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# Oceanographic Conditions on the Flemish Cap During the Summer 1995, with Comparisons to the 1961-1990 Average

by

E. Colbourne

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

## ABSTRACT

Oceanographic data from the summer of 1995 on the Flemish Cap are examined and compared to the long-term (1961-1990) average and to conditions during 1993. The results indicate that the colder than normal temperatures experienced over the continental shelf and on the Flemish Cap since the late 1980s continued into 1995 with some improvement over values experienced in 1993, particularly in the upper water column. In 1995 temperatures were up to -0.5 °C below normal in the upper 50 m of the water column compared to -2.0 °C in 1993 and from -0.5 to -1.0 °C below normal below 50 m depth which were near 1993 levels. Upper layer salinities were above the long-term mean in 1995 and slightly below in 1993, otherwise about normal. Dissolved oxygen levels indicate a well oxygenated water column over the Cap in both 1993 and 1995. Finally, ADCP current measurements show the presence of a general anticyclonic circulation around the Cap in July 1995, however the gyre was not as well defined as indicated in July 1993 data.

## 1. INTRODUCTION

This report describes oceanographic conditions on the Flemish Cap during the summer of 1995 with a comparison 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 1995 observations were made by the Department of Fisheries and Oceans on an oceanographic survey in July aboard the research vessel Parizeau. During this survey 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. 1). Measurements included vertical profiles of currents, temperature, salinity, chlorophyll and dissolved oxygen.

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 et al., 1978, Bailey, 1982, Akenhead, 1981). A more recent review of oceanographic conditions in the region compared 1993 observations with the long-term mean and also presented time series of temperature and salinity anomalies at various depth ranges around the Cap (Colbourne, 1993). This review represents an update to the 1993 report by including data up to the summer of 1995.

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 (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 most of the continental shelf in Atlantic Canada (Drinkwater, 1992). An examination of the temperature and salinity anomaly time series from 1970 to 1993 indicated similar conditions existed in the Flemish Cap region as on the adjacent continental shelf (Colbourne, 1993).

## 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 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 °C at 50 m depth to about 10 to 11 °C near the surface. In deeper water (50 m to the bottom) the temperatures ranges from 2.0 to 3.5 °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 33.5 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 greater than 34.75 psu.

## 3. 1995 TEMPERATURE AND SALINITY

The vertical temperature distribution in July of 1995 along the standard NAFO transect shows temperatures ranging from about 5.0 °C at 50 m depth to about 10 °C near the surface (Fig. 3). In the depth range of 50-100 m temperatures ranged from 5.0 to 2.8 °C along the Flemish Pass in the offshore branch of the Labrador current and about 5.0 to 3.5 °C on the eastern slope of the Cap. In the depth range of 100 m to the bottom temperatures ranged from 2.8 to 3.5 °C. Temperatures along the transect running across the northwestern section of the Cap show similar values below a slightly cooler surface layer (Fig. 4). The corresponding salinities (Fig. 3, 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 34.75 to 34.0 psu across the Cap in the upper 50 m. In the depth range of 50 m to the bottom salinities ranged from 34.0 to 34.75 psu with very small horizontal gradients across the Cap.

## 4. 1995 DISSOLVED OXYGEN AND CHLOROPHYLL

The vertical distributions of dissolved oxygen saturation and chlorophyll concentrations along the standard NAFO transect across the Flemish Cap are shown in Fig. 5. 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.

Dissolved oxygen levels during 1995 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. 5, top panel) ranged from 100 % from the surface to about 50 m depth and from

97.5 % to 90 % in the 50 to 150 m depth range. Below 150 m to the bottom saturation values ranged from 90 % to 87.5 %, slightly lower than that reported in 1993, however these values indicate a well oxygenated water column.

The July chlorophyll concentrations show relatively high values (between 2.0 to 2.5 mg/l) over the Flemish Cap which were confined to a surface layer from 0 m to about 75 m depth (Fig. 5, bottom panel). These values were much higher than values over the adjacent Grand Bank (0.75 to 1.0 mg/l, not shown) along the same transect and may indicate a delayed or extended offshore plankton bloom relative to the Newfoundland Shelf areas.

## 5. TEMPERATURE AND SALINITY ANOMALIES

The vertical distribution of temperature and salinity anomalies for 1995 over the Flemish Cap are shown in Fig. 6. These anomalies were calculated by subtracting the gridded averaged 1961-1990 data from the 1995 transect data (collected on July 18) without any adjustment for temporal biasing arising from variations in the number of observations throughout the month. An examination of the historical data distribution for July shows that about 40 % of the data were collected before July 20 with a median date of July 25. 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 18 to 25 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 into the ocean.

