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OCEANOGRAPHIC CONDITIONS ON THE FLEMISH CAP DURING THE SUMMER OF 1997, WITH COMPARISONS TO THE PREVIOUS YEAR AND THE 1961-1990 AVERAGE

by

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ABSTRACT

Oceanographic data from the summer of 1997 on the Flemish Cap are examined and compared to the long-term (1961-1990) average and to conditions during the summer of 1996. The cold near-surface temperatures (0.5 to 2.0 °C below normal) experienced during 1993, 1995 and 1996 had warmed to 0.5 to 1.5 °C above normal in July of 1997. In water depths of 50 m to the bottom temperatures ranged from 0.25 °C above normal on the east side of the cap to 0.0 to 0.5 °C below normal directly over the cap and from 0.0 to 0.25 °C below normal on the west side. Upper layer (top 50 m) salinities were above the long-term mean (by 0.2-0.5 PSU) during the last three years from 1995 to 1997, otherwise about normal. The colder than normal temperatures experienced over the continental shelf and on the Flemish Cap since the late 1980s continued into 1993 and 1995 but shows some moderation by the summer of 1996 and certainly during July of 1997. As in previous years the chlorophyll measurements show higher summer values in the upper 50 m of the water column over the Cap compared to the adjacent Grand Bank. Dissolved oxygen levels indicate a well oxygenated water column over the Cap in 1997 similar to values in 1993, 1995 and 1996. Additionally, current estimated from direct ADCP measurements and from geostrophic calculations clearly show the presence of a general anticyclonic circulation around the Flemish Cap. Current speeds however, were much weaker in July 1997 than that measured during the same time period in 1996.

1. INTRODUCTION

The Flemish Cap is an isolated bank located east of the Grand Banks of Newfoundland centered at about 47° N, 45° W with minimum water depths of 126 m. To the west, the Cap is separated from the Grand Bank by the Flemish Pass with maximum water depths of about 1100 m. The water mass over the Flemish Cap is a mixture of Labrador Current and North Atlantic Current water, the general circulation of which is shown in Fig. 1a. Since the early 1970s the water masses over the Atlantic continental shelves have been dominated by three anomalous periods: early 1970s, mid 1980s and the early 1990s (Colbourne et al. 1994). 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 the continental shelf of Atlantic Canada (Drinkwater et al. 1992). An examination of the time series of historical temperature and salinity data from the Flemish Cap indicated similar conditions existed in the Flemish Cap region as on the adjacent continental shelf (Colbourne 1993).

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 of the late 1970s and early 1980s (Hays et al. 1978; Bailey 1982; Akenhead 1981). More recent reviews of oceanographic conditions in the region compared 1993 and 1995-1996 observations with the long-term mean and also presented time series of temperature and salinity anomalies at various depths around the Cap (Colbourne 1993; Colbourne 1995; Colbourne 1996). Stein (1996), summarized the most recent studies of oceanographic conditions on the Flemish Cap. Additionally, Cervifio and Prego (1996) presented hydrographic conditions on the Flemish Cap in July of 1996 from a fisheries research survey conducted by the European Union. This review presents an update to these studies by including data up to the summer of 1997.

The report describes oceanographic conditions on the Flemish Cap during the summer of 1997 with a comparison to 1996 conditions and to the long-term mean, based on all available historical data. The normal has been defined as the 30 year period from 1961-1990 in accordance with the convention of the World Meteorological Organization and recommendations of the NAFO Scientific Council. The 1996 and 1997 observations were made by the Department of Fisheries and Oceans on oceanographic surveys in mid July aboard the Canadian Scientific Ship Parizeau. During these surveys oceanographic observations were made along the standard NAFO Flemish Cap transect (47° N) as well as several stations along a transect across the northwestern portion of the bank (Fig. 1b). Measurements included vertical profiles of currents, temperature, salinity, chlorophyll and dissolved oxygen.

2. AVERAGE TEMPERATURE AND SALINITY

The vertical distribution (depth versus horizontal distance from the Avalon Peninsula) of the average temperature and salinity over the Flemish Cap along the standard NAFO transect (47° N) for the period July 1 to July 31, based on all available historical data from 1961-1990 is shown in Fig. 2. An examination of the data distribution for July indicates a bias in the observations towards the latter half of the month. No attempts were made here to adjust the mean for possible temporal biasing arising from variations in the number of observations within the time interval.

The average temperature for July (Fig. 2, upper panel) based on this analysis in the upper water column ranges from 4.0 to 5.0 °C at 50 m depth to about 10 to 12 °C near the surface. In deeper water (50 m to the bottom) the temperatures ranges from 2.0 to 4.0 °C in the Flemish Pass area, in the offshore branch of the Labrador current, and from 3.5 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 ranges from 33.25 psu near the surface to 34.75 psu near the bottom over the Flemish

Cap in water depths of about 300 m. In water depths greater than 300 m salinities are generally around 34.75 psu.

3. 1996 AND 1997 TEMPERATURE AND SALINITY

The vertical temperature distribution in July of 1997 (Fig. 3, bottom panel) along the standard NAFO transect shows temperatures ranging from about 4.0 to 5.0 °C at 50 m depth to about 10 to 12 °C near the surface, about 1.0 to 2.0 °C warmer than 1996 values (Fig. 3, upper panel). In the depth range of 50-100 m temperatures ranged from 4.0 to 2.8 °C along the Flemish Pass, in the offshore branch of the Labrador current, and about 5.0 to 3.25 °C on the Cap. In the depth range of 100 m to the bottom over the Cap temperatures ranged from 3.0 to 3.5 °C.

The vertical distribution of temperature anomalies for 1996 and 1997 over the Flemish Cap are shown in Fig. 4. These anomalies were calculated by subtracting the gridded averaged 1961-1990 data from the current transect data (collected on July 12). A temporal adjustment of the calculation was made by restricting the historical data in the time period of June 27 to July 26. An examination of the historical data distribution for that time period shows that about 36 % of the 475 profiles were collected before July 12 with a median date of July 17. An examination of the annual temperature cycle over the Flemish Cap indicates that the temperature normally changes by approximately 0.5 °C in the time interval from July 12 to 17 in the near surface layers (0 to 20 m) and about 0.1 °C at 50 m depth. This indicates that in near surface areas, where the annual cycle is the strongest, the temperature anomalies may be biased low, assuming normal atmospheric heat flux.

