METER
ENVIRONMENT

UNDERSTANDING AVALANCHES: THERMAL CONDUCTIVITY OF SNOW

When Wired Magazine wrote up Dr. Ed Adams and his colleagues, they didn't refer to them as a team of civil engineers studying granular mechanics. Instead, they named them one of seven teams of "Mad Scientists" and called them "Snow Bombers."
It's not hard to find articles about Montana State University's avalanche studies program. Just describing a typical field study makes for a good story: to investigate real-world avalanche conditions, MSU researchers sit in an outhouse-sized shack bolted to the side of a mountain while colleagues trigger an avalanche up-slope.

But this isn't just a story about explosions and extreme sports. At its heart, it's a story about the microstructure of a very fascinating and difficult material. Rich Shertzer, who finished a PhD in the program at Montana State, thinks snow may be unique among natural materials because "the thermal environment it's exposed to every day can cause pretty remarkable changes in its microstructure." A cold, sunny day in the mountains can cause significant changes in snow crystals. It can change their size and shape, but more significantly it can cause a directional orientation in snow layers.

It's long been empirically understood that avalanches tend to form above "weak layers" of snow. Shertzer and his colleagues are studying how the orientation of snow crystals correlates with weak layers. Most models of granular mechanics assume that the material's microstructure is randomly arranged. However, snow layers seem to show a regular arrangement.

As Shertzer explains, "Qualitatively, people have known for a while that when you look at certain snow layers, chains of these ice grains seem to be forming. What I was trying to mathematically model is how that might affect the material properties [of snow], including thermal properties."

In order to study the thermal properties of snow samples, the research team wanted a way to measure thermal conductivity in three directions. That ruled out flux plates. Thermal probes were an obvious alternative, but they brought a different set of challenges. Snow has a very low thermal conductivity, and as Shertzer explains, "if you add a lot of thermal energy to snow, since it's very insulative, you'll tend to raise the temperature. Not only do we want to avoid melting the snow in the neighborhood of the probe, but we want to prevent the probe from artificially inducing the same thermal processes we're measuring—the ones that cause the crystals to change size, and shape, and orientation."

Shertzer read an article about measuring thermal conductivity in liquids, where if you add too much heat, you induce convection. "Our situation is similar to that," he explains. "Heating the needle induces local phase change." The article gave him some ideas about delivering low levels of heat for a relatively long period of time, and he contacted METER to see if that option was a possibility.

TEMPOS thermal properties analyzer

Unbeknownst to him, METER's research scientists had just completed a year-long project focused on reducing the contact resistance errors that occur when using the large TR1 (now TR3) needle in METER's thermal properties analyzer to measure thermal conductivity in large-grained samples. This made the TR1 needle a good candidate for measuring thermal conductivity in snow. The scientists were excited about modifying the thermal properties analyzer firmware to produce a low-power version that would work in snow. The resulting modification has given Shertzer some good data.

"I can definitely say that the anisotropy is there [in the snow samples]. It's measurable and it's significant. As the crystals reorient in these depth hoar like chains, the ice network is more conductive than the air in between. The orientation of the chains follows a direction of increased conductivity, and the directions that are perpendicular to the chains tend to decrease in conductivity. Qualitatively, it's always made sense, and we were just looking for a way to actually relate it to properties like conductivity. Using needles to measure in three different directions simultaneously has given us the ability to measure those properties like conductivity. We expect that this orientation also affects other properties like strength and stiffness.”

Thermal conductivity studies may ultimately lead to a better understanding of the conditions that cause the snowpack to fracture and trigger an avalanche—and information that may help save lives among the growing number of people who ski and snowboard the backcountry.

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