Navigator

NAVO MSRC SPRING 2004

News and information from...

The Naval Oceanographic Office Major Shared Resource Center

Validation of the 1/8° Global Navy Coastal Ocean Model Nowcast/Forecast System

Charlie N. Barron, Lucy F. Smedstad, Robert C. Rhodes, A. Birol Kara, Clark Rowley, Richard A. Allard, and Harley E. Hurlburt, Naval Research Laboratory, Stennis Space Center, MS

One of the primary concerns driving the development of U.S. Navy global models is improved performance and nesting support in shelf and nearshore regions with short notice applicability anywhere on the globe. The global implementation of the Navy Coastal Ocean Model (NCOM) is a product of the effort at the Naval Research Laboratory (NRL) to meet this need.[1]

NCOM is the latest transition of the NRL first-generation global system, a progression of planned ocean analysis and forecast systems delivered for Navy operations at the Naval Oceanographic Office (NAVOCEANO).[2]

These systems include the Modular Ocean Data Assimilation System (MODAS)[3] and the 1/16° Navy Layered Ocean Model (NLOM).[4]

NLOM is a deep-water ocean model with higher horizontal resolution, soon to be increased to 1/32°, to better resolve mesoscale ocean dynamics.

The delivery of global NCOM provides a medium-resolution (1/8° or 14 kilometer (km) midlatitude) source for fully global upper-ocean prediction and boundary conditions for higher resolution coastal models.

Its 40 sigma-z levels are concentrated toward the surface to maintain a minimum rest thickness of 1 meter (m) in the uppermost layer.

In addition, NCOM provides a capability to be the ocean component for a global air-ocean forecast and embedded Arctic ice models. In joining the operational model suite at NAVOCEANO, NCOM extends prognostic model coverage to the entire global ocean, including coastal, Arctic, and Antarctic regions. Figure 1 illustrates the coverage in an Atlantic hemispheric view of assimilative NCOM 1998-2000 mean Sea Surface Temperature (SST). Together these model systems offer improved Navy operational global ocean analysis/prediction capability in coastal and open oceans.

The global NCOM system consists of the numerical model, associated databases, the assimilation system, and data extraction software. (Detailed descriptions of the NCOM controlling equations and numerical implementations are given in Barron et al.[5])

NCOM solutions are driven by atmospheric forcing from the Navy Operational Global Atmospheric Prediction System (NOGAPS) and assimilate temperature and salinity fields produced by MODAS using NLOM Sea Surface Height (SSH).

In addition, an NRL-compiled global database of monthly mean river discharge has been incorporated into NCOM, and model topography is based on a global, 2-minute gridded bottom topography produced at NRL.

Tides are not included in global NCOM but are optionally added by post-processing using the Oregon State University global tide constituent databases.[6]

Before transitioning global NCOM to operations, an evaluation of the system was necessary to quantify the accuracy of its products. The assessments provide measures of performance and model error that can be used to estimate product confidence and improve real-time assimilation. They also indicate a baseline for future upgrades to the global modeling system. A validated real-time, fully global ocean modeling system not only continually provides model nowcasts and forecasts wherever they are needed, but also affords a level of confidence in these products based on the verified level of performance in prior products.

Three interannual 1/8° global NCOM model simulations were integrated on

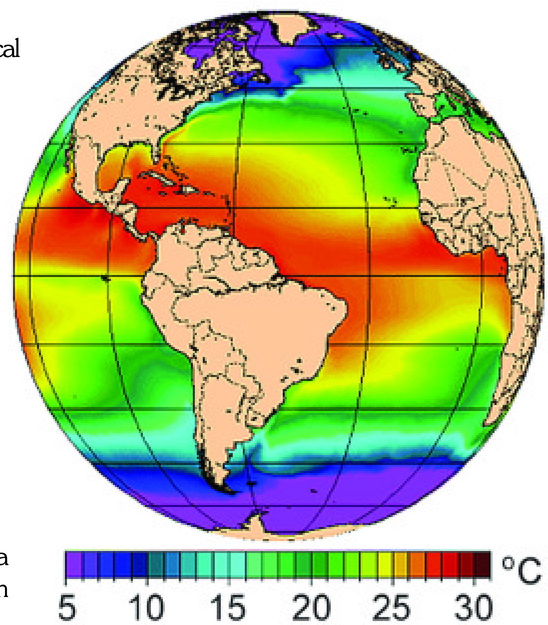

Figure 1. Assimilative 1/8° global NCOM 1998-2000 mean SST.

