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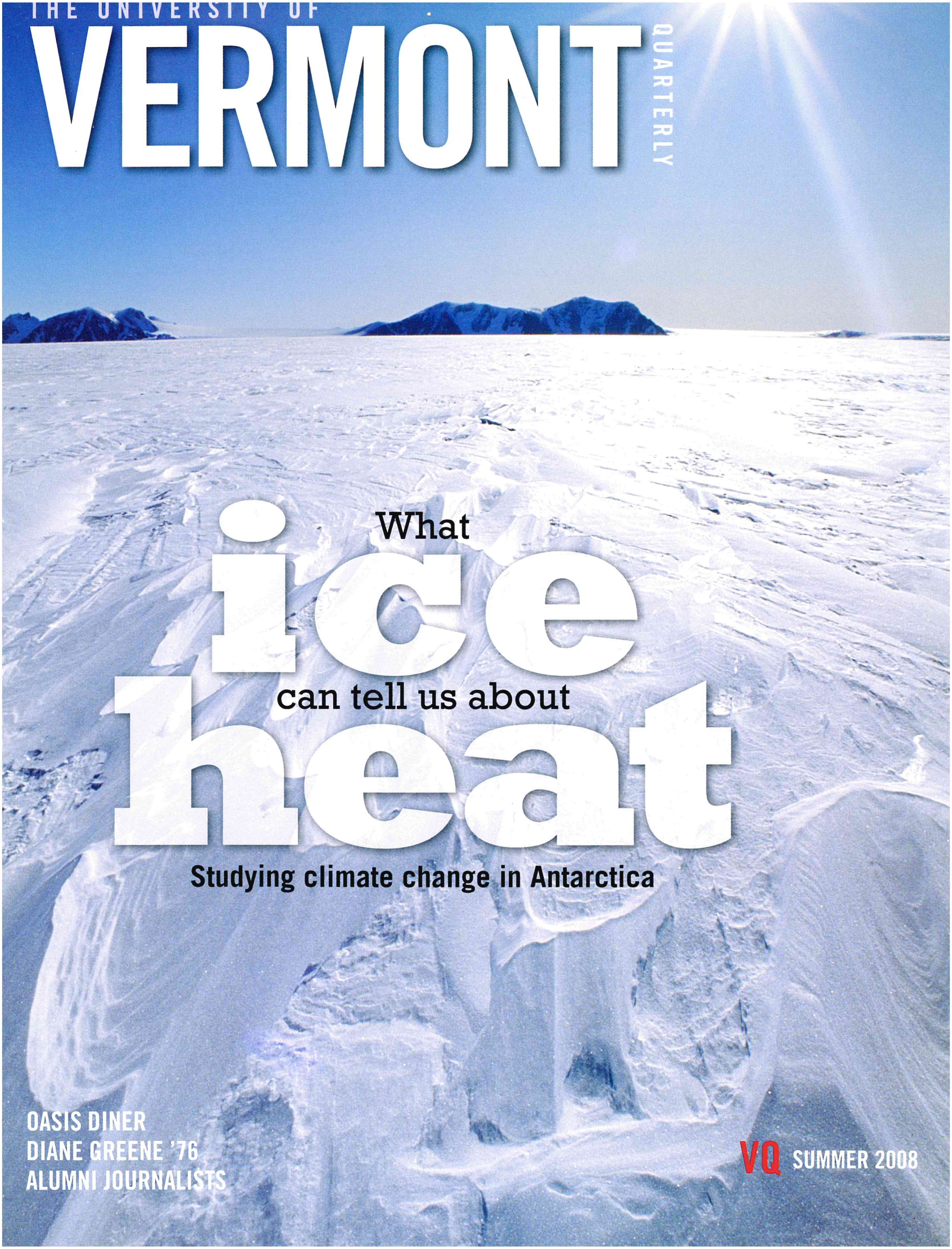


What ice can tell us about heat

Studying climate change in Antarctica

OASIS DINER
DIANE GREENE '76
ALUMNI JOURNALISTS

VQ SUMMER 2008

Geologist Tom Neumann uses a hand-powered drill to collect an ice core that will yield a picture of past yearly snowfalls in Antarctica.

Clues to the future of Earth's climate are frozen in its past.

Drilling Down

DATE: November 28, 2007
POSITION: 76 degrees 4 minutes south, 22 degrees 28 minutes east, 11,768 feet above sea level.

by JOSHUA BROWN

Here, about 500 miles inland from the coast of Antarctica, University of Vermont geologist Tom Neumann looks out the window of a twenty-foot-long box on skis being pulled by a tractor—and describes what he sees.

