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Nonlinear Response of Iceberg Melting to Ocean Currents

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Icebergs discharged from the Greenland and Antarctic ice sheets constitute a combined annual mass flux of roughly 1800 km^3 to the ocean and as such they act as a significant distributed source of freshwater as they are carried away from their source regions and melt along their trajectories. Hence icebergs constitute an important component of the interaction between the ocean and ice shelves and tidewater glaciers. Icebergs calving into Greenlandic Fjords frequently experience strongly sheared flows over their draft, but the impact of this flow past the iceberg on the melt buoyant plumes generated along the iceberg sides is not fully captured by existing parameterizations. We present a series of novel laboratory experiments to determine the dependence of side submarine melt rates on a background flow. We show, for the first time, that two distinct regimes of melting exist depending on the melt plume behavior (side-attached or side-detached). These two regimes produce a nonlinear dependence of melt rate on velocity, and different distributions of meltwater in the water column. Iceberg meltwater may either be confined to a thin surface layer, when the melt plumes are side-attached, or mixed down to the iceberg draft, when the melt plumes are side-detached. In a two-layer vertically sheared flow the average flow speed in existing melt parameterizations gives an underestimate of the submarine melt rate, in part due to the nonlinearity of the dependence of melt rate on flow speed, but also because vertical shear in the velocity profile fundamentally changes the flow splitting around the ice block and consequently the velocity felt by the ice surface. Including this nonlinear velocity dependence in melting parameterizations applied to observed icebergs increases iceberg side melt in the attached regime, improving agreement with observations of iceberg submarine melt rates. We show that both attached and detached plume regimes are relevant to icebergs observed in a Greenland fjord.