SURFACE LAYER CURRENTS AND MESOSCALE THERMAL PATTERNS IN THE BLACK BLACK SEA DURING APRIL 1993

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CTD and ADCP measurements carried out in April 1993 are used to describe the circulation in the western Black Sea. Figure 1a shows horizontal current vector distributions at 10 m level. Maximum velocities measured at stations did not exceed 45-50 cm/s, while measurements reached 70 cm/s during ship was under way. Large-scale structures coinciding to the Rim Current west of the Crimean peninsula and along the Turkish coast are well identified. Weaker flows are observed on the North-West shelf (10-15 cm/s), and in central regions of the sea (maximum ≈20 cm/s).

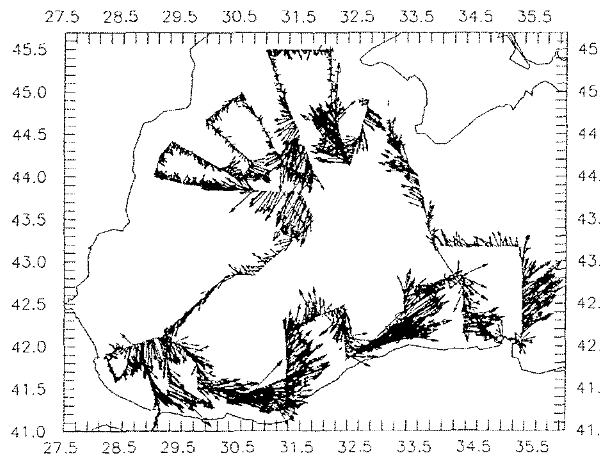
The nearest cloud free AVHRR scene to the cruise obtained in April 19, 1994 (Figure 1b) clearly shows the meandering band of warm water corresponding to the Rim Current west of Sevastopol. To the South, along 44.2°N the cold water area is formed possibly by flow divergence and separates into two branches. Amplitude of cold anomaly is -1.2 °C at the foot of northern current branch of cyclonic meander west of the Crimea. To the west of this meander, the anticyclonic Sevastopol eddy has a diameter of 55 km (centered at 44.5°N, 32.1°E). Further to the West there is another cyclonic meander separating the Sevastopol eddy from the next anticyclonic eddy centered at 43.3°N, 30.5°E.

The North-West shelf is colder (1.5-2.0°C) than the Rim Current water along the continental slope. Near the western shore, the Danube waters are well differentiated, since they are warmer than shelf water by about 1.5°C. The Danube waters enter the sea from three clearly distinguished three river mouths (Kilija, Sulina and St.George) and spread in a narrow band along the coast towards the South, forming the off-shore anticyclonic eddy south of Cape St.George. The cold shelf water zone connected with north-eastern shelf is seen in between the near-shore jet and Rim Current flowing along the shelf edge.

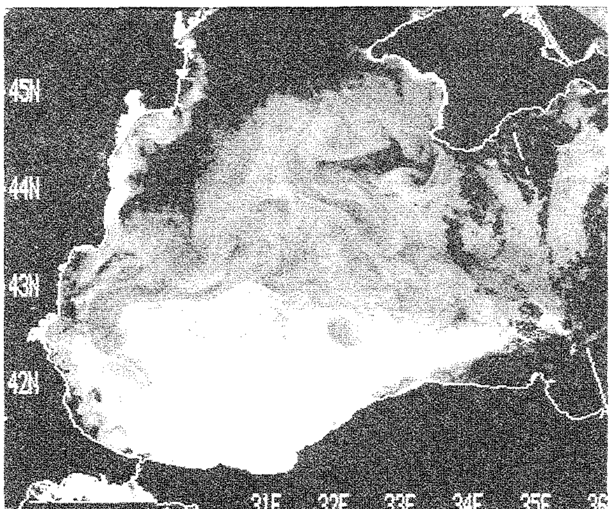
Along the southern coast, the Rim Current is distinguished by maximum temperature. An anticyclonic eddy north of this jet (centered at 42.5°N, 31.7°E) a diameter of ≈40km and temperature difference of ≈6°C between its center and periphery. The cold eddy was possibly generated by the instability of the Rim Current. Numerous frontal boundaries separating bands of water advected eastwards are observed in the region.

Very good correspondence exists between the currents and thermal structures. The velocity maxima coincide with the frontal regions. The combined use of ADCP and satellite data provides a better description of the mesoscale circulation as compared to the individual sets of data.

Figure 1. (a) ADCP current measurements at 10 m depth, ...



...and (b) infrared AVHRR images in April 1993.



