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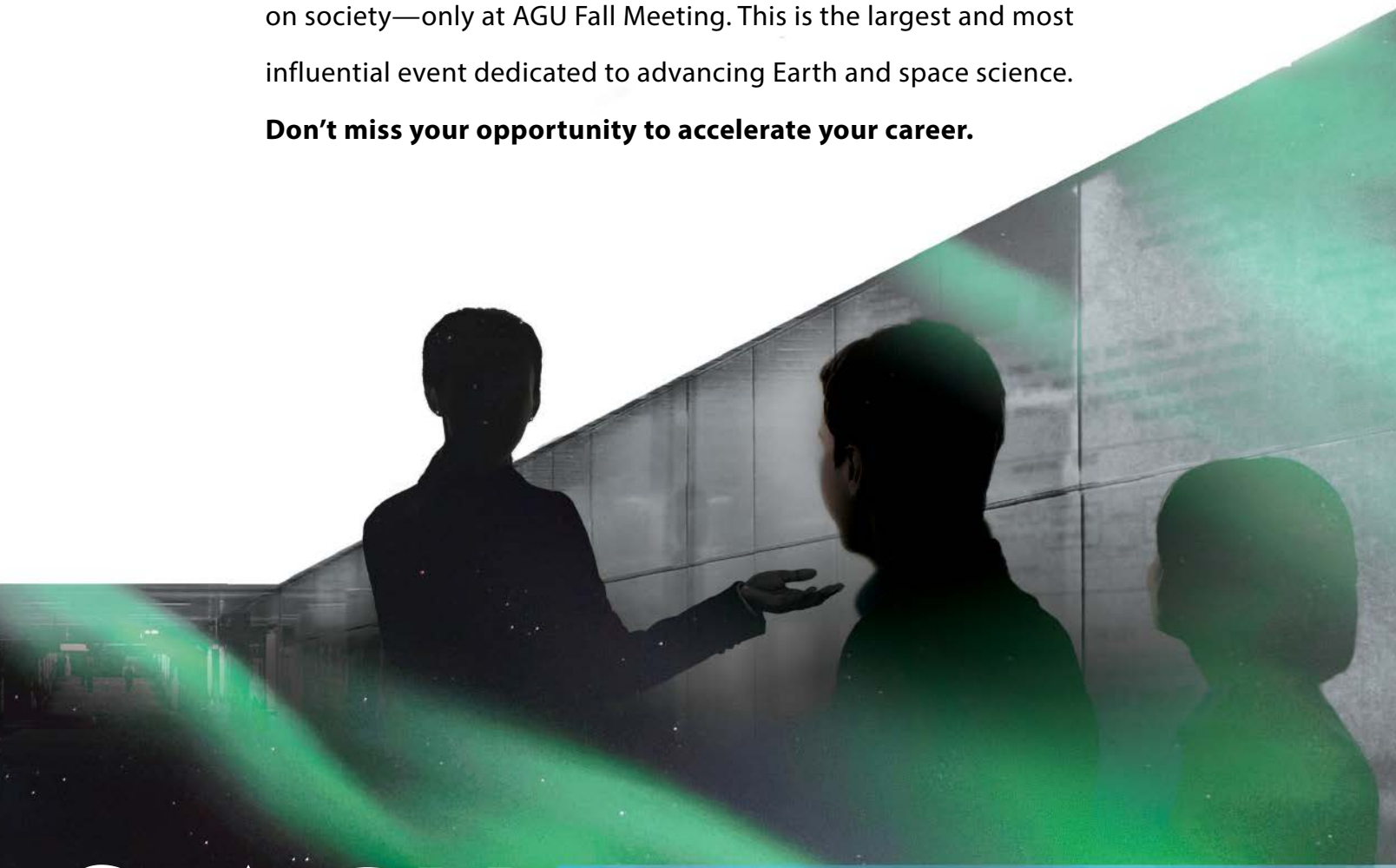

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JULY 2017
VOLUME 98, ISSUE 7

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Eos (ISSN 0096-3941) is published monthly by the American Geophysical Union, 2000 Florida Ave., NW, Washington, DC 20009, USA. Periodical Class postage paid at Washington, D. C., and at additional mailing offices. POSTMASTER: Send address changes to Member Service Center, 2000 Florida Ave., NW, Washington, DC 20009, USA.

Member Service Center: 8:00 a.m.–6:00 p.m. Eastern time; Tel: +1-202-462-6900; Fax: +1-202-328-0566; Tel. orders in U.S.: 1-800-966-2481; Email: service@agu.org.

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Tornado Casualties Depend More on Storm Energy Than on Population

A scene of destruction in Concord, Ala., after the 2011 Tuscaloosa–Birmingham tornado, which caused more than 1500 casualties. A new study indicates that storm intensity is a better predictor of casualty counts than the size of the local population. Credit: National Weather Service

When a dark, swirling funnel cloud dips toward the ground, people living in a U.S. region in and near the Great Plains popularly known as Tornado Alley know to move to a safe spot. Tornadoes can destroy concrete buildings and send railcars rolling, and these violent windstorms account for roughly 20% of natural hazard–related deaths in the United States.

Despite tornadoes' danger, the correlations among the number of storm-related casualties, a twister's energy, and the size of the population in its path are not well understood. Better understanding of those relationships could help scientists, policy makers, and emergency management personnel predict future tornado deaths and injuries based on trends in population growth and tornado activity.

Now, in a new study, researchers have used a principle of economics to show that a tornado's casualty count depends more strongly on the energy of the storm than on the size of the local population.

This work is "likely to spur conversation and additional research," said Todd Moore, a physical geographer at Towson University in Towson, Md., who was not involved in the study. "It provides a framework that can be modified to include additional risk variables."

> "By understanding tornado behavior better…we get a deeper understanding of what may be causing the death and destruction we see in these storms."

Fear Becomes an Obsession

Tyler Fricker grew up hearing his father's stories of the 1974 Xenia, Ohio, tornado that killed 33 people and injured more than 1000 others. Fricker, now a geographer at Florida State University in Tallahassee and the lead author of the new study, has also lived through a few tornadoes of his own. He explains his fascination with tornadoes as "fear becoming an obsession."

In the new research, he and his colleagues analyzed 872 casualty-causing tornadoes that swept through parts of the United States between 2007 and 2015. They defined "casualty" as a death or an injury related to a storm. "By understanding tornado behavior better…we get a deeper understanding of what may be causing the death and destruction we see in these storms," Fricker said.

The team borrowed a principle of economics known as elasticity to investigate how a tornado's casualty toll scaled with its energy and the size of the nearby population. Elasticity is commonly used by economists to investigate how two measurements—for example, supply and demand—are related.

The researchers used National Weather Service data to determine the energy dissipated by a tornado. They calculated this energy as proportional to the area of a tornado's path multiplied by its average wind speed raised to the third power. Knowing this quantity for each tornado allowed the team to uniformly define the intensity of each storm. The researchers then collected population measurements in roughly 1-kilometer by 1-kilometer squares for the path of each tornado using a database of world population maintained by Columbia University in New York.

Predicting Casualties

Armed with these two parameters and the published casualty counts for each of the tornadoes in their sample, Fricker and his colleagues investigated how casualties scaled with storm energy and the size of the nearby population. The scientists found that storm energy was a better predictor of the number of storm-related injuries and deaths: Doubling the energy of a tornado resulted in 33% more casualties, but doubling the population of a tornado-prone area resulted in only 21% more casualties. These results, which the team reported in April in *Geophysical Research Letters* (http://bit.ly/GRL-tornado), can inform emergency planning, the team suggests.

The relatively larger impact of tornado energy on casualties might be cause for con-

cern, Fricker and his colleagues note. If climate change is triggering more powerful tornadoes, an idea that's been suggested and debated, emergency managers might have to contend with larger casualty counts in the future. But scientists are by no means certain that larger tornadoes are anticipated. "There is no doubt climate change is influencing hazards, but for tornadoes, we just simply don't know to what extent yet," said Stephen Strader, a geographer at Villanova University in Villanova, Pa., who was not involved in the study.

It is "far more likely" that the population, rather than the tornado energy, will double in the future, notes Victor Gensini, a meteorologist at the College of DuPage in Glen Ellyn, Ill., who also was not involved in the study. Effective communication and good city planning might help reduce storm-related casualties, Fricker and colleagues suggest. "It's hard to control the behavior of tornadoes, but it's somewhat within our control to smartly advance how we organize cities and suburbs," said Fricker.

> "You might have only 10 or 15 minutes to get to a safe spot."

Many More Factors

Of course, changes in storm energy and population can't fully explain all variations in storm-related deaths or injuries. "There are also more factors that combine to determine a casualty, one of the most important being what type of structure a person is in when the tornado strikes," said Gensini.

Fricker said that he and his colleagues look forward to examining factors such as how a victim's age, socioeconomic status, and race might correlate with vulnerability to harm from a tornado. "Maybe we'll be able to profile communities more susceptible to casualties based on all of these other determinants," he said.

The team hopes that their findings will be useful to emergency personnel, who could target these most vulnerable populations when they disseminate information about tornado preparedness, for example. After all, "you might have only 10 or 15 minutes to get to a safe spot," said Fricker.

By **Katherine Kornei** (email: hobbies4kk@gmail.com; @katherinekornei), Freelance Science Journalist

Between Outbreaks, Did Plague Lurk in Medieval England?

Dead carts, such as the one depicted in this antique engraving, were used in London to collect corpses during the last major bubonic plague epidemic in England, from 1665 to 1666. Credit: iStock.com/duncan1890

Researchers of the bubonic plague, also known as the Black Death, have long debated why the disease broke out repeatedly in medieval Europe: Did traders from elsewhere bring the dreaded pestilence with them from infected areas, thus sparking new epidemics? Or was the *Yersinia pestis* bacterium, now known to cause the plague, present but for some reason inactive during the 5 to 12 years that typically passed between outbreaks?

Now a researcher has found a pattern of recurrence by looking at ancient records of the Black Death and climatic conditions in what today is an eastern region of England called East Anglia. "It looks like, after a run of 1, 2, or 3 years of relatively average or slightly cool summers, once there is a jump to warm and dry weather, there is a large likelihood" of a plague epidemic, said Kathleen Pribyl of the University of East Anglia in Norwich, U.K., in April during the General Assembly of the European Geosciences Union in Vienna, Austria. Her findings (http://bit.ly/EGU-plague) suggest that the bacterium lingered silently in rodents during periods between plague flare-ups, only to threaten humans again when the rodent population exploded.

Rediscovering Past Climate

A climate historian, Pribyl reconstructed English climate between 1256 and 1431 using indirect evidence, for example, the date of the start of the grain harvest. She wondered whether she might discover in these data the influences that triggered plague epidemics or quelled them. She realized that she needed to extend her climate record to the end of the 15th century, when public health measures such as quarantining were introduced, which confined outbreaks and lowered their impact.

Pribyl found the data she needed in the work of a Dutch independent climate historian, Jan Buisman, who has been compiling reports on weather phenomena and climate in the Low Countries, the coastal region now

occupied mostly by the Netherlands and Belgium. This area, lying only 200 kilometers east of East Anglia across a stretch of the North Sea, was close enough for its weather records to be suitable to supplement the English data, Pribyl told *Eos*. Buisman's records date from as early as 764 C.E.

With a sufficiently long temperature record thus established and with data on rainfall readily available via tree ring sequences, Pribyl could characterize each year: Was the winter cold or not? Was the summer cool, warm, dry, wet? At first, just like researchers before her, she saw no particular circumstances that would coincide with a plague outbreak. But that changed when she grouped summers not by their temperature but by the difference in average temperature from the preceding summer. If a warm summer followed a normal one, then a plague outbreak was much more likely, she found.

This pattern, according to Pribyl, shows that it was not repeated arrivals from outside England that made the plague return again and again but the waxing and waning of the population of some host animal. Knowing the preference of *Yersinia pestis*, it was likely a rodent, she explained.

Vole Toll

In England, the field vole and the common vole are likely candidates to have played the role of plague reservoirs, and these species have naturally fluctuating population sizes. A normal year or, better yet, a few normal years, followed by a warm year, said Pribyl, is just what sets up the population structure, the food situation, and the number of predators for a population explosion. This increase will, in turn, bring these rodents, and the fleas they carry, into closer contact with humans than in normal times, "especially after the population collapses again, which always happens at some point," she said. "Because then the fleas will try to move to other hosts, and humans are as good as anything else. And that's when transference of the disease becomes quite likely."

Other signs from climate data also point to rodents as the reservoir. A slightly cold winter seems to have helped the plague: More snow would have insulated and hid the voles' burrows. But outbreaks almost never occurred after a very cold winter, which would have killed a lot of voles, or a very mild one, when abundant rain would have flooded many burrows.

Imported Outbreaks?

In an earlier study (http://bit.ly/pnas-plague), Boris Schmid, an evolutionary biologist at the University of Oslo in Norway, and his colleagues analyzed a data set of 7711 plague outbreaks in Europe and compared them to precipitation records from tree ring samples from Europe and Asia. Weather conditions that might have caused rodent numbers to spike, they reported, generally did not coincide with outbreaks. They concluded that most outbreaks of the plague must have been caused by renewed introduction of *Yersinia pestis* from Asia, brought into Europe by rats on merchant ships.

A scanning electron micrograph shows the bubonic plague bacterium Yersinia pestis *(yellow green) infesting the digestive tract of a flea. Credit: NIAID, CC BY 2.0 (http://bit.ly/ccby2-0)*

Pribyl, however, questions that research team's analysis. "They looked at climate fluctuations for the whole of Europe and expected to find one kind of pattern. But that's actually quite unlikely. With my data, I could look at just one region," she noted.

Genes, Too

Hendrik Poinar, an evolutionary biologist at McMaster University in Hamilton, Ont., Canada, who did not participate in Pribyl's study, told *Eos* that he found Pribyl's conclusion that the plague did not enter Europe again and again but resided in a rodent reservoir "convincing and interesting." Poinar took part in an investigation of the genome of a strain of *Yersinia pestis* that was found in Marseille, France, in the teeth of buried victims of one of the last outbreaks in Europe, in 1722. Last year, his group reported that this strain had descended from bacteria identified in 14th-century victims in London. So genetics, too, points at the plague emerging repeatedly from a reservoir in or near Europe, Poinar said.

Could the source of the repeated English outbreaks have been in England itself, and could the field voles that Pribyl suspects indeed have been the reservoir? It's quite possible, Poinar said. "All these small, human-associated rodents could be important. All these should be tested. If she has samples, we'd be happy to test them!" he said.

By **Bas den Hond** (email: bas@stellarstories.com), Freelance Science Journalist

New Technique Reveals Iceberg Calving Process

Walking near the end of a massive tongue of glacial ice rising hundreds of meters above the sea, a group of scientists spotted an unexpected and ominous sign. About 100 meters from the edge of the glacier was a crack a few meters wide. The crack was fresh—there had been no sign of it the day before. "We decided we wouldn't walk farther," said Guillaume Jouvet, a glaciologist at ETH Zurich in Switzerland.

He and his colleagues were on a 2015 expedition to Bowdoin Glacier in northwestern Greenland for the express purpose of deepening scientists' understanding of when, how, and why such fissures form. But the fissures were just a means to an end; the team was out to piece together the series of events from the start of a crack to the moment when an iceberg breaks free at the glacial front.

