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The dynamics of temperate ice-stream margins: englacial melting, water weakening and drainage

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Temperate ice (ice at the melting point) is expected to form in the margins of fast moving ice streams. Experimental data suggest that water in the ice matrix changes the mechanical properties of ice by decreasing its viscosity. However, the implications of this weakening for ice sheet dynamics are poorly understood. Here, we investigate how the coupling between temperate ice properties, ice mechanics, and drainage of excess melt water from the ice stream margin to the bed alters the energy balance of ice streams. We model the steady-state ice flow, temperature, water content, and subglacial water drainage in the ice stream cross-section. Temperate ice dynamics are modelled as a coupled two-phase flow, with gravity-driven water transport in the compacting ice matrix according to Darcy's law. We find that the dependence of ice viscosity on melt water content leads to a strong focusing of the temperate ice region in ice stream margins, thereby strengthening heat dissipation there. This increases the amount of melt water delivered to the ice stream bed, and consequently elevates the water content in the bed. Our results demonstrate that the strength of these processes is controlled by the permeability of the temperate ice region and the dependence of the ice viscosity on the melt water content, both of which are poorly constrained properties.