During 1995, in the 0 to 50 m depth range, temperature anomalies ranged from -1.5 °C in the Flemish Pass to -0.5 °C over the Cap and to normal values over the offshore portion of the continental slope (Fig. 6, top panel). In the depth range of 100 m to the bottom over the Cap temperatures were -0.5 to -1.0 °C below normal and about -0.3 °C below normal below 300 m depth. For comparison, during 1993 temperature anomalies in the upper layer were up to -2.5 °C below normal and about -1.0 to -1.5 °C below normal in the depth range of 100 m to the bottom over the Cap. In deeper water (below 250 m) anomalies were generally around -0.5 °C below normal in the Flemish Pass (Fig. 7).

Salinities in 1995 were saltier than normal by 0.2 to 0.4 psu in the depth range of 0 m to 50 m and about normal over the rest of the water column (Fig 6, bottom panel). In contrast 1993 salinities in the upper layer over the Cap were slightly fresher than normal by 0.2 to 0.3 psu (Fig 7, bottom panel) and near normal below 150 m depth.

## 6. 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 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 survey were mapped with a hull-mounted 150 kHz RDI Acoustic Doppler Current Profiler (ADCP) at a spatial resolution of 4.0 m vertically by approximately 1.5 km horizontally. Current measurements were only available in water depths less than 500 in the top 250 m of the water column. Figure 8 (top panel) shows the vertical distribution of the N-S currents over the Flemish Cap on July 18, 1995, negative values correspond to southward flowing water. Over the Flemish Cap the circulation was generally anticyclonic with a northward component ranging from 5 to 10 cm/s over the shoreward portion of the Cap and southward currents over the offshore portion of the

Cap in the upper layer with speeds ranging from 5 to 15 cm/s. The east-west components (Fig. 8, bottom panel) shows a westerly flow over the inshore portion of the cap and a strong easterly component over the outer portion. The anti-cyclonic circulation around the Cap although present was more pronounced in 1993.

**ACKNOWLEDGEMENTS**

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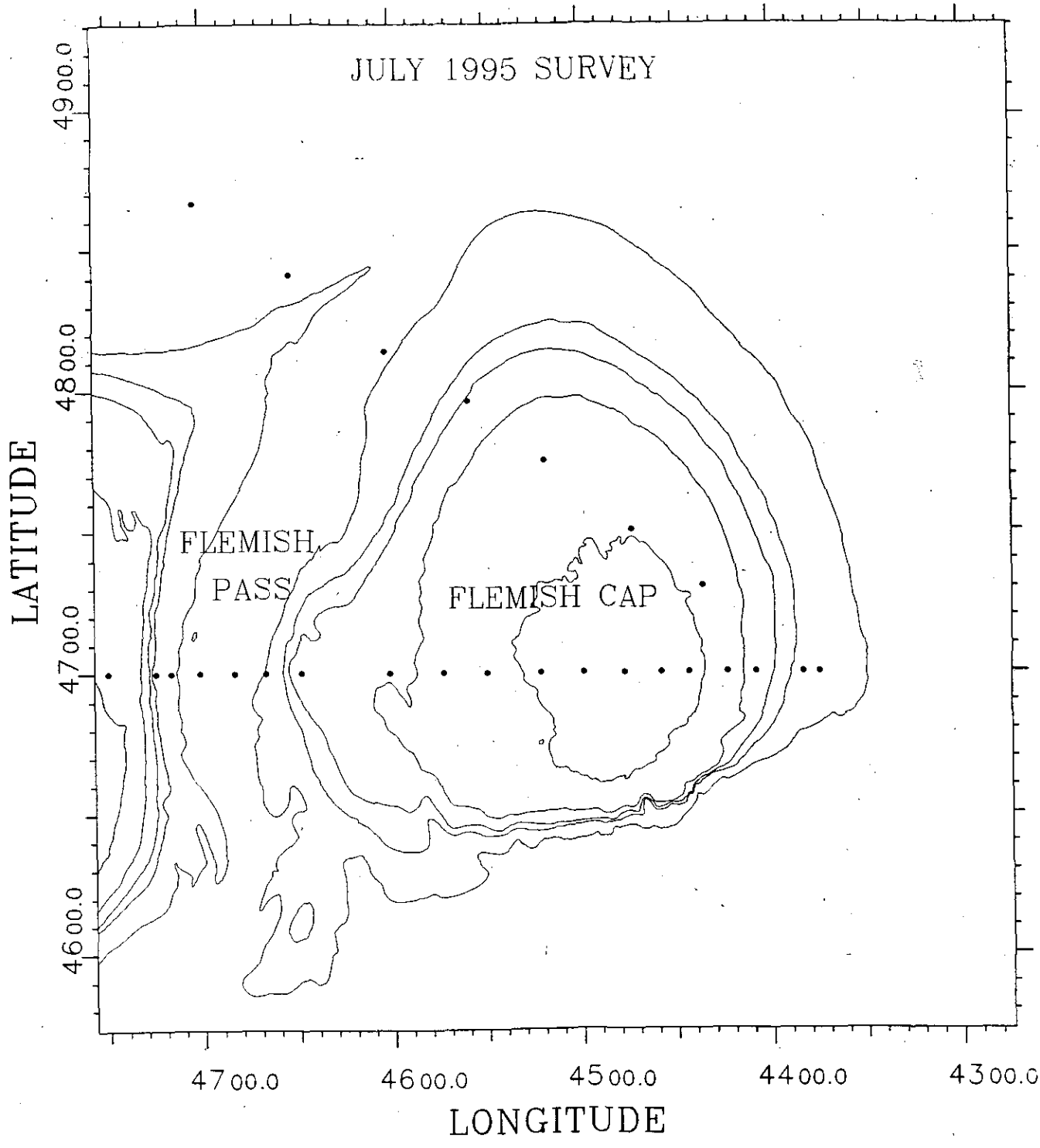


