

## National Ocean Partnership Project Advances Real-time Coastal Ocean Forecasting

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A 1999-2000 National Ocean Partnership Project (NOPP) has demonstrated highly accurate predictions of ocean temperatures, currents, and surface elevation through a model that integrates the state of the ocean to routinely produce real-time nowcasts and forecasts. The success is attributed to a new technology for model-assimilation of satellite-derived surface observations with observations from in situ equipment.

Because the Chesapeake Bay and the northwestern Atlantic boarding the east coast of the United States is an area of intense ocean harvest, recreational boating, and major shipping—activities that depend on near-term prediction of near-surface conditions of the waters off the eastern coast—it served as the test-bed for the “Coastal Marine Demonstration Project” (CMDP). The project showed that the assimilation of data available in real-time can produce ocean fields that agree well with independent observations, which is an exciting development for mesoscale ocean forecasting.

Successful prediction of the ocean state with a numerical model has lagged far behind atmospheric weather prediction despite the availability of satellite measurements and imagery of ocean surface conditions. This has been due to the lack of subsurface data and the need for a suitable methodology for multi-level assimilation of available observations.

Knowledge of present and near future temperatures in the upper, nutrient-rich levels of the ocean is of vital interest to the fishing industry. Knowledge of near-surface currents and sea-surface height is vital for the navigation planning of recreational boaters, ocean transport vessels, and Coast Guard search and rescue operations.

Obtaining accurate nowcasts and forecasts by effectively coupling high-resolution models with real-time data from atmosphere- and ocean-observing platforms has been a challenging problem both scientifically and technically. High-resolution ocean modeling and the assimilation of ocean data are extremely complex undertakings, especially for the Atlantic with the strong gradients of the Gulf Stream. Direct measurements of ocean currents are virtually nonexistent and reports from subsurface observing platforms are few and far between.

Space-based observing platforms provide much of the available information about ocean conditions, and inferential/statistical relationships between remotely observed and ocean variables allow this data to be interfaced with ocean models using newly developed data assimilation technology.

### Impacts of Assimilating Satellite Altimetry and Gulf Stream Location Data

The NOPP-funded partnership enabled a model-based coastal ocean forecast system, which has been running semi-operationally at

NCEP with assimilation of surface-only temperatures, to be enhanced with the ingestion of satellite-derived data for adjustment of subsurface temperature and salinity values. The new algorithm assimilates data on the location of the north wall of the Gulf Stream (NWGS) and sea-surface height anomalies (SSHAs) derived from TOPEX altimeter reports, in addition to sea-surface temperature data. In the deep ocean, changes in SSHAs reflect internal changes in vertical temperature structure. The SSHA assimilation algorithm is based on the statistical, vertical coupling of SSHA with subsurface temperature anomalies, where the immediate impact of the assimilation is felt. Model dynamics distribute the anomalies' influence back toward the surface.

The surface height field, the 1-m current field, and the 100- and 200-m temperature fields show significant impact of the newly ingested data. Most profound is the appearance of cold and warm pools in nowcast and forecast temperature fields and eddies in 1-m velocity fields; these are not evident in the control-model output. The existence of the cold and warm pools was verified through comparison with GOES images.

Figures 1a and 1b show velocity fields for the two versions of the model. Figure 1a shows the 1-m velocity field produced by the control run with temperature-only assimilation, and Figure 1b displays the product of the run with additional assimilation of SSHA- and NWGS-location data. Figure 1c shows independent data from the imager on the GOES-8 satellite. The surface velocity field derived after inclusion of the TOPEX data reveals an anti-cyclonic eddy just north of the

Gulf Stream, centered at 39.5°N and 65°W, which is not present in the control-run velocity field. In the GOES image for the same date this eddy appears as a meander about to pinch off from the Gulf Stream.