The international team of researchers, including Jouvet, led by glaciologist Martin Funk, also of ETH Zurich, recently reported in *The Cryosphere* (http://bit.ly/bowdoin-calving) that they used images collected by an unmanned aerial vehicle (UAV) to model how ice fractures propagated in this glacier, which is about half the area of Manhattan Island. The crack resulted in a 1-kilometer-long iceberg breaking away from the front of the glacier. Combining observations of visible ice fractures with modeling of a glacier's interior, as the team has done, is a powerful technique for better understanding, and potentially predicting, when and where glaciers will produce icebergs, the researchers suggest.

This work "yields insights into the production of icebergs, which are increasingly affecting human societies," said Mark Carey, a glacier researcher at the University of Oregon in Eugene, who was not involved in this research. The current number of icebergs drifting into North Atlantic shipping lanes is "among the highest in a century," he added.

A video (http://bit.ly/bowdoin-video) that the researchers made of this revealing fieldwork includes footage taken by the UAV's camera.

Flying Eye

The team's 2015 observations of the glacier built on previous studies of the flowing ice there by some of the same researchers using automatic cameras, GPS measurements, and ice-penetrating radar. This time, however, the scientists brought with them a piece of technology that's becoming popular in geophysics research: a UAV.

Team members mounted a camera on the battery-powered craft. Then, on 11 July, after overcoming reliability issues with the UAV's compass related to the nearby North Pole, they guided the craft over the terminus of Bowdoin Glacier.

A large crack splits the ice about 100 meters from the face of Bowdoin Glacier in Greenland. Credit: Julien Seguinot, ETH Zurich

The camera snapped roughly 1000 overlapping photographs during the 30-minute flight. The researchers then used computer software to construct a three-dimensional model of the glacier from the data. The resulting image was "like a satellite view, but [of] very high resolution," said Jouvet.

The next day, the team explored the glacial front and noticed the crack near the glacier's edge. But when they later reviewed the previous day's UAV images, they saw no sign of the crack.

Five days later, the team launched the UAV again and assembled another three-dimensional image of Bowdoin Glacier. This time, the researchers found the crack easily: It had grown to 750 meters long. By comparing the two high-resolution UAV data sets using a feature-tracking algorithm, Jouvet and his colleagues traced how the ice moved and calculated its velocity at 1-meter intervals. But the UAV images revealed only the glacier's surface—the real mystery lay within. "We wanted to somehow enter the glacier," said Jouvet. For that, the researchers turned to modeling.

Hundreds of Artificial Glaciers

Members of the research team, which included scientists from ETH Zurich and Hokkaido University in Sapporo, Japan, simulated on a computer more than 100 versions of the terminus of Bowdoin Glacier, each characterized by different internal properties such as bedrock topography, friction between bedrock and ice, and ice stiffness. They also modeled whether, at the time of the 16 July second flight, the crack might have been partially filled with water, a condition that would have widened it more than had it been empty.

By comparing the properties of these artificial glaciers with the actual surface features of Bowdoin Glacier, the team found a best fit model indicating that the crack was water filled and 175 meters deep, roughly two thirds of the total thickness of the glacier. "The fracturing process was quite advanced" by then, said Jouvet.

He and his colleagues didn't attempt to predict exactly when Bowdoin Glacier's massive iceberg would detach. That happened on 27 July, about a week after the researchers had left Greenland. A roughly 1-kilometer-long section of the glacier calved off as an iceberg, which then broke apart in the water. "Fishermen saw a lot of icebergs coming from Bowdoin Fjord" that day, Jouvet noted.

He added that the team's technique of modeling ice fractures could "absolutely" be applied in more places than just Greenland. For instance, the method could be used to infer the properties of the enormous crack that's currently developing in Antarctica's much larger Larsen C ice shelf, which spans hundreds of square kilometers. However, he said, monitoring such a large area might be better accomplished with satellite images than with UAV images.

Now Jouvet is leading a project to actually predict the formation of cracks responsible for massive icebergs. The project is deploying a fleet of UAVs in northwestern Greenland this summer to collect its first data. Jouvet said that he hopes to record a large event, from the initiation of the first crack in the ice to the final launch of the iceberg.

By **Katherine Kornei** (email: hobbies4kk@gmail.com; @katherinekornei), Freelance Science Journalist

Balloons of Lava Bubble into the Ocean from Seafloor Blisters

Lava balloons are pieces of hollow, cooled lava burped up from the seafloor after some types of undersea volcanic eruptions. This balloon was recovered from the 1998–2001 eruption near the Azores, Portugal. Credit: Ulrich Küppers

Imagine you're a fisherman at sea and suddenly your boat is surrounded by dozens of floating pieces of hot, dark rock, hissing and spewing vapor. Some rocks are no bigger than footballs and some are larger than refrigerators. But just a few minutes later, the mysterious chunks sink below the surface with no hint of where they came from.

That is exactly what happened to a group of fishermen in the Azores, Portugal, in late 1998. It turns out that they were witnessing the appearance of lava balloons: floating lumps of hollow, cooled lava burped up from the seafloor after an undersea volcanic eruption.

The fishermen described the balloons as "hot steaming stones whose high temperature caused minor damage to the fishing ropes," with "fire coming out from the seawater spreading on the air like sparks of fireworks," according to a report (http://bit.ly/lava-balloons) by Portuguese scientists who were called to the scene. The fishermen later noticed a "large quantity of dead or injured fish" at the sea surface.

The balloons are a strange and rare phenomenon that serve a scientific purpose: They alert researchers to underwater eruptions that might otherwise go unnoticed, said Ulrich Küppers, a volcanologist at the University of Munich in Germany.

> Fishermen described the balloons as "hot steaming stones whose high temperature caused minor damage to fishing ropes."

Küppers is trying to find out how and why these weird features form. He suspects that they are the result of trapped magmatic gas pushing upward through lava during some kinds of undersea eruptions. Küppers presented his theory at the AGU Chapman Conference on submarine volcanism in January in Hobart, Tasmania, Australia.

A Rare Thing to Behold

Lava balloons are hollow pieces of cooled basalt, a fine-grained dark lava rock. These rough ellipsoids can be as small as 50 centimeters and as long as 3 meters. They rise to the sea surface during some submarine eruptions, and after a few minutes of bobbing on the surface, they absorb water and sink back down to the seafloor.

"When they're floating at the sea surface, they're a bit like icebergs," Küppers said. "They're mostly below the surface."

So far, humans have documented the appearance of lava balloons only five times: off the coast of the island of Hawaii in February 1877; near the Mediterranean island of Pantelleria, Italy, in October 1891; near the Mexican island of Socorro in late 1993 and early 1994; off the coast of the Azores, from 1998 to 2001; and in the Canary Islands, Spain, in October 2011.

But Küppers suspects that lava balloons may occur more often than volcanologists think. Because they float on the surface for only a few minutes, it's hard to catch them in the act. Only for the Socorro, Azores, and Canary Island eruptions have scientists been able to directly observe the balloons while measuring other aspects of the eruption, like seismicity and water temperature.

How Did the Balloons Get There?

After studying data—some collected by him, some collected by others—from the most recent three eruptions, Küppers noticed a few common traits. The balloons didn't seem to explode or implode as they rose in the water column, and their size didn't change along their journey to the sea surface. Maps of the seafloor around the eruptions revealed that the balloons all emerged from submarine eruptions in shallow water no deeper than a few hundred meters.

"There's really a lot of open questions still about how…they form, but we have now a good couple of data sets about eruptive activity ongoing at the ocean floor," he said.

After gathering balloons from the Azores eruption and analyzing data from the other four eruptions, Küppers has come up with a hypothesis for how the balloons emerge. Every now and then during a submarine eruption, gas accumulates just below the interface between the volcano's magma and the water above.

The gas continues to rise because it's less dense, bringing a coating of magma along with it. The magma that rises above the interface is

Lava balloons floating in the ocean on 18 January 2012 during an eruption off the coast of the Canary Islands, Spain. Credit: Laura García-Cañada, CC BY 3.0 (http://bit.ly/ccby3-0)

instantly quenched when it meets cold seawater, creating a thin crust of cooled lava over a gas-filled interior.

The rising gas keeps pushing the shell up. Under the right conditions, the balloon becomes buoyant enough that it detaches from the seafloor and rises through the water column. Some are light enough to reach the sea surface, whereas others absorb water and sink back to the seafloor.

What Gas Propels the Balloons?

Lava balloons appeared intermittently during the Azores eruption, which continued until early 2001. At one point, researchers from Portugal's Research Institute for Volcanology and Risk Assessment explored the eruption area with a remotely operated vehicle.

The team got lucky—they spotted some of these balloons as they rose and filmed them with the vehicle's camera. Küppers and other researchers studied the footage and found gas bubbles emanating from the balloons that had traveled through the water column.

"If that was water steam, in contact with water in the Azores at 20 degrees [Celsius], it would instantly quench, condense, and the bubble would implode, disappear," he said. "These bubbles survive over several frames, and this is reason for me to believe that these bubbles are primarily filled with carbon dioxide."

He suspects that the carbon dioxide originates from the magma but separates from the melted rock and accumulates below the lava interface, bulging it outward, perhaps triggering the process of lava balloon formation.

Lava Blisters

During a research expedition to the Azores in July 2016, Küppers and his colleagues studied the 1998 eruption site in detail. "We have observed many balloon fragments in a heap at the seafloor," so lava balloons have been launching at the spot for quite some time, he said. "I call it making lava blisters."

Küppers hopes next to quantify the conditions of blister and balloon formation, such as how much gas is needed to bulge the lava interface, drive the lava out, and make it detach from the seafloor.

By **Lauren Lipuma** (@Tenacious_She), Contributing Writer

Predictive Capability for Extreme Space Weather Events

Workshop on Modeling and Prediction of Extreme Space Weather Events
College Park, Maryland, 22–24 August 2016

Space weather research is motivated by the quest to understand the effects of solar activity on the near-Earth space environment and the severe impacts these effects can have on infrastructure systems and technologies in space and on Earth. As this sensitive infrastructure grows, so does the vulnerability of our society to solar storms. The growing importance of extreme space weather events underscores the need to develop modeling and predictive capabilities for these low-probability but high-impact events.

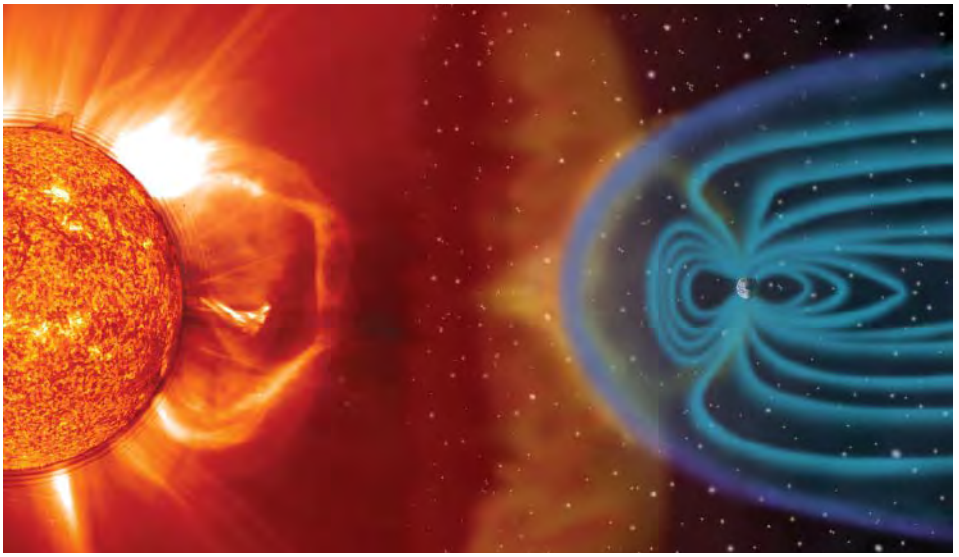
A workshop last August brought together participants from universities, research centers, and federal agencies. Participants assessed current capabilities in modeling severe space weather events, and they addressed potential approaches for developing capabilities that can facilitate preparedness and transition from research to operational forecasting.

A Developing Response to an Established Risk

The famous solar storm referred to as the Carrington Event of 1859 illustrates the potential consequences of space weather events for everyday life on Earth. This event sparked auroras as far south as the Caribbean and blew out telegraph systems. A comparable storm today would be devastating.

Several recent intense geospace storms also serve as a warning. In particular, the 23 July 2012 solar storm, which had a magnitude comparable to the Carrington Event, narrowly missed Earth but provided clear evidence of the likelihood of such intense events.

The U.S. government has provided a strong impetus to study space weather. In October 2015, the White House Office of Science and Technology Policy released the National Space Weather Strategy (see http://bit.ly/space-weather-strategy) and an accompanying action plan (see http://bit.ly/space-weather-action). A 13 October 2016 presidential executive order calls for space weather preparedness and efforts to minimize the extent of economic loss and human hardship from space weather (see http://bit.ly/space-weather-EO).



Artist's representation of the Sun-Earth connection. When storms on the Sun emit solar flares and coronal mass ejections, the effects can extend to electrical grids and telecommunications systems on Earth. At a workshop last August, experts looked at current capabilities for modeling severe space weather events and discussed how they could develop ways to help with preparedness and forecasting for such events. Credit: NASA/GSFC/SOHO/ESA, CC BY 2.0 (http://bit.ly/ccby2-0)

Workshop participants noted that despite major developments in space weather models, space weather forecasting is still in an early stage. One of the challenges they discussed is the dearth of spacecraft monitoring the solar wind between Earth and the Sun. At present these are limited to the L1 point, where Earth's and the Sun's gravities balance out and where several spacecraft are stationed (Advanced Composition Explorer (ACE), Deep Space Climate Observatory (DSCOVR), Wind, and Solar and Heliospheric Observatory (SOHO)).

Because of this dearth of data, a strategy for integrating data and modeling is essential, attendees noted. They agreed that the example of terrestrial weather forecasting provides compelling guidance: Data assimilation and ensemble forecasting have produced dramatic improvements in predictions. Such a strategy should aim to overcome the "valley of death"—the difficulties in the transition from research to operations that infamously claim so many promising ideas.

A Need for Advanced Modeling Capabilities

At the workshop, participants discussed challenges in modeling and prediction of extreme events in general. However, they agreed that the severe consequences of such events require developing strategies or frameworks that combine the capabilities of first principles and data-driven approaches. Data-driven modeling is based on complexity science and does not require modeling assumptions, so it is an important framework that has provided methods to quantify uncertainty. In space weather, such approaches are very relevant, especially considering the current state of numerical models.

Workshop participants identified the need for increasing open access to models in space weather research. To move toward forecasting, testing and validating models are essential, which requires that models be readily accessible to the community. As in the case of terrestrial weather, there is a fundamental need for open-access numerical models to accelerate model development and their transition from the research community to operational use.

This workshop was funded by NSF/PREEVENTS grant AGS 1638499.

By **A. Surjalal Sharma** (email: ssh@astro.umd.edu) and **Eugenia E. Kalnay,** University of Maryland, College Park; and **Michael Bonadonna,** National Oceanic and Atmospheric Administration, Silver Spring, Md.

Acquiring a Taste for Advocacy

On the Sunday before last year's AGU Fall Meeting—about a month after the U.S. elections—I found myself in a windowless room, deep in the basement of the San Francisco Marriott Marquis Hotel. It was 8:00 a.m., and I was shaking off jet lag to attend a science communications workshop hosted by AGU's Sharing Science program.

