DFO Atlantic Fisheries
Research Document 94/10

MPO Pêches de l'Atlantique
Document de recherche 94/ 10

Variability in the Position of the Shelf/Slope Front Near the Mouth of the Laurentian Channel

by

K.F. Drinkwater and G.L. Bugden

Department of Fisheries and Oceans, Scotia-Fundy Region
Physical and Chemical Sciences Branch, Bedford Institute of Oceanography
Box, 1006, Dartmouth, N.S. B2Y 4A2

ABSTRACT

Variability in the position of the Shelf/Slope front at the mouth of the Laurentian Channel is investigated from 15 years of digitized satellite thermal imagery. The front is shown to exhibit an annual cycle being furthest offshore in late winter and furthest onshore in late summer and autumn. Its amplitude is 40 km. The largest variance is due to interannual fluctuations with an amplitude of approximately 100 km. The front was furthest offshore in 1980, moved onshore to a maximum northward position in 1984, returned to a position close to its long-term mean for several years and most recently has begun to move northward again. The relationship between the position of the front and the deep water temperatures in Cabot Strait found in an earlier study could not be confirmed when tested with 7 years of new data.

RÉSUMÉ

La variabilité de la position du front de la plate-forme/pente continentale située à l'embouchure du Chenal Laurentien est étudiée à l'aide des images thermiques numérisées recueillies par satellite pendant 15 ans. On observe que le déplacement du front obéit à un cycle annuel, le front se trouvant le plus loin au large des côtes à la fin de l'hiver et le plus proche des côtes à la fin de l'été et à l'automne. L'amplitude de cette variation est de 40 km. Le plus grand écart observé est attribuable à des fluctuations interannuelles d'une amplitude d'environ 100 km. Le front a été observé le plus loin au large des côtes en 1980, puis il s'est rapproché des côtes jusqu'à sa position la plus septentrionale en 1984. Il est ensuite revenu pendant plusieurs années à une position proche de sa position moyenne à long terme et il vient de commencer à se déplacer à nouveau vers le nord. La relation entre la position du front et les températures en eaux profondes dans le détroit de Cabot, qui a été trouvée dans une étude antérieure, n'a pu être confirmée à l'aide des nouvelles données recueillies sur sept ans.

INTRODUCTION

The waters on the continental shelves from Cape Hatteras to the Grand Bank of Newfoundland are separated from the warmer offshore "slope" waters by a relatively narrow boundary known as the Shelf/Slope front. The surface expression of this thermal gradient is readily detected in satellite IR imagery. Recently, Drinkwater et al. (1994) compiled monthly statistics of the position of the front from Cape Hatteras to the Tail of the Grand Banks based upon digitizations of the 1 to 3 times weekly satellite images published initially by the U.S. Naval Oceanographic Office and later by NOAA between the years 1973 to 1992. The mean position of the surface Shelf/Slope front lies near the shelf break from Cape Hatteras to the Georges Bank (Fig. 1). In this region, the subsurface front (in temperature and salinity) slopes downward intersecting the bottom near the shelf break. To the east the shelf waters extent further offshore, being approximately 70 km from the mouth of the Laurentian Channel (Fig. 1). There, the depth of the shelf waters in the vicinity of the surface front typically is of order 50 m.

In a study of the low-frequency variability of the deep (200-300 m) waters of the Laurentian Channel from Cabot Strait to the St. Lawrence Estuary, Bugden (1991) showed that the temperatures are determined by the proportions of the Labrador and Western North Atlantic waters. He also found that the temperature could be monitored by the positon of the Shelf/Slope boundary (Fig. 2). It was argued that a shoreward movement of the Shelf/Slope front likely results in warmer waters at depth near the mouth of the Laurentian Channel. These warmer conditions were then transferred slowly up the Channel through a combination of advective and turbulent diffusive processes. The time lag from appearance of temperature events at the mouth of the Channel to their appearance in the St. Lawrence Estuary was found to be of the order of several years. The frontal data were obtained as part of an earlier analysis based upon the area between the 200 m isobath and the Shelf/Slope front as described in Myers and Drinkwater (1989).

In this paper we discuss the variability of the Shelf/Slope front at the mouth of the Laurentian Channel and re-examine the relationship with Cabot Strait deep water temperatures found by Bugden (1991) using the recent and more complete digitization of the frontal positions (Drinkwater et al., 1994). An additional 7 years of data are used to test if the relationship has held up.

