field notes
The Polar Field Services Newsletter
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Viewing Greenland's past climate with cosmic ray vision

By Marcy Davis

To understand earth's climate through time, scientists must use proxy data--paleoclimate information recorded by tree rings, fossil pollen, ocean sediments, coral, ice cores, and even rocks. This summer Paul Bierman and Tom Neumann (University of Vermont) embarked on an experimental study to look at how the Greenland Ice Sheet (GIS) has grown and shrunk over the last million years. Bierman and Neumann will use the isotopic signatures of rocks found this summer at today's ice sheet margin to get a picture of where and when Greenland rocks may have been exposed at the surface. Then they will combine these data with other climate proxy information and compare the results to today's climate. In simplest terms, these are the questions: when was the climate at least as warm as it is today and what did the GIS look like at that time, consequently, and how can we use this information to predict the future behavior of the GIS?

"The idea for this project came over a breakfast with Richard Alley, a glaciologist from Penn State. We were discussing a set of samples from the GISP2 core at Summit. The rocks from the bottom of the core had Beryllium and Aluminum isotopes in them, which showed that they were last exposed half a million years ago. We thought, hmmmm, what would it take for us to be able to use this technique on a larger scale?" explains an enthusiastic Bierman, who runs UVM's Cosmogenic Isotope Laboratory. "So, we will study the products of subglacial erosion (rather than punch holes in the ice sheet to get at the rocks below) and identify when Greenland was ice-free or partially ice-free. Results may be able to tell us how the GIS responded to intervals of major climate warming over the past several million years."

Cosmogenic isotope analysis of rock from the bottom of the GISP2 hole suggests that the Summit area was deglaciated about half a million years ago. Measuring in-situ-produced cosmogenic nuclides in samples collected from below the ice sheet has potential to date past episodes of deglaciation through analysis known as burial dating.

Cosmic rays originating from space invade earth's atmosphere and travel through all things on the planet, including us. These rays periodically interact with an atom, split and change it – oxygen, for example, becomes a variety of beryllium (Be) found rarely on Earth otherwise. By analyzing the amount of this Be, along with a particular type of aluminum (Al) and a few other elements, Bierman hopes to quantify times when the extent of the GIS shrank.

The penetration depth of most cosmic radiation is only the upper meter or two of the earth's crust. What this means to Bierman and Neumann is that rocks located in Greenland's interior may once have been exposed at the surface during ice sheet retreat and, consequently, may carry the cosmic ray isotopic signature. And in the intervening milennia, the rocks Bierman and Neumann need to sample may have been excavated and carried to the margins of the ice sheet by outlet glaciers.

To find potential sampling sites, Neumann, who has been in Greenland studying glacier dynamics during the last two field seasons, will use publicly available 3-D ice flow models (GLIMMER and ELMER) to determine the origins of the rocks now found on the edges of the island.

"We must try to figure out where the rocks we find at the margins came from. Given where we find the rocks now, when and how did they get there? Where would the ice sheet likely have melted and then refroze to entrain rocks and bring them to the margin? We hope

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Top: Geomorphologist Paul Bierman surveys a snowy landscape in Southern Australia. All photos provided by Paul Bierman and Thomas Neumann unless otherwise noted.

Left: Tom Neumann prying a clast loose from debris-rich basal ice, just over the bedrock on which Tom is standing. Right: (L-R) Lee Corbett, Tom Neumann and Joseph Graly collecting clasts from a dead ice zone. The team picked 5 to 10 clasts from each of several accumulations like this to ensure they had a mix of angular and rounded samples as well as different types of rock. Both sites are near Kangerlussuaq.

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to choose two contrasting sites on the western margin of the GIS: one in the south with historically unstable ice coverage and one in the north with more stable coverage," explains Neumann.

Prior to the field effort, graduate students working with Bierman and Neumann analyzed satellite and aerial photos to get a better feel for the terrain near potential field locations since transporting rock samples from remote collection sites is a challenge. They identified places with high concentrations of quartz-rich rock material that have been quarried by the ice and delivered to the ice margin. In two such areas, Bierman and Neumann and the students, along with Robert Finkel from Livermore Lab, collected samples directly from outcropping ice.

"We could run around and bang on a bunch of rocks with a hammer or let nature do the work for us," says Bierman. "We'll rely on sub-glacial erosion to sample previously-exposed rock surfaces and sediment for us. Then, we will use isotope ratio analysis to identify past times when the rock and sediment beneath the GIS were exposed."

