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EOS

Earth & Space Science News

Special Issue

CLIMATE CHANGE IN CONGRESS...

...and Other Ways Scientists Are Leading Discussions on Air Pollution, Flood Risks, Mineral Stocks, and More

AGU 100
ADVANCING EARTH AND SPACE SCIENCE

This Moment in Time

As geoscientists, we hold unique views about time. We stare at road cuts, at landscapes, at tiny minerals in rocks, and we rewind time, seeking the exact scene that unfolded to generate the features we now see. We comb through data, analyzing, synthesizing, interpolating, and extrapolating so that we can spin up models to show us the future.

While we look back and look ahead on minuscule and vast timescales, our feet remain firmly planted in the now. We need open access to data now to fulfill our calling to thoroughly examine the past and future. We need to bring full attention to scientific findings now, to prevent irreparable harm to our society.

This issue of *Eos* focuses on now, on this moment in time. Regimes openly hostile to science are rising around the globe. State and federal science budgets are being slashed; programs and even the very vocabularies that capture scientific consensus on climate change and health are threatened with erasure. Many of our colleagues worry that we're sliding into a post-truth world in which facts, scientific rigor, and logical analyses don't matter. What can scientists do?

In the pages that follow, *Eos* gives snapshots of what we are already doing.

Some scientists frame their research to exigent concerns, showing how pollution already affects cognition (see "Heavy Air Pollution May Lower Cognitive Test Scores" on p. 8 of this issue) and accumulates in our bodies ("Microplastics Found in Human Stool," p. 4). They demonstrate with data that people can simultaneously keep their eyes on their pocketbooks and the environment ("Conserving Riverside Habitat Could Bolster Bottom Lines," p. 47). They provide context about the extent to which the United States relies on other countries' natural resources ("Meeting the Mineral Needs of the United States," p. 26)—important information given the current rush toward trade wars.

Other scientists offer imminent warnings of clear-cut threats to human lives in the next months or years. They note that government models fail to capture two thirds of people who could be exposed to severe floods ("Millions More Americans Face Flood Risks Than Previously Thought," p. 16). And when those disasters play out, airways clogged with commercial wireless services could hinder disaster responses ("Wireless Frequency Sharing May Impede Weather Satellite Signals," p. 13).

Still more scientists strive toward concrete solutions. They create models that will help communities to better understand the cascading effects of natural disasters ("How Landslides Become Disasters," p. 32). They also band together to provide opportunities to refugees with scientific backgrounds who are fleeing disasters, both natural and political ("New Initiative Aims to Help Displaced Scientists," p. 3).

A few, particularly those who study climate and environmental change, have gotten creative with getting the message out. They find allies in politicians who are poised to assume greater leadership roles ("The Push for a Climate Change in Congress," p. 20). And they're succeeding at spreading their messages to those who help define popular culture ("Dive into Ocean Issues with *Sherman's Lagoon,*" p. 37).

In short, researchers are making strategic moves right now to ensure that society understands, embraces, and acts on science.

This month, thousands of scientists from around the world will gather at AGU's Fall Meeting 2018 to discuss their research in the shadow of the U.S. Capitol. As AGU's president reminds us ("Solidarity Among World's Scientists Needed Now More Than Ever," p. 19), the very act of meeting en masse here and now sends its own powerful message.

That message is simple: Science, sound science policy, and the truth matter. And with a little strategy, even at this moment in time, we can share this message with the world.

Mohi Kumar (@scimohi)
Interim Senior News Editor

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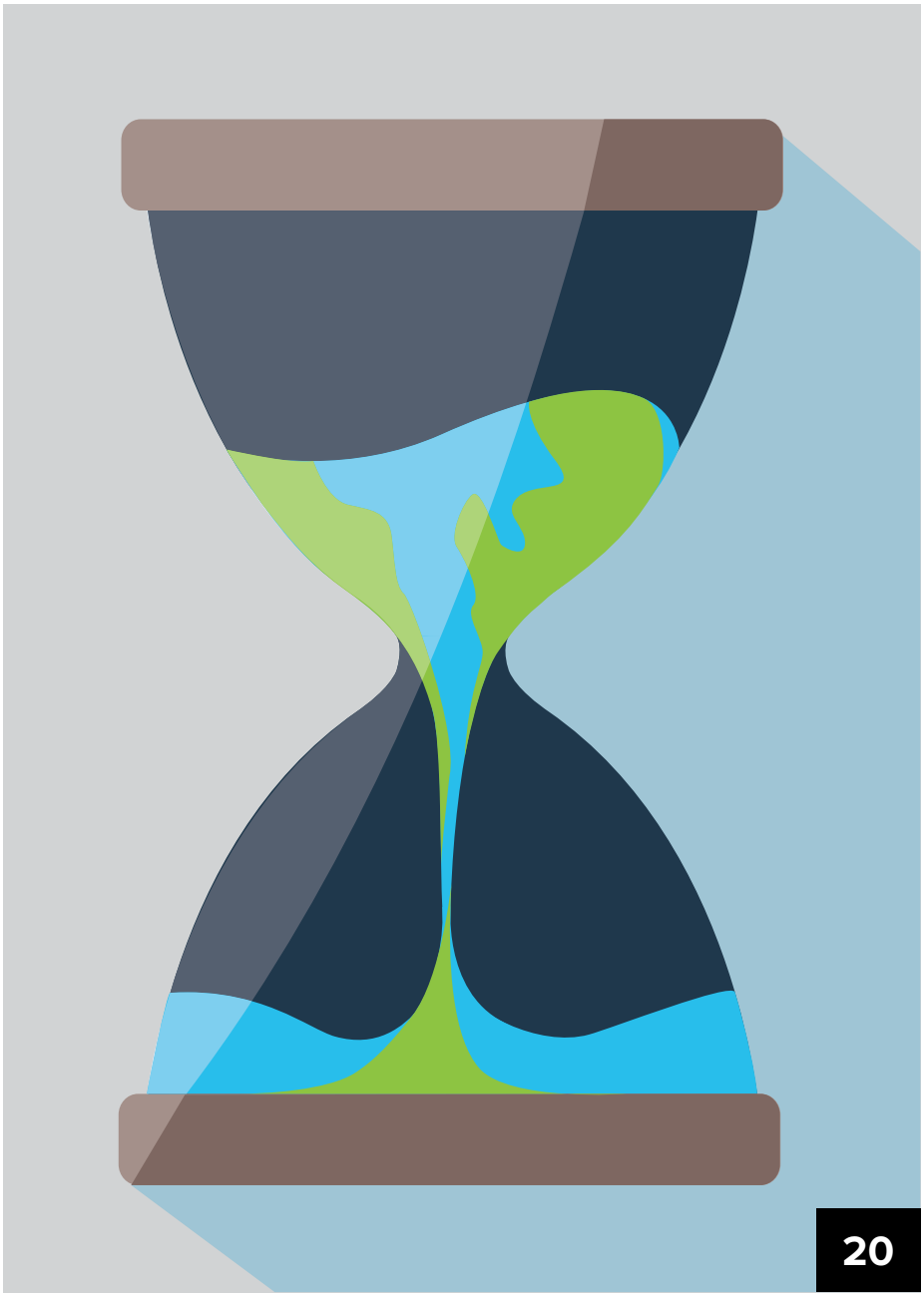


FEATURE

The Push for a Climate Change in Congress

Rep. Ted Deutch (D-Fla.) is on a mission to find bipartisan solutions, further Democratic goals, and end the dark money that spurs members of Congress to oppose climate measures.

FEATURE

Meeting the Mineral Needs of the United States

The U.S. Geological Survey tracks the supply streams of 90 key mineral commodities. Its work pinpoints where the United States is most dependent on mineral imports and highlights ways to reduce this dependence.

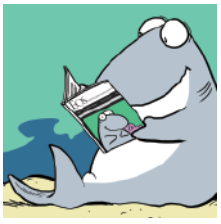
PROJECT UPDATE

How Landslides Become Disasters

A new modeling platform, tested on two recent natural disasters, simulates conditions that dump landslide debris into rain-swollen rivers, often causing more damage than the landslides themselves.

FEATURE

37 Dive into Ocean Issues with *Sherman's Lagoon*



The creator of *Sherman's Lagoon* talks to *Eos* about providing light-hearted entertainment while weaving in ocean facts and larger messages about threats to the ocean and its creatures.

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Christine W. McEntee, Executive Director/CEO

AGU 100 ADVANCING EARTH AND SPACE SCIENCE

New Initiative Aims to Help Displaced Scientists

iStock.com/Martin Barraud

Among the estimated tens of millions of refugees worldwide, thousands might be scientists, engineers, medical doctors, and students in those fields. A new joint initiative by 10 Italian science institutions hopes to help scientific refugees who have been displaced because of conflicts or instabilities in their home countries.

The institutions have agreed to develop research and study opportunities for scientists in need, according to a statement issued on 17 September in Trieste, Italy (http://bit.ly/italy-statement).

The parties to the agreement will work together "to promote, develop and consolidate opportunities and common initiatives to identify, enhance and develop professional and scientific expertise of refugees and asylum seekers," according to a statement signed by the institutions, all of which are based in Trieste and the northeastern Italian region of Friuli Venezia Giulia.

The parties "will offer opportunities to affected scientists to enrich their professional skills, to foster their human and professional development and integration, and encourage their reintegration in their country of origin once conditions allow," the statement continues. Science institutions that signed on to the initiative include the World Academy of Sciences (TWAS), Italy's National Institute of Oceanography and Experimental Geophysics (OGS), Italy's National Institute for Astrophysics (INAF), and others.

> The parties to the agreement will work together "to identify, enhance and develop professional and scientific expertise of refugees and asylum seekers."

The initiative suggests some initial steps that include identifying the skills of affected scientists, establishing research and training positions for some affected scientists, and developing collaborations with other organizations active in this issue, such as the Scholar Rescue Fund, Science4Refugees, and Scholars at Risk.

A Responsibility to Assist Displaced Scientists

"The scientific community has a responsibility to assist these people," Peter McGrath, coordinator of the TWAS science policy and science diplomacy program, told *Eos*. McGrath, who also is the coordinator of the InterAcademy Partnership, a global network of 130 academies of science and medicine, said that there might be about 10,000 displaced scientists, engineers, medical doctors, and students in those fields among the millions of refugees worldwide and that the numbers could increase with growing conflicts and other causes of instability such as climate change.

McGrath said that the science community can help those displaced keep up to date with current science so that when it is safe for them to return to their own countries, they can make a positive difference there. Although not all of the displaced scientists may want to return to their home countries or be able to do so, the initiative is not meant to be a brain drain, he added.

A Resource, Not a Cost

Maria Cristina Pedicchio, president of OGS, stressed that the idea is to provide displaced scientists with opportunities in Italy "but then to support them going back home to rebuild a new, more peaceful national context in their home countries."

She added that politicians and others who may be wary of refugees should understand that helping displaced scientists is a win-win for the scientists as well as for host countries that view the scientists as a resource rather than a cost.

Looking for Ways to Help

"We are looking for ways to be helpful in this type of initiative," said Giovanni Vladilo, director of INAF's Astronomical Observatory of Trieste. Vladilo said that concrete actions could include conferring with other astronomy organizations about considering special programs to help refugees.

The new initiative is crucial for the scientists in need and for the broader scientific community, Vladilo added. "It's important to give a signal that scientists are involved in society," he said.

A Small Start

The initiative "is a small start," McGrath said. He added that he hopes that the accord can serve as a model for other research centers and universities in Europe or elsewhere.

Beyond that, he said, "What we need is either a European-level or global-level clearinghouse where refugee scientists can register, can connect, and can find ways to stay in the scientific system."

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

Microplastics Found in Human Stool

Mussels, sea salt, and shrimp: These are just a few of the things that scientists have found riddled with microplastics in the past year. According to research to be presented at a conference in October, scientists can now add another example to the list: humans.

The study tested stool samples from eight healthy adults and found microplastics in every stool sample tested (see http://bit.ly/stool-microplastics). The research, which was presented at the annual United European Gastroenterology (UEG) Week in Vienna, Austria, is another step in what researchers hope will reveal how microplastics move through the environment.

"This is the first study of its kind," said Philipp Schwabl, lead author of the study and a physician scientist in the Division of Gastroenterology and Hepatology at the Medical University of Vienna. The study, he said, "confirms what we have long suspected, that plastics ultimately reach the human gut."

The study "confirms what we have long suspected, that plastics ultimately reach the human gut."

Plastic water bottles, which contain polyethylene terephthalate (PET), are one possible source of microplastics that enter into water and food streams bound for human consumption. Credit: iStock.com/EasternLightcraft

The Facts from the Feces

"Plastics are pervasive in everyday life, and humans are exposed to plastics in numerous ways," Schwabl said. Previous research has revealed that little flecks of plastic frequently end up in our food and water. A study released earlier this year found that 93% of water in plastic bottles sampled was contaminated with microplastics. Despite the mounting evidence of human exposure to microplastics, little research has quantified the risk and the impact.

In this new study, Schwabl and his colleagues chose volunteers from countries around Europe and Asia and asked them to keep a food journal. After 1 week, they tested the subjects' stool using a Fourier transform infrared (FTIR) microspectrometer, which identifies materials on the basis of the wavelengths they absorb.

They found that every stool sample contained microplastics. They tested for 10 types of microplastics; the stool, collectively, contained all but one type.

"Personally, I did not expect that each sample would test positive," Schwabl said. He noted that the small sample size limited the reach of the findings, but statistician Daniela Dunkler at the Medical University of Vienna said that it is reasonable to estimate that more than half of the world's population may have microplastics in its stool. Dunkler was not involved in the current research.

Two of the most common polymers found in the study were polypropylene (PP) and polyethylene terephthalate (PET). "All participants had PP and PET particles in their stool samples," Schwabl added. PP and PET are components of plastic bottle caps and plastic bottles.

Dinner with a Side of Plastic

All of this begs an important question: How are microplastics making their way into people's guts?

Although it is still unclear where exactly each fragment came from, Schwabl noted that "it is highly likely that during various steps of food processing, or as a result of packaging, food is being contaminated with plastics. In our study, most participants drank liquids from plastic bottles, but also fish and seafood ingestion was common."

It's too soon to tell whether these microplastic shards could have any human health risks, Schwabl said, because currently there are "no human studies that give answer to this question." Studies in animals show that microplastics can harm intestines, hinder iron absorption, and even make their way into the bloodstream.

"Now that we have the first evidence for microplastics inside humans, we need further research to understand what this means for human health," Schwabl said.

By **Jenessa Duncombe** (@jenessaduncombe), News Writing and Production Intern

Huge Blades of Ice May Partially Cover Jupiter's Moon Europa

Europa, a moon of Jupiter, has long been heralded as one of the most promising places to look for life in the solar system. That's because it contains an ocean of liquid water beneath its surface that might, much like Earth's ocean, be a habitable place.

But now scientists have proposed a potential hitch to safely placing a lander on Europa: Blades of ice up to 15 meters tall might be clustered around the moon's equatorial region.

These features, which exist in cold, dry areas on Earth and have been spotted on Pluto, are formed when the Sun's rays shine on ice, causing it to completely skip melting into a liquid and instead turn directly into a gas. Known as penitentes—the Spanish term for religious figures kneeling in penance—because of their appearance, these blades could prevent a lander from exploring parts of Europa.

Remarkable Sculpting

Penitentes are found on Earth in cold and dry conditions at tropical latitudes, for example, in the Andes mountains of northern Chile. They begin to form when a field of ice naturally develops small pits on its surface.

When the Sun is nearly overhead, its rays preferentially strike the bottoms of these pits, warming the ice. This warming ice doesn't melt in a traditional sense: The air is so dry that the heated ice immediately gets transformed into gas in a process called sublimation.

