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# EOS

Earth & Space Science News

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Welcoming Women into the Geosciences

The Seismic Reach of Injection Wells

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Aerial view of an emerging methane source: thawing Arctic landscapes. Credit: Jens_Lambert_Photography/iStock/Getty Images Plus



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Christine W. McEntee, Executive Director/CEO

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# New Arctic Science Cooperation Agreement Comes into Force

*An iceberg floats past Bylot Island in the Canadian Arctic Archipelago in July 2017. Credit: AP Photo/David Goldman*

Scientists and diplomats are applauding an agreement on international scientific cooperation in the Arctic, which entered into force on 23 May. They said that it will help to advance Arctic research across borders and reduce obstacles to research at a time when the region is undergoing rapid changes. Administrative obstacles sometimes have blocked or delayed scientists from having access to Arctic research sites in other countries, they noted.

"The main concern that led to the negotiation of the agreement was that Russia from time to time denied access to its land and water areas in the Arctic to researchers from other states," U.S. ambassador David Balton told *Eos*. Balton headed the Senior Arctic Officials group of the Arctic Council from 2015 to 2017, when the United States chaired the council. "In this regard," he added, "it's quite important—and interesting—that Russia cochaired (along with the United States) the negotiations that produced the agreement."

The legally binding Agreement on Enhancing International Arctic Scientific Cooperation promises "to increase effectiveness and efficiency in the development of scientific knowledge about the Arctic." It focuses on facilitating access to research areas, research infrastructure, and data. It also calls for education, career development, and training opportunities, and it encourages the use of traditional and local knowledge in planning and conducting scientific activities. In addition, the document (http://bit.ly/arctic-science-agreement) calls for each party to the agreement to designate a "competent national authority" as a point of contact to facilitate communication between and among parties, which could help with efficient implementation.

The agreement was signed last year by the United States, Russia, and the six other countries that are members of the Arctic Council, an intergovernmental forum: Canada, Denmark, Finland, Iceland, Norway, and Sweden. The U.S. National Science Foundation's Office of Polar Programs led the U.S. delegation to the Arctic Council's task force that developed the agreement.

## Lowering Administrative Barriers for Arctic Scientists

The Arctic states negotiated the agreement "to reduce administrative barriers to scientific research in the Arctic," a U.S. State Department official who works on Arctic issues and is familiar with this agreement told *Eos*. (The State Department provided its responses to questions from *Eos* on the condition that this official would be identified only in the above manner.) Once the parties have sufficient experience implementing the agreement, "the science community should notice increased effectiveness and efficiency in the development of scientific knowledge about the Arctic," the official continued.

A key benefit of the agreement "is its facilitation of access to certain areas in the Arctic that have been long-term challenges for scientists," stated the official, who added that the agreement ideally would have been open to signature by non-Arctic states. That, the official said, could have helped "to lower administrative barriers for all Arctic scientists worldwide. The parties did agree, however, to allow scientists from non-parties to realize the benefits of the agreement if they partner with a party in their research activity."

The agreement "facilitates scientific cooperation beyond national borders, and it paves the way for joint responses of the Arctic states to new challenges in the region caused by global climate change and increased human activity," Vladimir Barbin, senior Arctic official for the Russian Federation, said in a statement provided to *Eos* on 21 May, in advance of the agreement coming into force.

## Advancing Arctic Research

The agreement "offers an opportunity to advance Arctic research beyond what was previously possible," John Farrell, executive director of the independent federal agency the United States Arctic Research Commission, told *Eos*. Farrell, as executive director of the commission, is the U.S. government's "competent national authority" with respect to the agreement. He said that in a broader sense, the agreement "is important because it provides yet another mechanism by which the conduct of scientific research serves as a means of soft diplomacy among nations that sometimes experience tensions in other sectors."

Balton, who currently is a senior fellow for the polar initiative at the Woodrow Wilson International Center for Scholars in Washington, D. C., also praised the agreement, calling it important for multiple reasons.

"It will facilitate the work of scientists across national boundaries in the Arctic and the bringing of their equipment, material, and data across those borders. This may well usher in a new age of scientific research in the Arctic, particularly by helping ease restrictions on such research that Russia has put in place from time to time," he said.

"The agreement demonstrates once again that the Arctic states are able to cooperate with each other, despite tensions that exist between Russia and the others," added Balton, who previously was deputy assistant secretary for oceans and fisheries in the State Department, where he also worked with the Arctic Council.

## An Improved Research Climate

For Robert Rich, executive director of the Arctic Research Consortium of the United States (ARCUS), the agreement means there could be an improved research climate in the Arctic region. "The Arctic research community is excited by the prospects of reduced barriers that effective implementation of the agreement could achieve," he told *Eos*.

Rich said that he has heard of "many situations where researchers have run into problems that hindered, delayed, or prevented their studies from proceeding." He

said that although he cannot speak to motivations of different countries, sometimes researchers have run into problems exporting their samples from Russia and other countries back to where they can be effectively analyzed; seemingly arbitrary decisions made at the regional or local level have precluded access to certain ships, research stations, or field sites; and some specific Russian-U.S. joint research cruises were canceled by Russian authorities.

Between 1990 and 2014, Russia withheld permission 43% of the time from U.S. researchers to conduct scientific research in the Russian exclusive economic zone, by explicitly denying permission or by providing no response, Farrell noted. He said that the State Department interprets a lack of response to mean no.

"The agreement may help to lower the percentage of time our requests are denied," he said. "The proof is in the pudding. The agreement consists of great words and intents, but it will have to be exercised to determine its effectiveness and value. When issues addressed by the agreement arise, will they be quickly, efficiently, and effectively resolved to advance Arctic science?"

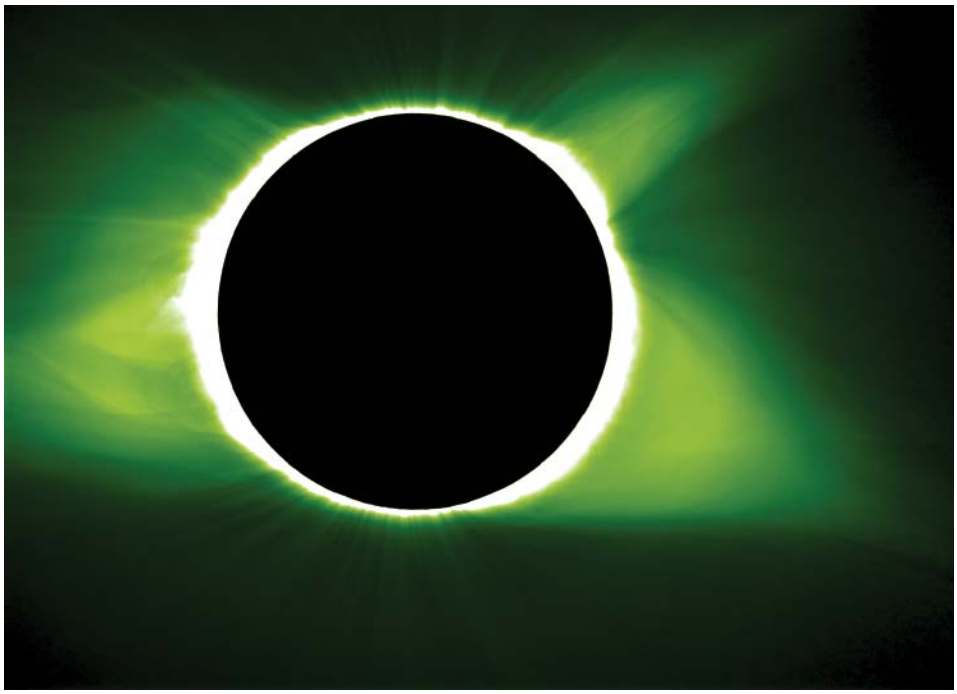
### Hoping the Agreement Makes a Difference

Julie Brigham-Grette, chair of the Polar Research Board of the U.S. National Academies of Sciences, Engineering, and Medicine, said that scientists have faced "tremendous challenges" in conducting shared research on land and sea "because of our own bureaucracies," but she called the agreement "really wonderful" and "a win-win agreement for everyone who signs on."

"This agreement is extremely important to foster scientific collaboration among all Arctic nations, as we are witnessing the rapid transition of the entire Arctic system due to climate change. The massive loss of summer sea ice and the reality of ice-free Arctic summers perhaps only 10 years from now [are] an international game changer," Brigham-Grette, a professor in the Department of Geosciences at the University of Massachusetts Amherst, told *Eos*. "The sea ice is changing, commercial fisheries are migrating, the permafrost is thawing, shipping routes are changing, etc. As the Arctic opens up to new challenges and opportunities, we need to collectively manage and share responsibilities for what humans do to the Arctic. Honestly, we cannot screw this up!"

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

# Seeing Green: A Stratospheric View of the 2017 Total Eclipse



Dan Seaton (University of Colorado)/Amir Caspi (SwRI)/Southern Research/NASA WB-57F Eclipse Team

Light from the Sun's upper atmosphere silhouettes the Moon in this photo of the 21 August 2017 total solar eclipse, which was taken from Earth's stratosphere. Light green wisps and tendrils of the corona extend outward. This image is an integration of multiple observations taken in a narrow green wavelength range.

Scientists chased the eclipse using two of NASA's WB-57F high-altitude research aircraft to create this image and obtain other measurements. The aircraft flew at altitudes higher than 15 kilometers along the path of totality. The team continuously observed the eclipse using two 22-centimeter telescopes mounted aboard the craft. The telescopes were tuned to see in green (approximately 530 nanometers), in the visible continuum (400–700 nanometers), and at medium-wave infrared (3- to 5-micrometer) wavelengths. Imaging the Sun in green light helped the team focus on the light emitted by the corona itself rather than on light produced by lower layers and scattered by the ultrahot, diffuse gas.

Observing the eclipse from the stratosphere has major advantages, the researchers explained at the Triennial Earth-Sun Summit in Leesburg, Va., where they presented their initial results on 23 May (http://bit.ly/tess-313-02). By moving up to the stratosphere, the observers avoided weather and other atmospheric disturbances that would have degraded the quality of the measurements or prohibited them entirely.

What's more, the team greatly increased the overall eclipse observing time. An observer on the ground may have had up to 2 minutes and 40 seconds of totality, but the pair of flying telescopes continuously observed the eclipse for more than 7 minutes and 30 seconds as they chased totality across the United States.

The researchers are continuing to process the results from this observing campaign and plan to make available to the public all of their raw and processed data, as well as additional measurements obtained during the partial and total eclipse phases. They also hope to repeat these and other observations with better eclipse-specific instruments that can take sharper and cleaner images during the 2019 and 2020 total solar eclipses over South America.

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

# Postal Service Honors First American Woman in Space


*The Sally Ride stamp issued in May by the U.S. Postal Service. Credit: ©2018 USPS*

Nearly 35 years after space shuttle *Challenger* mission STS-7 launched on 18 June 1983 with astronaut Sally Ride as a mission specialist, the U.S. Postal Service (USPS) has honored her, America's first woman in space, with a Forever stamp launched on 23 May. The first-day-of-issue dedication ceremony for the stamp took place at the University of California, San Diego (UCSD), where Ride served as a physics professor after retiring from NASA.

The stamp, featuring a beaming portrait of Ride next to a portrayal of the liftoff of *Challenger,* would have "put a big smile on her face," said Tam O'Shaughnessy, Ride's widow and the executive director of Sally Ride Science at UCSD. O'Shaughnessy and several other colleagues cofounded the organization with Ride to motivate students, particularly girls and minorities, to stick with STEM (science, technology, engineering, and mathematics) education. Ride, who would have turned 67 on 26 May, just a few days after the stamp's release, died of pancreatic cancer in 2012.

"Because she loved stamps and collected them, I just think that would be fun for her," being featured on a stamp, O'Shaughnessy told *Eos.* She said that Ride began collecting stamps at age nine and particularly liked collecting sports and space stamps. "But at a deeper level, I just think she would be very proud of how she lived her life and what she accomplished. And I think the stamp would kind of put a stamp on that."

### Selecting Who Gets Featured on Stamps

Bill Gicker, manager and creative director of stamp development at USPS, said that the postal service receives about 40,000 suggestions for stamps every year. "What we're looking to do is represent the best of the United States," he told *Eos.* He said that Ride was "a natural" for a stamp. "She is one of our national assets."

Gicker said that stamps with space topics "always are very popular" with the American public. "But to be able to be doing the first female astronaut, that was pretty exciting."

Criteria for determining the eligibility of subjects on U.S. stamps state that "the Postal Service will honor extraordinary and enduring contributions to American society, history, culture or environment." Ride contributed to all four areas, said O'Shaughnessy. "Certainly history. Certainly our culture and showing that girls and women can do anything they want to do; and society, because they're kind of related," she said. Regarding the environment, O'Shaughnessy said that many of the books that Ride and she coauthored "are focused on Earth and protecting the Earth and taking climate change seriously, as 99.9% of scientists around the world do."

*Sally Ride floats in the space shuttle* Challenger *flight deck during the shuttle's STS-7 mission in 1983. Credit: NASA*

### Sally Ride's Legacy

Another big fan of Ride is Ellen Ochoa, the first Hispanic woman in space and the newly named vice-chair of the U.S. National Science Board, who retired in May as director of NASA's Johnson Space Center in Houston, Texas. "I admired Sally for her intellect that she applied as a scientist, her focus and passion for STEM education, and her astounding competence in so many areas, including her critical contributions to NASA and the nation," Ochoa told *Eos.* She participated in the stamp dedication ceremony and in a women in leadership event at the university that evening.

"As much in demand as she was, she always made time to meet with young women who dreamed of becoming astronauts," Ochoa said. "I am thrilled to be part of the Sally Ride Forever stamp dedication,

"I am thrilled to be part of the Sally Ride Forever stamp dedication, continuing her legacy of inspiring people across the country, and indeed around the world."

continuing her legacy of inspiring people across the country, and indeed around the world."

**Drama in the Stamp**

Paul Salmon, an award-winning illustrator who painted the images of Ride and the space shuttle that appear on the stamp, was a NASA artist in the 1980s and observed the landing of one of the shuttles on which Ride flew. The landing "was very exciting, and I remember feeling an extremely patriotic feeling. It almost brought me to tears," Salmon recollected to *Eos*.

Salmon, working with USPS stamp designer Ethel Kessler, started the stamp project by making a series of small black-and-white charcoal sketches that he drew from a NASA photo of Ride with the entire STS-7 shuttle mission crew. Those sketches then progressed into a comprehensive color design before being digitized and further refined. "I was trying to get drama into it. I was trying to get light and shade," he said of the stamp. "I wanted the drama of the liftoff and just the idea of this brave woman putting her life on the line."

**Squeezing Art onto a Postage Stamp**

All of that drama needed to squeeze into the size of a postage stamp, Gicker noted. "It's a very small space, and we have a lot to convey. That's why in this instance it was important to us to have both the image of Sally and the shuttle flight so that people immediately make the connection between the two and it starts to tell the story."

"Of course, we can't tell long, involved stories on stamps," he added. "But we hope that it's sort of the tip of the spear [and] that people will wonder about it and look up the information and find out more."

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

# Former AGU Executive Director A. F. "Fred" Spilhaus Jr. Has Died

*A. F. "Fred" Spilhaus Jr. Credit: AGU*

Former AGU executive director A. F. "Fred" Spilhaus Jr. died on 30 April at the age of 79. Spilhaus was executive director from 1970 to 2009.

Under his leadership, AGU experienced enormous growth and achieved numerous significant accomplishments. During his tenure, membership grew from 7,000 to more than 56,000, and the staff size increased from about 20 to 180. In addition, the organization's net worth went from a negative number in 1970 to approximately $60 million by the end of 2007.

Spilhaus said that he "had the best job in the world from 1967 to 2009."

Spilhaus oversaw such new publications as *Geophysical Research Letters*, which was launched in 1974; the addition of new discipline sections; the 1975 initiation of small, single-topic meetings called Chapman Conferences; establishment of a fully electronic publication system; and tremendous growth of the annual AGU Fall Meeting, which in recent years has typically drawn more than 20,000 attendees. In addition, he collaborated with other scientific societies worldwide.

