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Hydrographic Conditions on Flemish Cap in July 2001

by

Jose M. Cabanas

Instituto Español de Oceanografia. Centro Oceanográfico de Vigo.
P.O Box 1552. 36280 Vigo, Spain
e-mail: jmanuel.cabanas@vi.ieo.es

Abstract

Hydrographic conditions on Flemish Cap in July 2001 are described after a survey with 94 CTD stations. Current conditions over Flemish Cap are described and compared with those observed in previous years.

The superficial water around the Cap at shallow depth is Labrador Water that advents favoured by the anticyclonic circulation over the cape. Since the middle-1990s temperatures have been increasing until 1999. In 2001 the superficial waters (<100 m) are warmer (+1ºC) and saltier (+0.5) that the mean of 25 past years. In depth, a well-developed layer with temperatures around 3.5ºC and salinity 34.85 was observed all around the Cap over 200 m depth.

Introduction

The Flemish Cap is an isolated bank located east of the Grand Banks of Newfoundland cantered at about 47ºN 45º W, with 95 Km radii, 28 000 Km^2 surface and average water depths of 280 m (Fig. 1). To the west, the Flemish Pass with maximum water depths of about 1 100 m separates the Cap from the Grand Bank. The water mass over the Flemish Cap is a mixture of Labrador Current and North Atlantic Current water.

The general circulation of water masses in the area is determined by the confluence of Labrador Current (LC, waters with 3-4ºC and 34-35 salinity), and the North Atlantic Current (NAC, >4ºC and >34.8). In the Northwest of Flemish Cap, the offshore branch of LC, that flows southwards, is divided into two branches, one continues southwards through Flemish Pass and the other surrounds the bank by the East. The NAC flows northwards surrounding the 4 000 m isobath in the South and East of Flemish Cap (Krauss *et al*., 1987). On the centre of the Cap, the general circulation is usually anticyclonic. 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, as cod, redfish and shrimp (Kudlo and Borovkov, 1977; Kudlo and Boytsov, 1979).

The anticyclonic motion of the water mass around the Flemish Cap was described by Kudlo and Burmakin (1972) and Kudlo *et al.* (1984) using geostrophic currents estimated from density measurements. The geostrophic currents perpendicular to the 47ºN transect calculated from the density data collected during the July of 2001 are shown in Fig. 6. These estimates, referenced to 200 m, shows some of the well-known features of the circulation over the Cap showing evidences of anticyclonic circulation in summer 1996 (Colbourne, 1997), summer 1998 (Gil *et al*., 1999), summer 1999 and 2000 (Colbourne, 2000).

Time series of temperature anomalies on Flemish Cap at standard depths (0, 20, 50, 100 m) shows three main cold periods: the 1970s, the late-1980s and early-1990s. Temperatures have been warming since 1995 in the top 100 m to above normal conditions. At 100 m depth temperature was about 1ºC under normal in the early-1990s; temperature increased until about 1ºC above normal from 1995 in 1999 (Drinkwater *el al*., 2000). In summer 2001, surface temperature decreased with respect to those of 1999 reaching values near normal

In the upper 100 m layer, thermohaline properties on the centre of the Cap are mainly derived from Labrador Current waters modified by the gyre retention and the atmospheric influence (Akenhead, 1986). In deeper waters, where temperature generally ranges from 3'5 to 4ºC, there is a mixture between the cold and relatively low salinity of Labrador Current waters and the warmer high salinity of North Atlantic waters. Other recent surveys with wider spatial coverage show that temperatures higher than 4ºC were frequent under 100 m depth in the summer of 1998 and 1999 (Garabana *et al*., 2000) giving more weight to the influence of North Atlantic waters in the warming of the Flemish Cap deep waters in the last years.

This paper shows the hydrographic conditions on Flemish Cap in July 2001 compared with those observed in summer 1999 and 2000.

Materials and Methods

In July 2001 a stratified random bottom-trawl survey was carried out on Flemish Cap on board of R/V Cornide de Saavedra. The survey was performed from July 3rd to July 20th following the same method that has been used since 1988 (Vázquez, 2000). A total of 120 CTD station was established to cover all the survey area (Fig. 1).

