Assimilation of science-quality ocean color products from Visible Infrared Imager Radiometer Suite (VIIRS) into HYbrid Coordinate Ocean Model (HYCOM)

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Recent advances in biogeochemical (BGC) models and data collection programs with greater spatio-temporal coverage make it possible "to predict and assess trends of marine biogeochemical cycles and to safeguard marine ecosystems" [1]. Implementation of various data assimilation (DA) schemes for the National Center for Environmental Prediction (NCEP) operational Real-Time Ocean Forecast System (RTOFS-Global), along with data streams of real-time/near-real-time physical, biological, and chemical data allow the analysis and forecasting of global BGC states. The main motivation of this study, funded by Joint Polar Satellite System (JPSS) - Proving Ground and Risk Reduction (PGRR) Program at NOAA's National Environmental Satellite, Data, and Information Service (NESDIS), is to demonstrate how various satellite ocean color products can be used in a global ocean modeling framework.

This study presents preliminary results from a series of numerical experiments run for a Gulf of Mexico testbed, exploring combinations from: 1) science-quality ocean color products from the Visible Infrared Imager Radiometer Suite (VIIRS) on the Joint Polar Satellite System (JPSS); 2) the HYbrid Coordinate Ocean Model (HYCOM), the ocean modeling component of the RTOFS; 3) a 3-component Nutrient-Phytoplankton-Zooplankton (NPZ) model [2]; and 4) the NOAA version of the Navy Coupled Ocean Data Assimilation (NCODA) system [3]. Within the context of NOAA's on-going Ecological Forecasting Roadmap (EFR) efforts, we examine the suitability, at short- to mid-range time scales, of the proposed approaches for building biogeochemical data assimilation capabilities into the current operational system.

The global HYCOM (GLBb0.08 hereafter), with recti-linear coordinates (66°S – 47°N) and an Arctic bipolar patch (>47°N), is used. This HYCOM has 1/12-th degree horizontal resolution and vertical coordinates employing 41 layers, following isopycnals in the deep sea, z-levels near the surface, and terrain-following σ-coordinates near coastal areas [4]. K-Profile Parameterization (KPP) [5] is used as the vertical mixing scheme. GLBb0.08 is forced by hourly atmospheric fluxes from NOAA's Global Data Assimilation System (GDAS). For this effort, the Gulf of Mexico (GOMl0.04) is selected as the testbed for various DA numerical experiments. GOMl0.04 has 1/25-th degree horizontal resolution and vertical coordinates with 36 layers following isopycnals. For a realistic initialization, the physical state variables are initialized with the previous run of RTOFS-Global, with the initial conditions for the BGC variables (NPZ concentrations) being obtained from the Hadley Ocean Carbon Cycle Model (HadOCC) [6].

The NCODA system is an oceanographic implementation of the three-dimensional variational (3DVAR) technique. NCODA 3DVAR, a unified and flexible oceanographic analysis system (Figure 1), is transitioning to NCEP for operational use as the data assimilation component for RTOFS-Global. The analysis variables include temperature, salinity, geopotential (dynamic height), *u*, *v* vector velocity components, and chlorophyll concentration from ocean color products. All ocean variables are analyzed simultaneously in three dimensions. The horizontal correlations are multivariate in geopotential and velocity, thereby permitting adjustments to the mass fields to be correlated with adjustments to the flow fields.

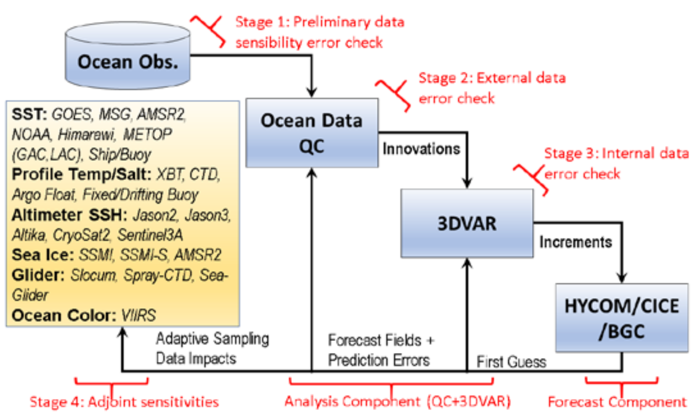

Figure 1. A schematic diagram of ocean data assimilation in the NCODA system. Note that oceanographic and satellite data products are available as of 2018.

The velocity adjustments (or increments) are in geostrophic balance with the geopotential increments, which, in turn, are in hydrostatic agreement with the temperature and salinity increments. The chlorophyll assimilation is used to constrain the BGC properties of the ocean in the NPZ model. Two experiments are made: 1) a free mode with no data assimilation; and 2) a data-assimilative mode. For data assimilation, only physical oceanographic data from various platforms (e.g., satellite sea-surface height anomalies, satellite sea-surface temperatures, temperature and salinity profiles, etc) were assimilated. All simulations were initialized at February 1, 2017, with, as previously mentioned, physical state variables being restarted with RTOFS-Global simulations and BGC state variables being initialized with HadOCC model output. The simulation period is 20 days. Figure 2 presents examples of sea surface height (SSH), nitrate (NO_3^-), and phytoplankton concentration for the free and data assimilative modes 10 days after initialization. It is noteworthy that the SSH structure becomes slightly different between the two simulations, which is also true for the BGC tracers. There are subtle discrepancies in the distributions of nitrate and phytoplankton, presumably due to changes in mesoscale eddy features. More investigation is required.

