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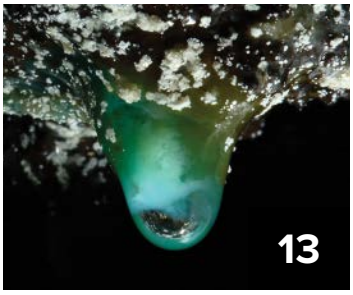

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Emperor Penguins' Huddles Change in Response to Weather

Adult emperor penguins on an ice floe at Pointe Géologie, Terre Adélie, in western Antarctica. Credit: © Fabien Petit/IPEV/CNRS/CSM

On the frozen landscape of Antarctica, emperor penguins huddle together to shield against cold, windy, and harsh conditions. This lets the penguins share warmth and conserve energy during extended times between forages and during breeding.

Now scientists have used advances in remote sensing techniques to observe the evolution of an emperor penguin huddle at Atka Bay in eastern Antarctica. Their study revealed the primary trigger that prompts the birds to huddle and reaffirmed the main purpose of the groupings.

Huddle locations often lie kilometers from the nearest permanent research station amid extremely cold (-50°C) and windy (150-kilometer-per-hour) conditions. They also tend to migrate around.

These factors "have made it very challenging to get information from over there," according to Céline Le Bohec, an ecologist at the Centre National de la Recherche Scientifique in Paris, France, and the Centre Scientifique de Monaco. However, thanks to remote sensing observatories established by researchers in recent years, especially ones with instruments linked to the Internet, "we can go online anytime and instantly see what is happening in the [emperor penguin] colony," she said in a press release (http://bit.ly/WHOIPenguins).

> "We can go online anytime and instantly see what is happening in the [emperor penguin] colony."

Huddling for Warmth

During May 2014, sensors at the remotely operated Single Penguin Observation and Tracking (SPOT) observatory monitored huddles' shapes and total areas of coverage and estimated the number of penguins within each huddle. Additional SPOT instruments simultaneously recorded the local wind speed, ambient temperature, solar radiation, and relative humidity.

By comparing the local weather conditions to the penguins' huddling habits, the researchers found that during a typical month, the penguins were more likely to huddle when a windchill-like parameter—which they call the phase transition temperature—decreased to -48.2°C.

Penguins as Proxies

The transition temperature, which combines four meteorological parameters into a single metric measured in degrees, can serve as a proxy for the penguins' foraging success, according to the team. So if the penguins for some reason began to huddle at warmer temperatures, scientists would know that they likely had smaller energy reserves from food to keep them warm.

The findings agree with the well-established idea that the penguins huddle primarily for warmth and not for protection against predators and reconcile lingering questions about the main environmental trigger for huddling. The researchers published the first results from the study this spring in the *Journal of Physics D: Applied Physics* (http://bit.ly/JPD-penguins).

With ongoing, near-continuous data beginning in 2013, the researchers noted that the penguins' huddle behavior can track how the Antarctic biome is changing in response to global warming and better inform conservation efforts.

"It's important to know which colonies are going to be the…most affected by climate change," said coauthor Daniel Zitterbart of the Woods Hole Oceanographic Institution in Woods Hole, Mass. So if it looks like penguins in a certain colony could withstand future climate-related changes, "conservation measures like marine protected areas can be established to better protect them," he said.

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

Does Your Institution Foster a Culture of Sexual Harassment?

pic_studio/iStock/Getty Images Plus/Getty Images

U.S. colleges and universities need to fundamentally transform their cultures to prevent sexual harassment, a new report released in June by the National Academies of Sciences, Engineering, and Medicine concludes.

The report, *Sexual Harassment of Women: Climate, Culture, and Consequences in Academic Sciences, Engineering, and Medicine,* notes that "at the same time that so much energy and money is being invested in efforts to attract and retain women in science, engineering, and medical fields, it appears women are often bullied or harassed out of career pathways in these fields."

The fruit of a 3-year effort, the report synthesizes extensive past research on sexual harassment in academic settings and presents new insights from individual interviews conducted specifically for the report. The result is a sweeping analysis of factors that contribute to sexual harassment in science, engineering, and medical fields, along with recommendations on how colleges and universities can reinvent their cultures to prevent this harassment [*National Academies of Sciences, Engineering, and Medicine,* 2018].

A summary of the report along with a video on its highlights are available on the report's website (http://bit.ly/NASEMharassment).

But what exactly does the information in the report mean for your academic institution? Building on the report's foundations, we created a preliminary list of questions to help you softly gauge the culture of sexual harassment present in your departments, colleges, or universities. The list is by no means exhaustive; rather, it aims to strike at unexpected sources revealed in the report that contribute to environments that promote harassment.

But first, a quick baseline:

Sexual Harassment Rates in Academia Are Very High

The report notes that according to the best estimates they could study, 58% of women faculty and staff at U.S. colleges and universities have experienced sexual harassment. That's the highest rate of incidence for any employment sector outside of the military.

Specifically for science realms, "more than 50 percent of women faculty and staff and 20–50 percent of women students encounter or experience sexually harassing conduct in academia," the report notes. Surveys analyzed through the report reveal that women students in academic medicine are more frequent targets of sexual harassment perpetrated by faculty and staff than are their counterparts in science and engineering.

The report unequivocally states that "the greatest predictor of the occurrence of sexual harassment is the organizational climate in a school, department, or program, or across an institution."

Red Flags

Within this culture are some red flags, identified in the report. The prevalence of any of these red flags may create environments in which sexual harassment not only goes unreported but also could rise and fester.

With this in mind, does your school, department, program, or institution...

1. ***Struggle with recognizing that gender harassment is sexual harassment?*** Sexual harassment encompasses sexual coercion—for example, "sleep with me or you're fired"—as well as unwanted sexual attention. The latter includes stalking, pressuring for dates, and assault. But sexual harassment also encompasses gender harassment, which the report defines as

> *verbal and nonverbal behaviors that convey hostility, exclusion, or second-class status about members of one gender. Examples include use of language like "bitch," jokes such as "Don't be a pussy," and comments that denigrate women as a group or individuals in gendered terms....[A] woman may be gender harassed for taking a job traditionally held by a man or in a traditionally male field. Gender harassment in such a situation might consist of actions to sabotage the woman's tools, machinery, or equipment, or telling the woman she is not smart enough for scientific work.*

The report notes that gender harassment is the most common form of sexual harassment. However, it's often unrecognized, which leads to it being underreported. And the report quantifies this: Women who experience gender harassment are 7 times less likely to label it as sexual harassment.

2. ***Have male-dominated leadership?*** The report says it best:

> *Most department chairs and deans are men. Most principal investigators are men. Most provosts and presidents are men....This is not to suggest that all or even most men are perpetrators of sexual harassment, but that this situation of majority male leadership can, and has, resulted in minimization, limited response, and failure to take the issue of sexual harassment or specific incidents seriously. Thus, this underrepresentation of women in science, engineering, and medicine and in positions of leadership in these fields creates a high-risk environment for sexual harassment.*

3. ***Have a culture of incivility?*** The report defines incivility as "low-intensity deviant behavior with ambiguous intent to harm the target, in violation of workplace norms for mutual respect." Workplace cultures that foster respectful behavior will have fewer problems with sexual harassment than workplace cultures that don't, the report concludes.

4. ***Promote rigid hierarchies, particularly in circumstances of spatial or geographic isolation?*** Power structures that are led predominantly by men, with power "highly concentrated in a single person, perhaps because of that person's success in attracting funding for research," can exacerbate risks of harassment, according to the report. "When hierarchy operates out of habit rather than as something that is constantly reflected on and justified due to experience or expertise, misuses of power can increase." Risks increase when

coupled with isolation in the field, on research ships, in labs, or in medical students' night shifts.

5. ***Incentivize confidentiality and nondisclosure agreements that limit the ability of those targeted by sexual harassment to speak with others about their experiences?*** This can serve to shield perpetrators who have harassed people repeatedly, the report states.

6. ***Foster a culture of alcohol use?*** Here's one perhaps relevant to many field sites: "Environments that allow drinking during work breaks and have permissive norms related to drinking are positively associated with higher levels of gender harassment of women," according to the report.

7. ***Leave its members with a vague idea surrounding what constitutes sexual harassment, what should be done to report it, and what consequences may result?*** In some cases, there is a "lack of clear policies and procedures on campus, and within departments, that make clear that all forms of sexual harassment, including gender harassment, will not be tolerated; that investigations will be taken seriously; and that there are meaningful punishments for violating the policies," the report states. Particularly in field environments, "there was a lack of awareness regarding codes of conduct and sexual harassment policies, with few respondents being aware of available reporting mechanisms."

8. ***Have informal "whisper networks" that serve to warn women away from particular scientists who are serial harassers?*** Such networks are common across many male-dominated environments but have "the effect of automatically reducing [women's] options and chances for career success," the report concludes.

9. ***Ask in surveys whether respondents have experienced sexual harassment?*** Asking for this information outright will skew results toward underreporting, the report concludes. It provides the following example:

> *[Past] surveys revealed that when respondents were asked simply, "Have you been raped?" estimates of the number of people raped in the college population were very low, yet when asked whether they had experienced a series of specific behaviors that would meet legal criteria for rape, estimates of the number of people raped were much higher. Subsequent studies of sexual harassment found similar results.*

10. ***Provide sexual harassment training without following up to see whether those trainings are effective?*** The report noted that institutions may focus on "symbolic compliance" with Title IX and Title VII, two laws that protect women against gender discrimination. Such symbolic compliance fosters policies and procedures that "protect the liability of the institution but are not effective in preventing sexual harassment."

For example, mandatory sexual harassment training may be required by law in some cases, but there's no requirement to evaluate whether the training assigned actually helps prevent sexual harassment. This is a missed opportunity, the report concludes. "Training programs should not be based on the avoidance of legal liability."

11. ***Focus training on changing the minds of harassers?*** Such endeavors aren't efficient, the report concludes. "Anti–sexual harassment training programs should focus on changing behavior, not on changing beliefs. Programs should focus on clearly communicating behavioral expectations, specify consequences for failing to meet these expectations, and identify the mechanisms to be utilized when these expectations are not met." The approach works, the report adds: "Experiments show that sexual harassment is less likely to occur if those behaviors are not accepted by authority figures."

12. ***Gauge the success of their training efforts on the number of incidents of sexual harassment officially reported?*** Many training efforts hold the underlying assumption that a target will promptly report harassment without worrying about retaliation. However, the report shows that this assumption is far from reality. "The least common response for women is to formally report the sexually harassing experience," the report states.

13. ***Punish harassers with a reduction of teaching load or time away from campus responsibilities?*** The report takes such punishments to task. Such punitive measures are "often considered a benefit for faculty," it notes. In other words, perpetrators should not be rewarded for their behavior by losing responsibilities while still collecting the same pay. "Instead, consequences should take the form of actual punishment, such as cuts in pay or even termination."

The Way Forward

The report delineates multiple paths forward, focused on transforming a given workplace culture into one in which sexual harassment has no place. To name just a few, institutions can start by taking explicit steps toward greater gender and racial equity in hiring and promotions. They can recognize that gender harassment can be just as corrosive to work environments as other forms of sexual harassment and can take concrete measures to break down the "one student, one mentor" model pervasive in academia and instead adopt mentoring networks, committee-based advising, and departmental funding structures. They should be as transparent as possible regarding how they handle reports of sexual harassment, providing annual reports to be shared broadly that detail how many incidents are currently under investigation.

> "When hierarchy operates out of habit rather than as something that is constantly reflected on and justified due to experience or expertise, misuses of power can increase."

Support services—social, legal, medical—should be readily available to the targets of harassment. Institutions should provide less formal means of recording information about the sexual harassment faced—for example, through an ombudsperson—if some are not comfortable filing a formal complaint.

"Academic institutions should convey that reporting sexual harassment is an honorable and courageous action," the report stresses.

All of these recommendations strike at the heart of what may be the most essential takeaway message of the report: "Academic institutions should consider sexual harassment equally important as research misconduct in terms of its effect on the integrity of research." When put in those terms, the report indicates, shifting the culture of academic science, engineering, and medical programs becomes a paramount goal for us all.

References

National Academies of Sciences, Engineering, and Medicine (2018), *Sexual Harassment of Women: Climate, Culture, and Consequences in Academic Sciences, Engineering, and Medicine*, edited by P. A. Johnson et al., Natl. Acad. Press, Washington, D. C., https://doi.org/10.17226/24994.

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

Editor's Note: A coauthor of the recently released report is Billy Williams, vice president of ethics, diversity, and inclusion at AGU. A blog post about the report, written by AGU's executive director Chris McEntee, can be found at http://bit.ly/AGUHarassmentProw.

Scientists Discover an Environment on the Cusp of Habitability

A researcher analyzes minerals near the banks of Laguna Caliente. Credit: Geoffroy Avard, OVSICORI-UNA

Nestled on a stratovolcano in Costa Rica, Laguna Caliente was one of the most inhospitable places on Earth. Its ultra-acidic waters, heated by magma, often approached boiling temperatures. Clumps of sulfur floated on its steamy surface, which ranged in color from bluish green to yellow. But was it a dead zone? Apparently not, new research has found.

A team of scientists sampled the lake's waters and showed that Laguna Caliente contains life but predominantly just one form of it: a single genus of the bacterium known as *Acidiphilium* ("acid lover"). This is a surprise, because most ecosystems on Earth are home to diverse communities or utterly devoid of life, said Brian Hynek, a planetary scientist at the University of Colorado Boulder who led the work.

"Laguna Caliente is one of the most extreme habitats on our planet and may well represent the edge of the habitable range," he and his team wrote in a paper published earlier this year in *Astrobiology* (http://bit.ly/Hynek-Astrobiology). This place is otherworldly, the scientists also note; it probably resembles ancient Martian terrain from that planet's wetter, more volcanic days. Hence, bacteria like those prevalent in Laguna Caliente may have thrived on Mars in the past, they propose.

Foreign and Wild

Hynek and his team traveled to central Costa Rica in 2013 to investigate the minerals around Poás volcano and its acidic crater lake. They found an unpredictable and dangerous landscape: Geyserlike eruptions from Laguna Caliente launched ash and mud hundreds of meters skyward, and sulfuric acid and hydrochloric acid permeated the air. "Even in a full gas mask, your eyes are tearing up," said Hynek. "It's a foreign, wild environment" with a geochemistry similar to that of Mars. What life-forms, the researchers wondered, might exist in this harsh place?

Hynek and his colleagues collected water and sediment from Laguna Caliente using test tubes attached to a 2-meter-long aluminum pole. The pole protected their hands from the water, which had a pH of 0.29, 50 times more acidic than stomach acid. The researchers froze the samples and brought them back to Colorado for analysis. In the lab, they extracted and sequenced the DNA entrained in the samples. This so-called environmental DNA revealed the organisms that had passed through Laguna Caliente's waters.

Just a Single Thing

The scientists found that 98% of the environmental DNA from Laguna Caliente could be traced to that one genus of *Acidiphilium*. "There's just a single thing there," said Hynek. More intriguing, none of the known species of the *Acidiphilium* genus tolerate pH levels as low as Laguna Caliente's, the researchers noted. Hence, it's likely that this is an organism that hasn't been described previously, said Hynek.

Is it also otherworldly? The Red Planet is rich in sulfur and iron, the nutrients on which *Acidiphilium* thrives, Hynek and his colleagues noted. What's more, ancient Mars's volcanic hot springs would have provided wet, acidic niches for similar bacteria, they remarked in their paper.

These kinds of studies are "highly relevant" to finding evidence of previous life on Mars, said Manfred van Bergen, an Earth scientist at Utrecht University in the Netherlands who was not involved in the research. "The more we know about what could be expected, the more efficient this quest can be."

Nature's Logistics

The team hopes to return to Costa Rica this year to continue to sample the area's microbiology and conduct aerial surveys of Poás volcano using drones. Any trip would have to focus on sediments rather than water—Laguna Caliente itself is gone after draining last year when Poás volcano became active again. But the biggest stumbling block to traveling comes down to overcoming nature's logistics, said Hynek. Poás Volcano National Park is currently closed because of "increased and unpredictable volcanic activity," the park's website notes.

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

NSF and Air Force Plan to Better Coordinate Research Projects

A ski-equipped plane takes off from a remote science research site on Greenland's ice sheet. The aircraft and crew currently provide support to the National Science Foundation's polar research program. Credit: DOD/Fred W. Baker III

The U.S. National Science Foundation (NSF) and the Department of the Air Force signed a letter of intent in May to develop a new partnership to coordinate mutual research interests. Since then, the agencies have been continuing to refine the nature and structure of the partnership and explore four mutually identified initial focus areas for consideration. Those areas are space operations and geosciences, advanced material sciences, information and data sciences, and workforce and processes, according to the letter (http://bit.ly/NSF-AirForce-letter).

The letter states that the partnership, which is one of many for NSF, will foster increased research information exchange, support collaboration in common research areas, and identify opportunities for complementary research and development activities. With the two agencies having "many overlapping research goals," the Air Force would benefit from greater access to NSF's expertise in basic research, the document continues. NSF, meanwhile, would benefit by having "a direct pathway" for the maturation of some research efforts and products "and increased relevance afforded by its direct support of the Nation's defense posture."

> "What the American people get out of this is more efficient use of their tax dollars."

NSF director France Córdova told *Eos* that it's too early to know what specific projects and themes the two agencies might consider for partnerships. However, she said that some topics of mutual interest might include researching weather, better understanding a new and rapidly changing Arctic, and mapping the night skies. "Anything that the Air Force and NSF think is useful and important to do together could be under the umbrella, in principle, of these four areas of initial focus," she stated.

"What the American people get out of this [partnership] is more efficient use of their tax dollars," Córdova continued. "When we fund basic research, we want to be sure that investment is open to every possible application and that it eliminates duplication and accelerates the pace of breakthroughs and the development of useful tools."

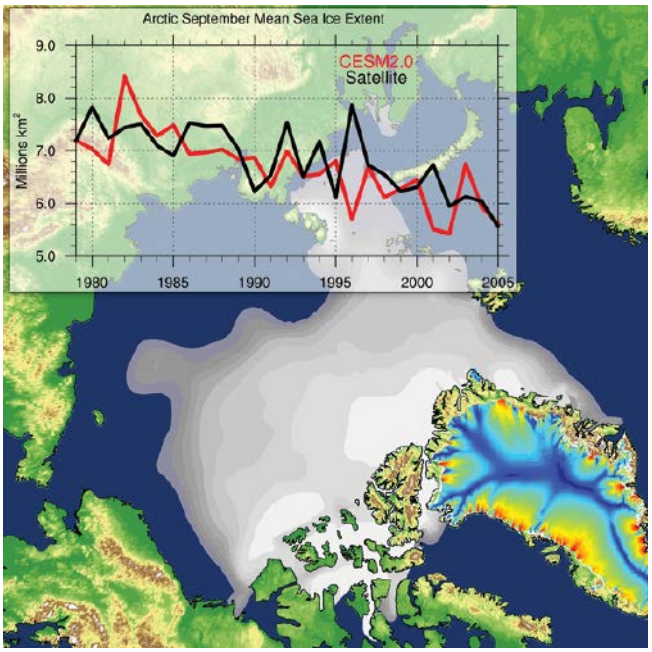
Building on Previous Agreements

Córdova, who signed the letter along with Secretary of the Air Force Heather Wilson, noted that the partnership builds on previous agreements between the two agencies, including their cooperation on some polar operations. Córdova added that the partnership "aligns with [NSF's] goal of supporting national security through basic research." NSF's foundation act of 1950, which established the agency (http://bit.ly/NSF-Act1950), states that one of the agency's principal purposes is "to secure the national defense."

