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Modeling the Response of Monterey Bay to Diurnal

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MODELING THE RESPONSE OF MONTEREY BAY TO DIURNAL WIND AND TIDAL FORCING

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LONG TERM GOALS

Long-term goals of this project are to improve high-resolution numerical models of the ocean circulation for the regions with complex bottom topography, coastlines and multi-scale physical fields using enhanced grid technology, nested open boundary and, ultimately, data assimilation of new observational data type like current maps from High Frequency (HF) radar installations.

OBJECTIVES

The program seeks to apply new technologies to Navy coastal ocean modeling activities. This includes validation of the Monterey Bay (MOB) curvilinear, nearly-orthogonal multi-block grid coastal ocean model developed at the NPS (Ly and Luong, 1997a,b,c,d,e) and Princeton Ocean Model (POM, Blumberg and Mellor, 1988) against observed diurnal current variations in Monterey Bay.

APPROACH

In order to validate MOB and POM (or other models) in a comprehensive high-resolution 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. To this end, strong current fluctuations in Monterey Bay forced by diurnal sea breeze winds and semi-diurnal tidal oscillations are being used. Monterey Bay is also the site of unique radar measurements of two-dimensional surface current patterns. The MOB model includes data routines, grid generation routines, 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 (Ly and Luong, 1977a,b,c,d,e). 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.

WORK COMPLETED

The MOB curvilinear nearly-orthogonal grid model (multi-block grid code version with 131 x 131 x 25 grid points) for a single-block grid has been newly initialized. The summer diurnal observed and mesoscale model (NCAR MM5, Koracin et al., 1997) winds have been analyzed. A new three dimensional MOB temperature and salinity fields of all available observational data has been generated. They are ready for use in the following stage. The model has been run with winds of station M42, heat and salinity fluxes to study the model output. A map of seasonal CODAR surface currents has been generated for studying CODAR data applications to the MOB model. Some numerical experiments have

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been carried out using nudging to study the propagation of the information contained in the CODAR data.

Extensive work has been done on the HF radar (CODAR) data for Monterey Bay to produce maps surface current variability at diurnal and semidiurnal periods. The data set is most for the period of August through December, 1994. Harmonic analyses have been conducted month-by-month for that period (Paduan and Cook, 1997; Paduan and Graber, 1977). The rotated Monterey Bay POM domain has been produced so that simulations of sea breeze and forcing can be accomplished using the offshore and along shore open boundary conditions produced by E. Petruncio in his dissertation work (Naval Postgraduate School, Sept. 1996).

RESULTS

The preliminary results of 90-day run show the some physics of the MOB summer circulation such as upwelling locations, magnitudes of current, temperature and salinity fields. Fig. 1 shows the model surface temperature field. The corresponding surface currents have magnitudes up to 0.5 m/s in the northeastern part of the model domain and MOB. An anticyclonic eddy is located off Monterey Bay (south part of the model domain). There is a band of cold and saline water with a surface temperature of less than 10˚ C and a salinity of greater than 33.7‰. This cold and saline water flows equatorward, which can be seen from Fig. 1. This indicates an upwelling center at the northeastern corner of the model domain and the northern part of MOB. The above upwelling location, magnitudes of surface temperature and salinity are observed features (Rosenfeld et al., 1994).

The model generated CODAR data is shown in Fig. 2. Our preliminary results of simulations by nudging show that the model six-hour interval CODAR data reduce rms of the two velocity components. It is expected that the two-hour interval CODAR data will reduce the rms faster. The model (NCAR MM5) wind speeds and directions at the NPS-Fort Ord point for June 22 and 23 are presented in Figs 3 and 4. These winds show a clear diurnal (sea breeze) signal in the model wind forcing.

The observed CODAR data show distinct differences on the physical processes responsible for diurnal and semidiurnal fluctuations in Monterey Bay. The former is largely driven by diurnal (sea breeze) variations in the wind forcing, while the latter is a highly spatially dependent response to tidal forcing. Initial POM simulations on the realistic Monterey Bay grid using observed diurnal wind variations show a reversing surface similar to that observed in CODAR maps (Fig. 5). Now that the model domain is configured, detailed comparisons can be made under various wind and stratification conditions. POM results on this rotated, rectangular domain can also be compared with those from MOB.

IMPACT/APPLICATIONS

The coastal ocean system is used to study the model forecast capability using surface current data (CODAR) for regions with complicated coastlines and bottom topography. The system can be used in sea-wave coupling study. Application of numerical grid generation is a new advance in coastal ocean modeling. The technique and our grid routines are interested by various research groups.

