Northwest Atlantic Fisheries Organization

Serial No. N2300 | NAFO SCR Doc. 93/107

SCIENTIFIC COUNCIL MEETING - SEPTEMBER 1993

Oceanographic Conditions on the Flemish Cap During the Summer 1993, with Comparisons to the Long-Term Average

by

E. Colbourne

Science Branch, Department of Fisheries and Oceans
P.O. Box 5667, St. John's, Newfoundland A1C 5X1

ABSTRACT

Oceanographic data around the Flemish Cap area were examined to compare conditions during the last few years to the long-term average. The results indicate that the large oceanographic anomalies experienced over the continental shelf in Atlantic Canada also existed around the Flemish Cap area during the same time periods. In particular, temperatures have been up to 2.0°C below normal in the upper 100 m of the water column since the late 1980s and about normal in water depths below 300 m. These anomalies are generally associated with strong winter northwesterly circulation, colder than normal air temperatures and heavy ice years in the Northwest Atlantic. In addition, the presence of a general anticyclonic circulation around the Flemish Cap was confirmed on a July 1993 cruise, using an acoustic doppler current profiler.

1. INTRODUCTION

This report describes oceanographic conditions on the Flemish Cap during the summer of 1993 with a comparison to the average conditions based on all available historical data. The report presents a subset of the data collected on an oceanographic cruise in July 1993 to NAFO divisions 2HJ and 3KL funded by the Northern Cod Science Program (NCSP) aboard the chartered vessel PETREL V. During this cruise oceanographic observations were made along the standard NAFO Flemish Cap transect as well as several stations along a line across the northeast portion of the bank. Measurements included vertical profiles of currents, temperature, salinity, chlorophyll and dissolved oxygen. In addition water and zooplankton samples were collected at each station for salinity, chlorophyll, oxygen and biological analysis.

The monthly mean temperature and salinity along the standard Flemish Cap Section have been published by Keeley, 1981 and includes observations from 1910 to 1980. Spatially averaged temperature and salinity from all available bottle data from 1910 to 1982 over the Flemish Cap area were published by Drinkwater and Trites, 1986. Numerous reviews and studies of the physical oceanography around the Flemish Cap were conducted during the Flemish Cap Project during the late 1970s and early 1980s (Hays, 1978, Bailey, 1982, Akenhead, 1981). More recent reviews and studies of the oceanography in the region have been confined to Atlantic Canada's continental shelf area (Petrie, et. al., 1992, Narayanan, et. al.,1991, Drinkwater, et. al.,1992,1992, Colbourne, 1993). This review represents the most recent examination of the oceanographic conditions over the Flemish Cap area and includes data up to and including the summer of 1993.

Since the early 1970s the oceanographic, meteorological, and ice conditions of the Northwest Atlantic have been dominated by three anomalous periods: early 1970s, mid 1980s and the early 1990s. During these periods strong positive winter North Atlantic Oscillation (NAO) index anomalies were mainly responsible for colder than normal air temperatures over the Northwest Atlantic resulting in increased ice cover and eventually colder and fresher than normal oceanographic conditions over most of the continental shelf in Atlantic Canada.

This report examines the vertical distribution of temperature, salinity, and oxygen along the outer portion of the standard Flemish Cap transect (Fig. 1) in comparison to the long-term average. In addition, spatially averaged time series of temperature and salinity anomalies in several areas around the Flemish Cap (Fig. 1) will be examined. Finally a snap-shot picture of the ocean circulation around the bank will be discussed.

2. VERTICAL TEMPERATURE AND SALINITY FIELD

The vertical distributions (depth *versus* horizontal distance from the shore) of the mean temperature and salinity over the Flemish Cap for the period June 20 to July 20, based on all available historical data from the early 1930s to 1992 are shown in Fig. 2. No attempts were made to adjust the mean for possible temporal biasing arising from variations in the number of observations within the time interval. An examination of the data indicates that the observations are reasonably well distributed across the time interval.

The temperature for this time period in the upper water column ranges from 4.0°C at 50 m depth to about 9.0 to 10.0°C near the surface. In deeper water (50 m to the bottom) the temperatures range from 2.0 to 3.5°C in the Flemish Pass area, in the offshore branch of the Labrador current and from 3.0 to 5.0°C offshore of the Cap where the influence of the Gulf Stream is evident. The corresponding average salinities (Fig. 2 bottom panel) generally range from 33.5 psu near the surface to 34.75 psu near the bottom over the Flemish Cap in about 300 m depth. In water depths greater than 300 m salinities were generally greater than 34.75 psu.

The vertical temperature distribution in early July of 1993 together with the temperature anomalies are shown in Fig. 3. Temperatures ranged from 2.0°C at 50 m depth to between 6 to 7°C near the surface, about 1.5 to 3.0°C below normal (Fig. 3, bottom panel). In water depths greater than 50 m to the bottom the temperatures ranged from 1.0 to 3.5°C along the Flemish Pass in the offshore branch of the Labrador current, about 0.5 to 1.5°C below normal. On the offshore portion of the bank in deep water temperatures ranged from 2.0 to 3.5°C, about 0.0 to 1.5°C below normal. The corresponding salinities in July, 1993 ranged from 33.25 psu near the surface to 34.75 psu at 300 m depth, generally about 0.1 to 0.3 psu fresher than normal in the upper 100 m of the water column to near normal values near the bottom over the Cap (Fig. 4).

3. VERTICAL OXYGEN DISTRIBUTION

The Flemish Cap oxygen data collected in conjunction with the temperature, salinity and chlorophyll data are shown in Fig. 5. These measurements were made with a Beckman model 5739 type polarographic element dissolved oxygen sensor with factory calibrated end-points at zero and air-saturated water oxygen levels. The sensor was interfaced to a Seabird-9 CTD system. A total of 300 water samples were collected at standard oceanographic depths for field oxygen calibrations. The oxygen levels of these samples were determined by semi-automated analytical chemistry using a modified Winkler titration technique. A least-squares fit of the titration measurements to the electronic sensor measurements was then computed. The corrected sensor readings were found to be related by a linear equation with a slope of 0.9648 and an intercept of 0.3576 (ie. corrected probe value = 0.9648 x titration value + 0.3536).

This survey shows corrected dissolved oxygen levels of 7.0 to 8.0 ml/l in the upper 100 m of the water column over the Flemish Pass area and values ranging from 6.0 to 6.5 in water depths of 150 m to the bottom over the bank. The area of surface water between 450 to 530 km offshore with oxygen values ranging between 7.5 to 8.0 ml/l correspond to very high chlorophyll concentrations confined to the surface layer over the Flemish Pass area. The corresponding oxygen saturations ranged from 100 % from the surface to about 40 m depth and to 80 % in the deeper water over the bank indicating a well oxygenated water column.

4. TEMPORAL ANOMALIES IN TEMPERATURE AND SALINITY

To investigate the spatial variability around the Flemish Cap in the temperature and salinity anomaly field over time, the historical data set for the region was grouped into 4 areas labelled FC1, FC2, FC3 and FC4 in Fig.1. These areas were selected based on the local bathymetry, available data and on local oceanographic conditions.

The data for each area for all years were then sorted by day of the year to determine the annual cycle. Data points considered as outliers were rejected. Following the general methods of Akenhead (1987) the mean annual cycles in the temperature and salinity fields at selected water depths were determined by fitting a least-squares regression to the mean and a sum of 4 sine and cosine pairs representing 4 harmonics. Temperature and salinity values for all years at depths of 0, 20, 50, 100, 200 and 300 m for the FC1 area show the temporal distribution of the data throughout the year as well as the scatter from the mean (Fig. 6 and 7). These plots indicate sufficient data to adequately define the annual cycles at least to water depths of 200 m for both temperature and salinity. As usual the largest annual cycle in the water temperature occurs in the upper layers where the strongest coupling to the annual solar flux exists. The amplitude of the annual cycle for both temperature and salinity decreases with depth and is not significant at 100 m depth. The phase of the temperature cycle increases with depth at a rate of approximately 1.5 days/m in the upper water column.

