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Ice stream shear margin migration

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Ice streams are the major conduits through which ice drains from the interior areas of an ice sheet to its margins. Their discharge can be highly sensitive to their geometry: simple models of ice streams suggest that their discharge scales as their width to the fifth power. The migration of ice stream margins is therefore an important component of ice stream dynamics, but the processes involved are poorly understood. The flow of ice streams is caused by the presence of lubricating subglacial meltwater, and the margins of an ice stream correspond to a transition from high basal water pressure under the ice stream to low pressure or a frozen bed outside. In order for an ice stream to widen, meltwater must be supplied to its margins. Fast sliding in the centre of the ice stream leads to the frictional dissipation of heat, which produces meltwater, but this meltwater is not immediately available to weaken the margins. Here, we investigate how subglacial drainage from the centre of the ice stream and the disspiation of heat due to shearing of ice in the margins leads to widening of an ice stream (or to shrinking, if the sum of meltwater sources is too small). We find that a highly nonlinear diffusion model can capture the meltwater drainage-induced migration of shear margins, and that considerations of frost heave processes are necessary for a complete description of shear margin migration. Surprisingly, the strength of hydrological and thermal controls in the migration process seems to overwhelm the effect of different sliding parameterizations, and subglacial drainage parameters may play a bigger role in controlling ice stream dynamics than the details of the basal friction law.