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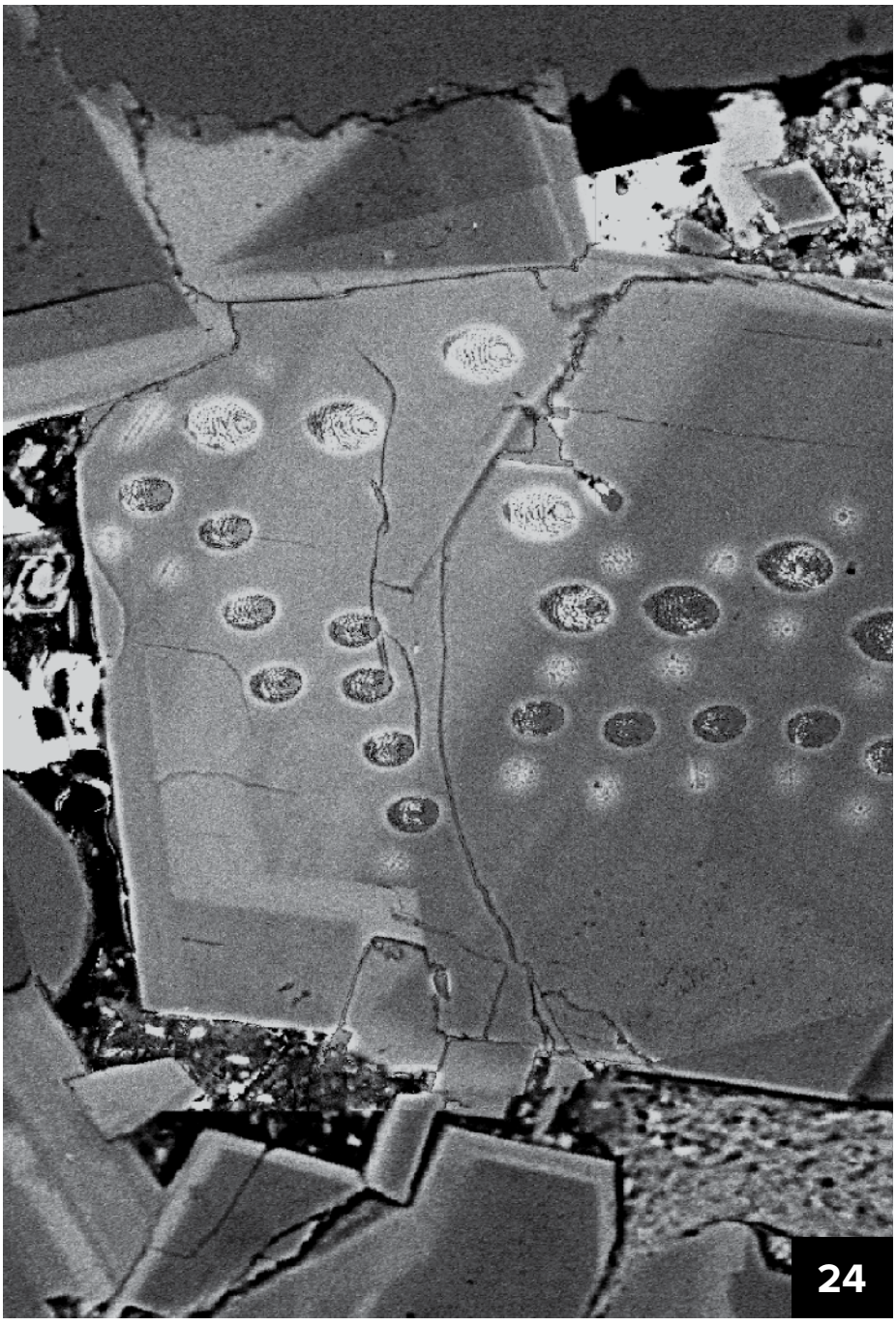

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Anonymous review of scientific manuscripts was intended to encourage reviewers to speak freely, but other models may be better for accountability and inclusivity.

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Eos

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Christine W. McEntee, Executive Director/CEO

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Tiny Algae May Have Prompted a Mass Extinction

More than three quarters of all marine life died off about half a billion years ago. At least that's what the rocks say.

Below a certain depth in the stratigraphic record, trilobites, corals, and brachiopods are found in abundance. Above it, many types of these organisms are missing. What could have caused 85% of marine species—at a time when life largely existed only in the oceans—to perish?

New research offers an unlikely linchpin in this vast die-off: tiny algae. Around the time of this extinction event, algae populations were rising ocean-wide. When these abundant organisms lived, they soaked up atmospheric carbon and stored it in their tissues. But when they died, they may have sunk quickly through the water column, scientists have proposed, rapidly sequestering carbon in the depths of the ocean as more and more such organisms lived and died.

The planet then cooled as a result of having less carbon dioxide in the atmosphere, plausibly triggering the widespread glaciation that's believed to have prompted one of Earth's largest mass extinction events, the new work suggests. The research was published 11 June in *Nature Geoscience* (http://bit.ly/Nature-Geosci-Shen).

The new study "reveals how algal evolution could have been vital in regulating the Earth's carbon cycle," said Richard Pancost, a biogeochemist at the University of Bristol in the United Kingdom not involved in the research. "It is a fascinating hypothesis based on some exciting new data."

Ocean Sediments in Nevada

The key to this hypothesis lies in ancient ocean sediments unearthed in Nevada dating to the very end of the Ordovician period, roughly 444 million years ago. Jiaheng Shen, lead author of the paper and a geochemist at Harvard University, and her colleagues collected samples of these sediments—mostly shale and limestone—and found that they contained compounds derived from chlorophyll.

Analysis showed that the ratios of isotopes of nitrogen in these compounds matched those found in modern-day algae. Thus, the researchers proposed that the presence of these compounds means that they were created by ancient algae, which died and sank to the seafloor to create the sediments.

As the researchers analyzed samples from younger rocks, they found a trend: The sediments appeared to contain more and more material from algae. Over a period of just a few million years, the amount of the telltale compounds increased by approximately fivefold, the team estimated. The measurements implied that algae must have flourished during the Late Ordovician at the expense of other phytoplankton like cyanobacteria.

Illustration of sea life that flourished after the Ordovician period ended with a mass extinction event about 444 million years ago. New research suggests that algae may have precipitated the events that led to this mass extinction. Credit: Science History Images/Alamy Stock Photo

Size Matters

Did this shift in population, perhaps in response to an increase in nutrients released by weathering or volcanism, result in carbon being sequestered deep in the ocean? The answer, the authors posit, rests on a key factor: the relative sizes of algae and cyanobacteria. Most types of modern algae are several times larger than cyanobacteria.

If the algae that rose to prominence were at least twice as large as their cyanobacterial counterparts, the population shift could have triggered rapid cooling, explained Ann Pearson, an environmental scientist at Harvard University and one of the study's coauthors. That's because according to particle settling rates described by Stokes's law, more massive algae sink more rapidly through water than smaller, lighter cyanobacteria. Because of those different sinking rates, carbon would have been pulled into the deep ocean nearly 4 times faster than it was when cyanobacteria dominated the oceans, the researchers estimated.

The team wasn't able to precisely calculate how much larger the ancient algae were compared with cyanobacteria, however. "We cannot say directly what the sizes were, only how much relative change would have been sufficient to make a difference," Pearson told *Eos*.

Rapid Cooling

The hypothesized rapid carbon sequestration would have, in turn, rapidly pulled carbon from the ocean-atmosphere system and trapped it on the seafloor. If the hypothesis is correct, this rapid sequestration would have had important repercussions for Earth's carbon cycle and therefore the planet's temperature.

The team used a model of nutrient cycling in the ocean and atmosphere to calculate that atmospheric carbon dioxide levels would have been cut in half. This decrease, in turn, would have caused rapid cooling of several degrees Celsius over just a few million years, which may have prompted the Late Ordovician glaciation.

Algae may therefore have been the time period's "indirect killers," the authors wrote in their paper. That's a powerful statement, explained coauthor Greg Henkes, a geochemist at Stony Brook University in Stony Brook, N.Y., and a coauthor of the paper. "Seemingly benign effects, such as primary producer size and organic carbon burial, can magnify [over] geologic intervals of time," he said.

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

What Can NASA Do to Better Protect the Planets It Probes?

NASA's policies to protect solar system objects against earthly contaminants need significant updates, according to a new report. The report, released in early July, was compiled by a committee of the Space Studies Board (SSB) of the National Academies of Sciences, Engineering, and Medicine.

In the report, the committee emphasizes that many current policies concerning robotic and human exploration are governed by outdated protocols, some of which were issued during the Apollo era 50 years ago [*National Academies of Sciences, Engineering, and Medicine,* 2018]. Since then, however, we've discovered that the most tenacious microbes can survive extended time in the vacuum of space, that water is pervasive throughout much of the solar system, and that more places than we knew may be capable of supporting life.

The risks of perpetuating those outdated policies are great, the report explains. If scientists don't thoroughly sterilize spacefaring technology before launch, they could get false positives in the search for life beyond Earth. Such contamination could also permanently alter off-planet environments should those Earth microbes grow and flourish elsewhere. We've even started contemplating returning samples from Mars and other bodies back to Earth—are we protected from any microorganisms that may hitchhike back? The possibility of back contamination, which refers to extraterrestrial microbes reaching Earth, adds another layer of complexity to the problem.

Advances in scientific understanding of the solar system combined with new sample return initiatives and shrinking budgets have created new challenges for planetary protection, noted Joseph Alexander, chair of the committee that wrote the report. Hence, the report's purpose: to help NASA maintain its decades-long success in developing planetary protection policies.

"Soundly framed and executed planetary protection policies will play a critical role in ensuring that space exploration efforts will deliver unambiguous answers about the possibility of life elsewhere in the solar system," Alexander said.

"NASA welcomes the release of the Space Studies Board report," NASA's Office of Planetary Protection (OPP) told *Eos*, adding that the report's recommendations "are consistent with the collaborative decision-making process to be used for missions scheduled to Mars and Europa."

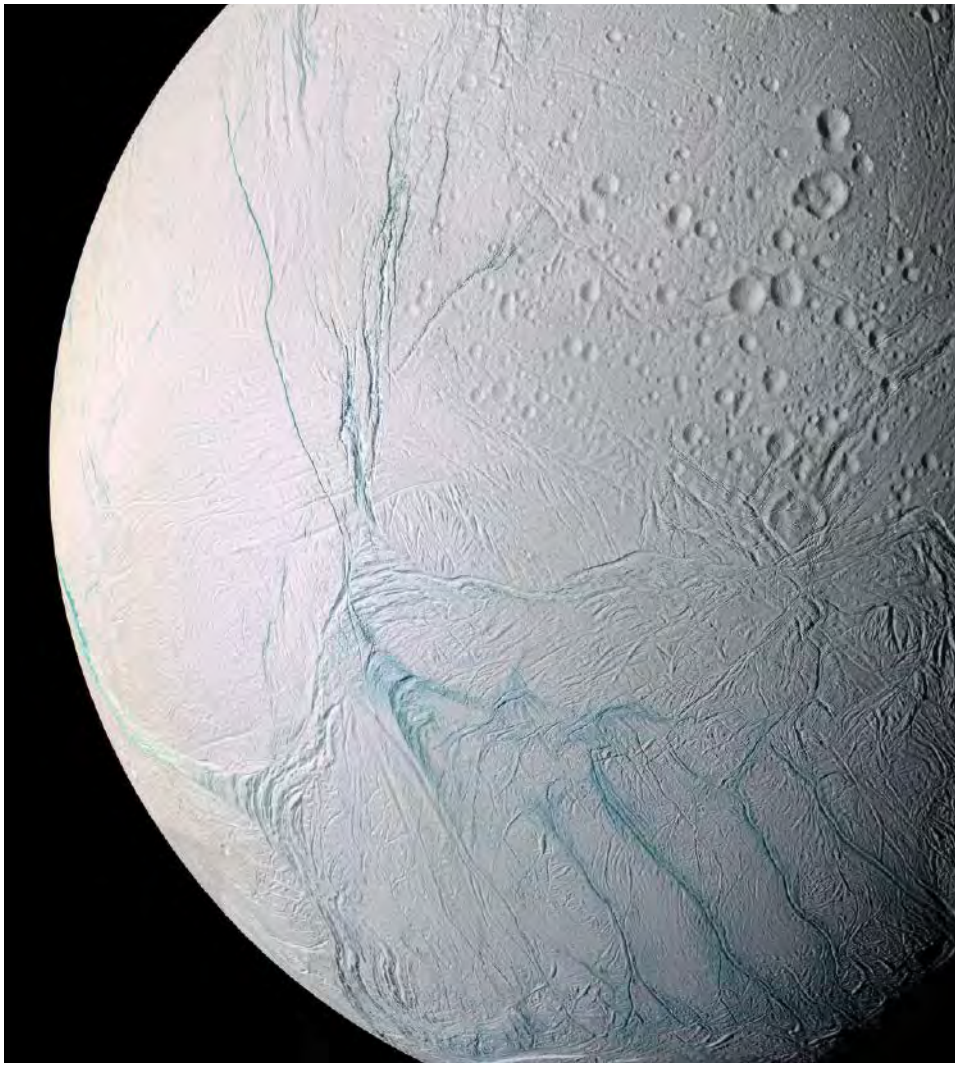
Here are four key recommendations from the report.

1. Keep with International Policy

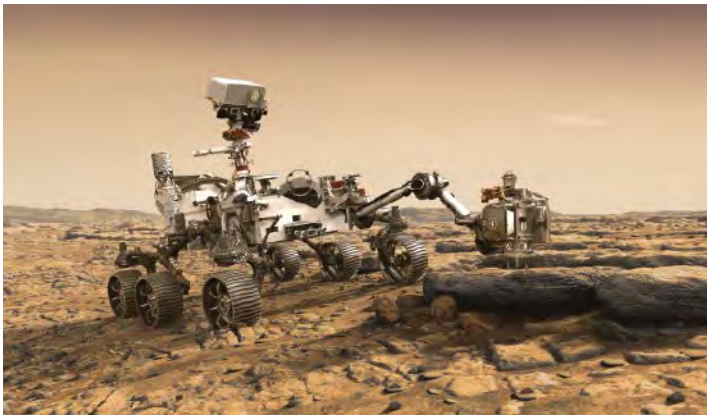
Planetary protection has been international policy since the 1967 ratification of the United Nations' Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, colloquially dubbed the Outer Space Treaty (http://bit.ly/UNOOSAtreaty). Among its provisions is the agreement that signatory nations, which include the United States, must ensure that they avoid harmful contamination of any celestial bodies.

The SSB committee advises that NASA needs to keep up to date with changes to international planetary protection policies made by the Committee on Space Research (COSPAR). COSPAR has maintained the de facto, international consensus planetary protection policy since its establishment in 1958. COSPAR's Panel on Planetary Protection issued its most recent policy update in December 2017 (http://bit.ly/COSPARppp).

In addition, the committee calls out NASA's current process for developing new policies and updating its old ones as ill defined, unregulated, and too slow to keep up with current consensus. "The current planetary



An enhanced color image of Saturn's moon Enceladus taken by NASA's Cassini spacecraft. The blue streaks mark areas where the surface ice has cracked and the subglacial ocean has upwelled. Credit: NASA/JPL/Space Science Institute



Artist's conception of the Mars 2020 rover examining a rocky outcropping. Credit: NASA/JPL-Caltech

protection policy development process is inadequate to respond to progressively more complex solar system exploration missions," the report says. Increasingly ambitious mission goals, like returning samples from Mars or exploring regions with the potential for life, have begun to outpace the development of policies to regulate how to safely meet them.

To avoid setting mission objectives that it later finds violate policy, NASA should consider "securing relevant outside expert advice" and "developing a long-range forecast of future solar system exploration missions having planetary protection implications," the report notes.

2. Update Apollo-Era Sample Return Protocols

The report highlights an instance in which the lack of clear policy and oversight led to conflict. In 2015, scientists used the Mars Reconnaissance Orbiter to discover a region near the Curiosity rover on Mars where water was thought to intermittently flow. Curiosity couldn't traverse the distance, but even if it could have, it would not have been allowed to investigate further because it had not been decontaminated to the proper extent before launch.

NASA's current plan to carry Curiosity's now obsolete protocols forward may hinder the Mars 2020 sample return mission, which led to a "3-year long…and often contentious discussion" between the Mars 2020 project team and NASA OPP, the report says. The discussion focused on whether the project's planetary protection plans were now sufficient, whether the team accounted for all possible contamination sources, and whether the team was accurately modeling the spread of contaminants.

The bottom line is, "The current U.S. government process to oversee samples returned from Mars and elsewhere dates back to the Apollo era and is out of date," according to the report. Furthermore, some of the Mars sterilization procedures were developed for Viking in the 1970s and are not compatible with Mars 2020's more delicate technology.

Early collaboration between project teams, mission developers, science teams, and microbiologists is key when creating protection policies for sample return missions, the committee says. The report also points out that NASA has not yet defined policies protecting Mars from microorganisms, foreign organic carbon, and human biological matter like waste during its proposed human exploration missions. Those protection plans must be in place before mission development proceeds, the committee states.

3. Consider the Added Risks to Ocean Worlds

Landers and orbiters around ocean worlds like Europa, Enceladus, and Titan present further contamination risks due to the known presence of water or other liquids on their surfaces. "It's not just the landers that have planetary protection requirements," NASA's current planetary protection officer (PPO), Lisa Pratt, told *Scientific American* (http://bit.ly/SciAmPratt), "it is the flybys and the orbiters because of the possibility that they could come down on the surface."

One issue highlighted in the report concerns the Europa Clipper mission, in which a spacecraft will target the Jovian moon. During development, a former PPO had imposed on the project team illogical or scientifically inaccurate parameters for use in a contamination algorithm without giving the science team an avenue for rebuttal.

The incident highlighted for the SSB committee that the most accurate science was not always used to assess contamination risks, a problem that could have affected Europa Clipper, the proposed Titan explorer Dragonfly, and a proposed spacecraft to fly through Enceladus's plumes.

To prevent these problems in the future, the report recommends early definition of protection requirements for a project, following standard procedures for conflict resolution, and reevaluating legacy protocols to ensure their accuracy for current missions. This course of action will keep mission costs low and streamline project development, it notes.

4. Account for and Include the Private Sector

Some U.S.-based private spaceflight companies have recently set their sights on exploration and tourism on the Moon and Mars, which compromises the United States' ability to comply with the Outer Space Treaty, the report finds.

As the report summarizes, the treaty requires signatories to "authorize and continually supervise non-governmental entities, including private sector enterprises, for any space activity that implicates the treaty, including its planetary protection provisions."

The report points out that no federal agency has jurisdiction to authorize or supervise in such a way, presenting a potentially dangerous regulatory gap. This regulatory gap became apparent when SpaceX launched its Falcon Heavy rocket in February, complete with an unsterilized Tesla Roadster on a Mars-crossing orbit. Beyond SpaceX, Pratt has also expressed concern about private development of CubeSats, which are often not hardy enough to withstand rigorous sterilization. Not closing this gap could quickly render all federal efforts at planetary protection moot, the report says.

To integrate the private spaceflight sector into the planetary protection policy, the committee recommends that the regulations apply equally to government and private sector space endeavors, particularly for future missions to Mars. It also recommends that private sector representatives be involved in developing these policies and that Congress authorize a federal agency, NASA or another body, to oversee private sector activities that could compromise planetary protection.

NASA OPP told *Eos* that it strongly agrees with "the call to work with multiple stakeholders to develop clear policies on the biological cleanliness of commercial and private spacecraft with destinations at Mars, Europa, and Enceladus."

The agency said that it will conduct a thorough review of the report's recommendation and give "a comprehensive response in due time."

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National Academies of Sciences, Engineering, and Medicine (2018), *Review and Assessment of Planetary Protection Policy Development Processes*, 170 pp., Natl. Acad. Press, Washington, D. C., https://doi.org/10.17226/25172.

By **Kimberly M. S. Cartier** (@AstroKimCartier), Staff Writer

New EPA Head Says His Priorities Include Regulatory Relief

Andrew Wheeler, the new acting administrator of the Environmental Protection Agency, spoke to staff and the press on 11 July. Credit: EPA

Andrew Wheeler, the newly appointed acting administrator of the U.S. Environmental Protection Agency (EPA), turned on a charm offensive while he tried to turn a new page at the agency following the resignation of scandal-plagued Scott Pruitt in July.

Wheeler's introductory speech on 11 July to an overflow audience of EPA staff and the press at EPA headquarters in Washington, D. C., outlined his priorities and promised more openness and dialogue at the agency. EPA spokesman John Konkus added in a statement that Wheeler "puts a premium on transparency" and that Wheeler will bring a change in approach and tone at the agency.

However, some critics charge that Wheeler, a former coal lobbyist, is reading from the same page as Pruitt in his desire to weaken environmental regulations in the name of regulatory reform. Those critics also note that Wheeler will more effectively achieve those goals because he may not be burdened by scandals.

In his speech, Wheeler claimed that the agency has "made tremendous progress" over the past year and a half under Pruitt by accelerating the remediation of Superfund pollution sites, financing critical investments to improve the nation's water infrastructure, enhancing air quality, and improving how chemicals are reviewed for safety, among other accomplishments.

> "I did work for a coal company, and I'm not at all ashamed of the work I did for the coal company."

"We will continue to press forward on all of these fronts," he added. "We're also restoring the rule of law, reining in federal regulatory overreach, and refocusing EPA on its core responsibilities. As a result, the economy is booming and economic optimism is surging."

Focus on Three Things

When President Donald Trump called on Wheeler to lead the agency, Trump said that Wheeler's focus should be on three key areas, the new EPA leader explained in his speech. "[Trump] said, 'Clean up the air, clean up the water, and provide regulatory relief.' I think we can do all three of those things at the same time."

Wheeler said that the agency needs to provide more regulatory "certainty" to businesses. With that need in mind, Wheeler said that he is setting a new goal for the agency to make a decision on all permitting requests, whether for or against, on a 6-month time frame.

He also called for quicker decisions on enforcement actions. "I'm not advocating for letting people off the hook or reducing fines," he said. "Rather, I'm advocating for making enforcement decisions in a timely and consistent manner. Accomplishing this will dramatically improve our relationship with American businesses and take away a lot of the criticisms that [have been] lobbed at the agency."

In his speech, Wheeler also referred to the problems facing the agency in the wake of Pruitt's departure. "I understand firsthand the stress that goes along with a change in management," he told EPA staff. "I will try to minimize the stress that you all deal with on a daily basis as employees here at the agency."

Not Ashamed of His Work for a Coal Company

Wheeler also confronted head-on the criticism that he has received for having worked as a lobbyist for Murray Energy, a coal company. Wheeler said it was just one among more than 20 clients he worked with while he was employed by the Faegre Baker Daniels consulting firm.

"I did work for a coal company, and I'm not at all ashamed of the work I did for the coal company," said Wheeler, who began his career in 1991 as a special assistant in EPA's pollution prevention and toxics office. After working on Capitol Hill and as a lobbyist, Wheeler was confirmed by the Senate as EPA deputy administrator on 12 April 2018. Trump appointed Wheeler as acting EPA administrator beginning on 9 July following the departure of Pruitt, who had worked to roll back dozens of environmental regulations and was enmeshed in a number of scandals, including charges of misusing taxpayer money.

For the last 4 or 5 years that Wheeler worked for the coal company, the number one issue it asked him to focus on was bipartisan legislation to shore up health care and pensions for miners, Wheeler said.