Time series of temperature and salinity anomalies for each area were then formed by taking each observation and subtracting the least squares fitted value for the same day of the year. Observations made on the same day within the same area were averaged. The time series of the anomalies were then low pass filtered to suppress the high frequency variations within seasons. Time series of temperature and salinity anomalies for the these areas are referenced to a 1950-1992 mean. Unlike the time series at fixed points (eg. Station 27) these time series are based on a smaller data set distributed over a wider geographical area, hence the anomalies may be subject to larger spatial and temporal biasing.

The time series of temperature anomalies in area FC1 (the Flemish Pass side of the bank) at various standard depths down to at least 100 m (Fig. 8) are characterized by 3 major cold periods: most of the 1970s, mid 1980s and the late 1980s to early 1990s. The cold period beginning around 1971 continued until 1977 in the upper layers where temperature anomalies reached peak values of -1.5°C by 1974 over the upper water column, temperature anomalies below 200 m were insignificant. From 1978 to 1984 the temperature anomalies showed a high degree of variability in the upper water column with a stronger tendency towards positive anomalies. By 1985 in the top 100 m of the water column, intense negative temperature anomalies had returned with peak amplitudes reaching -3.0°C to 50 m depth. This cold period moderated briefly in 1987 but has continued a cooling trend up to the summer of 1993 with anomalies reaching -2.0°C by July of 1993. In general these temperature anomalies patterns are very similar to that at Station 27 and elsewhere on the continental shelf over the same depth ranges.

The time series of salinity anomalies (Fig. 8 right panels) shows large fresher than normal conditions from 1971 to 1976 and from 1983 to 1986 in the upper 100 to 200 m of the water column with peak amplitudes reaching 0.5 psu below normal. Salinities during the early 1990s appear to be about normal from the available data in the area. Like the temperature anomalies the salinity anomaly amplitude is maximum in the upper mixed layer where the influence of ice melt over the continental shelf is the largest.

In area FC2 (the north side of the bank, Fig. 9) the time series suffer from a lack of data in the 1970s and early 1990s but do show large negative temperature anomalies in the mid 1980s, again in the upper 100 m of the water column, similar to conditions on the shoreward side of the bank (FC1). Similarly, the salinity time series show fresher the normal conditions during the mid 1980s. In areas FC3 (Fig. 10), the offshore portion of the bank and area FC4 (Fig. 11), the central bank the time series is again characterized by three colder and fresher than normal periods: the early 1970s (except area FC3), mid 1980s and early 1990s, at least in the upper 100 m. In area FC4 very little data exist below 300 m depth.

In all four areas examined around the Flemish Cap the temperatures have been decreasing since 1988 and are up to 2.0°C below normal by July of 1993. These anomalies are mainly restricted to the upper 100 m of the water column. In general these anomalies are highly correlated with severe meteorological and ice conditions experienced over the same time intervals in the Northwest Atlantic.

5. CIRCULATION

The general circulation in the region consists of the offshore branch of the Labrador current which flows through the Flemish Pass more or less trapped to the Grand Bank side of the continental slope area and a jet that flows to the east north of the bank. To the south the Gulf stream flows to the northeast merging with the Labrador current to form the North Atlantic current. In the absence of strong wind forcing the circulation over the Flemish Cap is dominated by a topographically induced anticyclonic gyre over the central portion of the bank (Kudlo *et. al.*, 1984, Ross, 1981). The stability of this circulation pattern may influence the retention of ichthyoplankton on the bank and is probably a factor in determining the year-class strength of various fish species such as cod and redfish (Kudlo and Borovkov, 1977; Kudlo and Boytsov, 1979), this hypothesis however has yet to be confirmed.

The currents along the transects occupied on this cruise were mapped with a hull-mounted 300 kHz RDI Acoustic Doppler Current Profiler (ADCP) at a spatial resolution of 4.0 m vertically by approximately 1.5 km horizontally. Figure 12 shows the vertical distribution of currents over the Flemish Cap during early July 1993, the negative values correspond to southward flowing water. Preliminary analysis of this data shows the offshore branch of the Labrador current in the Flemish Pass area up to 200 meters deep with current velocities of about 15 cm/s in a general southerly alongshelf direction, further onshore near the center of the offshore branch, current velocities reached 40 to 50 cm/s. Over the Flemish Cap between 500 to 700 km offshore the circulation was predominately anticyclonic with northward currents ranging from 5 to 15 cm/s over the shoreward portion of the Cap and southward currents over the offshore portion with speeds again ranging from 5 to 15 cm/s. A gyre with a nominal width of about 200 km and an average current speed of about 10 cm/s corresponds to a rotational period along its periphery of approximately 10 weeks.

As mention above, one of the main mechanisms for the breakdown of the anticyclonic circulation is the strength and frequency of wind forcing in the area resulting from the passage of major storms events. Kudlo et. al. (1984) have shown that the frequency of meandering type flow across the bank is greatest during the winter months when the mean wind speed is the greatest. To determine the relative stability of the gyre over time, particularly in the spring and summer when the retention of fish larvae is most important, it will be necessary to analysis the climatic data in the area to determine if conditions were favourable for prolonged periods of anticyclonic circulation. Most likely variations in the Labrador current and the Gulf stream also play important roles in the circulation in the area as well.

6. SUMMARY

Time series of temperature and salinity anomalies around the Flemish Cap area indicates three anomalous periods since the early 1970s, similar to conditions on the adjacent continental shelf at least over similar depth ranges. The latest cold period which started around 1988 is continuing into the summer of 1993 with temperature anomalies up to 2.5°C below normal throughout the upper 100 to 200 m of the water column. In general, temperatures have decreased from an average of about 4 to 10°C in the upper layers to about 2.0 to 7.0°C. The time series show weak salinity anomalies during the late 1980s and early 1990s compared to the mid 1980s. In addition, the circulation around the bank in July of 1993 was generally anticyclonic, consistent with early findings. More research in needed however to determine trends in the ocean circulation in the area, in particular, the stability of the anticyclonic gyre which probably plays an important role in the retention of ichthyoplankton in general.

ACKNOWLEDGEMENTS

I would like to thank the technical staff of the oceanography section at NAFC for the professional job done in data collection and processing and for the computer software support. I also thank D. Foote for data processing and technical assistance in the preparation of this document. I would also like to thank the captain and crew of the Petrel V.

REFERENCES

Akenhead, S. 1987. Temperature and Salinity off Newfoundland: Station 27 annual cycle and residuals. NAFO SCR Doc. 87/66, 20 p.

Akenhead, S. 1981. Local Sea-surface temperature and Salinity on the Flemish Cap. NAFO SCR Doc. 87/66, Ser. No. N426 20 p.

Bailey, W.B., 1982. A Time-series of Sea-surface Temperature on the Flemish Cap, 1962-81. NAFO SCR Doc. 82/4, Ser. No. N489 7 p.

Colbourne, E.B., 1993. Oceanographic conditions during the Annual Groundfish Survey in NAFO Divisions 2J3KL., DFO Atlantic Fisheries Research Document 93/2.

Drinkwater, K. F., and R. W. Trites. 1986. Monthly means of temperature and salinity in the Grand Banks region. Can. Tech. Rep. Fish. Aquat. Sci. 1450:iv+111 p.

Drinkwater, K. F., B. Petrie and S. Narayanan. 1992. Overview of Environmental Conditions in the Northwest Atlantic in 1991. NAFO SCR Doc. 92/73, 36p.

Drinkwater, K. F. 1993. Overview of Environmental Conditions in the Northwest Atlantic in 1992. FOS Working paper. 93/45, 48p.

Hays, R. M., D.G. Mountain, and T.C. Wolford. 1978. Physical oceanography and the abiotic influence on cod recruitment in the Flemish Cap region. ICNAF Res. Doc. 77/54, Ser. No. 5107, 33p.

Keeley, J.R., 1981. Mean conditions of potential temperature and salinity along the standard Flemish Cap Section. Mar. Environ. Data Serv. Tech. Rep. No. 9: 148 pp.