In July, the team camped at each location for several days, chiseling from the glacier terminus a hundred or so hand-sized rock and surrounding ice samples. These were shipped along with melted ice samples to the University of Vermont via (very heavy) coolers for further analyses.

Back in the cosmogenic isotope lab (CIL), Bierman and students will work for nearly a year to analyze the rock samples for populations of burial ages. First, they will isolate quartz from the samples. The students crush the rock with hammers, a jaw crusher, and a plate grinder until the pieces that remain are less than one millimeter in size. Sieves separate pulverized material into even smaller sized groups. Then the samples are cleaned with hydrofluoric and nitric acid, which dissolves just about everything but quartz. Just in case, the remaining material is placed in liquid-filled flasks where quartz sediment sinks and everything else floats to the top. Following a second acid etching in the ultrasonic bath, the samples are tested for their quartz purity. If they check out, samples go on to a final etching before the quartz is dissolved and minute quantities of Be and Al are extracted.

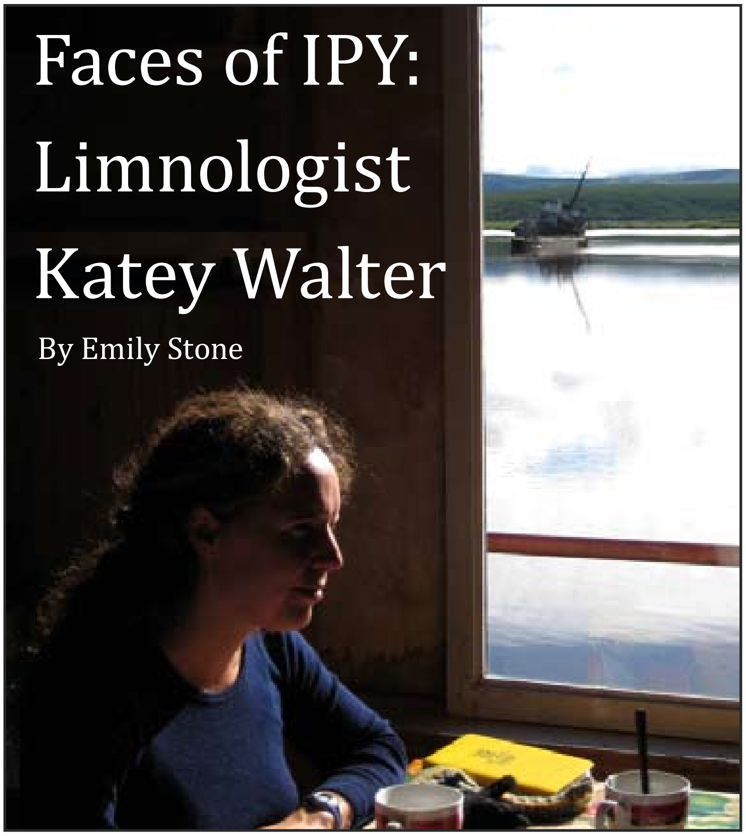
"It's a lot of wet lab chemistry," says Bierman. "In September the rock samples will arrive at the University of Vermont and by January we'll have pure quartz. Then it's months of lab work and in the later spring we go to Livermore. Students go from the ice sheet where it's cold and dirty to lots of lab work to a big machine at an old national weapons facility. They get lots of good training."

Beryllium and aluminum oxides are packed into stainless steel containers called targets. Bierman says that he and students will then, finally, "travel with a batch of the bullet-sized packages containing fruit-fly sized oxide samples to Lawrence Livermore National Laboratory's [Center for Accelerator Mass Spectrometry] [CAMS] to use the 'football field-sized mass spectrometer." At the CAMS, researchers will analyze the samples for amounts of Be and Al isotopes. Using the half-lives of these elements, which radioactively decay over a known time, the group will then calculate how long it has been since the samples were exposed at the surface. Additional isotopic analyses will be done by Nat Lifton at the University of Arizona.

"We envision this as a pilot project. Paul is really a pioneer with this technique," explains Neumann. "If it works, we'll be able to take a much closer look at regional distributions and begin to get a handle on how the ice sheet shrinks and swells over time in Greenland and in other ice-covered areas which are susceptible to climate warming." ●

Faces of IPY: Limnologist Katey Walter

By Emily Stone



As a schoolgirl, Katey Walter decided she would one day get a Ph.D. She wanted to study an important research question, though she didn't yet know exactly what it would be.