Communications, in this context, means talking about science to people who aren't scientists. The workshop covered three topics: interacting with the general public, which I love; talking to journalists, which is what drew me; and interactions with politicians. I figured I'd zone out through that last bit.

But that isn't how things turned out.

A Eureka Moment

Let's back up a bit. Even when I was a postdoc in the Washington, D. C., area, almost 2 decades ago, I avoided politics like the plague.

This disengagement isn't just unreasoned distaste. Some years ago, prompted by a request from a scientist I greatly admire to sign a policy statement I wholeheartedly agreed with, I thought long and hard about whether to engage in political discourse as a scientist.

In the end, after hearing a timely and terrific set of talks (see http://bit.ly/scipolicy), I did not sign that statement. Instead, I settled on the idea that science can tell us what is true but not what to do—that policy might be grounded in truth but ultimately reflects values.

That principle served me well enough for a decade, even in the face of growing unease about increasingly counterfactual arguments against the increasingly deep understanding of climate change. But times have changed, and it's become unnervingly normal to advance political agendas by denying the truths that science provides.

Our democratic system means that I expect power to be mutable. But I also expect the rules to stay more or less the same, and these days that's not such a sure bet.

Sitting in that basement room, listening to the people who argue for our work to the people who use what we learn (and pay for our curiosity), I knew that even if I'm unwilling to advocate for particular policies in my role as a scientist, I am more than ready to advocate for what we do and to make the case for stability, intellectual freedom, and openness in how we do it.

A Visit to Congress

With this readiness to advocate, I took advantage of a trip to Washington earlier this year to spend a day of my own time visiting members of Congress.

The visits were arranged by AGU's public affairs staff, the same people who run AGU's Congressional Visits Days. In the weeks before the trip, the staff helped me craft a message, then refine a script with stories and concrete requests. They identified whom I could meet with and what committee memberships or legislative sponsorships would make the visit most relevant. They joined me on those visits, guiding me through a bewildering building and an even more bewildering social world.

A sign held at the 21 January 2017 Women's March in Washington, D. C. Credit: Liz Lemon

The legislative side of the federal government is like another country: unfamiliar, sometimes uncomfortable, but easy enough to get the hang of, once I had dusted off my interview suit.

Capitol Hill runs on young people. Most staff are the age of graduate students, the really senior staff about as old as postdocs. Nonetheless, it quickly becomes apparent that these are smart people with knowledge and power.

Some social customs take getting used to. In everyday conversation, it would be rude to make a request without establishing a connection, but on the Hill "the ask" is the first thing on the table because this gives your hosts the chance to calibrate who you are and how to respond to you.

One-off stories have little value in scientific arguments, but they are gold in congressional offices. That's partly because time is short (most visits last 30 minutes or less). But it's also because anecdotes make facts personal—and people, after all, are far more important than ideas.

My biggest surprise, however, was learning firsthand how hard congressional staff work to find common ground. For my visit, AGU had arranged meetings with representatives from both political parties, guaranteeing that some of the people I met would have viewpoints different than my own. And yet every single staff member went out of his or her way to hear what I had to say, respond thoughtfully, and identify one or more points on which our agendas aligned.

Anecdotes make facts personal—and people, after all, are far more important than ideas.

No Landscape Is Permanent

Of course, no single visit by one scientist is going to change any legislator's well-developed policy stance. Does that mean the visits are pointless or self-indulgent?

I don't think so. On the most basic level, politicians respond to public pressure and opinion, and newly engaged, vocal, and organized communities can be valuable support or formidable opponents.

More fundamental, politicians have to triangulate an enormous range of priorities. The fate of Earth science is rarely the most pressing or compelling. And yet they listen, and I'd like to think that positions might change.

Musing on the way home from my congressional visit, I couldn't shake the image of a stream running over rocks. The landscape right now might seem so permanent, but then there's the Grand Canyon....

By **Robert Pincus** (email: robert.pincus@colorado.edu), University of Colorado Boulder

Editor's Note: For more information on AGU's Sharing Science program and Congressional Visits Days, see https://sharingscience.agu.org/ and http://bit.ly/AGUcvd.

UNDERSTANDING KAMCHATKA'S EXTRAORDINARY VOLCANO CLUSTER

By Nikolai M. Shapiro, Christoph Sens-Schönfelder, Birger G. Lühr, Michael Weber, Ilyas Abkadyrov, Evegeny I. Gordeev, Ivan Koulakov, Andrey Jakovlev, Yulia A. Kugaenko, and Vadim A. Saltykov

Klyuchevskoy volcano, soaring 4750 meters above the Kamchatka Peninsula near the western shore of the Bering Sea, is one of the most active in the world. Many international flights connecting North America and Asia fly over the peninsula, where a group of active volcanoes, including Klyuchevskoy, occasionally fill the air with ash and dust. What drives the unusually high volcanic activity here? Do these volcanoes all feed from the same large pool of magma?

The Klyuchevskoy volcanic group (KVG), a part of the Kuril–Kamchatka volcanic belt, is located in a subduction

The Klyuchevskoy volcano in eastern Russia during a 2016 eruption. The photograph was taken in July; the eruption began in April and lasted about 6 months. To the right is the Kamen volcano. Both volcanoes are part of an especially active group on Russia's Kamchatka Peninsula, near the Bering Sea. Credit: Segrey Chirkov

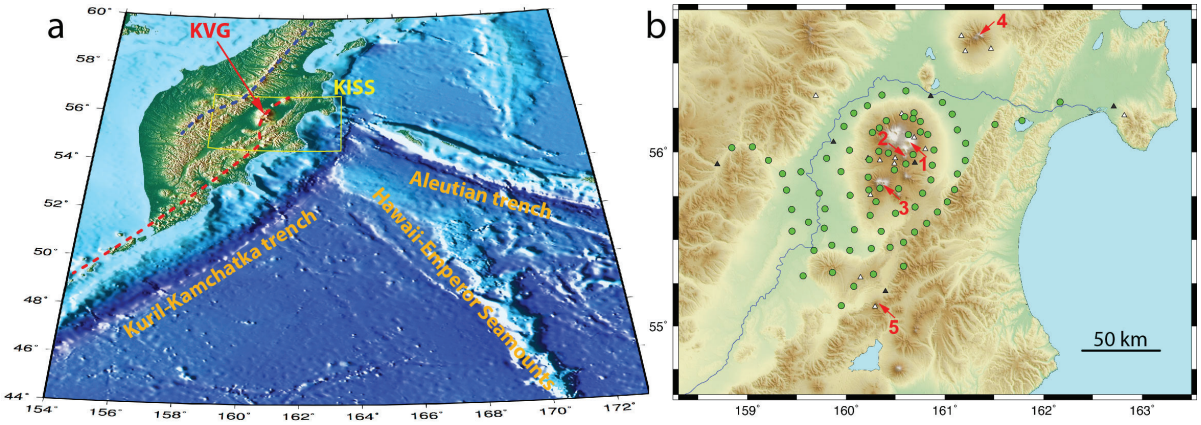


Fig. 1. KISS project setup. (a) Three-dimensional view of the Kamchatka–Aleutian tectonic plate junction. The red arrow indicates the location of the Klyuchevskoy volcanic group (KVG). The approximate positions of the active and extinct volcanic chains are indicated with red and blue dashed lines, respectively. (b) Region surrounding the KVG where the KISS seismic stations (green circles) collected data from July 2015 to July 2016. Broadband and short-period stations of the permanent seismic monitoring network are shown with black and white triangles, respectively. Red arrows show the locations of volcanoes that erupted during the past decade: 1, Klyuchevskoy; 2, Bezymianny; 3, Tolbachik; 4, Shiveluch; and 5, Kizimen.

zone where the Pacific oceanic plate plunges beneath the tectonic plate that carries the peninsula (Figure 1a). The strength and variety of volcanic activity in the region make it a natural laboratory to study where magma sits and how it moves in a subduction zone.

Previous surveys have been limited to the area around Klyuchevskoy. That changed in 2015–2016, when an international collaboration conducted the first geophysical survey of the entire KVG. The effort was named the Klyuchevskoy Investigation–Seismic Structure of an Extraordinary Volcanic System (KISS) experiment.

Data from KISS's instrument network offer an unprecedented look at one of Earth's most active volcanic regions and could reveal whether the underlying magma reservoirs are connected by one large volcanic supercomplex. The instruments also provided a real-time record of an unfolding eruption: They recorded the full sequence of events that preceded the most recent eruption of Klyuchevskoy, in April 2016.

KISS experiment fieldwork often took place in remote locations. Here, a Kamaz truck and Robinson helicopter transport equipment and field crews. Klyuchevskoy (erupting) and Kamen volcanoes are seen in the background. Credit: Sergey Chirkov

The Klyuchevskoy Volcanic Group

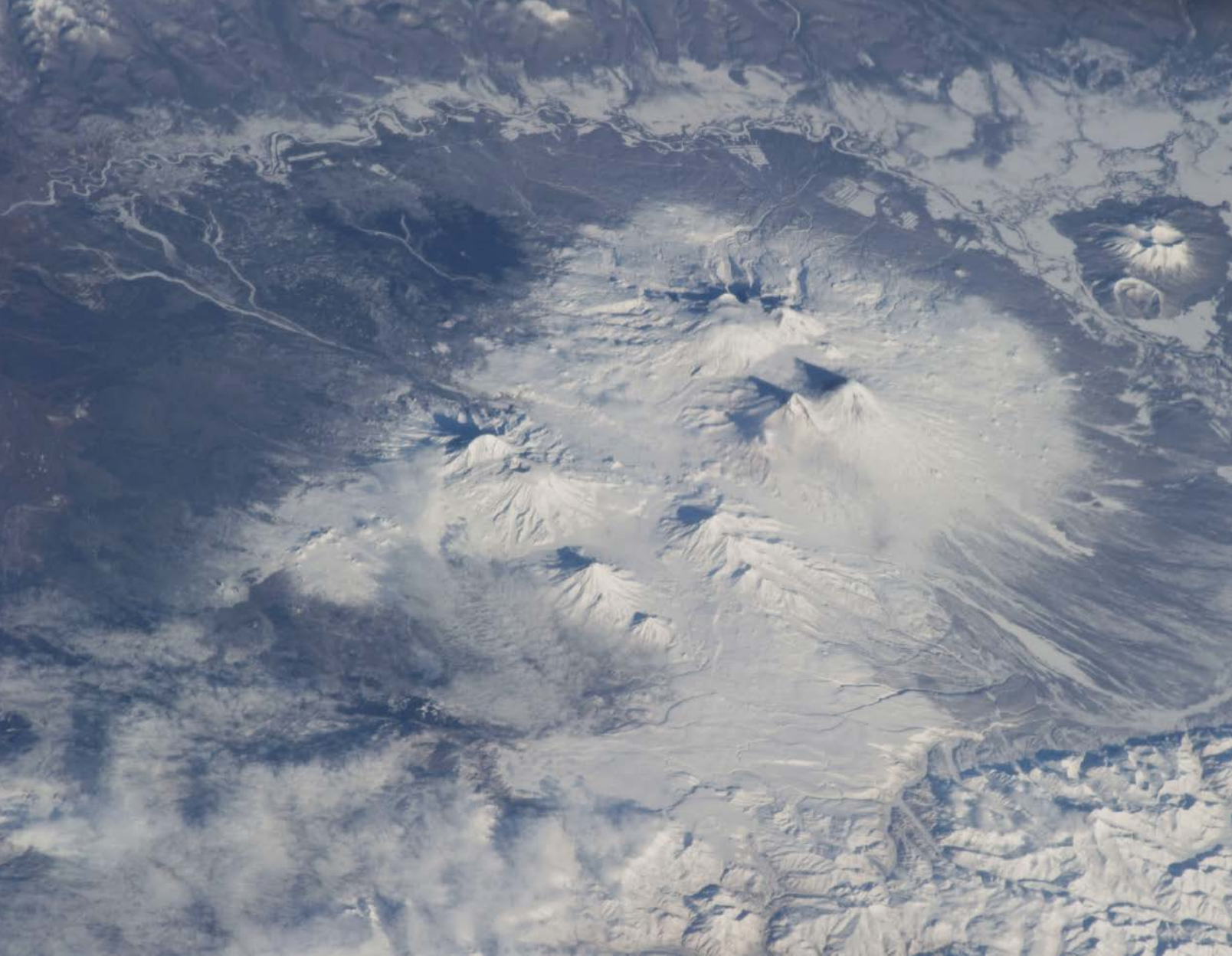
Over the past 10,000 years, Klyuchevskoy volcano has produced an average of 1 cubic meter of erupted rock every second [*Fedotov et al.*, 1987]. This eruption rate is much higher than that of most volcanoes associated with subduction and is comparable to the growth of the Hawaiian volcanic chain, often considered one of the most vigorous volcanic systems of modern Earth.

Besides Klyuchevskoy, the KVG contains 12 other large volcanoes. Two of them, Bezymianny and Tolbachik, have been very active in the past few decades. Two other active volcanoes, Shiveluch and Kizimen, are located only 60 kilometers north and south, respectively, of KVG (Figure 1b).

A whole spectrum of eruptive styles is present in the KVG, ranging from steady Hawaiian-type eruptions, as seen during the two most recent eruptions of Tolbachik, to the strongly explosive eruptions of Bezymianny in 1956, which were among the world's largest in the 20th century. (The word bezymianny means "unnamed" in Russian. Until the 1956 eruption, the volcano was considered to be extinct, so no one bothered to give it a name.)

The region's exceptional volcanic activity is related to the unique tectonic setting of the KVG, located at the sharp corner between the Kuril-Kamchatka and Aleutian trenches. This corner is where the Hawaiian–Emperor seamount chain, the underwater mountain range that stretches down to Hawaii, is subducted, and the KVG is perched above the edge of the subducted slab (Figure 1a).

Geodynamic models that attempt to explain the voluminous volcanism in the KVG are complex and include many factors. These include the release of fluids from the thick, highly hydrated Hawaiian-Emperor crust [*Dorendorf et al.*, 2000], the mantle flow around the corner of the Pacific plate [*Yogodzinski et al.*, 2001], and the recent detachment of a portion of the slab due to an eastward jump of the subduction zone beneath Kamchatka [*Levin et al.*, 2002]. The large variability of lavas and eruption styles reflects the complexity of the feeding system of magma sources and reservoirs in the upper mantle and the crust.



The Klyuchevskoy volcanic group in northeastern Russia, as seen from the International Space Station, viewed from the southeast. Credit: Earth Science and Remote Sensing Unit, NASA Johnson Space Center

A Unique Natural Laboratory

Because of its strong and variable activity, the KVG is a unique natural laboratory for studying volcanism in a subduction zone. Understanding how this zone functions requires detailed knowledge about the configuration of the subducted oceanic plates and about the distribution of magma conduits and reservoirs within the mantle wedge and the crust. A particularly important question is whether the individual KVG volcanoes are fed from independent magma sources or whether they form a single interconnected magmatic supersystem.

Gathering information about the deep KVG structure requires the use of geophysical methods. Past seismological studies [*Koulakov et al.*, 2011] have revealed possible pathways of melts ascending from the subducting slab and a multilevel system of magma reservoirs in the crust. However, the structures that these studies illuminated are restricted mainly to a few tens of kilometers surrounding Klyuchevskoy volcano, where most existing permanent seismic stations are located (Figure 1b). A full understanding of the behavior of the KVG magmatic system requires an investigation of subsurface structures at a much larger scale.

