An Operational Forecast Modeling System for the Mississippi Sound/Bight

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ABSTRACT

An operational forecast modeling system for the Mississippi Sound/Bight has been developed. The system integrates a triple nested coastal ocean forecast modeling systems and a meteorological forecast model. The Mississippi Sound/Bight model based on ECOMSED, forms the central core of the operational forecast system. At its eastern and southern boundaries, the ECOMSED is coupled to a regional Gulf of Mexico (GOM) model in a manner that ensures seamless energy transfer between the two models. Meteorological forcing is provided by the Coupled Ocean/Atmospheric Mesoscale Prediction System, COAMPS. The forecast system automatically retrieves all available real-time river discharge data along the Gulf coast to be imposed as coastal boundary conditions.

The operational MS Sound/Bight forecast model produces two 12-hour hindcast and two 48-hour forecasts every day, at 0000 and 1200 hours. The system is scheduled to run for 12 hours in a hindcast mode and then 48 hours in a forecast mode. However, these simulation periods can vary. Depending on the availability and lengths of inputs from the coupled GOM and COAMPS models, the operational system automatically sets the periods for hindcast and forecast simulations. The model saves the proper hydrodynamic information for a restart so that a smooth and seamless execution is possible to start the next cycle. All of the simulations of the model are performed and archived on the Major Shared Resource Center (MSRC) high-performance computers resident at NAVOCEANO, Stennis Space Center, MS. The archived model output includes hourly three-dimensional fields of salinity, temperature and currents and water level across the model domain. Quality control is performed before the results go to a post-processing phase. A post-processing routine, which runs autonomously, generates surface current, temperature and salinity distributions after the completion of each cycle of forecast. The model results are available on the NGLI website (www.navo.navy.mil/NGLI) for public use.

I. INTRODUCTION

The Northern Gulf of Mexico Littoral Initiative (NGLI) is a multi-agency program established through a partnership between the Commander, Naval Meteorology and Oceanography Command (CNMOC) and the US Environmental Protection Agency's Gulf of Mexico Program Office. The goal of NGLI is to produce a sustainable comprehensive modeling and observational system for the Mississippi Sound and Bight area that functions as both an operational Navy product and a research tool used to foster a sustained economic growth with managed environmental resources of the Gulf Coast. The program integrates a calibrated/validated coastal ocean modeling system and timely meteorological forecasts with in-situ and remotely sensed observations. The products of NGLI are available to a wide range of users in near-real time. NGLI is organized around four functional components: modeling, in-situ and remote sensing observations, data distribution and outreach. The current paper will focus only on the operational forecast modeling components.

II. MODELING COMPONENTS

The NGLI modeling system is designed to provide reliable and timely meteorological and oceanographic nowcasts/forecasts not only for the MS Sound/Bight but also for the adjoining rivers and estuarine systems such as, Mobile Bay, Biloxi Back Bay and Bay St. Louis. The modeling suite consists of triple-nested three-dimensional circulation models (global ocean, Gulf of Mexico, and Mississippi Sound/Bight), a sand-silt sediment transport model, an atmospheric model, and wave/surf models. Fig. 1 illustrates the nested hierarchy of models. The various model components that form the basis for the modeling system are shown in Fig. 2. Each will be described in turn.

A. Global Ocean Model

The global model for the current operational system has not yet been fully transitioned to operational status. The planned global ocean model is NCOM, the Navy Coastal Ocean Model (Martin, 2000). It is presently configured on a curvilinear 2048x1280 horizontal grid that covers the global ocean to depths of 5m with nominally 1/8 degree midlatitude resolution, coarser toward the equator and finer toward the poles. The vertical implementation uses 19 sigma coordinates in the upper ocean over 22 (21 active) z-level (constant depth) coordinates in the lower ocean, with transition between sigma and z near 138m. The vertical coordinate is logarithmically stretched to provide minimum upper level thickness of 1m at maximum bottom depth of 5500m.