Spilhaus, who also served as editor in chief of *Eos*, joined AGU in 1967 as assistant executive director under the organization's first executive director, Waldo E. Smith. At the time, Spilhaus was only a few years out of graduate school, having received his Ph.D. in physical oceanography in 1965 from the Massachusetts Institute of Technology.

In 1996, Spilhaus was elected as an AGU Honorary Fellow in recognition of his lifetime of achievement on behalf of AGU; he is one of just a few people ever to have received that recognition. In 2010, after his retirement, Spilhaus received the Waldo E. Smith Medal for "extraordinary service to geophysics."

The citation for the medal noted, in part, "For most of the past 40 years, Fred Spilhaus led AGU with dedication, creativity, and leadership, making AGU a model union and a strong integrating force and professional home for Earth and space scientists across the globe. That AGU is held in such high regard stems mainly from Fred's insistence that the Union be inclusive of all Earth and space scientists and that scientific quality and integrity hold the highest priority. Fred also bequeathed to AGU long-term financial stability."

In response to the citation, Spilhaus wrote, "The principles Waldo lived by, and which I tried to emulate, were (1) our scientific mission always comes first and (2) the members are AGU. AGU welcomes members of the scientific community worldwide. (3) By watching the pennies, we build the resources needed to serve in the future." Spilhaus added that he "had the best job in the world from 1967 to 2009."

Donations in Spilhaus's memory may be made to the Woods Hole Oceanographic Institution in Woods Hole, Mass.

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

# Fresh Take on a Gold Treasure's Origins Using Geochemistry

The Treasure of El Carambolo, a collection of 7th century BCE gold jewelry, has provoked archaeological debate for decades. Since its accidental discovery 60 years ago inside a vase near Seville, Spain, studies of the ancient jewelry have suggested two conflicting stories of origin set thousands of kilometers apart. Recently, researchers used techniques more commonly found in the geosciences to try to locate precisely where the gold was mined and have come up with a third option.

"The origin of the gold need not be from thousands of kilometers away, in the Atlantic or eastern Mediterranean," said anthropologist Francisco Nocete of Universidad de Huelva in Spain and lead researcher on the new analysis. Instead, Nocete's analysis suggests a much more local origin for the gold: the ancient economic and political hub of Valencina de la Concepción, located a mere 2 kilometers from El Carambolo.

Nocete and his team used a combination of laser ablation mass spectrometry and lead isotope analysis to get detailed geochemical measurements of the treasure without damaging or altering the valuable artifacts. The researchers compared the Carambolo measurements with those from other artifacts discovered on the Iberian Peninsula. They found that the Carambolo gold is chemically similar to gold artifacts created at Valencina de la Concepción nearly 2,000 years earlier, which suggests that the Carambolo Treasure used the same gold source.

Geoscientists commonly use these same techniques to measure the elemental composition and age of a solid sample, like a rock or a fossil, without significantly altering the sample itself. In this Carambolo research, which was published in the April issue of the *Journal of Archaeological Science,* scientists for the first time have used the combined techniques to trace the provenance of archaeological artifacts of unknown origin (see http://bit.ly/treasure-analysis).

## A Controversial Past

The Carambolo Treasure was discovered in 1958 in the Camas region near Seville. Archaeologists initially linked the gold treasure, which consists of 21 intricate jewelry pieces, to the prosperous and metal-rich Tartessos culture. Tartessos spanned the southern coast of the Iberian Peninsula (near what is now Andalusia, Spain) from the 9th to 6th centuries BCE.

Once determined, the gold's origin will tell us more about why the set was created and what it was used for, archaeologists said.

However, the treasure's design recalls the Phoenician style of the time, and the hoard came from what had been a Phoenician temple. Phoenicia, an eastern Mediterranean civilization and a trade partner with Tartessos, built a few colonies along the Iberian coast.

With Tartessian and Phoenician influences, archaeologists wondered whether Phoenicians mined and shaped the gold and then brought it to Tartessos or whether Phoenician-influenced artists mined and created the jewelry in Tartessos. Once determined, the gold's origin will tell us more about why the set was created and what it was used for, archaeologists said.

## Modern Methods, Ancient Artifacts

Despite the controversy about the Carambolo Treasure's origin and purpose, researchers have hesitated to use classical analysis techniques on the hoard, fearing it would damage the unique and valuable artifacts, explained Sonia García de Madinabeitia in a press release about the research (see http://bit.ly/U-Basque-Country). García de Madinabeitia, a mineralogist and petrologist at the University of the Basque Country in Vizcaya in Spain, helped perform the analysis on the gold.

To gain a new perspective on the treasure's provenance, Nocete's team extracted 100-micrometer-diameter samples from two of the Carambolo pieces using laser ablation. They then used mass spectrometry to identify the composition of tiny impurities—silver, copper, lead, zinc, and platinum—in the gold.

Combined with a lead isotope analysis of the samples, the chemical impurities make up a "signature" of the gold, which the team could then quantitatively compare with other treasures or gold mines. The modern techniques have the "minimum possible impact" on the artifacts, said García de Madinabeitia.

The team found that the two Carambolo pieces they tested likely came from the same source of gold. If those two pieces are representative of the entire set, this result supports the long-held assumption of archaeologists who have studied the treasure that the jewelry all comes from one place.

## More Clues in the Gold's Chemical Fingerprint

The team then compared the Carambolo measurements with those of artifacts discovered across the Iberian Peninsula that date to the same period and also with those of artifacts that are 2,000 years older, which the team had dated in a prior study (http://bit.ly/jas-jan2014). The researchers found the composition of the gold itself to be similar to that of items from a well-studied nearby archaeological site called Valencina de la Concepción. The 3rd millennium BCE site "behaved like a gateway for raw materials of regional and transconti-

*The Carambolo Treasure comprises these 21 gold items. Credit: Consejería de Cultura de la Junta de Andalucía/J. Morón*

nental origin…and as a space for artisanal transformation into products, including gold metallurgy," said Nocete.

*Dolmen de la Pastora, a monolithic stone tomb in Valencina de la Concepción in Seville, Spain. The similar chemical compositions of the Carambolo Treasure and of older gold artifacts found in and around Valencina de la Concepción suggest that the artifacts are made from gold from the same as yet unidentified source. Credit: Juan Carlos Cazalla Montijano (Instituto Andaluz del Patrimonio Histórico, http://bit.ly/la-pastora-dolmen), CC BY-SA 3.0 (http://bit.ly/cc-by-sa-3-0)*

In other words, the study shows that the gold in Carambolo was likely shaped in Valencina de la Concepción but mined, along with other gold found at that site from an earlier era, at some unknown location.

"The most remarkable [aspect of the research] is the methodological issue and the new options that this opens for future research," said Ignacio Montero Ruiz, an archaeologist and archaeometallurgy researcher at the Center for Human and Social Sciences in Madrid, Spain.

Nonetheless, Ruiz, who was not involved with this research, said that the findings of Nocete's team would have been stronger had the team analyzed more than just two Carambolo pieces. Such analysis could have provided clues to the gold's region of origin, wherever it may be, he explained. He also suggested that future research should look into the possibility of even more diverse origins for the gold.

### Toward a Database of Gold

This blending of geochemistry and archaeology is nothing new to Nocete and his interdisciplinary research group.

"Geochemical and isotopic studies have been part of our methodology" since the research group formed in the early 1990s, he explained. "These chemical and isotopic techniques were already known [in] the 80s," Nocete said, but he and his team pioneered their combined application to archaeological gold to learn more about the artifacts' history.

Nocete plans to keep improving this analysis technique to minimize the impact of testing methods on other artifacts. The researchers are also working to compile a database of natural gold sources on the Iberian Peninsula and hope to expand to other areas of Europe, as well as to Asia, Africa, and South America.

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

# Satellite Data Archives Reveal Unrecorded Himalayan Floods

*Imja Lake—the long, silty lake in this 2010 photo—has grown in front of Imja and Lhotse Shar glaciers (top right) in the Himalayas. In 2016, engineers lowered Imja Lake by 3.5 meters to reduce the chances of a large glacial lake outburst flood. Credit: Jeffrey S. Kargel, Planetary Science Institute, Tucson, Ariz.*

A flood that tore through central Nepal in July 2016, destroying houses and roads, came from a seemingly placid source: a glacier. The Himalaya region encompasses thousands of glaciers, so glacial lake outburst floods like that summer 2016 torrent are a perennial problem. Glacial lake outburst floods occur when large bodies of glacial runoff water suddenly breach the fragile, naturally formed piles of rocks and other glacial debris, referred to as moraine dams, that hold them in place. But monitoring these deluges using ground-based observations is often impractical because of challenging mountainous terrain and harsh weather conditions.

Now researchers have used satellite data spanning nearly 3 decades to assemble a census of glacial lake outburst floods across India, Nepal, Bhutan, and China. The team's algorithm identified all but one of the region's 11 previously reported floods as well as 10 previously undocumented events, observations that shed light on the prevalence of these unpredictable—and sometimes deadly—torrents.

"This work is very important," said Christian Huggel, a geographer at the University of Zurich in Switzerland not involved in the research. "It fills gaps in knowledge and understanding about glacial lake outburst floods' occurrence in a region as vast as the Himalayas."

## Unstable Lakes

Georg Veh, a geoscientist at the University of Potsdam in Germany, and his team looked for floods that had occurred in the Hindu Kush Himalayan mountain ranges, which run from Afghanistan in the west to Myanmar in the east. This region is home to a large fraction of the world's roughly 200,000 glaciers, but these majestic ribbons of ice at Earth's "third pole" are shrinking as global temperatures climb. Melting glaciers create thousands of lakes ringed by unstable debris that can give way at any moment and inundate villages, farmland, and important infrastructure like hydropower stations.

"It fills gaps in knowledge and understanding about glacial lake outburst floods' occurrence in a region as vast as the Himalayas."

Veh and his collaborators used data from NASA's Landsat series of satellites, which were first launched into near-Earth orbit in the 1970s and which reobserve locations on the planet roughly every 16 days. The team analyzed nearly 2,500 Landsat images encompassing roughly 10,000 square kilometers of the Hindu Kush Himalayan region that were captured between 1988 and 2016.

The researchers' use of a computer algorithm created to spot changes in patterns of pixels in the Landsat images that correspond to the shrinking of bodies of water led to their 91% success rate for already documented floods. The one known flood missed by the algorithm occurred in India in 2013.

Confident that their algorithm was effective at spotting real glacial lake outburst floods, Veh and his team then looked for signs of floods that hadn't been previously reported. The 10 previously unknown floods that the scientists detected took place in China, Nepal, and Bhutan, the researchers reported in March in *Remote Sensing of Environment* (see http://bit.ly/glof-landsat).

By nearly doubling the known number of glacial lake outburst floods, the researchers assembled a more complete inventory of these events. Not surprisingly, the team noted, those new-to-science glacial lake outburst floods tended to be smaller than their already known brethren.

## Expanding the Survey

Veh and his colleagues have examined an even larger data set of Landsat images to extend their analysis to satellite observations from 2017. At the European Geosciences Union 2018 General Assembly in Vienna, Austria, the researchers presented on 11 April newer findings, an additional nine previously unreported floods (see http://bit.ly/egu2018-7699).

This work, which will help local residents, government officials, and other concerned parties more accurately assess the risks that these floods pose, could be replicated in similar glacier-rich regions such as Alaska and Patagonia, the University of Zurich's Huggel suggested.

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

# Dynamic Ice Sheet and Sea Level Response to Past Climate Change

**PALSEA2 5th Workshop: Phasing of Ice Sheet and Sea-Level Responses to Past Climate Change**

Playa del Carmen, Quintana Roo, Mexico, 6–9 November 2017

*Coral reef and subtidal sands are exposed in the walls of the Underground Rivers at Xcaret, Mexico. Credit: Alexandra Skrivanek*

Models of past climate conditions, including sea level changes and the advance and retreat of land-based glaciers and ice sheets, rely on numerous sources of information. Tree rings, fossils, and sediment layers are only a few examples. These data sources preserve the past in different ways and with differing degrees of precision. Constructing an accurate, coherent model requires accessing and integrating these various types of data, as well as understanding the strengths and limitations of each type.

The exquisitely exposed last interglacial (LIG) fossil coral reef on the Yucatán Peninsula in Mexico served as the backdrop to the fifth and final meeting of the Paleo Constraints on Sea Level Rise 2 (PALSEA2; http://bit.ly/PALSEA2) working group. The workshop highlighted current research on ice sheet and sea level reconstructions; addressed critical gaps in field observations; and assessed the current knowledge of causes, rates, and mechanisms related to sea level and ice sheet dynamics during past warm periods. The 5-day program included more than two dozen presentations, a poster session, and field excursions to a fossil coral reef at Xcaret and a coastal limestone cave at Rio Secreto (see http://bit.ly/PALSEA2-workshop).

A major theme throughout the conference was the need to combine existing paleodatabases into a centralized global paleo–sea level/ice sheet compilation with a streamlined user interface. Participants discussed standardizing, interpreting, and assessing the quality of field data as key components for integration and application by the modeling community. For instance, some presenters considered how sample elevation does not necessarily equate to relative paleo–sea level and must be viewed in the context of indicative range, whereas others discussed complications of interpreting sea level from coral reef structures where accretion is often determined by storm deposition of coral rubble.

Glacial isostatic adjustment (GIA), how land deforms under the decreasing weight of melting glaciers, was another key topic; participants discussed ways to improve quantifying the uncertainties of GIA in global sea level signals. These uncertainties can have profound effects on calculated local sea levels that must be accounted for during the course of an interglacial period.

Participants examined GIA uncertainty stemming from ice sheet configuration and 3-D Earth model parameters, and they emphasized the need for additional paleo–sea level elevation data. They also stressed the need to understand glacial ice sheet volume and spatial coverage prior to the last glacial cycle, especially for the penultimate glacial maximum. This understanding is essential for determining peak LIG sea level reconstructions. Discussions included how cosmogenic nuclide techniques have the potential to help constrain these glacial ice extents over million-year timescales.

Dynamic topography caused by mantle convection is another parameter that could have substantial effects on the elevation of sea level indicators from the LIG to the Pliocene. Determining these effects currently involves substantial uncertainty in terms of vertical errors. Thus, participants recommended larger uncertainty bars for reported estimates of the peak sea level reached during the LIG, currently assessed at 6–9 meters above the present global mean sea level.

Attendees also stressed that Pliocene sea level is still of key interest because atmospheric carbon dioxide concentrations during this period were similar to those today. Thus, information from that time could offer insights into the relations between greenhouse gas concentrations in the atmosphere and climate-induced sea level changes.

Attendees agreed that long-term objectives for the paleoclimate modeling community should include creating broader consistency across the various scientific disciplines to define model error and standard results and endorsing transparency and open-source records for modeling and data acquisition.

We thank the organizers of the PALSEA2 workshop, namely, Andrea Dutton, Anders Carlson, Glenn Milne, Antony Long, and Paul Blanchon, as well as the funding organizations: Past Global Changes (PAGES) and the International Union for Quaternary Research (INQUA).

By **Michael R. Sandstrom** (email: rms@ldeo.columbia.edu), Lamont-Doherty Earth Observatory, Columbia University, Palisades, N.Y.; **Alexandra Skrivanek,** University of Florida, Gainesville; and **Jeremy Shakun,** Boston College, Chestnut Hill, Mass.

# *You* Should Advocate for Science

Credit: solidcolours/iStock.com/Getty Images Plus

Science advocacy is pretty simple. You just have to *ask*—in Congressional parlance—for what you want.

The idea of such an ask may seem strange, but it is key to getting heard on Capitol Hill. And it isn't wholly unfamiliar. After all, every time we write a grant proposal, we're embarking on an ask.

After taking time to learn and practice how to craft our asks, we now have an ask of you: Contact your elected representatives and ask them to fund Earth and space science research robustly and predictably (including appropriations for Earth and space science funding agencies) and to oppose policies that impede scientific progress. Seek to talk to people at all levels of government: city, state, and national.

Why do we think you should become an advocate for science? Because those engaged in rigorous science are the best advocates for it.

What's more, many of you will be coming to Washington, D. C., later this year for the 2018 AGU Fall Meeting. Wouldn't that be the perfect opportunity to advocate for science on the Hill en masse?

