Global HYCOM Initial and Boundary Conditions for Regional and Coastal Models

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LONG-TERM GOALS

The long-term goal of this effort is to evaluate global HYbrid Coordinate Ocean Model (HYCOM) initial and boundary conditions supplied to regional and coastal nested models, including coupled COAMPS® and NCOM. As part of the larger NOPP-funded program, HYCOM will be run with data assimilation in an eddy-resolving, fully global ocean prediction system that is scheduled to transition to the Naval Oceanographic Office (NAVOCEANO) at .08° equatorial (~7 km mid-latitude) resolution in 2007 and .04° resolution in 2011. Projected outcomes of our component will include the operational capability to run globally-relocatable high-resolution NCOM using HYCOM initial and boundary conditions, improvements to treatment of boundary conditions and exploration of the relative sensitivity of coupled model skill to boundary, initial and surface forcing perturbations.

OBJECTIVES

This project will focus on the development of an accurate and generalized ocean model nesting capability in support of regional and littoral applications when global HYCOM becomes operational. This will include the capability to provide boundary conditions to nested models with fixed depth z-level coordinates, terrain following coordinates, generalized coordinates (HYCOM), and unstructured grids. Specifically, the scientific objectives of this long-term effort are to: (1) establish the infrastructure for ingestion of HYCOM boundary and initial conditions (b.c.'s and i.c.'s) into globally-relocatable coupled COAMPS®/NCOM, as well as stand-alone NCOM and coastal HYCOM (2) quantitatively evaluate HYCOM sources of i.c.'s and b.c.'s against other comparable available sources and provide feedback for improvement in HYCOM fields, (3) improve NCOM treatment of lateral b.c.'s to best facilitate information exchange across the boundaries, and (4) explore ensemble techniques to quantify the relative impacts of i.c.'s, b.c.'s and surface forcing on the predictive skill of the coupled system for selected coastal regions throughout the world.

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APPROACH

NRL-Stennis and NRL-Monterey are collaborating on the nesting of both HYCOM and NCOM into .08° global HYCOM so that the resulting nesting capability will become an integral component of COAMPS®. Test bed areas for this project include the entire region off the U.S. west coast, a separate Southern California Bight domain, high resolution coastal models of Monterey Bay, and the region encompassing the Philippines Archipelago and Seas. Our approach is to quantitatively evaluate these model implementations against satellite and in situ observations available for the local region. Furthermore, NRL is represented on the International GODAE Coastal and Shelf Seas Working Group by J. Kindle and we are active within the NOPP-HYCOM community in sharing our research results and distributing software for manipulating and visualizing model results.

WORK COMPLETED

Model Nesting. We have finished several tasks related to the nesting of regional and coastal models within Global HYCOM. In FY06 and early FY07, a generalized coupler, called the 3-D Generalized Mapper (3DGM), was developed that facilitated the implementation of coastal and regional NCOM models (Shulman et al, 2004) receiving initial and boundary information from any large –scale model, including HYCOM. The regional, data-assimilative model for the US west coast (NCOM-CCS) was used to examine the sensitivity of the regional simulation to various large-scale models, including the operational Global NCOM, the data-assimilative Global HYCOM (HYCOM/NCODA) and the free-running global HYCOM. In a parallel effort, we have built the capability of using these same global sources in our relocatable COAMPS®/NCOM system. We evaluated these global sources in numerical studies focused on the Philippines region. December 2004-February 2005 winter monsoon conditions were simulated using COAMPS (triply nested down to 8 km resolution, courtesy of Jim Doyle) forcing a regional NCOM ocean model (3 km resolution).

Data management and processing. A one day global HYCOM archive file exceeds 12GB. Two innovative wrapper scripts have been written to improve and make global HYCOM data management and processing (e.g., regridding) more efficient. These have become standard procedure and are now widely used by HYCOM group.