"Seventy years after our founding, we are ensuring that that important part of our mission is revitalized, and it will carry in this day and age new meaning and new discoveries," Córdova said, adding that the partnership will not affect other aspects of what NSF does.

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

New Version of Popular Climate Model Released



A screenshot from a CESM2 simulation of the Arctic climate system. Warmer colors on the Greenland ice sheet indicate regions of faster ice flow. This simulation, which covered the end of the 20th century and the beginning of the 21st, shows that the model's output matches observational data from satellites; that is, both show Arctic sea ice cover steadily decreasing over time. Credit: Alice DuVivier, Gunter Leguy, and Ryan Johnson/NCAR, ©UCAR

In June 2017, climate researchers met at a workshop in Boulder, Colo., to fix a big glitch in the second version of the Community Earth System Model (CESM), a computer program that scientists around the world use to simulate Earth's complex climate system. Last July, *Eos* reported on that glitch and the befuddlement it had caused the model's developers (http://bit.ly/CESM2-stalled).

Now, a year later, at the same annual CESM workshop, held again in Boulder, the team behind the model's development released the promised second version, CESM2. This version offers a slew of new features that will help modelers explore the climate in far greater detail than CESM1 ever could have.

The glitch, however, meant that the ride to this new version was not exactly smooth. Jean-François Lamarque, an atmospheric chemist at the National Center for Atmospheric Research (NCAR) who was the chief scientist behind CESM a year ago, likened the glitch to having car trouble: "You're driving this car, and you know it doesn't work as well as it could," he said. Fixing that car ended up taking a great deal of work, he explained.

Fixing the Glitch

Lamarque and his team had hoped that CESM2 would debut in August of last year, but their CESM2 car kept sputtering. The issue arose when the program ran climate simulations and returned results that did not match those seen in reality—a problem if the main aim of the model is to mimic Earth's actual climate.

Specifically, in CESM2 simulations, there was a stretch of about 2 decades in the middle of the 20th century that showed global temperatures minutely falling by 0.3°C or 0.4°C, despite real-world observations showing a steady rise in global temperatures over the same 20-year period. This contrary trend occurred when the model calculated how sulfate aerosols changed the properties of clouds, a phenomenon known as the aerosol indirect effect. When sufficiently strong, this effect can cause cooling on a global scale.

To fix the glitch, a team of about 10 climate experts assembled soon after last year's workshop to reexamine emissions data sets and to tinker with the model. "We spent 4–5 months really digging into the model," Lamarque said.

The researchers thoroughly reviewed how the model captured cloud-aerosol interactions and compared their parameterizations against current knowledge from observations and high-resolution simulations. Through that scrutiny, they identified several problems with their real-world emissions data. They reported these problems to the data suppliers, who then gave them a new, corrected version of the data. This work revealed that "our initial choice of parameters could, and should, be modified to reduce the strength of the aerosol indirect effect," Lamarque explained.

Despite their efforts, the contrary trend still crops up in CESM2. "But it's much, much reduced from last year," Lamarque said, adding that it will take many more years of work "by very smart people" to untangle what is really going on under the model's hood. The cloud-aerosol mechanism currently outputs a temperature drop of about 0.1°C, effectively curtailing the glitch by more than half.

New Ride

Despite that lingering glitch, CESM2 boasts several never-before-seen features. "We went from a standard car to a car with more features," Lamarque said. These "include quite substantial improvements in the representation of the physics that they are using," added Gokhan Danabasoglu, an ocean and climate modeler at NCAR who is the current chief scientist behind CESM.

One of those new features is a capability to model the behavior of Greenland's ice sheet in greater detail. "You can have prognostic evolution of the Greenland ice sheet," Danabasoglu said. This means that when the model runs, the parts of the ice sheet abutting the ocean melt at a relatively faster rate than ice farther inland, a process that more closely matches reality. This mechanism, Danabasoglu explained, is rather new among today's climate models.

Researchers from around the world discussed the new features at the recent workshop in Boulder. One attendee, Gretchen Keppel-Aleks, an atmospheric scientist at the University of Michigan, described some of the features that she thinks will help advance her research into the ways elements like carbon and nitrogen cycle through the environment.

"The new representation of carbon–nitrogen cycling in CESM2 will likely yield more robust projections for how terrestrial carbon cycling will change in the future," she said. Such projections should help reduce one of the largest uncertainties for our future climate: how much anthropogenic carbon dioxide will remain in the atmosphere over time. This, she said, means that CESM2 offers a "much more sophisticated framework compared to CESM1."

Now researchers will drive their new ride until they trade it in for the next model.

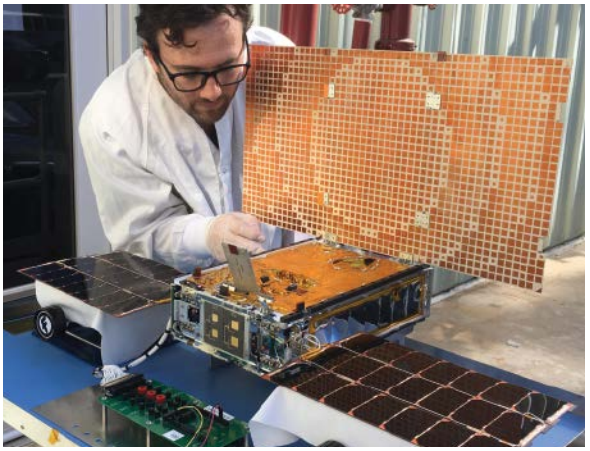
A full list of features new to CESM2 can be found on NCAR's website (http://bit.ly/NCAR-CESM2).

By **Lucas Joel** (email: lucasvjoel@gmail.com), Freelance Journalist

New Lander en Route to Probe the Red Planet's Interior

The InSight lander in a holding facility at Vandenberg Air Force Base undergoing prelaunch preparations. Credit: NASA/JPL-Caltech

The newest mission to put a lander on Mars was launched on 5 May and is expected to arrive at the Red Planet on 26 November. Called Interior Exploration using Seismic Investigations, Geodesy and Heat Transport, or InSight, this NASA mission aims to improve understanding about the formation and evolution of Mars and other small, rocky planets by looking beneath Mars's surface (see http://bit.ly/Mars-Insight).



JPL engineer Joel Steinkraus tests solar panels on one of the MarCO CubeSats. Credit: NASA/JPL-Caltech

The mission will be the first to probe the interior of a terrestrial planet other than Earth, explained NASA chief scientist Jim Green at a prelaunch press briefing on 3 May. InSight will give scientists an idea of the sizes of Mars's core, mantle, and crust, which they can then compare with interior structures of Earth's. Such knowledge "is of fundamental importance for us to understand the origin of our solar system and how it became the way it is today," Green said.

InSight hosts three primary instruments: a seismometer, a heat probe, and a radio science system. With data from those instruments, the InSight team hopes to learn more about Mars's interior structure and composition, its rate of heat loss, its current tectonic activity level, and the frequency of meteorite impacts on the planet. These data will also help researchers learn more about precession of the planet's rotational axis.

Knowing more about Mars's history and evolution will lead to better understanding of Earth's, explained InSight principal investigator Bruce Banerdt. "When we start to look back into the Earth's history," he said, "we run into a brick wall because the Earth is so active that the evidence of [early geological] processes has gotten erased." Mars is a good substitute, said Banerdt, because it has "a lot of geologic activity on the surface, but all of the fingerprints of those early processes are still retained in the deep interior." Banerdt is a research scientist at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, Calif.

InSight also hosts two cameras, and their purpose is to gauge the scientific potential and hazard level at possible landing sites in Elysium Planitia, a plain near Mars's equator. They will not provide detailed images of the Martian surface. After landing, placing surface instruments, and deploying its subsurface heat probe, the entire lander must remain as steady as possible to obtain ultraprecise measurements of seismic activity and surface impacts. Wary of vibrations that might affect those measurements, the mission plans no postlanding movements of its cameras.

Launch Included First Interplanetary CubeSats

To send data back to Earth, InSight will team up with NASA's Mars Cube One (MarCO) mission, which was launched aboard the same rocket on 5 May but will independently travel to Mars. MarCO comprises a pair of CubeSats, the first two to visit another planet. If they arrive intact, MarCO will act as part of a communications relay for InSight data.

The CubeSat mission will be the first "field" test of miniaturized deep-space communications equipment and will assess the viability of using CubeSats on interplanetary missions. Should MarCO fail, InSight will still be able to transmit its data back to Earth with its own equipment and through other Mars orbiters.

InSight and MarCO were launched aboard a United Launch Alliance Atlas V-401 rocket from Vandenberg Air Force Base Space Launch Complex 3 in California. This was the first interplanetary launch from the U.S. West Coast. After InSight lands on Mars, it will begin a 708-sol (roughly 2-Earth-year) mission.

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

Harry W. Green II (1940–2017)

I. Pittalwala, UC Riverside

Harry W. Green II

Harry W. Green II, an AGU Fellow and distinguished professor at the University of California, Riverside, passed away on 22 September 2017. He was 77.

Harry was a giant in high-pressure, high-temperature mineralogy and petrology, publishing more than 150 papers, many with high impact. He had unparalleled vision, energy, and enthusiasm and considerable personal charm. His contributions were as broad as they were deep. He relished tackling key problems from innovative perspectives and did so with a prodigious ability to connect wide-ranging evidence, be it intriguing papers or curious outcrops.

Early Life and Work

Harry grew up in Colorado and earned his B.A. (with honors), M.S., and Ph.D. (with distinction in 1968) degrees from the University of California, Los Angeles. In his doctoral work, he studied deformation and annealing of fine-grained quartz with David T. Griggs and John M. Christie and made the fascinating observation that coesite formed outside of its stability field in highly strained quartz.

Harry then took a postdoctoral fellowship in the Division of Metallurgy and Materials Science at Case Western Reserve University (with S. V. Radcliffe), where he was among the first researchers to investigate experimentally deformed rocks with transmission electron microscopy (TEM). No other scientist used this powerful tool more effectively to investigate the sources of mantle rocks and the conditions under which they ascend to Earth's surface. Using naturally deformed peridotites in xenoliths from the mantle, Harry focused on deformation processes that control the strength of the upper mantle.

He demonstrated that microstructures around small fluid inclusions were consistent with the notion that fluid inclusions were exhumed from depth with the host xenoliths, corroborating the subsolidus nature of the asthenosphere and revealing the impact of fluids on deformation of mantle rocks. Beginning in the mid-1970s, Harry also teamed with U.S. Geological Survey scientist Dale Jackson and Adolphe Nicolas at the University of Nantes to sample and study mantle xenoliths from Hawaii and the classic Alpine peridotites of southern Europe. Thus, as Harry began his illustrious career as a professor in the University of California (UC) system (first at UC Davis and then, starting in 1993, at UC Riverside), he had already defined the broad scientific themes that became the hallmarks of his career: the interaction between deformation and phase transformations, the importance of microscopic features, and a lifelong interest in the rheology of the mantle.

Phase Transformations and Earthquakes

Building on his early interest in the interaction of phase transformations and deformation, Harry and his graduate student Pamela Burnley discovered unequivocal evidence of faulting associated with the kinetic onset of transformation from olivine-structured magnesium germanate (Mg_2GeO_4) to its spinel phase. The team found that faulting was accompanied by a unique microstructure, which consisted of lenticular bodies of ultrafine-grained spinel and spinel-filled shear zones. Realizing the similarity between the stress state around the spinel lenses and that around stylolites, Harry dubbed the spinel lenses "anticracks," a term coined earlier for stylolites.

Kinetically hindered transformation of metastable olivine is expected in cold subducting slabs; thus, transformational faulting provides an elegant mechanism for triggering deep-focus earthquakes. Harry and Pamela's landmark discovery [*Green and Burnley*, 1989] appeared in a series of publications in the early 1990s and spawned a flurry of seismological and experimental studies to test this mechanism further. Harry also advanced this work by using acoustic emissions to "hear" the seismic events both in germanate analogues and in samples of true olivine compositions at higher pressures [*Green et al.*, 1990]. In addition, he worked on other phase transformations and dehydration reactions in eclogite and serpentinite to explain the occurrence of intermediate-depth earthquakes.

The observation that fault surfaces induced by phase transformation are filled by ultrafine-grained spinel led him to pursue a unified mechanism of earthquake ruptures. One of his final papers [*Green et al.*, 2015] showed convincing evidence that the propagation of all earthquake ruptures is likely a consequence of grain boundary sliding of a very thin and exceedingly weak "gouge" of nanocrystalline particles that form at the onset of sudden sliding. Such a rheological

behavior is insensitive to pressure, a trait that makes it quite counterintuitive to our notions about brittle ruptures. Nonetheless, this new finding is entirely consistent with the odd, near-orthogonal pattern of rupture propagation that occurred during the great 2012 earthquake sequence in the Indian Ocean.

Subduction Zones and Ultrahigh-Pressure Metamorphism

Harry was always convinced that careful studies of microstructures and mineralogy could reveal the rich geologic history of xenoliths and mantle rocks. In 1995, together with Larissa Dobrzhinetskaya, Harry used exsolved mineral precipitates in olivine crystals of garnet peridotite to demonstrate that the Alpe Arami massif had been exhumed from a depth of 300 kilometers, more than double any previous estimates of deep exhumation. This study prompted researchers around the world to look for microstructural evidence of deep exhumation in peridotites, eclogites, and metasedimentary rocks. The result is wide recognition of the very deep origin of such rocks, with major implications for tectonic processes during subduction of lithospheric plates and continental collision.

Harry and his colleagues played a key role in ultrahigh-pressure metamorphism by demonstrating how an integration of field studies, carefully planned high-pressure experiments in state-of-the-art apparatuses, and microanalytical techniques on both natural and synthetic samples can constrain depths of rock exhumation. Their arsenal of techniques included nanoscale secondary ion mass spectrometry, scanning electron microscopy, TEM, focused ion beam, Raman spectroscopy, and Fourier transform infrared spectroscopy. Harry also collaborated with colleagues on the formation of nanodiamond from supercritical fluids. This collaboration also identified the first nitrides in mantle rocks, including the first boron-bearing mineral from the mantle, qingsongite, and found the first evidence of the coesite-stishovite transformation in metamorphic rocks from orogenic belts and in ophiolitic metasedimentary rocks. In doing so, Harry helped establish the new field of "nanomineralogy," demonstrating that microminerals and nanominerals often retain unique petrological information, similar to the way in which trace elements carry geochemical information not available from major elements alone.

Service and Community

Harry was a generous collaborator across disciplines and an effective mentor to many young scientists, students, and postdocs, all of whom remember him as fair and kind, with integrity and a wry sense of humor.

His service to the science community included serving as chairman of the Executive Committee of the Consortium for Materials Properties Research in Earth Sciences and as president of the Tectonophysics section of AGU and therefore as a member of the AGU Council. At UC Riverside, he served as the vice chancellor for research, in which role he impressively streamlined the process of proposal submission, and as chair of the Department of Earth Sciences several times.

A fellow of the Mineralogical Society of America (MSA), the American Association for the Advancement of Science, and AGU, Harry delivered AGU's fourth Birch Lecture in 1995. He received the Norman L. Bowen Award from AGU's Volcanology, Geochemistry, and Petrology section, MSA's Roebling Medal, and, shortly after his passing, the European Geosciences Union's Louis Néel Medal.

Harry is survived by his wife and many children and grandchildren, as well as numerous students, postdocs, and colleagues.

References

Green, H. W., and P. C. Burnley (1989), A new self-organizing mechanism for deep-focus earthquakes, *Nature, 341,* 733–737, https://doi.org/10.1038/341733a0.

Green, H. W., et al. (1990), Anticrack-associated faulting at very high pressure in natural olivine, *Nature, 348,* 720–722, https://doi.org/10.1038/348720a0.

Green, H. W., et al. (2015), Phase transformation and nanometric flow cause extreme weakening during fault slip, *Nat. Geosci., 8,* 484–489, https://doi.org/10.1038/ngeo2436.

By **Pamela C. Burnley** (email: burnley@physics.unlv.edu), University of Nevada, Las Vegas; **Wang-Ping Chen,** Faculty of Geophysics and Geomatics, China University of Geosciences, Wuhan; also at Department of Geology, University of Illinois at Urbana-Champaign, Urbana; **Larissa F. Dobrzhinetskaya,** Department of Earth Sciences, University of California, Riverside; **Zhen-Min Jin,** School of Earth Sciences, China University of Geosciences, Wuhan; **Haemyeong Jung,** School of Earth and Environmental Sciences, Seoul National University, Seoul, South Korea; **Robert Liebermann,** Department of Geosciences and Mineral Physics Institute, Stony Brook University, Stony Brook, N.Y.; **Manuela Martins-Green,** Department of Molecular, Cell and Systems Biology, University of California, Riverside; **Alexandre Schubnel,** Laboratoire de Géologie, Ecole Normale Supérieure/Centre National de la Recherche Scientifique, PSL Research University, Paris, France; **Yanbin Wang,** Center for Advanced Radiation Sources, University of Chicago, Chicago, Ill.; and **Junfeng Zhang,** School of Earth Sciences, China University of Geosciences, Wuhan

How Paleofire Research Can Better Inform Ecosystem Management

Paleofire Knowledge for Current and Future Ecosystem Management
Saint-Hippolyte, Quebec, Canada, 10–14 October 2017

Ecological restoration is rooted in the understanding of past ecosystem dynamics, and paleoecological reconstructions provide a long-term perspective on landscape change, vegetation dynamics, and fire history. Increasingly, paleorecords are used as historical baselines for landscape management, conservation, and restoration. These data help land managers better mitigate fire and understand vegetation responses to future global changes. Integrating past ecological information in ecosystem management requires a research framework linking a diverse collection of those who need information about past fires—policy makers, nonprofit workers, resource managers, and emergency responders, to name a few—with scientists.

The Global Paleofire Working Group 2 (GPWG2) is an international group focusing on the history, drivers, and ecology of fire (see http://www.gpwg.paleofire.org/). Last fall, the group brought 26 researchers from 11 countries to Canada's Laurentian Biology Station in Quebec for a 1-week workshop titled "Paleofire Knowledge for Current and Future Ecosystem Management." The workshop was initiated to foster collaboration among different research communities interested in fire impacts and vegetation dynamics.

Prior to the meeting, GPWG2 members interviewed more than 20 stakeholders, none of whom were meeting participants. Stakeholders included firefighters, ecosystem managers, conservation practitioners, protected-area managers, and foresters. Responses to the questionnaire highlighted that most of the stakeholders are interested in long-term fire data but find that data formats are often too technical and conceptually difficult to use, even when data are freely accessible.

On the basis of the questionnaire results, workshop attendees split into three subgroups and discussed (1) identifying a common vocabulary between paleofire experts, fire practitioners, and stakeholders, (2) developing a framework for transferring knowledge from paleofire research to ecosystem management, and (3) evaluating the benefits of management policies based on long-term fire histories and associated processes.

Workshop attendees agreed that integrating the language from studies on fire history, fire ecology, and ecosystem policy would establish a shared vocabulary understandable across interest groups. If such "standardized language" were operational, then attendees agreed that dialogue between scientists and stakeholders would encourage the development of future paleostudies tailored to a specific ecosystem's (including forest, grassland, and savanna) management or restoration targets.

