Evaluation of Global HYCOM Initial and Boundary Conditions

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LONG-TERM GOALS

The long-term goal is to evaluate the global HYbrid Coordinate Ocean Model (HYCOM) as an initial and boundary condition provider to regional and coastal nested models which may be based on ocean models other than HYCOM. Global HYCOM has been running in near real time in an eddy-resolving, data-assimilative, fully global ocean prediction system that is being transitioned to the Naval Oceanographic Office (NAVOCEANO) at .08° equatorial resolution, and by 2011, it will be upgraded to .04° resolution. Operational HYCOM will be used as the primary provider of initial and boundary values to finer-resolution nested models whose accurate representation of initial state and boundary forcing is of major importance in operational forecasting and prediction.

OBJECTIVES

The objectives of this research include the capability to run operational, high-resolution, relocatable Navy Coastal Ocean Model (NCOM), HYCOM, and other regional and coastal models using global HYCOM initial and boundary forcing. The major effort is concentrated on the development of a generalized nesting methodology that allows accurate coupling of regional and coastal models within global HYCOM. Specific scientific objectives include (1) extensive evaluation and validation of nesting methodologies to establish a community accepted infrastructure for nesting in global HYCOM, (2) quantitative, comparative study of the skill of global HYCOM as an initial and boundary condition provider against that of global NCOM and other available sources, (3) quantify the relative impact of boundary forcing as well as atmospheric surface forcing on the predictive skill of these coupled systems, including sensitivity to perturbations in the forcing functions, and lastly (4) inherently evaluate global HYCOM and global NCOM as viable Global Ocean Data Assimilation Experiment (GODAE) products.

APPROACH

The California Current Modeling System (CCMS) encompasses a multi-model, multi-nested approach that includes both, HYCOM and NCOM based regional models (30°-49° N), as well as higher resolution NCOM-based Monterey Bay (MB) coastal models (Shulman et al., 2004) which can be

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14. ABSTRACT
The long-term goal is to evaluate the global HYbrid Coordinate Ocean Model (HYCOM) as an initial and boundary condition provider to regional and coastal nested models which may be based on ocean models other than HYCOM. Global HYCOM has been running in near real time in an eddy-resolving, data-assimilative, fully global ocean prediction system that is being transitioned to the Naval Oceanographic Office (NAVOCEANO) at .08? equatorial resolution, and by 2011, it will be upgraded to .04? resolution. Operational HYCOM will be used as the primary provider of initial and boundary values to finer-resolution nested models whose accurate representation of initial state and boundary forcing is of major importance in operational forecasting and prediction.

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nested in the global models directly, or indirectly through the regional models. The research conducted during this period was focused on data assimilative models which use either the Modular Ocean Data Assimilation System (MODAS) (used in global NCOM), or the Navy Coastal Ocean Data Assimilation (NCODA) system (used in global HYCOM). The CCMS models include a bio-optical component (Chai et al., 2002), implement data assimilation using either MODAS (for regional) or NCODA (for coastal), and are forced by high-resolution (as high as 3Km) atmospheric forcing from the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) (Hodur, 1997). Complemented by a comprehensive archive of observational data and ongoing field experiments, the CCMS constitutes a valuable research platform which is suitable for transition to other coastal regions of the world. This approach was used to examine the sensitivity of the regional, coastal, and regional-coastal simulations to large-scale model initial and boundary forcing.

WORK COMPLETED

The 3-D Generalized Mapper (3DGM) was developed in FY07 and improved in FY08 to include horizontal mapping of curvilinear and unstructured grids. This improvement was necessary to handle the orthogonal curvilinear grid configuration of the Monterey Bay model, and be able to nest this type of grid within global HYCOM. Utilizing the 3DGM for nesting in the GODAE global models, numerical studies focused on the US West Coast were conducted using the CCMS modeling framework (deRada et al., 2008). The current effort expands on past research nesting the California Current System (CCS) regional NCOM and HYCOM based models, to now include nesting of a high-resolution Monterey Bay model (Shulman et al., 2007) directly (and indirectly through the CCS regional models) within data assimilative global HYCOM and NCOM. The results of this study have been presented at HYCOM Consortium meetings and at the GODAE Final Symposium.

The 3DGM methodology and related software were major contributions in this effort, allowing consistent, systematic nesting of regional and coastal models in either of the global models. Other innovative tools were developed to manage the large amounts of global HYCOM and NCOM data efficiently, including automation software for pre/post processing and dynamic analysis/visualization of the results using software like Google Earth and Vis5D. Most of these tools have been shared and are being used by the HYCOM community.