During 1997, upper layer (0-50 m) temperature anomalies (Fig. 4 bottom panel) ranged from 0.5 to 1.5 °C above normal on the Flemish Pass side of the cap, around 0.0 to 1.0 °C above normal over the Cap and from 1 to 2.0 °C above normal on the eastern side of the cap. East of the cap on the continental slope temperatures were 1.0 to 1.5 °C below normal. These values were considerably warmer than the 1996 values (Fig. 4 top panel). Below the surface layer temperature anomalies ranged from 0.0 to 0.5 °C below normal, similar to 1996 values in some areas however the bottom temperatures on the cap from 150 to 300 m depth were near normal. The positive surface anomalies over the Flemish Cap are in contrast to the generally negative anomalies over most of the Grand Bank during the same time period and the negative anomalies experienced over the cap in July of 1993, 1995 and 1996.

The vertical distribution of salinities for July of 1997 (Fig. 5, bottom panel) show values ranging from less than 33.25 psu near the surface in the Flemish Pass, where the influence of the Labrador current is felt, to between 33.75 to 34.0 psu across the Cap in the upper 50 m, somewhat higher than the 1996 values (Fig. 5, upper panel). In the depth range of 50 m to the bottom salinities generally ranged from 34.0 to 34.75 psu.

The corresponding salinities anomalies in both 1996 and 1997 were similar, with a saltier than normal (by 0.2 to 0.6 psu) surface layer (0 to 50 m thick) across the Cap (Fig. 6). In the depth range of 50 m to the bottom over the cap anomalies were slightly positive in 1997 and slightly negative in 1996. In the deeper water of the Flemish Pass and on the continental slope to the east of the cap values were near normal. In contrast, 1993 salinities in the upper layer over the Cap were slightly

fresher than normal by 0.2 to 0.3 psu (Colbourne 1993).

4. 1997 CHLOROPHYLL AND DISSOLVED OXYGEN

The vertical distributions of chlorophyll and dissolved oxygen saturation for July of 1997 along the standard NAFO transect across the Flemish Cap are shown in Fig. 7. These data were collected in conjunction with the temperature and salinity data using a YSI type polarographic element dissolved oxygen sensor and a fluorometer interfaced to a Seabird-9 CTD system. The oxygen sensor was factory calibrated at zero and air-saturated water oxygen levels and also field calibrated by taking water samples at standard depths. The oxygen levels of the samples were determined by semi-automated analytical chemistry using a modified Winkler titration technique. The sensor readings were then corrected by using a least-squares fit of the titration measurements to the electronic sensor measurements. No field calibrations were applied to the chlorophyll measurements presented here.

The chlorophyll concentrations show relatively high values over the Flemish Cap compared to over the adjacent Grand Bank during 1997, 1996 and 1995 (Colbourne 1996). The higher values were confined to a surface layer from 0 to 50 m depth (Fig. 7, top panel). The higher chlorophyll values over the Flemish Cap during mid summer appear to be a common occurrence and may indicate a delayed or extended offshore plankton bloom relative to the Newfoundland Shelf areas.

Dissolved oxygen levels during 1997 were about 7.0 ml/l in the upper 100 m of the water column over the Flemish Pass area and from 7.0 to 6.5 in water depths from 100 m to the bottom over the bank. The corresponding oxygen saturations (Fig. 7, bottom panel) ranged from 97.5 to 110 % from the surface to about 50 m depth and from 90 to 97 % in the depth range of 50 m to the bottom. The super saturated values in the top 50 m of the water column correspond to the high chlorophyll concentrations encountered over the Flemish Cap. These saturation levels are similar to that observed during 1995 and 1996 and indicate a well oxygenated water column.

5. CIRCULATION

The general circulation in the Flemish Cap 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 cap. To the south the Gulf stream flows to the northeast merging with the Labrador current to form the North Atlantic current (Fig. 1a). 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 never been investigated in detail.

From 1993 to 1997 (except 1994) mid July currents on the Flemish Cap were measured with hull-mounted 150 kHz RDI acoustic Doppler current profilers (ADCP) at a spatial resolution of 4.0 m vertically by approximately 1.5 km horizontally.

Measurements were restricted to water depths less than 500 where bottom referencing was possible. The useful range of the 150 kHz ADCP for current measurements in this area is about 10 to 300 m depth. The circulation around the Flemish Cap is predominately anticyclonic in all surveys since 1993 with typical recirculation times ranging from 50 to 70 days. Figure 8 shows a vertical cross-section of the north-south currents over the Flemish Cap during July of 1996 and 1997 along the 47° N line. The 1997 measurements show a northward component ranging from 2.5 to 10 cm/s over the shoreward portion of the Cap in the Flemish Pass area and over the cap in water depths below 50 m depth. In the surface layer and east of the cap currents were generally southward with speeds ranging from 2.5 to 10 cm/s. In general these measurements indicate a much weaker circulation than that observed in 1996 (Fig. 8, top panel) currents were in excess of 25 cm/s.

The anticyclonic motion of the water mass around the Flemish Cap was first described by *Kudlo and Burmakin (1972), Kudlo and Borovkov (1975) and Kudlo et al.* (1984) using geostrophic currents estimated from density measurements. The geostrophic currents perpendicular to the 47° N line estimated from the density data collected during 1996 and 1997 are shown in Fig. 9. These calculations which are referenced to 300 meters, or the bottom, in water depths less than 300 m, show the well known features of the circulation. The strong baroclinic component of the offshore branch of the Labrador Current shoreward of the cap, the general anticyclonic circulation around the cap and the northward flowing water of the North Atlantic Current east of the cap are all evident. The results however differ significantly from the direct current measurements made with the ADCPs, thus showing the potential importance of wind driven and tidal currents on the Flemish Cap. Finally, both the directly measured currents and the geostrophic estimates show considerable variability between different years, for example, the 1997 geostrophic currents indicate a much weaker anticyclonic gyre than the 1996 results.

ACKNOWLEDGEMENTS

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REFERENCES

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.

Cervifio, S. and R. Prego. 1996. Hydrographic Conditions on the Flemish Cap in July 1996. NAFO SCR Doc. 97/17, Ser. No. N2847 13 p.

Colbourne, E.B. S. Narayanan, and S. Prinsenberg. 1994 Climate Change and

Environment Conditions in the Northwest Atlantic during the period 1970-1993. ICES mar. Sci. Symp., 198:311-322.

