Water impurities key to an icicle's ripples

October 9 2013

This is a natural ripply icicle, collected to measure water composition. Credit: Stephen Morris

A group of physicists from Canada have been growing their own icicles in a lab in the hope of solving a mystery that has, up until now, continued

to puzzle scientists.

The presence of characteristic ripples along the surface of icicles, which remarkably have the same wavelength no matter how big the icicle or where in the world it grows, have led to several studies examining exactly how the ripples form.

In a new study published today, 10 October, in the Institute of Physics and German Physical Society's *New Journal of Physics*, the researchers, from the University of Toronto, have proposed that small impurities in the water may be a critical factor in the process.

An analysis of 67 icicles, grown under carefully controlled conditions in a refrigerated box, showed that icicles grown using pure distilled water exhibited no ripples, but those grown from water with salt impurities did have the characteristic ripples.

Furthermore, the ripples grew at a much faster pace, and therefore reached higher amplitudes, when there was a higher concentration of salt in the water. The overall shape of the icicle also became more distorted.

While the research has been motivated purely by the curiosity about patterns in nature, it is possible that a deeper understanding of the formation of icicles may have real world applications, specifically in engineering.

Lead author of the research, Professor Stephen Morris, said: "Ice build-up on structures during freezing rain events is a serious hazard. Power lines, ships, bridges and airplanes must all be protected from, and designed to withstand, ice accumulation. In most engineering applications, only the total amount of ice really matters, not its precise shape. We are interested in the shape, which is much less understood."

There are currently two general theories of why ripples form on icicles, the first of which attributes the formation to the way that heat is removed on the peak of a ripple. It is believed that water freezes more quickly on the peaks because heat is removed quicker from these areas; therefore, any small defect on the icicle can cause ice to build up more quickly in these regions and trigger the formation of ripples.

An alternate theory puts the ripples down to surface tension between the freezing water as it flows in a thin layer over the icicle and the surrounding air – if the surface tension is high, it is predicted that the ripples will grow at a slower pace and reach lower amplitudes.

In their experiments, the researchers carefully controlled the temperature, the flow rate of the water, the composition of the air and the state of its flow around the icicle. The icicles were grown from a wooden support which rotated within the refrigerated box so that the icicles grew evenly and could be imaged from all sides with a camera.

Icicles were grown from pure distilled water, which was then contaminated separately with salt and a surfactant. The researchers also collected melting water from natural icicles on a nearby roof in Toronto and performed a chemical analysis to see if it was sufficiently impure to account for natural ripples – the results showed that it was.

Whilst the presence of salt encouraged the formation of ripples, the researchers also found that the presence of the surfactant, which lowered the surface tension of the water, did not increase the growth rate of ripples, which contradicts one of the previous theories.

"Existing theories of how icicle ripples form have been supported by very few observations of natural or lab-grown icicles. We have performed a really controlled and complete study of icicles ripples that has never been done before.

"Our results have provided strong empirical evidence, but as of yet we don't have a theoretical explanation as to why the impurities have this effect. Neither do we have a theory for why the ripples have a universal wavelength – this still remains a central mystery," continued Professor Morris.

More information: "On the origin and evolution of icicle ripples" Chen et al 2013 *New J. Phys.* 15 103012. iopscience.iop.org/1367-2630/15/10/103012/article

Provided by Institute of Physics