VOL. 98 • NO. 4 • APR 2017

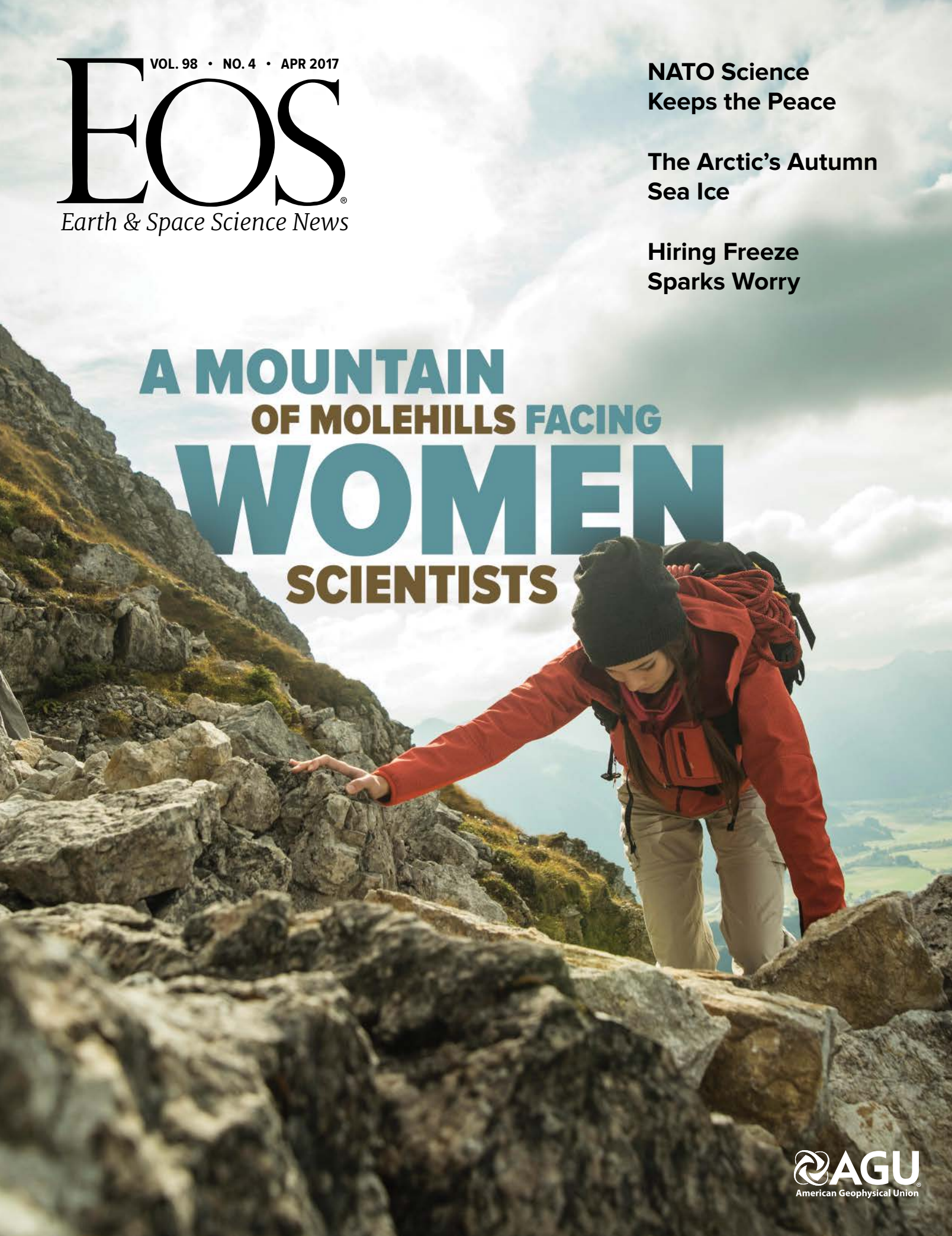
# EOS

*Earth & Space Science News*

**NATO Science Keeps the Peace**

**The Arctic's Autumn Sea Ice**

**Hiring Freeze Sparks Worry**



# A MOUNTAIN OF MOLEHILLS FACING WOMEN SCIENTISTS

AGU
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2018 OCEAN SCIENCES MEETING

AGU • ASLO • The Oceanography Society

11—16 February • Portland, Oregon, USA

# Call for Session Proposals and Tutorials

**Submission Deadline: 3 May 2017, 11:59 P.M.**

## Session Proposals

Proposals can span a broad array of marine science topics, and strong interdisciplinary themes that address new and emerging areas of research are strongly encouraged.

## Tutorials

Tutorial talks are meant to provide a review and synthesis of multiple results across a field of study, and not be primarily presentation of the proposer's own work. These talks should be designed to have a broad appeal to participants seeking an overview of a given topic.

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APRIL 2017
VOLUME 98, ISSUE 4


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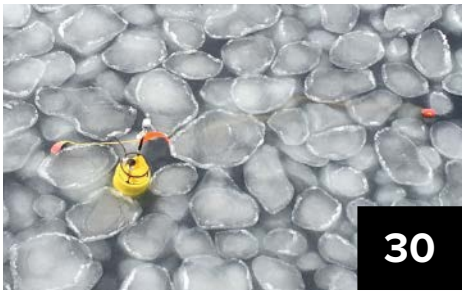


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Credit: Westend61 GmbH / Alamy Stock Photo.



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Christine W. McEntee, Executive Director/CEO

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# Hiring Freeze Sparks Worries at Science Agencies

Ron Sachs, MediaPunch/IPx

*President Donald Trump signed three executive orders, including the hiring freeze, on 23 January.*

A temporary freeze on hiring federal employees has put a chill in the air at some federal science agencies, employee union leaders and others told *Eos.*

President Donald Trump announced the freeze in a memorandum in January, ordering that no vacant positions be filled and no new positions be created, except in limited circumstances (see http://bit.ly/potusmemo-freeze). The order applies across the executive branch, including federal science agencies such as the Environmental Protection Agency (EPA), NASA, the National Oceanic and Atmospheric Administration (NOAA), and the National Science Foundation (NSF).

The freeze, which excludes military personnel, calls for the director of the White House Office of Management and Budget (OMB), in consultation with the director of the White House Office of Personnel Management (OPM), to recommend, within 90 days, a long-term plan "to reduce the size of the Federal Government's workforce through attrition."

The 23 January order, which is set to expire when the OMB plan is implemented, makes some exceptions for positions related to national security or public safety. The order forbids contracting outside of the government "to circumvent the intent" of the memo. A follow-up 31 January document from OMB and OPM provides guidance and an exemption for appointing seasonal and short-term employees (see http://bit.ly/freeze-guidance).

## Concern That This Freeze Is Different

Other presidents, including Ronald Reagan and Jimmy Carter, ordered hiring freezes. However, a 1982 report by the U.S. Government Accountability Office said that those then-recent freezes were "ineffective" in managing federal employment, "disrupted" agency operations, and, in some cases, increased costs to government (see http://bit.ly/GAO-1982).

Trump's hiring freeze is different, said Jeff Ruch, executive director of Public Employees for Environmental Responsibility (PEER), a Washington, D. C.–based alliance of local, state, and federal natural resources professionals.

"It's just the opening shot of a hostile takeover," he told *Eos.* "More than this [freeze], we are concerned about the next shoe to drop, which will be a bigger shoe," he said, referring to budget cuts that could be proposed by the Trump administration.

"We think there are going to be significant funding cuts," Ruch added. "A hiring freeze compounded by spending cuts means a lot of these agencies will crumple. They have to cease doing a lot of the functions they are now doing."

Trump promised to shrink the size of the federal government, but the order runs counter to some of the president's campaign promises, such as increasing domestic energy production, according to Ruch. "Even something like the Dakota [Access] pipeline is going to take hands on the ground in order to make sure it's properly approved and not subject to litigation challenges," he said.

Before this issue of *Eos* went to press, preliminary White House documents indicated steep drops in funding for EPA and NOAA for the upcoming fiscal year 2018. However, President Trump had not yet released his official budget request.

## Worries at EPA

John O'Grady, president of the American Federation of Government Employees (AFGE) Council 238, which represents about 9000 EPA employees, told *Eos* that although other presidents have instituted hiring freezes at one point or another, "the difference is that this one seems to be linked with potential draconian actions to be taken in the near future."

The number of full-time EPA employees sank from 18,000 to 15,000 during the Obama administration, according to O'Grady. In that light, "if the hiring freeze extends long into the future, it will have an impact on EPA's ability to fulfill its mission to protect human health and the environment," he said.

O'Grady worries about calls by some, including Myron Ebell, former head of Trump's EPA transition team, to slash EPA down to 5000 employees. "The thing [that] bothers me is that these people in Washington talk so glibly about the federal government being so big that we have to reduce it," he said. "The fact is, we have roughly the same number of federal employees today as under JFK [President John F. Kennedy] in 1962."

## Questions About Who Are Essential Personnel

General counsel and legislative director Richard Hirn of the National Weather Service Employees Organization told *Eos* that the rank and file employees of NOAA's National Weather Service (NWS) are worried about the hiring freeze and whether it will increase workloads and restrict promotions. The U.S. Department of Commerce includes NOAA.

The effect of the freeze on NWS remains unclear because the order allows exemptions for employees deemed essential to meet public safety responsibilities, Hirn noted. He didn't know how many NWS employees, such

as meteorologists and people tracking satellites, would fall into that category. During the confirmation hearing for commerce secretary, nominee Wilbur Ross said that properly staffing the NWS is important and that if confirmed, he would do his best "to quickly fill all essential positions" there.

Scott Smullen, acting director of NOAA communications, told *Eos* that "it's not yet certain how this [freeze] memorandum will specifically affect our workforce and operations, which [are] mainly focused on protecting life and property and supporting the economy. At this time, we will not speculate on potential impacts, and all official guidance will be provided to our workforce as soon as possible." He said that NOAA currently has between 1100 and 1200 full-time job vacancies.

PEER's Ruch said that as far as he knows, agencies such as the U.S. Geological Survey and NSF "are not suffering from direly thin staff levels." Spokespeople from both of those agencies and NASA told *Eos*, before this magazine went to press, that their administrators were assessing the impacts of the freeze memo.

### Impact on NSF

Dave Verardo, president of local chapter 3403 of AFGE, which represents NSF employees, expressed concern that the freeze might impair NSF's ability to best serve the science community on behalf of the American public. If NSF lacks enough people to manage the merit review system, for instance, that process could slow down, he said.

Verardo added that NSF is already a fiscally lean organization, with about 96% of its budget getting passed through to congressional constituents as research grants.

Because the freeze order is not very specific, it's unclear how it will affect NSF, Verardo said. Although the freeze probably will have a direct effect on hiring new people, he does not know if it will affect new "rotators," including NSF assistant administrators, who temporarily work for NSF through Intergovernmental Personnel Act (IPA) assignments. Bill Easterling, a rotator under the IPA who will become NSF's assistant director for geosciences on 1 June, told *Eos* that his appointment will not be affected by the freeze.

Whatever other impact the freeze order might have, it has hurt the morale of NSF employees, Verardo said. "People feel that the freeze is reflective of a negative view of the federal workforce by the president. They're not sure if there is an economic reason behind it or if there is an ideological reason behind it."

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

# Seven Earth-Sized Planets Seen Whizzing Around One Cool Star

NASA/JPL-Caltech

*An artist's representation of a view from the surface of one of TRAPPIST-1's planets. In late February researchers announced that they had discovered seven exoplanets, all within the temperate zone of their parent star, where liquid water could exist and perhaps foster conditions for extraterrestrial life.*

Forty light years away, seven Earth-sized planets circle a small, dim, "ultracool" dwarf star, orbiting up to 20 times per Earth month. These exoplanets, four of them previously unknown, "are the best targets so far to search for signs of life" outside our solar system, said Julien de Wit, a planetary scientist at the Massachusetts Institute of Technology in Cambridge and coauthor of a recent *Nature* paper (see http://bit.ly/7exoplanets) about the planets.

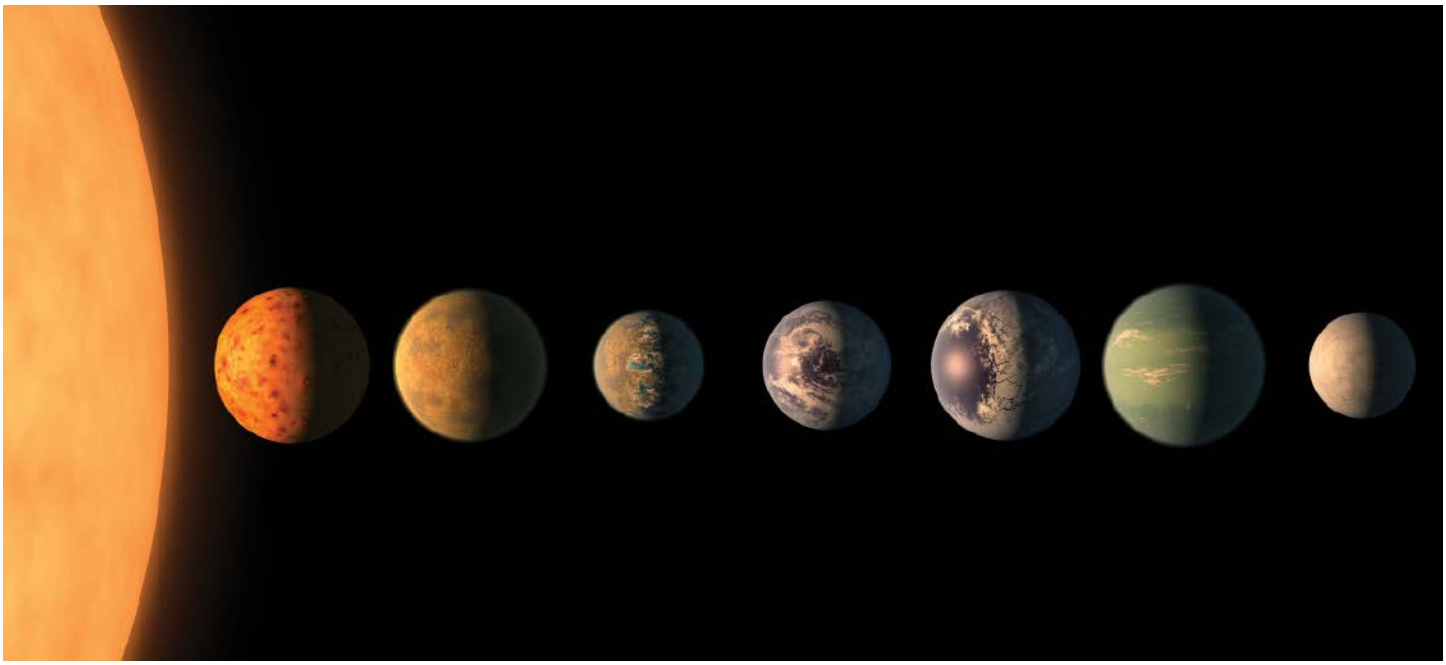
These remote worlds orbit close to their dim star, so enough energy may reach the outermost planets to provide liquid water. In addition, the orbits do not dip very much below or above the plane of the star, allowing for the star's gravity to push and pull the planets enough to perhaps produce heat. There might even be enough internal heat to generate strong volcanic activity on some of the planets, de Wit said.

The seven planets serve as "true Rosetta Stones" for studying exoplanets, de Wit added. They offer observers a "winning combination" of revealing information because they regularly pass between the star and Earth, throwing doors wide open for detailed atmospheric studies, he continued.

### The Transit Method

To find the seven bodies, the team used the most common method by which scientists find exoplanets: the transit method. The scientists observed the star, called TRAPPIST-1, via ground-based and space-based telescopes, looking for dips in its brightness. A periodic dip in the star's brightness means that something, like a planet, moves between the star and Earth on a regular basis.

Recently, exoplanet hunters have focused attention away from observing stars like our Sun—large and bright—to the smallest, coldest stars to look for planets. Michaël Gillion, lead author of the 22 February paper, said that this is because the light from Sun-like stars often drowns out any signal from small, rocky, Earth-sized planets. Instead, many scientists began to wonder, Why not look where our current technology can clearly see? This would be around small, ultracool dwarf stars like TRAPPIST-1, which is one ninth the diameter of our Sun and only half as bright.



NASA/JPL-Caltech

*An artist's representation of the seven TRAPPIST-1 planets, based on new measurements of their masses and diameters.*

Following this logic, the researchers used the ground-based Transiting Planets and Planetesimals Small Telescope (TRAPPIST) at the European Southern Observatory's La Silla site in Chile. Last year, the researchers spotted the three outermost planets but suspected that there were more because previous exoplanet discoveries from the Kepler mission "show that multiplanet systems are very common," said Katherine Deck, an astronomer at the California Institute of Technology in Pasadena and coauthor of the paper.

So the researchers turned to the Spitzer Space Telescope, which observes the solar system in infrared light—light with wavelengths longer than the human eye can see. For 20 days, Spitzer observed the TRAPPIST-1 system, watching the star's brightness decline, then rise again as planets passed by.

Combining the Spitzer data with more ground-based measurements, the researchers observed 34 different transits, from which they teased out not three planets but seven. Although the team hasn't defined the orbital period of the outermost planet, the orbits of the other six range from 1.5 to 12.7 Earth days. Because the star is so small, "the signal of TRAPPIST-1's planets is about 80 times larger than what it would be if they were orbiting our Sun," de Wit said. Only Jupiter passing in front of the Sun could produce as pronounced a dip in solar intensity for an observer watching our solar system from a similar distance, the researchers noted.

The transits provided researchers with diameter estimates, calculated from the degree to which the starlight diminished as the planet passed between the star and Earth. Larger-diameter bodies obscure more of the stellar surface, causing proportionately more dimming.

The researchers also looked at how the planets gravitationally tugged on one another as they orbited TRAPPIST-1, which "causes the timing of their transits to change a little," de Wit said. Sometimes the transits come early, sometimes late. By measuring these variations, the researchers can start to determine the masses of the planets. In a year or so, he continued, they should be able to pin down the masses fairly precisely.

### Search for Life

Because of the proximity of the planets to their star, the team suspects that the innermost planets exhibit a runaway greenhouse scenario, much like Venus. This means that liquid water is unlikely to be sustained on their surfaces.

> "In our search for planets like Earth and possible extraterrestrial life, it really pays to concentrate on the smallest stars."

The outer three planets, however, could orbit far enough from their star to harbor liquid water. To investigate further, the researchers plan to take a closer look at the exoplanets' atmospheres. Researchers investigate exoplanet atmospheres by examining patterns in the star's light as it passes through the atmosphere. If the planet has an envelope of gases surrounding it, the light's signature will indicate that.

Researchers note that when the James Webb Space Telescope launches next year, they could have an unprecedented opportunity to observe seven newfound atmospheres to search for possible biological signatures such as methane, ozone, and carbon dioxide. Already, the Hubble Space Telescope has determined that two of the TRAPPIST-1 planets probably do not host hydrogen- and helium-dominated atmospheres—if they do, it would bar habitability.

"We already knew that Earth-like exoplanets are common in the Milky Way, but this new finding suggests that they are even more abundant," said Ignas Snellen, an astronomer at the Leiden Observatory at Leiden University in the Netherlands who wasn't involved in the new research. These observations show that "in our search for planets like Earth and possible extraterrestrial life, it really pays to concentrate on the smallest stars."

By **JoAnna Wendel** (@JoAnnaScience), Staff Writer

# Mounting Litter Spotted on Arctic Seafloor

Alfred-Wegener-Institut/Melanie Bergmann/OFOS

*Plastic fragments found deep in Fram Strait between Greenland and Svalbard mingle with sponges.*

Litter isn't a problem only on land: It's also found deep in the ocean. Despite an international treaty banning waste disposal at sea, trash from illegal dumping, commercial fishing, and maritime accidents has accumulated on the ocean floor.

