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OCEANOGRAPHIC CHARACTERISTICS OF THE CANARY ISLANDS WATERS

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Abstract

From the temperature and salinity data obtained in 61 CTD stations from 15 April to 5 May 1988 aboard the Oceanographic/Hydrographic ship TOFIÑO in the Canary Islands waters, the area oceanographic conditions, thermohaline structure, waters masses and surface geostrophic currents have been determined.

Temperature values show an upwelling between the Eastern Islands and the African continent, with a thermic increase towards the West, and a cold water nucleus at SW of La Palma Island.

NACW (Northern Atlantic Central Water) is located below the thermocline; there is also a Mediterranean water influence.

Depth water masses have not been determined because of the CTD's depth limit of 1000 m.

Surface geostrophic currents depicts a flow to the South, corresponding to the Canary Islands current, however the values are numerically small and show evidence of three eddies in both the Eastern and Western regions of the Islands area.

INTRODUCTION

The Canary Islands spread over in front the Atlantic coasts of the African continent, from which they are 55 miles away, and are located between the parallels 27°37'-29°26' N and the meridians 10°19'-18°10' W, taking up an extension of 280 miles from East to West (IHM 1984) (Fig. 1a).

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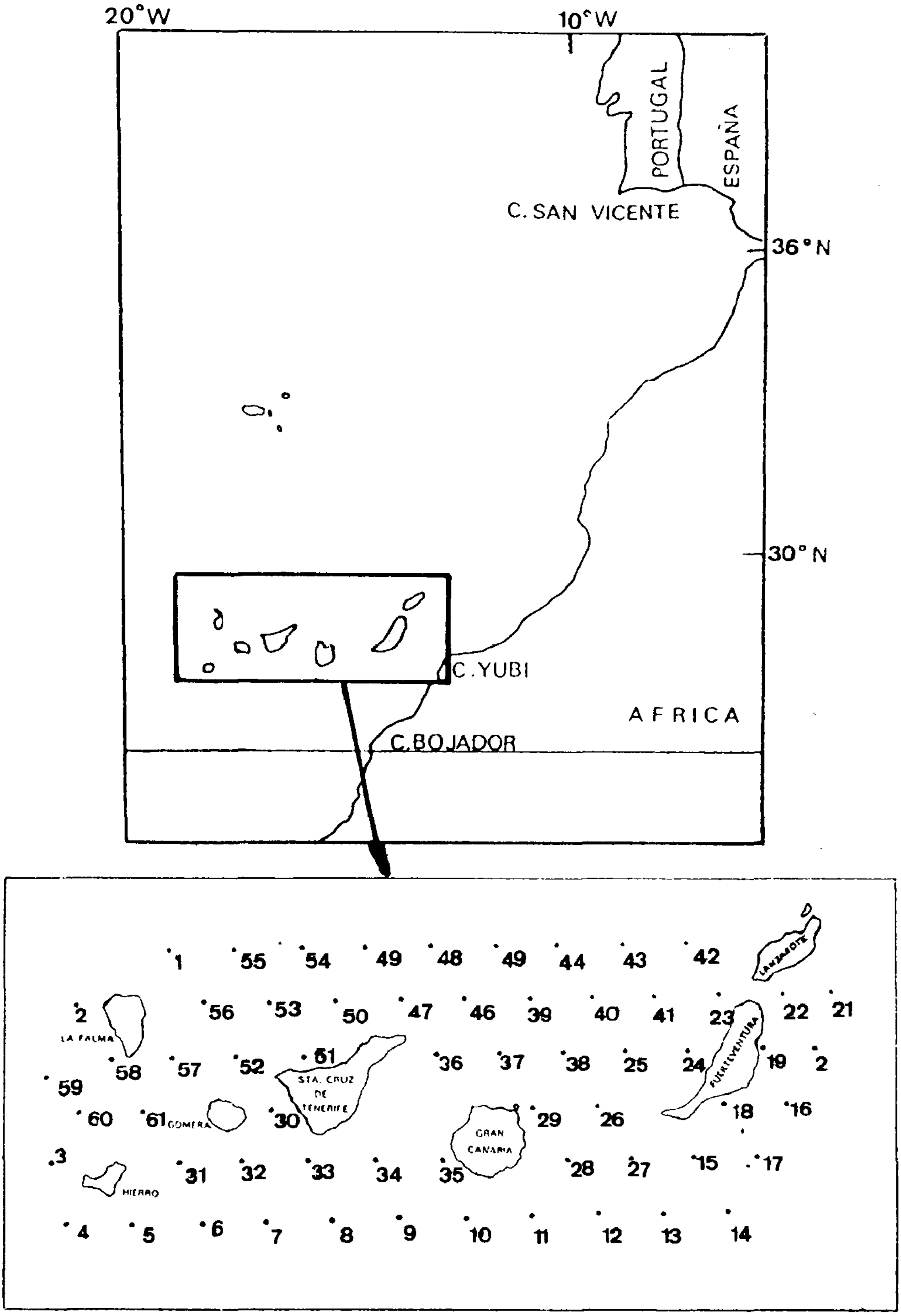