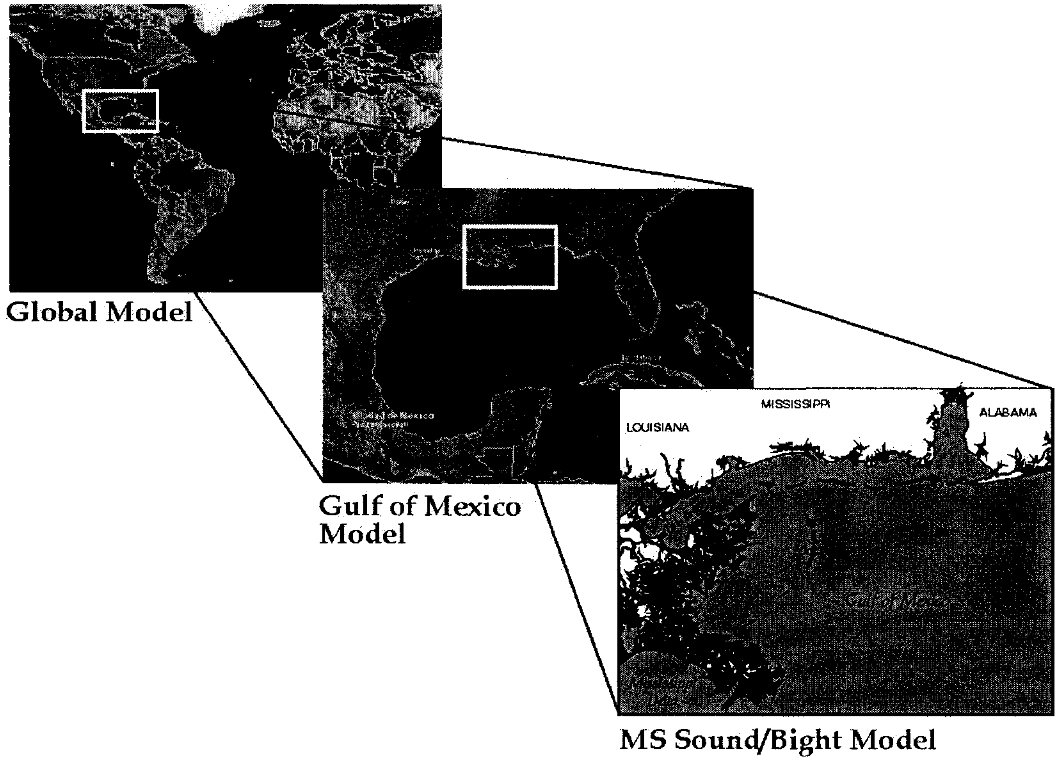

Fig. 1. The triple nested hierarchy of circulation models forming the NGLI ocean modeling system.

