Development of a Monterey Bay Forecasting System Using the Regional Ocean Modeling System (ROMS)

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LONG-TERM GOALS

The long-term goal of Autonomous Ocean Sampling Network II (AOSN-II) is to build an adaptive coupled observation/modeling system. The system will use oceanographic models to assimilate data from a variety of platforms and sensors into synoptic views of oceanographic fields and fluxes. The system will adapt deployment of mobile assets to improve performance. Such a system will be useful for highly mobile and opportunistic deployments as well as for "fixed" efforts that need to be sustained over long periods.

Modeling is fundamental in these "observatory" efforts for the following reasons: 1) the ocean will always be undersampled; there is a need to synthesize the available field data and extrapolate it to a full 4-D real-time view, 2) we cannot go back in time to make additional measurements in an attempt to understand a set of observations; modeling can be used for retrospective studies, and 3) there is often a need to forecast into the future, for reasons of natural security or spills of hazardous material for example, and models have this forecasting capability.

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14. ABSTRACT
The long-term goal of Autonomous Ocean Sampling Network II (AOSN-II) is to build an adaptive coupled observation/modeling system. The system will use oceanographic models to assimilate data from a variety of platforms and sensors into synoptic views of oceanographic fields and fluxes. The system will adapt deployment of mobile assets to improve performance. Such a system will be useful for highly mobile and opportunistic deployments as well as for ???fixed??? efforts that need to be sustained over long periods.

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AOSN II plans a Monterey Bay field experiment during the summer of 2003. The strategy for AOSN II is to develop the system incrementally, coupling proof and test of the system to specific scientific objectives. The scientific focus of the 2003 AOSN experiment will be on the day-to-day physical and biological variability of an upwelling center off central California in relation to local atmospheric forcing and the general circulation of the California Current System.

OBJECTIVES

The objective of this proposal is to develop an operational Monterey Bay (MB) ocean forecasting system using a state-of-the-art Regional Ocean Modeling System (ROMS) coupling physical and biogeochemical processes. Given the short development period (less than a year), it is possible that the nascent ROMS operational forecasting system may not yet have the day-to-day accuracy required by AOSN-II. Nevertheless, our participation will greatly accelerate progress towards this capability, and we believe ROMS will provide unique contributions to AOSN-II with a different coupled physical-ecosystem model and a novel data assimilation method. A further contribution to AOSN-II will be our proposed interactive web portal for analyzing/visualizing observational data sets and ocean model output, which is a key requirement for any automated operational system like AOSN-II.

APPROACH

Our approach to accomplish the proposed objectives is to develop an end-to-end ocean forecasting system (see Figure 1).