128 processors of the NAVO MSRC IBM SP3 (HABU): (1) free-running (i.e., atmospheric forcing only) 1998-2002, (2) assimilative (i.e., with ocean data assimilation of MODAS temperature and salinity fields) 1998-present, and (3) forecast mode 1998-2002 using restarts from the assimilative experiment.

Continued Next Page...

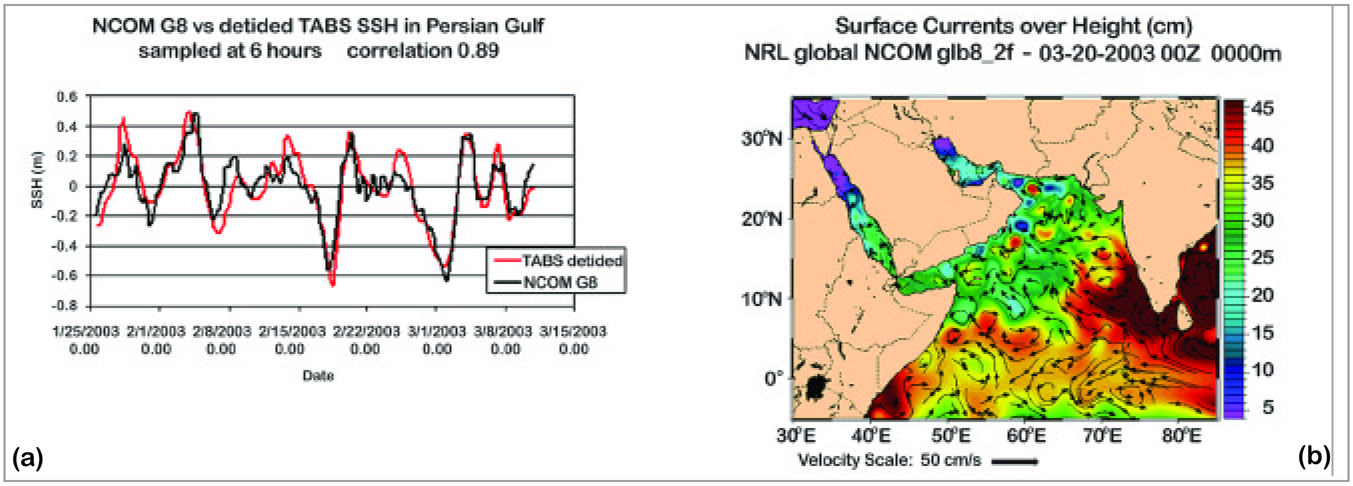

Figure 2. Assimilative 1/8° global NCOM SSH (a) compared with NAVOCEANO TABS buoy measurements 25 January - 15 March 2003 and (b) over the Arabian Sea on 20 March 2003.

The assimilative case corresponds to the operational implementation (although excluding in situ observations to allow independent validation), while the free-running case provides a reference for assessing stand-alone model skill and impact of assimilation.

All NCOM figures in this article are from the assimilative case. More information regarding global NCOM validations are reported by Kara et al.[7] and Barron et al.[8]

The validation test report[9] covers comparisons between unassimilated observations and a variety of NCOM results: temperature, transports, currents, kinetic energy, drifter trajectories, SSH, mixed-layer depth, and boundary conditions. The validations are broad and global but not exhaustive; more detailed examinations are possible for any aspect or region. An example of an SSH comparison is shown in Figure 2a.

Information for the model SSH is extracted at the location (not shown) of a NAVOCEANO observing buoy during the period before Operation Iraqi Freedom, and the two show good agreement. Results at this specific location combined with a validation of about 600 individual yearlong SSH time series around the world, showing a median correlation of .76, increase confidence in the accuracy of model SSH in other, non-corroborated locations, such as the broader Arabian Sea region in Figure 2b.

Means of observations offer another avenue for model evaluation. Eddy kinetic energy at 700 m from a 1998-2000 NCOM mean (see Figure 3a) shows similar patterns but lower energy than a mean of historical observations taken from Schmitz[10] (see Figure 3b).