DATA AND METHODS

The monthly mean latitudinal positions of the Shelf/Slope front along each whole degree of longitude between 50°W and 75°W were calculated from digitized satellite images by Drinkwater et al. (1994). Details of the charts used and the digitization methods are found in their report. For this study we use the data between 54°W and 59°W, inclusive, which began in the late 1970s. Long-term monthly averages were calculated based on all available data for the years 1978-1992. The annual means were determined from the monthly averages. The monthly averages were subtracted from the available data to determine anomalies of the frontal positions. The anomalies were then low-pass filtered using a Cartwright filter with 25 weights and a 50% power reduction at a period of 15 months which removed most of the energy at periods of 1 y or less. The low-pass filtered anomalies were subtracted from the monthly anomalies to obtain a time series of high-frequency variability. In addition, an empirical orthogonal function (EOF) analysis was carried out on the anomalies.

The average temperatures in the deep (200-300 m) waters of Cabot Strait (Bugden, 1991) were updated to 1993.

VARIABILITY OF THE FRONT

The time series of the monthly means of the Shelf/Slope front averaged over the longitudes 54-59°W are plotted in Fig. 2. While high-frequency and annual variability are evident, there are also large interannual fluctuations. The long-term monthly means show that the front is furthest offshore in winter and onshore in late summer and early autumn (Fig. 3). The amplitude of the seasonal cycle near the mouth of the Laurentian Channel is of order 40 km. This pattern is consistent with the annual cycle of the front averaged over the entire longitudinal range, i.e. Cape Hatteras to the Tail of the Bank but is approximately twice the annual amplitude of the average. The seasonal pattern is similar to that for of the Gulf Stream (Drinkwater and Myers, 1993).

The monthly averages in Fig. 3 were subtracted from the time series to obtain an anomaly time series of frontal positions. These were low-passed filtered and the result is plotted in Fig. 4. The front moved rapidly northward (onshore) from a minimum around 1980 to a peak in 1984, then decreased to near its long-term mean position in 1986, remained there for several years and has recently moved northward again. This filtered record is similar to the first mode in an EOF analysis that we performed on the monthly time series at the six longitudes (54°W-59°W).

We also subtracted the filtered record from the anomaly time series to obtain a high frequency time series. Calculations of the variance for the high, low and annual records reveal that for the average positions over 54°W-59°W (Fig. 3), 63% of the total variance is attributed to the low-frequency trends (Fig. 5), 22% to the high-frequency and 15% to the annual cycle. At each individual degree of longitude the amount of variance due to the high-frequency record is typically 35-40% of the total but this has been significantly reduce by averaging over the 6 degrees of longitude.

RELATIONSHIP WITH DEEP WATER TEMPERATURES IN CABOT STRAIT

The temperatures in the deep waters of Cabot Strait (200-300 m) decreased through the 1950s and early 1960s to a minimum in the mid to late 1960s, with a negative anomaly of over -1°C (Fig. 6). Rapid warming occurred in the late 1960s, remained near normal for several years before increasing again in the late 1970s. Temperatures remained high until the late 1980s when temperatures decreased reaching a minima in 1991. During the last 2 years temperatures in the deep waters of Cabot Strait have warmed significantly and are now near 1°C above normal. Similar trends have been observed in Emerald Basin and other areas of the Gulf of Maine and Scotian and have been attributed to changes in the Slope Water characteristics (Petrie and Drinkwater, 1993).

As mentioned earlier and shown in Fig. 2, Bugden (1991) found a relationship between the position of Shelf/Slope front and the deep temperatures in Cabot Strait. When the front was further inshore temperatures were warmer. The temperatures were advanced 2.5 years to account for the time required to traverse the distance from the mouth of Laurentian Channel to Cabot Strait. This lag was based upon the results of an advective-diffusive model.

We have updated the time series and the comparisons are shown in Fig. 7. We again emphasize that the temperatures have been lagged by 2.5 years. The data have been transformed to obtain a zero mean and unit variance for both time series. Whereas the rise in temperature in the 1980s corresponded to the onshore movement of the front as was noted by Bugden (1991), the more recent rapid temperature decline and the subsequent equally rapid rise are not related to any corresponding changes in the position of the Shelf/Slope front near the Laurentian Channel.

Although we have been unable to confirm the relationship between deep water temperatures in Cabot Strait and the surface position of the Shelf/Slope front, the conclusion by Bugden (1991) that the temperatures are dependent upon the proportions of Labrador and Western North Atlantic waters remains valid. Petrie and Drinkwater (1993) have highlighted the importance of changes in the transport of the deep Labrador Current waters on the water properties of the Scotian Shelf and in the Laurentian Channel. Future studies will examine the possible role of the position of the Gulf Stream in controlling the amount of Labrador Current water that makes it beyond the Tail of the Bank and westward towards the Scotian Shelf.

Acknowledgements

We greatly appreciate the technical assistance provided by R. Pettipas and T. Wright in the preparation of this working paper.

REFERENCES

Bugden, G.L. 1991. Changes in the temperature-salinity characteristics of the deeper waters of the Gulf of St. Lawrence over the past several decades, p. 139-147. *In* J.-C. Therriault [ed.] The Gulf of St. Lawrence: small ocean or big estuary? Can. Spec. Publ. Fish. Aquat. Sci. 113.