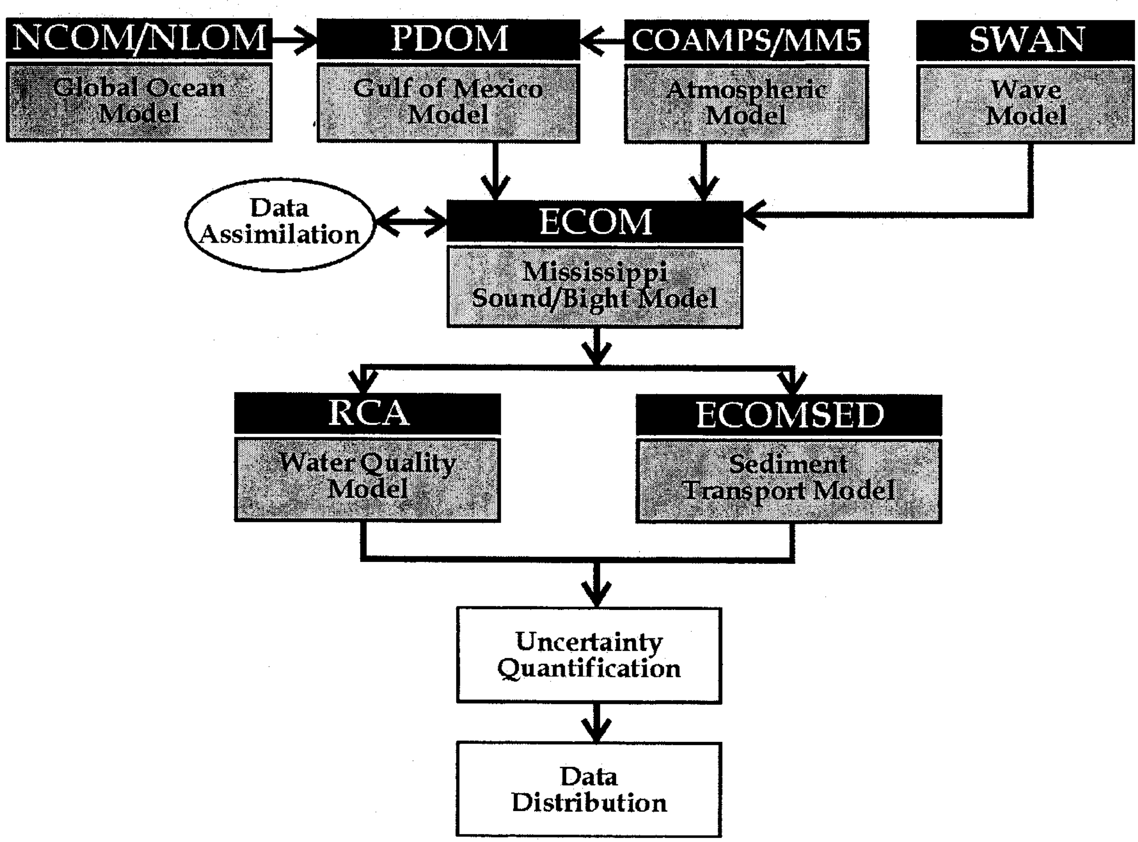

Fig. 2. The various models in the NGLI forecast modeling system.

B. *Gulf of Mexico Model (GOM Model)*

A basin-wide three dimensional circulation model of the Gulf of Mexico has been developed using PDOM, the Princeton-Dynalysis Ocean Model (Herring and Patchen, 1999). The gulf domain extends into the western Caribbean and to the northern limits of the Florida Straits. The model employs an orthogonal, curvilinear grid with horizontal resolution which enables realistic simulation of eddies 50 km in diameter and larger. The model is configured with 37 sigma levels in the vertical, with sufficient resolution placed in the near surface and near-bottom to resolve boundary layers.

The operational Gulf-wide nowcast/forecast model produces two 12-hour hindcasts and two 48-hour forecasts a day and a month-long forecast each week. Meteorological forcing is provided by COAMPS, the Coupled Ocean/Atmospheric Mesoscale Prediction System (Hodur, 1997). The system retrieves the COAMPS 27-km forecasts twice daily; uses the fields to compute the wind stresses and the atmospheric pressures to prescribe surface conditions; and also retrieves all available real-time river discharge data along the Gulf coast to be imposed as coastal boundary conditions.

Data assimilation is implemented using Modular Ocean Data Assimilation System (MODAS). While the MODAS fields are available at daily intervals everywhere in the Gulf, the correlations are less accurate further from the center of the satellite ground track where the satellite measures the SSH and also less accurate the longer the time since the last satellite over flight. Furthermore, the SSH correlation is less accurate on the well-mixed continental shelf. This model can serve as a stand-alone system, should the Global Model not become operational although with some loss of predictive skill.

C. *Mississippi Sound/Bight Model*

The Mississippi Sound and Bight model is built with the three-dimensional circulation model, ECOMSED (Ahsan et al., 2002; Blumberg et al., 1999). ECOMSED is the estuarine and coastal ocean version of the Princeton Ocean Model of Blumberg and Mellor (1987). Within ECOM are a cohesive and non-cohesive sediment transport submodel (SED), and a fate and transport capability for water quality (RCA). Together these models are used as a basis to forecast littoral circulation, sediment suspension and transport, and water quality constituents. The model is driven by mechanisms that include hydrographical (freshwater inflow), meteorological (surface wind), and open ocean (large-scale ocean circulation) forcing functions.

The MS Sound/Bight model represents the highest spatial resolution component of the triple-nested series of three-dimensional circulation models. At its eastern and southern boundaries, the MS Sound/Bight model is coupled to the regional Gulf of Mexico model in a manner that ensures that energy transfer between the two models is consistent. Fig. 3 illustrates the coupling of the MS Sound/Bight and the overlap portion of the Gulf of Mexico model grid. The grid alignment facilitates models information exchange seamlessly.

