Convection-driven melting near the grounding lines of ice shelves and tidewater glaciers

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Ocean circulation beneath or in front of ice shelves and tidewater glaciers is usually considered as being forced by the buoyancy generated by melting at the ice-seawater interface. However, most fast-flowing glaciers have an active (and variable) sub-glacial drainage system, and the discharge of freshwater across the grounding line will provide an additional (variable) source of buoyancy forcing on the ocean. This paper considers the region where this additional (conventionally-neglected) source of buoyancy dominates. When the discharge of freshwater is small, this region is also small, but it can grow to cover 10's of kms, a substantial fraction of many ice shelves. For tidewater glaciers with no floating tongue, the vertical face of the calving front will generally lie entirely within this region. Melt rates are found to be a linear function of water temperature, because the feedback whereby higher temperature produces higher melting that leads to greater buoyancy forcing is, by definition, negligible. However, melting is also a function of the initial freshwater flux to the power of one third. This means that an order of magnitude increase in sub-glacial discharge leads to a doubling of the melt rate.

These findings have some important implications. For many tidewater glaciers the seasonal cycle in sub-glacial drainage may have a bigger impact than seasonal change in the ocean temperature on the seasonal cycle of melting at the glacier terminus. Increases in summer melting, driven by a warming atmosphere, will lead to increases in melting at the terminus, independent of any increase in ocean temperature. Drainage of a sub-glacial lake across a grounding line will lead to a temporary increase in the melt rate at and downstream of the grounding line of an ice shelf. Such processes could conceivably have played a role in recent changes that have been observed in outlet glaciers of the Greenland and Antarctic ice sheets. The combination of high seawater temperature and freshwater discharge can explain the exceptionally high melt rates (~10 m/day) reported by Motyka et al (2003) for LeConte Glacier, Alaska.

Motyka, R.J., L. Hunter, K.A. Echelmeyer and C. Connor. 2003. Submarine melting at the terminus of a temperate tidewater glacier, LeConte Glacier, Alaska, U.S.A., Ann. Glaciol., 36, 57-65.