The positive impact of the assimilation of SSHA- and NWGS-location data on subsurface temperatures has also been verified by comparing model-temperature profiles with temperature profiles from independent bathythermograph reports (For example, see Figure 2). For the model that assimilates TOPEX data through the correlation structure of SSHA and subsurface temperature anomalies, model-temperatures at greater depth are significantly closer to the direct measurements of subsurface instruments than those derived by the model that uses surface-only assimilation.

Both results signify that a major step has been made in real-time ocean prediction, through the cooperative efforts of NCEP and Princeton University.

In the first demonstration period, which took place in June and July of 1999, real-time ocean nowcast and forecast products were provided on a public-access Web site and practical evaluation of their utilities was solicited from the marine community. A second demonstration period, scheduled for February and March of 2000, will allow winter testing with product and delivery improvements based on the feedback of the first period.

NCEP's Coastal Ocean Forecast System (COFS) is an experimental system based on the Princeton Ocean Model [Blumberg and Mellor, 1987], with wind forcing and energy fluxes from NCEP's high resolution, regional atmospheric Eta model [Black, 1994]. Assimilation of surface temperatures from the Advanced Very High Resolution Radiometer ships and buoys uses the technique of Kelley, Behringer, and Thiebaut [1999]. Altimeter and NWGS-location data is assimilated with an

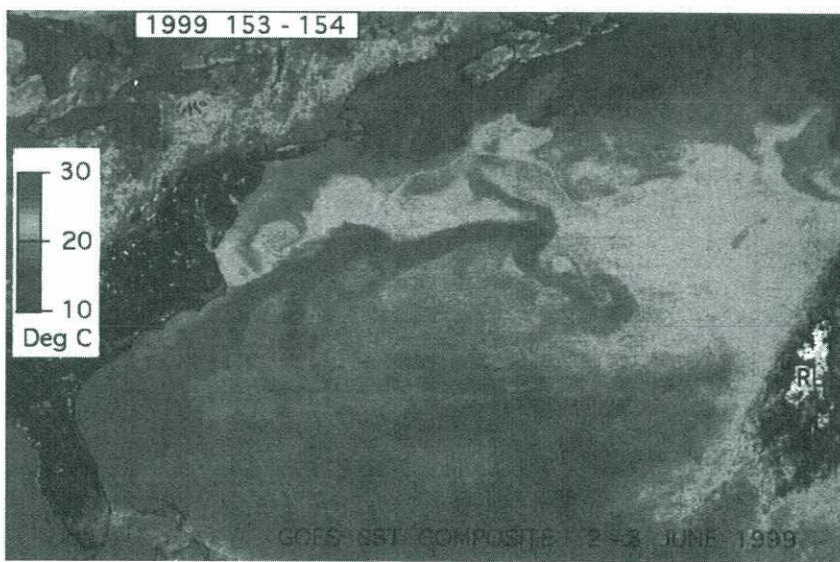
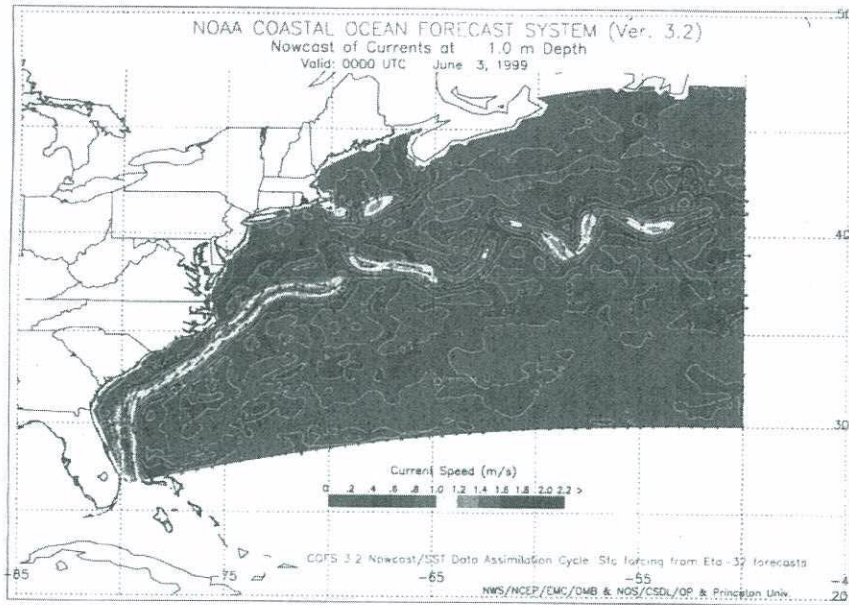
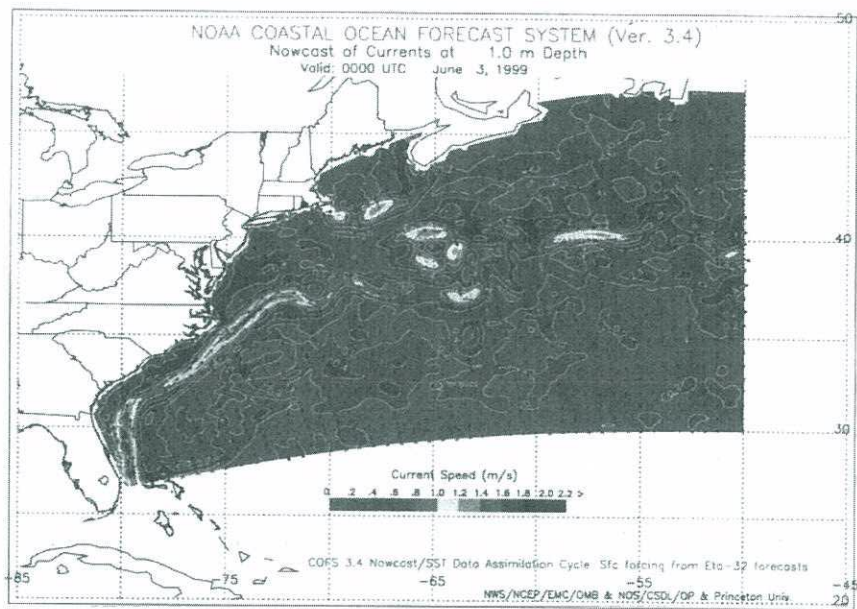