Drinkwater, K.F. and R.A. Myers. 1993. Investigations of the mean, seasonal and interannual variability in the position of the north wall of the Gulf Stream 45°W to 75°W. NAFO SCR Doc. 93/49, 6 p.

Drinkwater, K.F., R.A. Myers, R.G. Pettipas and T.L. Wright. 1994. Climatic data for the Northwest Atlantic: The position of the Shelf/Slope front and the northern boundary of the Gulf Stream between 50°W and 75°W, 1973-1992. Can. Data Rep. Hydrogr. Ocean Sci. 125: 103 p.

Myers, R.A. and K. Drinkwater. 1989. The influence of Gulf Stream warm core rings on recruitment of fish in the northwest Atlantic. J. Mar. Sci. 47: 635-656.

Petrie, B. and K. Drinkwater. 1993. Temperature and salinity variability on the Scotian Shelf and in the Gulf of Maine 1945-1990. J. Geophys. Res. 98: 20079-20089.

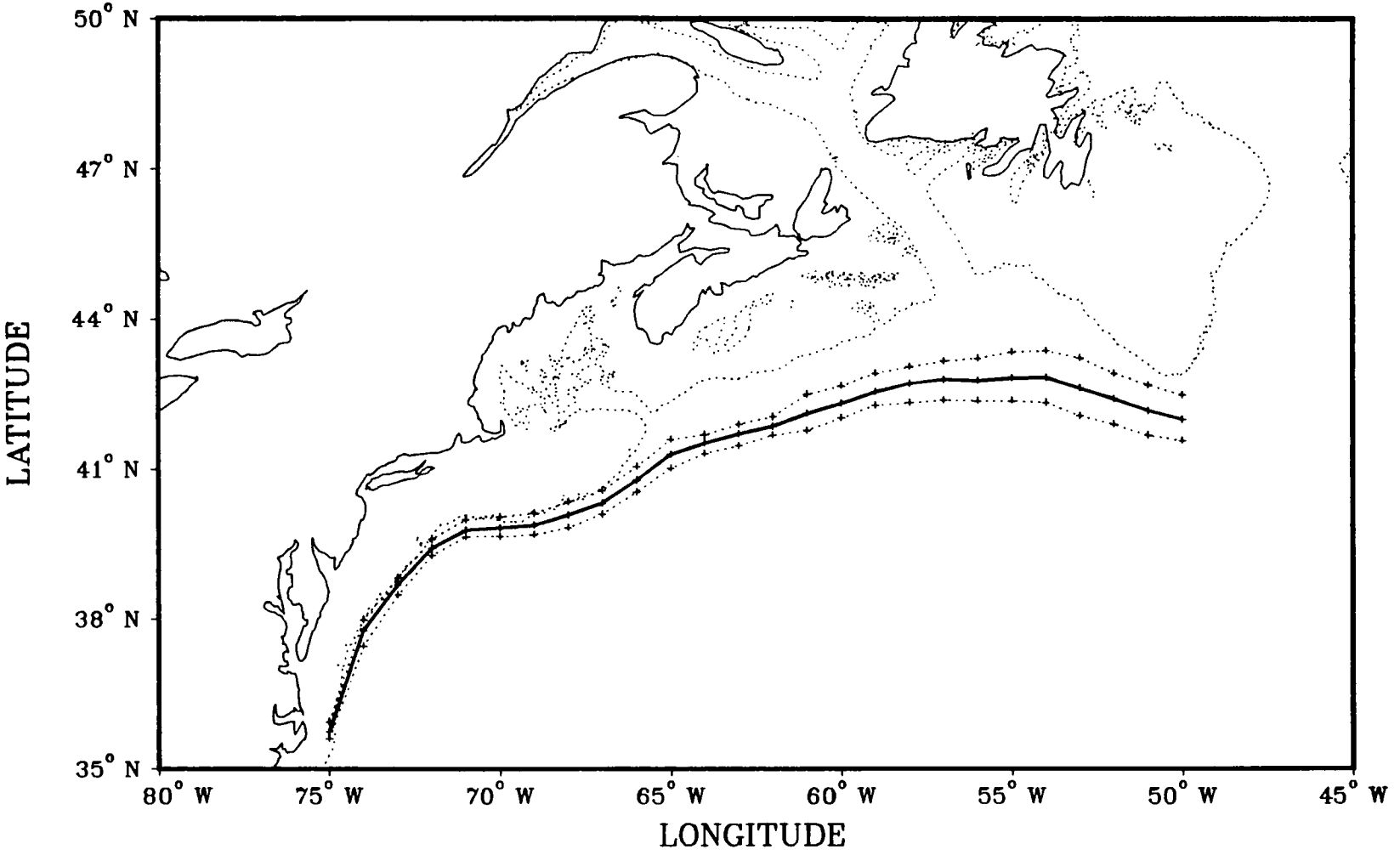

Fig. 1. The long-term (1973-92) mean location of the Shelf/Slope front together with the maximum and minimum monthly averages.

