Hot research/Cool science:

An investigation of permafrost in a changing alpine environment

By Cheri Yost and Jason Janke

DR. JASON JANKE WAS SILENT ON the phone. I thought perhaps he was already calculating his costs or planning his next research move. He confessed the next day that he was just in shock. He had never had anyone call and offer to fund his research. As a staff member of the Continental Divide Research Learning Center, I had worked with scores of researchers on projects in Rocky Mountain National Park. Never had I been able to call and offer funding.

The Research Learning Center had recently convened a meeting, attended by partner scientists, to synthesize the effects of climate change on the park's ecosystems. As Ben Bobowski, the park's chief of resource stewardship, noted, "We are left with more questions than answers." But attendees gave clear suggestions for future research and monitoring efforts. One recommended priority was to "conduct field investigations of permafrost and determine its relationship to vegetation communities." We had a small amount of money and a clear need. Dr. Janke's dissertation focused on modeling the extent of permafrost across northern Colorado. I called to ask if he could check the accuracy of that model for just $10,000. He accepted. Soon our simple project of mapping permafrost had transformed into a fruitful partnership that not only tackled practical scientific research but also benefited students, park staff, and the public in unexpected ways.

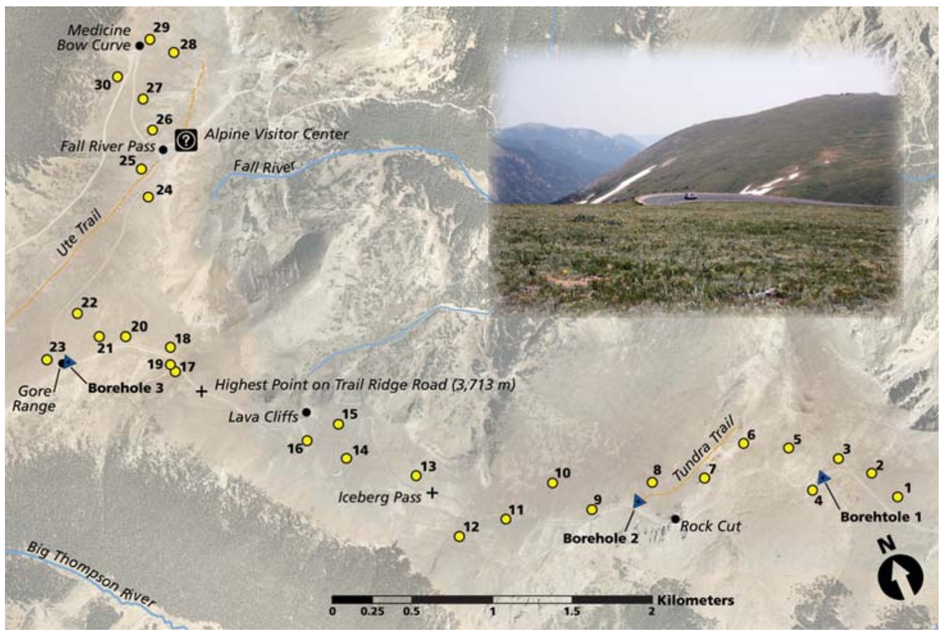

Figure 1. The map and photo of Trail Ridge Road show the 30 sites and the alpine tundra environment typical of the study area.

Monitoring permafrost temperatures

Permafrost is ground that remains at or below 0°C (32°F) for at least two consecutive years. Several researchers have modeled it using geographic information system (GIS) techniques in alpine areas of the world. For his 2005 dissertation at the University of Colorado–Boulder, Dr. Janke showed that a 2.0°–2.5°C (3.6°–4.5°F) temperature increase could dramatically reduce permafrost extent by about 95% in the Front Range of Colorado. After graduating, Dr. Janke landed a position at Metropolitan State College of Denver (now Metropolitan State University of Denver), a school that serves a diverse urban population and emphasizes undergraduate education. As an associate professor of earth and atmospheric sciences, Dr. Janke was committed to involving his students in hands-on field activities, so he quickly began considering how the park's permafrost project would integrate with his teaching.

