Boundary Conditions, Data Assimilation, and Predictability in Coastal Ocean Models

Roger M. Samelson
College of Oceanic and Atmospheric Sciences
Oregon State University
104 COAS Admin Bldg
Corvallis, OR 97331-5503
Phone: (541) 737-4752 FAX: (541) 737-2064 E-mail: rsamelson@coas.oregonstate.edu

John S. Allen, Gary D. Egbert
College of Oceanic and Atmospheric Sciences
Oregon State University
104 COAS Admin Bldg
Corvallis, OR 97331-5503
Phone: (541) 737-2928 FAX: (541) 737-2064 E-mail: jallen@coas.oregonstate.edu
Phone: (541) 737-2947 FAX: (541) 737-2064 E-mail: egbert@coas.oregonstate.edu

John C. Kindle
Ocean Sciences Branch, Code 7331
Naval Research Laboratory
Stennis Space Center, MS 39529-5004
Phone: (228) 688-4118 FAX: (228) 688-4149 E-mail: kindle@nrlssc.navy.mil

Chris Snyder
Mesoscale and Microscale Meteorology
National Center for Atmospheric Research
PO Box 3000
Boulder, CO 80307-3000
Phone: (303) 497-8966 FAX: (303) 497-8171 E-mail: chriss@ucar.edu

Award Number: N00014-05-1-0891
http://www.coas.oregonstate.edu/faculty/samelson.html

LONG-TERM GOALS

The long-terms goals of this research are to improve our ability to understand and predict environmental conditions in the coastal ocean.

OBJECTIVES

The specific objectives of this research are to determine the impact on coastal ocean circulation models of open ocean boundary conditions from Global Ocean Data Assimilation Experiment (GODAE) Pacific Ocean models, and to address closely related issues of uncertainty and predictability in coastal ocean models.

APPROACH

The research will address the direct impact on coastal models of boundary conditions from GODAE large-scale models and two intermediate-scale models. The intermediate-scale models will have high-resolution atmospheric forcing, and boundary conditions from the large-scale GODAE model. The domain of the coastal model for the project will cover the 'coastal transition zone' (CTZ), which includes the continental shelf and slope, and the adjacent ocean interior. The CTZ, which extends offshore about 200 km in this region, is the natural oceanographic regime of interest for coastal modeling applications off Oregon and northern California. It is characterized by energetic wind- and buoyancy-driven flow over the shelf, accompanied by complex, lower-frequency eddy, jet and filament dominated flow over the slope and in the ocean interior, which is unlikely to be properly resolved by basin scale models. The impact on the CTZ-domain model simulations of assimilating satellite remote sensing observations, including sea-surface heights and temperatures, and of using scatterometer wind stress fields, will also be addressed. Validation of the simulated coastal ocean circulation will be provided by existing elements of the Oregon coastal ocean observing system, including short-range and long-range coastal HF radar arrays, and by extensive in-situ data sets from major observational programs during 2000-2003. The impact of the boundary conditions will be assessed quantitatively through data assimilation, using a variational representer-based generalized inverse method. The closely related issues of uncertainty and predictability in coastal ocean models will be addressed using a variety of empirical and theoretical methods to study disturbance growth mechanisms and to develop uncertainty budgets for these models.

In addition to PIs Samelson, Allen, Egbert, Kindle, and Snyder, other senior personnel are A. Kurapov and R. Miller, both at College of Oceanic and Atmospheric Sciences, Oregon State University. Dr. Scott Springer has been hired as a full-time research associate to pursue the physical circulation modeling, data assimilation and boundary condition assessment studies, with guidance and collaboration of Allen, Egbert, Kurapov, Miller (OSU) and Kindle (NRL). Postdoctoral investigator Sangil Kim (Ph.D. Johns Hopkins, 2005) joined the project in July 2006 to work with Samelson (OSU) and Snyder (NCAR) on the predictability and uncertainty studies. All investigators share responsibility for the synthesis tasks.