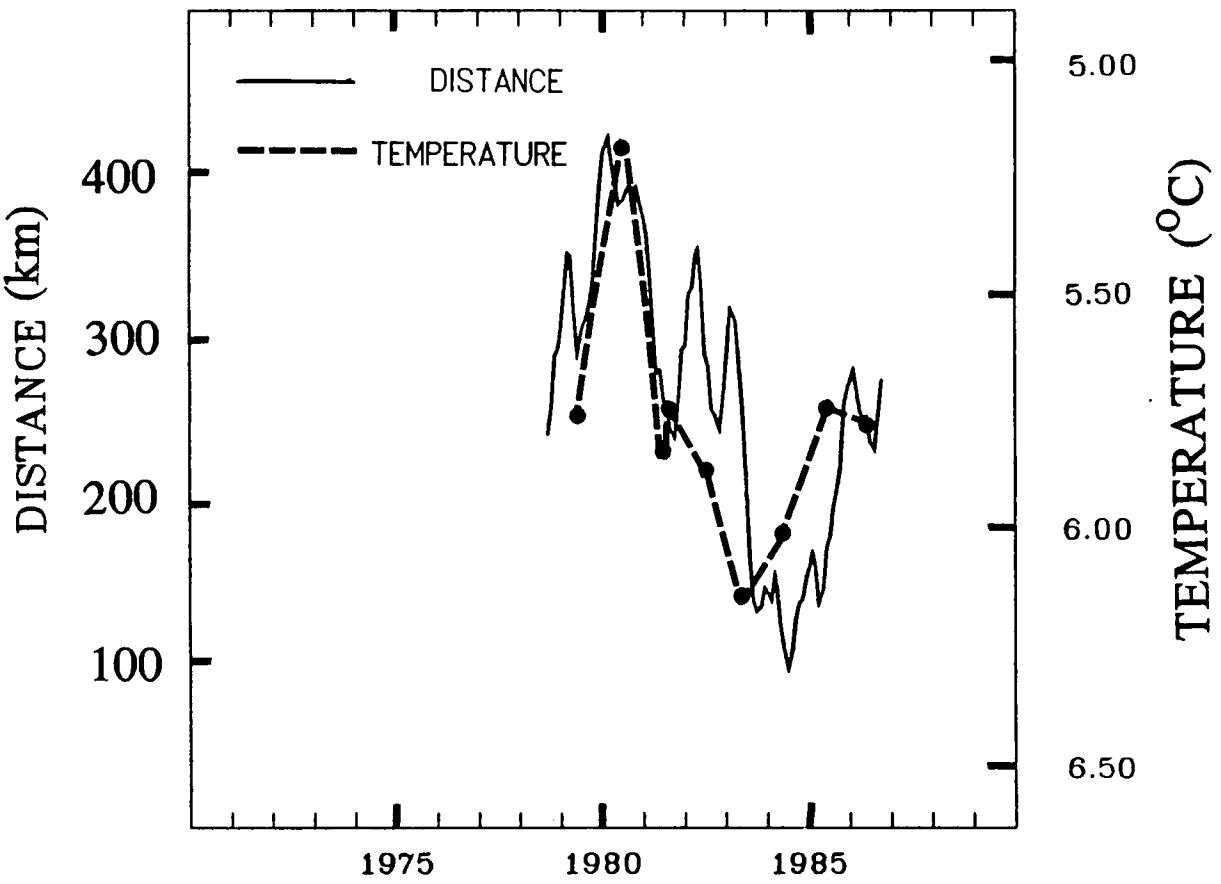

Fig. 2. Variations in the position of the Shelf/Slope front and the average deep (200-300 m) temperature at Cabot Strait plotted on an inverted scale from Bugden (1991). Note the temperature has been lagged by 2.5 y to account for the expected travel time from the mouth of the Laurentian Channel to Cabot Strait.

