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Higher-order ice-sheet modelling accelerated by multigrid on graphics cards

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Higher-order ice flow modelling is a very computer intensive process owing primarily to the nonlinear influence of the horizontal stress coupling. When applied for simulating long-term glacial landscape evolution, the ice-sheet models must consider very long time series, while both high temporal and spatial resolution is needed to resolve small effects. The use of higher-order and full stokes models have therefore seen very limited usage in this field. However, recent advances in graphics card (GPU) technology for high performance computing have proven extremely efficient in accelerating many large-scale scientific computations. The general purpose GPU (GPGPU) technology is cheap, has a low power consumption and fits into a normal desktop computer. It could therefore provide a powerful tool for many glaciologists working on ice flow models.

Our current research focuses on utilising the GPU as a tool in ice-sheet and glacier modelling. To this extent we have implemented the Integrated Second-Order Shallow Ice Approximation (iSOSIA) equations on the device using the finite difference method. To accelerate the computations, the GPU solver uses a non-linear Red-Black Gauss-Seidel iterator coupled with a Full Approximation Scheme (FAS) multigrid setup to further aid convergence. The GPU finite difference implementation provides the inherent parallelization that scales from hundreds to several thousands of cores on newer cards. We demonstrate the efficiency of the GPU multigrid solver using benchmark experiments.