Fig. 1. Location map of the Flemish Cap area showing the stations occupied during the summer of 1995. Bathymetry lines are 1000, 500, 400, 300, and 200 m.

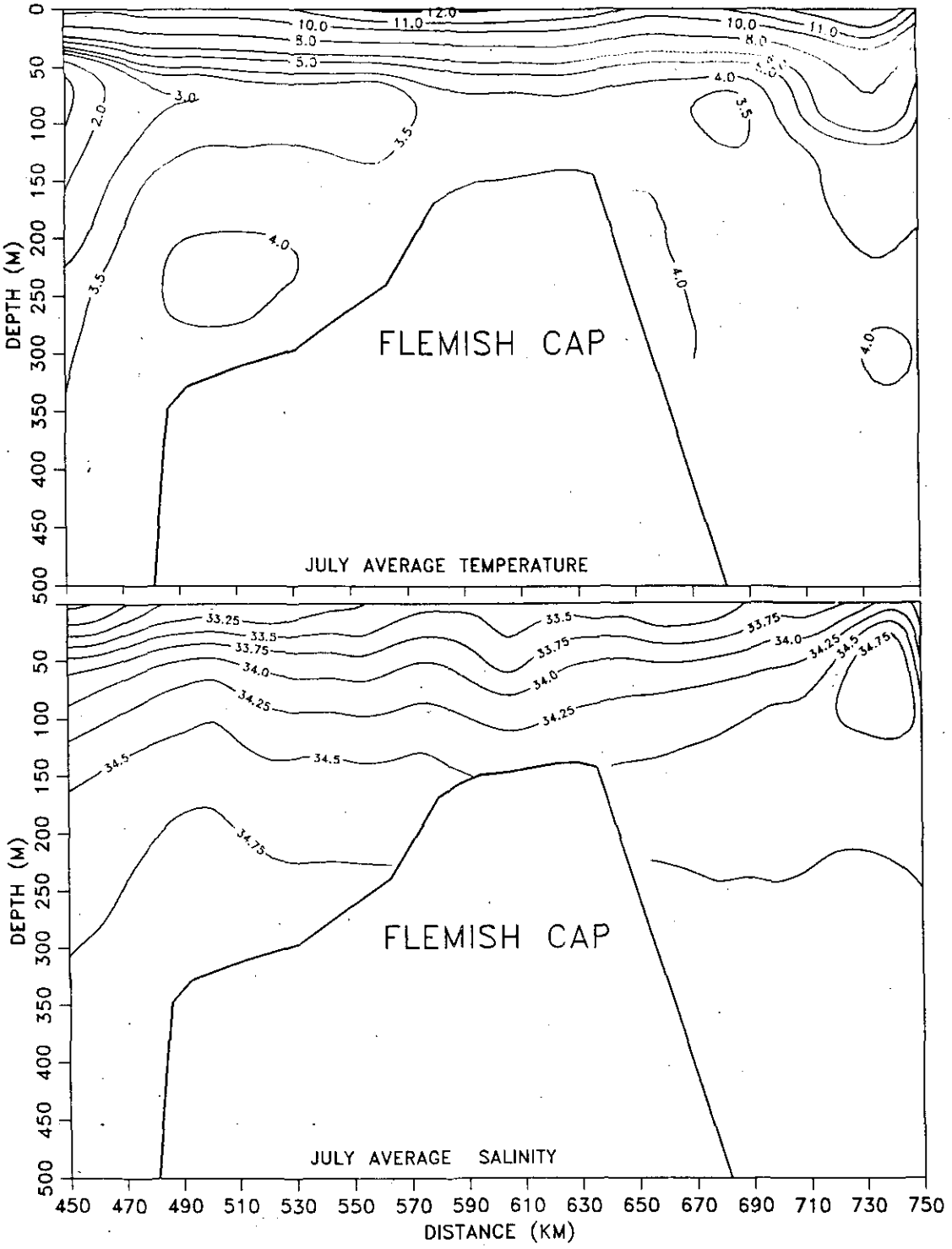


Fig. 2. The vertical distribution of the average temperature and salinity over the Flemish Cap based on all available historical data from 1961-1990.