As sublimation continues, the pits deepen. Over time, the cumulative sublimation eats away at the ice, creating penitentes with typical heights of 1–5 meters.

Penitentes can last a year or two on Earth, and they've even been re-created in laboratory experiments. The New Horizons spacecraft has also spotted these features on Pluto, where the towering columns are believed to be made of frozen methane.

> These blades could prevent a lander from exploring parts of Europa.

Now Jeff Moore, a planetary geologist at NASA Ames Research Center in Moffett Field, Calif., and his colleagues have proposed another location where penitentes might form: on Europa.

"The raw ingredients seem to be there," Moore said. These ingredients include the moon's icy surface, its cold temperature (between −203°C and −141°C), and the relatively constant angle at which sunlight strikes it.

"We hypothesize that penitentes can grow, and indeed have grown [on Europa]," the researchers write in their study, which was published in *Nature Geoscience* in October (http://bit.ly/europa-penitentes).

Penitentes in the Andes mountains in Chile. Credit: ESO

Towering Tall

Using estimates of noontime temperatures on Europa and the reflectivity of its surface, among other parameters, the researchers estimate that ice on the moon sublimates at a rate of roughly 30 centimeters per million years. That's millions of times slower than the rate on Earth, mostly because Europa is much farther from the Sun. At the distance of Europa, "the Sun is 25 times less bright," Moore said.

But even the creeping pace at which ice turns into water vapor on Europa is faster than the rate at which Europa's surface is eroded by charged particles from Jupiter. And because penitentes form more rapidly than they're eroded, they should exist on the Jovian moon, the researchers reason.

Given that Europa's surface is about 50 million years old—on the basis of its relative lack of craters—Moore and his colleagues estimate that penitentes as tall as 15 meters might tower over Europa's equatorial region.

"The Sun sculpts these special features in a way that is remarkable," said Douglas MacAyeal, a geophysicist at the University of Chicago who was not involved in the research. But remarkable or not, the spires themselves might not be good news. Penitentes would "imply a hazard of attempting to land on an equatorial surface of Europa," MacAyeal said.

Awaiting a Flyby

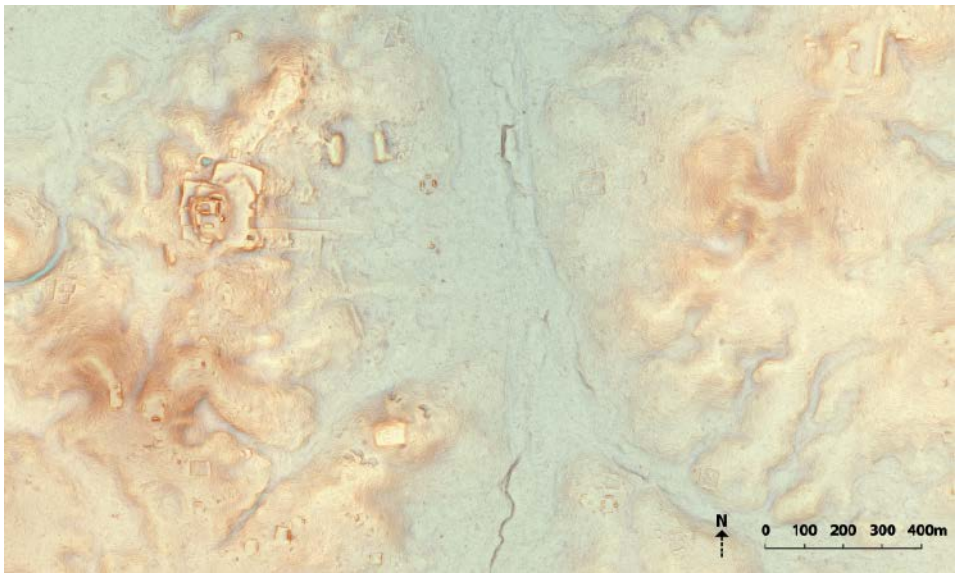
Unfortunately, images of Europa taken by spacecraft aren't detailed enough to reveal or refute the presence of penitentes. However, radar data of the Jovian moon are consistent with the existence of penitentes near Europa's equator, Moore and his colleagues note. Microwave wavelength radar observations of Europa have revealed that its equatorial region tends to reflect less radiation than its higher latitudes. If the moon's surface is rough near the equator—due to penitentes, for example—that could explain these measurements: The deep pits of these ice blades tend to scatter and absorb radiation.

In the coming decade, NASA's Europa Clipper mission is expected to put a spacecraft in orbit around Jupiter that will complete flybys of Europa's surface, and scientists hope that a lander might follow. Moore and his colleagues are looking forward to mining the first data from the Europa Clipper mission, which will skim as close as 25 kilometers above Europa, to look for penitentes.

"If they're there, we'll see them," he said.

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

Lidar Uncovers Thousands of New Maya Structures



Finely scaled topography stands out in this lidar-generated map of Maya settlements north of the ancient city of Tikal, in what is now Guatemala. The large structure on the right is roughly 200 meters wide. Credit: Luke Auld-Thomas/ PACUNAM

(Top) A photo of the Maya lowland city of Tikal seen from above the trees, coupled with (bottom) an image of the same view with the vegetation stripped away. Credit: Francisco Estrada-Belli/PACUNAM

A team of 18 researchers has now mapped more than 61,000 structures in the Maya lowlands. How? Two words: airborne lidar.

The scientists conducted aerial surveys of northern Guatemala, repeatedly flying over long-abandoned sites of the ancient Maya civilization that thrived between 1000 BCE and 1500 CE. The lidar data collected from these surveys map in fine detail the 3-D topography of the region, resolving ground features as small as 1 meter. The researchers published their maps and their interpretations of those maps on 28 September in *Science* (http://bit.ly/maya-lidar).

One such map is the image above. Made from the lidar measurements, it shows topography under the jungle canopy, revealing Maya settlements that stood north of the ancient city of Tikal in what is now Guatemala. A smattering of large and small buildings dot the hillsides, some of them newly discovered in the most recent study.

Archaeologists can toil for years mapping one ancient Maya site by foot, wading through the dense tangle of jungle that blankets the region. But with lidar instruments, scientists can map in fine detail, from above, buildings hidden beneath the undergrowth.

The trick to peeling back dense vegetation involves lidar's lasers, which rapidly pulse from low-flying planes. These pinpoints of light penetrate tiny gaps between leaves to get to whatever may lie below, before reflecting back to the aircraft above. With a little processing, scientists can use the time it takes for light to travel and reflect back to reveal precise information about the elevations of the ground and structures upon which the jungle grows.

What they found calls into question many of the accepted theories of Maya life.

The team scanned more than 2,100 square kilometers of terrain in what it says is "the largest single lidar survey of Mesoamerican archaeology." What they found calls into question many of the accepted theories of Maya life, the authors explain.

For example, evidence of extensive agricultural practices, from terraces to modified terrain, hints at a civilization intimately linked to agriculture, a fact not well understood before the study. The team also found evidence of elevated roads linking many of the urban centers, suggesting a closer connection between cities than previously thought.

"Seen as a whole, terraces and irrigation channels, reservoirs, fortifications and causeways reveal an astonishing amount of land modification done by the Maya over their entire landscape on a scale previously unimaginable," first author Marcello Canuto said in a press release about the project.

These findings may revise what scholars believe about Maya economics, population, and agriculture, the authors speculate, and the data in hand could fuel more discoveries yet to come.

Lidar is "revolutionizing archaeology the way the Hubble Space Telescope revolutionized astronomy," coauthor Francisco Estrada-Belli told *National Geographic* earlier this year. "We'll need 100 years to go through all [the data] and really understand what we're seeing."

By **Jenessa Duncombe** (@jenessaduncombe), News Writing and Production Intern

Large Exomoon Likely Orbits a Faraway World

A team of astronomers has announced new evidence supporting the existence of an exomoon in orbit around a distant exoplanet.

"Within our solar system, satellites are abundant," said David Kipping, assistant professor of astronomy at Columbia University in New York. "We have long assumed that when it comes to exomoons, the question is not if they exist but, What are the physical properties of such a population?" Kipping, who has been hunting exomoons for nearly a decade, coauthored a *Science Advances* research paper that announced the discovery on 3 October (see http://bit.ly/teachey-exomoon).

Using the Hubble Space Telescope (HST), the team observed a Jupiter-sized planet as it transited its host star and blocked a fraction of the star's light. It found that the timing, shape, and strength of the planet's transit showed peculiarities that strongly suggest that it hosts a Neptune-sized moon.

"We are looking forward to the scrutiny of the scientific community on this work," said lead author Alex Teachey, "and we hope that we will have an opportunity to observe the target again before too long." Teachey is a graduate student in the Department of Astronomy at Columbia University.

If future observations validate this hypothesis, the exomoon candidate, tentatively dubbed Kepler-1625b-i, will be the first moon detected around a planet outside of our solar system.

Two Telescopes, One Target

The planet, called Kepler-1625b, first came to the researchers' attention as a possible exomoon host in 2017 after they analyzed data from the Kepler Space Telescope. Kepler observed three transits of the Jupiter-sized world during its primary mission. The planet, about 8,000 light-years from Earth, takes about a year to orbit an old star that is slightly larger and more massive than the Sun.

The Kepler data contained hints—subtle blips in the host star's emitted light that were slightly offset from the planet's signal—that an exomoon might be orbiting the planet. Kepler-1625b was the only planetary system out of nearly 300 viable targets that showed any hint of a moon.

The preliminary results from Kepler were tantalizing enough for the team to observe a fourth transit in October 2017 using HST. Hubble provided a fourfold improvement in precision over Kepler for this star and also made observations at infrared wavelengths. The team obtained about 40 hours of observing time on Hubble, then got to work meticulously scrutinizing the data.

Anomalies in Timing and Brightness

Teachey and Kipping found that two aspects of the transit data from Hubble were consistent with their exomoon hypothesis. First, the planet transited the star 1.25 hours earlier than expected on the basis of the orbital period measured by Kepler. "That is indicative of something gravitationally tugging on the planet" during this particular transit, Kipping explained.

If a moon did exist, he continued, the position of the moon in its orbit about the planet could help explain why the timing of the Hubble transit differed from that of the Kepler data. Imagine the influence of the moon to be like pushing someone on a swing: Depending on when you push, the direction of your push, and where you're standing when you do push, you (the moon) could make the swing (the planet) move faster or slower or not change speed at all.

Second, the Hubble observations of the host star's brightness showed two dips in brightness instead of just the one from the planet. "The location, shape, and depth of this event appear consistent with a Neptune-sized moon [also] transiting in front of the star," Kipping said. The team also saw this secondary dip in the star's light in some of the Kepler transits.

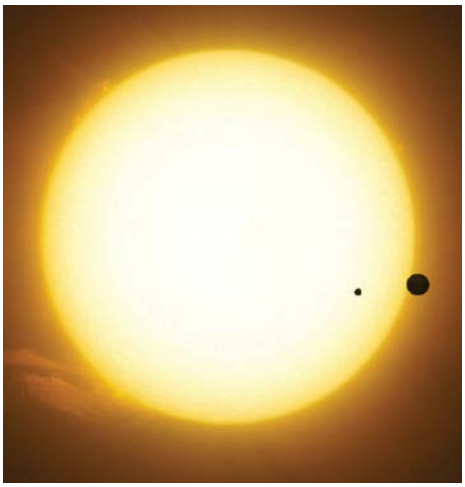
The team compared its data with outputs from a variety of transit models—some that included or excluded exomoons and some that included or excluded other exoplanets. "We have tried our best to rule out other possibilities such as spacecraft anomalies, other planets in the system, or stellar activity," Kipping said, "but we are unable to find any other single hypothesis that can explain all of the data that we have."

"The combination of Hubble data with the Kepler data is really an essential part of the moon search," Teachey said.

Moon of a Surprising Size

The exoplanet-exomoon system suggested by the new observations has mass and radius ratios similar to those of the Earth-Moon system but that are scaled up by a factor of 11. If you were on a spaceship flying through the planet's atmosphere, the exomoon would appear to be around twice as large in the sky as our Moon does, Teachey explained.

Artist's rendering of the Jupiter-sized exoplanet Kepler-1625b with its hypothesized Neptune-sized moon, Kepler-1625b-i. Credit: Dan Durda



Artist's impression of the exoplanet Kepler-1625b (larger black dot) and its potential exomoon (smaller black dot) transiting their host star. In this rendering, the planet and moon orbit the star from left to right. New data from HST first showed a dip in the star's brightness as the planet transited the face of the star. This dip was followed by a second, smaller dip, which the team attributed to a smaller exomoon. Credit: Dan Durda

The team was surprised that a Neptune-sized moon seemed to orbit a Jupiter-sized planet. Moons in our solar system formed as by-products of a collision (like our Moon), by the capture of asteroids or other objects (like the moons of Mars and Neptune), or as leftovers of planet formation (like Jupiter's Galilean moons). A Neptune-sized moon around a Jupiter-sized planet does not fit any of these formation scenarios, the team said.

"A moon like this is not necessarily readily explainable," said Teachey. However, "you certainly can't rule it out on those grounds, because nature makes all sorts of things that we are still struggling to explain," he said.

Cautious Optimism

The exomoon-hunting team received media attention in 2017 when its planned observations appeared on Hubble's public schedule. This sparked unsupported claims that the team was more confident in a Kepler-1625b moon than they had said.

With this paper, "we are urging caution here," Teachey said. "The first exomoon is obviously an extraordinary claim, and it requires extraordinary evidence." The researchers hope to observe the May 2019 transit of Kepler-1625b with HST to further test their exomoon hypothesis.

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

Heavy Air Pollution May Lower Cognitive Test Scores

Deteriorating air quality around the globe has long been linked to declines in physical health, including lung cancer, heart disease, stroke, and overall life expectancy. Now new research published in *Proceedings of the National Academy of Sciences of the United States of America* suggests that high levels of pollution can lead to a decline in cognitive ability too (see http://bit.ly/zhang-2018).

The study analyzed scores on cognition tests taken by nearly 32,000 participants across China, searching for demographic trends that may be associated with pollution levels. And it found them.

"Long-term exposure to air pollution impedes cognitive performance in verbal and math tests," Xiaobo Zhang, lead author on the study, told *Eos*. Zhang is a professor at the National School of Development at Peking University in Beijing and a senior research fellow at the International Food Policy Research Institute in Washington, D. C.

"The negative impact on verbal scores was more pronounced for men than women," he said. "The damage increases as people age."

The researchers note that most cities in developing nations, including China, fail to meet international air quality standards, so this study may have implications beyond China's borders.

"The damage to cognitive ability by air pollution also likely impedes the development of human capital," Zhang explained. "Therefore, a narrow focus on the negative effect on health may underestimate the total cost of air pollution."

Sifting Through Scores

Zhang's team mined cognition test results gathered in 2010 and 2014 by the China Family Panel Studies (CFPS), a national demographics survey conducted by Peking University. Among other questions, the survey included 24 standardized math questions and 34 word recognition questions of increasing difficulty. Responses to the survey, gathered from 162 counties spread over China, are representative of the Chinese population, according to CFPS.

Demographic data collected with the survey allowed researchers to group participants on the basis of personal factors like age, sex, and education level, which in China likely determine whether a person works predominantly outdoors and breathes unfiltered air. The data also supplied researchers with background information on test participants such as where they have lived and for how long.

By isolating these individual factors, the researchers could classify a benchmark value for each group. Assuming that a person's scores started at the benchmark when they were young, the researchers began to ponder the factors that could have led to changes in a person's cognition over time.

Given respondents' age distribution as well as the spatial distribution of scores over much of China, the factor the researchers kept circling back to was air pollution.

Pollution on the Brain

Personal experience led Zhang to consider the health effects of air pollution. Zhang told *Eos* that when he returned to China from the United States in 2012, he immediately began experiencing headaches and found it hard to concentrate on research on days when Beijing had heavy air pollution.

