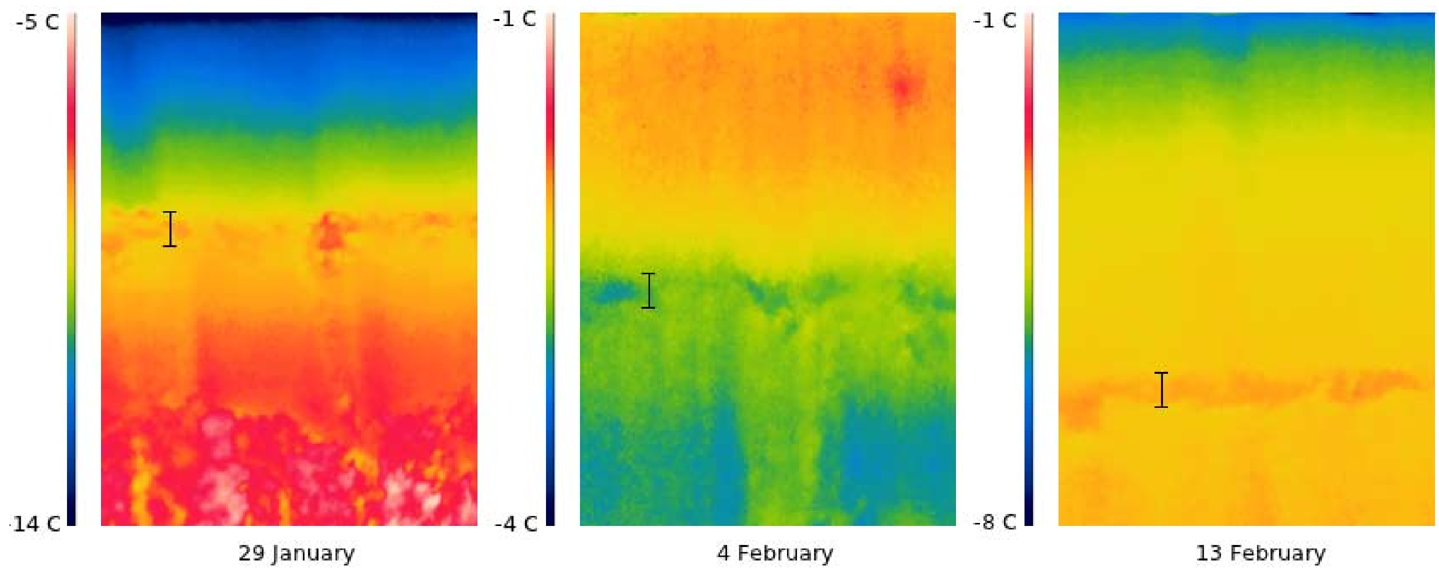

Figure 1: The relative temperature of the crust changed from day to day over the season. The crust is marked by the black line in each image; it is about 1cm thick. Each image has the snow surface at the very top. On January 29, the crust was warmer than the snow above and below. On February 4 it was cooler than the snow above and below. And, on February 13, the gradients reversed again when the crust became relatively warm. The absolute temperature of the crust followed that of the snowpack – on cold days the crust was colder than on warm days, just like the rest of the snow.

Hot Crust, Cold Crust

Story by Cora Shea, Bruce Jamieson, and Karl Birkeland

For this crust issue of *The Avalanche Review*, we thought you might be interested in our study from the Canadian Rocky Mountains.

This past winter, we tracked a crust in a very shallow snowpack of less than 70cm. We looked at the temperatures in and around the crust by using a thermal imager. With a thermal imager, we could measure the amount of heat coming from a pit wall on a very fine scale. This allowed us to measure temperature gradients across snow layers as small as a few millimeters.

In the case of the crust, we expected it to be buried with a certain amount of heat. We also expected that this heat would then dissipate over time and grow facets.

However, that is not what happened. Instead, we saw the relative temperature of the crust – warmer or cooler than the adjacent snow – go back and forth over the season. You can see an example of this in Figure 1. And, when we looked at the temperatures around the crust every hour over a single day, we saw the relative crust temperature reverse within hours.

So, our data show that crusts undergo much more complex temperature changes than we originally thought. We believe this hot crust, cold crust effect may have been from temperature gradients across the entire snowpack. At some times, the crust may have had good conduction through the ice matrix alone. But at other times, the gradient from ground to surface may have exceeded the ability of the ice to conduct, and so forced more heat transport via vapor through the pores. This would bring heat – latent heat – to the crust as the vapor crossed the pores and deposited.

The depositing vapor would then also do other things, like form facets. This may explain why facets tend to grow at the top and bottom of a crust – these areas may be gaps in ice conduction, and thus more dependent on water vapor motion for transport of heat.