Kudlo, B.P., V.A. Borovkov and N.G. Sapronetskaya. 1984. Water Circulation Patterns on the Flemish Cap from Observations in 1977-82. NAFO Sci. Coun. Studies, 7:27-37.

Narayanan, S., S. Prinsenberg, and E. B. Colbourne. Overview of Environmental Conditions in 2J3KL NAFO subareas in 1991. NAFO SCR Doc. 92/6, 25p.

Petrie, B., J. Loder, J. Lazier and S. Akenhead. 1992. Temperature and salinity variability on the eastern Newfoundland shelf: the residual field. Atmos.- Ocean 30: 120-157.

Ross, C.K., 1981. Drift of Satellite-tracked Buoys on the Flemish Cap, 1970-80. NAFO Sci. Counc. Studies, No. 1: p47-50.

Sainza, C., 1993. Nothern Shrimp (Pandalus borealis) stock on the Flemish Cap. NAFO SCR Doc. 93/22, Serial No. N2199.

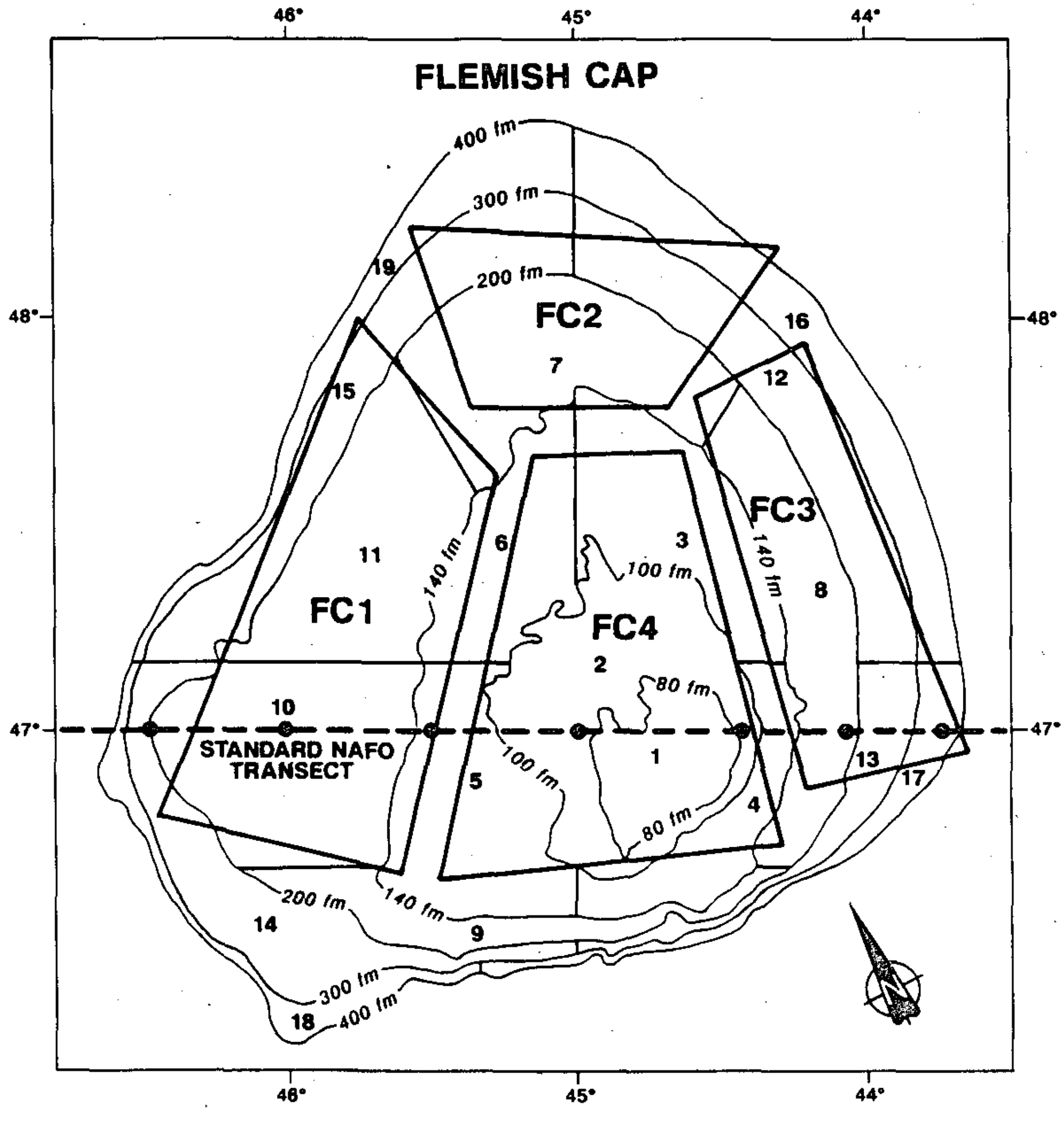

Fig. 1. Location map of the Flemish Cap area showing the standard NAFO transect and the areas (FC1 to FC4) where temperature and salinity anomalies were examined. The numbers are trawl survey strata (Sainza, 1993)

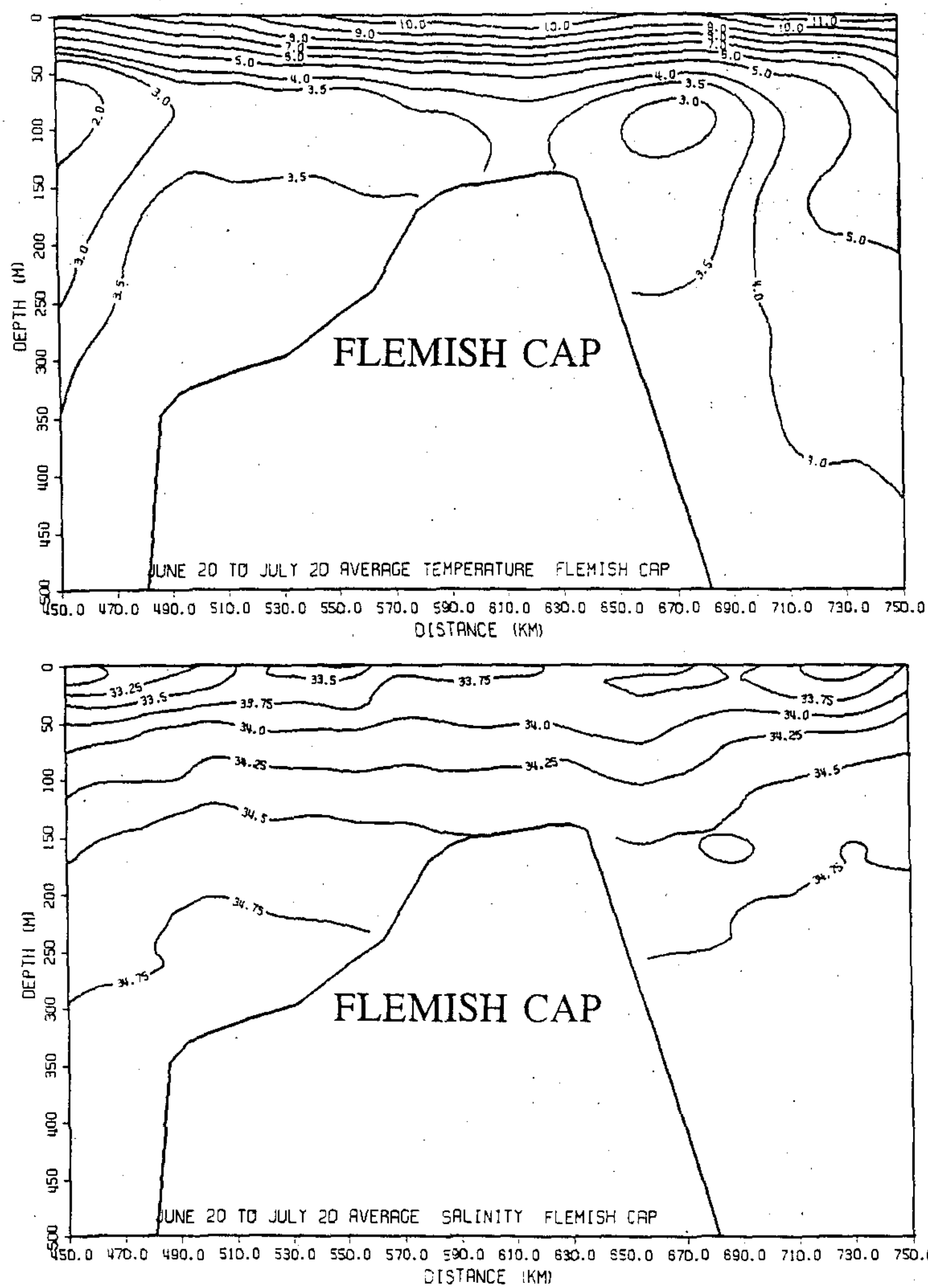

Fig. 2. The vertical distribution of the average temperature and salinity over the Flemish Cap based on all available historical data.

