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Modeling the Turkish Straits System with a Multi-Scale Model

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Two narrow, shallow straits, i.e. the Dardanelles and the Bosphorus, form a physical connection between the Marmara Sea and its adjacent water bodies, the Aegean Sea to the southwest and the Black Sea to the northeast. This collection of seas and straits is known as the Turkish Strait System (TSS). Saline, dense water from the Aegean flows in a deep, lower layer through the Marmara Sea to the Black Sea while fresher and lighter Black Sea water flows in a surface layer to the Aegean Sea. Flow within the TSS is often interpreted in terms of classic two-layer estuarine flow. Though the TSS dynamics are the result of interconnections between the straits and the ocean basins, earlier modeling efforts have focused dynamical studies on individual straits or seas. Often the geometric complexity, the broad range of spatial scales present, and the computational resources required to represent such disparity have prevented a study of the entire TSS as a whole.

For this study, we utilize state-of-the-art modeling practices to capture the range of spatial scales, geometric complexity and interconnected dynamics of the TSS. A model based on unstructured grids has the resolution, using a minimum element edge length of 20 m, necessary to model flow in the narrow straits whose minimum width is approximately 600 m. The ADvanced CIRCulation Model (ADCIRC), solves the three-dimensional flow and transport equations using a finite element discretization with a terrain-following, generalized, stretched coordinate system applied in the vertical. Flexibility of the finite element mesh not only captures the fine scales within the straits but is also able to represent mesoscale variability in the Marmara Sea while coupling to a basin scale model in the Aegean and Black Seas. Basin-wide dynamics are captured by the HYbrid Coordinate Ocean Model, HYCOM, which applies the finite difference method over a structured grid to solve the primitive mass and momentum balance equations. HYCOM's hybrid vertical coordinate allows the use of three vertical coordinate types (depth, terrain-following and isopycnal) which better represents thermohaline dynamics in waters of rapidly varying bathymetric change. Within the HYCOM Aegean-Marmara-Black Sea model (HYCOM-AMB), both straits are represented as idealized channels since the current resolution ($\sim$1.3 km) is not sufficient to resolve the geometry of the straits.

Model experiments presented focus on the time period of the TSS08 sea trial (a joint project between the NATO Undersea Research Center and the U.S. Naval Research Laboratory), starting in late August and extending through November 2008. ADCIRC is initialized by temperature, salinity, velocity and water surface elevation fields from HYCOM-AMB solutions over the same region. At the open ocean boundaries, HYCOM-AMB values for elevation, temperature and salinity are updated daily throughout the ADCIRC model simulation. Surface forcing for both models is derived from the Navy's Coupled Ocean-Atmospheric Mesoscale Prediction System (COAMPS) at a resolution of 3 km. The capability of ADCIRC to represent two-layer stratified flow dynamics both in the straits and in the Marmara Sea is examined. The response of the currents and density structure over the water column to wind forcing will be examined. Observations include measured currents from ADCP moorings located at the ends of each of the two straits in the TSS, CTD casts along the Dardanelles Strait and drifter deployments in the Marmara Sea. Observed features of interest include flow reversals in the straits during strong storm events, the coincidence of tidal and current variability, and the persistence of circulation gyres in the Marmara Sea.