Fig. 1. (a) Velocity field at 1 m depth, June 3, 1999, produced by COFS with surface temperature assimilation only. Original color image appears at the back of this volume.



b



c

Fig. 1. (b) Velocity field at 1 m depth, June 3, 1999, produced by COFS with additional assimilation of surface heights derived from TOPEX altimeter data and the NWGS-location data. (c) GOES-8 composite temperature image for the northwest Atlantic, with June 2 and 3 data, from Richard Legeckis, Office of Research and Applications, NESDIS. Original color image appears at the back of this volume.

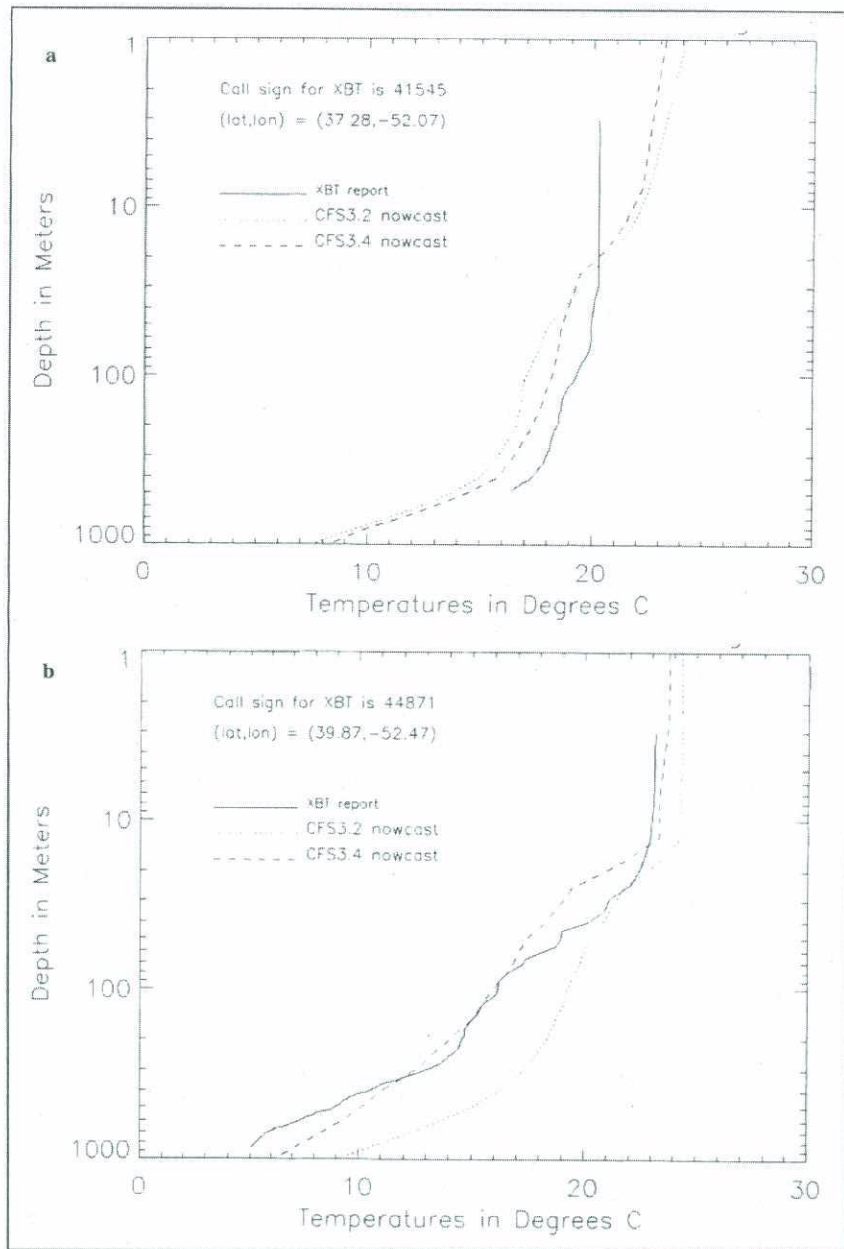


Fig. 2. XBT and COFS temperature soundings, in which CFS3.2 is the control, with assimilation of surface temperatures only and CFS3.4 is run with addition of TOPEX and NWGS data. a) Data for 37.28°N, 52.07°W, on May 17, 1999; b) Data for 39.87°N, 52.47°W, on July 5, 1999.

algorithm developed by G. L. Mellor, T. Ezer, and N. Kim (personal communication, 1998).

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**Authors**

Jean Thiebaux, Bert Katz, John Kelley, Laurence Breaker and Bhavani Balasubramanian. For more information, contact Jean Thiebaux, National Centers for Environmental Prediction, 5200 Auth Rd., Camp Springs, Md., 20746 USA; E-mail: Jean.Thiebaux@NOAA.gov. Thiebaux is a senior scientist with NCEP which is an NOPP partner in this project.

**References**

Black, T.L., The new NMC mesoscale Eta model: Description and forecast examples. *Weather and Forecasting*, 9, 265-278, 1994.  
 Blumberg, A. F. and G. L. Mellor, A description of a three-dimensional coastal ocean circulation model, *Three-Dimensional Coastal Ocean Models, Coastal Estuarine Science, Vol. 4*, AGU, Washington, D.C., pp. 1-16, 1987.  
 Kelley, J. G. W., D. W. Behringer, and H. J. Thiebaux, *Description of the SST data assimilation system used in the NOAA Coastal Ocean Forecast System (COFS) for the U.S. East Coast*, Technical Note, U.S. Department of Commerce, NOAA, National Weather Service, Washington, D.C., 1999.