Colbourne, E. 1993. Oceanographic Conditions on the Flemish Cap During the Summer of 1993, with Comparisons to the Long-Term Average. NAFO SCR Doc. 93/107, Ser. No. N2300 36p.

Colbourne, E. 1995. Oceanographic Conditions on the Flemish Cap During the Summer 1995, with Comparisons to the 1961-1990 Average. NAFO SCR Doc. 95/102, Ser. No. N2625 12p.

Colbourne, E. 1996. Oceanographic Conditions on the Flemish Cap During the Summer 1996, with Comparisons to the Previous Year and the 1961-1990 Average. NAFO SCR Doc. 96/87, Ser. No. N2770 12p.

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.

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.

Kudlo, B.P., and V.V. Burmakin. 1972. Water Circulation in the South Labrador and Newfoundland areas in 1970-71. ICNAF Redbook 1972 (iii):22-33.

Kudlo, B.P., and V. A. Borovkov. 1975. Circulation of waters in the ICNAF area in 1973-1974. ICNAF Res. Doc. No. 79, Serial No. 3506, 12 p.

Kudlo, B.P., and V.A. Borovkov. 1977. Hydrological regime of the Labrador current and reproduction of commercial fishes. Syezd Sovetskikh Okeanologov, Tezisy Dokladov, Moskva vyp. ii:133-134.

Kudlo, B.P., and V. D. Boytsov. 1979. The effect of water dynamics on year-class strength of cod on Flemish Cap. ICNAF Sel. Papers, 5: 7-9.

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

Stein, M. 1996. Flemish Cap - A review on Research Activities with Focus on Oceanographic Conditions. NAFO Sci. Coun. Studies, 25:1-24.

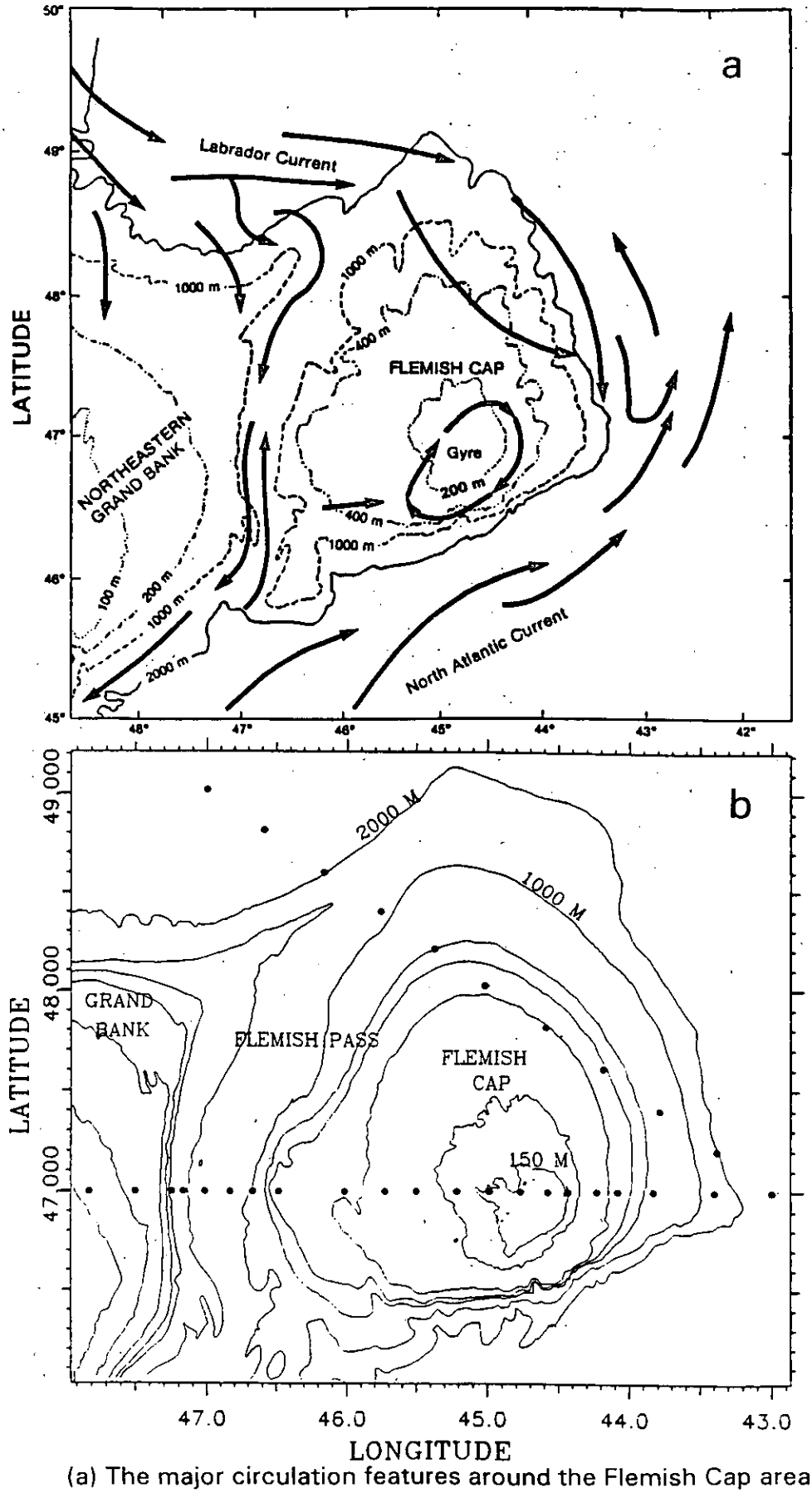

Fig. 1. (a) The major circulation features around the Flemish Cap area (Adapted from Anderson, 1984) and (b) the location of stations occupied during the summer of 1997. Bathymetry lines are 2000, 1000, 500, 400, 300, 200 and 150 m.