D. *Atmospheric Model*

The meteorological forcing for the NGLI oceanographic models is provided twice a day by COAMPS. COAMPS is configured with a coarser mesh of 27-km covering much of the southern U.S. and northern Gulf of Mexico, and a higher-resolution 9-km mesh (covering the Louisiana, Mississippi, and Alabama Gulf Coast) is currently being imbedded in the coarse mesh for future upgrade of the system. Only a one-way nest is used to simplify the validation studies, and to provide faster operational runs. Initial and boundary conditions were provided by NOGAPS in a "cold-start" mode for 00Z and 12Z runs.

III. MISSISSIPPI SOUND/BIGHT MODEL CALIBRATION AND VALIDATION

The NGLI maintains an operational ocean observing system that is being optimized to support multidisciplinary ocean modeling. These data have been the basis of calibration and validation of the NGLI modeling systems. The Mississippi Sound/Bight Model based on ECOMSED, provides a reliable means of predicting the littoral circulation and, the salinity and temperature structure of the region. The modeling framework adopts a high-resolution orthogonal curvilinear grid, which resolves the relevant bathymetric and coastline features, especially in the vicinity of the barrier islands and ship channels. A thorough calibration and validation effort has been conducted to ensure that the model provides a high level of confidence in predicting the oceanography of the Mississippi Sound/Bight. Point-to-point and spatial comparisons of sea surface elevation, temperature and salinity have been made.

Model simulations were conducted for a three month period from July through September 2000. Fig. 4 demonstrates the calibration of model results against observed water level, temperature and salinity data. The model performance in predicting water level is quite good. Regression between model results and the observed temperature demonstrates a high correlation ($R^2 \approx 0.8$). Correlations between model results and observed salinity are a bit lower ($R^2 \approx 0.27$ to 0.62) but are still sufficiently high to establish the utility of the forecast system. In general, model is fresh than the observed data at these sections, suggesting that the model freshwater input flow could possibly be overestimated. This underscores the need for re-evaluating the procedure adopted for estimating ungaged flow. More rigorous calibration and skill assessment have been demonstrated in Ahsan et al. (2002), and will not be discussed here.

The calibration and validation efforts have been supplemented by rigorous sensitivity analyses to understand the sensitivity of the model predictions to various forcing functions. The estuarine processes controlled by winds and freshwater discharges have been identified and quantified for Mobile Bay, Biloxi Back Bay, Bay St. Louis and Mississippi Sound/Bight through a series of model sensitivity simulations. Estimates of the variances in model prediction have been