Past studies, the team notes in the paper, had looked at how air pollution affects children's test scores in school, so Zhang wondered whether the effects were the same for everyone. He became curious about how low air quality might affect different subpopulations in China. Do air pollution's effects differ for older populations, for men and women, or for those who work primarily outdoors?

So Zhang instructed his team to learn more about air pollution at the locations and times that the CFPS tests were administered. The survey fortuitously recorded the precise times and locations of the tests, which the researchers used to gather local air quality data for the testing period. Specifically, the team examined each location's air pollution index, a metric recorded by the Chinese Ministry of Ecology and Environment that accounts for levels of sulfur dioxide, nitrogen dioxide, and inhalable particulate matter smaller than 10 micrometers, such as smog, smoke, ash, and dust (see http://bit.ly/air-quality-index).

High Pollution, Low Scores

Several areas in China are hot spots of poor air quality as defined by the air pollution index. The country's northeastern coast from Shanghai to Beijing, in particular, has consistently been a source of unhealthily high pollution.

Most research into the cognitive impacts of air pollution "have focused on the U.S. or

A person wears a mask to protect against heavy air pollution outside the Palace Museum in Beijing, China, on 5 January 2017. Credit: Kyodo News/Getty Images

Europe, where ambient air pollution levels are relatively low," said Dave Marcotte, a professor of public administration and policy at American University in Washington, D. C. "Because China has relatively high levels of air pollution, it is a setting highly relevant for other parts of the globe, including south and southeast Asia and urban areas in Africa." Marcotte, who was not involved in this research, has studied educational impacts of air pollution.

When mapping these locations to test scores, the researchers found that overall, lower verbal test scores matched times with heavy air pollution, regardless of age, sex, or education level. This effect was stronger than what was seen in math scores. The researchers also found that 1 week of exposure saw a roughly 0.3-point drop in verbal scores, but 3 years of exposure saw a 1.1-point drop.

Men's verbal test scores dropped nearly twice as much as women's after 3 years of exposure to heavy pollution when compared to the benchmark. For men, but not women, the decrease in verbal cognition after exposure to heavy pollution was more pronounced with increasing age and even more so for men with less than a middle school education. Men's and women's math scores dropped roughly the same amount in each age group in those with the highest exposure to pollution.

The researchers speculate that the difference between men's and women's verbal scores corresponds to differences in how white and gray matter are activated in men's and women's brains during testing. Past research has shown that white and gray matter, used for more verbal and more math cognition, respectively, have different sensitivities to air pollution.

Marcotte called this research "an excellent and convincing study." He explained that unlike previous research focused mainly on pregnancies and infants, it expands our understanding into pollution's cognitive impacts on other groups. He added that future work should also seek to account for personal behaviors, like smoking, which may affect cognitive performance.

Reduce Air Pollution to Save Cognitive Function

Cognitive decline with age, the team notes, is a risk factor for Alzheimer's disease, which costs hundreds of billions of dollars in health services each year and affects almost 2% of the adult population over 65. "The damage to the aging brain by air pollution likely imposes substantial health and economic costs," the team writes, "considering that cognitive functioning is critical for the elderly for both running daily errands and making high-stakes decisions."

Reducing air pollution in China to meet the air quality standards published by the U.S. Environmental Protection Agency could increase verbal scores by 2.41 points and math scores by 0.39 point nationwide in future populations, the team estimated. Had these standards already been in place, men older than 64 who have been exposed to long-term heavy pollution might have seen average verbal scores more than 9 points higher than currently reported, or the equivalent of moving from the median score to the 87th percentile.

"Investment in cleaning up air pollution is good not only for health," Zhang said, "but also for the intellect of society at large."

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

A. F. "Fred" Spilhaus Jr. (1938–2018)

Alik Ismail-Zadeh

A. F. "Fred" Spilhaus Jr.

"He was bigger than life." "His legacy will not soon be forgotten." "He left a lasting mark on all he touched." These sentiments, which are often spoken about a recently deceased individual, can seem like clichés.

But for A. F. "Fred" Spilhaus Jr., executive director emeritus of AGU, who died on 30 April just 3 weeks shy of his eightieth birthday, they are far from just words.

Those who were fortunate enough to know and work with Fred may speak of his vibrant personality, his strong work ethic, his generosity with ideas, his seemingly unflagging energy, or his attraction to good food and wine. And Fred embodied all of that.

However, those committed to the advancement of science know that there are fathoms more. Fred held an unwavering passion for AGU and was deeply dedicated to its members.

When asked, shortly before his retirement, what he felt was most important among his contributions to AGU, Fred noted, "the openness of AGU and the ability for anyone involved in the Earth and space sciences to join and stay a member. Of equal importance to me is the fact that AGU always puts the integrity and quality of science first."

A Commitment to Communication and to Keeping Dues Affordable

Fred held three degrees from the Massachusetts Institute of Technology, including a Ph.D. in physical oceanography. After a short stint as an analyst for the CIA, he was hired in the summer of 1967 by AGU to be assistant executive director.

One of his early assignments was to make the stodgy quarterly *Transactions, American Geophysical Union* into a monthly magazine, which he did with the January 1969 issue, adding *Eos* to its title. Ten years later, *Eos* became a weekly tabloid newspaper. Fred served as editor in chief of *Eos* for 40 years.

Early in Fred's tenure as AGU's executive director (1970–2009), he attended a conference for society managers at which a speaker talked about the importance of reducing the financial threshold for membership so that more could join. The principle was to have a low entry fee and then charge for the products and services members used. Fred was so struck by the concept that for more than 3 decades—until his retirement—he was able to convince the Council (today's Board of Directors) to keep dues at $20 for members and to reduce and maintain dues for students at $7. Fred had a strong numeric base for keeping the dues low: The dues must always cover the incremental costs of serving an average member; they always did.

Fostering an International Organization

When Fred joined the staff of AGU, he became an employee of the National Academy of Sciences. AGU had been founded within the academy as the U.S. national committee for the International Union of Geodesy and Geophysics. Only U.S. residents could be full voting members of AGU because each member was also a member of the committee; others were classified as associates and could not vote or hold office.

When AGU was "invited" to leave the academy and it became a separately incorporated nonprofit organization in 1972, Fred thought it would be good to get rid of the two-tiered approach to participation. Although the Bylaws Committee put forward a document that eliminated all geographic distinctions, before adopting the proposed bylaws the Council reinserted U.S. residency as a condition of holding the office of president.

Five years later, when Canadian J. Tuzo Wilson was nominated as a candidate for AGU's president-elect, no one checked the bylaws. Tuzo won the election. So that he could serve, a special election to change the bylaws was held, and the last vestige of AGU's being a U.S. society was removed by vote of the membership.

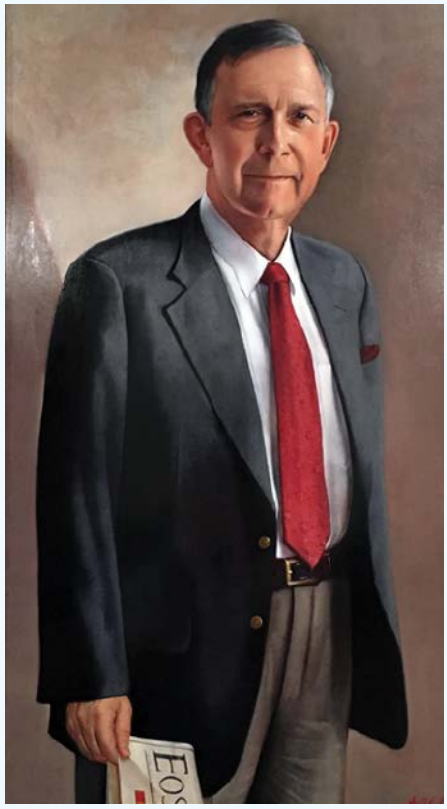
The Importance of Giving Back

AGU had strong publications and meetings programs, but Fred said there needed to be a third leg to the stool, one from which AGU could give back to the broader community. The education, public affairs, and public information programs became that third leg.

With the help of thoughtful members, a public policy effort took shape. Fred had seen such activities become divisive in other organizations when politics rather than policy took over. Thus, AGU's public affairs program became firmly rooted in providing solid scientific information that could be used by decision makers in legislative and regulatory entities rather than a program that lobbied for particular legislation. The first public policy statement adopted by AGU, issued in 1981, dealt with the importance of underlying scientific principles when Earth science was being taught at the precollege level.

Having clear guidelines for how policy statements would be prepared was critical to maintaining AGU's position as a learned society. The guidelines ensured that members had the means to provide input to the policy statements before they were finalized.

Fred was also a great believer in the importance of having strong national and



A painting of Fred Spilhaus, executive director of AGU from 1970 to 2009. Credit: AGU

regional scientific societies. He saw a worldwide network of such societies serving the advancement of science at local, national, and international levels.

Although he wanted AGU to be welcoming to all Earth and space scientists and students anywhere in the world, Fred did not want the size and success of AGU to keep other societies from developing. He gave unstintingly of his advice to the leaders of other organizations and helped to lend AGU's resources for the good of others. As new societies got started, it was common to hear their leaders explain their programs with "you know, it's like AGU's" Chapman Conferences or Macelwane Medal.

A Strong Leader

Fred's mantra was "There is no end to the good you can do if you don't care who gets the credit." He had an uncanny gift for listening to what members were saying, especially in committee meetings, and was quick to figure out how to shape those thoughts into a policy, an action, or even a new direction for AGU. Fred brought the mind-set of a scientist to analyzing problems and developing solutions.

He loved being in the midst of the action, but he didn't seek to be the center of attention. He had no need for personal aggrandizement. Those who experienced his infectious laugh or shared in his joy in a good story, especially a self-deprecating one, may be unaware that Fred relished solitude, in which he could recharge his batteries.

He was a man of strong opinions; this meant that Fred didn't always see eye to eye with everyone in the various walks of his professional life. Fred appreciated that others held passionate views that differed from his own. He enjoyed intellectual sparring and having well-founded, civil arguments. He never took arguments personally and never held a grudge.

Fred had the greatest respect for his predecessor, Waldo Smith, and frequently said that he was glad to have had a 3-year apprenticeship under Waldo's tutelage. When Fred was nearing retirement and the AGU officers insisted that he have his likeness painted, Fred refused to have it hung until a portrait of Waldo was painted and hung first. Fred's last official act as executive director was to host a small reception of members in the Washington, D. C., area to unveil Waldo's portrait.

In 2010, Fred was delighted to receive the AGU tribute that had been named for his mentor: the Waldo E. Smith Medal. It is perhaps fitting that Fred was one of the last to receive the medal before it was designated an award.

A Lasting Legacy

Many of us who saw the energy and passion Fred devoted to supporting the volunteer leaders, especially during difficult financial times, know that AGU would not be as strong as it is today if Fred Spilhaus had not answered the call and made AGU his life's mission. Today's members and leaders can count themselves fortunate that Fred had broad shoulders on which they could stand.

Fred Spilhaus—scientist, executive, mentor, man of courage, bon vivant, colleague, friend—turned his zeal for defending the integrity of science and for advancing our understanding of Earth and space into a career that enriched individuals and organizations around the world. Although his legacy will remain, the man who built it will be sorely missed.

By **Judy C. Holoviak** (email: jholoviak@gmail.com), former Deputy Executive Director, AGU

Join AGU for an informal gathering during Fall Meeting 2018 to honor Fred's life and work.

9 December from 5:30 p.m. to 7:30 p.m.

Renaissance Hotel
999 9th St NW, Washington, DC 20001
Room Congressional B

A Cross-Sectoral Approach to Tackle Ocean Plastic Pollution

Plastic in the Oceans: Challenges and Solutions
Cambridge, United Kingdom, 7 March 2018

*An Antarctic fur seal (*Arctocephalus gazella*) is entangled in plastic fishing netting at Bird Island, South Georgia, South Atlantic Ocean. Research team members removed the netting shortly after this photo was taken. Credit: Claire Waluda*

Plastic plays a vital role in our lives; however, plastic waste is a burgeoning environmental, social, and economic problem across the globe. The estimated 8 million metric tons of plastic entering the oceans every year pose one of the greatest modern-day threats to the health of global marine ecosystems. A great deal of relevant research and progress is currently under way, but effectively addressing ocean plastic pollution requires a multidisciplinary and collaborative approach with engagement from a wide range of sectors.

Last March, the British Antarctic Survey convened a 1-day workshop to address these issues and identify potential solutions. More than 160 delegates attended, representing academia, media, nongovernmental conservation and policy organizations, and industry. About a quarter of the delegates attending were representatives from international companies, small businesses, and start-ups. The aims of the workshop were to identify knowledge gaps, explore solutions, and highlight future actions on ocean plastics.

Plastic pollution is a truly global issue—floating garbage patches have been observed in all five subtropical oceanic gyres. The workshop highlighted that plastic is now prevalent even in areas far removed from human habitation. Attendees raised concerns regarding the levels of plastic debris in the polar regions and their potentially profound effects on Arctic and Antarctic ecosystems.

Plastic pollution is a truly global issue—floating garbage patches have been observed in all five subtropical oceanic gyres.

Workshop participants recognized that although the impact of large-sized plastic debris is well documented, large pieces can break down into smaller microplastics and nanoplastics. The effects of these breakdown products, along with particles originally produced as microplastics, are poorly understood. Other key knowledge gaps include the effects of bioaccumulation of plastics in food webs and potential effects on human health.

Workshop participants concurred that innovative approaches and systemic changes are required to achieve the goal of zero plastic waste, end the existing "throwaway culture," and move from a linear production-to-disposal system toward a circular economy.

Delegates presented solutions that embrace science, including replacing plastic with natural materials and biopolymers; green chemistry and fiber engineering; chemical recycling of end of life plastic into virgin materials; and reducing pollution via ocean cleanup schemes, including wastewater screening, collaboration with the fishing community, and robotic and floating waste collection technologies.

Workshop participants identified a number of priorities for action, including the need for coherent, clear, and simple scientific messages for politicians, the public, and other stakeholders; the creation of best practices guidelines for monitoring the marine ecosystem; and the establishment of appropriate certification schemes.

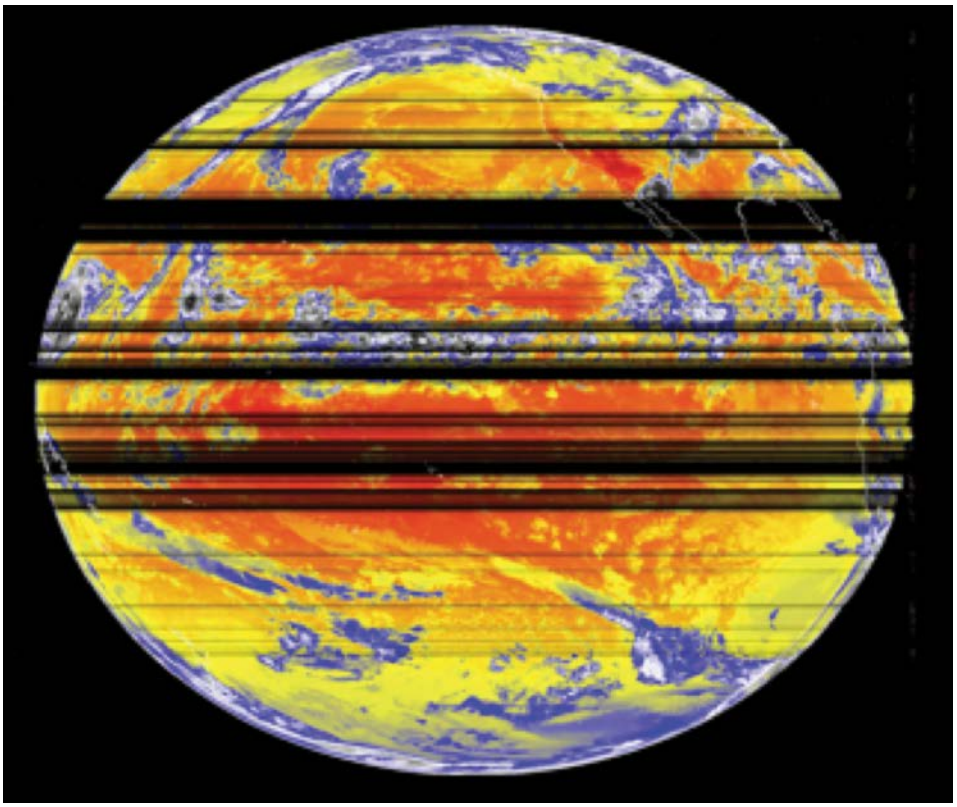
The workshop highlighted the value of cross-sectoral engagement and collaboration in finding solutions to the global issue of ocean plastic pollution. Workshop participants agreed that to tackle the problem effectively, we need to move beyond the traditional "science-policy interface" to a network of scientists, industry representatives (large to small scale), nongovernmental organizations, and policy makers working together toward solutions. They emphasized that to genuinely change the system, these solutions must embrace science, encourage industry innovation, and be amenable to policy facilitation.