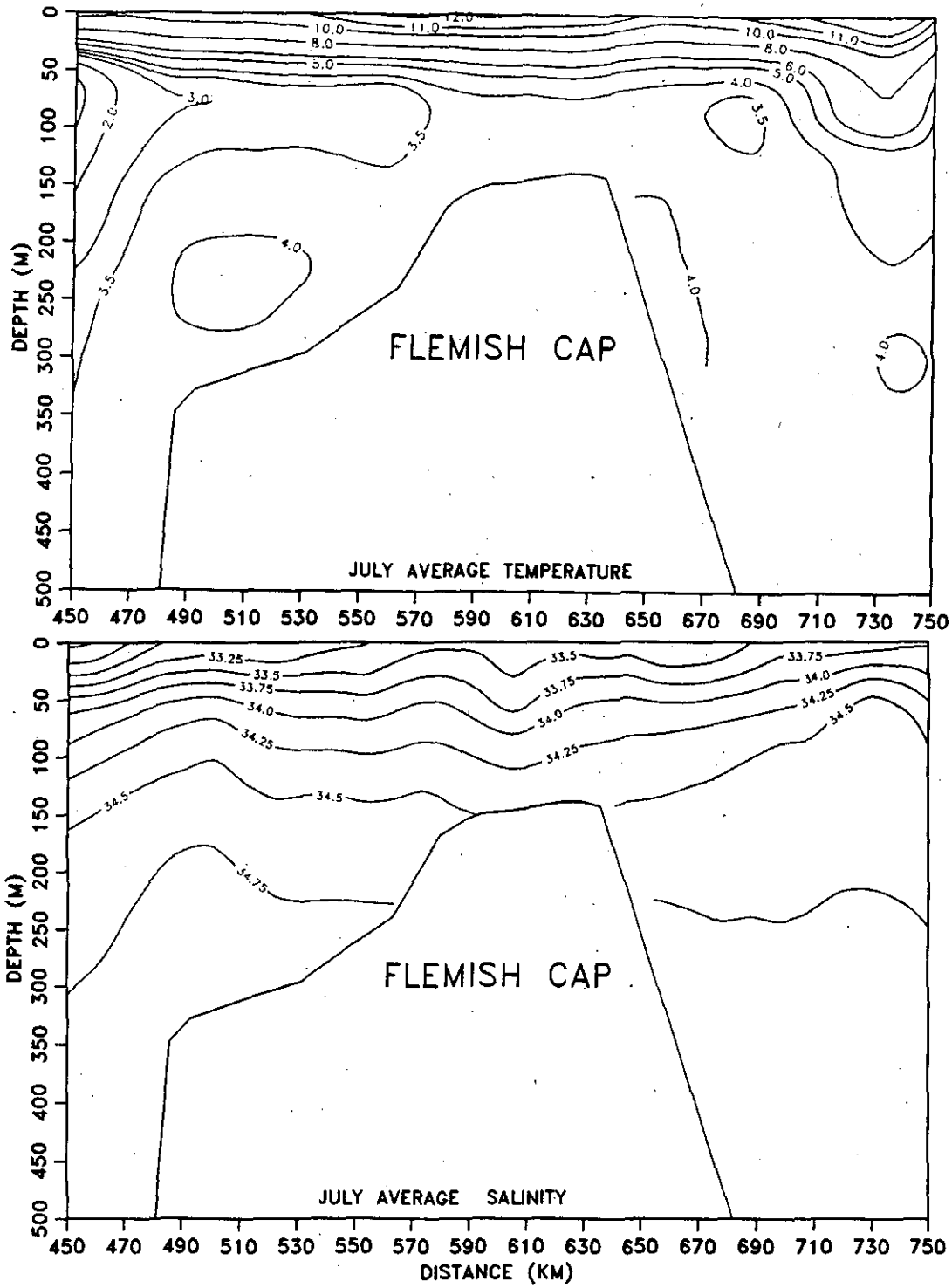

Fig. 2. The vertical distribution of the average temperature and salinity over the Flemish Cap based on all available historical data from 1961-1990.