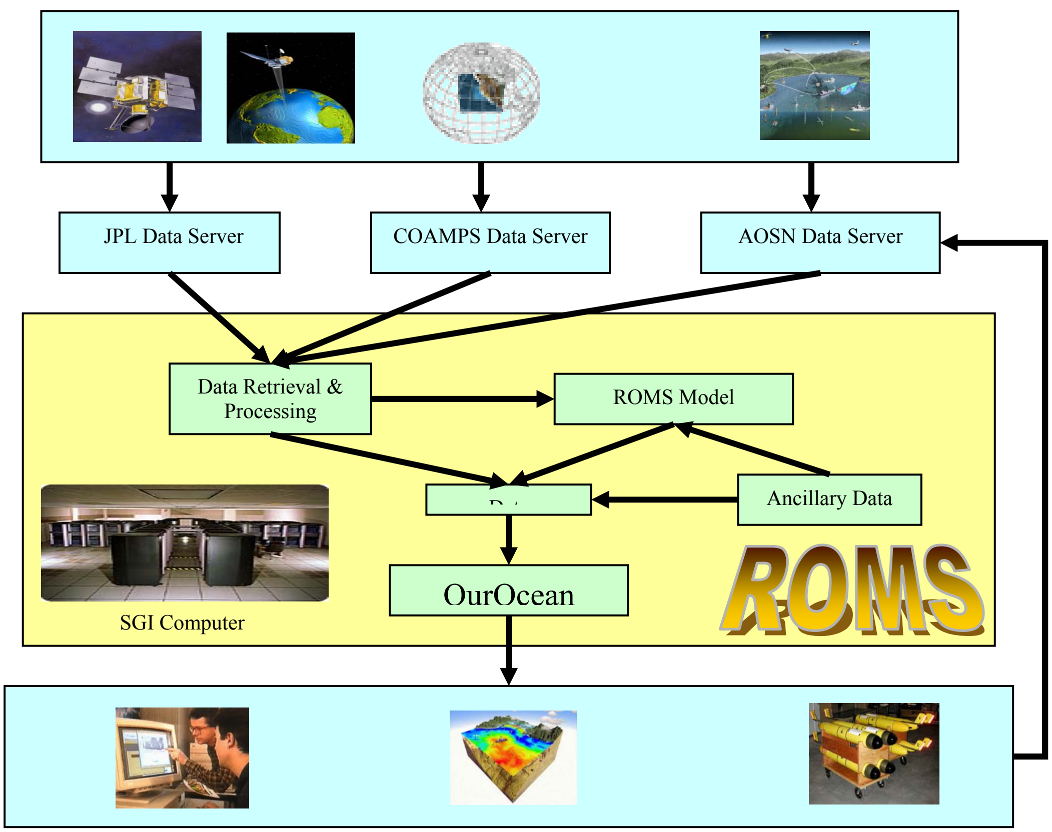

Figure. 1 A schematic diagram of the MB ROMS forecasting system.

WORK COMPLETED

Over the period of one year, we plan to develop the following essential components for the MB ROMS forecasting system:

- Real-time data processing, including both *in situ* and remote-sensing observations. Of particular interest is the real-time blended wind product of high-resolution mesoscale atmospheric model winds and satellite scatterometer observed winds.
- High-resolution modeling around the Monterey Bay including both physical and ecosystem components
- Assimilation of both *in situ* and remote-sensing data sets
- A web-based interface to visualize and analysis assimilated model output

RESULTS

Atmospheric Forcing Fields. We have developed a blended coastal wind product using high-resolution atmospheric models (http://www.nrlmry.navy.mil/projects/coamps/) and satellite scatterometers (http://winds.jpl.nasa.gov/). We have demonstrated this product off the coast of central California using the 9-km COAMPS (Coupled Ocean/Atmosphere Mesoscale Prediction System: Hodur, 1997) over a period of two years (1999 and 2000). The blending algorithm is based on a 2-dimensional variational method (Chao et al., 2003). The blending algorithm puts more (less) weight on QuikSCAT in the offshore (near-shore) region, and puts more (less) weight on COAMPS^{tm} in the near-shore (offshore) region, according to their error structures. When compared with independent in situ observations, the resulting optimal combination of QuikSCAT and COAMPS^{tm} consistently shows an increase in correlations and a reduction of RMS errors in both offshore and near-shore oceans.

Physical Modeling using ROMS. We have developed a hierarchy of ROMS (Shchepetkin and McWilliams, 2003) models with different domains and spatial resolutions. The boundary conditions from the smaller ROMS domain are obtained from the larger ROMS domain. In this proposal, we have implemented three ROMS domains: the U.S. West coastal ocean at 15-km resolutions, the central California coastal ocean at 5-km resolutions, and the Monterey Bay at 1.5-km resolutions. All three ROMS configurations have 20 vertical sigma layers. The 15-km, 5-km, and 1.5-km regional ROMS will be nested as a single system and run simultaneously exchanging boundary conditions at every time step of the parent grid.

ROMS is discretized on a structured grid, so local refinement can be performed via nested grids (i.e., fixed high-resolution local models embedded in larger coarse-grid models). The interactions between the two components are twofold: the lateral boundary conditions for the fine grid are supplied by the coarse-grid solution, while the latter is updated from the fine grid solution in the area covered by both grids (Blayo and Debreu, 1999). Long-term simulations have been made to obtain the equilibrium solution. The embedded solution shows no discontinuities at the nested domain boundary and a valid representation of the upwelling structure, at a CPU cost only slightly greater than for the inner region alone. The ROMS boundary condition has been documented in Marchesiello et al. (2001).