Meeting participants hold a section of a core from the bed of Lake Geai in Quebec. Charcoal particles extracted from the sediment–water interface are indicative of recent fire events that occurred in the area around the lake. Data collected will be added to the Global Charcoal Database. Credit: Marcisz Kataryzna

Most interviewees also emphasized the difficulty of knowledge transfer from paleoresearch to more applied fields, such as ecosystem management and restoration. Workshop participants discussed the need to standardize communication and data transfer tools to better reach a larger audience that includes land managers, decision makers, and the public. For example, the Global Charcoal Database (GCD; see http://www.paleofire.org/) is an open-access database of charcoal data largely used by the paleocommunity but hardly understandable outside of it. Standardized Web services that can provide fire metrics for specific ecosystems, based on the long-term perspective, would greatly extend the database's usefulness to a wider community of researchers and stakeholders.

Finally, workshop participants discussed how long-term ecological studies can provide a more direct contribution to fire risk assessment and management policies by identifying a "safe fire-operating space" for specific regions on the basis of knowledge from past fire variability and its relative drivers.

In summary, this workshop was urgently needed to evaluate stakeholder expectations, foster collaboration between communities, and develop a common communication framework for transferring knowledge. The GPWG2, supported by Past Global Changes (PAGES; http://www.pastglobalchanges.org/), will continue to foster cooperation between ecologists, stakeholders, and policy makers interested in the relevance of fire for future ecosystem changes by holding a follow-up meeting in September 2018 titled "Diverse Knowledge Systems for Fire Policy and Biodiversity Conservation" in Egham, U.K. A regional workshop was held in July 2018 on "African Fire History and Ecology: Building Understanding and Capacity Through Collaboration and Knowledge Exchange" in Nairobi, Kenya.

The workshop was undertaken as part of the PAGES project, which in turn received support from the U.S. National Science Foundation and the Swiss Academy of Sciences. We acknowledge workshop coordinators Olivier Blarquez and Pierre Grondin and the GPWG2, chaired by B. Vannière.

By **Marion Lestienne** (email: marion.lestienne@univ-fcomte.fr), Chrono-Environnement Laboratory, University of Burgundy Franche-Comté, Centre National de la Recherche Scientifique, Besançon, France; **Julie C. Aleman,** Department of Geography, University of Montreal, Montreal, Que., Canada; and **Daniele Colombaroli,** Centre for Quaternary Research, Department of Geography, Royal Holloway, University of London, Egham, U.K.

What Would Earth Be Like Without Life?

Workshop on a Cosmic Perspective of Earth: A Planet Permeated and Shaped by Life—Implications for Astrobiology
Tokyo, Japan, 13–15 September 2017

A drop of water clings to a chrysocolla speleothem (copper-rich stalactite) at the Kipuka Kanohina Cave Preserve in Hawaii. The speleothem is composed of microorganisms and their precipitated minerals, including white calcite. The width of the drop is approximately 0.5 centimeter. Credit: Kenneth Ingham

Microorganisms have inhabited nearly all of our planet's surface and near surface, Earth's critical zone, for the past 3.5 billion years. Given the vast time that Earth has been teeming with life, it is hard to imagine what the planet would be like without its biosphere.

But Earth without life is exactly what participants at a recent meeting sought to contemplate. More than 30 scientists from eight countries attended an international workshop hosted by the Earth-Life Science Institute Origins Network (EON) at the Tokyo Institute of Technology in September 2017. The participants contributed expertise in Earth science, planetary science, biology, chemistry, and mathematics.

To begin this thought experiment, participants sought to answer the question, What are the key characteristics of an abiotic Earth compared with the Earth that we know? Exploring this question may help uncover essential aspects of what makes our home planet habitable. What we learn may help us to assess the possibility of extraterrestrial life elsewhere in the universe.

Attendees contemplated the hypothesis that "everything on Earth that is or has been influenced by water is inseparably coupled with life." Scientists debated such questions as whether any surface process on Earth is truly abiotic, to what degree a process has been influenced by life, and whether everything in the critical zone (the Earth's surface and near-surface environment), deeper in the crust, and even in the mantle has been affected by life.

Participants engaged in spirited debates about how best to evaluate abiotic processes. They concluded that developing a set of standards for abiotic and biotic characteristics could help advance community understanding by providing quantitative metrics for comparison across what are often very different data types and observed time frames. Long discussions focused on whether enough is presently known about the boundaries of life on Earth to make such assessments, especially in light of continuing revelations about the many challenging conditions to which extremophiles have adapted.

Attendees agreed that evidence for life falls into three primary categories of biosignatures:

- objects: physical features such as mats, fossils, and concretions
- substances: elements, isotopes, molecules, allotropes, enantiomers, and minerals (including their identities and properties)
- patterns: physical three-dimensional or conceptual *n*-dimensional relationships of chemistry, physical structures, etc.

Small breakout groups addressed many different expressions and the preservation potential of biosignatures in these three broad categories.

Participants also identified five key issues that warrant further development:

- the criticality of examining phenomena at the right spatial scale and how biosignatures may elude us if not examined with the appropriate instrumentation or modeling approach at that specific scale
- the need to identify the precise context across multiple spatial and temporal scales to understand how tangible biosignatures may or may not be preserved
- the desire to increase the community's capability to mine big data sets to reveal major relationships, for example, how Earth's mineral diversity may have evolved in conjunction with life
- the need to leverage cyberinfrastructure for data management of biosignature types, classifications, and relationships
- the utility of 3-D to *n*-D representations of biotic and abiotic models overlain on multiple overlapping spatial and temporal relationships that can provide new insights

The lively and engaged mood of the participants resulted in emerging collaborations to pursue these challenges into the future.

By **Marjorie A. Chan** (email: marjorie.chan@utah.edu), Department of Geology and Geophysics, University of Utah, Salt Lake City; **H. James Cleaves II,** Earth-Life Science Institute, Tokyo Institute of Technology, Tokyo, Japan; and **Penelope J. Boston,** NASA Astrobiology Institute, Moffett Field, Calif.

Our Spectacular Earth

Our Earth is breathtaking, always. No matter when we look down, where we are, day or night, the perspective is exceptional.

From space, you can see the drama of Earth's past and present. At nearly 300 miles per minute, continents flash by in the time it takes to review a new photo.

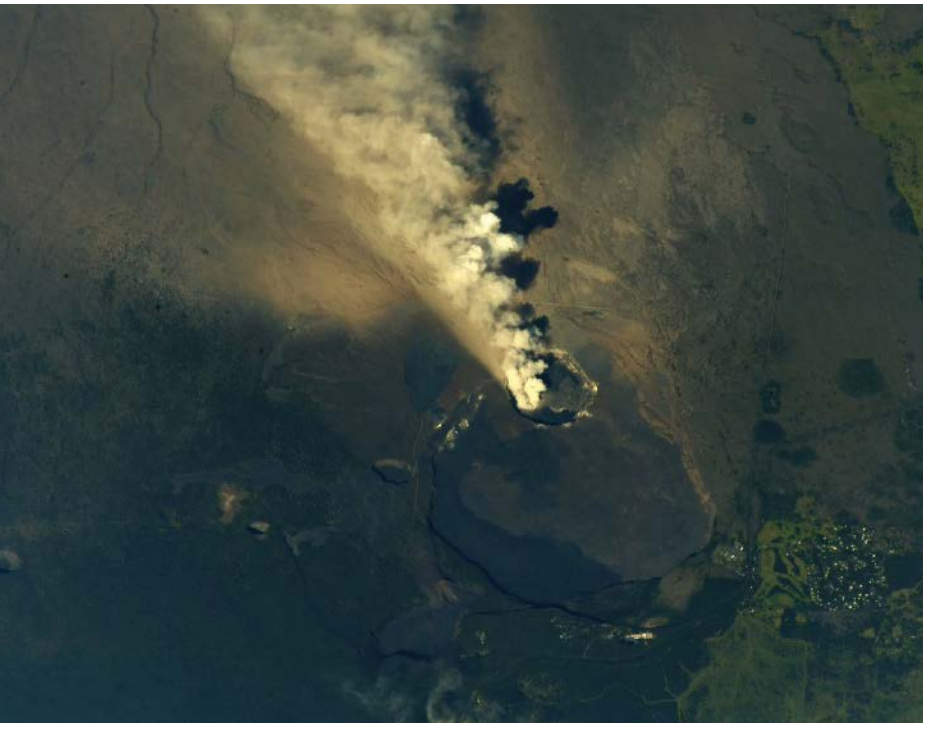
Each day, this view impresses upon me the importance of the work we all do as geoscientists. We strive to understand how this planet works, how it can provide resources for our use, and how we can protect it so that we may continue traveling through space on this spaceship we call Earth.

All of us who are geoscientists need to continue to share our stories of discovery.

By **Andrew J. "Drew" Feustel** (@Astro_Feustel), NASA Astronaut

Editor's Note: In early June, Drew Feustel became the commander of the International Space Station's Expedition 56. He is scheduled to return to Earth in early October.

During a 16 May space walk, Drew Feustel installs external wireless antennas and replaces an external light and camera on the International Space Station's truss. Credit: Ricky Arnold/NASA



It's easy to see activity on Hawaii's Kīlauea volcano from the International Space Station. Photo taken in mid-May. Credit: Drew Feustel

A view of the mighty Amazon River in mid-May. Credit: Drew Feustel

Rugged mountains of southeastern Spain near the Mediterranean coast (37.4°N, 1.8°W). Photo taken in late May. Credit: Drew Feustel

Peer Review's Psychological Potholes

Peer review is an essential component of scientific publishing. I was at the sharp end of it for many years as a journal editor and, as is typical of one in that role, suffered the slings and arrows of outrageous fortune from authors and reviewers both.

I argued in a past opinion piece [*Helffrich*, 2013] that the review process should be rewarded by publishers through in-kind means involving the publishing process itself. Here I highlight the need for the reviewer to have seamless access to review materials. I also suggest a way to achieve this.

Small Bumps in the Road Can Stall Reviews

Reviewers freely donate their time to advance science, to the benefit of their community and of society at large. But getting reviewers is hard because their time is precious. A reviewer is easily deterred and will quickly carp or quit at any impediment to a smooth review process.

With the emergence of commercial platforms to manage the manuscript-handling process, from submission to decision, reviewing is becoming commoditized. By this, I mean that most manuscript-handling platforms require reviewers to open an account with them to submit a review.

Platforms usually demand that the reviewer enter some information prior to accessing the manuscript and providing the review. There is, in fact, no need for this because the review request and response already established a communication link and a reviewer identity (Figure 1, light blue box).

Although opening an account on the manuscript-handling platform might be dismissed as a minor irritation given the greater one of a review, my experience taught me that 15% of reviews arrived as emails with notes to the effect that the system was too hard to deal with.

A Seamless, Easy Fix

A straightforward way to avoid these issues is to adopt a one-stop-shop approach to identification of authors and reviewers.

Just as some news outlets allow access through credentials provided by social networking platforms (e.g., Facebook and LinkedIn), author and reviewer access to manuscript-handling platforms should be allowed via services such as Open Researcher and Contributor ID (ORCID) and ResearcherID, which identify individual scientists. Two side benefits are that services like ORCID and ResearchID likely adhere to limits placed on information sharing with commercial organizations (the extent of which many professional societies rightly and rigorously codify) and that the user would have fewer accounts and passwords to maintain.

To clarify, contrast the information given in a submission process with any given for a review (Figure 1, green box). A potential author needs to be identifiable and contactable. If giving this information is too burdensome, he or she can choose to submit elsewhere. A reviewer has already been identified by the editor (Figure 1, yellow box). The email contacting that reviewer is all that's needed to provide a unique and verifiable identifier for that reviewer. Anything more could impede the review process.

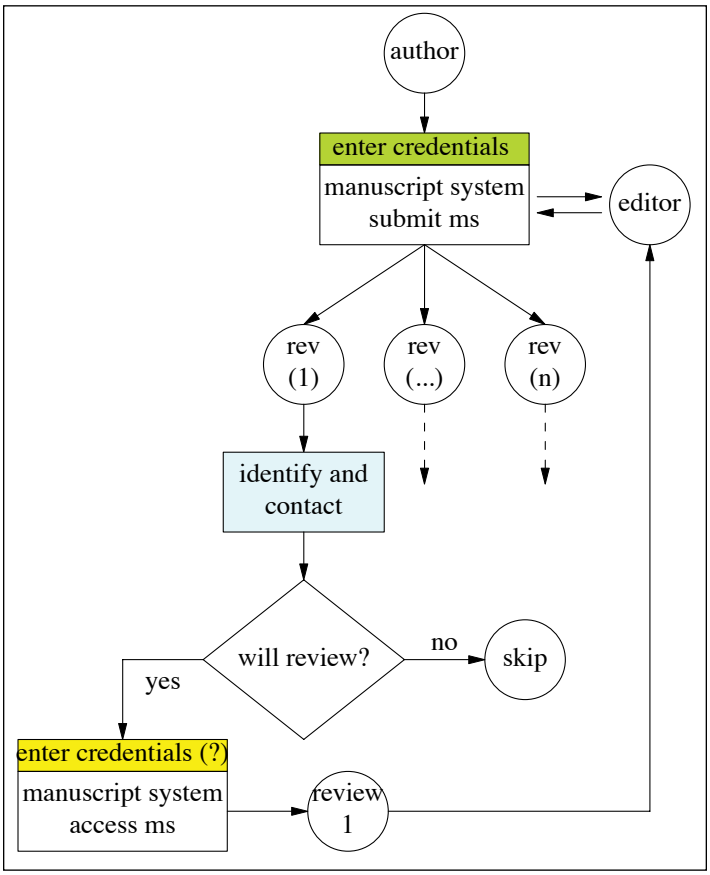


Fig. 1. Key steps in the review process. The decision steps are omitted for clarity.

It Isn't a Credit Card Application; It's a Review

How important are such seamless reviews? Well, when 15% of reviewers are annoyed, that's a lot of reviewers.

More personally, I resigned my editorial duties after the manuscript-handling system I worked with asked me—after 6 years—to enter my fax number to "complete" my personal contact information. Without this fax number, I was blocked from accessing my active manuscripts.

Professional societies such as the American Association for the Advancement of Science, AGU, and the European Geosciences Union should take the lead in protecting their members (and their editors!) from procedural potholes dug by poor design and support of the manuscript-handling software systems that front their journals. It is only with their collective clout that professional societies can steer the review process onto smoother pavement and get more and better reviews with less ire.

References

Helffrich, G. R. (2013), A modestly rewarding proposal concerning peer review, *Eos, 94*(48), 459, https://doi.org/10.1002/2013EO480004.

By **George Helffrich** (email: george@elsi.jp), Earth-Life Science Institute, Tokyo Institute of Technology, Tokyo, Japan

Touring the Solar System with Science Art

Look around during any science presentation and you'll see scientists of all career stages jotting down notes. This is especially true at conferences, where the hundreds or thousands of presentations can become one big blur after a week of sleep deprivation and science.

James Tuttle Keane's approach to taking notes at conferences is, well, a bit different than most. Keane is a postdoctoral scholar at the Joint Center for Planetary Astronomy at the California Institute of Technology in Pasadena. He's also a scientific illustrator. During conferences, Keane takes notes by creating elaborate sketches of presentations he attends. He outlines them live during each talk and then details and colors them later.

"I've always taken graphical notes because I'm a very visual person and I like to sketch," Keane said. "They started out as just black-and-white pen sketches. Then I started adding color, and now they're very detailed and take a lot of time and are very colorful. They've evolved and become more artistic."

In his sketches, Keane tries to capture a few of the key points of a presentation, but from his own point of view. "I want them to have my perspective, my flavor," he said. "I want them to either show something that wasn't shown explicitly or say something in a different way."

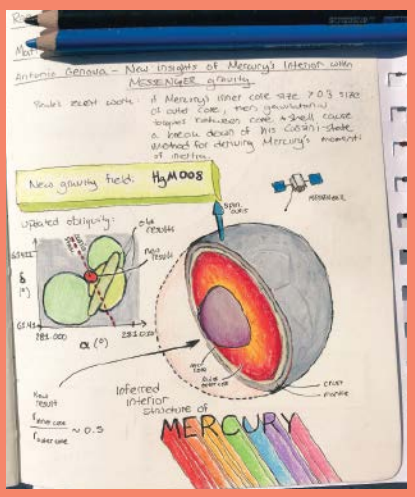
Keane started his conference live sketching in 2014, and the science community's response, he said, has been overwhelmingly positive.

"It's been exciting to watch this become more of a thing," he said. "I think that it's useful to show how you can fold art into science. I think that it's been beneficial to everyone."

Eos first noticed Keane during the 49th Lunar and Planetary Science Conference (LPSC) in Texas earlier this year. All told, he created around 20 different sketches from some of the talks he attended, with topics ranging from Mercury to Pluto and beyond.

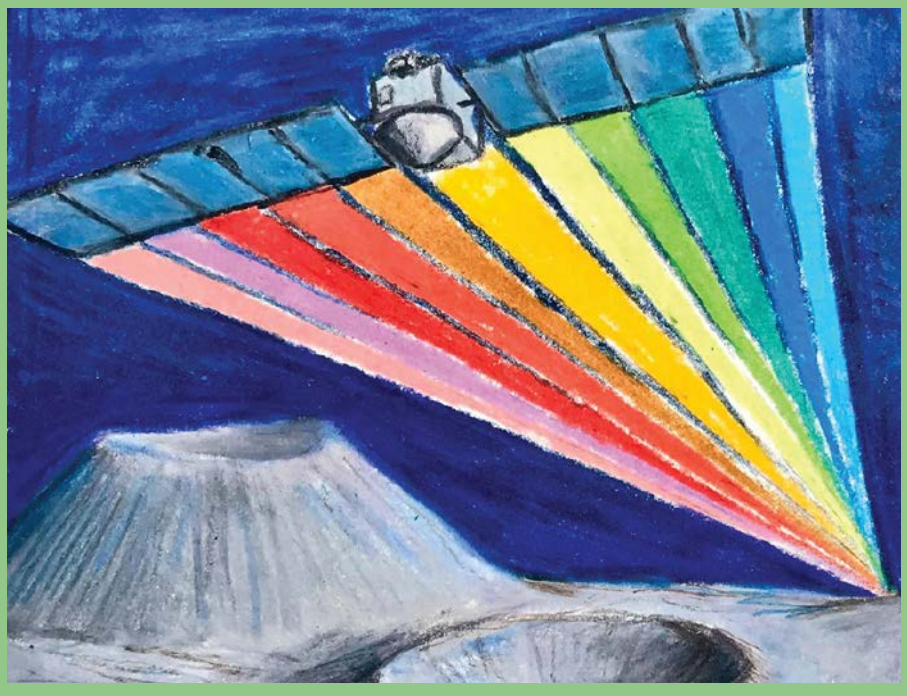
Take a tour of the solar system with some of his (and our) favorite illustrations from that conference.

What Does Mercury Look Like Inside? Ask Its Gravity



Gravity field measurements taken by NASA's MESSENGER spacecraft gave scientists a peek at Mercury's solid inner core. Credit: James Tuttle Keane, Caltech

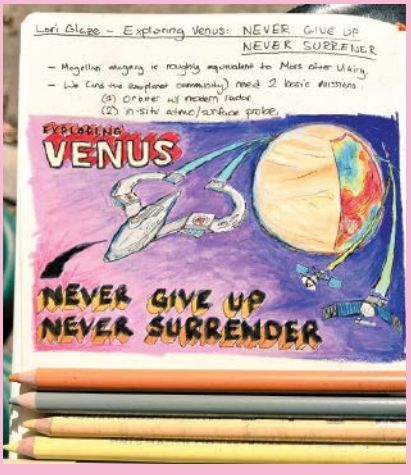
Dawn Is Flying High in the Asteroid Belt



The Dawn spacecraft soars above the cratered surface of Ceres in this hand-drawn illustration. Credit: James Tuttle Keane, Caltech

By Grabthar's Hammer, Go Back to Venus!

