BISICLES - AMR for Ice Sheets

The dynamics of ice sheets like those found in Antarctica and Greenland span a wide range of scales. Regions like grounding lines and the shear margins of ice streams require very fine (better than 1 km) resolution to resolve the dynamics. Resolving all of Antarctica at such fine resolutions is computationally prohibitive. However, there are also large regions where such fine resolution is unnecessary, making ice sheets an ideal candidate for adaptive mesh refinement (AMR). Developed as part of the ISLICS initiative, and in collaboration with the University of the UK, we have developed a scalable, finite-volume code built upon the FASTMath-supported Chombo framework. AMR allows BISICLES to achieve unprecedented spatial resolution to resolve behavior like grounding line retreat. BISICLES uses a vertically-integrated formulation of the momentum balance based on that of Schoof and Hindmarsh (2010), which preserves the essential physics of the problem while also enabling additional computational efficiencies.

Structured AMR

- Automatic cost of irregular operations over large number of regular structured operations
- Define in logically rectangular patches
- Use simple, uniform discretizations throughout the domain
- Simplifies dynamic remeshing, to follow changing features

The Grid-Downloaded Chombo C++ framework allows additional code development and provides built-in scalability.

Antarctica

- Ice velocity field (right) computed using AMR - mesh spacing from 5' (base mesh) to 0.25m (finest level)
- Birefringence (based on grounding lines, L10a(sensitivity))
- Mesh resolution (at right): 3x 4 base mesh with 4 refinement levels: 1 pixels away from 100 x 100 km (best mesh)
- 0.25 m (finest level)
- 0.001 m (coarsest level)

Solvers

--based on structured and unstructured basis functions
- Linear and quadratic scheme improvements
- Extends with embedded analysis for better performance

FELIX

The FELIX (Finite Element Components for Land Ice-processes) dyad delivers libraries (e.g., Trilinos, Dakota, BINGO) to deliver an unstructured grid Finite Element Model (FEM) simulator that is born with advanced software tools, robust and scalable solvers, and embedded analysis capabilities. The parallel Stokes dyke uses hypre and BINGO AMR. FELIX is being used to conduct whole-ice-sheet simulations of the entire Greenland and Antarctica. The data for these simulations will be exported to a hexahedral, structured grid, an unstructured central voronoi fitting (CVF) grid for nebulous configurations, and climate models.

Solution/Convergence Verification

- Solution verification of all benchmark and test cases (e.g., ISMIP-HOM, Dome, Dome), done efficiently and in parallel for a number of different resolutions

Code-to-Code Comparisons

- Code-to-code comparisons between FELIX and existing codes (e.g., Glaciol, GLACAT). Comparison made at high spatial and temporal resolutions.

Greenland Results

- Location of Amundsen Sea Sector

Scalability on Hopper

- Right: Weak scaling of ISMIP HOM simulations on Hopper blueGene/L in showing modest speedup for moderate core counts
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New Code Development under PISCEES

PISCEES will leverage software tools, robust and scalable solvers, and embedded analysis capabilities. The parallel Stokes dyke uses hypre and BINGO AMR. FELIX is being used to conduct whole-ice-sheet simulations of the entire Greenland and Antarctica. The data for these simulations will be exported to a hexahedral, structured grid, an unstructured central voronoi fitting (CVF) grid for nebulous configurations, and climate models. The parallel Stokes dyke uses hypre and BINGO AMR. FELIX is being used to conduct whole-ice-sheet simulations of the entire Greenland and Antarctica. The data for these simulations will be exported to a hexahedral, structured grid, an unstructured central voronoi fitting (CVF) grid for nebulous configurations, and climate models.