to directly verify predictions such as those of Fig. 2. Such efforts will require an interdisciplinary approach, involving NRL researchers with expertise in a variety of areas: design of acoustic experiments, scattering theory, materials science, laser profilometry, ground-truth geoacoustic measurements, and the operation of NRL tank facilities with computer-controlled sources and receivers.

[Sponsored by ONR]

**References**

[1] R.F. Gragg, D. Wurmser, and R.C. Gauss, "Small-slope Scattering from Rough Elastic Ocean Floors: General Theory and Computational Algorithm," *J. Acoust. Soc Am.* **110**, 2878-2901 (2001).

[2] R.J. Soukup and R.F. Gragg, "Scattering from a Rocky Bottom at 2-3.5 kHz: Measurements and Modeling," *J. Acoust. Soc Am.* (to appear).

## Global Ocean Nowcasts and Forecasts with the Navy Coastal Ocean Model (NCOM)

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**Introduction:** The global ocean is a seamless body where open-ocean systems shape and are shaped by nearshore conditions, surface processes drive and respond to interior circulation, and localized events often can be predicted and understood only within a larger context. To support Navy operations and other research and operational activities within such an environment, we have developed and are transitioning to the Naval Oceanographic Office (NAVO) a fully global implementation of the Navy Coastal Ocean Model (NCOM). We have endeavored to produce a friendly environment for nesting higher resolution models wherever the need should arise. Some global NCOM data products of particular interest include surface currents and temperature, mixed-layer depth, current and thermohaline profiles, and shelf circulation.

Global NCOM extends present global Navy operational model capabilities[1] into the Arctic and to nearshore regions, with a minimum depth of 5 m. Operational roles of global NCOM include providing standalone data where global resolution is sufficient and timely overviews of local circulation as detailed localized products are prepared. Perhaps its most important purpose is to provide boundary conditions used by regional or relocatable models, giving required information regarding the surrounding environment to localized models more specialized for a particular task or domain. In general, nested models will have more detailed forcing, topography, additional data for assimilation, or higher resolution necessary for improved local detail. The global model includes inflow from almost 1000 rivers to improve the fidelity of coastal salinity. Global NCOM is designed to be suitable for inclusion in a coupled ocean-atmosphere modeling system, and it is also designated as the host for an embedded ice model, PIPS3, which is in development for transition.

**Implementation:** NCOM is a free-surface, primitive-equation model based primarily on two other models, the Princeton Ocean Model and the Sigma/Z-level Model.[2] In its global configuration, we have implemented NCOM on a curvilinear horizontal grid designed to maintain a grid-cell horizontal aspect ratio near 1. Horizontal resolution varies from 19.5 km near the equator to 8 km or finer in the Arctic, with midlatitude resolution of about 1/8° latitude (~14 km). Figure 4 shows a sea surface temperature (SST) snapshot from the full domain in a projection that shows the actual distribution in the logical domain. Horizontal resolution has been sacrificed to allow increased vertical resolution. To improve the detail of upper-ocean dynamics, we maintain a maximum 1-m upper level thickness in a hybrid sigma/z vertical configuration with 19 terrain-following sigma-levels in the upper 137 m over 21 fixed-thickness z-levels extending to a maximum depth of 5500 m. Model depth and coastline are based on a global 2-minute bathymetry produced at the Naval Research Laboratory (NRL).

The present daily model run consists of a 72-hour hindcast to assimilate fields that include recent observations, and a 72-hour forecast. Longer forecasts are being evaluated. Global NCOM uses atmospheric forcing from the Navy Operational Global Atmospheric Prediction System, with latent and sensible heat fluxes calculated internally using NCOM SST. Tidal heights and currents can be added using a separate user-specified model, with validation and boundary condition experiments focusing on using the NAVO operational model PC Tides.

**Assimilation**: Data assimilation is based on global profiles of temperature and salinity derived using operational sea-surface fields and in situ data within the Modular Ocean Data Assimilation System (MODAS)[3]. The operational global 1/16° Navy Layered Ocean Model (NLOM), while limited to subpolar waters deeper than 200 m, has higher horizontal resolution than Global NCOM and is better suited to directly assimilate altimeter data and fore-