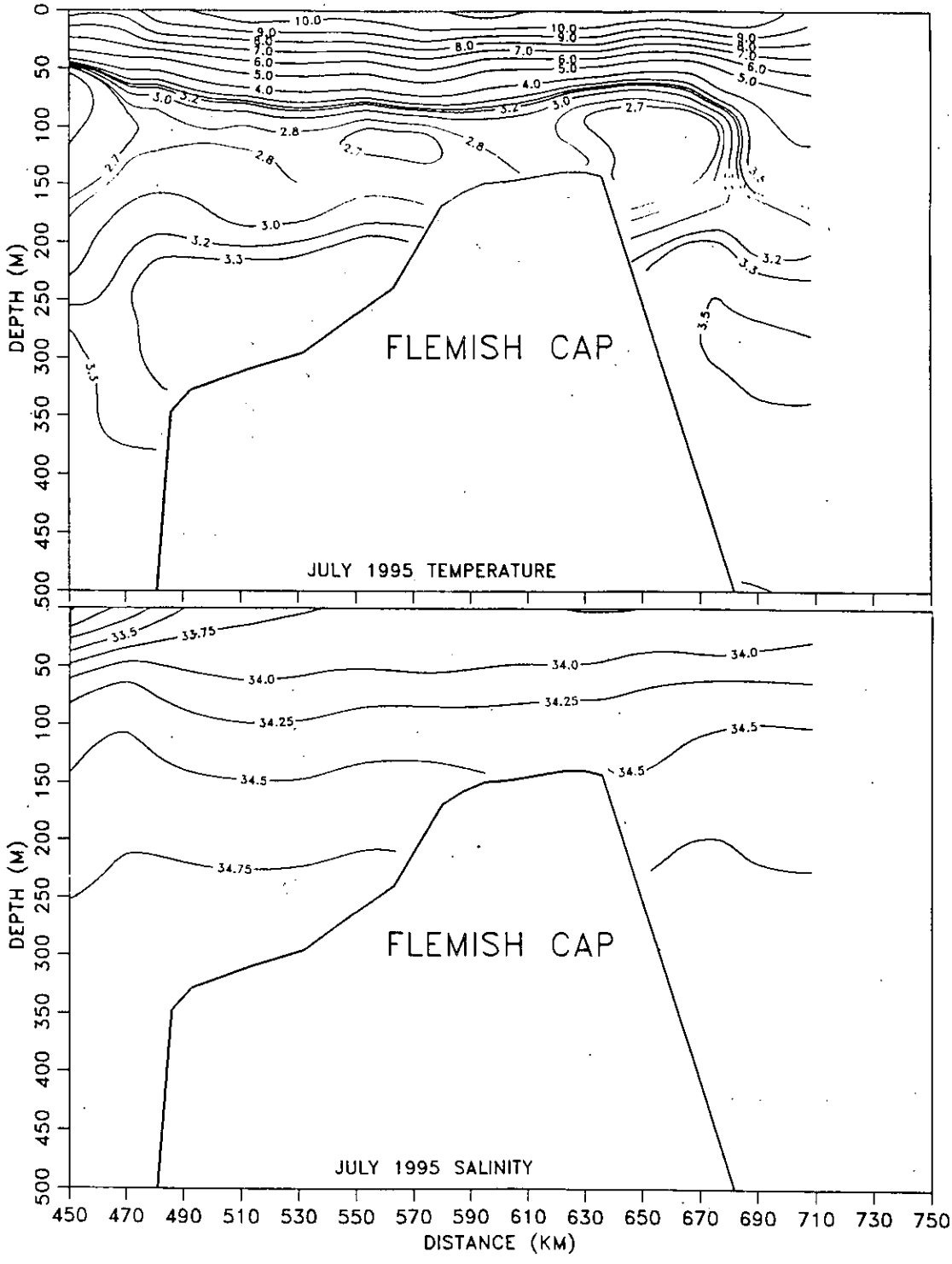


Fig. 3. The vertical distribution of temperature and salinity over the Flemish Cap for July 1995.