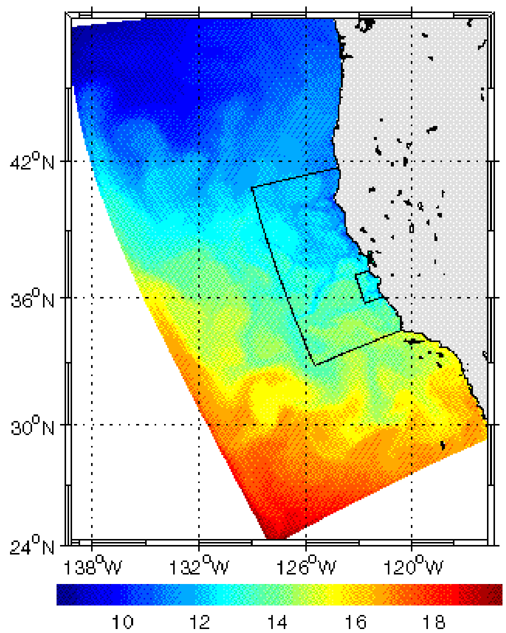

Figure 2. Sea surface temperature simulated by the 3-level nested model.

Ecosystem Modeling. Currently, the MB ROMS includes a ten-compartment ecosystem model developed by Chai et al. (2002). This model consists of ten compartments: two classes each of phytoplankton (P1, P2) and zooplankton (Z1, Z2), dissolved inorganic nitrogen in the form of nitrate (NO_3) and ammonium (NH_4), detritus nitrogen (DN), detritus silicate (DSi), and total CO_2. Nitrate and ammonium are treated as separate nutrients, thus dividing primary production into new production and regenerated production. Below the euphotic zone, sinking particular organic matter is transformed into inorganic nutrients by a two-step regenration process. Further development of this ecosystem model is an ongoing effort. We are in the process of implementing a second ecosystem model into ROMS. Ultimately, we will adopt the best choice of model configurations and parameters for our proposed operational modeling system in support of AOSN-II.

Data Assimilation using 3DVar. For the data assimilation, we have implemented a 3-dimensional variational (3DVar) data assimilation method into the operational ROMS forecast system. The 3DVar is selected because it can propagate observational information, which is often sporadically and irregularly distributed, in both horizontal and vertical directions. The major accomplishment of our 3DVar implementation in ROMS is the novel technique in estimating the error covariance. In our implementation, a 3-dimensional, seasonally dependent error covariance is developed. We have adopted the limited-memory quasi-Newton method (Li and Navon, 2000), which has been used at ECMWF.

Web-based data visualization and distribution. One of our unique contributions to AOSN-II is the interactive web interface developed for data visualization and distribution. The developed real-time wind products and ROMS output have been made available to the AOSN-II community through a web-based user interface. Our web server interface will be based on the Live Access Server (LAS) developed by NOAA (http://ferret.wrc.noaa.gov/Ferret/LAS/ferret_LAS.html). LAS is a highly configurable Web server designed to provide flexible access to geo-referenced scientific data.

IMPACT/APPLICATIONS

During the August 2003 AOSN-II field experiment, we have demonstrated the capability of MB ROMS in assimilating both *in situ* and remote-sensed observations and making near real-time (within 24 hours) 3-day forecast. We should be able to implement our developed MB ROMS forecasting system operationally in near real-time in the Monterey Bay. Ultimately, we would like to relocate our ROMS operational forecasting system to any part of the world ocean. The long-term goal is to develop an end-to-end, re-locatable ocean forecasting system. Such a re-locatable ocean forecasting system would be a powerful tool to design the adaptive sampling strategy and would be an essential component of the future AOSN experiments both within and outside the Monterey Bay.

RELATED PROJECTS

Our work described here is closely coordinated with two AOSN-II projects: "Adaptive Sampling during AOSN-II", PI: S.J. Majumdar, Award Number: N00014-03-0559

"Implementing FORMS (Feature oriented regional modeling system) for the Monterey Bay forecasting system using HOPS and ROMS", PI: A. Gangopadhyay, Award Number: N00014-1-0206

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