The CTD probe used was a Sea Bird, SBE 19, provided with pressure, temperature and conductivity sensors. It was dropped at a speed of 1m/s and it was configured to acquire two samples per second, down to a maximum depth of 410 m. Its calibration parameters had been checked before the cruise and data were processed according to standard techniques (Unesco, 1991).

Results

Temperature and salinity distribution charts at different depths: 10, 50, 100 and 200 m (Fig. 2, 3); vertical temperature and salinity distribution along two transects; one in N-S direction near the 45º W meridian and the other in W-E direction near the 47º N parallel (Fig. 4); TS diagram (Fig. 5) and Dynamic Height relative to 100 and 200 m depth (Fig. 6) where built.

Horizontal temperature distribution at different depths (Fig. 2) show that near the surface (10 m) temperature reaches 12ºC in the central part of the bank and decreases northwards with values below 9ºC. At 50 m, temperature ranges between 3ºC and 6 ºC. At 100 m depth, temperature ranges from 3ºC in the North to 5.5ºC in the Southwest. At 200 m depth, with the same pattern as 100 m, temperature ranges between 3.4ºC and 4.6ºC. In the 200 m upper layer, warmer values are found in the central and South-western region of the bank, and colder ones appear in the Northeast.

Horizontal salinity distribution (Fig. 3) at 10 m depth that salinity ranges between 33.7 in the West and 34.2 at the Southeast; at 50 m depth it ranges between 34.1 and 34.6 with lower values in the centre; at 100 m ranges between 34.2 in the centre of the Cap and 34.7 in the rest; at 200 m salinity as 34.6-34.9. In general, it was observed that at surface, fresher water (33.7) comes from the Northeast and salinity increases with depth reaching 34.85 at 200 m.

Vertical distribution of temperature and salinity (Fig. 4), show in the S-N transect a strong gradient in the upper 30 m and that decreases towards deeper waters getting 3.5ºC at about 70m depth where a cold water tongue of 60 m thickness that was detected; below the tongue the temperature increase to 4ºC. Salinity increases progressively from 33.90 in surface to about 34.85 at the bottom. In the W-E transect a similar pattern was observed and the tongue of cold water (t<3.5ºC) are on the eastern part of the bank. Surface water is saltier in the eastern part and in depth salinity increase gradually until 34.8 near the bottom in a similar way as that observed in the other transect.

Figure 5 shows the TS properties for waters over the Flemish in 2001. The typical Labrador Water with less than 4ºC and about to 34.85 are dominant in waters deeper than 100 m where also North Atlantic Water (t>4ºC) was detected.

The Dynamic Height in surface respect to 100 and 200 m level, Fig. 6, show high values in the western part of the cap and low values in the eastern part and the boundaries; these induces an anticyclonic circulation over the cap centered in the western part with currents of 3.5 cm/s at 10 m and 1.3 cm/s at 50 m.

Respect to historical data over the north slope of the Flemish Cap, the July 2001 temperature had little negative anomaly (-0.18ºC) and positive (0.32) in salinity. Respect to previous years, Table 1, temperature at the surface was slightly coldest; between 25 and 100 m are warmest due to the intrusion of cold water was less intense this year, and from 100 to 400 m are coldest that the year 2000. Respect to salinity, in year 2001 the upper 100 m are most salty and below are quite similar.

Discussion

The anomalies annual in the thermohaline properties in 2001 respect to historical mean are small and lesser than previous years.

The fresh and cold water from the Labrador Current that flowing at intermediate depth from the North, heated in surface by the atmosphere, is the main responsible of the thermohaline properties of upper Flemish Cap waters. Below 150 m the temperature and the salinity increase by mixture with the nearby North Atlantic water, warmer and saltier, that flows northwards surrounding Flemish Cap.

As previous years, in summer 2001 the cap effect (Akenhead, 1986) is observed in the centre of anticyclonic gyre where the surface water is warmer and fresher. Between 70 and 120 m depth temperature gets the lowest values coinciding with the incoming Labrador Current (typical LW is colder than 4ºC). From 120 m to the bottom, all around the Cap, the temperatures increase to 4ºC due to a mixture between Labrador and North Atlantic water.

Acknowledgements

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Table 1 – Water temperature (ºC) and salinity in Flemish Cap in 1999, 2000 and 2001.