A comprehensive report from this workshop is available at http://bit.ly/plastics-in-oceans.

We thank the British Antarctic Survey (BAS), Cambridge Conservation Initiative, and Cambridge Cleantech; the workshop organizing committee; the BAS Plastics Group; BAS students for documenting the proceedings of the meeting and helping with the event; and all workshop participants.

By **C. M. Waluda** (email: clwa@bas.ac.uk; @clairewaluda), **R. D. Cavanagh** (@RachieCav), and **C. Manno** (@claramanno), British Antarctic Survey, Cambridge, U.K.

Wireless Frequency Sharing May Impede Weather Satellite Signals



Black lines mar this 17 August 2015 image of Earth from the GOES-15 weather satellite wherever data were irretrievably lost to radio frequency interference during transmission. A GOES imager records data as it scans across the planet's face and then transmits the data to ground stations in the same sequence. In this view, mainly of the Pacific Ocean with overlying clouds, colors indicate temperatures, from red (warmest) at the ocean or land surface to progressively cooler and higher-altitude clouds, shown in yellow, blue, and white. Credit: CIMSS/SSEC

"Can you hear me now?" Verizon Wireless created its popular television ads years ago to highlight the commercial value and public interest in wireless voice and data access across the United States. Today, as the number of wireless users across the nation and their appetite for more and faster data continue to grow, government initiatives that wireless service providers support are pushing to open more radio frequencies to commercial wireless (4G, LTE, and eventual 5G services).

The timing could not be worse.

Petitions now in front of the Federal Communications Commission (FCC) urge sharing a portion of the radio frequency spectrum that is reserved for federal use, particularly for National Oceanic and Atmospheric Administration (NOAA) geostationary satellites. The requests would allow new wireless users into the lowest quarter of the allocated band that spans from 1,675 to 1,695 megahertz.

The advanced NOAA satellites, each designed to last 10 years in a mission expected to span most of the next 2 decades, enhance a long-standing method of delivering weather data. The satellites' wireless broadcasts to receiving antennas include remote surface and flood gauge observations in addition to imagery essential to meteorologists, scientists, and emergency managers. NOAA satellites provide data needed by researchers investigating extreme weather and other natural hazards and retransmit government weather forecasts and bulletins.

Adding new users to the band used by satellites would likely interrupt timely communication of weather and other environmental information essential for effective responses to hazardous and extreme weather, flooding, fires, and other dangers. In other words, such disruptions could decrease the accuracy and precision of weather forecasts and warnings, impeding the work of disaster responders and putting lives at risk.

Will We Hobble Our Newest and Best?

NOAA recently launched the first two of four satellites in the Geostationary Operational Environmental Satellite–R (GOES-R) series, designed to conduct imaging of the Americas into the 2030s. The primary instrument for weather monitoring on these satellites, called the Advanced Baseline Imager (ABI), can image a full hemisphere of the planet every 15 minutes [*Schmit et al.,* 2017] and capture localized imagery up to every 30 seconds for monitoring regional severe weather.

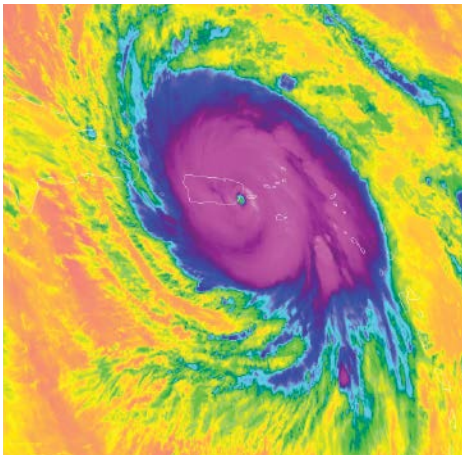
Disruptions could decrease the accuracy and precision of weather forecasts and warnings, impeding the work of disaster responders and putting lives at risk.

Although ABI is essential for specialists who produce warnings and forecasts that help protect life and property, it also provides weather imagery for television weather broadcasts and online animations. Such frequent imaging from ABI is one of the major improvements that the GOES-R series of spacecraft provides compared with previous satellites.

GOES-R satellites also deploy space weather instruments, a lightning mapper, and a host of communications channels that retrieve and disseminate ground and satellite observations.

For the data that GOES-R satellites collect to reach operational meteorologists, scientists, and emergency managers, the spacecraft communicate on four channels at central frequencies from 1,679.9 to 1,694.1 megahertz. These channels provide data at tremendous reliability to the users who depend on them.

However, this reliability hinges on the current spectrum environment in which there are few other users to create sources of interference that can disrupt the faint satellite signal. The signal strength from satellites thousands of kilometers away is much less than that from cellular phones and towers. Listening for a satellite signal amid a network of cell phones



The GOES-16 weather satellite's ABI captured Hurricane Maria striking Puerto Rico on 20 September 2017. This infrared image was color enhanced to depict cold cloud top temperatures in blue and magenta and warm ocean surface temperatures in orange. Credit: CIMSS/SSEC

and towers at a similar frequency would be akin to listening for a whisper in a crowded sports arena.

At Risk: Advanced Weather and Hazard Monitoring

Should the FCC make 1,675–1,680 megahertz, the lowest fourth of the allocated spectrum for GOES-R satellites, available to commercial wireless services, two of the four GOES-R communication channels would be most at risk because their central frequencies are closest to the proposed range for sharing.

One of them, called the Data Collection Platform Relay (DCPR), transmits at around 1,679.9 megahertz. Among other uses, DCPR transmits reports from river gauges and other remote ground observation platforms whose timely receipt is crucial to flood and weather forecasting. During Hurricane Irma, for instance, the Florida Department of Transportation used such gauge readings to decide whether to close highways that served as evacuation routes. In the West, instruments near remote wildfires use DCPR to share local conditions, providing information that is essential for ensuring the safety of communities and firefighters.

The other channel at greatest risk, known as the GOES-R Rebroadcast service (GRB) and operating at around 1,686.6 megahertz, beams satellite imagery to operational and research meteorologists in academia, government, and industry at a data rate of around 31 megabits per second, slightly faster than most fourth-generation long-term evolution (4G LTE) cell service. Mainly because of ABI's rapid, nonstop imaging, GRB data continuously flow from the satellite to antennas on Earth. Because the timeliness of weather information is of utmost importance for public safety, the service-level agreement for GRB uptime is 99.988%, allowing only 5 minutes of downtime every month.

GOES-R and other satellites provide the only method to monitor much of the weather over the oceans as well as conditions above many of the world's volcanoes [*Pavolonis et al.,* 2006], including those along critical air routes between North America and Asia. The safety of airline passengers flying between the United States and Asia depends on the uninterrupted receipt of volcanic eruption and ash information derived from images transmitted via GRB.

Also in Harm's Way?

The remaining two GOES-R communications channels, the High Rate Information Transmission (HRIT) and the Emergency Managers Weather Information Network (EMWIN), both at around 1,694.1 megahertz, might also experience interference from new transmissions above 1,695 megahertz. HRIT sends lower-resolution and less frequent satellite imagery data to users who cannot handle the more substantial stream of imagery from GRB. EMWIN provides weather forecasts and warnings from the NOAA National Weather Service to emergency managers in near-real time. Users of HRIT or EMWIN include the U.S. Department of Defense and other federal agencies, as well as state and local officials and emergency managers.

Vulnerabilities: Interference and Cloud Failure

If there were interference with the satellite signal, receiving antennas would not capture the data, and the transmission would be irrecoverable, much like disruptions to over-the-air high-definition television. The weather community has experienced the effects of interference before, with the GOES-N, -O, and -P generations of geostationary satellites that preceded the GOES-R satellites. In 2015, interference temporarily obscured the view of a tropical cyclone over the Pacific Ocean. Although this interference was momentary, it illustrates the potential for irreversible harm to the weather monitoring and natural hazards alerting process that the American public has come to rely on.

Petitioners in favor of sharing have recommended the creation of an Internet-based cloud service as a suitable alternative to satellite transmissions of the data. This service is not achievable, even with the best enterprise-grade terrestrial Internet services available today. Moreover, when disaster strikes, it is often the power and communications infrastructure that is the first to fail, rendering a potential cloud service inaccessible. In contrast, satellite transmissions remain robust unless the receiving dish is destroyed.

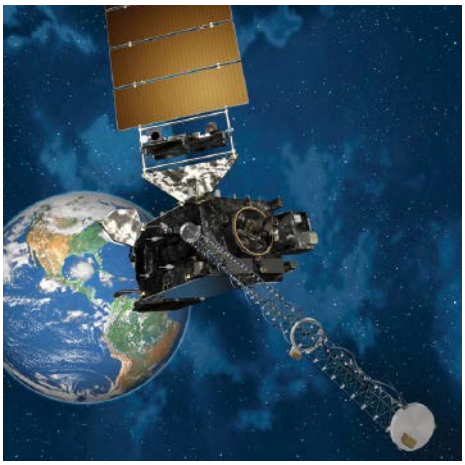
Penny-Wise, Pound-Foolish

Unfortunately, disasters are becoming more frequent and, in recent years, increasingly expensive. The cost of weather disasters in the United States hit record highs in 2017, exceeding $230 billion according to the NOAA National Centers for Environmental Information (NCEI). Those tremendous losses resulted largely from three strong, landfalling hurricanes that the first GOES-R satellite, GOES-16, helped meteorologists track. After Hurricane Maria destroyed the weather radar in Puerto Rico, GOES-16 was the primary asset to support weather monitoring for the island in the months that followed.

Weather disaster costs may increase in future years. New research has found that the speeds of hurricanes are decreasing [*Kossin,* 2018], which will inevitably increase the severity and extent of flooding from associated heavy rains. In addition, a recent NCEI study found that frequencies of high-tide flooding along Gulf of Mexico and eastern states' coastlines are increasing at an accelerating rate [*Sweet et al.,* 2018].

Slow moving hurricanes in combination with high tides could prove recurrently disastrous in future decades. We will need the imagery from GOES-R satellites during and after these disasters to monitor and better adapt to this trend.

Although the revenue from selling the spectrum currently reserved for government



The first weather satellite in the GOES-R series, now designated GOES-16, observes Earth from geostationary orbit in this artist's rendering. The satellite became fully operational in December 2017. Credit: NOAA/Lockheed Martin

use entices lawmakers looking to balance the federal budget without raising taxes, it is a minuscule fraction of just 1 year's disaster losses. The FCC estimates that sharing 1,675–1,680 megahertz could result in revenues of $60 million a year, but only for a decade [*Federal Communications Commission*, 2017]. That 10 years of revenue would amount to only 0.26% of the $230 billion estimated by NCEI as the lower limit of weather disaster costs for 2017 alone.

In contrast to the relatively small revenue the U.S. government could realize from a 1,675–1,680 megahertz spectrum auction, the nation will have spent around $11 billion on the GOES-R program by 2036 to ensure that Americans are aware of adverse weather for the next 2 decades. With that cost comes an expected return on investment: that adequate research and Earth monitoring will be conducted using GOES data to understand natural hazards facing the world today and in the future. Much of that will be lost if airways are jammed and scientists can't hear the signals from the state-of-the art satellites overhead.

We must preserve the clear airwaves for reliable satellite relays of weather and other environmental information. Those uninterrupted signals will help meteorologists and emergency managers continue to provide advance warning and effective, lifesaving responses to protect the American people, their property, and the country's commerce.

Tell Your Story

Interested parties, particularly regular consumers of weather satellite information, can file a comment with the FCC in proceeding RM-11681 at the FCC's Electronic Comment Filing System (see http://bit.ly/fcc_ecfs).

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By **Jordan Gerth** (email: jordan.gerth@ssec.wisc.edu), Cooperative Institute for Meteorological Satellite Studies, Space Science and Engineering Center, University of Wisconsin–Madison

Millions More Americans Face Flood Risks Than Previously Thought

This hurricane season, the United States saw floodwaters rise on the eastern seaboard in the aftermaths of devastating storms. Hurricane Florence's floods in particular took a heavy toll as swollen rivers effectively cut off Wilmington, N.C., a city of some 119,000 residents, for days; residents in surrounding regions were ordered to evacuate as rivers continued to rise and test the strength of dams. Hurricane Michael, the strongest storm to hit the United States since 1969, brought with it storm surges nearly 3 meters high. Floodwaters from both storms inundated septic systems, causing raw sewage to spill through the streets. Thus far, Michael and Florence have together claimed at least 87 lives in the United States alone.

The cost in lives and property damage from Florence and Michael will take years to assess; initial estimates suggest that it could total nearly $40 billion. Add this total to last year's triumvirate of devastating U.S. hurricanes—Harvey, Irma, and Maria—which saw a combined death toll of 3,100 and damages estimated to be $275 billion. Not surprisingly given these events, decision-makers and the American public are focusing on issues related to flooding from hurricanes and other sources.

To mitigate potential losses from floods yet to come, we first need an idea of where these damaging floods can occur. In the United States, this information is provided by the Federal Emergency Management Agency (FEMA), which produces maps of flood zones to help enforce regulations under the National Flood Insurance Program.

The approach FEMA takes involves developing separate hydraulic models for individual river reaches and then stitching the model outputs together to generate a nationwide view. This traditional "bottom-up" approach is the gold standard in flood inundation modeling.

But although the approach allows important local details to be captured, it also requires significant resources and time to accomplish. Also, there is no efficient way to rerun a given simulation to incorporate new data or test new scenarios. As a result, FEMA mapping currently covers only about 60% of the conterminous United States (CONUS), and the maps may not represent headwater areas and smaller floodplains.