## A Pathway for Your Ask: AGU's Congressional Visits Days

In May of last year, we were among 11 AGU members from Alabama, Florida, Illinois, Louisiana, and Mississippi who congregated in Washington for one of AGU's Congressional Visits Days (CVDs).

CVDs can be sponsored by many different groups; for example, the American Association for the Advancement of Science and the Geological Society of America hold several a year. AGU-sponsored CVDs (currently, three or more per year) provide an opportunity for AGU members to meet their legislators and their staffers in Washington. During visits, participants discuss the importance of federally funded science and its influence on their research.

> To begin as an advocate, just show up and be heard. Senators and representatives rarely hear from their constituent scientists.

Some AGU CVDs include nearly 100 AGU members; others, like this third annual AGU members–only day, are smaller, allowing for more direct training and preparation of the participants. CVDs are a great way to start advocating for science.

We all had different reasons for attending CVD 2017. Kim Popendorf (Florida) wanted to inform her congressional representatives of the critical importance of federal funding for infrastructure, such as ships and satellites; Denise Hills (Alabama) wanted to emphasize the value of supporting open science; and Ron Doel (Florida) wanted to highlight science, technology, engineering, and mathematics (STEM) education.

AGU Public Affairs staff briefed us with information about the budget and appropriations process, along with what topical and timely legislative issues were of highest importance to discuss. But most important of all, they gave us guidance on how to craft our asks.

CVDs aren't just a day on the Hill, AGU's Public Affairs team informed us. They're about building long-term relationships with legislators and becoming valuable resources in the future.

## Understanding Pitfalls

To appreciate the challenging decisions that members of Congress face, the Public Affairs staff had us work through a budget allocation exercise.

After an introduction to the federal budget, we were asked to distribute a set amount of money across several different agencies handled by the House Appropriations Committee's subcommittee on Commerce, Justice, Science, and Related Agencies. This subcommittee sets funding levels for the Department of Defense and Department of Justice, as well as for our nation's federal science agencies, including NASA and the National Science Foundation (NSF).

In our budget exercise, the overall funding was modestly increased, although at subinflationary levels, from the previous fiscal year.

We were asked, How would we prioritize which agencies got an increase? Which ones could be level funded or even decreased? Do we sacrifice justice reform efforts to increase spending elsewhere? If a group of lawyers or police officers were asked to do the same task, what would have been the result? This task was a realistic representation of the scope of budget decisions handled by policy makers.

*Team Alabama with Rep. Mike Rogers (R-Ala.) at the recent 2017 AGU members–only CVD in Washington, D. C. From left to right, Adam Kobelski, Rogers, Prabhakar Clement, Denise Hills, and Lexi Shultz (AGU director of Public Affairs). Credit: Adam Kobelski*

### Your Science Is Your Ask's Strength, but Have Patience

Armed with context on budget appropriations, it was easy to see how science can fall by the wayside.

We learned that few members currently serving in Congress have a background in natural science. With such limited science representation, policy makers often underestimate or overlook the value of scientific pursuits unless their staff is well versed in these issues. With limited time and resources, they may not fully comprehend the connection between federally supported scientific research and its value to their local communities.

Therefore, advocacy for publicly funded science falls to us, the practitioners.

The Public Affairs team cautioned that success in advocacy may take time, especially as legislation can move slowly through Congress. Keys to success include effective communication, patience, persistence, sound science, good ethics, respect, politeness, finding champions, talking to the right staffers, good timing, and luck. And, of course, a well-structured ask.

### Honing Your Ask: Approach Is Key

The Public Affairs team's key advice: "Flip the pyramid" and put your ask up front. Instead of building on a broad foundation of facts, we should put our main point first and make it specific, contrary to how many scientists have learned to communicate (Figure 1).

For example, "Hi, my name is Dr. Downs. Please support increasing NSF's budget to $8 billion in fiscal year 2018, a 4% real increase from fiscal year 2016." Congressional staffers are acutely listening for that ask—if you don't make it, they're left guessing why you have come. The narrative details that support the ask come later, but the ask is key.

The ask approach felt strange to us. It was opposite of how we typically talk about our research. Public Affairs staff provided some encouragement: To begin as an advocate, just show up and be heard. Senators and representatives so rarely hear from their constituent scientists that just being there to start the conversation was much of the goal.

Then, tell your story, make yourself available, and relate your ask to the state or district of the congressional member you are talking to. Show how your issue will have an impact on the people back home. The congressional member knows that an impact on the people they represent means an impact on potential voters.

### Practicing the Ask

The morning of 3 May 2017 was warm and bright, with everyone ready for a long day of congressional visits. Each group of two to three AGU members was paired with an AGU Public Affairs representative to help navigate the mazelike congressional office buildings' hallways.

On that day, AGU's CVD participants met with more than 30 congressional offices and several members of Congress, including Rep. Mo Brooks (R-Ala.), Rep. Ileana Ros-Lehtinen (R-Fla.), and Rep. Debbie Wasserman Schultz (D-Fla.). Most meetings, however, were with congressional staffers, a common occurrence whether in Washington or back home in district offices. Staffers are sometimes subject matter experts, tend to focus on policy specifics, and generally have more time to learn about your issues and concerns. They play a critical role in keeping members of Congress up to date on topics that matter to their constituents.

Between office meetings, we walked the halls of the House and Senate buildings. We saw staff members taking calls and meeting with constituents like us. It became clear that Congress does not operate in a vacuum. Citizens like us bring their messages to their representatives, hoping to find a champion for their ask.

It was an eye-opening experience to lead with the ask—pens hit paper as soon as we started talking. We were often queried for additional supporting information, so we shared brief stories of research projects or transformative technologies enabled by federal research dollars.

We connected our stories to the community: how improved weather forecasting leads to more accurate storm prediction, saving lives; how federal investment in energy research enables matching funds from industry to provide jobs and move us toward energy independence; how water research informs water (and other) resource management decisions; how student support encourages our best and brightest to remain in the United States to better our economy. We closed each meeting with invitations to visit us at our institutions and an offer to act as resources on science issues in the future.

The work we did that day was just the start of ongoing communication with congressio-

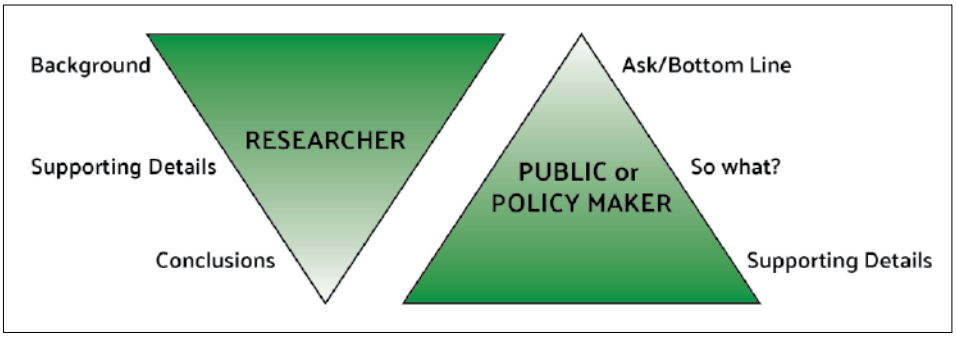



*Fig. 1. Scientists tend to want to start with a broad foundation leading to a well-supported conclusion. Nonscientists first want to know the ask (or conclusion) so that they know why they should care about what's being said. Credit: Modified from* Somerville and Hassol *[2011]*

nal staff; many of us have already followed up by attending local congressional home offices and town hall events and sending emails to staffers. We know that our policy and appropriations goals will be difficult to achieve, but our experience at AGU's CVD tells us it all starts with a simple ask.

## Our Asks of You

We, the participants of AGU's CVD, have an ask of you, our fellow citizen scientists: Engage with your elected representatives—local, state, and federal. If you're not up to coming to Washington, seek your officials at their local offices. Discuss the importance of science and science support.

Share your research in your community and with your neighbors. As they see how your science influences their lives, they may add their voice to our science advocacy chorus. Many drops make an ocean, and participatory democracy is not confined to the voting booth—*everyone* can advocate.

We also have an ask of the AGU community: Let's organize an Earth and space science CVD in conjunction with the 2018 Fall Meeting in Washington. This event could be bigger, with more geoscientists doing face-to-face visits.

Let AGU leadership and Public Affairs staff know that you'd relish the opportunity to talk science with your senators and representatives when you come to Fall Meeting.

Won't you join us in being an advocate for science?

## Acknowledgments

AGU's 2017 CVD class is grateful for the efforts of the AGU Public Affairs staff to make their CVD a success and to provide ongoing support to our continued advocacy efforts. The authors appreciate the thoughtful reviews that improved this article.

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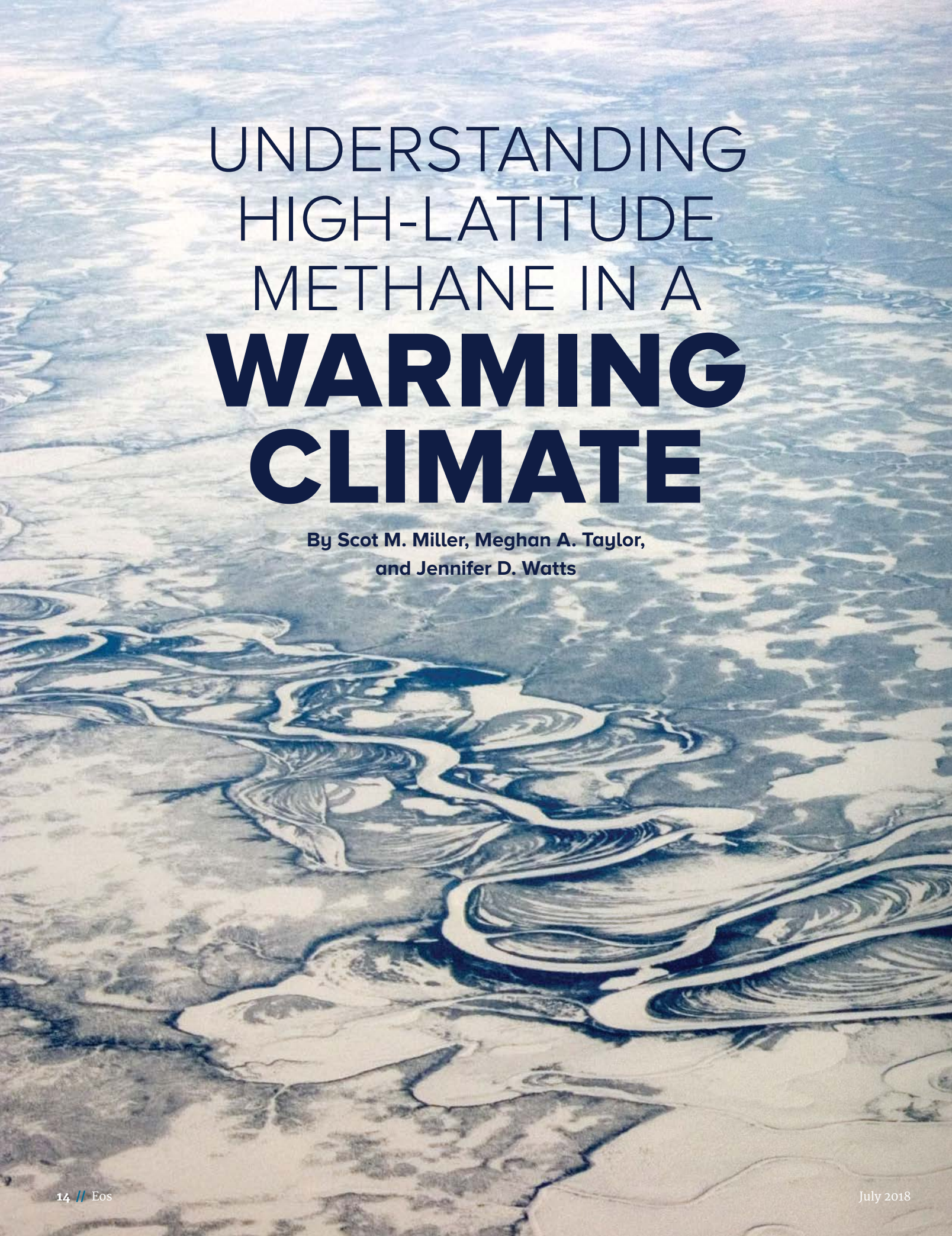


# UNDERSTANDING HIGH-LATITUDE METHANE IN A WARMING CLIMATE

By Scot M. Miller, Meghan A. Taylor, and Jennifer D. Watts

**Climate change could spur greenhouse gas release from the Arctic. A new project will synthesize existing data to improve uncertain predictions.**

Beneath vast plains of Arctic tundra and swampy taiga forests lies permanently frozen ground, or permafrost. As northern polar regions continue to warm at a rate twice the global average, this permafrost begins to thaw. Unfrozen, waterlogged soils are like witches' cauldrons for methane, a greenhouse gas 25 times more potent than carbon dioxide.

In these environments, organic material from plants and other sources slowly decays with the help of microorganisms called Archaea, releasing methane ($CH_4$) into the atmosphere [*Schuur et al.*, 2015]. Scientists know that this process is occurring, but the precise amount of Arctic carbon released as $CH_4$ remains uncertain. Also, atmospheric measurements of the amounts of methane released by permafrost (a top-down

*Aircraft view of northern Russian tundra, wetlands and bogs, and large areas of frozen water. Credit: Malcolm Fairman/Alamy Stock Photo*

*Scientists from Northern Arizona University use eddy covariance flux towers to measure methane ($CH_4$) release from thawing permafrost near the Stampede Trail in Alaska. This trail was made famous by the tragic plight of Christopher McCandless in Jon Krakauer's book* Into the Wild. *The research site, which sits in the foothills near Denali, the tallest peak in North America, is experiencing various stages of soil warming following rising summer temperatures and declining frozen conditions in winter. Credit: Marguerite Mauritz*

approach) are far less than estimates of these amounts made using point-based field assessments and ecosystem modeling (bottom-up approaches). Thus, how a changing climate has affected and will affect future $CH_4$ emissions remains a topic of debate among scientists.

The Study of Environmental Arctic Change (SEARCH; https://www.searcharcticscience.org/) launched a $CH_4$ synthesis project with the goal of estimating contemporary budgets for $CH_4$ in the Arctic and projecting rates of future release. This effort aims to outline the current $CH_4$ budget and provide guidelines for monitoring future $CH_4$ release from the northern permafrost region. The project was initiated at the International Workshop to Reconcile Northern Permafrost Region Methane Budgets held in Seattle, Wash., in March 2017, and it includes a broad consortium of more than 40 scientists (see http://bit.ly/methane-budgets).

Here we highlight what we know, as well as a selection of important knowledge gaps in our understanding of terrestrial, marine, and atmospheric environments that affect the development of Arctic $CH_4$ budgets (Figure 1). We also summarize new work focused on improving our understanding of $CH_4$ dynamics in this region.

### Inland Emissions

*What We Know.* Total global $CH_4$ emissions are likely 550–650 billion kilograms per year (550–650 teragrams). Overall, wetlands and lakes are likely the largest sources of $CH_4$ emissions, followed by contributions from submerged permafrost along the Arctic Ocean shelf. Human activities (e.g., oil and gas drilling), geologic seeps, and fire also contribute to the total budget.

For latitudes above 60°N, emissions are estimated to be 18–29 teragrams $CH_4$ per year on the basis of top-down atmospheric model approaches. Wetlands, lakes, and other riparian areas are responsible for more than 70% of annual $CH_4$ emissions from northern land regions, whereas seeps, fires, and fossil fuel burning account for the remainder (Figure 2).

Permafrost thaw in the Arctic can initially lead to wetter landscapes, development of new lakes and wetlands, and increased $CH_4$ emissions [*Olefeldt et al.*, 2016]. Continued thaw results in draining of surface waters and drying of upper soil layers, which might mitigate $CH_4$ loss to the atmosphere [*Watts et al.*, 2014].