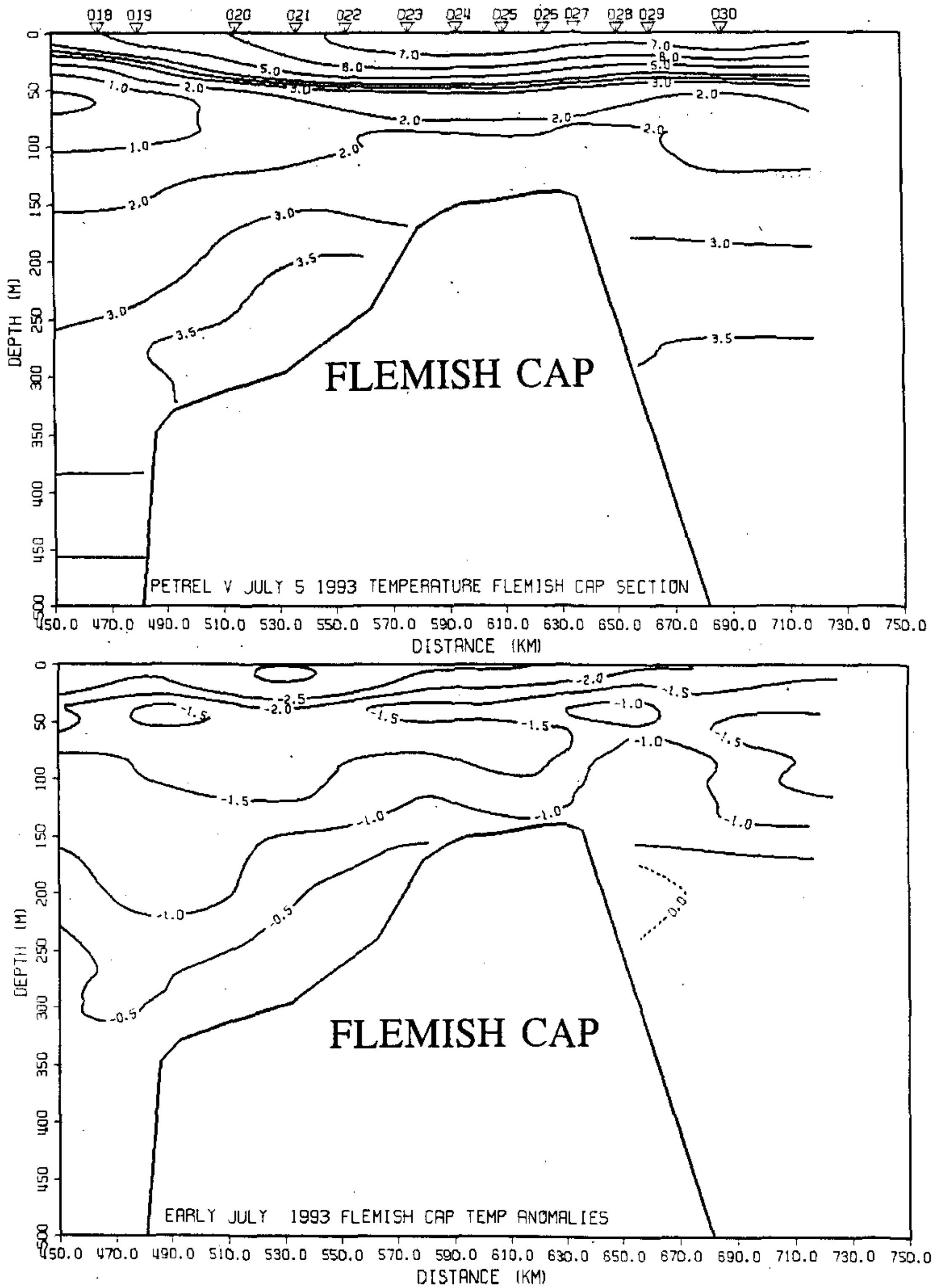

Fig. 3. The vertical distribution of temperature and anomalies over the Flemish Cap for early July, 1993.

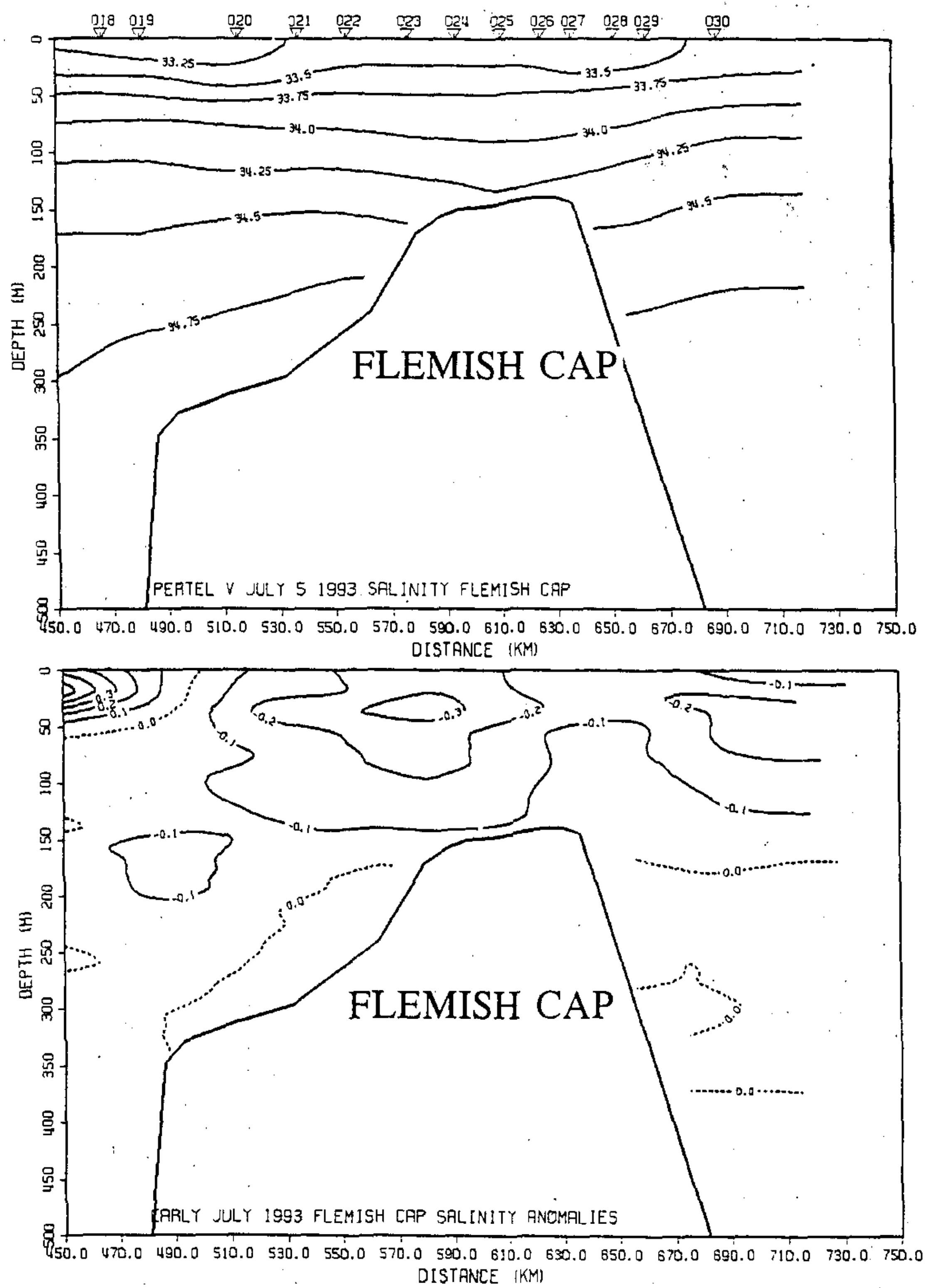

Fig. 4. The vertical distribution of salinity and anomalies over the Flemish Cap for early July, 1993.