Analysis and graphical display. New capabilities have been developed for graphical analysis and comparisons of model results. The software developed has been generalized for use with either NCOM or HYCOM, as well as other models. Software enhancements include Google Earth Visualization, Vis5ncDf, Geometry Editor and Generator, and a coastline extraction tool. These tools have been shared with the HYCOM community and are in use by others.

RESULTS

Model Nesting: US West Coast. Model results were compared to the AVISO SSH product based on satellite altimeters as well as observations using the coastal tide gauges and quarterly ship surveys offshore from Monterey. Anomaly correlations relative to the AVISO SSH anomaly product for the period 2005-2006 revealed that the NCOM-CCS simulation, using the information from data-assimilative global HYCOM, provided a slightly more accurate solution in the open ocean relative to the Global NCOM or free-running HYCOM forced solutions. The comparisons with the coastal tide gauge stations revealed the ability of the HYCOM-NCOM nesting or the NCOM-NCOM nesting to accurately represent the effects of remotely forced Kelvin waves that propagate from the Central America coast along the US west coast. Figure 1 depicts a Kelvin wave pulse propagating from Global HYCOM to the NCOM-CCS domain in July 2006. Figure 2a is a Hovmoeller diagram showing the propagation of SSH anomaly signals between the two models during the period May-September 2006; Figures 2b and c shows comparisons of the model SSH anomalies relative to observations, revealing that the data-assimilative global HYCOM forced solutions were slightly more accurate near San Diego and Monterey. In FY08 efforts will include the examination of the sensitivity of high resolution Monterey Bay models to the input from these global simulations; results from the ASAP MURI field experiment in August of 2006 will be used to evaluate the simulations.

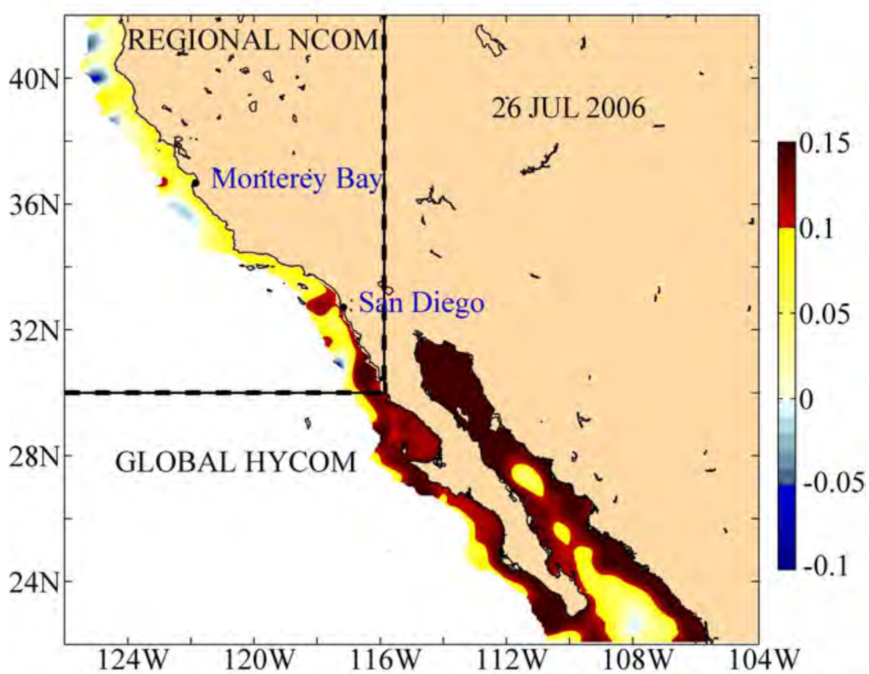

Figure 1. Sea surface height anomaly (SSHA) propagating as a coastal Kelvin wave from the Global HYCOM model to the nested NCOM-CCS model in July 2006. The leading edge of the high amplitude portion of the wave is shown near San Diego.