The KISS Project

To undertake such a large-scale seismological investigation of the KVG, we formed a consortium of institutions from Russia, France, and Germany and designed the KISS experiment. We operated a temporary network of 83 seismographs between August 2015 and July 2016.

The experiment took place in difficult terrain; helicopters and off-road trucks were needed to transport the equipment and field crews to the installation sites. An eruption-triggered mudflow destroyed one site, and a few others were wrecked by bears. Despite the harsh environment, the team recovered data from 77 instruments (Figure 1b).

Initial inspection of seismograms indicates that the network successfully recorded many tectonic and volcanic earthquakes and volcanic tremors. The collected data set, combined with records from permanent seismic stations, will be used to study various types of earthquakes associ-

The Klyuchevskoy volcano puffs gas during its 2016 eruption. Kamen and Bezymianny volcanoes are to the left. In 2015 and 2016, an international collaboration conducted a large-scale geophysical survey of the active group of volcanoes that includes Klyuchevskoy. Credit: Benoit Taisne

ated with the volcanic and magmatic activity and to image the crust and upper mantle with multiscale seismic tomography.

These results will help us understand why exceptionally large amounts of melts are generated in the upper mantle at the Kamchatka–Aleutian subduction corner and how these magmas are transformed during the ascent through the crust, producing the vigorous and very variable volcanism we see at the surface.

Monitoring the KVG for Hazardous Eruptions

Volcanic eruptions regularly affect a few small settlements located near the KVG, and they pose a significant threat to aviation because many international flights that connect North America and Asia pass over Kamchatka. Large explosive eruptions such as those of Bezymianny in 1956 and Shiveluch in 1964, when about 1 cubic kilometer of erupted material was ejected, might be particularly dangerous.

Moreover, Kamchatka has a well-established record of even larger caldera-forming eruptions in the Holocene [*Braitseva et al.*, 1995], with the largest of them forcibly ejecting about 150 cubic kilometers of rock fragments (tephra).

Considering that at present more than half of Kamchatka volcanic magmas are generated below the KVG, we cannot ignore the possibility of a future extreme explosive event in this region. We expect the results of the KISS experiment to help us evaluate such extreme event scenarios by improving our knowledge of the size of the KVG crustal magmatic reservoirs, along with the volume of potentially explosive magmas they might contain.

When the Klyuchevskoy volcano rumbled back to life and erupted in April 2016 (see http://bit.ly/Klyuchevskoy-eruption), the KISS network recorded the full sequence of reactivation leading up to the eruption. We will use this data set to improve our knowledge of how the rise of magma and the preeruptive buildup of pressure are expressed in the continuous seismic signals. The data will also help refine the routine monitoring of the KVG and other nearby volcanoes performed by the Kamchatka Branch of Russia's Geophysical Survey and by the Kamchatka Volcanic Eruption Response Team, which is operated by the Institute of Volcanology and Seismology.

Acknowledgments

The KISS experiment was supported by the Russian Science Foundation (grant 14-47-00002), the French project Labex UnivEarth, and the Université Sorbonne Paris Cité project VolcanoDynamics. Sixty seismographs were provided by Geophysical Instrument Pool Potsdam (GIPP) from the Helmholtz Center Potsdam-GFZ German Research Centre for Geosciences, and 23 were provided by the partner institutions from the Russian Academy of Sciences: the Institute of Volcanology and Seismology, the Trofimuk Institute of Petroleum Geology and Geophysics, and the Kamchatka Branch of the Geophysical Survey. KISS data are stored in the GFZ Seismological Data Archive operated by the GEOFON program and will be openly available after a 3-year embargo period. We are grateful to Sergey Abramenkov, Benjamin Heit, Pavel Kuznetsov, Ekaterina Kukarina, Roman Kulakov, Alexey Kotlyarov, Valeriy Gladkov, Petr Voropaev, Dmitry Droznin, Sergey Senyukov, and Vitaly Bliznetsov, who participated in the fieldwork. Special thanks are owed to Sergey Chirkov for providing field photographs and to the truck driver, Igor Uteshev, as well as to the helicopter pilot, Gennady Kroshkin.

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A BIKE BUILT FOR MAGNETIC MAPPING

By Uri Schattner

A mountain bike scrambling across rough terrain is a common sight in many areas. Seeing one equipped with a magnetic sensor and other gear doing the same thing, however, may cause you to do a double take.

A team of researchers from the University of Haifa and the Geological Survey of Israel has designed such a sensor-equipped mountain bike. The setup holds promise to improve ground data collection for regional mapping.

Although walking with a magnetic sensor may be the cheapest and most widely used method of collecting field data, riding a sensor-equipped bicycle offers significantly

Uri Schattner (author) rides a mountain bike equipped with GPS and a magnetometer past an encampment of shepherds near the upper Jordan River valley in Israel. The GPS antenna is mounted behind the rider, about 2.1 meters above the ground, and the magnetic sensor extends 1.65 meters in front of the bike. The rider wears a magnetic receiver strapped to his chest. Both sensors are wired to this receiver to check the quality of the measurements as a run proceeds. Credit: Amit Segev

Mounting a magnetic sensor on a bicycle offers an efficient, low-cost method of collecting ground magnetic field data over rough terrain where conventional vehicles dare not venture.

Uri Schattner tests the bike-mag system across the shoulder of the Dead Sea fault valley in northeastern Israel. Credit: Amit Segev

more efficient data collection while maintaining data quality and lowering costs considerably.

Measurements of ground magnetism are an important component of mapping the distribution of magma pools and other magnetic features beneath the surface. To obtain such data, a surveyor typically walks along a planned route carrying the necessary sensors, often in a backpack.

The measured magnetic values are used to create maps of subsurface magnetism. Further modeling produces a three-dimensional distribution showing where magnetic bodies lie beneath the surface. Combined with other data, the distribution of these bodies can be used as the basis for advanced modeling of lateral stress variations and seismic wave propagation in the subsurface. Such measurements are used for calculating earthquake propagation and hazard assessments.

A researcher collecting magnetic measurements on foot can typically cover 10 to 12 kilometers in a day. Although this remains the cheapest and simplest method for traversing almost all types of terrain not covered by roads, the method has limitations.

For example, very few of the surveyors have the endurance of a marathoner. They often tire after walking a distance of 2 to 3 kilometers while carrying the instruments.

To cover longer distances, at least two or three surveyors go out to collect data. One surveyor walks a segment, and the others follow along in a car. When the walker tires, another surveyor takes over and walks the next segment. Every segment of measurement is planned according to the topography to maximize time spent going downhill. This method requires funding to cover paying one or more additional persons, renting a large enough car to accommodate everyone, and paying for food and lodging because, normally, a measurement campaign takes more than 1 day.

The Search for Off-Road Magnetic Mappers

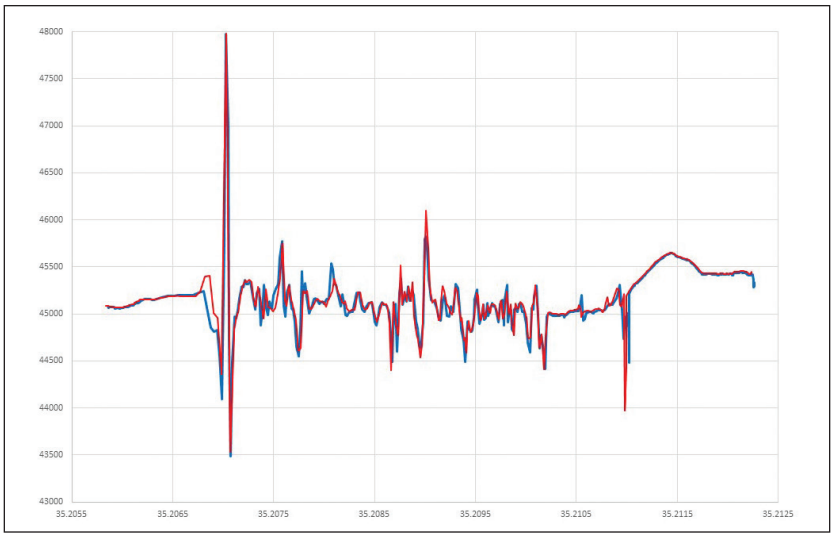
How do we ease the burden of all this walking? One solution involves placing sensors on a nonmagnetic cart that can be dragged by a vehicle operated by remote control or programmed to operate autonomously. Such devices have proved useful for detecting, for instance, unexploded mines, but they are limited to roads or fields accessible to the cart.

Aerial surveying overcomes such challenges. It provides dense data coverage over a wide swath and allows mapping of areas inaccessible to ground measurements. However, the technology and support required for aerial surveys are sophisticated, expensive, and beyond the means of many developing nations.

However, bicycle-mounted magnetic sensors provide an efficient, economical, low-tech design that maintains data accuracy. The new design is potentially suitable for use in remote areas and developing countries.

While collecting data on the bike, we need only one driver and one rider. A segment of data collection can be several tens of kilometers long, with no replacement of surveyors along the way. The extra expenses are also lower than those used by walkers for the car, fuel, food, and accommodation if the measurements take more than 1 day.

In addition, over topographically flat regions, the rider does not need the technician or the accompanying car at all. This gives the rider more uninterrupted stretches of time to collect data.



Measurements of total magnetic intensity (TMI, in nanotesla) acquired while walking (blue) and bike riding (red) along 2 kilometers of flat terrain show almost identical results. Because the bike was moving faster, the distance between data points is greater, and the bike data show less prominent spikes as the bike passes passes over buried pipes and other infrastructure. The horizontal axis shows longitude values in decimal degrees. Credit: Uri Schattner

Equipping a Mountain Bike

We fixed the components of the magnetometer system to an aluminum-framed, hard-tail mountain bike. We used a design called the All-Terrain Bicycle Geomagnetic Mapping System (ATBGMS; see http://bit.ly/ATBGMS), created by researchers from the University of South Florida. In ATBGMS, the magnetic sensor is fixed to a pole extending about 1.3 meters in front of the bike handlebar and turns along with the handlebar [*La Femina et al.*, 1998].

This design worked well on paved roads and relatively smooth dirt roads. We could also easily carry the bike over obstacles such as fences and stairs.

However, the ATBGMS design was not robust enough to support the weight of the magnetic sensor over rougher terrain. Stresses on the equipment bent the handlebar and broke the front pole, dropping the magnetic sensor to the ground.

Designing a New Prototype: Bike-Mag

Our solution to the problems we encountered with ATBGMS was to make the sensor mounting more robust, using a set of polypropylene pipes assembled into a framework of vertical triangles. Anchored to the bike frame, this new framework placed the sensor at a fixed height above ground (2.2 meters), 1.65 meters in front of the handlebar.

In the new design, the sensor does not turn along with the handlebar but remains aligned with the bike frame and the direction of motion during measurements. At the same time, the framework is flexible enough to absorb shocks at a wide range of velocities during a ride.

Our "bike-mag" design has several advantages. The location of the sensor on the framework rather than on the handlebar gives the rider more maneuverability. Moreover, the robustness and flexibility of the polypropylene framework extend data collection to rougher terrain, such as dirt roads, single tracks, and footpaths along uphill and downhill slopes.

Testing the Bike-Mag

We tested the accuracy of our bike-mag system by comparing data collected on foot along a 2-kilometer stretch of flat dirt road between agricultural fields with corresponding data collected using the bike-mag system.

Both sets of measurements used an Overhauser magnetometer (GEM GSM-19) with the same instrumental sample rate (once per second). Both surveys followed exactly the same path. The walker (the author) collected data at a pace of 5 kilometers per hour, and the cyclist (also the author) collected data at 15 kilometers per hour. The surveys were conducted within an hour of each other to eliminate possible external effects such as diurnal changes in the magnetic field.

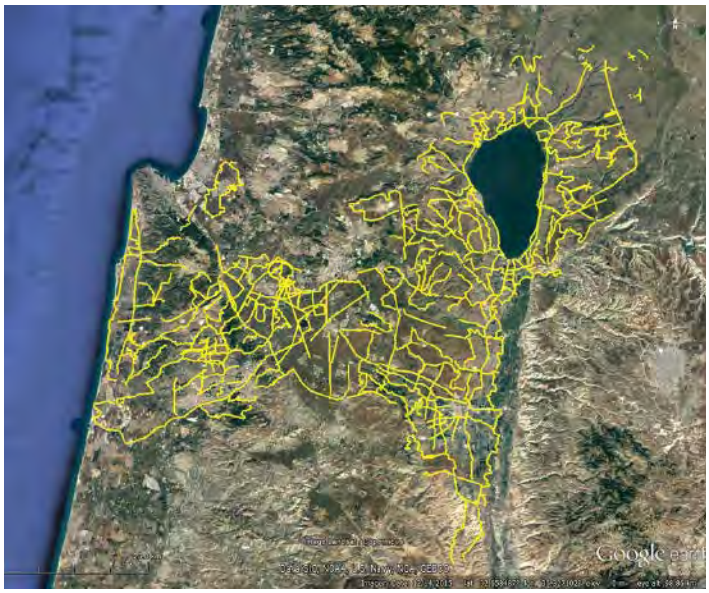
The measurements resulting from the two trial surveys were almost identical. The spikes in the plotted curves coincided, confirming the presence of buried pipes and trenches evident under the road.

The spikes themselves, however, appear smaller in the bike-mag results. The higher velocity during bike measuring increased the distance between sampling points, smoothing out the curve. Indeed, the faster travel rate acted as a low-pass filter that enhanced the signature of magnetic bodies of geological significance over signals from buried infrastructure.

In principle, we could apply a similar adjustment to improve "walk-mag" measurements, but the bike-mag approach allows for continuous acquisition of data over longer distances, with fewer operators, less data storage, and lower processing times.

Mapping a Larger Region

In the second stage of our experiment, we mapped a seismically active region of northern Israel, covering about 2500 square kilometers along roads that are roughly 1 to



Location of the bike-mag transects collected in northern Israel. Since April 2016, the bike-mag surveyed about 2100 kilometers of terrain. Only about 900 kilometers of data were collected by foot in the decade prior. Credit: Uri Schattner/Google Earth™ imagery © Google Inc. Used with permission.

2 kilometers apart. Previous walk-mag campaigns, spanning 20 years, had covered an accumulated distance of 900 kilometers.

Our bike-mag mapping started along topographic valleys and included the Dead Sea fault valley. We covered 500 kilometers in 10 days between April and June 2016, and we have since completed data collection over more than 1000 kilometers (see http://bit.ly/Bike-Mag-map). Most of the data were acquired at speeds of 15 to 45 kilometers per hour.

A single operator (the author) carried out data collection over gentler topography. In steeper, more rugged terrain, we acquired data mostly during downhill runs. An accompanying vehicle transferred the bike, gear, and rider from the base of one hill to the top of the next one.

A Geological Survey of Israel vehicle carries the bike-mag system to the top of Mount Arbel in northern Israel in preparation for a downhill run to collect data. Credit: Uri Schattner

Fieldwork Efficiency

We expected that we could map the entire region in about 60 days of fieldwork. Ten days into the effort, it was clear that our bike-mag approach offered a low-cost, simple, and efficient solution for regional ground mapping, with no more than a minimal investment required for data acquisition, transport of gear, and occasional repairs. We are still in the process of collecting data, and we are making good progress.