Park managers were concerned about melting ice—both aboveground and belowground—as it relates to snowpack, ground ice, and water quality. Facility managers wondered about the stability of structures and road surfaces in the alpine tundra. The park also faces increased nitrogen deposition from anthropogenic sources, which might cause plants to increase their biomass. Initially this removes some carbon from the atmosphere, but in the long term the excess biomass will decompose, which could cause soils to lose more carbon to the atmosphere. Since a large portion of Trail Ridge Road crosses suspected permafrost, park managers wanted to know if warming would lead to more localized slumping, loss of soil cohesion from melted ice, and regional subsidence. Dr. Janke agreed to take direct temperature measurements of soil along Trail Ridge Road, to refine his map of permafrost, and to monitor long-term temperature change as an indicator of changing climate.

Dr. Janke, a select group of his students, and the park's Geoscientist-in-the-Parks intern used a hand auger to install temperature data loggers at 30 sites within a half mile of the road in 2008 (fig. 1). Each site

JASON JANKE, USED WITH PERMISSION

ANDREW EVANS, USED WITH PERMISSION

Figure 2. In 2008, students, a park intern, and Dr. Janke (in grey sweatshirt, at left in right photo) used a hand auger to install temperature data loggers at 30 locations along Trail Ridge Road.

BECKY BRICE, USED WITH PERMISSION

Figure 3. Dr. Janke and students returned to the sites to download data. For many students, this was their first trip to the park—and their first field experience with applied science.

had a near-surface and a deeper sensor. The first sensor recorded temperatures at 10 cm (4 in) depth and a second sensor made recordings at depths ranging from 30 cm (12 in) to 85 cm (33 in), basically as deep as the scientists could place the sensors using a hand auger (fig. 2). They set the loggers to record temperature at two-hour intervals. At each location they measured elevation, slope, and aspect; they also collected soil samples.

Back at the college, Dr. Janke's undergraduate soil classes analyzed the properties of the soil. They measured nutrient concentrations (nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur), conductivity (a measure of the soil's salt concentration), and pH. To determine a possible relationship between soil properties and ground temperature, the students measured bulk density (a measure of the mass of a soil including pore spaces in relation to its volume), particle density (a measure of the mass of just the soil particles in relation to the volume), and porosity (a measure of the void spaces in the soil). The analysis took two semesters to complete. Each of the following summers, Dr. Janke has taken additional students to the park to download the temperature data from the sensors (fig. 3).

Results and discussion

Dr. Janke and the students analyzed the data and concluded that along Trail Ridge Road, permafrost is likely to be dry, sporadic, and not as abundant as previously thought. However, they found that only 2 of the 30 sites had an average temperature greater than 0°C for the near-surface sensor. Elevation, aspect, and slope as well as the aforementioned soil properties all exhibited weak correlations with mean annual soil temperature (MAST). The strongest correlation was between slope and MAST. Sites with colder temperatures tended to have steeper slopes because deep snow, which can act as an insulator that warms the ground underneath it, will not accumulate. In fact, high snowfall seems to have a greater impact on warming ground than do rising air temperatures. For example, ground temperatures during the 2010–2011 winter were about 5°C (9°F) warmer on average because of well-developed snowpack (fig. 4, next page). Dr. Janke recommended further study of a few sites that exhibited unique thermal signatures, which possibly indicate permafrost presence.

In summer 2010, the park funded ongoing monitoring of the existing data loggers and the drilling of three 6 m (19.7 ft) boreholes on the shoulder of Trail Ridge Road. A borehole temperature profile is shown in figure 5, page 22. This site, along with the other two borehole sites, did not remain continuously frozen through the year. The boreholes will continue to be monitored to determine how climate change affects soil temperature change at depths greater than those investigated at the original 30 locations.

Educational and practical benefits

Beyond addressing scientific questions, the project engaged students and informed interpretive programs at Rocky Mountain National Park. For many students, this was their first visit to the park. Dr. Janke believes that "employers seek employees who have the ability to handle tasks independently and think critically. We teach students these concepts by engaging them in active learning to convey content and weaving students into the research process. This greatly relieves the burden on me to acquire data and gives students a chance to gain some hands-on experience." Over the past three years, more than 150 students in three soil classes ana-