"My grandfather was a coal miner during the Depression. My grandmother raised her children in the coal camps in West Virginia," he said. "The work that I did on behalf of the

company to try to help the retirees of the United Mine Workers is the reason [it] endorsed my confirmation when I was nominated [as EPA deputy administrator] last year."

Hopes and Concerns About Wheeler

The replacement of Pruitt with Wheeler was "like a giant air conditioner being turned on and sweeping out the old air" at the agency, said one EPA staffer who heard Wheeler's speech and spoke to *Eos* on the condition of anonymity because staffers were not authorized to speak with the press. "I hope that [Wheeler] is a moral person and that he cares more for the health of 300 million people than for a company."

Ilana Solomon, director of federal campaigns for the Union of Concerned Scientists, told *Eos* that Wheeler "struck a more conciliatory tone with EPA staff than Scott Pruitt ever did, but let's not forget: Pruitt's mistakes reached far beyond his scandals. As the EPA's leader, Pruitt repeatedly undermined the agency's mission, obscured his actions from the press and taxpayers, and cut out the voices he didn't want to hear—including experts at his own agency. If Wheeler truly wants to defend the good work at the EPA, he needs to fix that problem first and foremost.

"Ultimately, the real test for Mr. Wheeler will be his actions on the many critical issues before the EPA, such as his predecessor's efforts to restrict science use at the agency. This administration has demonstrated time and time again that talk is cheap. When it comes to Andrew Wheeler, his actions as the EPA's acting administrator will speak louder than today's words."

Wheeler "will continue to champion deregulation and permit big polluters to evade compliance altogether," charged Denise Morrison, acting president of the American Federation of Government Employees' (AFGE) Council 238, which represents more than 8,000 EPA workers.

"Plain and simple, this 'regulatory certainty' is the new unregulated capitalism," she said. "Quietly, Wheeler has replaced EPA's mandate to defend public health with political appointees who apply arbitrary science to protect industry, and put the kibosh on laws preventing air pollution, water contamination, and toxic lands remediation. AFGE Council 238 doesn't expect anything to change in this EPA, whose toothless enforcement represents a bar that is now too low to even trip over."

By **Randy Showstack** (@RandyShowstack), Staff Writer

Heat Waves, More Than Coral Death, May Cause Fish to Flee Reefs

A school of fish swims in the Coral Sea. Survey data showed that fish populations at the Great Barrier Reef shifted to cooler waters in response to a heat wave in 2016. Credit: Rick Stuart-Smith

It's no secret that global warming is bringing dramatic changes to coral reef ecosystems. Scientists have widely believed that habitat loss caused by coral death has the biggest effect on reef fish and invertebrates.

New research now has found that reef fish populations shift in direct response to temperature itself and that changes caused by warm water actually occur faster and are more widespread than the effects of habitat loss.

The findings are significant for coral reef protection because a loss of biodiversity, especially of fish that eat harmful algae, could make it harder for reefs to recover from heat waves.

> Changes caused by warm water actually occur faster and are more widespread than the effects of habitat loss.

"I was surprised by how dramatic the response was over such a short time period," said Chris Brown, a marine ecologist with the Australian Rivers Institute at Griffith University in Queensland who coauthored the paper.

The paper was published 25 July in *Nature* (http://bit.ly/NatureStuart-Smith).

Clues in a 2016 Heat Wave

The research looks at the effects of a marine heat wave that hit the Australian Great Barrier Reef in 2016. During the event, temperatures in northern parts of the reef reached as high as 32°C, 2°–3° higher than the average hottest summer temperatures for the area.

"While 32 degrees is experienced at some places like [Indonesia] and the Red Sea, it is unusually high by the standards of any coral reefs, let alone the Great Barrier Reef," said lead author Rick Stuart-Smith, a marine ecologist with the Institute for Marine and Antarctic Studies at the University of Tasmania in Hobart, Australia.

Corals stressed by warm water can expel the microscopic plants that live in their tissues. The process, called coral bleaching, turns the coral white. Corals can sometimes recover from bleaching events, but over long periods they will die, eventually breaking down into rubble and sand.

A diver records data as part of a marine life census at the Great Barrier Reef in Australia. Credit: Rick Stuart-Smith

For the study, the researchers looked at data from monitoring surveys—efforts that seek to count fish and invertebrate populations, as well as coral cover—at 186 sites along the Great Barrier Reef and at isolated reefs in the Coral Sea. They compared data obtained between 2010 and 2015 with data from surveys taken 8–12 months after the heat wave.

They found that although the reef saw a net loss of coral, those losses weren't uniform. "It was actually quite patchy," Brown said. However, changes in fish populations were consistent across the board, regardless of where coral died.

Fish populations and biodiversity declined in northern reefs, but they increased in cooler southern waters. Thus, after the heat wave, southern reef communities more closely resembled what northern ecosystems used to be before temperatures started to rise. Certain invertebrates, like sea urchins, saw a similar change. "Things just jumped to the south," Brown said.

*An ember parrotfish (*Scarus rubroviolaceus*) swims at the Great Barrier Reef. A survey found that herbivorous fish like these, which help prevent algae from overtaking damaged reefs, were among the species most affected by a heat wave. Credit: Rick Stuart-Smith*

A Delicate Ecosystem Balance

Other studies have shown that coral loss does affect fish populations, and a few species in the new study, especially coral-eating species like butterfly fish, did see changes that were directly tied to coral loss, Brown said.

But the warming waters likely triggered a series of effects, the researchers note. Larger fish may have migrated south; the northern fish that remained may have become weaker and more likely to be picked off by predators.

The scientists also looked at temperature preferences for the different species, indicated by the highest latitude at which a particular fish is found and the latitude at which it is most abundant. They found that fish species that prefer cooler waters were more strongly affected by the heat wave and saw the biggest population shifts.

That's bad news for coral, because many algae-eating species, like parrotfish, prefer cooler water. "One of the groups that responded most strongly was herbivorous fish," Brown said. These grazing species help prevent algae from covering stressed coral, so the loss of these fish could make it harder for reefs to recover from bleaching events than scientists previously realized.

Habitat Protection in a Warming Ocean

Brown said that the research could help guide efforts to protect coral reefs from climate change. The paper shows that warming will affect reefs differently at different latitudes and points to the special importance of protecting reefs at cooler latitudes, which are likely to play an important role in preserving biodiversity as oceans warm.

The research could also be used to inform fisheries managers in making such decisions as restricting the take of parrotfish or other algae-eating species in areas that are most likely to see higher temperatures. Such protections could avoid making the problem worse, Brown noted.

Alastair Harborne, a reef fish ecologist with Florida International University in Miami who was not involved with the study, called the new paper especially noteworthy because of its large data set. The work, he noted, spanned a huge swath of the Great Barrier Reef, from tropical to subtropical waters.

> Protecting reefs at cooler latitudes, which are likely to play an important role in preserving biodiversity as oceans warm, is especially important.

The research also shows that climate change affects different parts of the fish community differently. "Some of those fish actually benefit in the south because they like warmer water, whereas in the north, if you're closer to their thermal limits, just a little increase will have a big effect," Harborne said.

He found it striking to see how fast fish populations could change. "What people haven't talked about is how these short bursts of temperature seem to have a direct effect on fish," he added. The research helps to start that conversation, he noted, showing results that he finds "surprising."

By **Ilima Loomis** (email: ilima@ilimaloomis.com; @iloomis), Freelance Journalist

Why Are Siberian Temperatures Plummeting as the Arctic Warms?

Residents of Yakutsk, a city in northeastern Siberia, endure harsh winter weather. This year, January temperatures in Yakutsk fell below –60°C. Credit: Amos Chapple/Lonely Planet Images/Getty Images

Climate change is warming the Arctic and melting sea ice, yet Siberia has experienced significantly colder and harsher winters for the past few decades. A study published 25 July in *Science Advances* shows that interactions between melting regional sea ice and the stratosphere—an atmospheric layer spanning about 10–50 kilometers above Earth's surface—play a key role in creating these frigid winter conditions (http://bit.ly/SciAdvancesZhang).

This stratospheric pathway "significantly contributes to the occurrence of the surface cold events over the Eurasian midlatitude, especially in Siberia and East Asia," Pengfei Zhang, lead scientist on the study, told *Eos*. Zhang is a postdoctoral researcher in climate science at Purdue University in Lafayette, Ind.

Scientists previously have observed that Siberia experiences colder winters when the Barents and Kara Seas, two sub-Arctic seas off the northern Eurasian coast, exhibit greater sea ice loss in the preceding autumn months (e.g., http://bit.ly/JCLIInoue). Zhang and his team modeled the cascading effects of that regional sea ice loss to see what factors may lead to a colder Siberia.

They found that modeling the circulation changes in the stratosphere was key to reproducing the observed Siberian chill. "The impact of sea ice loss in late autumn–early winter persists throughout the whole winter due to the long timescale of stratospheric processes," Zhang explained.

Autumn Thaw, Winter Chill

The Barents and Kara Seas usually reach their minimum in sea ice concentration by November each year. Years that have seen the lowest concentrations of sea ice because of warm Arctic temperatures have been followed by Siberian cold anomalies lasting through the next 3 months. Average winter temperatures in the region typically hover around −18°C, but sometimes temperatures drop to −25°C for spans of a week or more. One northern Siberian town even saw temperatures plummet to −66°C this past January (see http://bit.ly/ColdOymyakon).

The explanation for this "warm Arctic, cold Siberia" pattern remained elusive. Scientists debated whether the harsh winter conditions were caused by natural variability in the troposphere—the atmospheric layer closest to Earth's surface—or whether higher atmospheric layers, as some models have suggested, also played a role. Differences between atmospheric circulation models as well as incomplete treatments of the stratosphere within those models complicated the debate, Zhang explained.

In this research, Zhang and his team used an advanced atmospheric general circulation model to link sea ice loss in the Barents and Kara Seas with Siberian surface climate and weather extremes. The models, which include state-of-the-art stratosphere calculations, used observed sea ice concentration to predict sea and air surface temperatures, surface wind velocities, and cold air outbreaks, as well as circulation patterns in the troposphere and the stratosphere.

Then they tried to find a distinct trigger. "We switched on and off the stratosphere–troposphere coupling in the model to explicitly isolate the solid pathways underlying the Arctic–Eurasia linkage," Zhang explained.

When the models considered only air circulation near the surface, the researchers' simulations yielded a Siberia warmer than what was observed. To get the region as frigid and windy as it has been during recent winters, they needed to include stratospheric circulation as well as mixing between the troposphere and the stratosphere.

In short, they found that decreased sea ice concentrations weaken and shift the stratospheric polar vortex, a low-pressure phenomenon that helps drive regional climate patterns. This weakened polar vortex then causes a colder Siberia.

Toward Better Forecasts

By accurately accounting for the stratosphere, the team was able to reproduce observed climate conditions in Siberia using only regional sea ice loss rather than ice loss across the entire Arctic.

Can the technique be used to predict, say, winter climate events over Eurasia? Perhaps, Zhang said, but accuracy depends on whether climate and weather models "can simulate a realistic stratosphere."

The team is currently exploring whether the stratosphere plays a similar role in linking regional sea ice loss to extreme weather events in the northern reaches of North America.

By **Kimberly M. S. Cartier** (@AstroKimCartier), Staff Writer

Climate Research Funding Still Under Threat, Report Warns

Ernest Moniz (right), who served as secretary of energy in the Obama administration, speaks about climate science research and threats to funding with John Podesta, founder and director of the Center for American Progress. Credit: Constance Torian/Center for American Progress

Despite recent congressional appropriations that reversed many of the Trump administration's efforts to reduce science funding for fiscal year 2018, a new report raises an alarm about what it says are the administration's attacks on climate research and funding for it.

According to the report, "The Trump administration's budget proposals and explicit attacks on science, scientists, and scientific norms indicate their intent is to undermine not just individual programs, but the entire scientific process, and in so doing to cast doubt upon the severity of the climate challenge facing the United States and the world." The report, titled "Burning the Data: Attacks on Climate and Energy Data and Research," was issued on 14 June by the Center for American Progress (CAP), a left-leaning think tank based in Washington, D. C. (http://bit.ly/CAP-climate-report).

The report cautions that even though Congress passed legislation in March to maintain or increase science funding for a number of federal agencies, political appointees have broad discretion to reprogram funding away from climate change–related activities, to leave funds unspent, and to make policy changes to alter how science is used in federal decision-making, among other measures.

Funding cuts or shifts in spending could create gaps in data for U.S. and international climate studies, according to the report. It notes "the critical importance of the federal budget process to building and maintaining the foundation of domestic and international climate and energy research."

Appropriating the Dollars "Isn't Enough"

"Simply appropriating the dollars just isn't enough," said Christy Goldfuss, CAP's senior vice president for energy and environmental policy, at a 14 June briefing to discuss the report.

"There is a lack of transparency in the budgeting process that will make this an extraordinary challenge for Congress and those compelled to protect the data necessary to protect the planet," she said.

A Call for Vigilance Beyond the Appropriations Process

Ernest Moniz, who served as secretary of energy during the Obama administration, said at the event that "a state of vigilance is required beyond the appropriations process" and that "international concerns already have been expressed about what is going to happen if the United States creates data gaps" in climate studies.

"The things that should be completely noncontroversial are the underlying data to understanding what's happening to the Earth system," said Moniz, now a principal with the Washington, D. C.–based Energy Futures Initiative. And yet, he explained, it is concerning that those underlying data could be in jeopardy.

"It doesn't matter if you choose the frankly completely unsupportable decision about questioning the need to respond to global warming in a policy sense," Moniz said. "No matter where you stand on that, it is completely illogical to not want to see those data continue, unless, frankly, you don't have a pursuit for the truth and for the necessary responses at the heart of what you are doing."

By **Randy Showstack** (@RandyShowstack), Staff Writer

After a Glacier Retreats, Plants Thrive, Thanks to Phosphorus

Puca glacier in the Peruvian Andes. Credit: John Darcy

High in the Peruvian Andes, Puca glacier is receding and exposing lifeless, rock-covered land, like other glaciers around the world. Researchers have now shown that a single dose of phosphorus fertilizer kick-starts plant growth on these barren stretches of land.

This finding comes as a surprise because nitrogen, rather than phosphorus, has long been pegged as the limiting nutrient in developing ecosystems. As glacial retreat yields new landscapes, the exposed slopes potentially are prone to mudslides. Spurring plant growth will help to stabilize these slopes and sequester atmospheric carbon, which is contributing to climate change, the research team suggests.

This study shows that "phosphorus on its own increases plant and microbial abundance by a couple orders of magnitude," said Duncan Menge, an ecologist at Columbia University in New York who was not involved in the research.

A Martian Landscape

In 2010, Steve Schmidt, a microbial ecologist at the University of Colorado Boulder, and his colleagues traveled to Puca glacier in southern Peru. They were there to study whether plant and microbial life might be coaxed into existence in the harsh, high-altitude environment. Schmidt and his team focused on the area exposed by the receding Puca glacier, which has been retreating by about 30 meters per year. Some of the rocks revealed by the glacier were tinged red, evoking landscapes on another planet. "It looked like Mars," Schmidt said.

> "It was really obvious that the plants were just taking off."

He and his colleagues sprayed solutions containing nitrogen and phosphorus onto square-meter plots. These common ingredients in fertilizers are "the two most essential elements for life besides carbon," said Schmidt. Would a single pulse of nutrients be sufficient to kick-start life, the researchers wondered, in a frigid, arid environment 5,000 meters above sea level?

An Explosion of Plant Life

Over the next 6 years, Schmidt and his team returned to Puca glacier five times to carefully analyze the plots for signs of microbial life and plant life like grasses, small flowers, and mosses. By 2013, they started seeing differences between the plots that had received phosphorus and those that hadn't. "It was really obvious that the plants were just taking off" in the phosphorus-infused plots, Schmidt said. "That was totally unexpected."

Plant and microbial life was likely starved for phosphorus because the element was still locked up in rocks, Schmidt and his colleagues hypothesized. In more temperate environments, bacteria and weathering events like acid rain leach phosphorus from rocks. But high in the Andes, rainfall is scarce. Nitrogen, on the other hand, was already present in the soil—cyanobacteria were functioning as "nitrogen fixers," capturing nitrogen from the atmosphere and converting it into forms that plants could use.

Three years later, the researchers counted hundreds of plant stems in the eight plots fertilized with only phosphorus or both phosphorus and nitrogen. The four plots fertilized with only nitrogen contained about a fifth as many stems, and the four plots that had received only water had almost no stems. Complementary analyses, including remote chlorophyll sensing and measurements of plant coverage, revealed similar results. The researchers reported their results recently in *Science Advances* (http://bit.ly/Sci-Advances-P).

Thriving Plants Protect Land and Air

Demonstrating that plant life can thrive in the harsh environment around Puca glacier is more than just a proof of concept, the team maintains. If you can get these lands to be productive, they will sequester more of the atmospheric carbon that is leading to climate change, Schmidt said. Plants also stabilize slopes against mudslides, a perennial problem in steep alpine environments.

These results reveal that life can thrive in seemingly inhospitable places, Schmidt suggests. This work "expands the boundaries of life."

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

Exploring the Interplay Between Ocean Eddies and the Atmosphere

Ocean Mesoscale Eddy Interactions with the Atmosphere: A CLIVAR Workshop
Portland, Oregon, 17–18 February 2018

Mesoscale eddies, circling currents a few hundred kilometers across, are omnipresent in the ocean. Ever improving observations from satellites, moorings, and autonomous floats show that eddies differ from their surroundings and can transport oceanic heat and salt over large distances. The imprint of eddies on sea surface temperature affects the overlying atmosphere, and these interactions feed back to affect the eddies themselves. With rapid advances in numerical modeling, climate models, for the first time, have sufficient resolution to capture these eddies and their interactions with the atmosphere.

As we learn more about the rich dynamics of these ubiquitous features, three questions emerge: How can we use direct measurements to better assess the interactions of eddies with the atmosphere? How do such interactions affect ocean dynamics? Can eddies, despite their small size, influence weather and climate?

A U.S. Climate Variability (CLIVAR) and Predictability Program workshop earlier this year addressed just these questions. More than 50 oceanographers and atmospheric scientists from 10 nations met to assess the state of knowledge about ocean eddy–atmosphere interactions and to plan research.

> New model results suggest that the atmosphere, at weather scales or larger, responds to cumulative effects of the much smaller ocean eddies.

Presentations described observations showing that the temperatures associated with the eddies influence winds in the atmospheric boundary layer by modulating atmospheric pressures and vertical mixing. Winds, in turn, affect how hard the atmosphere pushes on the ocean surface, as do the eddy currents themselves, with consequent effects on eddy energies and the ocean circulation.

Participants agreed that we need a better understanding of how the wind stress and air–sea fluxes of heat and moisture are controlled—these are represented by empirical formulas containing uncertain parameters. When models treat the ocean independent of the atmosphere, how should feedbacks from the atmosphere be represented?

Finally, intriguing new model results presented at the workshop suggest that the atmosphere, at weather scales or larger, responds to cumulative effects of the much smaller ocean eddies. Such a response requires a "rectification" of local effects, but how this may happen in nature is not yet understood.

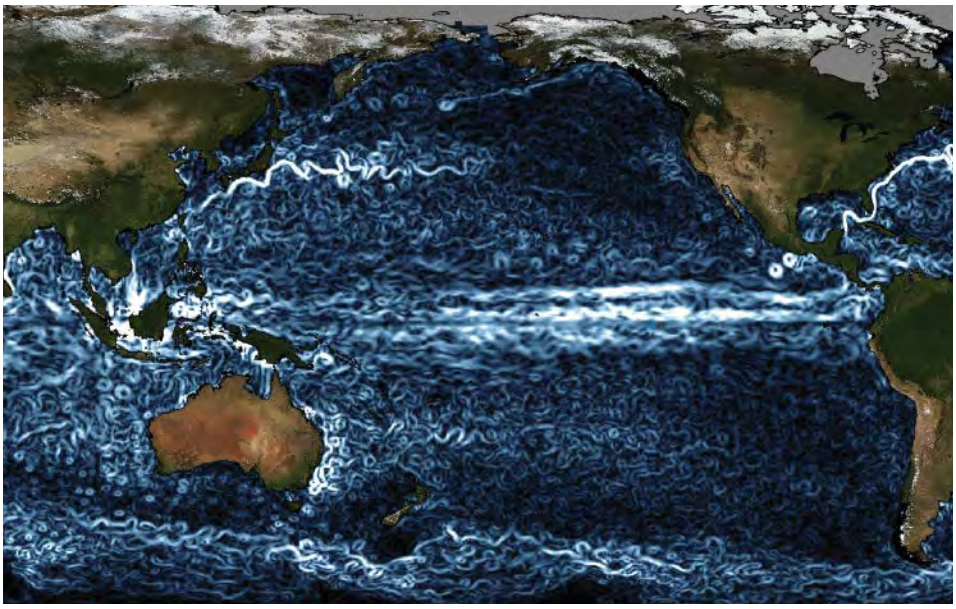
Participants decided on several actions to advance the science:

- develop plans for modeling experiments with ocean-only and atmosphere-only models
- explore different representations in each of the fluids not simulated within these models
- develop protocols for diagnosing interactions within coupled models
- develop new approaches to analyzing the increasing number of available data sets
- make the case for new observations in field campaigns and from satellites

The consensus among workshop participants is that eddy–atmosphere interactions are important for the ocean and the atmosphere at space scales and timescales much larger and longer than those of an individual eddy. We are on the cusp of new modeling and observational results that will show us how all this works.

More information on the workshop is available at the workshop's website (http://bit.ly/eddy-workshop).

We thank the following for support: NASA's Physical Oceanography program, the National Oceanic and Atmospheric Administration's Climate Variability and Predictability Program, and the National Science Foundation's Physical Oceanography and Climate and Large-Scale Dynamics programs. Kristan Uhlenbrock, Jill Reisdorf, and Jing Li provided expert staff support, and Ping Chang helped with this write-up.



A snapshot of ocean surface velocity intensity in the Indian and Pacific Oceans on 31 December 2013, estimated from the global Map of Absolute Dynamic Topography derived from satellite altimetry (see https://go.nasa.gov/2uFmKur). Stronger currents are indicated by lighter colors, with white representing about 0.75 meter per second. Credit: CLS/CNES

By **Walter Robinson** (email: warobin3@ncsu.edu), North Carolina State University, Raleigh; **Sabrina Speich,** École Normale Supérieure, Paris, France; and **Eric Chassignet,** Florida State University, Tallahassee

Geoscientists Collaborate to Understand Silicic Magma Systems

AGU Chapman Conference on Merging Geophysical, Petrochronologic, and Modeling Perspectives of Large Silicic Magma Systems
Quinamavida, Chile, 7–12 January 2018

Geophysicists take GPS measurements at Laguna del Maule in Chile on 30 March 2015. Credit: Brad S. Singer

The most voluminous caldera-forming eruptions on Earth are related to silica-rich magma; however, no one has directly observed or recorded any such eruption, which may eject hundreds to thousands of cubic kilometers of volcanic material. The lack of direct observations creates considerable uncertainty about how these systems evolve and what the warning signs of a large eruption might be. Thus, scientists rely on a variety of indirect approaches to understand magmatic processes in these systems.

Seventy-nine scientists from 13 countries participated in an AGU Chapman Conference about large silicic magma systems and their associated hazards (see http://bit.ly/magma-chapman). Fittingly, the conference took place near Laguna del Maule, a young, silica-rich volcanic center in Chile that exhibits active surface deformation. Participants included scientists at various career stages who have studied large silicic systems from various disciplinary perspectives, including geologic mapping, geophysics, structural geology, petrology, geochemistry, geochronology, and geodynamic modeling.

