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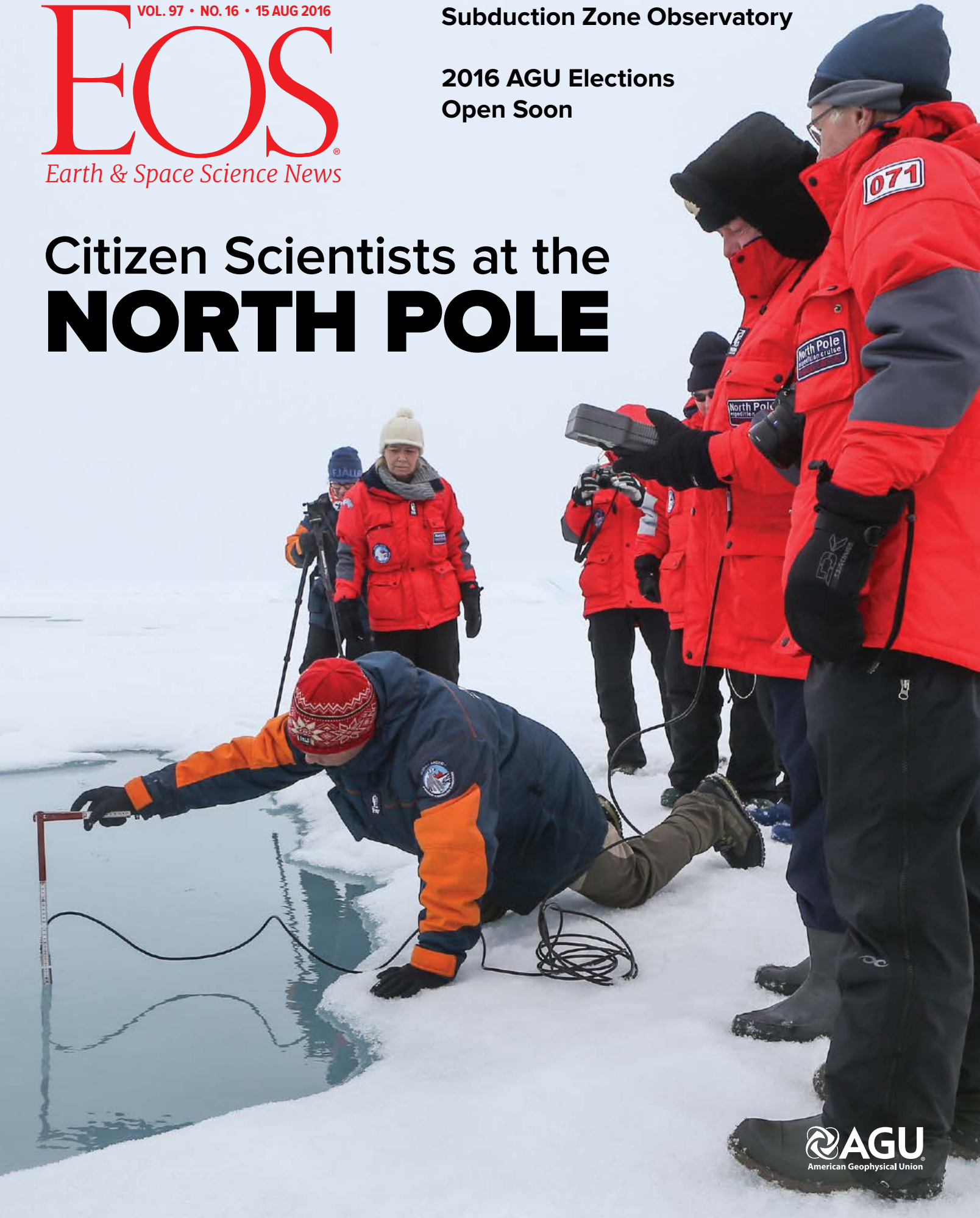
EOS

Earth & Space Science News

Subduction Zone Observatory

2016 AGU Elections Open Soon

Citizen Scientists at the NORTH POLE



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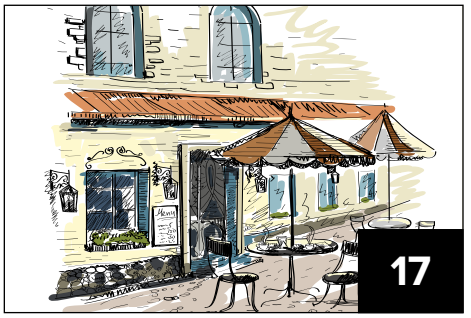
COVER

Citizen Scientists Train a Thousand Eyes on the North Pole

During expedition cruises, tourists participate in collecting scientific data and contribute to ongoing observations of sea ice conditions in the Arctic.

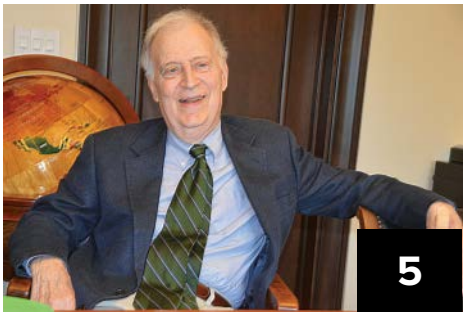
PROJECT UPDATE



Teens and Scientists Come Together at Science Cafés

"Science cafés" bring scientists and the public together for relaxed conversation in restaurants and coffee shops. The Teen Science Café Network shows that the concept isn't just for adults.

NEWS



Academy Head Says Political Rancor Harms Science, Society

The recently retired National Academy of Sciences president says allegations that climate change is a fraud are deeply upsetting. But he hopes rabid partisanship can be eased.

OPINION

9 Planning for a Subduction Zone Observatory

An international, interdisciplinary effort to study and observe earthquakes, volcanoes, landslides, tsunamis, and continent building at subduction zones could advance science and protect communities.

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Christine W. McEntee, Executive Director/CEO

AGU American Geophysical Union

Eyjafjallajökull Gave Lava and Ice Researchers an Eyeful

Boaworm, Wikimedia Commons, CC BY 3.0 (http://bit.ly/ccby3-0)

Scientists used white plumes of steam like these to track lava from the 2010 Eyjafjallajökull eruption as it melted the glacier.

When the Eyjafjallajökull volcano in Iceland erupted in 2010, clouds of ash led to massive delays for airlines across Europe. On the slopes of the volcano, other plumes were rising as well: Billowing white steam rose from holes in the glacier as lava flowed underneath and melted the ice from below.

For scientists eager to better understand the interplay between lava and glaciers, as well as the deadly hazards such interactions can cause, the eruption provided a unique opportunity to gather data and insights.

"This was the first eruption where we could document, in a lot of detail, what happens as the lava flow is moving under ice for a pretty good distance," said Benjamin Edwards, a volcanologist at Dickinson College in Carlisle, Pa., and coauthor of a paper in the July *Bulletin of Volcanology* (see http://bit.ly/subglacial-lava). The findings by Edwards and his colleagues could shed light on past under-ice volcanic eruptions and future dangers from the meltwater floods they cause, Edwards added.

Ice Increases Hazards

Ice-covered volcanoes can produce more hazards than their ice-free cousins. When the heat from lava rapidly melts ice at the top of a mountain, torrents of meltwater can cascade below, overwhelming glacial lakes and causing extensive flooding downstream.

> "This was the first eruption where we could document, in a lot of detail, what happens as the lava flow is moving under ice for a pretty good distance."

During the 2010 Eyjafjallajökull eruption, for instance, the threat of floods forced the evacuation of about 800 people downstream of the glacier. Nobody died, but part of the ring road that runs along the island's coast was washed out.

In addition, when moving meltwater mixes with mud and ash, the flowing slurry (called a lahar) can pose extreme dangers. Like torrents of volcanic "concrete," lahars can cover and entomb people and houses. Notable examples include lahars from the 1991 Mount Pinatubo eruption in the Philippines, during which such flows destroyed thousands of homes, and a 1985 eruption of Nevado del Ruiz in Colombia, in which lahars contributed to a death toll of about 23,000 people.

A Research Opportunity

In the recent paper, which published online on 8 June, the research team describes how they tracked the eruption using aircraft, satellite images, and other data-gathering means. "Iceland is so well prepared for eruptions that as soon as something kicked in, they had all kinds of measurements [from seismometers, webcams, and other instruments] that monitored the eruption," Edwards explained. The scientists then constructed a timeline of the eruption and mapped the lava's eventual path.

In addition, a year after the eruption, when it was safer, the team went out to the glacier to examine the lava flows and their impacts on the glacier. The team was initially worried that carbon dioxide levels would be too high—but it was good that they got there when they did, Edwards said. The team was able to observe mostly intact tunnels and arches of ice carved by lava before ice closed them in again.

Evaluating Hazards

Through their analysis, the team learned that the risk from meltwater was greatest during the initial explosive phase of the eruption, when vast amounts of ice melted, triggering torrential bursts. These sudden releases could overflow glacial lakes below, causing severe floods called jökulhlaups, which the authors called "one of the largest hazards associated with volcanic eruptions in Iceland."

Later, when the lava began to move beneath the glacier, the flow of lava mixed with water carved channels under the ice, localizing and limiting potential dangers and allowing meltwater to escape more regularly.

Clues in Pillow Lavas

Other observations by the team revealed how ice can quench and cool lava, which affects the shape and flow of molten material. These insights should help volcanologists more accurately envision the circumstances of past eruptions under ice, according to the study authors.

When lava interacts with ice, it solidifies into different forms, one of which is pillow lava. The ice cools the skin of the lava rap-

idly, creating a glassy, smooth exterior. The still-molten interior lava pushes through this skin and itself rapidly cools, forming distinctive bulbous lumps.

The resulting shapes serve as vital tools for geophysicists who study ancient glaciers. The locations where the pillow lava gives way to other lava forms along the slopes of a volcano give scientists an indication of how far glaciers extended at the time of past eruptions.

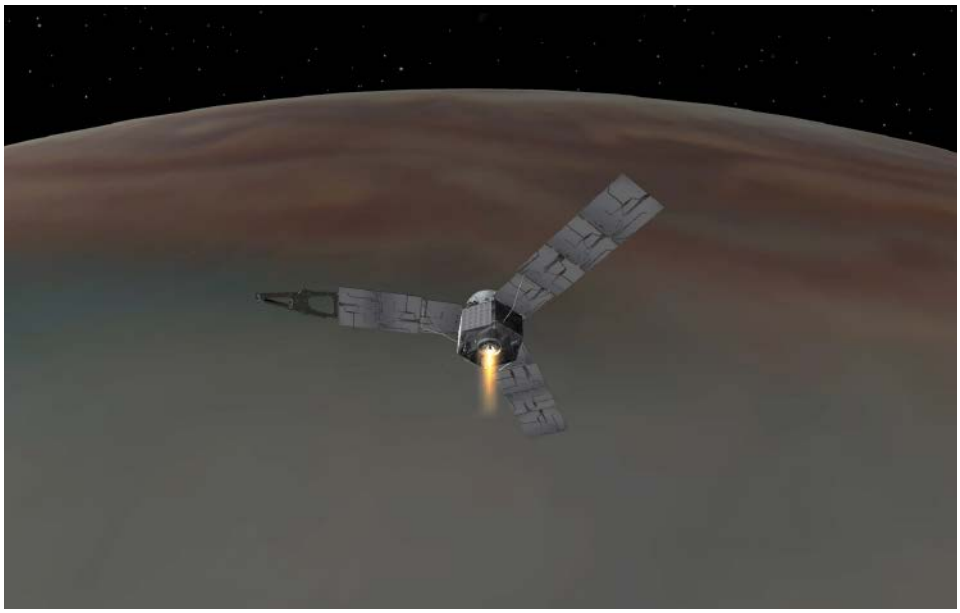
Other aspects of ice-influenced lava can tell researchers about the temperature and characteristics of the lava as it emerged. For instance, as opposed to the relatively smooth contours of hardened Eyjafjallajökull lava that had penetrated the ice, the roughly 10% that flowed on top of the glacier or beside it formed fields of sharp, jagged `a`a lava, according to the study.

"For someone like me, who looks more at the prehistorical geological record, it's really important to have these…real-time observations of lava-ice interactions," said Chris Conway, a volcanologist at Victoria University of Wellington in New Zealand, who was not involved with the study. Researchers can read layers of lava from multiple eruptions to learn how glacial shapes changed over time, he noted.

Although further snowfall can rebuild a glacier diminished by lava, remnants of the path that the molten rock carved through the ice on Eyjafjallajökull remained visible a couple of years ago, when the study authors last returned to the site, Edwards said. Monitoring the remains of ice after an eruption is important because it may help researchers studying ancient volcanoes better understand the changes to lava deposits that were later eroded by reformed glaciers, he explained. Some of the upper portions of the formerly 7.5-kilometer-long glacier at Eyjafjallajökull had filled back in by 2012, Edwards said. However, for the foreseeable future, the glacier will likely remain a kilometer or more shorter than it used to be.

By **Elizabeth Deatrick,** Freelance Writer; email: edeatrick@elizabethdeatrick.com

Juno Spacecraft Nails Its Orbit Around Jupiter



NASA/JPL-Caltech

An illustration depicting the Juno spacecraft successfully entering Jupiter's orbit.

On the night of 4 July, NASA's Juno spacecraft successfully entered orbit around Jupiter following a 35-minute engine burn that slowed the craft enough for the planet to capture it. At 8:53 p.m. Pacific Daylight Time, scientists received a signal from Juno confirming the orbit insertion.

"We're there. We're in orbit. We conquered Jupiter," exclaimed Juno principal investigator Scott Bolton at a news briefing later that night at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, Calif. Bolton works at the Southwest Research Institute in San Antonio, Texas.

"Tonight, through tones, Juno sang to us, and it was a song of perfection," said Rick Nybakken, Juno project manager from JPL. "After a 1.7-billion-mile [2.7-billion-kilometer] journey, we hit our burn targets within 1 second on a target that was just tens of kilometers large."

Prep for Science Observations

The day after Juno entered orbit around Jupiter—a risky maneuver during which its science instruments were shut down—the spacecraft restored high-rate communications. Then, on 6 July, the mission switched on five science instruments, according to NASA.

Juno's handlers plan to power up the remaining science instruments by the end of July. Then the spacecraft will spend approximately a year and a half studying Jupiter's core, mapping its magnetic field, and measuring the amount of water and ammonia in the Jovian atmosphere. Juno will travel around Jupiter in elliptical polar orbits to avoid an intense radiation region around Jupiter's equator and to limit damage to the craft's titanium-shielded instruments.