This sketch is Keane's favorite from the conference.

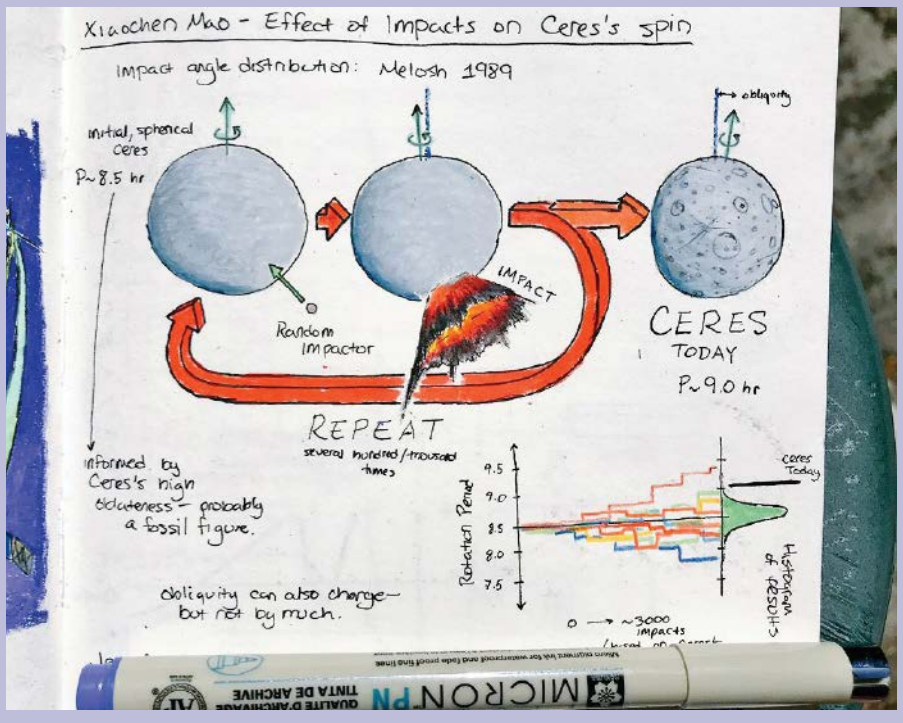


Planetary scientists aren't giving up, or surrendering, their goal of future missions to Earth's sister planet. Credit: James Tuttle Keane, Caltech

Our Moon Might Soon Receive Some Visitors from China

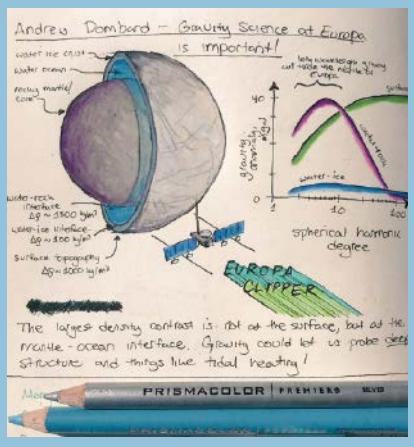
China has plans in the works to explore the Moon. Credit: James Tuttle Keane, Caltech

Ceres Was Getting Dizzy...



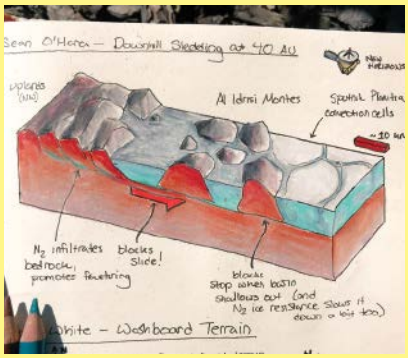
Don't judge Ceres for its minor spin-down. You'd move more slowly, too, if asteroids kept hitting you in the head. Credit: James Tuttle Keane, Caltech

Don't Forget Europa's Rocky Center



Hype may surround Europa's subsurface ocean, but the rocky mantle has science mysteries to unlock, too. Credit: James Tuttle Keane, Caltech

Pluto's Chaotic Surface Is Really Just an Icy Slip 'n Slide



Chaos reigns when Pluto's water ice bedrock fractures, slides, and gets hollowed out by frozen nitrogen. Credit: James Tuttle Keane, Caltech

Since LPSC, Keane has been busy sketching aspects of the Mars InSight mission, New Horizons, even recent papers about Venus—you can see those sketches on his Twitter account (@jtuttlekeane). Keep an eye out for more of Keane's work during the New Horizons flyby of Ultima Thule on New Year's Eve 2019.

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

SNOWFALL RATES FROM SATELLITE DATA HELP WEATHER FORECASTERS

By Ralph Ferraro, Huan Meng, Brad Zavodsky, Sheldon Kusselson, Deirdre Kann, Brian Guyer, Aaron Jacobs, Sarah Perfater, Michael Folmer, Jun Dong, Cezar Kongoli, Banghua Yan, Nai-Yu Wang, and Limin Zhao

A new data product calculates snowfall rates from weather data beamed directly from several satellites, helping meteorologists provide fast, accurate weather reports and forecasts.

In the early morning hours of 28 January 2014, satellite data showed snow accumulating in the clouds over Birmingham, Ala., but weather forecasters predicted only a light dusting of snow for the day ahead. Over the course of the next several hours, snow began to fall—and kept on falling. Although the area got only a couple of inches of snow, it was enough to bring this southern city to a standstill. Commuters abandoned their cars on freeways and spent the night in office buildings and shopping centers. Children slept in classrooms and day care centers because their parents could not come to bring them home.

Rainfall rates derived from satellite data have a long legacy in operational weather forecasting because their information complements ground observations such as weather

AP Photo/Butch Dill

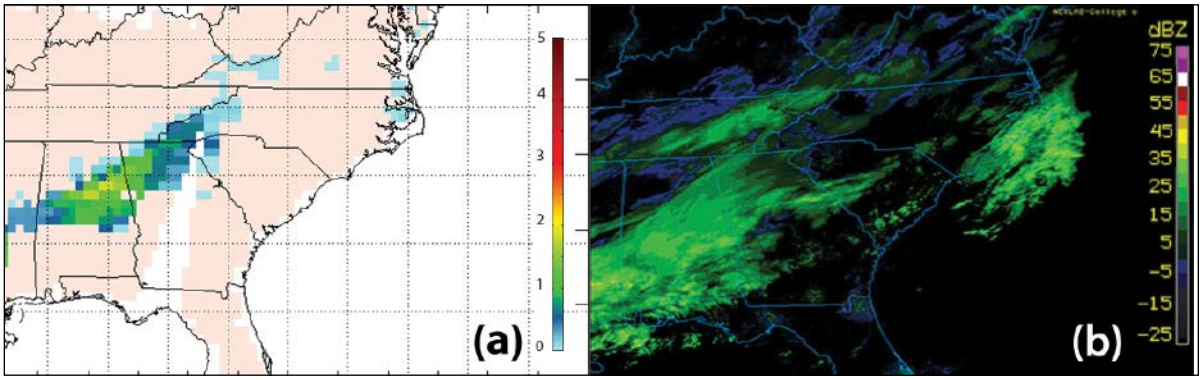


Fig. 1. Snowfall rate estimates for a 28 January 2014 storm that blanketed the southeastern United States. (a) Satellite snowfall rates captured by the SFR product at 11:19 a.m. and (b) the corresponding Next Generation Weather Radar (NEXRAD) composite radar reflectivity map. Credit: UCAR

radar and rain gauges. Satellite precipitation estimates also fill in voids where ground measurements are lacking, for example, in mountainous regions. Until recently, however, satellite-derived snowfall rates have been difficult to achieve because of the challenges in detecting and quantifying them from space.

Recently, our multiagency team of scientists developed an operational data product that uses satellite data to calculate snowfall rates (SFR) over land, stated as a water equivalent intensity (in millimeters per hour) at a satellite footprint diameter of approximately 15 kilometers on the ground (see Figures 1, 2, and 3). Previously, satellite data were downloaded in batches after the completion of each full orbit, creating about 2 hours of lag time between observations and data delivery. This new product, however, exploits direct broadcast (DB) capability from several satellites in low-Earth orbit that take microwave measurements over the continental United States and Alaska. These satellites send SFR measurements directly to ground-based receivers within 20–30 minutes of satellite observations.

These estimates aid National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) forecasters during snowfall events. Data-sparse forecast regions of the NWS like Alaska can benefit from using all available low-Earth-orbiting satellites and the DB capability to obtain regular, timely updates of the SFR.

The Need for Real-Time Snowfall Information

Snowstorms are among the most significant weather events, yet historically, accurately measuring snow has been challenging. Satellite snowfall retrievals can help fill in surface observational voids.

Falling snow can have significant economic impacts and can interrupt transportation on the ground and in the air. Major storms regularly cause disruptions over the course of several days in highly populated regions; however, even minor snowfall affects local commuting and highway travel, disrupting the commercial trucking industry.

The satellite maps that hinted at the impending "Snowpocalypse 2014" (see http://bit.ly/snowpocalypse-2014) are examples of data products. These maps rely on mathematical models that process raw data on the amounts of microwave radiation that reach a variety of satellite sensors from cloud ice content and the land and ocean surfaces below. The maps display the relevant data (e.g., rainfall or snowfall rates) in a form that weather forecasters can interpret and use.

Geostationary satellites are capable of frequent infrared measurements, but these measurements correlate poorly with snowfall rates on the ground. Conversely, low-Earth-orbiting passive microwave measurements can reliably detect snowfall within clouds, but these observations are less frequent, and there is a longer lag between when the observations are made and when they are received at ground-based stations (data latency).

Product Motivation, Development, and Evolution

In 1998, the first advanced microwave sounding unit (AMSU-B) was placed into operation on board the NOAA-15 satellite. After several years of demonstrating the utility of AMSU-B for monitoring global rainfall [*Ferraro et al.*, 2005], many studies showed the potential for monitoring falling snow as well [e.g., *Kongoli et al.*, 2003; *Skofronick-Jackson et al.*, 2004]. The AMSU-B sensor was followed by the Microwave Humidity Sounder (MHS) on NOAA and European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) satellites. The most recent instrument, the Advanced Technology Microwave Sounder (ATMS), flies on board the Suomi National Polar-orbiting Partnership (Suomi NPP) and NOAA-20 satellites and the NASA Global Precipitation Measurement Microwave Imager (GMI).

All these sensors take measurements at critical frequencies at and above 85 gigahertz; sensors measure microwave emissions at 183 gigahertz, the signature frequency band emitted by water vapor, making it feasible to detect frozen hydrometeors (snow, ice, and the like) in the atmosphere. Earth's surface is generally masked enough by atmospheric water vapor to isolate the 183-gigahertz signal associated with snow in the atmosphere from the signal at this frequency originating from snow on the ground [*Kongoli et al.*, 2015; *Meng et al.*, 2017].

The current operational SFR product was developed by scientists at NOAA and the National Environmental Satellite, Data, and Information Service (NESDIS), working in conjunction with training and product assessment special-

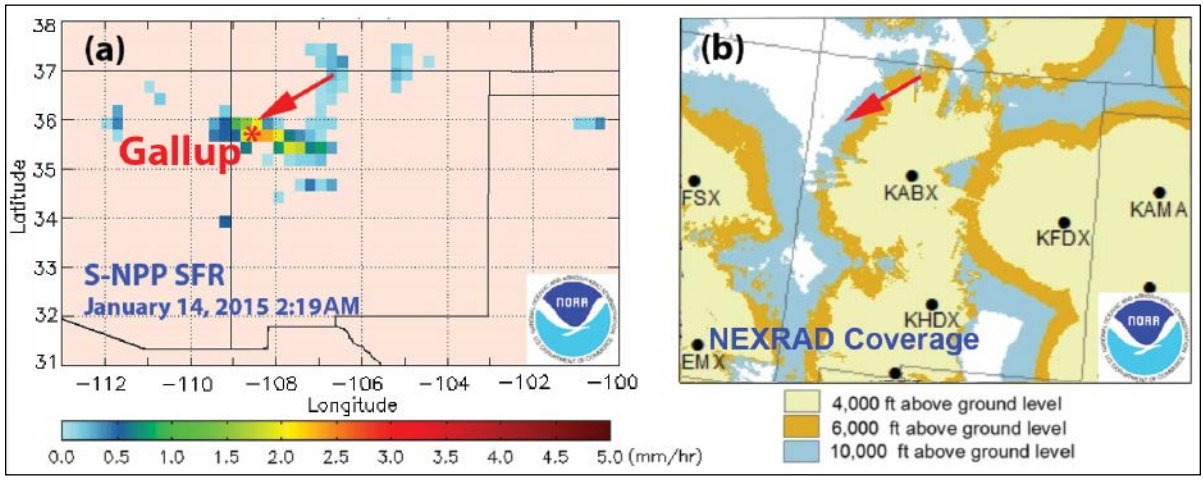


Fig. 2. (a) The Suomi NPP SFR data product captured a snowfall event in northwestern New Mexico on 14 January 2015 that was also observed at the local weather station at Gallup. (b) The white areas in the NEXRAD coverage map show that radar coverage is limited to nonexistent in this area (indicated by the red arrow).

ists at NASA's Short-term Prediction Research and Transition (SPoRT) Center.

Product Assessment

To evaluate the usefulness of the SFR product for NWS forecast operations, NASA's SPoRT Center led product assessments in collaboration with NOAA algorithm developers at several NWS weather forecast offices from 2014 to 2016. Important feedback from the first winter season indicated that latency was a major factor limiting its application.

To solve the problem, the project team turned to DB data. With DB, a satellite can instantaneously transmit its observations to any ground station on Earth that has the appropriate antenna; most of the continental United States, Alaska, and Hawaii are equipped with such ground stations. Compared with the standard operational delivery options (batch downloads delivered to a few designated ground stations after the completion of each 100-minute orbit), DB of the data from the satellite to the user reduces the latency time by about 1 hour.

The SFR project team retrieves the DB data, generates the SFR product, and sends the SFR data to SPoRT for

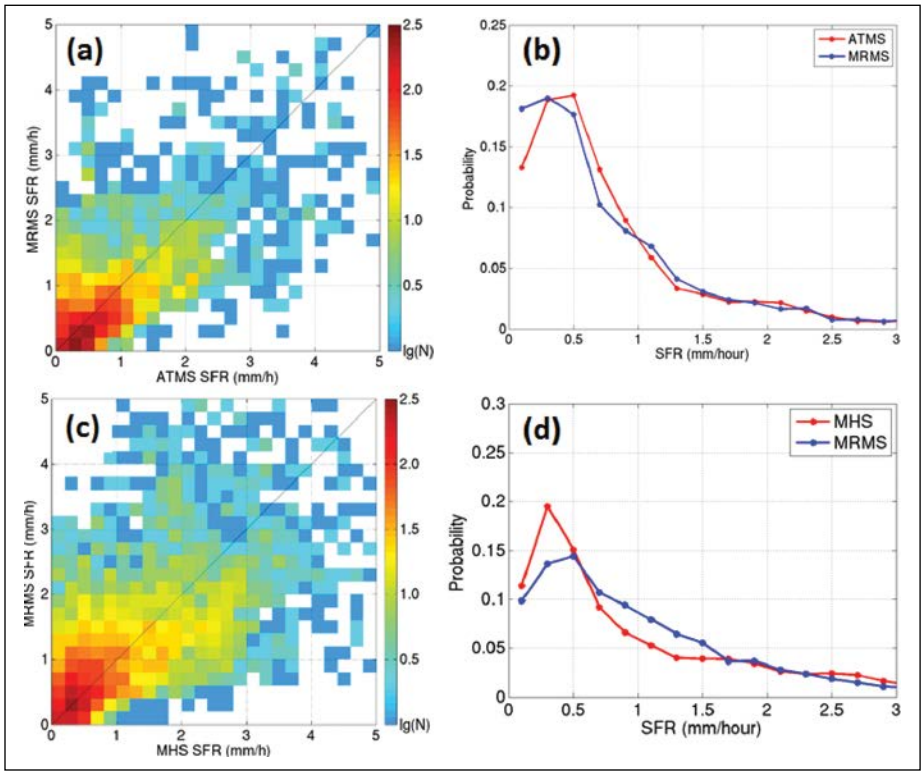


Fig. 3. SFR data product performance for the 14 March 2017 nor'easter on the U.S. East Coast. (a) Comparison of snowfall rates calculated using Advanced Technology Microwave Sounder (ATMS) data and the SFR product with those calculated using Multi-Radar Multi-Sensor (MRMS) radar precipitation data and (b) comparison between ATMS SFR and MRMS probability distribution functions. (c) A similar comparison between MHS SFR rates and MRMS radar precipitation data and (d) the corresponding probability distribution functions. The ATMS SFR performs slightly better than the MHS SFR: Note the smaller spread in the scatterplots (Figure 3a versus Figure 3c) and the better fit of the SFR distributions (Figure 3b versus Figure 3d).

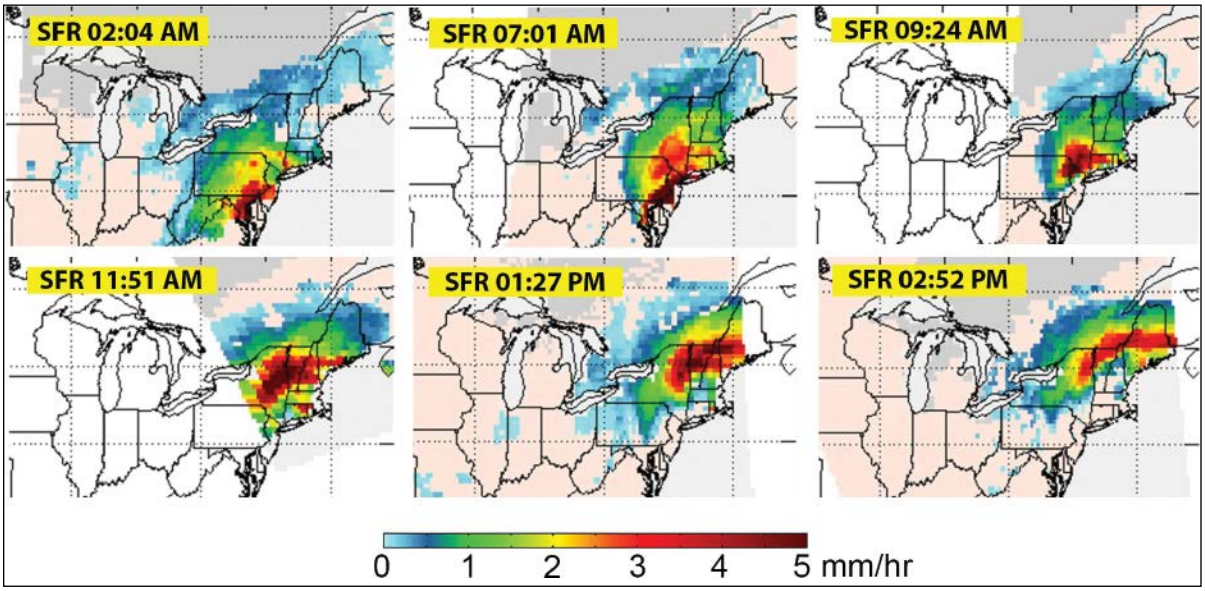


Fig. 4. SFR time series showing the evolution of the 14 March 2017 nor'easter. The scale indicates the water equivalent of the SFR, ranging between 0 and 5 millimeters per hour. Satellite data were obtained from the areas shaded in pink; no data were available from the white areas.

reformatting within 30 minutes of satellite observations. SPoRT then delivers the resulting imagery to the weather forecast offices. SFR developers at NOAA and NASA also maintain web pages where SFR images are posted in near-real time (see http://bit.ly/NOAA-SFR and https://go.nasa.gov/2K0Ixn6).