RESULTS

The research was focused on data assimilative nested systems, inherently evaluating global HYCOM (assimilating data via NCODA) and global NCOM (assimilating data via MODAS) GODAE products. The results were evaluated against tide-gauges, satellite measurements, and surface and subsurface temperature and salinity observations. The study concentrated on the suitability of global HYCOM as provider of initial and boundary forcing for regional and coastal models whose results were evaluated against observations as well as the current operational global NCOM.

Figure 1 illustrates a coastal Kelvin wave propagating from global HYCOM into a nested regional NCOM configuration whose boundary lies just south of San Diego. As this pulse propagates northwardly, it travels as far as Monterey where a tide-gauge station is used to evaluate its amplitude (see Figure 2). This wave starts dissipating north of Monterey as local forcing influence dilutes the remotely forced signal as it travels farther away from the boundary.

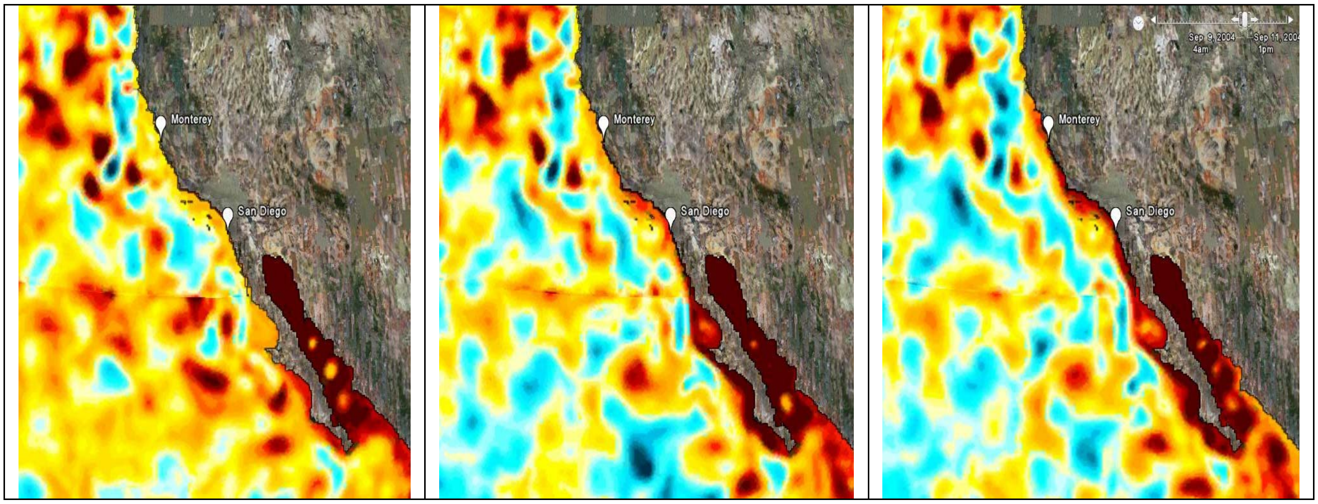

Figure 1. Sea-surface-height anomaly (SSHA) snapshots of a Google Earth animation illustrating the northwardly propagation of a coastal Kelvin wave (red color) generated in Global HYCOM, entering and leaving the Gulf of Baja California (left panel), crossing the boundary (south of San Diego) into the nested regional model (center panel) and later reaching the Monterey Bay (right panel). The balloon markings represent the locations of San Diego and Monterey. A coherent single image is seen in each snapshot, but careful inspection reveals the southern boundary between outer and inner nests.

Figure 2 depicts this same coastal Kelvin wave propagating northwardly from Global HYCOM and Global NCOM (bottom row) into their respectively nested CCS regional model (middle row), and into their directly nested MB coastal model (top row). The layout of figure 2 represents the natural nesting configuration as the global model signal propagates from south to north (bottom-up in the figure). The Hovmoeller diagrams (phase plots of SSHA), representing the modeled signal traveling in time along the coast, are used to interpret the penetration, phase, and amplitude of the pulse as it travels across nests. Significant differences are seen between global HYCOM and global NCOM, most notably the higher, broader amplitude of the global HYCOM signal penetrating farther into the respectively nested regional model (2e). The separation of this Kelvin wave into 2 distinct peaks (Sep 30 to Aug 6) is well represented by both, the regional and the coastal nested systems, but only the models nested in HYCOM have amplitudes, for both peaks, as high as those observed by the Monterey Bay tide-gauge station (time-series plots, regional: 2b and 2e; coastal: 2c and 2f).