FIG. 1.- a) Part of the Western Atlantic where you can observe the Canarian Archipelago.
b) Position of the stations in the study area.

The oceanographic conditions of the Islands are affected by the current named after them, i.e. the Canary Islands current, and by the upwelling of the NW African coast. Several studies have been made, both on the current and the upwelling (MADELIAN 1967, FEDOSEEV 1970, MARGALEF 1971, FRAGA, et al, 1985, etc.), as well as many aspects of the Canary Islands current itself (MOLINA 1973 and LAATZEN 1986 (a); 1986 (b); 1989, where it is evident that, with a geostrophic transport of an approximate value from 2.8 to 1.8 * 10^6 m^3/s in some transects (MOLINA, 1973), it is almost 20 times lower than the Gulf Stream transport ($55*10^6$ m^3/s, SVERDRUP et al. 1942).

The water masses general distribution, according to its T-S characteristics can be summarized in the following way: from 150 to 800 m it spreads Western Northatlantic Central Water, characterized by an almost straight T-S curve between the values T=19°C, S=36.70°/$_{oo}$ and T=8°C, S=35.10°/$_{oo}$; below, Deep Northatlantic Water spreads out (T=2.5°C S=34.9°/$_{oo}$). At intermediate depths it can be found other types of water, as the Mediterranean water (T=11.9°C, S=36.5°/$_{oo}$) and the Intermediate Antarctic water (T=22°C, S=33.8 °/$_{oo}$). The origin of the first one is in the Mediterranean water flow through the Strait of Gibraltar and its later circulation in the Atlantic, while the second one has its origin in the Southern Atlantic. Once it comes in the Northern Atlantic, it appears to influence on the waters density close to 27.4 (SVERDRUP op.cit. 1942).

WORTHINGTON (1976) also finds a surface water of highest salinity (T=19°C, S=36.6°/$_{oo}$) which could be defined as Subtropical Water, formed in the Southern part of the Central Northatlantic, as a result of the intense evaporation by the trade winds and the high insolation under the clear skies, associated with the semipermanent Azores High. These types of waters are present in the Coast of Portugal (FUGLISTER, 1960), being good indicators for the flow of the Canary Islands current (FIUZA et HALPERN, 1982).

NW African coastal upwelling areas are not permanent, presenting seasonal variation. From 20°N to 25°N there is an upwelling area showing stronger activity in Spring (when it moves to the South) and in Autumn (when it goes back to the North). Southern of these latitudes another upwelling area can be detected at the end of Winter and in Spring, while northern of 25°N (where the Canary Islands are located) an upwelling prevails during Summer and Autumn, with a maximum at 30°N (SPETH and DETLEFSEN, 1982).

METHODS

Between 15 April and 5 May 1988, an oceanographic cruise was carried out aboard the hydrographic ship "TOFIÑO" (Spanish navy) in the Canary Islands waters, as a part of an Oceanographic Research Project to determine the large scale structure and circulation of water masses. (RUIZ et al, 1989).

A total of 61 CTD stations were observed, using Neil Brown "Smart CTD's". Due to physical constraints of the instruments, a limit of 1000 m was imposed.

Water masses deeper than that limit were not detected. However, it is from 1000 m and deeper when the CTD parameter values become stable. Many authors identify the no-motion level in this area, over 800 m (DEFANT, 1961, MOLINA and LAATZEN, 1986a), which is within the range of the data and allows to determine geostrophic currents.

