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A finite-volume approach for coupled simulations of ice, sediment, and melt-water transport

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Glaciers and ice-sheets are highly dynamic systems showing temporal changes occurring over several timescales, ranging from days/weeks (glacier surges), to years/centuries (e.g. ice streams), to millennia (ice ages). While long-term variability relates primarily to changes in global earth surface temperatures, feedbacks related to water- and sediment-modulated basal sliding is thought to provide the main control on the short-term and spatially localised variability. Process oriented computational exploration of the importance of such feedbacks requires numerical platforms for simulating the coupled flow of glacier ice, melt-water, and sediments.

Here we present a new computational approach for simulating coupled ice-related flow processes on a three-dimensional topographic surface. The method employs 1) irregular finite volume discretization of the topographic surface, 2) local 2nd order polynomial approximation of the bed topography and ice surface and 3) explicit time marching. Ice flow is computed using a second-order shallow-ice approximation (SOSIA) including contributions from longitudinal stress gradients, rugged bed topographies, and localised ice-thickness variations.

The finite-volume approach leads to a general and highly parallel algorithm based on discrete cell interactions, which is well suited for simulating coupled sub-glacial flow systems as well as other types of surface flow processes, like fluvial and hill-slope related sediment transport. The inherent benefit of the method thus relates primarily to the ease with which several types of earth surface processes may be simulated simultaneously. We illustrate the potentials of the approach by simple model scenarios related to the dynamics of alpine glaciers.