Testing the SFR Product in Albuquerque, N.M.

The SFR product provides a unique, space-based perspective from which to easily identify the extent of a snowstorm, the location of the most intense snowfall, and the rain-snow boundary. These features are not generally apparent from traditional satellite imagery or surface radar.

On 14 January 2015, the Albuquerque weather forecast office used the SFR product near the northwestern New Mexico town of Gallup, an area with very limited radar coverage. Feedback from this office indicated that the 2:19 a.m. Suomi NPP SFR image (Figure 2) matched ground-based observations better than did the precipitation forecast from the North American Mesoscale Forecast System (NAM), a NOAA weather forecast model, within this data-sparse region.

The NWS Albuquerque forecaster said, "From this information I was able to determine [that] the NAM forecast was too slow with the evolution of the precipitation. The radar values dropped off away from the KABX [Albuquerque] radar, which is expected, whereas the SFR product increased in the area of heaviest snowfall. Rates were close to the observed value at KGUP (Gallup)."

Ground observations also included information from the web page for the New Mexico Department of Transportation (http://bit.ly/NM-roads), which showed difficult driving conditions within this region. Although New Mexico is not a very densely populated state, the commercial trucking industry relies heavily on its interstate highways. Thus, knowing the likelihood of snow-covered conditions or active falling snow (which reduces visibility) in remote areas is vital to the NWS for issuing travel advisories.

SFR Product Maps the March 2017 Nor'easter

A major nor'easter (a storm that blows in from the northeast) swept over the U.S. East Coast on 14–15 March 2017. The SFR product retrieved data from five satellites to capture the evolution of the snowstorm. Comparison of the SFR data with Multi-Radar Multi-Sensor (MRMS; http://bit.ly/NOAA-MRMS) radar precipitation data produced by NOAA for the same location [*Zhang et al.,* 2016] yielded strong correlations and low bias.

These results create confidence in the reliability of the SFR in other regions where radar observations are limited. Figure 3 shows scatterplots and probability distributions of ATMS and MHS SFR compared to MRMS. Because the ATMS sensor has a fuller set of channel complements at the 183-gigahertz water vapor band, it performs slightly better than the SFR from MHS. Figure 4 provides a series of satellite SFR images, showing the progression of the snowfall rates during the storm.

Meeting the Snowfall Rate Challenge

Snowfall is an important weather element, yet it is challenging to measure accurately and consistently, especially because ground measurements are limited in many regions. By exploiting DB data from low-Earth-orbiting satellites, an operational snowfall rate product can play an important role in providing timely observations for improved situational awareness, short-term forecasts, warnings, and verification in these regions. Operational weather forecasters have provided valuable feedback on the product's strengths and limitations, and this feedback has led to substantial improvements to the algorithm over the past several years [*Meng et al.,* 2017].

In the near term, SFR algorithms for the Global Precipitation Measurement Microwave Imager and the Defense Meteorological Satellite Program's Special Sensor Microwave Imager Sounder are undergoing final evaluation and will be ready for the 2018–2019 winter season, further improving the temporal coverage of the product. Within the next 3 years, we will focus on extending the algorithm to offshore retrievals. Radars in these areas have limited range but are important to weather forecasts as active areas of snow approach, then move over land.

Acknowledgments

The authors acknowledge NOAA's Joint Polar Satellite System Proving Ground and Risk Reduction Program, the NASA Earth Science Division, and the NESDIS Center for Satellite Applications and Research for supporting this project. We also acknowledge our NASA partners at the Global Precipitation Measurement and SPoRT programs, with whom we have worked jointly on various aspects of snowfall rate retrievals for many years. The views, opinions, and findings contained in this article are those of the authors and should not be construed as an official NOAA or U.S. government position, policy, or decision.

References

Ferraro, R. R., et al. (2005), NOAA operational hydrological products derived from the AMSU, *IEEE Trans. Geosci. Remote Sens., 43,* 1,036–1,049, https://doi.org/10.1109/TGRS.2004.843249.

Kongoli, C., et al. (2003), A new snowfall detection algorithm over land using measurements from the Advanced Microwave Sounding Unit (AMSU), *Geophys. Res. Lett., 30*(14), 1756, https://doi.org/10.1029/2003GL017177.

Kongoli, C., et al. (2015), A snowfall detection algorithm over land utilizing high-frequency passive microwave measurements—Application to ATMS, *J. Geophys. Res. Atmos., 120,* 1,918–1,932, https://doi.org/10.1002/2014JD022427.

Meng, H., et al. (2017), A 1DVAR-based snowfall rate retrieval algorithm for passive microwave radiometers, *J. Geophys. Res. Atmos., 122,* 6,520–6,540, https://doi.org/10.1002/2016JD026325.

Skofronick-Jackson, G., et al. (2004), A physical model to determine snowfall over land by microwave radiometry, *IEEE Trans. Geosci. Remote Sens., 42,* 1,047–1,058, https://doi.org/10.1109/TGRS.2004.825585.

Zhang, J., et al. (2016), Multi-Radar Multi-Sensor (MRMS) quantitative precipitation estimation: Initial operating capabilities, *Bull. Am. Meteorol. Soc., 97,* 621–638, https://doi.org/10.1175/BAMS-D-14-00174.1.

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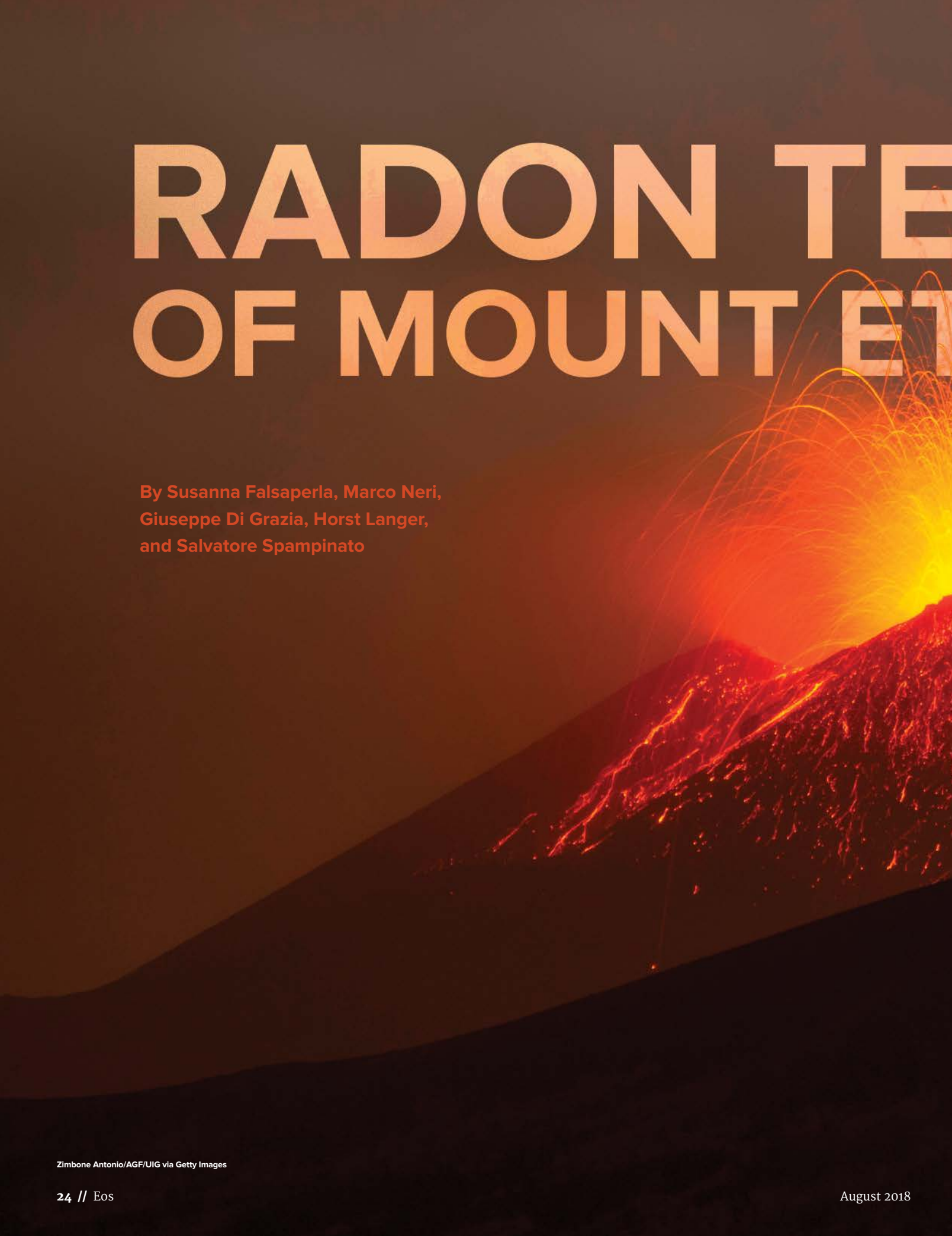
RADON TE
OF MOUNT ET

By Susanna Falsaperla, Marco Neri, Giuseppe Di Grazia, Horst Langer, and Salvatore Spampinato



Zimbone Antonio/AGF/UIG via Getty Images

ELLS TALES TNA'S UNREST

Some researchers view radon emissions as a precursor to earthquakes, especially those of high magnitude [e.g., *Wang et al.*, 2014; *Lombardi and Voltattorni*, 2010], but the debate in the science community about the applicability of the gas to surveillance systems remains open. Yet radon "works" at Italy's Mount Etna, one of the world's most active volcanoes, although not specifically as a precursor to earthquakes. In a broader sense, this naturally radioactive gas from the decay of uranium in the soil, which has been analyzed at Etna in the past few years, acts as a tracer of eruptive activity and also, in some cases, of seismic-tectonic phenomena.

To deepen the understanding of eruptive and tectonic phenomena at Etna, scientists analyzed radon escaping from the ground and compared those data with measurements gathered continuously by

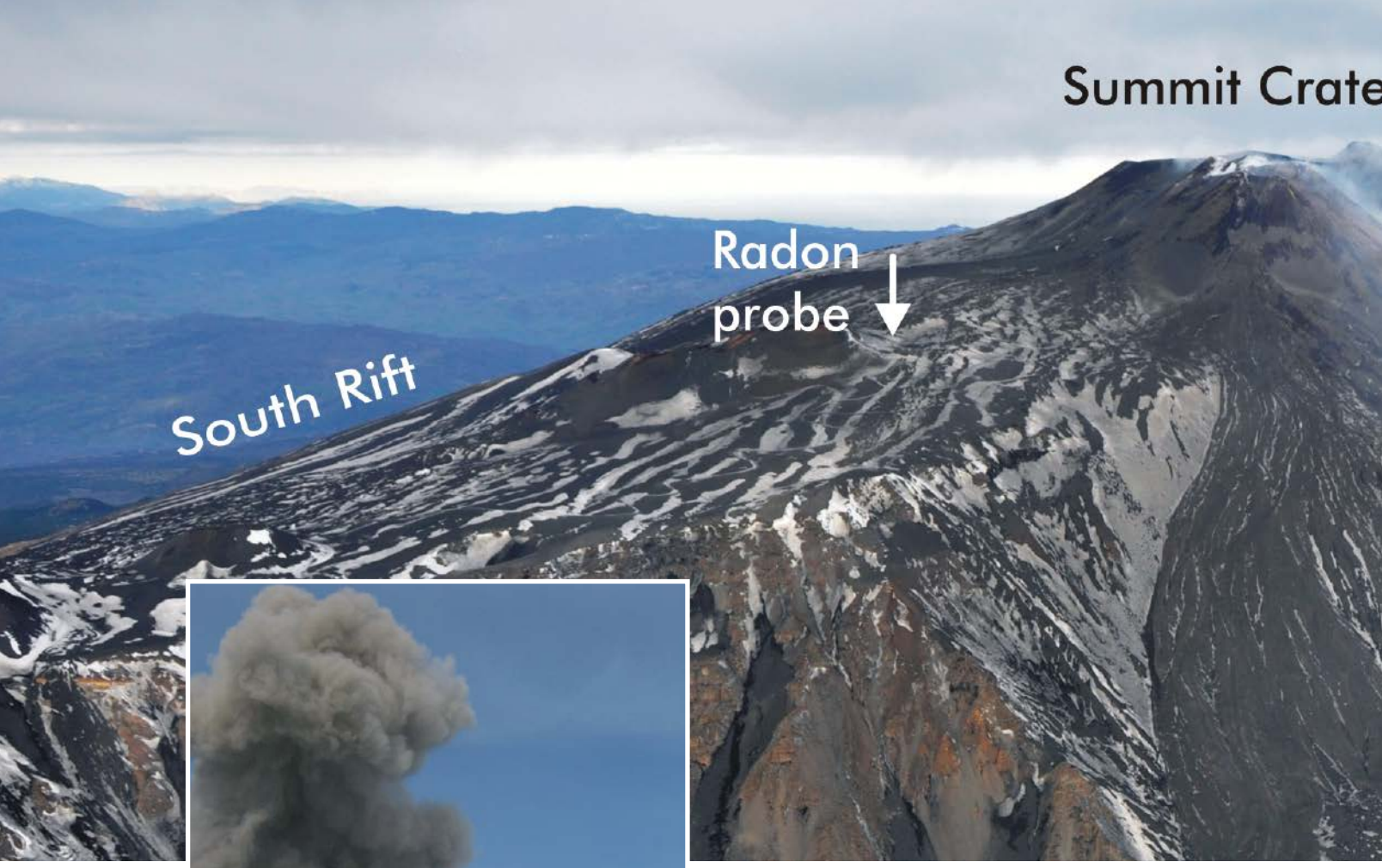


Fig. 1. Panoramic view of Mount Etna as it appeared during 2008–2009.

Volcanologist Marco Neri during the winter of 2008–2009 downloads data onto a laptop from the ERN1 radon sensor at the site (later buried in lava) known as the Tower of the Philosopher. Behind him, less than 1 kilometer away, ash billows from the summit craters of the volcano. Credit: Marco Neri

instrument networks on the volcano (Figure 1). Here Etna is a boon to scientists—it's traced by roads, making it easy to access for scientific observation.

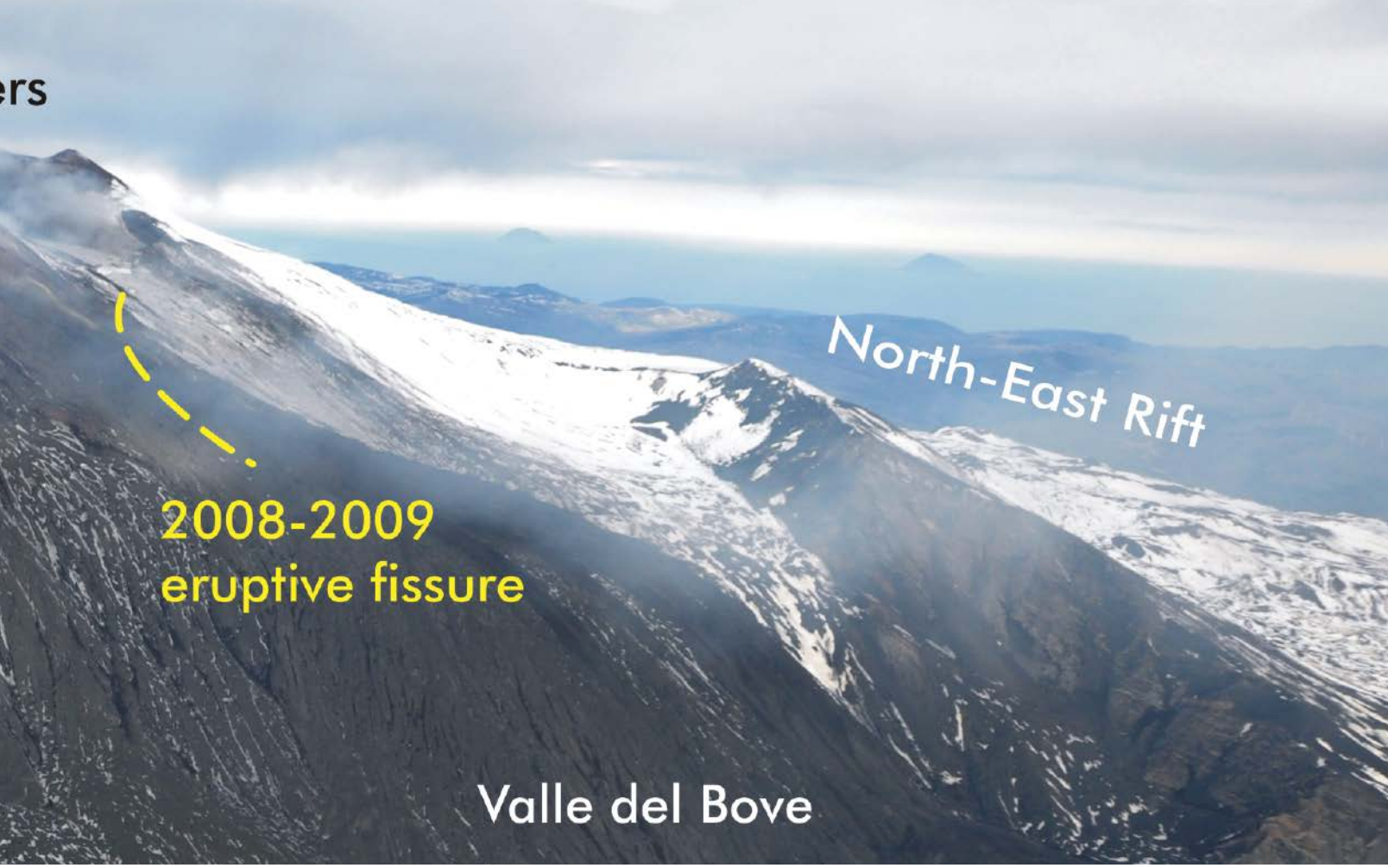
Dense monitoring networks, managed by the Istituto Nazionale di Geofisica e Vulcanologia, Catania-Osservatorio Etneo (INGV-OE), have been continuously observing the volcano for more than 40 years. This continuous dense monitoring made the volcano the perfect open-air laboratory for deciphering how eruptive activity may influence radon emissions.

Tower of the Philosopher

In a recently published study [*Falsaperla et al.*, 2017], we analyzed a period of dynamic and variable volcanic activity at Etna between January 2008 and July 2009. In those 19 months, the volcano produced seismic swarms, surface ground fractures, a vigorous lava fountain, and an eruption lasting 419 days.

In short, the volcano delivered enough diverse behaviors to test whether radon detected by a station located near the top of Etna, at an altitude of about 3,000 meters, showed any patterns that matched eruptive behavior recorded by the networks. The station is at a place formerly known as the Torre del Filosofo (Tower of the Philosopher), which in 2013 became buried below meters of lava flows that completely changed the location's appearance.

The network's data are plentiful and are related to physical occurrences, such as the vibrations produced by magma movements in the feed conduits, known as volcanic tremor. They also relate to the tremor source's localization within the volcano; isolated seismic events or



swarms; and ground fractures accompanying the opening of eruptive fissures and associated explosive and effusive events. We conducted an analysis of this enormous amount of data through a statistical-mathematical approach that revealed possible correlations and, in many cases, obvious synchronicities with radon emissions.

What Did We Discover?