WORK COMPLETED

The work plan primarily involves the implementation, evaluation, and analysis of a nested CTZ-domain model based on the ROMS (Regional Ocean Modeling System) primitive equation modeling code. Since the GODAE Pacific HYCOM model at present is not yet functioning with full data assimilation capability, it was decided, in consultation with NRL partner John Kindle, to proceed with nesting the CTZ-domain ROMS model in the NRL regional NCOM-CCS (Navy Coastal Ocean Model-California Current System) model. The latter regional model is nested in the NRL real-time Global NCOM model, which is the present Pacific Ocean GODAE system. Both Global NCOM and NCOM-CCS include assimilation of satellite altimeter and sea-surface temperature measurements. NCOM-CCS has higher horizontal grid resolution than Global NCOM (9 km vs. 12 km) and, in addition, is forced by atmospheric fluxes from a high-resolution COAMPS (Coupled Ocean Atmospheric Mesoscale Prediction System) reanalysis product. NRL partner John Kindle has provided the OSU investigators with NCOM-CCS model output for years 2000-2003, along with COAMPS forcing fields. NRL has work underway on implementing and evaluating a higher resolution (4 km) version of NCOM-CCS. When output from that model is available, it will be utilized for nesting a yet higher resolution CTZ-domain ROMS model. As a necessary part of the CTZ domain and evaluation

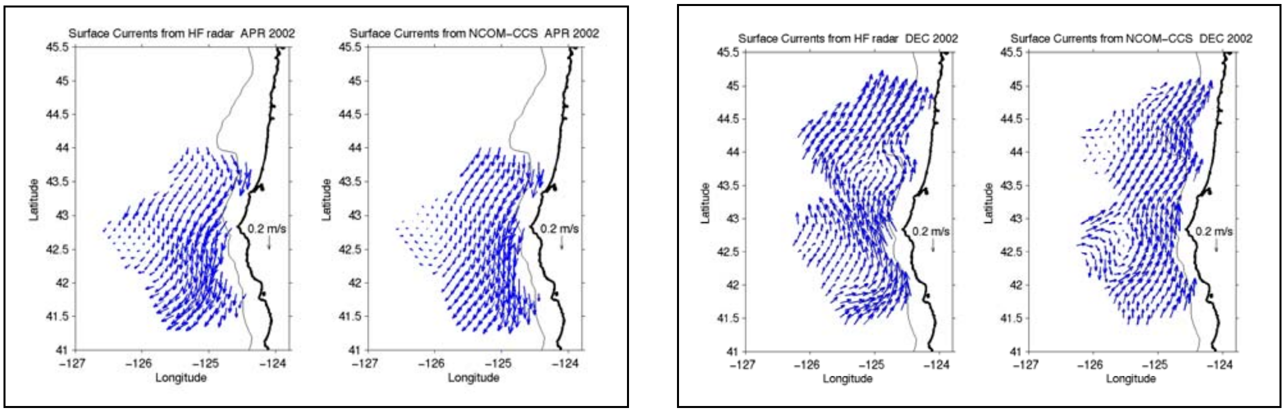

Figure 1: Mean surface horizontal velocity vectors off the southern Oregon coast during April 2002 (left pair of panels) and December 2002 (right pair of panels) from HF radar observations (left panel in each pair) and the NRL NCOM-CCS model (right panel in each pair).

procedure, the model results from both the NCOM-CCS and the CTZ-domain ROMS models will be compared with in-situ measurements from the COAST (Coastal Ocean Advances in Shelf Transport) 2001 and 2003 and GLOBEC/NEP (Global Ocean Ecosystem Dynamics/Northeast Pacific) 2000 and 2002 field experiments.

Model results from NCOM-CCS (9 km) for year 2002, together with the associated COAMPS wind stress forcing fields, have been compared with available satellite, HF radar, and in-situ measurements. In general, reasonable correspondence, for an outer domain regional model, has been found. For example, the monthly-mean surface currents from long-range HF radar measurements (provided by M. Kosro) for April and December 2002 are compared with corresponding values from NCOM-CCS in Figure 1. The presence of generally southward surface currents in April and northward currents in December is evident in the HF radar observations, with very similar qualitative behavior evident in the NCOM-CCS model results. Presumably, a higher-resolution CTZ model with data assimilation capabilities will result in improved quantitative agreement.

As the first step in the uncertainty and predictability studies, five-member ensembles of 30-day and 60-day ROMS simulations of wind-forced coastal ocean circulation in a periodic alongshore-channel version of the CTZ domain have been constructed, and preliminary analysis of the variability and associated dynamics has been completed.

