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Real-Time Modeling, Data Assimilation and Forecasting off the California Coast

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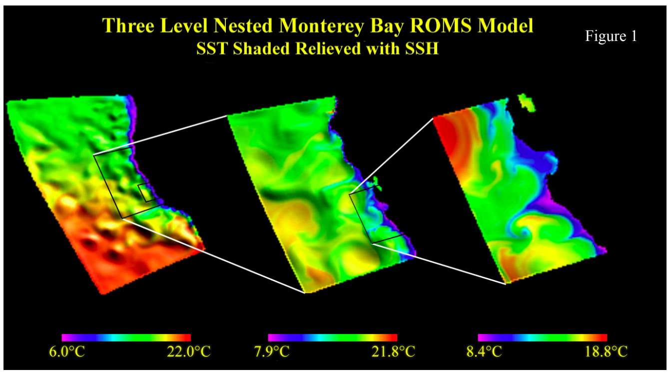
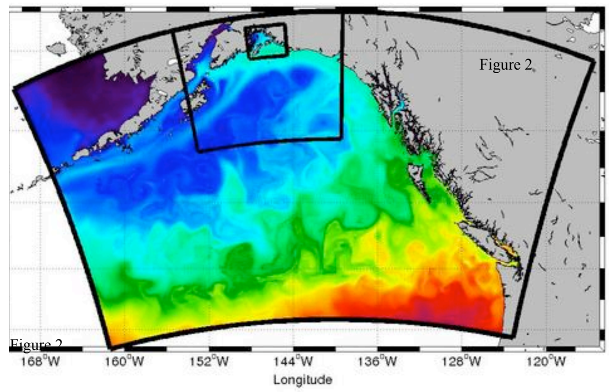
Real-Time Ocean Forecasting

Motivated by the success of weather forecast and the emerging needs of regional forecast on both weather and climate scales, the JPL OurOcean team has been collaborating with the UCLA ROMS group led by Prof. Jim McWilliams to develop an end-to-end real-time ocean modeling, data assimilation and forecasting system. The developed forecasting system has been tested in several field experiments including the 2003 AOSN (Autonomous Sampling Ocean Network) and the 2006 ASAP (Adaptive Sampling and Prediction) in the Monterey Bay, California, and the 2009 Prince William Sound field experiment in Alaska. Today, we are operating this real-time ocean forecasting system in several areas off the US west coast.



Regional Ocean Modeling System (ROMS)

The ocean forecasting system is based on the Regional Ocean Modeling System (ROMS), a community model for regional applications (see http://www.myroms.org & http://www.atmos.ucla.edu/cesr/ROMS_page.html for more descriptions). The ROMS configuration consists of multi-level nested domains with increasing spatial resolutions. For example, the Monterey Bay ROMS configuration covers the U.S. West coast, central California coast, and Monterey Bay at 15-km, 5-km and 1.6-km, respectively (Figure 1). The Prince William Sound ROMS also has three nested domains with 9-km, 3-km, and 1-km resolutions (Figure 2).



Multi-Scale 3-Dimensional Variational Data Assimilation

Both in situ and satellite measurements that are available in real-time are assimilated into ROMS using the multi-scale 3-dimensional variational (MS-3DVAR) data assimilation scheme (Figure 3). An incremental 3DVAR data assimilation scheme is implemented in ROMS using an assimilation window of six hours. The ROMS nowcast (also known as analysis) is issued every six hours at 03, 09, 15, and 21 GMT hours. The first guess is first obtained from the 6-hour forecast starting from the ROMS nowcast six hours before. During this six-hour data assimilation window, all the available data (e.g., Satellite SST, HF radar surface current, vertical profiles of temperature and salinity from moorings and gliders) are assimilated. The data assimilation produces a data correction term that corresponds to the minimal model and data misfit averaged over the entire model domain. The ROMS nowcast is simply the addition of the first guess and data correction. A 48-hour or 72-hour forecast is issued daily depending upon the availability of the atmospheric forecast.

$$x = \begin{pmatrix}\varsigma\\ u\\ v\\ T\\ S\end{pmatrix} = \begin{pmatrix}x_\varsigma\\ x_{uv}\\ x_{TS}\end{pmatrix} = \begin{pmatrix} x_\varsigma^f + \Pi\delta x_{TS} + \delta x_{a\varsigma}\\ x_{uv}^f + \Gamma\delta x_{TS} + \Phi_a \delta x_{a\psi\chi}\\ x_{TS}^f + \delta x_{TS}\end{pmatrix}$$

$\delta x_{uv}^G = \Gamma \delta x_{TS}$ Geostrophic balance

$\delta x_\varsigma^S = \Pi \delta x_{TS}$ Hydrostatic equation

MS-3DVAR Implementation

There are five control variables: temperature *δT*, Salinity, *δS*, non-steric SSH, $\delta X_{a\zeta}$, ageostrophic streamfunction, $\delta X_{a\psi}$, ageostrophic velocity potential, $\delta X_{a\chi}$. The geostrophic & hydrostatic balance equations are applied to the corrected temperature and salinity profiles. Streamfunction and velocity potential are used to avoid direct use of vector velocity.

