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Adaptive mesh refinement for ice-sheet models

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The class of model that has been used to predict the future evolution of Greenland and Antarctic ice sheets is typically based on a fixed finite-difference grid in the horizontal. Much recent work suggests that features such as ice streams, outlet glaciers and the grounding line play an important role in controlling the gross dynamics of ice-sheet response to climate change. Accurate modelling of these areas may demand horizontal grid resolution of the order of a km or less. Several strategies are available to address the issues that this requirement creates, ranging from modelling the whole ice sheet at fine resolution to the use of unstructured grids. We report progress on an intermediate solution which employs a set of numerical grids at varying spatial resolutions. This has the distinct advantages that it does not require major reconfiguration of existing ice-flow solvers based on fixed grids, and that third-party software exists to handle the many logistical problems associated with grid management.

We illustrate the application of this technique using the CHOMBO software package in combination with an existing higher-order solver for ice flow. The basic methodology is that grids at a finer resolution operate over a subset of the area covered by a coarser grid and this coarser grid provides both boundary and initial conditions (upon creation of the fine grid). Finer grids can operate at fixed, predetermined locations or be generated as the simulation evolves according to specified criteria such as solution error, proximity to the grounding line or speed of flow. Typically a refinement ratio of 2 to 4 is employed. CHOMBO was originally designed for astrophysical problems and is a suite of C++ routines that handle tasks such inter-grid communication, grid refinement and clustering, MPI-based parallelization, and output. This particularly software was chosen after an analysis of the many free, public-domain mesh refinement packages available (e.g., PARAMESH, SAMRAI and AGRIF).

Issues that arise in the application of CHOMBO to ice sheets will be highlighted. These include the need to incorporate realistic geography in the model's representation of bedrock topography and climatic forcing; as well as moving from the explicit approximations typically used in astrophysics to the strongly implicit nature of much ice-sheet code.