**The appearance of new lakes and the disappearance of older water bodies can substantially affect localized methane fluxes.**

*Knowledge Gaps.* The emissions estimates shown in Figure 2 are compiled from the *Arctic Monitoring and Assessment Programme (AMAP)* [2015], *Walter Anthony et al.* [2012], and expert opinion. These numbers are highly uncertain because of the remoteness of the northern regions and the limited extent of data networks for long-term monitoring. Ongoing changes in land components, including the appearance of new lakes and the disappearance of older water bodies as subsurface permafrost erodes and opens new drainage passages, can substantially affect localized $CH_4$ fluxes and further complicate regional emission mapping.

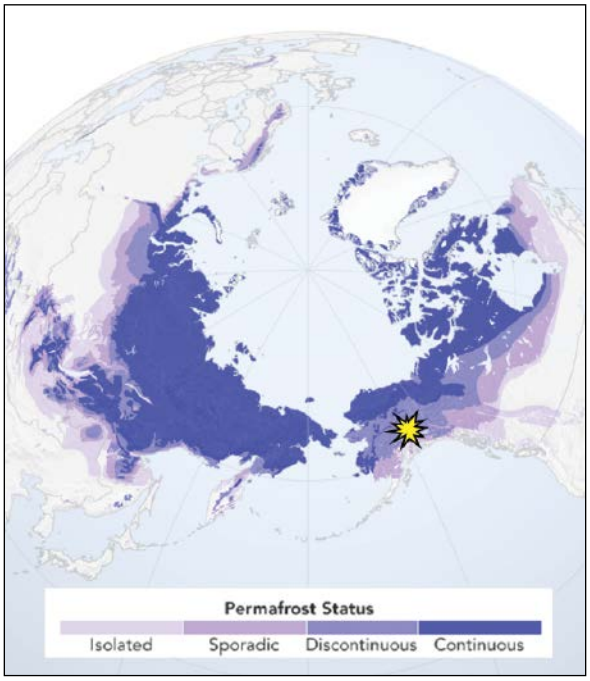



*Fig. 1. This map displays permafrost regions of the Arctic. Dark purple indicates continuous permafrost coverage, and lighter colors indicate discontinuous, sporadic, or isolated coverage. The Stampede Trail research site is identified with a yellow star. Credit: NASA Earth Observatory using data from the National Snow and Ice Data Center*

Resolving the magnitude and location of change in $CH_4$ emissions, especially those from wetlands and lakes, remains a formidable task for researchers. Winter $CH_4$ release could account for more than 50% of the annual budget, but more research is needed to better understand the magnitude of emissions occurring during cold seasons [*Zona et al.,* 2016]. Scientists still lack landscape-scale monitoring and mapping systems capable of detecting short-term (e.g., monthly) and decadal changes in surface wetness and temperature.

There's also a need for accurate soil carbon and land cover maps that distinguish between wetlands, lakes, and rivers to avoid double counting emissions budgets [*Wrona et al.,* 2016]. A better understanding of the ways that vegetation regulates $CH_4$ production and mediates $CH_4$ transport will help to inform models and explain why emission response differs for different landscapes.

## Marine Methane

*What We Know.* Ongoing changes in the Arctic Ocean will affect future $CH_4$ emissions. A reduction in sea ice extent could increase the direct transfer of gas from the ocean to the atmosphere. Warming ocean temperatures can increase $CH_4$ production as permafrost underlying the continental shelf begins to thaw.

Bubbling from shallow shelf sediments creates hot spots of $CH_4$ emissions to the atmosphere [*Shakhova et al.,* 2015]. In deeper shelf regions, much of the produced $CH_4$ is dissolved and oxidized in the water column or transported into deeper, dense waters [*Myhre et al.,* 2016].

*Knowledge Gaps.* Bottom-up estimates for marine environments differ greatly depending on which offshore ocean shelf is investigated, reflecting different processes among the circum-Arctic shelves [*AMAP,* 2015]. New shipboard direct sampling methods for air-sea $CH_4$ exchange will enable researchers to better quantify marine fluxes and will help the community address disparities in marine $CH_4$ emissions estimates among different regions [*Thornton et al.,* 2016].

## Methane in the Atmosphere

*What We Know.* Atmospheric scientists measure the amount of $CH_4$ gas in the atmosphere and use these data, along with models of atmospheric transport, to estimate the amount of $CH_4$ released at Earth's surface. Scientists observe atmospheric $CH_4$ using a network of about 20 towers across the Arctic, and they intensively measure atmospheric $CH_4$ from intermittent aircraft flights.

*Knowledge Gaps.* These efforts produce regional- and continental-scale estimates of where, when, and how much $CH_4$ is released, but estimates vary according to the method used. For example, atmospheric studies indicate less $CH_4$ from boreal forests in North America and more from cold, Arctic tundra relative to bottom-up estimates [e.g., *Miller et al.,* 2016].

Integrating these $CH_4$ observations is a key challenge. Various methods collect data at different scales: Chamber measurements collect data over square-meter areas, tall towers and aircraft observe larger areas, and satellites (e.g., Greenhouse Gases Observing Satellite, or GOSAT) observe areas larger than a square kilometer. Top-down and bottom-up estimates that use only one of these data sources often arrive at very different $CH_4$ totals, and they extrapolate emissions over time and space in ways that are difficult to compare.

A challenge for the scientific community is to find consensus in the methodologies used to scale $CH_4$ from sample locations to the larger domain and to integrate information obtained from these various data sets. An

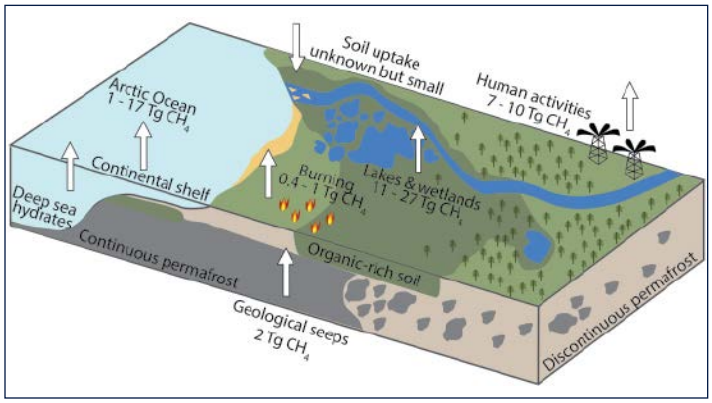



*Fig. 2. Lakes and wetlands are the largest of the primary sources of $CH_4$ emissions from northern high latitudes (60°N–90°N). Current emissions estimates are shown in teragrams (Tg) per year.*

*Airborne sampling near Inuvik, Northwest Territories, Canada, provides a bird's-eye view of $CH_4$ across a large region. Credit: NASA/Katy Mersmann*

integrated approach could better elucidate patterns and trends in $CH_4$ fluxes and help pinpoint the underlying mechanisms driving these changes.

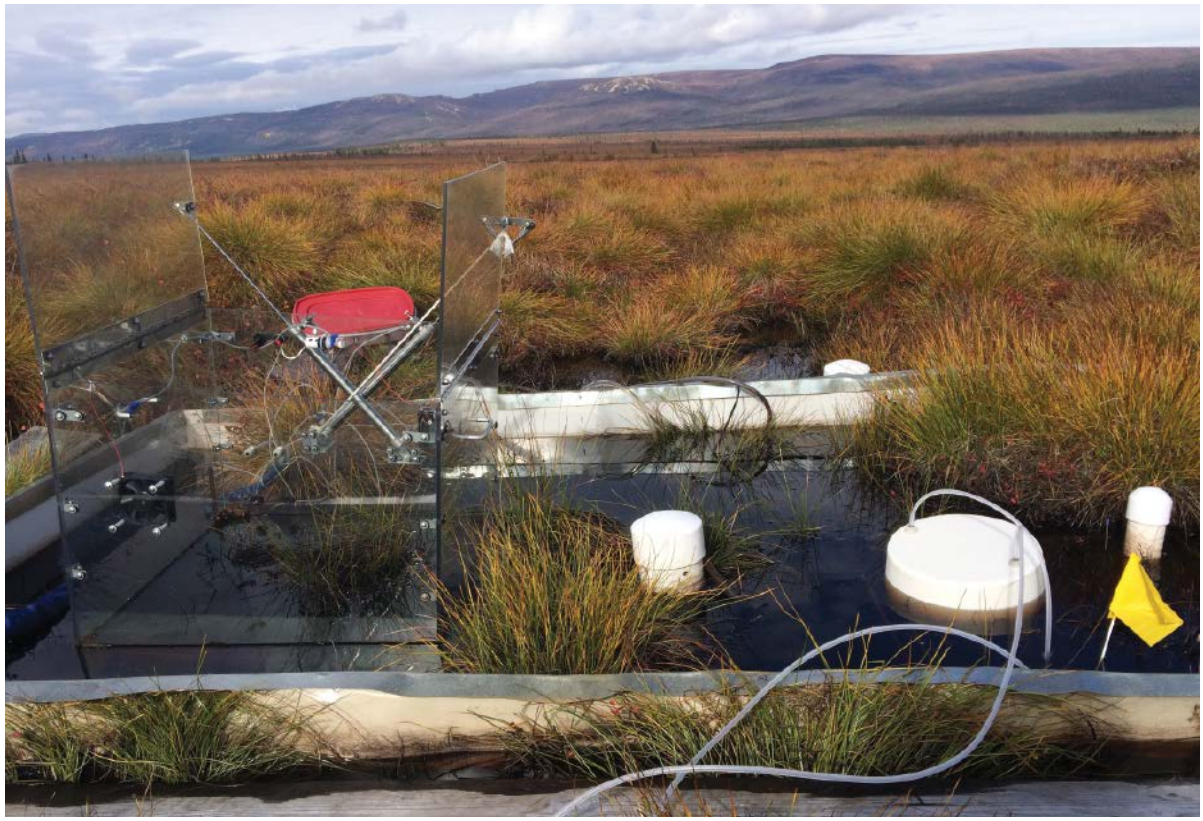
These results could help flag the regions of greatest concern for future $CH_4$ release. Overall, the total amount of $CH_4$ emissions that atmospheric scientists see from high latitudes is half of that in bottom-up estimates, and scientists are working to understand this discrepancy [*Bruhwiler et al.*, 2014]. Furthermore, the answer to the question of whether $CH_4$ emissions are increasing remains elusive. In many regions, the atmospheric data record is too short (30–35 years at most) to conclusively quantify long-term $CH_4$ trends [e.g., *AMAP*, 2015].



### Efforts to Reconcile the Northern $CH_4$ Budget

Scientists participating in the SEARCH $CH_4$ synthesis project are working to better constrain the $CH_4$ budget in the northern permafrost region.

- Researchers are creating a comprehensive database of Arctic $CH_4$ observations from disparate measurement platforms. Data availability has been an obstacle for existing studies, and the resulting database will allow future studies to better synthesize existing observations.
- Project members are working to improve the methodology used to extrapolate from site-level measurements to continental scales. These measurements are often sparse, and varying extrapolation methods can result in large differences in terrestrial and marine $CH_4$.
- Scientists will conduct a data synthesis of understudied winter emissions, which may account for a large fraction of total emissions in the region.
- SEARCH participants will make recommendations for how to improve and expand existing $CH_4$ observing networks. For example, they are evaluating whether the existing atmospheric observation network could detect a



*Chamber-based measurements near the Stampede Trail capture fine-scale relationships between $CH_4$ fluxes and environmental drivers, providing a detailed understanding of $CH_4$ release from an Arctic tundra. Credit: Meghan Taylor*

broad emissions trend, and they are outlining the new observations that would be needed to detect such a trend.

Project members are also planning to incorporate new, forthcoming data into the SEARCH synthesis activities. These data include new aircraft observations from the northern permafrost region (e.g., the NASA Arctic-Boreal Vulnerability Experiment; https://above.nasa.gov/) and measurement of sea–air gas exchange (e.g., the U.S. Geological Survey (USGS) Gas Hydrates Project; https://on.doi.gov/2GjSyJ6).

Taken together, these efforts will enable a better understanding of present-day $CH_4$ budgets and the underlying environmental drivers that will help scientists predict future $CH_4$ release and the associated impacts on global climate.


## Acknowledgments

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# WELCOMING WOMEN

By Emily V. Fischer, Amanda Adams, Rebecca Barnes, Brittany Bloodhart, Melissa Burt, Sandra Clinton, Elaine Godfrey, Ilana Pollack, and Paul R. Hernandez

Women are underrepresented in the geosciences, in part because of systemic attitudes and behaviors [e.g., *Rosen,* 2017]. Why do we need to close this gap? Diverse teams produce better ideas—they set the bar for scholarly excellence [*McLeod et al.,* 1996]. So what are the best ways to welcome the next generation of women into geoscience careers?

## Born of Collaboration

The Earth Science Women's Network (ESWN; https://eswnonline.org/) set out to find and test some answers to this question. ESWN, an organization with more than 3,000 members around the world, focuses on the peer mentoring

*Early-career scientists and their mentors share a lighthearted moment while learning firsthand about snow crystal formation and snowpack metamorphism at a snow science event in Laramie, Wyo. Credit: Ilana Pollack*

# INTO THE GEOSCIENCES


*Students from the Colorado–Wyoming Front Range region participate in a networking bingo game at the PROGRESS fall 2016 workshop. Credit: Melissa Burt*

and professional development of early-career women at the graduate and postdoc levels. This organization grew out of an informal gathering of six early-career women at the 2002 AGU Fall Meeting.

In 2014, members of the ESWN Leadership Board sought out expertise in gender and quantitative educational psychology. We wanted to find out the effects of connecting undergraduate women to a same-gender mentoring network and challenging their perceptions of their ability to succeed in science. We designed an experiment to quantify and qualify such effects on first- and second-year undergraduate women.

We implemented our experiment at nine universities in two U.S. regions (Colorado–Wyoming Front Range and North and South Carolina) between fall 2015 and fall 2016. We are now halfway through our National Science Foundation–funded project, and we see positive results [*Hernandez et al.,* 2017]: Undergraduate women with large mentoring networks that include faculty mentors are more likely than those without such networks to identify as scientists and are more intent on pursuing the geosciences.

Our experiment has developed into an effective and scalable program that benefits the undergraduate women it serves and thus may be part of the solution to the gender gap in the geosciences. Although we are still learning the full effect of our intentionally designed mentoring experiment, the early results are robust enough for us to share the general format of the resulting program in the hope that similar programs can be implemented at additional universities.

*At the 2016 Front Range workshop, PROGRESS students launched a sonde (a weather instrument balloon) to collect an atmospheric profile of temperature, pressure, and humidity. Credit: Melissa Burt*

## A Recipe for PROGRESS

Our program, the Promoting Geoscience, Research, Education and Success (PROGRESS) framework, offers three resources to undergraduate participants: a professional development workshop, access to women mentors and role models, and online discussions and resources. Many of the PROGRESS volunteer mentors and role models are also members of ESWN.

Here we explain the essential components of our professional development workshop, because this module of PROGRESS is mature and ready to be propagated. The goals of this first intervention component are as follows:

- to introduce women to geoscience careers
- to establish connections among students
- to help participants identify role models and the value of mentoring
- to discuss how to overcome expected hurdles

The workshop module begins with an introduction to the geosciences that focuses on teamwork and societal context. Why? People value people-oriented work environments [*Su and Rounds,* 2015], and linking to societal context enhances learning.

Two panel discussions follow this introduction. Each panel features women representing different ethnic, career, and other perspectives, because when people see others like themselves succeeding, they feel like they belong [*Rattan et al.,* 2012]. Panelists give Ignite-style presentations—5 minutes, 20 slides—followed by student questions (see http://www.ignitetalks.io/). In the first panel, the women present their career and personal pathways. The second panel has a "day in the life" theme, because exposure to women succeeding in counterstereotypical roles helps break down stereotypes [*Zawadzki et al.,* 2013].

## Engaging the Participants

Seeing specific factors that fuel curiosity, frustration, and the thrill of discovery in the geosciences is important to students. To add more exposure to women doing science, we offer our workshop participants hands-on activities, including a weather balloon launch, a Doppler on Wheels demonstration (see http://bit.ly/Doppler-on-Wheels), and a water quality experiment.

