Melting-driven evolution of an ice shelf coupled to a buoyant meltwater plume

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Melting at the base of floating ice shelves, in both Greenland and Antarctica, can impact ice-sheet flow and hence have consequences for sea-level rise. Recent measurements have revealed significant heterogeneities in ice-shelf thickness, including channels and undulations in the ice-shelf base. However, the precise conditions for genesis remain unclear. The buoyancy-driven flow of meltwater under an ice shelf is sensitive to ice-shelf geometry, with faster flow under steeper basal slopes providing a feedback that increases melting rates. To build insight into the potential for melting-driven instability, I consider the simplified setting of a two-dimensional stationary ice shelf melting into a warmer ocean. A theoretical model is developed to describe the coupling of a meltwater plume to an evolving ice-shelf geometry. When there is negligible subglacial discharge, the subsequent weak-flow regime near to the grounding line results in a planar ice-water interface being neutrally stable to small perturbations. Hence, the amplitude of perturbations to the basal slope neither grows, nor decays. In the absence of ice-deformation, the nonlinear evolution of melting results in cusp-like features in the ice-shelf base. These results provide a starting point for future detailed stability analysis of the ice-ocean interface.