Figure 3 illustrates the skill of the Monterey Bay model nested directly in global HYCOM as evaluated against satellite SST on August 10, 2006 during a wind upwelling event well captured by the COAMPS 3Km winds. The model response to the upwelling favorable winds is easily depicted in the figures by the presence of colder water north and south of the Monterey Bay.

In general, the solutions based on global HYCOM initial and remote forcing were, although slightly, consistently more accurate than those based on global NCOM. Since both global models use the same atmospheric forcing from the Navy Operational Global Atmospheric Prediction System (NOGAPS) model, the better accuracy is likely due to the higher resolution of global HYCOM (1/12º vs. 1/8º in NCOM), and perhaps also to the contribution of NCODA data assimilation in global HYCOM over that of MODAS in global NCOM.

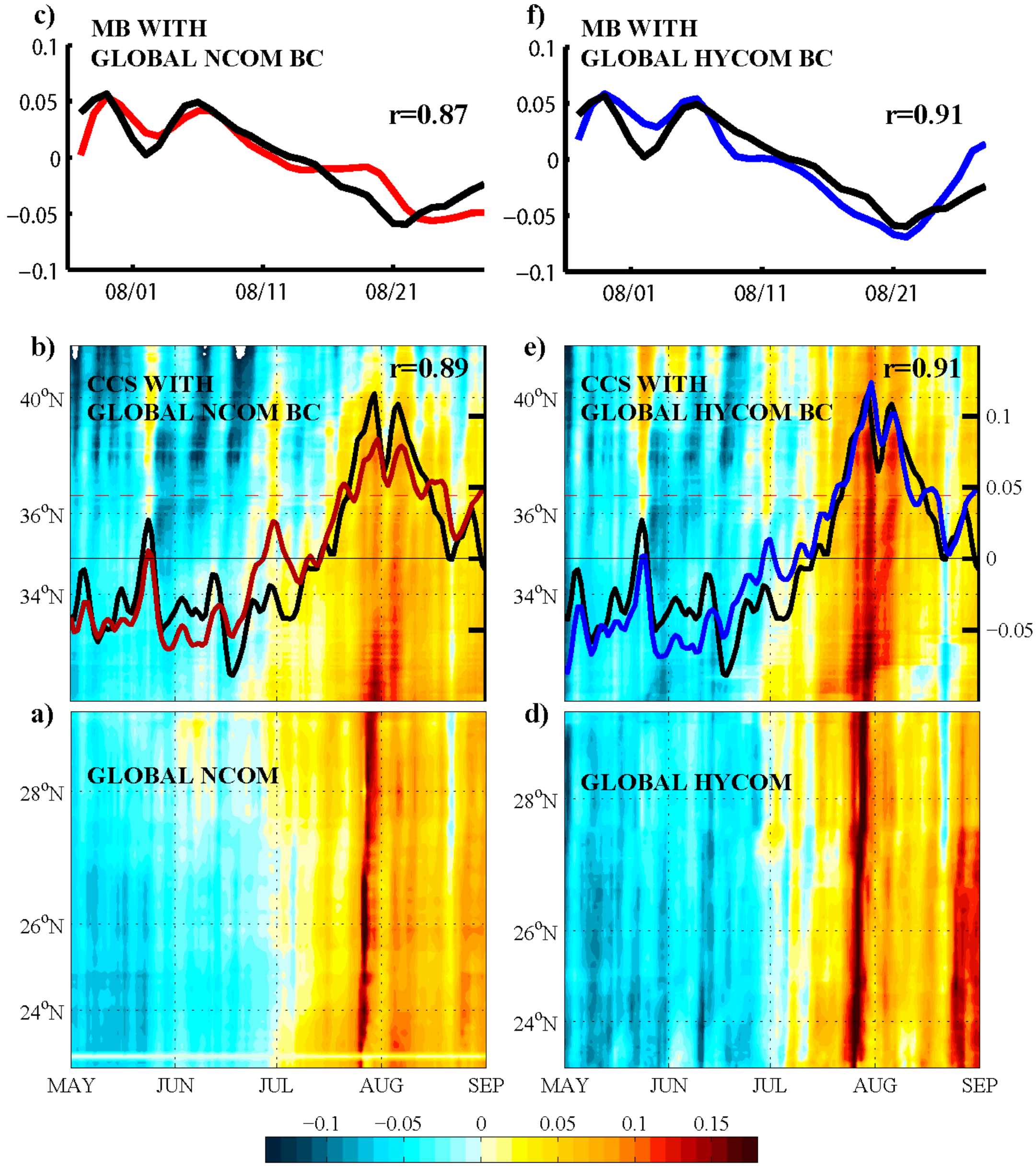

Figure 2. SSHA is used to evaluate a coastal Kelvin wave as it propagates from (a) global NCOM and (d) global HYCOM into the respectively nested regional (b and e) and coastal (c and f) model simulations. The regional model results, (b) nested in global NCOM, (e) nested in global HYCOM, evaluated using a time-series of model SSH relative to the Monterey tide gauge measurements, show that the HYCOM-based signal (blue line) is much closer to the observations (black line) than the global NCOM-based signal (red line). This same signal is also evaluated in the MB model nested in (c) global NCOM and (f) global HYCOM, using the same tide-gauge observations. In this case, a filtered time-series for the month of August isolates the separation of the signal followed by a drop off. Both regional and coastal simulations capture the signature of this Kelvin wave, but a slight improvement is consistently seen, corroborated by the correlation values (r), when using HYCOM initial and boundary forcing.