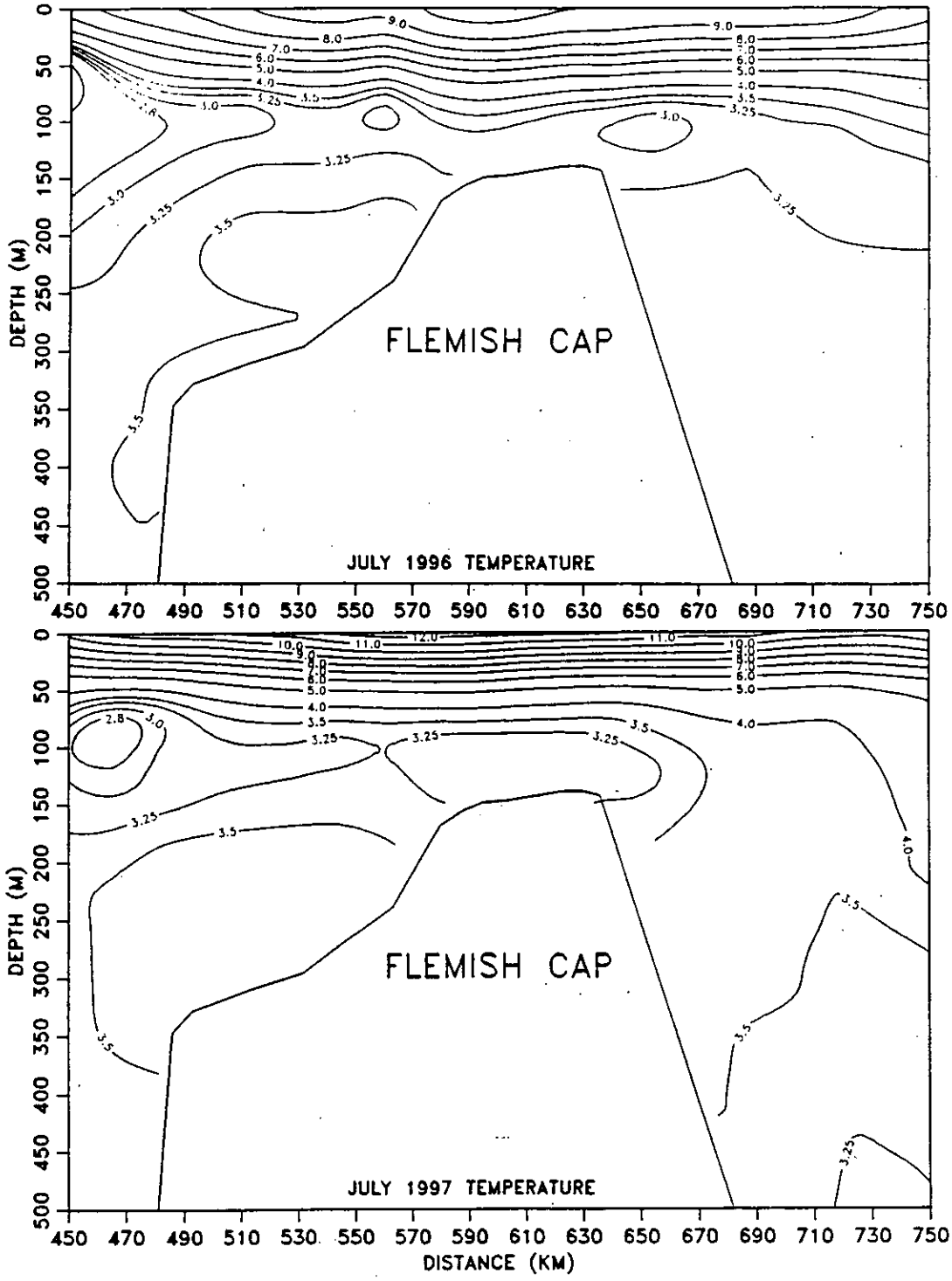

Fig. 3 The vertical distribution of temperature over the Flemish Cap (along 47°N) for July of 1996 and 1997.

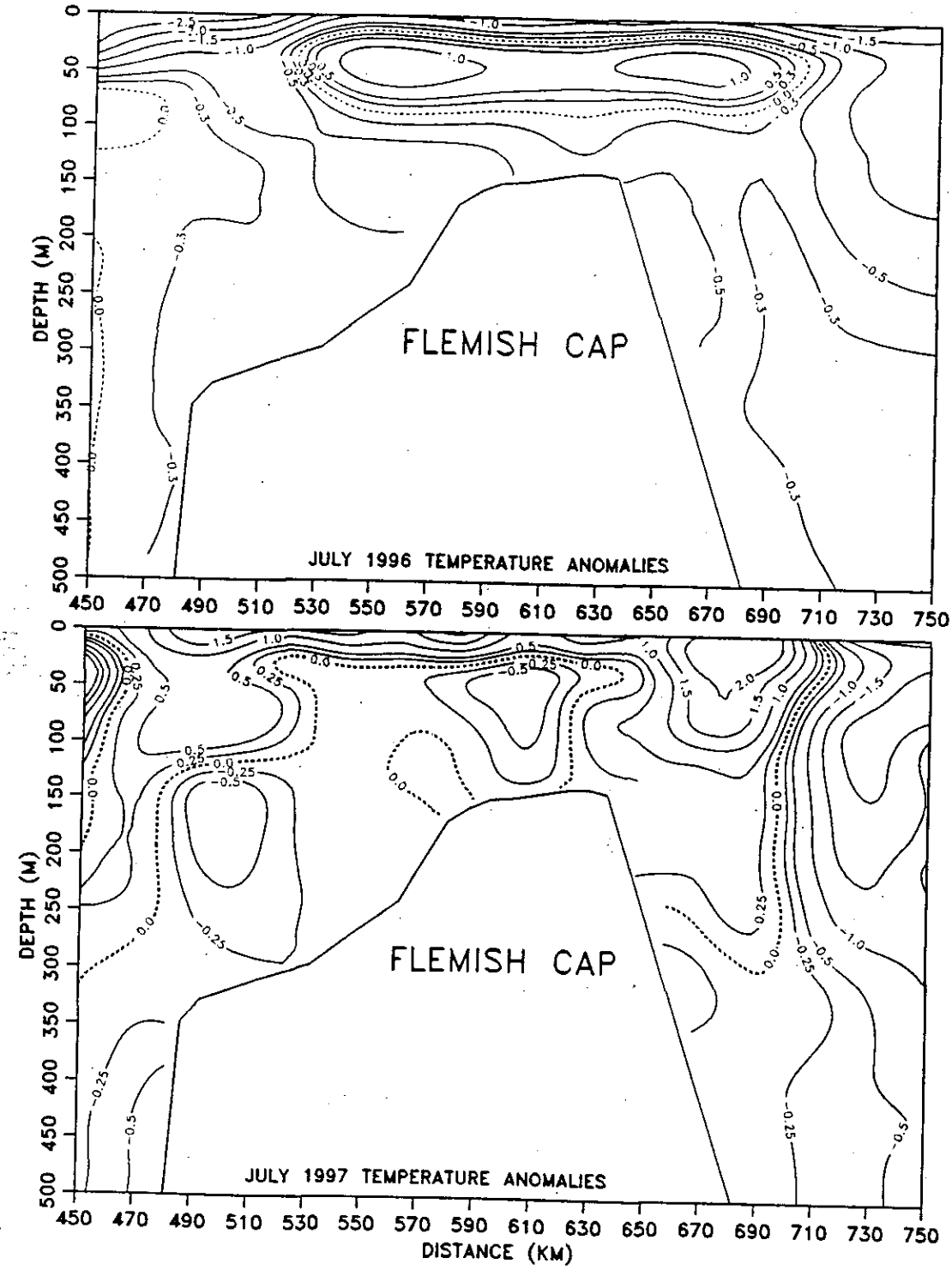

Fig. 4. The vertical distribution of temperature anomalies over the Flemish Cap (along 47° N) for July of 1996 and 1997.

