Modeling the Response of Monterey Bay to Observed and Model Winds and Tidal Forcing

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LONG-TERM GOALS

The long-term goals of our project are to improve comprehensive high-resolution numerical models of the coastal ocean circulation for regions with complex bottom topography, coastlines, and multi-scale physical phenomena using enhanced gridding technology, nested open boundary conditions, and ultimately, data assimilation of new observational data types such as surface currents from the Coastal Applications Radar (CODAR). The goals include model validations against observed data.

OBJECTIVE

This program seeks to apply new technologies to Navy coastal ocean modeling activities. It includes numerical simulations of the responses of the Monterey Bay (MOB) circulation to tidal and wind forcing using the MOB curvilinear, nearly-orthogonal, multi-block grid coastal ocean model developed at the NPS. It also includes the model validation against observed data in Monterey Bay.

APPROACH

The MOB coastal ocean system (COS) has been developed at the NPS and is used in the study. The MOB COS includes data processing routines, a grid generation routine, a grid-model coupling package, and visualization routines. Its curvilinear, coastline-following (coastline fitted) orthogonal and nearly-orthogonal, multi-block grid options represent a new advance in coastal ocean modeling. The system also includes a hybrid vertical grid that combines aspects of z-level and sigma-coordinate grids to better model surface and bottom boundary layers. The data fields used for this project include all available hydrographic data, real-time and retrospective surface current and winds from a network of the CODAR sites around MOB and the NCAR MM5 atmospheric mesoscale model. The Schwiderski tidal forcing with eight tidal constituents is inserted into the MOB COS to study the response to tidal forcing. To validate MOB COS in a comprehensive high-resolution, coastal domain, it is necessary to focus on robust processes with high frequency signals that are relatively unaffected by the conditions prescribed on the open boundaries. The strong current fluctuations in Monterey Bay forced by diurnal sea breeze winds and tidal oscillations are being used. Monterey Bay is also the site of unique high frequency radar measurements of two-dimensional surface current patterns.

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WORK COMPLETED

The coastal system for MOB is initialized with the July monthly mean values of new climatological three dimensional temperature and salinity fields from all available datasets to date. The NCAR MM5 monthly mean surface wind for July has been used for the system. The wind model domain consists of coarse and nested grids with resolution of 9 and 3 km, respectively. The nested grid is centered at the middle of the MOB. The barotropic tidal model has also been developed for the Monterey Bay region with various open boundary conditions, realistic topography with 131 by 131 grid points, and the Schwiderski tidal forcing of eight tidal constituents (M2, S2, N2, K2, K1, O1, P1, Q1). The model has been tested with various classical open boundary conditions, including a modification of Red and Bodine (RB, 1968), to filter out reflected waves in the barotropic forcing. We have tested the sensitivity of our MOB COS to nudging toward surface currents in preparation for tests with CODAR data. We have also proposed a wave-dependent roughness length parameterization to be used to project the near-surface CODAR observations onto the variable-thickness sigma level.

RESULTS

Our study (Ly and Luong, 1998b) has shown that the MOB COS can be stably forced for many months with realistic complicated bathymetry and horizontal density gradients form new 3-D MOB temperature and salinity fields from all available observational data to date. The simulations with MM5 July winds and a new dataset of temperature and salinity show that the summer (July) upwelling-favorable (equatorward alongshore component) winds in the Monterey Bay region move surface water away from shore so that it must be replaced by colder and higher salinity upwelled water (Ly and Luong, 1998b). The simulations also show that coastal regions have strong upwelling activity in the summer (upwelling centers) and strong coastal currents. The signatures of the upwelling and coastal current activity are shown by more contours in comparison with the rest of the model domain. The surface current vectors (which are not shown here) show more clearly the summer upwelling and coastal current activities. These equatorward currents have typical speeds of 20-30 cm/s. This magnitude of the coastal cold equatorward current is also observed . The summer period of year is characterized by strong upwelling which is reproduced by our coastal ocean system for Monterey Bay. The upwelling location can be seen from the surface temperature field (Fig. 2). The upwelling regions have a surface temperature of less than 11 C-degrees. The upwelling locations and surface temperature magnitude are observed. It is noted that the MOB COS with ne data fields of temperature, salinity and wind reproduce a new upwelling center off the Pt. Sur region (Fig. 2) which agrees better with observations in comparison with the model with an old data field (Ly, Luong, Paduan and Garwood; 1998). We have developed a barotropic tidal model for the MOB region. The model has eight constituents and realistic topography (Ly, O'Connor and Paduan, 1998). The tidal model was tested with various open boundary conditions (OBC) including our modification from RB OBC. We found that both sea water levels and the tidal currents are sensitive to OBC. Both clamped (CL, Ippen, 1966) and Reid and Bodine (RB, 1968) OBC produce good surface elevations, but neither produce good tidal current fields. Both may work well for shallow water where dissipation is large. For the MOB region, the model domain has three OBC with deep bathymetry and almost no shallow depths, the dissipation is small and reflection is large, so that neither clamp nor RB work well in comparison with our OBC in Fig. 1 (LP-OBC, Ly, O'Connor and Paduan, 1998).