Depth	1999		2000		2001	
	Temperature (º C)					
	mean	**range**	**mean**	**range**	**mean**	**range**
10	11.23	9.24 - 12.86	11.89	9.04 - 14.81	10.19	8.60 - 12.0
25	8.86	3.83 - 12.33	6.46	2.59 - 12.21	8.91	5.71-11.07
50	4.64	0.79 - 10.24	3.26	0.81 - 5.75	4.31	3.03 - 6.56
100	4.22	1.99 - 6.51	3.20	1.37 - 4.62	3.46	2.98 - 5.62
200	4.06	3.30 - 5.11	3.96	3.33 - 5.03	3.84	3.34 - 4.62
300	3.90	3.63 - 4.32	4.03	3.50 - 4.92	3.85	3.66 - 4.41
400	3.76	3.48 - 4.11	3.85	3.55 - 4.03	3.72	3.61 - 3.88
	Salinity					
	mean	**range**	**mean**	**range**	**mean**	**range**
10	33.41	33.03 - 33.82	33.03	32.60 - 33.40	33.92	33.65 - 34.25
25	33.61	33.06 - 34.53	33.50	32.91 - 34.08	34.09	33.79 - 35.05
50	34.04	33.14 - 34.38	33.86	33.50 - 34.27	34.30	34.12 - 34.66
100	34.39	34.04 - 34.64	34.27	33.93 - 34.58	34.37	34.20 - 34.69
200	34.70	34.59 - 34.87	34.69	34.52 - 34.80	34.73	34.60 - 34.86
300	34.80	34.69 - 34.87	34.83	34.76 – 34.91	34.83	34.70 - 34.90
400	34.82	34.78 - 34.86	34.84	34.82 – 34.86	34.85	34.84 - 34.87