The workshop introduces gender stereotypes and biases—discussing these issues is important for overcoming their effects. We introduce these topics via a board game [*Shields et al.,* 2011] and using group exercises, including a modified version of the Implicit Association Test (IAT) that helps reveal unconscious attitudes toward gender. The students also identify other stereotypes (e.g., socioeconomic status and race), and we review the ubiquity of these issues.

Throughout the session, the facilitator reiterates that ability can be improved with effort [*Paunesku et al.,* 2015]. This conception appears important for building academic tenacity [*Dweck et al.,* 2014] and overcoming the effects of stereotype threat—the idea that people underperform when they feel at risk of conforming to negative stereo-

types surrounding their social group [*Good et al.,* 2003]. Discussions also offer the chance for students to validate sexism and racism they may have experienced [*Moss-Racusin et al.,* 2012].

## A Network of Support

PROGRESS students consider all the support they will need by completing a mentor map exercise, in which they reflect on who advocates for them, who they turn to for scientific advice, who gives them safe spaces to discuss their frustrations, etc. [*Glessmer et al.,* 2015]. Supportive connections help students attain academic goals [*Skahill,* 2002]. We also teach skills like composing emails to help students connect themselves to faculty.

Following the workshop, students can be paired with a mentor who also identifies as a woman in science, technology, engineering, and mathematics (STEM), or they can continue their interactions with each other via campus get-togethers. There is evidence that same-gender mentoring can be more effective for female undergraduates than cross-gender mentoring [*Blake-Beard et al.,* 2011].

As discussed in a recent National Academy of Sciences report (http://bit.ly/NAS-undergrad-STEM), more research is needed on how to foster effective mentoring relationships. We are exploring multiple models, such as one-to-one versus group mentoring, and also different ways of pairing students with mentors on the basis of perceived similar interests [*Gehlbach et al.,* 2016].

We do not yet know which strategy is better, but our program is already serving women across multiple institutions in two U.S. regions, which speaks to its transferability. In addition to a website (https://geosciencewomen.org/), we have a closed Facebook group where we share news, internships, and other professional development opportunities, and students can also seek advice on their "challenge du jour" [*Ellison et al.,* 2007].

## PROGRESS to Date

We found, as a result of our study, that PROGRESS participants develop larger mentor networks than their peers and that having a faculty mentor is related to greater personal identity as a scientist and greater intent on pursuing the geosciences. This is a critical result, because most students who change their major away from STEM do so early in their college education (see http://bit.ly/STEM-WH-report).

Many of our PROGRESS participants, who began the program as freshmen and sophomores, are now thinking about graduation and planning for their next steps. As we continue to track the women in the PROGRESS program, we will continue to update the geoscience community on widely transferable aspects of our research. All of our PROGRESS materials are available online for anyone who wants to start a similar program (see http://bit.ly/PROGRESS-workshop).


## Acknowledgments

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*PROGRESS students from North and South Carolina play a board game designed to teach the cumulative effects of subtle gender bias. Credit: Amanda Adams*


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# FLUID INJECTION WELLS CAN HAVE A WIDE SEISMIC REACH

By Shelby L. Peterie, Richard D. Miller, Rex Buchanan, and Brandy DeArmond

Seismologists attribute widespread earthquakes in southern Kansas and northern Oklahoma over the past several years largely to injection of extracted oil field brine deep into Earth's crust. Recently, however, the frequency of earthquakes has increased significantly in areas of Kansas well beyond the initial high-seismicity zones near injection wells.

Because the vast majority of high-volume injection wells in the region are near and south of its border with Oklahoma, Kansas has a unique vantage point for observing far-field effects of injection.

Recent measurements show that subsurface fluid pressures are elevated across south central Kansas, including areas where injection practices have been relatively consistent for decades. The findings

*This valve assembly is the aboveground portion of an injection well, which can be used to dispose of fluid deep in the subsurface. Credit: Leonid Eremeychuk/iStock/Getty Images Plus/Getty Images*

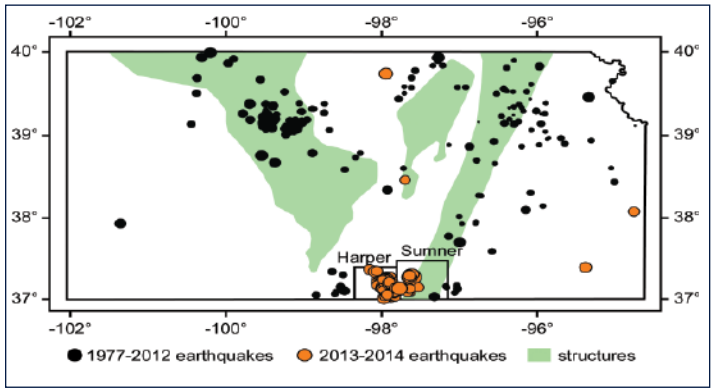


*Fig. 1. On this map of Kansas, dark circles show locations of earthquakes reported by USGS and the Kansas Geological Survey from 1977 to 2012; orange circles indicate earthquakes reported by USGS from 2013 to 2014. Nearly all of the recent earthquakes occurred within two southern counties (Harper and Sumner), which have seen a large increase in high-volume fluid injection. Light green areas show prominent subsurface geological structures.*

suggest that the cumulative effects of high-volume injection to the south have had an extended influence on fluid pressure in the pores of subsurface rocks.

This regional pressure change has the potential to trigger earthquakes far from the high-volume injection points, especially in areas where fluid pressure may already be elevated from local injection operations.

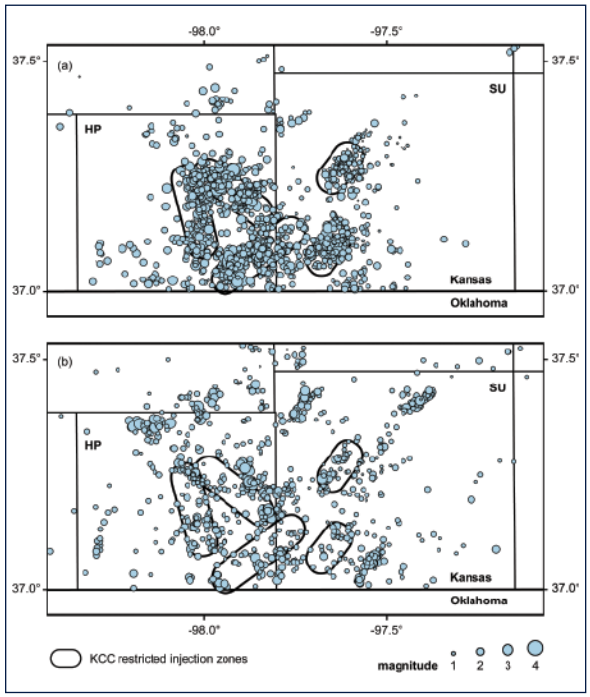


*Fig. 2. Earthquakes recorded by the Kansas Geological Survey network in Harper (HP) and Sumner (SU) Counties showed a sharp decrease between (a) January to June 2015, prior to the Kansas Corporation Commission's (KCC) sorder restricting fluid injection volumes, and (b) July to December 2016, a year after the order went into effect. The ellipses show the zones where the Kansas Corporation Commission restricted injection volumes. Credit: Modified from* Peterie et al. *[2017]*

## Human Activity and Earthquakes

Published studies have long indicated that human activity can cause earthquakes. Such earthquake-inducing processes include fluid injection for enhanced oil recovery, solution mining, hydraulic fracturing, geothermal stimulation, and disposal of waste fluids from industrial or oil and gas operations [*Ellsworth*, 2013].

Fluid injection into deep wells can increase underground pore pressure sufficiently to overcome frictional resistance and trigger slip on faults in the crystalline basement rock near an injection site, especially where large crustal stresses have brought a fault close to failure [*Nicholson and Wesson*, 1990].

Most induced earthquakes are too small to be felt. However, if a fault of sufficient length is subjected to the right stress conditions, the potential exists for triggering an earthquake with ground motion large enough to cause damage. This potential is a concern for both the public and the state agencies that regulate injection wells.

## Wastewater Disposal in Deep Wells

Over the past decade, innovations in horizontal drilling and hydraulic fracturing technologies have helped drive interest in extracting oil and gas from the Mississippian limestone in Kansas and Oklahoma. Oil and gas production began to rise in Oklahoma in 2009, followed by Kansas in 2012.

The process of extraction from the Mississippian limestone produces large volumes of highly saline formation water, which is typically disposed of in deep saltwater disposal wells. Operators of many newly completed disposal wells initially were permitted to inject fluid into the ground at rates 3–4 times historical levels.

Most of these high-volume wells inject fluid into a rock formation called the Arbuckle Group (see http://bit.ly/Arbuckle-Group), made up of highly permeable Cambrian-Ordovician age sedimentary rocks. With no underlying confining layer in many places, these rocks are hydraulically linked to the Precambrian granite basement that lies below. Such basement rocks typically have many faults, mapped and unmapped, but generally with sparse historical earthquake activity.

## Oklahoma and Kansas Earthquakes

Kansas and Oklahoma are located in a tectonically stable region with low risk for damaging natural earthquakes. Before 2009, both states had a history of seismic activity, with an average of one to two earthquakes of magnitude 3 or larger occurring annually.

A historically unprecedented increase in the rate and magnitude of earthquakes followed the dramatic rise in saltwater disposal in the area. Oklahoma began experiencing an unusually large number of earthquakes in 2009, followed by south central Kansas in 2013.

In 2014, the U.S. Geological Survey (USGS) reported 42 earthquakes of magnitude 3 or larger in Kansas, including a magnitude 4.9 temblor, the largest recorded in Kansas using modern instruments. All but a few epicenters

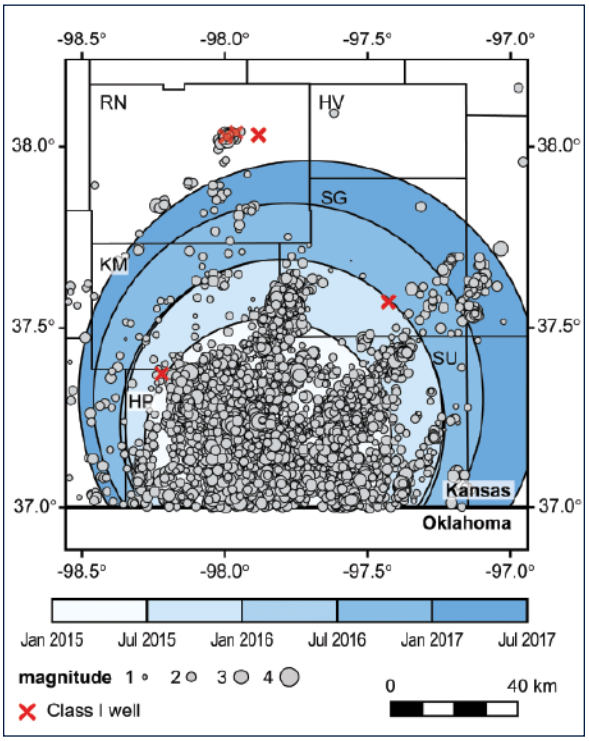


*Fig. 3. Nearly 7,000 earthquakes (gray) were recorded by the Kansas Geological Survey seismic network in Harper (HP), Sumner (SU), Sedgwick (SG), and Reno (RN) Counties from January 2015 through June 2017. Shaded blue circles represent the concentration of earthquake epicenters at 6-month intervals and demonstrate the progression of earthquakes with time to the north and northeast. Injection rates for industrial injection wells (red crosses) in some counties with recent earthquake swarms have remained consistent for years, if not decades. Credit: Modified from* Peterie et al. *[2018]*

were located within five distinct zones in Harper and Sumner Counties, a part of the state with few reported earthquakes in previous years (Figure 1).

## Fluid Injection in Kansas

Numerous industries in Kansas use underground injection control wells for fluid disposal. The state currently manages 50 deep industrial wastewater wells (Class I), regulated by the Kansas Department of Health and Environment, and approximately 5,000 saltwater disposal wells (Class II), regulated by the Kansas Corporation Commission.

Cumulative injection volumes in most areas of the state have been consistent for the past several years. However, by far the most dramatic change in approved volume increases occurred in south central Kansas. The annual saltwater disposal volume in Harper County alone increased from the historical rate of about 10 million barrels to more than 100 million barrels by 2015.

In response to the increased earthquake activity in south central Kansas, Governor Sam Brownback in January 2014 appointed a task force consisting of representatives from the Kansas Geological Survey (KGS), the Kansas Department of Health and Environment, and the Kansas Corporation Commission to consider the matter. The task force developed a response plan for mitigating induced earthquakes and recommended enhanced seismic monitoring.

## Monitoring Seismic Activity

In early 2015, KGS installed six temporary seismograph stations in south central Kansas to closely monitor and better understand the seismic activity. During the first 6 months of monitoring, earthquake epicenters persisted in dense clusters primarily within the same high-seismicity zones identified in 2014.

Conversations with the Oklahoma Geological Survey and the Oklahoma Corporation Commission made it clear that restrictions on individual disposal wells did not always reduce seismic activity. Indeed, the majority of the Oklahoma and Kansas earthquakes do not directly correlate with injection operations at a single nearby well. Rather, the widespread seismicity appears to be a result of cumulative injection in numerous disposal wells [*Walsh and Zoback,* 2015].

Hence, the Kansas Corporation Commission took a geologically based mitigation approach designed to reduce pore pressure around known active fault zones.

Earthquake clustering was used to identify likely basement structures sensitive to changes in deep fluid pressure. The commission ordered reduced injection volumes for saltwater disposal wells located within a set of ellipses defined around the high-seismicity zones in Harper and Sumner Counties. By July 2015, saltwater disposal rates were reduced to near the maximum historical rate in the area prior to the uptick in earthquakes.

## Earthquake Migration

A year after saltwater disposal volumes were restricted, earthquake activity within the injection-restricted footprint dropped dramatically. Only about 250 earthquakes of magnitude 2 or larger were recorded in 2016, compared with nearly 800 in 2015 (Figure 2).

However, earthquake epicenters began gradually migrating into other areas at increasingly greater distances from the initial high-seismicity zones. This earthquake migration followed a distinct northern progression, often along linear trends that suggest fault zones [*Peterie et al.,* 2018]. By early 2017, earthquakes had advanced more than 50 kilometers from Harper and Sumner Counties into neighboring counties with a history of minimal earthquake activity (Figure 3).

This unexpected migration does not fit the traditional model of induced seismicity, where locally elevated pressure triggers earthquakes near the causal well. Owners of industrial injection wells (Class I), which had previously operated for years without incident, became concerned that they would be held responsible for earthquakes in their areas and be required to stop injection operations.

As a result, the Kansas Department of Health and Environment intensified a long-standing wastewater reduction effort for these industrial wells. By 2017, some facilities had already implemented comprehensive wastewater reduction programs, and most were continually refining their processes to reduce wastewater disposal.