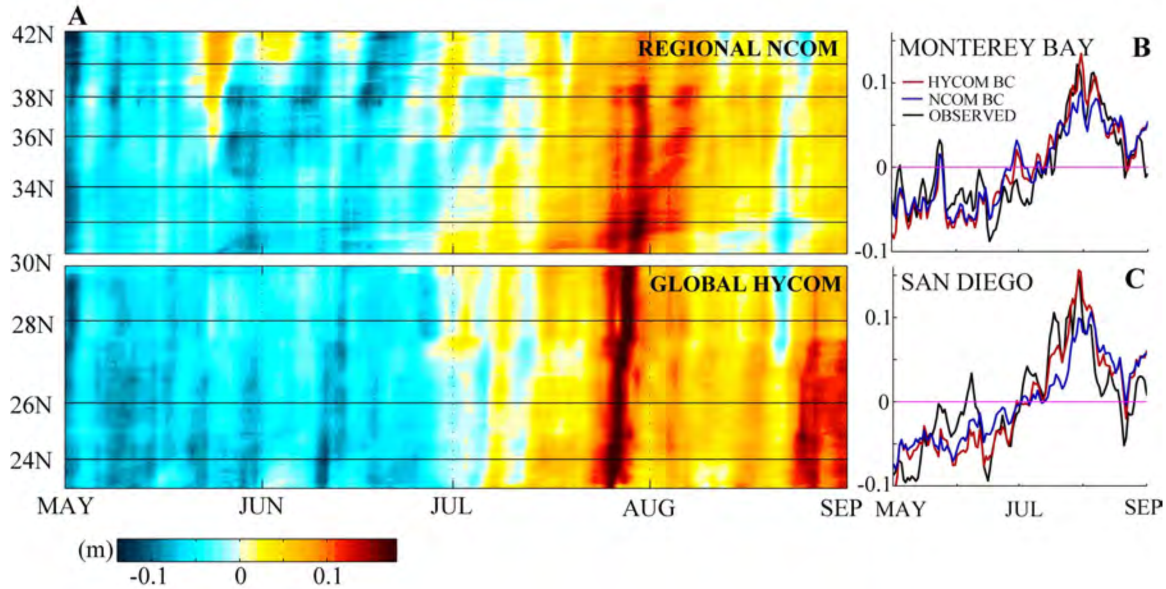

Figure 2. a) Hovmoeller diagram of model sea surface height (SSH) anomaly along the west coast from 23N to 42N during May to September of 2006. The lower panel is from the Global real-time HYCOM model, which provides boundary values to the regional NCOM-CCS model, shown in upper panel. Note large amplitude Kelvin wave traveling northward along the boundary in July; the wave propagates through model boundary at 30N with little change in amplitude and extends past 38N. b) Time series of model SSH anomaly amplitude at Monterey Bay relative to observations from tide gauge. Red line denoted SSH from NCOM–CCS model forced by Global HYCOM while blue line shows solution form NCOM-CCS forced by Global NCOM. c) same as b) except for San Diego. The NCOM-CCS run forced by HYCOM represents Kelvin wave more accurately than the global NCOM forced run.

Model Nesting: Philippines. High-resolution Philippines COAMPS simulations produce intense wind jets associated with the mountain orography and gaps between islands during the northeast monsoon. The strong curl of these wind jets leads to a double gyre west of Mindoro in the simulations that used initial/boundary conditions from global NCOM and global HYCOM/NCODA (Figure 3). Elsewhere, the simulations display significant differences. For instance, in the southeast of the domain the run using global HYCOM/NCODA produces a cyclonic eddy east of Mindanao while the run using global NCOM generates a southwest flowing boundary current.

The global models were evaluated against subsurface temperature observations available in the Philippines region for February 2005 (Figure 4). There were approximately 90 XBT and Argo profiles during this time period. Global HYCOM/NCODA produced the lowest mean bias in the upper 200 m of the water column and smallest RMSE in the top 20-30 m.