Our study revealed that essentially two processes influenced radon levels at the monitoring station. The first, easily imaginable given the location of the measuring probe less than a kilometer from the summit craters of Etna, is linked to the rise of magma in the volcano's central conduit. Short, intense radon bursts, which researchers refer to as gas pulses, occur when a carrier gas that conveys the radon to the surface also bursts from the volcano (Figure 2). In the area in question, this carrier consists mainly of water vapor that feeds the local fumarolic activity.

The second process is rock fracturing from an earthquake or seismic swarm. Radon rising from rock fractures

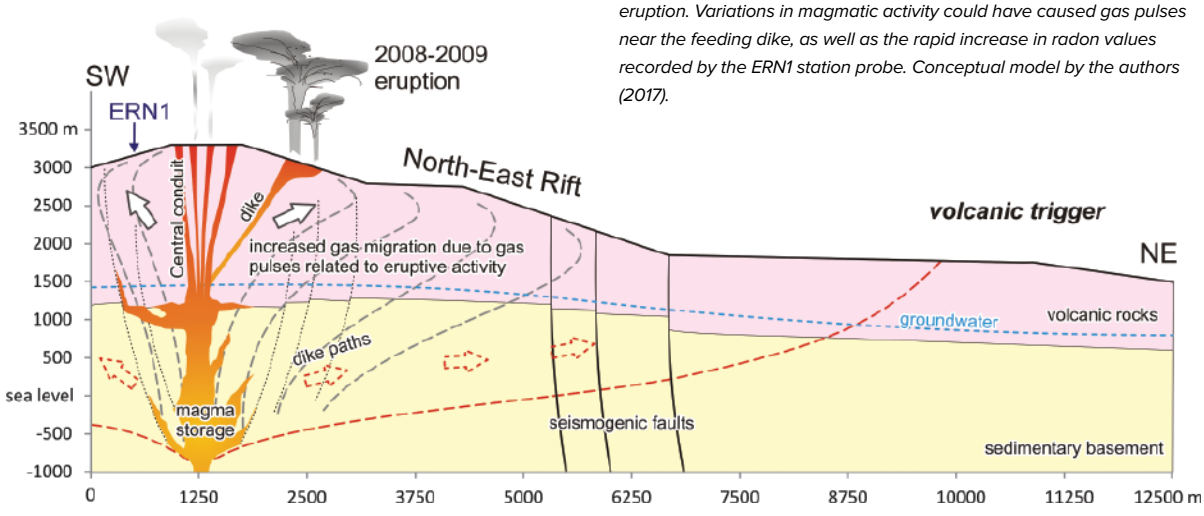


Fig. 2. Volcanic processes may have influenced the flux of radon recorded by the ERN1 probe during Mount Etna's 2008–2009 flank eruption. Variations in magmatic activity could have caused gas pulses near the feeding dike, as well as the rapid increase in radon values recorded by the ERN1 station probe. Conceptual model by the authors (2017).

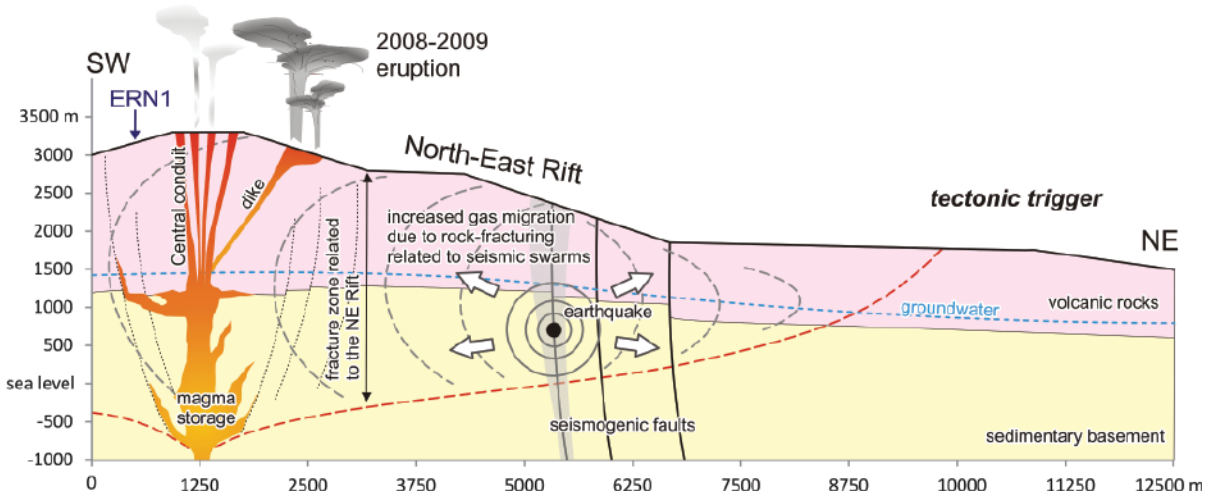


Fig. 3. Along with volcanic triggers (Figure 2), tectonic activity may have influenced the flux of radon recorded by the ERN1 probe during Mount Etna's 2008–2009 flank eruption. Seismicity in the rift zone could have caused microfracturing of the rocks, changing their porosity and permeability. Resulting gas migration inside the highly fractured zone related to the rift may have led to fluctuations in radon emissions recorded by the ERN1 station. Conceptual model by the authors (2017).

is a well-known, recurrent phenomenon caused by greater permeability of the ground following earthquake-induced breakage of rock.

Action at a Distance

We have also discovered that the radon probe of the Torre del Filosofo was sensitive even to relatively small earthquakes taking place several kilometers away. We noted a clear synchronism between seismic swarms more than 10 kilometers away from the probe and significant variations of radon, impossible to explain by the diffusion of radon gas to rocks and toward the surface. We therefore had to find a different solution, which we identified as a sloshing phenomenon, like the lapping of waves.

We have discovered that the radon probe was sensitive even to relatively small earthquakes taking place several kilometers away.

Slosh dynamics describes the movement of liquids within a container [*Ibrahim*, 2005]. Experimental observations prove that sloshing may occur inside the conduits of volcanoes, promoting magma oscillations [*Namiki et al.*, 2016].

Applied to Etna, sloshing may explain how rock shaking induced by a seismic swarm can cause oscillatory motion in the groundwater and in the magmatic fluids contained within the volcano (Figure 3). These oscillations can propagate quickly inside the mountain, reaching far greater distances in relatively short times than had been imagined. Sloshing may also be favored by flank instability affecting the eastern and southeastern sectors of the volcano, as it can produce tensile stresses both on the summit and on the rift zones, increasing the permeability of the rocks in those areas [*Acocella et al.*, 2016].

In some ways, these remote influences are an unforeseen discovery that implicitly reveals that the volcano is in a perpetually precarious balance and is therefore easily disturbed. Reminiscent of a butterfly effect, even a small phenomenon occurring, for example, on the north side of Mount Etna can make its effects felt on the opposite side.

Acknowledgments

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References

Acocella, V., et al. (2016), Why does a mature volcano need new vents? The case of the new Southeast Crater at Etna, *Front. Earth Sci., 4,* 67, https://doi.org/10.3389/feart.2016.00067.

Falsaperla, S., et al. (2017), What happens to in-soil radon activity during a long-lasting eruption? Insights from Etna by multidisciplinary data analysis, *Geochem. Geophys. Geosyst., 18*(6), 2,162–2,176, https://doi.org/10.1002/2017GC006825.

Ibrahim, R. A. (2005), *Liquid Sloshing Dynamics: Theory and Applications,* 948 pp., Cambridge Univ. Press, Cambridge, U.K., https://doi.org/10.1017/CBO9780511536656.

Lombardi, S., and N. Voltattorni (2010), Rn, He and CO_2 soil gas geochemistry for the study of active and inactive faults, *Appl. Geochem., 25,* 1,206–1,220, https://doi.org/10.1016/j.apgeochem.2010.05.006.

Namiki, A., et al. (2016), Sloshing of a bubbly magma reservoir as a mechanism of triggered eruptions, *J. Volcanol. Geotherm. Res., 320,* 156–171, https://doi.org/10.1016/j.jvolgeores.2016.03.010.

Wang, X., et al. (2014), Correlations between radon in soil gas and the activity of seismogenic faults in the Tangshan area, north China, *Radiat. Meas., 60,* 8–14, https://doi.org/10.1016/j.radmeas.2013.11.001.

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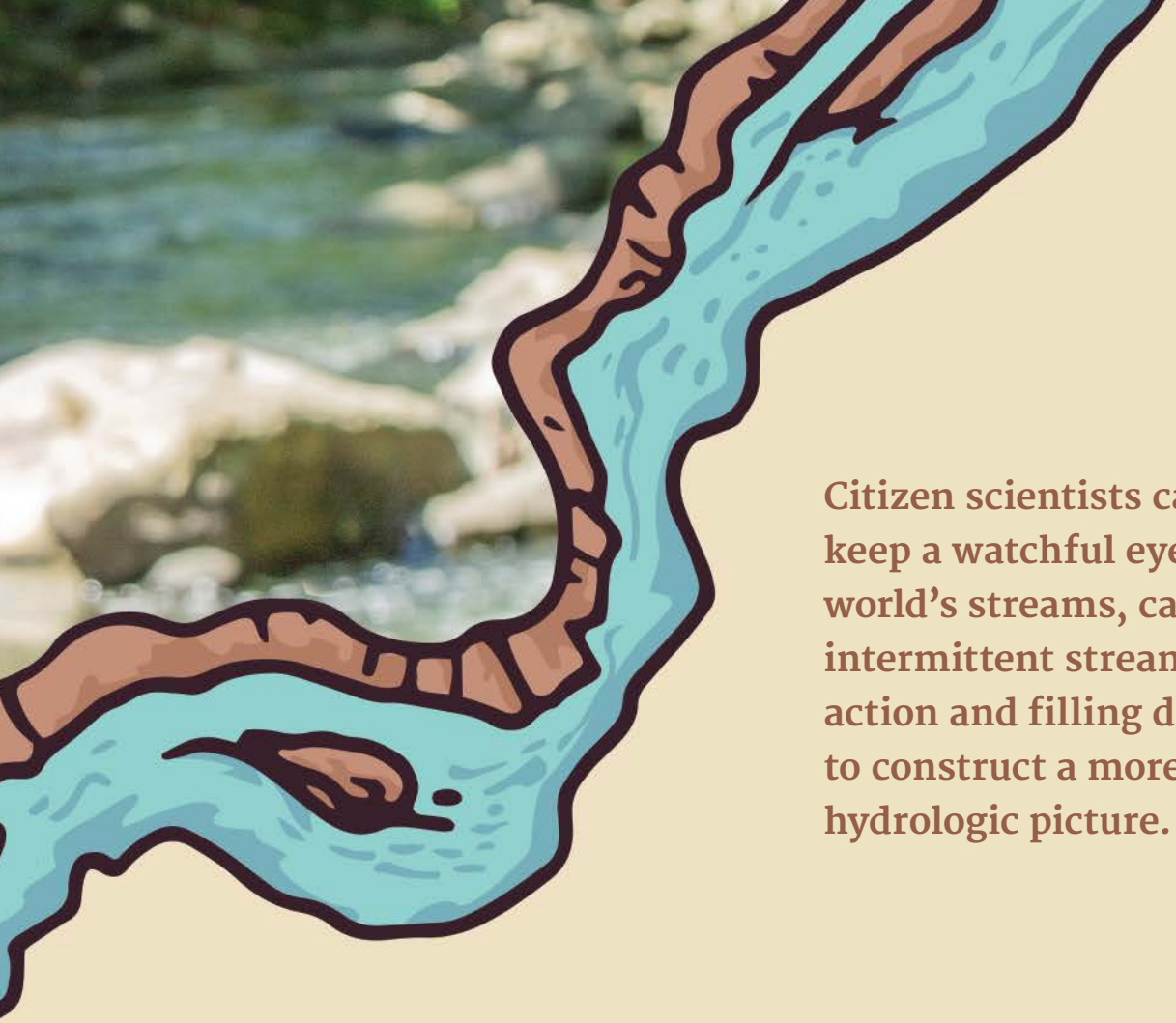
AT&T LTE
10:20 AM
crowd water
ADD SPOT
HOW MOIST IS THE SOIL?
SAVE

Beth Bagley



Citizen scientists can now keep a watchful eye on the world's streams, catching intermittent streams in action and filling data gaps to construct a more complete hydrologic picture.

Testing the Waters

Mobile Apps for Crowdsourced Streamflow Data

By Stephanie Kampf, Barbara Strobl, John Hammond, Alyssa Anenberg, Simon Etter, Caroline Martin, Kira Puntenney-Desmond, Jan Seibert, and Ilja van Meerveld

Do you drive, bike, or hike by streams on your way to a field site, the office, or home? Are you interested in how streams change through seasons and years? If so, consider joining a growing crowd of people logging streamflow data using their mobile phones.

Two new projects—CrowdWater and Stream Tracker—focus on crowdsourced hydrologic measurements, and both have recently launched free smartphone applications to facilitate data collection along stream networks.

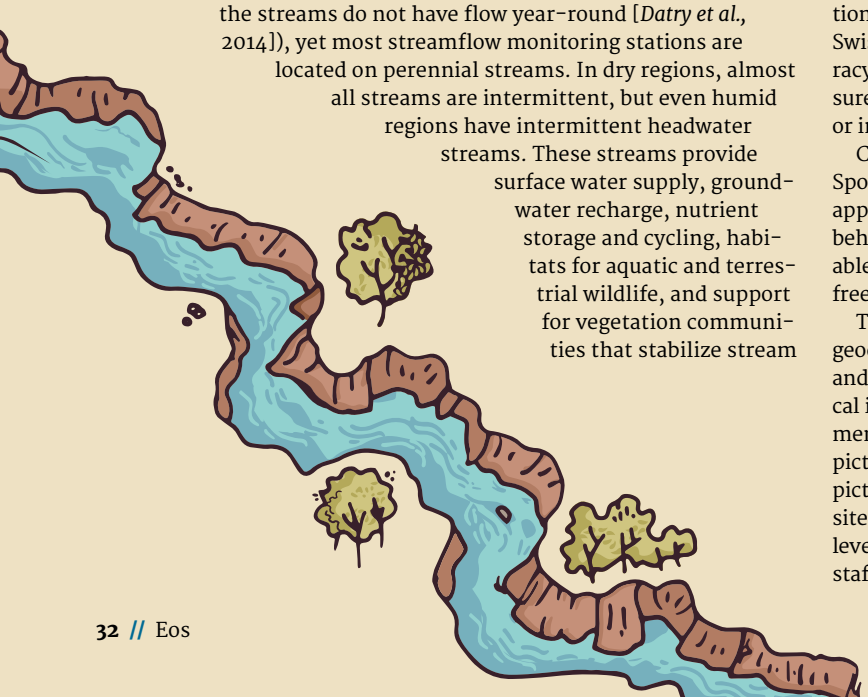
Many of us regularly rely on crowdsourced mobile phone data for traffic conditions, restaurant reviews, and recommended news articles. Environmental scientists use crowdsourcing to map biodiversity, invasive species, phenology, and bird locations [*Tweedle et al.,* 2012]. Increasingly, crowdsourcing is also providing valuable hydrologic data for research and watershed management [*Turner and Richter,* 2011; *Lowry and Fienen,* 2013; *Little et al.,* 2016].

Keeping an eye on the world's streams is a daunting task. If you add up the length of all the streams around the world, the total is at least 89 million kilometers [*Downing*

A citizen scientist uses a smartphone app to collect streamflow data and other hydrological information. Credit: Simon Etter

et al., 2012]. Even in regions with good hydrologic monitoring networks, it is unrealistic to monitor all streams with in-stream sensors. Crowdsourcing is a practical method to increase the accuracy of stream maps and expand understanding of when, where, and how streams flow.

Not only do the world's streams span an immense spatial extent, but also many of them require frequent checking to catch them in action. More than half of the global stream channel network is likely intermittent (i.e., the streams do not have flow year-round [*Datry et al.,* 2014]), yet most streamflow monitoring stations are located on perennial streams. In dry regions, almost all streams are intermittent, but even humid regions have intermittent headwater streams. These streams provide surface water supply, groundwater recharge, nutrient storage and cycling, habitats for aquatic and terrestrial wildlife, and support for vegetation communities that stabilize stream banks [*Levick et al.,* 2008]. Existing map layers often classify stream types incorrectly [*Fritz et al.,* 2013], so many areas lack accurate information on intermittent stream locations.



CrowdWater Tracks Hydrologic Variables

The CrowdWater project's goal is to improve hydrologic forecasts with the help of crowdsourced data that include water level, streamflow, soil moisture, and the flow condition of intermittent streams. This project, funded by the Swiss National Science Foundation, also assesses the accuracy of the data, the effectiveness of quality control measures, and how useful citizen science data are to calibrating or improving hydrologic models.

CrowdWater data are collected with an app developed by Spotteron (https://www.spotteron.net), a citizen science app development company based in Vienna, Austria, on behalf of the University of Zurich. The app has been available for Android and iOS since April 2017 and can be used free of charge.

The CrowdWater project uses an approach similar to geocaching: Every participant can establish a new station and contribute data for already existing stations. No physical installations or sensors are needed for the measurements. For stream-level measurements, the user takes a picture and uses the app to add a virtual staff gauge to the picture. When that person or another user returns to the site at another time, the user can determine the new water level by comparing the current water level to the virtual staff gauge on the picture.

The status of intermittent streams can be recorded using six categories: flowing water, trickling water, standing water, isolated pools, wet streambed, and dry streambed. Measurements for streams that are not on the map help to document the existence of the intermittent stream network. For soil moisture, another qualitative scale (based on the work of *Rinderer et al.* [2012]) is used.

So far, 533 CrowdWater stations have been established, and 172 different participants have made more than 1,550 measurements. Everyone can participate, and all participants in the project can view and request the data. Participants can see a time series of the data collected at each site when they enter new data in the field, and they can use the data to monitor their environment or to plan kayak outings or fishing trips.

The project organizers will also use the data to test their usefulness for hydrologic model calibration and for improving understanding of streamflow dynamics. The long-term goal is to be able to obtain crowdsourced data in countries that have little hydrometric data or to supplement the available data.

Stream Tracker focuses on documenting flow patterns in intermittent streams.

Stream Tracker Monitors Intermittent Streams

Stream Tracker focuses on documenting flow patterns in intermittent streams. This project started in April 2017 with funding from the Citizen Science for Earth Systems Program of NASA (https://go.nasa.gov/2JWI1Gt).

Stream Tracker's goal is to improve intermittent stream mapping and monitoring using satellite and aircraft remote sensing, in-stream sensors, and crowdsourced observations of streamflow presence and absence. The crowdsourcing component is critical for understanding intermittent streams because remote sensing provides data infrequently, and widespread sensor installation is infeasible. Crowdsourcing can fill in information on streamflow intermittence anywhere people regularly visit streams—during a hike or bike ride or when passing by while commuting.

Stream Tracker sites can be established on any stream through the project website on the citizen science platform CitSci.org. Ideal sites are streams that do not flow continuously, are publicly accessible, and have an evident channel that will be easy to see even when the stream is not flowing. Anyone can join the project, establish sites in locations of interest, and track the streams over time.

Current participants range in age from elementary school students to retired teachers and include not only stream experts but also people who have never monitored streams before. Project members can navigate to the sites using mobile phones or GPS units and can enter data on whether the stream is flowing using the free CitSci.org mobile app.

