EXPERIENCE GAINED DURING THE IMPLEMENTATION OF NOAA'S COASTAL OCEAN FORECAST SYSTEM[1 2]

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ABSTRACT

A Coastal Ocean Forecast System (COFS) is being developed at NCEP, in collaboration with NOS and Princeton University, to forecast the physical state of U.S. coastal waters. It is based on a state-of-the-art ocean circulation model which is forced at the surface by heat, momentum, and moisture fluxes provided by a high-resolution atmospheric forecast model. The present version of COFS has been running off the U.S. East Coast since 8/93 and has been providing 24-hour forecasts of surface elevation, and temperature, salinity, and currents for the entire water column.

During the past four years, we have gained considerable experience in the development and implementation of COFS. We have encountered problems as well as successes during this period. Model predictability has been examined and is relatively high near the coast. With respect to the problems, some have been solved and some remain to be solved. These problems include the specification of appropriate surface fluxes from the atmosphere, how to specify realistic forcing along the open boundaries of the model domain, and the specification of realistic freshwater fluxes along the coastal boundary in order to generate representative salinities where the salinity gradients are strongest. Another problem that appears to be generic to ocean circulation models which include the Gulf Stream, is how to generate the correct pattern of flow near Cape Hatteras where the Gulf Stream separates from the coast. Finally, a number of problems arise with respect to ocean data assimilation which have yet to be satisfactorily addressed, ranging from data availability and distribution, to the appropriate methodologies to be employed. Following a brief description of the COFS, model predictability together with other positive results are discussed. Then the problems indicated above are discussed along with the solutions that have been found, or, in some cases, are still being sought.

I. THE COASTAL OCEAN FORECAST SYSTEM

COFS will provide regional ocean forecasts for coastal waters around the continental U.S. on an operational basis (Kelley et al., 1997). It is based on a three-dimensional ocean circulation model called the Princeton Ocean Model (Blumberg and Mellor, 1987). This model is based on the primitive equations, employs a free upper surface, and has a second order turbulence closure submodel to parameterize mixing (Mellor and Yamada, 1982). The model employs a terrain-following sigma coordinate system in the vertical, and a coastline-following curvilinear grid in the horizontal. The model has 18 layers with increased vertical resolution in the mixed layer and the upper thermocline. The spatial resolution increases from 20 km offshore to 10 km near the coast. The coastal boundary corresponds to the 10 m isobath. The model bathymetry is based on the U.S. Navy's digital bathymetric database (DBDB-5) with 5-minute resolution. The COFS domain for the U.S. East Coast extends from 27° to 47°N, and from the coast out to 50°W (Fig.1). COFS is coupled to a high-resolution regional atmospheric forecast model called the ETA model (Black, 1994) which provides surface fluxes of heat, moisture and momentum. Coupling between the atmosphere and ocean is presently one-way, i.e., there

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is no feedback from the ocean to the atmosphere. Tidal forcing for six tidal constituents is included in the model (Chen and Mellor, 1998). The model is forced along its open boundaries using climatological

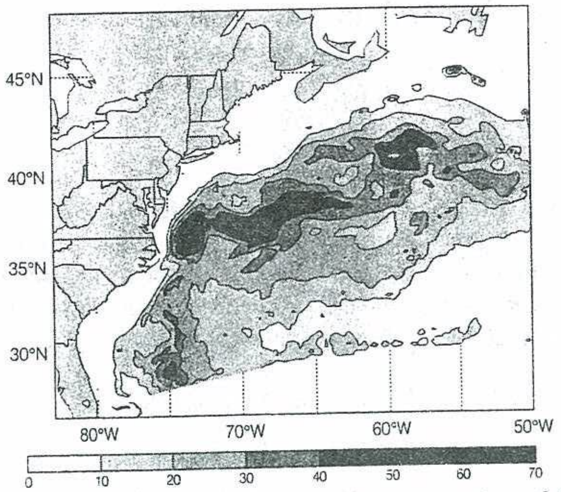

Fig. 1. Model domain for the east coast version of the COFS showing model predictability in terms of the root-mean-square difference in surface velocity between a control run and a parallel run using slightly different initial conditions (see text for details).

estimates of temperature and salinity, and volume transports which are specified separately. Freshwater inputs are specified for 16 rivers, bays and estuaries along the U. S. East Coast and are based on monthly climatological data (Blumberg and Grehl, 1987).

The U.S. Navy's Generalized Digital Environmental Model (GDEM) is used to provide the model's initial state for temperature and salinity when it was initially started from rest (Teague et al., 1990). Subsequently, the initial conditions for the model are provided each day by advancing the previous day's initial conditions using analyzed atmospheric forcing fields from the previous 24-hours and the assimilation of available data during this period. The data assimilation procedure for the present version of COFS uses *in situ* SSTs and satellite retrievals of SST from the Advanced Very High Resolution Radiometer (AVHRR). The assimilation procedures *per se* are based on the assimilation scheme of Derber and Rosati (1989) and Behringer (1994). The influence of the SST data are projected below the surface using a mixed layer adjustment procedure (Chalikov and Peters, 1997). Preliminary evaluations of COFS which include data assimilation have shown a significant improvement in model performance (Kelley et al., 1997).

II. MODEL PREDICTABILITY AND OTHER POSITIVE RESULTS

In 1994, a model predictability experiment was performed using COFS (Sheinin and Mellor, 1994). The results from two, three month-long model integrations were compared. A control run using initial conditions from climatological data was compared with a second run where the initial conditions were "perturbed". The perturbed initial state for the second run was obtained from the control run after it had run for approximately five weeks. The same surface forcing was used in each case and there was no data assimilation. At the end of the three-month period, output fields from both runs were compared. Model predictability (e.g., root mean square differences between the fields for each run) was calculated for surface elevation, surface velocity, and SST. For surface elevations and velocities, in particular, model predictability was relatively high everywhere except for the Gulf Stream region (Fig. 1). Because of the inherent instability of the flow in this region, data assimilation is required in order for the model to realistically portray this feature. Our experience with COFS since this experiment was conducted has generally confirmed these results.

Consistent with the above, COFS has shown considerable skill in predicting waters levels at the coast with, and without, tidal forcing (e.g., Aikman et al., 1998). The highest skill has been achieved for the subtidal water levels which are strongly influenced by the wind-driven set-up and set-down at the coast. The wind-driven influence, of course, also reflects on the quality of the wind forcing which is provided by the ETA model. Additional improvements in wind forcing are also being incorporated into COFS using surface winds from the ETA nowcast cycle which will replace the use of previous day's forecast to provide today's initial conditions for COFS. Comparison of subtidal water levels at two locations along the East Coast over a 6-month period showed that using the nowcast winds from ETA did, in fact, improve the subtidal response of the model (Aikman et al., 1998).

The bathymetry for COFS is based on the Navy's DBDB-5 bathymetric database (5-minute resolution). However, certain deficiencies were found in the Navy database, particularly along the continental shelf and slope between the Florida Straits (~28°N) and approximately 44°N. As a result, the existing bathymetry in this region was replaced with more recent, higher-resolution (15-second) bathymetry from National Ocean Service (NOS). Details of the