Turkish Straits System

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Abstract- The Turkish Straits System (the Dardanelles, Bosphorus Straits and the Sea of Marmara) is sensitive to environmental changes, and potentially can induce such changes in the adjacent basins. Acting as the limiting element of the Turkish Straits System, the Bosphorus Strait controls the exchange of mass and materials between the Black and the Mediterranean Seas. A full understanding of the current system in the Bosphorus and modelling is essential for prediction of the environmental effects in the adjoining seas and for safe navigation through the Strait, currently threatened by massive shipping activities. Recent measurements in the Bosphorus and Dardanelles Straits using ADCP and CTD profiling, and current-meter recordings are described.

Key words- Turkish Straits, Bosphorus, exchange flows.

Results and Discussion

The Turkish Straits System (consisting of the Dardanelles, Bosphorus Straits and the Sea of Marmara) is sensitive to climatic changes, and potentially can induce such changes in the adjacent basins (Özsoy, 1999). Acting as the limiting element of the Turkish Straits System, the Bosphorus Strait controls the exchanges of mass and materials transport between the Black and the Mediterranean Seas (Ünlüata *et al.*, 1990; Özsoy *et al.* 1995b; Özsoy and Ünlüata, 1997).

The Turkish Straits System is a highly stratified (fjord-like) two-layer system, acting as buffer for waters flowing in both directions between the Black and Aegean Seas. Mixing and turbulent entrainment processes in the two Straits and at their junctions dominate the evolution of the salinity of waters transported away from their original reservoirs (Beşiktepe, et al., 1993, 1994, Gregg and Özsoy, 1999; Gregg *et al.*, 1999; Özsoy *et al.*, 2001). Straits conveying waters of foreign origin, as well as fresh waters from large rivers act as buoyancy sources for the adjacent basins of the Aegean, Marmara and Black Seas. The complex topography of the Straits, continental shelf, slope and abyssal regions play important roles in channeling and the subsequent transformation of waters of different origin.

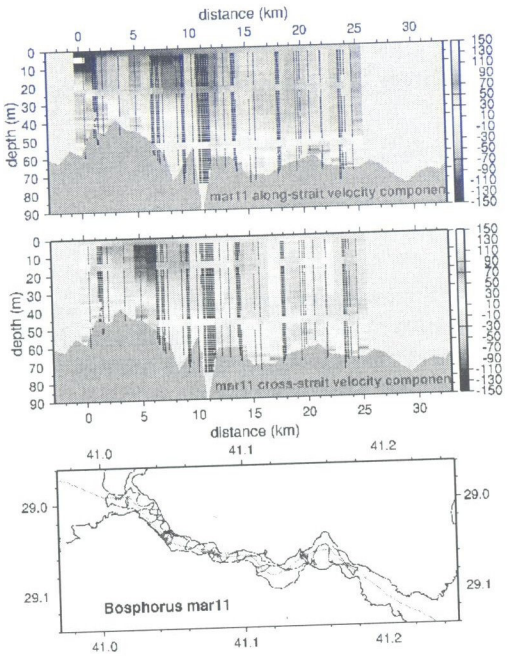

Fig. 1. ADCP current measurements in the Bosphorus March 11, 1999. Along channel (top panel) and cross-channel (middle panel) currents and the ship track (bottom panel).

Based on budgets the upper layer flow is about two times larger than that of the lower layer, yielding a net flux of about 300 km^3/yr from the Black Sea to the Sea of Marmara (Latif *et al.*, 1991; Ünlüata *et al.*, 1990). Geometrical features (Oğuz *et al.*, 1990; Özsoy *et al.* 1998) make the Bosphorus predisposed to 'maximal exchange', with contraction and sill controls (Farmer and Armi, 1986). An example of two-layer currents, measured by shipborne ADCP is shown in Fig. 1. Local topographic features have significant influence on the flow, and determine its detailed structure. The exchange flows respond dynamically to time-dependent meteorological and hydrological forcing in the adjacent basins (Özsoy *et al.* 1995a, 1996, 1998; Gregg and Özsoy, 1999). Observations suggest (Fig. 2) increased entrainment south of the contraction (upward) and past the northern sill (downward) in the Black Sea (Gregg *et al.*, 1999, 2002; Özsoy *et al.*, 2001; 2002).

