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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.

REFERENCES.

ARMI, L. and ZENK, W., 1984. Large lenses of highly saline Mediterranean water. J. Phys. Oceanogr., 14 (10): 1560-1576.

ARMI, L., HEBERT, D., OAKEY, N., PRICE, J.F., RICHARDSON, P.L., ROSSBY, H.T. and RUDDICK, B., 1989. Two years in the life of a Mediterranean salt lens. J. Phys. Oceanogr., 19 (3): 354-371.

CARTER, D.B., 1956. The water balances of the Mediterranean and the Black Seas. Publ. Climatol., Centerton NJ, Drexel Inst. Technol., Lab. Climatol. 9: 123-175.

CHARNOCK, H., 1989. Temperature and salinity changes in the deep water of the western Mediterranean basin. Communicated at the third POEM Workshop, Harvard, USA.

GRANCINI, G. and MICHELATO, A., 1987. Current structure and variability in the Strait of Sicily and adjacent area. Annales Geophys. 5B (1): 75-88.

HECHT, A., PINARDI, N. and ROBINSON, A.R., 1988. Currents, water masses, eddies and jets in the Mediterranean Levantine Basin. J. Phys. Oceanogr., 18 (10): 1320-1353.

LACOMBE, H., TCHERNIA, P. and GAMBERONI, L., 1985. Variable bottom water in the Western Mediterranean. Progress in Oceanogr., 14: 319-338.

NOF, D., 1979. On man-induced variations in the circulation of the Mediterranean Sea. Tellus, 31 (6): 558-564.

OREN, O.H. and HORNUNG, H , 1972. Temperatures and salinities of the Israel Mediterranean coast. Bull. Sea Fish. Res. Stn., Haifa, No. 59: 17-31.

OZSOY, E., HECHT, A. and UNLUATA, U., 1989. Circulation and hydrography of the Levantine basin. Results of POEM coordinated experiments 1985-1986. Prog. Oceanogr., 22: 125-170.

UNLUATA, U. and OGUZ, T., 1983. A review of the dynamical aspects of the Bosphorus. In: NATO Advanced Workshop on the Atmospheric and Oceanic Circulation in the Mediterranean, La Spezia, Italy, Sept. 7-14, 1983. H. CHARNOCK, ed. (in press).