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Deep water renewals and oxygen deficiency in the Sea of Marmara

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The Marmara Sea is located between the Black Sea and the Aegean Sea, connected to those adjacent basins via the narrow, shallow and long straits of Bosphorus and Dardanelles. The results and analyses of recent repeated surveys are reported in the following.

A distinguishing feature of the Sea of Marmara is the permanent oxygen deficiency below the halocline. The deficiency of oxygen is due to natural causes and dates back at least to the most recent geological evolution of the basin (3000 years b.p.). In the Black Sea, oxygen ceases to exist below a mean depth of 200m, while in the Aegean Sea the whole water column is effectively ventilated. The Marmara Sea is stratified in two layers with a sharp pynocline located at a depth of 25m. The density changes are mainly accounted by the differences of salinity between the layers, with fresh (brackish) waters of Black Sea origin overtopping the high salinity Mediterranean waters below the halocline.

The Black Sea surface waters entering the system through the Bosphorus Strait and the Aegean waters entering through the lower layer of the Dardanelles Strait are both in saturated in oxygen. In spite of this supply of oxygen, the subhaloclinic waters in the basin are deficient (20-30% of saturation). The sharp pycnocline ($\Delta\rho/\rho \approx 0.01$) prevents ventilation of the deep waters by mixing from the surface and the organic decomposition processes in the deep layer partially utilize the oxygen supplied by the Dardanelles underflow to the deep waters. The renewals of deep Marmara basin waters by the dense, saline and oxic Dardanelles inflow prevents the basin from becoming anoxic, although this input is insufficient to completely meet the oxygen demand. Therefore, the competing effects of oxygen utilization by the sinking flux of organic matter and supply by the Dardanelles underflow are in a state of equilibrium.

The relatively deep Marmara trough (≈1300m at the deepest points of its three sub-basins) acts as a settling basin for POC, which is predominantly generated by its own primary productivity, with POC in-out fluxes playing secondary roles.

The annual mean primary productivity is estimated to be 60 gC/m^2, and supported by estimates obtained from the carbon content of the bottom sediments.

The sinking flux of POC is estimated from New Production, and is found to be equally contributed by upward mixing of neutrients in the Bosphorus exit region adjoining the Marmara Sea (a permanent biochemical cycle related to hydraulic jump/jet induced mixing in this zone) and the supply of neutrients from the Black Sea. The sinking POC is entrapped in the basin and utilizes oxygen with an estimated rate of 0.50-0.75 mg/l/yr.

The deep water renewals which make up for the oxygen losses occur in the spring months when the Aegean water density is a maximum. The dense water sinks to the bottom of the western sub-basin and relatively enriches the deep oygen concentrations (1.7 ml/l) as well as increasing the bottom water density. This patch of water then partially penetrates into the central and eastern sub-basins over the sills (≈700m) separating the basins, but by the time it reaches the eastern basin oxygen decreases to values less than 1.0 ml/l. The sinking water is also identified by small but significant salinity and temperature anomalies and fine structure superimposed on an otherwise constant temperature (14.5 °C) and salinity (38.5 ppt) distribution in the subhalocline waters.

The water entering with the Dardanelles underflow is modified in the Strait by mixing and further evolves during a sinking plume stage. The interior density distribution is continually modified by the horizontal intrusions after the sinking plume stage, and in the seasons other than spring, intermediate level (100-300m) intrusions can also be observed. Since the sinking process dependes on the Aegean seasonal conditions, the mixing in the Dardanelles and the plume stage and the evolution of the interior density, it appears to be highly intermittent although the traces of renewal are always observed since the residence time of the subhalocline waters are sufficiently long (6-7 years). In general, the sinking water is denser due to its higher Mediterranean salinity, but occasions where the excess density is caused by low temperatures of the inflowing water have also been observed. Immediately below the halocline (50-70m), a permanent warm layer (15 °C) exists, which also has lower oxygen and relatively longer estimated transit times than the deeper waters.

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POEM-V-87 General circulation survey : Maps of the Eastern Mediterranean Basin variability

POEM Group

444 CTD and 124 XBT were collected during the period August-September 1987 in the whole Eastern Mediterranean basin. Preliminary analysis of the isoltherm depths (14°, 15°C) and dynamic height topography (referred to 800 m) reveals a new picture of the basin circulation: large anticyclonic centers (south of Cyprus and Crete, in the middle of the Ionian basin) and a meandering cyclonic Rhode Gyre. The general circulation flow is there difficult to be seen as a basin-wide current: the picture hints at an intense mesoscale/gyre circulation pattern dominating the instantaneous circulation flow. Both LIW and AW are found interspaced or trapped in this mesoscale/gyre system.

Dyn Ht (250/800)

Dyn Ht (400/800)

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