SOME FEATURES OF WATER CIRCULATION AND HYDROLOGICAL STRUCTURE IN THE NORTH-EASTERN PART OF THE LEVANTINE SEA

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Hydrophysical observations performed by r/v "Vityaz" in the Levantine Sea were assumed as basin of studies. They were carried out in the region between the island of Cyprus and Syrian coast in winter 1992 and autumn 1993. During the 24th expedition in the course of two hydrophysical surveys (February 15-22 and March 5-8, 1992) 105 stations were made. During the 27th expedition the similar surveys were performed in October 8-13 and 24-28 and comprised 107 stations. The measurements of z, T and S were carried out with Neil Brown probe to the depth of 800-1000 m with the distance between the stations about 10 miles. First of all, it is necessary to note that in severe winter 1992 the whole water column down to the main pycnocline (to the upper boundary of deep waters) was covered by convection. That is why with the increasing of winter circulation the whole homogenous water was covered by the complex but mostly unidirectional transport from the South to North. In autumn 1993 within the region of measurement, the well-pronounced multilayer water structure was yet preserved. Therefore in the most upper layer over the seasonal thermocline and under it the water circulation had sometimes large differences including opposite directions of currents.

In recent years, a great attention is paid to theoretic and experimental studies of the meandering processes of the Main current in the Mediterranean Sea and eddy making at its lateral boundaries. As is seen from the comparison of dynamic maps estimated relative to 500 dbar depth for several surveys, both in winter (the dynamic map is not given in the summary) and in autumn (Fig. 1) the water circulation in the region under studies is characterised by the strong meandering of the Main Stream, complex eddy structure of currents, their considerable synoptic and seasonal variation. It differs essentially from a classic concept of the main South to North water transport within the polygon. According to the data of four surveys the cyclonic system of circulation with two or several smaller centres is observed to the left of the Main current near the eastern coast of Cyprus. The cyclonic gyre developing to the east of Cyprus is the most stable. The co-ordinates of its centre are 34°45' N and 34°30'-34°45' E. The forming of large anticyclonic meanders with closed anticyclonic eddies inside was observed to the right of the Main current. In winter 1992, the anticyclonic circulation was formed between the eastern coasts of the Levantine Sea and 35° E. According to the data of the first winter survey, the anticyclonic eddy was located to the south-west of Latakia and had its centre co-ordinates 35°15' N and 35°30' E. According to the data of the second survey, the development of cyclonic system in the north-western part of the polygon and of anticyclonic circulation to 35° E in its southeastern part was noted. The anticyclonic circulation was outlined at the northern boundary of the polygon (35°50' N). In such a way, in winter 1992 the general South to North water transport through the most part of the polygon was well traced not only at the surface but also at the intermediate depths. The water circulation at the surface in autumn 1993 (Fig. 1) was characterised by the intensive development of large anticyclonic system in the North and the weak development of anticyclonic circulation near the eastern coast (as compared to winter). That is why the water transport to the North in the north-western part of the polygon turned out to be shifted to the West (to Cyprus), but in the South-East it was traced almost along Syrian coast (with the exception of small local cyclonic eddies near the shore). Dynamic maps for the deeper layers (250/500 dbar; Fig. 1b) are essentially different from the water circulation at the surface. The intensive anticyclonic eddy in the northern part of the polygon weakens with depth and is shifting to the North. In the central part of the polygon, the intensive anticyclone is found with its centre co-ordinates 35°15' N and 35°15' E (Fig. 1b) which covers almost the whole polygon to 34°40' N. This eddy is absent at the surface and is slightly traced only at the depth of 50 m. The maximal development of the eddy was observed between 100 and 250 m where its diameter reached 30 miles. This large anticyclonic eddy which is very weak in the surface layers, has an anomalous vertical hydrological water structure in the form of a lens. In the upper layers, including the layer of seasonal thermocline, the rising of isolines is observed, but their sharp lowering is observed below (to 1000 m). The most interesting are the peculiarities of intermediate water structure of the eddy. They are characterised by the inversions of hydrological properties (some intermediate maxima of temperature and salinity), weak baroclinic stability and convection due to salinity in thin layers.

The near-shore surface waters with anomaly high salinity (39.50-39.78‰) and high temperature (26-27°C) which were observed in autumn, are of great interest. These waters formed in the local climatic conditions, may be isolated as a separate surface water mass. The high temperature of the near-shore waters in autumn provides for their baroclinic stability. But it may be supposed that these waters in the process of advective transport and in proper conditions of cooling may commence formation of the new Levantine intermediate waters. The discovery of the large anticyclonic meanders of the Main current (with the local intensive eddies inside) spreading from the shore to the open sea, allow to extend the concept of the water exchange between the near-shore and deep waters which is of a great importance for the ecology of the Mediterranean Sea.