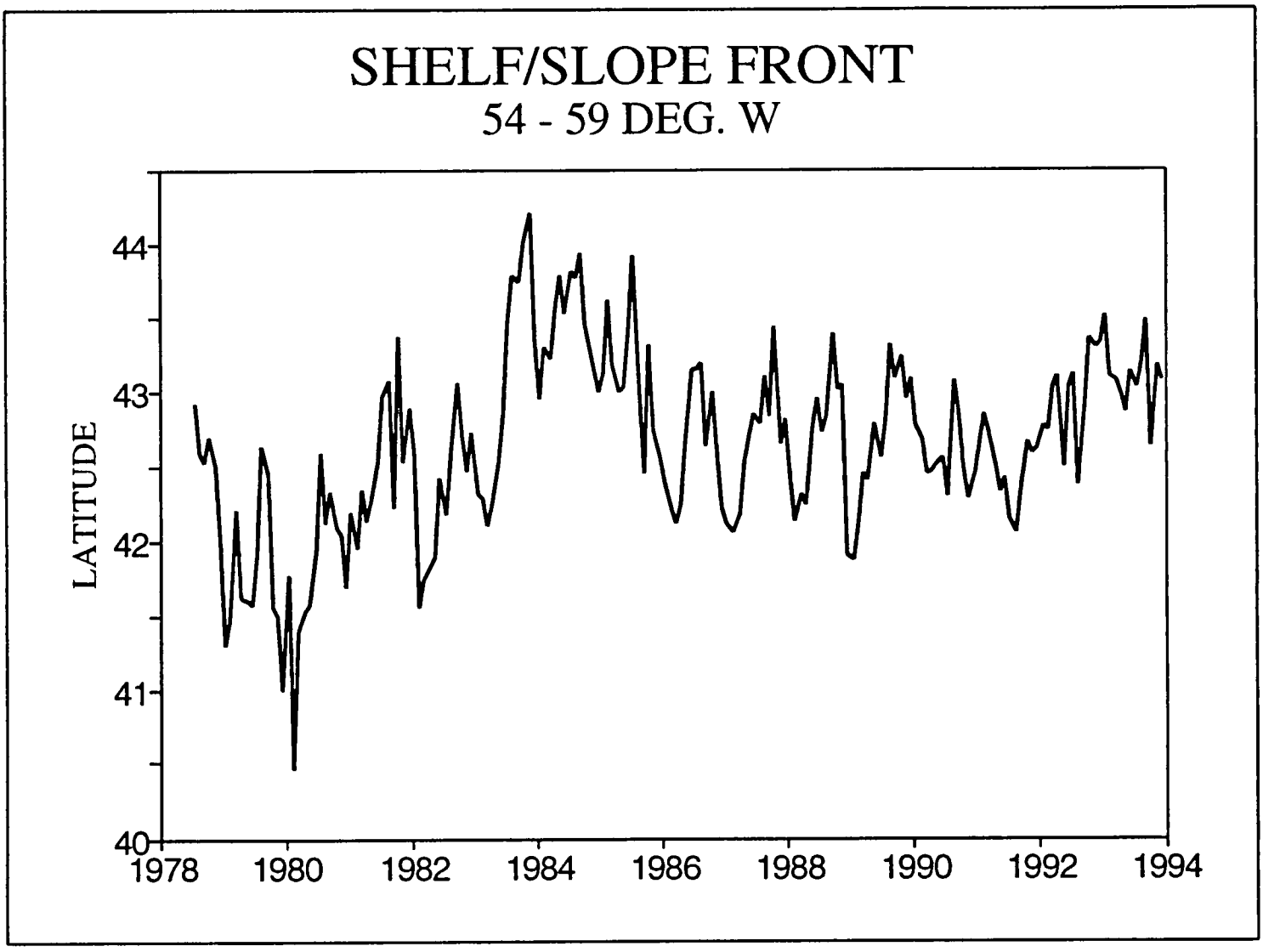

Fig. 3. The time series of monthly means for the positions of the Shelf/Slope front averaged over 54°-59°W.