You may ask, Is there a better way to evaluate flood risks? The short answer is yes. It involves a "top-down" approach, harnessing big data to automatically create flood

An 84-year-old resident of Spring Lake, N.C., is carried from her flooded home on 17 September 2018. The home flooded when the Little River, a small tributary to the Cape Fear River, crested its banks after Hurricane Florence made landfall. Credit: Joe Raedle/Staff/Getty Images News/Getty Images

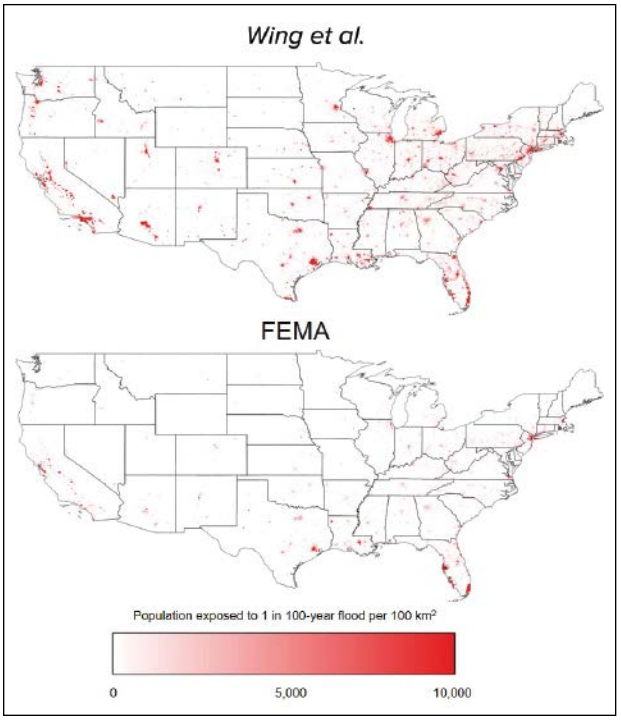

*Fig. 1. (top) A large-scale modeling approach [*Wing et al., *2018] estimates the nationwide distribution of people exposed to a 1-in-100-year flood to be about 3 times the estimate arrived at by (bottom) a local FEMA model approach.*

inundation models from local to global scales.

A New Approach to Calculating the 100-Year Floodplain

Over the past 5 years, researchers across the globe have started to develop a set of these alternative top-down approaches to flood inundation modeling over vast areas, taking advantage of increasingly available large data sets and high-performance computing resources. These methods take available digital elevation models (DEMs), river hydrography, and gauging station data and use them to automatically create flood inundation models of whole regions, countries, or even the world.

Such approaches do not currently outperform local bespoke modeling, but many flood management questions can be answered only by consistent flood maps with the type of complete coverage that these top-down methods produce. For many flood management questions, it may also be acceptable to sacrifice a small amount of local accuracy to achieve a national-scale view.

We recently conducted a study [*Wing et al.,* 2018] to quantify the number of people exposed to flooding in the CONUS using just such a top-down approach. Our team spanned both sides of the Atlantic, from the University of Bristol and Fathom (a flood analytics company) in the United Kingdom and The Nature Conservancy and the Environmental Protection Agency in the United States.

The regulatory flood zone mapped by FEMA captures the areas of land that have a 1% or greater chance of being inundated in any given year, or to put it another way, areas that would be expected to experience at least one flood every 100 years. Using bottom-up approaches to calculating population exposure (i.e., within these FEMA flood zones), we estimated that 13 million people are at risk of this so-called 100-year flood (Figure 1).

Our transatlantic team performed the same calculation with an automated, large-scale hydraulic model covering the entire CONUS at roughly 30-meter resolution [*Wing et al.,* 2017]. We found that almost 41 million people—more than 3 times the FEMA estimate—are exposed to the possibility of a 100-year flood [*Wing et al.,* 2017; *Smith et al.,* 2015; *Sampson et al.,* 2015].

Comparing the Flood Maps

Both flood maps are the output of hydraulic models that in their simplest sense receive input in the form of an extreme river flow. The models then work out how this translates to flood extent on the ground.

Two key pieces of information are required: the magnitude of the extreme river flow and the elevation of the adjacent land. The input to both models, the 1-in-100-year maximum discharge for a particular stretch of river, is calculated on the basis of historic annual river gauge records. The lay of the land is determined by a DEM. The quality of DEMs varies across the United States; the majority of densely populated areas are covered by highly accurate airborne laser scanning (lidar) data, with correspondingly sparser coverage in less populated areas.

Thus, although both FEMA's bottom-up approach and our top-down approach use the same input, the two methods produce different estimates of exposed populations. Examining the simulation results obtained using both approaches highlights why the discrepancy in flood-exposed population estimates arises. Unlike the FEMA map, our map is able to estimate flood hazard in all basins down to just a few square kilometers in area, thus capturing the risk posed by smaller streams (Figure 2).

How does our top-down approach achieve higher precision than FEMA's bottom-up approach? Our approach's ability to represent smaller streams is not by virtue of obtaining better or more localized data. Rather, our spatially consistent, automated, and efficient model-building process, coupled with our computational capacity, can produce flood maps in every river basin. In contrast, FEMA's highly detailed approaches take skilled operators several months to perform for river reaches a few tens of kilometers in length, and this is why spatial coverage is relatively low. FEMA engineers triage the larger streams in a catchment, often to the detriment of the headwaters, whereas our approach captures conditions in the headwater areas as well.

The caveat here is that our approach sacrifices some local accuracy to achieve this broad view of flood hazard across the CONUS. In areas where FEMA models do contain detailed surveys of flow-controlling structures (e.g., levees, culverts, dikes, bridges), these models will likely supersede the large-scale alternative. However, a study that performed a point-by-point comparison between the FEMA model and large-scale models suggests that where FEMA maps exist, the two approaches often produce similar results (Figure 3).

Compared to high-quality FEMA flood maps, the large-scale model captured 86% of the specified floodplain [*Wing et al.,* 2017]. The correspondence was even better on larger rivers, in temperate climates, and in more rural basins. This top-down model therefore fills in the areas that the bottom-up FEMA maps miss, such as areas around small streams and

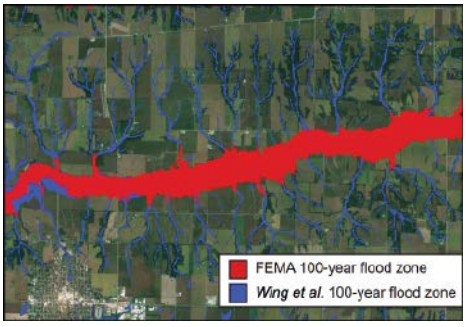

Fig. 2. A typical snapshot of the flood maps produced by each model approach for an area of Illinois demonstrates FEMA's tendency to focus on larger rivers, missing the flood risk associated with smaller streams. Our modeling method, on the other hand, captures a finer level of detail.

across broad swaths of the midwestern and northwestern United States.

We find that this data gap equates to an extra 28 million Americans living in the 100-year flood zone. This difference is so large that even amid likely model uncertainties, it is a significant result.

Implications for Flood Risk Management in the United States

Scientists and policy makers require comprehensive floodplain mapping to manage U.S. flood risk in a coordinated way. Accurate, engineering-grade flood models in every river basin in the CONUS would be ideal, but given realistic financial constraints, it is clear that we need new, affordable approaches to generating comprehensive national maps.

An understanding of flood risk across the nation, rather than in patches, could lead to fewer surprises akin to Hurricanes Harvey in Texas and Irma in Florida. Such a comprehensive understanding could also assist opponents of continued development in risky areas and ensure that the culture of preparedness FEMA wishes to build becomes a reality across the country.

In addition, a large-scale modeling approach can answer a number of crucial questions that cannot be addressed by a patchwork of local models. Because nationwide flood maps can be produced quickly and relatively cheaply, a wealth of new products could be generated. For example, in addition to the 100-year floodplain, other return periods can be mapped, which enables improved risk management through a graded system. With this information, community authorities could perhaps seek to impose more stringent regulations on buildings in the 1-in-20-year floodplain while relaxing those in the 1-in-500-year floodplain.

This nuanced approach could also lead to more realistic risk assessments and flood preparation measures. Right now, risk zones in maps are treated as binary, which can be problematic: People who live just outside the currently mapped 100-year flood boundary do not face considerably less risk than people who live just within it. Yet new development tends to cluster around these boundaries, often still in risky areas. Maps that contour risks in a more detailed way could prevent this effect through ensuring a smoother gradient of development increase farther outside of the higher risk zones.

Large-scale and automated modeling approaches offer flexibility as well: The ability to rerun multiple flood maps allows modelers to test the effect of different scenarios by perturbing inputs to the model. For example, the effects of climate change, population growth, land use change, and flood risk management scenarios can be included for making decisions on a national scale.

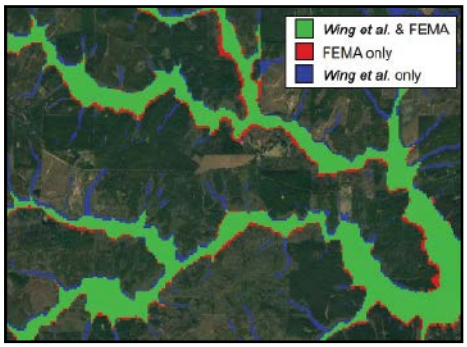

Fig. 3. A map comparing our large-scale model with FEMA's model for an area of Alabama. The two approaches produce similar results here, where the FEMA data exist, with our large-scale floodplain model capturing more than 90% of the FEMA floodplain with minimal genuine overprediction. From Wing et al. *[2017].*

Large-scale models won't completely replace the bottom-up approach: Certain decisions require accurate local modeling techniques. There is unambiguous value to engineering-grade local models. Such models are needed, for example, when exploring the effect of installing or removing levees. Highly localized decisions will still require a FEMA-style analysis.

What Next for Hydraulic Modelers?

Flood inundation models, two types of which are outlined here, are subject to fundamental constraints with regard to their accuracy. The performance of FEMA-style models is approaching a ceiling: The characterization of extreme flows often imposes a fundamental limit on further model improvements. Errors of 25% or more are common in gauge observations [*Di Baldassarre and Montanari,* 2009], and there are gaps in the data required for the statistical analysis used to calculate flow return periods [*Smith et al.,* 2015].

For modeling results to be meaningful, any improvements in calculations must be accompanied by commensurate improvements in the measured data and other factors in the modeling approach. For instance, there is little value to a centimeter-scale hydraulic model if you don't actually know how big the 100-year flow is.

This need for better data, coupled with the need for many more decades or even centuries of river flow observations and an expanded river gauge network, means that the flow characterization gap is not likely to be resolved any time soon.

There is, however, still plenty of room for improvement in large-scale modeling. For example, scientists have yet to generate seamless, hyperresolution DEMs of entire continents, and the remote detection of local-scale, hydraulically important features is not yet feasible. With solutions to these problems on the horizon, it may not be long before large-scale models, too, reach the limit imposed by extreme flow characterization.

Despite these limitations, scientists assessing flood risk could expand and deepen their insights using a multimodel approach similar to the one that climate scientists use. Also, on an international scale, the next big step is to run flood models with data from the high-accuracy DEM of the world. Creating a high-resolution global flood hazard model [*Sampson et al.,* 2015] could help identify at-risk populations in areas like Africa, South America, and Southeast Asia that don't have FEMA-style local flood maps.

Floods of Data Can Help Address Flood Risk

Without freely available data, we could not have conducted our assessments, which means that we could not have identified that millions of Americans face flood risks beyond those charted in FEMA maps. One thing, then, is clear: To help protect people from floods, we will continue to need a deluge of data.

Ultimately, better predictions also require better data, which is why it's so important that the United States continue to fund U.S. Geological Survey (USGS) efforts to maintain river gauges and expand lidar data coverage to areas in the United States that lack this coverage. And it is equally important that USGS continue to make these data public.

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Solidarity Among World's Scientists Needed Now More Than Ever

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Frustration is mounting over nationalistic policies in the United States and other countries that are obstructing the free exchange of ideas and effective collaboration among scientists.

These policies have multiple impacts. The most immediate and visible human tragedies are borne by refugees and immigrants. At the same time, several academics have lost their jobs or their ability to carry out their missions where nationalistic governments have restricted academic freedoms and defunded science and education. Sadly, enrollment of foreign students in U.S. universities appears to be on the decline, perhaps due to uncertainties regarding visas and concerns over reported xenophobic sentiments that our leaders appear to condone. Tightening visa restrictions in the name of national security also impedes the ability of scientists to work collaboratively to advance scientific discovery that benefits humanity.

While these trends are widespread, the actions and words of the Trump administration are receiving particular attention, for good reason. We must respect differences of opinion regarding immigration policy and national security, but we cannot remain silent when human dignity is violated, as we have witnessed since last summer on the southern U.S. border. Equally disturbing are statements and actions that disregard the value of science-based evidence in policy making. So what are the appropriate responses for scientific societies like AGU and its international membership? With about 40% of our members living outside of the United States, this question clearly extends beyond American politics.

Support "What Science Stands For"

We must stand together to insist that scientific collaboration remain international and interdisciplinary. I can certainly empathize with those outside the United States who might be considering boycotting U.S. meetings as a protest to several of President Donald Trump's policies and statements. But I would argue that such boycotts would simply advance the type of nationalism that we need to stand up against. The negative impacts of boycotts would not be felt by this administration, but the consequences for our science would be very real indeed! As we face global challenges of managing the Earth system with human populations destined to exceed 8 billion or 9 billion people, we urgently need the diverse scientific expertise and cultural perspectives that international meetings offer to finding effective solutions.

This year's fast approaching Fall Meeting 2018 in Washington, D. C., from 10 to 14 December is a particularly opportune time for showing solidarity. In addition to engaging key administration officials and bipartisan representatives of the U.S. Congress, AGU is inviting science attachés from several embassies and international agencies located in Washington. As always, the scientific program addresses Earth and space research. Consistent with this year's theme, "What Science Stands For," the program will also feature sessions on ethics and workplace issues, such as sexual harassment, diversity, and inclusion, and on career development matters, such as tenure and promotion. These topics are universally relevant, but they often have important culturally specific aspects that require diverse perspectives.

On the basis of what AGU leaders are hearing from our members, I pledge that we will add a session on promoting international science in an increasingly nationalistic world (see http://bit.ly/intl-science). We need you to help us stand up for "What Science Stands For."

Communicating in Washington, D. C. and Beyond

Although solidarity at meetings sends a huge signal, AGU is also working diligently in quieter ways. We are advancing bipartisan support in the U.S. Congress for science funding and policies protecting scientific integrity. We have established good working relationships with key administration appointees and career professionals within the agencies who are dedicated to advancing science. We are providing training and tool kits for our members across the world to learn to tell their stories effectively to community groups, school groups, congregations, businesses, the media, and decision makers at all levels. Engaging broadly in civil society to demonstrate the importance of science to society will be our most enduring strategy to counter the shifting political winds that follow election cycles and nationalistic movements.

Science always benefits from diversity, and this is no time to allow the political climate in the United States and elsewhere to deter us from making our science great by fostering diverse contributions from our international membership. Whether it is at this year's AGU meeting in Washington, D. C., or any other scientific society's meeting in the United States or elsewhere, I call on scientists across the globe to show solidarity for our shared values and to advance international science for the benefit of humanity.

