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Multi-GPU three dimensional Stokes solver for simulating glacier flow

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Here we present how we have recently developed a three-dimensional Stokes solver on the GPUs and apply it to a glacier flow. We numerically solve the Stokes momentum balance equations together with the incompressibility equation, while also taking into account strong nonlinearities for ice rheology. We have developed a fully three-dimensional numerical MATLAB application based on an iterative finite difference scheme with preconditioning of residuals. Differential equations are discretized on a regular staggered grid. We have ported it to C-CUDA to run it on GPU's in parallel, using MPI.
We demonstrate the accuracy and efficiency of our developed model by manufactured analytical solution test for three-dimensional Stokes ice sheet models (Leng et al.,2013) and by comparison with other well-established ice sheet models on diagnostic ISMIP-HOM benchmark experiments (Pattyn et al., 2008). The results show that our developed model is capable to accurately and efficiently solve Stokes system of equations in a variety of different test scenarios, while preserving good parallel efficiency on up to 80 GPU's. For example, in 3D test scenarios with 250000 grid points our solver converges in around 3 minutes for single precision computations and around 10 minutes for double precision computations. We have also optimized the developed code to efficiently run on our newly acquired state-of-the-art GPU cluster octopus. This allows us to solve our problem on more than 20 million grid points, by just increasing the number of GPU used, while keeping the computation time the same.
In future work we will apply our solver to real world applications and implement the free surface evolution capabilities.

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