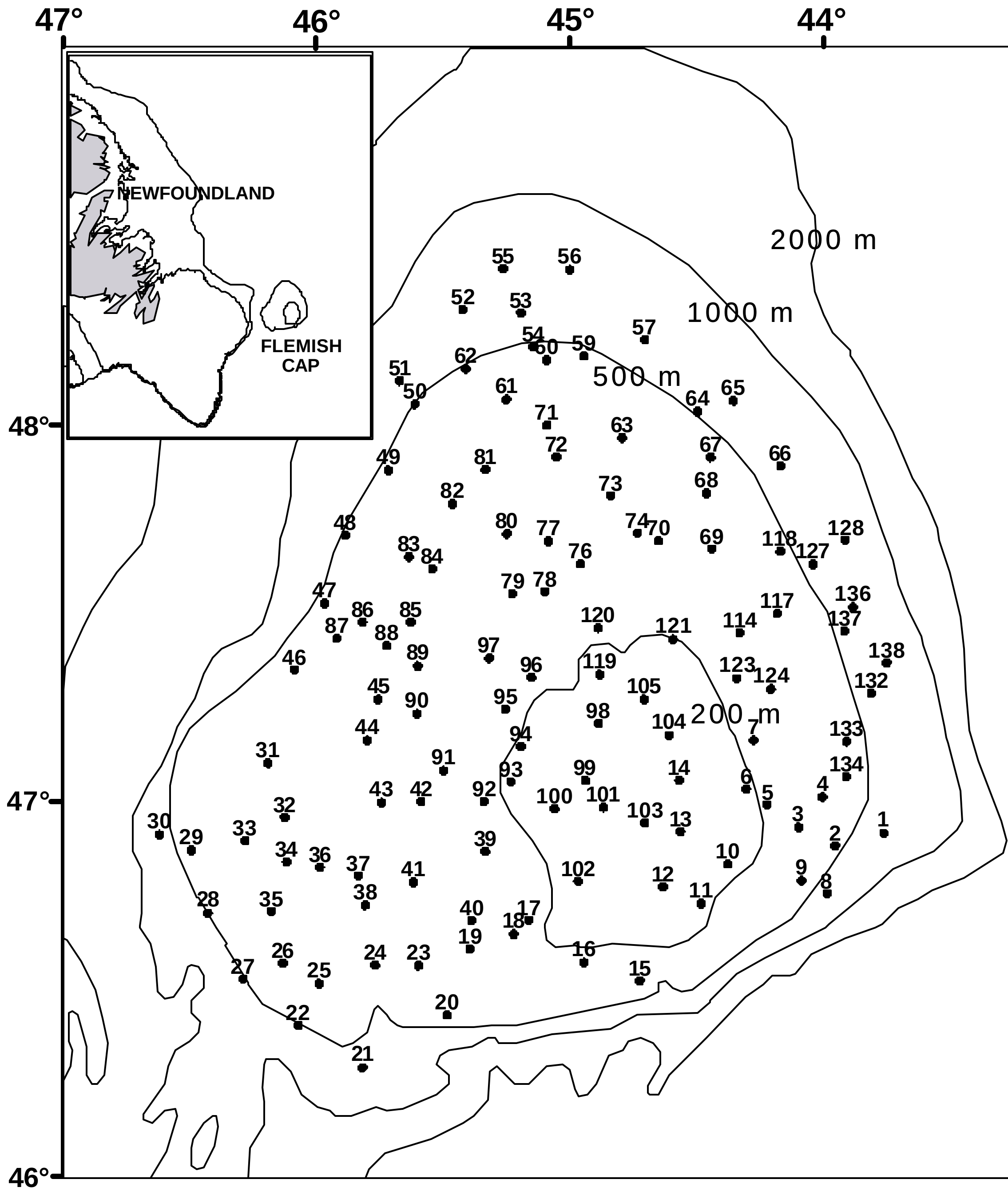

Figure 1 – Location of CTD stations.

