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Scaling laws for the melt rate and overturning circulation beneath ice shelves derived from simple plume theory

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Both the Antarctic and Greenland ice sheets are experiencing rapid change, at least in part as a result of acceleration of some of their larger, marine-terminating outlet glaciers that has been driven in turn by the ocean, through changes in the submarine melt rate. Much progress has been made in incorporating the key ocean processes into Ocean General Circulation Models and the coupling of these to dynamic ice sheet models is now an active area of research. However, at the resolutions currently used in global ocean models, some of the smaller ice shelves and almost all marine-terminating outlet glaciers will be sub-grid-scale features. Parameterisations of the ice-ocean interactions will therefore be needed for the foreseeable future. Those currently available in the literature rely on the specification of a length scale over which the ice-ocean interaction takes place or the strength of the overturning circulation that results. These unknown parameters must be chosen to match current melt rates, and the implicit assumption made that those choices remain valid as ocean temperatures evolve. However, within a coupled model the length-scale of the interaction and the overturning strength are parameters that will almost certainly change. One-dimensional plume theory provides the simplest physical description of the overturning circulation appropriate for the sub-grid-scales of interest. In this presentation it is shown how the melt rates and overturning strength produced by a plume model scale quite simply with ocean temperature and with the depth and slope of the ice-ocean interface. The simple scalings mean that plume model results can be well represented by a single polynomial expression that is accurate to about 20% for melt rates that range over many orders of magnitude. Such a polynomial could provide the basis for a powerful and versatile parameterisation of the interaction between an ocean model and sub-grid-scale features generated at the marine margins of an ice sheet model.