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Seasonal variability of the surface circulation in the Channel of Sicily

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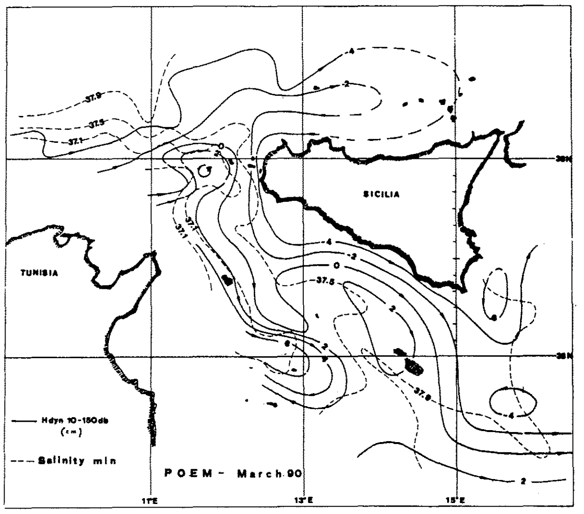
The seasonal variability of the surface marine currents in the Channel of Sicily is discussed on the basis of hydrological and surface current data collected by the Institute of Meteorology and Oceanography in the framework of the POEM project.



The surface flow patterns which resulted from the surveys of September 1987 and March 1990 are considered as they represent the typical summer and winter situations, and because the fair meteorological conditions which prevailed during the surveys allowed a good set of observations on the whole area. The patterns, as resulted from the analysis of the hydrological data, are supported by both the direct current measurement recorded on board R.V. Bannock while at station, and by the NOAA satellite imagery. They show a NW to SE meandering path with well defined cyclonic and anticyclonic gyres on its sides.

In summer time a frontal system having Atlantic Water (AW) in the south part of the channel and higher salinity water on the Sicily continental shelf, is seen. It is oriented NW - SE with meanders of 100 nautical miles wave lenght and 20-40 nm amplitude. Velocities close to 40 cm/s resulted by both direct and indirect methods. A few cyclonic gyres about 20 nm in diameter are well seen down to 50 meters. The results match fairly well with the thermal front shown by the imagery of the NOAA satellite during the same period.

In winter the mixed layer formed over the Sicily continental shelf is missing, and the area is characterized by a cyclonic flow along the Sicilian coasts as far as the Ionian sea. The AW is easyly recognized through the subsurface salinity minimum distribution which follows the geostrophic flow in the south part of the channel and turns toward the African coast (Fig. 1).

Moreover the two sets of observations point out that between Tunisia and Sicily the AW keeps always the same salinity values (37.0-37.1). In summer, the AW flows out of the channel around Malta Island and reaches the western Ionian basin. In winter the AW layer is shifted toward the African coasts and leaves the channel far south.

O-II6

Temporal variations of the principal water masses of the Levantine Basin

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The principal water masses of the Mediterranean Sea, the ingressing Atlantic Waters (AW) and the egressing Levantine Intermediate Waters (LIW) are defined, intuitively, as the subsurface salinity minimum and the subsurface salinity maximum, respectively. These are definitions of extrema points on a profile and, therefore, are inadequate for any quantitative estimates, such as the volume of those water masses or the boundaries of the respective layers. Moreover, these water masses are not homogeneously and isotropically distributed throughout the basin, and in this respect salinity profiles from different parts of the basin can differ significantly from each other. Finally, there is conclusive evidence of patches or pockets of those waters trapped and maintained for long periods of time inside mesoscale or small scale eddies both inside the Mediterranean (e.g. HECHT et al. 1988, OZSOY et al. 1989) and outside the Mediterranean in the Atlantic Ocean (e.g. ARMI and ZENK 1984, ARMI et al. 1989).

The MC series of cruises, a series of twenty cruises carried out in the southeastern Levantine basin at relatively short intervals over a period of five years, presents us with the opportunity to attempt an objective determination of the boundaries of the AW and LIW for the limited region of the cruises and, following that, to attempt the investigation of the seasonal variability of these water masses. From the data of those cruises, we computed climatological temperature and salinity profiles, as well as cruise average profiles, i.e. the level by level averages of the measured temperatures and salinities for all the cruises or for a particular cruise, respectively (HECHT et al. 1988).

