Operational Ocean Data Assimilation with Global HYCOM

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A three-dimensional variational ocean data assimilation system has been developed that produces simultaneous analyses of temperature, salinity, and vector velocity. The system is referred to as NCODA (Navy Coupled Ocean Data Assimilation). NCODA 3DVAR is the data assimilation component of the real-time, global, 1/12° resolution HYbrid Coordinate Ocean Model (HYCOM) forecast system operational at the U.S. Naval Oceanographic Office [1]. It makes full use of all sources of the operational ocean observations (both *in situ* and remotely sensed). Observations are assimilated at their measurement times using the first guess appropriate time (FGAT) method. Hourly forecast fields are used in FGAT for surface data types, while daily averaged fields are used at depth to assimilate late receipt profile and altimeter sea level anomaly (SLA) observations (observations received at the center later than the 24-hour update cycle interval).

NCODA is a unified and flexible oceanographic analysis system. The adjoint of the 3DVAR is available and is routinely used to estimate the impact of observations assimilated on reducing HYCOM model forecast error [2]. Satellite sea surface temperature (SST) radiances are directly assimilated using forward and inverse modeling based on radiative transfer. SST radiance assimilation is a true example of coupled data assimilation where observations in one fluid (top-of-the-atmosphere radiances) create innovations in the other fluid (ocean SST). Adaptive data thinning of the high-density satellite SST observations is performed using a water mass classification scheme and covariance length scales that vary with location. This approach maintains adequate data density in dynamic ocean regions while removing data redundancy and reducing correlated errors elsewhere. NCODA performs data consistency checks within the minimization algorithm itself as a form of internal data quality control. Work is underway to assimilate SLA as geostrophic velocity observations estimated from the dynamically important along track slopes of the altimeter data. This method avoids the non-trivial problem of specifying a mean dynamic topography matching that contained in the altimeter data. NCODA has components for computing analysis error covariance and the ensemble transform for generating perturbed ensemble initial conditions. A prototype NCODA 3DVAR-hybrid has been developed that uses ensemble-based covariances to augment the existing multivariate background error covariances. Optimum values for weighting the ensemble and multivariate covariances in the hybrid are determined from a time history of model-data misfits and ensemble variances.

In this presentation development and evaluation of the NCODA 3DVAR data assimilation system is described. Special emphasis is placed on documenting the new capabilities listed above (adjoint-based data impacts; SST radiance assimilation; altimeter velocity assimilation; 3DVAR-hybrid) in the global system.

[1] Cummings, J. and O.M. Smedstad. Variational Data Assimilation for the Global Ocean. In, *Data Assimilation for Atmospheric, Oceanic & Hydrologic Applications (Vol. II)*. S. Park and L. Xu (eds). Springer, pp. 303-343, 2013.
[2] Langland, R. and N. Baker. Estimation of observation impact using the NRL atmospheric variational data assimilation adjoint system. *Tellus* 56A:189-201, 2004.