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ECOHYDRODYNAMICAL STUDY OF THE LIGURO-PROVENCAL FRONT (CORSICA)
I. HYDROLOGICAL DATA.

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ABSTRACT

Hydrological measurements (temperature, conductivity, salinity, etc...) have been realized in 1982 and 1984 along the Calvi-Nice axis from Corsican coast to 35 miles offshore. These data have shown a thermohaline front separating low saline coastal waters of atlantic origin from high saline offshore waters of eastern deeper origin.

A succession of divergences and convergences is associated to that discontinuity. During the spring, the front is emphasized and the water upwellings reach the surface. During the summer, the upwellings are limited by the vertical stratification but an isopycnal inclination is always observed from the front to the coast.

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Introduction

In the oligotrophic offshore sea waters, the biological production in mainly influenced by discontinuity zones, as front and thermocline. In Liguro-provençal area, for instance, the front at the edge of the continental shelf forms a boundary between the general circulation and the shallow waters circulation, limiting the lateral diffusion. The vertical motions associated to frontal phenomenon bring back to the surface nutrients rich waters increasing the biological productivity (see PRIEUR, 1981). On the other hand produced biological material is exported perpendicularly to the front and far from it. Since a few years, ecohydrodynamic studies are led in the Corsican area of the Liguro-provençal front by University of Liège (*) at Stareso Station in Calvi with Cdt Bruneau and Dr Bay assistance.

These studies are integrated in an international program directed by L. Prieur, chief scientist (Station zoologique of Villefranche-sur-Mer, France).

General circulation

The Mediterranean is a deep semi-enclosed sea with low range tides. So the water circulation is mainly generated by the exchange with atmosphere. The evaporation exceeds precipitations and river runoff. The water balance is negative and in this concentration basin, the deficit is compensated for by an important flux through the Strait of Gibraltar.

The Atlantic surface waters (0-100 m) of low salinity flow eastwards along the Nord African coast; one branch goes north to the Liguro-provençal basin (Fig.1) where a large cyclonic circulation is obvious (BETHOUX, 1980).

During the summer, heating of surface layers leads to a seasonal thermocline formation. During the winter, cooling by dry and cold continental winds and difference between air and sea temperatures generate an important evaporation and a heat transfer from the sea to the air. The density of surface waters increases

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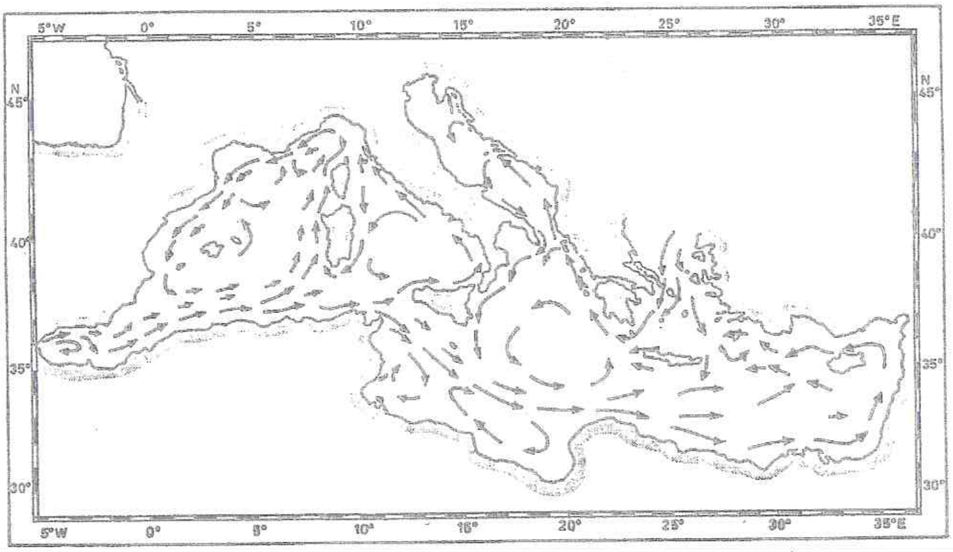

Fig. 1 : Summer superficial circulation (after LOFFET 1981).

and an instability is induced. The mixing and convection give rise to deep waters especially in Levantine basin and in Adriatic Sea (GASCARD,1978). These denser waters formed during the winter in the Levantine basin cross the Strait of Sicily and form in Liguro-provençal basin an intermediate layer (at between 100 and 600 m depth) of high salinity. That water exhibits also a cyclonic circulation.