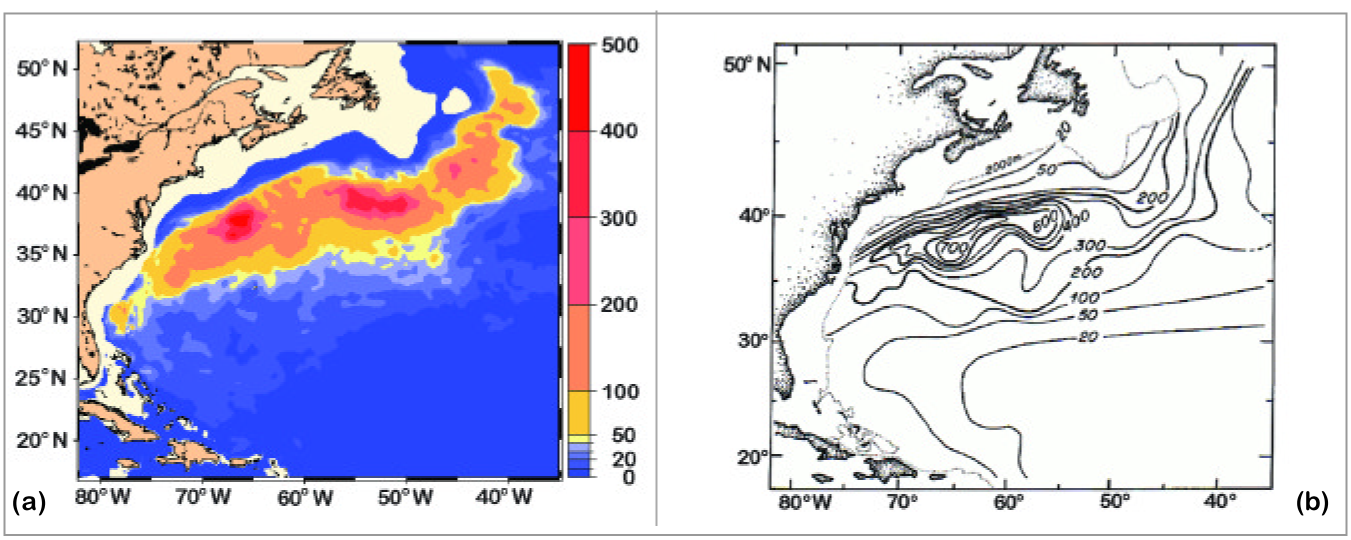

Figure 3. Eddy kinetic energy at 700 m from (a) the 1/8° global assimilative global NCOM 1998-2000 mean and (b) a mean of historical observations taken from Schmitz (1996).