Recently, scientists analyzed thousands of photographs of a swath of the bottom of the Arctic Ocean taken between 2002 and 2014 and calculated changes in marine litter over time. The results are troubling: The litter has become 4 times denser since 2004, and in one place its density has shot up 23-fold.

## Litter, Litter Everywhere

Mine Tekman, a marine scientist at the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research in Bremerhaven, Germany, and her group conducted this catalog of litter on the ocean bottom off the coast of Greenland. "A key strength of this study is its relatively long-term [analysis of debris]," said Chelsea Rochman, an ecologist at the University of Toronto in Canada who was not involved in the study.

The oceans cover more than 70% of Earth's surface, but "the deep sea is still one of the least studied ecosystems on the planet," Rochman continued.

As coastal cities grow and more ships ply the world's cargo routes, marine litter is piling up in places, including the Mediterranean Sea and the Indian Ocean. However, only a limited number of investigations have focused on changes in litter density over time.

Some marine litter is readily visible—like the trash in the ocean's five enormous floating garbage patches—but a lot of it sinks because it's denser than water. This "invisible" litter, in addition to being harder to clean up, is also more likely to persist on the deep seafloor because it is shielded from solar radiation, which can promote decomposition.

## Thousands of Pictures

On expeditions between 2002 and 2014, the researchers towed an underwater camera on a 2500-meter-long cable in Fram Strait near HAUSGARTEN observatory, a 21-station underwater Arctic research base. They programmed the camera to take a picture every 30 seconds, using strobe lights to illuminate the muddy seafloor. Tekman and her team then manually examined all 7058 images to look for litter. They found 89 pieces of garbage—mostly plastic, glass, metal, rope, and fabric—in 82 of the images, they reported in the February 2017 issue of *Deep Sea Research Part I: Oceanographic Research Papers* (see http://bit.ly/marine-lit).

The team determined the litter density for observations from each year by calculating the number of pieces of litter per square kilometer of seafloor. Tekman and her collaborators calculated litter densities separately for the images obtained near two of the HAUSGARTEN observatory stations and obtained values ranging from 390 to 7710 items per square kilometer. These densities were, on average, significantly higher than those recorded in the Atlantic and Indian oceans by another research group (see http://bit.ly/deep-sea-lit). This discrepancy might be explained by the complex seafloor topography of Fram Strait, which could cause litter to accumulate there, Tekman hypothesized.

## Dramatic Increase

The researchers next investigated how litter densities changed over time. Near the HAUSGARTEN observatory's N3 station, they found that the annual litter density increased by a factor of 23 between 2004 and 2014. Tekman and her team suggest that sea ice near this station may be responsible for the dramatic increase in litter. "Small-sized plastics may have been released from sea ice during melting events," said Tekman. The increase at the other station was less dramatic—roughly fourfold—but still a cause for worry, the researchers contend. "Humans have invaded the Arctic with their litter," said Tekman.

The team also investigated how marine life was interacting with the 89 pieces of litter in the images. They found that creatures such as sea anemone, shrimp, and sponges were in, on, or around more than 50% of the litter. The researchers caution that such interactions aren't always benign. When animals become entangled in litter, the litter can scrape their tissues or even cause these tissues to die, said Tekman.

The scientists are now gathering data about the global distribution of marine litter, a project they hope will reveal more information about the health of the world's oceans.

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

# Revived Climate Change Forum Focuses on Threats to Human Health

A long-planned summit on climate change and health that was abruptly canceled by the Centers for Disease Control and Prevention (CDC) after the 2016 presidential election got a second chance in Atlanta, Ga., in February. Detached from the federal agency and cut to one third of its originally intended length, the resurrected conference likely earned much more attention than it otherwise would have.

The renamed Climate and Health Meeting took place on 16 February a few kilometers from the CDC at the Carter Center, a nonprofit organization founded by former president Jimmy Carter, thanks to a rescue mission by former vice president Al Gore, who was scheduled to be one of the original meeting's keynote speakers.

The CDC canceled the original conference just as President Donald Trump's new administration—known to be hostile to the idea that human activity is causing climate change—took office. When the decision became public, Gore mobilized the Climate Reality Project, the nonprofit he had founded, along with a slate of other climate-concerned organizations.

"I got a call from the vice president, who asked what we could do to get this back on track," Georges C. Benjamin, executive director of the American Public Health Association (APHA) and an organizer of the original meeting, told *Eos* in an interview as the reinstated conference got started. "[Gore] said he had already talked to President Carter, and he would find the money, and in 15 minutes we had a decision. And now we've got 340 people here, [and] more than 700 wanted to come; there are thousands of people on the livestream, and look at the excitement in this room," he said.

REUTERS/Soe Zeya Tun

*Volunteers fumigate against Zika-transmitting mosquitoes along a street in Yangon, Myanmar, last November. Scientists met in Atlanta on 16 February to discuss impacts of climate change on human health, including how increasing temperatures exacerbate mosquito-borne diseases like Zika.*

### Pathogens Without Borders

The revived 1-day meeting retained the basic objective of the 3-day original—to examine ways in which altered climatic conditions impinge on human health or are expected to do so—but not the original's broad slate of abstracts about specific effects of climate change on pathogens, chronic health conditions, public safety, and food.

Giving an overview at the event, Ashish Jha, director of the Harvard Global Health Institute in Cambridge, Mass., one of the new meeting's sponsors, said that "as the world warms, and as hot places get hotter and dry places get drier, we will see more droughts, we will see more famines, the nutritional content of foods will change, and children and families that are thriving now will face hunger, will face malnutrition, will face diseases."

"Here's the catch," he added, in a glance at politics that was rare for the day and a line that brought loud applause, "Walls will not keep these pathogens out."

### Neglected Consequences of the Climate Crisis

Gore remarked early in the day that "with all the work that has been done on the climate crisis, and solutions to the climate crisis, many would argue that too little attention has been paid by many to the health consequences of the climate crisis, and we hope to help remedy that today."

Protecting vulnerable groups is a core public health concern that speakers addressed. "Disproportionately, children and the elderly and the underserved, particularly in minority communities, are less climate resilient," Benjamin said in remarks to the meeting audience. "The uneven burden of climate change is, by definition, climate injustice."

In a rapid succession of presentations later, speakers and panelists reviewed familiar observations and predictions of climate scientists through the less familiar lens of likely health impacts. Presenters discussed rising temperatures that encourage mosquito-borne diseases such as Zika, greater flooding that increases the dispersal of waterborne pathogens such as cholera, plant diseases that attenuate the nutrients in major crops, and extreme weather events that destabilize societies.

### More Meetings to Follow

Because the original 3-day meeting was collapsed into 1 day, additional meetings are planned. The Harvard Global Health Institute will hold a Symposium on Climate Change and Public Health on 27 April. Benjamin said that APHA's annual meeting, which will bring 12,000 attendees to Atlanta in November, may host some of the canceled sessions as well.


The Climate Reality Project

*Ashish Jha, who directs the Harvard Global Health Institute in Cambridge, Mass., spoke at the Climate and Health Meeting in Atlanta. The institute cosponsored the 16 February meeting.*

Although two CDC scientists appeared at the 16 February meeting, one speaking on a panel and one introducing a keynote address, it's unclear whether federal scientists will come to future gatherings, said Jonathan Patz, director of the Global Health Institute of the University of Wisconsin–Madison.

He and others at the meeting seemed to be preparing for a reality in which government-funded climate research is muted for now, but they didn't seem daunted by it. "Even if, at an international level, things stall out, even if things at the federal level stall out, there is so much innovation and progress happening at local levels," he noted at the meeting during an informal midday press conference. What's more, he said, "the private sector is moving forward to a healthy low-carbon society."

By **Maryn McKenna** (email: marynmckenna@gmail.com; @marynmck), Freelance Journalist

# New UCAR Leader Sees Scientific, Administrative Challenges Ahead

Carlye Calvin/UCAR, CC BY-NC 4.0 (http://bit.ly/ccbync4-0)

*UCAR president Tony Busalacchi (right) takes a tour of one of NCAR's atmospheric chemistry labs with Geoff Tyndall, senior scientific section head for NCAR's Atmospheric Chemistry Observations and Modeling Laboratory.*

Antonio "Tony" Busalacchi, president of the University Corporation for Atmospheric Research (UCAR), has a sense of history and the future.

He sees that atmospheric science is now at a juncture similar to the one it faced in the 1950s, when UCAR and the National Center for Atmospheric Research (NCAR) were formed to help accelerate atmospheric research in support of numerical weather prediction. This new juncture, he says, involves the growing ability, brought about by advances in science and an explosion in observational and computer capacity, to observe and predict the behaviors of the interlinked physical, chemical, and biological processes that form the coupled Earth system.

That earlier effort led to a multibillion-dollar weather enterprise across academia and the public and private sectors that has made detailed weather forecasts readily and widely accessible. Busalacchi said that the "grand challenge" of predicting the coupled Earth system could lead to significant societal benefits in numerous areas related to agriculture, water resources, energy, extreme weather, and space weather.

Busalacchi took the reins at the nonprofit UCAR in Boulder, Colo., last August (see http://bit.ly/UCAR-Busalacchi). He spoke with *Eos* about challenges such as developing Earth system prediction capability and the role of science during politically choppy times. He also talked about organizational priorities, including an upcoming competition to select an organization to manage and operate NCAR that is expected later this year. UCAR, a consortium of 110 colleges and universities in North America (see http://bit.ly/UCAR-members), currently manages NCAR for the U.S. National Science Foundation (NSF) and hopes to continue doing so.

## The Grand Challenge

Busalacchi says that the challenge of predicting the Earth system requires a better understanding of the complex interactions among physical systems—including the atmosphere, oceans, land, and cryosphere—with chemistry, biology, ecosystems, humanity, and the effects of humanity on the environment.

Helping to meet that challenge, he said, are advances in observational capacity that include Earth-observing satellites and new platforms such as CubeSats, drones, and the Internet of things. If, for instance, even a small fraction of the 40 billion smart sensors that could be in place by 2020 enable environmental observations, that could mean "disruptive change in a positive sense," he said.

"There are some tantalizing clues that, yes, we can make considerable progress on the prediction of the Earth system to the point where it will yield actionable information, very much akin to what we saw coming out of the weather enterprise," Busalacchi told *Eos*. He emphasized, too, the importance of seamless prediction from the microscale to the macroscale and at different timescales.

## An "Amphibious" Background

Helping to lead the charge with that grand challenge is a key reason he took the job at UCAR, said Busalacchi, who previously was director of the University of Maryland's Earth System Science Interdisciplinary Center and a professor in the university's Department of Atmospheric and Oceanic Science. Busalacchi received his doctorate in oceanography from Florida State University in Tallahassee, but he calls himself "amphibious" because he has also studied other areas, including meteorology and geophysical fluid dynamics.

Although he grew up in a suburb of Milwaukee, Wis., Busalacchi loved the oceans from an early age. He knew that they were relatively uncharted scientifically, and he wanted to be an oceanographer. At age 11, he scuba dived for the first time, in Mexico, and later dived in Wisconsin's rock quarries.

Busalacchi, who comes from a family of restaurateurs, is an advanced sommelier, and he sees a link between his expert knowledge of wine and the Earth sciences. His wine consulting firm, Vino Veritas Consulting, provides weather and climate forecasting services for vineyard management, and he gives public lectures on the impact of climate change on global viticulture.

## Competition for a New Cooperative Agreement

At UCAR, one of the top internal priorities Busalacchi faces is an upcoming competition for a cooperative agreement to manage and operate NCAR, he said. This cooperative agreement will run from 1 October 2018 to 30 September 2023. Last August, NSF

Busalacchi hopes that the new Congress and the Trump administration will support science efforts at UCAR and NCAR.

announced that it expects to issue a program solicitation early in 2017 (see http://bit.ly/NSF-NCAR-announce).

UCAR has managed NCAR from its beginning, but the organization is "not resting on [its] laurels," Busalacchi said. "We have an all hands on deck approach" to the upcoming competition, he added. When this issue of *Eos* went to press in mid March, NSF had not yet issued the solicitation.

Busalacchi said that he looks at UCAR's management of NCAR not from an institutional perspective but for what it means "in terms of the science we can deliver to the country." He pointed to the NCAR-supported community Weather Research and Forecasting Hydrologic model (WRF-Hydro) as a good example of what NCAR, and UCAR's management of it, should and could be doing. WRF-Hydro forms the core of the National Oceanic and Atmospheric Administration's National Water Model, which simulates streamflow throughout the continental United States.

### A View to Washington

Busalacchi hopes that the new Congress and the Trump administration will support science efforts at UCAR and NCAR. He noted two bills before Congress, the Weather Research and Forecasting Innovation Act of 2017 (H.R. 353; http://bit.ly/HR-353) and the Space Weather Research and Forecasting Act (S. 141; http://bit.ly/S-141), that aim to improve forecasting in those areas.

Prior to the November 2016 election, UCAR prepared a white paper for the new Congress and new administration to highlight research and education priorities for federal investment in academic research (see http://bit.ly/UCAR-white-paper). Those priorities include a continued focus on weather, water, climate, air quality, space weather, and training the next generation of scientists.

"That's remained unchanged because when you come down to the very heart, [the] core elements of what we do, it's about the protection of life and property, support of economic development, and support of national security," said Busalacchi. "Those four topics are apolitical. It doesn't matter what side of the aisle you are on; those things remain the same."

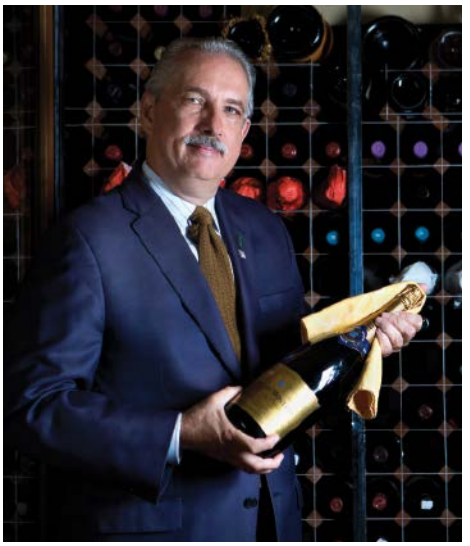
With the Trump administration stirring concern among many scientists about restricting federal agency communications with the public, instituting a temporary federal hiring freeze, and threatening sharp cuts to the Environmental Protection Agency, Busalacchi said he is taking a wait and see attitude for now.

"Bottom line, I'm a scientist, I'm not a politician," he said. "My job as a scientist is to describe the state of science: What is it we know, what is it we don't know, and what is it going to take to move us from what we don't know to what we do know."


Democratic Staff of the House Science Committee

*Tony Busalacchi (right) testified at an 18 June 2016 congressional hearing on private-sector weather forecasting, convened by the House of Representatives Science Committee, a few months before taking the helm at UCAR.*

Busalacchi said that hiring freezes are nothing new and that previous administrations also instituted them. Other actions of the new administration, however, are causing more immediate concern at UCAR. For example, UCAR issued a letter stating that President Donald Trump's January executive order banning citizens from seven countries from entering the United States "is counter to UCAR's mission and values" (see http://bit.ly/UCAR-immigration).



John T. Consoli, University of Maryland

*Tony Busalacchi, an advanced sommelier, holds a bottle of wine in the wine cellar at his former Maryland residence.*

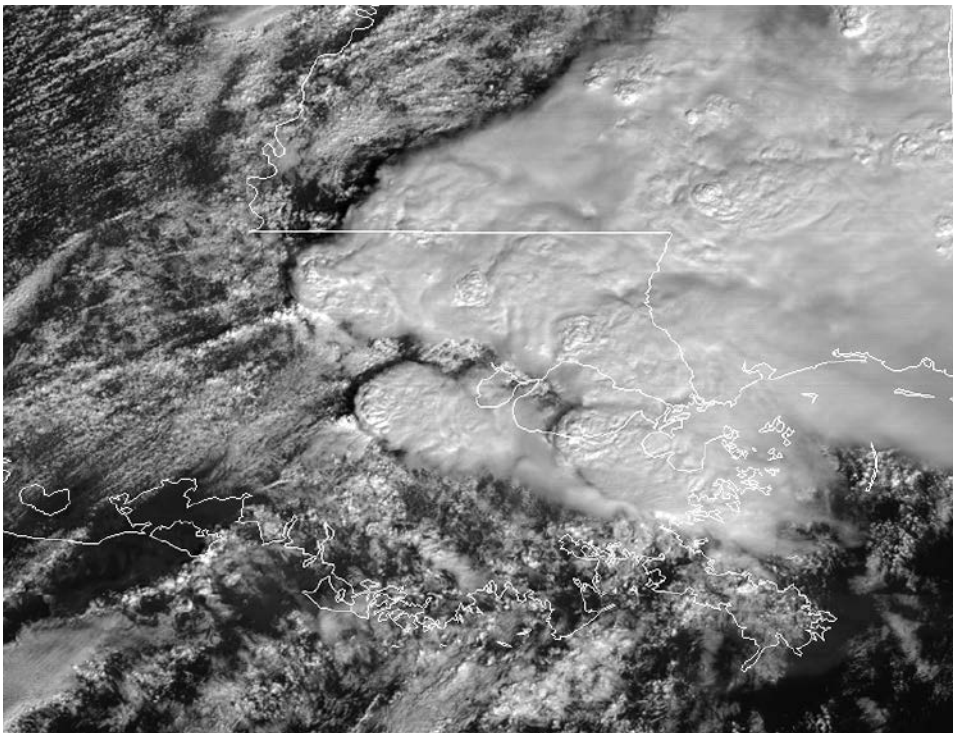
In addition, Busalacchi expressed concern about the consequences if the United States significantly reduces its climate research. He said that one telltale sign of the administration's view of science would be its budget request for fiscal year 2018 (FY 2018). Leaks of preliminary budget documents before this issue of *Eos* went to press indicated that the White House might seek a 17% cut to the FY 2018 budget of the National Oceanic and Atmospheric Administration, a leading federal climate research agency. However, the administration's official budget request had not yet been released.

Busalacchi said that climate research would continue internationally with or without the United States but that it would be to the country's disadvantage if another nation such as China stepped into a potential void as a leader in that field.

He added that the science community needs to be vigilant about whether the administration's initial measures are just interim actions or whether they become policy. "Once you start muzzling the civil servants, the scientists employed by government whose job it is to inform the nation, then you are on a slippery slope," he said. "I do believe it is too soon to tell."

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

# NOAA Video Shows Satellite Views of Louisiana Tornadoes



NOAA/NASA

*A still from a brief video of storms sweeping across southeastern Louisiana on 7 February. Tornadoes spawn in the thick mass of clouds at upper right where concentrated bumpy regions indicate upwelling winds that may form tornadoes. NOAA's newest weather satellite, GOES-16, took the image.*

When tornadoes ripped through southeastern Louisiana early this year, a brand-new weather satellite was watching. A brief video released by the National Oceanic and Atmospheric Administration (NOAA) the day after the twister onslaught shows a sequence of images of the episode captured by the agency's Geostationary Operational Environmental Satellite 16 (GOES-16).

NOAA meteorologists said the clip demonstrates the enhanced ability of new satellites to provide bird's-eye views of extreme weather as it develops. GOES-16, which is the first in NOAA's new GOES-R satellite series, was launched on 19 November 2016.

## Real-Time Resolution

The tornadoes that struck on 7 February injured dozens and caused major damage to parts of New Orleans, particularly in the eastern part of the city. In all, nine tornadoes touched ground, NOAA reported.

