Entrain or detrain? Flow from ice sheet melting in a stratified ocean

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Melting at submerged ice faces is a key driver of mass loss from the Greenland ice sheet, with implications for ice sheet discharge and sea level rise (Straneo and Cenedese, 2015). Fresh meltwater and subglacial discharge drive the flow of turbulent buoyant plumes along the submerged ice face, rising through an ocean that is often stratified. Models of meltwater plumes typically assume turbulent entrainment of mass into the rising boundary layer flow. However, contrasting laboratory experiments show that plumes in stratified environments can either entrain or detrain, with the respective plume mass flux either increasing due to turbulent mixing, or persistently decreasing due to peeling of fluid into the stratified background at a neutral density level. Wall plumes from both line sources or distributed sources are seen to either entrain or detrain depending on the slope and stratification, (for example see Baines, 2002, 2005; McConnochie and Kerr, 2016; Hogg et al., 2017; Bonnebaigt et al., 2018). However, there is currently no dynamical criterion for this transition that is consistent across all experiments.

The goal of this project is to build understanding of when wall plumes entrain and when they detrain, via a careful combination of laboratory experiments and theory. The results will provide valuable dynamical insight into the buoyant plume flows that control turbulent ocean heat transfer and melting at submerged ice faces in Greenland fjords.

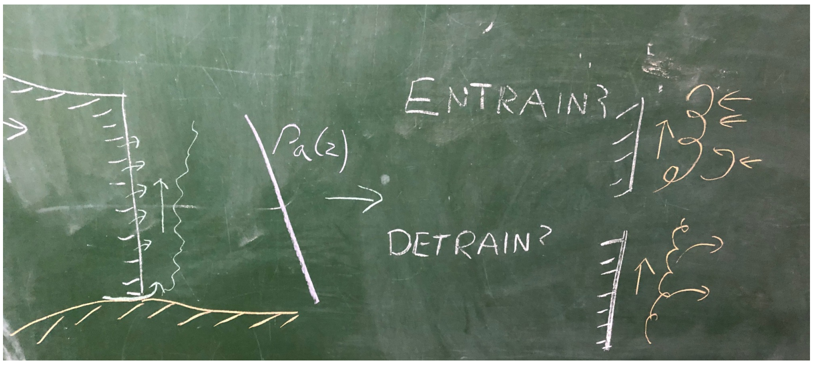

Figure 1: Sketch of a buoyant meltwater plume rising along a glacier calving face. In a stratified fluid, the plume can either entrain or detrain.

Modus operandi: This project has an experimental focus. We will first investigate a plume from a buoyant line source (emulating pure subglacial discharge) flowing along a sloping boundary in a stratified ambient, considering a range of source fluxes and slopes, with the option to vary stratification if interesting. The next step will consider the corresponding plume at a melting ice face (which provides an added distributed buoyancy source). The aim is to identify a regime diagram of entraining and detraining states as parameters are varied, and explore scaling/theoretical arguments to understand the resulting dynamical transition.

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