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CUDA GPU based full-Stokes finite difference modelling of glaciers

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Many have stressed the limitations of using the shallow shelf and shallow ice approximations when modelling ice streams or surging glaciers. Using a full-stokes approach requires either large amounts of computer power or time and is therefore seldom an option for most glaciologists. 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.

Our full-stokes ice sheet model implements a Red-Black Gauss-Seidel iterative linear solver to solve the full stokes equations. This technique has proven very effective when applied to the stokes equation in geodynamics problems, and should therefore also preform well in glaciological flow probems. The Gauss-Seidel iterator is known to be robust but several other linear solvers have a much faster convergence. To aid convergence, the solver uses a multigrid approach where values are interpolated and extrapolated between different grid resolutions to minimize the short wavelength errors efficiently. This reduces the iteration count by several orders of magnitude. The run-time is further reduced by using the GPGPU technology where each card has up to 448 cores. Researchers utilizing the GPGPU technique in other areas have reported between 2 - 11 times speedup compared to multicore CPU implementations on similar problems.

The goal of these initial investigations into the possible usage of GPGPU technology in glacial modelling is to apply the enhanced resolution of a full-stokes solver to ice streams and surging glaciers. This is a area of growing interest because ice streams are the main drainage conjugates for large ice sheets. It is therefore crucial to understand this streaming behavior and it's impact up-ice.