TRANSITIONS

Our works are closely in-cooperated with NAVO (Dr. Phu Luong). Our model development efforts and coastal ocean modeling products are shared with NAVO.

RELATED PROJECTS

This program is related to Ly's air-wave-sea interaction project in efforts of sea-wave interaction study. This program is also closely related to the ONR project on coastal atmospheric mesoscale modeling for the northern California coasts using NCAR MM5 by Prof. Koracin of the Desert Research Institute

(Reno, NV) regarding high-resolution model surface wind fields for the northern California and Monterey Bay regions.

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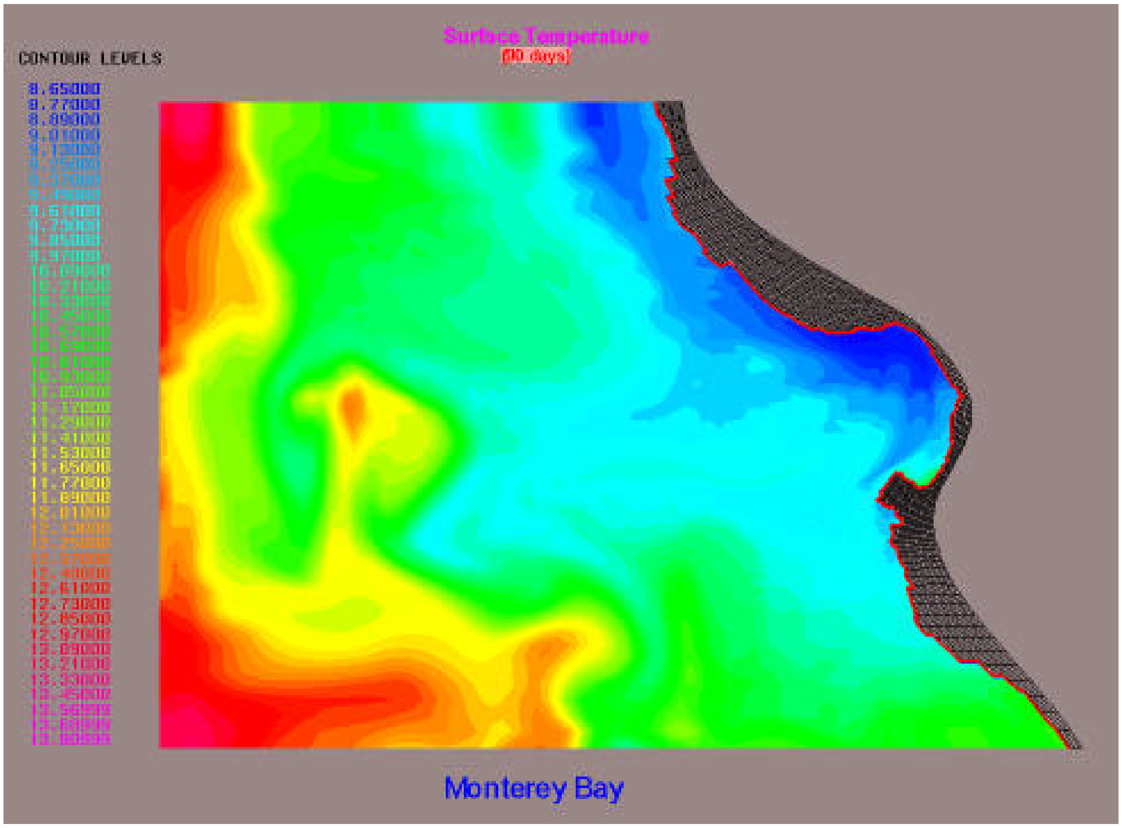

Fig. 1. Surface temperature field produced by 90 day MOB model run.