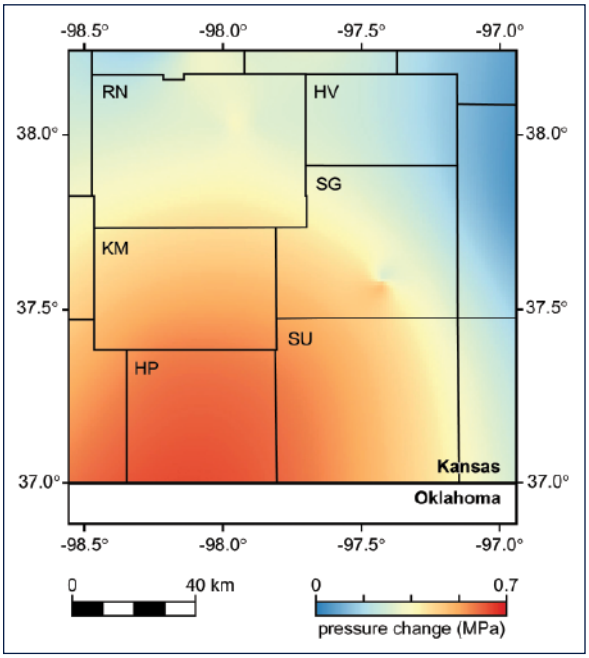


*Fig. 4. Preliminary map of the pressure change measured in Class I industrial wastewater disposal wells in 2016 relative to 2002 baseline measurements. Fluid pressure in the Arbuckle Group has increased across south central Kansas and is most prominent in Harper (HP) County, which experienced a sharp increase in high-volume saltwater disposal starting in 2012. MPa = megapascals.*

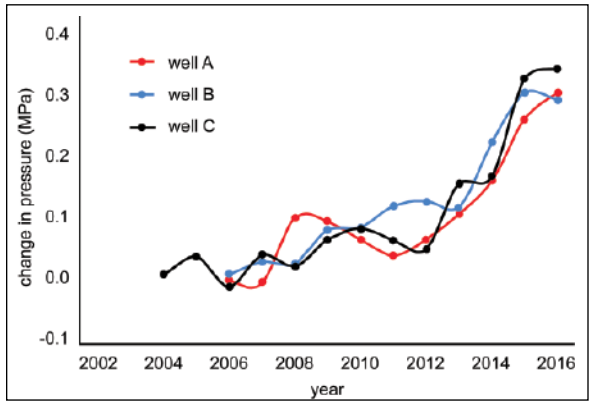


*Fig. 5. Changes in bottomhole pressure (relative to baseline) measured at three Class I facilities in Reno County followed nearly identical trends despite the 5- to 10-kilometer separation between facilities and vastly different injection volumes.*

## Regionally Elevated Fluid Pressure

Numerous studies suggest that a pressure increase of as little as 0.01–0.2 megapascal along a critically stressed fault may be sufficient to trigger an earthquake (by comparison, the air pressure in a car tire is usually about 0.2 megapascal) [e.g., *Keranen et al.*, 2014].

Measurements of pressure at the bottom of wells (bottomhole pressure) that terminate in the Arbuckle Group can provide insight into fluid pressure affecting basement faults. Facilities with active Class I wells, all but one of which terminate in the Arbuckle Group, are required to measure and report bottomhole pressure to the Kansas Department of Health and Environment annually. Bottomhole pressure is not reported for saltwater disposal (Class II) wells, which are subject to different regulatory requirements.

Historically, most Class I facilities measured only small (on the order of 0.05 megapascal) annual bottomhole pressure fluctuations with a relatively flat multiyear trend. Beginning in 2012, increasing bottomhole pressure was measured at several facilities across central Kansas. The most dramatic increase was observed at the southernmost facility, located in Harper County, where by 2016 pressure had increased by more than 0.4 megapascal relative to historical pressures (Figure 4).

Similar but smaller pressure increases were observed in Sedgwick and Reno Counties near areas where earthquakes had advanced in 2016 (Figure 3).

A particularly revealing trend was observed at three facilities in Reno County located within 10 kilometers of an earthquake cluster. Although these facilities inject vastly different disposal volumes and were 5–10 kilometers apart, the bottomhole pressure trends were nearly identical, rising by about 0.2 megapascal in the past few years (Figure 5).

Because annual injection volumes in these and other nearby wells have been consistent for about a decade, it seems highly unlikely that local injection practices alone are responsible for the abrupt and unprecedented increase in formation pressure and seismicity.

## Far-Reaching Effects

The combination of regionally elevated Arbuckle Group fluid pressure (most prominent to the south), a gradual northward progression of earthquake trends well outside the initial high-seismicity zones, and the lack of commensurate changes in local injection volumes supports the hypothesis that the observed pressure increases are predominantly influenced by regional increases in high-volume injection as far as 90 kilometers to the south.

It is not surprising that seismic activity has increased in counties with elevated bottomhole pressure. What is surprising is that the observed rise in bottomhole pressures does not appear to correlate with local (within 20 kilometers) injection volumes in or near the wells where these measurements were made. Rather, the rise in fluid pressure closely tracks significant increases in saltwater disposal volumes several counties to the south.

This observation is notable because the largest previously reported distance between a causal well and an induced earthquake (and thus critically elevated pore fluid pressure) is about 20 kilometers [*Keranen et al.*, 2014].

## Twofold Effect

Although it is unprecedented to suggest that injection practices could influence fluid pressure and seismic activity much more than 20 kilometers away, the volume of fluid injected into this formation is also unprecedented (Figure 6).

A study of the central and eastern United States found that an earthquake is statistically more likely to occur near

wells injecting more than 300,000 barrels per month than near wells injecting at lower rates [*Weingarten et al.*, 2015]. In an area about the size of two counties that spans both sides of the Kansas–Oklahoma border, nearly 50 saltwater disposal wells were each injecting at or above this rate in 2015. Most widely recognized cases of induced seismicity had one or, at most, a few wells injecting near this rate.

The effects of such high-volume injection appear to be twofold. Pressure is locally elevated near a high-volume well shortly after injection begins. This local pressure change directly affects nearby faults and is likely the dominant factor influencing induced earthquakes.

Far-field pressure increases occur as a cumulative effect resulting from fluid migration and pressure diffusion from high-volume injection wells along high-permeability pathways, such as permeable fault zones. Because highly detailed fault maps do not exist for south central Kansas and hydraulic properties can vary widely, predicting fluid flow and migration rates away from an injection site is difficult, at best.

Like local pressure, far-field pressure diffusion triggers earthquakes only where pore fluid pressure exceeds the critical pressure for initiating slip on an appropriately stressed fault. As fluid moves into areas where pressure is locally elevated because of nearby injection operations, a minimal pressure increase may be sufficient to raise absolute pore pressures above the triggering threshold.

This may explain why earthquake swarms have developed in areas with a long history of fluid injection but with no previously known injection-induced earthquakes.

## Regulatory Challenges

Because fluid disposal is widespread and generally involves multiple operators regulated by different agencies within the same state and across state borders, developing equitable practices to minimize increased formation pressures poses unique challenges for regulators.

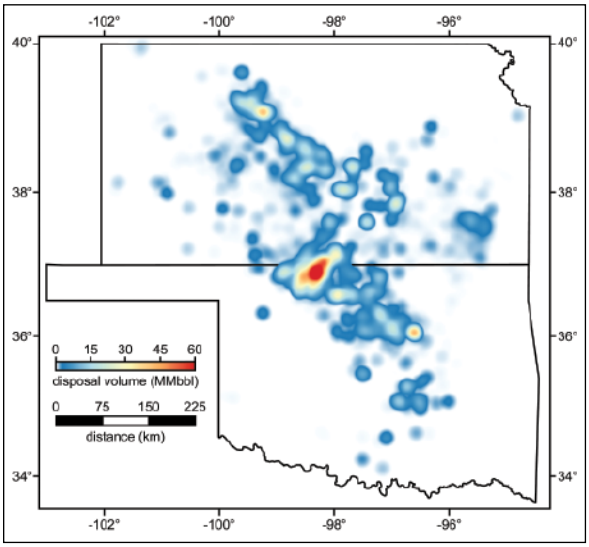


*Fig. 6. Volume of fluid injected into the Arbuckle Group in Class II saltwater disposal and Class I wells in Kansas and Class II saltwater disposal wells in Oklahoma in 2015. MMbbl = million barrels.*

Mitigation of earthquakes caused by local high-volume injection is relatively straightforward: Reduce injection volumes near critically stressed faults sufficiently to reduce pressure below the triggering threshold, and local seismic activity will decrease.

Mitigating earthquakes caused by far-field pressure diffusion is more complex. Just as it took months or years before distant high-volume disposal practices raised the far-field pressure above the triggering threshold, regulatory actions to reduce distant high-volume disposal may take months or years to affect far-field pressure.


*A member of the Kansas Geological Survey field crew installs a seismic station in south central Kansas. Credit: Shelby Peterie*

In addition, because far-field pressure from distant injection combines with local injection pressure to elevate local pressures beyond the earthquake-triggering threshold, seemingly independent injection operations may contribute to triggering earthquakes.

## A Cooperative Approach

After recognizing the synergistic effects of local and far-field pressure changes, the Kansas Corporation Commission and the Kansas Department of Health and Environment, the two state agencies that regulate injection wells, met with KGS to discuss the agency's findings.

Industries currently use Arbuckle Group disposal wells for everything from drinking water treatment to oil production and refinement, each of which has unique operational processes, business models, and stakeholders. Not only do two separate agencies regulate injection wells, but also the diversity of industries performing Class I and Class II injection operations, ownership of mineral rights as well as other legal and regulatory issues, and movement of fluids across state lines add to the complexity of seeking efficient solutions.

Both regulating bodies are currently providing data to and meeting with KGS regularly in a collaborative effort to develop and implement recommendations. Joint policies between state agencies to address injection volumes and establishment of other best management practices would be an equitable and effective approach to mitigating induced seismicity from regional pressure changes.

Data used in this study can be found in the supporting information of *Peterie et al.* [2018]. Injection volumes for Oklahoma Class II wells are provided by the Oklahoma Corporation Commission (see http://bit.ly/OCC-data-files).

## Acknowledgments

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AGU Publications again recognizes a number of outstanding reviewers. They were selected by the editors of each journal for their work in 2017.

Peer-reviewed literature plays an important role in advancing science. Less well known is the growing use of peer-reviewed literature in our legal systems and governments as a basis for regulations, policies, and laws. This literature also provides reliable scientific information for such advisory groups as the Intergovernmental Panel on Climate Change and the National Academies.

Quality peer review is thus a critical part of the social contract between science and society. As the uses for this literature have grown, so has the complexity of papers, which now typically include more authors bringing more techniques, data, simulations, and results.

The outstanding reviewers listed on the following pages have all provided in-depth evaluations, often over more than one round of revision, that greatly improved the final published papers. This increase in complexity, in turn, has increased the challenge and the role of reviewing.

### Many Reviewers: A Key Part of AGU Journals

While we note these few outstanding reviewers here, we also acknowledge the broad efforts of all AGU reviewers in helping ensure the quality, timeliness, and reputation of AGU journals. Overall, AGU in 2017 received more than 14,300 submissions and published nearly 6,400 papers. Many of these submissions were reviewed multiple times—in all, representing more than 34,000 reviews in 2017.

This happened in the past year while every AGU journal worked to shorten the time from submission to first decision and publication or maintained already industry-leading standards. Several AGU journals regularly return first decisions within 1 month of submission, and most others do so now within 2 months. Reviewers represent a key part of this improvement.

> Our thanks are a small recognition of the large responsibility that reviewers shoulder in improving our science and its role in society.

Our thanks are a small recognition of the large responsibility that reviewers shoulder in improving our science and its role in society. Editorials, some already published, some upcoming, along with recognition lists, express our appreciation.

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In addition, we are working to highlight the valuable role of reviewers through events at the Fall Meeting and other meetings.

We are extending subscription benefits to those reviewers who repeatedly provide quality reviews. Each reviewer also receives a discount on AGU and Wiley books. We will continue to work with the Open Researcher and Contributor Identification (ORCID) network to provide official recognition of reviewers' efforts, so that reviewers receive formal credit there. To date, we have more than 39,000 ORCIDs linked to GEMS user accounts, compared with 26,000 at this time last year.

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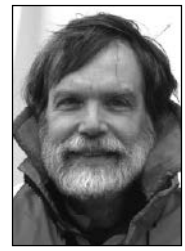

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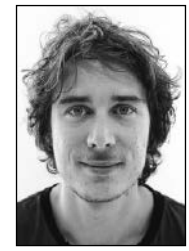

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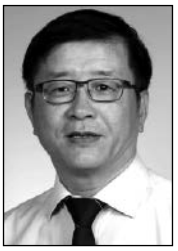

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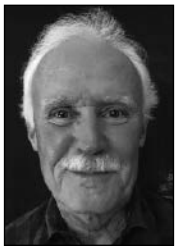

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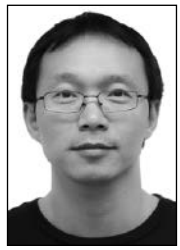

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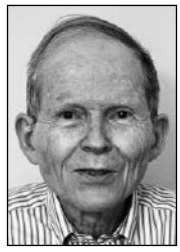

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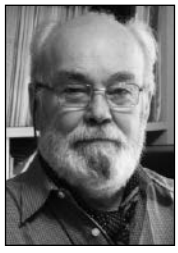

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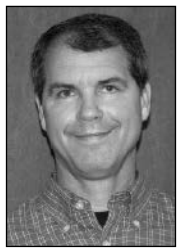

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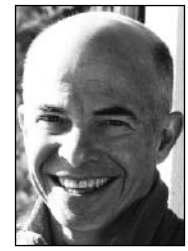

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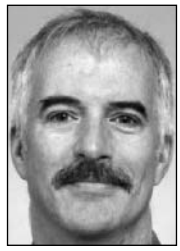

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# Improving Tropical Cyclone Predictions in the Gulf of Mexico

*Hurricane Harvey, the first major hurricane to strike the United States since 2005, killed at least 88 people and caused an estimated $125 billion in damage after making landfall along the Texas coast on 25 August 2017. Credit: NASA*

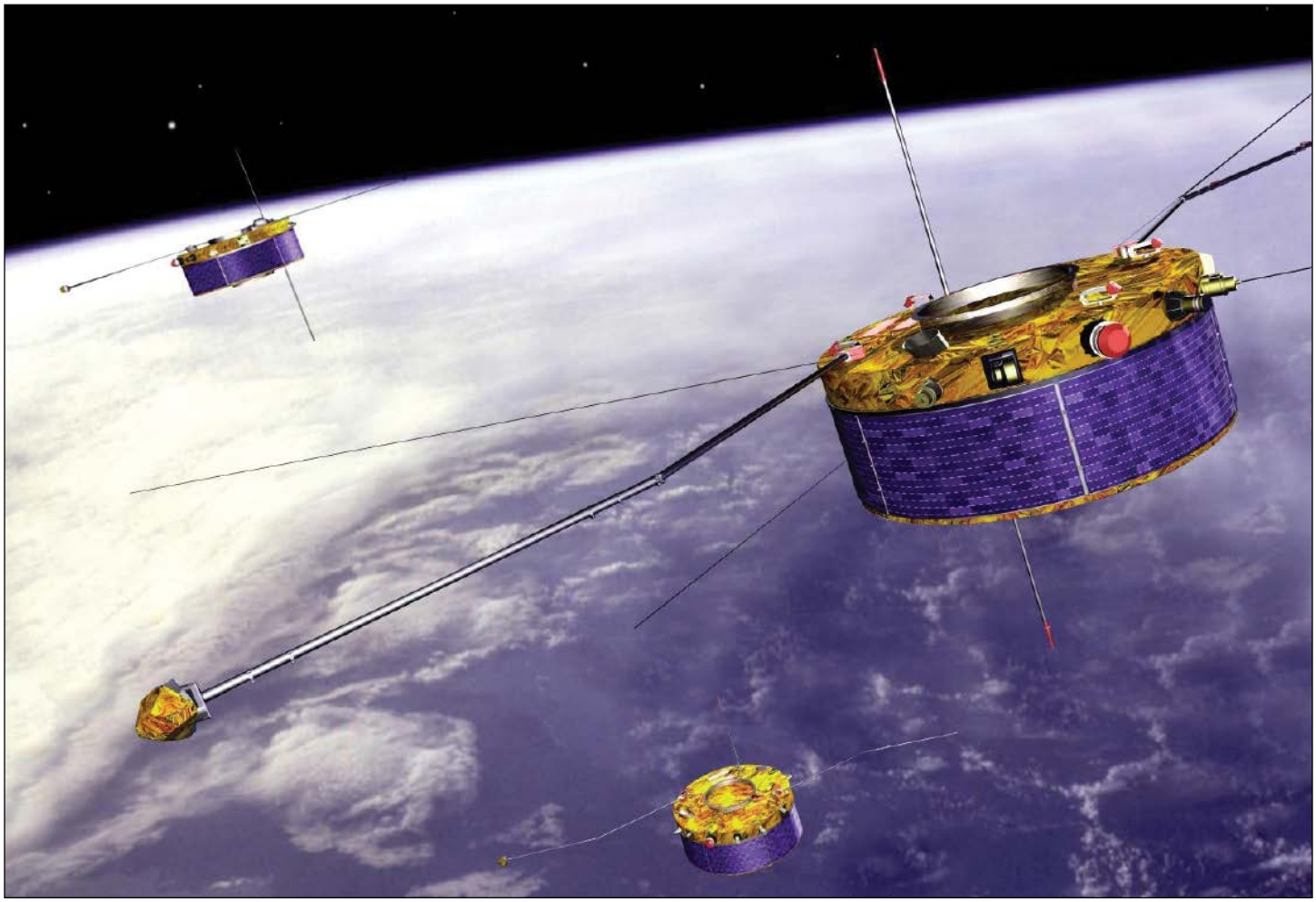
When tropical cyclones—storm systems ranging in strength from tropical depressions to major hurricanes—form over the Gulf of Mexico's warm waters, they have a high chance of causing many deaths as well as widespread property damage in coastal communities. Although accurate predictions of cyclone activity could help reduce such destruction, global models do not yet have a good track record of predicting tropical cyclone formation in this region.