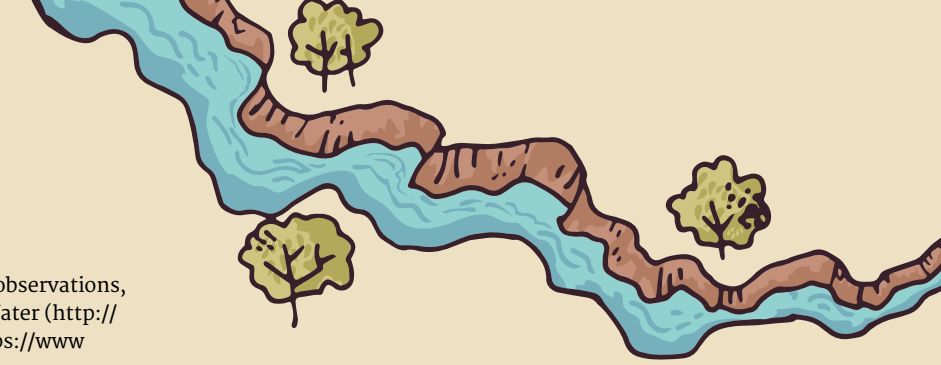
For researchers who regularly visit field sites, stream tracking is an easy add-on to a field day. Researchers can identify stream crossings on their route to field sites, add these locations as monitoring points to Stream Tracker, and upload data after each field visit. All Stream Tracker data are freely accessible through the project website.

This observer is using the Stream Tracker app to fill in information on an intermittent stream (left) during a dry period and (right) when the stream is flowing. Credit: Kira Puntenney-Desmond

Why Are Crowdsourced Hydrologic Data Useful?

Crowdsourcing projects in hydrology can vastly increase the number of monitored tributaries in a watershed. For example, over its first year of measurements in the Cache la Poudre basin of northern Colorado, Stream Tracker revealed which parts of the watershed contributed snowmelt or rainfall runoff to the main river channel at different times of the year, helped improve maps of stream types, and documented habitat conditions for species relying on intermittent streams. As streams change with climate, land use, water use, and other stressors, crowdsourced data can help reveal when, where, and how these changes affect flow.

Crowdsourcing hydrologic data is also an easy way to promote public engagement and education about streams and watershed processes. As these and other hydrology-related citizen science projects develop, we will continue to work toward creating accessible tools suited for a wide variety of locations and applications. We welcome any input from others interested in crowdsourcing hydrologic data. You do not need to be a hydrologist to contribute to these projects. It is easy and accessible, and anyone can participate. So get outside and track some streams!



To learn more, share your own streamflow observations, or get involved, visit our websites for CrowdWater (http://bit.ly/Crowd-Water) and Stream Tracker (https://www.streamtracker.org).

Acknowledgments

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References

Datry, T., S. T. Larned, and K. Tockner (2014), Intermittent rivers: A challenge for freshwater ecology, *BioScience, 64,* 229–235, https://doi.org/10.1093/biosci/bit027.

Downing, J. A., et al. (2012), Global abundance and size distribution of streams and rivers, *Inland Waters, 2*(4), 229–236, https://doi.org/10.5268/IW-2.4.502.

Fritz, K. M., et al. (2013), Comparing the extent and permanence of headwater streams from two field surveys to values from hydrographic databases and maps, *J. Am. Water Resour. Assoc., 49,* 867–882, https://doi.org/10.1111/jawr.12040.

Levick, L., et al. (2008), The ecological and hydrological significance of ephemeral and intermittent streams in the arid and semi-arid American Southwest, *Rep. EPA/600/R-08/134,* 116 pp., U.S. Environ. Prot. Agency, Washington, D. C.

Little, K. E., M. Hayashi, and S. Liang (2016), Community-based groundwater monitoring network using a citizen-science approach, *Groundwater, 54,* 317–324, https://doi.org/10.1111/gwat.12336.

Lowry, C. S., and M. N. Fienen (2013), CrowdHydrology: Crowdsourcing hydrologic data and engaging citizen scientists, *Groundwater, 51,* 151–156, https://doi.org/10.1111/j.1745-6584.2012.00956.x.

Rinderer, M., et al. (2012), Sensing with boots and trousers—Qualitative field observations of shallow soil moisture patterns, *Hydrol. Processes, 26,* 4,112–4,120, https://doi.org/10.1002/hyp.9531.

Turner, D., and H. Richter (2011), Wet/dry mapping: Using citizen scientists to monitor the extent of perennial surface flow in dryland regions, *Environ. Manage., 47,* 497–505, https://doi.org/10.1007/s00267-010-9607-y.

Tweedle, J., et al. (2012), *Guide to Citizen Science: Developing, Implementing and Evaluating Citizen Science to Study Biodiversity and the Environment in the UK,* Nat. Hist. Mus., London.

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ADVANCING EARTH AND SPACE SCIENCE

New Program Enables Scientists to Be Voices for Science

Credit: AGU

Voices for Science is designed to create a network of skilled and dedicated scientists who are ready to share their science with a variety of important audiences.

With science helping to inform societal decisions on everything from national security to keeping us safe in the face of natural disasters, it's more important than ever for scientists to share the value and impact of Earth and space sciences with policy makers, journalists, and public audiences, such as community groups.

That's why AGU has been helping to equip scientists with the skills they need to effectively communicate with a wide array of audiences in their home communities. Interest in and excitement about such activities have been steadily growing within the science community over the past few years, especially with the antiscience rhetoric expressed during and after the 2016 presidential election.

Participants in AGU's Voices for Science policy track visit Capitol Hill in Washington, D. C. Credit: AGU

To build on the increased enthusiasm and dedication, AGU launched a new outreach effort called Voices for Science (http://bit.ly/Voices4Science). Modeled on a combination of the Sharing Science and Congressional Visits Days programs, Voices for Science is designed to create a network of skilled and dedicated scientists who are ready to share their science with a variety of important audiences in key locations.

Meet Your New Voices for Science Advocates

The program was launched in February with an application process designed to identify a group of diverse individuals from 17 target states and districts in the United States. After nearly 100 applications were reviewed, 30 individuals were chosen because of the role their national elected officials play in influencing science policy and funding efforts on Capitol Hill.

The 30 Advocates, as we termed them, were drawn from many disciplines and work in labs, universities, and nonprofits. Each participated in one of the program's two tracks: policy and communications.

The first cadre of the Voices for Science program includes the following Advocates:

Susan Bates, Climate and Global Dynamics Laboratory, National Center for Atmospheric Research, Policy Track

Tracy Becker, Southwest Research Institute, Communications Track

Soumaya Belmecheri, Laboratory of Tree-Ring Research, University of Arizona, Policy Track

Sarah Benish, University of Maryland, Policy Track

AGU's Voices for Science communications track participants spend the day learning how to talk to the media and use social media and multimedia. Credit: AGU

Jennifer Blank, Blue Marble Space Institute of Science/NASA Ames Research Center, Communications Track

Claudia Corona, Jacobson James & Associates, Inc., Communications Track

Kimberly Duong, University of California, Irvine, Policy Track

Robert Goldman, University of Illinois at Urbana–Champaign, Policy Track

David Heath, Colorado State University, Fort Collins, Policy Track

Denise Hills, Geological Survey of Alabama and AGU Council Member, Policy Track

Tai–Yin Huang, Pennsylvania State University Lehigh Valley/Integrated Energy Solutions for Entrepreneurs, Policy Track

Brendan Kelly, Study of Environmental Arctic Change, University of Alaska Fairbanks, Policy Track

Kathy Kelsey, University of Alaska Anchorage, Communications Track

Rachel Kirpes, University of Michigan, Policy Track

Rafael Loureiro, Blue Marble Space Institute of Science/SETI Institute, Policy Track

Russanne Low, Institute for Global Environmental Strategies, Communications Track

Jessica Moerman, Smithsonian National Museum of Natural History, Communications Track

Tashiana Osborne, Scripps Institution of Oceanography, University of California, San Diego, Communications Track

Elizabeth Padilla, Inter American University of Puerto Rico, Communications Track

Joshua Papacek, University of Florida, Policy Track

Sriparna Saha, Rice University, Communications Track

Dork Sahagian, Lehigh University, Policy Track

Meredith Schervish, Carnegie Mellon University, Policy Track

Sanjoy Som, Blue Marble Space Institute of Science, Communications Track

Heidi Steltzer, Fort Lewis College, Communications Track

Sarah Straka, University of Miami, Communications Track

David Trossman, Institute for Computational Engineering and Sciences, University of Texas at Austin, Policy Track

Evelyn Valdez–Ward, University of California, Irvine, Communications Track

Jackson Watkins, Colorado State University, Communications Track

Jane Wolken, Alaska Climate Science Center, International Arctic Research Center, University of Alaska Fairbanks, Communications Track

A Plan of Action

The Voices for Science Advocates came to Washington, D. C., on 12–13 April for an intensive skills–building session that included shared sections between the two tracks as well as opportunities to break out and go into depth in their areas of interest.

Policy track participants visited Capitol Hill and participated in nearly 40 meetings with congressional offices; communications track participants learned about working with the media by giving mock interviews, as well as using social media and multimedia to share their science. Each of the 30 Advocates also created, and committed to, an action plan for conducting at least one activity in their community each month for the next year and engaging their peers in some of those activities.

Over the next year, AGU staff will provide hands–on support to the Advocates to help with their various outreach activities. Then, in December 2018, the Advocates will return to Washington for the AGU Fall Meeting, where they will participate in additional training and a variety of other activities.

By participating in the Voices for Science program, the Advocates are helping to build public support for Earth and space science, protect critical science funding, and advance federal support for science policy. We look forward to sharing their success stories and lessons learned, and we hope that they will serve as an inspiration for other AGU members to embark on their own science advocacy journeys.

By **Dana D. Rehm** (email: sharingscience@agu.org; @AGU_SciComm), Senior Vice President, Marketing, Communications, and Digital Media, AGU; and **Alexandra Shultz** (@AGUSciPolicy), Vice President, Public Affairs, AGU

Understanding the Effects of Anthropogenic Space Weather

The August 2017 launch of Taiwan's Formosat-5 satellite atop a SpaceX Falcon 9 rocket and the resulting plasma hole over the western United States. Credit: SpaceX

The ionosphere, the layer of Earth's atmosphere where gases have been stripped of their electrons by solar and cosmic radiation, hosts a large number of charged particles that can affect the propagation of radio waves. Although scientists have long known that natural disturbances like solar flares can interfere with radio wave transmissions, more recent studies have shown that rocket launches also create ionospheric disturbances that can introduce additional errors into navigation, positioning, and other satellite-based systems.

To better understand the effects of anthropogenic space weather, *Chou et al.* evaluated the ionosphere's response to the August 2017 launch of Taiwan's Formosat-5 satellite atop a SpaceX Falcon 9 rocket. The team measured perturbations in Global Navigation Satellite System signals, which are routinely used to determine changes in the ionosphere's electron content, and determined that the launch generated a circular shock wave that spanned an area 4 times larger than the state of California. The researchers attribute this megawave—the largest rocket-induced shock wave on record—to the launch's unique, nearly vertical trajectory.

The results indicate that this circular wave was followed by an even larger disturbance that developed as chemical reactions between the ionospheric plasma and the second-stage rocket exhaust temporarily depleted the layer's electrons. This created a 900-kilometer-wide plasma hole that persisted for several hours. Although the perturbations generated by the circular shock wave amounted to just 3% of background conditions, the plasma hole created electron depletions of up to 70%, a disturbance consistent with navigating and positioning errors of about 1 meter.

Because payload launches are expected to increase in the near future, these findings underscore the importance of understanding how space vehicle launches and other anthropogenic disturbances affect space weather and, in turn, GPS and other positioning, navigation, and timing services. (*Space Weather,* https://doi.org/10.1002/2017SW001738, 2018) **—Terri Cook, Freelance Writer**

How Fast Is the Nile Delta Sinking?

The Nile Delta makes up just 2% of Egypt's total area, but it's home to 41% of its population—roughly 95 million people. These communities are under threat, however; much of the northern delta is gradually sinking into seawater, drowning rich agricultural land and communities. But just how quickly is it going under? A new study based on satellite data provides an estimate: If sea level rise, oil and gas drilling, and groundwater pumping continue unchecked, nearly 3,000 square kilometers of the delta will sink by 2100.

The delta's subsidence can be traced to many factors. One key contributor is the upstream Aswan High Dam, built in the 1960s, which has reduced by more than 98% the amount of sediment that reaches the delta. Unable to replenish sediment lost to erosion, the delta gradually has been starved of its fertile mud. Simultaneously, over the past 30 years, Egypt has been pumping groundwater for agricultural, industrial, and urban use at an exponentially increasing rate, causing large areas to subside. In addition, Egypt has rapidly become Africa's second-largest producer of natural gas, extracting much of that fuel from the thick layers of sand and shale underlying the delta and exacerbating subsidence.

Although scientists have long known that large swathes of the delta are caving in and will be flooded by seawater, other regions appear to be uplifting because of flex in the sedimentary basin's geology. To track the region's deformation, *Gebremichael et al.* decided to take a bird's-eye—or, rather, a satellite's—view of the entire >40,000-square-kilometer delta and surroundings. They obtained a series of 84 highly detailed images taken between 2004 and 2010 and used a technology called persistent scatterer interferometry to reveal subtle changes in its topography.

The Nile Delta at night. Credit: NASA

The analysis revealed which regions of the delta are sinking and which are gradually lifting upward. Between the northern and southern parts of the delta, the team found an east–west zone of uplift roughly 40 kilometers across at its widest point, slowly rising at rates of up to 7 millimeters per year. The highest rates of subsidence occurred in the northern delta and in regions where natural gas and groundwater extraction is booming, such as the Menoufia Governorate and the Abu Madi gas field. Overall, the team concluded, 2,660 square kilometers of the northern delta will be flooded by seawater by 2100 if the current rate of topographical deformation continues. This calculation assumes a climate scenario in which atmospheric carbon dioxide levels remain below 500 parts per million and global sea levels rise 0.44 meter. Under that scenario, the loss of land in the delta would displace or otherwise affect nearly 5.7 million people, the scientists report. (*Journal of Geophysical Research: Solid Earth*, https://doi.org/10.1002/2017JB015084, 2018) **—Emily Underwood, Freelance Writer**

How to Build a Better Light Trap

Light is the ultimate escape artist. Scientists have spent centuries trying to capture it, most recently by building nanoscale materials that screen, absorb, and reflect its waves. Yet some light always seems to elude capture, either by leaking out or fading away. Now scientists have devised minuscule chambers that can theoretically hold precise quantities of light forever, a discovery that could hasten the development of light-based computers.

The ability to carefully control and confine light in small spaces is a key goal for scientists developing technologies like ultrafast optical computers, which use photons rather than electrons to process information. When light enters a cavity, its interaction with the container typically gives rise to microscopic oscillations that fritter energy away. *Silva et al.* present a way to prevent this decay, using nanoscopic, plasma-covered chambers called meta-atoms.

The team's first successful meta-atom, modeled using a computer program that simulates electromagnetic (EM) waves, was a spherical dielectric cavity surrounded by an electron-gas shell. When light enters the spherical cavity, its wavelength is squeezed to fit within the walls of the chamber, ensuring that the trapped light energy has a precise value that can be contained by its plasma-filled shell. Typical material structures are intrinsically bidirectional, so if one wishes to pump the nanosized chamber from the outside, then the cavity walls will necessarily leak some of the energy contained in it. To solve that problem, the team used a nonlinear mechanism that enables an EM wave to pump just enough energy into the container to keep the oscillations under control and the light contained.

Next, they used a similar approach to produce 2-D square and kite-shaped chambers, which may be easier to stack on computer chips than spheres. In this manner, they demonstrated that it is possible to confine the light in nanosized chambers of arbitrary geometry. Similar to their spherical counterparts, the 2-D chambers can trap light if zapped with a precisely titrated EM wave. In addition to optical computers, these nanoscale light trappers could potentially be used for chemical and biological sensors. (*Radio Science*, https://doi.org/10.1002/2017RS006381, 2018) **—Emily Underwood, Freelance Writer**

Impact of Hurricanes and Nor'easters on Coastal Forests

Coastal forests in Virginia show the effects of Hurricane Sandy. Tree rings provide a natural record of a forest's age and health and major disturbance events. Credit: William Kearney

As climate change continues to make hurricanes and other storms across the globe on average more frequent, long lasting, and severe, scientists are looking to pinpoint the impacts of these storms on the ecosystems in which they occur. In 2017, for example, GPS data of Houston, Texas, showed a depression in Earth's crust almost 2 centimeters deep caused by the weight of massive flooding from Hurricane Harvey. When Hurricane Irma passed through Florida later that year, it tore up seagrass beds and mangrove forests. And, to some extent, the Gulf Coast is still recovering from wetland loss and erosion caused by Hurricanes Katrina and Rita in 2005.

Coastal regions, where these effects are felt the most, are home to some of nature's most valuable—and vulnerable—ecosystems. The U.S. Mid-Atlantic coastal region is made up of wetland forests, saltwater and freshwater marshes, bays, and estuaries. Forests make up about 70% of land cover in the region.

Fernandes et al. investigated the impact of hurricanes and nor'easters on coastal pine forests in Virginia. The researchers used annual tree ring data and a mathematical model to analyze the forests' response to severe storms over the past few decades.

For the most part, the width of the tree rings signified age, regional climate trends, and other effects on the individual tree. In some cases, however, the team found that the rings showed signs of growth disturbances matching up with the timeline of known storms.

Specifically, the team looked at seven examples of severe storms that hit the Virginia coastline between 1904 and 2015: the Chesapeake-Potomac hurricane of 1933, the Ash Wednesday nor'easter of 1962, a strong nor'easter in 1998, Hurricane Isabel in 2003, a November 2009 nor'easter related to Hurricane Ida (Nor'Ida), Hurricane Irene in 2011, and Hurricane Sandy in 2012.

The researchers observed that tree ring growth declined following the years during which these storms occurred. The magnitude of these declines, they found, correlates well with the magnitude of the storm in terms of storm surge height and wind speed. These declines continued for about 3 years after the storm, after which ring growth started to recover.

This study is an interesting look at coastal forests' response to severe storms, as well as their resilience—something that becomes ever more important as climate change alters the frequency and severity of storms. (*Journal of Geophysical Research: Biogeosciences*, https://doi.org/10.1002/2017JG004125, 2018) **—Sarah Witman, Freelance Writer**

One of the World's Oldest Animals Records Ocean Climate Change

The sea is home to some 5,000 species of sponges. These multicelled animals first appeared about 800 million years ago. Although they lack muscles, bones, and a nervous system, one particular species has something that scientists want: information on the state of the climate thousands of years ago.

In most species of glass sponges, the spicules consisting of silica are microscopic and can be found littered in sediments underneath where they lived and died. However, *Monorhaphis chuni*, found in the Pacific Ocean at depths below about 1,000 meters, can live for several millennia and produce a single giant basal spicule that can reach 3 meters in length.

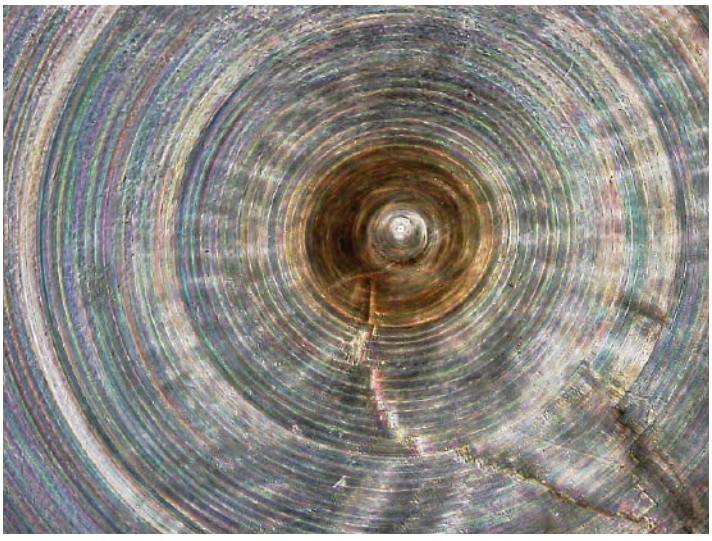
In a new study, *Jochum et al.* present data collected from five sponges ranging in age from 5,000 to 18,000 years. The *M. chuni* sponges were collected alive from the depths of the East China Sea, the South China Sea, and the southwestern Pacific Ocean. Their spicules are silent sentinels that record changes in the ocean content of dissolved silica, an essential seawater nutrient.