Salinity check samples were taken at each station, using Niskin bottles. The check samples were analyzed using a Guildline Autosal salinometer model 8400a with standard water batch P-92. The conductivity ratios were converted to practical salinity units using the algorithm of FOFONOFF and MILLARD (1983), the same algorithm used to compute salinities from the CTD data.

The accuracy of the data is 0.003 ppt for salinity; 0.001°C for potential temperature and 0.5% of the range for the depth.

The geostrophic current (Fig. 9) for the internal pressure gradient has been calculated following the dynamic method (LACOMBE, 1965; NEWMAN and PIERSON, 1966). The level of no motion was selected at 800 m, and the current speed has been determined using the Processing Oceanographic Data Tables (1951) and taking as references the latitude, the dynamic height and the distance between stations.

DISCUSSION

Surface temperature

In order to suppress the effect of daily variations, the surface temperature was taken at 10 m depth (Fig. 2).

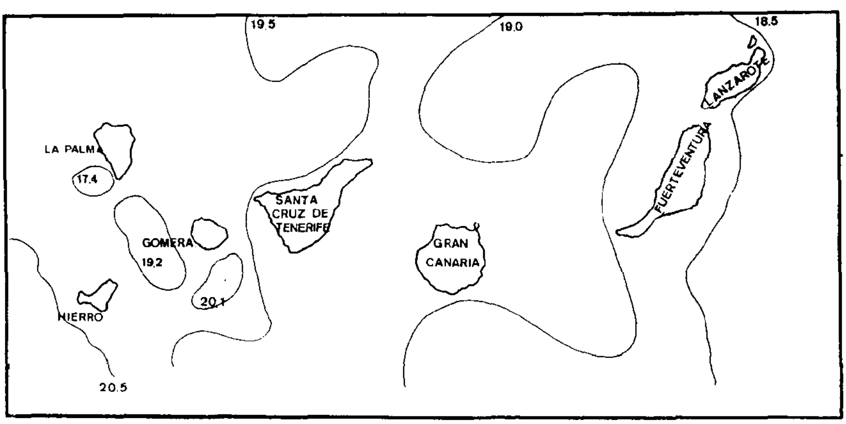

FIG. 2.- 10 m depth isotherms.

The superficial distribution shows a minimum of 18.50°C in the eastern zone and a maximum of 20.50°C in the western one, i.e. there is a horizontal variability of 2°C along 250 miles between the Eastern and Western Islands.

The lowest temperatures are, in general, located between the Lanzarote, the Fuerteventura Islands and the African coast, where the 18.5°C isotherm appears parallel to the coast. The temperature decrease from open ocean to the coast. This upwelling seems to be confined to the area included between the Western Islands (Fuerteventura and Lanzarote) and the African continent, as a consequence of the barrier effect that both islands offer to the upwelled waters. The horizontal temperature gradient between the Eastern Islands is higher than between the Western Islands, even though the trend of the isotherms to maintain a type of parallelism and temperature increases towards the West.

There are, however, two anomalies, quite significant, that correspond to two cold water structures, one of which is located SW of the Gomera Island, with a temperature of 19.2°C and another one, more remarkable, at SW of La Palma Island, with a horizontal gradient of 2°C in only 20 miles.

Subsurface temperature

On Figure 3 is represented the 100 m depth temperature. Its configuration is similar to the surface temperature as the lower values isotherms are located between the Eastern Islands and the African continent, and their values are increased towards the West. The temperature drop of about 1.5°C with respect to the surface, demonstrates the existence of a clear thermocline. It is remarkable that the isotherm distribution shows a lower temperature at the North, i.e. we can observe a heating towards the South. The cold water nucleus which is found in the surface at SW of Gomera Island is not clearly detected at 100 m depth. but the one existing SW of La Palma Island is present here, even reaching a larger dimension.

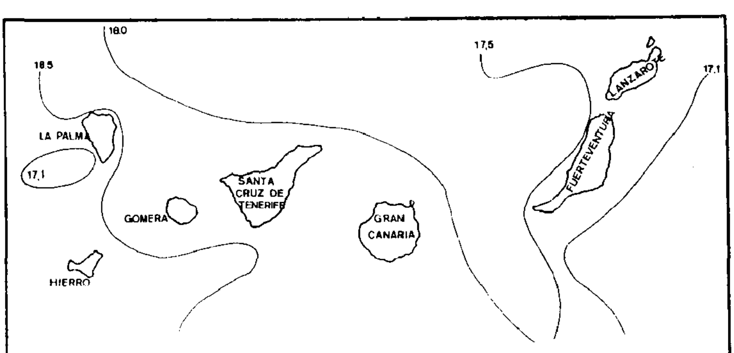

FIG. 3.- 100 m depth isotherms.