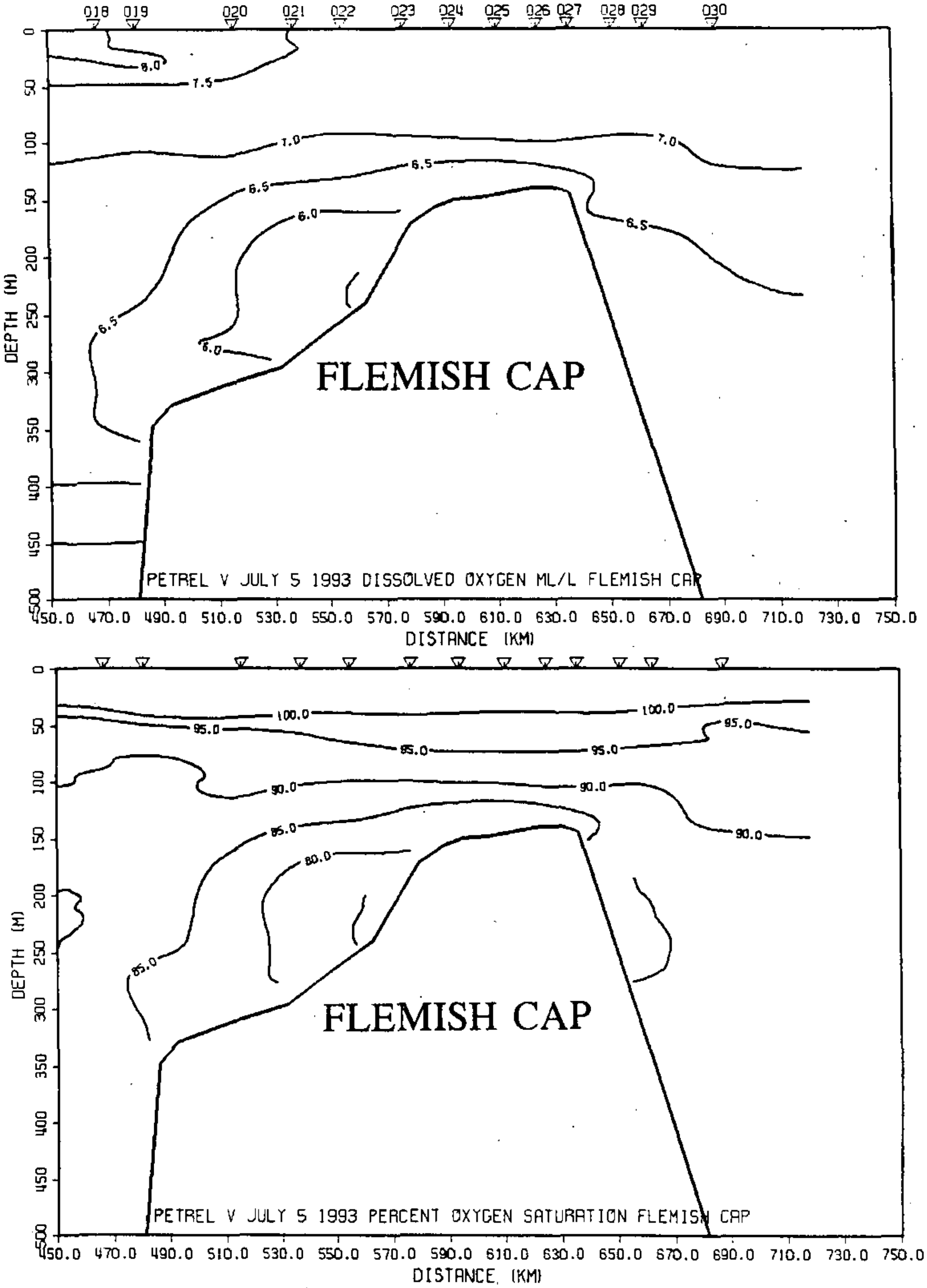

Fig. 5. The vertical distribution of dissolved oxygen concentration and saturation over the Flemish Cap for early July, 1993.

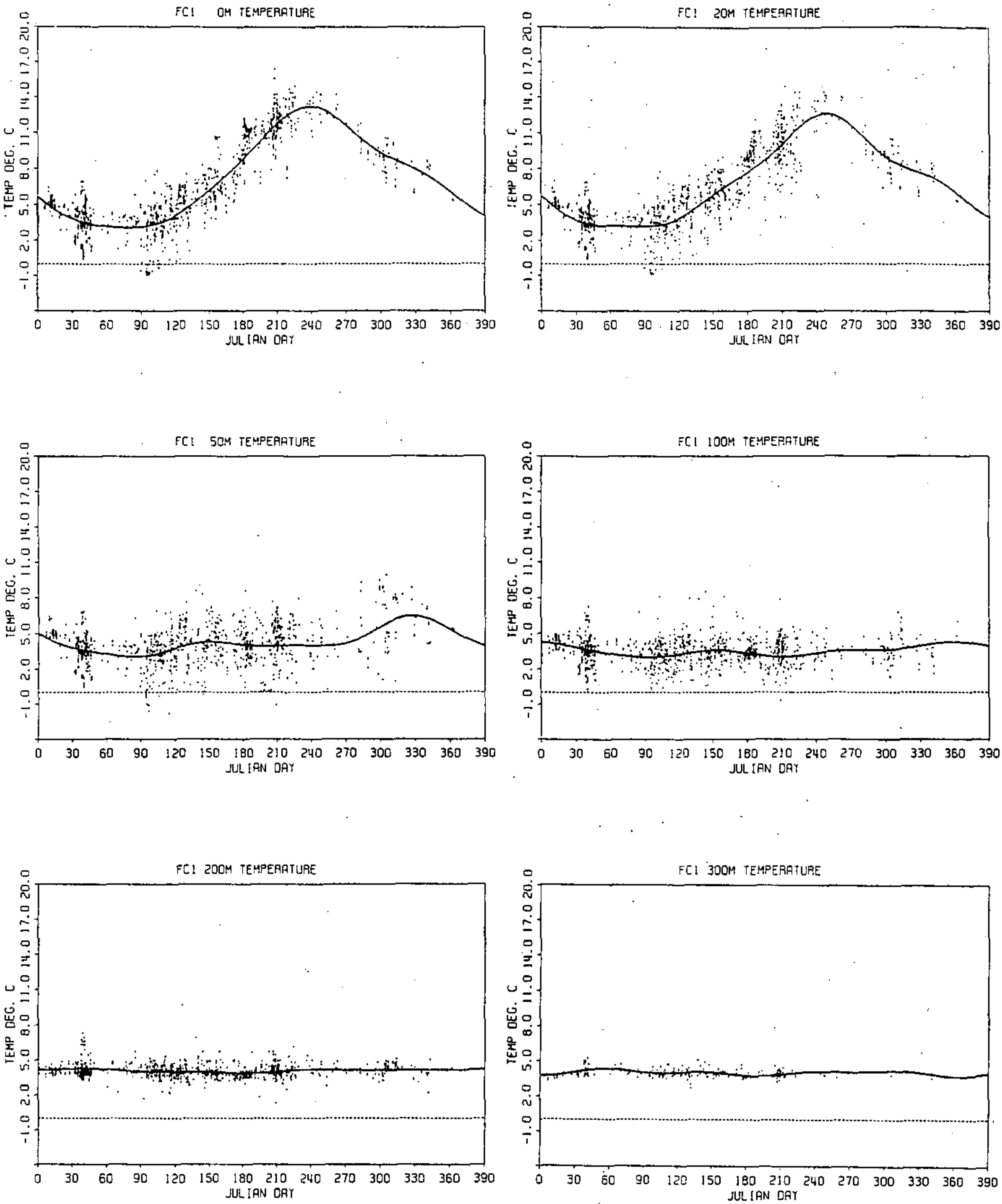

Fig. 6. Temperature values for all years at depths of 0,20, 50,100,200 and 300 m for area FC1 in Fig. 1, together with the fitted regression curves.