Silica in the deep ocean is important, because diatoms, microscopic algae that live in the sunlit surface ocean, make their shells out of dissolved silica. Every year they use up all the available silica in the surface layers of the ocean. The carbon dioxide that diatoms convert to organic carbon during photosynthesis is responsible for about half of all the marine carbon that falls into the deep sea. This sinking of carbon (and silica) out of the surface ocean helps keep this atmospheric greenhouse gas in check. Fortunately, most of it dissolves, and then upwelling brings the nutrients back into the sunlight so that the diatoms' annual supply is replenished. How fast this cycle turns and how much silica is supplied for diatom growth are very important to warming or cooling our climate.

However, these fluctuations in the silica content of seawater are difficult to study. Fortunately, deep-sea glass sponges are recorders of the historical fluctuations of these critical climate indicators.

Just like the rings in a cross section of a tree trunk provide information about past wildfires or droughts, cross sections of the sponge spicule reveal rings. Silicon isotope ratios within these rings provide information about the silica concentrations in the seawater that bathed the sponge when the ring formed.

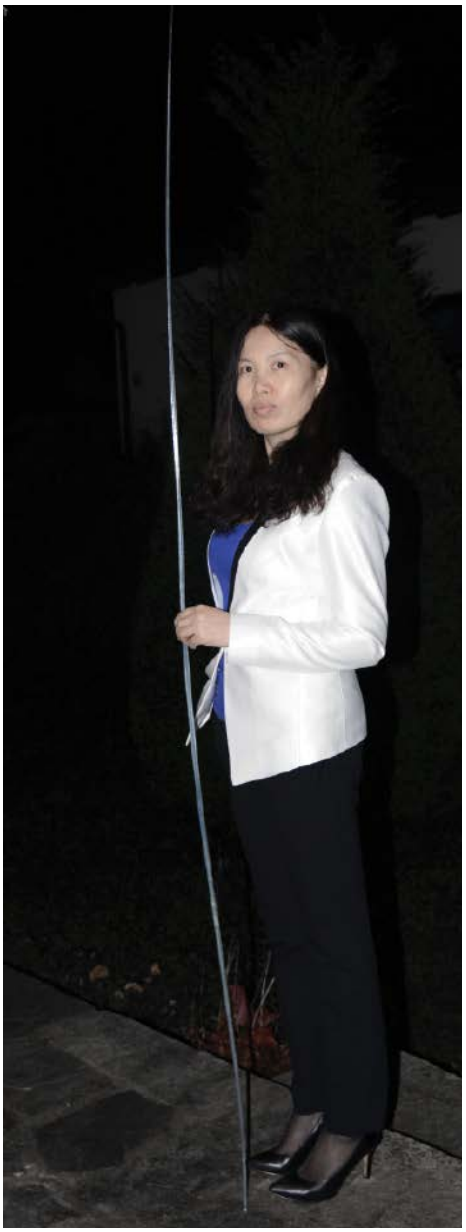
The researchers examined these rings, as well as nearby bottom seawater samples in contact with the modern outer rings of *M. chuni* spicules. They first compared the outer ring of the spicules with the surrounding seawater to affirm that silica concentrations in the seawater are reflected by the specific silicon isotope ratios of the outer layers of the spicule. After they established that agreement, they analyzed deeper layers in the spicule. Assuming that silicon isotope ratios in those deeper layers also reflect the waters that bathed them when they formed, the authors were able to tease out fluctuations in the concentrations of dissolved silica at each sponge's location over time.



Cross section of a Monorhaphis chuni *spicule showing its lamellae (rings). Each ring is about 10 micrometers thick. Isotope ratios of silicon within these rings give clues to the silica concentrations present in the seawater when they formed. Credit: W. E. G. Müller*

They found that during the early deglacial period (14,000–18,000 years ago), the concentrations of dissolved silica in the deep Pacific were about 12% higher than current levels. This result suggests that continental sources, such as winds and rivers, supplied more silica to the ocean during the deglacial or that the natural burial of diatom shells in deep-sea sediments was lower, enhancing the deep silica entrained into the upwelling currents. Either of these possibilities would have affected the past global carbon budget. (*Geophysical Research Letters*, https://doi.org/10.1002/2017GL073897, 2017)

—Mohi Kumar, Scientific Content Editor



Researcher Xiaohong Wang holds a 2.7-meter-long silica spicule of M. chuni *obtained from a living specimen raised from a depth of 2,100 meters in the South China Sea. Credit: W. E. G. Müller*

The Upside to a "Bad" Ozone Precursor

Heathland in Abisko, Sweden, with vegetation communities enclosed in plastic open-top chambers that mimic climate warming. Credit: Riikka Rinna

Just as humans breathe in oxygen and exhale carbon dioxide, plants and soil release chemical compounds of their own: biogenic volatile organic compounds (BVOCs). In the atmosphere, BVOCs react with nitrogen to form tropospheric ozone, which is also known as "bad" ozone because it pollutes the air that humans breathe. In addition to harming human health, tropospheric ozone is damaging to forests and crops and can deteriorate rubber, nylon, and other materials.

However, in areas where there are low to no nitrogen emissions, such as the Arctic, BVOCs react with other chemicals in a more positive way. Some of these reactions can actually help mitigate climate change by forming tiny particles known as aerosols, which scatter sunlight, and increasing cloud cover, which promotes cooling.

Of all the BVOCs emitted each year, about 70% are a chemical compound called isoprene, and about 11% are chemical compounds called monoterpenes. Because these compounds are largely dependent on light and especially temperature, BVOC production and emissions are expected to increase as the planet continues to warm in coming decades. Global temperatures are likely to rise by more than 2°C by 2100. This could double BVOCs' global contribution of carbon to the atmosphere.

In Arctic and sub-Arctic regions, where temperatures are expected to increase at double the global rate, it is all the more important to study local BVOC emissions and how they might react to warming conditions. In the past, temperature increases of 2°C (or less) are known to have triggered dramatic BVOC increases in these regions.

Tang et al. evaluate the time it would take for a temperature increase of that scale to have a noticeable impact on BVOC emissions in the sub-Arctic. The researchers conducted their experiment on a wet heath in Abisko, Sweden. They set up specialized measurements to follow BVOC emissions and carbon dioxide exchange in vegetation communities, enclosed in plastic structures (known as open-top chambers) that warmed their environment for 13 years.

After just 3 years in the chambers, with a 1°C–2°C temperature increase, isoprene emissions had increased by about sixfold, the researchers found, and monoterpenes had increased by about fourfold. The warmer weather likely led to an increase in the amount of vegetation and diversity of plant species in the area, the researchers reasoned, causing the BVOCs to flourish. Despite this significant spike over the first 3 years, however, BVOC production leveled out over the next 10 years, suggesting that the ecosystem eventually adapted to the warming.

This study illustrates how sub-Arctic ecosystems are likely to respond to ongoing and future changes in climate. It also highlights the important role that BVOCs play as indicators of change in this highly sensitive ecosystem. (*Journal of Geophysical Research: Biogeosciences*, https://doi.org/10.1002/2017JG004139, 2018) **—Sarah Witman, Freelance Writer**

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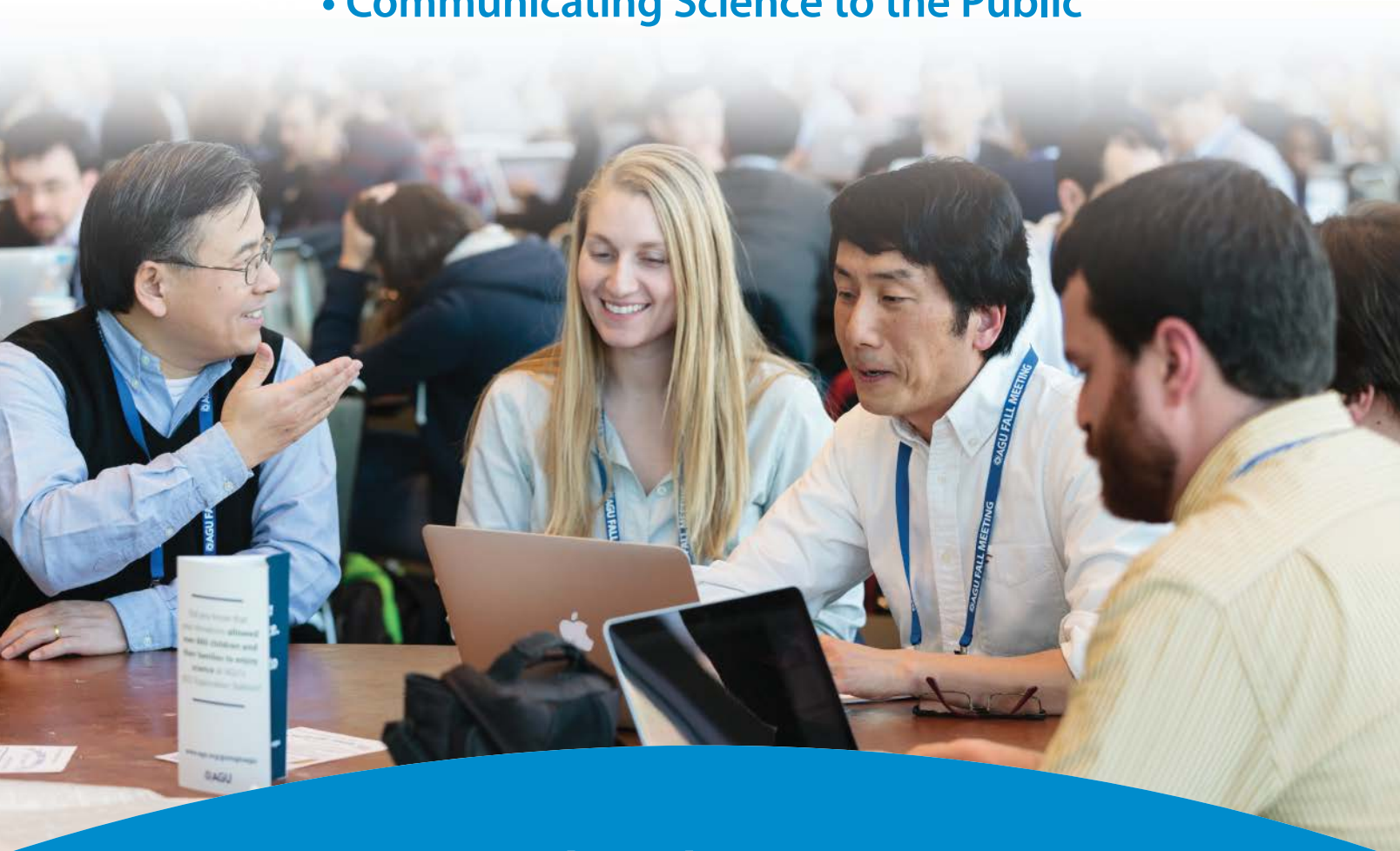

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Biogeosciences

Two Faculty Positions at Shanghai Ocean University

The Shanghai Engineering Research Center of Hadal Science and Technology (HAST), College of Marine Sciences, Shanghai Ocean University invites applications for two faculty positions.

Analytical Scientist: This Analytical Scientist is an expert in analytical mass spectrometry and preferably, has prior experience in high resolution accurate mass spectrometry. The successful candidate will be responsible for maintenance support and day-to-day operations of an ultrahigh resolution mass spectrometer, the Panorama, which will be delivered to HAST in 2018. Preference will be given to individuals with a proven track record and a combination of skills in laboratory management, instrument troubleshooting, data handling and method development. Extensive experience in the operation of on-line sample preparation, maintenance of vacuum systems, and in diagnosis of instrument mechanical and electronic problems is also desired.

Assistant/Associate Professor: We are seeking a highly motivated, collaborative scientist to conduct research in clumped isotope science. The scientist's principal responsibility is the design, development, validation and implementation of analytical procedures utilizing the Panorama, and publishing research papers. The chosen candidate will have full access to other state-of-the-art instrumentation in microbiology and biogeochemistry. Teaching responsibility is reduced or eliminated for the first three years of the position, per negotiation with the College. This scientist is expected to maintain an active, externally funded research program.

HAST was established to explore the largely unknown hadal zones of the world's oceans. The center's activities are a balanced mix of basic and translational scientific research in microbiology, biogeochemistry, paleoceanography and isotope geochemistry. We are interested in innovative and integrative research that will complement existing faculty strengths in above areas.

Both positions are full-time. The chosen candidate will be offered a highly competitive salary and start-up package. Applicants should submit a cover letter, curriculum vitae with a publication list, a statement of research interests, and the names and contact information of three references. Send electronic materials to Ms. Li (mailyan@163.com) with Analytical Scientist, Assistant (or Associate) Professor Position in the subject line. Review and evaluation of applications will begin immediately. Applications will continue to be accepted until all available positions are filled.

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

Department Head–Geology and Geological Engineering

The Department of Geology and Geological Engineering at Colorado School of Mines is seeking a dynamic and enthusiastic leader to head the Department. We seek a recognized teacher and researcher with a proven track record of leadership, management, vision, and mentoring. We invite candidates excited to share in our mission to address the challenges of creating a sustainable global society by educating the next generation of leading scientists and engineers, and by expanding the frontiers of knowledge through research. The Department Head will demonstrate a commitment to excellence in research and teaching. We are especially interested in candidates with a passion to advance the University's diversity and online commitment.

Applicants must have a Ph.D. in Geology, Geological Engineering or a related field, and a proven track record in teaching, research and service. Applicant should meet the criteria for the rank of Professor.

Please visit our website at http://jobs.mines.edu/cw/en-us/job/493021/professor-and-department-head-geology-and-geological-engineering for the complete announcement and instructions on how to apply.

IRIS

DIRECTOR, DATA SERVICES

Incorporated Research Institutions for Seismology (IRIS) is hiring a **Director of Data Services (DS)** to manage its Data Services directorate.

Responsibilities include the day-to-day operation of our Data Management Center (DMC) in Seattle, WA which has a staff of 23 people and an annual budget of ~$5M. The DMC currently archives roughly ½ petabyte of seismic waveform and other geophysical data and annually distributes nearly one petabyte of data to users in over 170 countries. Other responsibilities include management of four contracts/ subawards to UC San Diego, U. of Washington, Lawrence Livermore National Laboratory, and the Kazakh National Data Center, strategic planning and budgeting for DS, collaboration with other IRIS directorates and programs, obtaining support for DS activities beyond IRIS' core award from NSF, serving as the primary interface between DS and the IRIS community, and continuing the leadership role played by IRIS to coordinate international seismological data activities.

An in-depth position description may be found at **www.iris.edu/hq/employment.** Please submit your resume and a short statement (2 pages max) describing your qualifications for this position and your vision for IRIS Data Services to **HR@iris.edu.** Evaluation of applications will begin **September 1, 2018.**

Wold Family Professorship in Environmental Balance for Human Sustainability

The Department of Earth and Atmospheric Sciences at Cornell University is searching for a visionary Earth scientist to be the next Wold Family Professor in Environmental Balance for Human Sustainability. We seek candidates with significant experience and a strong reputation in the energy and/or mineral resources industries who can lead innovative research. Preferences will be given to candidates who can establish connections between industry and academia, and spur transfer of innovative ideas from university research to practice. The appointment is a *half-time academic year* position on a 5-year term (renewable once). Whereas the position is ideally suited for an individual seeking flexibility for external commitments, the holder of the Chair must be eager to engage in innovative education of the next generation of global leaders in this field, and to conduct research.

Human development will require the continuing supply of energy and minerals, discovered and delivered responsibly. Fulfilling this goal will require increased understanding of natural availability, new technologies, environmental systems, and human needs, all supported by dialogue and communication. The Wold Family Professor will be expected to conduct scientific research that helps the academic community, industry and government develop the sustainable supply of natural resources. Through teaching classes, research projects, and other activities the Wold Family Professor will help students understand the scientific challenges related to resources, and the approaches required to achieve sustainable management of resources in the future. The successful candidate will also be able to contribute to or lead faculty research teams that tap the extensive capabilities available at Cornell. A Ph.D. and at least 5 years of experience in the minerals or energy or similar industries are required.

Applicants should submit the following: a curriculum vitae, statements of research, of teaching, of contributions to diversity, and of your leadership efforts, and complete contact information for at least three professional references.

All materials must be submitted online at:
https://academicjobsonline.org/ajo/jobs/11291.
Applications will be accepted until the position is filled, with review beginning on July 15, 2018.

Cornell University is an innovative Ivy League university and a great place to work. Our inclusive community of scholars, students and staff impart an uncommon sense of larger purpose and contribute creative ideas to further the university's mission of teaching, discovery and engagement. With our main campus located in Ithaca, NY Cornell's far-flung global presence includes the medical college's campuses in Manhattan and Doha, Qatar, as well as the new Cornell Tech campus located on Roosevelt Island in the heart of New York City.

Diversity and Inclusion are a part of Cornell University's heritage. We are a recognized employer and educator valuing AA/EEO, Protected Veterans and Individuals with Disabilities.

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.

Postdoc and PhD-student openings at EPFL:

Studies of diagenetic processes in marine biogenic calcite

Funded by the ERC Advanced Grant UltraPal, the Laboratory for Biological Geochemistry at EPFL is opening several research positions at the Postdoc and/or PhD-student level during the fall of 2018.

The isotopic and elemental compositions of calcite structures formed by organisms (such as foraminifera, brachiopods, mollusks…) are frequently used for paleo-environmental reconstructions. However, visually imperceptible, ultrastructure-level processes that occur during sediment burial/diagenesis can introduce a strong bias in these records. The objectives with UltraPal are to experimentally constrain these processes, quantify their impact, and correct paleo-environmental records.

For this work we are seeking people with a strong background or interest in the following disciplines:

1) biomineralization/biology of calcifying marine organisms
2) low-temperature geochemistry
3) petrology/mineralogy/surface chemistry

The selected candidates will work in a highly interdisciplinary environment with multiple international partners, on complementing projects that will include growth of bio-calcites under controlled laboratory conditions, stable isotope labeling and autoclave experiments, high precision stable isotope (incl. clumped isotopes) and trace element measurements, and correlated ultra-structural characterization with techniques such as TEM, SEM, AFM, and NanoSIMS.

Interested candidates are invited to submit a letter of motivation, CV and publication list, and contact information of three professional references to anders.meibom@epfl.ch.

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 paleoceanography, 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 progra

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.

Postcards from the Field

Howdy!

We're on Galveston Island in Texas right now, studying summer convection with cool, new phased-array radar technology. We were the lucky early-morning crew taking the latest Doppler on Wheels (DOW8) radar out to capture the rapid growth of this towering cumulus cloud. Our radar scans a six-beam volume in 7 seconds, which is insanely fast!

Did anyone remember the doughnuts?

—Courtney Schumacher, Research Experiences for Undergraduates (REU) Site: Atmospheric Science in the Gulf Coast Region at Texas A&M University, College Station

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

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