INNER WORKINGS

Imaging permafrost

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Last October, when Susan Hubbard and her team pulled sleds full of sensitive sensors across the snow near the northernmost point in Alaska, temperatures hovered in the single digits and low teens (e.g., 8–15 °F). Foremost in the researchers' minds, aside from collecting data on the frozen ground beneath their feet, were two things: keep an eye out for polar bears and keep their equipment from freezing. Hubbard, an earth scientist at Lawrence Berkeley National Laboratory, had hired a polar bear guard to deal with the first problem and perfected the art of wrapping pieces of equipment up and periodically warming them in heated huts to deal with the second.

Hubbard and her colleagues trek to the same plot of land in Alaska throughout the year to follow changes to the permafrost, which is soil that is permanently frozen hundreds of meters into the ground. Only the active layer, a thin layer on the surface of permafrost, thaws and freezes depending on the season, providing an ever-changing habitat for microbes that degrade soil organic matter and in the process give off carbon dioxide. Researchers like Hubbard want to understand what dictates the physical features of permafrost (such as cracks in the soil and polygons of ice across wide swathes of land), how the permafrost affects the overlying active layer, and how climate change will influence the trajectory of the permafrost system, which currently covers an estimated 24% of the land in the Northern hemisphere (1).

In the past, researchers have pieced together data from a number of sources to obtain measurements on the thickness and temperature of the permafrost and its active layer and the way water flows in the landscape. Many researchers turn to data collected by an airborne laser, some drill into the soil and remove cylindrical cores to study, and others use handheld devices that measure the electrical conductance of the ground or collect ground penetrating radar data along the surface.

Susan Hubbard tugs a ground-penetrating radar device attached to skis across the Arctic permafrost to get measurements of the frozen ground below. Image courtesy of Susan Hubbard.

"People have tried all these methods, in one form or another," says Hubbard. "But the real beauty of our approach is that we're using these all together in one place, at very high resolution and over time, which is allowing us to study the interactions between land surface, active layer, and permafrost variations."

Each member of Hubbard's team spearheads a different piece of the data collection—from laying out cables and inserting electrodes into the ground, to walking or pulling by snowmobile an electromagnetic sensor back and forth across the plot, to collecting ground-penetrating radar data. Team members not only want to get the most complete dataset possible on their plot of Arctic tundra, but want to know how different measurements stack up against each other and how different aspects of the permafrost influence one another.

"By using all these geophysical methods, we're getting a window into this pretty complex subsurface Arctic permafrost environment," says Hubbard.

Already, the researchers discovered that the shapes of ice polygons on the ground, which can be characterized from the air, are correlated with subsurface properties important for microbial activity (2). The subsurface beneath regions having low-centered polygons, one particular shape, were wetter, warmer, and had a thicker active layer than regions beneath high-centered polygons. The team's detailed studies have revealed an entirely new section of the permafrost active layer—a deep, possibly saline layer that may have a lower freezing point than the rest of the active layer, allowing microbes to survive all winter. They'll return to the Arctic this year to drill into this deeper layer to test their interpretation. The challenging environment has taught them practical lessons too, of course. "I've learned to watch for that blinking low battery light," Hubbard says. "Batteries die very quickly up there."

1 Zhang T, et al. (1999) Statistics and characteristics of permafrost and ground ice distribution in the Northern Hemisphere. *Polar Geography* 29(2):132–154.
2 Hubbard SS, et al. (2013) Quantifying and relating land-surface and subsurface variability in permafrost environments using LiDAR and surface geophysical datasets. *Hydrogeol J* 21(1):149–169.