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A fast sub-glacial hydrology solver for continental scale modelling

M. Kavanagh and L. Tarasov
Dept of Physics and Physical Oceanography, Memorial University of Newfoundland, Canada

Sub-glacial hydrology is a potentially critical control in fast flow dynamics. It can also leave a strong signature on the post-glacial landscape, which is of high relevance to efforts constraining deglacial ice sheet evolution. However, to date most continental scale ice sheet models lack a physically realistic representation of sub-glacial hydrology. This is partly due to computational costs associated with previously applied discretizations of the governing partial differential equations.

We present a new physically-based basal hydrology model for glacial cycle and continental scale applications with minimal computational load. The solver only adds 2-4 hours to a North American glacial systems model run-time for a full glacial cycle at 50 km grid resolution (on single core of a commodity computing cluster). The model uses a combined leapfrog-trapezoidal predictor-corrector discretization of Darcy flow to represent the flow of water in a distributed drainage system and a down gradient solver for water flow to simulate channelized flow of water when the conditions for channel flow is met. Basal water pressure is limited to ice overburden pressures and dynamic time-steping is used to ensure that the maximum basal water velocity is lower than the CFL condition to help prevent any numerical instabilities.

Tests of the model with synthetic ice sheets display sub-glacial lake generation in hydraulic potential wells where expected. Channel formation occur periodically over different sections of the ice sheet and, when sizable enough to distinguish, display an arborescent pathway that is expected of Röthlisberger Channels. The sub-glacial hydrology model has been incorporated into the MUN glacial systems model. The latter (without basal hydrology) has been subject to Bayesian calibration for North American deglaciation. Along with a model overview and parametric sensitivity analysis, we present preliminary application of the solver to the calibrated ensemble of deglacial chronologies for North America with a focus on the evolution of sub-glacial lakes.