One reason for this deficiency may be that global models have so far proven incapable of capturing the complex relationship between cyclone activity and intraseasonal oscillations in the tropical atmosphere. Also called the Madden-Julian Oscillation, these large-scale wave patterns create eastward propagating pulses of anomalous wind, rainfall, cloud cover, and sea surface temperature variations that typically recur every 30–60 days. Despite previous studies indicating that intraseasonal oscillations in the northeastern Pacific Ocean can significantly influence cyclone activity in the western Caribbean Sea and the Gulf of Mexico, dynamic models have so far been unable to accurately reproduce this relationship.

Now *Gao et al.* evaluate the ability of the Geophysical Fluid Dynamics Laboratory's latest High Resolution Atmospheric Model (HiRAM) to simulate this relationship on the basis of retrospective seasonal predictions for the 25-year period between 1990 and 2014. Their results indicate that HiRAM successfully captures the influence of intraseasonal oscillations on tropical cyclone activity in the Gulf of Mexico region, including the formation of tropical storms and major hurricanes, as well as those that make landfall.

The authors attribute the model's success to its realistic representation of large-scale oscillations and moisture variations over the northeastern Pacific during the Northern Hemisphere summer, a finding that lends additional support to the idea that convection in the Gulf of Mexico is strongly influenced by atmospheric variability over the Pacific. HiRAM's overall success suggests that in the future, it could be used to predict regional tropical cyclone risk for periods ranging from 2 weeks to a couple of months—timescales that could potentially benefit the Gulf of Mexico's coastal communities. (*Journal of Geophysical Research: Atmospheres,* https://doi.org/10.1002/2017JD027756, 2017) **—Terri Cook, Freelance Writer**

# How Space Storms Affect the Satellite Superhighway



*Artist's rendering of the Cluster spacecraft. Credit: NASA*

Some 36,000 kilometers above Earth, more than 400 commercial, telecommunication, and weather satellites dance in geosynchronous orbit, circling the planet at precisely the same rate that it turns. This so-called satellite superhighway is occasionally whipped by solar wind and fluctuating magnetic fields, a chaotic environment that can damage and interfere with the spacecraft. Now a new 3-D mathematical model of the magnetic environment in the region could help researchers predict how storms affect the geosynchronous magnetic environment.

The researchers' previous attempt to model the solar wind's impact on the geosynchronous magnetic field was conducted more than 25 years ago and did not account for space storms that occur when solar particles slam into Earth's protective magnetosphere. It also used data from only a single satellite, which limited the model's ability to capture the complex dynamics in this zone.

In their new study, *Andreeva and Tsyganenko* used radial basis functions—a numerical methodology to crunch data from multiple satellites, including Time History of Events and Macroscale Interactions during Substorms (THEMIS), Polar, Cluster, and the Van Allen Probes. This computational approach takes into account all major sources of the geomagnetic field, such as the ring and tail currents that result from the solar wind flow around Earth's magnetosphere.

Previously, the team had shown that this approach can accurately model the magnetic field in a given region, including its disturbance by space weather. In their new study, the researchers took into account both the current state of the solar wind and the interplanetary magnetic field—the Sun's magnetic field that gets carried into space—and their previous history. They found that the radial basis function model performed better than earlier attempts to model the region, and they validated it using two separate data sets. Yet they were not able to fully model variations related to substorms, the violent and brief electromagnetic disturbances that cause auroras. The authors note that this is a major stumbling block that will have to be addressed in future research. (*Space Weather*, https://doi.org/10.1002/2017SW001684, 2018)

**—Emily Underwood, Freelance Writer**

# Dust Does Not Control Surface Ocean Productivity

In open-ocean, nutrient-depleted ecosystems, atmospheric dust is often considered a vital source of biologically important trace metals and limiting nutrients. By supplying such elements as phosphorus, iron, and nitrogen, this dust appears to increase primary productivity, which in turn modifies carbon and other biogeochemical cycles. Yet despite marine ecosystems' apparent dependence upon atmospheric dust, few studies have documented a direct, long-term connection between it and surface productivity.

To clarify this relationship, *Torfstein and Kienast* compared in situ surface concentrations of atmospheric dust and chlorophyll *a*—a common measure of ocean productivity—in the Gulf of Aqaba, a long, narrow extension of the nutrient-depleted Red Sea, limited in both phosphorus and nitrogen.

To overcome this complication, the team compared continuous, daily records of these parameters between 2012 and 2016, with the unique advantage of evaluating the impact of discrete dust storms on marine productivity. The high-resolution results show that no correlation exists between the gulf's surficial dust and chlorophyll *a* concentrations, even when the researchers account for lags in the marine ecosystem's response, between 1 and 10 days.

This finding contradicts the results of previous studies that indicated the importance of dust-derived nutrients for phytoplankton growth. This inconsistency suggests that the role of atmospheric dust in controlling ocean productivity in the northern Red Sea—and possibly other nutrient-poor regions—may have been overestimated. Because the impact of the dust extends throughout the water column, rather than solely at the surface, the authors suggest that future work should evaluate the relationship between these parameters across a greater depth range.

In the past, it has also been suggested that too much dust could have toxic effects on phytoplankton growth. In that case, one could expect a negative correlation between the two, but that was not observed by the team either. Because the Gulf of Aqaba is an important analogue for other warm, nutrient-depleted ocean waters, these study findings are likely to have important implications for understanding biogeochemical cycles in warmer and increasingly arid subtropical oceans. (*Journal of Geophysical Research: Biogeosciences,* https://doi.org/10.1002/2017JG004063, 2018) **—Terri Cook, Freelance Writer**

*A dust cloud smothers the waters of the Gulf of Aqaba in May 2017. Credit: Adi Torfstein*

# Evidence for Gravity Tectonics After the Great Sumatra Quake

Following the devastating $M_w$ 9.2 great Sumatra earthquake in 2004, the predominant types of aftershocks varied along the length of the nearly 1,500-kilometer-long megathrust rupture. On the northern Sumatra segment, where the earthquake began, compressional (thrust) earthquakes prevailed, whereas extensional earthquakes dominated in the Andaman segment farther north.

*Damage caused by the tsunami spawned by the 2004 great Sumatra earthquake. Credit: Robert Morton, U.S. Geological Survey*

To better understand puzzling aftershock patterns, a team of researchers created eQuakes, a computer program that helps apply basic structural geology principles to the analysis of aftershock sequences using data extracted from the Global Centroid-Moment-Tensor (CMT) database. *Lister and Forster* used the output to conduct a structural analysis of the highly seismogenic Sumatra margin.

The results indicate that the stress state along the megathrust varied widely across a short distance following the great Sumatra earthquake. In the south, the overriding crust was compressed perpendicular to the plate margin, a direction consistent with the relative motion of the adjoining tectonic plates. To the north, however, the researchers found that the overriding crust was stretched perpendicular to the plate margin, a direction that they argue is consistent with gravity-driven motion toward the gravity well that had accrued because of the earlier rollback of the Indian plate's subducting edge.

This gravity-driven motion was relatively short-lived, however; the team's analysis of an earthquake cluster in the Andaman Sea that occurred 15 months after the main shock shows that the margin had resumed its plate-driven motion by that time. According to the authors, this transition may be explained by fluid activity that temporarily reduced frictional constraints along the megathrust, allowing gravity to drive the motion while the fault was in a weakened condition.

These findings indicate that abrupt switches between tectonic modes are possible even within the duration of a single earthquake cycle. They also suggest that although plate tectonic–driven motion dominates during interseismic gaps, gravity tectonics may play an important postseismic role. In this case, the crust slid sideways (westward), toward the gravitational potential well caused by the rollback of the subducting edge of the Indian plate. This study has broad implications for understanding both the seismic cycle and the long-term dynamics of mountain building. (*Tectonics,* https://doi.org/10.1002/2017TC004708, 2018) **—Terri Cook, Freelance Writer**

# A Complete Picture of Southern Ocean Surface Circulation

The Atlantic, Pacific, and Indian Oceans meet in the Southern Ocean, an uninterrupted body of water that encircles the continent of Antarctica. It's one of the most climatically critical regions in the world. With no landmasses in the way, powerful westerly winds whip up the Antarctic Circumpolar Current (ACC), the strongest current system on the planet. Farther south, easterly coastal winds drive the Antarctic Slope Current (ASC), which flows along regions at the interface of the vast Antarctic ice sheet and the open ocean. Researchers rely on measures of the height of the ocean surface for insights into its currents and how those currents relate to weather and climate. But the remoteness of the Southern Ocean and its harsh climate have long limited researchers' ability to study the region.

Since the 1990s, radar altimeter measurements from instruments aboard satellites have provided scientists with an incomplete picture of sea levels and surface circulation in the open ocean around Antarctica. Space-based measures of the sea surface are often obscured by the presence of sea ice, which can cover as much as 19 million square kilometers of the Southern Ocean in winter. However, novel methods recently have been developed to estimate sea surface heights in ice-covered regions from radar altimeter data by picking out openings in the pack ice.

In a new paper, *Armitage et al.* combine conventional radar altimeter estimates of sea surface height in open regions with height estimates in ice-covered regions to create the first complete picture of sea levels and circulation across the entire Southern Ocean between 2011 and 2016. The study is the first to examine circumpolar sea surface height variability along the Antarctic margins.

The authors found that sea level changes are linked to two climate indices: the Southern Oscillation Index, which gives researchers some insight into the development and intensity of El Niño and La Niña events in the Pacific Ocean, and the Southern Annular Mode, which tracks the northward or southward migration of the westerly wind belt that blows around Antarctica. The strong 2014–2016 El Niño event, for example, was associated with drops in sea level around coastal West Antarctica and a weakened ASC in the Ross, Amundsen, and Bellingshausen Seas.

The combined data set was based on monthly measures, which allowed the scientists to investigate seasonal sea surface height changes as well. The data set showed that along the Antarctic coast, sea levels were highest in the fall and lowest in the spring, with the pattern reversed farther out in the deeper ocean. The seasonal height variability kicked the nearly circumpolar ASC into high gear; the current moved regionally up to twice as fast in the autumn months, according to the study.

The study, a first look at sea surface height and circulation across the entire Southern Ocean, provides researchers with new insights into the Antarctic continental shelves and the Ross and Weddell gyres, regions that drive important ocean overturning and affect ocean heat delivery to the Antarctic ice sheet. (*Journal of Geophysical Research: Oceans*, https://doi.org/10.1002/2017JC013534, 2018) **—Kate Wheeling, Freelance Writer**

*An iceberg floating in the Southern Ocean. Credit: Andrew Shiva/Wikipedia, CC BY-SA 4.0 (http://bit.ly/ccbysa4-0)*

# Evidence of Extensive Ice Deposits near Mercury's South Pole

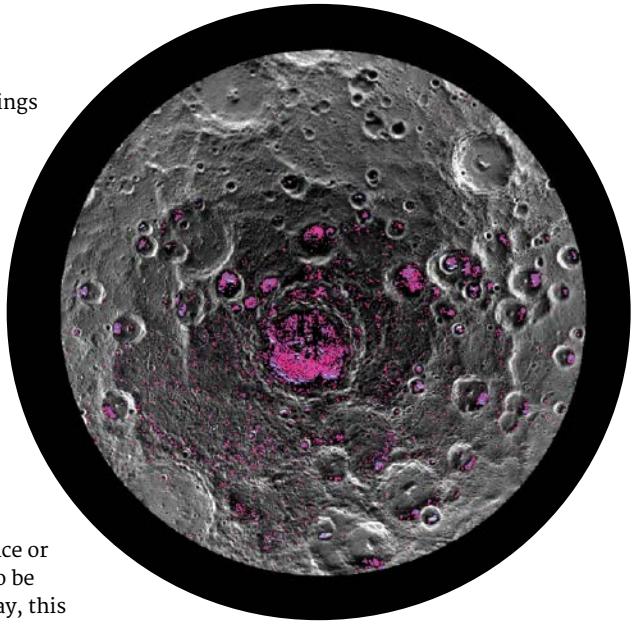
Earth-based radar and observations of Mercury by the Mercury Surface, Space Environment, Geochemistry, and Ranging (MESSENGER) spacecraft have revealed numerous, highly reflective "radar-bright" deposits near both of the planet's poles. Because of their correlation with permanently shadowed, low-temperature regions as well as distinctive characteristics associated with ice on other celestial bodies, these deposits have been interpreted as water ice deposits. However, imaging of the south pole has been limited and of lower fidelity than that of the north polar region, so comparisons between the two have not been possible—until now.

*Chabot et al.* present new radar observations of Mercury's south pole that significantly expand this coverage and, in combination with new solar illumination maps, allow the team to contrast the extent of radar-bright deposits and permanently shaded regions at both poles. By combining high-resolution data acquired at Arecibo in 2012 with previous radar observations, the researchers calculated that 4.4% of the area between 80°S and 90°S is radar bright—about twice the amount previously mapped in Mercury's north polar region.

The team also used standard and long-exposure camera images acquired by MESSENGER to estimate that 5.7% of Mercury's south polar region is permanently shadowed, roughly 50% more than the same area encircling the north pole. These findings are consistent with the southern region's older, more heavily cratered terrain, whose topography creates more permanently shaded areas with temperatures that are potentially low enough to harbor ice.

Although the researchers found that the radar-bright regions are consistently located in permanently shaded areas, they also discovered that nearly half of these nonilluminated regions do not contain radar-bright deposits. This discrepancy, they argue, could be because the shaded areas lack water ice or because the ice is too deeply buried to be detected in those locations. Either way, this uneven distribution implies that the polar water ice was not delivered by a steady source—like planetary outgassing or solar wind generation—but rather by an episodic event, such as a large comet impact.

These results support the observation that Mercury's south pole has a substantially higher volume of frozen water ice and other volatiles than Mercury's north pole and provide strong new evidence for a recent impact event as the source. In addition to offering exciting new evidence regarding the source of Mercury's ice deposits, these findings also provide additional resources to guide further exploration of the innermost planet's ice deposits by the upcoming BepiColombo mission, which is scheduled to launch in October. (*Journal of Geophysical Research: Planets*, https://doi.org/10.1002/2017JE005500, 2018) **—Terri Cook, Freelance Writer**



*Mercury's south pole to 80°S, with an Arecibo radar image in pink indicating locations of water ice. Credit: Nancy Chabot*

# Fossilized Caribbean Corals Reveal Ancient Summer Rains

*Fossilized corals (pictured here with a wristwatch for scale) from the coast of the Caribbean island of Bonaire. Credit: Thomas Felis, MARUM–Center for Marine Environmental Sciences, University of Bremen*

Near Earth's equator, southern winds meet northern winds in a rainy ring around the globe known as the Intertropical Convergence Zone (ITCZ). The ITCZ follows the Sun, migrating slightly north or south depending on the season. New research by *Brocas et al.* examines clues from ancient corals to reveal how seasonal ITCZ shifts under warmer climate conditions brought heavier summer rainfall to the southern Caribbean Sea.

Previous research has explored the effects of ITCZ migration on long timescales, including associated changes in the Atlantic Meridional Overturning Circulation, a system of currents that contributes to global circulation of ocean waters. However, it is unclear how global warming might affect seasonal ITCZ migrations, as well as the resulting regional weather effects, such as drought or heavy precipitation.

To explore the potential effects of climate change, the researchers turned to the last interglacial (LIG) period, when global temperatures were warmer than they are today. Fossilized corals from that period hold records of seawater temperature and salinity in the form of distinct ratios between different elements and isotopes. These records allow scientists to estimate the amount of freshwater in the ocean at a given time, which corresponds to rainfall.