Steven Levin, Juno project scientist from JPL, said he looks forward to 27 August, 53.5 days (one orbital period) from when the spacecraft started looping around the giant planet. Then, with all of Juno's instruments expected to be operating, "we'll get our first really good look [at Jupiter] from close up and learn how Jupiter is going to surprise us." Levin said he hopes the mission also can help answer bigger questions about the origins of the giant planet and the solar system.

Visit http://bit.ly/Juno-movie to see a time-lapse movie of Jupiter's largest moons orbiting the planet. The images were captured by the Juno spacecraft during its final approach to Jupiter.

By **Randy Showstack,** Staff Writer

Academy Head Says Political Rancor Harms Science, Society

Ralph Cicerone, an atmospheric scientist, retired 30 June from the position of president of the U.S. National Academy of Sciences (NAS), which he had held for two terms since 2005 as arguably the world's most influential scientific opinion leader. Marine geophysicist Marcia McNutt, former editor in chief of the *Science* family of journals and former director of the U.S. Geological Survey, took the NAS reins on 1 July.

During a wide-ranging interview about science and society given in Washington, D. C., the week before he retired, Cicerone discussed with *Eos* challenges that he and NAS faced during his tenure, including climate change and threats to science from political polarization. Cicerone also discussed funding pressures, diversity in the academy, support for science, and the broad value of the scientific method.

Cicerone and the Academy

Reflecting on his accomplishments as NAS chief, Cicerone counts among them influential NAS studies about climate change. Other highlights include the establishment of the Gulf Research Program following the 2010 Deepwater Horizon oil spill (see http://bit.ly/NAS-Gulf) and two visits to NAS by President Barack Obama.

Established by Congress in 1863, the academy is a private nonprofit society that provides independent, objective advice to the nation on science- and technology-related issues.

Several top U.S. geoscientists told *Eos* that they credit Cicerone with raising the academy's stature and relevance, championing climate and environmental change studies, and raising awareness of science and its importance to society. For instance, academy member Richard Alley of Pennsylvania State University in University Park said that Cicerone "has been a visionary leader for the academy, strengthening its long-standing commitment to the very highest integrity while making the science more useful and accessible to policy makers and the public."

He's "a forceful and highly effective spokesperson for climate change science and for the integrity of science," said Mary Lou Zoback of Stanford University in Stanford, Calif., who is also an academy member and a member of *Eos*'s editorial advisory board.

Science in an Age of Political Partisanship

Cicerone told *Eos* that his biggest disappointment in office was the "rabid partisanship" surrounding climate change, which has included congressional grilling of climate experts and officials. He also expressed concern about recent congressional moves to limit geoscience funding at the U.S. National Science Foundation and elsewhere.

"The most frustrating thing has been these political developments around climate change," said Cicerone, adding, "We are trashing our institutions. For example, the antigovernment feelings that anything the federal government touches is somehow dirty and wasteful and somehow morally wrong: This just drives me crazy."

He said that some opposition to government traces to the American Revolution with people seeking local control, continued with President Ronald Reagan saying that government is the problem, and has extended with Republican resistance to White House initiatives on climate change and "an all-too-loud group of people who oppose any authority, especially based on expertise."

"I could see this [divisiveness] developing," Cicerone continued, "but I think the extreme statements that we've seen and the allegations that climate science is a fraud and that the geosciences as a field is partly culpable: This just blows my mind."

Cicerone said that he "did not see the severity [of attacks on science] coming. I'm still hoping it's going to go away quickly, but it's been hard to deal with because it has raised a whole set of questions. When do we have to stand up and say that all of science is being tarred with the same brush?"

Fortunately for science, according to Charles Kennel, past chair of the NAS Space Studies Board, no one was better equipped than Cicerone "by temperament, judgment, and intelligence to have led American science through the period of unprecedented political division that fell to Ralph to cope with."

Looking for Other Potential Solutions

As one possible solution to the political divide, Cicerone suggested that the business community may want to weigh in and consider calling on the White House for stronger action on climate change. "What I'm hoping is that the current resistance to discussions [about climate change], which is largely [from] the Republicans in the House and some in the Senate, that that is going to go away," he said. "I think the facts just keep piling [up]. Eventually, people are going to have to come around. The business community has been missing for the last 2 or 3 years. If you haven't noticed, the business community is no longer the leader of the Republican party. That could change in November."

Cicerone, who is a former AGU president—as is new NAS president Marcia McNutt—also suggests that scientific success stories help boost the credibility of science. Such successes

Randy Showstack

Ralph Cicerone, recently retired president of the U.S. National Academy of Sciences.

in a variety of areas, including nuclear waste management and space exploration, could have cascading effects in reducing political discord and public distrust of science, he said. "A couple of success stories along specific lines will be very valuable, because otherwise these fears and these hatreds are very hard to confront."

Critical Support for and from Science

Cicerone also lauded some Republican and Democratic politicians for their support for science—particularly President Barack Obama. He said many members of the President's Council of Advisors on Science and Technology (PCAST) have told him that Obama's interest in science is what keeps them going. Obama is "really interested," Cicerone said. "I don't mean this to be a political statement. But from a science point of view, the demonstrated interest of the president in science and technology issues across the board—health, engineering, you name it—that keeps PCAST going and it certainly keeps [White House science adviser] John Holdren going."

Holdren "tries to bring science into decision making in the government where it has been neglected before," Cicerone said. "And it's frustrating. I think what keeps him going is a commitment to the cause as well as the interest of the president."

Cicerone said that Obama's appointment of respected and knowledgeable scientists to key administration positions paid off in many ways, including participation by some of them in coming up with solutions to the 2010 Deepwater Horizon oil spill in the Gulf of Mexico. For instance, Steven Chu, who was U.S. secretary of energy from 2009 to 2013, co-led a science team that developed analyses and plans to control the flow of oil from the well and provided a determination of the leak rate.

"Steve brought things to the government which had never been seen before, like gamma ray imaging to see whether the [shutoff] valves were functioning or not," Cicerone said. Appointing top scientists "is a way to take advantage of science in a democracy," he added.

Internal Challenges

Cicerone, who also served as chair of the National Research Council (NRC), an arm of NAS, said that "job number one" for him was maintaining the quality and suitability of the approximately 200 NRC reports issued annually although federal reimbursements that help pay for those reports have diminished.

"Financially, things have been tough," Cicerone told *Eos*. The 2015 NAS treasurer's report states that over the past 5 years the annual federal funding to reimburse project costs, which include scientific reports, dropped by about $71 million, or 25%, from approximately $278 million to $207 million. During that same period, funding from private and other sources increased $20 million, from $52 million to $72 million, making up for some of the decline (see http://bit.ly/NAS-Treasurer-2015).

Regarding diversity of the academy's membership, Cicerone said that the institution has been doing better at bringing in more women. In 2005 when he took the helm, women composed 9.5% of academy members (187 of 2062 members); by 2016 that number increased to 15.1% (354 out of 2351 members). This year, women composed 28.6% (24 out of 84) of newly elected academy members. "It's just happening because there are a lot of overqualified women coming through the ranks" who are among the best people in their fields, Cicerone said. "Bingo. It wasn't that hard."

> "The scientific community is capable of leading much of the country out of this terrible partisanship by our methods."

However, Cicerone expressed disappointment in the progress made to increase the number of academy members from underrepresented minorities. "We have not done a good job finding new members in minority communities," he said. "There are some marvelous success stories, but there aren't enough of them. We've made only minor improvements there in our membership."

Gender a Plus for New Academy President

New NAS president McNutt—the first woman to lead the academy—likely will face many of the same challenges that confronted him, Cicerone said, including attacks on the scientific evidence of human-induced climate change and a segment of the U.S. population that resents authority, particularly federal authority in Washington, D. C. However, "I don't think there is any resistance amongst the academy membership or larger forces to say, 'Gee, we don't want to deal with a woman.' I think it is going to be the opposite," he said. "I've been in places where I've had to represent American science one way or the other, and I could just sense that they want a woman."

Cicerone, who is 73, added that "they want someone younger. After all, I've gotten old in this job. So I think putting a face on American science that's female and younger is going to be really great." McNutt is 64.

"Marcia will be great because she's pretty energetic," Cicerone said. "I don't think she's going to have any disadvantages. I could be wrong. There are still some holdovers who will somehow not give full credence to a woman, but I think it will be fine."

Faith in the Scientific Method

Some solutions to the current political impasse lie in following the scientific method, Cicerone said. "The scientific method is just so broadly capable of self-correction that we have to stick with it. I also think we have to remind ourselves [of] what is good behavior and try to stick to it where we don't automatically embark on any political message but try to review the facts and set examples. I think the scientific community is capable of leading much of the country out of this terrible partisanship by our methods," Cicerone said.

He cited the recent United Nations accord on climate change as a positive measure, saying that an "ingenious" aspect requires each nation to present its plan to reduce greenhouse emissions that gets revisited every 5 years.

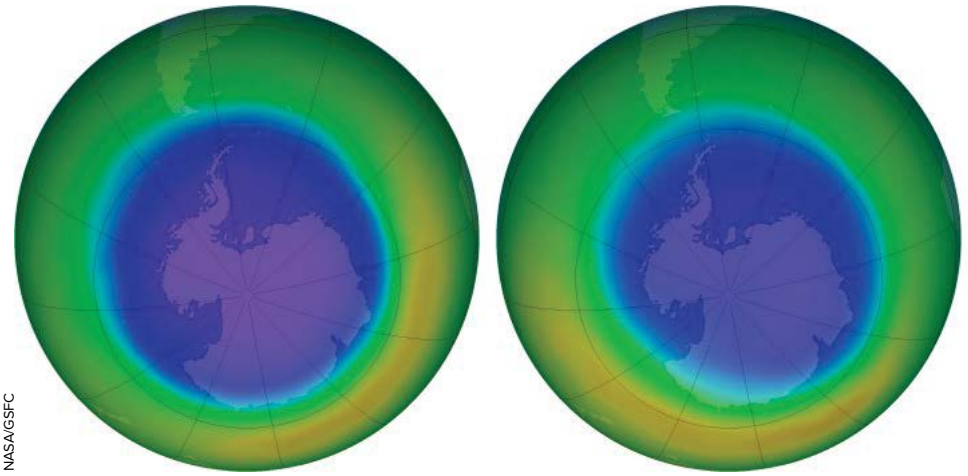
"There is going to be imposed a high-level, international, technically competent review to see if the claims are being met [and] what is the rate of progress," Cicerone said. "This gets to the issues where other people have said over the years that if we really want all nations to contribute, there can't be any BS here. The reduction of greenhouse gas emissions has to be verifiable, using modern technical means, which are really advanced."

He added, "I know I'm sounding like a nerd here, but I really do see a good parallel between democratic agreements, democratic processes, and the scientific method."

As Cicerone was about to exit the NAS presidency, a question lingered in his mind about how fast society can fix its mistakes. He said that he has a lot of confidence in the self-correcting capability of science but wonders whether science can help society quickly enough to correct its course. "Is something bad going to happen before something good happens? I think that's the race that we are in."

By **Randy Showstack,** Staff Writer

Antarctica's Ozone Hole Is Healing, Scientists Say



NASA/GSFC

False-color images of Antarctica's ozone hole in (left) September 2000 and (right) September 2014. The hole has shrunk by 4.5 million square kilometers since 2000, according to a new paper. Blue tones indicate areas of extremely low ozone concentrations. Purple tones indicate areas of lowest ozone concentrations.

First discovered in the 1980s, the hole in the Earth's ozone layer that stretches above Antarctica every October is an iconic example of how human activity and atmospheric chemistry are inextricably linked. This hole measured an average of about 18 million square kilometers in September 1987 and widened to nearly 25 million square kilometers in September 2000, thanks to industrial pollutants that destroy ozone in the stratosphere.

The ozone layer protects Earth's surface and the plants and animals that live on it from ultraviolet radiation from the Sun. Now scientists report that public policy efforts that banned ozone-destroying chemicals have paid off: The ozone hole has shrunk by more than 4 million square kilometers since 2000. That's a 16% decrease.

"We can now be confident that the things we've done have put the planet on a path to heal," said Susan Solomon, lead author of a *Science* paper published on 30 June (see http://bit.ly/science-ozone) and an atmospheric chemist at Massachusetts Institute of Technology in Cambridge.

Ozone-Destroying Chemistry

The ozone layer, found 20–30 kilometers above Earth's surface at the lower edge of the stratosphere, protects the planet from the Sun's ultraviolet radiation. At the time of the hole's discovery, industrial activities around the world emitted chemicals called chlorofluorocarbons (CFCs) into the atmosphere.

Thanks to the pioneering research of Solomon and her team in 1986 (see http://go.nature.com/29Ftz8R), scientists discovered that CFCs reduced stratospheric ozone concentrations all over the world. At that time, industries used CFCs in refrigeration and dry cleaning; even aerosol hairspray released the chemicals. The reduction was particularly bad over Antarctica, where even extremely low concentrations thinned the ozone layer enough that scientists referred to it as the ozone hole.

CFCs destroy ozone every Antarctic spring, but the process starts before winter even begins. When the Sun permanently sets in March, a vortex of cold polar wind swirls around the continent, cooling the stratosphere. Water vapor droplets collect around molecules of CFCs, forming clouds.

Once the Sun rises again in July, ultraviolet (UV) light strikes the CFCs, breaking chemical bonds and freeing chlorine. The free chlorine atoms subsequently strip oxygen from ozone molecules (O_3) to form other chemicals, destroying the ozone itself. The ozone hole reaches its peak size in October, and by November the stratosphere heats up enough to break apart this polar vortex and fill the hole.

Protecting Stratospheric Ozone

To scientists, the vast hole in the ozone layer over the Antarctic set off warning bells because the ozone layer absorbs UV radiation from the Sun. Without the ozone layer's protection, humans and other life would be exposed to the harshest UV rays, which can burn tissue and trigger mutations in DNA that cause cancer. Put another way, without the ozone layer's protection, life as we know it would not exist.

Once researchers, including Susan Solomon's team, found a link between the ozone hole and industrial CFCs, world leaders came together and signed the Montreal Protocol in 1987, which called for a ban on those and similar substances. Production and use of CFCs ended in developed countries in 1996 and developing countries in 2010.

The ban had an observable effect on the atmosphere: A National Oceanic and Atmospheric Administration report from 2010 stated that chlorine in the atmosphere from CFCs had declined by 1.3% since its peak in 2000 (see http://bit.ly/ozone-assess).

