

## THE RIPPLING INSTABILITY OF ICICLES

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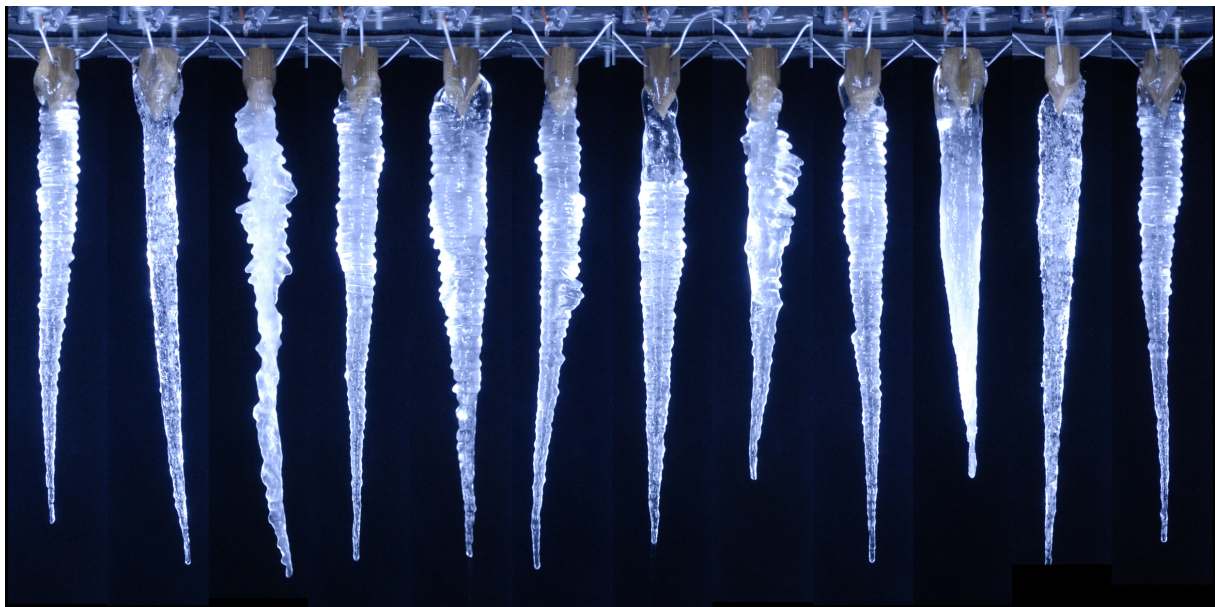
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*Key words* ice, solidification, instability, hydrodynamics, geomorphology.

Iceicles are a common ice formation, familiar to anyone who lives in a cold climate. The shape of an icicle emerges from a delicate dance between solidification, hydrodynamics and heat transport. Many, but not all, natural icicles are observed to be decorated around their circumference by ribs or ripples [1]. These features are presumed to be the result of a morphological instability in the growth process of the ice. The sides of an icicle are covered by a thin supercooled water film which flows down their nearly vertical surface. The wavelength of the ripples, which is always found to be near 1 cm, is surprisingly constant, even under diverse growing conditions. A recent detailed study in which hundreds of icicles were grown in controlled laboratory experiments [2] revealed that trace amounts of impurities are required for the formation of the ripples. Icicles grown from distilled water have no ripples. Ripples appear at a remarkably low concentration of impurity, becoming measurable above a concentration of just  $10^{-3}$  weight % of salt. Thereafter, they grow at a rate which is roughly logarithmic in the concentration of the impurity. These effects are not explained by linear stability theory [3 - 7], which does not account for impurities.

In this paper, we will discuss our recent experiments in which the concentration and molecular species of the impurity were varied, as well as our progress toward a generalized linear stability analysis of the growing ice surface, which includes the effects of impurities.



**Figure 1.** A selection of laboratory grown icicles with various morphologies. All of the data from this experiment is available online in the **Icicle Atlas**, [http://www.physics.utoronto.ca/Icicle\\_Atlas](http://www.physics.utoronto.ca/Icicle_Atlas).

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