Albany/FELIX: A New Parallel, Scalable and Robust First-Order Stokes Ice Sheet Simulation Code

Abstract:
This talk will give an overview of the Albany/FELIX (Finite Elements for Land Ice eXperiments) dynamical core (dycore) that is currently under development at Sandia as a part of the PISCEES (Predicting Ice Sheet and Climate Evolution at Extreme Scales) project. It is widely accepted that ice sheets behave like an incompressible non-Newtonian fluid, modeled by the Stokes equations with a nonlinear viscosity. The Albany/FELIX dycore implements an approximation to these equations, known as the "First-Order Stokes" model [1], an attractive alternative to the full Stokes model because of its reduced computational cost. Following a description of the PISCEES project, the First-Order Stokes model for ice sheets and its implementation within the Albany [2] code base using Trilinos [3] components will be detailed. Several methods for importing Greenland/Antarctica data (geometry, topography, surface height, basal friction, etc.) into Albany/FELIX will be described, in addition to some recent work on coupling Albany/FELIX to other land ice dycores (the CISM and MPAS codes). This latter effort enables dynamic simulations of the ice sheet evolution, and facilitates the integration of the Albany/FELIX dycore into a global earth system model (ESM) to be used to support DOE climate missions by providing sea-level rise predictions. Results for some steady-state as well as dynamic Greenland and Antarctica simulations obtained on three different kinds of meshes (structured hexahedral grids, structured tetrahedral grids, true unstructured Delaunay triangle grids) will be presented. Convergence of the code on a realistic Greenland geometry will be demonstrated. It will be shown that the Albany/FELIX code is scalable, robust and portable to new architecture machines. Finally, attention will be turned from forward to inverse ice sheet problems These problems are solved for the optimal Greenland/Antartica initial state and basal sliding coefficient, and entail minimizing a merit functional involving the mismatch between measured and computed fields (e.g., surface mass balance, surface velocities), either in a deterministic or stochastic (Bayesian) setting.

[1] Dukowicz JK, Price SF and Lipscomb WH (2010) Consistent approximations and boundary conditions for ice-sheet dynamics from a principle of least action. *J. Glaciol.*, **56**(197), 480–496
[2] M.A. Heroux et al. An overview of the Trilinos project. *ACM Trans. Math. Softw.* **31**(3) (2005).
[3] A.G. Salinger et al. Albany: A Component-Based Partial Differential Equation Code Built on Trilinos, submitted to *ACM Trans. Math. Software*.