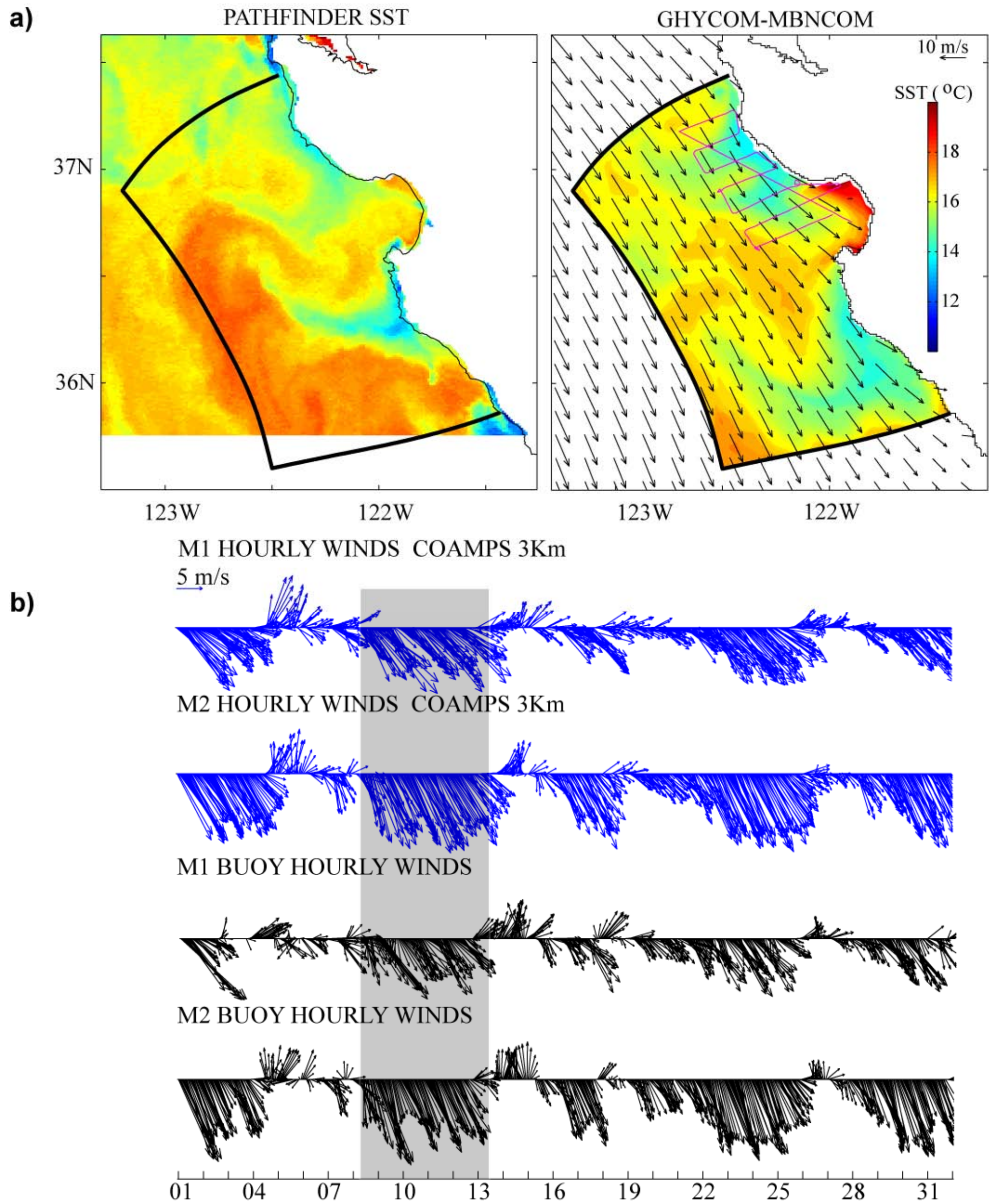

Figure 3. (a) The modeled SST (right), corroborated (r = .85) by the satellite observation (left) on August 10, 2006, captures the expected response to the (b) upwelling favorable wind event (gray box) measured by two Monterey Bay buoy observations (black vectors) and well represented by the COAMPS model (blue vectors).

IMPACT/APPLICATIONS

Global HYCOM initial and lateral boundary forcing have been found to be consistently more accurate than global NCOM and have a significant impact on the predictive skill of the nested regional and coastal models in the U.S. West Coast Region. The techniques and tools developed in this area have already been tested in other regions and are becoming standard applications in the community.

Implications of this specific R&D represent an important contribution to operational needs, HYCOM, and GODAE.

RELATED PROJECTS

This is a highly collaborative NOPP project involving several partnering groups including academic (with Eric Chassignet at Florida State as the overall lead PI), government (Navy and NOAA), industry, and international institutions. Some of the leveraging NRL projects include 6.1 Bio-Optical Studies of Predictability and Assimilation in the Coastal Environment, 6.3 Battlespace Environments Institute, and 6.4 Large Scale Ocean Modeling.

REFERENCES

deRada, S., Shulman, I., Kindle, J., Anderson S. Numerical Evaluation of Boundary Forcing from GODAE Global Products in the US West Coast, AGU Ocean Sciences Meeting, Orlando, Florida, March 2008. *(http://www.aslo.org/orlando2008/files/2008osm-abstracts.pdf)*