For example, measurements along a road descending to the Sea of Galilee, a distance of 14 kilometers, took about 25 minutes. The same distance would have required an entire day of measurements on foot. When one of the polypropylene pipes used to mount the equipment broke, we quickly replaced it with an off-the-shelf pipe from a nearby hardware shop for about US$4.

Public Engagement

The bike-mag effort also attracted public attention, offering opportunities to engage people with science in practice. People of all ages were intrigued by the strange bike passing through their villages and tried to guess what it might be for. Our bike-mag team welcomed this spontaneous curiosity, offering simple explanations, and enjoyed helping bring science and the joy of discovery to local communities.

Racing Ahead

We plan to complete our mapping of northern Israel and continue on to central and southern Israel, eventually producing a map of the entire country. We intend to combine our measurements with existing data collected from the air and at sea and to reach out for collaborators to map other regions worldwide.

We are in the process of raising more funding for this project. Visit our bike-mag blog (https://bikemagnetics.wordpress.com) for updates on the project's science, equipment design, and field campaigns.

Acknowledgments

The bike-mag team members are Uri Schattner, Vladimir Lyakhovsky, Amit Segev, and Michael Rybakov. We thank the editor and two reviewers for their helpful comments and Mor Kanari, Tal Golan, and Aya-Shani Schattner for their help during the prototype development. We also thank Moti Schattner and Michael Krom for their constructive remarks.

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NEW DATA BUOYS WATCH TYPHOONS from Within the Storm

By Sen Jan, Yiing Jang Yang, Hung-I Chang, Ming-Huei Chang, and Ching-Ling Wei

Two recently deployed ocean data buoys got a real test of their abilities last July when category 5 "super typhoon" Nepartak's center passed within a few kilometers of where they were moored. This meeting was no accident: The buoys were specifically designed to record data on passing typhoons and relay the information to Taiwan's Central Weather Bureau.

Typhoons, hurricanes that occur in the northwestern Pacific Ocean, threaten coastal and inland populations of nearly 1 billion people living in Taiwan, Japan, Korea, China, and the Philippines. Broadcasting timely warning messages to the public is an essential part of minimizing the disastrous effects of typhoons in coastal and inland areas. However, accurate and timely warnings require better forecasting of typhoon tracks and intensities. High-resolution data and real-time observations of typhoons in the open ocean are important to better understanding their formation and evolutionary processes and to improving the performance of numerical predictions.

Although satellite remote sensing is valuable, these sensors cannot see far beneath the sea surface, making a real-time data buoy network with subsurface observations the perfect complement during typhoons. However, establishing a high density of buoy stations requires a large number of reliable instruments, as well as considerable support in the form of mooring supplies, satellite communications, and ship time.

A research and technical team composed of scientists and technicians at National Taiwan University (NTU) is working to establish just such a buoy network (see http://bit.ly/NTU-data-buoys) in the northwestern Pacific. The team is working to reduce the cost of data buoys and their associated maintenance using low–power consumption technologies, building on the basic concept of the Autonomous Temperature Line Acquisition System (ATLAS) [Hayes et al., 1991]. The new data acquisition system accommodates more meteorological and oceanic sensors than a standard ATLAS mooring and can transmit data at adjustable intervals via satellite-to-ground stations.

Economical, Reliable Observation and Forecasting

Typhoons are capable of causing catastrophic destruction along their path. Typhoon Morakot, a category 2 storm, passed across southern Taiwan on 8 August 2009, bringing more than 2.7 meters of rain to Taiwan, the highest typhoon-related rainfall in 50 years. The heavy rain caused floods and mudslides, resulting in more than 600 deaths and

(left) A data buoy floats in the northwestern Pacific. This buoy was enhanced with functionality to help scientists monitor typhoons. (above) Researchers at the Institute of Oceanography, National Taiwan University, speed toward one of their enhanced data buoys in September 2016. Their efforts are part of a new program to build a network of similar buoys in the northwestern Pacific. Credits: Cheng-Chia Lien

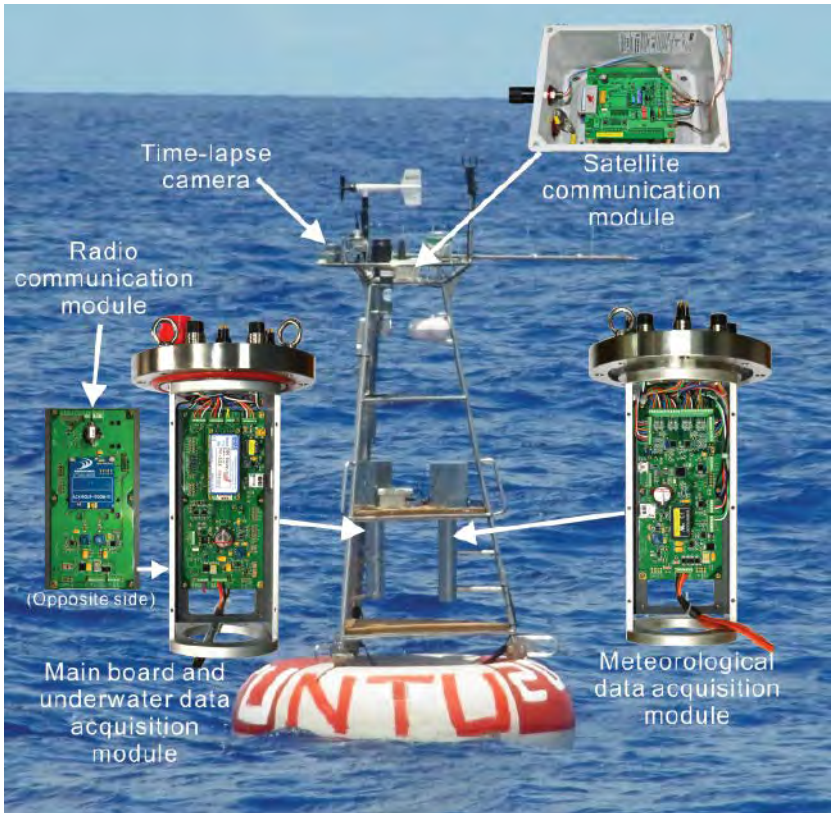

Fig. 1. The NTU buoy components, including the associated solid-state modules for surface and subsurface data acquisition and for satellite and radio communications.

US$5 billion in property damage [*National Disasters Prevention and Protection Commission,* 2009]. On 8 November 2013, Super Typhoon Haiyan ripped through the central Philippine islands, causing more than 6000 deaths and US$2 billion in losses [*Shull,* 2013].

The threat of such death and destruction creates an obvious need for buoy observations in the Philippine Sea. Unfortunately, these kinds of on-site observations are rare, presumably because of the high cost of setting up and maintaining deepwater buoy stations, the frequent failure of the buoys in extreme conditions, and the instrument damage and buoy relocation that can happen when the buoys become entangled in tuna fishing lines.

The new buoy project, initiated by the Institute of Oceanography at NTU, aims to overcome these difficulties with a less expensive but more robust data buoy, which we call the NTU buoy. The data collected by these new buoys will help improve our understanding of the ways in which the air and the sea exchange heat and how this exchange influences typhoon intensity. The NTU buoys will also provide real-time data to weather forecast centers when a typhoon is approaching.

A New Buoy System Design

The NTU buoy has a newly designed data acquisition system, electric power scheme, and satellite communications module (Figure 1), making it an improvement over the standard ATLAS mooring. The data acquisition system is controlled by a microprocessor that features low electric power consumption. The meteorological sensors can be in sleep mode between successive samplings to save energy.

Lithium batteries supply the buoy with electric power, and they can support buoy operations for more than 18 months. Solar panels, with their stainless-steel towers, are not required for this buoy system, so the wind drag on the buoy is greatly reduced.

Previous buoy systems have become entangled in fishing lines, but the new design minimizes this problem with unique cutter devices clamped onto the mooring cable. These cutters have four stationary blades that radiate out from the clamp, and they sever any fishing line that drapes across them before the line can become entangled around the mooring cable or the buoy. A customized stainless-steel connector and a high-density polyethylene-coated steel wire in the upper 500 meters of the approximately 5500–meter mooring line help the buoy survive in strong typhoons.

Two separate data loggers record air temperature, pressure, wind speed and direction, humidity, solar radiation, irradiance, precipitation, and the seawater temperature and salinity profile in the upper 500 meters of the ocean every 6 minutes. The system also measures ocean current velocity at 25- and 75-meter depths. The data can be transmitted to the home station every 30 minutes during normal weather conditions and can be adjusted by satellite communication to transmit every 12 minutes during the passage of a typhoon. Stand-alone time-lapse cameras (Figure 1) are mounted on the buoy to take sea surface images at 1-minute intervals.

Scientific Goals

Understanding typhoon dynamics is still one of the key challenges that limits the performance of forecast models. Our buoy project provides high-resolution measurements of the oceanic and atmospheric responses to typhoons, and it enables comparison of these observations with the forecasts produced by numerical models.

We hope to answer the following science questions [*D'Asaro et al.*, 2013] as we move forward with this buoy program:

- What is the buoy's best wind estimate in a typhoon?
- How does the ocean's mixed layer, where turbulence mixes the water, evolve under extreme typhoon winds?
- How do extremely strong winds affect the exchange of heat, salt, and momentum between the sea and the air?
- How can these new buoy data improve forecasting?

Into the Path of the Storm

To answer these questions, the NTU team took the most likely typhoon track into consideration. The team deployed a prototype NTU buoy 375 kilometers off southeastern Taiwan (123.9°E, 21.2°N) during June–September 2015. In June–October 2016, we deployed two improved buoys, NTU1 and NTU2, 375 kilometers (123.9°E, 21.1°N) and 175 kilometers (122.6°E, 21.9°N), respectively, off the coast of southeastern Taiwan.

These buoys measured nine typhoons. The first four, Chanhom, Linfa, Soudelor, and Goni, occurred in 2015, and the later five, Nepartak, Meranti, Malakas, Megi, and Aere, occurred in 2016.

Data collected by the buoys were sent in real time to Taiwan's Central Weather Bureau. These data provided valuable information on air–sea fluxes for use in improving forecast model output for validating and calibrating satellite observations during these typhoons.

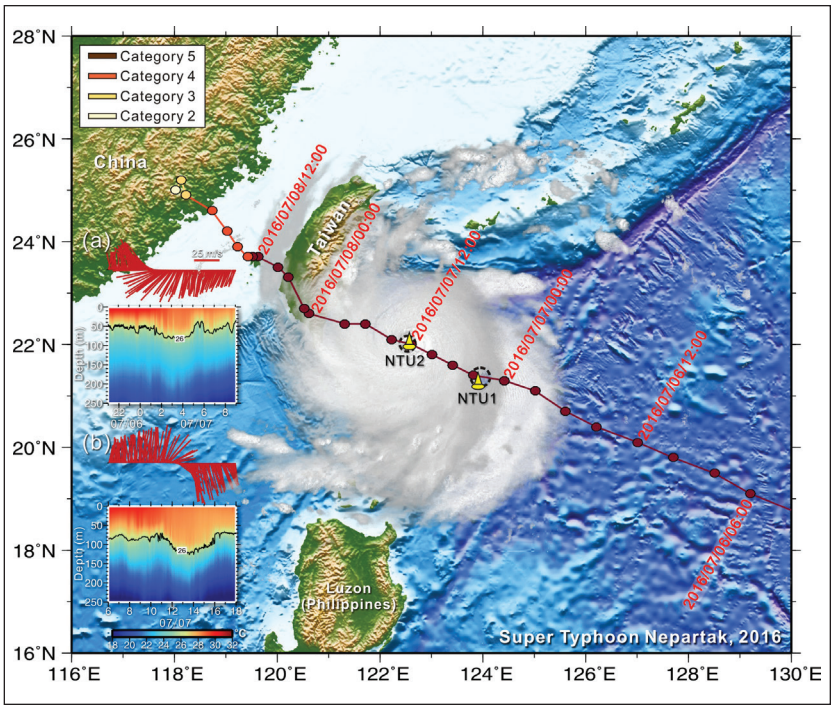

Fig. 2. This image of Typhoon Nepartak was captured by satellite Himawari-8 on 7 July 2016 at 02:30 and 12:00 UTC. The typhoon track is shown, along with the locations of the two buoys, NTU1 and NTU2. The insets show buoy-measured wind velocities (red lines) and seawater temperatures (colored depth profiles) in the upper 250 meters for (inset a) NTU1 from 21:00 UTC on 6 July 2016 to 09:00 UTC on 7 July 2016 and (inset b) NTU2 from 06:00 UTC on 7 July 2016 to 18:00 UTC on 7 July 2016.

Data from a Super Typhoon

Notably, two NTU buoys observed Typhoon Nepartak from their respective locations, which proved to be only a few kilometers from the typhoon's center (Figure 2). This typhoon became a category 5 super typhoon on 6 July 2016, and it reached NTU1 with a well-formed, distinguishable eye. As the eye of this storm approached NTU1, the buoy observed an atmospheric pressure of 940 hectopascals (standard sea level air pressure is 1013 hectopascals), a maximum wind gust of 41 meters per second (about 148 kilometers per hour), and a decrease of seawater temperature from 31°C to 28°C in the upper 100 meters. The typhoon's eye soon reached NTU2, and this second buoy recorded a rather low atmospheric pressure of 911 hectopascals and a maximum wind gust of 44 meters per second (about 158 kilometers per hour). The seawater in the upper 120 meters was well mixed by the strong winds (see temperature profile in Figure 2).

Next Steps

We successfully recovered the NTU buoys on 14 October 2016. We recently completed quality assurance and quality control operations on the complete data set that we retrieved from the buoys at that time, and these data are now available to the broader scientific community (contact us for access information).

We are also developing and testing prototypes, and the buoy observation serves as a modest start toward a more widespread network. Two more buoys were deployed this June from the R/V *Ocean Researcher I*, at the same locations as the two buoys deployed in 2016. Additional buoys and instruments are being prepared for deployment. Our goal is to complete and maintain five operational buoys in this region in the next 3 years.

Acknowledgments

The buoy project is sponsored by NTU under the Aim for the Top University Plan. Taiwan's Ministry of Science and Technology and Central Weather Bureau partially support this project. The technicians at NTU and the crew of R/V *Ocean Researcher I* helped deploy, maintain, and recover the buoys. H.-I.C. is supported by MOST 104-2611-M-002-012-MY2. We dedicate this report to Wen-Huei Lee, who was one of the technicians on the NTU buoy team.

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In Appreciation of AGU's Outstanding Reviewers of 2016

With this article, AGU Publications again recognizes outstanding reviewers selected by the editors of each AGU journal for their work in 2016.

Peer-reviewed literature plays a critical role in advancing science. However, peer reviewing has been generally undervalued in terms of its contributions and the collective level of effort involved. Despite the challenges of relying on volunteers, peer review is essential for helping to maintain the integrity of science and its efficient advancement (by forcing some quality checks on the official archive of progress). It also plays a vital role in the granting of awards and has value for society in that peer-reviewed literature increasingly has official, codified uses in law, regulations, and advisory input.

Much of the scientific community's outreach to the public is through the press and, thanks to quality publications, through our community's leading journals. Checks to enhance reproducibility and to drive improvements in the science help overall quality. In turn, quality peer review in many ways distinguishes leading journals from the growing threat of so-called predatory journals, which can degrade scientific integrity.