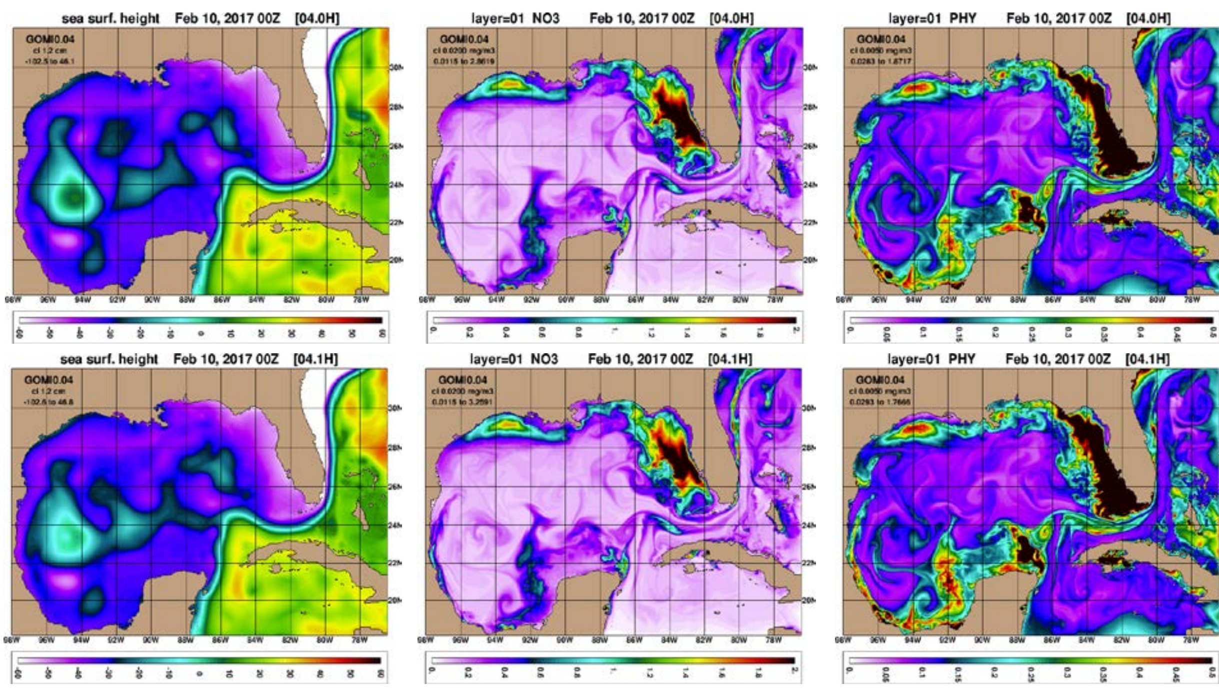

Figure 2. Comparisons between free (top) and data-assimilative runs (bottom) for sea surface height (1st column), nitrate nitrogen (2nd column), and phytoplankton nitrogen (3rd column).

[1] Brasseur, P., N. Gruber, R. Barciela, K. Brander, M. Doron, A. El Moussaoui, A.J. Hobday, M. Huret, A.-S. Kremeur, P. Lehodey, R. Matear, C. Moulin, R. Murtugudde, I. Senina, and E. Svendsen., 2009. Integrating biogeochemistry and ecology into ocean data assimilation systems. Oceanography 22(3):206–215, http://dx.doi.org/10.5670/oceanog.2009.80.

[2] Franks, P.J.S. , J.S. Wroblewski, and G.R. Flierl, 1986. Behavior of a simple plankton model with food level accumulation by herbivores. Mar. Biol. 91, 121–129.

[3] Cummings, J.A. and O.M. Smedstad, 2013. Variational data assimilation for the global ocean. In: S.K. Park and L. Xu (Eds.), Data Assimilation for Atmospheric, Oceanic and Hydrologic Applications Vol. II., doi: 10.1007/978-3-642-35088-7_13, Springer-Verlag, Berlin Heidelberg.

[4] Bleck, R., 2002: An oceanic general circulation model framed in hybrid isopycnic-Cartesian coordinates, Ocean Model., 37, 55-88.

[5] Large, W.C., J.C. McWilliams and S.C. Doney, 1994: Oceanic vertical ixing: a review and a model wit a nonlocal boundary layer parameterization. Rev. Geophys. 32, 363-403.

[6] Ford, D.A., K.P. Edwards, D. Lea, R.M. Barciela, M.J. Martin, and J. Demaria, 2012. Assimilating GlobColour ocean colour into a pre-operational physica-biogeochemical model. Ocean Sci. 8, 751-771.