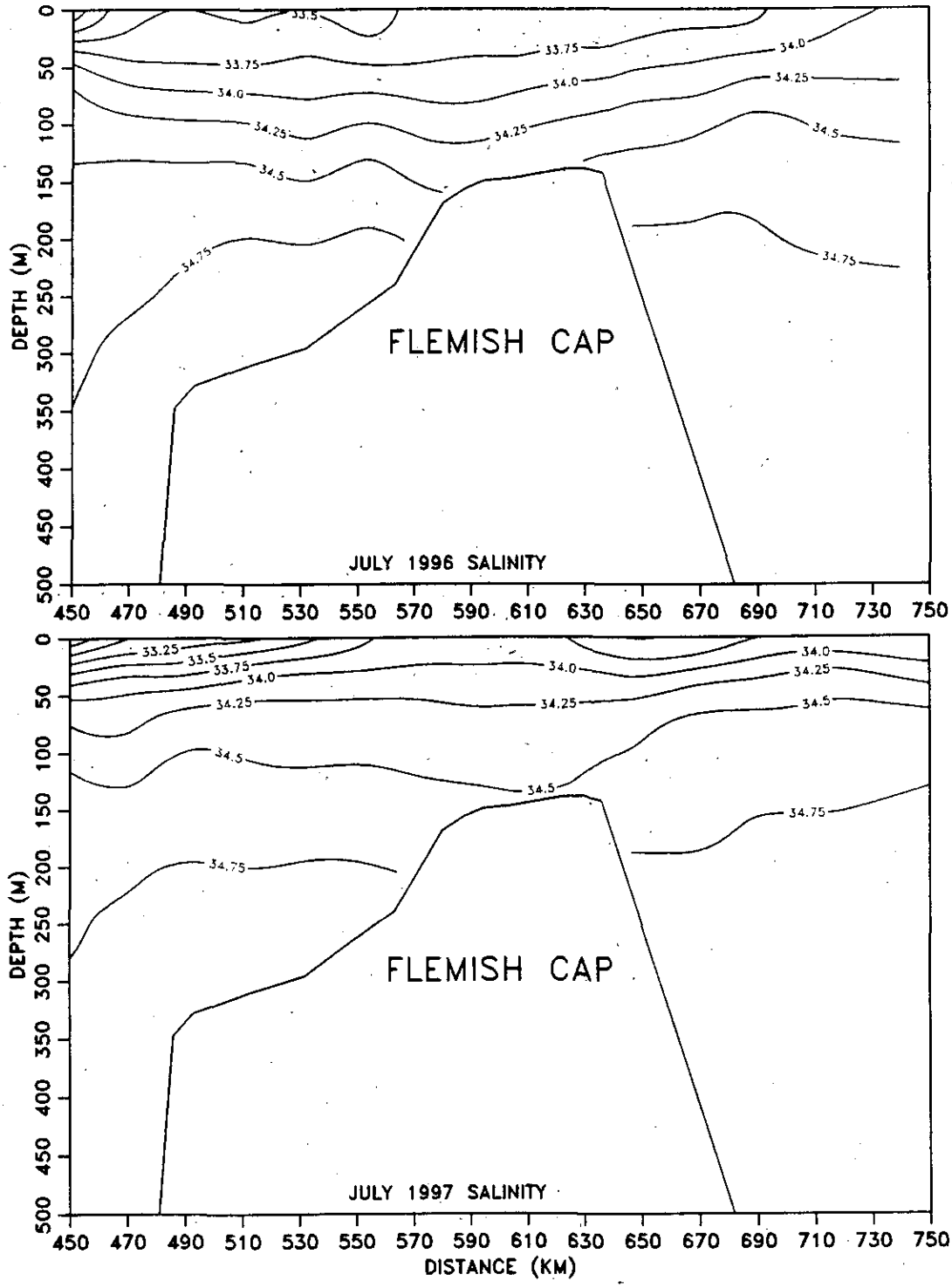

Fig. 5 The vertical distribution of salinity over the Flemish Cap (along 47°N) for July of 1996 and 1997.

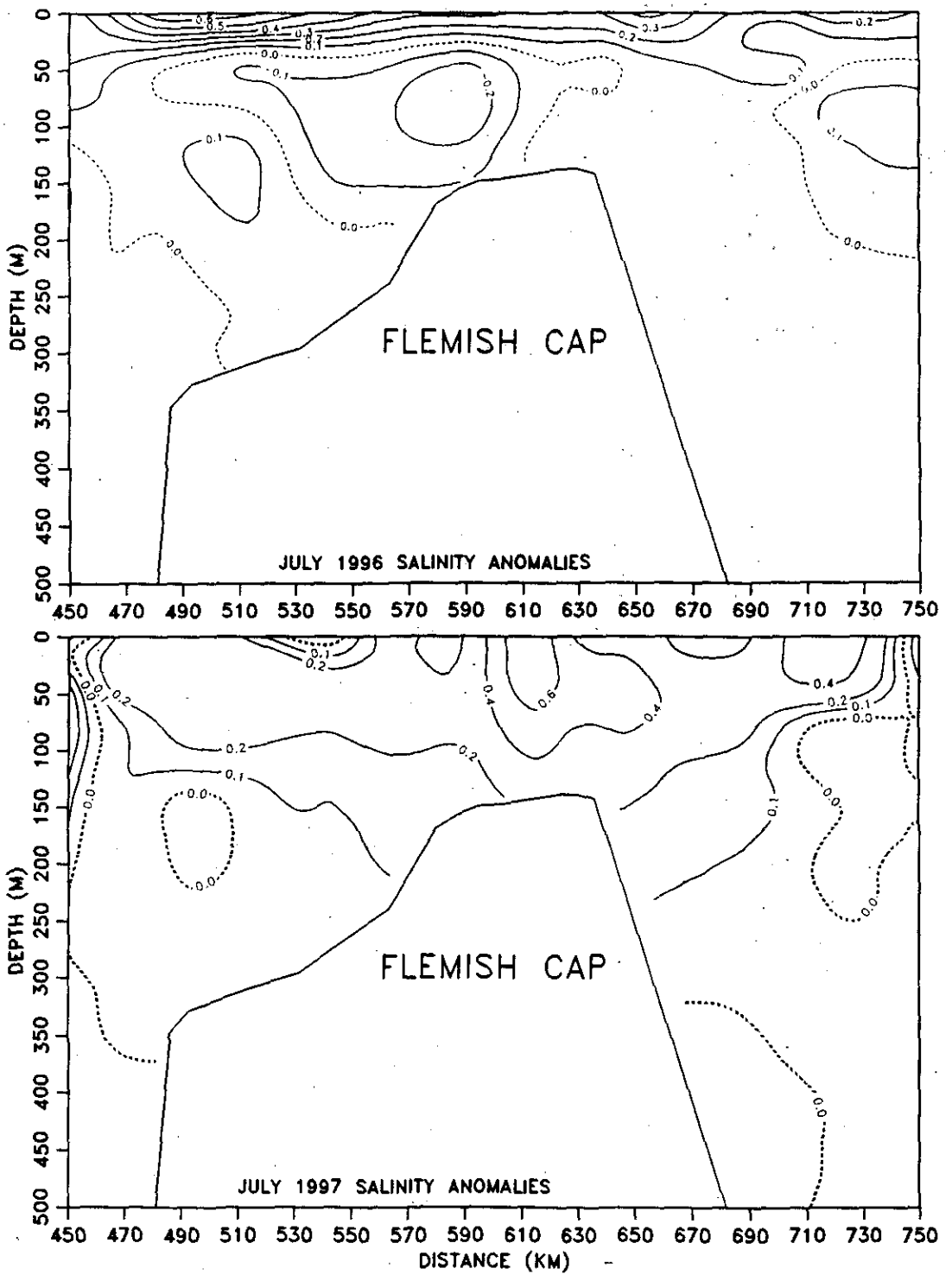

Fig. 6. The vertical distribution of salinity anomalies over the Flemish Cap (along 47° N) for July of 1996 and 1997.