RESULTS

A non-assimilating 3-km CTZ-domain ROMS model has been nested in NCOM-CCS (9 km) and successfully run for relatively long term (122-365 day) simulations during 2001 and 2002. Surface horizontal velocity vectors, together with sea surface temperature (SST) fields, and depth-integrated horizontal transport vectors, together with sea surface height (SSH) fields, from NCOM-CCS and from the CTZ-domain ROMS model for 8 August 2001 are shown in Figure 2. The capability of the CTZ ROMS model to represent smaller spatial scale eddies and coastal jet frontal deformations is clear.

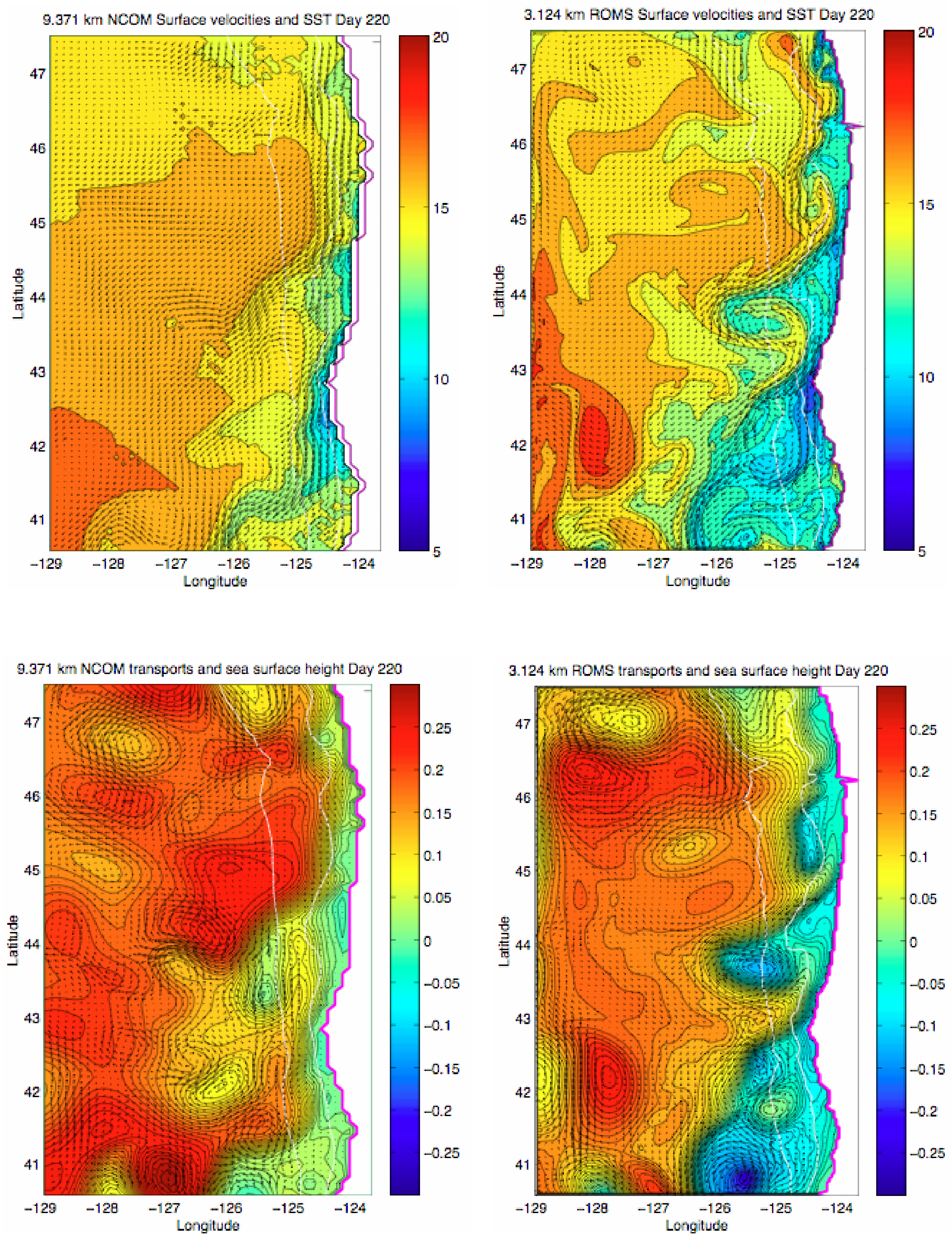

Figure 2: : Surface horizontal velocity vectors and SST (upper panels) and depth-integrated horizontal transports and SSH (lower panels) off the southern Oregon coast from day 220 of the NRL NCOM-CCS (left panels) and embedded ROMS (right panels) model simulations.