At 500 m depth (Fig. 4), a drop of about 6°C is produced with respect to the 100 m depth temperature, though the isotherms continue showing an increment towards the West despite the small horizontal gradient (0.7°C over the whole area).

At 700 m depth (Fig. 5), the isotherms distribution reveals a NE-SW orientation and a trend to become parallel to the equator. MOLINA and LAATZEN (1986 b) describe the E-W isotherms orientation between 1000 m and 1300 m depth

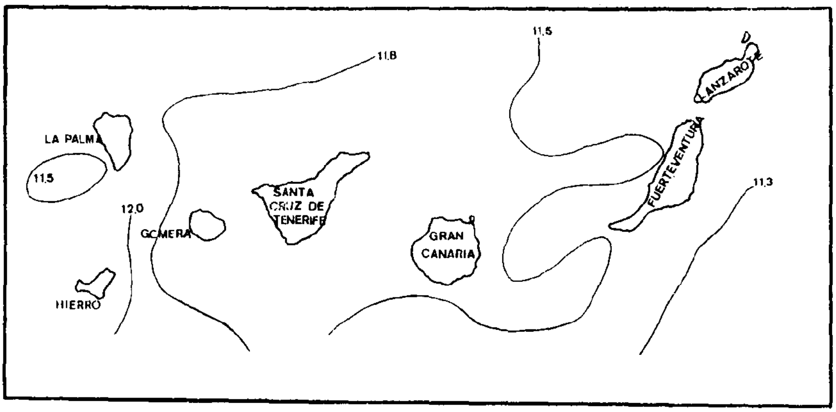

FIG. 4.- 500 m depth isotherms.

as the result of a clock-wise rotation. This same effect is also described in a later work (MOLINA and LAATZEN 1989).

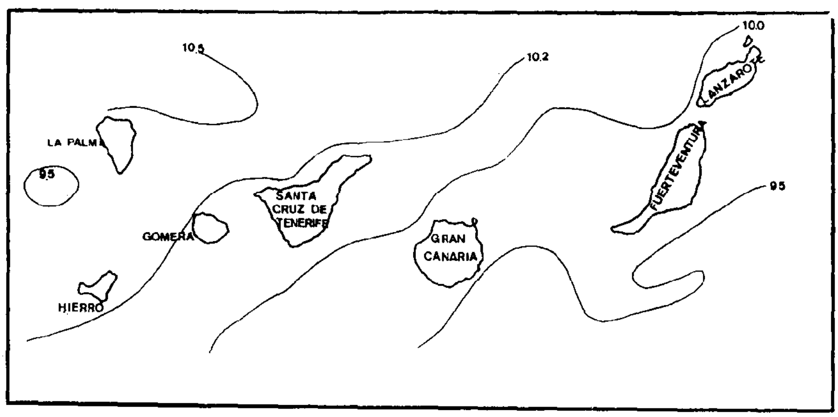

FIG. 5.- 700 m depth isotherms.

In our study, the horizontal gradient is 1°C over the whole area and the isotherms orientation makes evident a decrease in the thickness of the warm water mass towards the Equator. The cold water nucleus at SW of La Palma keeps existing and could be associated to an advective deep water flow, whose effect is shown very locally.

Salinity

The salinity surface distribution can be seen on Figure 6. The isohalines, as the isotherms, are parallel to the coast with a horizontal gradient of 0.40 ppt over the whole area.

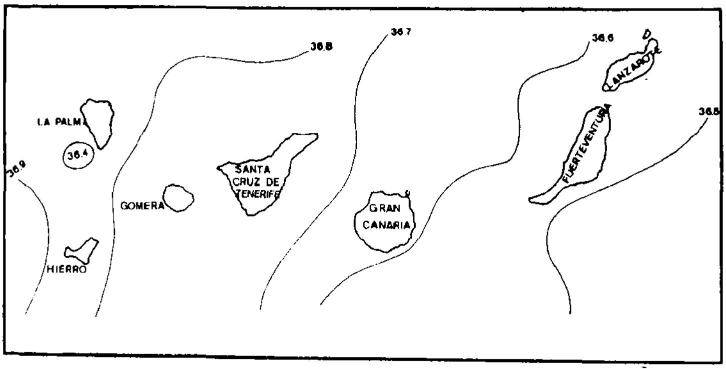

FIG. 6.- 10 m depth isohalines.