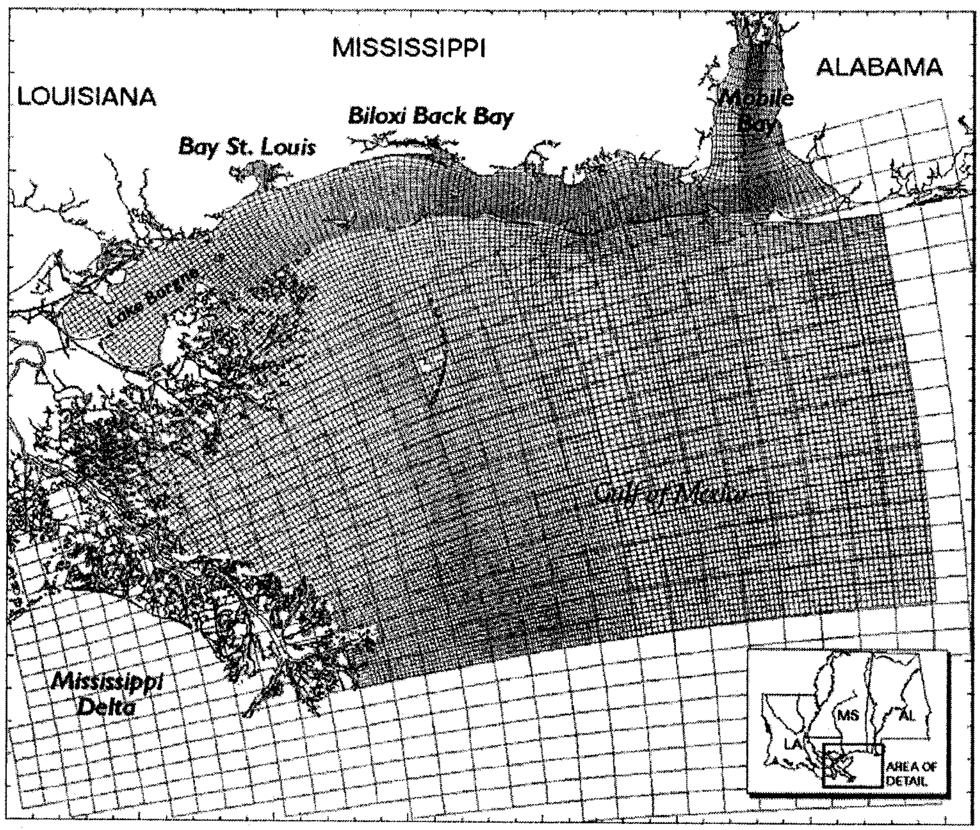

Fig. 3. The computational grid of the Mississippi Sound/Bight model (fine grid) and the overlap portion of the Gulf of Mexico model grid (course grid). The grid alignment facilitates the model information exchange seamlessly.

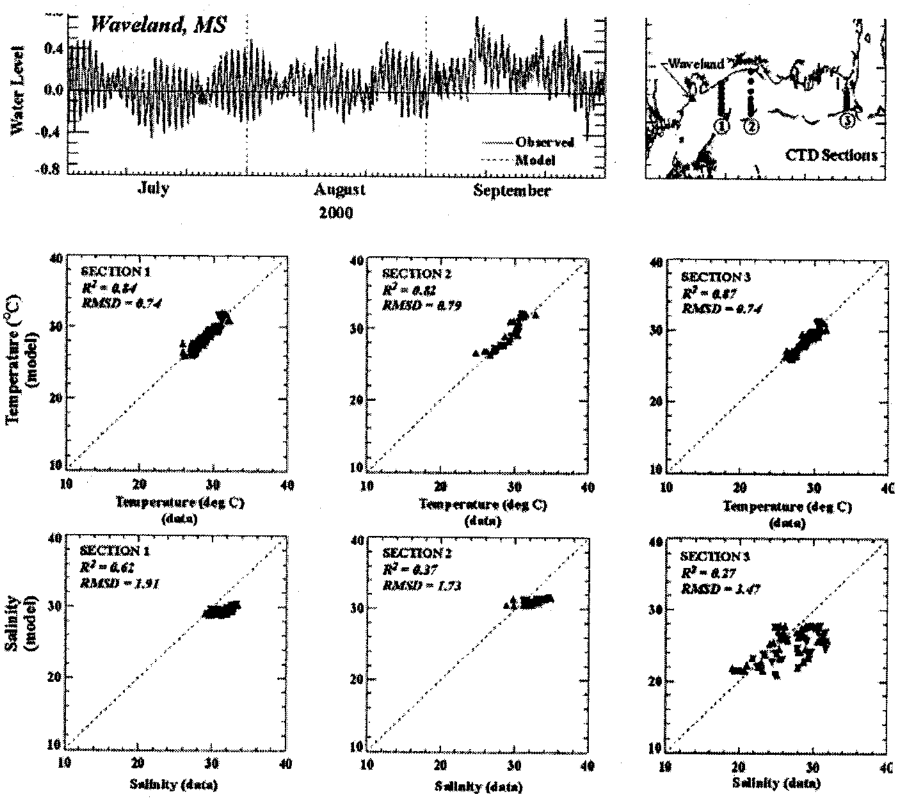

Fig. 4. Comparison of model computed water level against observed data at Waveland, MS and regression of model computed temperature and salinity at three transects in the Mississippi Sound.

made using a First Order Variance Analysis (FOVA) method. Percent contribution of bathymetry, and temperature and salinity boundary conditions to the variances of model predictions have been determined. Ahsan et al., (2002) describes the analysis in detail.

IV. OPERATIONAL FORECAST SYSTEM

A. Hindcast and Forecast Simulations

All of the simulations of the NGLI models are performed and archived on the Major Shared Resource Center (MSRC) high-performance computers resident at Naval Oceanographic Office (NAVOCEANO), Stennis Space Center, MS. Model hindcasts and forecasts are produced twice daily, at 0000 and 1200 hours. The system is scheduled to run for 60 hours, 12 hours in a hindcast mode and then 48 hours in a forecast mode. However, these simulation periods can vary. Depending on the availability and duration of input data from the coupled PDOM and COAMPS models, the operational system automatically sets the duration of hindcast and forecast simulation periods. Hindcast simulations are performed using observed forcing functions such as wind, water levels, freshwater flows, etc., and forecast simulations are performed using forecast forcing functions. For forecast simulations persistent river flows are used. The Mississippi Sound/Bight model saves the proper hydrodynamic information for a restart. A smooth and seamless execution occurs to start the next cycle, which is scheduled to start at 12 hours later (see Fig. 5).