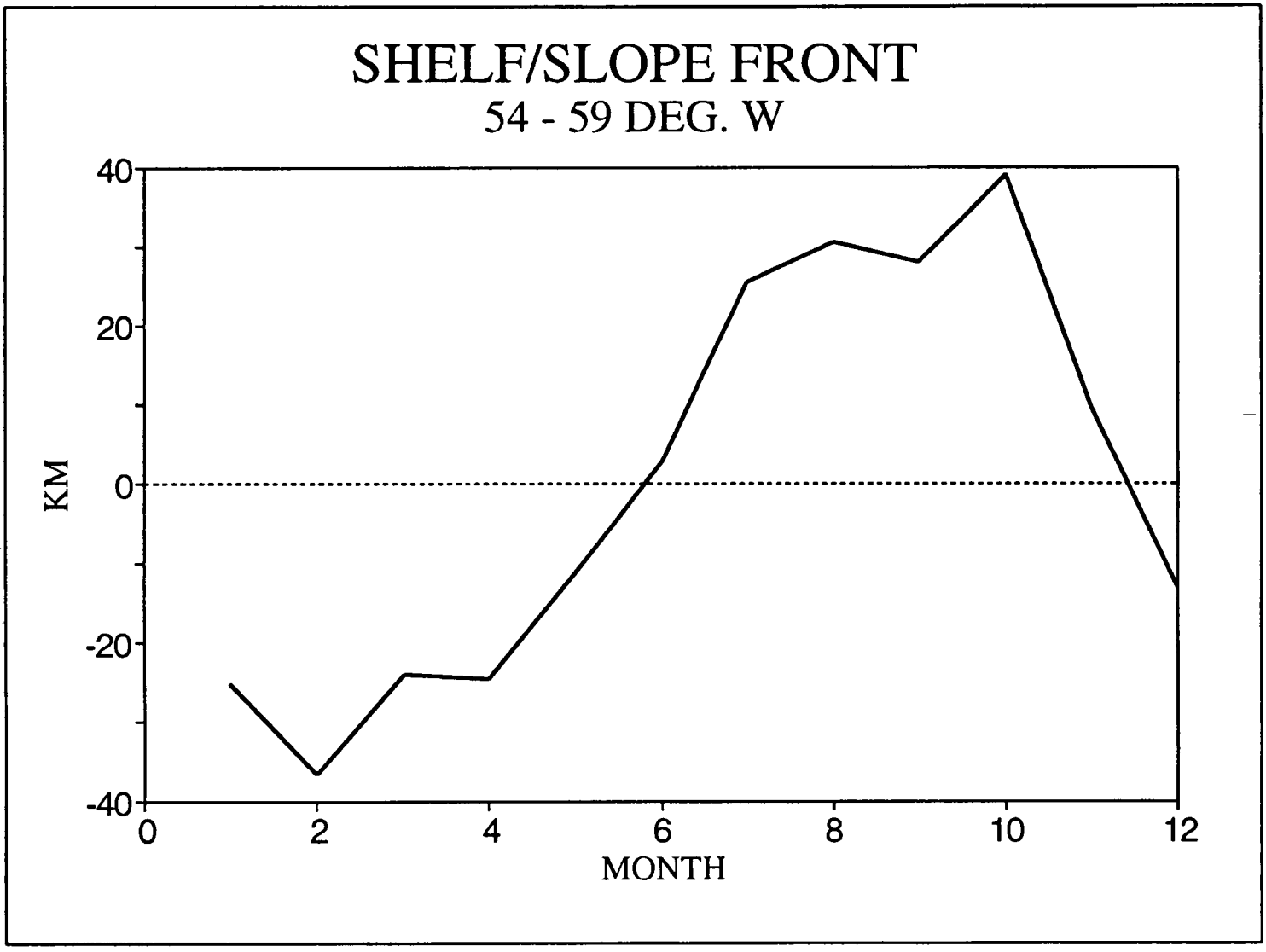

Fig. 4. The long-term monthly mean anomalies of the position of the Shelf/Slope front off the mouth of the Laurentian Channel.