Deeper layers (more than 600 m deep) probably without motion, are typically mediterranean deep waters.

In central part of Liguro-provençal basin, cyclonic circulation induces divergence of intermediate waters which are separated from Atlantic origin coastal waters by a permanent thermohaline discontinuity or front.

NOAA satellites infrared thermographies (provided by Centre de Météorologie spatiale of Lannion, France) give us the thermal upper limit of the front (Fig. 2).

Examination of oceanographic data

NOAA Satellite charts from Lannion provide us only thermal discontinuities distribution in the Liguro-provençal area. From this point of view, during winter, Liguro-provençal basin is

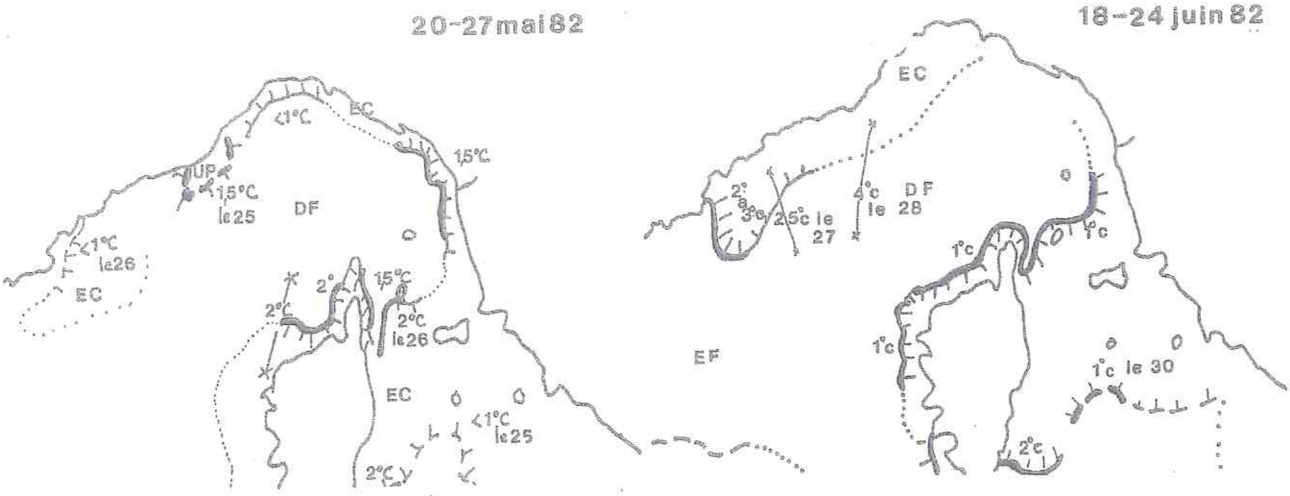

Fig. 2 : NOAA satellite infrared thermographies showing surface temperature gradient (![gradient symbol]) (from Centre de Météréologie spatiale, Lannion, France).

generally homothermal;at most, thermal gradients are ephemeral and not well indicated.

Study of hydrological data (temperature, salinity) collected in March, May, July and October 1982 (LICOT et al.), during several oceanographic cruises across the Liguro-provençal front (Corsican area), provide us a more detailed picture of water masses distribution and seasonal fluctuations. These campaigns are carried out on board of "Recteur Dubuisson", oceanographic ship of the University of Liège at Calvi (Corsica). Ten stations have been selected (Fig. 3) on the Calvi-Nice axis, from Calvi (station n° 1) to 30 nautical miles offshore (station n° 10).

At every station, conductivity and temperature are measured by means of a bathysonde every ten meters from 0 to 70 meters. At these various depths, salinity (conductivimeter Beckman) is measured on water sampled by using a reversing bottle. Means of different parameters, integrated over 70 meters, and standard deviations are presented on graphics as function of distance from the coast.