PUTTING WATER MASSES, CIRCULATION AND SURFACE FLUXES TOGETHER FOR THE MEDITERRANEAN : A BOX-MODEL STUDY

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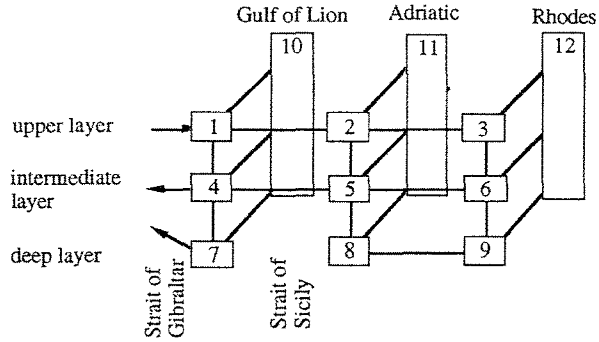
Water masses, circulation and air-sea interactions are three important components of the Mediterranean system. The estimates of these three components should be consistent in terms of heat and salt balance in differents sectors of the Mediterranean basin. In this study, we put the water masses, circulation and surface fluxes together in a box model to examin the heat and the salt balance. We estimates the latter two by asking the question : What circulation and surface fluxes give the Mediterranean temperature and salinity distributions ?



The 12-box model is shown in fig. 1. The southern 9 boxes represent the major body of the Mediterranean seea which is divided into three subbasins and into three layers, their thickness being 150 m, 450 m and about 1 500 m, respectively. Each of the northern three boxes represent the whole water column of the small region where deep or intermediate water is formed. Boxes are connected by horizontal and verticals flows and mixing. Surface heat and fresh water fluxes are applied to the six surface boxes. Atlantic water enters into box 1 and the Gibraltar intermediate and deep water outflows are from box 4 and 7, respectively. The average temperature and salinity for each of the nine southern boxes is calculated from the Levitus'data. The heat balance of the box model can be written as A x = b, where A depends on the flow and mixing rates, x is a vector of temperature for the 12 boxes, and b depends on the surface and Gibraltar heat flux. The temperature can be solved as $x = A^{-1}b$. Then the difference between the model temperature x of boxes 1-9 and the Levitus' is minimized by adjusting the flow and mixing rates and the surface heat flux. The flow and mixing rates are adjusted manually, guided by estimates from previous studies, and the surface heat is then determined by a linear optimization aquation. A similear procedure is followed to minimize the difference in salinity.

After many tries of flow and mixing patterns, the solution shown in figure 2 was found to give a good match of water masses to Levitus'; the average differences between the model and the Levitus' are 0,15°C in temperature and 0,06‰ in salinity. In figure 2, the two numbers in each ocean box are temperature and salinity. The number above the line is the flow rate in Sv, the number below the line and enclosed in parentheses is the mixing rate in Sv. The two numbers in a gray line box are the heat and fresh water fluxes into the ocean, in W/m^2 and m/year respectively. The flow and mixing rates and the surface fluxes that produce the fit in fig. 2 are in good agreement with other estimates in general. A major problem in reproducing the Levitus'water masses is that the intermediate water in the western Mediterranean (box 4) cannot be cooled enough; box 4's temperature is 13,73°C, 0,4° higher than the Levitus. The warmer box 4 leads to a smaller temperature difference between the inflow and outflow at the strait of Gibraltar, thus a smaller basin-wide heat loss (3,5 W/m^2) than other estimates. In fig. 2, box 4 is cooled mainly by the 0,2 Sv upwelling. What else can also cool the western Mediterranean intermediate water ? When we changed the horizontal mixing between boxes 4 and 10 from the backgroung mixing of 0,6 Sv to 3 Sv, representing a 2-3 intermediate water production in the western Mediterranean, box 4 is cooled to the Levitus'value, and the overall fit becomes much better, the average difference between the model and the Levitus being reduced to 0,05°C and 0,3‰. A plausible argument for this large amount of intermediate water formation in that, in a less severe winter storm, the cooling in Gulf of Lions forms water that is no dense enough to penetrate to the deep layer but instead spreads to the intermediate layer. Increasing the deep water formation in Gulf of Lions and enhancing the mixing with deep water are other mechanisms to cool box 4. The basin wide average heat loss in fig. 2 is 3,5 W/m^2, set by the Gibraltar heat flux. unlike the other estimates, the distribution among the three subbasins is unevent large heat losses in the western and eastern subbasins and a heat gain in the central subbbasin. This flux distribution is determined by the circulation and ocean temprature. As the 1,1 Sv of water flows from box 1 to 2, the temperature jumps to 2°C, requiring a large amount of surface heating in box 2, while the 1 Sv intermediate water production in box 12 demands substantial surface cooling.