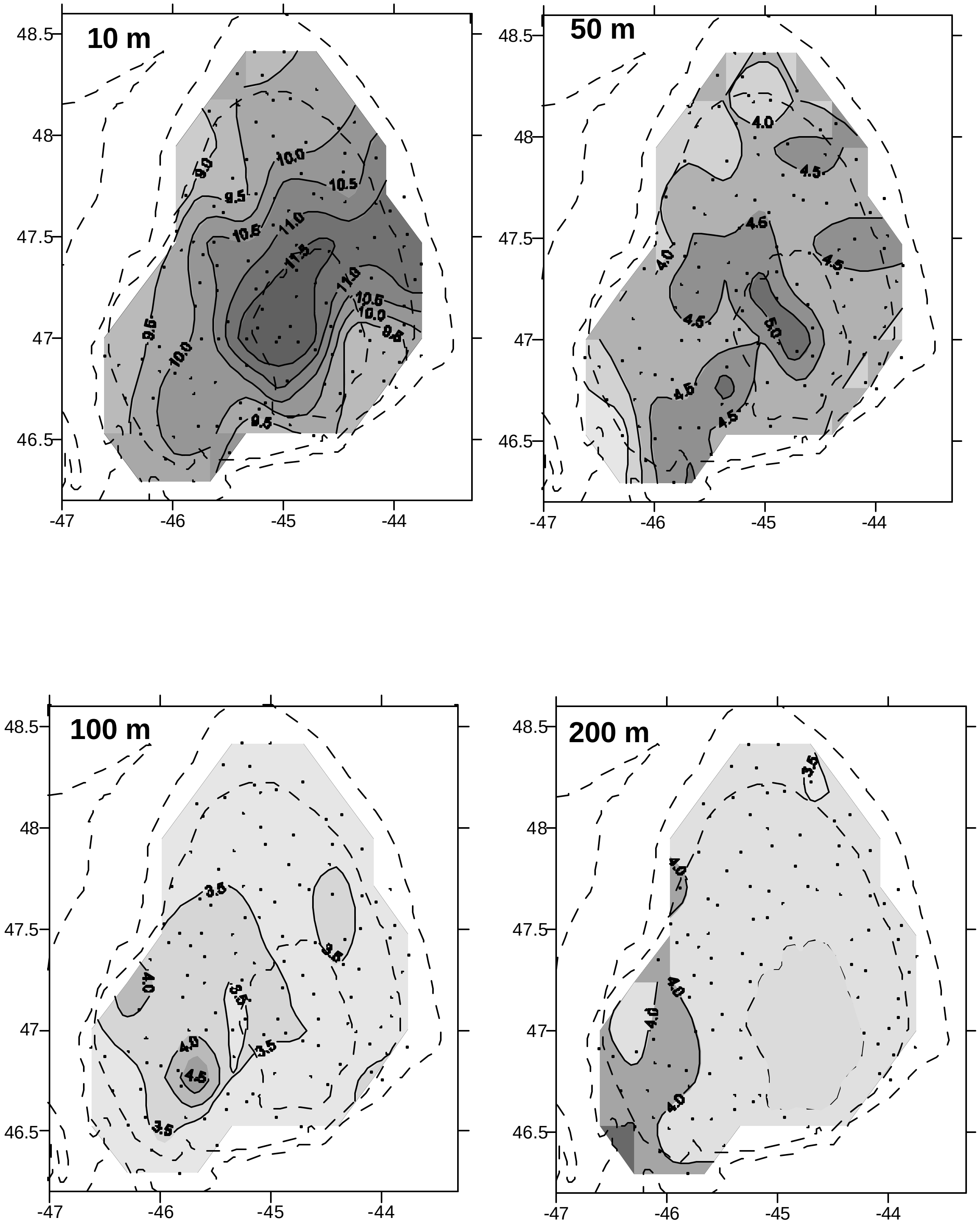

Figure 2 – Distribution of Temperature at several depth.