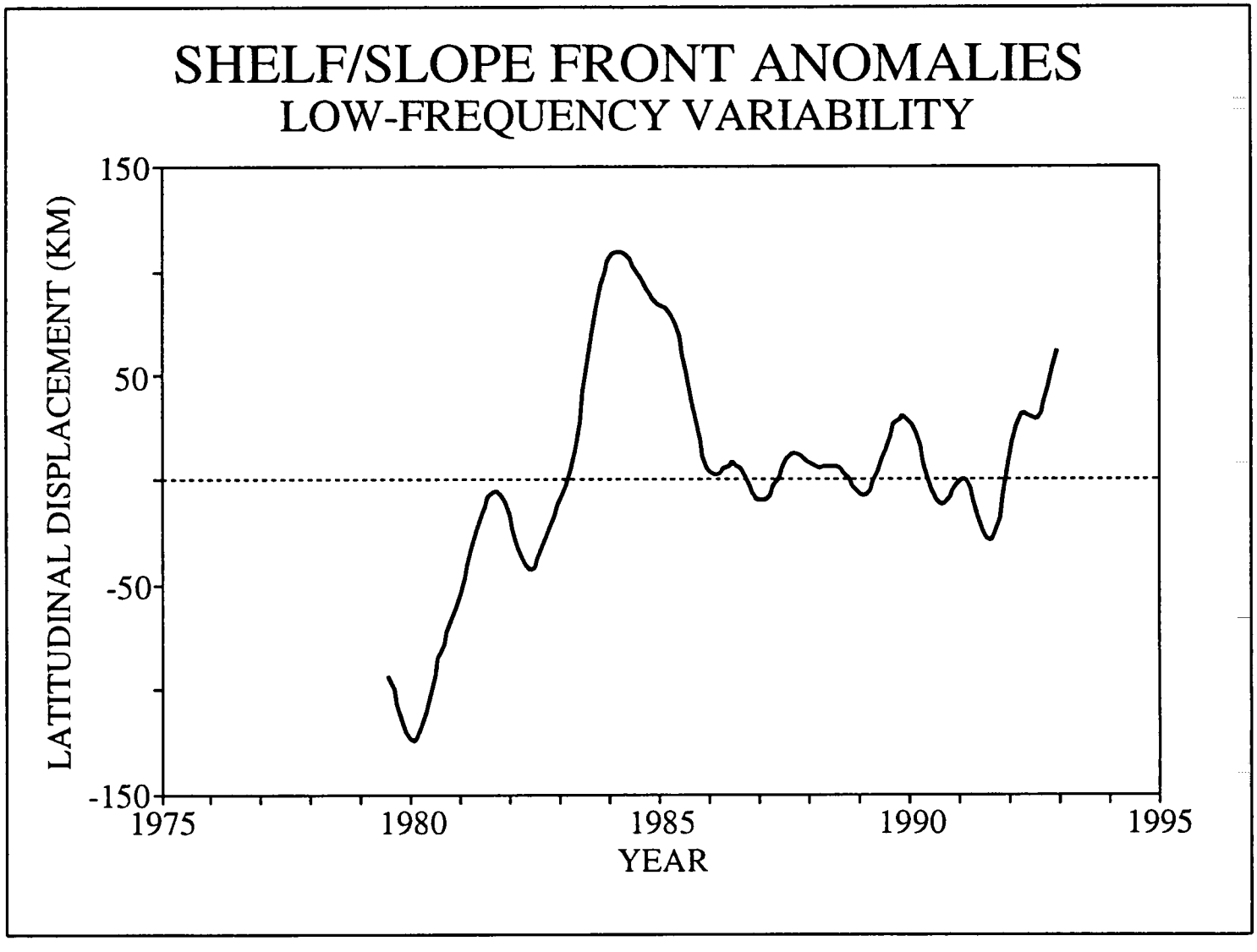

Fig. 5. The low-pass filtered time series of the Shelf/Slope front position off the mouth of the Laurentian Channel.