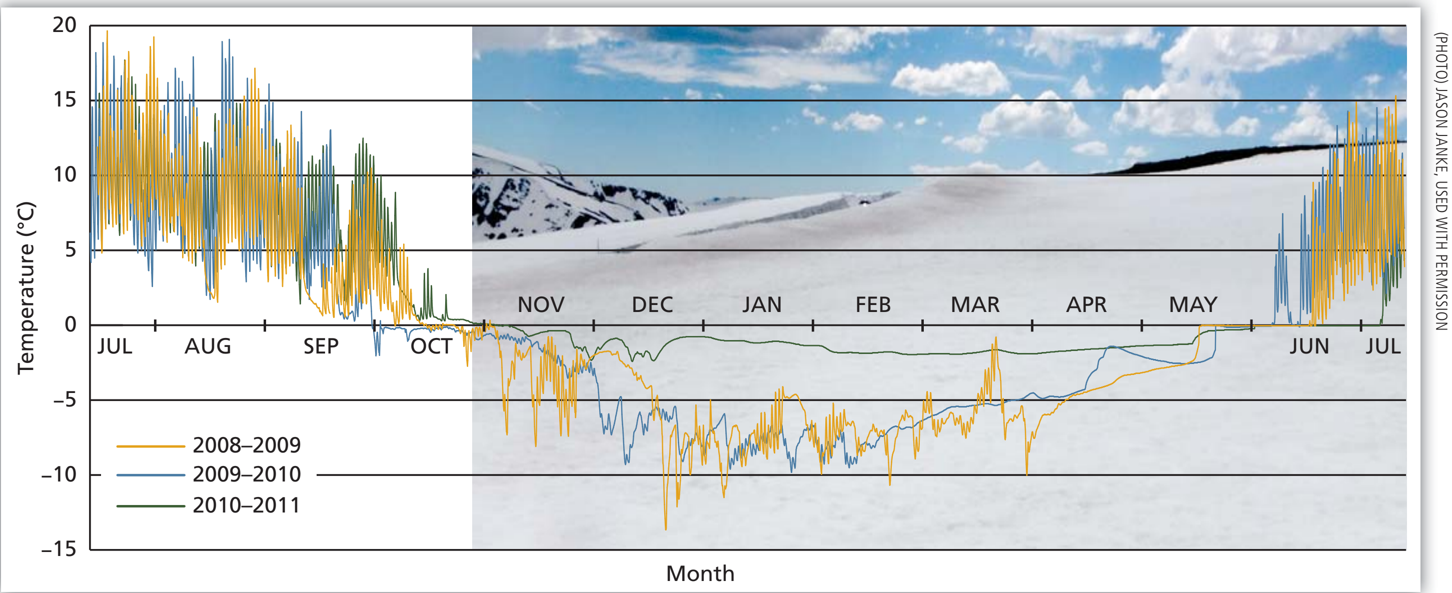

Figure 4. An example of a near-surface temperature plot for Site 4. The green line shows warmer ground temperatures during the winter of 2010–2011. Snowpack was approximately 1 m (3.3 ft) during mid-June 2011. The background photo is from mid-June 2011 and illustrates the unusually deep snowpack. Also, notice the snow ridges near the road from plowing and throwing snow.

lyzed the samples, with a subset of these coming to the park each year to check the data loggers and analyze findings.

The permafrost project along Trail Ridge Road was good for demonstrating how applied research results are used by land managers. In summer 2010, the Continental Divide Research Learning Center, with additional support from the Rocky Mountains Cooperative Ecosystem Studies Unit (RMCESU), hosted a daylong alpine tundra field school for students and park staff. These connections—among scientists, students, and staff—were important links to a successful research learning program. The park has selected two of Dr. Janke's former students as its climate change interns for the past two summers; one of their duties was to collect temperature logger data, ensuring continuing monitoring of the soil. Another student, based in part on her project involvement, accepted an internship in the Colorado River District as a park interpreter and has recently accepted a part-time position with the National Park Service.