The task of peer reviewing forces researchers to think deeply and broadly about others' contributions to science in ways that are fundamentally different from simply reading a paper. The process of reviewing helps scientists improve their careers and develop better networks. In the case of peer review, the collective whole is much more than the sum of its very important parts.

Reviewing on a Grand Scale

A large reviewing effort takes place at AGU and in the greater scientific publishing world. In 2016, AGU received more than 13,500 submissions and published nearly 6100 papers. Many of those submissions received multiple reviews, amounting to more than 30,000 reviews in all. More than 1100 reviewers completed five or more reviews, and 93 completed 10 or more.

Considering the broad array of journals available plus the evaluation of grant proposals, reviewing becomes a significant burden to the scientific community. A common saying is that in return for the valuable feedback they receive from reviews of their work, researchers should give back at least twice as many reviews as the number of papers and grants they submit. AGU journals continue to work to maintain their efficient times from submission to first decision and publication, and reviewers represent a key part of this achievement.

Reviewer Recognition and Rewards

Although we formally recognize but a few of the reviewers of AGU journals here, we also acknowledge the broad efforts by the many reviewers who help ensure their quality, timeliness, and reputation. AGU is working to provide individual recognition in ways beyond the citations given below. We are extending subscription benefits to those reviewers who repeatedly provide quality reviews. Each reviewer also receives a discount on AGU and Wiley books. We will continue to work with the Open Researcher and Contributor Identification network (ORCID) to provide official recognition of reviewers' efforts so that reviewers receive formal credit in that way. To date, we have more than 26,000 ORCID records linked to GEMS user accounts. Last year, 1844 individuals received credit for 2355 peer reviews on their ORCID records.

Although individual recognition is important and needs to expand, we here provide a collective thank-you to participants in the larger process and integrated effort that is helping to expand integrity across the scientific enterprise. Peer review can be improved in many ways, and experiments are being carried out across leading publishers (AGU among them), but the overall importance of peer review is growing, not declining, and needs broader support and recognition.

The process of reviewing helps scientists improve their careers and develop better networks.

The photographs and listings below of the 2016 outstanding reviewers chosen by AGU's journal editors begin with four individuals who were each selected by two different editors for this recognition.

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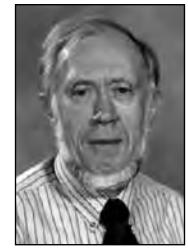

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Scientists' Freedom to Work Entails Responsibilities to Society

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The AGU Board of Directors approved on 13 April a new position statement on the rights and responsibilities of scientists. The position statement, "The Responsibilities and Rights of Scientists," emphasizes that the public-serving role of scientists charges them with certain ethical duties, and it also affords them the right to conduct science and collaborate freely (see http://bit.ly/AGU-responsibilities).

"The scientific profession makes enormous contributions to human health, economic prosperity, and environmental sustainability," said AGU president Eric Davidson in a press release (see http://bit.ly/responsibilities-press-release). "With that public-interest role comes great responsibility. This position statement acknowledges not only the importance of scientific excellence and integrity, but also the challenges of cultivating inclusivity, diversity, and safety throughout our profession. Finally, it articulates the essential rights of scientists to freely and openly exchange ideas in their pursuits and communications of knowledge."

The concept for this statement was originally proposed by an AGU member through the position statement proposal process, which is open to all AGU members (see http://bit.ly/AGU-position-proposal). The AGU Position Statement Task Force then convened a panel of experts charged with developing the statement. A draft version of the statement written by the panel was open for AGU member comment for 1 month, and member comments were reviewed before the statement was finalized. It complements a previous AGU position statement, "AGU Supports Free and Open Communication of Scientific Findings" (see http://bit.ly/AGU-free-communication), and it will be reinforced by a forthcoming update to AGU's Ethics Policy.

AGU develops and maintains position statements to provide scientific expertise on significant policy issues related to the understanding and application of the Earth and space sciences. Members are encouraged to use AGU's position statements to guide conversations with students, local communities, policy makers, and other members of the public. AGU's position statements are maintained in the AGU Resource Center (see http://bit.ly/AGU-resources). They, along with AGU's Advocacy Policy (see http://bit.ly/AGU-advocacy), are valuable resources for those looking to connect with members of the public on issues related to Earth and space sciences.

Panelists Who Developed the Statement

Michel Campillo, Institut des Sciences de la Terre
Jasmine Crumsey, Stanford University
Clinton Foster, Geoscience Australia
Linda Gundersen, U.S. Geological Survey
Rob Jackson, Stanford University
Susan Kieffer, University of Illinois
Scott Mandia (chair), Suffolk County Community College
Jerry Miller, Science for Decisions
Michael Oppenheimer, Princeton University
Karen Wayland, U.S. Department of Energy

By **Elizabeth Landau** (email: elandau@agu.org), Public Affairs Manager, AGU

Water Quality Database Offers New Tools to Study Aquatic Systems

Crater Lake in Oregon is famous for its clear blue waters. Researchers use water clarity data to explore the resources offered by the Water Quality Portal. Credit: Sobolevnrm

Understanding the state of Earth's aquatic systems is crucial to sustaining agriculture, protecting water resources, mitigating hazards, and even safeguarding national security. But the data on the globe's aquatic systems are collected by researchers from hundreds of different organizations and research groups, and data modeling, observational methods, formats, and data access can be inconsistent among these groups. Furthermore, not all of these data are available on the Web. These discrepancies confound the efforts of scientists to research freshwater systems.

To address this challenge, the U.S. Environmental Protection Agency (EPA), the U.S. Geological Survey (USGS), and the National Water Quality Monitoring Council have collaborated to produce the Water Quality Portal (WQP), a single Web interface that aggregates more than 297 million water quality records from more than 2.7 million distinct sites and offers data services as well. In a new study, *Read et al.* describe the framework of the WQP and conduct a case study of water clarity across the United States to demonstrate some of the project's capabilities.

The goal of the WQP is to offer researchers a common data standard, Web services, and a Web interface for freshwater quality data. It was first launched in 2012, with records from more than 450 organizations and three primary data sources: the USGS National Water Information System (NWIS), the U.S. Department of Agriculture's Sustaining the Earth's Watersheds–Agricultural Research Data System (STEWARDS), and the EPA Storage and Retrieval (STORET) system. The data can be queried by type of collection site, time, and geography, as well as by water quality variables from temperature and water level to complex physical, chemical, or biological characteristics. The data model the project uses as a standard is the Water Quality Exchange model, developed by the Environmental Information Exchange Network.

To test the capabilities of the WQP, the authors looked at regional water clarity in lakes, reservoirs, and impoundments (reservoirs formed by dams) across the United States. Specifically, they used WQP to analyze data records of Secchi depth measurements, which are calculated using an opaque disk (a Secchi disk) lowered into waters to gauge the depths at which the disk ceases to be visible from the surface. They were able to identify large-scale regional and seasonal changes in water clarity: Lakes in the southern United States had the lowest clarity, those in the Northeast had the highest, and those in the Midwest displayed the greatest seasonal variability.

According to the authors, large-scale water quality research using a water clarity metric like their case study could offer significant economic and ecological benefits, just one example of the kind of research possible using WQP resources. An exceptional volume and variety of water quality data are now available to the public, and community use and engagement will only help to improve the data model, quantity, and tools available. Such community use will strengthen scientific understanding of Earth's aquatic systems. (*Water Resources Research*, https://doi.org/10.1002/2016WR019993, 2017) **—Lily Strelich, Freelance Writer**

What Led to the Largest Volcanic Eruption in Human History?

In the northern part of the Indonesian island of Sumatra lies the Toba caldera, a massive crater formed by what scientists think is the largest volcanic eruption ever experienced by humanity. The eruption, called the Youngest Toba Tuff supereruption, took place about 74,000 years ago.

By dating zircon, a diamondlike gemstone, and other minerals in the area such as quartz, *Reid and Vazquez* have pieced together clues about the activity of magma below the surface prior to the supereruption.

Zircon is the oldest dated mineral on Earth. With a hardness rating of 7.5, it is resistant to chemical and mechanical weathering and can withstand metamorphism (structural changes due to heat, pressure, and other natural processes). All of these factors make it an ideal mineral for geological dating, especially for magma. Because zircon does not gain or lose uranium or lead even at magmatic temperatures, it typically contains high uranium and low lead levels, and scientists can use the ratio of these two elements in the zircon to determine the age of the sample.

A lake (black) fills Toba caldera in Sumatra, Indonesia, as seen in this false-color image from NASA's Landsat satellite. A supereruption 74,000 years ago is thought to be the largest eruption ever experienced by humans. Credit: NASA

The way in which zircon crystals in the Youngest Toba Tuff magma appear to have nucleated and grown over time, the researchers found, provides evidence of intermittent changes in the composition of the underground body of magma that eventually erupted. Certain characteristics of the zircon also indicate repeated episodes of magma recharge—fresh influxes of magma that often trigger eruptions—occurring tens of thousands to hundreds of thousands of years before the supereruption.

The team's findings are significant for modern humans, given that aerosols and ash that erupted from Youngest Toba Tuff are thought to have entered the atmosphere, causing global cooling and the near extinction of the human race. A supereruption of equal or greater magnitude today could therefore have similarly drastic consequences. By better understanding the conditions that led up to the supereruption, scientists can help paint a clearer picture of the future. (*Geochemistry, Geophysics, Geosystems*, https://doi.org/10.1002/2016GC006641, 2017)

—Sarah Witman, Freelance Writer

How Arctic Ice Affects Gas Exchange Between Air and Sea

Climate change is rapidly transforming the world's oceans, and researchers are scrambling to understand what that means for the physical and biogeochemical processes that govern ocean systems around the world. Scientists have measured dissolved carbon dioxide (CO_2) gas dynamics in many ocean regions to predict future CO_2 exchange between air and sea, which will influence ocean acidification and global warming. Nonetheless, such data are sorely lacking for remote polar regions, where sea ice hinders ship access.

To help fill the polar data gap, *Islam et al.* investigated gas exchange in the waters of the Arctic Ocean's vast Canada Basin. In August 2012, they deployed ice-tethered profilers in two regions, one with a dense cover of sea ice and another with only sparse ice. Each profiler included a bundle of sensor instruments suspended about 6 meters deep in the water and tethered to the ice floating above.

For almost 50 days, the sensors measured carbon dioxide and oxygen levels, temperature, salinity, and chlorophyll *a* fluorescence, which helps reveal biological production. The sites were 222 kilometers apart, on average, and as the sea ice drifted, the tethered sensors did too.

The team previously published their gas measurements in May 2016, reporting that carbon dioxide levels at both sites were below atmospheric saturation during the study period, whereas dissolved oxygen was slightly supersaturated. In the new study, the scientists compared the two sites to examine how ice cover influenced observed variability in oxygen and carbon dioxide levels. They used computational modeling to analyze sensor data in the context of concurrent oceanic and atmospheric conditions.

The results suggested that in the region with sparse ice cover, biological production, gas exchange with the atmosphere, and mixing between different layers of seawater all influenced oxygen and carbon dioxide variability. In the ice-dense region, mixing played a dominant role in gas variability, and biological production and gas exchange provided a negligible contribution.

Woods Hole and Purdue researchers auger an ice hole for deployment of equipment through the ice in 2014. Credit: C. Beatty, University of Montana

These findings could help improve understanding of gas exchange in the Arctic Ocean. Arctic sea ice is declining rapidly, and some researchers predict that fresh meltwater will inhibit nutrient transport and limit biological activity, allowing the surface ocean to come into equilibrium with atmospheric CO_2 and promoting acidification. The authors say that continued CO_2 monitoring in the Canada Basin is necessary to better understand current trends and future possibilities. (*Journal of Geophysical Research: Oceans*, https://doi.org/10.1002/2016JC012162, 2017) **—Sarah Stanley, Freelance Writer**

Global Drought Clustering Could Mean Big Losses for Mining

Mining and water have always been inextricably entangled. During the California Gold Rush of the 1850s, miners used millions of gallons of water to dislodge gold-bearing gravels with high-pressure jets. Modern mining operations still use copious amounts of water to extract and refine mineral resources, such as gold and copper.

This need for water often leads to conflicts with local communities. As global water supplies dwindle because of pollution, overallocation, and longer and more severe droughts caused by climate cycles and climate change, companies face significant financial risks from water shortages. These risks range from the mandate to build expensive desalination plants to augment supplies to partial or total shutdown of mines.

Barrick Gold Corporation's "Super Pit" gold mine in Kalgoorlie, Western Australia. Credit: Brian Voon Yee Yap, CC BY-SA 3.0 (http://bit.ly/ccbysa3-0)

Now *Bonnafous et al.* present a novel method for mining companies and their investors to take stock of financial risk from drought. First, the team obtained historical records of drought frequency and severity using the Palmer drought severity index, from 1950 to 2014. Combining those data with annual production values from mines of 15 companies, they calculated a risk index that reveals the likelihood of a severe drought occurring at each location each year and estimated how such an event would differentially affect mines' annual production values and the companies' overall portfolios.

For instance, Barrick Gold Corporation, the largest gold producer in the world, has mines all over the world, including Nevada, Peru, Argentina, Saudi Arabia, Australia, Zambia, and Papua New Guinea. Each year, there is a 5% chance that roughly 35% of the value extracted from those mines will be subjected to a major, once-every-10-years drought event, the researchers found. Making the assumption that every such drought event could dock the corporation's production by about 10%, Barrick would have a 5% chance of losing nearly $1 billion in production value every year. Following a similar thought process, another behemoth gold producer, Newmont Mining Corporation, runs a 5% risk of losing $0.63 billion per year because of drought.

However, for these globally distributed portfolios, the relative value (compared to the overall company's value) at risk is smaller than for companies whose mines are concentrated in zones likely to suffer droughts. Understanding this climate clustering could help companies better balance their portfolios, the study suggests.

Furthermore, the new approach isn't intended to help mining companies alone. The disclosure of companies' water risk management frameworks is required to enable government regulators—or investors whose portfolios include many enterprises subject to drought risk—to use similar approaches to better assess concentration risk from drought or floods, the team says. (*Water Resources Research*, https://doi.org/10.1002/2016WR019866, 2017) **—Emily Underwood, Freelance Writer**

Stream Network Geometry Correlates with Climate

Although dendritic river networks, whose branches join in treelike fashion to form increasingly larger streams, are found all over the world, the processes that shape them are still poorly understood. To explore whether climate influences the geometry of dendritic stream networks, *Seybold et al.* analyzed nearly 1 million digitally mapped river junctions in different climatic regimes across the contiguous United States.

An analysis of dendritic river drainages in the contiguous United States indicates that the junctions between tributaries are wider in humid regions and narrower in arid regions, such as at the Grand Canyon, pictured here in a three-dimensional Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) image taken by NASA's Terra spacecraft in 2011. Credit: NASA/GSFC/METI/ERSDAC/JAROS and U.S./Japan ASTER Science Team

Using the NHDPlus Version 2 database, which combines the best features of the National Hydrography Dataset (NHD), the National Elevation Dataset (NED), and the Watershed Boundary Dataset (WBD) and has a resolution of about 30 meters, the team calculated the angle between the average orientations of each stream and its tributary. They then averaged these junction angles across large hydrologic basins.

The results show that the branching angles vary systematically with climate, with a clear trend toward more acute angles (averaging 45°) in the most arid regions and wider angles (averaging about 72°) in more humid landscapes. This correlation, the researchers report, is found in all sizes of streams and is stronger than the relationship between branching angles and other factors, including topographic gradient and stream concavity, that have previously been proposed as major controls on stream network geometry.