In the video of the storms as seen by the NOAA satellite (see http://bit.ly/tornadoes-louisiana), wispy clouds in the west become an expansive roiling mass as the storms move to the east. Bubbly, cauliflower-shaped features arising from this churning stew are the storms that caused the tornadoes, said Steven Goodman, senior scientist for the GOES-16 satellite. The frothing shapes reflect vigorous upwelling of wind, which helps form the tornado's funnel shape.

> Once the satellite is fully operational this November, images like those in the video will allow meteorologists to track a storm in almost real time.

## A More Watchful Eye

From an earlier generation of satellites that remain in operation, meteorologists get updates about every 15 to 30 minutes. By contrast, GOES-16 scans the continental United States every 5 minutes.

With this new scanning frequency, "even before the radar shows you typical [tornado] signs, you've got some real indication that the storm environment is changing to a dangerous situation," Goodman said, which gives meteorologists better tools with which to warn the public of the coming danger. Goodman estimates that data from the new satellite may give affected areas 5-6 minutes more lead time to prepare for a storm—a nearly 50% increase from the prior 13-minute average.

## Future of Forecasting

Currently, NOAA scientists are testing and calibrating the satellite to ensure the accuracy of readings, so its images remain experimental. However, once the satellite is fully operational this November, images like those in the video, taken by its Advanced Baseline Imager, will allow meteorologists to track a storm in almost real time, Goodman said.

He hopes that the highly resolved data will "personalize the risk a lot better." Meteorologists already have trouble convincing the public of real and impending danger. Goodman suggested that having such rapidly updating information will help meteorologists and TV broadcasters better communicate hazards.

When it is fully operational, the satellite will image Earth every 30 seconds, with high-resolution images of the entire Earth disk every 15 seconds, the continental United States every 5 minutes, and areas of high storm activity every 60 seconds.

NOAA released the first images from GOES-16 on 15 January, showing a high-resolution view of Earth.

By **JoAnna Wendel** (@JoAnnaScience), Staff Writer

# Understanding How Geoengineering Can Offset Climate Change

**Sixth Meeting of the Geoengineering Model Intercomparison Project**
Oslo, Norway, 21–22 June 2016

WinkelmannPhotography

*Cirrus clouds distort a view of the Sun. Participants at a meeting in Oslo, Norway, presented new developments in modeling and simulating climate engineering approaches, including stratospheric aerosols, marine cloud brightening, cirrus thinning, and land and ocean brightening.*

Climate intervention, also called geoengineering or climate engineering, is an emerging, important area of climate science research. This research focuses on deliberate climate modification to offset some of the effects of anthropogenic greenhouse gas emissions. The Geoengineering Model Intercomparison Project (GeoMIP) was formed to better understand climate intervention through simulations conducted by multiple climate models.

GeoMIP held its sixth annual meeting at the University of Oslo in June 2016. The meeting was held in conjunction with the Norwegian project Exploring the Potential and Side Effects of Climate Engineering (EXPECT; http://bit.ly/EXPECT-project), which seeks to understand the implications of climate intervention and to stimulate interdisciplinary collaboration among scientists in the natural and social sciences.

Participants from a variety of natural science backgrounds presented modeling results from multiple climate intervention methods, including stratospheric aerosols, marine cloud brightening, cirrus thinning, and land and ocean brightening. The first results from multimodel sea spray climate intervention simulations showed strong features of commonality among the responses of different models.

GeoMIP continues to incorporate expertise from new areas. For example, this meeting was the first to present analyses of the modeled response of the ocean to GeoMIP simulations. Several scientists from social science disciplines attended the meeting, and they provided broader perspectives on the societal implications of the climate modeling results.

Of the approximately 35 participants, more than one third were attending a GeoMIP meeting for the first time, in keeping with the project's interest in expanding its scope and providing a forum for new ideas. Several new modeling and simulation concepts were presented to the GeoMIP Testbed, which is a forum for proposing new ideas to GeoMIP for possible adoption. These new concepts include land albedo modification in ways that are readily standardized across models, a proposal for idealized stratospheric aerosols, and simulations of localized ocean albedo modification.

Descriptions of these new areas of research are being added to the GeoMIP website (http://bit.ly/GeoMIP), which is the most up-to-date source of information on past, present, and future simulation designs. Also on the site are a timeline of start dates for the new simulations for Coupled Model Intercomparison Project Phase 6 (CMIP6; http://bit.ly/CMIP-phase-6) and a current list of Testbed experiments.

After the conclusion of the 1.5-day GeoMIP meeting, EXPECT held an open forum in which natural and social science experts on climate intervention presented to the general public the current thinking of the research community. There were approximately 50 participants, including GeoMIP attendees, other natural and social scientists, the media, and members of the general public.

In the future, GeoMIP will continue its mission of providing knowledge about key uncertainties in climate intervention research, particularly as an officially endorsed project under CMIP6. As new important areas of research emerge in this field, GeoMIP will continue to provide a scientific focus for addressing important unknowns and a forum for consideration of the full range of approaches to climate intervention.

We thank EXPECT, the Research Council of Norway, and the U.S. National Science Foundation for financial support and Bjørg Rognerud, Loretta Quinn, and the University Corporation for Atmospheric Research for logistical and travel assistance.

One of our authors, Jón Egill Kristjánsson, tragically passed away in a hiking accident on 14 August 2016. We dedicate this article to his memory and to his immense body of insightful, influential work on cloud modeling, aerosol-cloud interactions, and, most recently, cirrus thinning. His legacy of scientific contributions is indisputable, and those of us who had the privilege of working with him will miss him greatly.

By **Ben Kravitz** (email: ben.kravitz@pnnl.gov), Atmospheric Sciences and Global Change Division, Pacific Northwest National Laboratory, Richland, Wash.; **Alan Robock,** Department of Environmental Sciences, Rutgers, The State University of New Jersey, New Brunswick; and **Jón Egill Kristjánsson,** Department of Geosciences, University of Oslo, Oslo, Norway

# Tackling Unanswered Questions on What Shapes Earth

**Workshop on the Origin and Evolution of Plate Tectonics**
Ascona, Switzerland, 18–22 July 2016

Earth is the only body in our solar system with plate tectonics, but no one knows why or when the process began. To explore these questions, 62 geoscientists, representing all career stages and a wide range of disciplines, met at the Swiss Federal Institute of Technology's (ETH) Congressi Stefano Franscini conference center at Monte Verità. The conference center overlooks beautiful Lago Maggiore, which is situated on an ancient plate boundary in southern Switzerland.

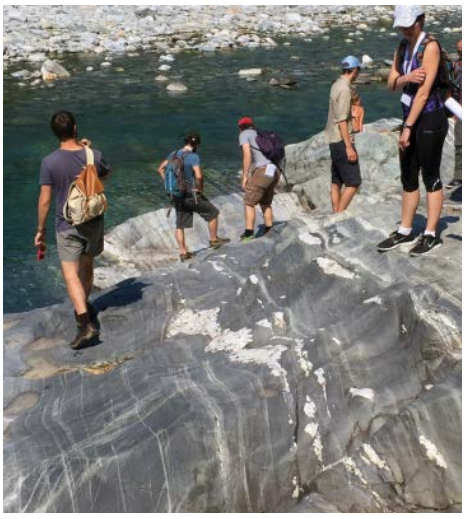
This was the fourth conference devoted to understanding the evolution of continental drift and plate tectonics. The series of discussions began with the 1926 American Association of Petroleum Geologists session on continental drift, followed by a 1975 Geological Society of America (GSA) Penrose Conference in Vail, Colo., "Pre-Mesozoic Plate Tectonics: How Far Back in Earth History Can the Wilson Cycle Be Extended?" The most recent conference was the 2006 GSA Penrose Conference in Lander, Wyo., "When Did Plate Tectonics Begin?"

Matt Leybourne

*Attendees at a conference on the origin and evolution of plate tectonics study garnet-bearing amphibolites of the Ivrea-Verbano zone at Monte Verità in Switzerland during a conference field trip.*

Conferees debated when plate tectonics began, how it began, what Earth's tectonic style was before plate tectonics, and how to define plate tectonics. Participants reached agreement on five key points:

- Because the sinking of dense oceanic lithosphere (the conductive outer thermal boundary layer of Earth) in subduction zones powers plate motions, we must understand modern subduction, especially the forces that favor and oppose it, to understand when conditions were ripe for plate tectonics to begin.
- Deep recycling of surface material began early in Earth's history, although it is uncertain how early and whether this required plate tectonics.
- Oceanic lithosphere must be sufficiently strong to remain intact and sustain subduction but locally weak enough to nucleate new subduction zones required for plate tectonics. That half of Earth's 65,000 kilometers of convergent plate margins formed in the past 65 million years implies that it is reasonably common for lithospheric collapse to make a new subduction zone.
- Because the early Earth's interior was hotter by 100°C to 200°C than it is now, pre–plate tectonic regimes likely involved weaker and more buoyant oceanic lithosphere than today, impeding the onset of sustained plate tectonics. Vigorous magmatic activity characterized pre–plate tectonic regimes, which were essentially single-plate, mobile "stagnant lid" tectonic regimes. At various stages, heat pipes, mantle plumes, drips, delaminations, and short-lived subduction zones accommodated convective overturn, similar to conditions on modern Venus.
- Continents assisted plate tectonic evolution by providing density contrasts at their margins and by shedding weak sediments to the seafloor, which is required to lubricate subduction zones.



Matt Leybourne

*A group examines migmatitic orthogneisses along the Maggia River in the Central Alps near Tegna. These migmatites formed as a result of protracted crustal melting from 32 million to 22 million years ago.*

Workshop participants recognized that Earth's modern plate tectonic regime evolved over time. Lithospheric damage led to the accumulation of weak zones that evolved into plate boundaries. Mantle plumes may have first induced lithospheric collapse and short-lived subduction zones.

Participants agreed that complex rheological interactions and mineralogical processes at the scale of crystal grains play a key role. There was also a sense that important changes occurred in Neoproterozoic time, when key plate tectonic indicators, including ophiolites, blueschists, and ultrahigh-pressure terranes, began to appear in abundance.

The presentation of the outstanding young scientist award to Kiran Chotalia (University College London, United Kingdom) brought the meeting to a close. The next meeting will be held in Sudbury, Ont., Canada, in 2018.

More details about the meeting can be found at the meeting website (http://jupiter.ethz.ch/~plates) and http://bit.ly/plates-supplement.

By **Robert J. Stern** (email: rjstern@utdallas.edu), Geosciences Department, University of Texas at Dallas; and **Taras V. Gerya** and **Paul J. Tackley,** Earth Sciences Department, Swiss Federal Institute of Technology, Zurich, Switzerland

# Why We Must Tie Satellite Positioning to Tide Gauge Data



*An acoustic tide gauge monitors the harbor at Burnie on the northern coast of Tasmania, Australia. To its right, a special pillar has a GNSS receiver on top.*

Many types of geophysical and environmental studies rely on accurate measurements of sea and land levels and knowledge of how they vary between locations and over time. Sea levels, however, can be particularly complicated to measure.

Sea level measurements at the coast require the use of tide gauges (sometimes called sea level recorders). Tide gauges measure changes in sea level relative to the land on which they are located, but that land can never be considered stable. Although we might not perceive it in our day-to-day experience, a range of natural geophysical factors (e.g., abrupt changes due to earthquakes or gradual changes due to glacial isostatic adjustment) and human activities (e.g., groundwater extraction) will cause vertical land movements and so complicate the sea level measurements needed for research.

To account for land influences on sea levels, scientists pair tide gauges with Global Navigation Satellite System (GNSS) positioning sensors, of which GPS instruments are the best known [*Intergovernmental Oceanographic Commission*, 2016]. These sensors measure the elevation of the land surface relative to the center of Earth. Unfortunately, positioning sensors are often located some distance away from tide gauges, making it difficult for researchers to know whether the vertical movement of the land is the same at both locations.

## Making the Ties

Tide gauges measure the level of the sea relative to the height of "benchmarks," located in the solid rock or sometimes on buildings on nearby land. In turn, the height of these benchmarks, which geodesists sometimes call "stations," can be measured relative to the center of Earth using advanced geodetic techniques such as the GNSS/GPS equipment.

In an ideal but uncommon situation, the GNSS equipment is attached directly to the tide gauge or located nearby (see, e.g., the photo above). In these cases, data from a given tide gauge and the corresponding GNSS equipment refer back to the same benchmark.

However, tide gauges and GNSS equipment are more commonly separated by distances of several meters to a kilometer or more. In these cases, the relative heights of the various marks must be measured by means of conventional spirit leveling in a procedure called "making a tie." When the distance between marks is short, this procedure can be performed in a short time. However, when the marks are some distance apart, a more exten-

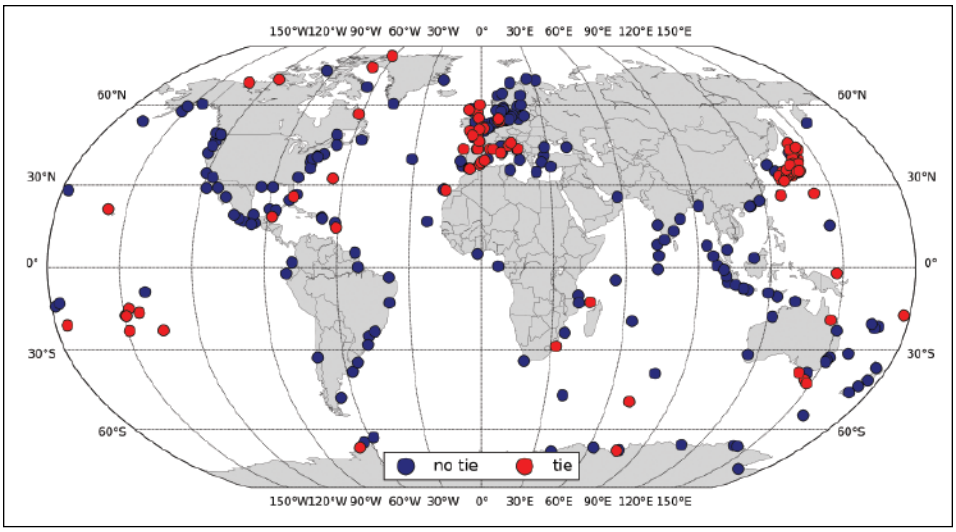



*Fig. 1. Locations of permanent GNSS stations near tide gauges (closer than 1 kilometer) that have data in SONEL. Sites where local ties between tide gauge and GNSS have been made and the information is included in the data bank are shown in red. Sites lacking such information are shown in blue.*

sive leveling exercise is necessary, which can require a greater commitment of staff time.

### Missing Information on Ties

Such ties are essential, yet they are not made at many tide gauges around the world, primarily because tide gauges and GNSS equipment are operated by different national agencies. These agencies do not accept making the ties as being their responsibility, in spite of this issue being raised with them many times by international sea level and GNSS programs, including the Global Sea Level Observing System (GLOSS) of the Intergovernmental Oceanographic Commission (IOC).

Figure 1 illustrates the problem. It shows tide gauge locations around the world for which a permanent GNSS station nearby (closer than 1 kilometer) has been identified in the Système d'Observation du Niveau des Eaux Littorales (SONEL) data bank at the University of La Rochelle in La Rochelle, France. SONEL is the official data bank for GNSS information for the GLOSS program. The map shows in blue that there are many sites for which information on ties is unavailable. In fact, this map underestimates the overall problem because sites are shown in red here if a tie has been made just once, rather than at regular intervals (e.g., annually) as required by GLOSS.

### Scientific Requirements

What are the scientific requirements for ties? The first requirement applies to studies of long-term sea level change. Consider a common situation: A well-established tide gauge that has recorded sea level for more than a century is a short distance from a permanent continuous GNSS station that has recorded land levels (ellipsoidal heights) for perhaps as long as 20 years. The rate of change of land movement recorded by the GNSS station can be compared with the rate of sea level change measured by the tide gauge record to understand how much of the record results from movement originating in the ocean or on land.

> Tide gauges and navigational satellite equipment are commonly separated by several meters to a kilometer or more.

In addition, the GNSS rate can be added to the tide gauge rate to obtain a geocentric rate of sea level change that is akin to that measured from space by a satellite radar altimeter. Consequently, the rates recorded by the different techniques can be used to validate each other. For example, altimeter and tide gauge data can provide estimates of land movement that can be compared with those of GNSS data. Similarly, tide gauge and GNSS data can be used to calibrate altimeter measurements.

Researchers have made such comparisons of rates using different techniques for many years [e.g., *Wöppelmann and Marcos*, 2016].

However, an implicit assumption is always that the level of the land on which the tide gauge is located is moving in the same way as the land under the GNSS and that there is no differential movement between them. Such an assumption may be reasonable where the two sensors are not far apart and are located within the same parcel of land.

However, it becomes more problematic when the two sensors are farther apart, when they are installed on dissimilar substrates (e.g., the GNSS is installed on hard rock and the tide gauge is on a nearby piece of reclaimed land), or when measurements are compared over a long period of time. When ties can be made and repeated at regular intervals, these assumptions become unnecessary.

### A Worldwide Height System

A second scientific requirement for ties comes from worldwide height system unification (WHSU), in which the geodetic community is moving toward the use of the geoid (a model of an equipotential surface of Earth's gravity field) as a datum, or geodetic reference level, that represents "zero" instead of the many national reference levels presently in use.

One of the oceanographic components of WHSU involves validating geoid models by comparing the mean dynamic topography (MDT) observed at tide gauges (the difference between the local mean sea level and the geoid) with the MDT values obtained from ocean models [*Woodworth et. al.*, 2012]. In this case, we need to know the mean sea level (MSL), expressed as an ellipsoidal height by means of a leveling connection, or "tie," between the tide gauge benchmark and other marks (stations) nearby at which either continuous or episodic (campaign) GNSS measurements have been made.

### Falling Between the Cracks

Why has it been so difficult to make the ties and include them in sea level and GNSS data banks?

One reason might be a lack of scientific appreciation for the importance of this activity. Most researchers consider only the rates of change of sea and land levels, measured by the tide gauge and GNSS, respectively, to be important. They seem to be happy enough to assume that the intervening land is relatively stable, so the same land movements occur at both locations, but this assumption cannot be made in long-term studies, for example, within the context of validating new satellite radar altimetry missions aimed at climate sea level applications. Scientists engaged in the relatively new field of WHSU are also disadvantaged by the lack of ties.

However, the main difficulty in making ties on a regular basis has been practical, rather than scientific, and has to do with the way that tide gauge and GNSS measurements are organized and funded in many countries. Tide gauges are usually operated by port authorities or agencies concerned with flood warning, and they may have little contact with the geodetic agencies that operate GNSS equipment. Thus, the ties often fall between the organizational cracks.

Sometimes international programs of organizations such as IOC, the International Hydrographic Organization, and the International Association of Geodesy make appeals to the various agencies responsible for collecting sea and land level data. However, in our experience, national agencies have taken little notice of such international recommendations. In addition, proposals that these organizations have developed for a coordinated international measurement program for ties have not been moved forward by national agencies.

This lack of coordination has been a frustrating situation so far. That's why we believe it is essential for yet another attempt to be made to break down these cultural walls and for the various national and international organizations to redouble their efforts. Without regularly repeated ties, their sea level and geodetic programs will be unsuccessful in the long term.

> National and international organizations must redouble their efforts toward a coordinated measurement program for ties.

Advice on measurement requirements, techniques, and formats for sending information to the data centers is readily available from the Permanent Service for Mean Sea Level (see http://www.psmsl.org) and SONEL. We hope that more information on ties will become available and be included in data banks alongside the sea level and GNSS data. This information will benefit future researchers of global sea level change, surveyors and geodesists concerned with WHSU, and those concerned with many other practical applications.

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# Three Reasons Why Earth Scientists Should Edit *Wikipedia*


iStock.com/Zmeel Photography

If you are a researcher who is looking to communicate science more broadly, an easy step involves *Wikipedia.*

*Wikipedia* is a frequent first stop for researchers, students, and the public. The world's largest free encyclopedia, it is also one of the largest websites based on traffic.