To address the fundamental question of how large silicic systems develop, presentations were organized into four main sessions:

- integration of geophysics, petrochronology, and numerical modeling
- reservoir dimensions and locations of melt
- growth and evolution of systems on long and short timescales
- interpreting signals of unrest to improve eruption forecasting

Each session comprised research from across disciplines to incorporate different perspectives on how large silicic systems operate. In this way, panel discussions focused on what is needed to create an integrative model that can explain these different observations.

Of course, the central question posed by this Chapman Conference could not be answered in a mere week. Instead, the interdisciplinary discussions that resulted from the presentations, often led by early-career scientists and students, provided a springboard for a new generation of collaborations and research.

An overarching conclusion from the conference is that cross-disciplinary collaboration is vital to developing an integrated model that ultimately will better represent the physical nature and dynamics of these systems. Several research needs stood out for their potential to lead to breakthroughs:

- understanding and communicating the physical representations of geophysical features and their associated uncertainty (e.g., understanding the geologic structure underlying the "big red blobs" commonly seen by geophysicists)
- understanding the relationship between geophysical observables (velocity, resistivity, density) and temperature and melt percentages in natural systems using new mineral physics and phase equilibria experiments, along with in situ scientific drilling
- gaining an integrated perspective of how large silicic systems operate at various timescales (from short term to millions of years) and spatial scales (from crystals to big red blobs) throughout the lithospheric column
- developing integrated models that relate physical processes to the state of magmatic reservoirs, which will improve our ability to forecast future eruptions and will help to propel the science forward, which, in turn, can benefit society

A special online issue of the *Journal of Geophysical Research: Solid Earth* will focus on bridging the observations and scales inherent in individual disciplines to enhance our knowledge of large silicic magma systems. Researchers may submit manuscripts until 31 December 2019 (see http://bit.ly/JGRSE-call), and we strongly encourage submissions that focus on an interdisciplinary approach to these systems.

By **Jonathan R. Delph** (email: jrdelph@rice.edu), Department of Earth, Environmental and Planetary Sciences, Rice University, Houston, Texas; **Brad S. Singer,** Department of Geoscience, University of Wisconsin–Madison; and **Josef Dufek,** School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta

Avoiding the Guise of an Anonymous Review

The scientific community takes the current structure of the peer review system as a given. But what if there were a better way to conduct reviews?

We are two colleagues, a Ph.D. student and an assistant professor, at Canada's University of Saskatchewan in Saskatoon. In summer, our daily work routine often ends with a leisurely walk on our way home along the South Saskatchewan River, strolling along footpaths shaded by trees. We enjoy something that everyone does: engaging in a good conversation with a good companion.

One day, we struck up a conversation on the role and quality of the peer review process in the scientific community, and we wondered which peer review system is best. As we continued this conversation, we realized that there are several differing ideas around peer review and challenges of blindness and openness from the points of view of both reviewer and editor.

Our talk revolved around some basic questions. Are anonymous reviews fair? Are they effective? What do you gain or lose by choosing to be anonymous? In practice, can you really be anonymous? Are there alternative ways of conducting quality reviews?

From our experiences and the data that we could find, we agreed that there are enough pitfalls in the current system of reviewing anonymously to warrant considering other approaches. We also feel that lifting the veil—allowing your name to be linked to your review and then making that review open to all—would be a self-regulating system in which only thoughtful reviews are submitted.

How did we reach these conclusions? Let's begin with the first author's experience.

A Beginner's Experience with Scientific Peer Review

After publishing a few papers, I started getting review requests from several journals. Apart from getting excited, I often found myself on the horns of a dilemma: whether to review a paper anonymously or sign my name.

This dilemma became worse when I received an invitation to review a manuscript written by a renowned researcher. In my review, I had several concerns about the manuscript. However, the author was in a position of power and influence in the scientific community, and I feared (perhaps foolishly) retaliation. I was thinking subconsciously (or consciously) about who the author is and how he might affect my career path in the future, and thus my review could not be completely objective. Finally, I submitted my review comments anonymously, albeit reluctantly! But if I had revealed my name, it probably would not have affected my career.

This story is an example of what may happen when reality collides with the idealism of objectivity. If someone decides when to anonymize a review on the basis of potential risks or benefits, she or he is simply making a personal value judgment on a case-by-case basis, which is against the ethical guidelines for peer reviewers. Therefore, "to be or not to be anonymous" is more than a question; it is a choice.

To Name or Not to Name?

The consensus within the scientific community is that peer review is a major driver of scholarly integrity, credibility of research, and commitment to the advancement of science. The peer review process traditionally has been anonymous in a single-blind manner, where the referees' identities remain hidden from the authors, or a double-blind manner, where the authors' identities are also withheld from reviewers. An "open review" process, where the identities of reviewers and authors are known to each other, is an alternative to the traditional process.

Does the anonymous peer review, as currently practiced, fail to do its job properly? This is a controversial topic that has long been debated among scholars. The proponents of anonymous peer review argue that it promotes objectivity, decreases sexism and nepotism, and prevents bland or timid reviews.

More specifically, advocates of double-blind review, which is an extreme view on anonymity, believe that it can decrease systematic biases such as the Matilda effect, in which the contributions of female scientists are overlooked compared with those of their male colleagues, and the Matthew effect, in which eminent scientists take more credit than those who are less well known but are almost equally qualified [*Rossiter,* 1993; *Lerback and Hanson,* 2017]. Note that in practice, a truly double-blind review may be rare because the identity of an author may be recognized by the language used, bibliographical references, access to specific data sets, prior presentations, or other factors.

Nevertheless, the anonymous peer review has been increasingly criticized, mainly because of its lack of transparency. Opponents of anonymous peer review assert that open review stops hostile, inflammatory, and unsubstantiated comments; mitigates discourtesy; and discloses possible conflicts of interest.

Although there are arguments for and against openness, it can enable researchers to

The anonymous peer review has been increasingly criticized, mainly because of its lack of transparency and accountability. Openness enables authors to see the "who, why, and what" behind the editorial decision-making process. Credit: gerait/Pixabay, CC0 1.0 (http://bit.ly/ccby1-0)

see the "who, why, and what" behind editorial decision-making. Also, the general policy of disclosure can lead reviewers to provide more objective comments, think more carefully about the scientific issues, and write thorough and fair reviews rigorously. In addition, reviewers can further discuss the results and critical issues directly with the authors.

Under any of the peer review models, the role of journal editors and the issues they face should not be understated. Editors direct the process, pay attention to detail, and make decisions. Furthermore, editors must confront the big, and perhaps growing, challenge of securing qualified reviewers and encouraging them to continue reviewing regularly. Given the sheer volume of submissions and the ever increasing number of journals, editors are finding it harder to persuade their colleagues to perform reviews [*Helffrich,* 2013]. In the second author's experience, fewer than half of his invitations to review manuscripts are accepted. This rate can further decrease in an open review system, which discourages reviewers who want to remain anonymous [*Almquist et al.,* 2017].

Improving Our System

How might we improve AGU's peer review system? Let's begin our analysis of AGU's policy by looking into its ethical guidelines for peer reviewers (see http://bit.ly/AGU-reviewer-ethics). Per these guidelines, which are based on the Committee on Publication Ethics's Ethical Guidelines for Peer Reviewers [*Hames,* 2013], reviewers should do the following:

- "decline to review if they have issues with the peer-review model used by a journal…"
- "determine whether the journal allows them to sign their reviews and, if it does, decide as they feel comfortable doing"

Apparently, these guidelines provide minimal freedom for reviewers to choose their review model of interest. Basically, the single-blind review model is currently adopted by AGU, with the option for reviewers to sign their reviews. If a reviewer disagrees with this model, he or she should reject the review request. Also, this model provides no flexibility for authors. For example, an author who prefers a double-blind review will be discouraged from submitting to an AGU journal.

Can AGU adopt an alternative review policy? Although a simple one-size-fits-all solution is unlikely to be achieved, the following strategies may be considered by AGU to improve this important and sensitive process.

Three Proven Models

First, both authors and reviewers need to have the freedom of choice. AGU journals may consider offering alternative review models to authors in the submission process and to reviewers during an invitation to review. *Nature Climate Change* and *Nature Geoscience* recognized this need in part, and since 2013 these journals have enabled authors to choose between single- and double-blind reviews. In March 2015, *Nature* and the monthly *Nature* research journals started to pursue the same strategy [*Nature,* 2015].

Second, the transparency of the peer review process can be improved by the inclusion of the peer review process documents (possibly excluding minor typographical comments) with published papers. This strategy will make the reviews accessible and referable, thereby increasing accountability. In 2008, the European Molecular Biology Organization began publishing reviewers' and editors' comments as well as authors' responses. This has been a viable and overwhelmingly positive move [*Pulverer,* 2010]. The European Geosciences Union has also adopted a similar strategy successfully.

AGU may develop an initiative that invites its community members to submit ideas to set up pilot peer review systems.

Third, AGU may develop an initiative that invites its community members to submit ideas to set up pilot peer review systems. Open to all, this call may seek new ideas that remarkably improve AGU's current peer review system. In 2012, Elsevier announced the "Peer Review Grand Challenge" competition. This global competition attracted some 800 innovative ideas, from which three winning ideas were announced to be further developed [*Lehane,* 2012]:

- systematically rewarding reviewers through an official accreditation system that they could cite on their curricula vitae
- developing online and cloud-based platforms to enable reviewers to easily view and annotate submissions
- launching a public reputation system to assign a "credit" to reviewers

Toward Removing the Veil of Anonymity

In 1987, William Hoover, a physicist at Lawrence Livermore National Laboratory, did an experiment. One of his papers had been rejected by two famous journals. So he made up an imaginary name, added it to the author list, and changed the title. He resubmitted the paper, and surprisingly, one of those journals accepted the new version. That new name was not only a fake name but also a very rude Italian phrase. The paper still exists, and the imaginary author has been cited in many articles (see http://bit.ly/Hoover-1987). The lesson to learn from Hoover's story is that papers must be reviewed purely on the basis of their merits and pitfalls, not on who wrote them.

Peer review is an integral part of the scientific enterprise. A Persian poet, Saib Tabrizi, once said, "If the first brick is laid askew, the wall will be built askew, even if it goes to the sky." Each paper resembles a brick used to build on and advance the structure of the scientific enterprise, and it needs to be examined before the next brick is placed on top of it. Screening overall quality, appreciating originality, and sustaining integrity require the collaborative and collective efforts of all the members of the scientific community in their interchanging roles as authors and reviewers.

Hiding behind the cloak of anonymity may not be a way out. To promote an open scientific dialogue, protect trust in the scientific community, and mitigate the burden on reviewers and editors, beginning reviewers should be trained through reviewer guidance workshops to have the courage, honesty, and dignity to sign their reviews without being fearful of reprisal. In arts, literature, and policy, it is common for critics to sign their review comments to bring a level of trust to the peer review process. Promoting that culture across the entirety of the AGU community may prove to be a game changer!

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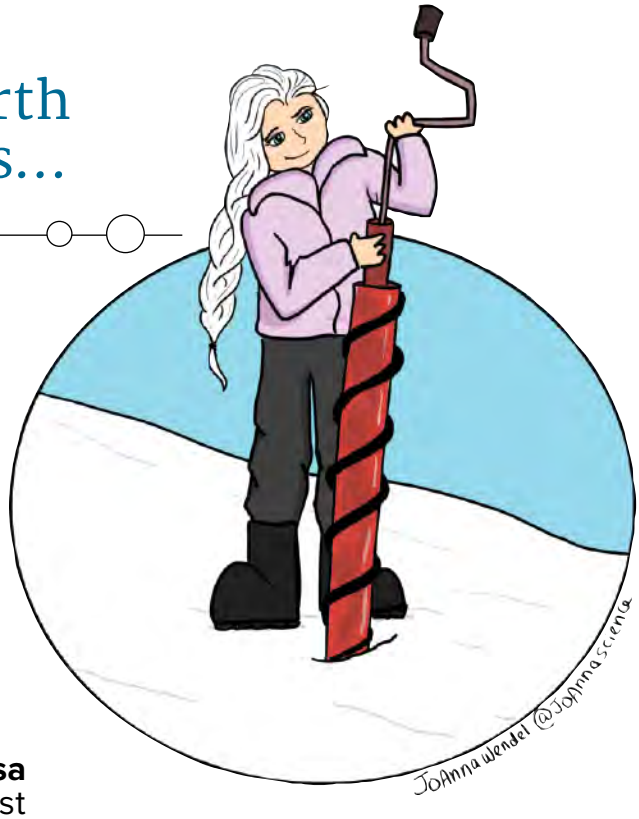
By **Razi Sheikholeslami** (email: razi.sheikholeslami@usask.ca) and **Saman Razavi,** Global Institute for Water Security, School of Environment and Sustainability, University of Saskatchewan, Saskatoon, Canada

If Disney Princesses Were Earth and Environmental Scientists...

Disney princesses are some of the most iconic figures in popular culture, and people love to reimagine them living in different worlds. A quick Internet search shows that there are zombie Disney princesses, the princesses as *Game of Thrones* characters, princesses reimagined as warriors, as hipsters...and even as cats.

But to science communicator and artist JoAnna Wendel, something was missing: science! In all their respective stories, these princesses prove themselves to be curious, resilient, adventurous, and determined: all good qualities in a scientist. So she drew them differently.

We picked up her drawings after she posted them on Twitter and fleshed out a bit of backstory behind each science-driven princess. In this alternate universe, Disney princesses do more than live luxurious, royal lives. They use their talents to learn more about the natural world.

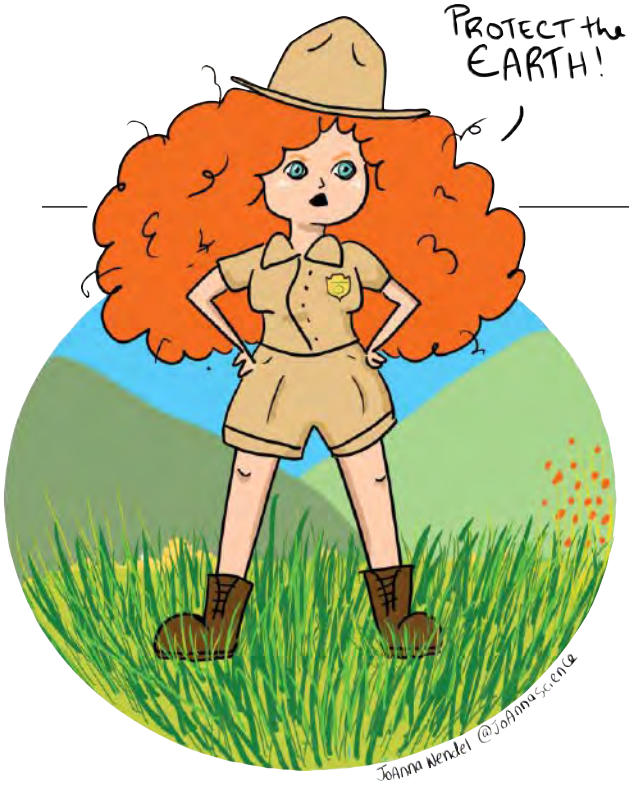


Queen Elsa
Glaciologist

A deep interest in the cryosphere comes naturally to a lady who can control ice with her will. After she noticed that the ice castle she pulled and shaped from a glacier's depths contained different ice phases and forms, she set out to parameterize the variables that govern the formation of the ice that she's able to conjure. Her latest claim to scientific fame? She can re-create all 18 known solid crystalline phases of water in less than 5 minutes.

Another pet project involves collecting cores and samples of sea ice, particularly in the harsh conditions of Arctic winter. But she dusts those hardships off like fresh snow powder.

"As you know, the cold never bothered me anyway," she explained. "But the dress was getting a bit cumbersome, so I opt for sturdy field pants and a light jacket when we're out on the ice." The sample she's collecting above will go into a climate-controlled lab for technician-snowmen that she animated to analyze and catalog.



Princess Merida
Conservation Ecologist/Park Ranger

These days you won't find Merida galloping through forests, shooting arrows hither and yon. "When your mom and baby brothers magically transform into bears and then back into humans because of something you did, it kind of sticks with you," she said. "You begin to pay closer attention to nature, to habitats. Bears and other species need us to keep our footprints at a minimum. After all, they were here long before us."

The tromping hooves and scattered arrows? They damage critical microenvironments that form the foundation of forest life, she explained. "I try to stay on trail as much as possible. And I still do target practice, but I pack out what I take in."

Merida still has no patience for marriage. "Seriously," she retorted, "would that be important to mention if I were a man who found a new calling? I think not." Rather, she spends her days roaming the forests of Scotland that she decreed as protected land. From dawn to dusk, she catalogs the park's species diversity and monitors ecosystem health. "My first quest was to change my fate," she said. "Now I want to change the fate of vulnerable life on Earth."

Fa Mulan
Paleontologist

While training for the emperor's army in northeastern China, Mulan stumbled on what she thought was an errant stone. Digging deeper, she uncovered a single, intact femur, about 1 meter long.

"I knew. I just *knew* right then that I had stumbled on a big find," she later recalled. She recruited her army buddies to grid off the site and start carefully digging. "They found bones upon bones. And then an amazingly well preserved skull. I thought to myself, 'Mister, I'll…make a dinosaur…out of YOU!'"

The site Mulan found may hold another key discovery: The strata immediately surrounding these bones were flecked with curious spindly impressions. "Actually, it was my lucky cricket who pointed it out," Mulan explained. "Now, anyone who's seen their companion dragon roll around in mud knows what impressions of reptile skin look like. These spindles were not that. Perhaps stage 1 feathers?"

If so, she noted, that would be quite the find: "There are a couple ideas for some journal scrolls I'm kicking around, so check back with me in a few years after they're published."

Princess Jasmine
Atmospheric Chemist

Frequent spins on a magic carpet through that endless diamond sky gave Jasmine a lot of time to ponder some big questions. For example, what sustains the hole in the ozone layer? What exactly is the provenance of particles of dust and pollution found at different altitudes? What's it like to be swept up in an atmospheric river?

So when she's not busy helping to rule her kingdom, Jasmine rides the skies, collecting data. "Aladdin was right—it really is a whole new world up here. And that means there are so many data we still need to collect," she said. Her current research involves using a magic carpet as her remote sensor to probe extremely high altitude targets in the upper stratosphere and the mesosphere.

Princess Ariel
Oceanographer

Anyone who's kept up with Ariel's life knows that after she helped defeat the witch-kraken Ursula, she got married, had a kid, and temporarily got her tail back with the help of magic from her father so that she could save her kid from Ursula's witch-kraken sister. We know: a lot to process, right?

What you may not know is that a year after those adventures subsided, she began to get restless. Motherhood and princessing couldn't be the be-all and end-all, she figured, not with her analytical mind and sense of adventure. So she began to read up on the ocean world she once called home and, in doing so, found her calling.

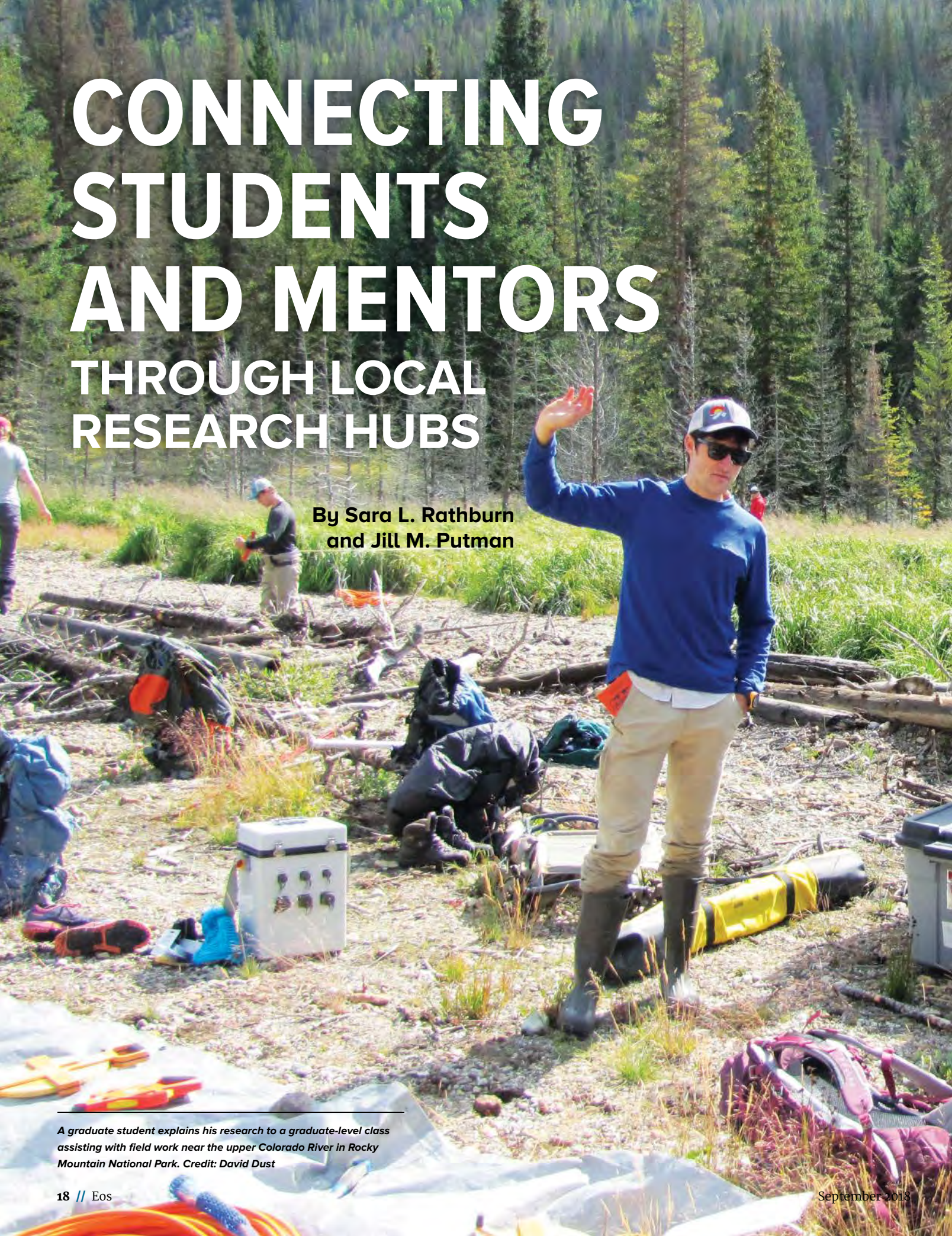
"I want to be where the deep waters are; I want to see, want to see them upwelling," she noted at the time. Inspired, she approached her father with a deal: He gives her freedom to flash in and out of her tail, and she swims far and wide, hunting for harbingers of changing ocean conditions. She shares her findings with her father and her husband so that the three of them can enact policies to lessen impacts on the ocean and protect merpeople and humans from ocean changes to come.

Her father agreed, and she's been collecting in situ data about the ocean ever since. "As a human–animal hybrid who loves to sing, I'm perfectly positioned to do this vital work," she noted. Not only does she swim to areas that submersibles find difficult to reach, but she can also talk to fishes, crabs, and other species. "And when I sing, I put these species at ease so that they are more likely to tell me their firsthand experiences of ocean life in a warming world," she explained.

By **Mohi Kumar** (@scimohi), Interim Senior News Editor

CONNECTING STUDENTS AND MENTORS THROUGH LOCAL RESEARCH HUBS

By Sara L. Rathburn and Jill M. Putman



A graduate student explains his research to a graduate-level class assisting with field work near the upper Colorado River in Rocky Mountain National Park. Credit: David Dust

Five undergraduate students, one graduate student, and two research associates unload equipment and supplies from the back of a car: coiled electrical resistivity cables, a metal control box, stainless steel stakes, car batteries, tarps, 100 containers of table salt, and surveying equipment. The pile builds in the parking lot as they await a llama train to help transport the gear to the field site.