Model-data comparisons for these two simulations, and for others obtained with variations in the open boundary and initial conditions, initialization times, and nested model configurations are in progress.

The variability in the ensemble simulations is dominated by instabilities and topographic interactions of the coastal upwelling jet, and has a strongly anisotropic and inhomogeneous structure. The jet develops over the shelf during the first 30 days, with its influence extending farther offshore during the second 30 days. The volume integrated velocity variance grows roughly linearly with time throughout the 60 day simulations. The regions of large ensemble variance are correlated with the regions of energetic mean flow (Figure 3).

RELATED PROJECTS

The model results obtained in the project are being compared with in-situ measurements from the National Science Foundation Coastal Ocean Processes/Coastal Ocean Advances in Shelf Transport (CoOP/COAST; http://damp.coas.oregonstate.edu/coast/) and Global Ocean Ecosystem Dynamics/Northeast Pacific (GLOBEC/NEP; http://globec.coas.oregonstate.edu/) field experiments. The research in this NOPP project is being closely coordinated with work in the OSU component of the GLOBEC/NEP project 'US-GLOBEC/NEP Phase IIIa – CCS: Effects of Meso- and Basin-Scale Variability on Zooplankton Populations in the CCS Using Data-Assimilative, Physical/Ecosystem Models' and in the OSU ONR project 'Data Assimilation in Shelf Circulation Models.'

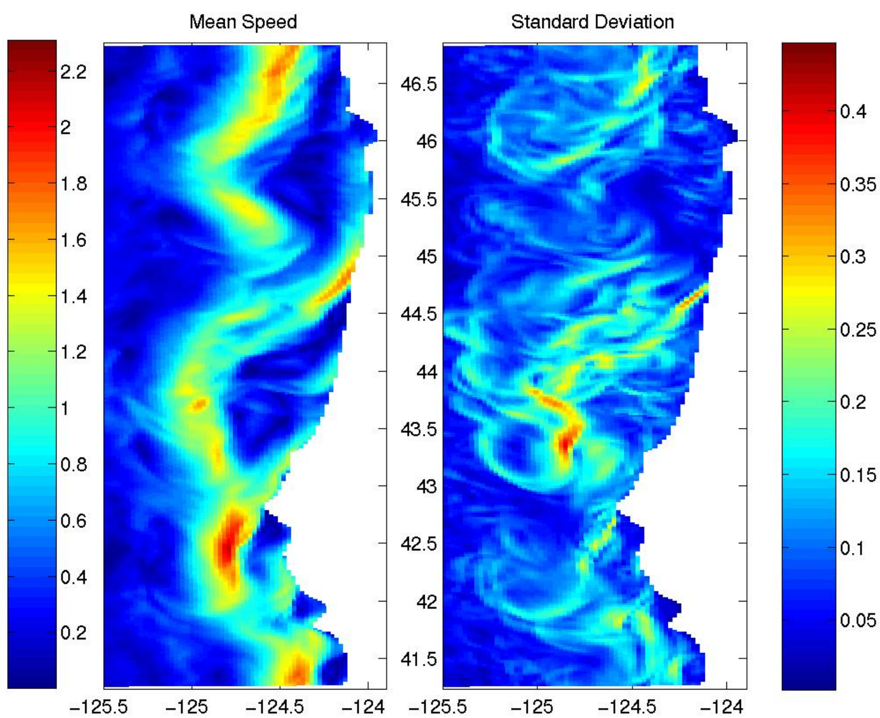

Figure 3: Speed of ensemble and time mean horizontal vector velocity (m s^{-1}, left panel) and standard deviation of velocity deviations (m s^{-1}, right panel) for a five-member ensemble of 60-day numerical simulations of wind-forced upwelling with perturbed initial conditions.