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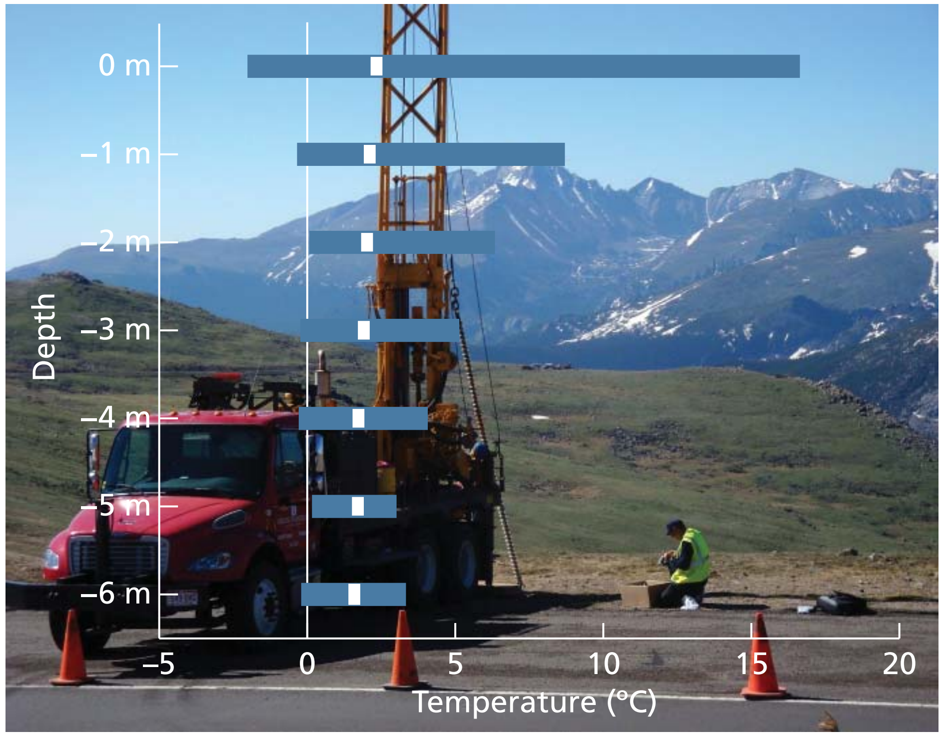
Rocky Mountain National Park's interpreters have been especially interested in this project. As Kathy Brown, district naturalist, noted, "Visitors know about the melting of arctic permafrost attributed to climate warming and they are surprised to hear that Rocky Mountain National Park tundra is also underlain by frozen ground." By participating in Dr. Janke's presentations and field day, park staff learned to use frozen ground processes as a "tangible" effect of climate change on park resources. Dr. Janke made his results readily accessible to park staff by creating a Web site and making presentations to the public and staff when requested. When the permit modification for drilling boreholes came up for review, park staff in all branches worked collectively to expand the project without damaging resources.

Partnership expansion

Both Rocky Mountain National Park and Dr. Janke plan to continue their partnership. The park sponsored a 2011 project focused on nitrogen and carbon soil dynamics on the tundra that involved funding two undergraduate researchers to analyze the genetic makeup of soil microbes. The project has expanded to



(PHOTO) CLINTON WHITTEN, USED WITH PERMISSION

Figure 5. A temperature profile for Borehole 1. The borehole was drilled to a depth of 6 m (19.7 ft). Blue bars show the range of temperature measurements from 2010 to 2011; white boxes indicate the mean annual temperature, which are all above freezing. Temperature generally decreases with depth but does not remain continuously frozen throughout the year; therefore, this site does not contain permafrost. The background photo shows the equipment used to install the borehole.

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>
> ***—Jason Janke***

support other Metro State faculty; Dr. Joanne Odden of the Biology Department is supervising students performing the DNA analysis of soil microbes; Dr. Andrew Evans has begun investigating the fate and transport of phosphorus through alpine soils. Metropolitan State University of Denver was recently accepted as a member of the RMCESU, a big step for a lesser-known university that only recently added graduate programs to its offerings. This membership in the consortium will allow Metro State to be part of the larger research and education community in the Rocky Mountain region. The university supports Dr. Janke's research involvement with the associated opportunities for applied learning. Dr. Janke noted, "The dean has funded the purchase of a freeze-thaw chamber to run undergraduate research projects on campus. We are planting the seeds of change!"

About the authors

Cheri Yost *is with the Cooperative Ecosystem Studies Units Network National Office in Washington, D.C. She was formerly the key official on this and other CESU projects at Rocky Mountain National Park. She can be reached at cheri_yost@nps.gov.* ***Jason Janke*** *is an associate professor of environmental science at Metropolitan State University of Denver. His research focuses on alpine periglacial environments and STEM (science, technology, engineering, and mathematics) education. He can be reached at jjanke1@mscd.edu.*

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