The llamas arrive in the back of a pickup truck. They are bedded down, and they peer sleepily over the side. We laugh as they shuffle down a ramp, spooked by an orange construction cone in the parking lot. Then we see that there are only three llamas; the fourth is recovering from an injury. The students don't know this yet, but they will have to cover for the injured llama: Each student will carry 40 extra kilograms to the field site 6 kilometers away.

This group of students, all from Colorado State University (CSU), had signed up for a learning experience to gain insight into anthropogenic influences on the upper Colorado

Graduate and undergraduate student volunteers from Colorado State University test the pumping rate during a conductivity tracer test at a local research hub on the upper Colorado River in Rocky Mountain National Park. Credit: Sara Rathburn

Students gain research experience at the same time the university tangibly broadens the impacts of faculty research.

River in Rocky Mountain National Park [*Rubin et al.*, 2012; *Rathburn et al.*, 2013; *Grimsley et al.*, 2016]. But shouldering the burden of a missing llama wasn't the only noteworthy aspect of their experience.

The students were contributing to the success of our research project, an effort that for nearly a decade was focused heavily on graduate student research. Their presence marked the beginning of increased undergraduate student participation, made possible by a database through which administrative personnel and faculty members could locate and recruit interested students to help with long-standing projects. By having different students come in and out of the project as needed, the project, in essence, became a local research hub.

Such research hubs, particularly for Earth and environmental sciences, are win-win endeavors. Students gain research experience, strengthen their ties to a cohort of fellow students, sustain their long-term commitment to geology, and cultivate their leadership skills as tomorrow's natural resources professionals. At the same time, the university tangibly broadens the impacts of faculty research and fosters exciting opportunities in science while helping researchers fill their logistical human-power needs.

A llama train transports gear into a field site in the upper Colorado River valley in Rocky Mountain National Park. Credit: David Dust

Creating a Research Hub

Field-based research is an effective way for students to learn [*Mogk and Goodwin*, 2012]. It provides a high-impact educational experience with lasting benefits for students. The Association of American Colleges and Universities cites undergraduate research as a "high-impact practice" because it relies on faculty interaction outside the classroom, promotes deep learning, and has been shown to have positive effects on students' overall personal and academic development, which in turn leads to increased academic performance and student retention [*Pascarella and Terenzini*, 2005; *Association of American Colleges and Universities*, 2007]. The experience of testing knowledge in different settings and preparing students to enter the workforce through developing field skills is a distinctive feature of a high-impact learning experience [*Kuh*, 2008].

It's no surprise that at universities like CSU, many undergraduate students express interest in gaining research experience. But despite the value of student field-based research, both to the pupil and to the project, finding inter-

Undergraduate students measure flow and sediment transport along the Colorado River in Rocky Mountain National Park. Credit: David Dust

ested students and communicating with them can be challenging. University faculty often require students on short notice, and they may need them only for short-term assistance. It can be difficult for faculty at a large university to find the time and resources to locate and vet potential student researchers.

To address this challenge, students and faculty members at CSU take advantage of a strategic partnership with an academic success coordinator (ASC), a trained student affairs professional. Our ASC implemented a free online database through Google Forms, where students apply for department positions. The database easily matches faculty needs (field assistance, independent study, or research) with student interests.

Furthermore, the database was designed to encourage students from underrepresented populations by providing a clear pathway for them to indicate interest in department-sponsored opportunities. Such populations include first-generation college students and representatives of racial or ethnic minorities who may lack "cultural capital"—networking skills, knowledge of social conventions, and other assets that help them fit in—and knowledge of university systems that connect directly with high-impact practices.

A Successful Experiment

We found the local research hub model to be effective, low cost, and sustainable. Research at the upper Colorado River field site has created a hub for learning, mentoring, and collaboration. In total, the work has involved 87 students, 1 postdoc, 9 faculty members from CSU and 3 from other universities, 2 university research associates, and 12 other staff scientists from state, federal, and private agencies within Colorado's Front Range.

Students have assisted with research in 1-day field outings with on-site training; multiday trips that required more intensive preparation and mentoring; and semester-long research projects for credit that involved analyzing, interpreting, and presenting their data. Students collected field data that included river flow and sediment transport measurements, channel geometry and bed grain size, and tree cores. They assisted with conductivity tracer tests,

Students lay cables for an electrical resistivity survey within a wetland along the Colorado River in Rocky Mountain National Park. Credit: Sara Rathburn

electrical resistivity and ground-penetrating radar surveys, and geomorphologic mapping.

Thanks to the online database, our project has seen a tenfold increase in undergraduate student involvement since 2015 and a 30% increase in the participation of first-generation college students and racial and ethnic minority students. In total, research activities at the hub have so far produced 4 peer-reviewed journal articles, 1 undergraduate and 7 graduate research presentations, and 16 professional meeting or seminar presentations.

In addition, the accessibility of the database has expanded beyond this project to include teaching and research opportunities for undergraduates. Six faculty members and more than 10 graduate students in our department have used the database to search for assistance on other projects. For the staff at Rocky Mountain National Park, the project has yielded citable journal articles, data that support other park initiatives, and public education for visitors through direct field contact and special presentations.

We expected the sole benefit of the field site database model to be more student research opportunities, so we were surprised by myriad other experiences that arose. These included mentoring, peer learning, and such curricular and cocurricular activities as field course excursions to the site. Now there is a self-sustaining cycle of ongoing research, generation of new project ideas, mentoring, peer learning, and overall student engagement.

Adopting the Idea

Is this an appropriate and transferable model for other institutions? We think so. Admittedly, field research in a natural park is unique and exciting, which makes it easy to recruit graduate and undergraduate students, hire field assistants, and solicit volunteers. However, any field site that is close to a campus will work.

To replicate this model, we recommend that other universities do the following:

- identify local research sites and potential partners for access and funding
- partner with a student support professional (e.g., an ASC) to identify student and faculty needs
- develop an online application form detailing student interests
- promote and market the potential for using the database to students and faculty members via email and social media, in classes, and during meetings

Online application forms can be submitted using readily available resources (e.g., SurveyMonkey, Typeform, Google

Docs, Dropbox). We modeled our form as a job application to give many students their first experience in professional resume preparation.

A First Taste at "Being Treated as an Actual Scientist"

Student participants have responded enthusiastically to their experience doing field research:

"Research on the upper Colorado River gave me a chance to apply the knowledge I gained in classes to the field," one of our students told us. "It really deepened my understanding of geomorphology and made me realize that river systems and surface water processes are something that I would like to pursue."

Another hit squarely on why we embraced the idea of a research hub in the first place: "It was a great opportunity to get some hands-on research without worrying about the grade. That lets a person relax and embrace the task at hand. I also liked learning about the entire project and being treated as an actual scientist."

Acknowledgments

We greatly appreciate financial and logistical support from Rocky Mountain National Park and the National Park Service and their genuine commitment to research and student learning. Canace Finley and Katherine Lininger provided useful feedback on an earlier draft, and we thank an anonymous reviewer for comments that improved this article.

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MAKING MAPS ON A MICROMETER SCALE

By B. J. Linzmeier, K. Kitajima, A. C. Denny, and J. N. Cammack

Researchers on the cutting edge of geochemistry are tracing Earth's history through the clues recorded in tiny mineral crystals. Often, they must work with the microscopic (or nanoscopic) features in rare, hard-won specimens to pull apart the complete history of the mineral's formation. Even in large pieces of rock, microscopic variability may be distributed throughout in patterns that contain valuable information. Researchers using microanalysis have read the information stored in layers of a single zircon crystal, the cements in a sandstone, tiny shells of sea creatures like ammonite hatchlings, and minerals in a meteorite.

A variety of imaging and chemical analysis techniques produce maps illustrating how chemical elements and crystal growth features are distributed across a specimen. These data currently are shared through static figures or images contained in a data repository, but this setup does not facilitate deeper inquiry and full use of spatial relationships. What if widely used geographic information system (GIS) software, which typi-

A zoned dolomite-ankerite grain roughly 120 micrometers wide from a polished rock surface. Pits indicate sites of chemical analyses. Geographic information system software, created for mapping cities and continents, works equally well on the scale of crystals such as this one. Credit: A. C. Denny


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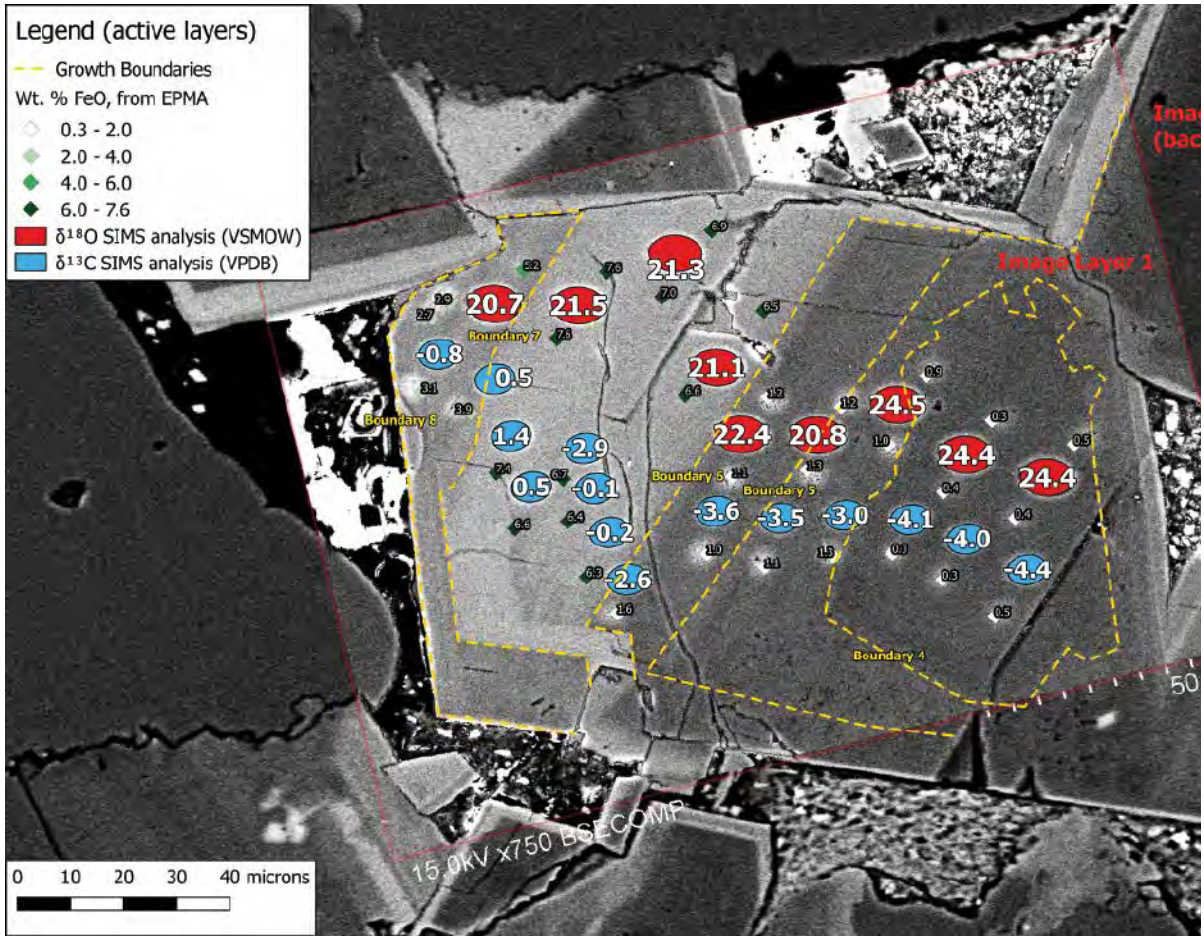

Fig. 1. To create this map of the grain seen on page 25, we used QGIS software to composite several SEM-backscattered electron image layers. We overlaid these with two secondary ion mass spectrometer transects and an EPMA data set. We added the final polygon layer (yellow dotted lines) to draw visual attention to different growth domains within the crystal. Data are from Denny et al. *[2017]. Credit: A. C. Denny*

cally deals with data on the scale of many square kilometers, could be applied to data on a microscopic scale?

Here we showcase use of the free and open-source software QGIS (https://qgis.org/en/site) to integrate in situ chemical data with images to enrich interpretation.

Integrating the Information

Minimally destructive geochemical analysis at the nanometer to micrometer scale can peel apart the events that took place over the formation of a mineral crystal and still preserve the crystal for future analyses. This analysis is especially important for deciphering the geological history of a specimen that is small, rare, or zoned, like a 4.4-billion-year-old zircon.

In situ microanalytical data also fundamentally contain spatial information that can be combined using GIS.

No one analytical technique, however, can provide all necessary information for many questions, and the range of instrument manufacturers and data types involved makes integrating data from various instruments difficult.

To understand, for instance, how cementation in a sandstone evolved or the chemical evolution of a magma, images from light microscopes or scanning electron microscopes (SEM) are used to examine petrographic relationships, and then electron probe microanalysis (EPMA) provides point analyses of elemental composition (Figure 1).

In situ microanalytical techniques have become faster and more precise, and they are now routinely used in the geosciences [*Valley and Kita,* 2009; *Sylvester and Jackson,* 2016]. Microanalytical instruments like secondary ion mass spectrometers (SIMS), electron probe microanalyzers, and laser ablation–inductively coupled plasma–mass spectrometers produce large data sets from individual thin sections or chips (Figure 1). Other techniques like optical

light microscopy, SEM, X-ray mapping, and nano-SIMS produce suites of images.

A Change of Scale

For years, scientists have managed field-scale data that span scales of meters to kilometers, incorporating images and point information using GIS software. However, in situ microanalytical data, like SEM images and SIMS or EPMA point analysis, also fundamentally contain spatial information that can be combined using GIS.

On a field scale, data in a map may have vector components (e.g., points, lines, or polygons) or raster components (e.g., images or similar pixel-based scans). In the case of microanalytical data, SIMS or EPMA data can be treated as vectors, and SEM scans or other images can be treated as rasters. Spatially overlapping sampling images and point analyses allows relating these data sets to each other for visualization and further exploration.

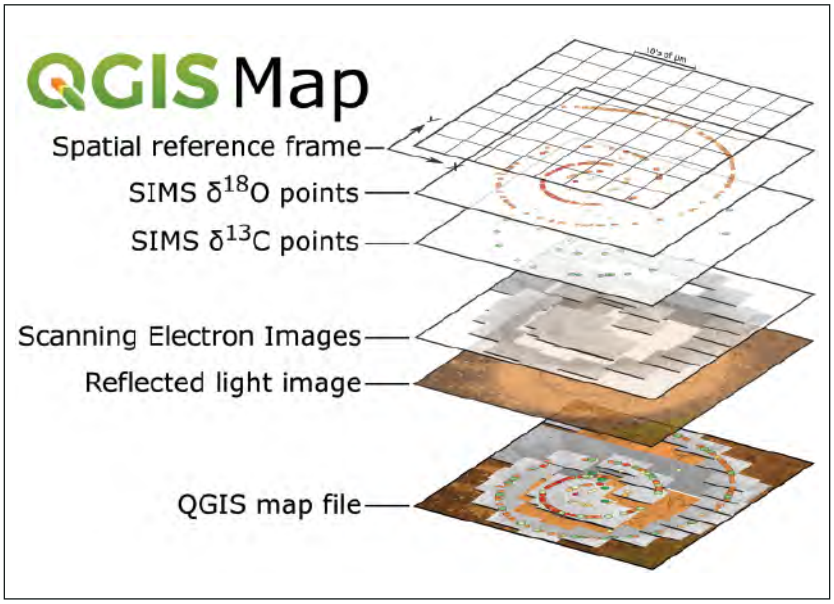

Fig. 2. This workflow for data import into QGIS relies on x–y coordinates from one instrument to calibrate the map units. In our examples, we use SIMS files from a CAMECA IMS 1280 instrument for calibration, and the units are micrometers. We also use our SEM Image Placer plug-in to position tens of SEM images simultaneously. Results of this data integration are shown in Figure 3. Data are from Linzmeier et al. *[2018]. Credit: B. J. Linzmeier and A. C. Denny*

Adapting an Open-Source Tool

QGIS is a free, open-source, user-friendly, cross-platform (Mac, Windows, Linux, Unix, and Android) software package for collecting and processing macroscopic geographic data. Under the banner of the Open Source Geospatial Foundation (see https://www.osgeo.org), a community of volunteers maintains and develops the software with financial support from corporate and nonprofit sponsors (see http://bit.ly/QGIS-sponsors).

Although QGIS was not originally designed for microanalytical techniques, we have compiled in situ microanalytical data from multiple instruments to create integrated maps of individual samples.

QGIS has many advantages, making it a good candidate for adoption by the wider microanalytical community for data visualization and management. First, the open-source nature removes the cost barrier to adopting the platform. Second, the software is supported by a growing international community of users and developers. Finally, custom plug-ins can be written in the Python, C++, and R computer languages, and these can provide ways of refining data input for different instruments. Plug-ins written in Python can be tailored to specific structured instrumental outputs to speed data compilation.

QGIS is a free, open-source, user-friendly, cross-platform software package for collecting and processing macroscopic geographic data.

Map generation in QGIS for microanalytical data sets is straightforward (Figure 2). A tutorial structured to teach refined use of QGIS is available at the WiscSIMS Micro-QGIS website (http://bit.ly/micro-QGIS).

Creating Plug-Ins

QGIS plug-ins can be created to solve specific problems relevant to a lab, analytical technique, or scientific question. We have used a plug-in called Plugin Builder (http://geoapt.net/pluginbuilder) to create several tools specific to the WiscSIMS laboratory at the University of Wisconsin–Madison. This platform provides a basic framework and files for building your own plug-in to interface with QGIS.

We have developed a plug-in that places images using the *x*–*y* coordinates of a microscope stage to align SEM images with data maps from other instruments. The software parses a text file made by our SEM (Hitachi S3400-N) that contains image dimension, stage coordinates, and pixel size and loads the associated images into a QGIS map. We are distributing our SEM Image Placer plug-in on GitHub (http://bit.ly/SEM-image-placer), so anyone can download, fork, modify, and make a pull

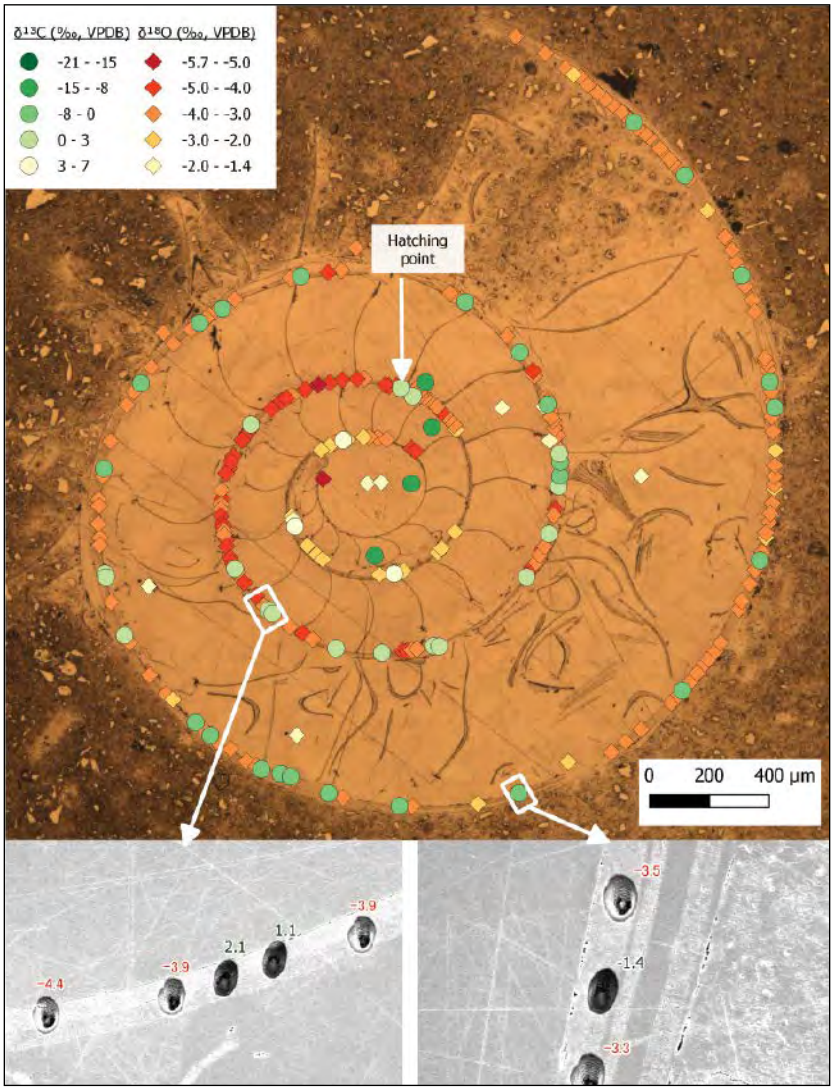

Fig. 3. This map for AMNH 75647, currently the most analyzed ammonite (extinct marine mollusk) in the world, was completely generated in the QGIS composer. After compiling the data, a user with intermediate-level skills could use this composer to create an initial figure in less than 20 minutes. The project file that was used to create this map integrates all the analytical data performed on this small SIMS mount. Data are from Linzmeier et al. *[2018].*

request for the development under the GNU General Public License (see http://bit.ly/GNU-license) to extend this functionality to other types of SEMs and other microscopes with stage coordinates.

Integrating and Archiving a Variety of Data

Using free, open-source QGIS software for the integration of in situ microanalytical data sets improves our ability to integrate data from multiple instruments. It also decreases the time spent annotating and reformatting supplemental data sets for publication (Figures 1 and 3).

Data collected from multiple instruments can be compiled quickly using built-in tools and custom-designed components. Adapting GIS software to the microscale also enables us to perform more complex spatial analysis. Most important, these compiled microspatial data can be shared between collaborators and used to explore patterns that may not be obvious from static displays of images and data points.

Our compilations use standard, widely used file formats, so they have the potential to interface easily with database infrastructure for archiving and depositing data collected with public funding [*Chan et al.,* 2016]. This potential will ensure that extensive, expensive, and cutting-edge in situ geochemical data sets are easily shared and integrated into existing databases like Macrostrat (https://macrostrat.org) using widely available formats and software.