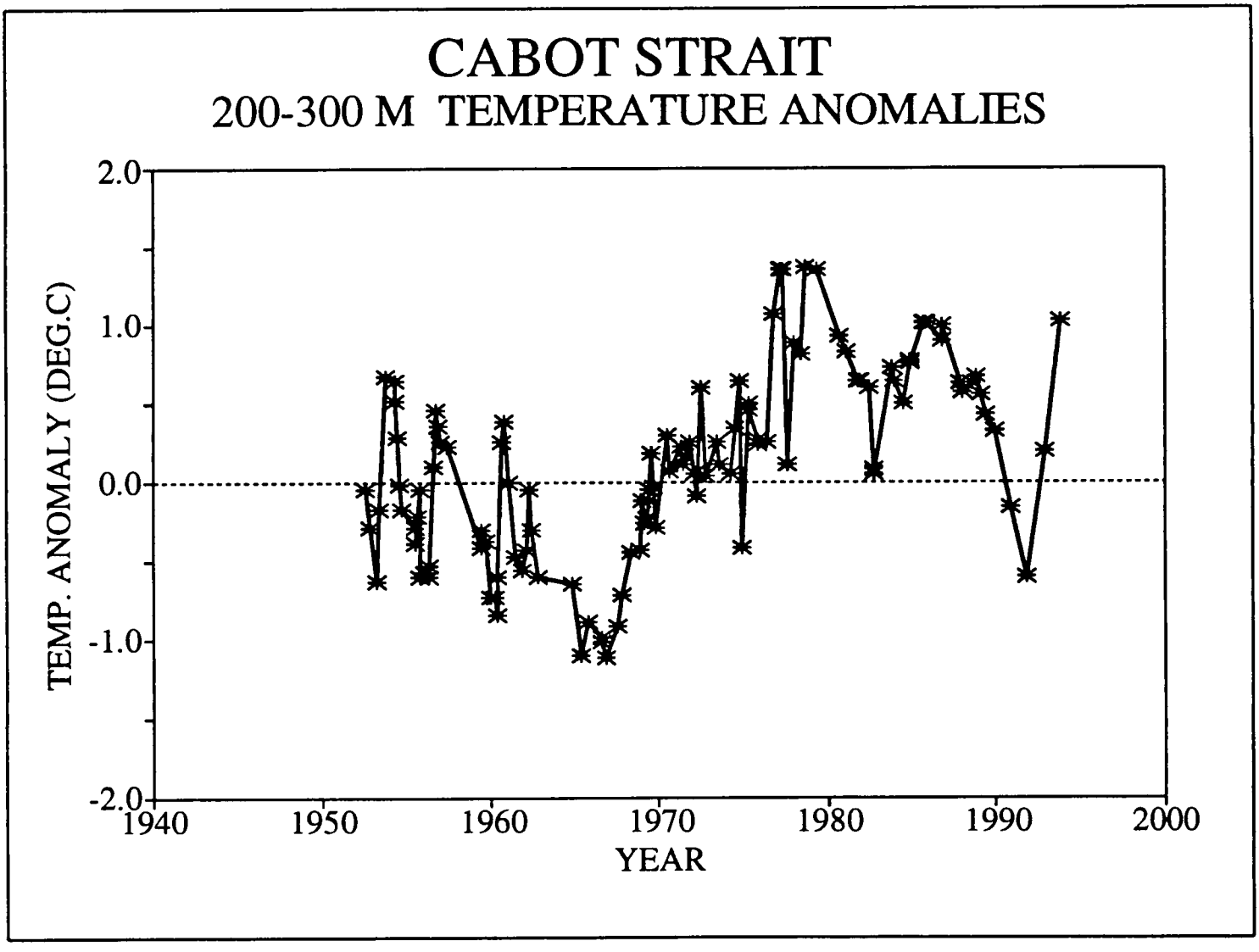

Fig. 6. Average temperatures between 200-300 m in Cabot Strait expressed as anomalies from the long-term mean.

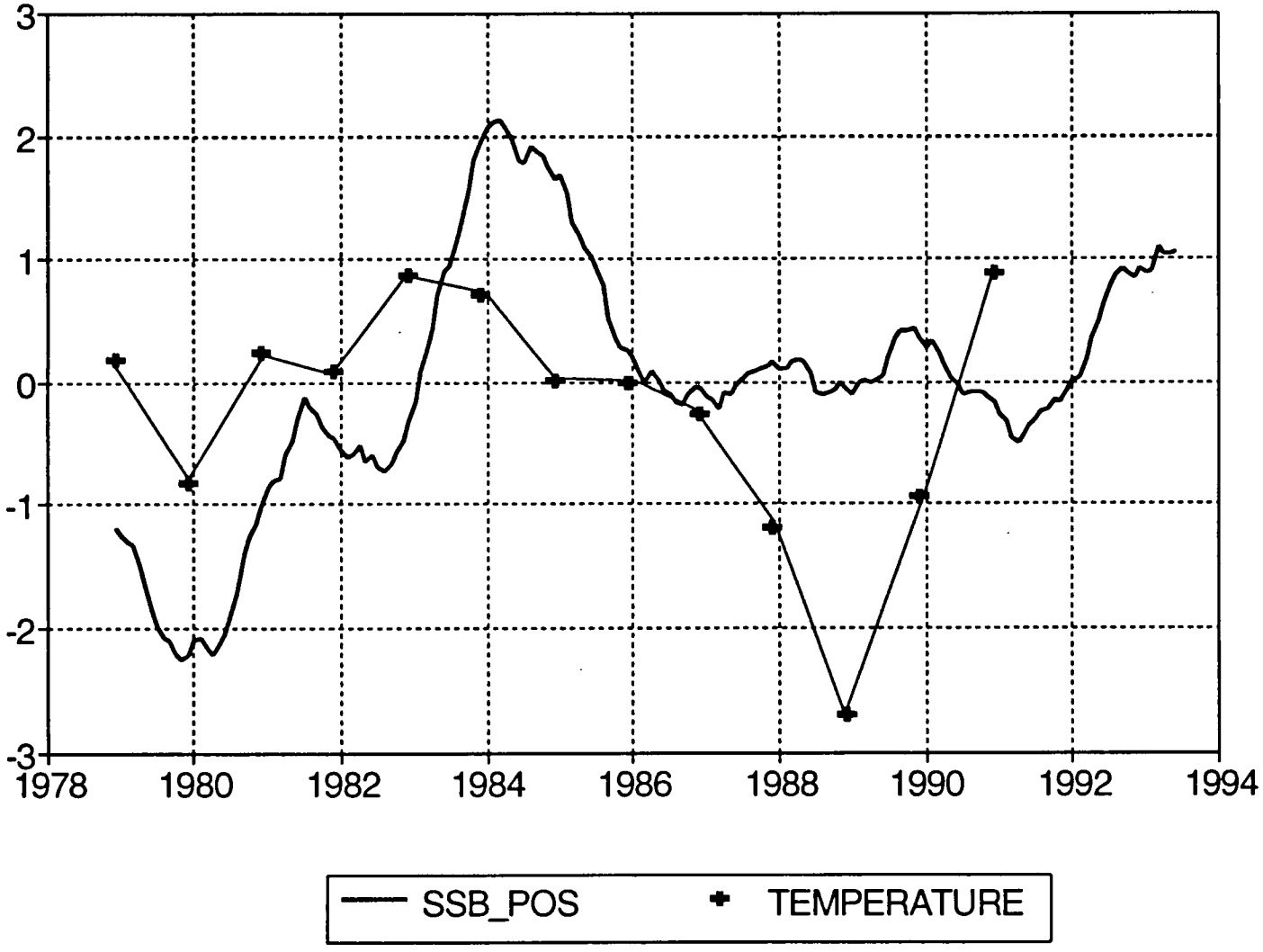

Fig. 7. The time series of the Shelf/Slope front (mode 1 of an EOF analysis) and deep temperatures in Cabot Strait transformed to have zero mean and unit variance.