1. OBJECTIVE

At present, the Marmara Sea is a forgotten component of the global ocean system. It is included neither in the high resolution eddy resolving ocean models nor in the existing operational models. Examples of such fine resolution models include

(1) 1/32° Naval Research Laboratory (NRL) Layered Ocean Model (NLOM): Wallcraft et al. (2003),

(2) 1/16° Mediterranean Forecasting System Toward Env. Prediction (MFSTEP): Pinardi et al. (2003),

(3) 1/12° HYbrid Coordinate Ocean Model (HYCOM): Chassignet et al. (2006),

(4) 1/12° Danish Meteorological Institute (DMI): Buch and She (2005),

(5) 1/8° Navy Coastal Ocean Model (NCOM): Barron et al. (2006),

(6) 1/3° MERCATOR: Ferry et al. (2005), and

(7) 1° Forecasting Ocean Assimilation Model (FOAM): Micheal et al. (2006).

The main reason for not including the Marmara Sea in the above mentioned systems is that it is connected to the Black and Aegean Seas through the vey narrow Bosphorus and Dardanelles Straits. The width of the former varies between 0.6 and 3.5 km and that of the latter varies between 1.2 and 7.0 km. Such narrow straits are difficult to be resolved by an ocean model grid. For example, global NLOM has the the finest resolution (approx3.5 km) ocean model, and that resolution is not sufficient to resolve straits.

Given the lack of reliable eddy-resolving numerical ocean models for investigating main oceanographic features in the Marmara Sea, including their dynamical and physical processes, there is a strong motivation to develop one. Global ocean models would also get great benefit from such a regional model as well. For example, the Marmara Sea is unique in a way that besides heat fluxes, evaporation and precipitation can have significant influences on the dynamics of water. Atmospheric forcing can therefore play a major role in predicting upper ocean quantities such as sea surface circulation, sea surface height (SSH), and sea surface temperature (SST).

2. APPROACH

Among the other ocean models mentioned previously (NRL, NLOM, and MFSTEP etc), HYCOM seems to be a good candidate for modeling of the Marmara Sea because of the flexibility in its coordinate levels. The hybrid coordinate is one that is isopycnal in the open, stratified ocean, but smoothly reverts to a terrain-following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas. The optimal coordinate is chosen using a hybrid grid generator at each model time step based on the mass continuity equation (Bleck, 2006). Therefore, the model combines the advantages of different coordinate systems within a single framework to allow for the optimal coordinate choice in simulating coastal and open-ocean features in the Marmara Sea. The hybrid coordinate extends the geographic range of applicability of above mentioned models, toward shallow coastal seas and unstratified parts of the Marmara Sea. One can use the switching capabilities of coordinate systems among the z-level, sigma, isopycnic levels, which are necessary for a region like Marmara Sea where complex interactions between coastal and open ocean are expected due to its unique geometry and the bathymetry.

Since there are not any fine resolution ocean models, examining dynamical and physical oceanographic features of the Marmara Sea, an eddy-resolving HYCOM (0.2 km resolution) will be configured for the region. There will be 15 or 25 hybrid layers in the vertical in this configuration, which will be sufficient for the relatively shallow region (max depth of $\approx$ 1000 m). However, further tests will be performed to come up with the optimal number of layers that need to be used in the simulations.

Previously, HYCOM was implemented to the Black Sea, a region where interactions between coastal and open ocean regions are of interest (Kara et al., 2005a,b,c,d). Using that model, a connection between the Marmara Sea and the Black Sea may be made through the Bosphorus Strait. It is possible to setup a Marmara only HYCOM at high resolution. The problem will be getting good boundary conditions in the Aegean and Black Seas.

Another possibility is to model the Black, Marmara, and Aegean in one HYCOM domain. This might be possible with a higher resolution Marmara if a curvi–linear grid can be worked out with the correct distribution. However, one problem with this approach is that the time step is set by the smallest grid size. A hybrid between the two approaches would be to add an on-line two-way coupling (nesting) option to HYCOM (currently we have off-line one-way nesting). Then, the high resolution Marmara Sea could be nested inside lower resolution Black and Aegean Seas. All these ideas present many challanges in modeling the Marmara Sea, involving both straits.

All model simulations will be climatologically–forced. HYCOM needs the following time-varying atmospheric forcing fields: wind stress, wind speed, and thermal forcing (air temperature, air mixing ratio, short wave radiation, and net solar radiation). There are strong uncertainties in the existing climatologies in the region, and the quality of these climatological data sources have not been confirmed in literature. We will use NOGAPS (The Fleet Numerical Meteorology and Oceanography Center (FNMOC) Navy Operational Global Atmospheric Prediction System) data, constructed during 1998-2005, to force the model. NOGAPS has a grid resolution of $0.5^{\circ} \times 0.5^{\circ}$ While atmospheric forcing variables from NOGAPS have coarse resolution, for forcing HYCOM in a relatively small region, like Marmara Sea, it is the only available one in addition to the COAMPS (Coupled Ocean/Atmospheric Mesoscale Prediction System), an analysis–nowcast and forecast tool applicable for any given region of the earth. A higher resolution (e.g., $0.2^{\circ} \times 0.2^{\circ}$) COAMPS may be set up for the Marmara regions to obtain atmopsheric forcing parameters as well. National Centers for Environmental Predictions (NCEP) has too coarse resolution of $1.875^{\circ} \times 1.875^{\circ}$ for the Marmara Sea, therefore it is not considered as a forcing source at all. Climatologically–forced simulation will then be extended inter–annually using atmospheric forcing from operational NOGAPS and COAMPS.

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