Here's the important thing: Numbers of page views of *Wikipedia* are immense compared with views of primary literature articles. As a result, if you edit a page to include results from your research, your audience will likely expand by at least an order of magnitude.

Editing *Wikipedia* is a way to show your notable work to more people, who, in turn, may benefit, use, or be interested in your research topic. I am not an expert *Wikipedia* editor, and my suggestion for researchers to edit *Wikipedia* is not novel [e.g., *Bateman and Logan,* 2010; *Bond,* 2011; *Logan et al.,* 2010], but I do want to discuss the benefits and present some (personal) data to convince you of the value of editing.

Here are three reasons you should edit *Wikipedia:*

## 1 Your Research, Out from Behind a Paywall, Gets into Public View

As an online encyclopedia, *Wikipedia* is a venue for summarizing previously published research, and therefore editing it is a form of public outreach and science communication. The article with your brief edits could be the only place on the web that isn't behind a paywall, where people can read about recent scientific work, making it more visible to scientists and nonscientists alike.

To make this point about increased visibility more quantitative, I show in Figure 1 a time series of monthly page views (users only, not bots) for four *Wikipedia* articles relevant to my primary research. Figure 1 also shows the page views of my research website and article views for a recent open-access journal article of mine for comparison. The log scale demonstrates just how many people peruse some *Wikipedia* pages versus primary sources.

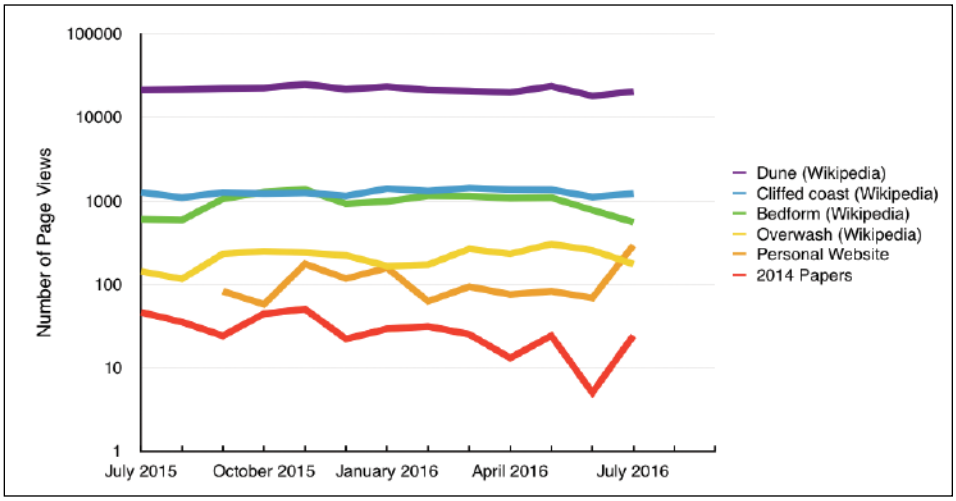
## 2 Editing Articles Is Quick and Easy

I want to stress that editing pages is not overly time-consuming. *Logan et al.* [2010] offer simple and clear guidance about editing *Wikipedia*. In addition to compiling a list of frequently asked questions about editing (http://bit.ly/Wikifaq), *Wikipedia* itself maintains extensive literature on common mistakes as well as guidance about what *Wikipedia* is and is not (see http://bit.ly/Wikimistakes and http://bit.ly/WikiIsNot).

The Wiki Education Foundation also maintains resources for instructors to integrate editing *Wikipedia* into the classroom (see https://wikiedu.org/). I have touched upon only a few of the available resources on *Wikipedia* editing; there are many more.

## 3 Editing Provides an Opportunity to Connect and Network

*Wikipedia* is a gateway to scientific literature [*Taraborelli,* 2016]. Citations of your work in *Wikipedia* not only increase the visibility of research but also connect *Wikipedia* to your journal article. If you have an Open




Evan Goldstein

*Fig. 1. Monthly page views for Wikipedia show the large audience compared with page views of the author's personal website and page views of a 2014 open-access journal article by the author. Note the logarithmic y axis.*

Researcher and Contributor ID (ORCID; many journals now require this), you are also eligible for an Impactstory profile (https://impactstory.org/). Impactstory aggregates the web links (from a variety of venues) to all works listed in your ORCID account.

As a result, mentions of your research on *Wikipedia* appear on your Impactstory profile. This information on usage (via Twitter, blogs, *Wikipedia*, etc.) can allow you to connect to people who are interested in your research but won't be citing it in peer-reviewed literature. I would add that if you are an early-career scientist or student, these nontraditional research mentions may have professional benefits (such as networking).

### Don't Game the System

However, I also want to mention a caveat.

There is a danger that some academic *Wikipedia* editors will attempt to "game" the research metrics system, tending toward outsized self-promotion as opposed to sharing notable new science with the public. *Wikipedia* provides information about conflict of interest and self-promotion to inform editors and prevent these issues (see http://bit.ly/WikiCOI).

Information on usage can allow you to connect to people who are interested in your research but won't be citing it in peer-reviewed literature.

Guidance on these topics is also given by *Logan et al.* [2010].

### A Warm-Up to More

Editing *Wikipedia* pages does not require a large time commitment but can have a significant effect on the communication of science because of *Wikipedia*'s large number of page views. Editing can be incorporated into your scholarly life as a "warm-up" exercise for scholarly writing, and I can imagine that a lab- or department-wide edit-a-thon could be a valuable and fun event.

In summary, I urge you to consider editing *Wikipedia* as public outreach, to get research into the hands of people who could benefit from your newfound knowledge.

### Acknowledgments

I thank E. Janke, E. Lazarus, and two anonymous reviewers for constructive feedback.

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By **Evan B. Goldstein** (email: evan.goldstein@unc.edu; @ebgoldstein), Department of Geological Sciences, University of North Carolina at Chapel Hill

From the peer-review process to the very concept of what it means to be brilliant, studies show that women face subtle biases and structural barriers to success in the geosciences.

# DATA ILLUMINATE A MOUNTAIN OF MOLEHILLS FACING WOMEN SCIENTISTS

By Julia Rosen

Every female scientist has a story.

One woman was warned not to wear her wedding ring to job interviews. Another noticed that her adviser showered more praise on his male students. On one occasion, a woman sat silent while the man next to her turned his back to her to talk to other (male) colleagues for the entire duration of a professional dinner.

What should the women on the receiving end of such slights make of them? They might be random, nothing more than the everyday ups and downs of life as a professional scientist. They could be isolated incidents of sexism. Or they could be symptomatic of broader trends that hinder women in science.

In cases like these, it's impossible to know. "As an individual, you don't really have the sample size to come up with this sort of conclusion," said Jory Lerback, a graduate student at the University of Utah. But now researchers like Lerback have harnessed the power of data to zoom out and identify systemic problems within the Earth sciences.

In one study, led by Lerback and published in January in *Nature*, researchers found that women make up a disproportionately small percentage of reviewers for Earth science journals [*Lerback and Hanson*, 2017]. Another study, published last year, revealed that women are less likely to receive glowing letters of recommendation when applying for postdoctoral fellowships in the geosciences [*Dutt et al.*, 2016].

Researchers say the new results don't reflect overt discrimination, which has declined dramatically in recent decades. Instead, women face more insidious challenges, such as subtle, unconscious bias held by people of both genders and built-in barriers to success.

And they add up. Psychologist Virginia Valian of Hunter College calls this the "accumulation of disadvantage." To borrow her metaphor, countless molehills pile up to create formidable mountains standing in the way of female scientists. In the geosciences, women still make up just 20% of faculty in the United States, despite earning almost a third of Ph.D. degrees in 2000 and more than 40% today [*Glass*, 2015].

By using hard data to illuminate lingering problems, many hope that the geoscience community can start bulldozing the remaining molehills. After all, to realize its full potential for innovation and success, science needs all kinds of scientists, said Tracey Holloway, an atmospheric scientist at the University of Wisconsin–Madison and president of the Earth Science Women's Network.

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"For the well-being of the human enterprise, we want all hands on deck," she said.

## Wanted: A Detailed Database

Reviewing papers may not be glamorous, but it plays a fundamental role in the scientific process.

"I like reviewing papers because I have an opportunity to improve the quality, breadth, and impact of a manuscript," said Heather Ford, an independent research fellow at Cambridge University studying paleoclimatology. Reviewing also provides important opportunities for early-career scientists like Ford to network with journal editors and interact with fellow scientists.

But it's hard to determine whether women are well represented among geoscience authors and reviewers, Lerback says. Most publishers don't ask scientists their gender, and assigning it based on names can be tricky business. Age is also important because the proportion of women decreases among older scientists—a consequence of historic barriers to entry.

AGU, however, was in a unique position to do such an analysis. It publishes a suite of scientific journals, and AGU possesses gender and age information for more than 38,000 geoscientists who belong to the organization or have participated in AGU-sponsored activities, like its sprawling Fall Meeting.

Merging these two data sets offered the chance to evaluate the gender ratio of authors and reviewers for AGU's journals and how those ratios stacked up against the field's demographic breakdown. Lerback undertook the task with Brooks Hanson, AGU's director of publications, and uncovered a complex landscape of small but significant gender differences in geoscience publishing.

## How Often Do Women Publish in AGU Journals?

Lerback and Hanson's results show that women published less than men, submitting an average of 0.79 fewer first-author papers to AGU's journals in the 4-year period between 2012 and 2015.

However, women were better represented among first authors (26%) compared with total authors (23%), in contrast to previous studies that found that women tended to be listed between the respected first and last author positions [*West et al.,* 2013]. Overall, women also enjoyed a slightly higher acceptance rate than men: 61% versus 57%.

The researchers attribute this greater success rate either to reverse discrimination (i.e., reviewers actually favoring women) or, more likely, to the fact that women perfect their papers before submission, anticipating heightened scrutiny. "When someone is faced with that sort of mentality, you cover all your bases," Lerback said. "You check and check and check."

## A Gender Gap in Peer Review

It is most worrying, Lerback and Hanson found, that women were chronically underrepresented as reviewers. In total, women made up only 20% of reviewers, even though they compose 28% of AGU's membership and 29% of all scientists who have created accounts with AGU.

"That's a pretty big gap of women who aren't reviewing," Lerback said. On its own, this disparity wouldn't make or break anyone's career, she added, but it's problematic because it plays into the larger pattern of gender inequality in the Earth sciences.

The researchers found that several factors were to blame: Authors didn't suggest enough women to review their papers, editors didn't invite enough women to review, and women declined to do reviews more often than men.

What's more, these disparities persisted across age groups. This eliminated the possibility that authors and editors simply sought reviewers from older and more experienced cohorts with fewer women

No comparable analyses have been carried out for journals published by the Geological Society of America or the European Geosciences Union. But the new results, based on an analysis of nearly 25,000 authors and 15,000 reviewers, are hard to dismiss as unrepresentative, said Mary Anne Holmes, a sedimentary geologist at the University of Nebraska–Lincoln and an advocate for gender equality in the Earth sciences. "The volume of data is pretty overwhelming."

## Brilliant or Intelligent?

Another recent study tells a similar story about differences in the quality of reference letters for male and female geoscientists.

Researchers realized decades ago that letters often reflect gender stereotypes, and disparities have been clearly documented in numerous studies [e.g., *Trix and Psenka,* 2003; *Madera et al.,* 2009]. But a new analysis [*Dutt et al.,* 2016], published last fall in *Nature Geoscience*, is the

Ajay Singh

*Heather Ford, an independent research fellow studying paleoclimatology at Cambridge University, examines a sediment core on the R/V* Melville*. Ford says that she enjoys reviewing papers, but new data show that women are underrepresented as reviewers in geoscience journals.*

first to look specifically at the Earth sciences and relies on a larger data set than previous work.

Researchers evaluated more than 1200 letters sent on behalf of scientists applying for postdoctoral fellowships at Columbia University's Lamont-Doherty Earth Observatory (LDEO) between 2007 and 2012. The letters came from men and women scattered across 54 countries.

The analysis revealed that letters for men and women differed significantly in tone. Roughly a quarter of male applicants received what the authors classified as excellent letters, which included phrases like "brilliant scientist" and "scientific leader," compared with 15% of female applicants. Instead, more than 80% of women got letters that praised them in more staid terms, calling them "highly intelligent" and "very knowledgeable."

After adjusting the results to reflect regional variations between the home country of recommenders and letter length, the researchers found that women were about half as likely to receive excellent letters. This disadvantages women at a critical stage in their careers, the authors wrote.

"It certainly makes me feel highly discouraged and pessimistic," says Cynthia Gerlein-Safdi, a Ph.D. student at Princeton University studying how plants respond to climate. She is currently in the process of applying for postdoc positions and was disheartened when she heard the results of the study.

Because of the archival nature of the study, the researchers could not control for differences in the qualifications of the applicants. However, that probably doesn't explain the results, said Kuheli Dutt, assistant director of academic affairs at LDEO and lead author of the study.

"It is highly unlikely that all over the world, there is a systemic deficit in the quality of just the women applicants," she said.

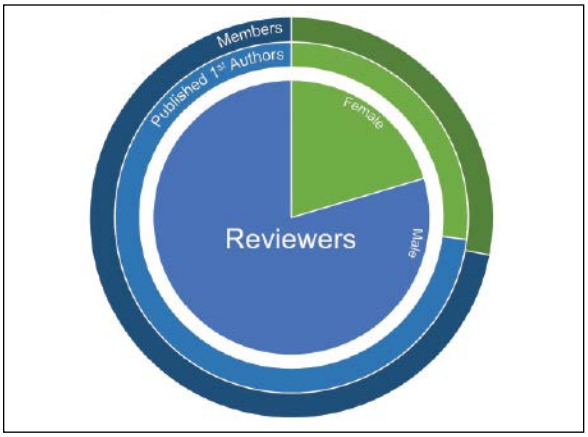
## A Competitive Disadvantage

Women remain at a competitive disadvantage even when they have the exact same qualifications as their male counterparts, according to previous studies.

Take the now-famous study in which identical job applications were sent out under different names [*Moss-Racusin et al.,* 2012]. Faculty rated the applicants with men's names as significantly more competent and hirable for a potential lab manager position than applicants with women's names. They offered to pay them more too. Another study found that men were twice as likely to be selected to perform a mathematical calculation on the basis of their appearance alone [*Reuben et al.,* 2014].

Holmes also points to the story of gender bias in orchestras [*Goldin and Rouse,* 2000]. Few women made the cut when judges could see them perform during auditions. But when they played from behind a screen, Holmes said, "the number of women who were hired just rose dramatically."

Researchers attribute such patterns of discrimination not to intentional exclusion but to the effects of implicit or unconscious biases. These are deep-seated beliefs about groups of people—in this case, women—that stem from common stereotypes and may even conflict with our conscious thoughts and attitudes, according to Mikki Hebl, an applied social psychologist at Rice University.




Lerback and Hanson, 2017, https://doi.org/10.1038/541455a

*A study published in* Nature *found that women were underrepresented as reviewers for AGU's journals. The proportion of female reviewers (20%) was smaller than the proportion of published female first authors (27%) and female AGU members (28%).*

For instance, many people may support women in science but subconsciously react to the ways in which stereotypes about women conflict with stereotypes about scientists.

In a 2008 *Nature Geoscience* study led by Holmes, some participants in a focus group tasked with examining why women choose to leave Earth science suggested that it is because they don't like doing fieldwork or have low interest in the subject matter, ideas that echo long-held stereotypes about women's fragility and disposition [*Holmes et al.,* 2008]. However, as "congenital players in the dirt," Holmes and her coauthors wrote that they don't believe these are major drivers.

Problems also stem from the fact that stereotypes about scientists evolved decades ago, when most were men. "We have so many cultural preconceptions of what a genius looks like, what a scientist looks like, what kind of behavior is indicative of somebody being truly devoted to their career," Holloway said.

"Sometimes it's very difficult to differentiate what are characteristics of a good scientist from what are characteristics of a male scientist," she said.

## An Equal Opportunity Challenge

Men aren't the only ones who fall prey to these subtle biases, however.

In Dutt's study, female recommenders were equally likely to write stronger letters on behalf of male applicants. And although female editors and authors of AGU's journals identified a higher proportion of women to review papers than male editors did, the gender ratio of those reviewers still failed to reflect the demographics of the field.

"It's not really about who's to blame," Lerback said. It's recognizing that everyone is part of the problem.

Men and women can harbor unconscious bias because it's based on "culturally learned information," Hebl said. "When we come into the world, we learn that girls wear pink and boys wear blue." As a result, psychologists have found that we tend to penalize anyone—man or woman—who doesn't conform to our subconscious expectations.

For example, in one 2016 study in which subjects were asked to rate the brilliance of various scientific discoveries, researchers found that people of both genders rated discoveries as more exceptional if they were described in ways that fit stereotypes of women as caregivers and men as geniuses [*Elmore and Luna-Lucero,* 2016].

For men, that meant having a flash of brilliance, and for women it meant nurturing the seed of an idea as it grew. Discoveries described with the opposite pairings (i.e., women having a flash of brilliance) received more tepid ratings.

Subtle though they may be, these biases make scientists less likely to think of their female colleagues when inviting colloquia speakers, according to Hebl's research. This may also explain why fewer women get nominated for awards and honors [*Holmes et al.,* 2011] or asked to author perspective pieces for prestigious journals. A 2012 analysis found that women wrote just 4% of Earth science News and Views articles in *Nature* [*Conley and Stadmark,* 2012].

It's no surprise, then, that these biases may also arise when authors or editors of a scientific paper brainstorm possible reviewers, Lerback said. "Who makes it through to the forefront of your mind?"

## Navigating Hidden Barriers

Unconscious biases aren't the only impediments to success. Women must also contend with troubling levels of sexual harassment and assault [*Clancy et al.,* 2014], a lack of mentors, isolation in male-dominated research groups, and a litany of other challenges. Sometimes the very architecture of science—designed mostly by and for men—can stand in the way [*Marín-Spiotta et al.,* 2016]. This becomes particularly evident as women progress beyond graduate school.

For instance, it has long been seen as advantageous for young scientists to move to a new institution immediately after finishing a Ph.D. Until recently, it was actually a requirement for recipients of the National Science Foundation's prestigious postdoctoral fellowships.


Franco Marcantonio

*Jennifer Hertzberg, paleoceanographer and postdoctoral fellow at the University of Connecticut in Avery Point, inspects a sediment core aboard the R/V* Melville *in the eastern Pacific Ocean. She's currently looking for a job but notes that the researcher's life of chasing funding could bleed into family time.*

But uprooting can be harder for women than men, said Holloway. Women generally marry and have children at a younger age, and female scientists are more likely to have a partner in academia.

The demands of certain faculty jobs that require constantly chasing funding can also be daunting to women as they consider starting families, said Jennifer Hertzberg, a paleoceanographer and postdoctoral fellow at the University of Connecticut in Avery Point. She is currently applying for jobs. "If I were having to write research grants all the time, I know that that would fall into after-hours and on the weekends." She's not sure it would be doable with children.

Academic jobs often require long hours, and data suggest that women have fewer to spare. Female scientists with male partners tend to do more housework, according to a survey conducted through the Earth Science Jobs Network, a listserv run by the Earth Science Women's Network that includes both male and female geoscientists [*Archie and Laursen,* 2013]. Sixty percent of women reported doing the majority of household upkeep, compared with 20% of men. Fifty percent of women with children also did the majority of parenting work, compared with 9% of men.

In addition, research suggests that women may also juggle more obligations at the office [*Misra et al.,* 2011]. Female associate professors, in particular, typically shoulder heavier administrative, mentoring, and teaching duties at the expense of research. They often serve on many doctoral committees, for example, as one of a few female faculty members in high demand from larger numbers of female students, Holmes said.

