Ice's Watery Surface Comes Into View

In the winter, a patch of ice can mean the downfall of a careless pedestrian. A figure skater, however, takes advantage of that same slipperiness to glide and spin. Now, some of the first molecular-scale images of its surface may help explain just why ice is so slick.

The images, taken by researchers at the Lawrence Berkeley (Calif.) National Laboratory, suggest that water molecules on the surface of ice vibrate faster than expected, forming a quasiliquid layer even at temperatures well below freezing. This mobile surface may not only explain how skating and skiing are possible but may also provide insight into a key step of the ozone depletion process in the upper atmosphere. Michel Van Hove and his colleagues will publish their work in an upcoming issue of SURFACE SCIENCE.

A pervasive myth, Van Hove says, is that ice is slippery because pressure causes melting: A skater's weight acting through a thin blade supposedly thaws ice to form a film of water, reducing friction. Experimental evidence hasn't supported that theory (SN: 10/21/95, p. 268). "There's not enough weight on the skate to make the surface of ice liquefy," Van Hove says.

He and his colleagues took images of a thin film of ice deposited on platinum. At -183°C, about half of the outermost surface molecules were essentially invisible to the technique they used, low-energy electron diffraction.

The researchers contend that those molecules go undetected because they are undergoing large vibrations, while staying bound to the surface. These moving molecules form a layer whose structure is intermediate to those of solids and of liquids. If the surface is amorphous at so low a temperature, the researchers argue, then it should become more liquid at higher temperatures.

Van Hove/SCIENCE

A computer-generated model of the structure of ice. Layer 1 is vibrating faster than Layer 2, the inner surface layer, and the deeper layers. The large spheres represent complete water molecules. The hydrogen atoms (small spheres) are not shown attached to the oxygen atoms (medium spheres) in Layers 3 and 4.

The scientists had to work at very low temperatures to prevent evaporation. Unlike the atoms in a metal or semiconductor, water molecules are bound very loosely in solid ice, so that even at -100°C, "you start to lose one layer of water molecules per second," says Steve George of the University of Colorado at Boulder.

From Van Hove's work, it's difficult to draw conclusions about the surface of ice at higher temperatures, such as those of an ice rink or even of the stratosphere, George says.

In the stratosphere, where temperatures hover around -90°C, tiny ice crystals catalyze the conversion of chlorine molecules into a form that breaks down ozone. A layer of liquid, rather than solid, water molecules on the crystal surface would be "more flexible for attacking incoming molecules and decomposing them," Van Hove says.

Indirect experiments have shown that chlorine molecules get into the surface, suggesting that the surface is disordered but not quite a liquid, says Mario J. Molina of the Massachusetts Institute of Technology.

George says, "The most important thing about the Berkeley work is that it shows how the surface of a molecular solid can be very different from a surface of a metal or semiconductor. There haven't been many experimental confirmations of that." —*C. Wu*

Spacecraft spies hills and valleys of sun

To the ancient Greeks, the sun represented perfection—a notion finally put to rest by Galileo's discovery of sunspots in 1611. However, anyone still looking to Sol for some constancy may be pleased by new findings indicating that a rigid, regular landscape adorns the boiling surface of Earth's star.

"It's pretty surprising. We see hills and valleys," says Jeffrey R. Kuhn of the National Solar Observatory in Tucson, who discussed his group's discovery at last month's meeting of the American Geophysical Union in San Francisco.

Using the Michelson Doppler Imager aboard the Solar and Heliospheric Observatory (SOHO) spacecraft, the researchers measured motions of gases at the sun's edge to within an accuracy of 3 meters (SN: 5/4/96, p. 277). Kuhn compares this resolution to an Earth-bound observer spotting a quarter on the moon. SOHO rests in an orbit where the gravitational force between Earth and the sun is equal.

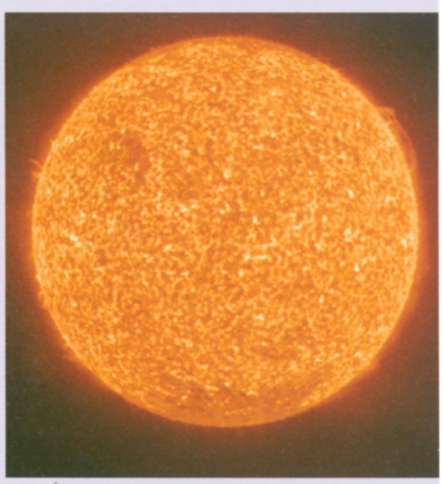
By observing the sun as it rotates, Kuhn and his colleagues built up a picture of its entire surface. They saw bumps of bright gas fixed in place on the bubbling outer layer of solar gas. The hills of superheated gas measure 40,000 kilometers across but only half a kilometer high. "They are, more or less, rotating in unison [with the sun]," says Kuhn.

The astronomers believe that fixed magnetic fields inside the sun guide heated gases from the interior to the surface where they continually renew the hills. In the 7 months of SOHO's operation, the solar landscape has changed little, Kuhn reports.

"It looks like a dimpled golf ball," says Juri Toomre of the University of Colorado at Boulder, who calls the finding part of a renaissance of discovery that has recently been reshaping helioseismography (SN: 8/31/96, p. 136).

By tracking the motion of powerful sound waves through the sun, the researchers hope to discover the source of its magnetic fields, sunspots, and 11-year sunspot cycle. "We're at the high-adventure stage of the field," says Toomre.

Despite its dimples, the sun can still stake a claim to excellence. According to Kuhn, it is a perfect orb to within 0.001 percent tolerance, orders of magnitude more spherical than Earth. —*D. Vergano*



SOHO/NASA

The sun—a place of surprisingly regular geography—as seen by SOHO.