Examining the Hole

NASA satellites have tracked ozone concentrations since the 1970s, so researchers involved with the new study tapped that database to investigate changes in the ozone layer each September since the year 2000. They also looked at direct measurements taken by scientific balloons that carry instruments into the stratosphere. Between 2000 and 2015, the researchers found that not only is the rate of ozone depletion decreasing but also the size of the annual hole has shrunk.

Although the hole reaches its maximum size in October, the researchers specifically looked at September, because at that point the swirling polar vortex is more stable, Doug Kinnison, a coauthor on the paper and an atmospheric scientist at the National Center for Atmospheric Research in Boulder, Colo., told *Eos*. In October the highly dynamic vortex is prone to shifts that can change the size and location of the hole in inconsistent ways, Kinnison said, so by focusing on September, the researchers teased out a stronger signal of changes in size and depletion rate year by year.

Volcanic Interruptions

The researchers hit a snag in the data for 2015. Curiously, the ozone hole reached a record-breaking size that year, a whopping 25.3 million square kilometers, prompting some scientists to rethink their previous estimates of its rate of healing. But Kinnison and his colleagues discovered that the eruption of Chilean volcano Calbuco in May of that year was to blame for the drastic drop in ozone.

The researchers confirmed this by running models of ozone depletion with and without the input of gases from volcanic eruptions. Large volcanic eruptions spew hundreds of thousands of tons of sulfur dioxide into the atmosphere, which reacts with water vapor to form sulfate aerosols. Along with slightly cooling the planet, these sulfur aerosols provide a surface on which ozone-destroying chemical reactions happen. This phenomenon has been well documented after every major volcanic eruption, including those of Mount Pinatubo in 1991 and Mexico's El Chichón in 1982.

Therefore, although the researchers continued to observe a drop in atmospheric chlorine in their models, Calbuco's 400,000 tons of sulfur dioxide led to an increase in polar stratospheric clouds and thus ozone destruction.

Ozone of the Future

"It's good to see some sign of improvement," Susan Strahan, an atmospheric scientist at NASA Goddard Space Flight Center in Greenbelt, Md., told *Eos*. Strahan wasn't involved in the research.

But because of how much temperature can affect the size of the ozone hole year by year, Strahan says it has often been difficult to pick out a signal of healing from the noise.

"We atmospheric scientists are anxiously awaiting the day when we can conclusively look at the observations of the ozone hole and say, 'Yup, it's definitely getting smaller and, yup, it's because of chlorine [decrease].'" The paper's results are "a small piece of the puzzle, and we expect that in years to come we'll see stronger evidence."

In 2009 scientists at NASA created a vision of a world without the Montreal Protocol. In their "World Avoided" simulation, the researchers predicted that by the year 2065, the ozone hole not only would have stuck around all year, but also a twin would have formed over the North Pole (see http://go.nasa.gov/29GbTF3). In that scenario, people in midlatitude cities would suffer sunburns after 5 minutes outside, and DNA-mutating radiation would increase 500%.

Instead, Solomon expects that the ozone hole will shrink and eventually seal up by midcentury.

Science was helpful in charting a path away from these molecules for countries to follow, Solomon explained. "Now we've actually seen the planet starting to get better," she said. "It's a wonderful thing."

By **JoAnna Wendel,** Staff Writer

Exoplanet Found in Curious Triple-Star System

A newfound exoplanet orbiting within a triple-star system has scientists scratching their heads.

Located some 340 light years from Earth, the gas giant called HD 131399Ab weighs in at about 4 times the mass of Jupiter, gets illuminated by not one but three stars, and takes 550 Earth years to complete one loop around its central star.

That star, dubbed HD 131399A, exceeds our Sun's mass by 80% and orbits a center of mass shared with a smaller star, HD 131399B, which is itself orbited by yet another star, HD 131399C.

Each of the stars exerts gravitational force on the exoplanet. For much of that giant planet's half-millennium orbit, someone on its surface would see triple sunrises and sunsets, its discoverers said.

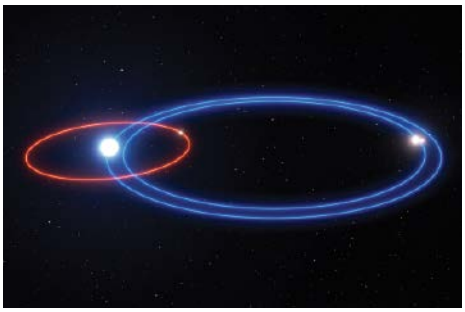
That spectacle may sound like a treat, but for about a quarter of the giant planet's orbit, the paired stars set while the big star rises (and vice versa), brightening up the exoplanet with constant starlight, said Kevin Wagner, a first-year Ph.D. student at the University of Arizona in Tucson and lead author on a paper reporting the discovery of the exoplanet. He and his colleagues published their findings on 7 July in *Science* (see http://bit.ly/Jovian-3stars).

Unlike many other recently discovered exoplanets, the researchers found HD 131399Ab with direct imaging, meaning that they observed and studied light from the planet itself. It was the first exoplanet discovered by the team in a new search for exoplanets made with the Very Large Telescope in Chile's Atacama Desert. The researchers used the telescope's new auxiliary Spectro-Polarimetric High-contrast Exoplanet Research (SPHERE) instrument, which is designed specifically to capture telltale infrared radiation from exoplanets while blocking out the light from surrounding stars.

Precarious Orbit

The planet isn't the first found in the middle of a three-star dance, but its position relative to the stars piqued the team's curiosity.

Generally, planets in three-star systems orbit close to one star while the other two stars orbit much farther away. In another three-star system, called 51 Eri, the planet orbits a star at 13 astronomical units (AU) while the other two stars orbit at 2000 AU. HD 131399Ab, however, orbits at 80 AU—that's twice the distance from the Sun to Pluto—while the twin stars HD 131399B and HD 131399C reside about 300–400 AU from the central star.



ESO

An artist's representation of a newly discovered triple-star system. Planet HD 131399Ab orbits on the red line around the star HD 131399A, whose orbit is represented by the outer blue curve. The other two stars, HD 131399B and HD 131399C, swivel around a center of mass represented by the inner blue curve. Stars A, B, and C all orbit around a shared center of mass.

That means the planet is trapped in a precarious balance, in a fragile orbit amid the stars' powerful gravitational fields. If it were a bit closer to stars B and C, Wagner said, it would have been flung long ago into space.

Wagner noted that HD 131399Ab doesn't look like it could have formed in its current position. Planets and stars form from collapsing clouds of dust that flatten into protoplanetary pancakes full of growing chunks of material. So "the other stars would have disrupted the disk at about the same location that we see the planet now," Wagner said. But with only a brief glimpse of the planet on its 550-year orbit, scientists know too little to determine how the planet got to its current position, he added.

The researchers plan to investigate the system more closely to learn about its origins. In the meantime, Wagner said, HD 131399Ab "tells us that there are systems out there that are kind of weirder than we can imagine."

Visit https://youtu.be/SrzJEkovZLw to see a simulation of the newly discovered solar system that shows the motion of the stars and exoplanet.

By **JoAnna Wendel,** Staff Writer

Planning for a Subduction Zone Observatory

USGS

A scientist investigates dramatic subsidence—in places up to 2 meters—along the northwestern coast of Sumatra in January 2005. Here tsunami waves spawned from the M_w 9.1 earthquake that shook the region on 26 December 2004 snapped off treetops; roots and lower trunks are now submerged in water.

Subduction zones contain many of Earth's most remarkable geologic structures, from the deepest oceanic trenches to glacier-covered mountains and steaming volcanoes. These environments formed through spectacular events: Nature's largest earthquakes, tsunamis, and volcanic eruptions are born here.

Great subduction zone earthquakes can cause coastal subsidence in minutes that has impacts comparable to a century or more of climatically driven sea level rise. They can radiate shaking waves that trigger widespread landslides and submarine slope failures and can spawn tsunami waves that reach distant lands. Eruptions can produce fast-moving mudflows as well as high-lofted ash clouds complete with their own lightning systems.

The geologic processes in subduction zones shape surface morphology, couple plate motions to mantle convection, control resource distributions, and even interact with Earth's climate—volcanic gases can cool the climate, and sediments at subduction margins are important reservoirs for greenhouse gases. In short, the diverse environments in subduction zones are natural laboratories for investigating a wide range of interlinked processes.

The myriad opportunities for collaborative work among scientific disciplines, institutions, and nations have inspired a grassroots movement to create a subduction zone observatory (SZO), now in a nascent stage of planning. Over the past few years, Earth scientists have been discussing options for its geographic scope and structure. For example, should such an observatory focus on one subduction zone or multiple zones? Should it be managed as a center or an umbrella organization? How should resources be balanced between new facilities and funds needed for research?

As part of these discussions, we held a series of seminars focused on SZO topics. A more official and much broader workshop will occur in September 2016 (see http://bit.ly/-297NRFT). Here we share ideas that have emerged from past talks in an effort to grow the movement, advance community discussion, and help shape a vision.

Lessons from Tohoku

Scientific focus on subduction zones has increased dramatically in the past decade, accompanying a recognition that large numbers of people are migrating to urban areas that lie within subduction zones. Scientists recognize the hazards inherent in living near tectonically active margins [*Bilham*, 2009] and are motivated to understand them so that they may provide the best advice to protect communities.

Investments in onshore and offshore instrument arrays have enhanced the resolution of our understanding of subduction-related processes. Multifaceted analyses can make monitoring systems and hazard assessments more robust. For example, the M_w 9.0 Tohoku earthquake, which shook Japan in 2011, occurred in an area with an abundance of onshore and offshore observations, including geodetic and seismic signals, marine seismic reflection profiles, bathymetry, tsunami wave heights, and novel seafloor acoustic GPS and pressure measurements. Offshore observations provided, for the first time, unambiguous evidence for why the tsunami was so large—they documented several tens of meters of fault slip near the Japan Trench (Figure 1). Rich data sets and multifaceted analyses also revealed that days before the Tohoku earthquake, the plate interface began slipping slowly, with slip propagating toward the initiation point of the M_w 9.0 earthquake [*Kato et al.*, 2012].

The 2011 Tohoku earthquake illustrated the potential of an SZO to significantly advance understanding of the processes at work before, during, and after a major event. It also prompted sobering retrospectives on the difficulty of anticipating its enormous size, even after meticulous paleoseismological studies [*Sawai et al.,* 2012], underscoring the need for further research investments that will make subduction zone populations more resilient.

Key SZO Features

Ideally, an SZO would produce research that is transformational, multidisciplinary, amphibious, and international. As illustrated by the Tohoku earthquake and tsunami, an SZO would enable transformational research by facilitating acquisition and analysis of disparate data with multiple synergistic applications considered from the start. An SZO must be multidisciplinary to understand linkages between processes within subduction zones and the transitions to adjacent tectonic environments.

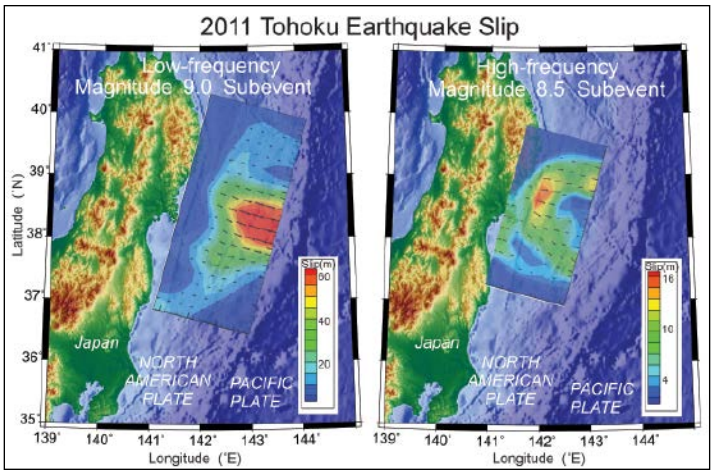


Fig. 1. Fault slip from the M_w *9 Tohoku, Japan, earthquake in 2011. Seismic and GPS waveform modeling revealed significant slip in patches with varying characteristics (amplitudes color coded), as if it were a composite of smaller earthquakes. The plate interface (fault) dips to the west. A downdip patch radiated the high-frequency waves that damaged buildings (right map), and the largest slip on an updip patch (left map) generated the enormous tsunami. Modified from* Frankel *[2013].*

The tremendous diversity of processes and physical characteristics displayed by the world's subduction zones begs for a global scope. Although the geographic scope of an SZO remains to be determined, we illustrate key features of an SZO with some examples of broad questions addressed in particular regional studies. Two of the three examples come from the Cascadia subduction zone (Figure 2a), only because it is where most of the authors reside and work.

How do accretionary prism sedimentation, geochemistry, ocean currents, and climate change interact with gas hydrate stability? Subduction margin sediments contain a significant fraction of Earth's greenhouse gas methane. This methane, derived from sediments of terrestrial origins and organisms at the sea surface, gets bound within the solid crystalline water lattices of gas hydrates. In Cascadia, multichannel seismic reflection profiles reveal a gas hydrate reservoir in a swath along the seafloor where the water depth exceeds 500 meters (depth contour in Figure 2a), above which hydrates decompose. However, seawater warming at these depths threatens to decompose some of this hydrate. This could increase bottom water acidity and lower the water's oxygen content, which could have dramatic negative effects on organisms and accelerate climate change.

How do subduction zones transition to other types of tectonic regimes? At the northern end of the Cascadia subduction zone (Figure 2b), the plate motions change from converging toward one other with associated subduction and thrust faulting along shallowly dipping planes to moving parallel to each other, accommodated by steeply dipping strike-slip faulting, in which most of the movement is horizontal. The Queen Charlotte Fault system is this latter "transform" boundary. The 2012 M_w 7.8 Haida Gwaii earthquake in British Columbia occurred on this system and illustrated the complexity of this transition, with surprisingly many of the characteristics of a subduction zone thrust event.

Recent studies of the Alaska subduction zone demonstrate that during great subduction zone earthquakes, as ruptures approach the seafloor, they sometimes propagate from the plate interface to secondary faults, sometimes also deforming ductile overlying sediments. Uncertainties in seafloor fault displacements remain the most significant unknown in local tsunami hazard assessments [*Geist*, 2002]. These hazards could be reduced with an SZO monitoring system and seafloor mapping before and after events.

How do subducting slabs and volcanism affect continental crust creation? Processes that generate magmas in subduction zones are the "factories" that create continents, based on the similarity between the compositions of continental crust and volcanic arcs. Numerous hypotheses exist about the processes by which slab materials accrete, subduct, melt, mix, and emerge at crustal depths or extrude from active volcanoes. Testing these hypotheses requires integrated studies spanning the disciplines of chemistry, petrology, fluid dynamics, geology, and seismology, with four-dimensional imaging.