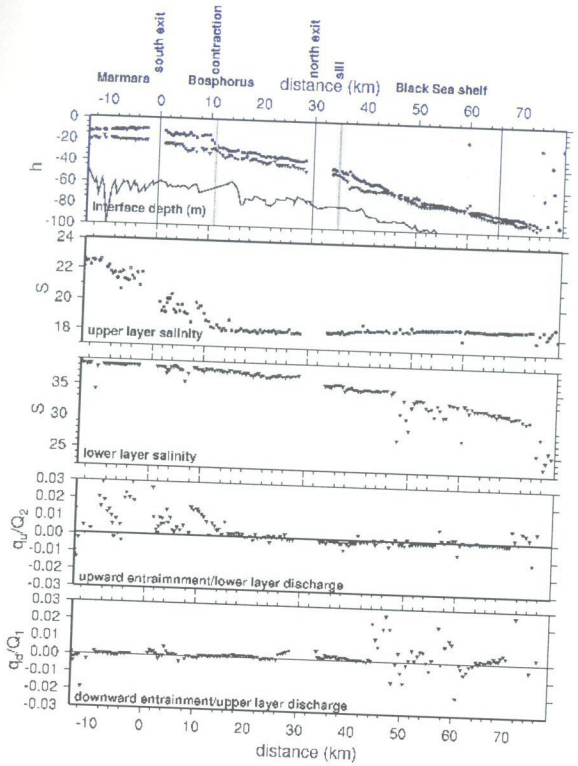

Fig. 2. Interface position, bottom depth, upper and lower layer average salinity, and calculated upward and downward entrainment fluxes in the Bosphorus Strait based on the 1994 measurements (Özsoy et al., 2001; Gregg et al., 2002).

The Sea of Marmara possesses a two-layer stratification and associated flow system, in which an approximately 25 m layer of relatively less saline water mass of the Black Sea origin is separated from the rest of the water body by a sharp permanent pycnocline. The two-layer structure is preserved even in the winter season when abrupt cooling of surface waters increases the density of the upper layer by about 1-2 kg m^{-3}. The corresponding flow system in the sea reveals a stronger circulation in the upper layer with its preferential direction towards the Aegean Sea. The upper layer circulation inferred from the existing hydrographic data (Beşiktepe et al., 1994) suggests the presence of a large anti-cyclonic loop of the surface circulation upon issuing from the Bosphorus into the Marmara Sea (Fig. 3). The currents in the lower layer are much weaker, and the time scale of their

transit across the sea towards the Bosphorus is approximately an order of magnitude longer than that of the surface layer.

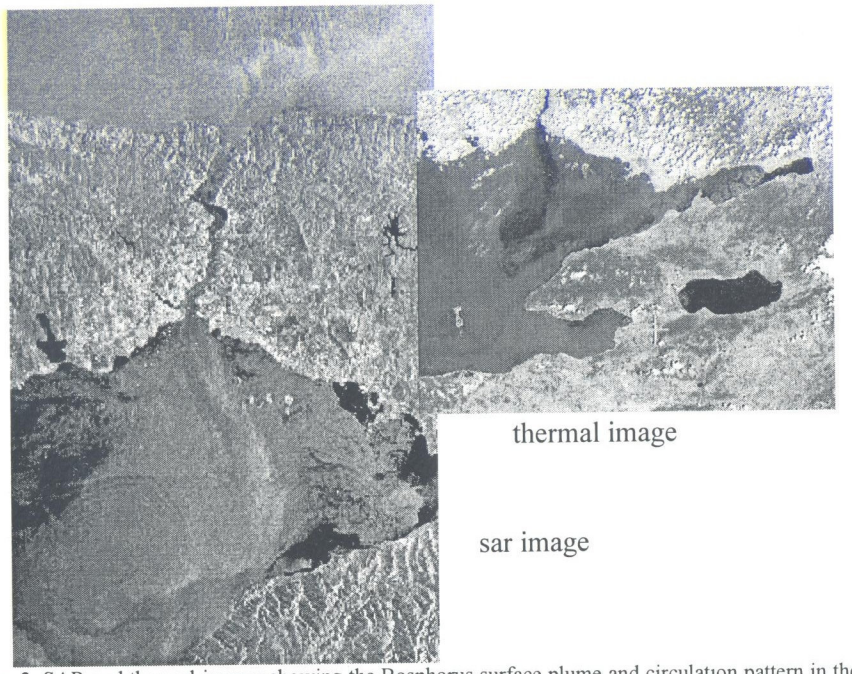

Fig. 3. SAR and thermal images showing the Bosphorus surface plume and circulation pattern in the Sea of Marmara