During winter period, mean water temperature, integrated on the 70 upper meters does not present significant variations from the coast to offshore. Together, a salinity horizontal discontinuity separates coastal from offshore waters (Fig. 4).

Fig. 3 : Location map and position of sampling stations.

At this season, water column is homogeneous, at least down to 200 meters; that explains the small standard deviation values calculated for all parameters.

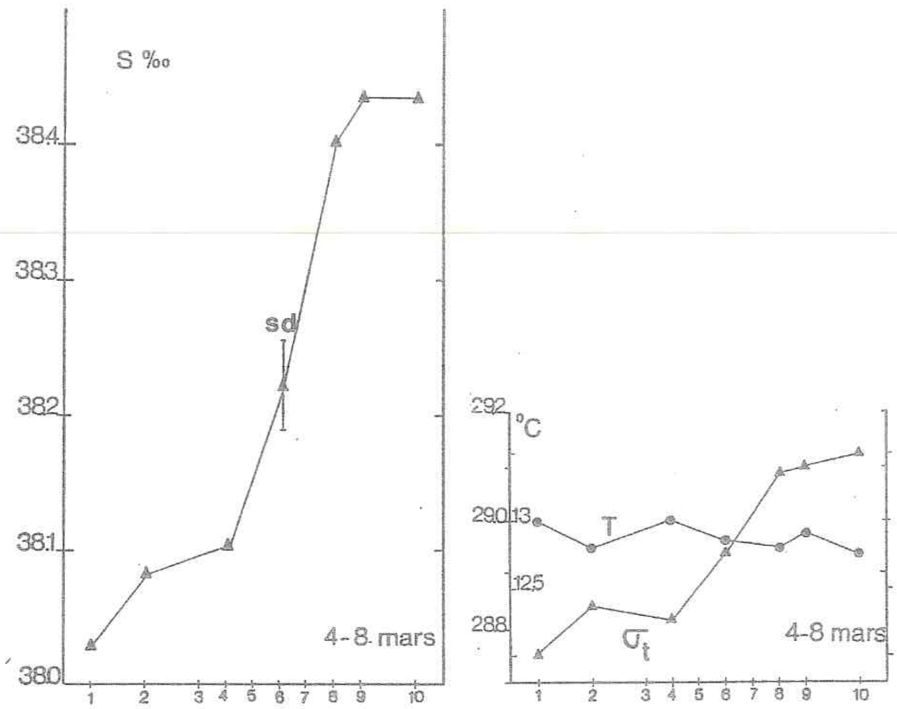

Fig. 4 : Campaign 4-5 Mars 1982 : Salinity, temperature, density distribution across the front. Mean values calculated over the upper 70 meters (each 10 m data).
sd : Standard deviation.
(horizontal axis : distance from the coast).

During spring (Fig. 5), densities, salinities mean values are lower and mean temperature higher than during winter. Standard deviation calculated for these parameters is increasing. These variations are related to water reheating which induces surface water density lowering, stratification and thermocline formation. That heating concerns more the coastal waters than the offshore ones.

