Enhancing Global Biogeochemical Cycles in the Community Earth System Model

Forest M. Hoffman\(^1\), Pavel B. Bochev\(^1\), Phillip J. Cameroon-Smith\(^2\), Richard C. Easter, Jr.\(^3\), Scott M. Elliott\(^4\), Julian Grineskau\(^5\), Oksana Guba\(^6\), Xiaohong Liu\(^7\), Robert B. Lowrie\(^8\), Donald D. Lucas\(^9\), Richard T. Mills\(^10\), William J. Sacks\(^11\), Timothy J. Tautges\(^12\), Mark A. Taylor\(^13\), Mariana Verstappen\(^14\), and Patrick H. Worley\(^15\)

\(^1\)Argonne National Laboratory; \(^2\)Lawrence Livermore National Laboratory; \(^3\)Los Alamos National Laboratory; \(^4\)National Center for Atmospheric Research; \(^5\)Tide-Pole National Laboratory; \(^6\)Pacific Northwest National Laboratory; \(^7\)Sandia National Laboratories

Abstract

The goal of ACES4BGC is to advance the predictive capabilities of Earth System models (ESMs) by extending the representation of biogeochemical cycles to include new science objectives and facilitate improved model performance. Here we describe recent results from ACES4BGC that expand the representativeness of biogeochemical models in the Community Earth System Model (CESM). These efforts span multiple ESMs, including a new spectral finite element dynamical core from the High Order Method Modeling Environment, new scientific capabilities, and improved performance contributions from the Mesoscale Modeling System (MMS) and Flexible Ocean-Atmosphere Model (FOAM) community. The following sections describe the state-of-the-art capabilities and future priorities of the MMS and FOAM communities, as well as the impact of ACES4BGC on the CESM software infrastructure.

1. Introduction

The goal of ACES4BGC is to advance the predictive capabilities of Earth System models (ESMs) by extending the representation of biogeochemical cycles to include new science objectives and facilitate improved model performance. Here we describe recent results from ACES4BGC that expand the representativeness of biogeochemical models in the Community Earth System Model (CESM). These efforts span multiple ESMs, including a new spectral finite element dynamical core from the High Order Method Modeling Environment, new scientific capabilities, and improved performance contributions from the Mesoscale Modeling System (MMS) and Flexible Ocean-Atmosphere Model (FOAM) community. The following sections describe the state-of-the-art capabilities and future priorities of the MMS and FOAM communities, as well as the impact of ACES4BGC on the CESM software infrastructure.

2. MMS

The MMS is a parallel finite element solver that is used to model fluid dynamics in three dimensions. It is designed to be flexible and scalable, allowing for the efficient simulation of complex geometries and large-scale systems. The MMS utilizes a adaptive mesh refinement technique that dynamically adjusts the mesh resolution based on the solution's features, enabling high accuracy in regions of interest while maintaining computational efficiency in less critical areas. The MMS is also capable of handling a wide range of physical processes, including turbulence, chemistry, and radiative transfer, allowing for comprehensive simulations of Earth system processes.

3. FOAM

FOAM is a community-driven project that focuses on developing and maintaining a high-performance, scalable, and open-source code that can simulate complex fluid dynamics problems. It is designed to be highly flexible and modular, allowing researchers to easily add new physics modules or adapt existing ones to address specific scientific questions. FOAM's modular design and efficient parallelization strategies make it well-suited for applications requiring high performance, such as climate modeling, oceanography, and atmospheric science.

4. ACES4BGC

ACES4BGC is an interdisciplinary project that brings together experts from various fields to advance the state of Earth System modeling and improve the predictive capabilities of ESMs. The project aims to enhance the representativeness of biogeochemical processes in ESMs and facilitate improved model performance. ACES4BGC involves multiple ESMs, including a new spectral finite element dynamical core from the High Order Method Modeling Environment, new scientific capabilities, and improved performance contributions from the MMS and FOAM communities. The following sections describe the state-of-the-art capabilities and future priorities of the MMS and FOAM communities, as well as the impact of ACES4BGC on the CESM software infrastructure.

5. Conclusion

In conclusion, ACES4BGC has made significant progress in advancing the predictive capabilities of Earth System models by extending the representation of biogeochemical cycles, improving performance, and facilitating collaboration among the MMS and FOAM communities. The project's success highlights the power of interdisciplinary collaboration and the importance of ongoing investments in Earth System modeling to support climate change research.

References