By **Eric Davidson** (email: president@agu.org), President, AGU

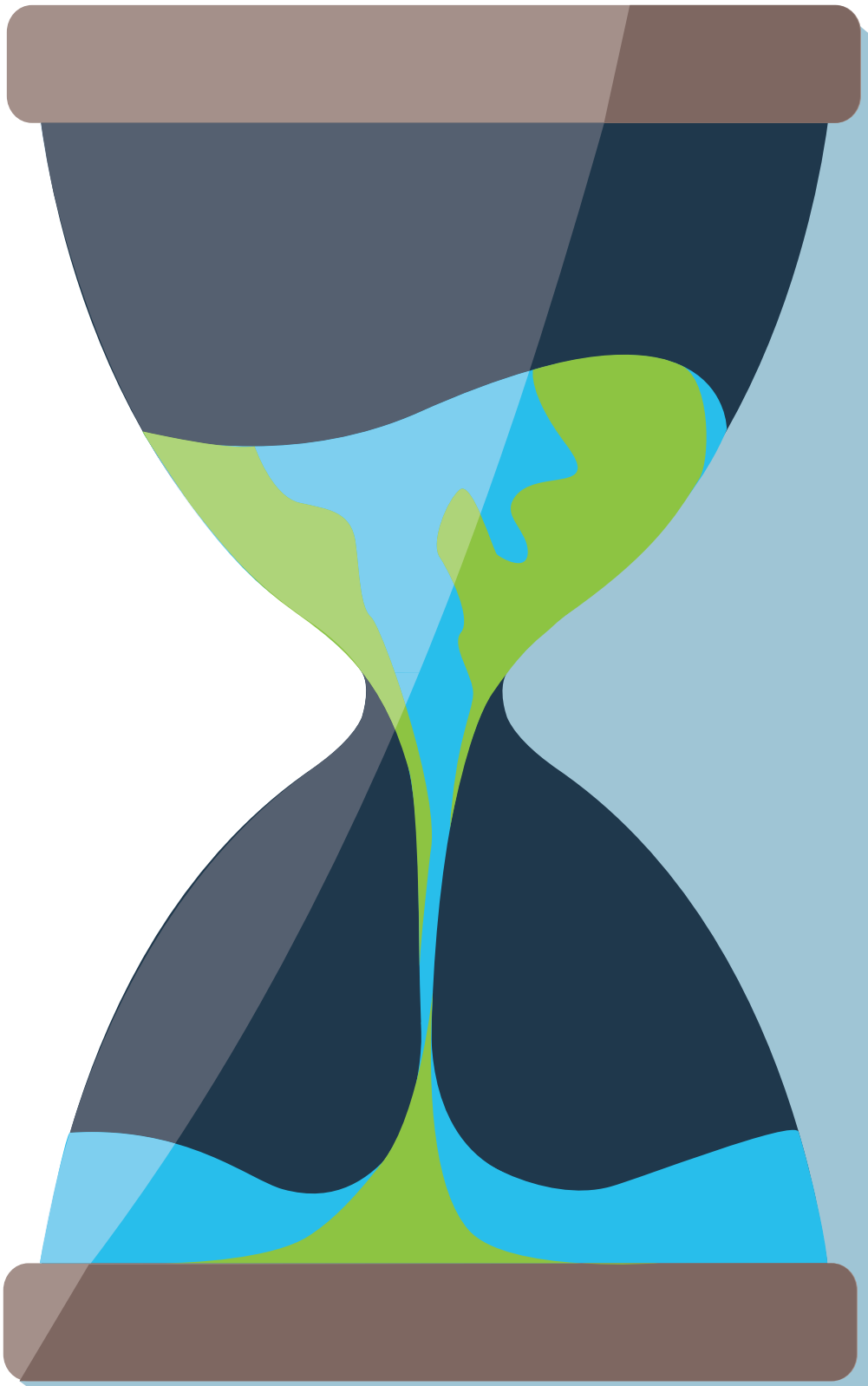

Illustration: Shany Muchnik/Shutterstock; Design: Valerie Friedman

THE PUSH FOR A CLIMATE CHANGE IN CONGRESS

By Randy Showstack

Rep. Ted Deutch (D-Fla.) is on a mission to find bipartisan solutions, further Democratic goals, and end the dark money that spurs members of Congress to oppose climate measures.

For congressman Ted Deutch, a Democrat who represents part of southern Florida in the U.S. House of Representatives, there is no time to waste in dealing with climate change. The effects of climate change, Deutch warns, threaten our national security, our economy, our health, and our daily livelihoods. And it's an urgent social, political, and personal issue that he sees is hitting his low-lying state hard.

Since his election in 2010 to represent Florida's 22nd district, Deutch has been on the forefront of congressional efforts to combat climate change. He cochairs the House's bipartisan Climate Solutions

Caucus, a group that he cofounded in 2016 with Rep. Carlos Curbelo (R-Fla.) to explore policy options that address climate change. That group currently has 90 members, with Democrats and Republicans represented equally. However, Curbelo and many other Republican members of the caucus lost their reelection bids in November's midterm election.

Deutch, 52, also is the likely next chair of the House Committee on Ethics, now that Democrats will control a majority in the House when Congress convenes in January. His work and insights on the legislative sides of climate change and ethics offer a window into congressional efforts to move forward on dealing with climate change in the current political climate. With President Donald Trump's pledge to withdraw the United States from the Paris climate accord and calling climate change "a hoax," Deutch and others who are concerned about the issue face a tough fight.

Eos recently spoke with Rep. Deutch about the urgency to act on climate change and about the Climate Solutions Caucus, climate legislation priorities, dark money in politics, and his personal concerns about the environment.

This interview has been condensed and lightly edited for flow and grammar.

Eos: *You have called climate change the greatest challenge in our lifetime and said that we must act now to prevent irreversible damage. Why do you think that's the case?*

Deutch: We are seeing the effects of human contributions to climate change now playing out, right in front of our eyes. Unless we take action now, these effects will simply be the start of a downward spiral. The impact of that on our environment, on our quality of life, on our economy would be so severe. We must recognize that we've got to face climate change at this moment and that we have to face it with urgency.

Eos: *What is your reaction to the Intergovernmental Panel on Climate Change's recent report that says that the world has until 2030 to cut carbon emissions by 45% before temperatures rise 1.5°C above preindustrial levels? The report also concludes that if emissions are not reduced, the current trajectory positions us for far higher temperatures by the end of the century.*

Deutch: The trajectory, they point out, is 3°C–4°C worldwide, which is unlivable. The report rightly talks about dramatically increasing the share of the primary energy we use from renewables to have any chance at reducing that increase.

Protesters at the 2017 March for Science in Washington, D. C., urge politicians not to dismiss science. Credit: Beth Bagley

"We must recognize that we've got to face climate change at this moment and that we have to face it with urgency."

The findings are terribly troubling, but they just confirm what we've known for a long time: We're not doing enough to reduce carbon emissions, and we have to move more quickly toward clean fuels.

This is urgent. It's urgent especially for a state like mine. The urgency expressed in that report is something that we can't move away from. It needs to help guide the policy decisions that we make.

Eos: *I understand that you recently toured an area of Fort Lauderdale hit hardest by king tide. What was that like?*

Deutch: In southern Florida, we're seeing the impact of climate change on sea level rise. That plays out most dramatically every year during king tide, which is the highest tide of the year. This morning, I met with a business owner in Fort Lauderdale whose salon faces rising waters, and as a result, there are periods when people can't come through the front door.

It's just powerful to speak to people for whom climate change isn't some concept of a far-off impact but something that they're feeling right now.

Rep. Ted Deutch (D-Fla.), cochair of the House Climate Solutions Caucus and the ranking Democrat on the House Ethics Committee, speaking in 2016 at the National Press Club about getting big money out of politics. Credit: Paul Morigi/Contributor/WireImage/Getty Images

Eos: *Given sea level rise, extreme weather, national security implications, and other concerns related to climate change, what do you say to people who dismiss the need for action now because they think that climate change is some event in the distant future?*

Deutch: It's just a matter of helping people to understand and be willing to acknowledge that this isn't all just a big coincidence, that these things [sea level rise, severe weather, and other phenomena] are happening all at the same time, and that climate change is causing these changes.

Eos: *How do you approach people who don't believe in the scientific consensus that humans are changing climate?*

Deutch: The example for the country, as set in south Florida, is that climate change is an issue that we have to tackle together. Those who continue to refuse to do it are going to have their voices become less and less relevant. That's how we find ways to go forward.

Eos: *Why did you cofound the Climate Solutions Caucus?*

Deutch: In southern Florida, climate change is an issue that's not partisan and that's not distant. It is here now, and the local community is dealing with it. Local government officials—Democrats and Republicans alike—and the local business community from small business owners to CEOs of some of our large corporations all are working together to find ways to invest in resilience, to work together to put a regional plan in place.

> **"Climate change is an issue that we have to tackle together. Those who continue to refuse to do it are going to have their voices become less and less relevant."**

Coming from here, it was frustrating that in Washington climate change is too often viewed through a partisan lens. So Rep. Curbelo and I started the Climate Solutions Caucus, working with our friends in the Citizens' Climate Lobby and some other groups, for the purpose of bringing people together to talk about these issues and to hear from experts.

Eos: *How has the caucus advanced the conversation? I understand, for instance, that the caucus played a key role regarding the 2017 National Defense Authorization Act (NDAA).*

Deutch: There was an effort to essentially eliminate from the Defense Authorization Act any reference to climate change and its impact on our national security. In that case,

Rep. Ted Deutch speaks with a constituent during king tide flooding in Fort Lauderdale, Fla., on 17 October 2016. Credit: Office of Rep. Ted Deutch

we were able to come together, and the majority of members of the caucus helped to defeat that amendment.

There is a whole lot more that we need to do. We've not been unified enough for me. We were not unified enough when the president pulled out of the Paris accord. There was more that we should have done. I think that there is more that we can do through legislation. But being able to at least stop the proposed NDAA amendment from going forward was a first step.

> **"We were not unified enough when the president pulled out of the Paris accord. There was more that we should have done."**

Also, getting people to sit around a table and listen to experts talk about the impact of climate change on our economy—and, frankly, the opportunities for economic growth that arise out of the many things we can do to combat it—is, I think, a positive step.

Eos: *I understand that the caucus is developing bipartisan climate legislation.*

Deutch: My hope is that we will be able get to a serious effort to pass a carbon fee bill, something that will both help to change behavior and bring Democrats and Republicans together. Because it's a bipartisan idea, we ought to be able to approach it in a bipartisan way.

Eos: *What do you mean by a carbon fee program?*

Deutch: It's a rebate program, so that people who produce carbon will pay a fee for it and then that money will be rebated to consumers throughout the country to help create economic growth that way.

My hope was that we could have a bipartisan bill to introduce even before the end of this Congress, and I've not given up on that hope. I'd like to get something on the table just as a starting point for further bipartisan efforts.

Eos: *Would a carbon fee be the key point of the bipartisan legislation?*

Deutch: Yes. I think putting a price on carbon and having a carbon fee with a rebate is the best way to generate bipartisan support.

In the meantime, there are lots of other issues, lots of other proposals about energy efficiency and further encouraging green energy at both the macro level and for the individual homeowner. There are a lot of ideas that hopefully we'll be building into a legislative agenda. That's an agenda that's probably going to have to wait until the start of the next Congress, however.

Eos: *How do you respond to criticism that some House members are trying to greenwash their image—for example, saying that they care about climate change by being part of the caucus but then not having very good voting records on environmental issues?*

Deutch: I don't really buy the greenwashing. There may be members who attempt to hide a bad voting record on climate and the environment by claiming membership in this caucus. But people are ultimately going to be judged by what they do, not just by what they say. And I want them sitting at the table to hear from these experts so that perhaps they'll be willing to do more.

Eos: *Do you think that bipartisan efforts are the most effective ways to move forward with climate solutions, or would partisan efforts by House Democrats be more effective?*

Deutch: I think people are tired of Washington refusing to approach issues using common sense, particularly given what's at stake.

I always think that if we could do something in a bipartisan way, that's the best way to effect lasting change. We're going to continue to push that. At the same time, I want the outside groups to increase the pressure as much as needed to get my colleagues to understand that there needs to be action as well, that they need to step up, they need to vote the right way, they have to speak out.

So it's a combination. I want this caucus to have a broad membership, with people who might not otherwise be part of the debate sitting at the table, but then I want them to also do the right thing as a member of Congress and support efforts to combat climate change.

Eos: *What will be the Democrats' first priority on climate change in the next congressional session?*

Deutch: I'm not prepared to point to a single piece of legislation that needs to pass. The first action that we need to take is to ensure that climate change is on the agenda, that it is part of the debate, and that it is seen for what it is:

> **“One of the reasons that we haven’t seen action on climate change is that the biggest polluters use their money to influence the politicians who will be casting votes.”**

an urgent threat to the future of our economy, of our country, and of our world. If we can accomplish that, it will be easier to highlight the work the private sector is doing and to finally get the government to do the job that it needs to do to turn back some of the dangerous policies that we’ve seen coming from this administration.

Eos: *In addition to putting a price on carbon and promoting green energy and energy efficiency, what are other legislative priorities? I know you’ve talked about infrastructure resilience as climate warms.*

Deutch: We’re going to put forth an infrastructure package that will help generate economic activity and will do all the things that we have traditionally talked about when we view our aging infrastructure. But we have to make sure that those investments in infrastructure include strong investments in making sure that we have resilient infrastructure. The whole idea of resilience matters enormously now.

Among all of the things that we can do, keeping climate change and the impact of climate change as central parts of any infrastructure plan is, I think, what can be the most effective right now.

Eos: *You have spoken out against hard-to-trace dark money in the political process. You are also a sponsor of the Democracy for All Amendment to the Constitution to counter the Supreme Court’s 2010* Citizens United *decision, which led to unprecedented political spending. What is the connection between dark money and climate change action, and how concerned are you?*

Deutch: I’m very concerned. One of the reasons that we haven’t seen action on climate change is that the biggest polluters use their money to influence the politicians who will be casting votes. They are using their money to try to safeguard their business interests. They refuse to acknowledge the impact that they are having on climate change and, ultimately, on our economy. They spend enormous sums—unlimited money—to protect these polluting businesses.

We’ve got to break that lock that some of these groups have on too many members of the House and the Senate. Trying to get big money out of politics and eliminating dark money are the best ways we can do that.

Eos: *Is there any traction on the Democracy for All Amendment?*

Deutch: There is a lot of traction in America. There’s more and more traction in Washington, and I think you’ll see a return to this issue as part of a broader accountability agenda that we hope to roll out in January.

Eos: *Why are you personally so concerned about climate change?*

Deutch: The data are clear; the stories that we read are compelling. When you see it firsthand, as we do in Florida, when you see the severity of the storms increase, when you know that the algae blooms that we’re dealing with are worse when the water temperature is higher and you see water in the streets as a result of sea level rise, you feel that you have to act.

In my case, its personal because I’m a parent. My wife and I have three kids. When we talk about what’s going to happen over the next 20 years, 30 years, and 50 years, the impacts will affect them and their children. I want the decisions that they make about where they live and what they pursue and how they enjoy life to be driven by their desires and not by the necessary ways to avoid the impact of climate change.

That’s the way I think about it. I’ve had the privilege over the past couple of years, especially through the caucus, to talk to so many people who have seen their lives impacted dramatically already. For them, for our kids, and for future generations, there is no time to waste.

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MEETING THE MINERAL NEEDS OF THE UNITED STATES

By Graham W. Lederer and Erin A. McCullough

The U.S. Geological Survey tracks the supply streams of 90 key mineral commodities. Its work pinpoints where the United States is most dependent on mineral imports and highlights ways to reduce this dependence.

The United States relies on mineral resources of all kinds: iron and aluminum for automotive parts, rare earth elements for consumer electronic devices, and titanium pigments for paints and coatings, to name only a few. The United States can produce enough of some of these mineral commodities to meet domestic demand, but for others it relies on imports from around the world. Political instability and competition from other nations could disrupt the flow of imported minerals, leaving U.S. markets to deal with shortages and high prices. Thus, it is necessary to keep track of what is imported and how much and from whom.

On 20 December 2017, the White House issued Executive Order 13817, entitled "A Federal Strategy to Ensure Secure and Reliable Supplies of

Stacks of aluminum ingots, ready for transport. Credit: Leonid Eremeychuk/Shutterstock

Critical Minerals," which cites the reliance of the United States on imports for certain mineral commodities vital to economic and national security interests. The order states that increased domestic exploration, production, recycling, and processing will reduce reliance on imports. And import reliance is one of many factors that determine the risks communities would face if foreign supplies were disrupted [*Fortier et al.*, 2015].

The U.S. Geological Survey's National Minerals Information Center compiles and publishes production, consumption, and net import reliance data for more than 90 nonfuel minerals and materials. By combining production, trade, and consumption data into a single statistic for each commodity, net import reliance provides a method to evaluate the status of the U.S. mineral supply.

Here the key components that determine net import reliance are described to better illustrate the role of the domestic mineral industry, natural resources, and international trade relations. Although other factors, such as geographic production concentration and the availability of alternatives, are important, reducing net import reliance is one way to mitigate supply risk.