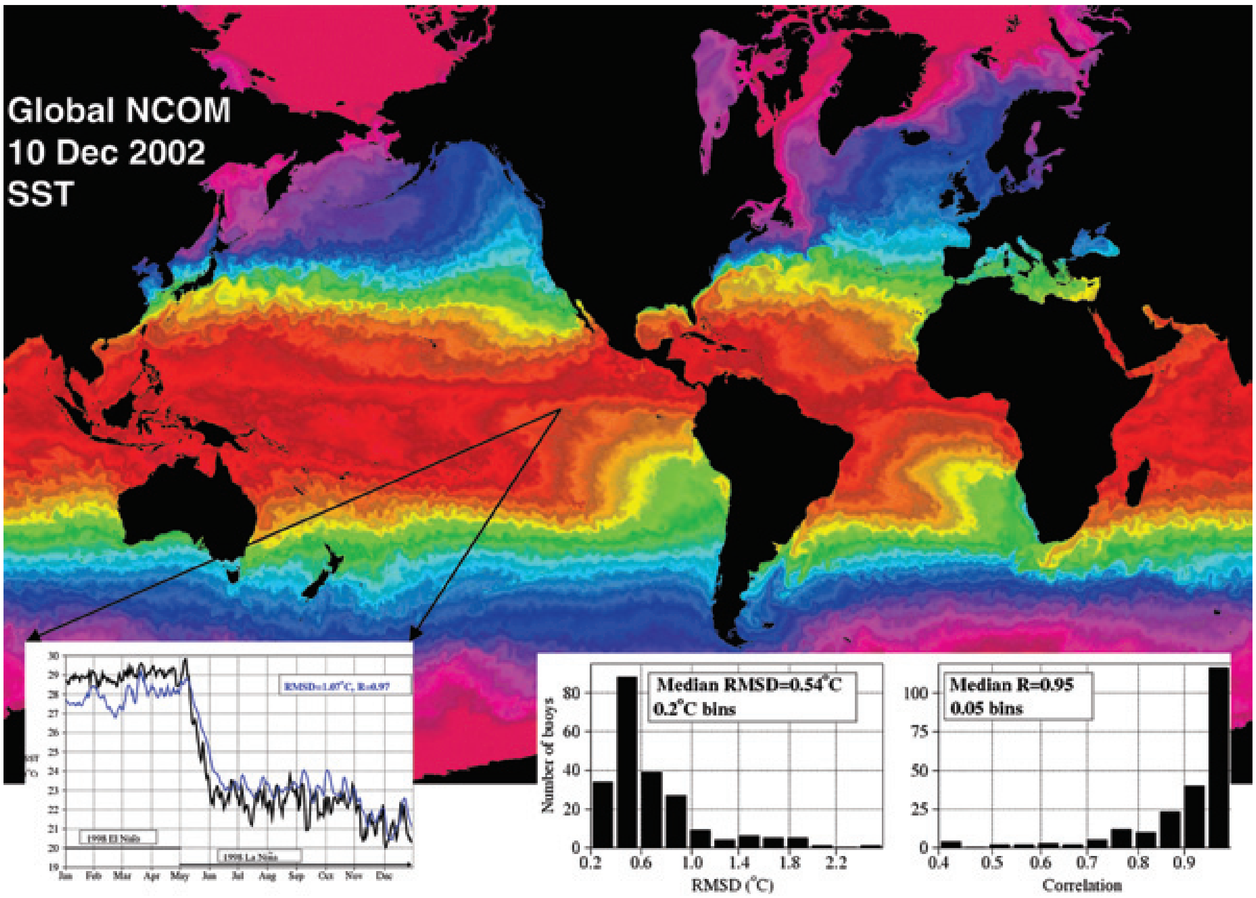


**FIGURE 4**
The global Navy Coastal Ocean Model (NCOM) extends from the Arctic Ocean to the coast of Antarctica and from the open ocean over the shelf break to nearshore regions. Plots of model products such as this sea surface temperature field are available from www.ocean.nrlssc.navy.mil/global_ncom. A variety of global NCOM validation tests continue. For example, the histograms summarize comparisons with 219 unassimilated, year-long buoy SST time series in the Equatorial Pacific, North Pacific, and shelf regions of the United States. One of these cases (line plot) shows NCOM agreement (blue) with one TAO buoy (black) during the extreme 1998 El Niño to La Niña transition.

cast the location of fronts and eddies. To take advantage of this capability, NLOM sea surface height (SSH) fields are paired with MODAS2D SST to derive temperature and salinity profiles using the MODAS dynamic climatology. NCOM relaxes toward these profiles according to a spatially variable weighting function. Figure 5 shows four year-long time series that demonstrate the progression from background climatology, to assimilation field, to model result, with the unassimilated observations for comparison.