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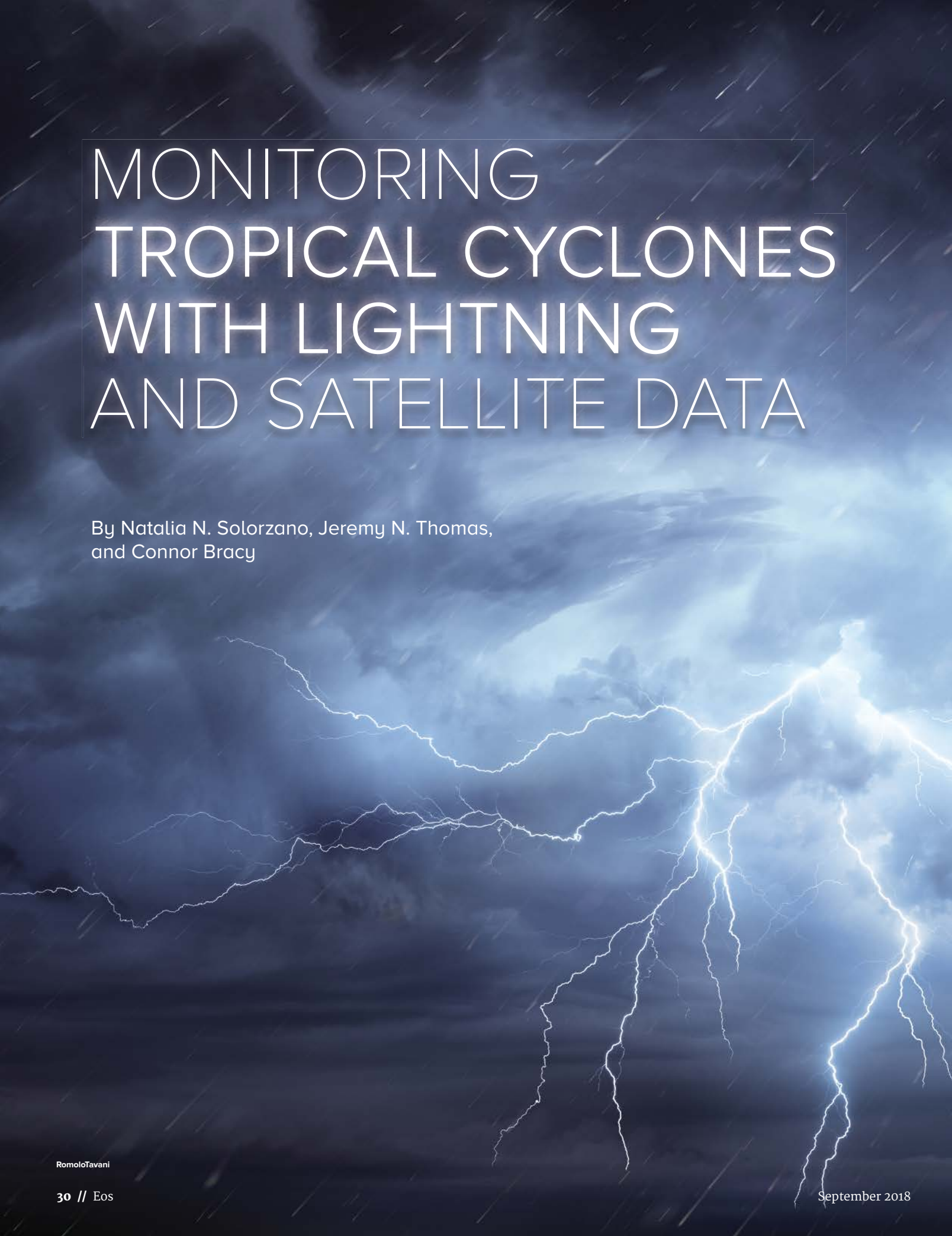
ADVANCING EARTH AND SPACE SCIENCE

MONITORING TROPICAL CYCLONES WITH LIGHTNING AND SATELLITE DATA

By Natalia N. Solorzano, Jeremy N. Thomas, and Connor Bracy



RomoloTavani

To better understand tropical cyclones, forecasters and researchers need to monitor these storms continuously. Keeping a real-time eye on lightning associated with tropical cyclones is an important step toward such continuous monitoring. The multiple physical connections between lightning, convection, precipitation, and rapid storm intensity changes make lightning a rich source of information on how these storms evolve.

The World Wide Lightning Location Network (WWLLN) team, a group coordinated by the University of Washington in Seattle, operates a network of lightning location sensors that produces regular maps of lightning activity all over the world. To tackle the demand for continuous tropical cyclone monitoring, the WWLLN team has developed a unique storm-following tool and a public website known as WWLLN Tropical Cyclones (WWLLN-TC; https://wwlln.net/storms/). The website visualizes lightning data in near-real time for all tropical cyclones across the globe. An archive of all of the

A nighttime astronaut's-eye view from the International Space Station of inner core lightning in Tropical Cyclone Bansi as it travels over the Indian Ocean in 2015. Credit: ISS Crew Earth Observations Facility and the Earth Science and Remote Sensing Unit, NASA Johnson Space Center

Together, lightning and microwave data can track a range of parameters in tropical cyclones; storm intensity changes are related to the density of lightning strokes.

more than 700 tropical cyclones that have occurred since November 2009 is also available to those who visit the site.

WWLLN-TC also integrates these data with microwave satellite data from the Naval Research Laboratory (NRL). Adding in the lightning data can help fill gaps in and between satellite microwave images.

Together, the lightning and microwave data can track a range of parameters, including intensity changes in tropical cyclones; past research has shown that intensity changes are related to the density of lightning strokes [e.g., *Solorzano et al.,* 2008; *DeMaria et al.,* 2012]. Thus, WWLLN-TC offers the potential to improve forecasts of tropical cyclone intensification and associated rainfall forecasts.

Monitoring Lightning and Tracking Cyclones

WWLLN provides real-time lightning locations globally by measuring electromagnetic pulses generated by lightning strokes (Figure 1). The network is a collection of more than 70 receiver stations around the world. At present, WWLLN data are being combined with lightning data collected by Earth Networks (https://www.earthnetworks.com), which greatly increases the overall lightning detection efficiency of the existing WWLLN.

WWLLN-TC users can access four categories of images to follow the lightning activity and satellite observations of tropical cyclones:

- The website provides a storm track map generated from data provided by NRL (Figure 2a).
- Lightning time series graphs include histograms of strokes per hour within 100 and 1,000 kilometers of the storm center, along with maximum wind speed and minimum pressure data from NRL (Figures 2b and 3) and a

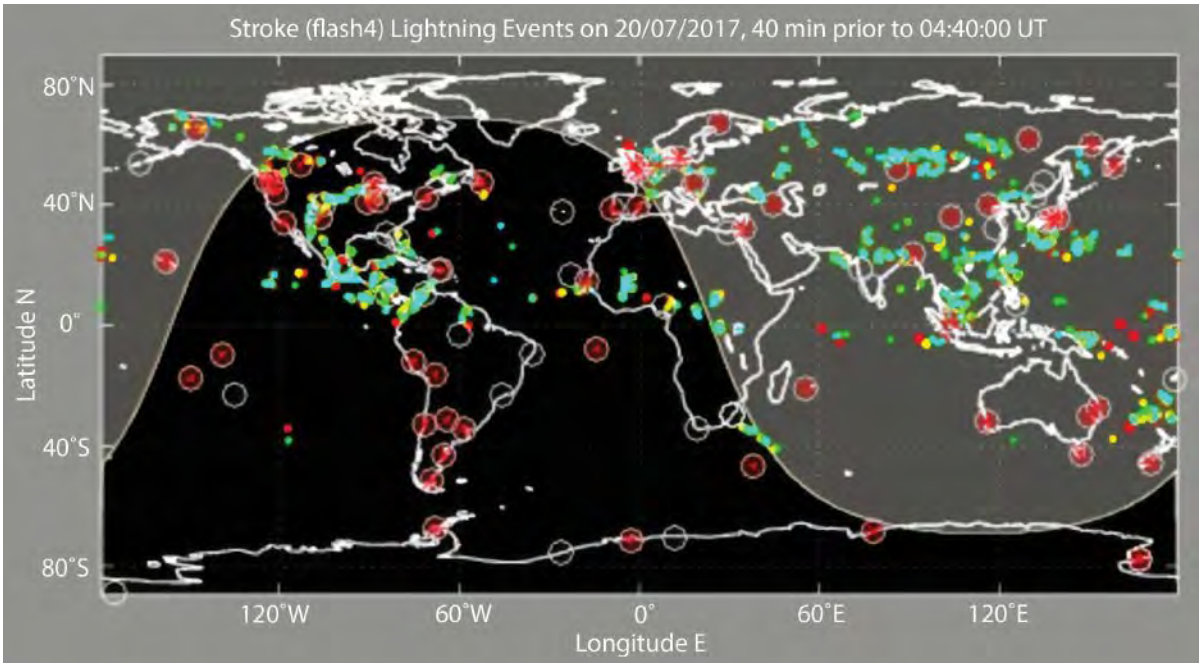


Fig. 1. WWLLN lightning strokes are shown as colored dots for 20 July 2017. Blue represents the most recent strokes (during the 10 minutes before the plot was made), followed by green and yellow and then red for the oldest (30–40 minutes earlier). Red asterisks inside white circles indicate active WWLLN lightning sensor locations. The terminator (the day–night boundary) is shown, with the daylit section of the globe in gray. Credit: WWLLN

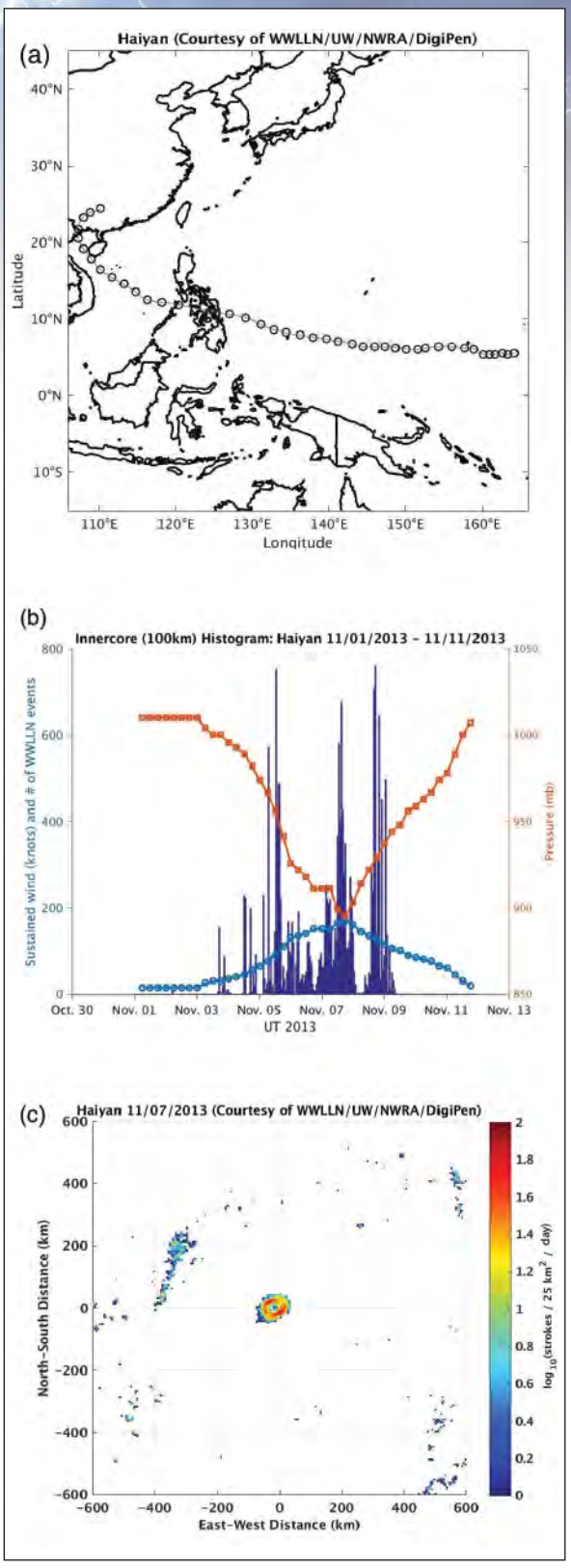


Fig. 2. (a) Storm track for Typhoon Haiyan in 2013. (b) Lightning and intensity histogram, with purple bars representing the number of lightning events, wind speeds depicted in blue, and atmospheric pressure depicted in orange. (c) Lightning density. Credit: WWLLN-TC

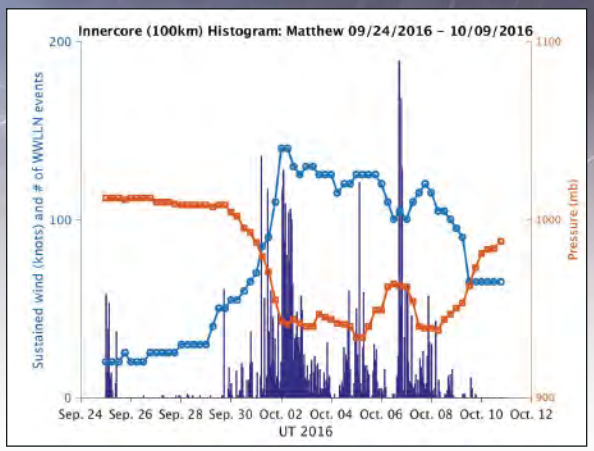


Fig. 3. Histogram of hourly WWLLN lightning, along with wind (purple) and pressure (orange) data, for Hurricane Matthew in 2016. A peak in lightning rate on 6 October precedes rapid weakening of the storm. Credit: WWLLN-TC

lightning density spectrogram binned by the distance from the storm center.

- Daily lightning density data relative to the center of the storm (Figure 2c) are available as static images; this information is also combined into animated GIFs.
- Satellite images from NRL are overlaid with lightning strokes occurring during a time window spanning 15 minutes before to 15 minutes after each satellite pass (Figures 4 and 5). Microwave data are from such satellites as NASA's Tropical Rainfall Measuring Mission (TRMM) and Global Precipitation Measurement (GPM), as well as from the National Oceanic and Atmospheric Administration's (NOAA) Defense Meteorological Satellite Program (DMSP). Infrared data are from geostationary satellites, including NOAA's Geostationary Operational Environmental Satellite (GOES).

Hurricane Matthew Provides a Test Case

Figure 4, an example of data visualization provided by WWLLN-TC, displays Hurricane Matthew at peak intensity (3 October 2016) on its path from the Caribbean to the United States. This figure is an overlay of a lightning stroke map from WWLLN (black circles) and 91-gigahertz brightness temperatures provided by the Special Sensor Microwave Imager/Sounder (SSMIS) radiometer on the low-orbit satellite DMSP F-18. Brightness temperatures, a measure of microwave energy coming out of Earth's atmosphere, are useful in estimating the intensity of convection in tropical cyclones.

The hurricane's eye wall is distinct in the image, and lightning in this case is present in both the eye wall and the rainbands. Lightning is often detected in the rainbands, and it occurs episodically in the inner core of tropical cyclones (within 100 kilometers of center). In storms, ice and liquid water not only are key ingredients for separating the positive and negative electrical charges that initiate a lightning strike; they also are the main features detected by microwave sensors on satellites. In general, clouds with more ice, and thus lower brightness tempera-

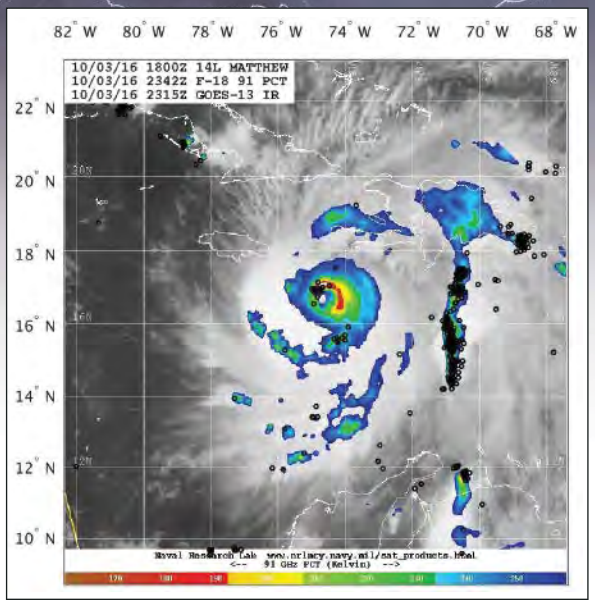


Fig. 4. Results from the WWLLN-TC data product, showing lightning (black circles) and SSMIS 91-gigahertz polarization-corrected temperature (PCT) brightness temperatures (color contours) for Hurricane Matthew in 2016, pinpointing regions of intense convection. Credit: WWLLN-TC

tures, are more likely to produce lightning and to have moderate to strong updrafts and precipitation.

Lightning is therefore an indicator of significant convection, although not all intense convective systems have lightning. This is important because deeper, organized convection tends to be more persistent, unless it is regulated by such external factors as vertical wind shear or insufficient moisture.

Hurricane Matthew exemplifies a storm with lightning and long-lasting convection. In Figure 4, lightning accompanies some areas of deep convection, indicating that the storm might persist. We can see that the environmental conditions were favorable for Matthew as it continued as a category 4 (and occasionally 5) hurricane until 6 October (Figure 3), with inner core lightning activity indicating that persistent convection was indeed present.

Lightning Surge Signals a Change in Storm Intensity

Atlantic hurricanes often have a significant peak in inner core lightning preceding rapid weakening [e.g., *Solorzano et al.*, 2008; *DeMaria et al.*, 2012]. Inner core discharges are typically episodic, and a peak in lightning occurrence can be straightforward to visualize by using the histograms and spectrograms available from WWLLN-TC. For

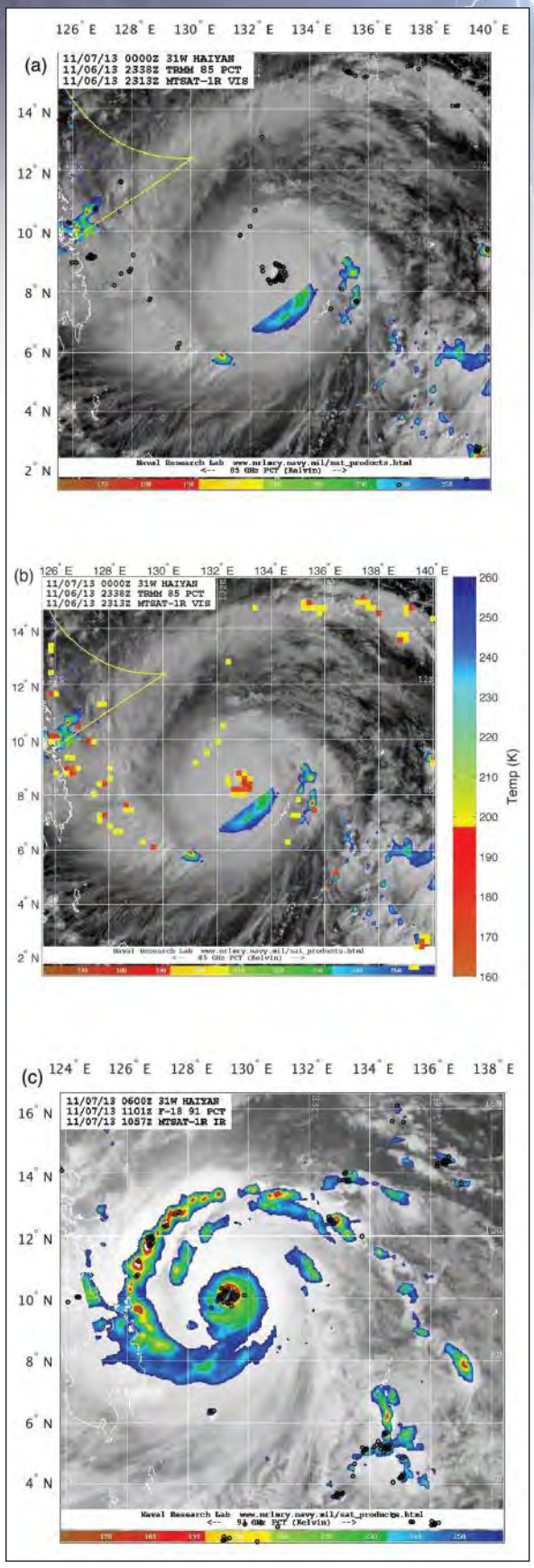


Fig. 5. Reconstruction of satellite data using lightning for Typhoon Haiyan in 2013 at its peak intensity. (a) WWLLN lightning (black circles) and TRMM TMI 85-gigahertz PCT brightness temperatures for a partial pass. (b) WWLLN lightning reconstruction of brightness temperatures for the partial pass. (c) DMSP SSMIS F-18 91-gigahertz PCT brightness temperatures and WWLLN lightning (black circles) 12 hours after the data in Figures 5a and 5b. Images in Figures 5a and 5c are from the WWLLN-TC product.

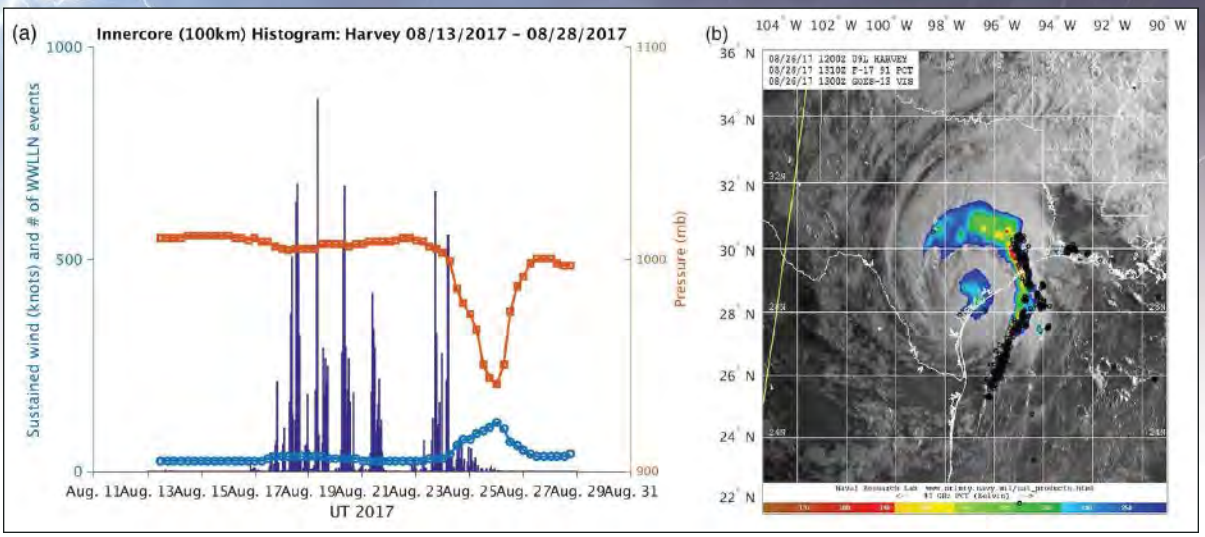


Fig. 6. Hurricane Harvey in 2017. (a) Lightning and intensity histogram and (b) WWLLN lightning (black circles) and SSMIS 91-gigahertz PCT brightness temperatures just after Harvey made landfall on 26 August as a category 4 storm. Credit: WWLLN-TC

example, a pronounced peak in stroke rate was present in the inner core of Hurricane Matthew minutes to hours before it weakened on 6 October, as shown in Figure 3. This peak was a revealing feature of Matthew's final stages.

However, relevant questions linking tropical cyclones and lightning in the inner core remain: Considering the limitations of lightning data, the importance of environmental factors, and the changing climate, how significant is the information provided by episodic discharges in the inner core for forecasting the intensity change? We hope to address these challenges with WWLLN-TC.

Atlantic hurricanes often have a significant peak in inner core lightning preceding rapid weakening.

Microwaves and Lightning

Microwave radiometers are a passive measurement technique; that is, they monitor Earth's own heat energy emissions in the 1- to 200-gigahertz frequency range. Radiometry is a technique complementary to radar, in which the instrument emits a signal and then detects that signal after it bounces off a surface. Microwave radiometry data are used to construct brightness temperatures: an indication of the intensity of electromagnetic energy at a particular wavelength that filters up through the atmosphere and reaches the satellite's sensor.

Mathematical relationships between lightning incidence and microwave-derived brightness temperatures can be used to reconstruct microwave radiometer data where these data are not available. This process can help scientists fill in (to a limited extent) satellite data gaps in areas where WWLLN finds lightning [*Solorzano et al.,* 2016], as shown in Figure 5 for Typhoon Haiyan in the western North Pacific in 2013.