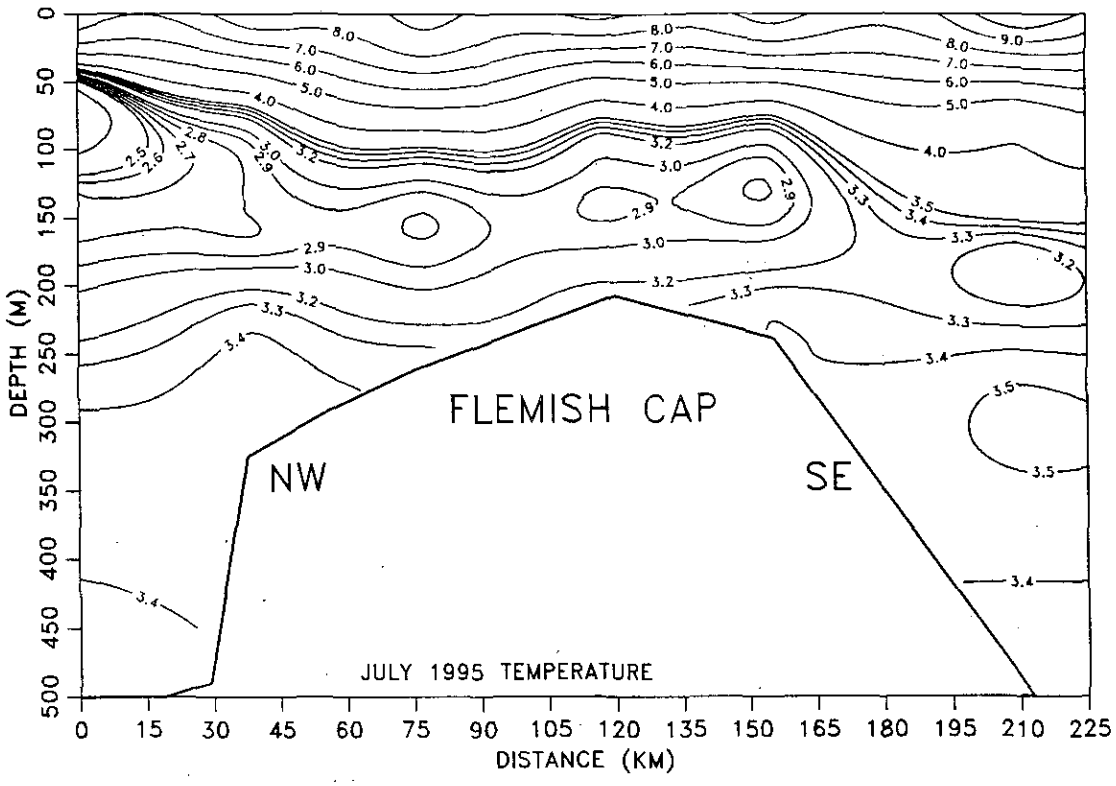


Fig. 4. The vertical distribution of temperature along a transect across the northwestern Flemish Cap for July 1995.

