PHYSICAL AND BIOGEOCHEMICAL VARIABILITY OF THE MARMARA SEA

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Abstract
A comprehensive set of data collected during 1986-2000 and satellite observations reveal seasonal and interannual variability in the physical, chemical and biological properties of the Marmara Sea. Incoming Black Sea and Mediterranean Waters with contrasting properties set-up the basin characteristics.
Keywords : Marmara sea, Circulation, Hydrography, Geochemistry.

1. Introduction
The Sea of Marmara, the central feature of the Turkish Straits System (TSS) linking the Black Sea through the Bosphorus and Dardanelles Straits to the Aegean Sea, is a relatively small, intercontinental basin with a surface area of 11500 km^2 and a volume of 3378 km^3. The Marmara Sea is occupied by two water masses of distinctive physical and biochemical properties, separated by a permanent halocline. An upper layer, 15-20m deep, of brackish water flows in from the Black Sea and a lower layer of the saline water of Mediterranean origin.

2. Physical structure
The mean upper layer circulation is anti-cyclonic, mainly driven by the southward flowing Bosphorus jet in the enclosed domain. However, this anti-cyclonic circulation is altered by local wind forcing. For example, during periods of low influx from the Bosphorus, strong winds from the south can disintegrate basin-scale gyres into smaller scale eddies. The Bosphorus inflow is well defined, except during the periods of low discharge in autumn and winter, when the jet becomes weaker and tends to flow along the west coast [1].
As the upper layer of the Marmara Sea is occupied by brackish Black Sea water flowing through the Bosphorus, and the renewal time of the upper layer is short (≈4 months), the biochemical structure of Marmara Sea surface waters reflects Black Sea coastal water characteristics. (Figure 1)

3. Chemical structure
Mediterranean water, entering from the Dardanelles, supplies the sub-halocline layer. The negatively buoyant plume of well-oxygenated water is the only means by which deep waters are renewed and partially compensates for the oxygen consumed through the degradation of organic matter sinking from the upper into the lower layer. Yet the sub halocline waters remain permanently deficient in oxygen, as a result of the internal balances of diffusion, advection and consumption. The depth to which the plume penetrates is a function of the seasonal characteristics of the inflow density (modified in the Strait) and the weak interior stratification. As shown by observations, the paths of the Dardanelles inflow in the Marmara Sea play a crucial role in the distribution of the biogeochemical variables.
The saline Mediterranean waters entering through the Dardanelles, initially poor in nutrients and almost saturated with oxygen, become enriched 10-fold with dissolved inorganic nutrients while oxygen decreases to 1-2 mg/l. These Mediterranean waters with modified chemical properties eventually leave the Marmara basin through the Bosphorus.
The oxygen utilization in the water column occurs mainly due to the sinking of particulate organic carbon generated by biological production at the surface. The sinking of large organic particles leads to a decrease in dissolved oxygen below the pycnocline. However, the sub-halocline waters of the Marmara Sea are due to the oxygen-rich Dardanelles inflow and thus the decrease in DO is not sufficient to cause anoxia.

4. Biological properies
In the Marmara Sea, incoming solar irradiance can penetrate to the lower limits of the pycnocline and the light is reflected at around 500 nm, with very low reflectance (2 %) at surface. In addition, the Marmara Sea is a typical example of the Case II waters, as the light absorbance is driven by the presence of particulate matter and the yellow substance is relatively high.

Light penetration is limited to the depth of the pycnocline and thus both phytoplankton biomass and primary production are always confined within the upper layer. Annual primary production occurs in the upper 10 meters of the water column and is estimated to be 500-550 g C m^2 $year^1$. The annual cycle of phytoplankton (as inferred from satellite chlorophyll measurements) in the Marmara Sea includes biomass peaks in winter-spring and fall, which is characteristic of Black Sea coastal waters.

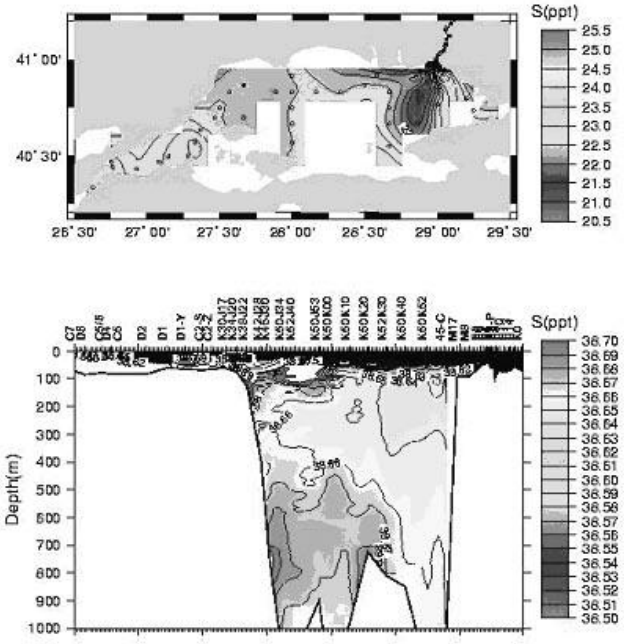

Fig. 1. Distribution of salinity in the Marmara Sea during September 1995.

Reference
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