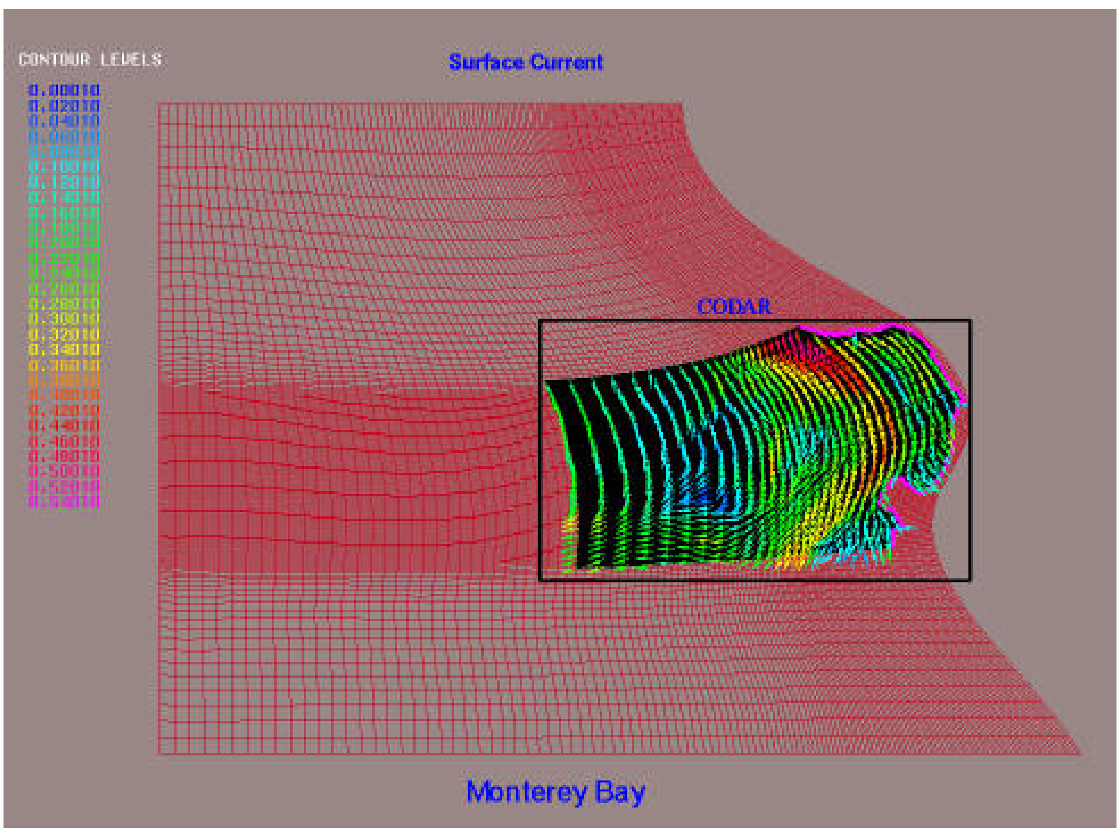

Fig. 2. MOB model-generated CODAR data.

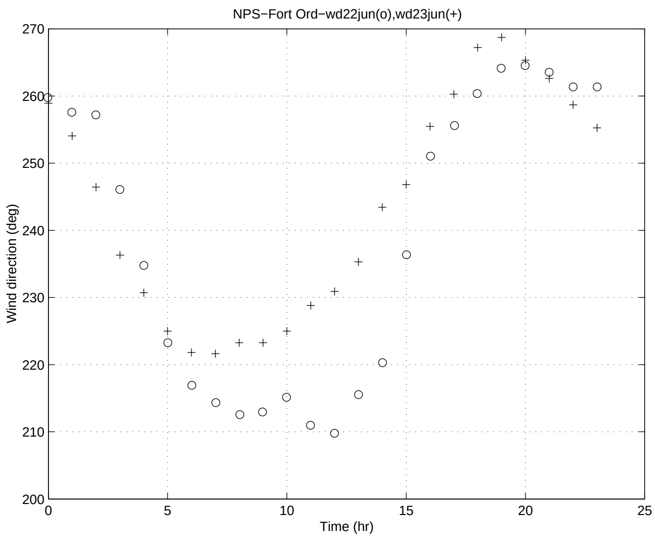

Fig. 3. Atmospheric model (MM5) wind speed at NPS-Fort Ord on 22 (o) and 23 (+) June 1996.

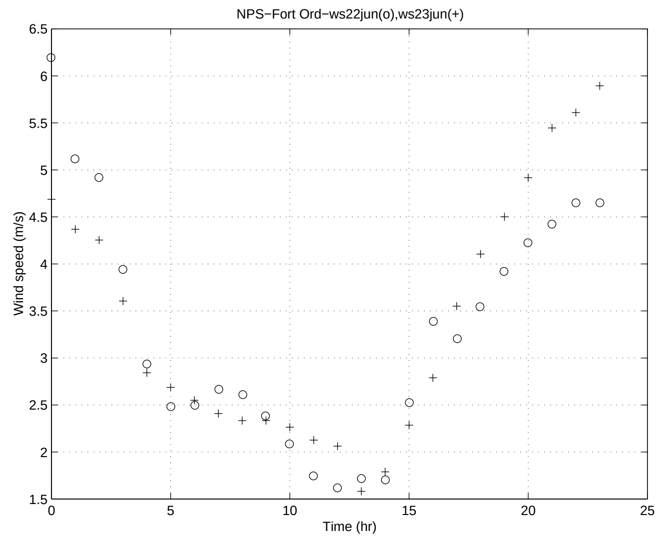

Fig. 4. Atmospheric model (MM5) wind direction at NPS-Fort Ord on 22 (o) and 23 (+) June 1996.