The TRMM satellite provided an incomplete pass of Typhoon Haiyan on 6 November 2017. Lightning data enabled reconstruction of the TRMM Microwave Imager (TMI) sensor brightness temperatures at the peak intensity of the storm. With the reconstruction, we can now identify regions in the inner core and rainbands that have large amounts of cloud ice, including a ring pattern at the inner core.

For forecasters, it is important to fill in those gaps because brightness temperatures are often used to estimate precipitation in tropical cyclones, along with rapid intensification or weakening. For example, a recent study has shown that ring patterns of microwave brightness temperature depressions in the inner core, like we see in Typhoon Haiyan in Figures 5 and 2c, are associated with intensity change [*Harnos and Nesbitt,* 2016].

WWLLN-TC has many other potential uses, most of them focusing on the observation and reconstruction of cloud data.

The 2017 Atlantic Hurricane Season

The hurricane season of 2017 was one of the worst on record, as one hurricane after another made its way across the Caribbean islands and drenched the U.S. Gulf Coast. WWLLN-TC was on the job: The network provided real-time monitoring of Hurricane Harvey as it made landfall in southern Texas as a category 4 storm, the strongest tropical cyclone to hit the United States in 12 years. Figure 6 shows a WWLLN-TC lightning and intensity time series and an overlay of microwave and lightning data for Harvey at landfall on 26 August.

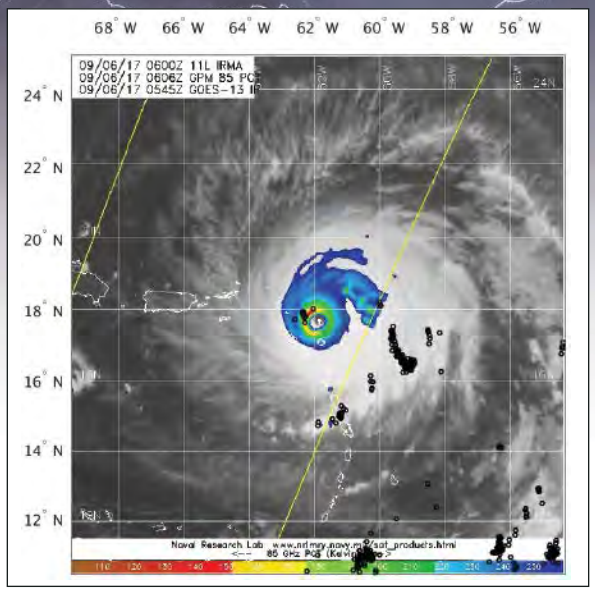


Fig. 7. Hurricane Irma passed over Barbuda on 6 September 2017. Shown here are WWLLN lightning (black circles) and GPM 85-gigahertz PCT brightness temperatures during Irma's maximum intensity as a category 5 storm. Credit: WWLLN-TC

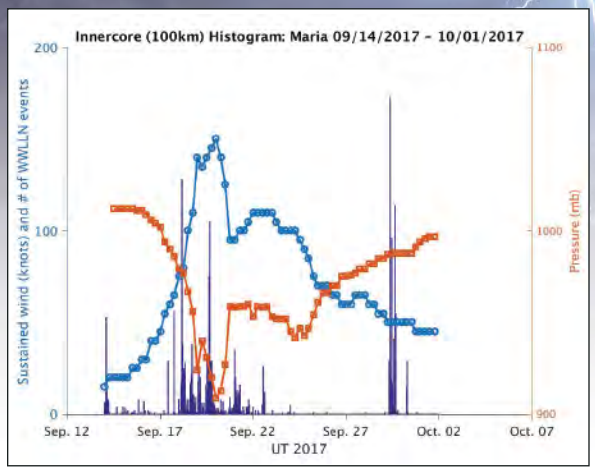


Fig. 8. Lightning and intensity histogram for Hurricane Maria, the most intense tropical cyclone of 2017 and the worst natural disaster on record for Puerto Rico. Credit: WWLLN-TC

Later, on 6 September, another hurricane, Irma, the first category 5 hurricane on record to strike the Leeward Islands, was near maximum intensity when it crossed Barbuda. Figure 7 shows an overlay of lightning and GPM microwave data as the storm's eye passed over Barbuda. Lightning in the eye wall preceded storm weakening and corresponds to cold brightness temperatures sensed by GPM, whereas lightning in the rainbands indicates regions of strong convection that the satellite missed.

Finally, on 20 September, Hurricane Maria made landfall in Puerto Rico, and its category 4 strength winds caused the National Weather Service radar to stop functioning. WWLLN-TC provided a way to monitor the storm's intensity and precipitation continuously while it crossed the island, as shown in the time series in Figure 8. As Maria was pummeling Puerto Rico, NASA researchers expressed to the WWLLN team the usefulness of WWLLN-TC data for tracking convection in the storm.

In the Future

WWLLN-TC, an automated storm-following product for lightning and satellite data, fills crucial data gaps related to tropical cyclones. It also enables a better understanding of precipitation and intensity changes of these storms.

Nonetheless, it is important that we recognize the limitations concerning these data sets and reconstructions. For example, some storms have insignificant lightning counts, which means that reconstructions are not possible.

We plan to progressively incorporate other sources of data, especially unprocessed satellite data, in addition to the satellite images: This feature is currently prototyped. We also plan to provide users with data organized in standard formats (.txt, .mat, netCDF, HDF, etc.) in addition to the image files currently available.

One of our main goals is to obtain input from forecasters and assist them in their preeminent role of predicting tropical cyclone intensity changes. We seek feedback from forecasters, researchers, and other potential users to help improve the visualizations and forecasts. Please contact us with your input and needs.

Acknowledgments

We acknowledge the World Wide Lightning Location Network, a collaboration among more than 50 universities and institutions, managed by Robert Holzworth at the University of Washington, for providing the lightning location data. We acknowledge the U.S. Naval Research Laboratory for providing data on storm tracks, winds, and pressure, as well as the microwave images. We thank Matthew Wendell (DigiPen Institute of Technology) and Carl Christofferson (University of Washington) for technical support and Owen Kelley (NASA) for testing our product.

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Every Vote Counts: Final Slate for 2018 AGU Elections

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

Leaders elected this year will begin their service on 1 January 2019, serving during AGU's Centennial celebration in 2019. The Centennial offers an opportunity to amplify the accomplishments and stories of the past 100 years to build support for the next 100 years of discoveries and solutions, as well as creating greater awareness and appreciation of Earth and space science among policy makers, media, current and prospective funders, and the public.

All regular and student members who joined AGU or renewed their membership by 1 August 2018 are eligible to vote in this election.

When Do the Polls Open?

The 2018 election will be held from 27 August through 25 September, allowing members 30 days to vote. Please mark your calendar and plan now to cast your votes for these critical leadership positions. This is a great opportunity for you to make your voice heard.

> The 2018 AGU election will be held from 27 August through 25 September, allowing members 30 days to vote.

How Many Ballots Will I Receive?

There are three types of ballots for the 2018 election: candidates for the AGU Board of Directors, student and early-career candidates for the AGU Council, and candidates for section president-elect and secretary positions. AGU has a paired-slate philosophy, so two candidates are required for each open position.

All members will receive ballots for the Board (six positions, 12 candidates) and student and early-career positions (four positions, eight candidates). Members will also receive a ballot for every section to which they belong.

How Long Does Voting Take?

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

What Is the Easiest Way for Members to Participate?

This year's election features 114 candidates for 57 open positions. That sounds like a lot, but you have the option to vote for only the positions that matter most to you. Here are some tips for navigating the ballots and casting votes.

1. Identify the positions for which you are eligible to vote, including the AGU Board, the student and early-career positions on the Council, and the officers of the sections to which you belong.
2. Read about the candidates for those positions online, and decide which candidates you prefer.
3. Watch for the email with your log-in information from AGU's election vendor, SBS, starting 27 August. The log-in email will come from AGU Election Coordinator, noreply@directvote.net, and will contain a personalized link for you to vote. Once you are logged in, you will be presented with a menu of all the ballots you are eligible to receive. If you have any questions, you can contact SBS from the voting site or the AGU Member Center (http://bit.ly/agu-member-center).
4. Cast your votes. You can vote in one log-in session or in multiple sessions. The online voting site will allow you to submit votes one ballot at a time until the election closes on 25 September.

Who Is Eligible to Vote?

All regular and student members who joined AGU or renewed their membership by 1 August 2018 are eligible to vote in this year's

election. Please log in to http://www.agu.org to ensure that your membership and section affiliations are up to date.

What Information Is Provided About Candidates?

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

The ballot also includes information on continuing volunteer leaders so that voters have a complete picture of the diversity represented on the Board, on the Council, and in section leadership.

How Were the Candidates on the Ballot Selected?

The Leadership Development/Governance Committee, which I chaired, selected the candidates for the Board and student and early-career candidates on the basis of recommendations from current and past volunteer leaders and AGU staff. Criteria for selection of Board candidates included demonstrated leadership skills and experience in dealing with challenges AGU faces now and will face in the near future. The committee was also committed to ensuring a variety of perspectives in the composition of the overall Board and interviewed potential candidates before making its final selections for the ballot.

Each section is responsible for selecting its candidates. Sections determine their own selection criteria and processes for choosing candidates, with assistance from the Leadership Development/Governance Committee as requested.

Members at large are also given the opportunity via a petition process to nominate additional candidates. No nominations were received.

In keeping with AGU's commitment to advancing scientific ethics, committee members agreed to implement AGU's revised Scientific Integrity and Professional Ethics policy in the nomination and selection process for the 2018 AGU elections. All candidates on the ballot have read AGU's conflict of interest and ethics policies (see http://bit.ly/agu-coi and https://ethics.agu.org/) and submitted disclosure forms.

When Will the Election Results Be Announced?

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

How Can I Participate?

- Watch your email on 27 August for instructions from AGU's election vendor, SBS, or go to https://elections.agu.org and click the button to receive a personalized link to the ballot.
- Identify the ballots you are eligible to receive and take a few minutes now to familiarize yourself with the candidates.
- Vote, and let your voice be heard!

By **Margaret Leinen** (email: pastpresident@agu.org), Past President and Chair, Leadership Development/Governance Committee, AGU

AGU Launches Centennial Celebration

When AGU was founded nearly 100 years ago, the world was a very different place than it is today. However, despite the century's worth of change between 1919 and today, the ability of Earth and space science to improve our society—and the desire of scientists to provide those benefits to humanity—has remained the same.

That's why, as we approach the celebration of our Centennial, we are

- using the energy of the past to start the next transformational era of Earth and space science;
- preparing to connect, inspire, and amplify the voices and contributions of the Earth and space science community for the coming decades; and
- bringing the global community together with the shared goal of transforming Earth and space science to meet the challenges of today and the opportunities of tomorrow.

Centennial festivities will formally commence at AGU's Fall Meeting 2018, which will take place 10–14 December in Washington, D. C. Some exciting programs are already under way, such as the recently launched "100 Facts and Figures."

> We are using the energy of the past to start the next transformational era of Earth and space science.

Public Outreach

From now through the end of December 2019, AGU will be running a series of public outreach campaigns designed to highlight different aspects of Earth and space science, including its diversity, its humanity, and its impact on society (see http://bit.ly/cent-campaigns). These campaigns are also designed to be replicable so that institutions, labs, and other organizations can create versions of the campaign for their own history and tie them in with AGU's Centennial celebration. You can see the beginning of the first campaign, "100 Facts and Figures," by following the Centennial hashtag, #AGU100, on Twitter and Facebook. This evolving collection of groundbreaking facts and figures showcases the history, breadth, and success of geoscience research (see http://bit.ly/100-FFs), as well as the scientists whose work has had, and will have, an impact on people's lives. I encourage you to share these campaigns with your own networks to help us spread the word about AGU's Centennial and the importance of Earth and space science.

AGU 100
ADVANCING EARTH AND SPACE SCIENCE

Science Storytelling

Our science has an immeasurable impact on society. That's why we are focusing on, and encouraging you to join us in, sharing inspiring stories of breakthrough scientific discoveries, amplifying the message of their impact on our global society.

Using historians, professional story gatherers, and public story-sharing opportunities, the AGU Narratives project will feature an array of individuals telling the diverse and captivating stories of how discoveries and careers were made, where inspiration was found, and how challenges big and small were overcome because of advances in science (see http://bit.ly/narr-project).

As part of this project, we have partnered with StoryCorps, which was present at the 2017 Fall Meeting, to record interviews with a number of AGU members and others. Zoe Courville and Lora Koenig's story—"'Mommy, You Can Do That': Navigating Work–Life Balance Thousands of Miles from Home"—was recorded at the 2017 Fall Meeting, then aired live on National Public Radio (listen at http://bit.ly/navig-balance).

We invite you to use the StoryCorps app (see http://bit.ly/stry-crps) to record your own story and upload it to a dedicated AGU Centennial community on the StoryCorps Archive website (see http://bit.ly/s-corps-agu).

Local Engagement

Equally important to hearing the voices of scientists is being able to interact with scientists, which is why we're encouraging our members and colleagues also to consider organizing their own events. AGU's Centennial is about amplifying the accomplishments and stories of the past 100 years to build support for the next 100 years of discoveries and solutions. I call on Earth and space scientists the world over to contribute to that important goal by communicating your science to society and inspiring the world to see how Earth and space science can create a more sustainable future for us all.

We have an array of online tool kits and other resources to help prepare you to engage with a wide variety of audiences. If you or your institution are planning an event in celebration of AGU's Centennial, please let us know by means of this online form: http://bit.ly/cent-event-form. AGU is also offering funding to support such efforts. You can learn more about these competitive grants and apply for funding at http://bit.ly/cent-grants.

A Sample of Our Centennial Programming

AGU's Thriving Earth Exchange (TEX)—which was the first project conceptualized to commemorate the Centennial—continues to help volunteer scientists and community leaders work together to use science to tackle community issues and advance local priorities related to natural hazards, natural resources, and climate change. By 2019, TEX is aiming to launch 100 partnerships, engage more than 100 AGU members, catalyze 100 shareable solutions, and improve the lives of 10 million people (see http://bit.ly/TEX-org).

Similarly, AGU's headquarters building in Washington, D. C., which began its net zero renovation in early 2017, was envisioned as a living embodiment of our mission (see http://bit.ly/AGU-HQ-cent). Now that the renovation is nearing completion, we are excited to have the building help advance understanding of the importance and impact of Earth and space science. The renovated building showcases real-world scientific advancement through innovative, sustainable technology

and a series of Earth and space science exhibits. I can't wait to welcome you into this exciting new space during Fall Meeting 2018.

AGU's journals are home to an exciting Centennial program that is already under way. A set of papers has been commissioned to explore where major research and discovery are needed to address fundamental questions in our understanding of Earth and the solar system. Each paper will review the history of the topic and the current state of knowledge, describing major unanswered questions and challenges and discussing what is needed to achieve the vision or provide solutions over the next decades. AGU will use the collection to showcase our science to policy makers, funders, and the public (see http://bit.ly/gchallenge-papers).

This ever evolving and ever growing celebration is made by and for our community.

Looking Forward to 2019

I am incredibly proud of each and every one of these examples. I'm equally proud to say that they are just one small slice of what AGU and our community have planned in celebration of our Centennial. This ever evolving and ever growing celebration is made by and for our community, and I'm excited to see what kinds of amazing ideas you come up with over the next 18 months.

Be sure to visit the Centennial website (http://bit.ly/cent-home) for the latest information about events, stories, and new ways in which you can participate and lend your voice and energy throughout the year. We have a library of resources to help you plan your own events and be part of the Centennial, as well as inspiring stories from scientists around the world and fascinating information about the history and future of Earth and space science. You can even sign up to become a Centennial volunteer or nominate someone to be interviewed as part of the AGU Narratives project.

Through our Centennial, we step into the next era of scientific discoveries prepared to connect, inspire, and amplify the voices and contributions of this community for decades—even centuries—to come. We look forward to having you join in this journey.

By **Chris McEntee** (email: agu_execdirector@agu.org), Executive Director/CEO, AGU

Eos.org Wins First Prize for Editorial Excellence

Eos.org received a gold EXCEL award for editorial excellence in digital media. Eos *magazine also received a silver and a bronze award for excellence in cover design. Credit: Beth Bagley*

This summer, *Eos* won three EXCEL awards, given by the Association Media & Publishing (AM&P) organization.

Eos.org won the top prize—a gold award—for editorial excellence in digital media. The website, which was launched almost 4 years ago, was judged to have the best overall editorial content and quality of all the websites submitted.

In addition, the April 2017 issue of *Eos* magazine won a silver award for cover photography. The cover depicts a woman climbing a steep and rocky slope, symbolic of the mountain of molehills that women scientists must surmount as they chart career paths through terrain strewn with gender bias.

The December 2017 print issue also won an award for cover photography. The cover, which received a bronze award, showcases Italy's Stromboli volcano, site of a recent effort that used drones to peer into and map the volcano's open vents.

All three awards were given for overall excellence, which means that *Eos* competed against publications of various circulations and reach. The website and the magazine have received a total of 11 awards since they were launched in December 2014 and January 2015, respectively.

Two award-winning Eos *covers. (left) The April 2017 cover won a silver EXCEL award, and (right) the December 2017 cover won a bronze EXCEL award.*

AM&P's website notes that its annual EXCEL awards recognize "excellence and leadership in nonprofit association media, publishing, marketing and communications." AM&P provides support to association publishers, business operations executives, communications professionals, designers, and content generators and the media they create.

By **Mohi Kumar** (@scimohi), Interim Senior News Editor

2018 AGU Section Awardees and Named Lecturers

The 2018 section awardees and named lecturers have been selected. AGU and its leaders wholeheartedly congratulate these awardees!

The selection of our colleagues for these prestigious awards and honors recognizes their sustained and unique contributions to enlightening our understanding of the Earth and its atmosphere and oceans, and of the solar system and exoplanets. The sciences encompassed by AGU are crucial for the health and well-being of our planet's inhabitants. These honorees have contributed to that health and well-being through their scientific advancements and outstanding service to the science and to AGU.

Among the 24 sections of AGU, there are 65 awards; 21 are for early-career scientists (up to 10 years post-Ph.D.) and six are for midcareer scientists (10–20 years post-Ph.D.). Twenty-seven awards provide named lectureships to further disseminate an awardee's meritorious accomplishments.

Named lectures offered by AGU sections recognize distinguished scientists with proven leadership in their fields of science. AGU inaugurated the Bowie Lecture in 1989 to commemorate the fiftieth presentation of the William Bowie Medal, which is named for AGU's first president and is the highest honor given by the organization. The 2018 Bowie Lecturers are denoted by asterisks in the list below. We look forward to attending as many of these lectures as possible at Fall Meeting 2018.

Many thanks to the nominators, nomination supporters, and section leaders, and particularly to the selection committees, for their important work in selecting these well-deserving colleagues. We thank you all for your continued commitment to the AGU Honors Program, and we look forward to recognizing the honorees and their achievements at AGU's Fall Meeting 2018 in Washington, D. C.

By **Robin Bell,** President-elect and Council Chair, AGU; and **Mary Anne Holmes** (email: AGU_Unionhonors@agu.org), Chair, Honors and Recognition Committee, AGU

Atmospheric Sciences Section

Atmospheric Sciences Ascent Award
Matthew Huber, Purdue University
Yi Ming, Geophysical Fluid Dynamics Laboratory, National Oceanic and Atmospheric Administration
David M. Romps, University of California, Berkeley
Joel A. Thornton, University of Washington

James R. Holton Award
Angel Francisco Adames-Corraliza, University of Michigan

Yoram J. Kaufman Unselfish Cooperation in Research Award
Daniel Rosenfeld, Hebrew University of Jerusalem

*Jacob Bjerknes Lecture**
Peter J. Webster, Georgia Institute of Technology

*Jule Gregory Charney Lecture**
Paul A. Newman, NASA Goddard Space Flight Center

Future Horizons in Climate Science: Turco Lectureship
Jennifer E. Kay, University of Colorado Boulder

Biogeosciences Section

Sulzman Award for Excellence in Education and Mentoring
Emily M. Elliott, University of Pittsburgh

Cryosphere Sciences Section

Cryosphere Early Career Award
Ludovic Brucker, Universities Space Research Association GESTAR and Cryospheric Sciences Laboratory, NASA Goddard Space Flight Center

John F. Nye Lecture
Jacqueline Richter-Menge, U.S. Arctic Research Commission and University of Alaska Fairbanks

Earth and Planetary Surface Processes Section

G. K. Gilbert Award in Surface Processes
Ellen Wohl, Colorado State University

Luna B. Leopold Young Scientist Award
Jill A. Marshall, University of Arkansas

Robert P. Sharp Lecture
Jill A. Marshall, University of Arkansas

Earth and Space Science Informatics Section

Greg Leptoukh Lecture
Benjamin J. K. Evans, Australian National University

Geodesy Section

Geodesy Section Award
Thomas Hobiger, University of Stuttgart

Ivan I. Mueller Award for Distinguished Service and Leadership
Richard S. Gross, NASA Jet Propulsion Laboratory

*William Bowie Lecture**
Byron D. Tapley, University of Texas at Austin

Geomagnetism, Paleomagnetism, and Electromagnetism Section

William Gilbert Award
Lennart V. de Groot, Utrecht University

*Edward Bullard Lecture**
Lisa Tauxe, Scripps Institution of Oceanography

Global Environmental Change Section

Bert Bolin Global Environmental Change Award and Lecture
Donald J. Wuebbles, University of Illinois at Urbana-Champaign

Global Environmental Change Early Career Award
George A. Ban-Weiss, University of Southern California
Rajan K. Chakrabarty, Washington University in St. Louis
Kaiyu Guan, University of Illinois at Urbana-Champaign

Piers J. Sellers Global Environmental Change Mid-Career Award
Markus Reichstein, Max Planck Institute for Biogeochemistry, Michael-Stifel-Center Jena for Data-Driven and Simulation Science

Stephen Schneider Lecture
Stephen E. Schwartz, Brookhaven National Laboratory

Tyndall History of Global Environmental Change Lecture
Inez Y. Fung, University of California, Berkeley

Hydrology Section
Hydrologic Sciences Early Career Award
Yoshihide Wada, International Institute for Applied Systems

Hydrologic Sciences Award
Bridget R. Scanlon, University of Texas at Austin

*Walter B. Langbein Lecture**
Dani Or, ETH Zurich Swiss Federal Institute of Technology

Paul Witherspoon Lecture
Elizabeth W. Boyer, Pennsylvania State University

Horton Research Grant
Frederick Y. Cheng, University of Waterloo
Caio Reis Costa Mattos, Rutgers University
Brianna R. Pagán, Ghent University

Mineral and Rock Physics Section
Mineral and Rock Physics Early Career Award
Zhu Mao, University of Science and Technology of China

Mineral and Rock Physics Graduate Research Award
Earl F. O'Bannon III, Lawrence Livermore National Laboratory
Esther Posner, Bayerisches Geoinstitut, Universität Bayreuth
Natalia Solomatova, École Normale Supérieure de Lyon

John C. Jamieson Student Paper Award
Christopher J. Cline II, NOVA Geotechnical

Natural Hazards Section
Natural Hazards Section Award for Graduate Research
Edward Max Brooks, Northwestern University

Gilbert F. White Distinguished Award and Lecture
Lucile Jones, Dr. Lucy Jones Center for Science and Society

Near-Surface Geophysics Section
GSSI Near-Surface Geophysics Student Grant
William Hardy Kochtitzky, University of Maine

Nonlinear Geophysics Section
Donald L. Turcotte Award
Meredith Plumley, University of Colorado Boulder
Ed Lorenz Lecture
V. Krishnamurthy, George Mason University