The model output fields that are archived hourly every cycle include three-dimensional fields of salinity, temperature, currents and water level fields throughout the Mississippi Sound/Bight. Uncertainty quantification and quality control are performed before the results go to a post-processing phase. A post-processing program which runs autonomously generates surface current, temperature and salinity distributions after the completion of each forecast cycle. These graphics are displayed on the NGLI website (www.navo.navy.mil/NGLI) for public use. A 15 day permanent archiving protocol has been established in which model output older than 15 days are removed from the present directories and permanently archived in the MSRC system.

B. Validation of Model Forecast Simulations using Drifter Trajectories

As mentioned earlier, the NGLI maintains an operational ocean observing system that is being optimized to support multidisciplinary ocean modeling forecasting. These data form the basis of continuing validation processes of the forecast models. As part of the observing system 24 drifting buoy deployments were performed by University of Southern Mississippi (USM), NAVOCEANO and Naval Research Laboratory (NRL) within the NGLI domain in April and May 2002. Three drifters were deployed on April 9 and 10, 2002 within the NGLI domain at locations that exhibited considerable spatial variability in currents. Fig. 6a and 6b illustrate the model forecast surface currents and the drifter trajectories. The agreement is remarkable. Detailed analysis of these drifter trajectories suggest that high current speeds in the vicinity of the mouth of the Mississippi River exist (Carl Szezechowski, NAVOCEANO, personal communication). These currents are very consistent with what the ECOMSED model forecasts, as can be seen in these figures. Most interesting in this forecast simulation is the signature of a persistent anti-cyclonic eddy in the south-east region of the NGLI model domain at least for the period of April 9-10, 2002.

V. CONCLUSIONS

The hindcasting and forecasting modeling components of the NGLI are being applied to the Mississippi Sound/Bight area by cascading information from a Gulf of Mexico model to a shallow-water Mississippi Sound/Bight model. The ability to nest model operations, cascading information through models of differing resolution, is a particularly important goal of NGLI circulation and wave forecasting. During the initial efforts of the NGLI, significant improvements and enhancements have been made to the models and modeling system. This study focuses on the operations of the modeling system on the MSRC. The model is running twice every day at 0000 and 1200 hours. For each cycle the model is scheduled to run for 12-hours in hindcast mode and 48 hours in forecast mode. A post-processing protocol is in place to generate surface currents, temperature and salinity distribution after the completion of each cycle of hindcast and forecast run. The model results are displayed on the NGLI website (www.navo.navy.mil/NGLI) for public use.

ACKNOWLEDGMENTS

This work was supported through cooperative programs for coastal ocean research and management at the University of Southern Mississippi and by joint funding from the Gulf of Mexico Program Office of the USEPA (Cooperative Agreement No. MX984633-99-0) and the Commander, Naval Meteorology and Oceanography Command, Stennis Space Center, MS, (contract No. N62306-01-D-B0001-0002.