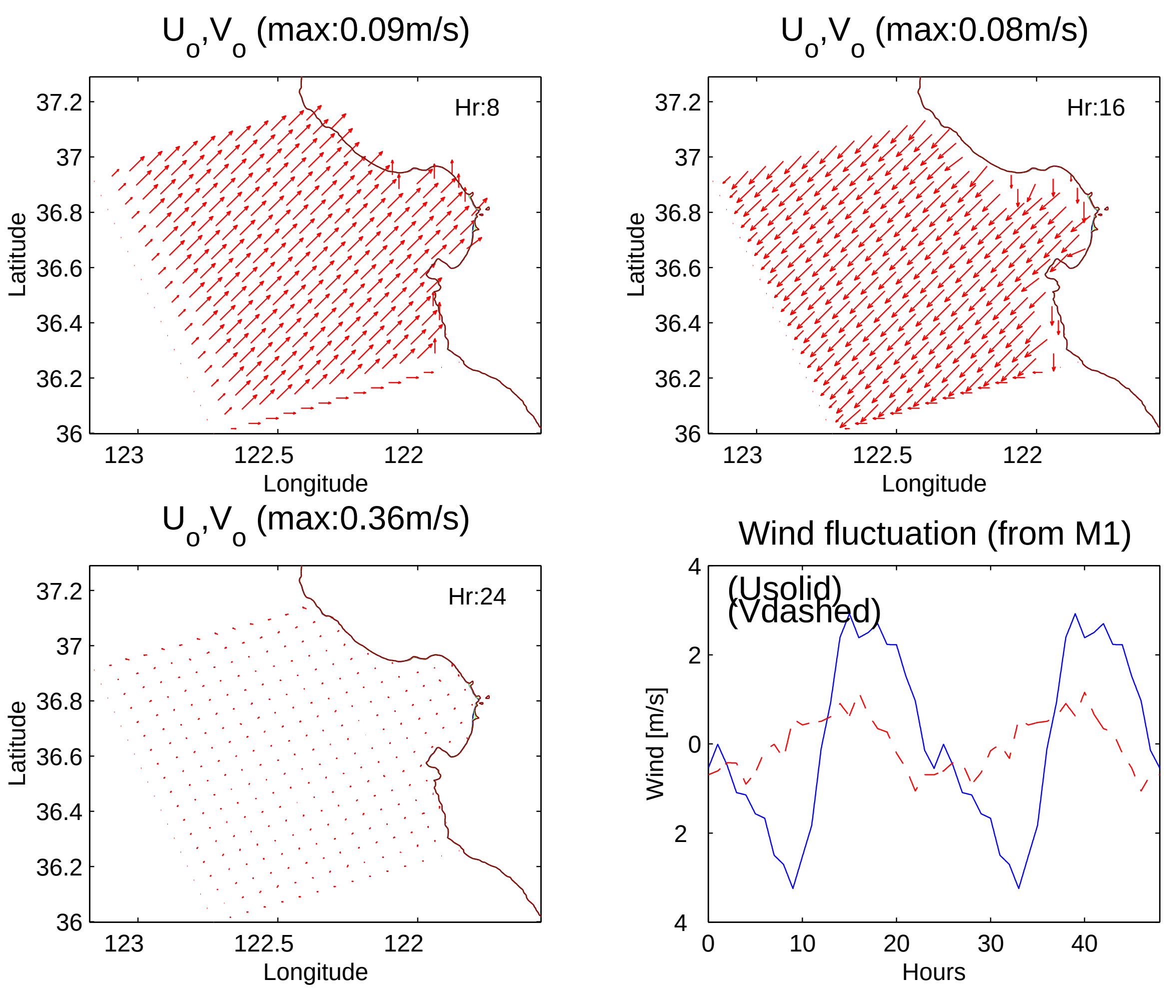

Figure 5. Surface currents at three phases of the diurnal wind forcing from initial POM simulations of Monterey Bay together with observed wind fluctuations from center of the bay. Horizontal model resolution is 1 km; every third vector is plotted.