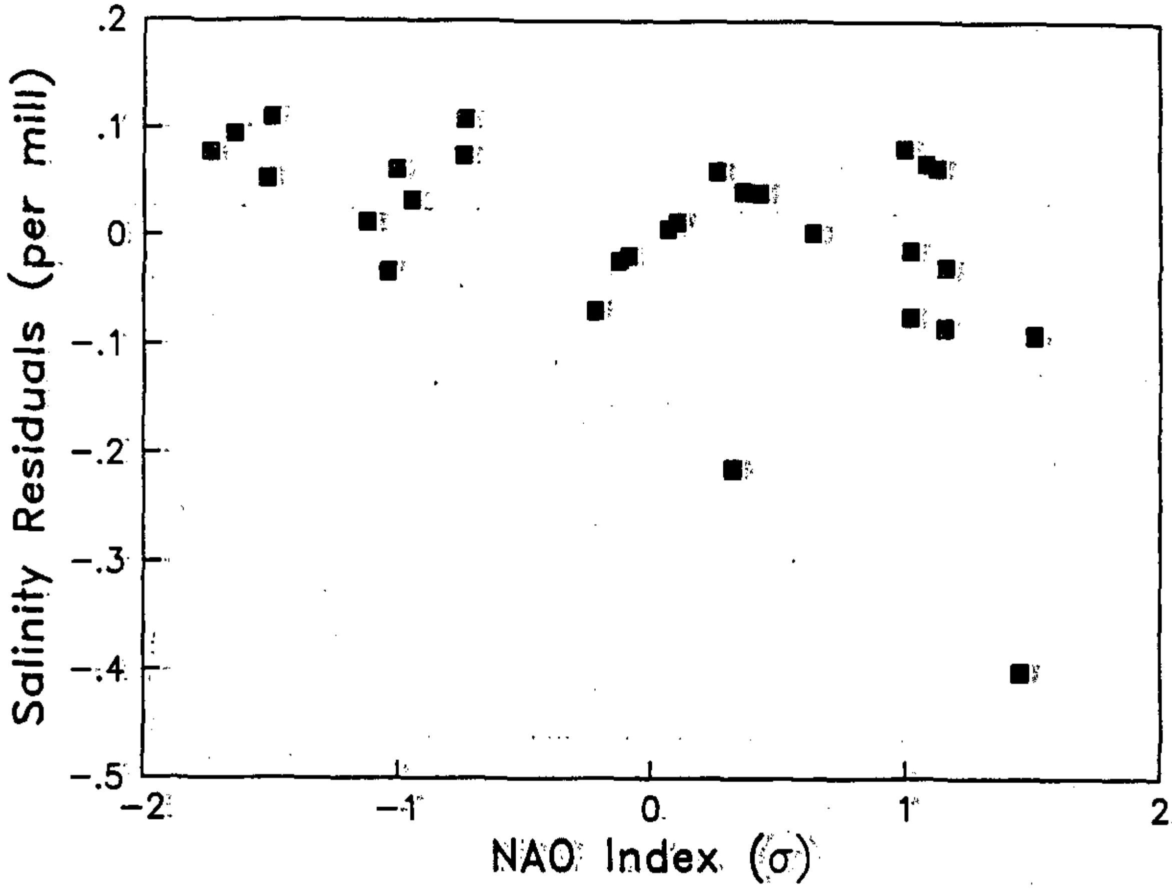


Fig. 13. The relationship between the NAO index and deep (400-600m) salinity anomolies on Fyllas Bank.