The data assimilation component of the real-time coastal ocean forecast system implemented off Oregon (US West coast)

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The real-time coastal ocean circulation forecast model has been developed and implemented off Oregon (the US West Coast). It has provided daily updates of 3-day forecasts of surface currents, SST, and other oceanic variables of interest. The forecast model is based on the Regional Ocean Modeling System (www.myroms.org), a three-dimensional, free-surface, fully nonlinear model featuring terrain-following coordinates, a comprehensive sub-grid turbulence parameterization scheme and advanced numerical algorithms (Shchepetkin and McWilliams, 2005). Our model domain is approximately 400×800 km (Figure 1). The forecasts are obtained at the 3-km horizontal resolution.

To improve quality of predictions, the system assimilates observations of SSH (alongtrack altimetry), hourly SST from the geostationary GEOS satellite, and surface currents from a network of high-frequency (HF) radars installed along the Oregon coast (Kosro, OSU). Assimilation proceeds using the variational representer-based method (Kurapov et al., 2011, Yu et al., 2012). To implement the variational algorithm, we have developed and utilized our own tangent linear (TL) and adjoint (ADJ) codes AVRORA (the Advanced Variational Regional Ocean Representer Analyzer). These are stand-alone codes that numerically and dynamically consistent with ROMS. Using AVRORA, instead of the TL&ADJ components embedded in ROMS, gives us greater flexibility incorporating new data types and designing the most appropriate model error covariance formulations. The AVRORA codes can be utilized not only with ROMS, but also with other forecast models. In our ongoing research, in collaboration with Dr. P. Oke (CSIRO), we are using AVRORA to provide improved initial conditions for the SHOC model, implemented along Australian coastal regions.

Variational assimilation is performed in a specified finite-length time window, in which dynamically consistent time- and space-interpolation of sparse data sets is obtained. In our forecast system, assimilation proceeds in a series of 3-day time windows (Figure 2). On the assimilation day, data for the previous 3 days are collected. The correction to the initial conditions at the beginning of the assimilation window is obtained iteratively. At each iteration, the ADJ and TL models are run once. With effective preconditioning, about 20 iterations are needed to find the optimum correction to the initial conditions, satisfying a specific optimization criterion. After the correction to the initial conditions (and in general forcing) is obtained, the ROMS is run for a period of 6 days,
providing the 3-day analysis (improved solution in the given assimilation window) and 3-day forecast. The forecast becomes the background solution for linearization in the next window.

4DVAR = dynamically based time- and space- interpolation of data

At every iteration step, the result of the ADJ model is convolved with the initial condition error covariance, which provides smoothing of the adjoint sensitivity field and may also introduce dynamical constraints in the correction. We have used the covariance based on the balance operator (Weaver et al., 2005), with modifications for the shallow water case (see Kurapov et al., 2011). Using this approach, the corrections to velocities, temperature, salinity, and SSH are in approximate balance (including geostrophic and thermal wind balances, as well as the linear T-S relation and the equation of state).

Our forecast fields have been distributed to the public via the visualization system of the regional ocean observing system association (www.nanoos.org). They have been popular among the local fishermen who used the forecasts to help planning their trips. In addition, the forecast fields have been provided via the OpenDAP server to our colleagues at the National Oceanic and Atmospheric Agency (NOAA) laboratory in charge of oil spill and other environmental hazard responses. In particular, they have been using our forecasts to track large pieces of marine debris originating from the 2011 Japanese tsunami and approaching Oregon and Washington coasts.

Our ongoing efforts include development of the model in the extended domain (41-50N), in which the Columbia River fresh water discharge is included. The Columbia River buoyant plume influences near-surface velocity and SST fields. Inclusion of the Columbia River makes

Figure 2. Assimilation using the variational algorithm proceeds in a series of 3-day time windows. In each window, observations of SST (hourly GOES), SSH (along-track altimetry), and surface currents from the HF radars are assimilated. The optimization problem minimizes a data functional, finding improved initial conditions for the model analysis and forecast.
the model more consistent with observations and may potentially improve the impact of assimilated data on forecasts. In winter, the Columbia River waters are deflected to the north. The velocity associated with the plume can be as large as 30 cm/s along the plume edge. The plume waters are colder than the ambient ocean in winter. In summer, the dynamics in our area are dominated by wind-driven upwelling, with the plume deflected toward south and offshore. The presence of the plume over the continental slope influences upwelling of near-bottom waters on the shelf, resulting in stronger cross-shore density gradients and near-surface currents.

Assimilation in presence of the river plume presents challenges. In particular, we may need to provide a new error covariance, which accounts for anomalous T-S properties in the thin near-surface layer associated with the buoyant plume. Such a covariance may include the modified T-S relation. Alternatively, the covariance may be built using an ensemble of ocean forecasts.

References.


