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Towards a conceptual model for water mass renewal and ice melt in proglacial fjords

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The Greenland and other ice sheets are fringed by marine-terminating glaciers discharging into the oceans through fjords. Such fjords mediate the transfer of heat from the ocean continental shelves towards the ice to drive melt, and the resulting export of fresh melt-modified waters out into the open ocean. Hence, the renewal of water masses in proglacial fjords has potential to impact both the ocean-forcing of ice sheet decay, and feedbacks on wider ocean stratification and circulation.

We develop a simplified conceptual model of ocean stratification and circulation in a fjord, coupled to a melting glacier terminus. We focus on fjords much narrower than the deformation radius, and neglect coriolis effects in a simplified two-dimensional model. The model describes a simplified description of baroclinic and barotropic exchange with the far-field ocean, heat and freshwater exchange with the ice face, and how these impact the vertical stratification and storage within the fjord. We apply this model to determine the fjord renewal time, and timescale for adjustment of the circulation in response to changing far-field ocean conditions (for example forced by wind stress variations over the continental shelf). We also consider the response to fluctuating ocean forcing, considering pycnocline oscillations with a superimposed spectrum of frequencies. We find that the modelled fjord circulation undergoes self-sustaining oscillations at a particular resonant frequency controlled by the fjord depth, length and properties of the ambient density stratification. Hence the strength of the circulation response may be sensitive to the frequency content of the ocean-forcing on the continental shelf, with different fjords likely to exhibit different responses depending on their geometry.