**Validation**: Validation of global NCOM against observation-based standards uses a variety of experiments and criteria. Some are climatological comparisons against historical means, including evaluation of mean eddy kinetic energy at various depths and transport and velocity distributions through straits or other sections. NCOM nowcasts and forecasts are compared with satellite observations, prior to assimilation, or with independent in situ data, as shown in Fig. 4. In situ data are also used to evaluate subsurface temperatures and mixed layer depth (Fig. 5). Validations of ocean currents are based on comparisons with drifter trajectories and ADCP sections. Finally, event comparisons in regions of interest may be made using a variety of observational sources, such as the comparison shown in Fig. 6 of ocean color products compared with NCOM surface height and currents in the Arabian Sea.

**Plans**: We are transitioning global NCOM to NAVO, with delivery for operational testing scheduled for February 2003. Testing continues on modified assimilation schemes, boundary condition extraction, and mixed-layer tuning. Global NCOM data provide boundary information for a number of ongoing research efforts.

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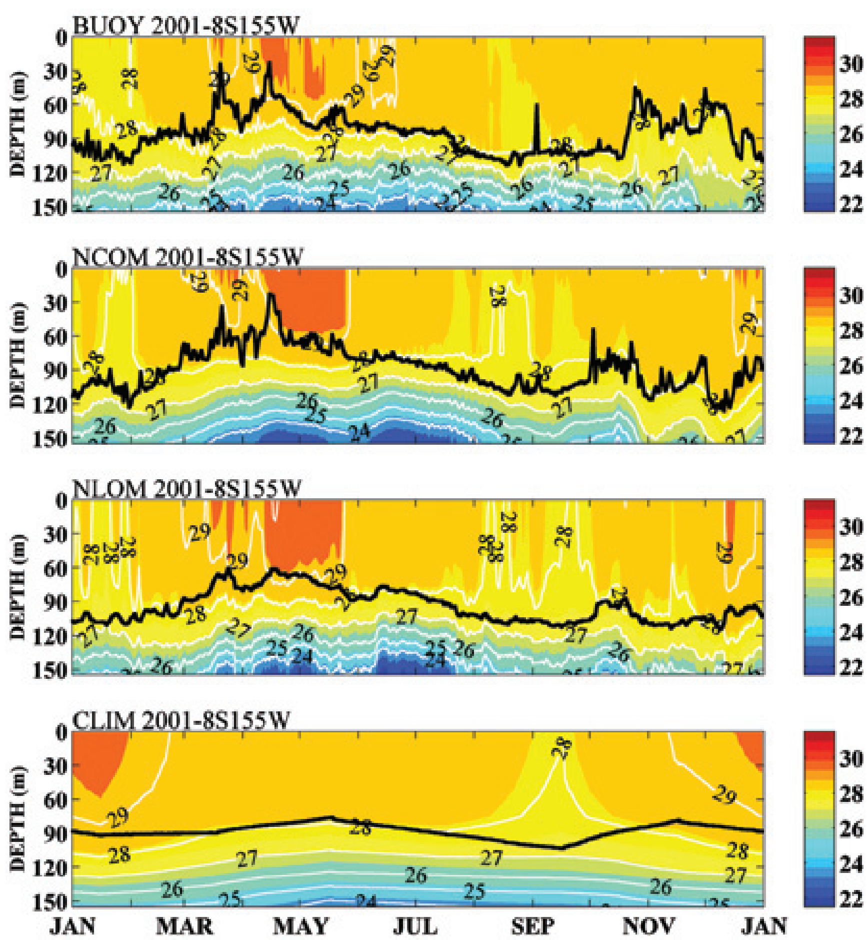


**FIGURE 5**
Time-series from 2001 at a TAO buoy location in the equatorial Pacific (8°S, 155°W). The bottom series indicates the MODAS climatological background. Using real-time MODAS SST and NLOM SSH, the MODAS dynamic climatology produces a field that is assimilated into global NCOM. The ability of global NCOM to resolve the mixed-layer dynamics allows it to produce a mixed-layer depth (black line on each series) in closer agreement with the variability measured in the observations.