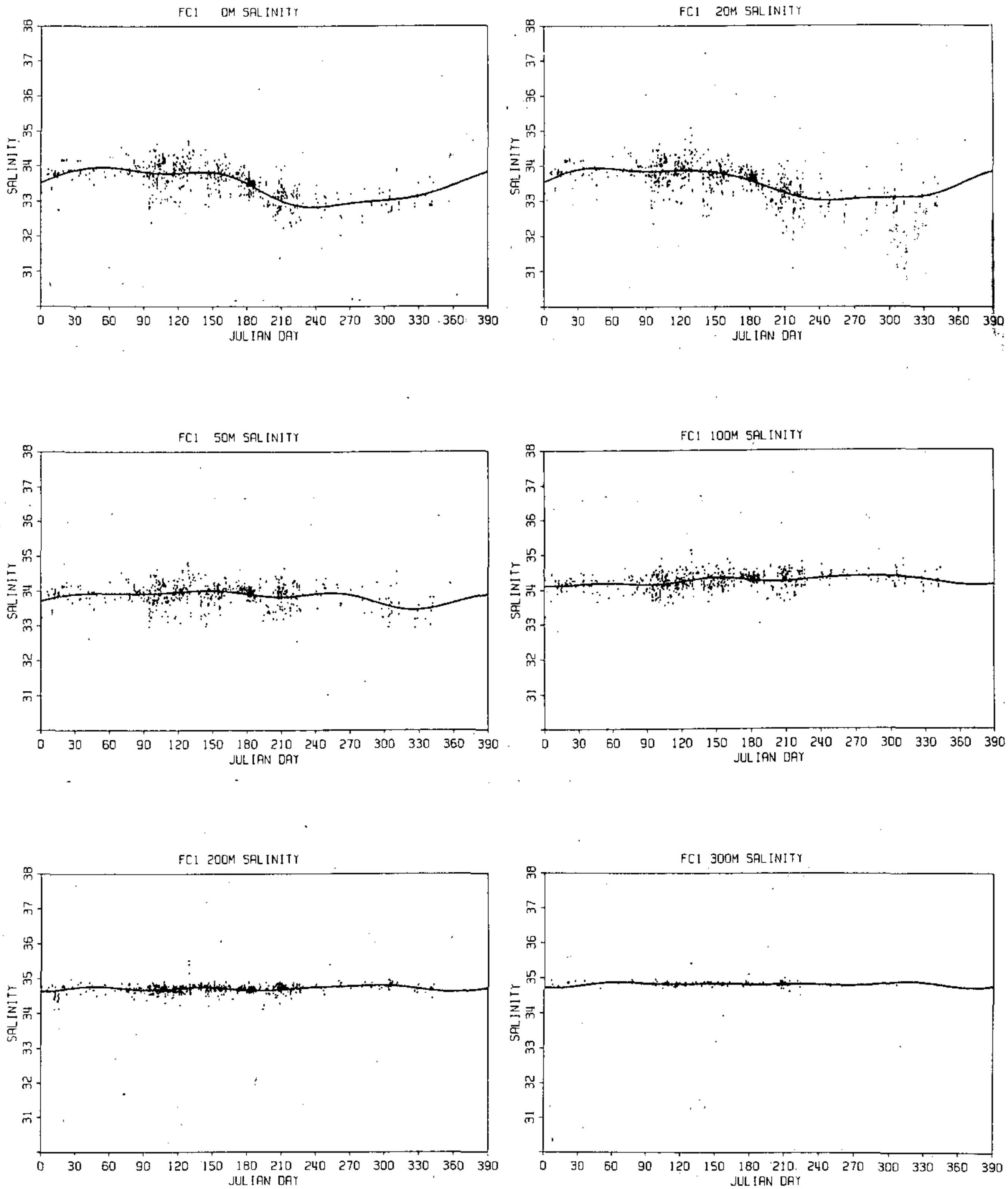

Fig. 7. Salinity values for all years at depths of 0,20, 50,100,200 and 300 m for area FC1 in Fig. 1, together with the fitted regression curves.

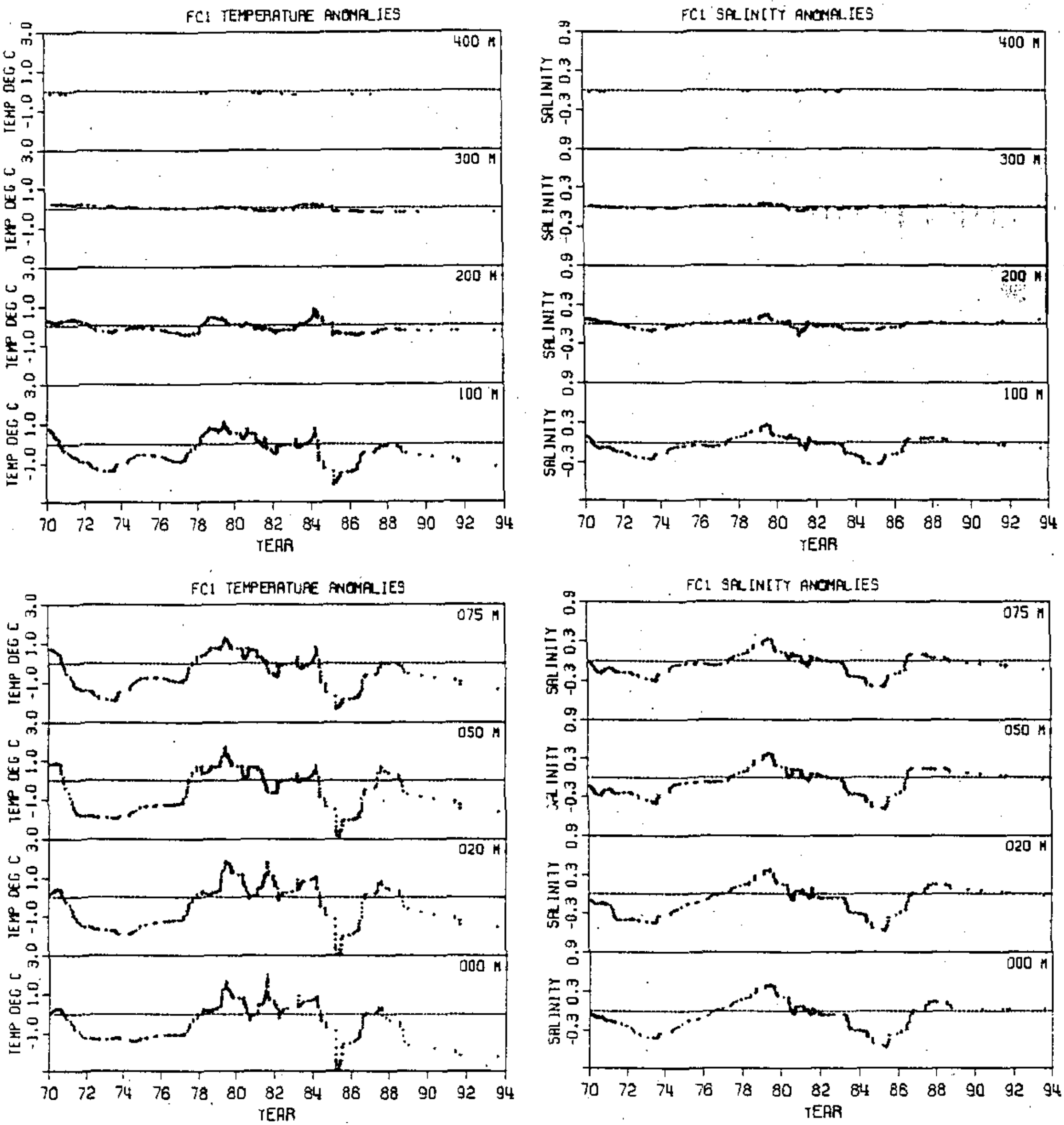

Fig. 8. Time series of temperature (left panels) and salinity (right panels) anomalies for area FC1 at standard depths.