"I imagined it would be such an interesting question to me that I wouldn't be able to sleep at night," she said.

After majoring in biogeochemistry in college and getting her master's degree in ecology, Walter headed to the University of Alaska, Fairbanks, to pursue her Ph.D. in aquatic ecology, though she was still unsure of exactly what her research focus would be. She joined her thesis advisor in 2000 on a five-year project in Siberia to study the effects of climate change on carbon and nutrient cycling there. Walter studied lakes while others focused on soil and rivers.

Walter, now 32, lived for five to seven months each year during her Ph.D. research at a tiny Siberian field station taking daily measurements of the lakes nearby. Her focus was on methane emitted from "thermokarst lakes," also called "thaw lakes," which are formed when arctic permafrost thaws and ice melts. Scientists had recently discovered that these lakes emit methane, a greenhouse gas far more potent than carbon dioxide. But no one knew how much methane was coming off the lakes. It was Walter's goal to find out. (For more on Walter's research, see below.)

It took a couple years of rigorous, daily measurements before Walter had her breakthrough. It was a moment that would define her thesis, shape her career, and potentially change the way climate modelers predict the rate of global warming, not to mention that it supplied her with a compelling research topic to keep her up at night.

Walter had been placing methane bubble traps around the lake in a randomized sampling design, as she'd been taught to do. But she realized that the random sampling was yielding extremely skewed results because methane isn't emitted evenly across the surface. There are discrete point sources of bubbling where methane comes off the surface at a much greater rate than the non-bubbling areas. Walter noticed that when the surface of a lake froze, the methane bubbles got trapped in the ice where she could see them.

"You get this beautiful map of where all these bubbles are happening," she said. And the map told her *exactly* where to place her methane traps.

Walter calculated that 95 percent of the methane coming off the lakes was from bubbling as opposed to the five

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Thermokarst lake research: A Cinderella story

By Emily Stone

Katey Walter's research on methane bubbling out of arctic thaw lakes has primarily focused on how much of the potent greenhouse gas individual lakes produce. But there are hundreds of thousands of these lakes spread across the Arctic, and their cumulative impact on past and future climate change is still unknown.

This is the question Walter and four collaborators hope to start to answer with a new International Polar Year grant. Beginning this summer, the interdisciplinary group will study thaw lakes in Alaska and Siberia over three years to understand how the thawing of permafrost, the process that creates these lakes and leads to the methane that comes out of them, affects long-term levels of greenhouse gases in the atmosphere.

The basics of the biological process are understood: when permafrost thaws it creates depressions where wedges of ice used to be. These basins fill up with water and form lakes. The thawing also defrosts organic-rich soil that stimulates microbial activity. In drier areas, microbes mainly produce carbon dioxide as a byproduct of decomposing the organic matter. In lake sediments, where there is little or no oxygen, different kinds of microbes make a living by converting organic matter into methane in addition to carbon dioxide. As a greenhouse gas, methane is 25 times more powerful than carbon dioxide.

Walter, an assistant professor at the University of Alaska, Fairbanks, is particularly interested in a type of permafrost soil called "yedoma." Yedoma, found in Siberia and Alaska, is rich in both ice and stores of ancient, Pleistocene-aged organic carbon. Its high ice content, ranging between 50 and 90 percent by volume, means that thawing of yedoma results in dramatic changes in the landscape, including increased lake formation. This warming and thawing of yedoma also

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percent that diffused more evenly off the lake's surface. This increased previous estimates of methane emissions from the same lakes five-fold. Extrapolating that data across north Siberian lakes means there could be 10 to 63 percent more methane bubbling into the atmosphere from northern wetlands than previously thought – a number that has big implications for climate modelers.

"One day things click and you realize, 'this is important,'" Walter said of the discovery of her bubble map.

Or, as her thesis advisor Terry Chapin puts it, "Suddenly she showed that there's this very, very important global process that had been essentially ignored up until that time."

Her thesis, which turned into a paper in *Nature* in 2006, earned Walter the highly prestigious first-place award for a dissertation in science, math or engineering from the U.S. Council of Graduate Schools. She's now an assistant professor at the University of Alaska, Fairbanks.

Chapin, a professor of ecology at the University of Alaska, Fairbanks, said Walter combines an extreme work ethic with palpable, contagious excitement about her research.

Walter will ignite methane plumes, letting out a big whoop when they light, ostensibly to verify that the gas really is methane. But "more than anything, it's fun," she says, even if it's cost her some singed eyebrows and hair.