The marine transport from the Eurasian hinterland to the Mediterranean, aimed towards other coastal states of the world, moves along the Black-Marmara-Aegean Seas and converges upon the Turkish Straits System (TSS) connecting these Seas. At present, over half of Russia's oil exports, which has doubled in the last 50 years, presently pass through the Turkish Straits. The resulting saturation of the traffic carrying capacity makes the Straits extremely predisposed to accidents, while the expected increase in the traffic load to almost triple the present level in the next decades calls for urgent measures. The Sea of Marmara and the historical city of İstanbul (Fig. 4) with a population of more than 10 million, is threatened by shipping accidents and pollution. The Bosphorus is unique among the 264 straits used by shipping worldwide, because this narrow waterway provides the only access to international waters for hinterlands of Eurasia through the Black and Caspian Seas. Linking three continents, the TSS is four times busier than the Panama Canal.

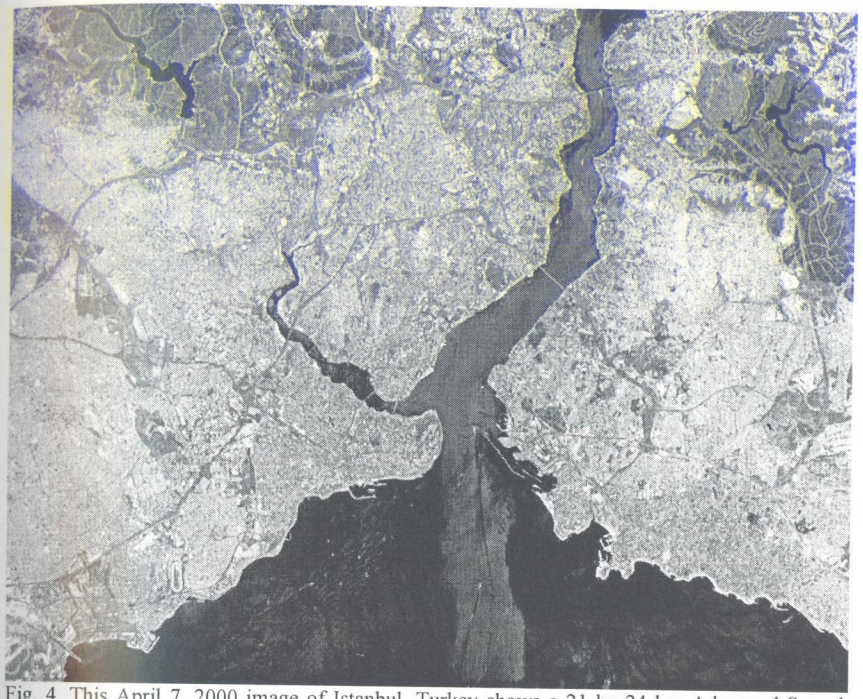

Fig. 4. This April 7, 2000 image of Istanbul, Turkey shows a 21 by 24 km Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) sub-scene in the visible and infrared channels. Bustling Istanbul, with its magnificent historical heritage, has spanned the divide between Europe and Asia for more than 2,500 years. Two bridges spanning the Bosphorus, and ships in the busy channel can be seen. The ships sailing along the Bosphorus encounter rapid surface currents, which have non-uniform spatial and temporal structure determined by the narrow constriction, the sharp bends of the channel, re-circulations created in the shallow banks, as well as hydro-meteorological and oceanic variability in the adjacent basins. *(Image courtesy ASTER science team. (http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=4189)*

On the other hand, the complexity of the marine and atmospheric climate processes, and the scarcity of some resources in the Turkish Straits region calls for integrated scientific investigations. Networks of observing systems, shared data bases and models, integrated through supporting institutions are essential for answering key questions with respect to the impact of climate change in the region, and to enable environmental prediction and management from the perspective of global change.

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