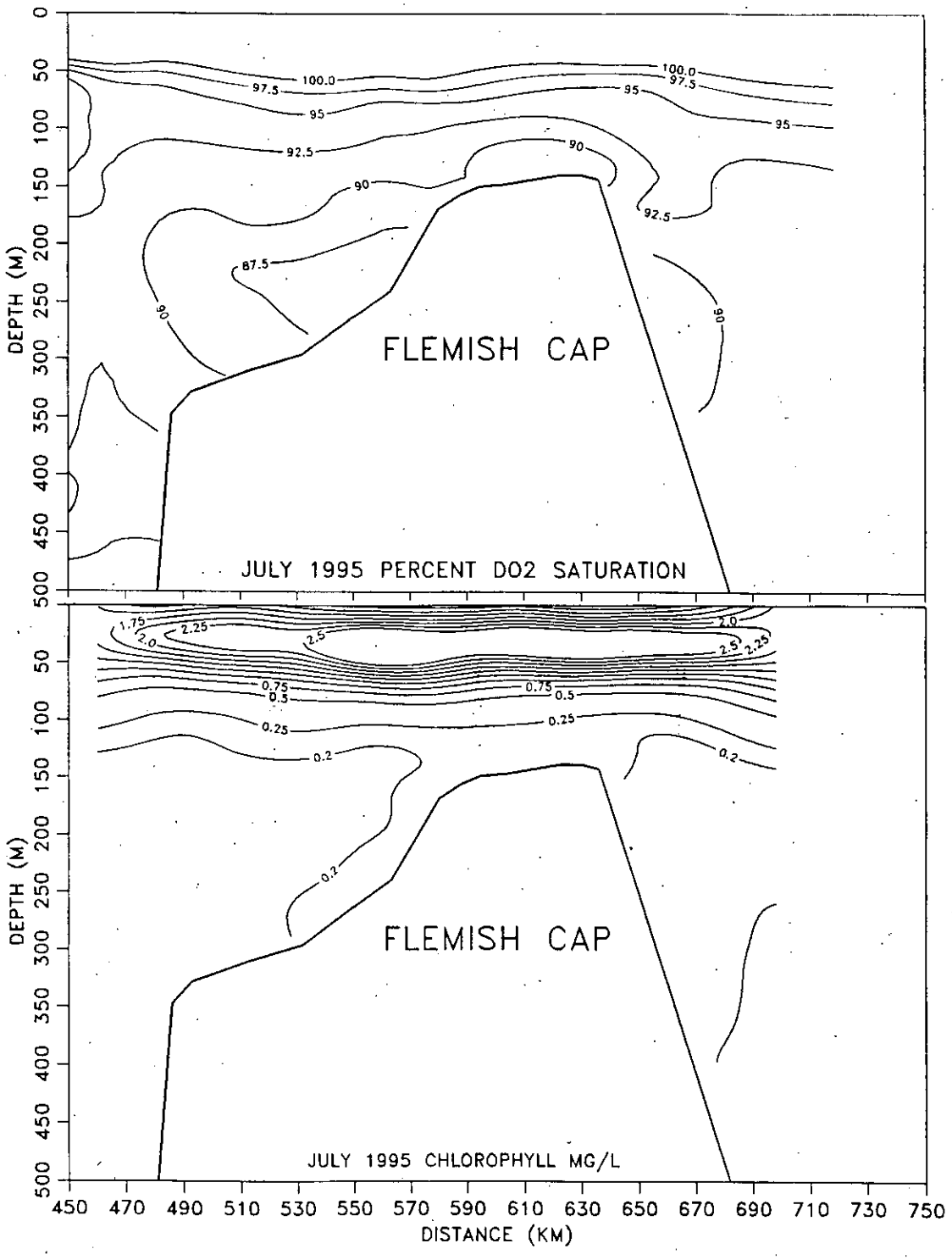


Fig. 5. The vertical distribution of dissolved oxygen percent saturation and chlorophyll concentrations over the Flemish Cap for July 1995.