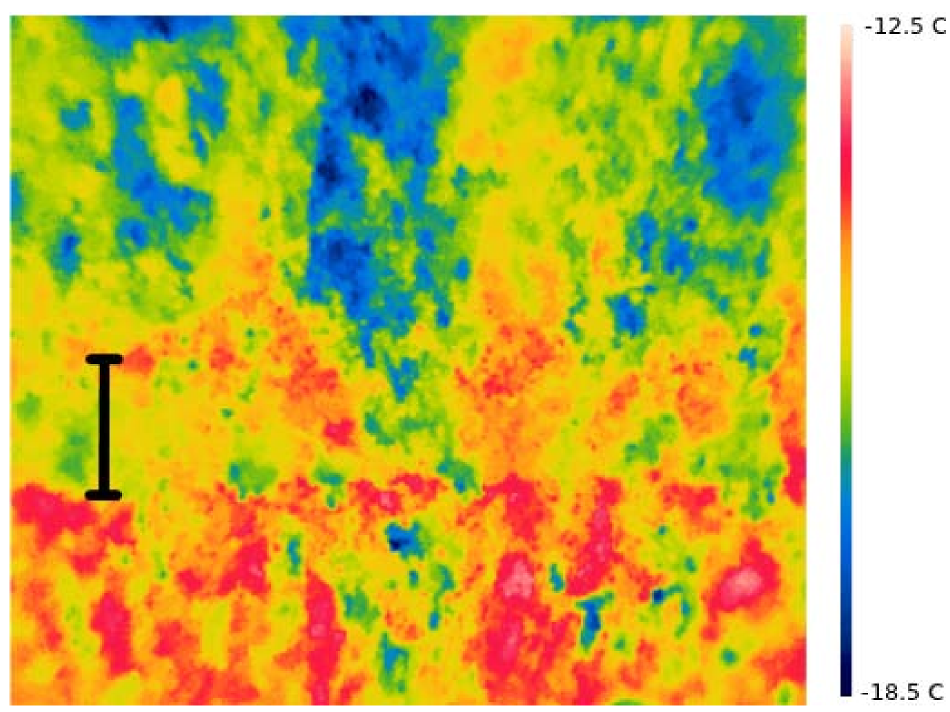

Figure 2: The black line shows where the crust is located on this small area on a snowpit wall. The crust is about 1cm thick. On average, the crust is warmer than the snow immediately above and below, but this is certainly not obvious. And, the complex structure of the temperature gradients might play a larger role than just relative warmth or coldness.

This appears to be a very complex process at the crystal scale. Figure 2 shows a close-up thermal image of a crust in a snowpit wall. The crust does not have a simple temperature gradient across it or within it. Yet despite their complexity, the end result of the strong gradients seems to be what we expect – we often saw facet growth around the crust as a result of the gradients.

We also observed the case of crusts being warmer than the surrounding snow in a deeper snowpack with old crusts. Figure 3 shows a spring snowpack from Silverton, Colorado. The snowpack has many crusts, and all of them are thermally distinct from the snow above and below them. Many thanks to HP Marshall and Andy Gleason for organizing a great Geek Week to visit this snowpack.

Still, we do not have many direct answers. We do not know whether this type of pore-space heat transport always grows a specific type of crystal – like facets – or not. If it grows facets only sometimes, we do not yet know how to recognize the temperature gradients for other types of growth. However, we hope to learn this during the current season.

It seems that the Martin Luther King Day crust of 2011 was especially complex. In some areas, two rain events bordered a snow event, which may have made a very complex set of layers for heat to conduct through. The thermal camera might provide new ways to observe these complex snow layers. And, a new way of thinking about how they change with heat flow may help as well.

Conclusion

If you would like to learn more about using thermal imaging for snow studies, feel free to contact us or visit www.ucalgary.ca/asarc. We too are learning as we go, but we welcome ideas and discussion.

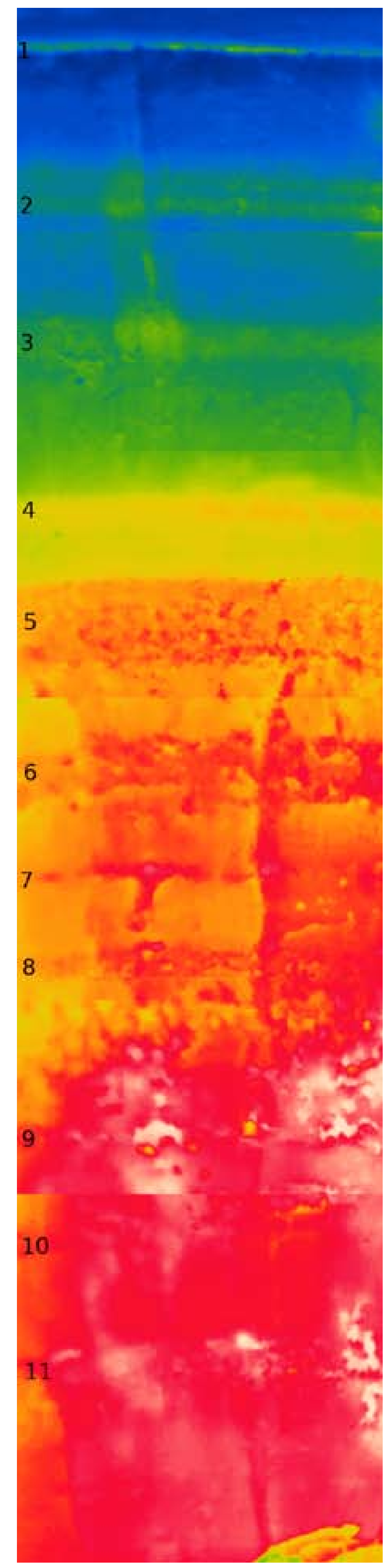

Figure 3: The snowpack above is about 1.5m in depth. Number 1 (upper left) is the snow surface. Numbers 2 through 11 are all individual crusts. Even these old, mature crusts are thermally distinct in March. These temperature gradients appeared on a cooler day with 8/8 clouds and snow.

Cora Shea finished her doctoral studies in geophysics at the University of Calgary this past October. Bruce Jamieson, Karl Birkeland, and Cora have joined in for another thermal investigation season in the Rockies, hoping for interesting layers to study and yet lots of safe skiing. ❄

Ice Crust Reminiscing
from Ron Perla

LaChapelle told me the most unstable condition he ever saw at Alta was the 1963 cycle that ran on a buried ice crust. One artillery hit and fracture lines propagated from gulch to gulch, canyon to canyon, Ray Lindquist said.

But I didn't see it since I was in SLC waiting for the road to open.

Ron Perla, December 9, 2011 ❄