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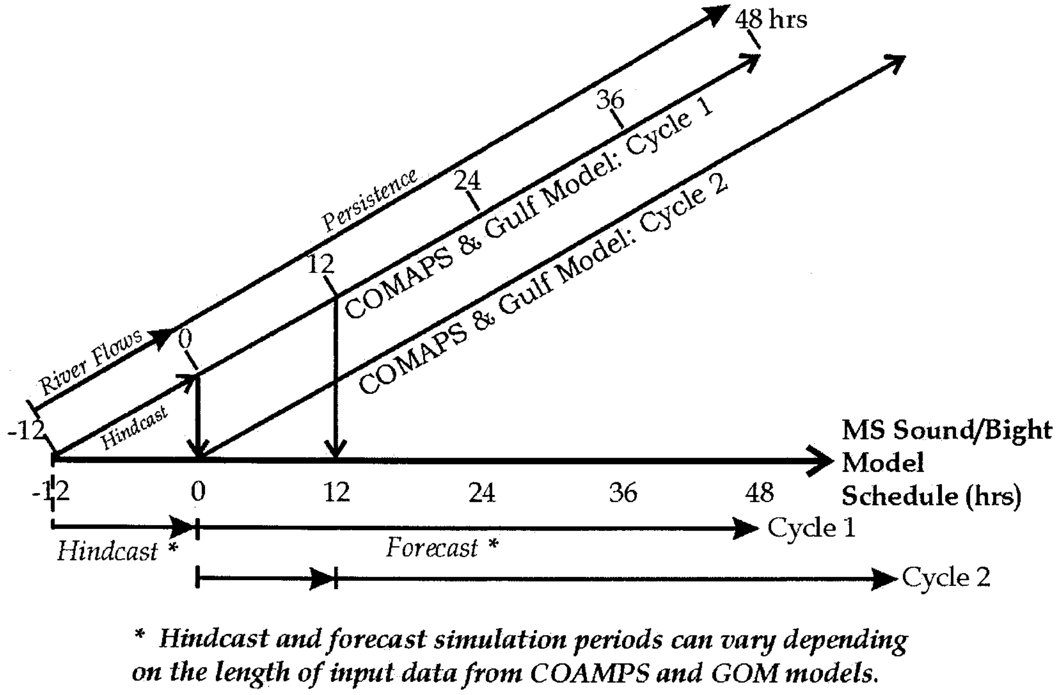

Fig. 5. The operational flow data into and out of the Mississippi Sound/Bight model. A forecast cycle consists of a 12-hour hindcast followed by a 48 hour forecast.

