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Reduced-Order Biogeochemical Flux Model for High-Resolution Multi-Scale Biophysical Simulations

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Biogeochemical tracers and their interactions with upper ocean physical processes such as submesoscale circulations and small-scale turbulence are critical for understanding the role of the ocean in the global carbon cycle. These interactions can cause small-scale spatial and temporal heterogeneity in tracer distributions that can, in turn, greatly affect carbon exchange rates between the atmosphere and interior ocean. For this reason, it is important to take into account small-scale biophysical interactions when modeling the global carbon cycle. However, explicitly resolving these interactions in an earth system model (ESM) is currently infeasible due to the enormous associated computational cost. As a result, understanding and subsequently parameterizing how these small-scale heterogeneous distributions develop and how they relate to larger resolved scales is critical for obtaining improved predictions of carbon exchange rates in ESMs.

In order to address this need, we have developed the reduced-order, 17 state variable Biogeochemical Flux Model (BFM-17) that follows the chemical functional group approach, which allows for non-Redfield stoichiometric ratios and the exchange of matter through units of carbon, nitrate, and phosphate. This model captures the behavior of open-ocean biogeochemical systems without substantially increasing computational cost, thus allowing the model to be combined with computationally-intensive, fully three-dimensional, non-hydrostatic large eddy simulations (LES). In this talk, we couple BFM-17 with the Princeton Ocean Model and show good agreement between predicted monthly-averaged results and Bermuda testbed area field data (including the Bermuda-Atlantic Time-series Study and Bermuda Testbed Mooring). Through these tests, we demonstrate the capability of BFM-17 to accurately model open-ocean biochemistry. Additionally, we discuss the use of BFM-17 within a multi-scale LES framework and outline how this will further our understanding of turbulent biophysical interactions in the upper ocean.