She fell in love with the outdoors while hiking in Oregon and Nevada as a kid, and with Russia while spending a year there as a high school exchange student. Being able to combine her passions for nature, science and Russia is a dream come true, and one Walter hopes to share with others.

To that end, she helped lead a group of 10 college students and young professors on a trip to the Northeast Science Station in Cherskiy, Siberia, this summer – the same place where she did her original thaw lake research – to introduce them to arctic science. The course, called Polaris, was modeled on one she did as a graduate student in Costa Rica. Along with chief scientist Max Holmes of the Woods Hole Research Center on Cape Cod, she received an International Polar Year grant to bring "rising stars" to the Siberian Arctic for three summers.

She also has her eye on how to harness methane as a power source for remote, native villages in Alaska as an alternative to expensive diesel, the cost of which has prompted some Alaskans to turn off their heat for hours at a time. Walter hopes that using local sources of methane from seeps could reduce the need to ship expensive diesel to remote Alaskan villages.

Walter is currently enlisting citizen scientists around the Arctic to help her study lake methane. She is teaching them how to survey bubbles trapped in

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Walter looks for methane hot spots. Photo: Marie-Laure Geai, Climate Change College

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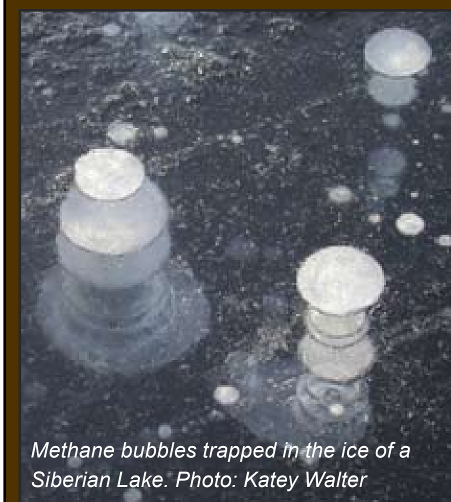
frees up organic carbon, which leads to the creation of methane, a process that could be a powerful force in accelerating the rate of future warming.

Walter and two of her collaborators on the project, along with others, published a paper in *Science* last year on the connection between methane bubbling from thaw lakes and the warming of global climate at the end of the last glacial maximum, about 15,000 years ago. Using ice core data and an understanding of yedoma thaw lakes, they hypothesized that methane



Methane bubbles trapped in the ice of a Siberian Lake. Photo: Katey Walter

bubbling contributed 33 to 87 percent of the increase in atmospheric methane at high latitudes, which contributed to the warming of the climate at the transition between the Pleistocene and Holocene eras.

The scientists will use the data they gather during fieldwork in Cherskiy and Yakutsk in Russia and the Seward Peninsula in Alaska to further explore this idea, as well as use their findings to predict changes 200 years into the future.

The group will take sediment cores of drained lake basins and cores of existing lakes. They'll use radiocarbon dating to determine how old the various lakes are. (Walter's previous work has shown that the carbon being eaten by methane-producing bacteria in Siberia can be as old as 43,000 years.) Ground-penetrating radar will help reveal how deep the carbon-rich

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alaska

The lengthening shadows on the Fairbanks daily paper's webcam tell the story, as do the masses of equipment awaiting maintenance in our Fairbanks warehouse: the second arctic summer season of this IPY is winding down in Alaska.

And a cold, wet, summer it's been in places, with snow flying at Toolik Field Station in mid-July—much different than the long, hot summer of 2007 when a mid-summer lightning storm sparked a tundra fire near the station. The Anaktuvuk River fire burned for about six weeks, scorching some quarter-million acres of tundra. It was the largest fire that year, and easily the largest ever to burn near the site of the arctic Long Term Ecological Research (LTER) project, which bases at Toolik.

While LTER scientists continued investigations of the area's streams, lakes, tundra, and landscape interactions (that is, how freshwater bodies, land and the atmosphere relate as an entire system), researchers also jumped on the opportunity to study a landscape that had been significantly altered, both to learn how the system responds, and to test models developed to predict these processes. LTER scientist Gus Shaver leads the initial LTER study of the Anaktuvuk burn site. The arctic LTER's chief scientist, John Hobbie of The Ecosystems Center (MBL, Woods Hole) describes the opportunity the fire presents and the work to be done here.