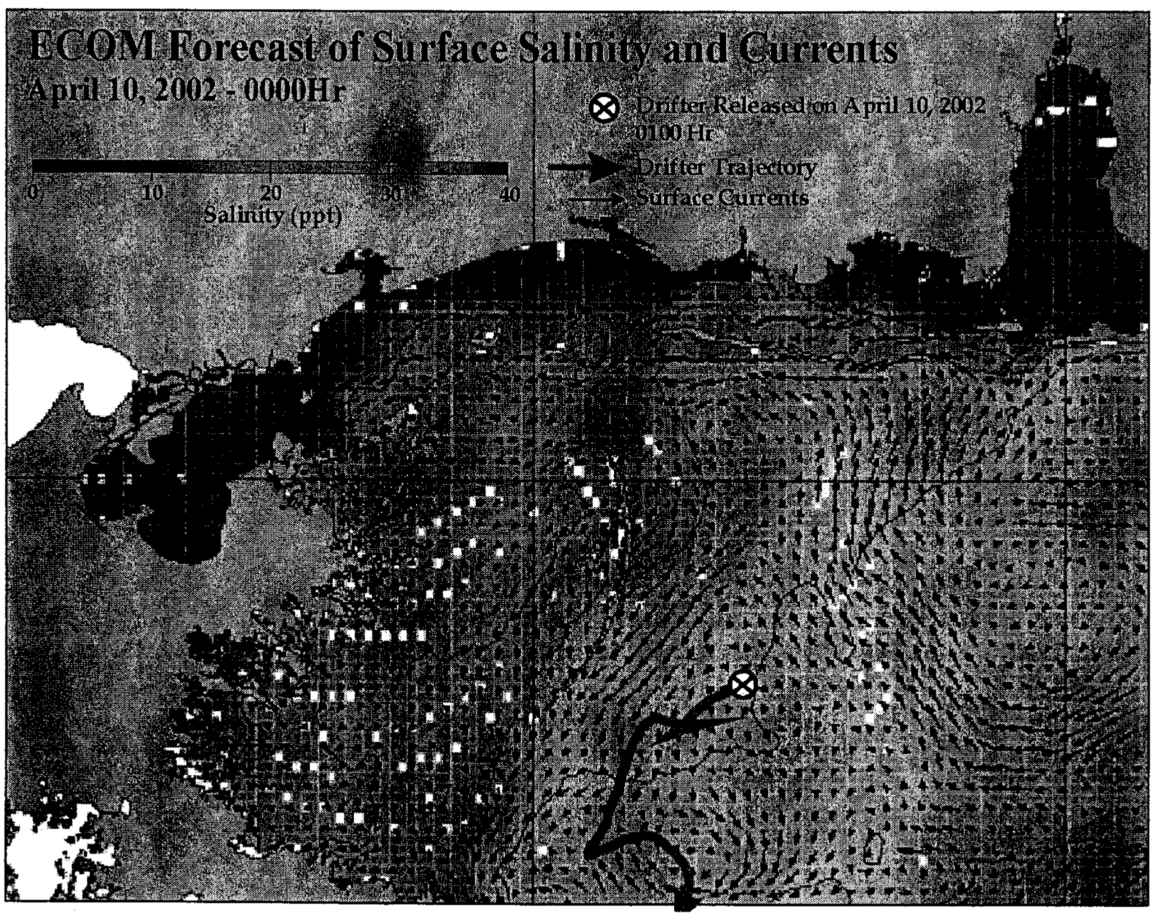

Fig. 6a. Forecasted surface currents and salinity at 0000 hour, April 10, 2002. The drifter trajectory, deployed at 0100 hour, shows agreement with the model predicted surface currents.

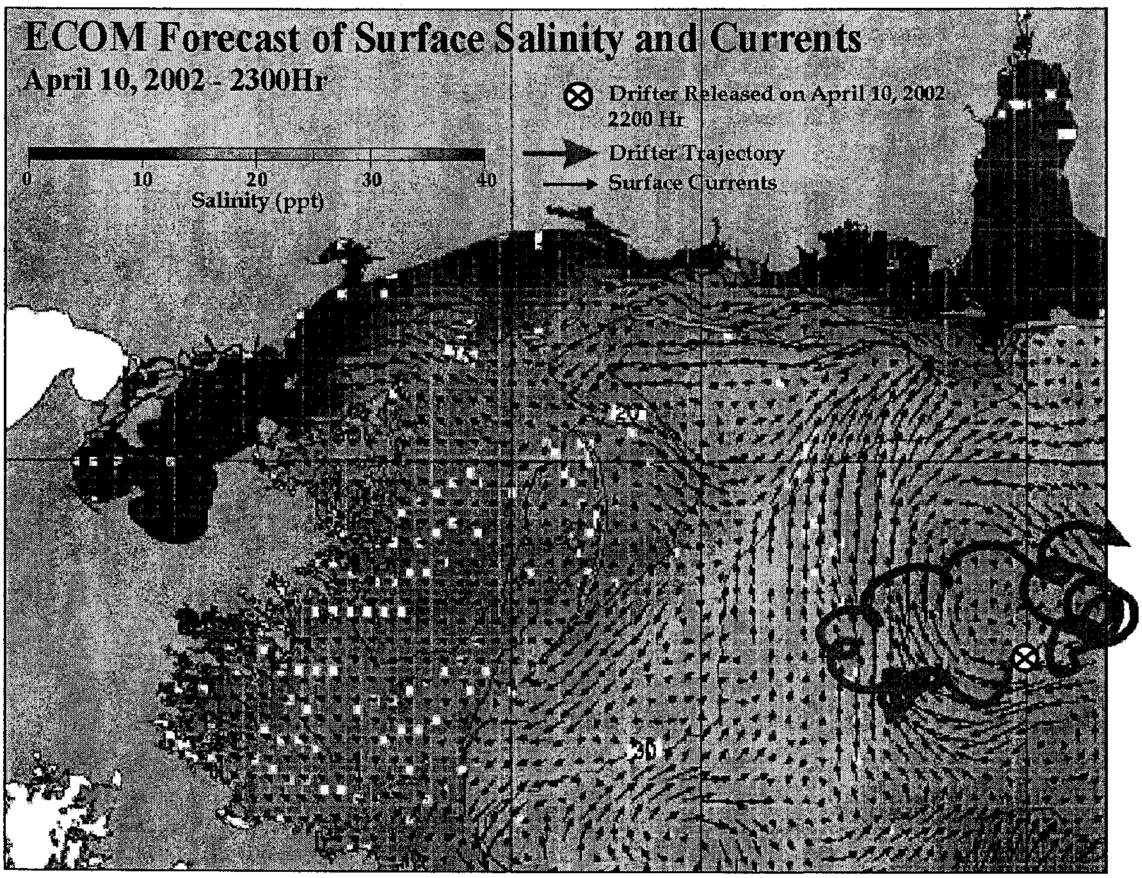

Fig. 6b. Forecasted surface currents and salinity at 2300 hour, April 10, 2002. The drifter trajectory, deployed at 2200 hour, shows agreement with the model predicted surface currents.

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