

**FINAL TECHNICAL REPORT DOE AWARD DE-SC0007206 Improving CESM
Efficiency to Study Variable C:N:P Stoichiometry in the Oceans
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The grant supported modeling, and data analysis research to improve the representation of biogeochemical cycles in the Community Earth System Model.

Publications [1] and [2] demonstrated that there are coherent large-scale patterns of C:N:P variability in suspended particles in the ocean. Publication [3] used an inverse-modeling approach combined with hydrographic tracer data to demonstrate that there are large-scale patterns in the C:P ratio of exported organic matter and that these patterns are consistent with patterns observed in suspended particles. This research demonstrated the importance of including variable stoichiometry in the marine biogeochemical component of CESM and provided the essential data needed to calibrate the model.

The grant supported the Ph.D. thesis of Ann Bardin [4], which developed a fast implicit tracer solver for CESM-POP2 the ocean component of CESM. The thesis led to publication [4] in which the implicit solver was used to simulate natural radiocarbon and demonstrate the existence of large biases in the model. Publications [6 and 7] used the fast solver calibrate an improved representation of the cycling of dissolved organic matter cycling in CESM that includes variable C:N:P stoichiometry and to explore the sensitivity of the changes to marine biogeochemical cycles.

A technical report [8] on the steps needed to construct tracer transport matrices for CESM-POP2 was prepared.

Two manuscripts supported from this grant are in preparation and will be submitted in the coming months. Manuscript [9] evaluates the errors obtained from using offline tracer transport matrices instead of using the full online POP2 model to spin-up tracers. The results show that for some applications annual average operators, which are computationally much cheaper, are sufficient. It also shows that with a 5-day resolution offline matrices yield extremely small errors when computing ideal age. Manuscript [10] uses the offline matrix transport operator to simulate idealized tracers for tracking the lateral transport of nutrients that sustains ocean productivity in the gyres.

The grant also supported the construction of a fast offline marine phosphorus cycling model. This model was still under construction at the end of the award. It's development continues with support from a new grant.

Publications:

- [1] Martiny, A.C., C.T.A. Pham, F.W. Primeau, J.A. Vrugt, J.K. Moore, S.A. Levin, and M.W. Lomas 2013: Strong latitudinal patterns in the elemental ratios of marine plankton and organic matter. *Nature Geoscience*, **6**, 279-283.
- [2] Martiny, A.C., J. A. Vrugt, F. W. Primeau, and M. W. Lomas 2013: Regional variation in the particulate organic carbon to nitrogen ratio in the surface ocean. *Global Biogeochemical Cycles*, **27**, 723-731, doi:10.1002/gbc.20061.
- [3] Teng, Y.-C., F.W. Primeau, J.K. Moore, M. W. Lomas, and A.C. Martiny 2014: Global-scale variations of the ratios of carbon to phosphorus in exported marine organic matter. *Nature Geoscience*, **7**, 895-898.
- [4] Bardin, A., 2014: Novel Analysis Tools for Ocean Biogeochemical Models. PhD. Dissertation, Department of Earth System Science, University of California, Irvine
- [5] Bardin, A., F. Primeau, and Keith Lindsay 2014: An offline implicit solver for simulating prebomb radiocarbon. *Ocean Modelling* **73**, 45-58
- [6] Letscher, R. T., J.K. Moore, Y.-C. Teng, and F. Primeau 2015: Variable C:N:P stoichiometry of dissolved organic matter cycling in the Community Earth System Model. *Biogeosciences*, **12**, 209-221.
- [7] Letscher, R, and J. K. Moore, 2014: Preferential remineralization of dissolved organic phosphorus and non-Redfield DOM dynamics in the global ocean: Impacts on marine productivity, nitrogen fixation, and carbon export. *Global Biogeochemical Cycles*, 10.1002/2014GB004904.
- [8] Bardin, A., 2015: Building Offline Transport Operators for CESM POP version 1.2. *University of California, Irvine, Earth System Science Technical Report*.
- [9] Bardin, Ann, F. Primeau, and Keith Lindsay, Evaluation of the accuracy of an offline seasonally-varying matrix transport model for simulating ideal age. (*in prep.*)
- [10] Letscher, R.T. , F. Primeau, and J. K. Moore, Lateral nutrient transport sustains ocean gyre productivity. (*in prep.*)