All this may explain the small but telling finding in Lerback's study that even when women were asked to review papers, they declined more often than men. "Maybe women aren't stepping up to do these reviews because they're too damn busy," Holmes said.

## Data Pave a Path to Progress

At the end of the day, the many challenges facing female scientists weigh on women just starting in their careers. Some feel lucky just to have made it as far as they have, given that the deck is often stacked against them.

"It's exhausting," said Ford.

"I feel like I have to work harder than a male at the same point in my career," said Hertzberg.

Many agree that the first step in addressing these problems is raising awareness. And the recent studies should help.

"Data are undeniable facts," said Claudia Jesus-Rydin, a program officer for Earth system sciences at the European Research Council, where she coordinates its gender balance initiatives. Scientists, of all people, should be persuaded of the problem.

But what can scientists do about it?

## Knocking Down Barriers

Unconscious bias and structural barriers can take many forms, and the solutions may be as diverse as the problems themselves.

Because unconscious biases are, by definition, unconscious, people can't just decide to change them. However, research suggests that simply recognizing the presence of implicit bias is an important way to reduce its effects. Harvard offers online bias tests (http://bit.ly/biastesting), and many organizations, including universities and professional societies, now offer implicit bias training for awards and hiring committees.

Voluntary training proved most effective at reducing bias, along with strategies like implementing mentoring programs and fostering social accountability, according to an analysis of diversity programs in the *Harvard Business Review* [*Dobbin and Kalev*, 2016]. However, the authors found that forcing people to participate in bias training can actually spark a backlash.

For AGU's part, Hanson said that the organization is "trying to expand the diversity of our editorial teams and reviewers." And because recommendation letter differences have come to light, many universities have compiled tips for reducing bias [e.g., *Commission on the Status of Women*, 2015]. They include emphasizing accomplishments over effort and steering clear of personal details, which crop up disproportionately in letters for female applicants.

Holloway has worked with AGU to increase the diversity of its awards, primarily by encouraging a more diverse pool of people to do the nominating. Award committees also stopped emphasizing a candidate's h-index—a measure of his or her citations—after studies showed that men self-cite more than women. And in 2016, female scientists represented 30% of nominees and winners, twice the ratio in 2014 and roughly equal to the proportion of female AGU members. A similar effort is under way within the European Geosciences Union (see http://bit.ly/GenderEGU).

Holmes cites other innovative efforts at places like Lehigh University and the University of California, Irvine, where men are trained to be so-called equity advisers. The idea is that men can then serve as advocates for women, for instance, on hiring committees.

"I really like that idea," Holmes said. "Y'all step up to the plate and take some of the burden."

## Finding a Way Forward

Gender equality is always a touchy subject, and addressing it as a community will require a careful balancing act, Hebl said. Scientists have to hold one another accountable whenever unconscious bias rears its head. But they should also be tolerant as people learn how to recognize and acknowledge it.

"We all make mistakes," Hebl said. "If there are not safe spaces to make mistakes and learn, it can harbor pools of hatred."

And as scientists work to address the challenges facing women, they shouldn't forget that the road is even harder for people of color and people who face discrimination because of their sexual orientation and gender identities, said Robyn Dahl, a paleontologist at Western Washington University in Bellingham. Dahl is biracial and a lesbian and works to increase diversity in fields involving science, technology, engineering, and math.

Policies and structures may need to change too, and that may entail a bit of trial and error. Some well-intentioned strategies, like paid parental leave for both men and women at research universities, appear to have backfired. A recent study suggested that it did not level the playing field, as hoped, but actually helped male faculty gain tenure while reducing women's chances [*Antecol et al.*, 2016].

Nonetheless, any efforts to increase flexibility mark a step in the right direction, Holmes said. The academic career path is often described as a pipeline toward professorhood from which women disproportionately "leak" out. But times are changing.

"The new metaphor is something more like an interstate expressway," Holmes said. "There are a lot of on-ramps, a lot of rest areas, and other destinations to go to."

Many early-career researchers are fueled up and ready for the ride, despite the curves ahead.

"I love my job, and I can't imagine myself doing anything else in life other than working in the geosciences," said Elizabeth Orr, a Ph.D. student studying glacial geomorphology at the University of Cincinnati.

"I am here to stay."

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# INTERNATIONAL EFFORT TACKLES LANDSLIDE HAZARDS TO KEEP THE PEACE

By Alessandro Tibaldi and Nino Tsereteli

The Republic of Georgia and the neighboring Russian-occupied region of Abkhazia depend on energy supplied by the Enguri hydroelectric plant. This plant not only straddles a contentious political border but also sits atop a seismically active region.

The hydroelectric power station lies in Abkhazia, a region that declared its independence from Georgia in 1999 (although Georgia treats it as an occupied territory of Russia). However, the water power comes from the 271.5-meter Enguri Dam, one of the world's tallest arch dams, located in Georgia (Figure 1). The 15-kilometer-long artificial water reservoir behind the dam is nestled among the southwestern mountains of the Caucasus, a mountain range that has experienced earthquakes with moment magnitudes ($M_w$) as strong as 7 [*Triep et al.*, 1995].

The eastern slopes of the Enguri artificial reservoir could be prone to earthquake-induced landslides. Such landslides could cause the Enguri hydroelectric plant to fail or be impaired temporarily, interrupting the energy supply and productive activities and possibly causing social tensions on both sides of the border. Landslide deposits could partially fill the reservoir and decrease the capacity of the dam in the long term. However, these

*The Enguri Dam and Jvari Reservoir are situated in a seismically active region of the Caucasus.*

Andrei Bortnikau / Alamy Stock Photo

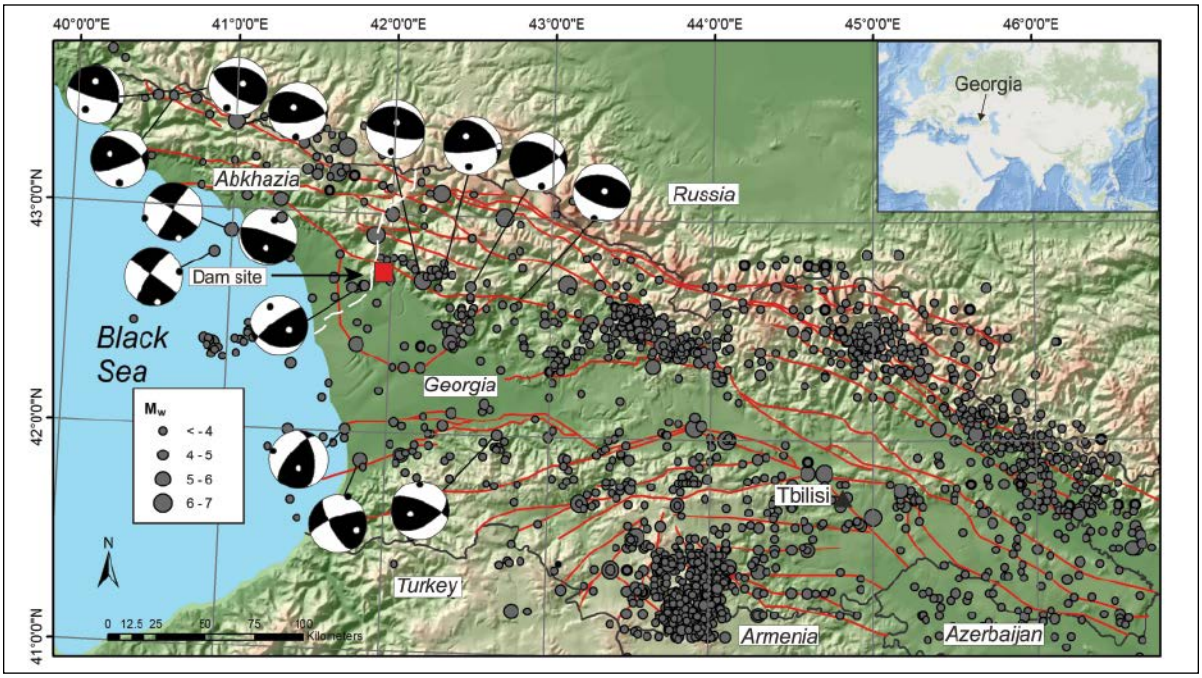


*Fig. 1. Active faults of the Caucasus in Georgia (red lines) and main earthquake epicenters (gray circles) with magnitude proportional to circle diameter. Note the main fault plane passing near the Enguri Dam (red square). Focal mechanism solutions (black and white circles) refer to earthquakes within 150 kilometers of the dam. The white dashed line represents the disputed border with Abkhazia. Faults after* Tsereteli et al. *[2014].*

hazards and their probabilities are not well defined, nor is there any system in place to warn nearby residents when a landslide is about to occur.

To improve understanding of the geological hazards affecting this important energy infrastructure and to provide mitigation measures that might help to prevent geopolitical problems in the area, a group of researchers recently embarked on a major collaborative research program under the aegis of the North Atlantic Treaty Organization's (NATO) Science for Peace and Security program (see http://bit.ly/Science-for-Peace). These researchers came from Italy, the United States, the United Kingdom, Switzerland, Georgia, Azerbaijan, and Kazakhstan.

## Scope of the Project

Despite the steep slopes and the potential for earthquake-induced landslides around the reservoir, no one has conducted a quantitative assessment of landslide hazard under seismic conditions here [*Gabrichidze*, 2013]. One such hazard, the active Khoko landslide (11 million to 21 million cubic meters), which is slowly creeping downslope, lies only a few kilometers from the dam and directly faces the reservoir.

A landslide collapse into the lake would have dramatic consequences: an arrest in energy production or, in the worst-case scenario, dam overtopping by a landslide-triggered tsunami. Either event would have consequences for people in surrounding regions.

What's more, these events might provoke repercussions for the political stability of the region. The latest war between Georgia and Abkhazia, which claimed 30,000 lives, ended in 1998, and the geopolitical situation has remained unsettled ever since.

The 2015–2018 NATO initiative has a series of major goals: improving knowledge about the seismicity of the area surrounding the dam, quantifying the landslide hazard under static and dynamic conditions (without seismicity and under seismic shaking, respectively), and identifying factors that might cause a tsunami to propagate in the artificial lake and flood the region below the dam.

The project also aims to train local young researchers to carry out similar studies autonomously in the future. Another goal is to involve end users, such as the hydroelectric company that runs the dam and the Georgia Ministry of Regional Development and Infrastructures, and encourage them to implement monitoring schemes and possible mitigation measures.

## A Seismically Active Region

The Enguri hydroelectric facility, with its steep reservoir slopes, is located along one of the most tectonically active areas of the world: the foothills of the Caucasus [*Tan and Taymaz*, 2006]. Earthquake occurrences in regions with steep slopes greatly increase the likelihood that landslides will occur. Ground shaking alone can trigger landslides, but it can also decrease the density of soil materials, allowing water to penetrate the ground rapidly and reducing the slope's stability [*Keefer*, 1994].

This region is crossed by active faults that can be as long as several tens of kilometers, which strike mostly parallel to the mountain range (Figure 1). *Philip et al.* [1989] pointed out that the western Greater Caucasus has concentrated deformation at its southern slope, whereas the northern flank is almost undeformed.

This suggests that the push of plate tectonic forces, which produces mountain uplift and shortening across the

western Greater Caucasus, is absorbed along the southern border where the Enguri Dam is located. *Reilinger et al.* [2006] concluded that movement along the Main Caucasus Thrust, located at the southern foothills, is one of the predominant processes accommodating Arabia-Eurasia convergence. In fact, analysis of historical and instrumental seismological data from Georgia indicates past earthquakes as strong as $M_w$ = 6.9 and with a macroseismic intensity of 9 on the Medvedev-Sponheuer-Karnik (MSK) scale.

The most recent seismic hazard zonation of Georgia indicates possible earthquake ground shaking with a peak ground acceleration of 0.3–0.5 *g* (gravitational units) [*Chelidze et al.*, 2002]. Although the hazard assessment identifies two faults passing near the Enguri Dam that could produce earthquakes as strong as $M_w$ = 6–7, the expected peak ground acceleration appears underestimated in light of more recent results suggesting 0.65–0.69 *g* [*Tsereteli et al.*, 2014].

This possible underestimation suggests the need for a careful reassessment by incorporating new investigations of ancient earthquakes. Such investigations will be a major future effort of this project.

### Field Surveys Characterize Local Geology

We conducted initial fieldwork within this NATO collaboration in November 2015 and May 2016. All the teams focused their efforts on collecting multidisciplinary data on the various aspects of geohazards. Field surveys integrated with interpretation of high-resolution satellite images allowed us to identify slopes that are actively moving, although slowly, and that in the future might accelerate their movements, producing a landslide failure. In fact, we recognized additional slope movements near the known Khoko landslide (Figure 2). The main road that winds up into the Caucasus requires continuous restoration because of deformation induced by slope movements.

Future large earthquakes in the area might trigger a sudden collapse of these already moving slopes and might also cause failures to develop on other slopes. To assess this possibility and identify the areas most susceptible to slope instability and failure, the international teams started to collect data on the mechanical properties of the rocks and samples. Determining these properties helps risk assessors conduct geotechnical tests as well as morphostructural and geological surveys all along the slopes surrounding the dam and the water reservoir.

Our preliminary results indicate that most of these unstable slopes are highly mobile, shifting on the order of 5–10 centimeters per year. Moreover, the whole area of active creeping (Figure 2b) corresponds to an estimated volume of 52 ± 17 million cubic meters. Researchers have also started conducting the first large-scale systematic survey of a wide area surrounding the Enguri Dam to recognize geological-geomorphological evidence of prehis-


Alessandro Tibaldi

*Fig. 2. (a) Enguri reservoir and dam. (b) Close-up of the area in the white box in Figure 2a. This area has a large number of moving slopes, which could evolve into landslide failure, and it faces the reservoir. White lines show the head scarps of major active slope sectors. (c) Minor landslides and rockfalls affect the service roads to the Enguri Dam. (d) A 20-centimeter-high scarp, formed over a couple of years, deforms the main road along the Enguri reservoir.*

toric surface fault ruptures. The region around the dam shows evidence of recent tectonics, including broad uplift of topography, fault scarps, and folds.

Overdeepened or migrated rivers and the widespread presence of fluvial deposits that date from late Miocene times to the present give evidence of vertical tectonic motions. This succession of sedimentary deposits can be interpreted as evidence of major uplift of this part of the Caucasus with consequent erosion, consistent with previous thermochronometric studies [*Vincent et al.*, 2011]. The fluvial deposits now lie as high as about 150 meters above the surrounding valley floor, and the Enguri River is excavating its own deposits.

In addition, the oldest portion of this continental succession shows evidence of tectonic folding, whereas locally we found fault scarps affecting the more recent Plio-Quaternary deposits. These data again attest to recent uplift as well as ongoing seismic deformation of this entire area.

### High Landslide Hazard

The first outcomes from this project show that a series of actively moving slopes shape the eastern flank of the Enguri artificial reservoir and suggest that this region should be considered an area prone to earthquake-triggered slope instability. The presence of historical and instrumental seismicity clearly suggests that some segments of the faults near the Enguri Dam are active. The seismic focal mechanism solutions highlight that these faults have reverse slip motions (Figure 1). These fault motions, together with the presence of uplifted fluvial deposits, the entrenching of the rivers, and the folding of the strata, indicate active tectonic compression.

From this perspective, several reverse faults in the region are potential candidates to trigger earthquakes in the future. The presence of folds and uplifted deposits may also suggest the presence of blind seismogenic faults, that is, earthquake-producing faults that do not break through to the surface.

### Toward Early Warning

In view of the high mobility and volume of actively sliding areas, the project coordinating committee agreed that we needed to install a series of digital extensometers at the major unstable slope sites. These instruments measure increases in length of less than a millimeter between a benchmark fixed in the stable slope and another benchmark fixed in the creeping slope. These instruments, together with 14 benchmarks and related GPS measurements, will be used to monitor, in real time and in great detail, slope movements and road deformation. Such instruments will enable us to assess the evolution of a landslide with respect to climate conditions and eventual future earthquakes. Detecting an increase in slope movements might lead to precautionary alerts.

None of the existing studies on these unstable slopes is aimed at assessing their present-day mobility and their possible behavior in the case of earthquake shaking under various meteorological conditions, so our hope is to fill this gap. Ultimately, we seek to forecast disasters better and possibly even prevent some natural catastrophes using a quantitative evaluation of the static and dynamic behavior of these landslides under various scenarios. We plan to improve on these assessments by analyzing other instability-prone slopes along the reservoir and their infrastructures.

### Cooperation Toward Averting a Disaster

The continued operation of the Enguri Dam may represent a major source of confidence building between Georgia and Abkhazia [*Bruch et al.*, 2009]. Thus, our efforts are currently devoted to planning an early-warning system to help ensure the protection of this dam.

We also seek to involve local and regional authorities and end users during the entire research process. We expect that the project's collaboration with Azeri and Kazakh scientists will have a positive impact on international stability because it increases cooperation with neighboring Georgia and with NATO countries. Moreover, because the Caucasus foothills in Georgia and Azerbaijan share the same tectonically active structures, an improvement in the knowledge of the faults along these zones would facilitate seismic hazard and risk assessment in both countries.

In politically and seismically unstable regions, efforts to protect critical infrastructure could be the solid ground on which to build a more lasting peace. Our project will continue to shore up this solid ground.


### Acknowledgments

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# THE BALANCE OF ICE, WAVES, AND IN THE ARCTIC AUTUMN

By Jim Thomson, Stephen Ackley, Hayley H. Shen, and W. Erick Rogers

# WINDS

Although summer sea ice loss in the Arctic is well studied, less is known about how ice comes back in autumn. A new program is changing that.

One of the most notable signals of rapid change in the Arctic is the loss of sea ice during summer months [*Jeffries et al.*, 2013; *Wang and Overland*, 2012]. Not only does the ice cover less area during the summer but also it's growing thinner [e.g., *Stroeve and Notz*, 2015]. Scientists have focused on studying the mechanisms responsible for summer ice loss, but they've paid less attention to the recovery of the sea ice in the autumn.

Most icebreaker-based research activity in the Arctic concludes by late September each year, resulting in a shortage of data for the autumn months. A new program, Sea State and Boundary Layer Physics of the Emerging Arctic Ocean (see http://bit.ly/SSBLPEAO), sponsored by the U.S. Office of Naval Research, has just completed a unique field campaign to investigate the dynamics of the autumn sea ice recovery in the Arctic.

Our expedition on board the newly commissioned R/V *Sikuliaq* collected data on the dynamics of air, sea, and ice from 28 September to 10 November 2015. During this time, the ice edge moved 250 nautical miles southward from the summer ice minimum in the Beaufort and Chukchi seas, reaching the Alaskan coast.