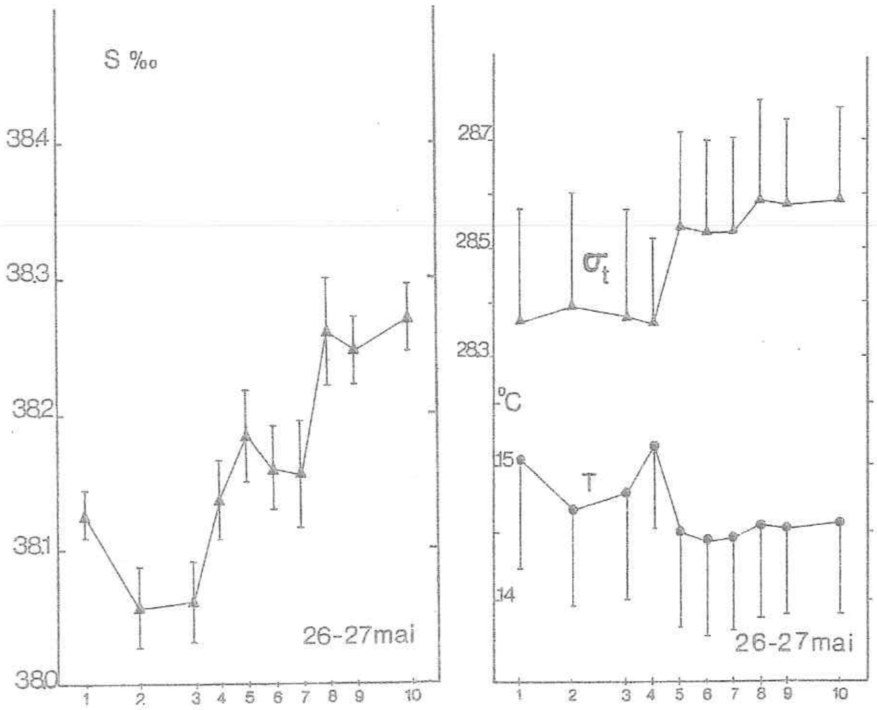

Fig. 5 : Campaign 26-27 May 1982.(Legend see Fig. 4).

During summer, hydrological individualisation of different surface water masses induces mean temperature and salinity rise and a decrease of density (Fig. 6). Water column reaches a maximum stratification degree. Standard deviations are at the highest.

During autumn, water retains the hydrological characteristics gained during summer (Fig. 7).

In 1984, temperature and salinity measurements have been carried out at the same stations, from the surface to 200 meters. The isotherms, isohalines and isopycnals distributions are presented as block diagrams in order to allow a better understanding of water masses superposition (Fig. 8).

In March, a heavy haline gradient separates coastal waters (S<38.2‰) from offshore waters (Fig. 8A)(S>38.4‰). The distribution of isotherms shows that the upper water layers are not

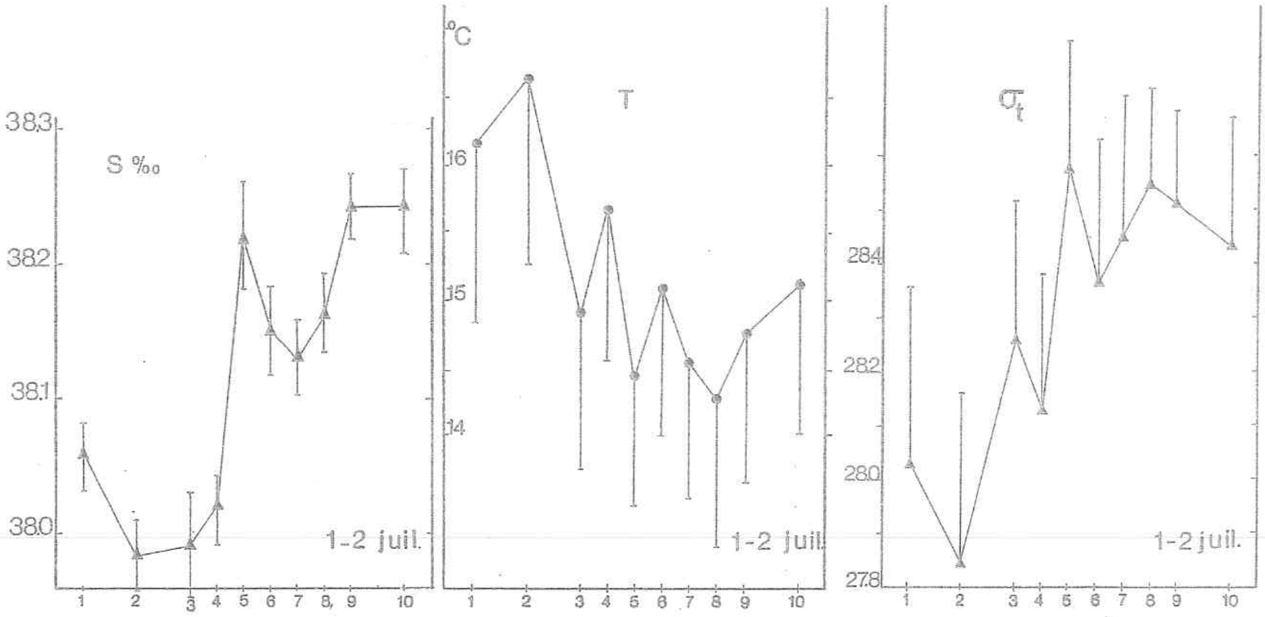

Fig.6 : Campaign 1-2 July 1982. Legend see Fig.4.