At 100 m depth (Fig. 7) the gradient decreases to 0.30 ppt, but the detected anomaly for the isotherms SW of La Palma continues.

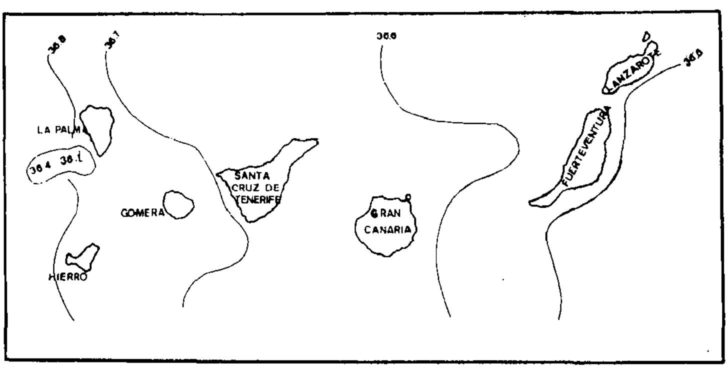

FIG. 7.- 100 m depth isohalines.

The isohalines maintain their parallelism to the coast, but the horizontal gradient decrease with depth. A small gradient inferior to 0.10 ppt is found at 700 m depth.

Water Masses

The stratification and the structure of the water masses results from the persistence of the vertical distribution of the temperature and salinity, i.e. these variables must be considered in almost-stationary conditions (HUGUES and BARTON 1974). However, evidence of a clear variability usually appears due to the advection and to internal waves.

The advective variation can be produced as a result of the motion of cold water nuclei (TOMCZAK, 1973). It has also been confirmed in this area the existence of horizontal gradients in the water parameters: these can be the result of vertical turbulences of seasonal variability.

Internal oscillations are produced in the levels, being more important where the density gradients are higher and possibly due to internal waves.

Taking into account that the maximum depth reached has been 1000 meters, which clearly limits the detection possibility for deep waters, the distribution of the water masses is as follows: at the surface appears a stationary thermocline, well pronounced in most stations, except for the Eastern ones. This thermocline spreads out to a depth of 170 to 200 meters with surface average values of temperature and salinity to 19.4°C and 36.65 ppt and 17.85°C and 36.50 ppt for the bottom of the thermocline.

The corresponding Eastern stations thermocline is not so neat, due to the regional upwelling effect in the area.

Below the thermocline it can be detected NACW (North Atlantic Central Water) from about 150 m to 700 or 900 m depth. Its temperature and salinity value ranges were 18°C, 36.57 ppt and 6.5°C, 34.95 ppt (FRAGA et al, 1985) producing an almost straight T-S curve, most of the profiles presenting typical NACW characteristics in the already mentioned depths.

A transition layer characterized by a salinity increase appears below the NACW. This layer reveals Mediterranean water influence that coming from the Strait of Gibraltar goes into the Atlantic through five canyons in the Gulf of Cádiz (MADELIAN 1970; ZENK, 1975), and having a high salinity at the Strait: 38.45 ppt (VILLANUEVA et al, 1989), dilutes into the Atlantic (HOWE and TAIT, 1970).

Off the Canary Islands this water mass has a 35.50 ppt salinity. In this paper, the depth where takes place an increase in the salinity curve has been taken as the Mediterranean water influence level (Fig. 8).

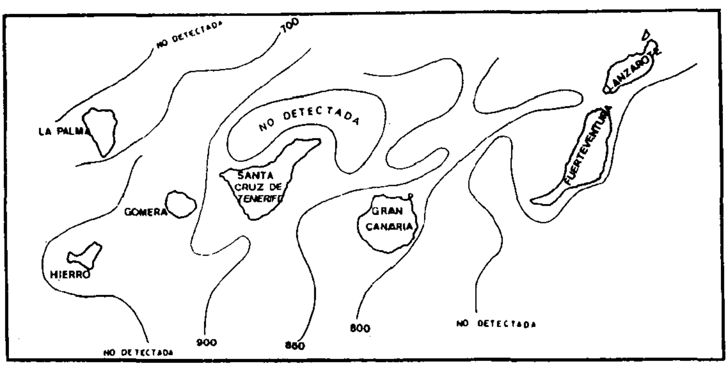

FIG. 8.- Topography of the upper detection level of Mediterranean water influence.