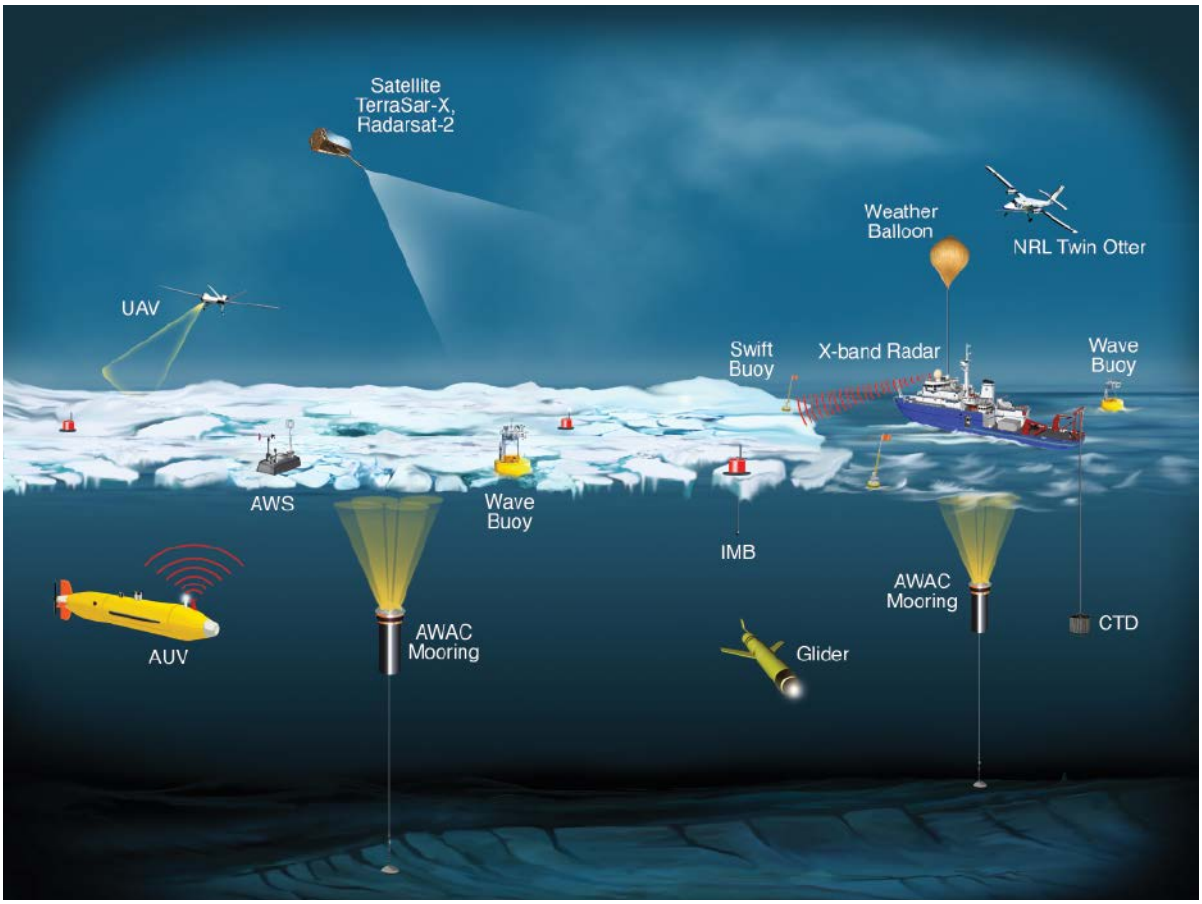
## Making Waves

The field program was designed specifically to understand the effects of an increasingly dynamic sea state (i.e., an increase in surface wave activity) on autumn ice recovery (Figure 1).

The loss of sea ice has not only increased the size of the open sea but also increased the size of the waves themselves, as surface waves have a greater distance

*A Surface Wave Instrument Float with Tracking (SWIFT) buoy measures waves amid pancake ice.*

Benjamin Holt, NASA/JPL-Caltech




Woods Hole Oceanographic Institution graphics department

*Fig. 1. Instrument platforms used in the Sea State and Boundary Layer Physics of the Emerging Arctic Ocean field campaign include unmanned aerial vehicles (UAV), autonomous underwater vehicles (AUV), automatic weather stations (AWS), Acoustic Wave and Current (AWAC) moorings, and underwater gliders. Various instruments are mounted on buoys and weather balloons, and floating instruments measure ice mass balance (IMB) and conductivity-temperature-depth (CTD) data. X band radar and airplanes are used to map the ice and waves around the ship.*

over which they can form and grow. To express this in nautical terms, fetch has increased [Thomson and Rogers, 2014].

This effect is most pronounced at the end of September, when sea ice extent is minimum (so fetch is maximum) and wind forcing is generally strong. Over the 6 weeks of the field campaign on board Sikuliaq, the simplest observation of all—visual confirmation of pancake ice formation—showed the effect of increased fetch on surface waves (Figure 2).

## Pancake Ice

Pancake ice forms when wave orbital motions (i.e., circular wave movements) disturb collections of ice crystals in the water, collectively called "frazil ice," as the ice forms. Frazil ice is "slushy"—soft and amorphous—because the water is moving too much to allow a solid sheet of ice to form. Quiet waters can form large, thin, flat sheets of new ice, called nilas, but the mobilized frazil aggregates into small floes that float on the sea surface and collide as each wave passes.

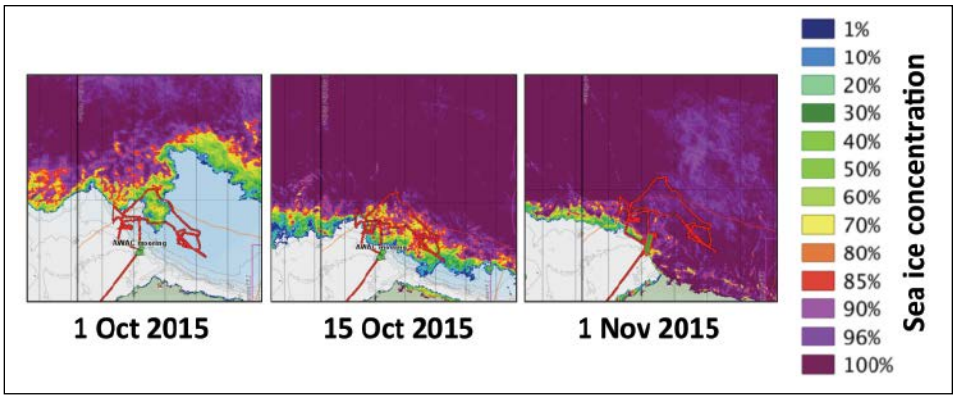
The collisions make floes round so that they resemble pancakes. Because the pancakes are typically 1 meter or less in diameter, they are below the resolution of most satellite imagery. This means that they are observed only from nearby, from ships or airplanes, or by autonomous platforms with cameras.

Pancake ice is relatively ubiquitous in the Antarctic sea marginal ice zone, but it has rarely been observed in the Beaufort and Chukchi seas. However, it was the dominant newly formed ice type that we encountered during this field campaign. We observed pancake ice with far greater regularity during this field campaign than in recent early autumn cruises in the eastern Beaufort conducted through the Joint Ocean Ice Study/Beaufort Gyre Exploration Project.

Clearly, the presence of pancake ice shows that wind events and the surface waves that come with them are important to the autumn ice recovery in the western Arctic Ocean. Wind and wave actions are perhaps also linked to the known trend of younger, thinner ice throughout the seasonal cycle [e.g., *Maslanik et al.*, 2011].

## Advance, Retreat, Advance

The prevalence of pancake ice has a large-scale effect on the autumn recovery of sea ice in the Beaufort and Chukchi seas. Figure 3 shows three maps of sea ice over 1 month; the daily progression is even more complex. As the wave




Ola Persson (NOAA)

*Fig. 3. Ship track (red path) of the R/V* Sikuliaq *as it traversed the Beaufort and Chukchi seas north of the Alaskan coast (gray landmass at bottom). Bathymetry (blue shading), and satellite-based ice concentrations (colors, representing the percentage of the area covered by ice in each pixel) show the recovery of sea ice during October 2015. These images were captured from the map server on board the R/V* Sikuliaq*, which was built and maintained by Steve Roberts of the University of Alaska Fairbanks. Ice concentrations, derived from data from the satellite-based Advanced Microwave Scanning Radiometer 2 (AMSR2), are from the University of Bremen.*

motion declined (in either time or space), the pancakes often rafted together and formed larger, thicker sea ice floes. The pancakes then consolidated (or "cemented") into surface sheets that were rougher than nilas sheets; these sheets of pancake ice aggregates presumably survived and became the winter ice pack.

Sometimes the pancakes' dampening of the wave energy appeared to accelerate this cementing process, which eventually protected the interior pancakes from wave motions and allowed larger floes to form. In some other events, however, strong wind- and wave-driven mixing of ocean heat prevented the ice edge from advancing, and the pancakes melted in place. Thus, the ice edge advanced one week, retreated the next, and eventually advanced again in an irregular pattern driven by regional storm cycles.

## Linked Effects from Air, Ice, and Ocean

The autumn recovery of sea ice is the result of a tightly coupled air–ice–ocean system. This system is described by a surface energy budget, which quantifies the flux of heat at the air–ocean interface. If the sea surface loses heat when its temperature is already near freezing, freezing occurs. Colder air temperatures can enhance ice formation, which we observed on several occasions when winds blew over existing ice and out to open water.

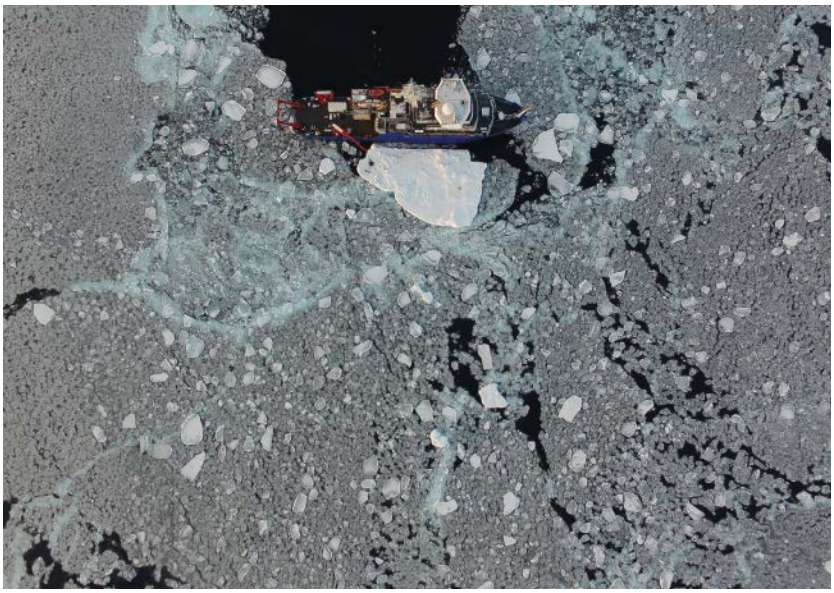
Heat flux from the upper ocean can also counteract or retard ice formation. With larger areas of the Arctic Ocean exposed to the summer Sun, the upper ocean accumulates more heat now than in previous years when it was ice covered for more of the seasonal cycle [*Perovich et al.*, 2007]. This heat is often trapped in a near-surface temperature maximum layer [*Jackson et al.*, 2010]. We observed strong winds and waves mixing this layer upward to the surface.

Diagnosing the freezing process and autumn ice recovery thus requires comprehensive air–ice–ocean measurements, including wave and wind forcing and sea ice transport. Observations from our fall 2015 field campaign, complemented by satellite, airborne, and shipboard remote sensing observations, are poised to improve our understanding of these processes.

## Planning and Forecasting

The *Sikuliaq* cruise used a dynamic planning strategy that was crucial to adapting to the fast changing region of our study. Every day, the whole onboard science team participated in updating our plans for the next 3 days, with detailed activities for the day to come and less detailed plans for the following 2 days.

The team based these plans on weather forecasts, wave forecasts performed aboard the ship, and ice data from satellite remote sensing telemetered to the ship by the shoreside team members. Our short-term wave forecasts



Guy Williams (University of Tasmania/ACE CRC) and Ted Maksym (WHOI)

*The R/V* Sikuliaq *is surrounded by new pancake ice (gray) and remnants of multiyear ice (white) during an "ice station," when the ship stopped at an ice floe immediately following a wave event on 17 October 2016. This photo was taken using a DGI Phantom unmanned aerial system.*

were accurate in open water but much less so inside the ice cover. The accuracy of the remotely determined ice edge strongly affected the performance of the wave forecast. These forecasts tended to deviate substantially from observations during a strong wind event or rapid ice growth.

### Analysis to Come

We have an enormous set of air, ice, and ocean measurements to analyze, from the ship and from numerous autonomous platforms used during the field campaign. The 2015 autumn ice recovery demonstrated the highly interactive nature of ice, wave, atmospheric, and oceanic processes. The winds and waves modulate this ice recovery, which, in turn, influences interactions between the atmosphere and ocean.

This strongly coupled problem is clearly a massive challenge for the models we use to forecast the ice, waves, ocean, and atmosphere. These interactions cannot be implemented in computational codes before we understand them empirically or, better yet, before the underlying physical principles are understood.

Our task now is to use these data to quantify the sea state and ice formation processes. The end goal is to improve prediction for immediate operational use and for long-term climate scenarios. We intend for the subsequent model improvements to be useful to both the broader research community and the local communities who live along the Arctic coastline and experience climate change firsthand.

Our results will be published in a special issue of *Journal of Geophysical Research: Oceans* that has been approved for 2017.

### Acknowledgments

The Sea State and Boundary Layer Physics of the Emerging Arctic Ocean program is sponsored by the U.S. Office of Naval Research. The R/V *Sikuliaq* is owned by the National Science Foundation and operated by the University of Alaska Fairbanks.

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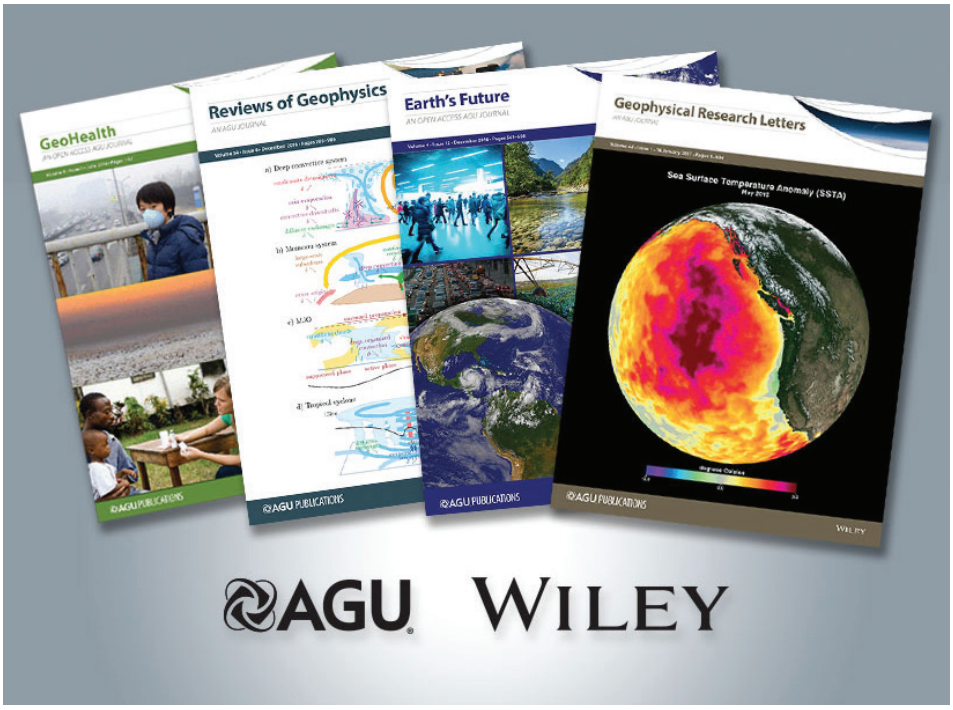


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By **Chris McEntee** (email: agu_execdirector@agu.org), Executive Director/CEO, AGU

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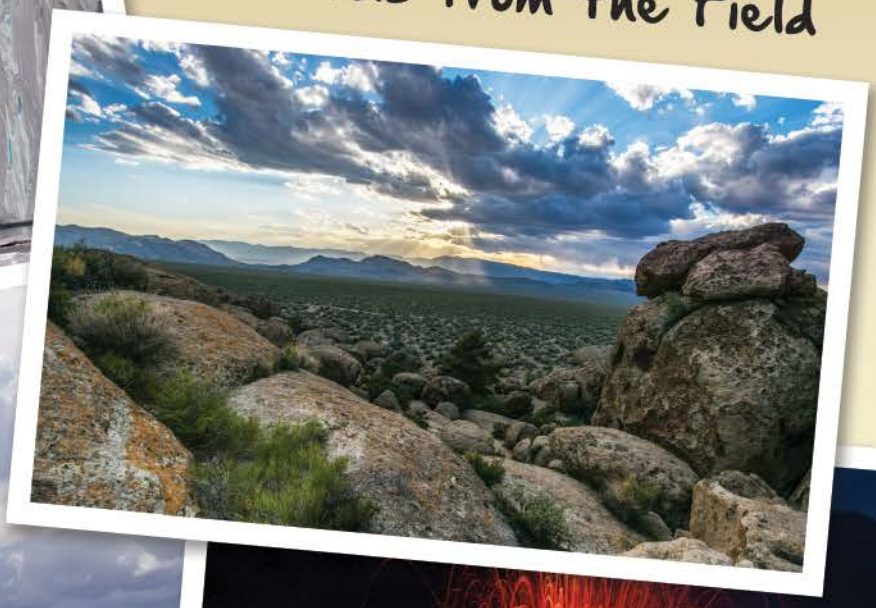

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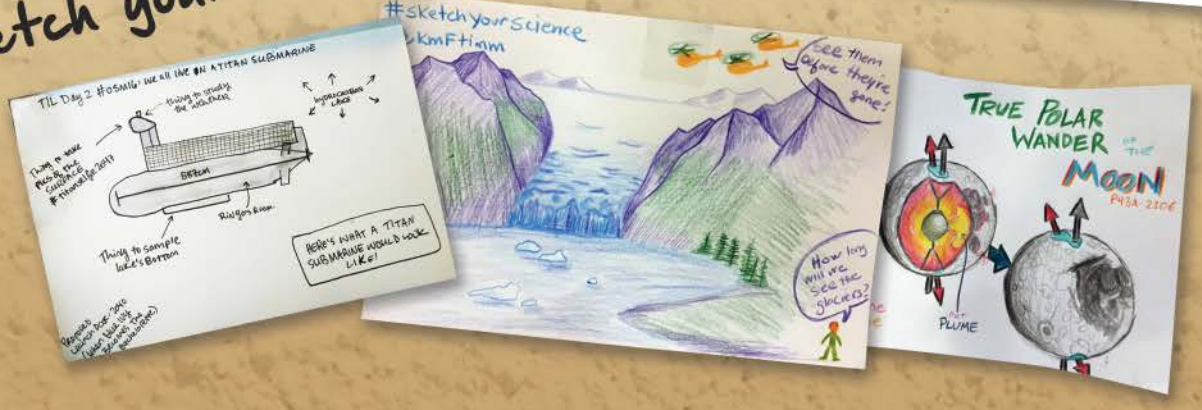


