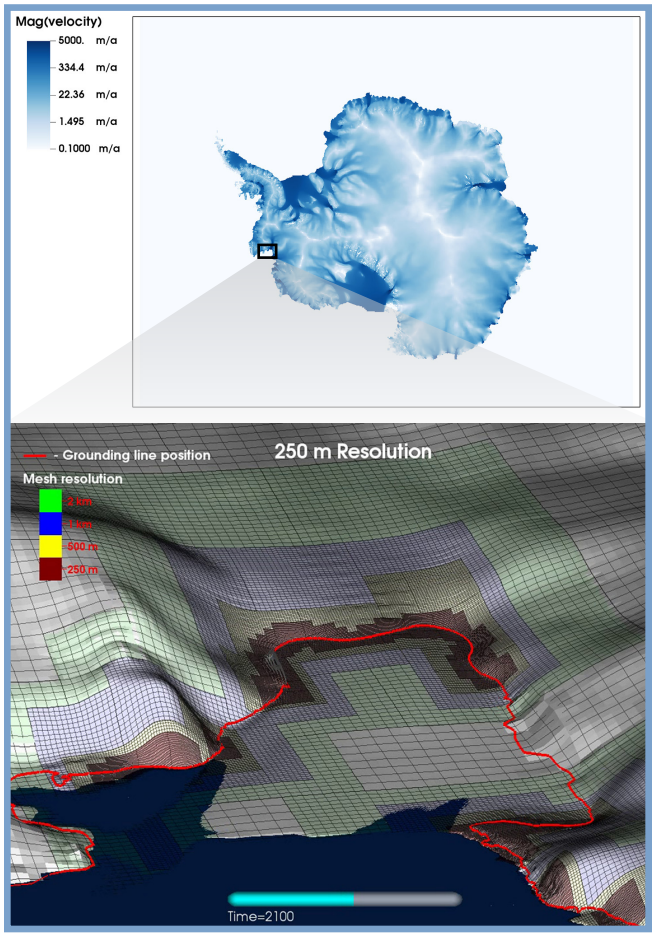
PREDICTING ICE SHEET AND CLIMATE EVOLUTION AT EXTREME SCALES (PISCEES)

As the climate warms, mass loss from the Greenland and Antarctic ice sheets is accelerating. The resulting fresh water input into the oceans will be the dominant contribution to future sea-level rise. Predicting Ice Sheet and Climate Evolution at Extreme Scales, or PISCEES, is a multi-institutional* project developing state-of-the-art computer models of large ice sheets to improve projections of ice-sheet mass loss and sea-level rise. The PISCEES team of scientists is also creating new tools and techniques for validating ice-sheet simulations against observations and for estimating the uncertainty surrounding future projections.

NEW ICE-SHEET MODELS

Large-scale ice-sheet computer models must represent the response of ice flow to changes in atmosphere and ocean conditions (i.e., climate change)—as well as to evolving conditions within and beneath the ice. This is particularly difficult near dynamically complex ice-sheet margins, like the "grounding line," where land-ice thins to floatation and flows out over the surface of the ocean. For the most accurate predictions, PISCEES researchers are developing robust, comprehensive models of ice-sheet dynamics that include variable-resolution meshes in order to simulate the evolution of the continental-scale ice sheets that cover Greenland and Antarctica.

These new models, named FELIX and BISICLES, focus spatial resolution and computational resources in fast-flowing and dynamically complex regions, such as ice streams, outlet glaciers, floating ice shelves, and grounding lines. FELIX uses finite element methods and unstructured meshes, while BISICLES uses finite volume methods and block-structured, adapative-mesh refinement. Both models allow for a range of reduced-order (and thus computationally less expensive, though less accurate) approximations to the governing equations for ice motion. These new models use advanced mathematical and computational techniques through collaborations with scientists at the Scientific Discovery through Advanced Computing (SciDAC) Institutes.



***Top**: Computed ice velocity (m/yr) for the Antarctic Ice Sheet, with Pine Island Glacier in black box. **Bottom**: Adaptive meshing (shaded boxes) and grounding-line location (red line) for the Pine Island Glacier. Regions with a relatively finer mesh track the dynamically complex grounding-line region as the simulation evolves.*

***Participating Institutions**

Los Alamos National Laboratory
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Florida State University
Massachusetts Institute of Technology
National Center for Atmospheric Research
Oak Ridge National Laboratory
Sandia National Laboratory
University of South Carolina
University of Texas, Austin

SCIDAC PARTNERSHIPS

The SciDAC program creates partnerships between SciDAC Institutes and application groups to improve modeling capability. The PISCEES project benefits from three such partnerships:

FASTMath – provides solver and meshing frameworks
http://www.fastmath-scidac.org/

SUPER – provides tools and expertise to improve computational performance on advanced computers
http://www.super-scidac.org/

QUEST – supplies tools and techniques to quantify uncertainty in model predictions
http://www.quest-scidac.org/

These partnerships are critical to the success of new ice-sheet models.

VALIDATING MODELS

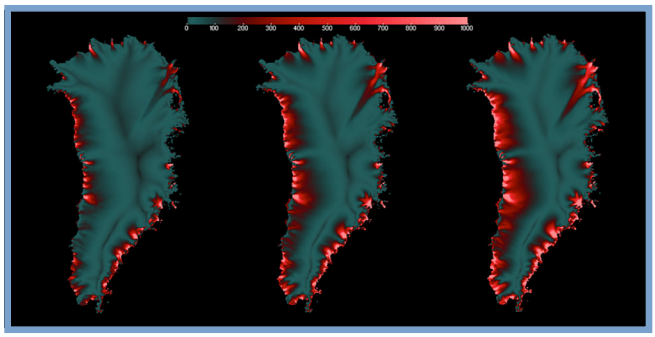
The PISCEES project is developing a comprehensive framework to verify new ice-sheet models against standard test cases and validate them against available observations. Reproducing existing observations increases confidence in our ability to predict future changes. By automating the validation process, researchers can rapidly test new model changes while ensuring the accuracy and computational efficiency of ice-sheet simulations.

UNCERTAINTY QUANTIFICATION

Projections of future ice-mass loss and sea-level rise are inherently uncertain, due to uncertainties in model physics, initial conditions, and future climate changes. PISCEES researchers are developing and applying tools for quantifying the uncertainty in these projections, thus providing decision makers with critical information for risk assessment. Similar tools can be used to estimate the values and uncertainties in poorly constrained physics parameters in the model.

INTEGRATION IN CLIMATE MODELS

In order to understand how ice sheets respond to climate change, ice-sheet models must be integrated into complete models of the Earth's climate system. As part of the PISCEES effort, these new ice-sheet models are



Simulated present-day ice speed (m/yr) for Greenland (left) with increased basal sliding by factors of 2x and 3x (middle and right, respectively).

being integrated into fully-coupled Earth System Models. Dynamic coupling with the ocean, atmosphere, and land-surface models provides the necessary feedbacks for comprehensive simulations of ice sheet and climate interactions. Using Earth System Models, PISCEES will simulate decade-to-century-scale evolution of the Greenland and Antarctic ice sheets and the resulting changes in sea level across the globe.

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