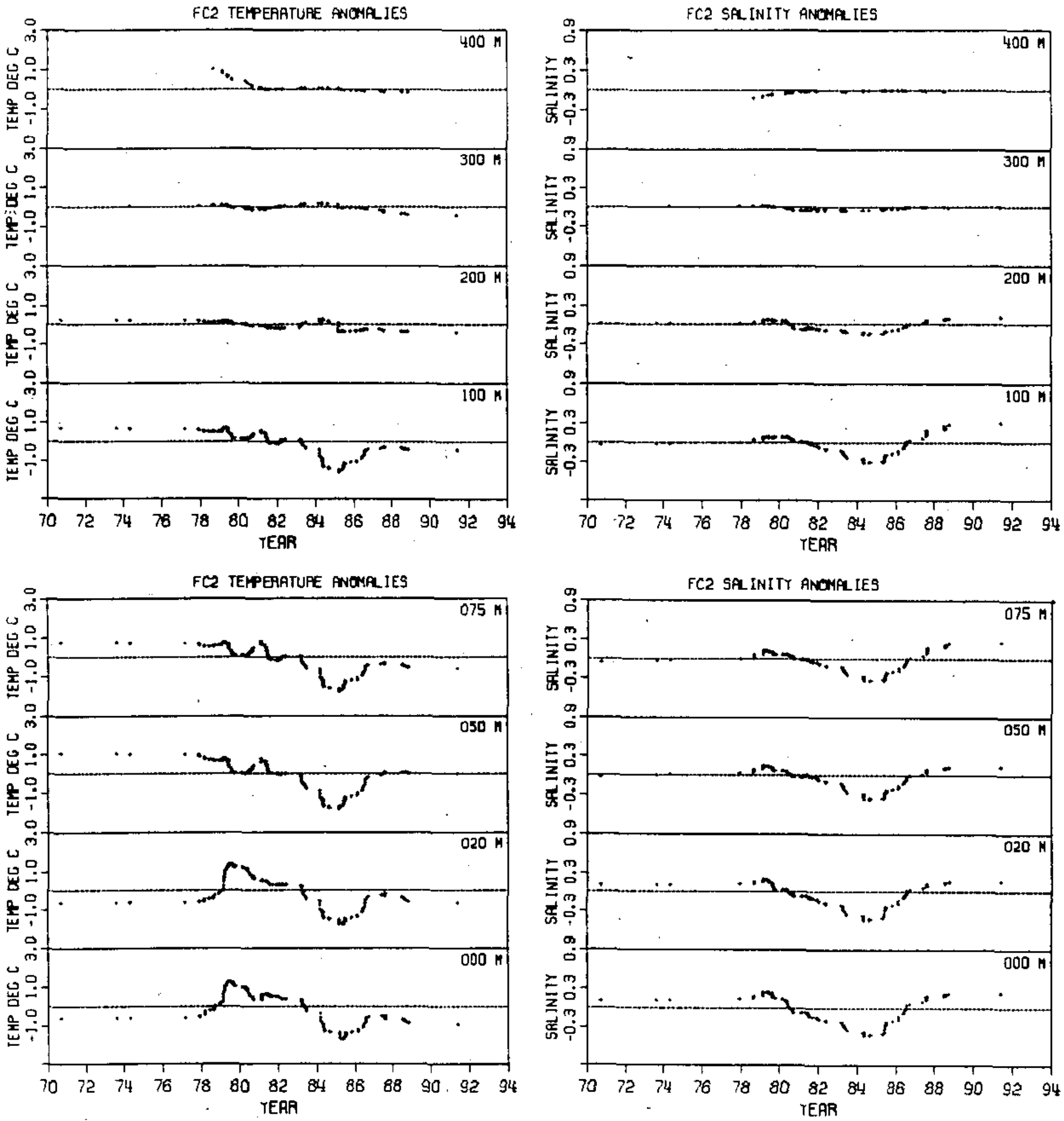

Fig. 9. Time series of temperature (left panels) and salinity (right panels) anomalies for area FC2 at standard depths.

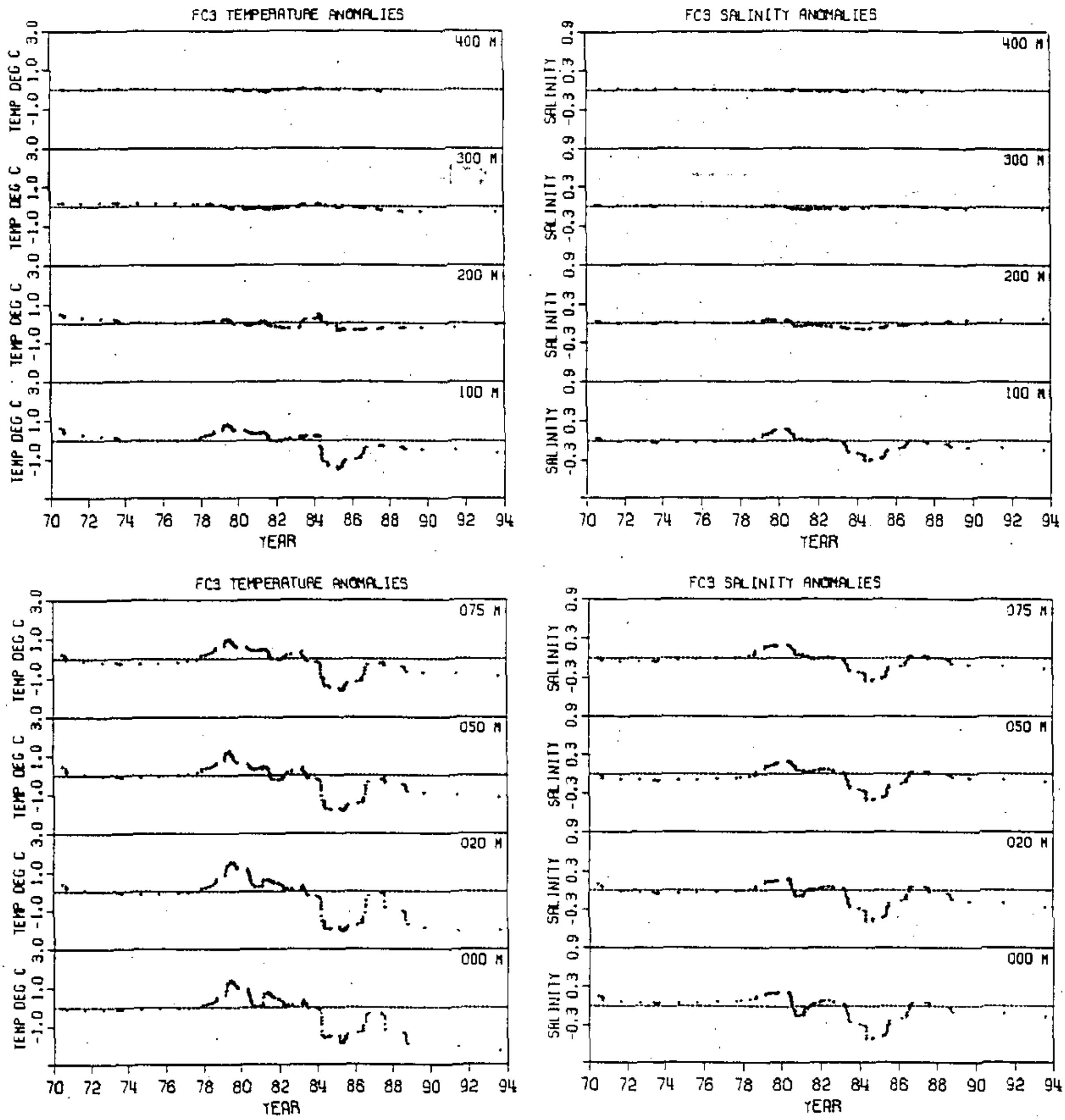

Fig. 10. Time series of temperature (left panels) and salinity (right panels) anomalies for area FC3 at standard depths.