In FY08, we will set up a nested model implementation for Japan (a relatively data-rich area) to contrast with the relatively data-poor Philippines area, and extend our analysis of i.c.’s and b.c.’s to this new domain. We also will conduct simulations within an ensemble framework.

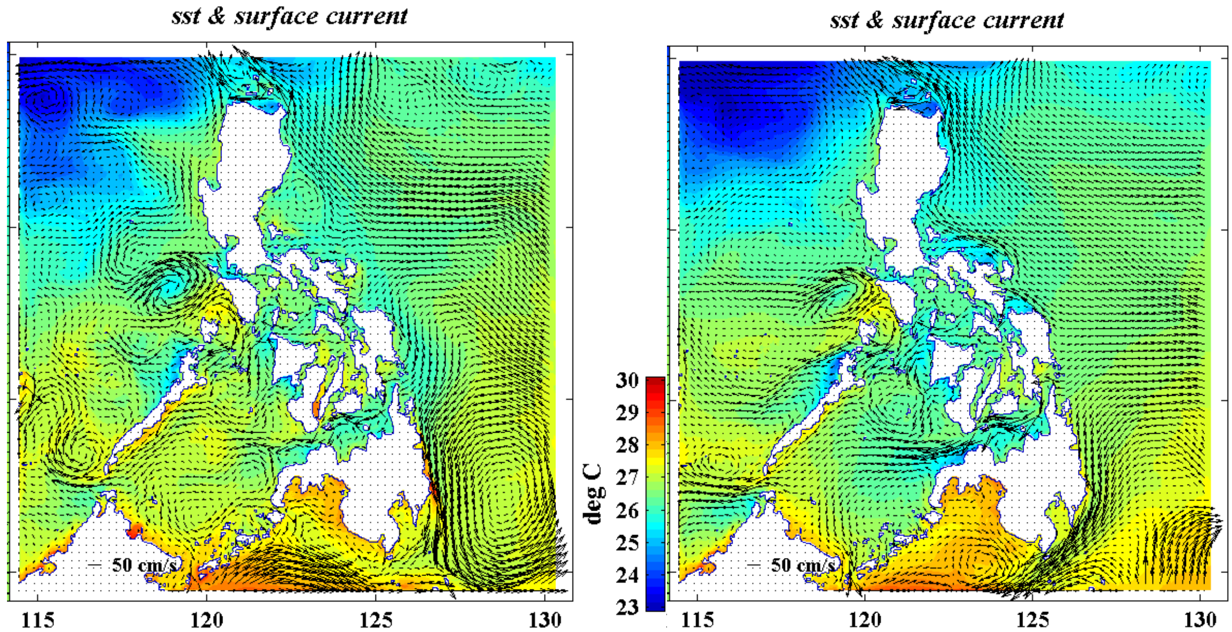

Figure 3: February 2005 mean sst and surface currents of 3 km NCOM using global data-assimilating HYCOM/NCODA (left panel) and global NCOM (right panel) i.c.'s and b.c.'s.

IMPACT/APPLICATIONS

Utilizing data-assimilating global HYCOM for initial and lateral boundary conditions has a positive impact on skill of the nested regional models for several locations that we tested around the globe. Our relocatable implementations of regional and coastal models represent a breakthrough in operational capability and we expect forecast skill to improve along with enhancements to HYCOM/NCODA.