An SZO must be amphibious, and this requires new means of collecting and integrating offshore and onshore observations. Scientists need sustained marine geodetic observations to characterize subduction zone deformation processes over many timescales, from plate motions (decades) to earthquake fault slip (seconds). A geodetic component of an SZO could include high-resolution repeat seafloor mapping, pressure gauges, and novel tools like fiber-optic strain meters. These and other frontier offshore measurements are applicable to multiple scientific questions and practical applications.

A High-Impact, Societally Relevant SZO

The envisioned SZO would contribute to the scientific understanding needed to build societal resilience in the face of natural hazards. It would also serve as an international educational resource. For example, recording earthquake ground motions using densely spaced networks would enable us to properly calibrate the simulations that underlie seismic hazard

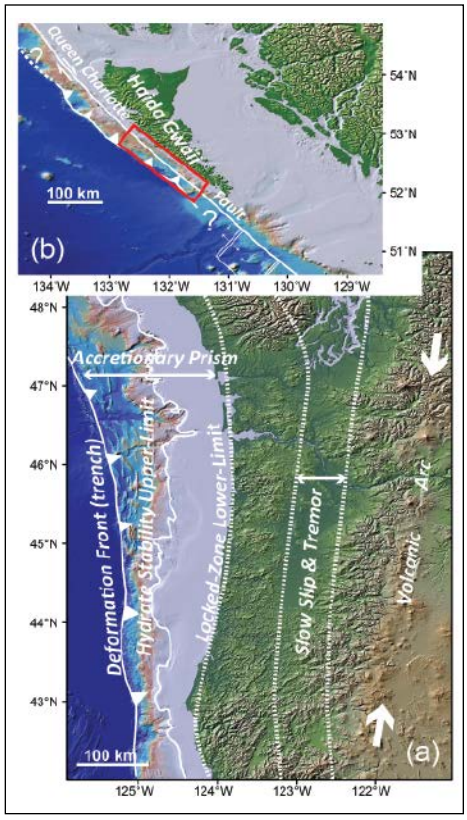


Fig. 2. The Cascadia subduction zone off the western coast of the United States and Canada provides examples of questions a subduction zone observatory could address. Merged bathymetry and topography (shaded) with superposed boundaries (white lines and arrows) illustrate the diversity of environments. (a) Southern and central Cascadia, from Pacific Ocean depths (dark blues) to high Cascade mountains and volcanoes (browns). Processes include formation of an accretionary prism, formation and dissolution of methane hydrates (jagged white line), consumption of the Juan de Fuca plate at the deformation front (hatchuring), and its descent beneath the North American plate. The plate interface is stuck (locked) at shallow depths and slips slowly at greater depths, generating tremors. Deeper, metamorphic changes lead to volcanic arc formation. (b) In northernmost Cascadia, the tectonic activity transitions from subduction to transform boundaries. The red rectangle outlines the rupture plane of the M_w *7.8 Haida Gwaii earthquake.*

assessments and building codes (Figure 1).

An SZO should be built collaboratively with those responsible for hazard mitigation and response. Perhaps most important, it could offer opportunities to involve citizens in research, through educating the public and making them stakeholders. For example, local scientists, students, and interested citizenry could be engaged to make biological and survey observations before and after events and to document coastal uplift and subsidence, tsunami inundation, or storm surge impacts. Such engagement could extend understanding of the effects of major natural events in places where we lack prior baselines, and it would fit naturally into educational programs that teach by doing.

A Path Toward an SZO

Moving an SZO from concept to reality will require coordination within and among academic and hazards assessment communities. Individually and as members of professional entities, we must lead, advocate for, and contribute to proposals to governmental and private sector institutions to support, design, and build an SZO. If the Earth science community collaboratively pursues creative strategies, developing an SZO may simultaneously serve to enrich observational tools, improve hazard models, and enhance our basic understanding of one of Earth's most dynamic environments.

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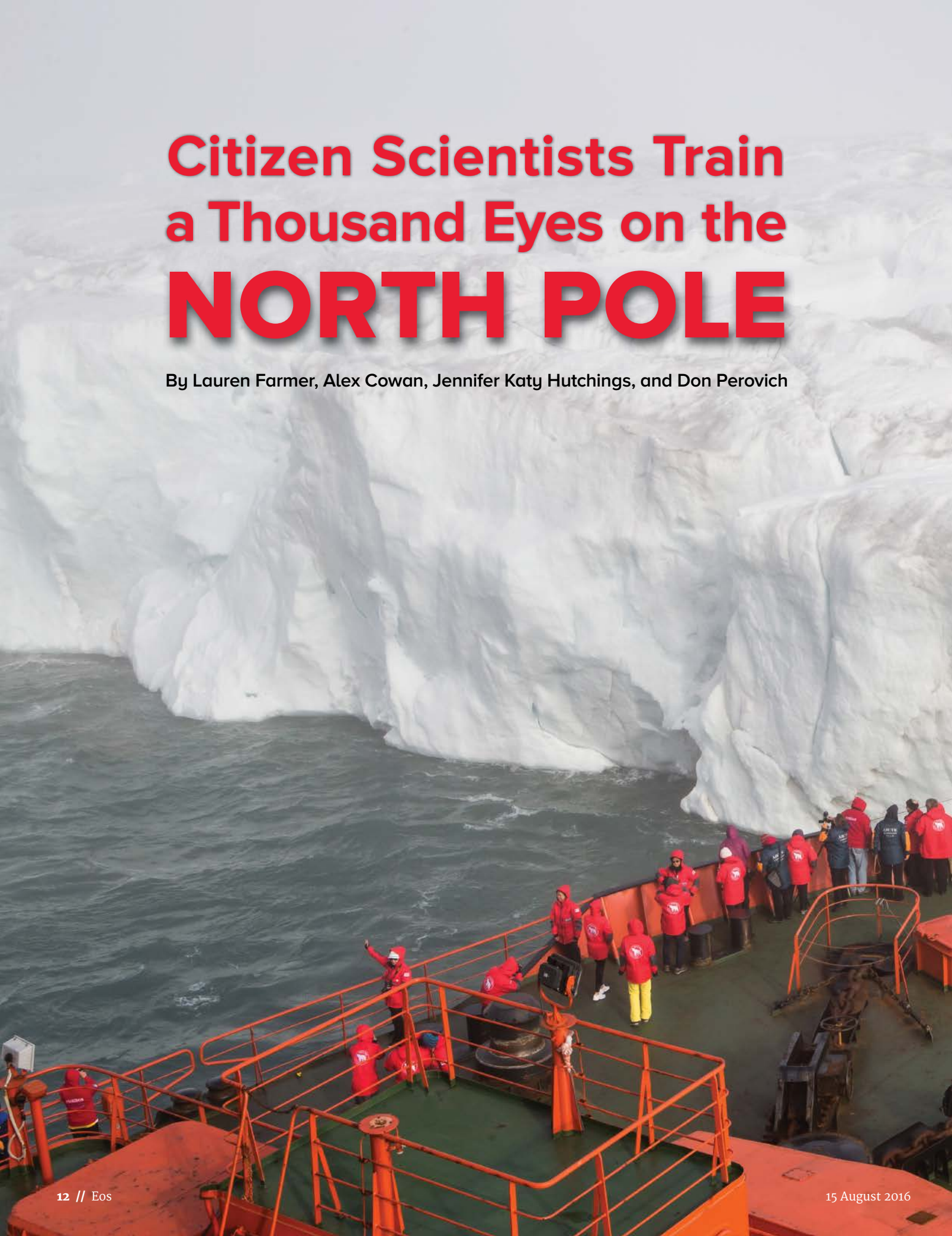
Citizen Scientists Train a Thousand Eyes on the NORTH POLE

By Lauren Farmer, Alex Cowan, Jennifer Katy Hutchings, and Don Perovich



During expedition cruises, tourists participate in collecting scientific data and contribute to ongoing observations of sea ice conditions in the Arctic.

All eyes were on the ice as the Russian icebreaker *50 let Pobedy* (50 Years of Victory) plowed forward. The destination was in sight for the 130 passengers on board for the cruise of a lifetime—the North Pole. They had sailed across the Arctic Ocean, which has undergone major losses of summer sea ice in recent decades. The ocean that once was covered by ice several years old and several

Lauren Farmer

The bow of Russian icebreaker 50 let Pobedy, *operated by Poseidon Expeditions, visits the calving face of the Vilchek Ice Cap in Franz Josef Land.*

Lauren Farmer

Citizen scientists measure depth profiles for a melt pond at the North Pole.

Cruises take paying "adventure travelers" to Franz Josef Land in the Russian Arctic and then to stand on top of the world at the North Pole.

meters thick is now dominated by a layer less than 1 year old and less than 2 meters thick.

Polar tourism is an established and increasingly diverse industry, and a significant portion of it consists of what is known as "expedition cruising." Relatively small (80–200 passengers) ice-capable cruise vessels, equipped with fleets of rubber boats for excursions, traverse large areas of the Arctic and Antarctic for months at a time during the summer season. These vessels can act as research platforms, an activity that tour operators and paying passengers increasingly see as a positive addition to the cruise, fitting well within a program that is already strongly focused on education.

During July and August of 2015, two of us (L.F. and A.C.) were employed as expedition staff for four round-trip cruises from Murmansk to the North Pole on the nuclear-powered Russian icebreaker *50 let Pobedy* with the tour company Poseidon Expeditions. The ship's itinerary included repeat traverses from the edge of the ice pack all the way to the North Pole and back again, making it an ideal platform for observing and recording the state of the sea ice cover over the course of a summer melt season.

The purpose of these North Pole cruises is to take paying "adventure travelers" to Franz Josef Land in the Russian Arctic and then to stand on top of the world at the North Pole while providing an entertaining and educational experience. As part of the guides' role as educators, we developed an observation program in which passengers were intimately involved in the collection of data about the state of the sea ice cover.

Because the research project was a late addition to the cruise program, we announced it to the passengers at the beginning of each cruise. Interested passengers learned more fully about the aims and techniques during a lecture

Lauren Farmer

Citizen scientists touring the Arctic aboard the Russian icebreaker 50 let Pobedy *examine a melt pond at the North Pole.*

Citizen scientists take a moment to stand "at the top of the world" as they encircle the North Pole.

on sea ice. The sea ice observation program included an ice watch while the ship was in motion, ship-based and aerial video and photography, and on-ice measurements at the North Pole.

Watching the Ice

The passengers conducted an ice watch while the ship was in ice-covered waters. The team implemented the exact protocols used by scientists on research cruises, using the Arctic Shipborne Sea Ice Standardization Tool (ASSIST; http://bit.ly/Ice-ASSIST) to create consistent data sets. Every 2 hours, passengers viewed the ice from the ship's bridge and described the ice conditions. They recorded data, including ice concentration, ice thickness, melt pond coverage, topography, and meteorology. We trained passengers by guiding them through each observation, using images and help sheets posted on the bridge.

Passengers recorded data, including ice concentration, ice thickness, melt pond coverage, topography, and meteorology.

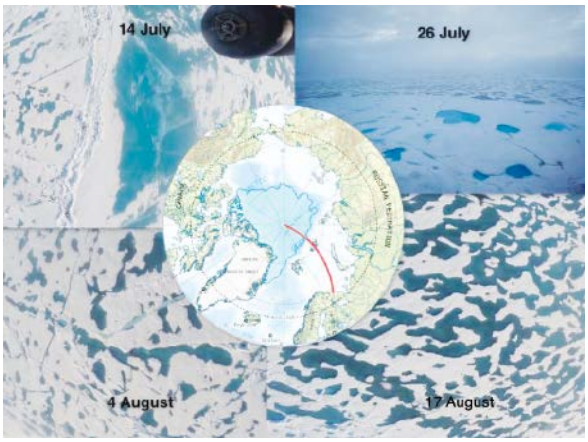
At all times, members of the expedition team, who had received training in advance of the cruises, were there to inform the observation process and ensure consistent observations. The data gleaned from these observations were rapidly made available to both Arctic researchers and the public. The findings from this and similar cruises can contribute to reports of ice conditions and to forecasts of sea ice, and they are generally of interest to people concerned about the state of the Arctic sea ice cover.

A rail-mounted camera provided continual video and photographs of ice conditions during bridge observations. Data on ship position, heading, and speed were integrated into the video stream; the combination of video and ship speed provides insight into the overall strength of the ice pack. In addition, researchers mounted a camera underneath a helicopter during sightseeing flights, giving an overview of ice conditions.

Walking at the Top of the World

Halfway through the cruise, the ship was moored to the sea ice at the North Pole for 8 hours, allowing the passengers a chance to walk on a frozen ocean and enjoy a moment on top of the world. It was also an opportunity for the team to make important measurements describing ice surface conditions, including melt pond characteristics, snow depth, and ice surface properties (see the photograph at the top of page 14). These are all critical components in determining the albedo of the ice cover.

There are very few opportunities for in situ observations of the state of the sea ice cover, and thus this project benefits the science community in a number of ways. Citizen scientists aboard cruise ships are providing valuable scientific information. In this instance, the round-trip cruises



Alex Cowan

Fig. 1. Photographs of the ice from each cruise, with a representative track from Murmansk to the North Pole via Franz Josef Land. These images can be analyzed to determine the seasonal evolution of melt ponds.

provided observations of the spatial variability of the state of the ice cover. We have conducted four of these cruises to the pole, which adds a temporal component that can follow the ice evolution from early melt through summer to fall freeze-up. The observations can be used to define current ice conditions and inform sea ice models, and they can be integrated with satellite observations. Figure 1 shows a typical cruise track of the ship and photographs of the ice from the four cruises.

Expedition cruise industry groups for the Arctic and Antarctic are very receptive to these efforts, developing a stronger focus on citizen science and facilitating research opportunities on board.

After the Cruise

In addition, this project accomplished a stated aim of the expedition cruise industry: to create a "corps of ambassadors" who return home feeling connected to the area in which they've traveled and who will work to protect the polar regions. On each of the four cruises, a small but remarkably dedicated group of passengers attended most or all of the ice watches and enthusiastically participated in the measurements at the North Pole ice station. Giving them the opportunity to participate in research aided in their understanding of the state of the Arctic sea ice cover, accomplishing the tour operator's aim of providing an educational and entertaining experience. In addition, some stated that opportunities to take part in scientific efforts would influence their cruise choices in the future.