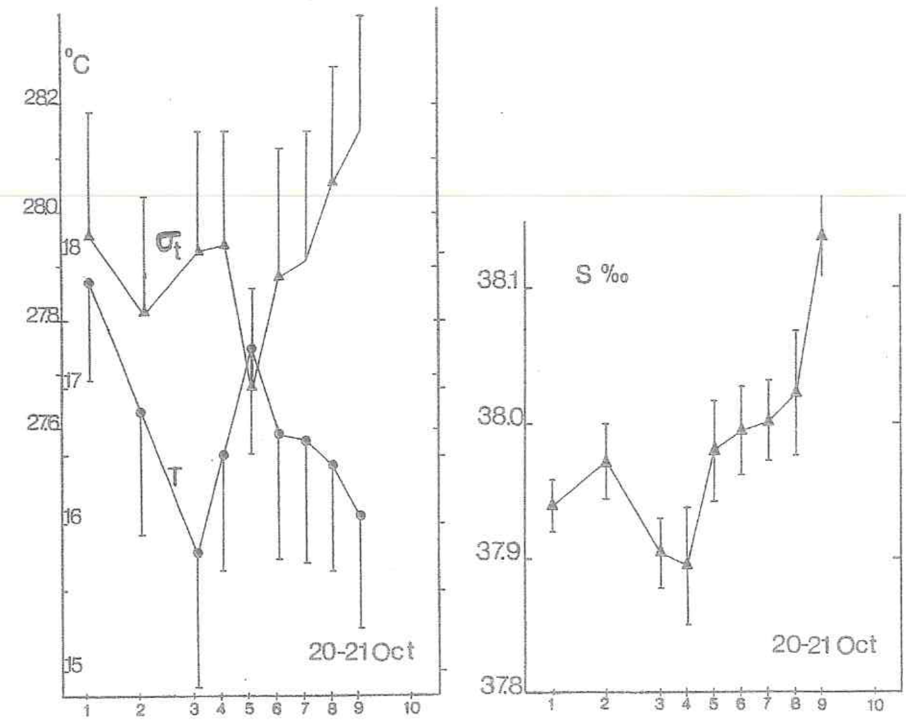

Fig.7 : Campaign 20-21 oct.1982. Legend see Fig.4.

really homothermal such as suggested by remote sensing. Fig. 8B shows that colder waters (T < 12.9°C) are situated beneath the haline gradient. Warmer waters (T > 13.4°C) are situated above the haline gradient. Density distribution (Fig. 8C) shows that the thermohaline front separated two areas :

- Offshore stations with waters of high density,characteristic of Levantive origin; this region is unstratified and seems to be a divergence area,

- Onshore stations with waters of lower densities, characteristic of Atlantic origin. This region is little stratified with a tendance of convergence close to the gradient. In that period, the front slope is 1.6%.

