Shocking mixing in meltwater plumes under ice shelves

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Much of the discharge of the Antarctic ice sheet occurs through floating ice shelves, with ocean-driven melting of ice shelves impacting ice sheet flow and sea level rise. Melting at the base of an ice shelf generates a buoyant plume or gravity current, which rises along slope, confined from above by the ice-shelf basal topography (Payne et al., 2007). Recent observations have revealed complex topography at the base of ice shelves (Fig. 1c-d), with significant local variations in ice shelf slope. Such changes to the basal slope suggests the potential to form hydraulic jumps (i.e. shocks) in the buoyant meltwater flow, as a result of rapidly accelerated flow in regions of steeper slope subsequently running into slower flow on adjacent shallow slopes (Fig 1a). Hydraulic jumps would locally enhance turbulent mixing and transfer of ocean heat towards the ice shelf to further enhance melting, and provide a feedback on the shape of the evolving ice-ocean boundary.

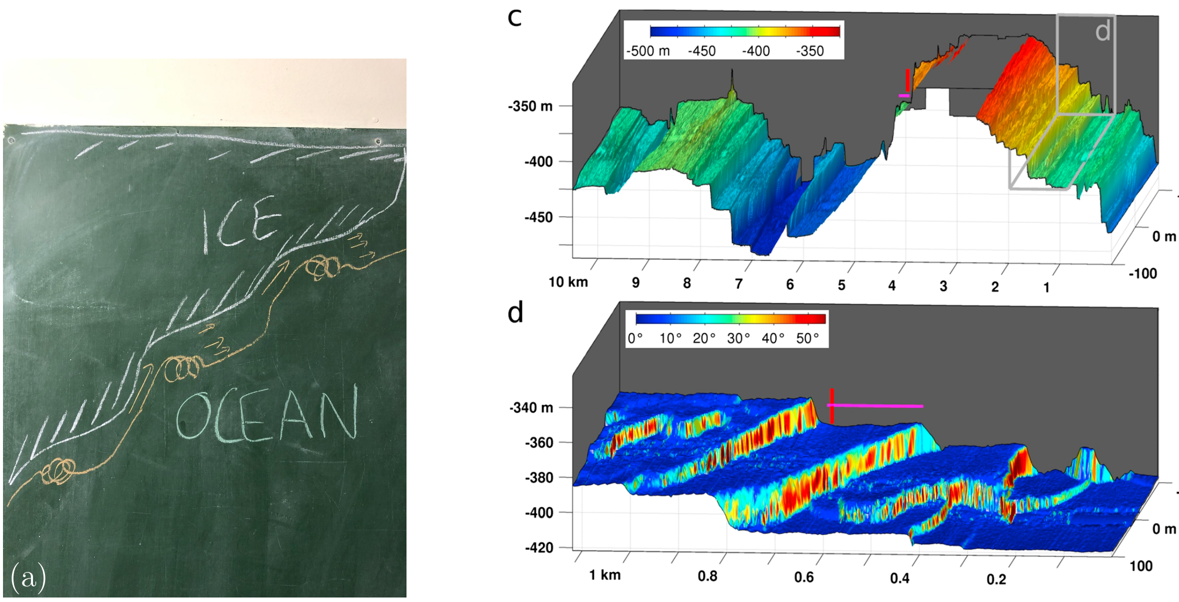

Figure 1: (a) Meltwater plumes under an ice shelf with variable topography. (c/d) Basal topography of sections of Pine Island Glacier ice shelf in Antarctica (Dutrieux et al., 2014). The colour scale shows basal draft in (c), and angle of the basal slope in (d).

Motivated by the close analogy to meltwater flows under ice shelves, **the goal of this project is to study how a buoyant gravity current evolves in response to a spatially variable basal slope. By varying the geometry of the boundary between experiments, we aim to understand (i) under what conditions do hydraulic jumps form, and (ii) what is the resulting impact on the magnitude of turbulent entrainment and mixing into the buoyant current.** The results will provide fundamental insight relevant to the mixing dynamics of meltwater plumes flowing under ice shelves, as well as ocean density currents and turbidity currents in the natural environment.

Modus operandi: This project has an experimental focus, with accompanying theoretical approach if desired. Laboratory experiments will consider gravity currents fed by a constant buoyancy flux, flowing along an adjustable bed with piecewise constant slope. On the theoretical side, models of gravity currents and meltwater plumes have a mathematical similarity with forced shallow water equations/compressible gas dynamics, allowing an exploration of hydraulic jump/shock formation using the method of characteristics for hyperbolic partial differential equations.

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