Of the more than 90 individual mineral commodities analyzed in 2017, the United States relied on imports for more than half its supply of 50 mineral commodities [*U.S. Geological Survey*, 2018]. Mineral commodities for which the United States was greater than 50% import reliant are shown in Figure 1. Mineral commodities for which the United States was less than 50% import reliant (e.g., lead and copper) or a net exporter (e.g., molybdenum) are not shown.

What Is Net Import Reliance?

Net import reliance measures the dependence of a nation—in this case, the United State—on imports to meet domestic consumption. This figure is the difference between imports and exports of mineral commodities, adjusting for changes in industry and government stocks.

Stock adjustments refers to changes in the amount of material held in inventories. Decreases in stocks contribute to net imports, whereas stock increases reduce net imports. Negative net imports indicate that the United States was a net exporter. For all other mineral commodities, net imports contribute to the total quantity consumed by the United States. This total quantity, referred to as apparent consumption, is the sum of primary production, secondary production, and net imports.

Primary production refers to material mined, refined, or manufactured domestically, whereas secondary production refers to material recovered from recycling of scrap. Net import reliance (NIR) is the percentage of domestic apparent consumption that comes from net imports.

Although the general form of the NIR equation is used consistently across mineral commodities, data on domestic production, industry stocks, or rates of recycling may not be available for each individual commodity. The relationships among the variables used to calculate NIR are shown in Figure 2, which shows how the apparent consumption of refined zinc is dominated by imports.

Consumption and Trade

Three sources meet domestic demand for mineral commodities:

- primary production
- secondary production
- net imports

The United States depends entirely on imports for 21 mineral commodities. For 19 of these, including cesium, rubidium, and tantalum, no domestic production takes place (NIR is 100%). Minimal quantities of fluorspar and sheet mica are produced domestically as by-products of limestone and feldspar mining, respectively.

For mineral commodities with less than 100% import reliance, primary and secondary productions satisfy the remaining portion of apparent consumption. In some cases, primary production data are withheld to avoid disclosing proprietary information; in these cases, approximate NIR values are used.

Imports and exports include raw materials such as ores and concentrates, metals, chemicals, and certain semimanufactured products. Materials embedded in finished consumer products are not considered in traditional net import reliance statistics. Exports of mineral commodities with no domestic production represent imported material that underwent a transformation process in the United States. For example, although gallium is not produced domestically, low-grade primary gallium imports are refined into high-purity gallium at a facility in Utah, some of which is then exported in the form of light-emitting diodes (LEDs), integrated circuits, and other products.

U.S. Supply Status

The domestic components of supply consist of primary production and recycling. Primary production refers to the mining of ore from reserves, the economic subset of identified resources. In Figure 1, a primary production box indicates that a mineral commodity is produced domestically, even if production data are withheld or excluded from apparent consumption.

A recycling box indicates that a mineral commodity is currently recycled in the United States. Quantitative estimates of the contribution of recycling to apparent consumption are not available for several mineral commodities. For example, gallium arsenide semiconductors are recycled as new scrap (distinct from postconsumer scrap) but are not included as secondary production of gallium or arsenic.

Resources are defined as naturally occurring concentrations of material in Earth's crust where economic extraction is currently or potentially feasible. Although resources of many mineral commodities occur in the United States, resources of some mineral commodities are insignificant or currently considered subeconomic (e.g., certain domestic resources of manganese, tantalum, and tin).

Reserves represent the portion of identified resources that could be economically extracted or produced at the time of determination. Reserves are dynamic and dependent on continued exploration and changing economic conditions such as commodity prices and extraction costs. Reserves and resource terminology are not applicable to

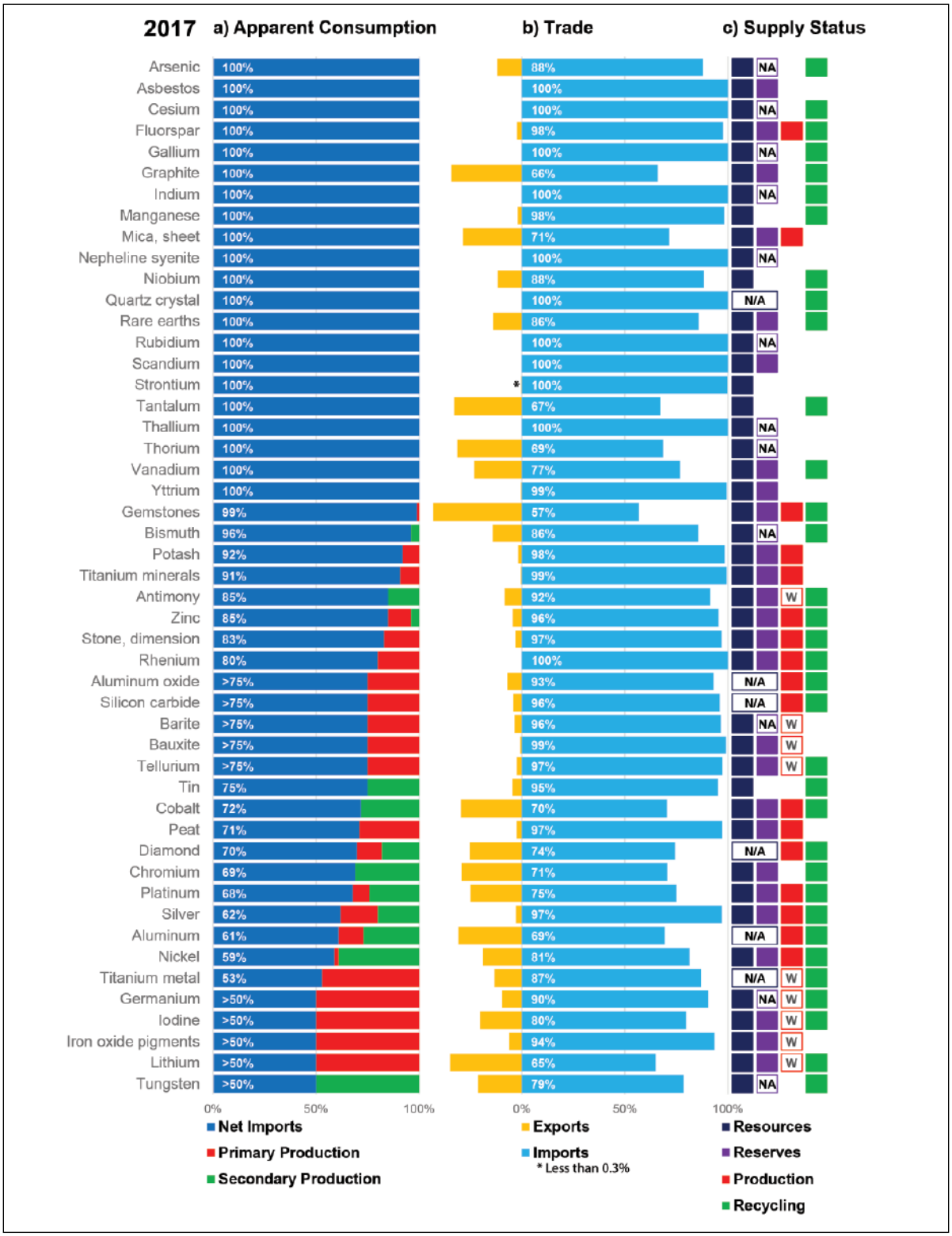

Fig. 1. Data for 2017 for apparent consumption, trade, and supply status of mineral commodities for which the United States is at least 50% import reliant. (a) Net imports, primary production, and secondary production are shown as a percentage of domestic consumption. (b) Imports and exports are shown as a percentage of total U.S. trade. (c) The status of U.S. supply is shown as a series of boxes. Solid boxes indicate that domestic reserves and resources exist and that a mineral commodity is produced or recycled domestically. Open boxes indicate that data are withheld (W), not available (NA), or not applicable (N/A). The N/A designation refers to manufactured materials. Note that iron oxide pigments (natural and synthetic) are combined because statistics are not reported separately. Credit: U.S. Geological Survey *[2018]*

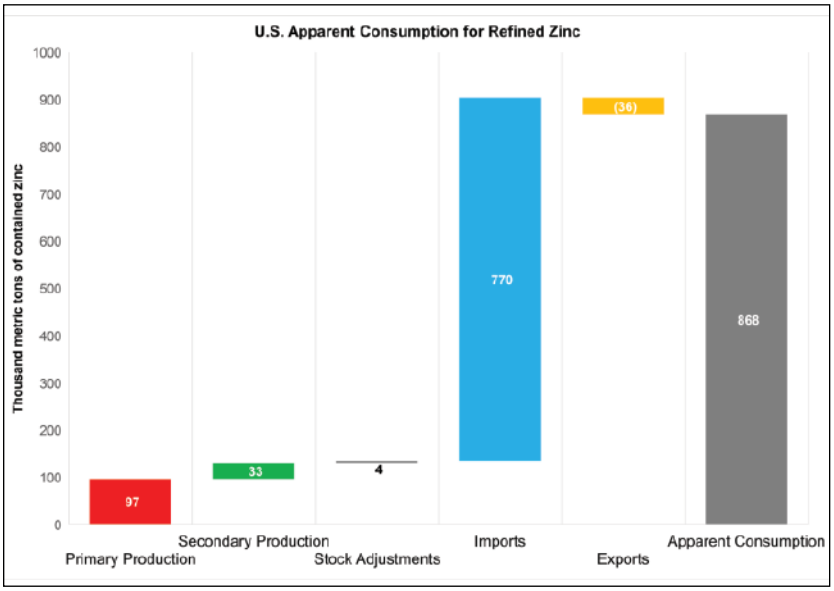

Fig. 2. A waterfall diagram of the relationship between the components of U.S. apparent consumption of refined zinc, including primary and secondary production, stock adjustments, imports, and exports.

manufactured products such as silicon carbide, aluminum, and aluminum oxide.

By examining the components of apparent consumption, trade, and supply alongside net import reliance, a few general trends become apparent. Reserves, production, recycling, exports, and by-product recovery each contribute to the overall import reliance picture.

Domestic Reserves

A common misconception is that the United States must import mineral commodities because no domestic resources exist. In general, the United States does not lack mineral resources. For example, it has resources of 43 mineral commodities with high NIR.

Reserves, on the other hand, are related to domestic production. Of the 26 mineral commodities with estimates of reserves, 19 are produced domestically. Seven mineral commodities with domestic reserves lack domestic primary production: asbestos, chromium, graphite, rare earths, scandium, vanadium, and yttrium.

Domestic reserves data are not available for 12 mineral commodities: arsenic, barite, bismuth, cesium, gallium, germanium, indium, nepheline syenite, rubidium, thallium, thorium, and tungsten. Estimates of reserves are not typically conducted for by-products and minor constituents of a mineral deposit. Of the 12 mineral commodities for which data are not available, eight are by-products that are not recovered domestically.

The United States lacks domestic reserves of five commodities: manganese, niobium, strontium, tantalum, and tin. Reclassifying resources as reserves requires considerable investment and effort to conduct exploration and economic feasibility analysis. Therefore, not all resources will become reserves, and not all reserves will lead to production. Reserves that may result in production include graphite projects under development in Alaska and Alabama and a niobium project under development in Nebraska.

Domestic Production

In general, mineral commodities with domestic reserves are also produced domestically. Several factors determine whether mineral commodities are produced, including market conditions, comparative advantage among countries, environmental and social issues, and other economic forces.

For example, although domestic reserves exist, asbestos has not been mined in the United States since 2002. U.S. demand decreased as a result of health and liability issues, and 100% of apparent consumption of asbestos is met through imports. Under different market conditions or regulatory policies, the United States could resume mining asbestos or other mineral commodities because reserves are available. Similarly, an increase in rare earth prices in 2011 led to the classification of reserves in California, but the subsequent fall in prices hindered domestic production. For any commodity, individual deposits are subject to similar market forces.

Several by-product mineral commodities have estimates of neither primary production nor reserves. In polymetallic ore deposits, mining operations target a specific mineral commodity, but the potential by-products are not recovered. For example, germanium, gallium, and indium are, in some cases, unrecovered constituents of zinc ore produced in the United States. Similarly, lead ores contain bismuth, but lead ores are no longer processed in the United States. In other cases, the primary mineral commodity is not mined domestically, and therefore there is no by-product recovery. For example, cesium and rubidium are produced as by-products of lithium minerals in pegmatites mined globally, but U.S. lithium production is from brine operations.

Increasing production of any mineral commodity is limited by economic factors and accessibility. For most mineral commodities, extraction costs for deposits in the United States in comparison with those in other countries are a factor in determining whether they are mined domestically. The overall financial attractiveness of a potential venture depends on all of the costs and risks (e.g., regulatory or political uncertainty) associated with the project.

For by-product mineral commodities, extraction and recovery costs control the economic viability of production. For example, sheet mica is produced as a by-product of feldspar mining in North Carolina but in such limited quantity compared with imports that NIR is essentially 100%. Despite limited production, the United States may be less susceptible to potential supply disruptions for mineral commodities with existing domes-

tic mines and processing facilities compared with commodities without domestic production. Furthermore, as demand for a by-product commodity increases, companies may be willing to increase by-product production with little additional cost if recovery capability exists at domestic plants.

Domestic Recycling

Domestic recycling has a twofold effect on net import reliance: It increases domestic supply and decreases demand for imported primary materials. Secondary production contributes to the domestic supply of 12 mineral commodities (aluminum, antimony, bismuth, chromium, cobalt, diamond, nickel, platinum, silver, tin, tungsten, and zinc).

Postconsumer scrap represents a significant unconventional "resource" for certain mineral commodities. For example, the United States does not mine chromium, but recycling of stainless steel scrap reduces net import reliance for chromium to 69%. Similarly, antimony, bismuth, cobalt, and tin all lack domestic primary production, but secondary production reduces their NIR values.

Several other mineral commodities are known to be recycled, but secondary production statistics may be limited or not available because of how material is reprocessed. Although some materials degrade during recycling, increased efficiency in the collection and processing of recyclable materials would further reduce NIR and allow the United States to recover waste and scrap that would otherwise be exported.

Role of Exports

Exports of mineral commodities occupy an important role in the U.S. economy, even when the United States is a net importer. Of the 50 mineral commodities analyzed, only 10 lack exports.

Exports contribute to the U.S. economy because imported raw materials and intermediate product forms may undergo transformative processing or manufacturing in the United States that adds value to their products. For example, the United States imports bauxite (an aluminum ore) and produces aluminum metal. NIR for bauxite exceeds 75%, but NIR for aluminum is 61%.

Lack of By-Product Recovery

Many mineral commodities with greater than 50% NIR are produced exclusively as by-products, and their production is contingent upon the production of other mineral commodities. Exploration efforts often do not focus on by-product minerals for a number of reasons. By-product minerals occur in very low concentrations, have limited impact on the economic feasibility of a project, and are traded in small quantities on opaque markets.

Therefore, estimates of reserves for by-products are limited and incomplete because producers do not routinely report information for by-product minerals, particularly if there are no plans to recover them. Comprehensive geologic exploration programs encompassing broad geographic areas and detailed mineralogical investigation would help identify domestic resources, reserves, and potential mining opportunities for by-product and minor metals.

In other cases, producers may be aware of potential by-products but choose not to recover them. This could be due to a lack of economic viability or processing infrastructure or because of the mineral composition of the ore. For example, zinc concentrates mined in Alaska and Washington contain germanium, but these concentrates are exported to Canada for processing and germanium recovery. Other by-products that could be recovered from domestically mined ores include arsenic, bismuth, gallium, indium, rhenium, and vanadium.

NIR could be reduced for many commodities, such as tellurium in copper ore, if unrecovered constituents were separated from gangue (economically worthless material associated with an ore deposit) and produced as by-products, instead of being lost as waste. Research on mineral processing technologies and marginal costs of recovery may improve the economic viability of by-product commodities.