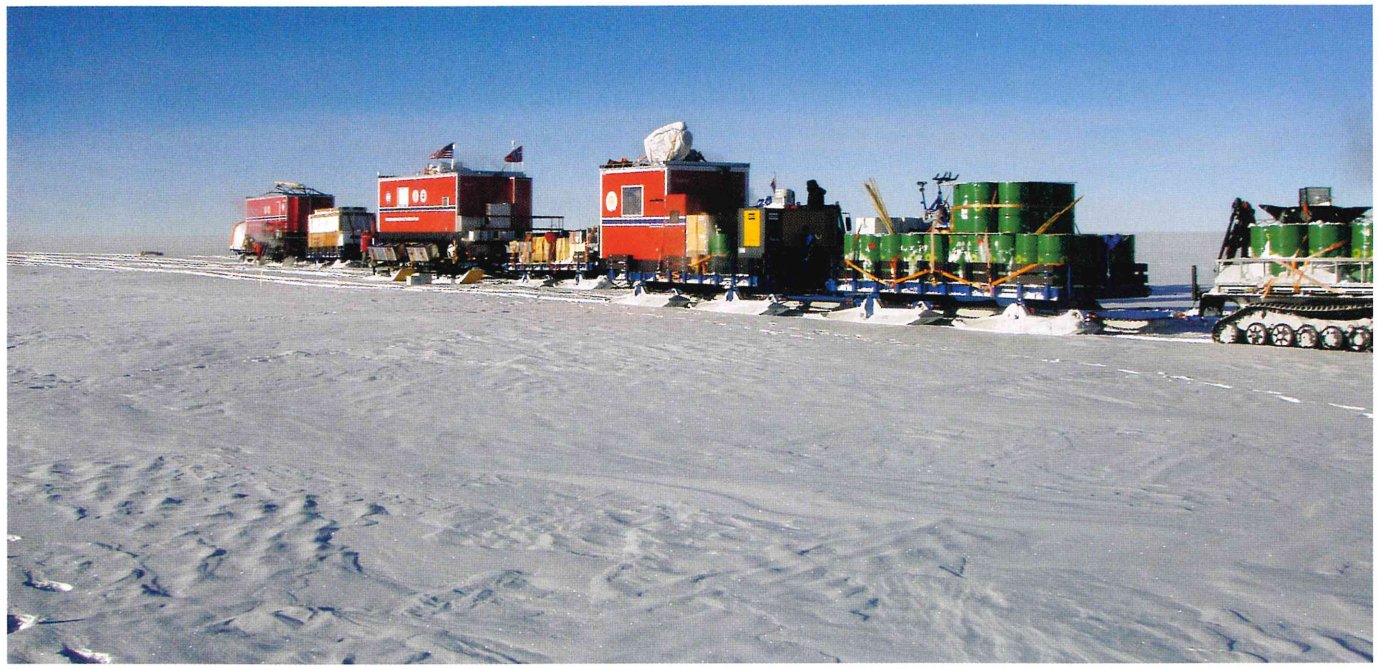
It's early evening, and the box casts a shadow across the vehicle tracks. Beyond, whiteness without relief stretches in all directions, like frozen mist under an ink-blue dome of sky. A north wind rag-whips Norwegian and American flags on the top of another tractor nearby.

Probably, no person has ever been to this spot before, Neumann says, speaking to me in Vermont by satellite phone. He's heading toward the South Pole as part of an expedition across the inner reaches of this frozen continent, collecting ice samples that will be used to understand the planet's warming oceans and atmosphere. Outside, it's twenty-five below and plunging. Inside, it's seventy above and the team of scientists he is traveling with are watching a surfing movie.

Antarctica is layered with contradictions. One of the driest places in the world, it holds more than 60 percent of the planet's freshwater in a vast ice sheet larger than the United States. The coldest place in the world, it may shape the consequences of global warming more than any other land mass.

But what these consequences will be, Neumann says, remains murky, despite a spate of recent scientific studies. It could be that warmer air, carrying more moisture, will deposit increasing amounts of snow over East Antarctica, building up the ice sheet faster than it melts at the coast. Or, it could be that a warming ocean will increase

COURTESY OF NRK TELEVISION



Left: Clipping along at six mph, ice tractors drag sleds loaded with supplies and living units for the expedition team. Above: Troll Station, 150 miles in from the coast of Antarctica, was geology professor Tom Neumann's home for several weeks in fall 2007.