The authors attribute this correlation between climate and branching angles to the relative importance of the underlying channelization processes. The wider average branching angles in humid regions, they argue, result from the greater importance of diffusive processes, such as groundwater flow, in the growth of stream networks. By contrast, the narrower branching angles in arid landscapes are shaped to a greater degree by surface and near-surface flows, which generally occur parallel to the downslope direction and thus create narrower junctions.

In addition to providing insight into modern geomorphic processes, these findings may offer a means of identifying channelization processes and reconstructing earlier climates in relict landscapes, such as those found on Titan and Mars. (*Geophysical Research Letters*, https://doi.org/10.1002/2016GL072089, 2017) **—Terri Cook, Freelance Writer**

Alteration Along the Alpine Fault Helps Build Seismic Strain

A researcher examines the principal zone of slip in an exposure of the Alpine Fault at Gaunt Creek, South Island, New Zealand. Credit: Hiroshi Sato

In New Zealand, the boundary between the Australian and Pacific plates is defined by the Alpine Fault, a major strike-slip feature considered to have a high probability of rupturing in a large earthquake (of moment magnitude greater than 8) within the next 50 years. To gain insight into the physical processes controlling a large fault near the end of its seismic cycle, an international team drilled two boreholes through the Alpine Fault's central segment as part of the Deep Fault Drilling Project.

As part of this investigation, *Boulton et al.* analyzed the rocks retrieved from both holes. Both successfully penetrated the fault, including its core, which hosts the principal zone of slip, where most earthquake displacement occurs. The boreholes also pass through the surrounding "damage zone," where the rocks are highly fractured from deformation associated with their journey along the fault. Here any given rock has undergone about 35 kilometers of vertical displacement and more than 200 kilometers of horizontal displacement over the past 5 million years.

The researchers identified eight characteristic rock units within the cores, the most distinctive of which is a gouge—a pulverized, claylike mixture formed along the principal zone of slip. The gouge contains abundant clay and white mica minerals, including smectite, the presence of which indicates that low-temperature alteration occurred within this unit. This alteration, the authors report, has resulted in the principal zone of slip having a fabric of slippery, sheeted minerals in which sliding preferentially occurs.

Unlike in a number of other faults, whose rocks display volume losses of up to 90%, the Alpine Fault material gained volume in and around its core zone as smectite, other clay minerals, and calcite gradually precipitated. Over time, these minerals sealed off fractures, decreasing the fault rock's porosity and permeability and increasing the fault's strength. Ultimately, the researchers argue, these changes allow the fault to build up strain and release this energy in a large earthquake.

The energy released during the rupture then refractures the surrounding rock, leading to increases in permeability, fluid migration, and mineral alteration that begin the cycle anew. In light of these results, the researchers argue, observations of fluid flow throughout the seismic cycle are needed to improve models of how rock-fluid interactions influence Alpine Fault seismicity. (*Geochemistry, Geophysics, Geosystems*, https://doi.org/10.1002/2016GC006588, 2017) **—Terri Cook, Freelance Writer**

ATMOSPHERIC SCIENCES

Assistant Professor (Probationary Tenure-Track)–Atmospheric Science, Department of Physics and Atmospheric Science, Dalhousie University

Dalhousie University invites applications from outstanding candidates for a faculty position in atmospheric science. This is a probationary tenure track position with the rank of assistant professor. Candidates will have a PhD in a related discipline, proven teaching ability or potential at the university level, and must demonstrate the ability or potential to establish a successful research program. The successful candidate will be expected to enhance and complement the existing activities of the atmospheric science group in both teaching and research.

The atmospheric science group (www.atm.dal.ca) and the broader department have an active research program with connections to many major national and international programs. Dalhousie is one of the top universities in Canada. For example, three of the last four recipients of the NSERC Herzberg Gold Medal, Canada's highest prize in science and engineering, have been Dalhousie faculty. Halifax offers an outstanding quality of life.

Applications should be submitted by September 4, 2017 and consist of a curriculum vitae, a research proposal (max 3 pages), a statement of teaching interests and experience, contact information for at least three referees, and a completed Self-Identification Questionnaire (available at: http://www.dal.ca/becounted/selfid). Please send application materials to:

Chair, Atmospheric Science Search
c/o Jennifer.Currie@Dal.Ca
Department of Physics and Atmospheric Science
Dalhousie University
6310 Coburg Street, Room 218
Halifax, Nova Scotia, B3H 4R2
Canada

Consideration of candidates will begin in September 2017 and continue until the position is filled. While it is intended for the position to commence on July 1, 2018, the start date can be negotiated at the time of offer.

Dalhousie University is committed to fostering a collegial culture grounded in diversity and inclusiveness. The University encourages applications from Aboriginal people, persons with a disability, racially visible persons, women, persons of minority sexual orientations and gender identities, and all candidates who would contribute to the diversity of our community. All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.

Postdoctoral research position on constraining desert dust–climate interactions, University of California, Los Angeles

UCLA's department of Atmospheric and Oceanic Sciences seeks a postdoctoral scholar for a project to constrain the global cycle of desert dust aerosols, and its interactions with radiation, clouds, and climate. Anticipated duties include analyzing climate model output, conducting climate model simulations, developing simple analytical theories, and supervising graduate and undergraduate students.

Desired qualifications include a Ph.D. in atmospheric science, physics, engineering, or a related field, strong quantitative and programming skills, knowledge of the global dust cycle and/or radiative transfer, experience running atmospheric models and analyzing their output, and strong scientific writing skills.

Applicants should send a CV with a cover letter, three references, and a one page summary of recent work and interests as a single PDF document to Prof. Jasper Kok (jfkok@ucla.edu). This appointment is for one year, renewable for up to three years pending satisfactory performance and continued funding. The start date is flexible, but would preferably be between July and October of 2017. Review of applications will continue until the position is filled.

For more information about Prof. Jasper Kok's research and the Earth, Wind & Particles group at UCLA, please visit http://jasperfkok.com.

The University of California is an Equal Opportunity/Affirmative Action Employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability, age or protected veteran status. For the complete University of California nondiscrimination and affirmative action policy please follow this link: <http://policy.ucop.edu/doc/4000376/NondiscrimAffirmAct>.

CRYOSPHERE SCIENCES

Assistant / Associate Professor of Physical Glaciology Climate Change Institute and School of Earth and Climate Sciences, University of Maine

Climate Change Institute and School of Earth and Climate Sciences

The University of Maine Climate Change Institute (CCI) and School of Earth and Climate Sciences (SECS) invite applicants for a full-time tenure-track Assistant/Associate Professor position in Physical Glaciology. The successful applicant will have a joint appointment salaried through the two units (55% CCI/45% SECS) with tenure home in SECS, and position responsibilities distributed as 60% research and 40% teaching. We seek an individual who integrates observations from field study and remote sensing of critical cryosphere phenomena into a physical framework that joins glacier dynamics to Earth's climate on short and long periods. The individual will be expected to develop and carry out glaciological field investigations with an emphasis on ice sheet dynamics, and to establish and maintain collaborations with UMaine, national, and international research programs. Potential research collaboration areas include those related but not restricted to: ice-ocean interactions and sea-level rise; understanding the tempo and causes of global climate change through geological observations; interpretation of ice core records with the larger Earth/climate system; ice sheets and mountain glaciers as indicators of past and future climate change; ice rheology; and coupled ice mechanics and geochemical evolution of glaciers. We do not expect one individual to lead research in all of these subdisciplines, but rather to have the expertise, flexibility, and creativity to communicate with UMaine researchers across the spatial and temporal boundaries that separate these subdisciplines. For more information, visit http://climatechange.umaine.edu and https://umaine.edu/earthclimate/.

A PhD in glaciology or closely related field is required. A documented ability to conduct high-quality scientific research, as evidenced by publications in peer-reviewed journals, is essential. Other measures of potential for success, such as postdoctoral experience, prior success in obtaining funding, student teaching and research mentoring, interdisciplinary research experience, collaboration capacity, polar field experience, international reputation and engagement, and excellent written and oral communication skills, are desirable.

Materials must be submitted at https://umaine.hiretouch.com/job-details?jobID=40766&job=assistant-associate-professor-of-physical-glaciology. Applicants will need to create a profile and application; upload a cover letter, a CV which fully describes their experience with specific reference to the required and desirable qualifications, statement of teaching philosophy and interests, statement of research vision, and contact information for three professional references. Review of applications will begin July 17, 2017 and will continue until the position is filled. Anticipated start date is January 2018. For questions about the position, please contact um.glaciologysearch@maine.edu.

The University of Maine is an EEO/AA Employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, sexual orientation, age, disability, protected veteran status, or any other characteristic protected by law.

EARTH AND SPACE SCIENCE INFORMATICS

Environmental Sensing, Data Analytics, and Computational Ecology Opportunities, US Army Engineer

Research and Development Center (ERDC)

The Environmental Systems Branch in the Environmental Laboratory (EL) of the US Army Engineer Research and Development Center (ERDC) are leaders in the areas of environmental characterization and change detection, application of geospatial and sensor technologies, and field collection and modeling of environmental data. This branch is composed of motivated and innovative people working in physical geography, biology, ecology, civil and electrical engineering, computer science, and physics who are involved in a wide range of civil and military research projects. We are currently expanding our capabilities in the areas of environmental sensor and instrumentation technologies, data analytics, and computational ecology. These research areas require significant expertise in computing, electrical engineering, mathematics, as well as spatial modeling and network science.

The ERDC is a world class research organization composed of seven laboratories and over 2,000 employees, which execute more than $1B per year in support of the US Army Corps of Engineers, Department of Defense, and a variety of other sponsors. The EL's 200+ scientists and engineers seek to "provide solutions to tomorrow's environmental challenges" through a broad array of basic and applied research. To obtain more information, please send a cover letter and curriculum vitae to: Mr. Mark Graves (mark.r.graves@usace.army.mil).

GEOCHEMISTRY

Hydrogeochemist – Geohydrology Section – Kansas Geological Survey – The University of Kansas, Lawrence. Full-time position to lead KGS hydrogeochemical investigations. Faculty-equivalent, sabbatical-eligible position at Assistant or entry-level Associate Scientist rank. Requires Ph.D. with emphasis on aqueous geochemistry related to groundwater resources, and scientific leadership potential. Background in hydrogeochemistry applied to regional-scale groundwater investigations is desired. The Geohydrology Section has 6 full-time professionals with additional support personnel. Emphasis on state-of-the-science field studies and complementary theoretical research. Complete announcement/application information at www.kgs.ku.edu/General/jobs.html. Review of applications will begin Sept. 30, 2017.

For further information contact Geoff Bohling (geoff@kgs.ku.edu) or Don Whittemore (donwhitt@kgs.ku.edu). For other questions contact Annette Delaney, KGS Human Resources, adelaney@ku.edu.

KU is an EO/AAE, http://policy.ku.edu/IOA/nondiscrimination.

GEODESY

Planetary Geophysicist/Geodesist, NASA, Goddard Space Flight Center

Position available at the National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland, Planetary Geophysicist/Geodesist.

The Solar System Exploration Division, Planetary Geology, Geophysics and Geochemistry Laboratory, is seeking a research scientist with expertise in analysis of planetary spacecraft radiometric tracking data and geophysical applications. We are especially interested in demonstrated capabilities using radio signals for precision orbit determination and planetary gravity field determination, specifically with expertise in measurement modeling and development of innovative inversion techniques. Experience in the use of altimetry data and complex radio data (e.g., VLBI) for orbit determination is desirable. Candidates must have demonstrated experience in spacecraft instrument modeling, data reduction and analysis, and applications to develop value-added products (e.g., crustal thickness, crustal density, internal structure, and localized gravity representations). Experience on recent lunar and/or planetary mission science teams (e.g., GRAIL, MESSENGER) and analysis of recent planetary spacecraft mission data for gravitational field determination are required. The incumbent is expected to participate in development of new flight mission concepts and proposals that improve knowledge of planetary topography and gravity fields.

A PhD in a relevant field of Physics, Geophysics, Geodetic Sciences or Planetary Sciences is desired. U.S. citizenship required. Salary will be commensurate with experience and qualifications. To view the full vacancy announcement, which contains further information, including how to apply, go to https://www.usajobs.gov/. For information about the research program and the Planetary Geology, Geophysics, and Geochemistry Lab, please contact Lori Glaze at 301-614-6466 or Lori.S.Glaze@nasa.gov.

NASA, GSFC is an Equal Opportunity Employer.

GLOBAL ENVIRONMENTAL CHANGE

Post-doctoral Fellowship at the University of Alberta in Integrated Assessment Modelling

Applications are invited for a two-year post-doctoral fellowship in the area of integrated assessment of global change, with a focus on energy systems, climate change, and the water-energy nexus. Based at the Department of Civil and Environmental Engineering at the University of Alberta in Edmonton, Canada, the successful candidate will also interact with researchers and modellers in Environment and

Climate Change Canada, Government of Canada, Ottawa, Canada, and at the Joint Global Change Research Institute (JGCRI), Pacific Northwest National Laboratory, Washington, DC, through short research stays. He/she will use and contribute to the development of JGCRI's Global Change Assessment Model (GCAM; see http://www.globalchange.umd.edu/gcam/).

Qualifications

• PhD in engineering, operations research, management science, computer science, economics, environmental science/policy or related field; preference will be given to candidates with expertise in modelling and model development, energy-economic modelling, integrated assessment modelling, systems thinking and analysis, and the water-energy nexus.

• Demonstrated scientific ability through publications in peer-reviewed journals, model developments, leadership, and successful grant applications.

• Computer programming skills in C++ and Python, R, and high performance technical computing.

• Demonstrated ability to organize and coordinate research projects involving multiple researchers.

• Excellent communication skills, ability to work in a group environment, and a demonstrated interest and ability in successful collaboration across disciplinary boundaries.

Anticipated Remuneration: Approximately $55,000 CAD/year

Anticipated Start Date: July 15, 2017

Please send your CV and a cover letter that describes your relevant qualifications and experience to,

Dr. Evan Davies, Associate Professor

Dept. of Civil and Environmental Engineering, University of Alberta

9211 – 116 St NW, Edmonton, AB, Canada, T6G 1H9

or email the above to evan.davies@ualberta.ca

Assistant Professor in Climate Change and Remote Sensing, University of Richmond

The Department of Geography and the Environment invites applications for a tenure-track position at the assistant professor level to begin August 2018. We seek a candidate with a strong commitment to high quality research and undergraduate education and primary expertise in climate change science with specialization in remote sensing. Applicants with an African focus are especially encouraged to apply; however, we welcome applications from any national and/or international areas of focus. Candidates must hold a Ph.D. in Geography or a related field, must be academically qualified to teach, and must meet all other position requirements at the time of selection. The position involves teaching courses in remote sensing and climate change and contributing to the department's core curriculum in physical geography. The department's spatial analysis laboratory includes a full suite of geographic information systems and remote sensing hardware and software. In joining the department, the applicant would contribute to an active, student-centered learning environment with ongoing collaborations throughout campus and the community. Excellent opportunities exist for interdisciplinary research and to work with faculty, staff, and students from diverse backgrounds. The position would be joint-appointed in the Environmental Studies Program.

