Comparisons of Two Biogeochemical Models Embedded in HYbrid Coordinate Ocean Model (HYCOM) Based Global Ocean Circulation Model

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The NOAA Ecological Forecasting Roadmap (EFR) for 2015-2019 states that its objective is "to provide dependable, higher quality forecast products, derived from the successful transition of research and development into useful applications…." In support of this NOAA-approved roadmap, this project proposes to evaluate different approaches to develop a prototype foundational global biogeochemical model within NOAA's global operational Real-Time Ocean Forecast System (RTOFS-Global) [1] to reliably provide the global modeling fields required to support ecological forecasts designed by EFR technical teams in a modular and expandable fashion. In particular, the objective is to establish a component for the national ocean modeling 'backbone' that will generate global predictions of physical and biogeochemical (BGC) variables of interest in ecological assessments (e.g., temperature, nutrients phytoplankton, oxygen, carbon and Chl-a) on a regional scale, which would enable regional applications to include the broader global context (forcings and fluxes) in their local/regional use.

In this study, using combinations of 1) the HYbrid Coordinate Ocean Model (HYCOM), ocean modeling component of the RTOFS-Global and 2) a multi-component BGC model [2][3], we present preliminary results from a series of numerical experiments run for the global domain. Within the context of NOAA's on-going Ecological Forecasting Roadmap (EFR) efforts, we are also considering 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 HYbrid Coordinate Ocean Model (HYCOM; GLBb0.08 hereafter) with cylindrical (78.64°S – 66°S); recti-linear coordinate (66°S – 47°N); and an Arctic bipolar patch (>47°N) is used. HYCOM has 1/12-th degree horizontal resolution and 41 vertical coordinates employing hybrid layers following isopycnals in the deep sea, z-levels near the surface and terrain-following σ-coordinates in the coastal areas [4]. K-Profile Parameterization (KPP) [5] is used as a vertical mixing scheme. GLBb0.08 is forced by hourly atmospheric fluxes from NOAA's Global Data Assimilation System (GDAS).

Two experiments are configured with different minimal complexity in biogeochemical governing equations: 1) the Nutrient-Phytoplankton-Zooplankton (NPZ) model [2]; and 2) the Nutrient-Phytoplankton-Zooplankton-Detritus (NPZD) model [3]. Figure 1 presents schematic diagrams of the two different BGC models. The major difference between the two includes the number of state equations that can simulate low-trophic level BGC components. The NPZD model includes detritus to more realistically parameterize cycling of organic particulate matter back to the dissolved inorganic nutrients' pool. In general, due to their small number of state variables, simple models such as NPZ or NPZD have advantages in parameterization, initialization and validation of the internal ecosystem dynamics with standard and commonly available biogeochemical oceanographic measurements (e.g., chlorophyll, nutrients, zooplankton biomass). This reduces uncertainties and computational costs significantly compared to other available complex models. However, even with the small number of state variables, the parameterization and validation of marine ecological processes sometimes remain challenging if

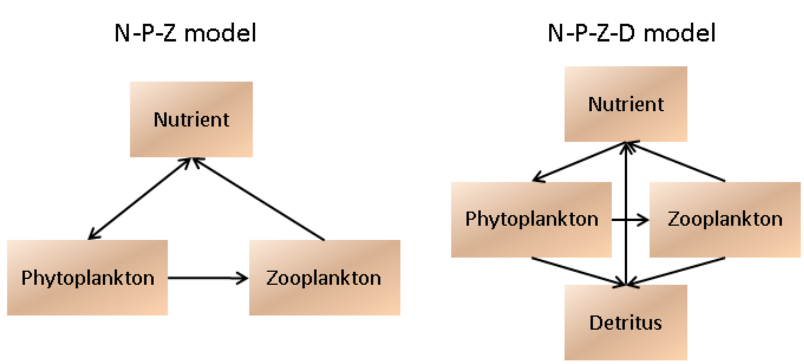

Figure 1. Schematic diagrams of the N-P-Z model (left) and N-P-Z-D model (right).

observations are sparse and incomplete. In addition, the simple models also have limitations in representing complicated ecosystem structure and functions of the real ocean that require additional measurements or experiments. This may render them less realistic, but overall, simple models are still sufficient to simulate a wide range of ecosystem phenomena.

All simulations presented here were initialized at February 1, 2017 with the HadOCC monthly mean. Model initialization for physical variables is based on the previous runs from RTOFS-Global and initial conditions for the BGC variables (e.g., lower trophic level components) are obtained from the Hadley Ocean Carbon Cycle Model (HadOCC) [6] for a realistic initialization. The simulation period is 20 days. Figure 2 presents examples of sea surface height (SSH), nitrate (NO_3^-) and phytoplankton concentration for the two numerical experiments. As tracers are not designed to influence physical properties, sea surface height (SSH) structure is identical between the two model simulations, whereas there is a noticeable discrepancy in the distribution of nitrate and phytoplankton, presumably due to varying ecosystem dynamics between the two models. Further investigations are planned for the future.

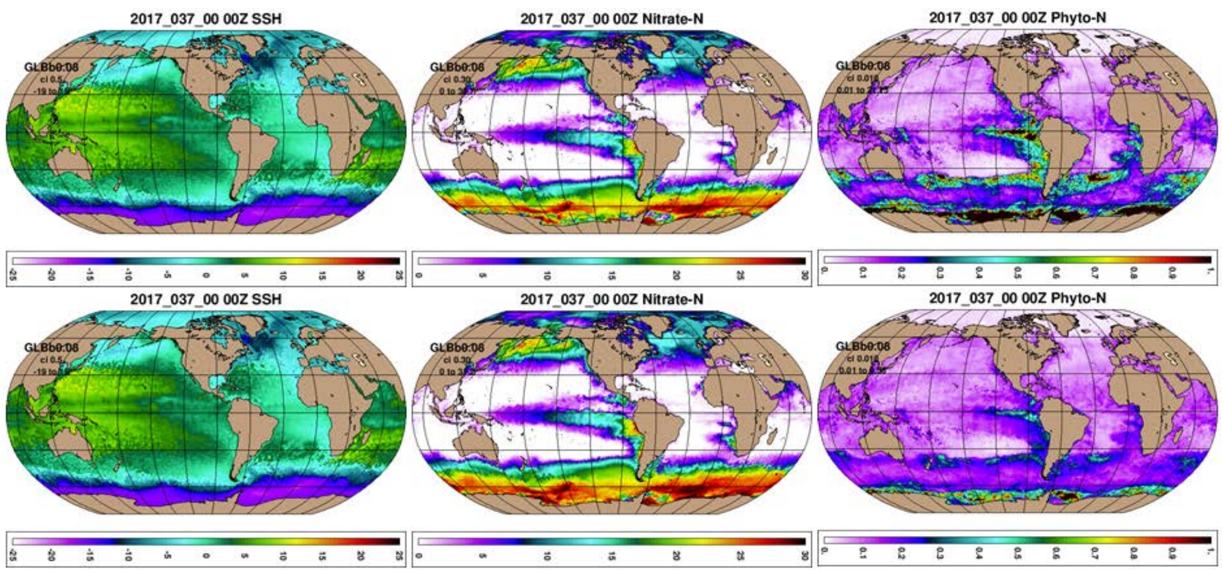

Figure 2. Comparisons between NPZ (top) and NPZD model (bottom) for sea surface height (1st column), nitrate nitrogen (2nd column), and phytoplankton nitrogen (3rd column). These snapshots are taken at 5 days (February 5, 2017) after model initialization.

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