COURTESY OF TOM NEUMANN

rates of melt and glacial discharge along the coast faster than the interior grows.

And on this question of "mass balance," as the scientists call it, balances the fate of the world's coastlines. Last year, the Intergovernmental Panel on Climate Change predicted that sea levels will rise in this century by between seven inches and two feet. But global climate models have a decidedly poor grip on what's likely to happen in Antarctica, and, since it holds almost all the planet's ice on land, a one percent reduction of this ice would raise sea levels more than two feet by itself.

If recent findings about accelerating glaciers and destabilization of the ice sheet in West Antarctica are right, then—Florida real estate owners hold your breath—sea levels will rise many feet in a few centuries or less.

That's a big if. In 2005, a paper in *Science*, using satellite radar data, showed the ice sheet in East Antarctica was gaining mass, and argued that global warming was increasing the amount of snowfall there. A growing Antarctic ice sheet, the authors concluded, would slow the rate of sea level rise caused by the melting of ice in the Arctic and Greenland.

However, another study published in *Science* in 2006 using data from computer models and ice cores, came to a nearly opposite conclusion, showing that "Antarctic precipitation is not mitigating global sea level rise as expected."

And then in January of 2008 a paper in *Nature Geosciences* used satellite radar data to argue that glacial discharge in Antarctica is accelerating, leading the authors to claim that, overall, the ice mass of Antarctica is heading down, but conceding that "large uncertainties remain in the current and future contribution to sea level rise from Antarctica."

All of these studies are to be taken with a frozen grain of salt, Neumann believes, since so little is known about East Antarctica's climate history or its effects on sea level. Huge and largely unexplored, this swath of the ice sheet sits like a great question mark at the bottom of the world.

"Nature is only doing one thing in East Antarctica," he says, "but we don't know what it is yet."

Which is a primary reason that Neumann, an expert on ice flow and polar snow chemistry, has spent the last two weeks bumping along at six miles per hour (max speed) in a long line of tank-like ice tractors. He and fourteen colleagues take turns behind the wheel, dragging sleds piled high with green drums of diesel fuel and bright red boxes stuffed with gear: ice core drills, remote control aircraft, frozen turkey dinners. It looks like some weird Siberian circus train.

Their mission is anything but frivolous. Neumann is a member of the first scientific expedition to East Antarctica since the 1960s, a joint US/Norwegian effort funded by the Norwegian Polar Institute and the US National Science Foundation. The trip is part of an international research effort to focus on the two ice-covered ends of the earth during the International Polar Year, a "year" that stretches from March 2007 to March 2009.

Neumann is traveling with the team for the first three weeks of a two-month expedition that began at the coastal Troll Station (yes, named for trolls by Norwegian schoolchildren). They're following a curving 1,800-mile course across the remote Dronning Maud Land, one of the world's most inhospitable places. For this leg of the trip, he's the science manager, where his boyish cheerfulness and episodic whiskers conceal a veteran's record of more than a dozen research trips to Antarctica, Greenland, Patagonia, and other forsaken ice-scapes. In the fall, when the team returns to complete the traverse from the South Pole back to the coast, Neumann has been asked to lead the whole expedition.

Although areas of the coast and of West Antarctica have been visited a bit more often, "East Antarctica is way, way under-sampled," Neumann says. "We're studying what are essentially blank spots on the map. Imagine if only three groups of people had ever crossed Texas. Then we're the fourth."

Their goal is to understand how the climate has varied in this high plateau, how snowfall rates change from place to place over recent decades—but also stretching back thousands of years. And for that, they must collect ice and snow, which is why they've stopped at Science Site 91—a howling expanse—to start digging.

Two days later, Neumann stands in a giant pair of Sorel glacier boots, thermal long johns from Lenny's, two hats, a fleece nose-cover, and a down parka—all covered by a sterile-white Tyvek suit—watching a motorized drill slowly turn downward.

To prevent contamination of the snow and ice samples, at each new drilling site, Neumann and his colleagues walk upwind from camp. Then, with bamboo sticks marking the drilling hole where no one should walk, they erect a wind shelter with a six-foot-high green plastic tarp stretched across aluminum poles. It makes a U shape behind which the scientists stand in a trench, shambling back and forth in slow-motion like frost-covered deep-sea divers.