IMPACT/APPLICATIONS

The MOB COS is used to study the model forecast capability using a new data type of CODAR surface currents and real-time MM5 surface winds for regions of complicated coastlines and bottom topography. The developed system is able to provide 4-D analyzed ocean structure for the MOB region as a prototype for coastal environmental systems. It may also be used for various applied sciences, including undersea acoustic and environmental applications. The system can be used in air-sea and sea-wave coupling. Application of the numerical grid generation technique is a new advance in coastal ocean modeling (Ly and Luong, 1998a). The technique and our grid routines are of interest to various research groups.

TRANSITIONS

Our work is done in close cooperation with NAVO and DoD HPC (Dr. Phu Luong, Stennis Space Center, MS). Our modeling efforts and products are shared with them.

RELATED PROJECTS

This program is closely related to the DoD and ONR projects on coastal atmospheric mesoscale modeling for the northern California coastal region using NCAR MM5 by Dr. Koracin et al. of the Desert Research Institute (Reno, NV) regarding high-resolution model surface wind fields for the northern California and the Monterey Bay regions.

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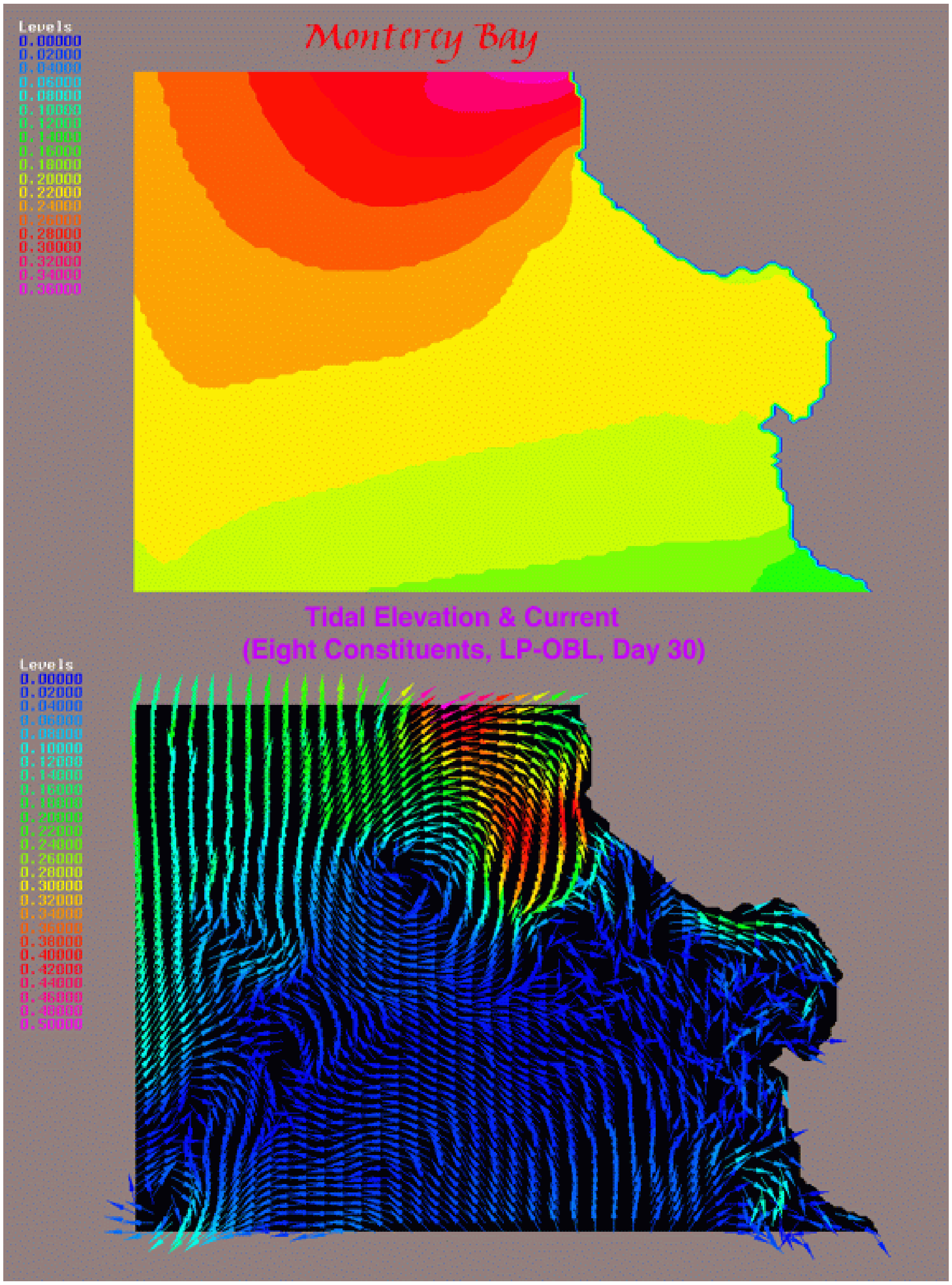