Ocean Sciences Section
Ocean Sciences Voyager Award
Andréa G. Grottoli, Ohio State University

Rachel Carson Lecture
Claire B. Paris-Limouzy, Rosenstiel School of Marine and Atmospheric Science, University of Miami

William S. and Carelyn Y. Reeburgh Lecture
Allan Devol, University of Washington

Harald Sverdrup Lecture
Raymond Schmitt, Woods Hole Oceanographic Institution

Paleoceanography and Paleoclimatology Section
Willi Dansgaard Award
Bärbel Hönisch, Lamont-Doherty Earth Observatory of Columbia University

Harry Elderfield Outstanding Student Paper Award
Kassandra Costa, Columbia University

Nanne Weber Early Career Award
Haojia Abby Ren, National Taiwan University

Planetary Sciences Section
Ronald Greeley Early Career Award in Planetary Sciences
Brandon C. Johnson, Brown University

Fred Whipple Award and Lecture
Philip R. Christensen, Arizona State University

*Eugene Shoemaker Lecture**
Carol A. Raymond, Jet Propulsion Laboratory, California Institute of Technology

Seismology Section
Keiiti Aki Young Scientist Award
Lingling Ye, Sun Yat-sen University

*Beno Gutenberg Lecture**
William Ellsworth, Stanford University

Space Physics and Aeronomy Section
Basu United States Early Career Award for Research in Sun-Earth Systems Science
Julia E. Stawarz, Imperial College London

Fred L. Scarf Award
Aleida K. Higginson, University of Michigan

Space Physics and Aeronomy Richard Carrington Education and Public Outreach Award
Patricia Doherty, Boston College

Sunanda and Santimay Basu (International) Early Career Award in Sun-Earth Systems Science
Zama T. Katamzi-Joseph, South African National Space Agency

*Eugene Parker Lecture**
David J. McComas, Princeton University

*James Van Allen Lecture**
Fran Bagenal, University of Colorado Boulder

Study of the Earth's Deep Interior Section
Study of the Earth's Deep Interior Graduate Research Award
Jie Deng, Yale University
Ross Maguire, University of Michigan

Tectonophysics Section
Jason Morgan Early Career Award
Ylona van Dinther, ETH Zurich and Utrecht University

*Francis Birch Lecture**
Carolina R. Lithgow-Bertelloni, University of California, Los Angeles

Volcanology, Geochemistry, and Petrology Section
Hisashi Kuno Award
Leif Karlstrom, University of Oregon

Norman L. Bowen Award and Lecture
Timothy Druitt, University of Clermont-Auvergne
Steven Goldstein, Columbia University

*Reginald Day Lecture**
Nicolas Dauphas, University of Chicago

Joint Award: Geodesy, Seismology, and Tectonophysics Sections
Paul G. Silver Award
Harold J. Tobin, University of Wisconsin-Madison and University of Washington

Joint Prize: Nonlinear Geophysics and Space Physics and Aeronomy Sections
Space Weather and Nonlinear Waves and Processes Prize
Robert Bruno, Istituto di Astrofisica e Planetologia Spaziali

Joint Lecture: Biogeosciences and Planetary Sciences Sections
Carl Sagan Lecture
Ken Caldeira, Carnegie Institution for Science

Joint Lecture: Paleoceanography and Paleoclimatology and Ocean Sciences Sections
Cesare Emiliani Lecture
Jean Lynch-Stieglitz, Georgia Institute of Technology

Joint Student Grant: Atmospheric Sciences and Space Physics and Aeronomy Sections
Edmond M. Dewan Scholarship
Lena Heuscher, University of Alabama in Huntsville

A Near-Real-Time Tool to Characterize Global Landslide Hazards

A new model that predicts the potential for rain to trigger landslides in near-real time may become an important tool for assessing potential hazards and expediting emergency responses to events like this 2005 landslide in Conchita, Calif., that killed 10 people. Credit: Mark Reid, USGS

Unlike earthquakes, cyclones, volcanic eruptions, and other natural disasters that are observed in real time by worldwide networks of satellites and sensors, landslides and other types of mass movement are not consistently monitored on a global scale, despite their widespread occurrence and strong likelihood of causing fatalities and disrupting critical infrastructure. This is due, in part, to the challenges of monitoring events that occur across a wide range of settings, lithologies, and climatic zones; that are triggered by both anthropogenic and natural factors; and whose volumes can span 10 orders of magnitude.

To help fill this gap, *Kirschbaum and Stanley* have developed a system that generates near-real-time estimates of potential rainfall-triggered landslide activity. Their Landslide Hazard Assessment for Situational Awareness (LHASA) model melds information regarding slope, lithology, deforested areas, and proximity to fault zones and roads to derive a map of landslide susceptibility, which is then combined with satellite-derived estimates of precipitation from the past week to develop "nowcasts" of areas that are susceptible to landslides.

When compared with a previously compiled landslide inventory, retrospective moderate- and high-hazard nowcasts coincided with a cataloged landslide up to 60% of the time. The team found that increasing the window between the issuance of a nowcast and the occurrence of a landslide from 1 to 3 days and also increasing the area involved raised the likelihood of detection by more than 10%. The authors attribute this improvement to multiple factors, including time zone differences and difficulties in pinpointing exactly where a landslide started.

The authors caution that the current version of the model has several inherent limitations, including an inability to detect landslides at high latitudes, due to shortcomings in the precipitation data, with the model considering only information between 50°N and 50°S. The nowcasts are also unlikely to predict landslides caused by factors not attributable to rainfall, such as earthquakes, freeze-thaw processes, extreme temperatures, and anthropogenic activities. Despite these limitations, the LHASA model represents an important step forward in our ability to routinely estimate potential landslide activity around the globe, the results of which may be used to support hazard assessments and study long-term trends in landslide distribution. (*Earth's Future*, https://doi.org/10.1002/2017EF000715, 2018) **—Terri Cook, Freelance Writer**

Studying Soil from a New Perspective

The study of soil moisture (defined as the amount of water held between soil particles) can be important for improving agricultural productivity, predicting floods and droughts, understanding Earth's weather and climate, and more. The amount of moisture in topsoil depends on land surface characteristics (e.g., soil texture) and recent weather conditions, like rainfall. Several prior studies have suggested that small-scale soil moisture patterns, which span roughly 3–30 meters, are influenced mainly by land surface characteristics. Large-scale patterns, which span from 1.5 kilometers to hundreds of kilometers, are influenced mainly by weather conditions.

However, a new study by *Dong and Ochsner* shows that these relationships are more complex. Past soil moisture studies have been limited by the area of land sensed by their measurement devices, as well as by the average and maximum distances between measurements. Traditional sensors installed in the soil excel at small-scale data collection, whereas satellite-based sensors are powerful tools for observing large-scale soil moisture patterns, but there are major gaps in data and understanding at the mesoscale—between about 1 kilometer and 100 kilometers.

The researchers applied the cosmic ray neutron method using a mobile neutron sensor called a rover to detect fast moving neutrons just above the ground—neutrons generated when cosmic rays interact with the atmosphere and Earth's surface. These fast neutrons can be slowed by collisions with hydrogen molecules in the water held by moist soil; the neutrons penetrate to anywhere between 15 and 55 centimeters deep. In this way, researchers can determine soil moisture of the surrounding landscape on the basis of the number of fast neutrons measured by the rover.

To determine the scale at which soil moisture is most affected by soil texture (as opposed to by rainfall), the researchers deployed the rover along 150 kilometers of unpaved public roads in the Great Plains, where soil ranges from sand to clay. Over roughly a year, the rover collected data on soil moisture patterns at the mesoscale a total of 18 times. The researchers also compiled radar-based rainfall data along the rover path. In all but one instance, they found that soil moisture patterns were more closely tied to variations in sand content than to variations in rainfall.

Former Oklahoma State University undergraduate research assistant Phillip Pope prepares a rover used to collect soil moisture data. Credit: Jingnuo Dong

This study offers a unique, detailed set of soil moisture data. It also shows that although the drivers of soil moisture at the mesoscale varied, it was generally more affected by soil texture than by rainfall. These findings have the potential to refine conceptual models about spatial patterns in soil moisture and to improve future studies in soil science, hydrology, and other fields. (*Water Resources Research,* https://doi.org/10.1002/2017WR021692, 2018) **—Sarah Witman, Freelance Writer**

A Novel Way to Map Debris Thickness on Himalayan Glaciers

The accelerated melting of Himalayan glaciers—vital sources of water for more than 800 million people—is anticipated to cause acute regional water shortages by 2050 as frozen stores of water disappear. How these glaciers will respond to a changing climate depends in part on the depth of the rock debris that covers up to 18% of their surfaces; a layer of debris less than a few centimeters thick enhances melting, whereas a deeper layer insulates the ice, reducing the amount of melt. Accurately quantifying the thickness of this debris remains a major challenge, however, especially on a glacier-wide scale.

Rounce et al. have developed a new method to remotely determine this metric. Using pairs of satellite-acquired, high-resolution digital elevation models gathered during different time intervals, the team calculated the changes in elevation and surface velocity for Nepal's Ngozumpa glacier and then combined the results with local meteorological data to estimate surface debris thickness.

The researchers validated the results by comparing them with two sets of previously collected field measurements and found that the debris thickness decreased higher up the glacier. The new method performed well across both stagnant and active portions of the ice. The researchers then applied this technique to two additional glaciers in the Mount Everest region, including Khumbu, whose maximum calculated debris thickness of 1.89 meters is in close agreement with a 1986 estimate of 2 meters that was based upon 50 field measurements.

This study is the first to validate estimates of glacial debris thickness with multiple independent data sets on a basin scale and thus represents an important advance in the field of glaciology. This method, which should be widely applicable, represents a significant improvement in glaciologists' ability to model the evolution of debris-covered Himalayan glaciers and changes in the availability of the crucial water they provide. (*Journal of Geophysical Research: Earth Surface,* https://doi.org/10.1029/2017JF004395, 2018) **—Terri Cook, Freelance Writer**

Toward More Realistic Modeling of the Mesosphere

When the atmosphere is disturbed, gravity waves ripple through the air, similar to ripples on the surface of a lake. Unlike ripples, however, gravity waves can propagate to very high altitudes, where they interact and dissipate. Gravity waves can have very large effects on the weather at these altitudes, even changing the direction of the wind. Scientists have struggled to accurately model these waves, however, which adds to the challenge of predicting weather on Earth's surface. To improve forecasts, modelers will need to explore the details of how gravity waves propagate, interact, and dissipate in the upper atmosphere.

In a new study, *Fritts et al.* modeled how gravity waves travel through the mesosphere, a layer of the atmosphere between 50 and 90 kilometers above Earth, and the thermosphere, the layer extending from 90 kilometers to much higher altitudes. Gravity waves reach much larger amplitudes in the cold, thin air of the mesosphere than they do closer to Earth: as much as 10 times or more larger. The large amplitudes cause them to break, like ocean waves on a beach. This generates strong turbulence and deposits large amounts of energy and momentum, which strongly influence the local environment.

The team focused on mesospheric inversion layers (MILs)—layers of the atmosphere that can be hundreds or thousands of kilometers wide—in which temperatures rise, rather than fall, with increasing altitude. These inversions can arise when gravity waves and larger planetary waves mix layers of air, which influences the propagation of new gravity waves entering these layers.

The team simulated what happens when gravity waves encounter an MIL. They found that when large-amplitude waves encounter MILs, atmospheric instability and turbulence develop at lower altitudes than normal, an important general finding with regard to weather close to Earth's surface. Smaller waves tended to pass through the inversions without losing fidelity or were merely partially reflected by them. Yet transmission also depended on the MIL itself: Waves could go farther through weak inversions, for example, whereas strong, deeper mesospheric inversions tended to pose a bigger obstacle.

The findings will help researchers more accurately model how energy travels through the whole atmosphere and will contribute to advances for predicting weather. Yet there is still a long way to go, the authors caution. One pressing challenge, for example, is to understand how gravity waves are likely to drive atmospheric dynamics as Earth's climate changes. (*Journal of Geophysical Research: Atmospheres,* https://doi.org/10.1002/2017JD027440, 2018) **—Emily Underwood, Freelance Writer**

Mysterious Aurora Borealis Feature Explained for the First Time

Roughly every other day at the Arctic Yellow River Station in Svalbard, Norway, astronomers observe a mysterious feature of the aurora borealis, the glowing ring of energetic particles around Earth's North Magnetic Pole. The equatorward edge of the aurora briefly erupts in a fanning starburst of light, which can span roughly 15,000 kilometers in length.

Scientists think that this display, called a throat aurora, results from high-speed jets of solar particles slamming into the outer boundary of Earth's magnetic field. It's well known that such jets can make temporary indentations in the magnetosphere, causing charged particles to collide and release energy as light. However, little direct evidence for such a connection to throat auroras has been found to date.

Establishing the link requires collecting satellite and on-the-ground measurements simultaneously, a tricky technical feat. To overcome that challenge, *Han et al.* pointed high-powered digital cameras in Svalbard at the same region of space that NASA's Magnetospheric Multiscale Mission spacecraft would pass through as it approached the magnetopause, the boundary between Earth's magnetic field and space. In January 2016, they captured a series of images of throat auroras from the ground while measuring fluctuations in Earth's magnetic field from space.

The throat auroras lined up beautifully with surges of solar energy into the magnetosphere, in a one-to-one correspondence, they found. Big jets of solar particles appeared to produce large throat auroras, whereas smaller ones led to fainter flares. This strong relationship suggests that throat auroras could be used as reliable signatures of disturbance in Earth's magnetic field, according to the researchers.

Photo of an aurora borealis taken from the cupola window of the International Space Station on 9 December 2014. Credit: ESA/NASA

Such indicators could help predict space storms, which can disrupt global communication networks. (*Journal of Geophysical Research: Space Physics,* https://doi.org/10.1002/2017JA024945, 2018) **—Emily Underwood, Freelance Writer**

Constraining Central Washington's Potential Seismic Hazard

Yakima Canyon in central Washington, where the Yakima River has incised through active fault-cored anticlines. The photograph was taken from the north facing limb of the Manastash Ridge anticline, looking southward into the canyon. The Umtanum Ridge anticline is visible in the background. Credit: L. M. Staisch

Off the United States' northwestern coast, the Juan de Fuca plate is diving beneath North America along the Cascadia subduction zone. Ensuing crustal shortening has created the Yakima Fold Province, a seismically active region in central Washington where deformation is focused along a series of arch-shaped anticlinal folds. The relative timing and rate of deformation along individual structures in this region are still poorly constrained, however, despite its potential to unleash earthquakes at least as powerful as the *M*6.8 Entiat event, which occurred there in 1872.

To better understand the province's tectonic history, *Staisch et al.* used several independent but complementary methods to analyze the signatures of deformation focused along three anticlines in the Yakima Canyon region. By using stream profile inversions, balanced cross sections, and geophysical mapping techniques, the team was able to constrain local slip rates and fault geometries and use the results to calculate the amount of time required for each fault to accumulate enough strain to rupture.

The results indicate that stream incision rates accelerated during the Pleistocene, a change the team attributes to tectonically driven uplift rather than to climate. The researchers also estimate that modern slip rates range between 0.4 and 0.5 millimeter per year, with motion accommodated along reverse faults coring each anticline, and that the region has been compressed by a total of 3.5 kilometers (11.5%) since the mid-Miocene.

The team's calculations indicate that large earthquake events ($M \geq 7$) could recur as often as every 200–6,000 years on faults within the fold province, a region that was previously considered aseismic. This study demonstrates how independent analyses of various data sets can complement one other and collectively improve our understanding of deformation history, as well as help estimate potential hazards, in seismically active regions. (*Tectonics*, https://doi.org/10.1029/2017TC004916, 2018) **—Terri Cook, Freelance Writer**

Atmospheric Sciences

COLORADO STATE UNIVERSITY

ATMOSPHERIC SCIENCE TENURE TRACK FACULTY POSITION

The Department of Atmospheric Science at Colorado State University invites applications for a tenure-track faculty position in the dynamics and physics of the climate system. We solicit candidates with expertise in geophysical fluid dynamics, coupling between clouds and radiation, climate dynamics, and/or planetary atmospheres across a range of spatial and temporal scales. Candidates will be considered at the assistant or associate professor level.

The new faculty member will be expected to build and maintain a strong, internationally recognized research program supported through external funding, complement and expand upon current research and teaching activities, and provide service to the University and broader community. She/he will contribute to teaching and intellectual leadership in our atmospheric science curriculum at the M.S. and Ph.D. levels by teaching courses in the Department's core graduate curriculum, advising graduate students, and developing advanced courses in his or her areas of expertise. Further information about the Department can be found at http://www.atmos.colostate.edu.

A Ph.D. in atmospheric science or a related field is required by the position start date. Candidates should have an outstanding research record in the areas of interest commensurate with experience and should demonstrate potential for continued extraordinary scholarship. Candidates must exhibit ability and enthusiasm to teach courses in their respective areas of interest in the Department's graduate curriculum. Reflecting departmental and institutional values, candidates are expected to have the ability to advance the Department's commitment to diversity and inclusion.

Applications and nominations will be accepted until the positions are filled; however, applications should be received by October 1, 2018 to ensure full consideration. The search will remain open until the position is filled. Application materials of candidates, including letters of recommendation, will only be made available for review by the broader faculty of the Department of Atmospheric Science if the applicant reaches the semifinalist stage. Applicants should submit a cover letter, one to two page statements on research and teaching interests, a diversity statement, a curriculum vitae, and the names of four references (who will not be contacted without prior notification of the candidate) at the following link: http://jobs.colostate.edu/postings/58106

RICE | EEPS
Earth, Environmental and Planetary Sciences

Wiess and Pan Post-Doctoral Research Fellowships
Department of Earth, Environmental and Planetary Sciences, Rice University

The Department of Earth, Environmental and Planetary Sciences at Rice University is inviting applications for the Wiess and the Pan Postdoctoral Research Fellowships. We are seeking candidates with independent research interests that intersect with one or more faculty within our department. Both domestic and international applicants are welcome, but applicants must have a Ph.D. awarded within three years of the time of appointment.

The research fellowships will be supported for two years, pending satisfactory progress during the first year, and covers an annual stipend of $60,000 with a benefits package and an additional annual discretionary research allowance of $3,500.

Applicants are requested to develop a proposal of research to be undertaken during the fellowship period. The principal selection criteria are scientific excellence, a clearly expressed research plan to address questions at the forefront of their field of study, and research synergies with at least one faculty. The proposed research should, however, encompass independent research ideas and explore new directions beyond the applicant's Ph.D. Preference will be given to applicants whose proposals demonstrate independence and originality, and also the potential for collaboration with one or more faculty in the Department of Earth, Environmental and Planetary Sciences.

The application for both fellowships is due on 1 November, 2018. Applicants are required to submit one application only at http://jobs.rice.edu/postings/15058. The application should include the following documents:

(1) A cover letter.
(2) A research proposal of no more than 3 pages (not counting references) of single-spaced text and figures.
(3) A current CV, including a list of publications.

As part of the online application, the applicant will also have to provide the names and contact information of three or more people who will be asked to submit reference letters by the same deadline.

The highest ranked applicants will be invited to visit Rice in early 2019. Following acceptance, the appointment may begin anytime before 1 January, 2020. For further information or questions contact the chair of the search committee at esci-postdoc@rice.edu.

Rice University is located in Houston, Texas, and is a private, coeducational, nonsectarian university that aspires to path-breaking research, unsurpassed teaching, and contributions to the betterment of our world. Rice fulfills this mission by cultivating a diverse community of learning and discovery that produces leaders across the spectrum of human endeavor.

Rice University is an Equal Opportunity Employer with commitment to diversity at all levels, and considers for employment qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national or ethnic origin, genetic information, disability or protected veteran status.

https:/earthscience.rice.edu/open-positions/

Please address inquiries about the position to:

Professor David Thompson, Search Chair
Department of Atmospheric Science
Colorado State University
Fort Collins, CO
80523-1371
david.thompson@colostate.edu

Colorado State University (CSU) strives to provide a safe study, work, and living environment for its faculty, staff, volunteers and students. To support this environment and comply with applicable laws and regulations, CSU conducts background checks. The type of background check conducted varies by position and can include, but is not limited to, criminal (felony and misdemeanor) history, sex offender registry, motor vehicle history, financial history, and/or education verification. Background checks will be conducted when required by law or contract and when, in the discretion of the university, it is reasonable and prudent to do so.

Colorado State University is committed to providing an environment that is free from discrimination and harassment based on race, age, creed, color, religion, national origin or ancestry, sex, gender, disability, veteran status, genetic information, sexual orientation, gender identity or expression, or pregnancy. Colorado State University is an equal opportunity/equal access/affirmative action employer fully committed to achieving a diverse workforce and complies with all Federal and Colorado State laws, regulations, and executive orders regarding non-discrimination and affirmative action. The Office of Equal Opportunity is located in 101 Student Services.

Two tenured/tenure-track faculty positions at Texas A&M University

The Department of Atmospheric Sciences at Texas A&M University is searching for candidates in the areas of atmospheric chemistry, aerosol science, physical meteorology, remote sensing and instrumentation, "big data" science, high-performance computing, extreme event attribution, boundary layer meteorology, or microphysics. Candidates working in other areas of atmospheric sciences that complement the current strengths of the department are also invited to apply. We anticipate filling two tenured or tenure-track positions—one of the positions at the associate or full professor level, while the other could be filled at any rank.

The successful candidates will be expected to establish and maintain an independent and externally funded research program and contribute to transformative teaching at the undergraduate and graduate levels. Applicants must have a Ph.D. in atmospheric sciences or a related field at the time of appointment. Postdoctoral experience is desirable but is not required. Applicants seeking appointment at the associate or full professor rank must be recognized leaders in the field with a record of scholarship and teaching commensurate with their rank.

Information about the Department of Atmospheric Sciences can be found at: https://atmo.tamu.edu/. The Department of Atmospheric Sciences is part of the College of Geosciences, which also houses the Departments of Geology and Geophysics, Geography, and Oceanography, and the interdisciplinary Environmental Programs and Water Management and Hydrologic Sciences degree programs. The College of Geosciences also includes the International Ocean Discovery Program and Texas Sea Grant, among numerous other interdisciplinary centers. Texas A&M University is a land- sea- and space-grant university, with a dynamic and international community of over 250,000 people. The Texas A&M System is an Equal Opportunity/Affirmative Action/Veterans/Disability Employer committed to diversity. Texas A&M University and the College of Geosciences are highly responsive to the needs of dual-career partners.

To apply, please submit your CV, statement of research, and teaching interests, and names and contact information for at least three references to: https://apply.interfolio.com/51962

Informal inquiries or requests for more information may be sent via email directly to the Search Committee Chair:

Prof. Andrew E. Dessler
Chair, Faculty Search Committee
Department of Atmospheric Sciences
Texas A&M University
College Station, TX 77843-3150
Email: adessler@tamu.edu

The position will remain open until suitable candidates are found. Initial review of application will begin on September 1, 2018

Biogeosciences

Assistant Professor Position in Soil Microbiomics

Assistant Professor Position in Soil Microbiomics, The Pennsylvania State University-University Park, College of Agricultural Sciences, Department of Ecosystem Science and Management. This position will constitute a 75% research, 25% teaching appointment in the Department, which houses the soil science program within a broader interdisciplinary unit. The Department seeks candidates interested in conducting research to understand the distribution, composition, diversity, and functional impact of microbial communities in soil-plant habitats. A successful applicant will have a Ph.D. in a relevant scientific field and a documented track-record of experience with soil microbiome or environmental sample analyses with high-dimensional data from metagenomics, metatranscriptomics, or metabolomics investigations. Successful applicant will have demonstrated abilities to 1) develop a strong, independent research program by securing extramural support and training graduate students; 2) engage in the highly collaborative Penn State research environment; and 3) teach undergraduate and graduate courses supporting soil science and related fields. Applicant should submit cover letter, current CV, statement of research interests, statement of teaching philosophy, transcripts of undergraduate and graduate degrees and names and contact information for three individuals who can provide references. All applications must be loaded into https://psu.jobs/job/80110. For any questions, please contact either Dr. Richard Stehouwer (rcs15@psu.edu) or Dr. Mary Ann Bruns (mvb10@psu.edu), Department of Ecosystem Science and Management, Penn State University. Applications will be reviewed beginning September 1, 2018 and the search will continue until the position is filled.

