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Rivulets and ripples: experiments on how dynamic wetting affects icicle growth

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The morphology of ice formed under flowing liquid water is a challenging free-boundary problem. A common case in nature is the formation of icicles, which grow as liquid water flows down the surface, freezing as it descends. Theories of icicle growth have always assumed a thin liquid coat over the entire icicle's surface. These theories predict the growth in length and mean diameter well, but have so far failed to explain how ripples form. The ripples that commonly wrap around icicles have been observed to be solely dependent on the presence of impurities in the source water in concentrations as low as 20ppm NaCl.

We present experimental observations of the flow and wetting behaviour of water on actively growing icicles using a fluorescent dye. Sodium fluorescein acts as both an indicator of liquid and instability triggering impurity. The water does not coat the entire icicle. Rather it descends in rivulets leaving trails of water or adding to liquid reservoirs already on the surface. The patches of water left on the surface are larger for higher concentrations and are distributed to match the ripples that form.

The wetting behaviour is affected by the ice's texture, surface chemistry, and topography. We examined these effects by growing icicles on of cylinders of ice to isolate these effects. While ripples began to form on roughened and salt-doped ice, they only wrapped around the icicle to form a rib at a hard edge or near the tip. In those locations the water spreads over the entire circumference, which may encourage the ripple pattern to wrap around the icicle. This incomplete coverage appears to affect the morphology of the growing icicle and may be an important component of the mechanism of ripple formation.

The presence of impurities appears to trigger a feed-back between the water distribution and the ice properties: the impurities
cause variations in texture, chemistry and shape, which in turn attracts more water to those locations, providing more material to freeze.

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