This is a fledgling event, but the expedition cruise and scientific communities have responded favorably. We are now working to expand this effort and have been attending various conferences to present the concept to both the expedition cruise industry and the scientific community. Expedition cruise industry groups for the Arctic and Antarctic are very receptive to these efforts, developing a stronger focus on citizen science and facilitating research opportunities on board. Current efforts are directed at extending this particular project to future summer seasons aboard *50 let Pobedy* and expanding the effort to include other tour operators, thereby increasing the scope of data collection.

A long-term aim is to demonstrate that a diverse range of projects could be incorporated into the itineraries of expedition cruise vessels and that passengers and tour operators are already interested in doing so. This would significantly increase the number of marine research platforms available to the science community, especially in polar regions.

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bioraven/Depositphotos.com

Teens and Scientists Come Together at Science Cafés

By Michael Mayhew and Michelle Hall

At the 2006 American Association for the Advancement of Science meeting in St. Louis, Mo., we happened upon a session about the "Café Scientifique" approach to engaging the public with science and scientists. Café Scientifique programs—also known as science cafés—combine two essential ingredients. First, they take place in a collegial social setting like a coffeehouse or restaurant where participants can interact with a scientist and each other. Second, they satisfy participants' curiosity about a science-based topic via conversation with a scientist. It is this blend of the two interactive ingredients that accounts for the Café Scientifique model's grow-

Michelle Hall

Matthew Schauer examines a skeleton, looking for clues on gender, age, racial features, and possible cause of death. He checks to see whether they match any of the profiles on a list of 12 victims provided by Amy Wyman (New Mexico Office of the Medical Examiner) at a Teen Café on "The Secrets Held Within a Bone."

ing popularity—from grassroots beginnings in England, it has grown to include nearly 400 organizations around the world.

We thought this was a splendid idea indeed, and it led us to wonder whether this might be a good way to connect science and that hard-to-reach segment of the public, the high school teenager. With a grant from the National Science Foundation (NSF), we began the experiment in four northern New Mexico towns with very diverse ethnic, socioeconomic, and population characteristics: Santa Fe, Los Alamos, Albuquerque, and the tiny town of Española.

Our primary goal was for the teens to increase their understanding of the nature of science and to develop a realistic perception of scientists and the lives they lead—which they typically do not get in school. We wanted to get across to the teens that a scientist is a real, complex, multidimensional human, like them. We wanted our presenters to convey that they are leading particularly interesting lives in science. We wanted to instill an appreciation of the relevance of all kinds of science to the students' own lives.

Our secondary goal was to help our scientist-presenters learn to effectively communicate the fruits of their own research to the public—especially our particular segment of the public, which, frankly, many scientists find to be intimidating!

We recently completed the ninth season of Café Scientifique New Mexico (Café NM; http://cafenm.org). As the details of our Teen Café model have been refined through trial and error over the years, the program has proven increasingly popular with the teens for much the same reason that adult science cafés are popular.

Our evaluations tell us that we have been successful. From the summative evaluation, "analyses indicate that the Café program succeeded at positively influencing attitudes about science. All the items designed to measure attitudes towards science, scientists, and science-based careers showed statistically significant differences between the participant and non-participant groups." The evaluation results show that teens find interaction with scientists interesting, fun, and eye-opening—71% of respondents agree that the

café has changed their view of the importance of science to their lives.

Michelle Hall

Neale Pickett (Los Alamos National Laboratory) explored "Cyber Attacks: First Google, Then You?" The teens solved puzzles and competed in teams to "capture the flag" in this Teen Café on white hat hacking and cybersecurity.

Teen Science Café Network

As a result of the success and maturity of our Teen Café model—and interest in other organizations in starting their own Teen Café programs—we got new funding from NSF to develop a network of such programs around the country. The Teen Science Café Network (TSCN; http://teensciencecafe.org) started its first season with five founding member organizations.

Now in its fourth year, the program has grown to more than 40 sites around the country, from Alaska to Florida and Maine to Texas. Each node in the network has applied the model with a delightfully unique flair appropriate to local institutions and demographics. Some of the nodes run cafés in multiple local venues, including museums, office parks, community centers, and churches. They have achieved a high degree of diversity by holding cafés where teens are, in the unique ethnic and social environments of their own communities, rather than having attendees travel to a central location.

Our Teen Café topics have covered a very wide range, from belly button biodiversity to cybersecurity to flocking behavior of birds to a day in the life of a teen dolphin to corals on acid to emergency room medicine to alternative-fuel cars. Presenters have come from a great variety of local institutions, including universities, research labs, and businesses.

Most nodes in the network offer cafés on the whole range of topics in science, engineering, and technology, but programs may focus on one discipline. For example, the Florida node focuses on ocean science; a new hospital-based node just coming on will focus on medical science. A program could well have a disciplinary focus in any area of the geosciences, such as tectonics, hydrologic science, or space physics.

There are other secrets of success associated with the teen audience. One is that the teens achieve a sense of ownership of the program through forming teen leadership teams at each site. We encourage the teens to lead all aspects of the program to the greatest extent possible, with adults in the background for support.

Another is that although we have deliberately avoided holding cafés in schools, we have made a point of building relationships with high school teachers, who have proven supportive and helpful in innumerable ways. And a third is that in every café, we work with the presenter to develop some sort of activity that the teens can engage in to complement their interaction with the presenter—teens like to *do* stuff.

Hands-on activities that actively engage the teens help to cement the science message. Activities can include examining artifacts to answer a question, handling or observing live animals, competing in team games like cybersecurity or robotics challenges, and taking *Jeopardy*-like quizzes. Activities can even engage the whole body, where students simulate the movements of animals or seismic waves.

How to Talk to Teenagers (About Science)

The degree of engagement needed to spark interest in science topics—especially for the teen audience—is unfamiliar and daunting to many café scientist-presenters, even those with experience in public speaking. Most have been trained to approach science communication in the "information deficit" mode, that is, "stuffing" the audience with information they think the audience needs without any attempt to interact and determine whether the audience understands the information or finds it meaningful. However, with coaching from the program staff and after some initial trepidation, the scientists typically rise to the occasion.

We begin this process by identifying potential café presenters within our local science organizations, looking particularly for scientists working in areas that our teen leaders have expressed interest in hearing about. We then carefully vet the potential presenters and have informal conversations in which we convey the essential ingredients of a successful café.

To help the speakers, we provide them with a guidance document intended to formally frame the process for preparing and conducting the café sessions. The document stresses the importance of knowing the audience. Teens will readily engage with a presenter on some hot science topic if it is accessible to them; hence, the presentation needs to be free of jargon. We encourage presentations organized around one essential provocative idea or concept, where presenters tell a story but leave some mystery in the story.

We also stress that interactivity is one of the most important ingredients of a Teen Café. In a café presentation, communication—meaning two-way verbal interaction, supported by a few simple graphics—is of the essence. A Teen Café—like a classic adult science café—needs to be a conversation, not a lecture.

International Ocean Discovery Program

IODP

CALL FOR APPLICATIONS

Apply to participate in *JOIDES Resolution* Expeditions

Application deadline: 1 October 2016

Creeping Gas Hydrate Slides and Hikurangi Slow Slip LWD (372)
26 November 2017 – 4 January 2018

Expedition 372 has two primary objectives. These are (1) to investigate the relationship between gas hydrate and underwater landslides (IODP proposals 841-APL2 & 841-Add); and (2) to characterize sediment and fault zone structures and physical properties associated with recurring shallow slow slip events along the Hikurangi subduction interface (IODP proposals 781A-Full & 781A-Add).

Submarine slides are thought to occur as catastrophic events, and as such pose a significant geohazard potentially causing tsunamis and damaging seafloor installations. Dissociation of gas hydrate has been proposed as a driver of seafloor destabilization, but there is evidence that gas hydrate itself may lead to seafloor weakening through creeping seafloor deformation. We will test the hypothesis that interstitial gas hydrate, like ice, may exhibit viscous behavior leading to slow deformation as observed in terrestrial rock glaciers. Alternatively, permeability reduction from gas hydrates may lead to overpressure, hydrofracturing, and seafloor weakening. To elucidate how gas hydrates promote creeping behavior, we will collect logging-while-drilling (LWD) data at three sites as well as APC cores, pressurized cores, and penetrometer data at one of the LWD sites.

As described for Expedition 375 below, shallow slow slip events (SSE) along the Hikurangi margin provide the opportunity to investigate the physical processes and in situ conditions that govern the spectrum of fault slip modes through a combination of LWD, coring, and continuous monitoring. On Expedition 372, we will acquire LWD data at a series of sites that will be cored and instrumented during the subsequent IODP Hikurangi Subduction Margin Expedition 375 (see below).

Hikurangi Subduction Margin (375)
8 March – 5 May 2018

Expedition 375 will investigate slow slip events (SSE) along the northern Hikurangi subduction margin (IODP proposals 781A-Full and 781A-Add). Hikurangi SSE recur every ~2 years so we can monitor changes in deformation rate and associated chemical and physical properties surrounding the SSE source area throughout an entire slow slip cycle. Sampling material from the sedimentary section and oceanic basement of the subducting plate and from primary active thrusts in the outer accretionary wedge, in combination with LWD data, will reveal the rock properties, composition, and lithological and structural character of the active faults involved in the SSE, as well as material that is transported downdip to the SSE source region. Coring and downhole measurements from four sites will be integrated with the LWD data collected during Expedition 372 (see above). In addition, borehole observatories will be installed at the thrust fault site and a site in the upper plate to monitor hydrologic, chemical, and physical processes during the SSE cycle.

For more information about the expedition science objectives and the *JOIDES Resolution* Expedition Schedule see http://iodp.tamu.edu/scienceops/ - this includes links to the individual expedition web pages that provide the original IODP proposal and expedition planning information.

WHO SHOULD APPLY: Opportunities exist for researchers (including graduate students) in all specialties – including but not limited to sedimentologists, petrologists, structural geologists, paleontologists, biostratigraphers, paleomagnetists, petrophysicists, borehole geophysicists, microbiologists, and inorganic/organic geochemists.

WHERE TO APPLY: Applications for participation must be submitted to the appropriate IODP Program Member Office – see http://iodp.tamu.edu/participants/applytosail.html

Practice Makes Perfect

We have found that it is highly valuable—and indeed essential—for presenters to do a dry run with a small group of teen leaders before presenting to a full house. This has proven exceedingly valuable in getting the presentations pitched at the right level and the graphics comprehensible. It also serves to overcome a certain intimidation factor for many presenters.

The attitude of this presenter about the value of the dry run is typical: "The dry run was immensely valuable. It helped me select appropriate verbiage and content for the presentation. It also helped me gauge the level of delivery.... After the dry run, I made significant changes to the presentation, including the elimination of confusing content, identification of real-world connections, and simpler examples."

Café NM has had more than 80 presenters. Without exception, they enjoyed and valued their experience engaging with teens, improving and broadening their communication skills.

Some have also benefited in an unexpected way: They have come to a new perspective on their own research. As an added benefit, the Teen Café program can be a vehicle for community outreach and for satisfying the "broader impacts" requirements of the scientific funding agencies. As one presenter put it, "The Café experience was beneficial to me as a scientist in that preparing an interactive talk for an audience of young people helped me identify the critical issues in my work: why I was doing it, why it is challenging, what we are trying to accomplish (versus being bogged down in technical details). This really focused my thoughts about my work."

Expanding the Network

Rather than being a collection of static, independent entities, network nodes are part of a dynamic network, a community of practice with active sharing of lessons learned, documents, images, videos, ideas for café topics and formats, expertise in social media, and many other resources. We want the network as a whole to be much greater than the sum of its parts. Any organization wishing to start a Teen Café can do so by registering on the Teen Science Café Network website and agreeing to adhere to six core design principles (see http://bit.ly/TSCN-Principles).

We expect the network to grow steadily over the next few years. At the Teen Science Café Network, we have resources to help others start a Teen Café, and it is part of the ethic of the network that existing members will actively help new members start and successfully run Teen Café programs. One member commented, "The commitment by the TSCN program to 'support and freely share expertise with new groups wanting to start TSCNs' has been so impressive. Every time I had a question or concern about how we might do something or how to make the program work for our specific situation, I heard from several different people. They were extremely generous with their time and very helpful."

Author Information

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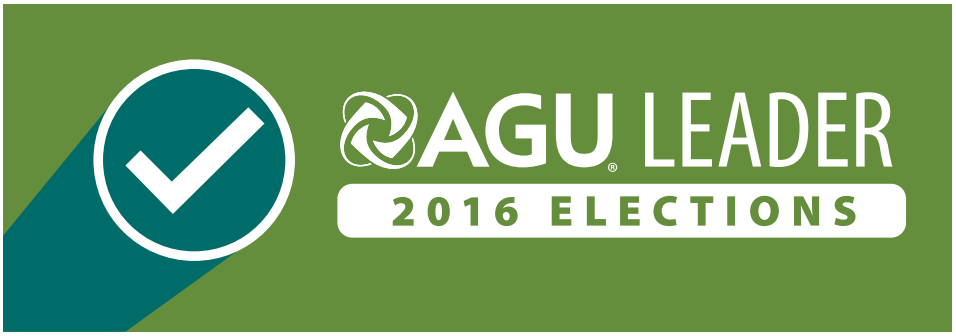
Every Vote Counts: Final Slate for 2016 AGU Elections



Every 2 years, AGU members elect the people who will lead the organization for the next 4 or more years. These volunteer leaders commit to advancing the mission, vision, goals, and core values outlined in AGU's strategic plan. Elected AGU leaders play an essential role in decisions on how to serve and engage members in AGU.

Leaders elected this year begin their service on 1 January 2017. They will still be in office during AGU's centennial celebration in 2019, which will recognize the value and contributions of Earth and space science over the past 100 years. The centennial celebration will also look forward to how Earth and space sciences will continue to add value to society at large, as well as creating greater awareness and appreciation of Earth and space science among policy makers, media, current and prospective funders, and the public.

All regular and student members who join AGU or renew their AGU membership by 1 August 2016 will be eligible to vote in this year's election.

When Do the Polls Open?

The 2016 AGU election will be held from 29 August through 27 September, allowing members 30 days to vote. Please mark your calendar and plan now to cast your votes for critical leadership positions. This is a great opportunity for your voice to be heard.

How Many Ballots Will I Receive?

There are three types of ballots for the 2016 AGU election: candidates for the AGU Board of Directors, student and early-career candidates for the AGU Council, and candidates for section and focus group president-elect and secretary positions. AGU has a paired-slate philosophy, so two candidates are required for each open position.

All members will receive ballots for the Board (four positions, eight candidates) and student and early-career positions (two positions, four candidates). Members will also receive a ballot for every section and focus group to which they belong.

How Long Does Voting Take?