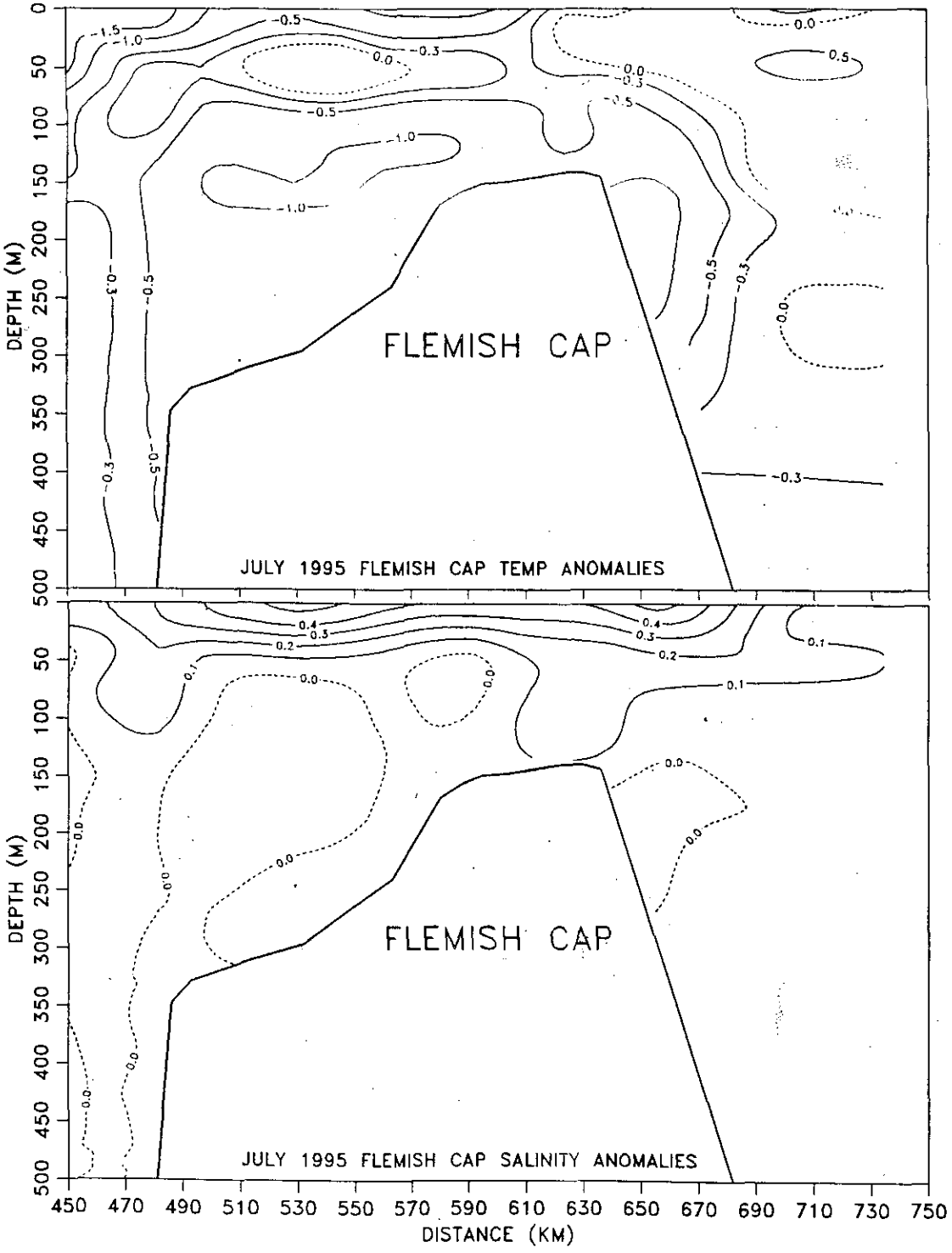


Fig. 6. The vertical distribution of temperature and salinity anomalies over the Flemish Cap for July 1995.

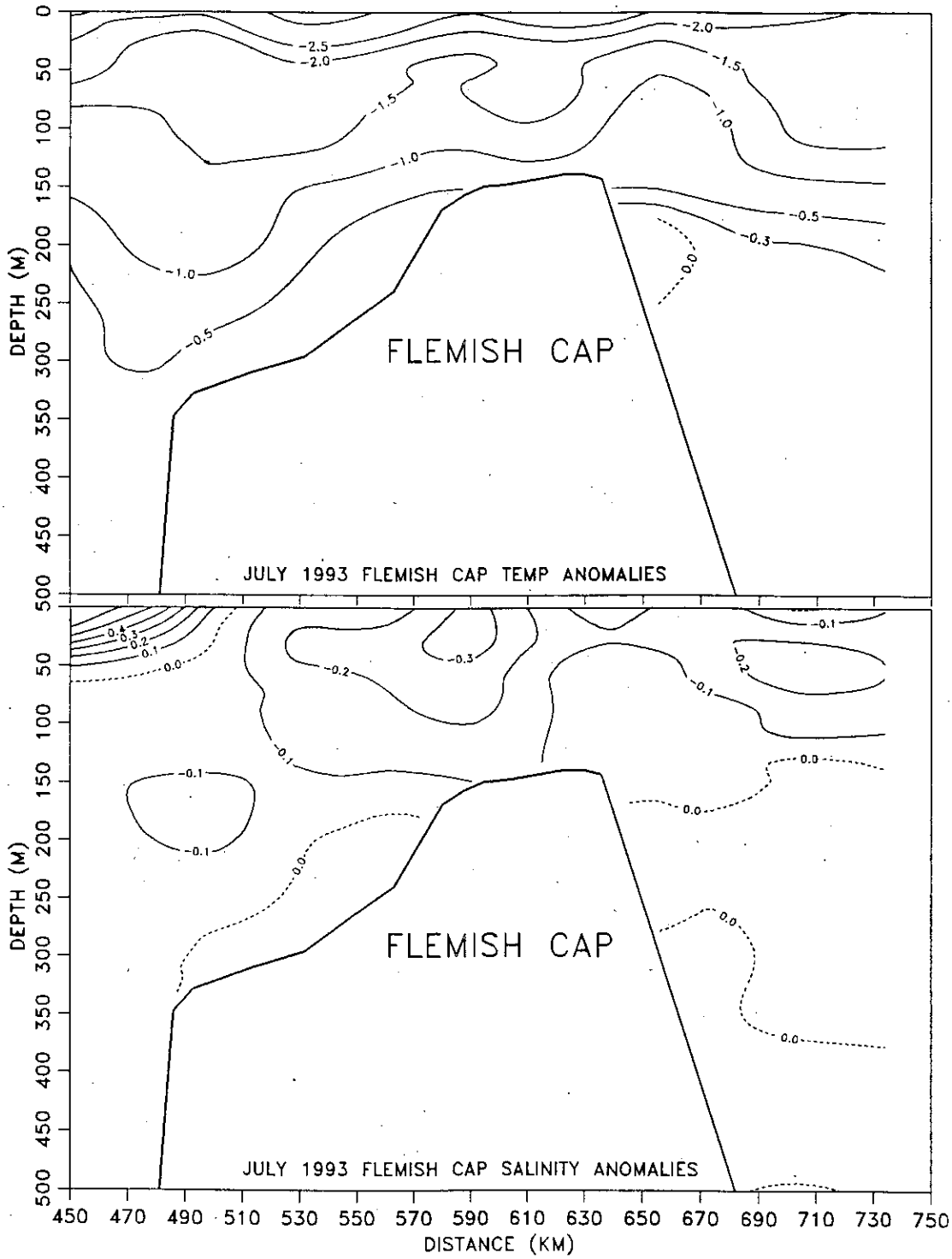


Fig. 7. The vertical distribution of temperature and salinity anomalies over the Flemish Cap for July 1993.

