Morphological stability and melting of the ice-shelf—ocean boundary

Goal. The goal of the project is to improve our understanding of the melting of ice shelves (Fig. 1A), which oppose the discharge of Antarctic ice into the Southern Ocean, and, ultimately, sea-level rise.[1]

Context. Ice shelves are floating extensions of the ice caps in Antarctica and Greenland, which hold about 60 meters of sea-level rise equivalent. The thicker ice shelves are, the more resistance (called buttressing) they provide against the seaward flow of continental ice sheets. Observations have shown that ice shelves are thinning rapidly because of increased (basal) melting at the ice-ocean boundary.[1] Predictions of basal melting remain plagued with large uncertainties, however, because of limited knowledge of the physical processes within the turbulent ice-ocean boundary layer controlling phase changes.[2] Thus, accurate knowledge of the melting rate of ice-ocean interfaces at present and under warming conditions is required to reliably predict ice shelf thinning and sea-level rise, which is one of the most severe consequence of climate change.

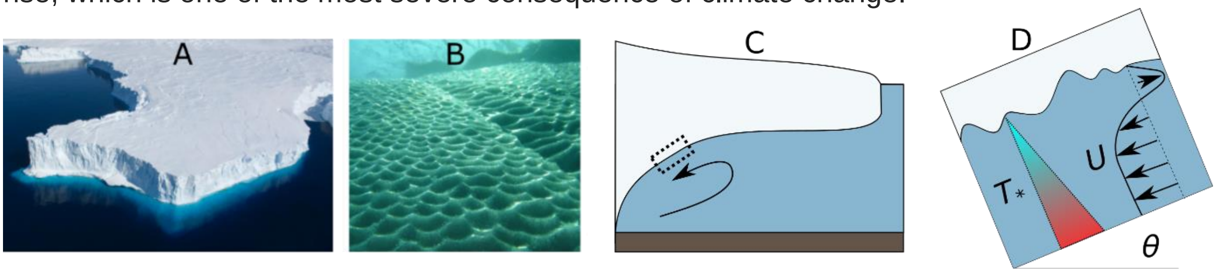

Figure 1: A. Antarctic ice shelf. B. Scallops on ice boundaries as observed in the field and laboratory experiments. C. Side view of an ice shelf. D. Zoom-in on the boundary-layer ocean flow interacting with an ice layer of interest to the project.

Proposed work. This PhD project will identify how ocean properties (particularly, free-stream ocean current U and thermal driving T_*), mean slope and basal topography influence the mean melting rate $\dot{m}$ of ice-ocean interfaces. The innovative nature of the work comes from the fact that the project will resolve explicitly phase changes (melting and freezing), which can be heterogeneous and lead to the emergence of topographical features (Fig. 1B) that can significantly modify the mean melting rates. We will focus on relatively-small critical regions of the boundary-layer flow beneath ice shelves (Fig. 1C,D). The complexity of the work will increase throughout the course of the PhD. We will first consider the morphological stability of the ice boundary in laminar conditions, before turning our attention to the fully coupled problem of a turbulent boundary-layer flow interacting with a freely evolving (through phase changes) ice interface. We will use a state-of-the-art open-source code (Dedalus, which is pseudo-spectral; dedalus-project.org),[3] combined with the domain-remapping or phase-field method to resolve the two-phase dynamics.[4]

Impact. The project will make progress on the fundamental physics of turbulent fluid-solid interactions and morphogenesis. It will also lay the foundation for designing a physically based universal parametrization of ice melting in climate models and pave the way for the development of an optimized code dedicated to ice-ocean interactions.

References.

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[3] Burns, Vasil, Oishi, Lecoanet, and Brown, Phys. Rev. Res. **2**, 23068 (2020).
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Contact.

Louis-Alexandre Couston, Laboratoire de Physique de l'ENS de Lyon, France.
louis.couston[…AT…]ens-lyon.fr

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