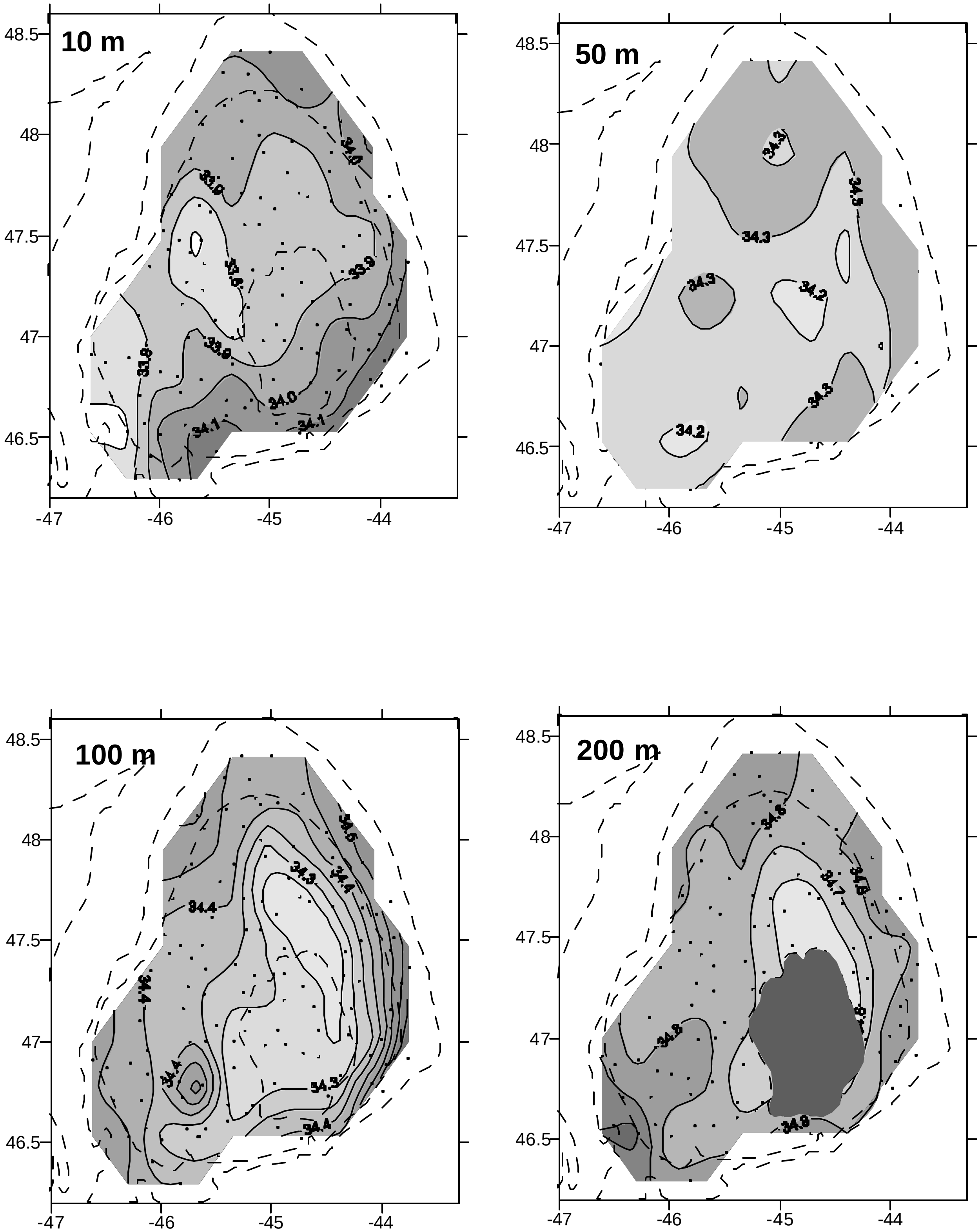

Figure 3 – Distribution of Salinity at several depths.

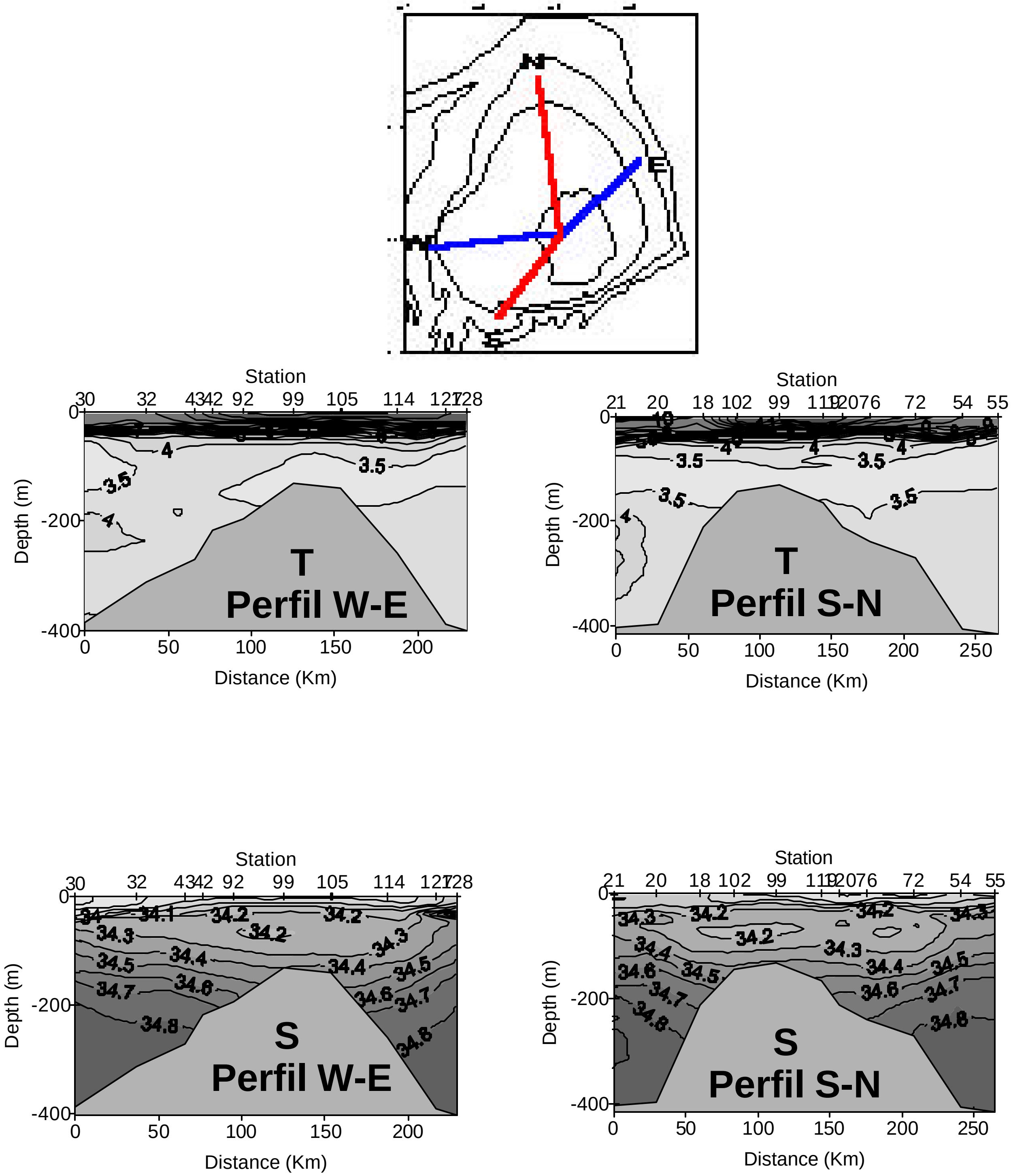

Figure 4 – Distribution of Temperature and salinity in transects.