They gingerly unload cylinders of ice from the drill and take them to a nearby processing area. "When the core comes up out of the ice we measure it; we weigh it; we bag it; label it and put it in a metal tube and then into a box," Neumann says. "When we get to South Pole Station, they're flown out to the coast and brought to California on a ship." From there, it's overland by truck to the National Ice Core Laboratory in Denver for cutting and cataloging. Then, finally, Neumann's slice of this frozen treasure is shipped to Vermont, where it goes into a freezer, awaiting laboratory testing. It's a tortuous trip to answer a straightforward question. "Is East Antarctica getting bigger or smaller?" Neumann says.

Faced with uncertainty about the present, climate scientists try to peer into the past. Neumann's studies of isotopes in the ice serve as a window onto past climates. As snow crystals form in the atmosphere, the ratio of heavier isotopes of oxygen and hydrogen to lighter ones

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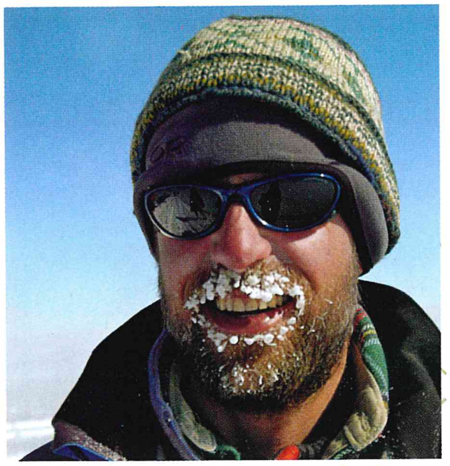

is determined by air temperature. These crystals fall and pile up for millennia, leaving layers of temperature-coded ice.

Some of Neumann's ice cores, 100 feet deep, will give him a picture of the last 200-300 years. Others, 300 feet deep, show the last 1,000 years. "The main idea is that understanding how the climate system worked in the past lets you look forward with some predictive ability," Neumann says.

Other researchers on the trip study the electrical properties of ice cores, look for layers of volcanic ash, investigate snow at the surface, and take deep images with ground-penetrating radar. Dragged behind one of the tractors, the radar traces the rise and fall of the bedrock and layers in the ice; "it helps connect the dots between the ice core sites," Neumann says.

At the same time, the travelers gather information to calibrate satellite images with on-the-ground conditions. They collect information from hypersensitive thermometers down boreholes, look for traces of salt blown overland from ancient ocean spray, study changing levels of elements "like magnesium as a tracer for continental dust," Neumann says, and find radioactive signatures from nuclear bomb tests in 1955 and 1964.

All of this information should help expose the ponderous forces that govern Antarctica. A full picture of what's happening there can only be drawn by integrating how short-term changes, like accumulation rates of snow at the surface and annual temperature variability, play out against much longer-term changes, like response to the end of the last ice age and centuries-long movements in the miles-deep ice sheet.

"By linking how temperature has changed to changing rates of snow accumulation—and integrating it with lots of other information—we may be able to solve the mass balance question about East Antarctica," Neumann says.

DATE: May 20, 2008
POSITION: Denver, Colorado

Half a year later, Tom Neumann is running a bandsaw through a tube of ice, one section of the miles of ice from around the world stored by the US Geological Survey in Denver. Later this summer, one of his graduate students in Vermont will take centimeter-thick slices of this ice, melt them, and process them.

The samples will then be tested in a mass spectrometer in UVM's Environmental Stable Isotope Laboratory to plot the shifting ratio of heavier forms of oxygen and hydrogen to lighter ones as the layers of ice—and associated years—go past. Isotope ratios from around the world serve as proxies for historical temperatures, among other things, and have been important in creating modern global climate models.

And these global climate models have, in turn, been important in creating the nearly unanimous opinion among scientists that our planet is heating dangerously. But these same models still have a few wobbly legs, such as ocean circulation changes, the role of clouds, the release of greenhouse gases from melting permafrost—and the dynamic response of ice sheets.

In the case of Antarctica, the weakness comes from "a lack of data!" Neumann says. "You can have a million satellite images, you can have a climate model with fine resolution, but if you don't have any calibration data on surface temperatures, topography, accumulation rates, if you don't know what the ice thickness is in different places, if you don't know what the satellite images mean—then your model is basically blind."

"How much snow falls on the continent now, today?" Neumann asks. "We don't really know. If you don't know that very well, how on earth can we be expected to predict what is going to happen in one-hundred years?"

"Our ice cores are going to fill in some big holes in the map. And that should lead to more robust predictions," he says, about the shifting ice and shifty future that rest on Antarctica.

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