Figure 1. Tidal Elevation and Current Fields for the Monterey Bay Region (Eight Constituents, LP Open Boundary Condition)

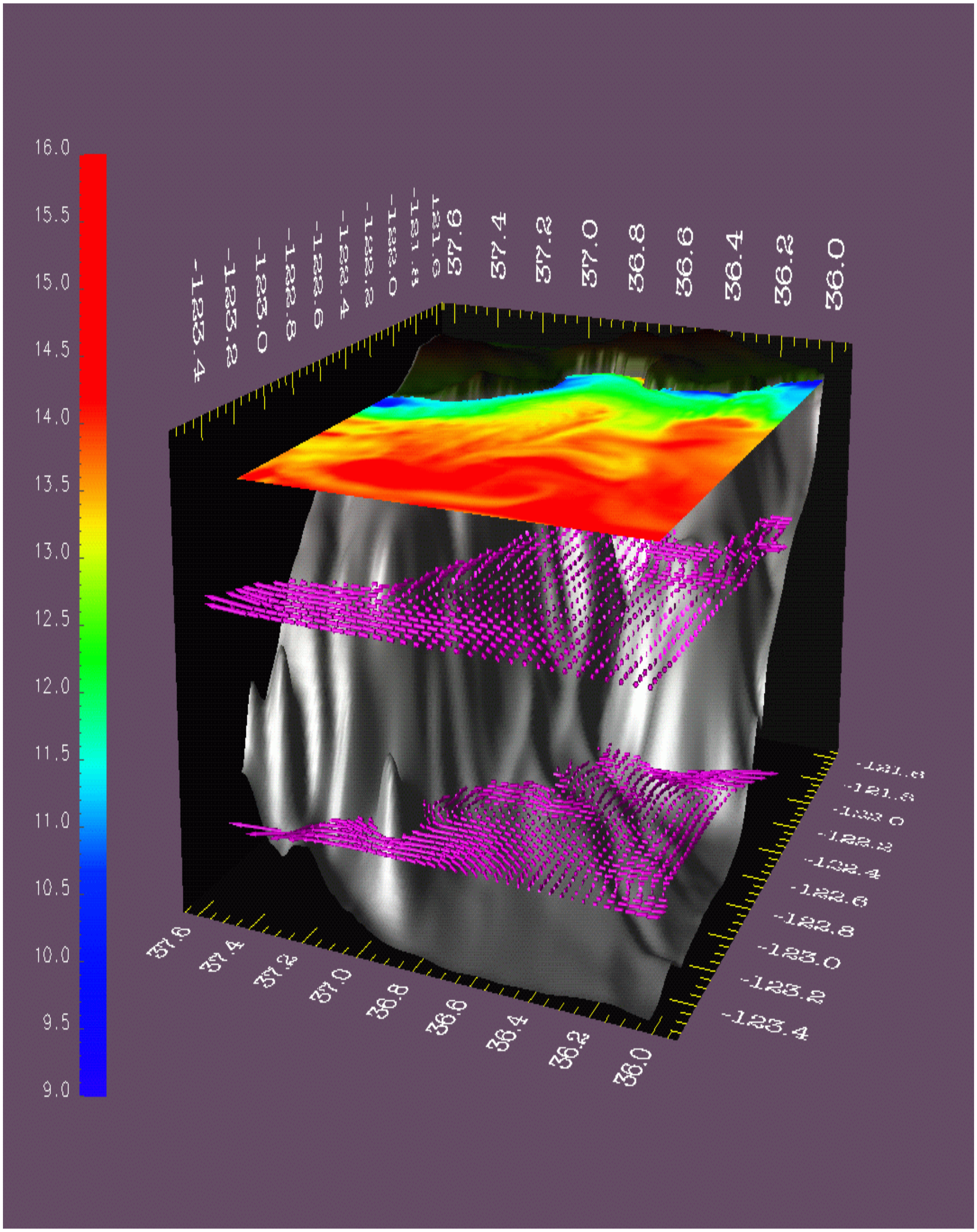

Figure 2. Model Surface Temperature and Current Fields for the Monterey Bay Region