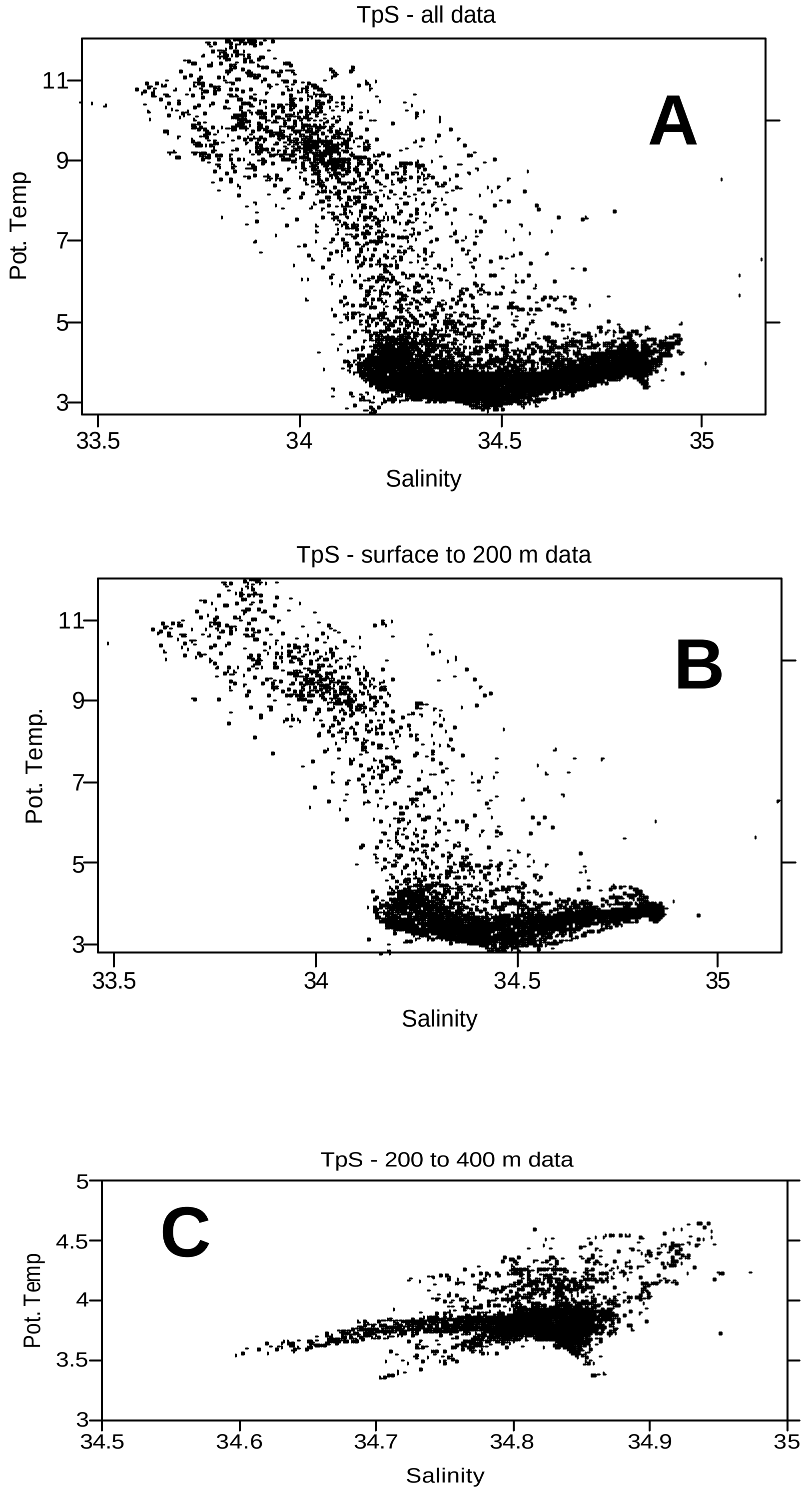

Figure 5 – TS diagram for all stations and depths (A); 0-200 m (B), 200-400 m depth (C)**.**