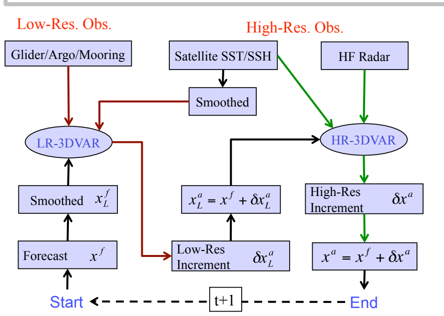


Figure 3. A schematic diagram of the MS-3DVAR data assimilation.

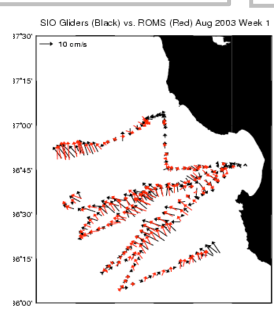


Figure 4. Vertically averaged current current derived from glider and ROMS.

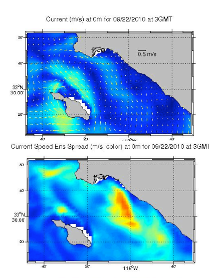


Figure 5. 72-hour ensemble forecast mean current & spread.

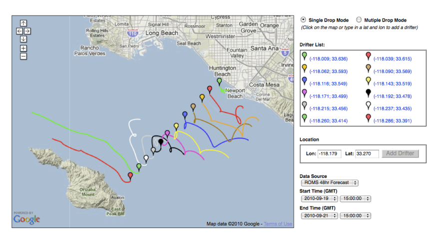


Figure 6. Web-based interactive trajectory tool for decision making.

Summary

✓ The ROMS MS-3DVAR data assimilation system has the ability to assimilate both in situ (vertical profiles of temperature and salinity from ships, moorings, profiling floats, gliders) and remote sensed (satellite SST and land-based HF radar) observations.

✓ Independent observations (e.g., glider derived current as shown in Figure 4) are used to validate ROMS analysis.

✓ With slightly different initial conditions, atmospheric forcing and lateral boundary conditions, ensemble model forecasts (with typically 20 members) are made to estimating forecast errors (Figure 5)

✓ Model derived tools (e.g., drifter trajectory in Figure 6) and products are being developed for application users for real-time decision making.

✓ The ROMS MS-3DVAR forecast system is running in 24/7 real-time off the southern California bight (http://ourocean.jpl.nasa.gov/SCB), Monterey Bay (http://ourocean.jpl.nasa.gov/MB), and Prince William Sound (http://ourocean.jpl.nasa.gov/PWS).

Publications relevant to this poster

(1) Chao, Y., et al., Development, implementation and evaluation of a data-assimilative ocean forecasting system off the central California coast. *Deep-Sea Research II*, 56, 100-126, 2009. (2) Wang, X., Y. Chao, et al., Modeling tides in Monterey Bay, California. *Deep-Sea Research II*, 56, 219-231, 2009. (3) Li, Z., Y. Chao, J.C. McWilliams, and K. Ide: A Three-Dimensional Variational Data Assimilation Scheme for the Regional Ocean Modeling System. *Journal of Atmospheric and Oceanic Technology*, 25, 2074-2090, 2009. (4) Chao, Yi, Zhijin Li, John D. Farrara, et al., Synergistic applications of autonomous underwater vehicles and the regional ocean modeling system in coastal ocean forecasting. *Limnology and Oceanography*, 53, 2251-2263, 2008. (5) Li, Z., Y. Chao, J. C. McWilliams, and K. Ide: A three-dimensional variational data assimilation scheme for the Regional Ocean Modeling System: Implementation and basic experiments. *Journal of Geophysical Research (Oceans)*, 113, C05002, 2008. (6) Li Z., Yi Chao, and J.C. McWilliams, Computation of the Streamfunction and Velocity Potential for Limited and Irregular Domains, *Monthly Weather Review*, 134, 3384-3394, 2006.