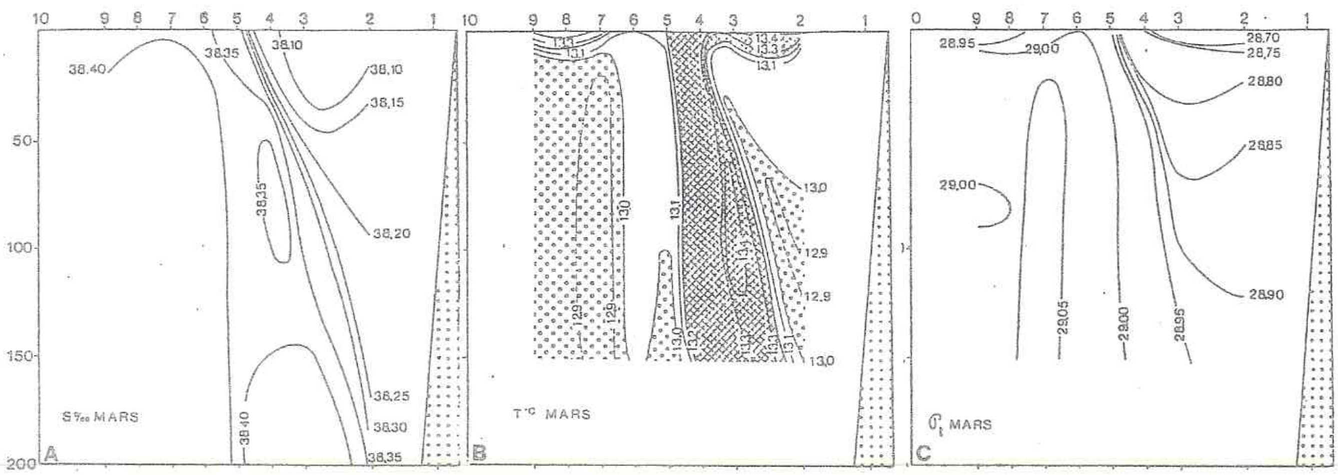

Fig. 8 : Distribution of isohalines (A), isotherms (B) and isopycnals (C) across Corsican frontal region (numbers of stations-depth in meters) in March 1984.

In June, a vertical stratification is initiated (Fig.9B) with the heating of upper layers. This horizontal gradient of temperature masks the vertical gradient at least in the 75 upper meters. From the point of view of the salinity (Fig. 9A),the haline gradient separating offshore and coastal waters is present below 50 m. The density diagrams (Fig. 9C) summarize water masses distribution. In the upper layer (surface to < 50 m), the distribution of isopycnals is approximately horizontal. Below 75 m. both a coastal stratified area and an offshore unstratified zone with high density values can always be observed. It can be supposed that divergence does not reach the surface but only affects the waters below the thermocline.

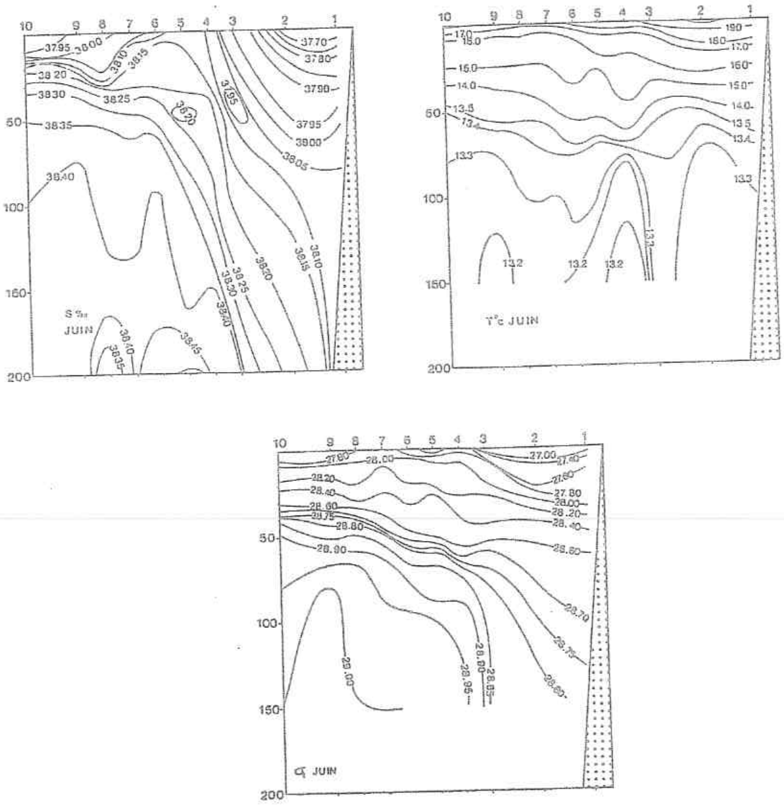

Fig. 9 : Distribution of isohalines (A), isotherms (B) and isopycnals (C) across Corsican frontal region in June 1984.