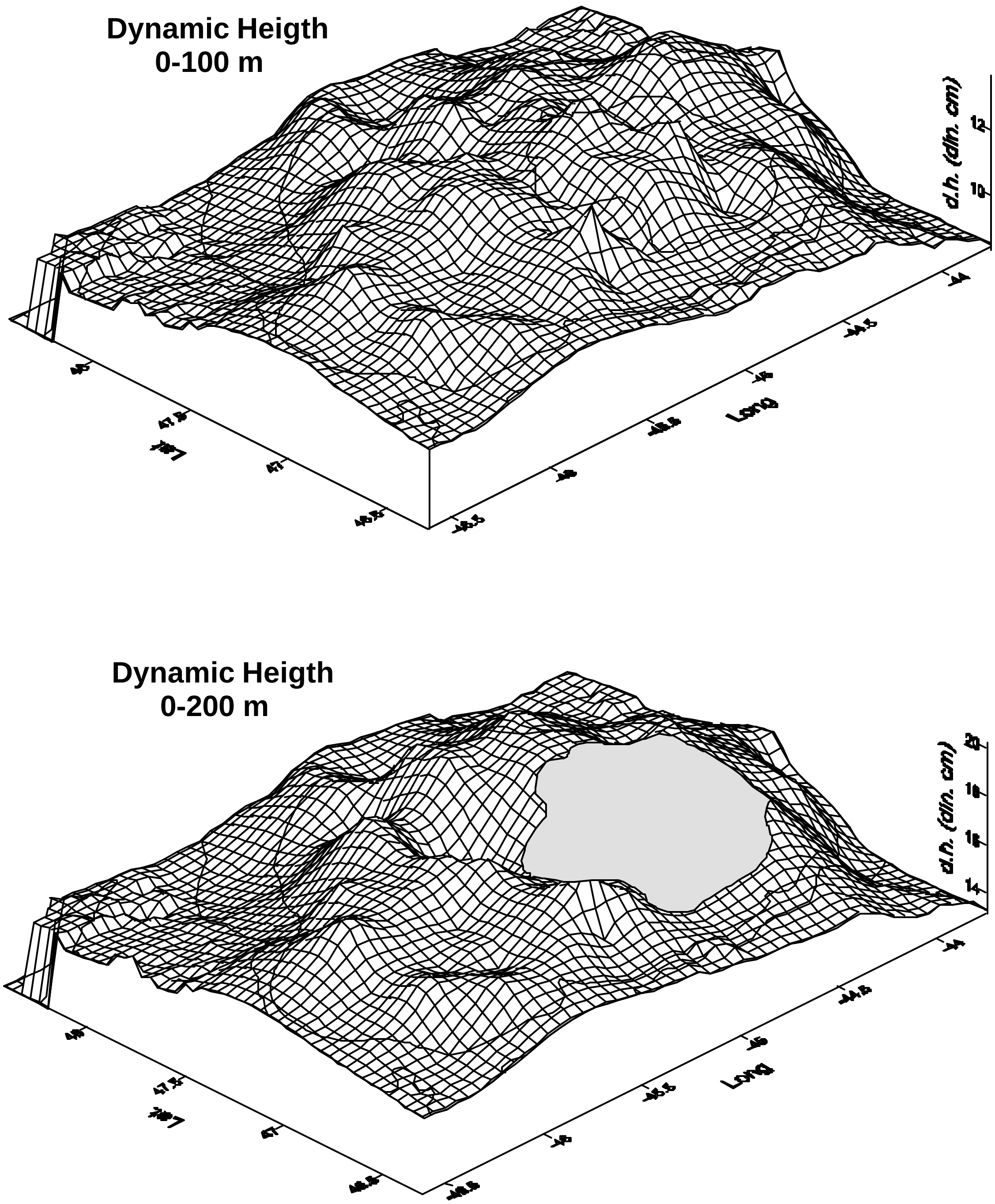

Figure 6 – Dynamic height 0-100 m and 0-200 m.