Submitting your votes is faster and easier than ever with our new online voting site. Get a head start on the election before the polls open by familiarizing yourself with the ballots now (see http://elections.agu.org/) and reviewing the candidate information. Once you receive your log-in email from Survey and Ballot Systems (SBS) at the end of August (check your inbox for mailto:noreply@directvote.net), just click the personalized link, select a ballot for the AGU-wide offices or for one of your sections or focus groups, mark the candidates of your choice, and hit the "submit" button. This process will take just a few minutes per ballot, especially if you've already read the candidate information before logging in. You will also be given an option to review the candidate information from the voting site. It's important to know that you can exercise your vote for just one ballot or for all the ballots you receive.

What Is the Easiest Way for Members to Participate?

This year's election features 110 candidates for 55 open positions. That sounds like a lot, but you have the option to vote for only the positions that matter most to you. Here are some tips for navigating the ballots and casting votes.

1. Identify the positions for which are you are eligible to vote, including the AGU Board, student and early-career positions on the Council, and officers of the sections and focus groups to which you belong.

2. Read about the candidates for those positions at http://elections.agu.org/.

3. Decide for whom you want to vote, and watch for the email with your log-in information from AGU's election vendor, SBS, starting 29 August. The log-in email will come from AGU Election Coordinator, mailto:noreply@directvote.net, and will contain a personalized link for you to vote. Once you are logged in, you will be presented with a menu of all the ballots you are eligible to receive.

4. Cast your votes. You can vote in one log-in session or in multiple sessions. The online voting site will allow you to submit votes one ballot at a time until the election closes on 27 September.

Who Is Eligible to Vote?

All regular and student members who join AGU or renew their AGU membership by 1 August 2016 will be eligible to vote in this year's election. Please log in to http://sites.agu.org to ensure that your membership and affiliations are up to date.

What Information Is Provided About Candidates?

Each candidate has provided a photo and brief biographical sketch, including a summary of relevant volunteer experience and a short CV. In addition, candidates were asked to reply to a specific question about AGU so that voters could gain perspective on the candidates' views of organizational challenges and opportunities.

The ballot also includes information on continuing volunteer leaders so that voters have a complete picture of the diversity represented in the Board, in the Council, and in section and focus group leadership. This year, the Governance Committee provided all affiliations for continuing Board members and Board candidates as an experiment in conjunction with the Affiliation and Engagement Task Force. Committee and task force members believe that this offers a more complete picture of each person's scientific interests.

How Were the Candidates Selected?

The Governance Committee, chaired by Past President Carol Finn, selected the candidates for the Board and student and early-career candidates on the basis of recommendations from current and past volunteer leaders and AGU staff. Criteria for selection of Board candidates included demonstrated leadership skills, experience in dealing with challenges AGU faces now and will face in the near future, and ensuring a diversity of perspec-

tives in the composition of the overall Board. This year, the Governance Committee also interviewed potential Board candidates before making its final selections for the ballot.

Each section and focus group is responsible for selecting its candidates. Sections and focus groups determine their own selection criteria and processes for choosing candidates, with assistance from the Governance Committee available on request.

Members at large are also given the opportunity via a petition process to nominate additional candidates. However, there are no such candidates on this year's ballot.

When Will the Election Results Be Announced?

As soon as the election closes, the Governance Committee initiates a process to verify the results and notify all candidates. We anticipate that all candidates will be contacted and the results publicly announced in mid-October.

Here's Your "Voter's To-Do" List:

- Log in to AGU and ensure that your 2016 membership and section and focus group affiliations are current.
- Identify the ballots you are eligible to receive, and take a few minutes now to familiarize yourself with the candidates.
- Watch your email on 29 August for instructions from AGU's election vendor, SBS.
- Vote and let your voice be heard!

By **Carol Finn,** Past President and Governance Committee Chair, AGU; email: pastpresident@agu.org

Watch your email on **29 August** for instructions from AGU's election vendor, Survey and Ballot Systems (SBS).

How Do Tropical Forests Slow Knickpoints in Rivers?

Gilles Brocard

Water flows along a knickpoint in the Luquillo Mountains.

High up on the northeastern edge of Puerto Rico are the Luquillo Mountains, which rise higher than 1000 meters. Because the island is sandwiched between the North American and Caribbean tectonic plates, it periodically experiences tectonic uplift.

Some rivers in the Luquillo Mountains run on top of an igneous rock called quartz diorite, on which they developed prominent knickpoints—places where the slope of the river increases significantly, converting quiet, meandering streams into tumbling torrents and mighty waterfalls. These knickpoints represent the front of aggressive waves of erosion that sweep through the landscape. They sharply influence soil mineralogy, nutrient pools, forest composition, and carbon storage.

A new study by *Brocard et al.* investigates how these knickpoints made their way upstream through the tropical montane forest. The authors first measured the concentrations of the isotopes beryllium-10 and aluminum-26 in quartz sediments deposited in caves close to sea level before the mountains were uplifted. The isotopes can form only when the rock surface is exposed to air, so the pair, in effect, dates the time of sediment burial.

From this age—about 4 million years ago—they tracked back to determine when uplift initiated and when the river knickpoints formed. The authors then calculated that the knickpoints have moved very slowly farther upstream since then.

They also measured the amount of beryllium-10 in the forest soils. The concentrations of beryllium-10 indicate the rate of erosion in areas close to the riverbed. They show that the knickpoints are still actively retreating today, at a rate that matches the speed at which they have been traveling since the island was uplifted.

Finally, the team investigated the factors that affected knickpoint retreat. They determined that the tropical, old upland landscape hinders the streams' ability to cut through rock. The hot, humid climate creates thick soils with small grains at the surface via chemical breakdown of rock into sand-sized particles. Sand is not as efficient a "tool" for abrading the riverbed. In addition, the gentle slopes in the uplands slow retreat; however, jointing or cracking of the rock can speed up retreat, which is dominated mainly by weathering along the rock fractures. (*Journal of Geophysical Research: Earth Surface,* doi:10.1002/2015JF003678, 2016) **—Wudan Yan, Freelance Writer**

Mysterious "Necklace Echoes" in the Sky Explained

To probe the plasma that surrounds Earth, space physicists have a useful tool: radar. Researchers can extract information about the plasma from reflected radar energy, such as how hot and dense the plasma is and how fast it's traveling. But for decades, space physicists have been unable to decipher a mysterious type of radar echo coming from the upper wisps of the Earth's atmosphere at heights of around 150 kilometers.

Scientists first detected the echoes in the 1960s, when the then brand-new Jicamarca Radio Observatory opened, just east of Lima, Peru. The echoes tend to appear throughout the day but migrate lower into the atmosphere around noon and then recede upward. When plotted over time, this distinctive signature earned them the nickname "necklace echoes" or "daytime valley echoes." More than 50 years after they were first reported, they are still a mystery.

Now *Oppenheim and Dimant* have devised a model that explains many of the phenomenon's unique characteristics. They propose that the necklace echoes are the end result of a cascading series of interactions taking place in the upper atmosphere. The process begins when the Sun's ultraviolet rays strike nitrogen and oxygen molecules, violently knocking off electrons. These suddenly liberated electrons are much more energetic than the surrounding electrons. Under the influence of the Earth's magnetic field, they cause cold ionosphere electrons to oscillate with enough intensity that they also make waves among the much heavier ions. Radar scattering off of these heavy ions generates the 150-kilometer-high echoes.

This model explains the characteristic necklace or valley shape because the Sun's rays penetrate deepest at noontime when the Sun is directly overhead. Early in the morning or late in the afternoon, the rays have to travel at an angle through the atmosphere and don't make it as far down. The model also explains observations of the echoes disappearing during a solar eclipse and intensifying during a powerful solar flare.

Jicamarca Radio Observatory (JRO)

The Jicamarca Radio Observatory opened in 1961 and shortly afterward made the first observations of the mysterious "necklace echoes."

The authors simulated on 1024 processors how they think necklace echoes form. They show that this chain of events plays out as hypothesized. They write that future simulations of this model could reveal in more detail the exact kinds of plasma waves and resonances that exist, which may explain more specific features in the echoes. (*Geophysical Research Letters*, doi:10.1002/2016GL068179, 2016) **—Mark Zastrow, Freelance Writer**

Chemical Boosts Ozone Production over Southern China

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Smog and Hong Kong's skyline, seen from Victoria Peak.

Previous studies have shown that the presence of nitryl chloride ($ClNO_2$), a gas that forms during the night when particulates containing chloride react with combustion-related nitrogen oxide compounds, can increase the concentrations of ozone the following day. Ozone is a potent greenhouse gas and widespread air pollutant linked to decreased lung function. However, because of the small number and limited extent of ambient measurements made to date, the global significance of $ClNO_2$ is still poorly understood.

To help address this knowledge gap, *Wang et al.* report the first measurements of $ClNO_2$ in the upper planetary boundary layer over the city of Hong Kong and the adjacent Pearl River delta, a region that frequently experiences severe haze and high levels of anthropogenic pollutants, including ozone. The team measured the concentrations of $ClNO_2$ and associated chemical compounds atop 957-meter-high Tai Mo Shan, the highest point in Hong Kong, for 12 consecutive nights in the fall of 2013. The readings included the highest concentrations ever reported in the literature for $ClNO_2$—4.7 parts per billion by volume (ppbv)—and its chemical precursor, dinitrogen pentoxide (7.7 ppbv). The readings also showed elevated concentrations of both compounds on six of the 12 nights.

Using a series of models based on these measurements, the researchers traced the source of the compounds to heavily polluted air from major industrial and urban areas to the north of the study site. Their calculations indicate that the presence of these compounds can increase peak daytime ozone concentrations by 5%–16% and can enhance the total production of ozone the following day by up to 41%.

These results, which are several times higher than previous model calculations, emphasize the importance of understanding the role of $ClNO_2$ in different environments and including its effects in models that predict ground-level haze and ozone concentrations. (*Journal of Geophysical Research: Atmospheres*, doi:10.1002/2015JD024556, 2016) **—Terri Cook, Freelance Writer**

Can Mangroves Buffer Ocean Acidification?

James Sippo

Mangroves at Coral Creek, Hinchinbrook Island, Australia.

The burning of fossil fuels, the production of cement, and industrial-scale agriculture have all contributed to a significant rise in carbon in our atmosphere. This ultimately takes a toll on our oceans, which have absorbed approximately one third of this anthropogenic carbon. When carbon dioxide (CO_2) dissolves in water, it decreases pH in a process called ocean acidification. This acidification ultimately harms ecosystems like coral reefs and affects the health of phytoplankton, a food source for many marine animals. Because alkaline solutions can buffer acidic ones, the phenomenon of ocean acidification has caused scientists to become interested in alkalinity-producing pathways.

One ecosystem in particular is thought to increase alkalinity: mangrove forests. Through natural biogeochemical cycling, mangroves are known to increase the alkalinity of the waters surrounding these ecosystems. In a new study, *Sippo et al.* investigate the extent to which mangroves can counter ocean acidification.

The scientists studied the dissolved inorganic carbon (DIC) content, alkalinity, and dissolved carbon dioxide in the waters of six pristine mangrove tidal creeks along the northern, eastern, and southern coasts of Australia. The researchers also collected water samples from nearby coastal waters to see whether the alkalinity of the mangroves' waters had a detectable influence on the surrounding area. Plants, like mangroves, naturally cycle carbon, meaning they remove it from the air and convert it into biomass. The high productivity of mangrove forests, and their unique location at the land-ocean interface, results in a large soil reservoir of carbon. The subsequent breakdown of this soil carbon can produce alkalinity. Using titration to measure the alkalinity in the mangrove forest waters, the scientists calculated the exchange of DIC, alkalinity, and dissolved CO_2 from the mangroves to the coastal ocean.

On average, the mangroves studied put out 59 millimoles of DIC per square meter per day into the surrounding coastal waters. Scaling up these estimates would result in global exports of more than 2.5×10^9 moles of carbon per year. The authors also calculated that mangrove forests can annually export up to 4.2 teramoles of alkalinity.

Overall, the effect of dissolved inorganic carbon and alkalinity exports from the mangroves caused nearby ocean pH to increase. The authors believe that this boost in pH from the mangroves is likely to have a greater effect in areas with large mangrove coverage. This localized effect may have important implications for other tropical coastal ecosystems, such as coral reefs.

According to the authors, this study is one of the most comprehensive assessments of the contribution of mangroves to ocean alkalinity to date. This new research shows that in addition to all of their other important ecological functions, mangroves are one of the greatest natural sources of alkalinity to tropical coastal oceans. (*Global Biogeochemical Cycles*, doi:10.1002/2015GB005324, 2016) **—Wudan Yan, Freelance Writer**

Adapting Weather Forecasting Techniques to Paleoclimate Studies

Scientists use climate models to understand current climate conditions, investigate natural processes and the anthropogenic activities that can affect them, and project future climate scenarios. A key challenge is testing the ability of climate models to accurately capture the natural variability of climate, which can dominate long-term climate change on decadal to centennial timescales.

Capturing natural variability requires data sets that are sufficiently long (centuries to millennia) to adequately characterize past variations in temperature and other variables. The instrumental record is too short to accomplish this, so researchers rely on proxy records from ice cores, tree rings, corals, and other paleoclimate archives.

They then use a number of methods to reconstruct spatial "fields" of data—such as precipitation, surface air temperature, and sea level pressure—interpolated from the information derived from those sparse proxy records. Most such methods rely on purely statistical relationships and do not take advantage of physical relationships embedded in climate models.

Here *Hakim et al.* fuse both sources of information—climate models and observations—taking a data assimilation technique commonly used for forecasting the weather and adapting it to paleoclimate analyses. The results are the first from their National Oceanic and Atmospheric Administration–funded project called the Last Millennium Climate Reanalysis (LMR). LMR aims to use paleoclimate proxies to extend gridded estimates of climate fields well beyond the 150-year instrumental record.

The results, based on a sparse, preliminary collection of proxy records, show good agreement with earlier reconstructions of the Northern Hemisphere's average near-surface air temperature. This includes an overall cooling trend over the past 2000 years, reversing abruptly during the Industrial Revolution, as well as multicentury fluctuations consistent with the nominal Medieval Warm Period and the Little Ice Age.

When compared with the 1880–2000 instrumental temperature data, the results are most skillful in reflecting the tropics. A comprehensive error analysis was used to quantify uncertainty, including verification of the results against independent (not assimilated) proxies.