In October (Fig. 10), the distribution of isohalines is quite similar to the situation in June and two regions are separated by a frontal discontinuity. Both temperature and density measurements suggest the start of a destabilization, as confirmed by an increase of isopycnal slope.

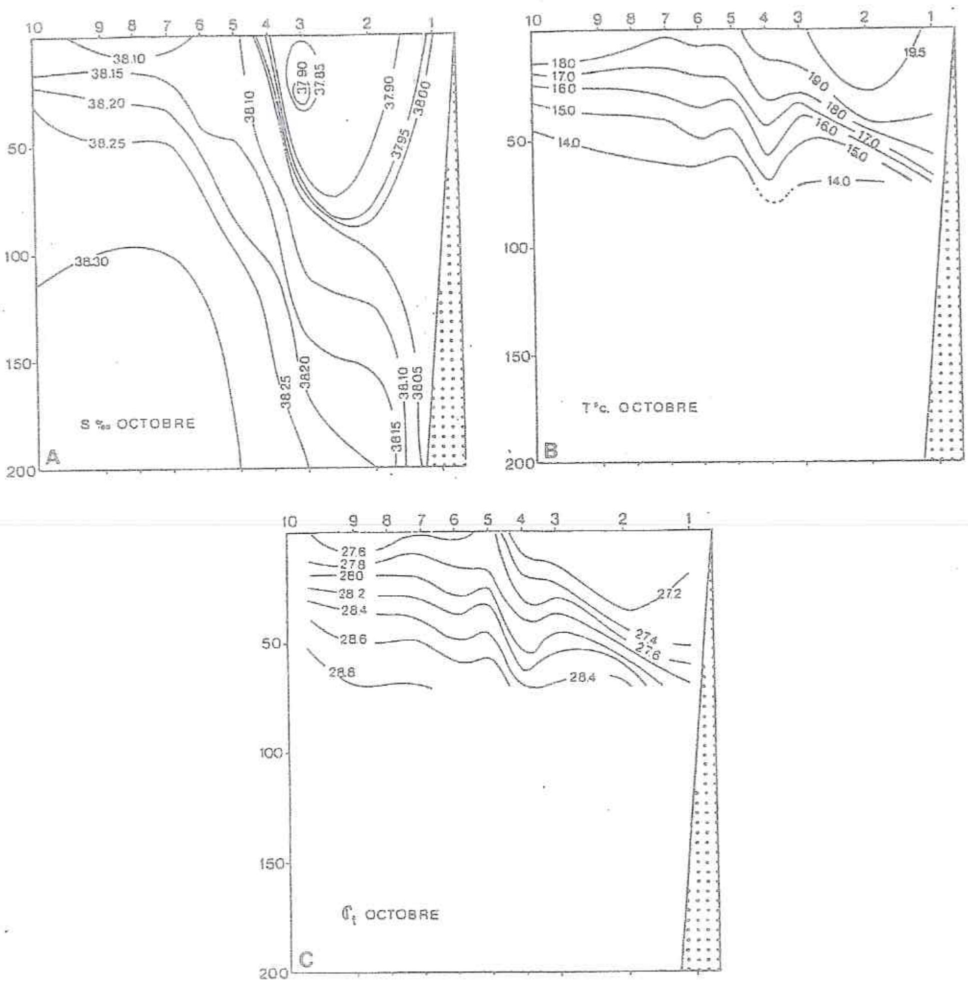

Fig. 10 : Distribution of isohalines (A), isotherms (B) and isopycnals (C) across Corsican frontal region in October 1984.

Conclusions

The "in situ" measurements confirm fairly well the existence of different water masses as detected by I.R. thermography.

The water situated between the front and the Corsican coast has the characteristics of an Atlantic water. The water situated beyond the front has the characteristics of an intermediate Levantine water.

In winter and at the beginning of spring, salinity influences the slope of isopycnals. These are going deeper and deeper from offshore to the coast. In that period, divergences reach surface layers.

During summer, surface temperature influences horizontal stratification of the upper layers and frontal divergence seems to reach only water layers lower than 100 meters deep.

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