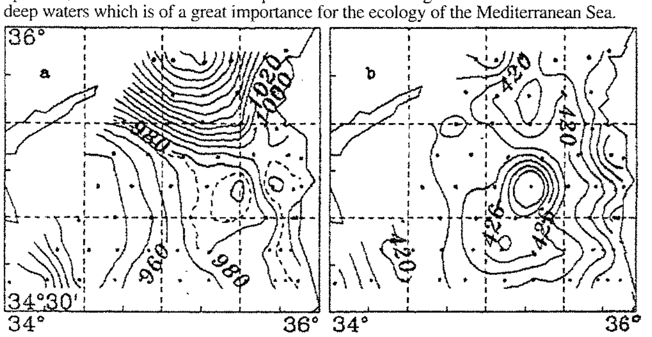

Figure : Dynamical topography of surfaces 0/500 db(a),250/500 db(b)

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THE NORTHERN CURRENT DYNAMICS IN THE WESTERN MEDITERRANEAN SEA

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In the western Mediterranean Sea, the Northern Current is a major component of the circulation, formed by the junction, in the Ligurian Sea, of the currents flowing northward along each side of Corsica. It flows all year long as an entity along the continental slope as far as the Catalan Sea, surrounding the central zone where convective phenomena occur in winter. The seasonal and mesoscale variabilities of the Northern Current have been analysed from a fortnightly hydrological survey carried out off Nice as far as ~55 km, from October 1990 to July 1991, and from ~30 current time series collected as deep as 2000 m, on 4 moorings set perpendicularly to the coast within a ~30 km coastal band, from December 1990 to May 1991, in the framework of the PRIMO-0 experiment (ALBEROLA, 1994; ALBEROLA *et al.*, 1994).

The hydrological characteristics of the different water masses have mainly evidenced some seasonal variations, concerning mainly the seaward spreading of LIW from the beginning of the formation of WMDW, the transformation of MAW into WIW in the deep winter, as well as the advection of less modified MAW. From a dynamic point of view, the seasonal variability is mainly depicted as a well-defined episode of narrowing, deepening and shoreward shift, from late January to mid-March, of a generally wide and shallow Northern Current. Currents have clearly appeared to be similar and highly correlated in an upper layer, the thickness of which is at least a hundred metres (between ~60 and 150 m), whatever the location of the points and the season are.

The flux of the Northern Current has ranged within 1-1.6 Sv, in agreement with the published values (e.g., BETHOUX *et al.*, 1982), and its temporal evolution has emphasized somewhat a rather long winter season (December-March) when relatively high values (>1.2 Sv) are maintained; the flux is maximum in December and slowly decreases till July at least. The maximum probably corresponds to the one reported by BETHOUX *et al.* (1982) and might be due to the maximum of the Eastern Corsican Current as hypothesized by ASTRALDI and GASPARINI (1992). The still-large values observed in winter might be due to the maximum of the Western Corsican Current expected to occur later on (ASTRALDI and GASPARINI, 1992), while the decrease from spring is coherent with the expected forcing phenomena and with the characteristics described by SAMMARI *et al.* (1994) who account for no marked variations from spring to early autumn.

A description of a complete annual cycle has been possible by using other observations (TAUPIER-LETAGE and MILLOT, 1986; SAMMARI *et al.*, 1994) with which ours are clearly coherent. Thus, the mesoscale activity increases from autumn to the deep winter and then displays a continuous decrease till summer at least; it has been clearly observed to propagate to the open sea in the deep winter. Mesoscale events have appeared to have a vertical extent of some few hundred metres, displaying quasi no rotation of the fluctuations with depth. So, such events should have a relatively simple vertical structure, corresponding mainly to the first baroclinic mode with its zero-crossing at 400-500 m. Currents are relatively well represented by the barotropic and first baroclinic modes, the baroclinic one being predominant and more energetic, especially in winter. However, consequently to the variations of the vein in width and depth, our most seaward mooring (~30 km) is either out or more or less in it; the dynamic regime is thus generally more complex there, except in the deep winter when the observed mesoscale events become the barotropic ones of the central zone governed by vigorous convection.

The fluctuations have generally time scales shorter in winter than in spring. Due to dramatic wintery transformations, the Northern Current is mainly altered by instability processes, leading to features looking like meanders. Indeed, it is very spectacular to note that its major fluctuations are quasi transverse within its core itself and that the anticlockwise energy increases while the clockwise energy vanishes when progressing seaward accross it. These meanders, steep and large, occur at 10-20 days and involve much more energy in winter than in spring when they have slightly shorter periods (~10 days). As previously observed (SAMMARI *et al.*, 1994), shorter fluctuations at 3-6 days are also associated with a meandering current and are expected to be intensified from spring-summer to the deep winter. The amplitudes of these meanders might be smaller than those of meanders at 10-20 days. In spring, while the flow is more stable, the predominant fluctuations look like pulses expected to have an horizontal extent of a few tens of kilometres. A fundamental observation for coastal oceanographic problems is that the circulation is actually unforeseeable in a very coastal zone (of ~10 km), dominated by turbulences. The main mesoscale phenomena, in this zone, have periods slightly shorter than well within the current.

The major seasonal and mesoscale features of the Northern Current (high flux values maintained during a relatively long winter season, narrowness and shoreward shift of the current leading the central zone to extend to the most seaward mooring) lead us to consider that the winter dense water formation should be one of the major forcings of the circulation in the northern part of the western Mediterranean Sea.

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