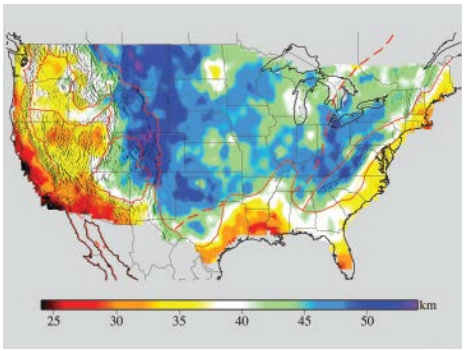
To demonstrate the advantages of their approach, the authors examined the climate reconstructions of the 1808–1809 "mystery" volcanic eruption, which is known about from ice core records but not from direct observations. The results clearly show an abrupt cooling in 1809, which is enhanced by the Pacific/North American teleconnection pattern. The dynamical conditions revealed by the analysis are also consistent with those of documented volcanic eruptions.

The results demonstrate the ability of the integrated data assimilation approach to capture climate fluctuations on multiple timescales and in multiple climate variables, providing confidence in its reconstructions. The approach also demonstrates the potential to improve historical climate estimates by combining climate modeling with proxy information. (*Journal of Geophysical Research: Atmospheres,* doi:10.1002/2016JD024751, 2016) **—Terri Cook, Freelance Writer**

Novel Technique Finds New Features Under the United States

For the past decade, USArray's large and dense grid of seismometers has gradually collected data on seismic waves across the contiguous United States. Using these data, seismologists calculate the speed of a seismic wave, which is influenced by the material the wave passes through. Variations in these speeds allow researchers to generate a three-dimensional map of deep-Earth structures that is somewhat analogous to a medical computed tomography (CT) scan. Such maps chart areas with different compositions or that are especially cold or hot in the Earth's underlying crust and upper mantle.

As part of a series of studies striving to improve the methods used to produce these deep-Earth maps, *Shen and Ritzwoller* have created a new type of three-dimensional model using a novel technique that jointly inverts data from earthquakes, ambient noise, and other sources collected beneath more than 1800 stations, then projects the results onto a map of the contiguous United States. The high resolution of the new model, which extends to a depth of 150 kilometers, highlights prominent structural differences beneath the eastern, central, and western United States, including the Cascadia Subduction Zone and the Snake River Plain in the Pacific Northwest and the Reelfoot Rift in the Southeast.



A map of estimated crustal thickness, which is taken from the mean of the posterior distribution of models at a location. Cool tones represent thicker crust (up to 54 kilometers), and warm tones represent thinner crust. Crustal thickness is an important attribute of the lithosphere, and this result illustrates the length scale of the variations imaged.

The new model also reveals some previously unknown features that warrant further study, including three relatively low velocity areas in the upper mantle beneath the Appalachians—one centered beneath northern Georgia, a second below the Blue Ridge Mountains in western Virginia—and an especially prominent anomaly beneath New England's White and Green mountains. It is intriguing that both the Virginia and New England anomalies are confined to the shallow mantle above 80-kilometer depth and are areas that previous research has tentatively linked to a Cretaceous hot spot track.

The results of this study, including the new methodology, discussion of potential error sources associated with the model, and the improved resolution of these deep-Earth maps, will be an important reference for other researchers interested in seismic tomography and the structure of the crust and upper mantle beneath the United States. (*Journal of Geophysical Research: Solid Earth,* doi:10.1002/2016JB012887, 2016) **—Terri Cook, Freelance Writer**

Shift in Pacific Sea Level Trends Will Affect the U.S. West Coast

In contrast to earlier trends, sea level has been rising off the West Coast of the United States since 2011, according to a new analysis of satellite altimetry data.

Since the early 1990s, sea level has appeared to be falling in the eastern Pacific Ocean and rising faster than the global average in the western Pacific. Previous studies linked these changes to winds associated with a long-term pattern of climate variability called the Pacific Decadal Oscillation, which has recently been in a "warm" phase distinguished by warmer temperatures in the eastern Pacific and cooler temperatures in the western Pacific.

Now, however, *Hamlington et al.* report the first evidence to suggest that this oscillation began to reverse itself in 2011 and, in the process, triggered a dramatic shift in sea level on both sides of the Pacific Ocean, causing it to decline in the western tropical regions and rise in the east. If confirmed, this finding could have profound implications for coastal communities—including the U.S. West Coast, where, for the past 20 years, sea level has barely risen while the global average increased 3.3 millimeters per year.

The team first identified the shift of the previous 5 years by using satellite altimeter data to compute regional sea levels from 1993, the start of the satellite record, through both 2011 and 2015 and then comparing the outcome. Next, to determine the source of the change, the researchers applied a new statistical analysis to extract the two leading modes of Pacific sea level variability—one biennial and the other decadal—from these data. The analysis provides compelling evidence that the observed shift in sea level is largely due to a change in the climate signal linked to the Pacific Decadal Oscillation.

Because this oscillation has a decadal-to-multidecadal signal, the results suggest that the dramatic changes observed over the past 5 years are likely to continue well into the future. On both sides of the Pacific, coastal communities will face the economic and societal implications of changing sea levels, including increased flood and storm surge risk and loss of wildlife habitats. In addition, communities on the West Coast could see substantially higher sea levels. Sea levels there have risen roughly 1 centimeter per year, but decadal variability could increase that by an additional 5–10 millimeters per year in the coming decade. (*Journal of Geophysical Research: Oceans*, doi:10.1002/2016JC011815, 2016) **—Terri Cook, Freelance Writer**

AGU's Career Center is the main resource for recruitment advertising.

All Positions Available and additional job postings can be viewed at **https://eos.org/jobs-support.**

AGU offers printed recruitment advertising in *Eos* to reinforce your online job visibility and your brand.

Visit **employers.agu.org** to view all of the packages available for recruitment advertising.

SIMPLE TO RECRUIT

- online packages to access our Career Center audience
- 30-day and 60-day options available
- prices range $475–$1,215

CHALLENGING TO RECRUIT

- online and print packages to access the wider AGU community
- 30-day and 60-day options available
- prices range $795–$2,691

DIFFICULT TO RECRUIT

- our most powerful packages for maximum multimedia exposure to the AGU community
- 30-day and 60-day options available
- prices range $2,245–$5,841

FREE TO RECRUIT

- packages apply only to student and graduate student roles and all bookings are subject to AGU approval
- eligible roles include: student fellowships, internships, assistantships, and scholarships

- *Eos* is published semi-monthly on the 1st and 15th of every month. Deadlines for ads in each issue are published at **http://sites.agu.org/media-kits/eos-advertising-deadlines/.**
- *Eos* accepts employment and open position advertisements from governments, individuals, organizations, and academic institutions. We reserve the right to accept or reject ads at our discretion.
- *Eos* is not responsible for typographical errors.

∗ Print-only recruitment ads will only be allowed for those whose requirements include that positions must be advertised in a printed/paper medium.

EARTH AND SPACE SCIENCE INFORMATICS

Assistant Professor of Earth and Planetary Sciences

The Department of Earth and Planetary Sciences at Washington University in St. Louis invites applications for a tenure-track Assistant Professor position in the fields of climate, carbon cycling, or paleoclimatology. The ideal candidate will study climate or the effects of climate change in modern systems and/or over Cenozoic Earth history. Areas of interest include but are not limited to: paleoclimatology and records of consequent environmental change; elemental cycling and associated climate feedbacks; the response of terrestrial, marine, and/or freshwater systems to climate change. The candidate is expected to employ quantitative tools and ideally will integrate field observations with laboratory measurements.

The successful candidate is also expected to develop a vigorous, externally funded research program, maintain a strong publication record, teach a range of undergraduate and graduate courses, advise students, and be active in university service. We are seeking candidates who will complement our research programs in biogeochemistry and environmental geology as well as foster collaboration with environmental scientists across the Washington University community.

Candidates must have a Ph.D. with a focus in environmental Earth science, or a related field, at the time of appointment, and should send a letter of application, curriculum vitae, statements of teaching and research interests, and names and contact information of at least four references as a single PDF to Alex Bradley, Climate Search Committee Chair, Department of Earth and Planetary Sciences, Washington University, Campus Box 1169, 1 Brookings Drive, St. Louis, MO 63130, or via e-mail: ClimateFacSearch@eps.wustl.edu. The Department seeks an exceptionally qualified and diverse faculty; women, minorities, protected veterans and candidates with disabilities are strongly encouraged to apply. Washington University in St. Louis is committed to the principles and practices of equal employment opportunity and affirmative action. It is the University's policy to recruit, hire, train, and promote persons in all job titles without regard to race, color, age, religion, gender, sexual orientation, gender identity or expression, national origin, veteran status, disability, or genetic information. Applications should be received by November 1, 2016 to ensure full consideration.

Tenure-line Position in Energy Resources Engineering at Stanford University

The Department of Energy Resources Engineering at Stanford University invites applications for a tenure-line faculty appointment. The position is at the assistant professor level. It is desired that the selected candidate be able to start no later than Autumn 2017. For more information about the Energy Resources Engineering Department, see the Stanford ERE web page at http://pangea.stanford.edu/ERE/.

The Department of Energy Resources Engineering focuses on a wide range of activities related to the recovery of the Earth's energy resources (e.g., hydrocarbons, geothermal, and other renewables). The department has core areas of expertise in computational (simulation and optimization) and experimental approaches to energy production. ERE offers degrees in both energy resources engineering (B.S., M.S., Ph.D.) and petroleum engineering (M.S., Ph.D.).

We seek scholars with a Ph.D. in an engineering or computational discipline who possess novel and innovative research capabilities in energy transitions engineering, renewable energy integration and optimization, and renewable resource planning and optimization. We envision intellectual engagement in one or more of the following areas:

Computational approaches for the design and dispatch of renewable or hybrid renewable-fossil energy systems

Optimal control of renewable- and flexible-power systems operation

Energy storage system design, including optimization, valuation, and novel technology evaluation

Multi-criteria optimization focusing on challenges associated with novel energy technologies including energy generation, land use, water consumption, materials abundance, and scalability

Analysis of technological change, including rigorous modeling of innovation, technology scale-up and deployment

We will begin reviewing applications on September 1, 2016 and will continue until a suitable candidate is identified. To apply, please submit the following application materials: cover letter, curriculum vitae with a complete list of publications, a statement outlining research and teaching interests, the names of three references including e-mail addresses, and copies of up to five selected papers published in refereed journals over the past three years. Please apply online at https://academicjobsonline.org/ajo/jobs/7416 in electronic format (pdf only).

Stanford University is an equal opportunity employer and is committed to increasing the diversity of its faculty. It welcomes nominations of, and applications from women, members of minority groups, protected veterans and individuals with disabilities, as well as from others who would bring additional dimensions to the university's research, teaching and clinical missions.

GEOCHEMISTRY

Tenure-Track Faculty Position

The Geology Department at Washington and Lee University, Lexington, VA seeks applications for a tenure-track assistant professor in environmental geochemistry starting in fall 2017. PhD required at the time of appointment. Courses taught by the successful candidate will include hydrology, geochemistry, and environmental field methods at the majors level, and physical geology at the introductory level. We seek a dynamic, creative teacher/scholar, dedicated to diverse teaching approaches, enthusiastic about teaching intensive field-based geology courses, and able to develop a strong research program including collaboration with undergraduates. W&L and the Geology Department value excellence in scholarship, meaningful engagement in professional activities, sustainability, and the development of a campus climate that supports equality and diversity among its faculty, staff, and students. W&L is a nationally ranked, highly selective liberal arts college. The Department (geology.wlu.edu) has excellent facilities and resources, makes great use of the Appalachians in field courses and labs, and belongs to the Keck Geology Consortium. Applications should include: curriculum vitae; teaching statement including teaching interests/experience; research statement; and contact information for 3 referees. Apply via email to wilsons@wlu.edu. Please address to Lisa Greer, Chair, Geology Department, Washington and Lee University. Initial review of applications will begin Sept. 1; we will be available to meet with potential candidates at the fall GSA meeting in Denver. Review will continue until the position is filled. The University is an Equal Opportunity Employer.

HYDROLOGY

2 PhD scholarships studying impacts of drought in New Zealand native forest

The project involves exploring the threat of seasonal drought to kauri and associated southern conifers using a field-based drought experiment. There are two scholarships on offer. The first involves measurement of sap flow and other plant water relations parameters. This PhD project will concentrate on native tree species including kauri at the University of Auckland Huapai scientific reserve where the drought experiment will be established. The other project will explore drought mortality mechanisms in southern conifers using field and glasshouse studies. There will be opportunity to work with a mechanistic model of the soil-plant-atmosphere pathway subject to student interest. The full scope of each project is negotiable for the right candidates, subject to fitting into the theme of drought in native forest.

Associate or Full Professor of Geology

The West Virginia University (WVU) Department of Geology and Geography invites applications for a tenured faculty position in the area of hydrogeoscience at either the Associate Professor or Full Professor level. Applicants with exceptional qualifications will be nominated for the Eberly Family Distinguished Professorship in Geology. The successful candidate is expected to bring a vigorous program of innovative, externally-funded research; build effective collaborations; and teach at the graduate and undergraduate levels.

Research on fresh water resources is currently an area of strategic growth at WVU (http://research.wvu.edu/about) including a new interdisciplinary water research institute. We invite applications from individuals with interests in basic and applied aspects of groundwater flow. Relevant specialties might include physical hydrogeology; fluid flow modeling; hyporheic or vadose zone processes; groundwater-surface water interaction; flow in fractured media; hydrogeology of energy-related activities; groundwater supply and sustainability; contaminant transport; ecohydrology; multiscale hydrologic modeling; critical zone processes; and/or karst hydrogeology.

To apply, please visit http://jobs.wvu.edu and navigate to the position title listed above as Job Number 03733. Upload (1) a single PDF file including a statement of research interests, a statement of teaching philosophy, and a curriculum vitae; and (2) pdf files of up to 4 publications. Please also arrange for three letters of reference to be sent to search chair Joseph J. Donovan at jdonovan@mail.wvu.edu. Review of applications will commence on October 15, 2016 and continue until a successful candidate is identified. For additional information, please see http://geology.wvu.edu.

WVU is an EEO/Affirmative Action Employer and welcomes applications from all qualified individuals, including minorities, females, individuals with disabilities, and veterans.

Doctoral Graduate Research Assistantship

As the effect of climate change on weather patterns becomes clearer, there are major concerns as to whether cities are protected against the anticipated increasing number of extreme events. One of the major concerns in many urban areas is stormwater management, where climate change threatens to overwhelm pipes that are in poor condition and undersized relative to shifting weather. A high quality Graduate Research Assistant is being sought to contribute to a research project funded through the National Science Foundation. The study will focus on: (1) developing a novel framework that can incorporate various (and sometimes conflicting) climate models while accounting for extreme weather events, (2) modeling the hydrologic response of a stormwater system to these scenarios to identify the vulnerability of the system, and (3) optimizing green infrastructure placement to buffer the effects of climate change while accounting for uncertainties in weather patterns over a long planning horizon. Collaborations will include the Department of Industrial and Systems Engineering at the University of Tennessee and Oak Ridge National Laboratory.