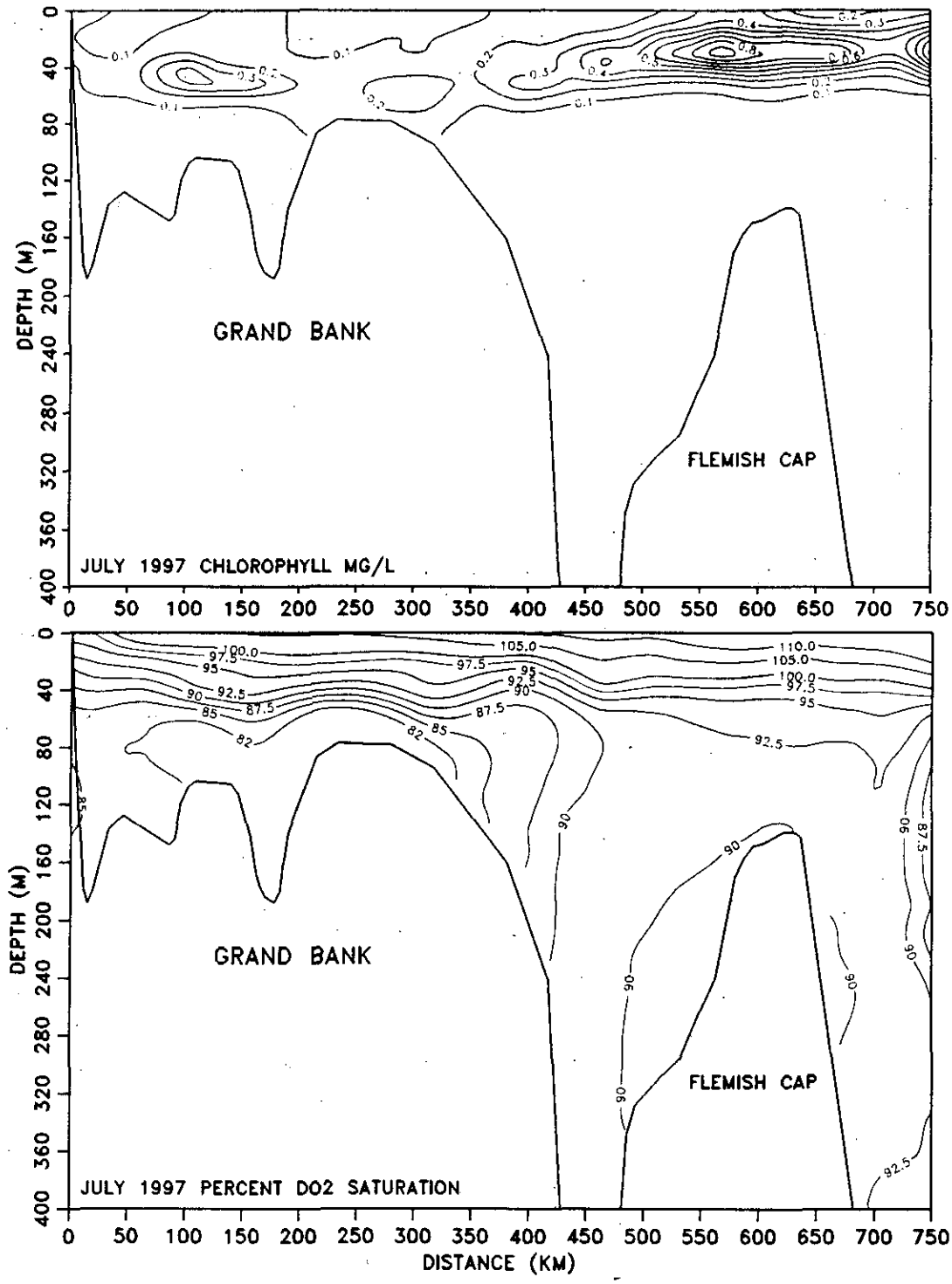

Fig. 7. The vertical distribution of chlorophyll concentrations along the 47° N transect for July of 1997 and the vertical distribution of dissolved oxygen percent saturation along 47° N for July of 1997.