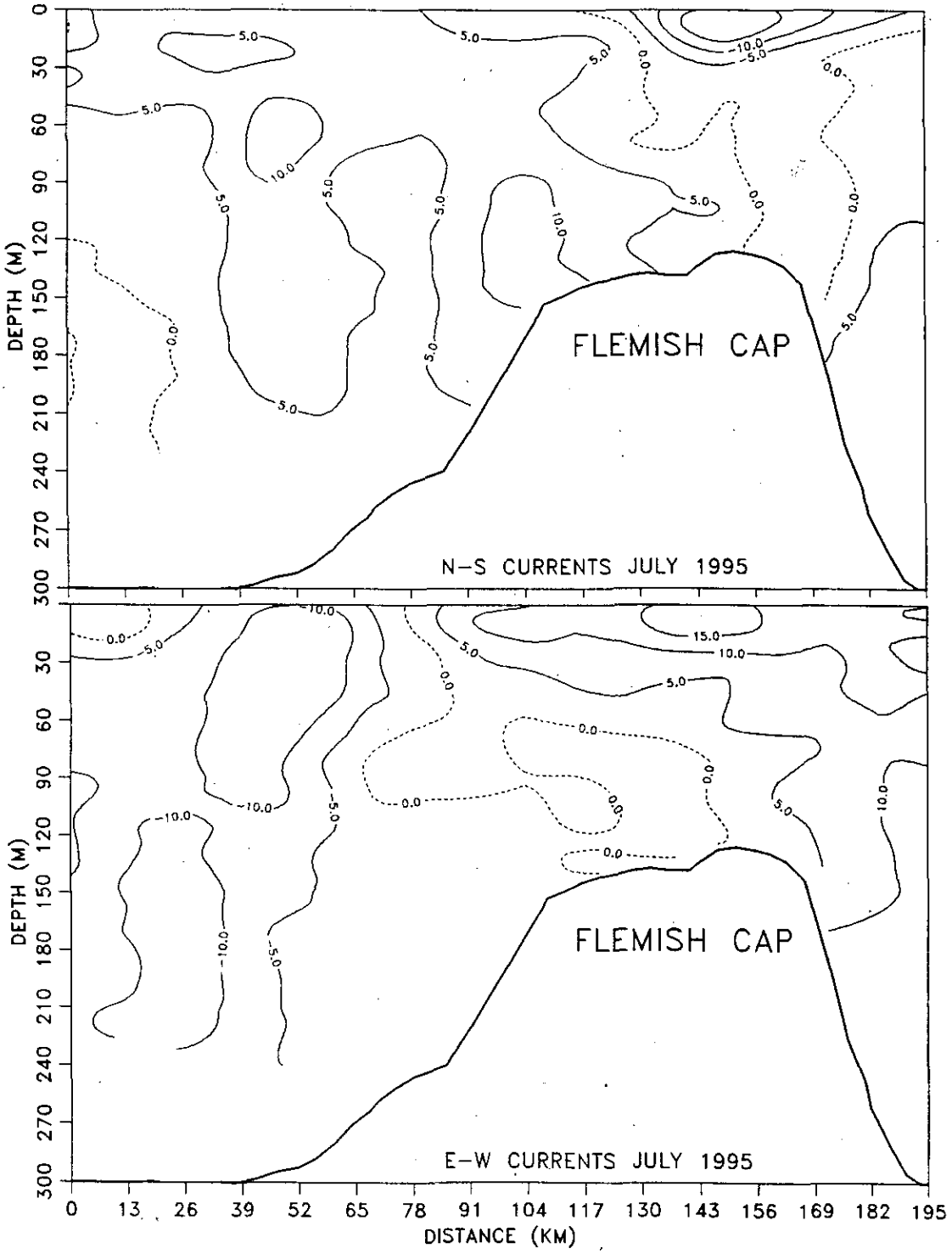


Fig. 8. The vertical distribution of the N-S and E-W current field over the Flemish Cap during July 1995 from a 150 kHz ADCP. Negative currents are southward and westward.