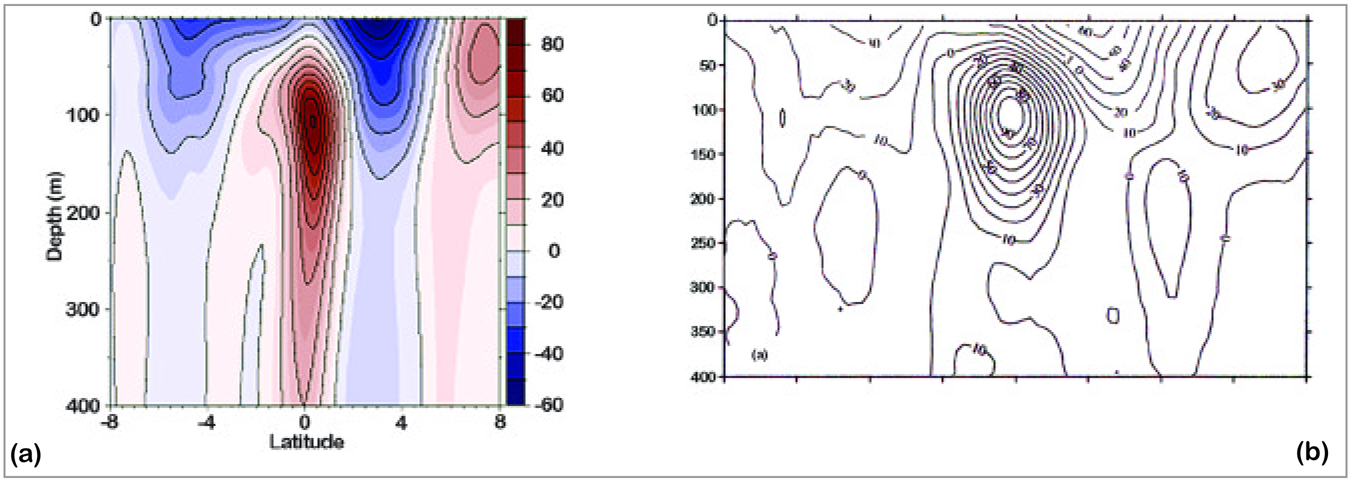

Figure 4. Equatorial cross section of eastward velocity at 135°W from (a) the assimilative 1/8° global NCOM 1998-2000 mean and (b) a 1991-1999 mean taken from Johnson et al.[11]

Despite different time spans, equatorial cross sections of velocity reflect good agreement between the 1998-2000 NCOM mean seen in Figure 4a and the mean calculated by Johnson et al.[11] for 1991-1999 (see Figure 4b), with the model yielding somewhat smaller peak speeds and showing vertical stretching at depth.

The resolution and model configuration for global NCOM is an attempt to best allocate resources for a timely, affordable, and useful system. Features and ocean processes on horizontal scales of 10 K or less cannot be represented by such a global model; these are instead relegated to nested models of smaller, regional domains with increasing resolution.

Figure 5 depicts some of these regional domains, including the East Asian Seas (EAS) NCOM and Intra-Americas Seas (IAS) that are in the transition pipeline. Global NCOM also supported nested relocatable models for Prestige oil spill clean-up activities off the coast of Spain in 2002-2003.

In addition, other areas and exercises have been supported, including activities in the Persian Gulf during Operation Iraqi Freedom.

Validation of the global NCOM system has shown the added value of the model transition. Areas for future improvements have also been identified. Presently the authors are continuing to improve the assimilation components by performing experiments with assimilation using the 1/32° NLOM, which is a planned upgrade, as soon as the NAVO MSRC expands to sufficient operational computing resources, likely late 2004. NCOM assimilation improvements will begin transition on a similar schedule, after completion of the NCOM operational testing.

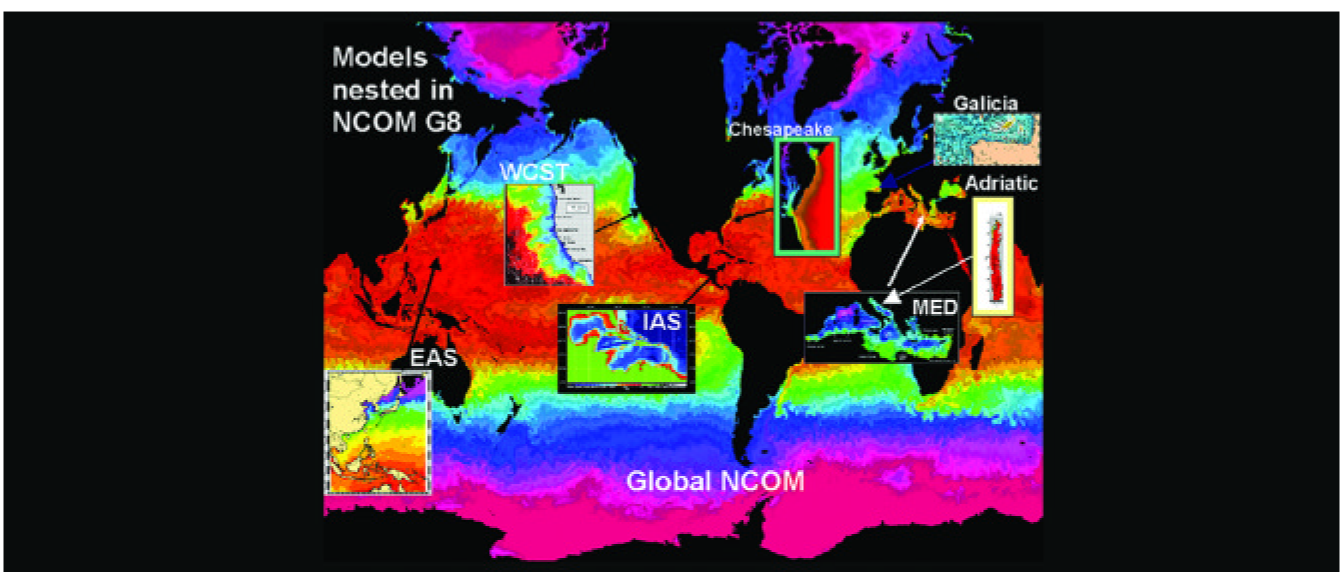

Figure 5. Snapshots from selected regional NCOM models that have been nested within global NCOM.