Hu collects lake sediment samples for fire history reconstruction. Photo: Feng Sheng Hu

Scientists quickly take samples from anesthetized bears. Photo: Chuck Redd

Feng Sheng Hu (U of Illinois) uses data from sediment cores drawn out of lakes to decipher connections between historic climate change and fire patterns. For Hu, the Anaktuvuk River burn site near Toolik offered a tantalizing opportunity to test climate modeling information against actual data sets, and so he stopped in at Toolik in late July fresh from visiting his study sites in the Copper River and Yukon-Old Crow basin. He did an aerial reconnaissance of the new burn site and collected samples there as well.

By the way, Amy Breen (UAF) writes about Toolik for Ice Stories, the NSF-funded outreach project that puts cameras and other recording equipment into the hands of researchers and others working on science projects in the North. At last, the secret of MGIFs revealed.

Way up on the northern coast of Alaska, NSF-funded investigator Hank Harlow (U Wyoming) spent much of August doing polar bear research based out of Deadhorse. His team seeks to describe the effect of long periods of fasting on the bears' overall health. The researchers will compare two groups of bears—those that follow the sea ice and those that remain land-bound during the period in late summer when the ice retreats from the coast.

Most polar bears follow the ice: it is a platform from which they hunt seals, their main prey. But a few stay, probably going largely without food. Are the bears that swim and hunt along the ice generally in better health than the late-summer fasting bears? How does a polar bear respond physiologically to long periods without food? And as the sea-ice continues to retreat for longer and longer periods of time (as many predict under a warming climate), will the bears on land be better off than those who will likely spend more and more time in the water hunting for prey?

These and other questions drive the research. Harlow's team captured a dozen or so of the land-based bears. After examining, taking samples from, and placing locating devices on their subjects, the scientists then released the bears–but they will return this fall to do the work again. The scientists will document the changes in each land bear as a result of the prolonged fast, and compare these to the data to be gathered from a similar sample of sea-ice–based bears next year. They hope to use the information from this comparison study to help inform policy makers as they consider an approach to stewardship of this species, now listed as "threatened" under the Endangered Species Act.

Eric Reigers (US fish and wildlife department) is a member of the research team. He spoke to Alaska public radio earlier this month. Hear the audio piece, which provides insight to the project goals (and how difficult it is to find the land bears) here.

greenland

From the ice sheet: Glacial meltwater swells a stream near Kangerlussuaq. Photo: Ed Stockard

Around the island

For NSF's arctic research program, mid-to-late August is closing time in Greenland. Turn out the lights at Raven Camp, the Air National Guard's training hub on the ice sheet. Roll up the runway at Summit Station for now. In Kangerlussuaq, where the hilltops are already sugared with a light dusting of snow, there's a flurry of work to be done.

Writes PFS' Kyli Olson, in Greenland to assist with end-of-season efforts, "It is cool and the fall tundra colors are blooming. But outside of enjoying the Greenland fall after the HOT Denver summer, it's just been busy, busy business as usual – shifting cargo, washing sleeping bags and clothing, inventorying equipment, etc." Soon, the Kangerlussuaq operation will be closed for winter.

NEEM, the international collaboration run by Danish researchers (Dorte Dahl-Jensen, U Copenhagen, lead) closed in mid-August after a long season mostly spent establishing the camp and preparing the drill hole for the major operation to begin in 2009. The NEEM team will drill down to dirt, some 2500 meters below the ice sheet surface, to collect an ice core revealing climate history back into the Eemian age, the period between about 130,000 and 115,000 years ago. The information extracted from tiny bubbles in the ice will help scientists explain previous periods of rapid climate change, and even more, reveal what Greenland was like during this period believed to be about 5C warmer than today's climate. Earlier cores extracted from Greenland tell us much about climate change, but the Eemian record is not clear: melting at the bottom of the ice sheet in another area where an earlier deep core was drilled tumbled the ice, making the signal difficult to read.

In Kangerlussuaq, Dorthe Dahl-Jensen and colleagues threw a party at a local restaurant to mark the closing. PFS staff attended, and they report that it was a high-spirited affair, complete with congratulatory speeches from several NEEM personnel. The menu included reindeer stew and muskox burgers.

Meanwhile, in August, SUNY-Buffalo's Jason Briner fielded a new project aimed at discovering how Greenland's ice sheet has responded to warming and cooling temperatures in the past (during the Holocene period--that is, roughly 11,000 years ago until now). He and a team spent several weeks based at a tent camp near the Jakobshavn Isbrae east of Ilulissat. They sampled glacier-scoured rocks and cored lake sediments for further study back in New York. Though weather mostly favored the work, colder temperatures late in August, with rain and snow, pinned the team near their campsite for a few days. Still the PI reports that they accomplished their goals.