Applicants should apply online at University of Richmond Online Employment website using the Faculty (Instructional/Research) link. Applicants will be asked to submit a cover letter, a statement of teaching interests and philosophy, evidence of teaching effectiveness (if available), a description of current and planned research programs, and a current curriculum vita. Applicants will also be asked to submit electronically the names of three references who will receive an automated email asking them to submit their reference letter. At least one of the three letters of recommendation should address teaching effectiveness or potential. Review of applications will begin on August 31, 2017 and will continue until the position is filled.

The University of Richmond is a private, highly selective, predominantly liberal arts institution. The University is committed to developing a diverse workforce and student body, and to modeling an inclusive campus community which values the expression of difference in ways that promote excellence in teaching, learning, personal development, and institutional success. Our academic community strongly encourages applications that are in keeping with this commitment. For more information on the Department of Geography and the Environment, see the department website. Please direct all inquiries about this position to Todd Lookingbill, Chair of the Search Committee, Department of Geography and the Environment, University of Richmond, VA 23173 (tlooking@richmond.edu).

INTERDISCIPLINARY

Assistant/Associate/Full Professors-Physical and biological Oceanography, marine geophysics/geology, The Southern University of Science and Technology

The department of oceanography at the Southern University of Science and Technology of China (SUSTech) invites applications for tenure-track (or tenured) faculty positions at the ranks of Assistant, Associate, and Full Professors. Applicants must have earned doctoral degrees in marine geophysics/geology, physical oceanography, biological oceanography and ocean engineering or closely related fields. Successful applicants will be expected to establish a robust, externally funded research program and demonstrate strong commitment to undergraduate and graduate teaching, student mentoring, and professional services. These positions will remain open until filled.

SUSTech is a young university at Shenzhen, China (next to Hong Kong) since 2010 which is set to become a world-leading research university, to lead the higher education reform in China, to serve the needs of innovation-oriented national development and the needs of building Shenzhen into a modern, international and innovative metropolitan. These positions are created with a significant development to establish a vigorous research program in oceanography at SUSTech to serve the national call for China's important role in deep sea research and resource-oriented exploration in the world oceans.

To apply send a cover letter, complete vitae with list of publications, and three names of references to hiring@sustc.edu.cn, or to Dr. Y. John Chen, Chair Professor at Department of Oceanography, Southern University of Science and Technology, No 1088, Xueyuan Rd., Xili, Nanshan District, Shenzhen, Guangdong, China 518055.

Cluster Hiring in Geo-Bioinformatics/Environmental Genomics and Organic Biogeochemistry, The Southern University of Science and Technology

The Southern University of Science and Technology (known as SUSTech or SUSTC) (http://www.sustc.edu.cn/en) was founded in 2011 with public funding from Shenzhen, a dynamic city that has been viewed as the vanguard of China's development in science and technology. The goal of SUSTech is to become a top-tier international university that excels in interdisciplinary research, talent development and knowledge discovery.

Siting at the mouth of the Pearl River flowing to the South China Sea, the newly born (2015) Department of Ocean Science and Engineering at SUSTech aims to become a major player in education and research in ocean sciences in China. It will be housed in a brand new building on the beautiful SUSTech campus, with ample laboratory space that is equipped with the latest technology for conducting cutting edge research. The 5000 ton R/V Shenzhen is in the planning stage of construction, which is expected to be built by 2022.

The Institute for Geo-Omics Research (TIGOR) at SUSTech aims to become an open platform for world class research in microbial oceanography and geomicrobiology, and an inviting home for domestic and overseas scientists to exchange ideas and together advance the field of ocean sciences. In the early stage of TIGOR's growth, the priority will be to build two research strengths: Geo-Bioinformatics/Environmental Genomics and Organic Biogeochemistry. The integration of

Fellowships for Postdoctoral Scholars at

Woods Hole Oceanographic Institution

Scholarships are available to new or recent doctoral graduates in diverse areas of research. Applications will be accepted from doctoral recipients with research interests associated with the following:

Departments - Applicants who wish to conduct research on topics of general interest to one or more of the departments are encouraged to apply. Interdepartmental research is also encouraged. The Departments are:

- **Applied Ocean Physics & Engineering**
- **Biology**
- **Geology & Geophysics**
- **Marine Chemistry & Geochemistry**
- **Physical Oceanography**

A joint USGS/WHOI award will be given to a postdoc whose research is in an area of common interest between USGS and WHOI Scientific Staff. The individual will interact with both USGS and WHOI based advisors on their research.

Recipients of awards are selected competitively, with primary emphasis placed on research promise. Scholarships are awarded for 18-month appointments with a stipend of $58,500 per year, a modest research budget and eligibility for group health and dental insurance. Recipients are encouraged to pursue their own research interest in association with resident Scientific and Senior Technical Staff. Communication with potential WHOI advisors prior to submitting an application is encouraged. **Completed applications must be received by September 20, 2017** for the 2018/2019 appointments. Awards will be announced by December. Recipients of awards can initiate their study and research period at the Institution any time after January 1, 2018 and before December 1, 2018.

Further information about the Scholarships and application forms as well as links to the individual Departments and Institutes and their research themes may be obtained through the Academic Programs section of the WHOI web pages at:

www.whoi.edu/postdoctoral

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these strengths will allow us to study systematically the evolution of life on early Earth, microbial ecology impacted by human activity, mechanisms of bio-organic interactions in the deep ocean, and fundamentals of biogeochemistry (e.g. lipid biosynthesis and bio-fractionation of isotopes of life-essential elements).

In Geo-Bioinformatics/Environmental Genomics hiring, we seek highly qualified candidates (at the assistant or associate professor levels) who are able to apply bioinformatics techniques (metagenomics, multi-omic integrative analysis, in silico lead discovery from microbial metabolites and computational biology algorithm/server development) to analyze data from the next-generation sequencing and other high-throughput sequence profiling to address fundamental questions mentioned above. Candidates with strong ecological backgrounds are particularly encouraged to apply.

In Organic Biogeochemistry hiring, we seek highly qualified candidates (at the assistant, associate or full professor levels) with strong skills in mass spectrometry and isotope geochemistry. The candidates are expected to apply GC-MS, LC-MS (Orbitrap or ion mobility Q-TOF), FT-ICR MS, or AMS to address questions mentioned above.

Highly competitive salaries and benefit packages will be provided to the hired candidates, who may also be eligible for additional government support such as the Shenzhen City's Peacock Program and the Chinese Government's One Thousand Talents Program (http://www.sustc.edu.cn/en/faculty_en).

Applicants are required to have a Ph.D. degree in earth sciences, biology, chemistry, computer science, or related disciplines. Post-doctoral experiences are preferred but not required. Candidates must have a proven and consistent track record of high-quality scientific publications and good communication skills. Chinese and English are required languages for teaching. To apply, please submit the following material electronically to wangy9@sustc.edu.cn: 1) Cover letter; 2) Curriculum vitae (with a complete list of publications); 3) Statement of research and teaching interests; 4) Reprints of three recent papers; and 5) Names and contact information for three references. All positions remain open until filled.

Faculty Positions available in the School of Environmental Science and Engineering, The Southern University of Science and Technology

The Southern University of Science and Technology (known as SUSTech or SUSTC) (http://www.sustc.edu.cn/en) was founded in 2011 with public funding from Shenzhen City. A thriving metropolis of 20 million people bordering Hong Kong, Shenzhen has often been referred to as the "Silicon Valley of China," with strong telecommunication, biotechnology and pharmaceutical sectors. The goal of SUSTech is to become a top-tier international university that excels in interdisciplinary research, talent development and knowledge discovery. English is the language of instruction.

The School of Environmental Science and Engineering at SUSTech was established in May 2015 to provide a new platform for performing cutting-edge research and for training a new generation of environmental scientists, engineers and managers who are interdisciplinary, innovative and global-thinking. Currently the school has 18 full time faculty members (http://ese.sustc.edu.cn/en/) with 30 or more tenure-track/tenured positions to be filled. In addition to a generous startup package to each tenured or tenure track faculty position, the school was recently awarded a 3-year grant of 50 million RMB (~7 million USD) to strengthen its 5 core areas of research. Moreover, the school is in line to receive 120 million RMB (~18 million USD) for research instrument capability development.

Applications are invited for faculty positions at all ranks. Areas of interest include, but are not limited to, water pollution and treatment, environmental (soil, groundwater, ecosystem) remediation and restoration, hydrology and water resources engineering, biogeochemistry, environmental microbiology, atmospheric chemistry, air pollution control, air quality engineering, solid waste treatment and utilization, environmental health risk assessment, environmental health interventions, remote sensing of the environment, global change, and environmental management. Highly competitive salaries and benefit packages will be provided to tenure-track/tenured faculty. New hires may be eligible for additional government support such as the Shenzhen City's Peacock Program and the Chinese Government's One Thousand Talents Program (http://www.sustc.edu.cn/en/faculty_en).

Applicants are required to have a Ph.D. degree in environmental science and engineering, earth and atmospheric sciences, or related disciplines. Post-doctoral experiences are preferred but not required. Candidates must have a proven and consistent track record of high-quality scientific publications and good communication skills. Chinese language skill is a plus but not required. To apply, submit the following materials electronically to iese@sustc.edu.cn: 1) Cover Letter; 2) Curriculum Vitae (with a complete list of publications); 3) Statement of research and teaching interest; 4) Selected reprints of three recent papers; and 5) Names and contact information for five references. All positions remain open until filled. For additional information, contact Xiaoli Wang, Email: wangxl@sustc.edu.cn, phone: +86-755-8801-0821.

Petroleum Geoscientist (2 positions) – Kansas Geological Survey, The University of Kansas, Lawrence. Full-time, faculty-equivalent, sabbatical-eligible positions at Assistant or entry-level Associate Scientist rank. Requires Ph.D. in geoscience or related field with experience in petroleum related research. Positions are expected to conduct, publish, and present the results of fundamental and applied research in petroleum geology and related areas that is of national stature and relevant to Kansas. The Energy Research at KGS has six full-time professionals with additional graduate student support. Complete announcements/application information at www.kgs.ku.edu/General/jobs.html Review of applications will begin Sept. 1, 2017.

For further information contact Eugene Holubnyak (eugene@kgs.ku.edu) or Tandis Bidgoli (tbidgoli@ku.edu). For other questions contact Annette Delaney, KGS Human Resources, adelaney@ku.edu.

KU is an EO/AAE, http://policy.ku.edu/IOA/nondiscrimination.

JOB TITLE: Sr. Geophysical Consultant (345456)

COMPANY: Aramco Services Company

LINK TO APPLY: http://aramcoservices.applytojob.com/apply/mhngZN/Sr-Geophysical-Consultant-345456?source=GSA

Basic Function

Serve as a senior technical consultant to Aramco Services Company (ASC) and to the Saudi Aramco Overseas (SAO) Exploration Organization in the geophysical field. Handle assignments that require the highest level of Professional expertise. Candidate capable of originating new concepts and approaches to problems and critically evaluating any aspect of the geophysical operation from data acquisition to final interpretation depending on their particular geophysical specialty.

Duties & Responsibilities

- Conduct research and geophysical technology development for industry scale applications
- Lead the development of advanced seismic depth image using frontier techniques such as RTM and FWI; this includes all stages of development from conceptual level to a complete industrial solutions
- Evaluate geophysical data in an area and either presents results that represent an satisfactory conclusions or recommends procedures to be inaugurated that would have a high probability of improving results

Education and Experience

- Bachelor's degree required in Geophysics or related field (e.g. Geology, Physics, Mathematics, Electrical Engineering). Graduate study or extensive formal training in specialty field is desirable
- Twenty (20) years of professional experience, at least five (5) years of which should be as a specialist in their discipline working in a research environment
- Must have a thorough knowledge of geophysical practices including scientific and economic principles, calculation methods, design details, and codes, standards and specifications
- Ability to design, implement and evaluate seismic processing algorithms on a high end workstation preferred

NO THIRD PARTY CANDIDATES ACCEPTED

OCEAN SCIENCES

Applied Physics Laboratory – Research Associate, University of Washington

The Applied Physics Laboratory at the University of Washington (APL-UW) is seeking Post-doctoral Research Associates with research interests in Oceanography, Polar Science, Remote Sensing, Environmental Acoustics and Ocean Engineering. This is a full-time appointment, with expected terms of two years subject to satisfactory performance and availability of funding.

Positions are not project-specific; a specific applicant is expected to define his/her research goals within the broad program areas of the participating APL departments: Air-Sea Interaction & Remote Sensing (AIRS), Acoustics Department (AD), Ocean Engineering (OE), Ocean Physics Department (OPD), Polar Science Center (PSC). Successful applicants must hold a recent (no more than 4-years) PhD or foreign equivalent in order to assume a post-doctoral position.

More information can be found http://ap.washington.edu/ahr/academic-jobs/position/nn23792/

Applicants are asked to submit electronically:

(1) A curriculum vitae,

(2) A publication list,

(3) A brief research proposal (no more than 5 pages, double-spaced, excluding bibliography and figures) describing research to be pursued during a two-year tenure at the University of Washington, and

(4) The names of four individuals who can provide a letter of reference.

In addition, a letter of support from a mentor in one of the participating departments (AIRS, AD, OE, OPD, PSC) is strongly encouraged. Further information on current research at APL, by department and principal investigator, can be found at: http://www.apl.washington.edu/departments/departments.php

Applications should be submitted via email:

Dr. Kevin Williams

Sr. Principal Physicist, Acoustics Department Chair, Liaison of Science and Engineering Group

williams@apl.washington.edu

VOLCANOLOGY GEOCHEMISTRY AND PETROLOGY

Faculty Position in Geological Sciences, Yonsei University

The Department of Earth System Sciences at Yonsei University, Korea, invites applications for a tenure-track faculty position in sedimentology, petrology-geochemistry, resource geology, and other related fields. All (assistant, associate and full) professor levels are considered. The Department of Earth System Sciences supports undergraduate, M.S. and Ph.D. programs in Geological and Environmental Sciences. Yonsei University is one of the premier universities in Korea, located in Seoul. The University may offer reasonable moving expenditure and initial housing for foreign nationals.

Qualifications Required: A successful candidate is expected to build his/her original independent research programs and to seek interdisciplinary collaborations with the Department faculty members and/or other researchers worldwide. The applicant should also have strong passion for teaching and advising students and must have a Ph.D. degree in geological sciences and related fields with postdoctoral research experience.

Application Procedure: Candidates should submit a CV with a list of publications, a statement of research and teaching plans, and the names and contact addresses for two references. Applications that arrive by 7/7/2017, will receive full consideration. Applications should be submitted to Yonsei University following the guideline outlined at the homepage (http://www.yonsei.ac.kr/en_sc/). Other inquiries can be E-mailed to: Tae-Kyung Hong, Chair, Department of Earth System Sciences, Yonsei University, Seoul 120-749, Korea, tkhong@yonsei.ac.kr.

Postcards from the Field

Dear AGU:

Hello from southern Utah! Here Paul and I are setting up a seismometer on the massive Owachomo Bridge in Natural Bridges National Monument (with National Park Service permission). We measured the ambient vibration of this and about 10 other arches in southern Utah to determine their resonant frequencies, and tracked these frequencies over time as a means of probing for changes in structural health. Here we're doing a routine checkup—about 1 hour of ambient motion is all we need to see whether there has been any change since our last measurement. Jacob Kirkegaard is behind the camera.

Wish you were here!

—Jeff Moore and **Paul Geimer,** University of Utah, Salt Lake City

http://geohazards.earth.utah.edu/arch.html
@UtahGeohaz

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

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