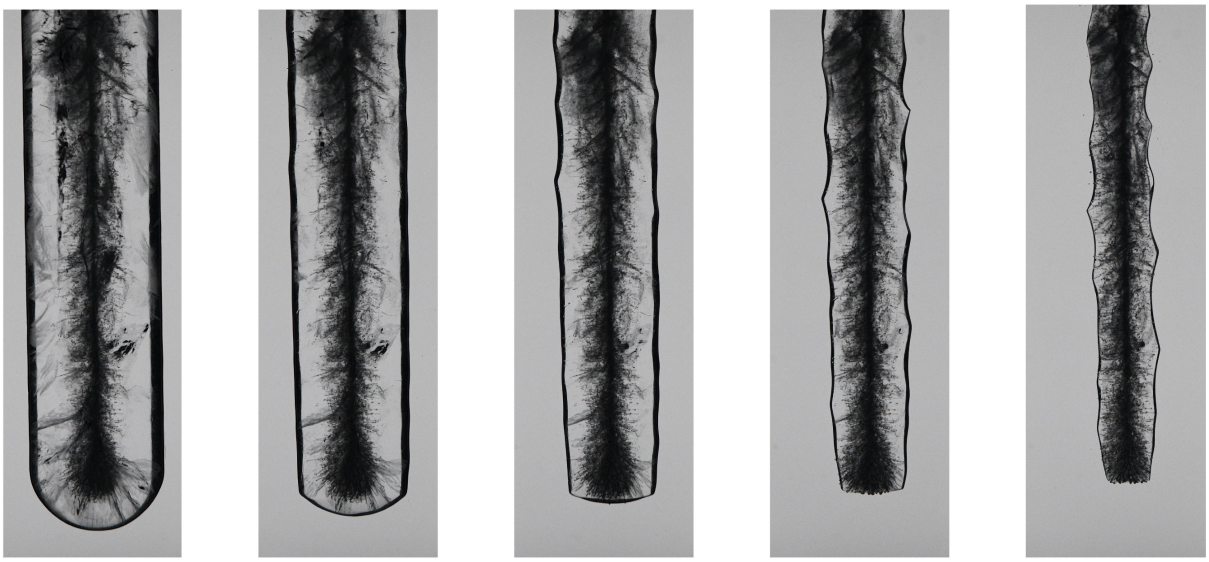
Chair: Physics of Fluids group

Ice sculpting for physicists

Description

In recent years, an academic interest in the morphology of an ice surface has sparked [1–3], as its relation to the melt rate could offer a better understanding of the physical mechanisms behind melting ice caps, yet ice morphology is often neglected in ice-ocean models.

A specific example of the formation of patterns on an ice surface, is that of the pattern sculpted in the side of a melting ice cylinder in salt water, shown in Fig. 1. In this case, a shear instability occurs between the fresh meltwater (less dense, so flows up) and the salty ambient water that is cooled by the ice (more dense, so flows down), carving a pattern into the ice surface. While the setup is relatively straightforward, many questions remain unanswered on this topic: Why does the pattern reach the observed length scale? How does this roughness affect the melt rate? Does the pattern develop towards a stable equilibrium?



(a) $t = 0$ min. (b) $t = 5$ min. (c) $t = 10$ min. (d) $t = 15$ min. (e) $t = 20$ min.

Figure 1: Pattern formation on a vertical ice cylinder in salt water over time. The labels indicate the elapsed time after the start of melting in minutes and the initial diameter of the cylinder is 5 cm.

Assignment

This assignment will involve making your own silicone mold using a 3D printer for freezing the ice objects. This mold will contain a specific pattern, similar to that in Fig. 1e, such that we can investigate how this pattern evolves over time and which patterns cause the ice to melt the fastest. A typical experiment will then involve taking photographs of the melting ice and extracting the ice-water boundary using image processing. During this assignment, you will learn how to prepare and perform your own experiments, how to use image processing techniques to analyse your data and how to write a great thesis on this highly relevant topic.

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References

[1] Pierre Dutrieux, Craig Stewart, Adrian Jenkins, K. Nicholls, Hugh Corr, E. Rignot, and Konrad Steffen. Basal terraces on melting ice shelves. *Geophysical Research Letters*, 41, 08 2014.

[2] Mitchell Bushuk, David M. Holland, Timothy P. Stanton, Alon Stern, and Callum Gray. Ice scallops: A laboratory investigation of the ice–water interface. *Journal of Fluid Mechanics*, 873:942—-976, 2019.

[3] Scott Weady, Joshua Tong, Alexandra Zidovska, and Leif Ristroph. Anomalous convective flows carve pinnacles and scallops in melting ice. *Phys. Rev. Lett.*, 128:044502, Jan 2022.