Alberto Behar (NASA-JPL) and Koni Steffen (CIRES, Colorado) blew through town late in the month to capture data on several moulins near Swiss Camp, Steffen's legendary home away from home on the ice sheet near Jakobshavn Glacier. The team spent several days out on the ice sheet, lowering video cameras and instruments into the moulins to measure depth and water flow rates. Moulins drain glacial meltwater on the surface into the glacier, and to the bottom of the ice sheet.

With the planes and outposts all buttoned up, everyone took some time to pause and celebrate the end of the season, this second summer of the 4th IPY. On a relatively poor day with intermittent rain, hail, and winds, researchers, locals, logisticians, and air guard personnel gathered around the BBQ at the Firehouse on Lake Ferguson, about 3 miles from Kangerlussuaq. PFS' Robin Abbott handled the marinades, Mark Begnaud helmed the grill, Ed Stockard worked the camera, and everyone relaxed and enjoyed the day (or huddled under a tarp when the weather kicked up).

PFS staffer Kyli Olson enjoys the end-of-season party. Photo: Ed Stockard

Summit Station

By the 22nd of August, Summit Station was closed for the season; the outbound flight carried over 20 personnel down from the roof of the world. "Summit population for winter phase one is now four and I suspect it will remain at that number for some time," reports station manager Steve Zellerhoff. Steve took the helm from Kathy Young, a 10-year station veteran. The team will now take care of ongoing experiments until sometime in November, when a fresh team relieves them.

media

Photos from someone else's summer trip that you shouldn't miss: Jason Box has posted a photo essay of his July glaciology work in Greenland!

Speaking of Jason Box, his time-lapse cameras and NASA satellite images have captured the most recent breakup and fracturing of Petermann Glacier (as well as the Jakobshavn) in Greenland.

A "treasure trove of dinosaur-age sea serpents, ancient shark teeth and piles upon piles of petrified poop," recovered decades ago but only recently studied, gives an international group of scientists an unprecedented look at ancient life in the Arctic, this story reports.

It's not just an education, it's an adventure! Visit the new adventure learning Web site, which will have a live session during the fall AGU: http://adventure-learningagu.ning.com/

Canadian researchers are searching for the lost ships from Franklin's last, doomed voyage.

Researchers on an aerial bowhead whale survey off Alaska's northern coast have spotted 10 bears swimming far offshore, reports *The New York Times.*

field notes

By Polar Field Services, a member of the CH2M HILL Polar Services team.

Jill Ferris, Operations Manager
field notes Production Team:
Oversight: Diana Garcia-Lavigne
Writing/Editing: Kip Rithner
Graphics/Writing: Susan Zager

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Bowhead whales. Courtesy: NOAA

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lake ice as part of the Pan-Arctic Lake Ice Methane Monitoring Network (PAL-IMMN). She's working with about 20 people now and has heard from many more who want to participate. She'd like to get funding to set up a database where everyone could enter their findings, resulting in a more comprehensive look at what's happening across the Arctic. She also thinks getting school kids involved would be a great addition to an elementary or high-school science curriculum.

Walter frequently hears from students and members of the public who have read her studies or heard her interviewed. They often ask for advice on how to start out in science. She tells them to find a good mentor and prove to him or her that they're a hard worker, even if that means starting out as a cook in a field camp. More generally, she encourages them to set their sights high, find the question that inspires them, and then have the courage and confidence to succeed.

"There are so many exciting things to be done and places to go in this world," she said. And for Walter, such exploration continues to be a gas.

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thawed sediments are beneath lakes and where the methane is being generated. And they will collect permafrost samples from lakes of different ages and incubate them in the lab to see how long the methane continues to be released. This will combine to give a clearer sense of the history of methane released from these lakes. The researchers will then use satellite images to examine the extent of thaw lakes in Siberia and Alaska to extrapolate their findings across a much larger swath of the Arctic.

One of Walter's collaborators is Mary Edwards, a paleo-ecologist at the University of Southampton in England. She used to steer clear of thaw lakes in her studies because they collapsed the ground around them and tended to muddle ecological data.

"I used to be really good at identifying them and saying, 'Oh no, we don't want to go there,'" she said. But now the lakes are being studied in their own right, in large part because of Walter's research on methane bubbling.

"They are the Cinderella," Edwards said. "They haven't been looked at very much. That's what makes it so interesting."