Its average depth is over 850 m but it exhibits a wide fluctuation. At the Eastern stations next to the African coast, and more pronounced to the South, the depth exceeds 1000 m, therefore it has not been detected.

A westward subsidence is also observed from 800 m between Gran Canaria and Fuerteventura to 900 m between Santa Cruz de Tenerife and La Gomera. This Mediterranean Water depth gradual increase is modified by an area, North of Santa Cruz de Tenerife, where it has not been detected; maybe this fact takes place because of a subduction phenomenon, related to the area topography as that non-detected zone corresponds to the northern profile of Tenerife Island.

In the Western coast of the Island, the water mass depth exceeds 1000 m and has not been detected.

Therefore, in general we can observe across the Islands a westward increase in the Mediterranean water depth.

Surface geostrophic current

The surface geostrophic current related to 800 m depth is represented in Figure 9. It has been determined following the dynamic method. We should remark that stations were observed in about 20 days and that the meteorological conditions, in particular the atmospheric pressure at the stations used, were not always similar; that is why artificial values can be introduced in the geostrophic currents calculations (NEWMANN and PEARSON 1966); it is then necessary to take a certain precaution in interpreting the obtained data: the results presented here should be taken as indicative. It would be necessary to complete them with direct measurements from current meters throughout the study area, what was not possible during the oceanographic cruise.

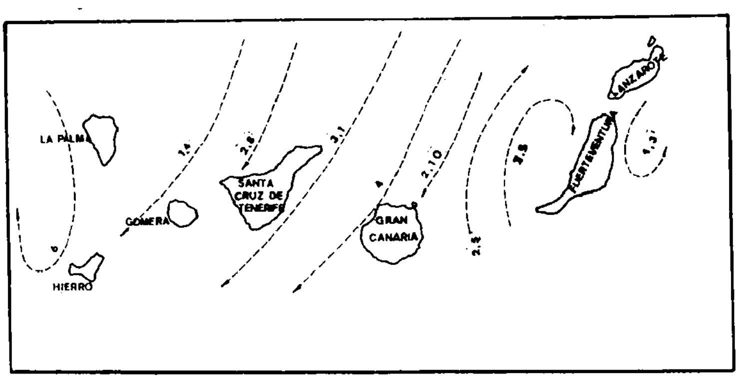

FIG. 9.- Superficial geostrophic current referred to 800 m.

On Figure 9, we can observe a southward flow, corresponding to the Canary Islands current.

The values are very low between La Palma and La Gomera (1.4 cm/s), increasing slightly westward and reaching a value of 2.8 cm/s between La Gomera and Santa Cruz de Tenerife. From there to Gran Canaria, values of 3-4 cm/s are reached decreasing again to the west down to 2 cm/s.

There is a northward flow between Gran Canaria and Fuerteventura, with a weak countercurrent system

Three eddies are also detected; one anticyclonic in the western area of the Islands, with speed close to 6 cm/s, and other, to the East showing a southward net flow.

The last one is located between Fuerteventura and the African coast, with a cyclonic pattern, producing a northward net flow of 1 cm/s, probably occurring because of the African NW upwelling countercurrent effect.

CONCLUSIONS

In summary, we consider that the noticed variability of the oceanographic conditions in the Canary Island Area is a major consequence of the upwelling phenomenon in the eastern region, that exhibits variability in both temporal and spatial scales, and affects the whole area, superimposing itself to the more steady, but weak, Canary current and the presence of diluted Mediterranean water.

The observed anomalies, specially the cold water structure located SW of Gomera Island and more remarkably, the one located SW of La Palma Island are very local effects of probably a combination of the abrupt topography around the islands and advective deep water flows.

Internal waves are potentially the agent causing turbulences in certain areas where density gradients are higher.

Finally, the countercurrent and eddies evidenced in the surface geostrophic current map suggest a more complicated dynamics in the circulation, through and around the Islands, that was expected, being necessary a more detailed study to establish the flow pattern and its variability.

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