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Ice melting in oscillatory flow

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Predicting accurately the melting rate of icebergs is critical to assess its impact on climate change[1]. It has been reported that the short time scale variability of ice bodies melting in nature is mainly due to the effect of ocean currents, and indeed melting rates have been observed to be modulated by tidal currents[2]. However, in many ice models the effect of tides is omitted: not only to reduce the computational complexity, but also because it involves using parameterizations whose results vary drastically depending on the assumptions made, such as entrainment coefficients and ice geometry[3].

We take a simplified approach to studying the effect that a time dependent flow has on melting, with the goal of understanding how the fundamental physical mechanisms involved contribute to the dynamics. Using two-dimensional direct numerical simulations, and modelling the phase transition with the phase field method, we consider an initially circular ice object of diameter D that melts while immersed in fresh water initially at $T_0 = 20°\mathrm{C}$ in the presence of an oscillatory flow. For simplicity, and focusing only on the effect of the forced convection, we neglect buoyancy effects, and consider a time-dependent inflow given by $U_0 \cos(2\pi f t)$, as depicted in Figure 1. We explore Reynolds numbers $\mathrm{Re} = U_0 D/\nu$ of up to 10^3, and vary the frequency of the inflow, using the melting time in the presence of a uniform flow as a reference time scale. We explore how the melting time is modified when compared to the case of a constant, unidirectional flow. We also investigate the changes in the ice morphology due to the oscillations, and how these are linked to modifications in the melting times.

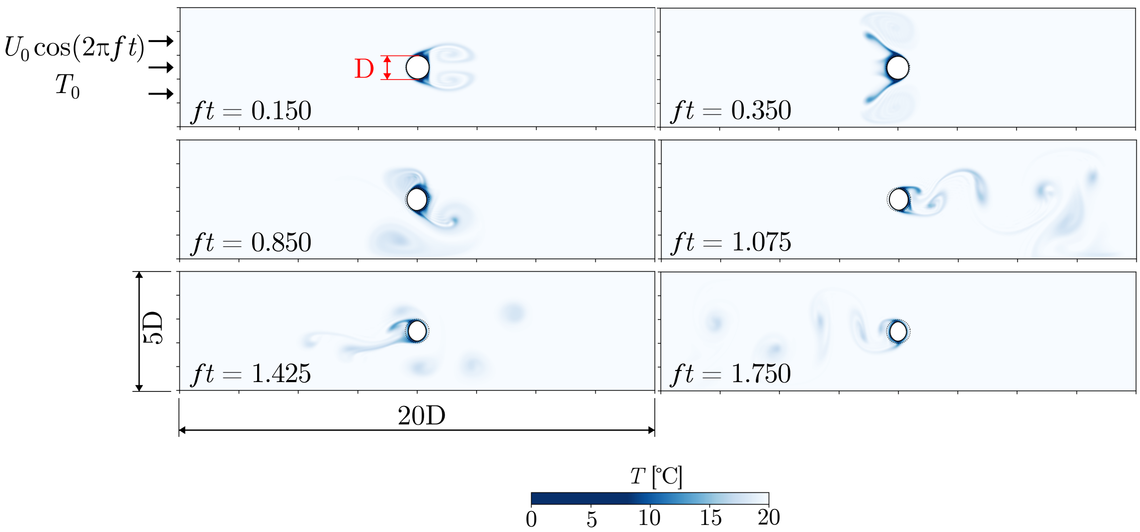

Figure 1: Instantaneous snapshots of the temperature field in the liquid, where light and dark colours indicates warm and cold, respectively. The initial circular contour of the ice is shown in all panels in dotted black lines. The temperature inside the ice is depicted in white for clarity.

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