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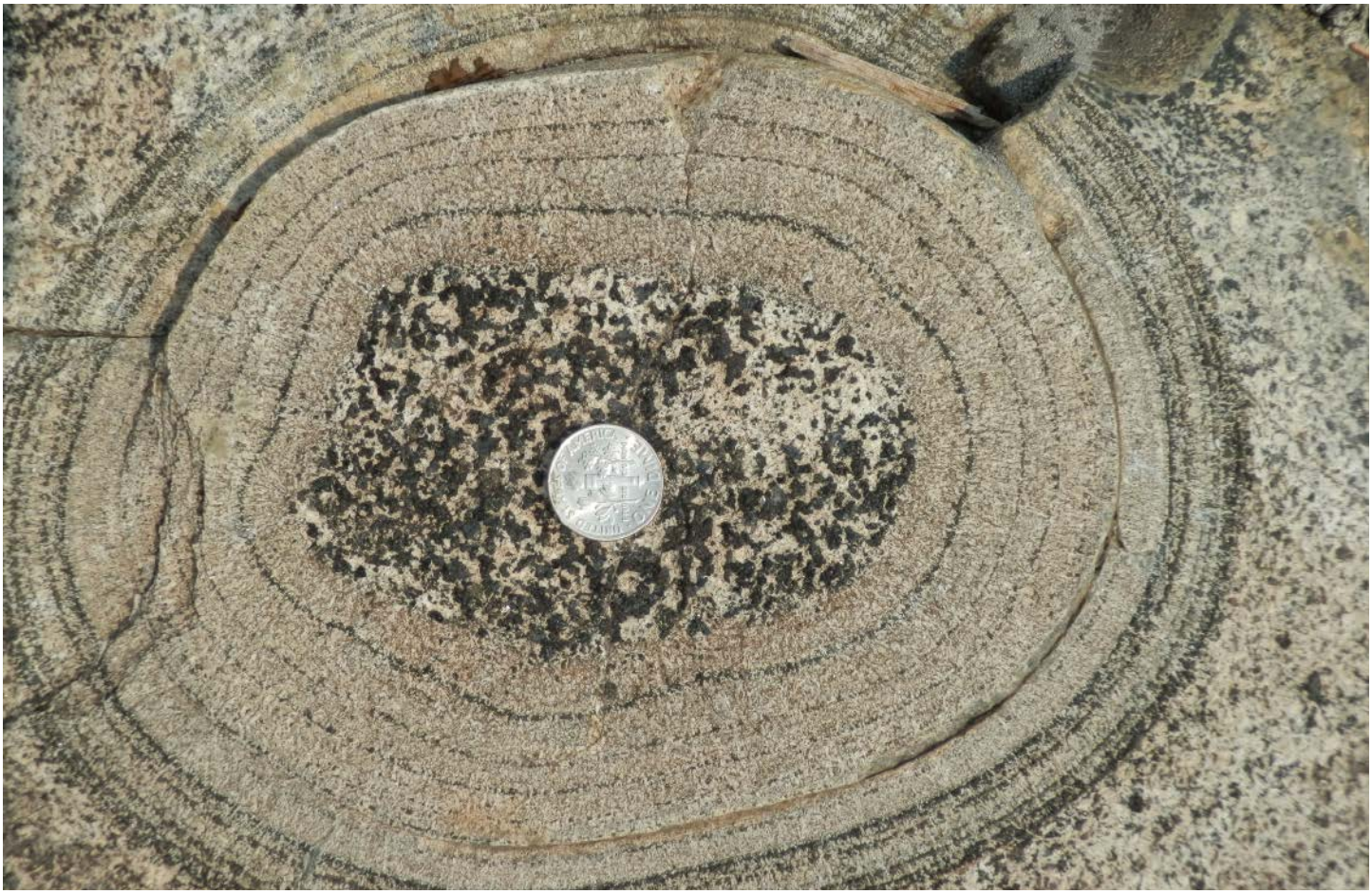
# Pulses of Rising Magma in Sierra Nevada's Past



Anders McCarthy

*Concentric layers of plagioclase (called comb layers) form an orbicule in the Fisher Lake pluton in California's Sierra Nevada mountain range (coin for scale). Orbicules and comb layers hold clues to the conditions of magma transfer below volcanoes.*

Understanding the processes that control eruptions in volcanic arcs requires identifying the mechanisms by which magma is extracted from shallow reservoirs and ascends to the surface. Although previous research has suggested that the melted material rises in rapid, low-volume pulses rather than in larger, lava lamp–like blobs, the timescales and pathways of these processes in arc settings are still poorly understood.

To better understand these dynamics, *McCarthy and Müntener* performed a detailed analysis of igneous layering found at the contacts between small igneous bodies that collectively compose California's Cretaceous age Fisher Lake pluton. Using field observations combined with textural and geochemical data, the pair studied the formation of comb layering, a distinctive texture characterized by long, branching minerals growing perpendicular to the wall of an igneous body. These layers can grow on the walls of an igneous body or on remobilized rock fragments, thereby forming spherical orbicules.

The results show that in 98% of the samples, crystallization began with the growth of the mineral plagioclase, whose nucleation was controlled by a reduction in pressure as magma rose through Earth's crust. The initiation of comb layering, the authors conclude, is controlled by magma's water content, the amount of degassing that occurs during its ascent, and the pathways through which the molten materials rise.

Although the global paucity of comb layering suggests that this type of decompression is not a widespread phenomenon in arc settings, the team argues that where present, it records the passage of individual pulses of magma through volcanic conduits rather than the mixing of magmas of different compositions, as previous studies had suggested. Using experimental plagioclase growth rates, the researchers estimated that the comb layering in the Fisher Lake samples took just a few years to a few decades to grow.

These results bolster the authors' argument that the comb layering preserves important information regarding the composition and rates of rising magma, whose degassing likely plays a role in triggering volcanic eruptions. (*Journal of Geophysical Research: Solid Earth*, https://doi.org/10.1002/2016JB013489, 2016) **—Terri Cook, Freelance Writer**

# An Up-Close Look at the Megaquakes That Cause Tsunamis

In 2011, a magnitude 9 earthquake occurred off the east coast of Japan, setting off a major tsunami. Furthering the devastation, this tsunami led to meltdowns at the Fukushima Daiichi Nuclear Power Plant.

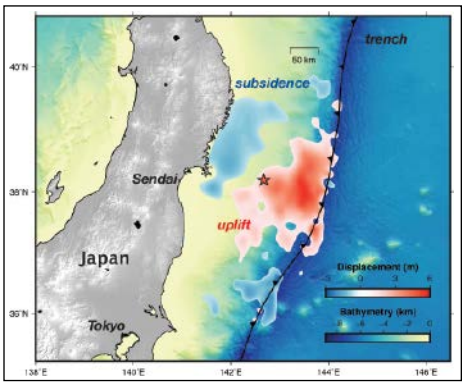
Various observations indicate that fault slip near the Japan Trench caused the underwater quake. The size and location of this event surprised scientists because conventional wisdom for subduction zones (where one tectonic plate slides below another) assumed that the shallowest part of the fault is aseismic.

In the years following the disaster, many scientists have reexamined the factors that may have led to the earthquake and resultant tsunami. Recently, *Jiang and Simons* developed a method that sheds new light on earthquake triggers.

Using observations only of the tsunami, the researchers developed two models, at two different scales of resolution, to infer the earthquake's likely seafloor displacement, the extent to which the seafloor shifts during an earthquake. According to these models, the tsunami was caused by the seafloor shifting upward about 5 meters over a wide area, but with the amplitude of uplift at a maximum of about 50 kilometers landward from the trench. This uplift shifted massive amounts of seawater and tilted the seafloor near the trench toward the open ocean.

Looking at this quake in the context of other major earthquakes in recent years, the scientists concluded that the shallowest subduction zone near the Japan Trench is capable of hosting large seismic slip in response to larger, deeper slip. In between major earthquakes, the shallowest parts of the primary fault most likely experience aseismic motion, the authors suggested.

Modeling the seafloor displacement from this event provides an illuminating visual of the characteristic features of tsunami-causing earthquakes. In the future, this visual could help scientists assess the potential of other shallow subduction zones around the globe to generate a large tsunami in the event of a major earthquake. (*Journal of Geophysical Research: Solid Earth*, https://doi.org/10.1002/2016JB013760, 2016) **—Sarah Witman, Freelance Writer**




Jiang and Simons [2016]

*Uplift and subsidence of the seafloor during the 2011 Tohoku-oki earthquake off the east coast of Japan, based solely on offshore tsunami observations. Note how the earthquake pushed down the seafloor near the coast and uplifted areas near the trench.*

# How Global Warming's Effect on Clouds May Make It Rain Harder

As Earth's climate warms, most scientists agree that there will be less frequent rain but more extreme precipitation—heavy downpours that dump abnormally large quantities of rain, sometimes causing dangerous floods. Just how much these events will increase is hard to say, however, and various climate models make conflicting predictions.

One reason for the disagreement is the challenge of accurately modeling the complex physics of convection, which is the movement of heat and moisture through the atmosphere. Convection helps to form the towering, heaped cumulus clouds that produce thunderstorms.

Previous studies have shown that changes in the temperature of the ocean's surface strongly affect whether convection remains diffuse, scattering clouds evenly across the globe, or forms just a few large clusters of storms. Scientists describe these patterns of convection as organized, with regular, distinct loci around which storms such as tropical cyclones tend to coalesce, or disorganized, with more scattered precipitation events.

To examine how such changes in convention will affect rainfall, *Pendergrass et al.* applied different surface temperatures to a simplified "aquaplanet" model of Earth's climate, which eliminated such variables as land and which distributed incoming sunlight evenly over the planet's watery surface. They started with a "cold" Earth, with a sea surface temperature of around 285 K, and gradually ramped up to a "hot" Earth scenario, stopping at roughly 307 K.

Rather than increasing steadily with warming, the frequency of extreme precipitation followed a surprising pattern. Colder conditions produced patchy areas of heavy rainfall, but as temperatures climbed to around 290 K, a more even, disorganized distribution emerged. At roughly 303 K, the model abruptly produced large clusters of exceptionally heavy rainfall that dwarfed those in both the cold and warm scenarios.

By isolating different inputs to the model, the authors found that an increase in the vertical velocity—the moisture-bearing air that rushes upward from Earth's surface—largely accounted for the rapid shift in the hotter scenario. This finding suggests that scientists should look not only to rising temperatures but also to shifts in atmospheric circulation when attempting to predict the likelihood of extreme precipitation events. (*Geophysical Research Letters,* https://doi.org/10.1002/2016GL071285, 2016) **—Emily Underwood, Freelance Writer**

# West Antarctic Ice Shelf Breaking Up from the Inside Out


*A rift in the Pine Island Glacier ice shelf in West Antarctica, photographed from the air during a NASA Operation IceBridge survey flight on 4 November 2016. This rift is the second to form in the center of the ice shelf in the past 3 years. The first resulted in an iceberg that broke off in 2015.*

Pine Island Glacier and its nearby twin, Thwaites Glacier, sit at the outer edge of the West Antarctic ice sheet. Like corks in a bottle, the two glaciers block ice flow and keep nearly 10% of the ice sheet from draining into the sea.

Studies have suggested that the West Antarctic ice sheet is particularly unstable and could collapse within the next 100 years. The collapse could lead to a sea level rise of nearly 10 feet (3 meters), which would engulf major U.S. cities such as New York and Miami and displace 150 million people living on coasts worldwide.

A nearly 225-square-mile (588-square-kilometer) iceberg—nearly the size of Chicago—broke off from Pine Island Glacier in 2015, but it wasn't until researchers were testing some new image-processing software that they noticed something strange in Landsat 8 satellite images taken before the event.

In the images, *Jeong et al.* saw a rift open in the surface of the ice shelf nearly 20 miles (32 kilometers) inland in 2013. The rift grew over 2 years until it set the iceberg adrift over 12 days in late July and early August 2015. During this period, another, similar rift opened 6 miles (10 kilometers) farther inland from the first.

Rifts usually form at the sides of an ice shelf where the ice is thin and subject to shearing that rips it apart. But this particular rift originated in the center of Pine Island Glacier's ice shelf and propagated out to the margins.

This implies that something weakened the center of the ice shelf. The most likely explanation is that a crevasse melted out at the bedrock level, driven by a warming ocean, according to the researchers.

Another clue that the center of the ice shelf is weak is that the rift opened in the bottom of a "valley" in the ice shelf where the ice had thinned compared with the surrounding ice shelf. The valley is likely a sign of something researchers have long suspected: Ocean water can intrude far inland and remain unseen because the bottom of the West Antarctic ice sheet lies below sea level.

The origin of the rift would have gone unseen too, except that the images that the researchers analyzed happened to have been taken when the Sun was low in the sky. Long shadows cast across the ice drew the team's attention to the valley that had formed there.

Although this is the first time researchers have witnessed a deep subsurface rift opening within Antarctic ice, they have seen similar breakups in the Greenland ice sheet, in spots where ocean water has seeped inland along the bedrock and begun to melt the ice from underneath. The satellite images provide the first strong evidence that these large Antarctic ice shelves respond to changes at their ocean edge in a way similar to that observed in Greenland.

The researchers note that this kind of rifting behavior provides another mechanism for rapid retreat of these glaciers, adding to the probability that there may be a significant collapse of the West Antarctic ice sheet in the next century. They point out that there are many similar valleys farther up the glacier. If these sites are prone to rifting, we could potentially see more accelerated ice loss in Antarctica. (*Geophysical Research Letters*, https://doi.org/10.1002/2016GL071360, 2016)

**—Lauren Lipuma, Contributing Writer**

# Deep Drilling Reveals Puzzling History of Campi Flegrei Caldera

At least 10% of the global population lives within 100 kilometers of a historically active volcano. Some of these people live near a collapsed volcano, like the residents of Naples neighboring the Campi Flegrei caldera. Although a caldera may appear to be more safe than a volcanic cone, the potential danger for natural hazard is not gone.

A collapse is often triggered by rapid magma loss from the magma chamber, usually following an eruption, which causes the hollow cone of the volcano to cave in on itself. However, calderas can remain active. Two massive eruptions in the past caused the Campi Flegrei caldera to collapse: the Campanian Ignimbrite, which occurred 39,000 years ago, and the Neapolitan Yellow Tuff, which occurred 15,000 years ago.

But scientists—and residents around the caldera—fear another eruption to come. Right now, the alert for the Campi Flegrei caldera has been raised from "base" volcanic activity to "attention" status.

To get an accurate understanding of the caldera, *De Natale et al.* turned to scientific drilling. The Campi Flegrei Deep Drilling Project (CFDDP) drilled to a depth of 501 meters in western Naples, the morphological limit of Campi Flegrei caldera.

Claudio Serio

*The base of the drilling rig operating at the former steel factory in Bagnoli, Naples, used for the Campi Flegrei Deep Drilling Project. In the foreground are the drill pipes after use.*

Drilling gives scientists a precise view into the deep structure of the caldera, its geothermal characteristics, and its magma chemistry. All these can reveal clues to how the caldera formed. The researchers took samples from different depths of the drill site and measured argon isotopes periodically so that they could estimate the age of various layers.

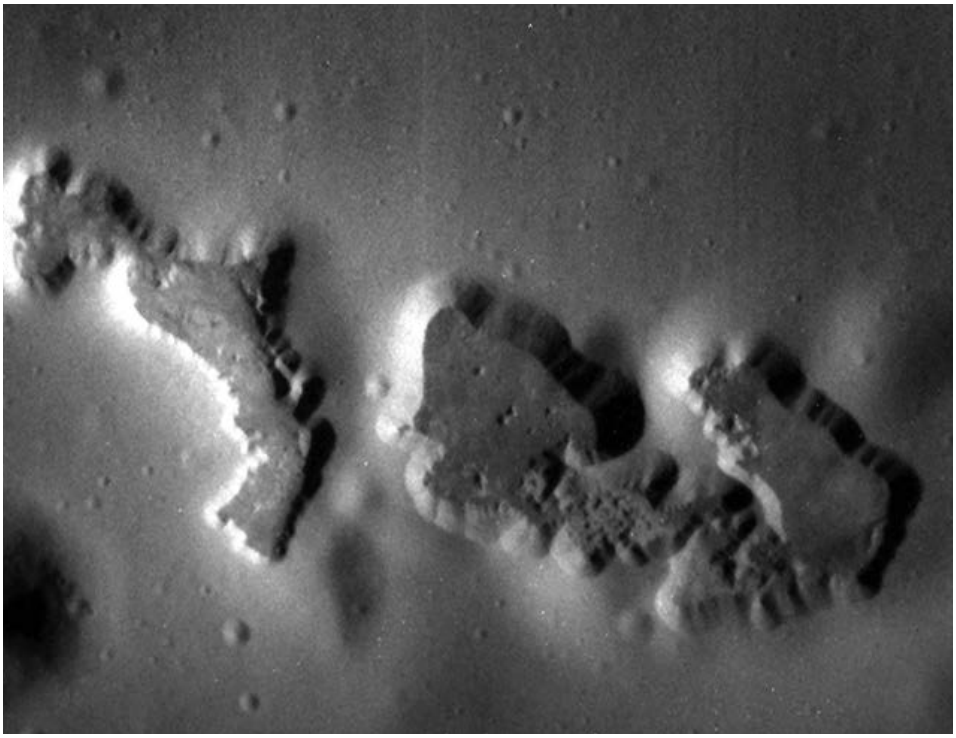
The scientists combined the isotopic ages, fossil findings, and historical sea level records to assess the history of the volcano and how Campi Flegrei changed over time. The deeper layers, between 250 and 501 meters, do not contain fossils, meaning that the volcano was well above sea level more than 35,000 years ago. In the shallower layers, the scientists found microfossils that indicate an ocean environment, confirming that sometime between 17,000 and 35,000 years ago the volcano collapsed.

The rock types and ages at the drill site also reveal a curious finding: The amount of collapse attributed to the older and larger Campanian Ignimbrite eruption is smaller than that which occurred after the eruption of the Neapolitan Yellow Tuff. Although there could be many reasons for the smaller collapse after the mega eruption, the authors discuss an alternative hypothesis: that the Campanian Ignimbrite did not erupt from Campi Flegrei (which was involved just as a peripheral eruption vent), but rather from fractures to the north of the caldera. This hypothesis would explain the low-level collapse in the caldera because the magma chamber would have remained intact.

Additional results from the drill site reveal that further caldera collapse won't extend into the central city of Naples. However, the authors conclude that there is a complex mechanism that drove the caldera collapse that requires further study to better predict future eruptions in this major metropolitan area of Italy. (*Geochemistry, Geophysics, Geosystems*, https://doi.org/10.1002/2015GC006183, 2016)

**—Alexandra Branscombe, Freelance Writer**

# Unprecedented Views of Mercury Constrain Hollow Formation



Blewett et al. [2016]

*This is perhaps the best-quality and highest-resolution image of hollows obtained by the Mercury Surface, Space Environment, Geochemistry, and Ranging (MESSENGER) mission. The morphology is very crisp, with flat floors and straight wall profiles. The hollows are about 21 meters deep. No impact craters are visible on the floors of the hollows, even though many small craters occur on the surroundings. The lack of impact craters suggests that the hollows are very young compared with most of Mercury's surface. The edges of the image are about 1.6 kilometers long, and illumination is from the right.*

Blewett et al. [2016]

*The Mercury impact crater de Graft, 68 kilometers in diameter. MESSENGER images taken though color filters at 996-, 749-, and 430-nanometer wavelength were combined as red-green-blue. The high-reflectance area of the floor (which appears here as white) consists of hollows, shallow depressions that likely form through a process of volatile loss. The dark blue central peak complex is composed of low-reflectance material, which may include remnants of Mercury's early graphite-bearing crust. The yellowish crater rim material originated at shallower depths and has a composition distinct from central peak material. The crater ray that crosses de Graft from the upper right to lower left originated at the Hokusai crater, approximately 1600 kilometers to the northeast.*

One of the key results of the Mercury Surface, Space Environment, Geochemistry, and Ranging (MESSENGER) mission was the discovery of thousands of "hollows"—shallow, fresh-looking depressions up to a few kilometers wide—scattered across the planet's surface. Although several lines of evidence indicate that these features form as a result of the loss of volatile materials present in surface rocks and are exposed by impacts, the specific process driving this loss is not yet known.

Now, using new morphological observations from unprecedented high-resolution MESSENGER images, *Blewett et al.* have proposed a new model for the formation and growth of hollows. The team used measurements of shadow lengths to calculate the depth of more than 2500 hollows and found that the depressions' average depth was just 24 meters, substantially less than the typical thickness of the layer of dark volatile-rich material in which the features are most often found.

This material, known as "low-reflectance material" (LRM), is generally kilometers thick, much thicker than the depth of the hollows. Thus, the researchers' finding of consistently shallow hollow depths across the planet suggests that the hollows' shapes are not controlled by the thickness of the host LRM. In other words, the hollows don't burn all the way down through the volatile-bearing dark material and stop once they reach the bottom of this layer.

