SciDAC Prospectus – Climate Application

Predicting Ice Sheet and Climate Evolution at Extreme Scales (PISCEES)

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Lawrence Berkeley National Laboratory (LBNL)
Oak Ridge National Laboratory (ORNL)
Sandia National Laboratories (SNL)
National Center for Atmospheric Research (NCAR)
Florida State University (FSU)
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Background and Motivation

During the past decade, mass loss from ice sheets has raised global mean sea level by 1 mm/yr, roughly equal to the contributions from ocean thermal expansion and the melting of smaller glaciers and ice caps. If recent trends continue, ice sheets will make a dominant contribution to 21-st century sea-level rise (SLR), far exceeding projections from the IPCC's Fourth Assessment Report. Growing ice mass losses not only could raise sea level, but also could affect other parts of the climate system, such as the Atlantic Meridional Overturning Circulation and its poleward heat transport, through increased freshwater discharge to high-latitude oceans. Although ice sheet models have improved in recent years, much work is needed to make these models reliable and efficient on continental scales, to couple them to earth system models, and to quantify their uncertainties.

Scope and Goals

Building on recent successes of SciDAC and the Ice Sheet Initiative for CLimate ExtremeS (ISICLES), PISCEES will develop two dynamical cores: (1) a finite-volume core on a structured mesh, using the Chombo adaptive mesh refinement (AMR) software framework, and (2) a finite-element core on an unstructured mesh, using the Model for Prediction Across Scales (MPAS) framework and the Trilinos software library. Both will include a hierarchy of solvers, which can be applied at variable resolution and in different regions of dynamical complexity, and will be engineered to optimize performance on new high-performance computers with heterogeneous architectures. PISCEES will also focus on developing new methods and tools for ice sheet model initialization, verification and validation (V&V), and uncertainty quantification (UQ), allowing for confidence ranges on projections of ice-sheet evolution and sea-level rise. These improved models and new tools will be implemented in the Community Ice Sheet Model (CISM) and the Community Earth System Model (CESM), providing a coherent structure for ongoing collaboration among glaciologists, climate modelers, and computational scientists. The outcome of PISCEES will enable quantitative predictions of coupled ice-sheet/climate evolution using a new generation of high-performance computers and computational tools.

Collaboration with SciDAC Institutes

PISCEES will work closely with the SciDAC applied math and computer science institutes (FASTMath, QUEST, and SUPER); team members from these institutes are integral members of the PISCEES team. By using scalable algorithms packaged in libraries from the FASTMath and QUEST, PISCEES will leverage ongoing ASCR investments and have greater access to the domain experts writing these libraries. Similarly, tools and techniques developed by SUPER will ensure that PISCEES-developed codes run efficiently on current and next-generation HPC systems supported by DOE. Of particular relevance are the solution of large systems of linear and nonlinear equations and block-structured AMR; PISCEES computational team leads are on the FASTMath executive committee and will coordinate computational activities in linear and nonlinear solvers and structured-grid AMR with FASTMath. Chombo and Trilinos - essential components of both dynamical cores to be developed under PISCEES - are supported by FASTMath. Of additional interest to PISCEES are SUPER technologies such as performance bounds, auto-tuning, and programming language extensions that support porting to and optimizing on heterogeneous architectures without sacrificing portability. PISCEES will leverage SUPER technologies in end-to-end instrumentation to enable performance characterization and tracking. Finally, PISCEES will rely on QUEST for expertise in modeling and algorithmic UQ, as well as for support in the use of the DAKOTA and other QUEST software tools.