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Interactive transient and steady-state analysis of regional ice flow

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Prescribing suitable domains and boundary conditions for regional ice flow models is typically a time-consuming process. Field observations which will be used for boundary conditions or constraints for inverse modeling are often available in different formats, projections, sampling frequency, and with different conventions about missing data. In this work, we present recently developed tools to "close the loop" between defining a problem in GIS and visualizing results from an ice flow model. Unstructured hexahedral meshes are generated from a polygonal description of the region of interest and user-defined refinement parameters, smooth geometries are produced for the enforcement of slip boundary conditions, and a variety of boundary conditions are easily specified. The geometry and boundary data need not be in any specific format or projection since the software transforms as needed for the simulation being run. Since internal fields such as enthalpy (temperature/water content) are unknown or poorly constrained, it may take a large amount of computational effort to "spin up" a model such that its response can be practically assessed. As an alternative, we offer fully implicit and steady-state solvers that produce a consistent enthalpy field at a cost proportional to a single time step of a transient model. These solvers are based on Newton-Krylov methods and use an extensible system for constructing scalable preconditioners for multi-physics problems. New constitutive relations, perhaps involving additional field variables, can be defined in symbolic form using Python or written directly in C. When written in Python, manufactured solutions are automatically generated to confirm the accuracy of the method, and C code is generated for efficient evaluation of the constitutive relations. High order spatial and temporal accuracy is demonstrated for sufficiently smooth solutions of the coupled systems.