Rather, the authors argue, a volatile-depleted "lag" deposit, which protects the underlying material once it becomes sufficiently thick, may inhibit deep hollows from forming. The frequent occurrence of hollows on the walls and central peaks of impact craters, locations too steep for lag to develop, is consistent with this proposed view.

The researchers conclude that the hollows' formation and growth may be due to the volatilization of carbon. Recent evidence indicates that carbon in the form of graphite is an important constituent of Mercury's crust. The loss of carbon, they suggest, could occur through either the process of ion "sputtering" or the conversion of graphite to methane via proton bombardment. This carbon loss may create the hollows.

In addition, because of the presence of hollows within several impact craters with ray systems, the team was able to estimate a lower limit for their rate of horizontal growth, which likely occurs via the retreat of scarps that form the hollows' walls. This retreat occurs at a rate of 1 centimeter per 10,000 years, which places an additional constraint on the formation and history of Mercury's mysterious landforms. (*Journal of Geophysical Research: Planets*, https://doi.org/10.1002/2016JE005070, 2016) **—Terri Cook, Freelance Writer**

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### Atmospheric Sciences

**Postdoctoral Research Associate Understanding Sources of Tropospheric Ozone Variability and Trends, Princeton University**

Princeton University Program in Atmospheric and Oceanic Sciences seeks an enthusiastic postdoctoral researcher to participate in modeling and observational studies of tropospheric ozone variability and trends. During the first year, the successful candidate will analyze intensive measurements from the 2017 Fires, Asian, and Stratospheric Transport–Las Vegas Ozone Study (FAST-LVOS), in conjunction with high-resolution global chemical transport models, to fingerprint the specific sources of high surface ozone events in the Las Vegas area and across the western United States. The candidate will work with Dr. Meiyun Lin, the Principal Investigator of the project, to estimate the importance of deep stratospheric intrusions and long-range transport of Asian pollution relative to US regional anthropogenic pollution and wildfires. During the second year, contingent upon satisfactory performance, the candidate will assist in a process-oriented study to assess how well the global models used in phase 1 of the IGAC/Chemistry-Climate Model Initiative (CCMI) represent observed interannual variability and long-term trends of tropospheric ozone at northern mid-latitudes over the past 20–40 years. The postdoctoral researchers will also have opportunities to interact with other researchers at NOAA Geophysical Physical Fluid Dynamics Laboratory and Earth System Research Laboratory.

The candidate must have a PhD, preferably in atmospheric chemistry. A good knowledge in air quality-climate modeling, strong statistical skills, and experience in joint analysis of observations and models to improve understanding will be appreciated. Postdoctoral appointments are initially for one year with the renewal for subsequent years based on satisfactory performance and continued funding. A competitive salary is offered commensurate with experience and qualifications.

Applicants must apply online. Complete applications, including a CV, copies of 2–3 recent publications, names of three referees who will be providing letters of support, and a titled research proposal, should be submitted to https://www.princeton.edu/acad-positions/position/701 no later than April 10, 2017, for full consideration. This position is subject to the University's background check policy.

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

### Geochemistry

**Part-Time Lecturer, Tufts University–Mineralogy and Petrology**

Tufts University invites applications for a one-year appointment as part-time lecturer in the Department of Earth and Ocean Sciences (EOS) to teach a 2-semester sequence in Mineralogy (Fall 2017) and Igneous and Metamorphic Petrology (Spring 2018). The successful candidate will be expected to teach these courses along with their labs to mostly undergraduate Geology and Geological Sciences majors. The EOS Department is well-equipped for undergraduate study in mineralogy and petrology with a teaching lab that has petrographic microscopes, a comprehensive collection of minerals and igneous and metamorphic rocks, rock saws, thin section preparation equipment, and a scanning electron microscope with EDS capability. Tufts University is located in the Boston area and is near a diverse array of different igneous and metamorphic rock terrains conducive to field trips in New England.

Preferred qualifications include a Ph.D. in mineralogy or petrology and teaching experience in these disciplines. All application materials must be submitted via Interfolio at https://apply.interfolio.com/40440. Please submit the following: 1) a letter of application including a statement of teaching philosophy and experience in both teaching and research or practice in mineralogy and petrology, 2) a curriculum vitae, and 3) the names (with contact addresses) of three references. Questions about the position can be directed to Professor Jack Ridge, Chair, Department of Earth and Ocean Sciences, at jack.ridge@tufts.edu. Review of applications will begin on March 10, 2017 and will continue until the position is filled.

Tufts University, founded in 1852, prioritizes quality teaching, highly competitive basic and applied research and a commitment to active citizenship locally, regionally and globally. Tufts University also prides itself on creating a diverse, equitable, and inclusive community. Current and prospective employees of the university are expected to have and continuously develop skill in, and disposition for, positively engaging with a diverse population of faculty, staff, and students. Tufts University is an Equal Opportunity/Affirmative Action Employer. We are committed to increasing the diversity of our faculty and staff and fostering their success when hired. Members of underrepresented groups are welcome and strongly encouraged to apply. If you are an applicant with a disability who is unable to use our online tools to search and apply for jobs, please contact us by calling Johny Laine in the Office of Equal Opportunity (OEO) at 617.627.3298 or at Johny.Laine@tufts.edu. Applicants can learn more about requesting reasonable accommodations at http://oeo.tufts.edu.

### Hydrology

**Multiple Faculty Positions in Water Sciences, College of Hydrology and Water Resources, Hohai University, China**

The College of Hydrology and Water Resources (CHWR) at Hohai University (HHU), China invites applications for multiple faculty positions in water resources, hydrometeorology and aquatic ecohydrology, to start as early as September 2017. The positions are open until filled. The salaries will be internationally competitive and commensurate with candidates' experience and skills.

Established in 1915, HHU is the leader of innovation and development of higher education in hydraulic engineering and water sciences in China. HHU has played as China's key force to solve its major water security issues. CHWR is a key component of HHU and is the first college established nationwide devoted solely to the study of water. The college is also key contributor of a national key laboratory and a national engineering center.

HHU is located at Nanjing, Jiangsu, China. Nanjing is the internationally recognized capital of Jiangsu province, one of the largest cities in China. Situated in the heartland of the Yangtze River Delta, it has long been a major center of culture, education, research, politics, economy, transport networks and tourism.

Positions:

CHWR seeks up to six faculty positions at the rank of full professor or associate professor, including 2 faculties in water resources, 2 in hydrometeorology, and 2 in aquatic ecohydrology.

Primary Duties & Responsibilities

The successful candidates will teach and supervise students at all levels, while conducting independent, externally funded research programs in their fields of expertise. Support for developing an active research agenda is provided through start-up funds and departmental support. CHWR will provide strong supports to the suc-

**Ocean Prediction Postdoctoral Positions Naval Research Laboratory, Stennis Space Center, MS**

U.S. NAVAL RESEARCH LABORATORY

The Naval Research Laboratory is seeking postdoctoral researchers to push forward the frontiers of ocean forecasting. The work covers a wide scope of physics including surface waves, thermohaline circulation, nearshore circulation, and ocean/atmosphere coupling from global to nearshore scales. This challenging work includes processing and analysis of satellite and in water observations, construction of numerical model systems on high performance computing systems and assimilation for predicting the ocean environment. For a quick overview of some of the research work within the NRL oceanography division at Stennis Space Center, visit the web site:
**https://www7320.nrlssc.navy.mil/pubs.php**

Applicants must be a US citizen or permanent resident at time of application. Applications will be accepted until positions are filled. Please e-mail a resume and description of research interests:

Gregg Jacobs: gregg.jacobs@nrlssc.navy.mil

cessful candidates to apply for national and provincial research grants and talent programs (e.g. Thousand Talents Plan and Thousand Youth Talents Plan).

Experience & Qualifications

All candidates must hold a Ph.D. in hydrology, water resources, and other related fields.

• Senior candidates must be established leaders in their field with developed excellent research programs and demonstrate strong research and teaching experience.

• Mid-career candidates should demonstrate strong records of publication and funded research, and participation in collaborations.

Application Instructions

Applications should be submitted electronically as a single PDF file, and should include:

• A cover letter that addresses your interests, qualifications and experience;

• A curriculum vitae;

• A statement of research interests;

• A statement of teaching philosophy;

• A copy of undergraduate and graduate transcripts.

Three letters of recommendation should be sent separately as a PDF by the recommenders. Review of applications will begin upon receipt until the position is filled. Materials should be sent to: kzhang@hhu.edu.cn.

**Multiple Post-doctoral Positions in Water Sciences, Hohai University**

Established in 1915, Hohai University (HHU) is the leader of innovation and development of higher education in hydraulic engineering and water sciences in China. HHU is located at Nanjing, Jiangsu, China. Nanjing is the internationally recognized capital of Jiangsu province, one of the largest cities in China.

The College of Hydrology and Water Resources (CHWR) at HHU invites applications for multiple post-doctoral positions in water sciences, to start as early as March 2017. The positions are open until filled, including (1) 3 positions in watershed hydrological simulation, (2) 3 positions in water resources management, water resources planning, water resources utilization and protection, or water resource policy, and (3) 3 positions in atmospheric-hydrological coupled modeling system, land surface model, or ecohydrology.

The successful candidates will conduct independent, externally funded research programs in their field of expertise. Support for developing an active research agenda is provided through departmental support. CHWR will provide strong supports to the successful candidates to apply for national and provincial research grants.

All candidates must hold a Ph.D. in hydrology, water resources, ecology, and other related fields. The candidates should demonstrate a strong publication potential in hydrology, water resources, and other related fields (at least 2 first-author papers published in internationally recognized journals).

Total income is up to 210,000 RMB/year (appx. 30,000USD/Year) and commensurate with research outputs. Review of applications will begin upon receipt until the position is filled. Materials should be sent to: tao.yang@hhu.edu.cn.

## Interdisciplinary

**Faculty Position in Water Resources, Stanford University**

Stanford University, in conjunction with its Woods Institute for the Environment, seeks nominations and applications for a faculty appointment in the area of water resources. We are interested in candidates who take a systems-based approach to water resources, regardless of their disciplinary background or training. Possible areas of expertise include but are not limited to hydrology and ecohydrology; water management and systems; governance and institutions; river geomorphology; risk management; multi-objective decision making; political science; big data and computation; and geochemical, geophysical, and remote sensing. Issue areas of interest include the design of effective water institutions and systems; climate change and adaptation (including management of extreme events); river and watershed restoration; dam removal & design; coastal river systems; and the nexus among food, water, and energy.

This is a tenure-line appointment and will be joint between the Woods Institute and a department appropriate to the candidate in any one of Stanford's seven schools. The Woods Institute (http://woods.stanford.edu) is the interdisciplinary hub for environmental research, teaching, and problem solving at Stanford. The level of the appointment is open, and candidates at all levels of experience are encouraged to apply.

We seek a motivated, broad-thinking scholar to pursue a vigorous research program and leadership role in Stanford's growing interdisciplinary water community. The successful candidate will be expected to be an active participant in the Water in the West program (http://waterinthewest.stanford.edu), as well as Stanford's other campus-wide water programs. A joint program of the Woods Institute and the Bill Lane Center for the American West (http://west.stanford.edu), Water in the West harnesses Stanford's resources toward solving the West's growing water scarcity problems. In addition to research, the successful candidate will teach classes and mentor students at both the graduate and undergraduate levels. We are particularly interested in candidates with an interest in interdisciplinary collaboration and working at the intersection of academic research and public policy.

Applicants are asked to provide a cover letter describing research and teaching experience as well as future plans in these areas as well as curriculum vitae. The committee will request letters of recommendation for finalists. Please submit the requested materials in a .pdf format via online at Academic Jobs Online, Job #8833. The job can be found at https://academicjobsonline.org/ajo/jobs/8833.

Review of applications will begin immediately and will continue until the position is filled.

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

**Hydrographic Science Faculty Position, University of Southern Mississippi**

The University of Southern Mississippi's School of Ocean Science and Technology (SOST), Division of Marine Science (DMS; http://www.usm.edu/marine/) at the NASA John C. Stennis Space Center (SSC) is offering a position in hydrographic science at the tenure-track, Assistant or Associate Professor level. Applicants should hold a Ph.D. in a hydrographic science, marine science, geomatics engineering, ocean engineering, or closely related field. Applicants will have demonstrated field and research experience in acoustic and LIDAR-based hydrographic and bathymetric surveying, and precise positioning at sea. Proficiency in commercial software packages used to collect and process hydrographic data is expected. Also desirable is an interest in applying hydrographic technologies to collaborative opportunities in marine science, including biological, chemical, physical, geological and fisheries oceanography. A nationally recognized record of publication, demonstrated successful grantsmanship, and at least 5 years service at a degree-granting institution or equivalent service at a non-degree granting institution are needed at the Associate-level. A successful candidate is expected to conduct an active research program and participate in the hydrographic science master's program, which is recognized at the Category-A (Cat-A) level by the International Hydrographic Organization. The latter efforts include curricula review, delivery and development of the program, and faculty experience in delivering a Cat-A hydrographic science curricula are highly

**Section Head, Integrated Activities Section**
**Division of Earth Sciences**
**National Science Foundation (NSF)**
**Arlington VA**

NSF's Directorate for Geosciences (GEO) seeks candidates for the position of Section Head for the Integrated Activities Section in the Division of Earth Sciences (EAR). The Section Head serves as a member of the Division leadership team and as a spokesperson for Earth Sciences research. The Section Head is responsible to the EAR Division Director for overall planning, management, and commitment of budgeted funds for the Section, which includes programs in instrumentation and facilities, education and human resources, and cross-division research programs including integrated Earth systems, EarthScope, and critical zone observatories.

Appointment to this Senior Executive Service position will be on a career basis, with a salary range of $160,300-$177,800. The job opportunity announcement (EAR-2017-0002) with position requirements and application procedures may be view at: https://www.usajobs.gov/GetJob/ViewDetails/462369900?org=NSF.

NSF is an equal opportunity employer committed to employing a highly qualified staff reflecting the diversity of our nation.

desirable. The development of courses for a new hydrography emphasis in the undergraduate Marine Science degree program is also expected.

Along with DMS, SOST integrates the Gulf Coast Research Laboratory, the Division of Coastal Sciences, and the University's fleet of five research vessels, to form a regionally, nationally and internationally recognized leader in marine science. DMS is home to an interdisciplinary program of graduate and undergraduate study and research in marine environments. Seventeen on-site faculty conduct research and teach courses in biological oceanography, marine chemistry, geological oceanography, physical oceanography, remote sensing, numerical modeling, and hydrography to ~50 full-time graduate students at SSC and ~40 undergraduates at the USM Gulf Park campus. The Division offers Marine Science B.S., M.S. and Ph.D. degrees and a Hydrographic Science M.S. Located at SSC, Marine Science is strategically situated at the single largest concentration of oceanographers and hydrographers in the world. Faculty interact with research scientists at government agencies located on site and at the Joint Airborne Lidar Bathymet y Center of Excellence (JALBTCX) including the Naval Oceanographic Office, Naval Meteorology and Oceanography Command (CNMOC), Naval Research Laboratory (NRL-SSC), USACE, NOAA, USGS, and NASA.

Applicants should submit a letter of interest outlining their qualifications for the position, including a research plan, teaching philosophy with a curricular plan, a curriculum vitae, and names and contact information of at least four references. Applications must be submitted online at https://jobs.usm.edu. For inquiries about the position, contact Stephan Howden, Chair of the Search Committee, at 1-228-688-5284 or stephan.howden@usm.edu. Review of applications begins 1 February 2017 and continues until the position is filled, with an anticipated start date of August 2017.

AA/EOE/ADAI

**PhD Studentship, Montclair State University**

PhD studentship, Department of Earth and Environmental Studies, Montclair State University, CELS building (overlooking Manhattan). Participate in research to assess changes in vegetation in erect dwarf-shrub and low-shrub Arctic tundra zones as part of the NASA Arctic-Boreal Vulnerability Experiment (http://above.nasa.gov). Remote sensing, GIS; and programming skills required. More: http://tinyurl.com/znf86gy

Contact: Mark Chopping (mark.chopping@montclair.edu).

## Faculty Positions in Environmental Science and Engineering

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

Applications are invited for faculty positions at all ranks. Highly competitive salaries and benefit packages will be provided. Applicants are required to have a Ph.D. degree in related disciplines. To apply, submit the following materials to iese@sustc.edu.cn: 1) Cover Letter; 2) Curriculum Vitae (with a complete list of publications); 3) Statement of research and teaching interest; 4) Selected reprints of three recent papers; and 5) Names and contact information for five references.


## Faculty Position in Petroleum and Natural Gas Engineering

Through support from the Institute of Natural Gas Research (INGaR), the Department of Energy and Mineral Engineering (EME) at The Pennsylvania State University invites applications for one (1) full-time, tenure-track faculty position in petroleum and natural gas engineering at Assistant, Associate or Full Professor level. The rank would depend on the qualifications of the individual including industry experience. Significant start-up funds are available for research support and new equipment. Applicants must hold a Ph.D. in petroleum engineering, or related field, and demonstrated expertise in drilling and well completions, defined broadly. Successful candidates will demonstrate the ability and willingness to establish a preeminent externally-funded research program and to conduct independent high-quality research. The candidates will also teach undergraduate and graduate courses, supervise graduate students at the MS and PhD levels and contribute in service to the university and profession. The EME Department (EME; http://www.eme.psu.edu) is home to 35 faculty, 140 graduate students, and 1600 undergraduate students. EME is home to Penn State's undergraduate degree programs in Petroleum and Natural Gas Engineering, Mining Engineering, Environmental Systems Engineering, Energy Engineering, Energy Business and Finance, and graduate degree program in Energy and Mineral Engineering. The successful applicant will help to build and maintain excellence in Penn State's petroleum and natural gas engineering program and will be an affiliate faculty of Penn State's Institute for Natural Gas Research (INGaR) to support the institute's mission of conducting research in the broad area of natural gas, within the applicant's area of specialization, working closely with interdisciplinary teams, industry and government partners to support the ongoing development of a natural gas-based economy.

Interested candidates should submit: (1) application letter highlighting qualifications for the position; (2) a curriculum vitae including educational background, employment history, and a list of peer reviewed publications and other technical papers; (3) statements of research and teaching interests; (4) names, addresses, and telephone numbers of four referees. Submit applications electronically as addressed to: Chair of PNGE Faculty Search Committee. Review of applicants will begin on March 1, 2017, and will continue until the position is filled.

Apply online at **http://apptrkr.com/962321**

**CAMPUS SECURITY CRIME STATISTICS:** For more about safety at Penn State, and to review the Annual Security Report which contains information about crime statistics and other safety and security matters, please go to http://www.police.psu.edu/clery/, which will also provide you with detail on how to request a hard copy of the Annual Security Report.

Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to all qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national origin, disability or protected veteran status.

# Postcards from the Field

Greetings from Costa Rica!

At a hot spring on Irazu volcano, our team is sampling microbes, water, and gases as part of the Deep Carbon Observatory's Biology Meets Subduction initiative. We've been in the field for almost 2 weeks and have sampled more than 20 springs and fumaroles throughout the Costa Rican subduction zone. You can read more about our progress on the expedition blog (see http://bit.ly/EOS_PFTF_subductCR) and on Twitter at #SubductCR.

Photo by Peter Barry.

**—Katie Pratt,** Deep Carbon Observatory, University of Rhode Island

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

# AGU FALL MEETING

New Orleans | 11–15 December 2017

Think Creative. Think Collaborative. Think Transdisciplinary.

# Have an Idea or Topic to Present at the Fall Meeting?

## Submit a Session Proposal

### Deadline:
### 19 April, 11:59 P.M. EDT

**You must have a current 2017 AGU membership to propose a session.**

**fallmeeting.agu.org**

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