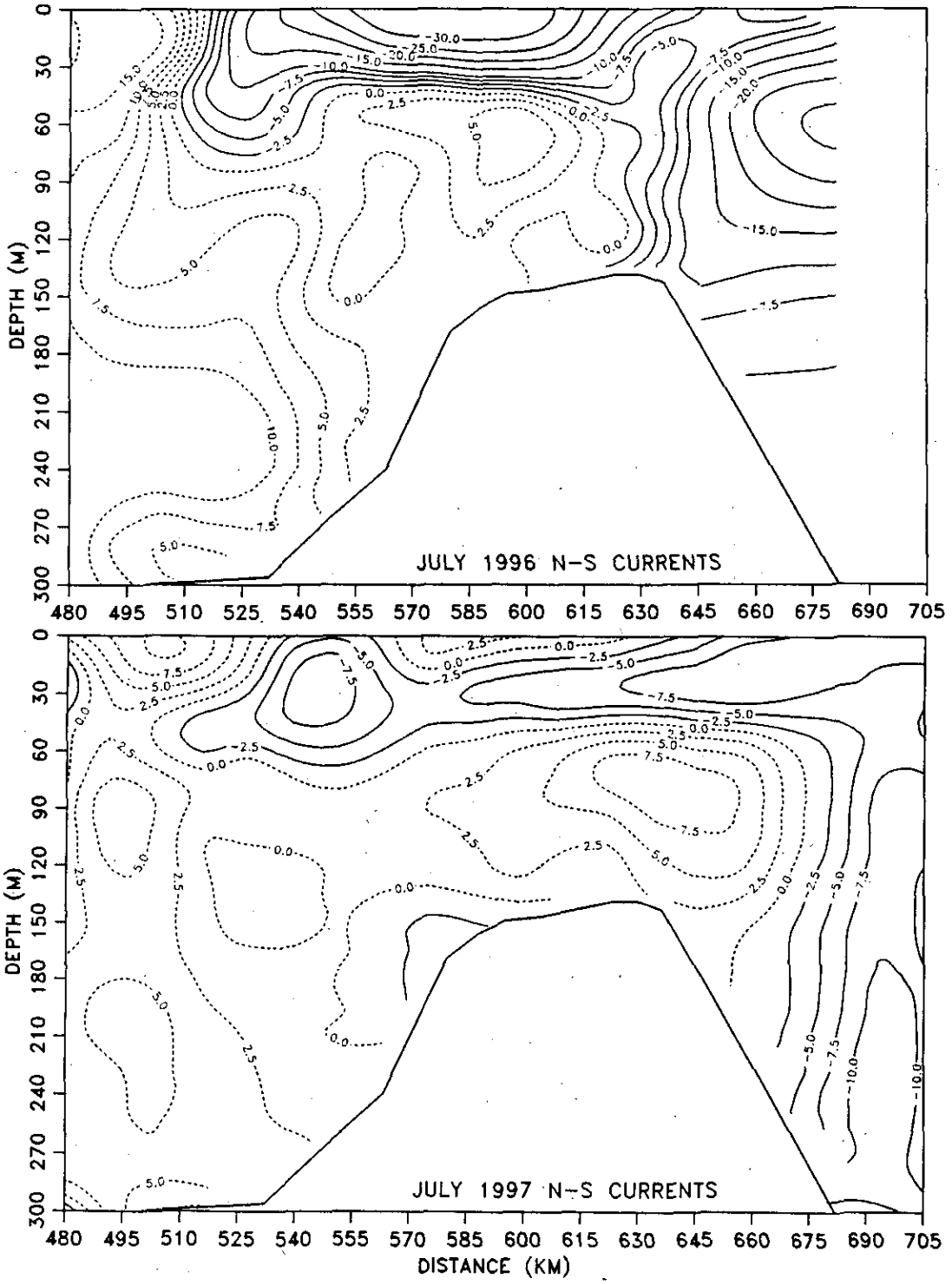

Fig. 8. A vertical cross-section of the N-S current field in cm/s over the Flemish Cap (along 47° N) during July of 1996 and 1997 from a 150 kHz ADCP. Negative currents are southward and positive are northward.

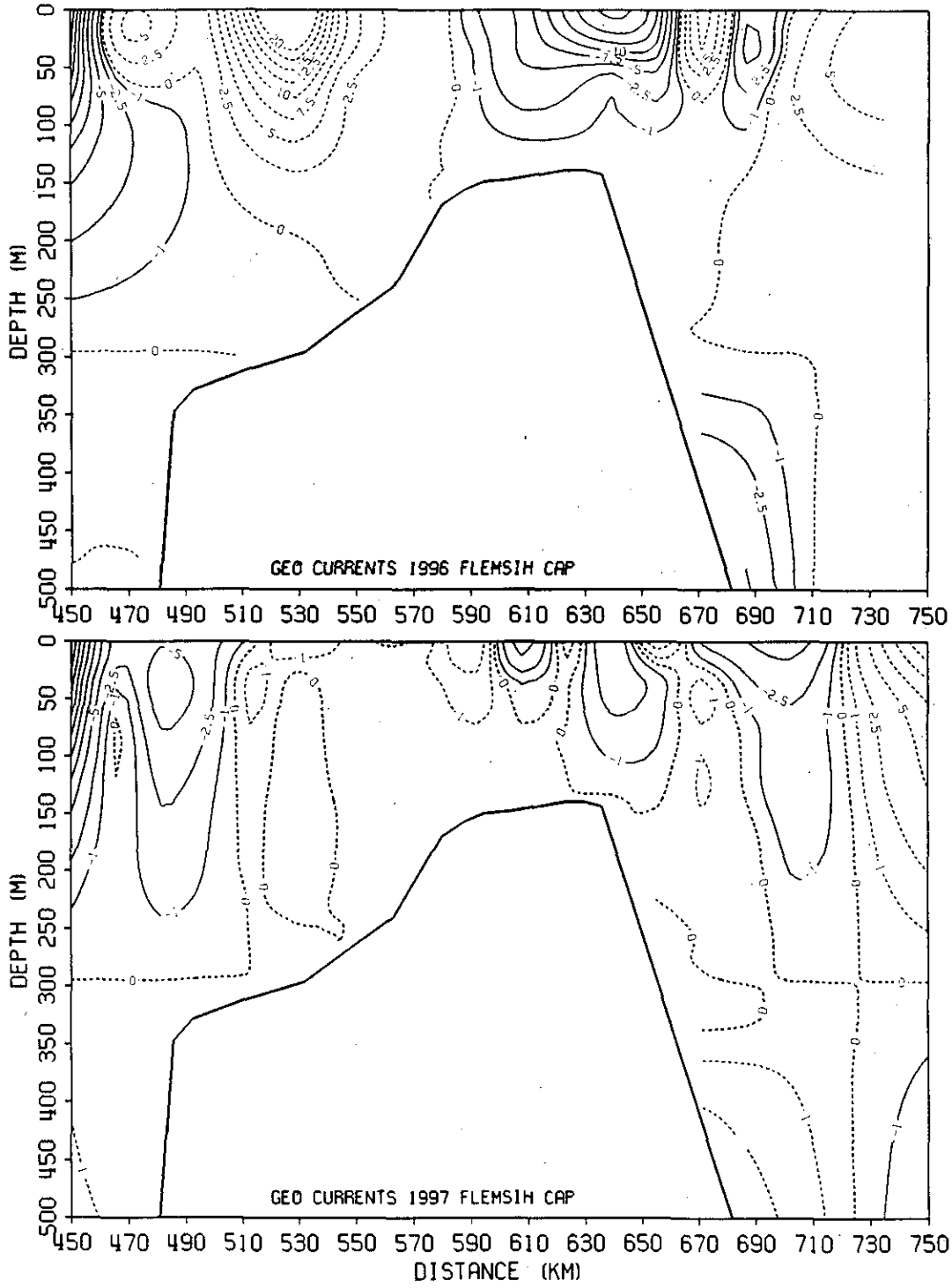

Fig. 9. The vertical distribution of the N-S geostrophic current field over the Flemish Cap during July of 1996 and 1997 calculated from the density data. Negative currents are southward.