Expected start date is January 1, 2017. Applications will be reviewed as they are received and until the position is filled (anticipated middle of August 2016 at the latest). Ability and willingness to work in both field and laboratory settings is vital. A strong computational background is desired, and experience with the Storm Water Management Model (SWMM) is particularly beneficial.

University of Minnesota - Department of Earth Sciences

The Department of Earth Sciences in the College of Science and Engineering at the University of Minnesota - Twin Cities is soliciting applications for a tenure-track faculty position in hydrology/hydrogeology at the assistant professor level. Exceptional candidates at the associate professor level will also be considered. This position will carry with it additional resources from the Gibson Endowed Fund for research activities over the first five years of the appointment.

Areas of research for this position could include physical, chemical, and/or biological aspects of hydrology or hydrogeology. Frontier topics of interest in this field include, among others, research at non-traditional spatial scales, grand challenges in water resource sustainability and security, novel measurement techniques and datasets, and links between the study of hydrological systems and subsurface geology, other portions of the earth system, and/or other disciplines, as well as other topics. The successful candidate is expected to develop a vigorous research program, attract external funding, and contribute to the instruction, research, and service efforts of the department. A Ph.D. in earth sciences or a related field is required at the time of appointment.

The Department of Earth Sciences is a vibrant interdisciplinary department whose research ranges from geobiology to deep earth dynamics. Alongside our commitment to excellence in scholarship, we seek to further the University of Minnesota's land-grant mission through developing ties with industry and/or governmental agencies that benefit the needs of our students, the state of Minnesota, and the broader community. The Department is in the N.H. Winchell School of Earth Sciences (http://www.esci.umn.edu/), which also includes the Institute for Rock

Magnetism, the Limnological Research Center/National Lacustrine Core Facility/Continental Scientific Drilling Coordination Office, the Minnesota Geological Survey, the National Center for Earth-surface Dynamics, and the Polar Geospatial Center. Other affiliated research units at the University include the Saint Anthony Falls Laboratory and the Institute on the Environment. The appointee will have access to large-scale computing facilities (Minnesota Supercomputer Institute, Digital Technology Center) and the interdisciplinary Water Resources graduate program.

Materials Required: A one-page letter of intent. A CV with a list of publications. A statement of research and teaching interests. Names and contact information of three referees who can address the candidate's research and teaching potential.

Applications must be completed online at: http://www1.umn.edu/ohr/employment/ - search for Job Opening ID: 311335

The review of applications will begin October 14, 2016. Applications will continue to be accepted until the position is filled. Questions may be directed to Prof. Jake Bailey (baileyj@umn.edu).

The University of Minnesota provides equal access to and opportunity in its programs, facilities, and employment without regard to race, color, creed, religion, national origin, gender, age, marital status, disability, public assistance status, veteran status, sexual orientation, gender identity, or gender expression. The University supports the work-life balance of its faculty.

INTERDISCIPLINARY

Faculty Positions at the University of Michigan

The Department of Earth and Environmental Sciences and the Program in the Environment at the University of Michigan anticipate two openings for joint tenure-track assistant professors for university-year appointments starting September 1, 2017. We are particularly interested in candidates whose strengths complement existing research programs within the Department and the Program.

Biological Oceanography: We encourage applications from candidates whose research interests encompass the role of biology in ocean chemistry, marine geology, or physical oceanography. Specific areas of interest include (but are not limited to) carbon and nitrogen cycling in the ocean, physical-biological interactions, biomineralization of marine organisms, sediment biogeochemistry, and the impact of global change on marine life and biogeochemistry. The position is open to candidates who use field, lab, and/or modeling approaches at scales ranging from molecular to global.

Geobiology: We encourage applications from candidates whose research interests encompass interactions between biology and geology, geochemistry, or hydrology. Specific areas of interest include (but are not limited to) soils, biomineralization, microbe-mediated water-rock interactions, nanoparticles, microbe-metal interactions, and organic geochemistry. The position is open to candidates who study any organism (e.g., microbes, fungi, plants, and animals), at all scales (molecular to global, individual to community), and with various approaches (e.g., isotopic, molecular, spectroscopic).

The successful candidate is expected to establish an independent research program and contribute to both undergraduate and graduate teaching. Applicants must have a Ph.D. at the time of appointment, and should submit a CV, statement of current and future research plans, a statement of teaching philosophy and experience, and evidence of teaching excellence, if available. Letters of recommendation from three to five references should be submitted directly by the recommender, before the application deadline, using a link that will be provided once the application is submitted.

Information about the Department can be found at www.lsa.umich.edu/earth and information about the Program can be found at www.lsa.umich.edu/pite.

To apply please go to: http://apps-prod.earth.lsa.umich.edu/search16/index.php. Complete the online form and upload the required application documents as a single PDF file. If you have any questions or comments, please send an email message to Michigan-Earth-Search@umich.edu.

The application deadline is September 8, 2016 for full consideration, but applications will continue to be reviewed until the position is filled. Women and minorities are encouraged to apply. The University of Michigan is supportive of the needs of dual career couples and is an equal opportunity/affirmative action employer.

NOTICE OF VACANCY
WASHINGTON STATE UNIVERSITY
Laboratory for Atmospheric Research
Department of Civil and Environmental Engineering
Voiland College of Engineering and Architecture
Position 55848

Washington State University, Department of Civil and Environmental Engineering and the Laboratory for Atmospheric Research (LAR) invite applications for a permanent 9-month tenure-track faculty position at the assistant to associate professor level on the Pullman campus with an effective start date from January 1, 2017 to August 16, 2017. This position is part of WSU's priority to build a diverse faculty; thus, female and minority candidates are strongly encouraged to apply.

Candidates are sought with expertise in numerical modeling related to air quality, atmospheric chemistry, and climate change at urban to regional scales. The successful applicant will help lead and grow the WSU AIRPACT air quality forecast system operation. The selected applicant will teach graduate and undergraduate air quality and environmental engineering courses, direct graduate student research, and develop a strong extramurally funded research program. The position requirements include:
1) expertise with urban to regional scale atmospheric chemistry models with applications to air quality, atmospheric chemistry, and/or climate change, 2) a record of research accomplishments demonstrated by peer reviewed publications and/or extramural grants, 3) demonstrated ability to work with diverse, interdisciplinary teams in a collaborative manner, 4) a record of outreach, mentoring, or teaching to diverse student populations, and 5) an earned Ph.D. or equivalent degree in a relevant engineering or science field. In addition, experience using remote sensing and in situ observations to evaluate and improve models and participation in the design and implementation of field campaigns is desirable.

Applicants should apply online at https://www.wsujobs.com by submitting the following: a cover letter, a detailed resume, a statement of research and teaching interests, and a list of five references with contact information. Screening of candidates will begin September 1, 2016, but applications will be accepted until the position is filled.

WASHINGTON STATE UNIVERSITY IS AN EQUAL OPPORTUNITY/AFFIRMATIVE ACTION EDUCATOR AND EMPLOYER.

UNIVERSITY OF ALBERTA

LABORATORY & FACILITY MANAGER - CANADIAN ICE CORE ARCHIVE
DEPARTMENT OF EARTH AND ATMOSPHERIC SCIENCES

The position of Lab and Facility Manager for the Canadian Ice Core Archive (CICA) is a research scientist appointment to manage the establishment and subsequent operation of the Canadian Ice Core Archive and its associated laboratory facilities and instrumentation. The incumbent reports administratively to the Executive Director of CICA, Dr. Martin Sharp. The position involves the oversight of a core storage facility, core processing laboratory, and an analytical facility that will initially house a line scanning camera, solid electrical conductivity measurement system, Picarro stable isotope analyzer, dual ion chromatograph system, particle size analyzer, and spectrofluorometer, as well as a core melter system designed to general input for continuous flow analyses of ice cores.

The incumbent will serve on CICA's Management Committee and its Ice Core Curation and Ice Data Working Groups. They will work with CICA investigators and external users to plan new scientific uses for the collection, to identify suitable material for specific uses, to design and construct specific workflows and core processing lines, and to schedule usage of the CICA facilities and provide training in their use. They will liaise with the managers of other UA labs (including trace metals, radiogenic and stable isotopes, organic contaminants, microbiology and genomics) in order to facilitate ice core research that uses these facilities. They will (in collaboration with staff from UA libraries) be responsible for accessioning the ice core collection and for developing and maintaining a digital database that relates to it.

The successful candidate will be responsible for day-to-day health and safety issues in the laboratory and for the administration of the facilities, including ensuring the continued running and performance of the cold rooms and instrumentation, quality control, supervision of technicians and facility users, and for scheduling, budgeting, and costing of services. They may also conduct independent research involving the collection and analysis of ice cores. This may include the training and supervision of undergraduate and graduate students in appropriate areas, and the planning of new ice core collection activities.

Working with the CICA Executive Director, Principle Investigators and Governance Committees, the facility manager will develop and implement a strategy to sustain and enhance CICA's capabilities and build its user base, and plan for the upgrading and replacement of CICA equipment as needed. They will also ensure that CICA operates in a manner consistent with the standards of other international ice core laboratories.

The successful candidate will have a PhD in ice core science, postdoctoral experience, and advanced knowledge and experience of relevant analytical techniques and instrumentation. Experience of ice core collection in the field and of collections management (including digital databases) would be assets. The position involves the co-ordination, supervision and interactions with a large number of students and faculty both internal and external to the university, including international visitors. As such, superior organizational and interpersonal skills are required along with excellent written/verbal communication skills in English.

The position is a full-tme academic appointment at the Faculty Service Officer II level and formally reports to the Chair, Department of Earth and Atmospheric Sciences. In accordance with the Faculty Service Officer Agreement, the position offers a comprehensive benefits package and an annual salary range of $75,404 - $104,828. The appointment is a continuing position with opportunity to progress through the Faculty Service Officer ranks.

Review of applications will begin August 31, 2016. The start date is January 1, 2017. Applicants should send a letter of application with a detailed curriculum vitae and arrange for three confidential letters of reference to be forwarded to the address below.

To assist the University in complying with mandatory reporting requirements of the Immigration and Refugee Protection Act (RSOE (3) (e)), please include the first digit of your Canadian Social Insurance Number in your application. If you do not have a Canadian Social Insurance Number, please indicate this in your application.

Interested applicants may apply to:
http://www.careers.ualberta.ca/Competition/A107929674/

M-J Turnell, Assistant Chair
Department of Earth and Atmospheric Sciences
1-26 Earth Sciences Building
University of Alberta
Edmonton, Alberta T6G 2E3

E-mail: mturnell@ualberta.ca

Fax Number: (780) 492-8190

All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.

The University of Alberta hires on the basis of merit. We are committed to the principle of equity in employment. We welcome diversity and encourage applications from all qualified women and men, including persons with disabilities, members of visible minorities, and Aboriginal persons.

careers.ualberta.ca

"uplifting the whole people"
— HENRY MARSHALL TORY, FOUNDING PRESIDENT, 1908

Postcards from the Field

Hi, Everyone,

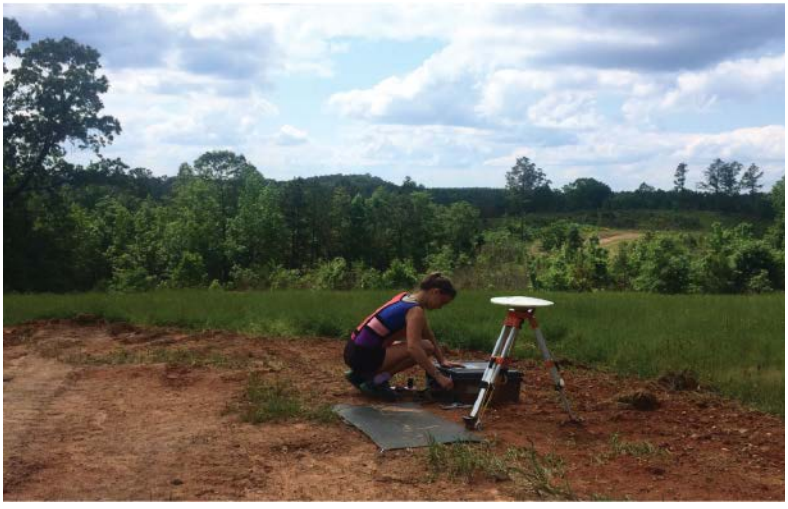
We are excited to report that the National Ecological Observatory Network (NEON) Airborne Observation Team has just arrived in Tennessee! In our most ambitious year to date, we are conducting aerial remote sensing surveys at 35 of NEON's terrestrial and aquatic field sites across nine of NEON's ecoclimatic domains. One of the most satisfying parts of the work is collaborating with researchers from the external science community, including a group of University of Florida ecologists who are collecting coincident field data at sites like the Talladega National Forest in Alabama to study plant and microbial diversity as well as map variations in tree growth (see bottom right photo).

We look forward to working with more researchers in the field! See our complete schedule for the season, and please feel free to follow the NEON flight operations team as we continue to chase "peak greenness" across the eastern United States (http://www.neonscience.org)!

Our next mission: collecting data over the beautiful Great Smoky Mountains National Park!

—Ivana Vu, Flight Operations, Airborne Observation Platform, National Ecological Observatory Network

View more postcards at *http://americangeophysicalunion.tumblr.com/tagged/postcards-from-the-field.*



EARTH & SPACE SCIENCE

virtual poster showcase

Abstracts Open for Fall 2016 Showcases

Students need to take only these three simple steps to gain valuable experience presenting their research.

1. **Submit an abstract**
2. **Upload a poster and accompanying video presentation**
3. **Evaluate the posters of peers and receive feedback on their own poster**

What students say about Virtual Poster Showcase:

"I especially liked that fellow students reviewed posters, as that gave me experience in critically thinking about the research other students were doing as well as my own."

"It was a really valuable experience for me, and I know I am much more ready to participate in a bigger, in-person conference."

Learn more about the biannual showcases:
virtualposter.agu.org

AGU

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HONORS PROGRAM

American Geophysical Union Recognizes
the Following Outstanding Scientists
in Earth and Space Sciences for 2016

Section and Focus Group Awardees and Named Lecturers

Union Awards, Medals, and Prize Recipients

Union Fellows

honors.agu.org