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Drainage network formation under glaciers

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Ice flow velocities in glaciers and ice sheets are known to depend sensitively on conditions at the base of the ice. In particular, switches in subglacial drainage network configurations can have a major impact on glacier and ice sheet sliding, as subglacial water at high pressure tends to favour rapid sliding. Abrupt changes in the style of subglacial drainage have therefore often been invoked as an explanation for the onset of fast ice flow in ice sheets in the form of ice streams (narrow bands of ice that move at speeds orders of magnitude larger than what can be explained by shearing in the ice), and for surges in glaciers (relaxation oscillations in ice velocity and ice thickness). To date, spatially extended models that could test some of the hypotheses about drainage networks have been conspicuously lacking. Here we review the state of the art in subglacial drainage, and present a new model that captures the dynamics of water-filled cavities and subglacial channels in a unified mathematical description, which is based on a network of discrete drainage elements. We show that this model can capture the formation and disappearance of an arborescent, channelized network under changes in water input and sliding velocity. We also show that this mechanism is insufficient to explain surging behaviour, and show how feedbacks with water storage are essential in causing the abrupt drainage transitions observed in some glacier surges.