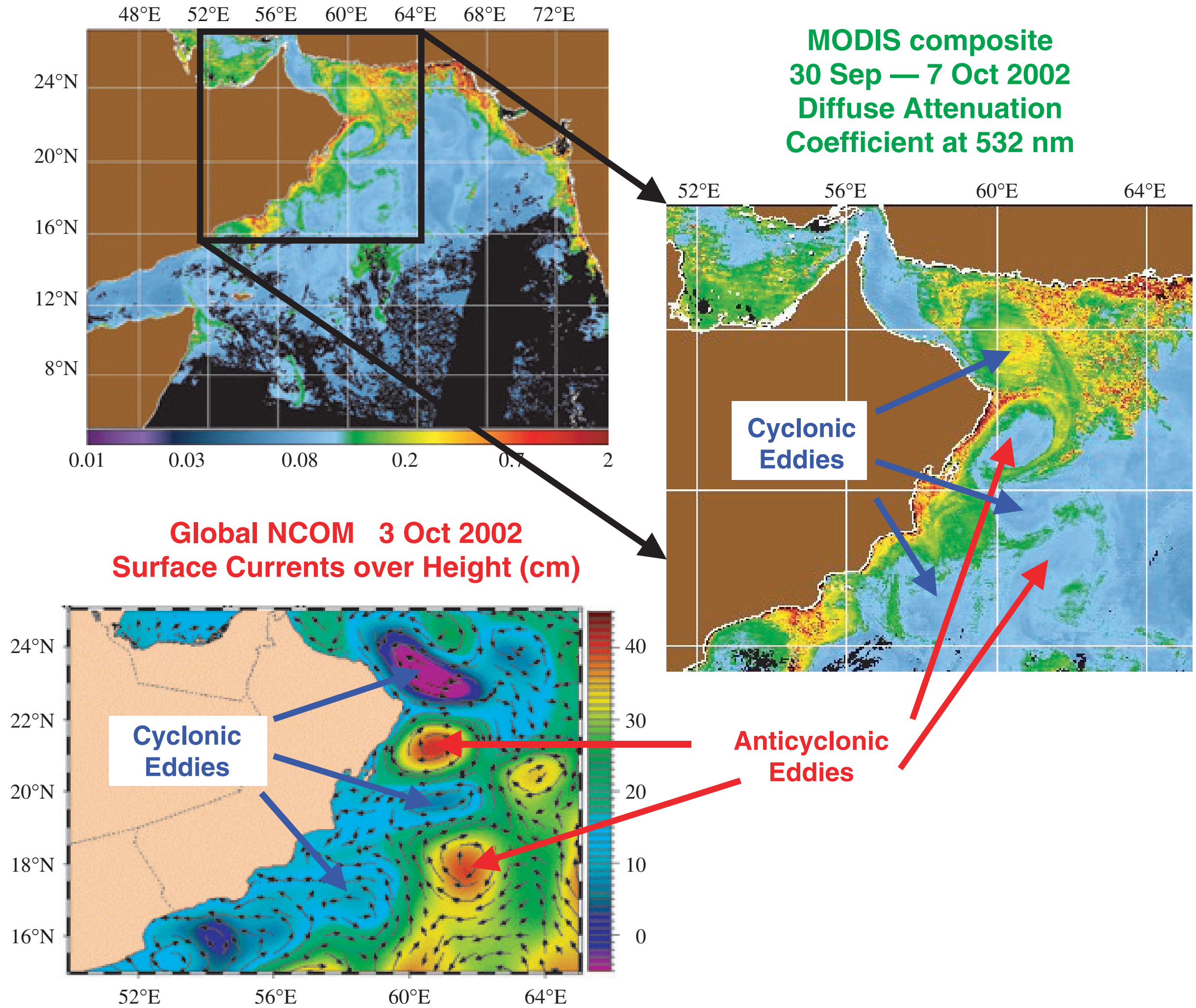


**FIGURE 6**
Global NCOM SSH and surface currents in the Arabian Sea are compared with a MODIS composite produced by the Ocean Optics section at NRL (Ocean Color at http://www7300.nrlssc.navy.mil/products.html). Eddies located in the global NCOM analysis agree with observed features delineated by gradients in diffuse attenuation coefficient.

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[Sponsored by SPAWAR]

**References**

[1] R.C. Rhodes et al., "Navy Real-time Global Modeling Systems," *Oceanog.* **15**, 29-43 (2002).

[2] P.J. Martin, "Description of the Navy Coastal Ocean Model Version 1.0," NRL Report FR/7322-00-9962, 45 pp. (2000).

[3] D.N. Fox, W.J. Teague, C.N. Barron, M.R. Carnes, and C.M. Lee, "The Modular Ocean Data Analysis System (MODAS)," *J. Atmos. Ocean. Technol.* **19**, 240-252 (2002).

## The Influence of Microbial Fe(III) Reduction on Clayey Sediment Flocculation

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**Introduction:** Understanding the role of flocculation of suspended sediments carried by rivers is important to industries and naval undersea operations. This "fluid mud" can be responsible for the variability of littoral sediment properties such as turbidity, shear strength, and compressibility. Many theoretical and laboratory studies have dealt with the physical chemistry and fluid dynamics of interactions among sedi-