The limits of the AW and LIW layers were determined on the climatological salinity profile by defining them, arbitrarily, as the extremum (minimum or maximum as the case may be) plus the respective standard deviation for the AW (38.86+0.16) and less the respective standard deviation for the LIW (38.97-0.05). While the definition of the LIW resulted in what may be considered a reasonable value, the layer defined as AW appeared to overlap the LIW layer. One can find some arbitrary solution for the AW definition problem, such as using the upper boundary of the LIW as the lower boundary of the AW. Obviously, this kind of definition obscures any temporal variations, but it is simple, convenient, and provides us with a layer depth. Moreover, one can use these definitions, via the climatological S/T diagram, to determine a temperature associated with these particular water masses.

At the straits of Gibraltar, Sicily, and Dardanelles, the ingressing as well as the egressing waters vary seasonally (e.g. CARTER 1956, UNLUATA and OGUZ 1983, GRANCINI and MICHELATO 1987). One could therefore expect a seasonal variation in the water masses within the basin as well. In order to obtain some information on temporal variations, one can determine the salinity extrema and the respective standard deviations on each of the cruise profiles. A few of the cruise average salinity profiles did not yield a clearly identifiable extremum of one kind or another. In particular, the MC21 of December 1982 did not seem to have either a minimum or a maximum salinity. An attempt to investigate seasonal variations by depicting those values on a compressed time series of cruise average salinity profiles (i.e. cruise average salinity profiles arranged according to the date they were measured within the year irrespective of the year in which they were measured) appeared to result in some seasonal trend as far as the AW is concerned (a deeper and narrower layer as the year progresses), but random fluctuations with respect to the LIW.

Therefore the cruise salinity average profiles were restored to their original sequential order. This did not seem to yield more information on the behavior of the AW; they still seemed to be deeper and the layer narrower towards the end of the year. However, from February 1979 (MC11) and until November 1981 (MC19), the LIW appeared to be at an almost constant level (271±7 dbars) with an average of 38.95±0.02. In May 1982 (MC20), we observe a decrease in the level of the salinity maximum, and in December 1982 (MC21), we could not find either a minimum or a maximum on the cruise average salinity profile. Following that, the salinity maximum level is less constant and at a shallower depth (187±0.30 dbars) and has a higher value (39.02±0.02).

For the sake of comparison, the overall average of the salinity maxima is 38.98±0.04 and the overall average of the depth of the maxima is 228±47 dbars. Thus, one may legitimately ask what is the accuracy of our measurements and what is their long term stability. As it is well known, for all practical purposes, the deep waters of the Mediterranean sea can be considered invariant. During the MC series of cruises, we found that the average salinities below 1000 dbars were completely stable (e.g. 38.70±0.02, 38.68±0.01 and 38.676±0.009 at 1000, 1500 and 2000 dbars, respectively).

As to the reasons for this change, one may well remember that the winter of 1982-1983 was the onset of one of the largest El-Nino events of the last century. Its repercussions were felt all over the world, and some of its effects may have reached as far as the eastern Mediterranean. Indeed, in retrospect, we already observed some anomalous behavior of the salinity in the May 1982 cruise (MC20) and more intensive in the December 1983 cruise, after which the salinity seems to return to "normal" behavior. However we have no explanation to connect the events. On the other hand, the continuous diversion of fresh waters from the Mediterranean basin, e.g. the damming of the Nile which, according to OREN and HORNUNG (1972), has already affected the coastal waters of Israel, is expected to change the water exchange regime between the Mediterranean, the Atlantic and the Black Sea (NOF 1979). Finally, some changes in the previously "stable" characteristics of the Mediterranean waters were observed in the western basin and linked to possible climate changes (LACOMBE et al. 1985, CHARNOCK 1989). In particular, LACOMBE et al. (1985) suspect a change in the LIW and suggest their close monitoring.

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