Global Environmental Change

Tenure-Track Assistant, Associate, or Full Professor in Climate Change

The Institute at Brown for Environment and Society (IBES)—jointly with the Departments of Anthropology; Earth, Environmental and Planetary Sciences (DEEPS); Ecology and Evolutionary Biology; Epidemiology; and Sociology—invites applications from rising leaders in the natural, socio-economic, public health, and environmental justice aspects of climate change.

This open rank search will seek to fill between 2 and 4 endowed university chairs with a tenure home in any of the participating departments. The endowed chairs are named faculty positions that include a small fund in perpetuity (in addition to start up funds) to assist chair holders in achieving their research and teaching goals. We are particularly interested in scholars who demonstrate research excellence, an interest in working to promote diversity and inclusion in environmental disciplines, and a dedication to teaching and research mentoring. The successful applicant will have an outstanding record of research and teaching that complements the strengths of both DEEPS and IBES, while demonstrating the potential to work across both units. The ideal candidate is likely to be a senior assistant or associate professor (or equivalent rank).

DEEPS seeks to build on current strengths in climate change and related sciences. Examples of research areas of interest include: modeling and observation of past, present and future climate; coastal environments and geomorphology; sea level change-

Swiss Federal Institute for Forest, Snow and Landscape Research WSL

The Swiss Federal Institute for Forest, Snow and Landscape Research WSL is part of the ETH Domain. It employs approximately 500 people working on the sustainable use and protection of the landscapes and habitats and a responsible approach to handling natural hazards. Please find further information on our homepage **www.wsl.ch.**

To facilitate international collaboration we invite up to 6 scientists a year to join the thriving community of research scientists in Birmensdorf, Davos, Lausanne or Bellinzona as a

Visiting Fellow in Switzerland

Photo: Markus Bolliger

You will work in innovative interdisciplinary science projects with collaborators of WSL and make significant contributions to the advancement of environment research. Furthermore, you will connect with, work with, or learn from world-class researchers across many scientific disciplines and contribute to critical environmental research that can improve lives and decisions.

You are faculty on leave or sabbatical, or research scientists on leave. You will get financial support to help cover additional costs while staying at WSL. Your application needs to be accompanied by a letter of support of one of our research units. For detailed information please consult your colleagues at WSL as well as the respective fact sheet you can get from them.

Please send your complete application online to Human Resources WSL on www.wsl.ch/fellowship. Deadline for applications is 31 October 2018. Fellowships can start as early as summer 2019.

including oceanography, glaciology, geophysics, and paleo-records; carbon cycling and biogeochemistry; water cycling, sustainability, and hydrogeochemistry; planetary climates; and remote sensing. Candidates whose work involves natural sciences of climate change in conjunction with societal aspects—such as hazards, resources, sustainability, and equity—are of particular interest.

Applicants must have a PhD at the time of starting work. Candidates should submit a teaching statement; a research statement; a diversity and inclusion statement; a CV; two writing samples (e.g., journal article, book prospectus, or book chapter); and a cover letter describing their interest in the position. Candidates currently holding tenured faculty positions should provide the names of three referees; these referees will not be contacted without prior authorization from the candidate. Candidates that do not currently hold a tenured faculty position should have three letters of reference submitted before the application deadline. Interested candidates should feel free to contact Prof. Greg Hirth (Greg_Hirth@brown.edu) for further information.

Full consideration will be given to applications received by October 1st, 2018, but we will continue to accept applications until the position is filled. Brown is an equal opportunity/affirmative action employer, and women and minorities are strongly encouraged to apply. Send materials to: http://apply.interfolio.com/50691

Brown University is committed to fostering a diverse and inclusive academic global community; as an EEO/AA employer, Brown considers applicants for employment without regard to, and does not discriminate on the basis of, gender, race, protected veteran status, disability, or any other legally protected status.

Hydrology

HYDROGEOLOGISTS – Geohydrology Section – Kansas Geological Survey – The University of Kansas, Lawrence.

Two full-time positions to lead KGS hydrogeochemical and groundwater hydrology investigations. Faculty-equivalent, sabbatical-eligible positions at the rank of Assistant or entry-level Associate Scientist. Requires Ph.D. with an emphasis on 1) aqueous geochemistry related to groundwater resources or 2) groundwater hydrology of sedimentary aquifer systems, and scientific leadership potential. Emphasis on state-of-the-science field studies and complementary theoretical research. Complete announcement/application info at www.kgs.ku.edu/General/jobs.html. Review of applications will begin Oct. 15, 2018.

Apply online at http://employment.ku.edu/academic/12288br for the Hydrogeochemist and at http://employment.ku.edu/academic/12289br for the Groundwater Hydrologist. For further information contact Geoff Bohling (geoff@kgs.ku.edu) or Don Whittemore (donwhitt@kgs.ku.edu). For further information about other aspects of the position, contact Annette Delaney, HR, at adelaney@kgs.ku.edu or 785-864-2152. KU is an EO/AAE, http://policy.ku.edu/IOA/nondiscrimination.

Interdisciplinary

Faculty Position in Solid Earth Geophysics or Geology

The Department of Earth and Environmental Sciences at the University of Michigan is searching for candidates in the areas of solid earth geophysics or geology for a tenure-track position at the assistant professor level. This is a university-year appointment with an expected start date of September 1, 2019. We anticipate additional hires in this direction in future years, and are particularly interested in candidates whose strengths will complement existing research programs within the Department.

In the area of solid earth geophysics, we encourage applications from candidates in any area of solid-earth geophysics. Fields of interest include, but are not limited to, geodesy, geodynamics, geomagnetism, rock physics, and seismology. We are particularly interested in those applicants whose work is focused at the global scale and complements our existing program strengths in tectonics, mineral physics, earthquake seismology and imaging of the deep Earth's interior.

In the area of solid earth geology, we encourage applications from candidates whose research interests encompass the origin, evolution, or dynamics of the continents. The successful candidate will develop a strong field-based research program, complemented by expertise in analytical techniques or in numerical or analogue modeling. Candidates with an interest in understanding continental evolution in deep geologic time or geochronology are particularly encouraged to apply.

The successful candidate is expected to establish an independent research program and contribute to undergraduate and graduate teaching. Applicants must have a Ph.D. at the time of appointment and should submit a cover letter, CV, statement of current and future research plans, statement of teaching philosophy and experience, evidence of teaching excellence, if available, up to four publications, and the names and contact information for at least four references.

Information about the Department can be found at: www.lsa.umich.edu/earth.

To apply please go to https://apps-prod.earth.lsa.umich.edu/search18/, complete the online form, and upload the required application documents as a single PDF file. If you have any questions or comments, please send an email message to Michigan-Earth-Search@umich.edu.

The application deadline is August 20, 2018 for full consideration, but applications will continue to be reviewed until the position is filled. Women and minorities are encouraged to apply. The University is supportive of the needs of dual career couples and is an equal opportunity/affirmative action employer.

NASA Postdoctoral Program–Application Deadline November 1, 2018

The NASA Postdoctoral Program (NPP) supports NASA's goal to expand scientific understanding of Earth and the universe in which we live.

This announcement reflects recent increases to the NPP annual base stipend and the annual travel allowance provided to fellows.

To learn more about specific opportunities and to apply, please visit: https://npp.usra.edu/opportunities/

The NASA Postdoctoral Program offers US and international scientists the opportunity to advance their research while contributing to NASA's scientific goals. The NPP supports fundamental science; explores the undiscovered; promotes intellectual growth; and encourages scientific connections.

Engage in NASA research in Earth science, planetary science, heliophysics, astrophysics, aeronautics and engi-

neering, human exploration and operations, space bioscience, and astrobiology.

Details:

• UPDATED! Annual stipends start at $60,000, with supplements for high cost-of-living areas and certain degree fields

• UPDATED! Annual travel budget of $10,000

• Relocation allowance

• Financial supplement for health insurance purchased through the program

• Appointments renewable for up to three years

• Approximately 90 Fellowships awarded annually

Available Fields of Study:

• Aeronautics, Aeronautical or Other Engineering

• Astrobiology

• Astrophysics

• Biological Sciences

• Cosmochemistry

• Earth Science

• Heliophysics Science

• Interdisciplinary/Other

• Planetary Science

• Technology Development

Available NASA Centers:

• Ames Research Center

• Armstrong Flight Research Center

• Glenn Research Center

• Goddard Institute for Space Studies

• Goddard Space Flight Center

• Jet Propulsion Laboratory

• Johnson Space Center

• Kennedy Space Center

• Langley Research Center

• Marshall Space Flight Center

• NASA Astrobiology Program

• NASA HQ

• Solar System Exploration Research Virtual Institute

• Stennis Space Center

• Wallops Flight Facility

NOTE: Not all centers participate in every application round… please refer to the website for current opportunity locations

Eligibility:

US citizens, Lawful Permanent Residents and foreign nationals eligible for a J-1 visa as a Research Scholar

Recent and Senior-Level PhD recipients

Application Deadlines

Three each year–March 1, July 1, and November 1

To learn more about specific opportunities and to apply, please visit: https://npp.usra.edu/opportunities/

Tenure-stream Assistant Professor in Sedimentary Geology

The Department of Geoscience at the University of Nevada Las Vegas invites applications for a full-time, tenure-track faculty position in sedimentary geology at the Assistant Professor level. Preferred research areas include, but are not limited to, sedimentary basin evolution with applications to tectonics or Earth-life-environment interactions across critical transitions in Earth history. We are particularly interested in individuals who integrate field investigations with innovative geochemical, geochronological, or other analytical techniques to pursue interdisciplinary research. The successful candidate is expected to establish a vigorous, externally-funded research program; teach effectively at both undergraduate and graduate levels, including undergraduate field courses; and perform service duties at all levels. Opportunities for collaboration exist with departmental research groups in tectonics/structural geology, paleoclimatology, paleontology/stratigraphy, petrology/volcanology, planetary geology, and hydrogeology/surface processes. The successful applicant could begin as early as January 2019.

The UNLV Geoscience Department (https://geoscience.unlv.edu/) has 21 faculty, 200 undergraduate students, and more than 50 MS/PhD students. The department hosts laboratory facilities including stable isotope, argon geochronology, fluid inclusion, XRF/XRD, ICP-MS, soils, and electron microprobe/SEM labs. This position requires a Ph.D. from a regionally accredited college or university. Salary competitive with those at similarly situated institutions. Position is contingent upon funding.

Application materials must include a cover letter, curriculum vitae, proposed research plans (five page limit), statement of teaching philosophy and interests, and contact information for five referees. Although this position will remain open until filled, review of candidates' materials will begin on October 1, 2018 and best consideration will be gained for materials submitted prior to that date. Materials should be addressed to Dr. Michael Wells, Search Committee Chair, and submitted at https://hrsearch.unlv.edu. For assistance with the application on-line portal, please contact UNLV Employment Services at (702) 895-2894 or hrsearch@unlv.edu.

Three (3) Tenure-Track Faculty Positions, Marine Geology/Geochemistry, Dept of Ocean, U of Hawaii

The School of Ocean and Earth Science and Technology (SOEST) was established at the University of Hawai'i at Mānoa to promote excellence in interdisciplinary research and undergraduate/graduate education in marine, atmospheric, and geological sciences. The Department of Oceanography within SOEST is inviting applications for three (3) tenure-track faculty positions in Marine Geology/Geochemistry.

We seek applicants at the assistant professor level with expertise and research experience in the broad category of Marine Geology/Geochemistry. Areas of interest include, but are not limited to, chemical oceanography, sediment geochemistry, biogeochemical cycles, climate dynamics, marine atmospheric chemistry and paleocean-

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

The Department of Physics and Astronomy at Heidelberg University invites applications for a

TENURE-TRACK PROFESSORSHIP (W1) IN ENVIRONMENTAL PHYSICS

Candidates are expected to develop a strong research program regarding the modeling of the earth environmental systems. Subject areas should be the terrestrial systems (soil, biosphere and/or cryosphere) within the climate system and/or the coupling between terrestrial systems and the other earth climate compartments. We particularly seek candidates, who will develop novel models, and/or make use of advanced statistical methods, inversion and/or data assimilation, but are not limited to those. Through this position, the Institute for Environmental Physics (IUP) seeks to consolidate a new research focus on modeling of environmental systems, taking advantage of the stimulating environment offered by the Department of Physics and Astronomy at Heidelberg University. The candidate should have a strong background in physics and/or climate dynamics or related fields.

The IUP provides an enthusiastic and motivating research environment presently representing experimental research on terrestrial-, atmospheric-, and aquatic systems and studies of past climates. Close cooperation exists with the Interdisciplinary Center for Scientific Computing (IWR). Moreover, the Heidelberg Center for the Environment (HCE) provides a multi-disciplinary framework for interaction across the University with regard to environmental research.

In accordance with Section 51 Landeshochschulgesetz Baden-Württemberg (the Baden-Württemberg State Higher Education Act), this appointment requires a completed university degree, an excellent doctorate, and pedagogical aptitude which has generally been proven through teaching experience. The professorship is a qualification position and we are thus searching for a young researcher with typically up to six years of experience.

The Tenure Track Professorship (salary grade W1) will initially be limited to six years and, following a positive tenure evaluation, will be converted to a permanent W3 professorship.

Further information on the Tenure Track program (e.g. the evaluation statute) is available at the website of the Human Resources Division (www.uni-heidelberg.de/tenuretrack).

The university aims to increase the number of women in areas in which they have been underrepresented in until now. Qualified female academics are especially invited to apply. Preference will be given to disabled applicants who are otherwise equally qualified for the position.

Applications along with the usual accompanying documents (research statement, curriculum vitae detailing the scientific career, full publication list and a list of previous lecture courses and talks) should be submitted electronically (as pdf) by **31.10.2018** to Prof. Hans-Christian Schultz-Coulon, Dean, Department of Physics and Astronomy, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg/Germany
e-mail: dekanat@physik.uni-heidelberg.de.

ography, with focus on observations and/or numerical modeling. Cross-disciplinary interests are a plus. The successful candidates are expected to develop world-class oceanographic research programs supported by extramural funding, and outstanding teaching/educational programs that include classroom instruction and contributions to both the graduate Oceanography and undergraduate Global Environmental Science programs.

Applicants must have a Ph.D. in oceanography, geochemistry, earth sciences, or another relevant discipline; excellent communication skills; demonstrated capability for creative, high-quality research; and the ability to contribute to teaching and mentoring of undergraduate and graduate students.

To apply, please submit electronic versions of three representative publications and a single electronic file (in pdf format) containing a cover letter, vita, statement of research and teaching interests, and the names and contact information for five references to ocnsrch@soest.hawaii.edu. Questions should be directed to the search committee Chair, Dr. Christopher Sabine (csabine@hawaii.edu). More information about the Department can be found at http://ocean.hawaii.edu.

Review of applications will begin on 15 September 2018, and will continue until the positions have been filled, subject to position clearance. The complete vacancy announcement can be found at http://workatuh.hawaii.edu.

The University of Hawaii is an equal opportunity / affirmative action institution.

Two Faculty Positions in Petrology/Volcanology and Mineral Resources/Economic Geology

The Department of Geological Sciences at the University of Alaska Anchorage (www.uaa.alaska.edu/ geology/) seeks to hire two tenure-track faculty members (open rank), with a start date of August 2019. We aim to expand and complement existing areas of research expertise in the Department which include geochemistry, structural geology, sedimentology, stratigraphy, petroleum geology, geophysics, hydrogeology, and planetary geology. The successful candidates are expected to teach undergraduate and graduate courses to a diverse student body in the B.S. and M.S. programs in geological sciences.

(1) Igneous/Metamorphic Petrology and/or Volcanology: teaching expectations for this position include igneous & metamorphic petrology, volcanology, geological field methods or field camp, advanced petrology, and other courses in support of the Department's teaching needs.

(2) Mineral Resources and/or Economic Geology: we encourage applications from individuals with expertise in one or more of the following areas: economic geology; mining geology; mineral resources in magmatic, hydrothermal, and/or placer deposits; structure and emplacement of ore deposits; or mineral exploration. Teaching expectations for this position include mineralogy, ore deposits, geological field methods or field camp, advanced mineral resources, and other courses in support of the Department's teaching needs.

We seek applicants with a commitment to teaching, research, and partnership building with resource industries and research organizations in Alaska and elsewhere. Successful candidates must develop externally funded research that actively involves graduate and undergraduate students. Both positions require a Ph.D. in geological sciences or a related field at the time of initial appointment, university teaching experience or potential, and demonstration of research experience and future potential. Relevant industry or post-doctoral experience will be considered favorably.

Please submit a cover letter, curriculum vitae, a statement of teaching and research interests that includes how you will involve students in research opportunities, contact information for at least three references, and unofficial academic transcripts to careers.alaska.edu for: (1) posting 509521 (petrology or volcanology); or (2) posting 509519 (mineral resources). Review of applications will begin September 24, 2018.

For more information regarding these positions, please contact the department director, Dr. Simon Kattenhorn: skattenhorn@alaska.edu.

UAA is an AA/EO Employer and Educational Institution. Applicant must be eligible for employment under the immigration Reform and Control Act of 1986 and subsequent amendments. Your application for employment with UAA is subject to public disclosure under the Alaska Public Records Act.

Ocean Sciences

Postdoctoral Research Associate in Climate Variability and Change

The Atmospheric and Oceanic Sciences Program at Princeton University, seeks a postdoctoral researcher or more senior position for research related to multi-decadal to centennial climate variability and change, including the connections to tropical cyclone activity. A key focus will be dynamical model experiments to understand the character of and causes behind changes over the past millennium, and an assessment of the causes behind past centennial changes in climate and tropical cyclone activity. This would include analysis of and modifications to coupled climate model experiments. The research will also examine the relationships and interactions between of natural multi-decadal to centennial variability, and the climate system response to radiative forcing changes. The research will make extensive use of both observations and a variety of modeling tools, including high-resolution global climate models. The selected candidate will have one or more of the following attributes: (a) a strong background in climate dynamics, atmospheric sciences, physical oceanography, or a closely related field; (b) experience using and analyzing advanced climate models and global observational datasets, and (c) strong diagnostic skills in analyzing large data sets.

The selected candidate will have a Ph.D. in meteorology, atmospheric sciences, or a related field. Initial appointment is for one year with the possibility of renewal subject to satisfactory performance and available funding.

Complete applications, including a CV, publication list, 3 letters of recommendation, and a statement of research interests, should be submitted online to https://www.princeton.edu/acad-positions/position/7561.

For additional information, contact Gabriel Vecchi (gvecchi@princeton.edu). This position is subject to the University's background check policy.

Princeton University is an Equal Opportunity/Affirmative Action employer and all qualified applicants will receive consideration for employment without regard to age, race, color, religion, sex, sexual orientation, gender identity or expression, national origin, disability status, protected veteran status, or any other characteristic protected by law.

Seismology

Lecturer / Associate Professor in Applied Seismology – University of Leeds

The School of Earth and Environment at the University of Leeds seeks to appoint an ambitious and collegiate Lecturer / Associate Professor in the discipline of Applied Seismology. You will join a diverse community of researchers, comprising over 125 academic staff and some 240 postgraduate researchers.

As a member of the School's Institute of Applied Geoscience (IAG), you would be supported in the development of a world-leading portfolio of Applied Seismology research. With a PhD in a relevant area of seismology, you will attract public/private sector funding, and an expanding research group, in fields including (but not limited to) hydrocarbon reservoir characterisation, rock physics, geological storage technologies, seismic waveform tomography and source process characterisation. Through IAG and its partner institutes, you will access diverse research programmes including glaciology, rifting, volcanology and basin evolution.

Your expertise will be shared, via research-led teaching, with geophysics students in the School, as an integral part of the delivery team of our prestigious MSc Exploration Geophysics programme. You will lecture in Applied Seismology in both classroom and field settings, and will mentor a cohort of dynamic project students. Your experience will help steer the direction of the MSc to ensure the sustainability of the course and the employability of its graduates.

Informal enquiries may be made to Dr Adam Booth, Tel: +44 (0) 113 343 9743, or email a.d.booth@leeds.ac.uk.

Please visit https://jobs.leeds.ac.uk/vacancy.aspx?ref=ENVEE1269

Closing date: 15th October 2018

Faculty Position in Geology & Geophysics, University of Hawai'i at Mānoa

The Department of Geology and Geophysics at the University of Hawai'i at Mānoa seeks applications for a faculty position in Earth Sciences at the rank of Assistant Professor (or Associate Professor for an exceptional candidate).

Earthquake seismologists with expertise in studying or imaging the lithosphere, ideally with an emphasis on volcano structure or processes, that will complement existing strengths with the Department and the School of Ocean and Earth Science and Technology are encouraged to apply. Scientists with field-based observation programs are preferred.

The successful candidate is expected to establish and maintain a vigorous, synergistic, and externally funded research program and to participate extensively in the undergraduate and graduate instructional programs of the department. Candidates with a demonstrated record of teaching excellence, innovation, and breadth are preferred. Applicants must hold a Ph.D. at the time of the appointment. Applications must be submitted electronically via email (gt@soest.hawaii.edu) as a single PDF file that includes the following: (1) a letter of application; (2) a curriculum vitae with a list of publications and research funding; (3) a statement of teaching experience, interests and philosophy, and evidence of teaching excellence; (4) a statement of research interests, synergistic activities, and future research endeavors; and (5) contact information for at least three references. Review of applications will begin October 1, 2018 and will continue until the position is filled. The anticipated start date is July 1, 2019. The Department is especially interested in candidates who contribute to our diversity and excellence. Women and minority candidates are encouraged to apply. The University is an equal opportunity/affirmative action employer. Information on the Department can be found at http://www.soest.hawaii.edu/GG/. The complete vacancy announcement can be viewed at workatuh.hawaii.edu.

Postcards from the Field

Hello from Bali, Indonesia!

We are students at the Asian School of the Environment at Nanyang Technological University in Singapore, and in this photo we are traversing Subak Pulagan on the beautiful island of Bali as part of our introductory field study.

Subak Pulagan is a UNESCO World Heritage Site dedicated to the promotion of understanding and cultivation of the Subak system in Bali. Subak is a cooperative and democratic water management system developed by the Balinese according to the Tri Hita Karana philosophy, which emphasizes harmony among the natural world, the human world, and the spiritual domain. Through the Subak system, Balinese rice farmers collectively manage how water is used in their rice paddy terraces through a system of canals and weirs, which they've been doing since at least the 12th century. It's a piece of living history at work!

For more information on the Subak system in Bali, check out this link: https://whc.unesco.org/en/list/1194.

Wish you were here!

—Sri Budhi Utami, Ph.D. Student at the Asian School of the Environment, Nanyang Technological University, Singapore

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

2018 HONORS

AGU100 ADVANCING EARTH AND SPACE SCIENCE

The Honors and Recognition Committee and the Union Fellows Committee are pleased to announce:

2018 Class of Fellows

Section Award and Lecture Honorees

honors.agu.org