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Toward more accurate basal boundary conditions: a new 2-D model of distributed and channelised subglacial drainage

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Basal boundary conditions are one of the least constrained components of today's ice sheet models. To get at these one needs to know the distributed basal water pressure. We present a new glacier drainage system model to contribute to this missing piece of the puzzle.

This two dimensional mathematical/numerical model combines distributed and channelised drainage at the ice-bed interface coupled to a water storage component. Notably the model determines the location of the channels as part of the solution. This is achieved by allowing channels (modelled as R-channels) to form on any of the edges of the unstructured triangular grid used to discretise the model. The distributed system is represented by a water sheet which is a continuum description of a linked-cavity system and exchanges water with the channels along their length. Water storage is parameterised as a function of the subglacial water pressure, which can be interpreted as storage in an englacial aquifer or due to elastic processes. The parabolic equation that determines the water pressure is solved using finite elements, the time evolution of the water sheet thickness and channel diameter are governed by local differential equations that are integrated using explicit methods.

To explore the model's properties, we apply it to synthetic ice sheet catchments with areas up to 3000km^2. We present steady state drainage system configurations and evaluate their channel-network properties (fractal dimensions, channel spacing). We find that an arborescent channel network forms whose density depends on the water sheet conductivity relative to water input. As a further experiment, we force the model with a seasonally and diurnally varying melt water input to investigate how the modelled drainage system evolves on these time scales: a channelised system grows up glacier as meltwater is delivered to the bed in spring and collapses in autumn. Water pressure is highest just before the formation of channels and then drops. Conversely, the diurnal variations in discharge affect the drainage system morphology only slightly. Instead they lead to large water pressure variations which lag meltwater input and coincide with changes in the volume of stored water. By incorporating an evolving R-channel network within a continuum model of distributed water drainage and storage, this 2-D model succeeds in qualitatively reproducing many of the observed and postulated features of the glacier drainage system.