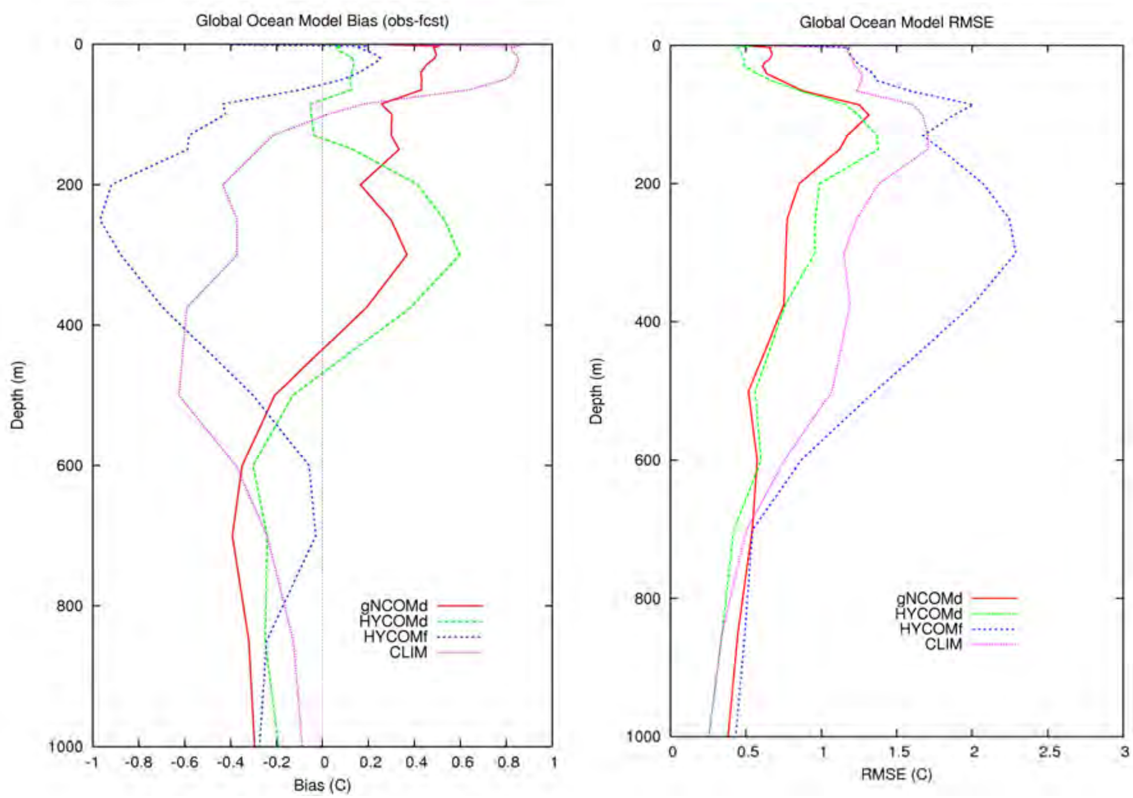

Figure 4: Bias and RMSE of global ocean models using available subsurface temperature measurements in the Philippines region during February 2005. The green line shows the errors of global HYCOM/NCODA while the red line shows errors of global NCOM. (Blue is free running global HYCOM while magenta is climatology.)

TRANSITIONS

None.

RELATED PROJECTS

This is a highly collaborative NOPP project with 24 partnering groups. These partners are universities (with Eric Chassignet at Florida State as the overall lead PI), government (Navy and NOAA), industry and international. Partnering projects at NRL include 6.1 Global Remote Littoral Forcing via Deep Water Pathways, 6.1 Air-Sea Coupling in the Coastal Zone, 6.1 Coupled physical and bio-optical processes in the Coastal Zone, 6.2 Coastal Ocean NESTing Studies (CO-NESTS), 6.2 NOPP – HYCOM Coastal Ocean Hindcasts and Predictions: Impact of Nesting in HYCOM GODAE Assimilative Hindcasts, 6.3 Battlespace Environments Institute – ESMF for Atmospheric-Ice-Ocean Coupling and Component Interoperability, 6.4 Large Scale Ocean Modeling, 6.4 Ocean Data Assimilation, 6.4 NPOESS/Mesoscale Oceanography, and RTP Rapidly Relocatable, Coupled, Mesoscale Modeling System for Naval Special Warfare. Additionally, the project received grants of HPC time from the DoD High Performance Computing Modernization Office.

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