Acknowledgements

This work was funded as part of the NRL 6.4 Large-scale Models and 6.4 Ocean Data Assimilation projects, managed by the Commander, Space and Naval Warfare Systems Command (COMSPAWARSYSCOM) under program element 0603207N. The numerical simulations were performed on the NAVOCEANO IBM-SP3 (HABU) at Stennis Space Center, MS, using grants of computer time from the Department of Defense High Performance Computing Modernization Program (HPCMP). Additional development and parallelization of NCOM were supported by the HPCMP's Common High Performance Computing Software Support Initiative under projects CWO-01 and CWO-07, and under the High-Fidelity Simulation of Littoral Environments Portfolio. Special thanks go to D.S. Ko for the topography and model grid, Joe Metzger for data comparisons, and Jan Dastugue for help with graphics.

References

1. Barron, C.N., R.C. Rhodes, L.F. Smedstad, P.J. Martin, and A.B. Kara, 2003: "Global Ocean Nowcasts and Forecasts with the Navy Coastal Ocean Model (NCOM)," 2003 NRL Review, 175-178.
2. Rhodes, R.C., H.E. Hurlburt, A.J. Wallcraft, C.N. Barron, P.J. Martin, E.J. Metzger, J.F. Shriver, D.S. Ko, O.M. Smedstad, S.L. Cross, and A.B. Kara, 2002: "Navy Real-Time Global Modeling Systems," Oceanography, 15, 29-43.
3. Fox, D.N., W.J. Teague, C.N. Barron, M.R. Carnes, and C.M. Lee, 2002a: "The Modular Ocean Data Assimilation System (MODAS)," Journal of Atmospheric and Oceanic Technology, 19, 240-252.
4. Smedstad, O.M., H.E. Hurlburt, E.J. Metzger, R.C. Rhodes, J.F. Shriver, A.J. Wallcraft, and A.B. Kara, 2003: "An Operational Eddy-Resolving 1/16° Global Ocean Nowcast Forecast System," Journal of Marine Research, 40-41, 341-361.
5. Barron, C.N., P.J. Martin, A.B. Kara, R.C. Rhodes, and L.F. Smedstad, 2004b: "Global Navy Coastal Ocean Model (NCOM): Description and Application," Ocean Modeling, submitted.
6. Egbert, G. and L. Erofeeva, 2002: "Efficient Inverse Modeling of Barotropic Ocean Tides," Journal of Atmospheric and Oceanic Technology, 19, 183-204.
7. Kara, A.B., C.N. Barron, P.J. Martin, R.C. Rhodes, and L.F. Smedstad, 2004: "Global Navy Coastal Ocean Model (NCOM): Description and Validation of Interannual Simulations," Ocean Modeling, in review.
8. Barron, C.N., A.B. Kara, H.E. Hurlburt, C. Rowley, and L.F. Smedstad, 2004a: "Sea Surface Height Predictions From the Global Navy Coastal Ocean Model (NCOM) During 1998-2001," Journal of Atmospheric and Oceanic Technology, submitted.
9. Barron, C.N., A.B. Kara, R.C. Rhodes, C. Rowley, and L.F. Smedstad, 2004c: "Validation Test Report for the 1/8° Global Navy Coastal Ocean Model Nowcast/Forecast System," NRL Formal Report in preparation.
10. Schmitz, W.J., 1996, "On the World Ocean Circulation: Volume I. Some Global Features/North Atlantic Circulation," Woods Hole Oceanographic Institution Technology Report, WHOI-96-03, 150 pp.
11. Johnson, G.C., M.J. McPhaden, and E. Firing, 2001: "Equatorial Pacific Ocean Horizontal Velocity, Divergence, and Upwelling," Journal of Physical Oceanography, 31, 839-849.