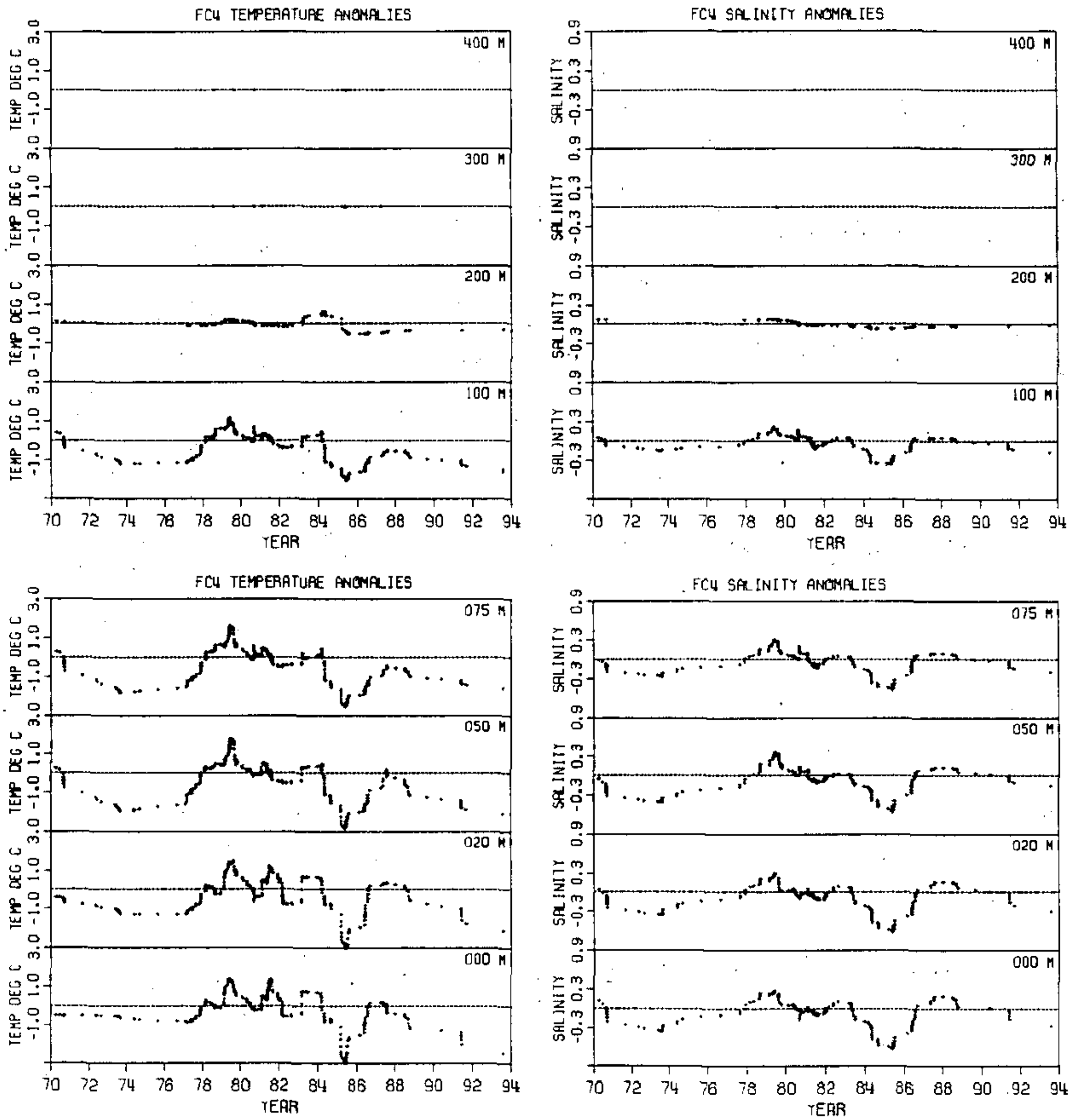

Fig. 11. Time series of temperature (left panels) and salinity (right panels) anomalies for area FC4 at standard depths.

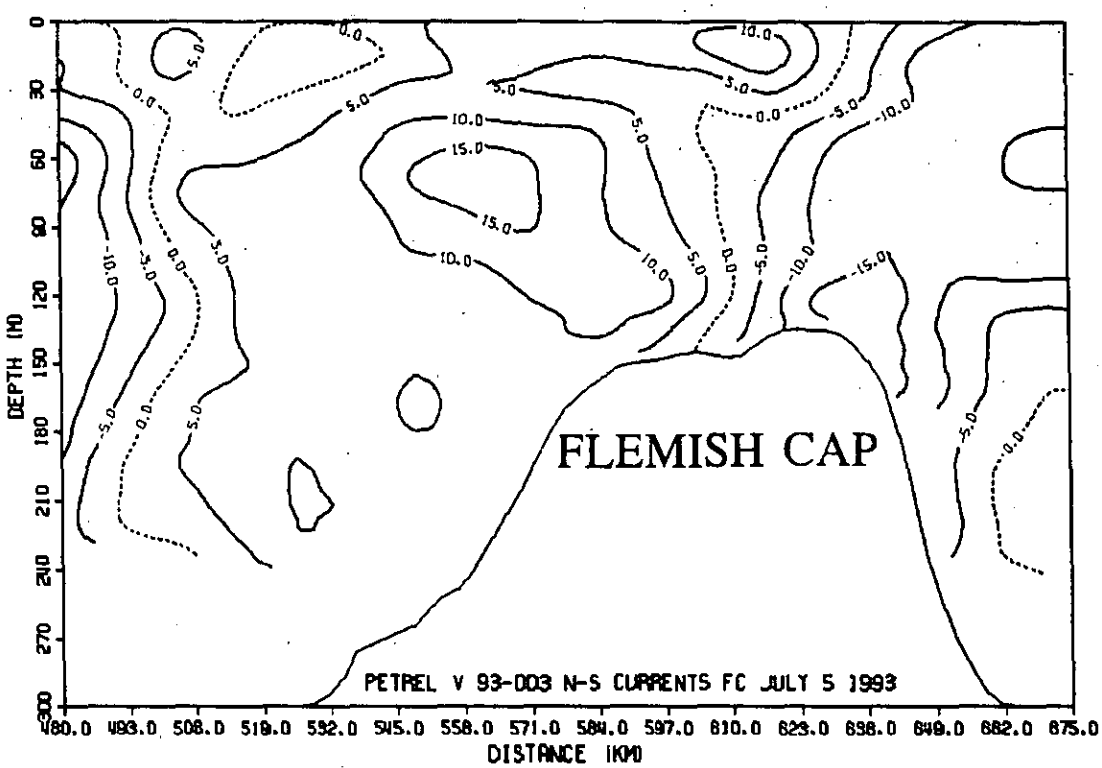

Fig. 12. The vertical distribution of the N-S current field over the Flemish Cap. Negative currents are southward, from an ADCP survey.