Shulman I., J. Kindle, P. Martin, S. deRada, J. Doyle, B. Penta, S. Anderson, F. Chavez, J. Paduan, S. Ramp (2007): Modeling of upwelling/relaxation events with the Navy Coastal Ocean Model. *Journal of Geophysical Research, Vol. 112 C06023,* doi:10.1029/2006JC003946

Hurlburt, H.E., E.P. Chassignet, J.A. Cummings, A.B. Kara, E.J. Metzger, J.F. Shriver, O.M. Smedstad, A.J. Wallcraft, C.N. Barron (2008): Eddy-Resolving Global Ocean Prediction. Ocean Modeling in an Eddying Regime, Ed., M Hecht and H. Hasumi, Geophysical Monograph 177, American Geophysical Union, Washington, DC. pp. 353-381.

Chassignet, E.P., H.E. Hurlburt, O.M. Smedstad, G.R. Halliwell, A.J. Wallcraft, E.J. Metzger, B.O. Blanton, C. Lozano, D.B. Rao, P.J. Hogan and A. Srinivasan (2006): Generalized vertical coordinates for eddy-resolving global and coastal ocean forecasts. *Oceanography*, ***19(1)***,*118-129*

Shulman I., J. Kindle, S. deRada, S. Anderson, B. Penta and P. Martin (2004): Development of hierarchy of different resolution models for study U.S. West Coast California Current Ecosystem. In Spaulding, M. L. (Ed.), *Estuarine and Coastal Modeling*, Proceedings of 8th International Conference on Estuarine and Coastal Modeling, 74-88

Chai, F.; R.C. Dugdale; T-H Peng; F.P. Wilkerson; R.T. Barber (2002). One Dimensional Ecosystem Model of the Equatorial Pacific Upwelling System, Part I: Model Development and Silicon and Nitrogen Cycle. *Deep-Sea Res. II 49: 2713-2745*

Hodur, R.M., (1997): The Naval Research Laboratory's coupled ocean/atmosphere mesoscale prediction system (COAMPS). *Mon. Wea. Rev.,* ***125 (7)****, 1414-1430*