To reconstruct month-to-month rainfall rates during the LIG, the researchers analyzed oxygen isotope ratios in fossil corals from the southern Caribbean island of Bonaire. They compared these results with seasonal rainfall patterns during modern, middle to late Holocene, and late LIG climates, which had previously been reconstructed using coral records from the same island.

The analysis revealed that oxygen isotope ratios varied more strongly between seasons during the mid-LIG (124,000–126,000 years ago) than today, reflecting greater seasonal variability in rainfall amounts. This increased rainfall seasonality accompanied the increased seasonal variation in sea surface temperature associated with seasonal differences in the amount of sunlight that reaches the Caribbean.

The researchers also performed climate model simulations for the mid-LIG that confirmed that increased summer rainfall in the southern Caribbean could be responsible for the summertime changes in oxygen isotope ratios seen in the fossil corals. If that's the case, these results would suggest a different regional climate from today's, which is semiarid and features a minor rainy season in wintertime.

Overall, these findings suggest that the ITCZ expanded northward into the southern Caribbean Sea during the mid-LIG. According to the authors, these results highlight the need to consider regional scales when examining ancient rainfall and other climate patterns. (*Paleoceanography and Paleoclimatology*, https://doi.org/10.1002/2017PA003216, 2018) **—Sarah Stanley, Freelance Writer**

## Atmospheric Sciences

### Postdoctoral research associateship in cloud parameterization

Applications are invited for a postdoctoral research associateship in the parameterization of turbulence and clouds. The project seeks to improve the higher-order closure parameterization of clouds in the Department of Energy's new climate model, E3SM. Duties include improving the simulation of all cloud types and improving the parameterization's numerics and efficiency.

The project involves close collaboration with scientists at DOE laboratories, and the applicant will work directly with Vincent Larson (http://www.uwm.edu/~vlarson) at the University of Wisconsin-Milwaukee (UWM). The initial appointment will last for one year but may be renewed for an additional year upon mutual consent.

Desired qualifications include a Ph.D. in atmospheric science or a related field, knowledge of Fortran or another compiled computer language, and experience working with a numerical model, such as a climate model, numerical weather prediction model, or large-eddy simulation model.

To apply, interested candidates should send a statement of interest, CV, and contact information of three references to Vincent Larson at vlarson@uwm.edu. Review of applications will start on 15 Jun 2018.

## Biogeosciences

### Two Faculty Positions at Shanghai Ocean University

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

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

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

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

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

## Interdisciplinary

### Asiaq, Greenland Survey announces a permanent position for a researcher and program coordinator within the Hydrology, Climate and Environment group

We offer a challenging position as a researcher within climate and cryosphere at Asiaq, Greenland Survey. Asiaq is leading the three ClimateBasis and one GlacioBasis sub-program of the Greenland Ecosystem Monitoring programme (GEM, www.g-e-m.dk). Within these programs our aim is to provide reliable data for interdisciplinary ecosystem studies since 1996 in Zackenberg, Northeast Greenland, since 2007 in Nuuk, Southwest Greenland and since 2016 in Qeqertarsuaq, West Greenland. The researcher will be responsible for (I) ensuring continuity in the monitoring; (II) organizing and conducting field work; (III) performing quality control, processing and analysis of the monitoring data; and (IV) publish the results to the scientific community and to public outreach. Tight collaboration and coordination with colleagues in Asiaq both technicians and academic personal, as well as international partners within GEM and beyond is essential and facilitated. Developing project ideas and preparing applications will be an important component of this position.

You are a researcher within the field of climatology or cryosphere and have an excellent publication record and a well-established international network. Ideally, you have Arctic experience and worked with interdisciplinary projects before. You have advanced programming skills and processing of large data amounts and/or database handling is natural to you. You are excited about working in an international environment, have substantial field experience, are willing to travel and can imagine living in fascinating Greenland. Excellent spoken and written English is required. Experience with project management, research applications and public outreach is essential.

Asiaq is a company owned by the Government of Greenland. With a total of 28 interdisciplinary and international employees we are responsible for monitoring the non-living environment in Greenland. Our tasks range from research, consultancy and commercial activities to monitoring and advisory for public authorities. You will be working within the Hydrology, Climate and Environment Department that includes a workshop with several technicians.

Conditions of Employment

Employment conditions follow the agreement between the Government and the respective union and are competitive at international standards. Workplace is in Nuuk, Greenland's capital with its thriving multi-ethnic community and its endless outdoor opportunities in the backyard. Staff accommodation will be assigned in accordance with applicable rules. Relocation and travel costs will be paid for the employee, accompanying partner and children at the time of taking up employment, as well as when leaving after at least three years of employment.

More information

Find information on Asiaq, products, tasks and research on www.asiaq.gl. You are welcome to contact Dr. Martin Olsen (Head of Department, mno@asiaq.gl), or Dr. Jordi Cristóbal Rosseló (Atmospheric Scientist, jcr@asiaq.gl), for additional information.

Application Deadline

Application deadline is 01-06-2018 and the position will be filled as soon as possible.

Please send a letter of motivation, CV, list of publications, relevant exam records and contact information for two referees with subject 'Researcher–Ice and Climate' to: asiaq@asiaq.gl

### Department Head–Geology and Geological Engineering

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

and teaching. We are especially interested in candidates with a passion to advance the University's diversity and online commitment.

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

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

### Ocean Science

**Applied Physics Laboratory – Research Associate**

The Applied Physics Laboratory at the University of Washington (APL-UW) is seeking Post-doctoral Research Associates with research interests in Oceanography, Polar Science, Remote Sensing, Environmental Acoustics and Ocean Engineering. These are full-time (100% FTE) appointments, with expected terms of two years subject to satisfactory performance and availability of funding.

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

More information: http://ap.washington.edu/ahr/academic-jobs/position/aa27897/

Applicants asked to submit electronically:

(1) A curriculum vitae,

(2) A publication list,

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

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

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

Applications should be submitted via email:

Dr. Kevin Williams

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

williams@apl.washington.edu

**Tier 2 CRC in Physical Oceanography**

The Department of Oceanography at Dalhousie University is seeking applicants for a Tier 2 Canada Research Chair (CRC) in Physical Oceanography. Applicants must hold a PhD in Physical Oceanography or a closely related discipline, and have a strong record of research excellence. The applicants' research should address ocean dynamics on a range of temporal and spatial scales, and it should complement the existing research activities by physical oceanography faculty in the Department, e.g., ocean models and observational analyses, shelf and deep ocean circulation, nearshore processes, air-sea interactions, climate variability, ocean acoustics, and mixing. Interests in cross-disciplinary oceanographic research are an asset.

The successful applicant will be appointed to a tenure-track position at the rank of Assistant or Associate Professor. The anticipated start date is 1 July 2019, or as negotiated. The application should include a detailed curriculum vitae, a two- to three-page statement of research interests, three representative publications, the names and contact information of three references, and a completed Self-ID questionnaire (www.dal.ca/becounted/selfid). Review of applications will begin on 4 June 2018 and will continue until the position is filled. Please send the complete application as a single pdf to:

Dr. Katja Fennel

Search Committee Chair, Tier 2 CRC in Physical Oceanography

POsearch@dal.ca

The CRC program was established to attract outstanding researchers to Canadian universities (see www.chairs.gc.ca for more information). Dalhousie University encourages applications from Aboriginal people, persons with a disability, racially visible persons, women, persons of minority sexual orientations and gender identities.

U.S. NAVAL RESEARCH LABORATORY

**POSTDOC POSITION AT NAVAL RESEARCH LAB SSC**

Marine Bioluminescence

The Naval Research Laboratory at Stennis Space Center, MS (NRLSSC) invites applications for a **postdoctoral scientist position** to conduct research in lab and field related to marine bioluminescence. The successful candidate will conduct studies that include modeling and measurement of biolum response function of various species under different conditions. Training in marine biology, optical and physical oceanography (particularly those related to microstructure modeling and measurement) is required. Research experience in more than one of the following areas is preferred: cell culturing, bioluminescence theory and measurement, turbulence modeling and measurements, imaging, ocean lidar, and in-situ oceanographic measurements especially ocean optical properties. The candidate is expected to conduct experiments both in lab and at sea, in a team environment, and will benefit from a diverse cutting-edge research portfolio. The candidate is strongly encouraged to develop his/her own research focus to advance his/her professional growth and career, while meeting long term Lab goals.

U.S. citizenship or permanent residency (Green Card) is required. The one year appointment can be extended for a maximum of three years at the lab's discretion. Detailed requirement and program information (including the yearly stipend level around $79,720, plus travel and relocation) can be found at the official website: **https://www.nrl.navy.mil/careers/post-doc/**. NRL is an Equal Opportunity Employer.

Inquires about the position should be made directly to:

**Dr. "Will" Weilin Hou**

Naval Research Laboratory

Stennis Space Center, MS 39529

228-688-5257

**hou@nrlssc.navy.mil**

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

# Faculty Position in Computational Environmental Sciences and Engineering

## at the Ecole polytechnique fédérale de Lausanne (EPFL)

The EPFL School of Architecture, Civil and Environmental Engineering (ENAC) invites applications for a faculty position in its Institute of Environmental Engineering (IIE), either at the tenure track level (Assistant Professor) or the tenured level (Associate or Full Professor). The appointee will join the newly formed EPFL Centre for Changing Alpine and Polar Environments (CAPE), based in Sion, Switzerland, and contribute to research and teaching activities within IIE. This appointment is one of several CAPE professorships, and offers unrivalled collaboration opportunities at the local and European levels.

Analogously to the early days of computational biology, computational environmental sciences and engineering are now on the rise. The role of computation in understanding changing environments is pervasive, being central to, for example, process-based models, design of sensor networks, and big data analysis and visualization. The research vision of CAPE includes developing understanding of connections between models across scales, from global earth system simulation to small-scale ecosystem functioning. The appointee will investigate multiscale analysis of environmental systems found at high latitudes or high elevations. Research foci of interest include, but are not limited to, development of multiscale models linked with widespread environmental data, sensor networks, biogeochemical fluxes across scales, hydrological and ecological networks, and data-driven environmental system modelling.

We seek an outstanding individual who will lead an internationally recognized research program that extends and leverages the opportunities offered by CAPE/EPFL. The professor will be committed to excellence in research and in undergraduate and graduate level teaching, and will contribute to the teaching program in Environmental Engineering at EPFL, which views basic and translational research as the foundation for environmental adaption and engineering design.

With its main campus located in Lausanne and its developing antennae in neighbouring cantons in Switzerland, EPFL is a growing and well-funded institution fostering excellence and diversity. It is well equipped with experimental and computational infrastructure, and offers a fertile environment for research collaboration between different disciplines. The EPFL environment is multilingual and multicultural, with English serving as a common interface. EPFL offers internationally competitive start-up resources, salaries, and benefits. It is committed to increasing the diversity of its faculty, and strongly encourages women to apply.

The following documents are requested in PDF format: cover letter including a statement of motivation, curriculum vitae including explicit mention of career breaks, publications list, concise statements of research and teaching interests (3-5 pages) as well as the names and addresses, including emails, of at least three references for junior positions or five references for senior positions (may be contacted at a later stage). Applications should be uploaded to the EPFL recruitment web site:

https://facultyrecruiting.epfl.ch/position/10977282

Formal evaluation of the applications will begin on **September 1, 2018** and the search will continue until the position is filled.

Further enquiries should be made to:
**Prof. D. Andrew Barry**
Chair of the Search Committee
**E-mail: searchenvironmental@epfl.ch**

For additional information on EPFL:
http://www.epfl.ch, http://enac.epfl.ch;
https://valais.epfl.ch/Home

*EPFL is an equal opportunity employer and a family friendly university.*

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

# Faculty Position in Terrestrial Ecology

## Joint Appointment between the Swiss Federal Institute for Forest Snow and Landscape Research (WSL) and the Ecole polytechnique fédérale de Lausanne (EPFL)

EPFL's School of Architecture, Civil and Environmental Engineering (ENAC) and the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) invite applications for either a tenure-track (Assistant) or tenured (Associate or Full) Professor in the Institute of Environmental Engineering. The appointee will lead the Swiss Romande WSL Site, and contribute to research and teaching activities within the EPFL Institute of Environmental Engineering.

The Institute of Environmental Engineering (IIE) in ENAC carries out basic and translational research spanning fundamental understanding of environmental systems and their resilience to design of adaption strategies. It covers a diverse portfolio in research, teaching and innovative technology development, including: Climate Change and Geochemical Cycles, Hydrology, Hydrodynamics, Precipitation, Water Quality, Bioremediation, Ecotoxicology, Air Quality, Renewable Energy, City and Landscape Development, Ecosystems, Ecology and Robotics. These research themes are underpinned by extensive facilities in, e.g., chemical, microbial and isotopic analysis. This professorship, along with the WSL Swiss Romande site, is located at EPFL's main campus at Lausanne. While IIE as a whole is mainly based in Lausanne, it is currently undergoing expansion at the EPFL Sion campus, with the creation of the new Centre for Changing Alpine and Polar Environments.

WSL is the national Swiss organization for basic and applied research into use and management of natural resources including forests, landscapes, and biodiversity. It focuses on use and protection of resources and the management of risks of natural hazards. Together with civic and governmental bodies, WSL seeks sustainable solutions to societally relevant questions.

The joint WSL/EPFL professor in terrestrial ecology will have acknowledged strengths in research related to forests, biodiversity and ecosystem services in dynamic environments. Areas of interest within these domains include, but are not limited to: functional biodiversity in different settings (urban to forested), responses and adaption of ecosystems to global changes, management of ecosystem services at local-to-global scales, plant-soil interactions, and ecosystem climate responses.

The WSL/EPFL professor will lead an internationally recognized research program that leverages the opportunities offered by WSL and EPFL. The professor will support WSL research and outreach activities, and enhance the group's integration into teaching and transdisciplinary research within ENAC. The appointee will promote excellence in research and in undergraduate and graduate level teaching.

The WSL/EPFL Professor of Terrestrial Ecology will be located at EPFL. EPFL is a growing and well-funded institution fostering excellence and diversity, with a highly international campus at an attractive location with excellent experimental and computational infrastructure. Teaching and research at EPFL covers essentially the entire palette of engineering and science, and offers a fertile environment for research collaboration between different disciplines. The EPFL environment is multilingual and multicultural, with English serving as a common interface. It is committed to increasing the diversity of its faculty, and strongly encourages women to apply.

The following documents are requested in PDF format: cover letter including a statement of motivation, curriculum vitae including explicit mention of career breaks, publications list, concise statements of research and teaching interests (3-5 pages) as well as the names and addresses, including emails, of at least three references for junior positions or five references for senior positions (may be contacted at a later stage).
Applications should be uploaded to the EPFL recruitment web site

https://facultyrecruiting.epfl.ch/position/10977284

Formal evaluation of the applications will begin on **August 15, 2018** and the search will continue until the position is filled.

Further enquiries should be made to:
**Prof. D. Andrew Barry**
Chair of the Search Committee
**E-mail:** SearchTerrestrialEco@epfl.ch

For additional information on WSL and EPFL:
http://wsl.ch, http://www.epfl.ch, http://enac.epfl.ch

*EPFL is an equal opportunity employer and a family friendly university.*

# Postcards from the Field

Dear Everyone:

At the end of the season, we are out on one of the Great Lakes' estuaries (Muskegon Lake in Michigan), retrieving a buoy observatory system that gathers time series data on weather and water quality, chronicling ecosystem changes such as pollution, eutrophication, harmful algal blooms, and hypoxia taking place in this urbanized environment (www.gvsu.edu/buoy/).

Each year we face the challenge of massive amounts of biofouling. Wipers on the face of all the underwater sensors and antibiofouling ablative paint on the main body of the buoy below the waterline deter significant biofouling in those locations and keep the observatory functional. Nevertheless, the extensive mooring cables and support ropes , such as the one I'm holding here, become hopelessly encrusted with dense colonies of sticky mussels and bryozoans (fuzzy extensions that stick out past the mussels in the photo), making the task of buoy retrieval and cleanup heavy and daunting.

**—Bopi Biddanda,** Annis Water Resources Institute, Grand Valley State University, Muskegon, Mich.

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

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