Assessing and Reducing Risk

Net import reliance is a conceptual tool that can be applied to any mineral commodity. Increased geologic exploration, economic assessment, production, processing, by-product recovery, and recycling can contribute to reducing NIR.

The significance of NIR as an indicator of supply risk depends on a variety of factors, including the utility, substitutability, production cost, market size, and price for each particular mineral commodity. Comprehensive assessments are needed to fully understand the supply risk of individual commodities.

Reducing net import reliance may reduce supply risk; however, evaluation of supply risk should consider several factors in conjunction with NIR, such as trade relations with import source countries, changes in material demand, the availability of substitutes, and the importance of a mineral commodity to the U.S. economy. For example, the risks associated with relying on imports for rare earths may outweigh the costs of developing a secure domestic supply, whereas for other commodities, such as asbestos, continued import reliance is likely.

Thus, ensuring that the United States has adequate mineral supplies to meet its needs involves many interacting factors, such as the dynamic balance between imports and exports and the economics of developing domestic resources. However, a metric like NIR can help untangle some economic complexities and pinpoint how best to mitigate risks from supply disruptions to the mineral resources needed for modern society.

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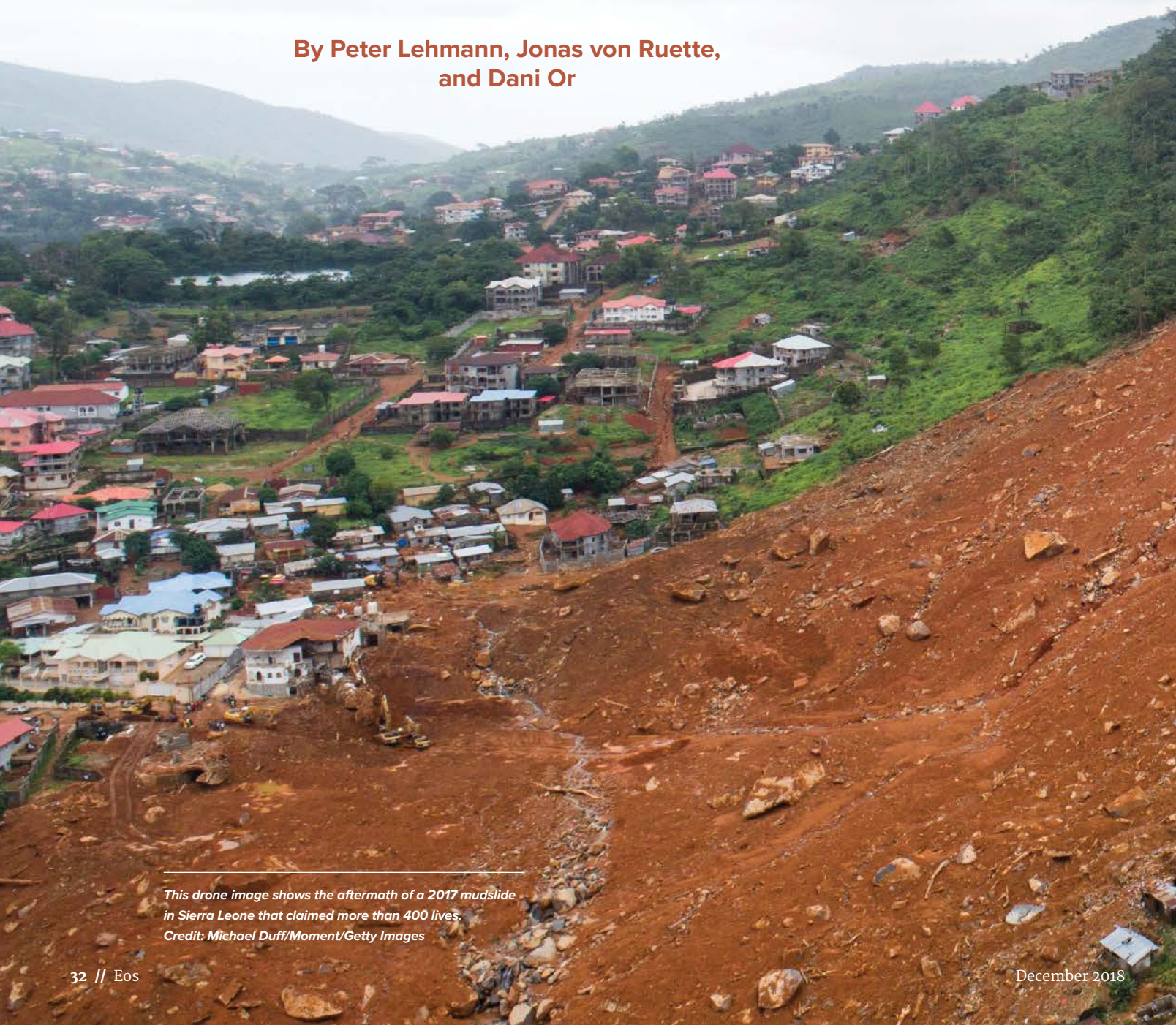
HOW LANDSLIDES BECOME DISASTERS

By Peter Lehmann, Jonas von Ruette, and Dani Or



This drone image shows the aftermath of a 2017 mudslide in Sierra Leone that claimed more than 400 lives. Credit: Michael Duff/Moment/Getty Images

In spring and summer of 2017, torrential rainfall triggered a series of landslides culminating in two catastrophic disasters: one in Mocoa, an inland city in southwestern Colombia, and another thousands of kilometers away in the coastal city of Freetown, Sierra Leone. The landslides triggered massive debris flows that destroyed neighborhoods and killed several hundred people.

Mocoa received 100 millimeters of rainfall within 6 hours, a rainfall that is statistically predicted to occur once every 30 years. Freetown received 70 millimeters of rain within 7 hours (based on rainfall data from Climate Hazards Group Infrared Precipitation with Station data, or CHIRPS), a statistical 5-year storm. These two regions are far apart, but they share a tropical climate, and their soils are predominantly clay loam, according to the SoilGrids database.

These intense rainfall events have triggered many landslides in both regions, just upstream from the edge of Freetown and several kilometers upstream from Mocoa. In both cases, however, the main cause of the damage was not the

Rescuers search for survivors on 2 April 2017 after floodwaters carrying mud and debris inundated parts of Mocoa, Colombia, killing at least 200 people and leaving many more injured and homeless. A new modeling platform assists in re-creating the paths and extents of debris flows caused by river transport of landslide materials. Credit: AP Photo/Fernando Vergara

direct impact of the soil mass released downslope but, rather, the mobilization of the released material (soil, rocks, and trees) by the river channels downstream.

These tragic events point to a gap in our ability to model at the catchment scale the interlinked processes that cause localized shallow landslides to become debris flows and the pathways such flows take. We present here a new type of model that addresses these links. This model can be applied at any catchment, is freely available, and includes a user interface for ease of use.

The main cause of the damage was not the direct impact of the soil mass released downslope but, rather, the mobilization of soil, rocks, and trees by the river channels downstream.

Landslides Trigger Devastating Debris Flows

Near Mocoa, masses of soil and uprooted trees released by the landslides reached the river channels while the rain-glutted streams were flowing at full capacity. The fast flowing river carried the soil and trees through the channel network. This debris quickly reached the outskirts of Mocoa, where it destroyed buildings and roads and caused more than 250 fatalities. Articles in local newspapers dating as far back as 2014 had warned of the potential hazards of debris-choked stream channels.

The story was similar in Freetown, where the released soil mass itself did less damage to the town than the subsequent debris flows.

Modeling Interlinked Natural Hazards Processes

We applied the new model STEP-TRAMM, which was developed in our Soil and Terrestrial Environmental Physics (STEP) group, as part of the research project Triggering of Rapid Mass Movements in Steep Terrain (TRAMM) to simulate landslide triggering and debris flow pathways. The model reconciles the highly localized landslide-triggering processes (on scales from 10 to 1,000 square meters) with a catchment-scale view of hydrologic processes (1–100 square kilometers).

The modeling platform offers several distinct advantages over existing landslide models (Figure 1):

- STEP-TRAMM can be applied anywhere on Earth using any publicly available global database that offers digital elevation data (e.g., EarthExplorer from the U.S. Geological Survey), forest maps (Global Forest Change), soil textural properties (e.g., SoilGrids), and rainfall data (e.g., Global Precipitation Measurement from NASA). These data sets are easily imported into the model as standard ASCII grid files. A digital elevation model is the minimum requirement to run a simulation; the software includes tools to define vegetation patterns and rainfall data, and it provides hydromechanical properties of different soil types.
- The model first estimates the distribution of soil depth across the catchment as a function of topography.

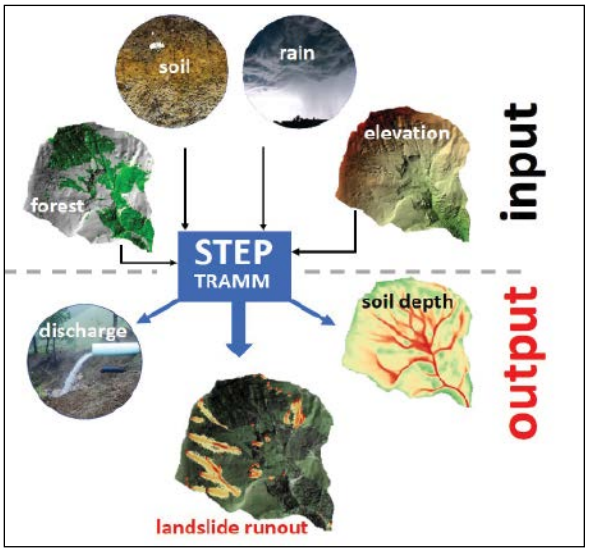


Fig. 1. The STEP-TRAMM modeling framework simulates rainfall-induced landslide triggering and debris flow runout pathways. Inputs to the STEP-TRAMM model include information on soil texture, vegetation cover (meadow and forest), topography, and the triggering rainfall event. These inputs can be downloaded from global data sets. The model computes outputs, including soil depth distribution, water flow into the river network, and—the main result—the time and location of mass release and the corresponding debris flow path.

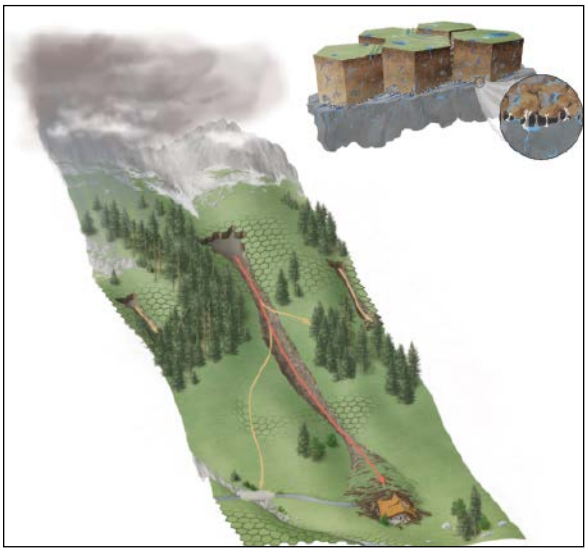


Fig. 2. Basic principles of model framework STEP-TRAMM. The soil mantle is represented by a collection of interconnected hexagonal soil columns. The water content, strength, and load redistribution are computed for each soil column and time step (see inset) to identify regions of mass release. The landslide simulation transitions to debris flow routing paths using a simple empirical model that relates landslide volume to runout distance and relief.

This is an essential step for constraining soil hydrologic and mechanical processes (forces, loads, and failure events).

- The landslide-triggering module considers dynamics of local hydrology and threshold mechanics where soil elements may abruptly fail (see below). The resulting landslide pattern is highly localized with relatively few landslides within a large catchment area.
- The released soil mass is routed as debris flows whose path and deposition areas are resolved on the basis of local topography, thus enabling assessment of landscape-scale debris flow hazards.

How the STEP-TRAMM Model Works

The model simulates highly localized landslides over a soil mantle represented by hydraulically and mechanically interacting hexagonal soil columns 1–10 meters across (Figure 2) [*Lehmann and Or,* 2012; *von Ruette et al.,* 2013]. This model, like other landslide models, calculates the balance of forces acting on each soil column, where soil strength varies with soil wetting and the presence of roots.

Unlike most other landslide models, STEP-TRAMM goes further, continuously calculating load redistribution among columns whenever the force exceeds a strength threshold. The local hydrology and water content play an important role in determining soil mechanical response—these metrics are calculated from infiltration rates, runoff, and water flow through the soil and along the underlying bedrock.

Within the model, an interconnected group of failed soil columns forms a landslide. The soil mass released in the simulated landslide event is fed into a debris flow runout module that calculates pathways and deposition on the basis of local topography. For simplicity, we opted for an empirical approach [*Rickenmann,* 1999] to relating runout distance to landslide volume and height difference. This approach provides reasonable estimates of flow paths and runout distances [e.g., *Fan et al.,* 2017].

The main differences between STEP-TRAMM and other landslide hazard models based on geographic information systems are the mechanistic representation of the local failure and load redistribution that precede an abrupt landslide, the simulation of catchment-scale soil depth, and the spatially resolved coupling of landslide triggering and debris flow runout pathways.

STEP-TRAMM Simulates the Mocoa and Freetown Events

We have used the STEP-TRAMM modeling platform and available data to compute landslide triggering and debris flow runout paths for the Mocoa and Freetown 2017 landslide events at a spatial resolution of 10 meters (Figure 3). For the Mocoa event, the simulations produced 80 landslides with a total soil volume of 200,000 cubic meters, and these were transformed into simulated debris flows.

The simulations show that many debris flows reached the streams at the bottom of the slopes and were subsequently transported to Mocoa. For the Freetown event, the impact of the debris was more direct because the released mass advanced directly toward the town.

Satellite images allow us to compare simulated debris flow pathways with the actual path of the damage, as shown for Mocoa in Figure 4. The simulations do not reproduce all observed pathways, but they do capture the

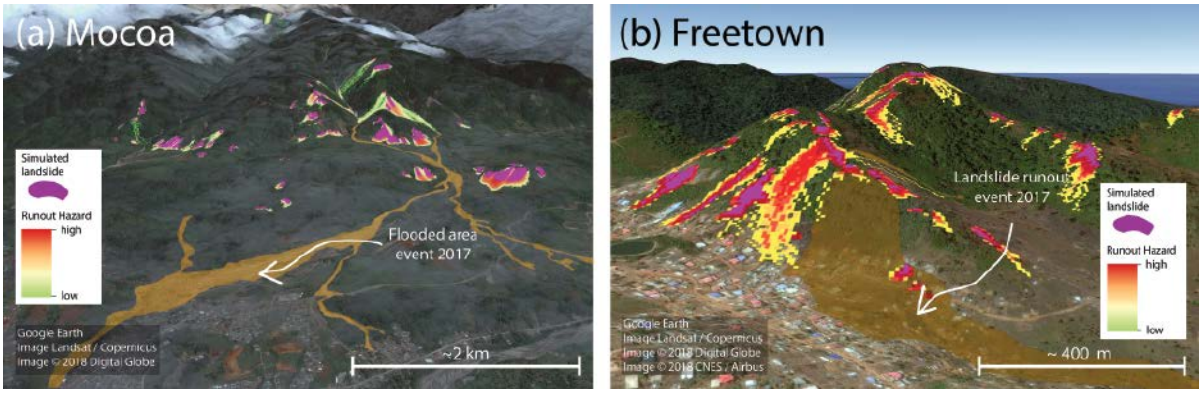


Fig. 3. STEP-TRAMM simulations of landslide soil mass releases (purple areas) and debris flow runout (warm colors indicate different calculated probabilities of runout). The brown shapes show the actual debris flow and river areas causing damage, as delineated from satellite images. (a) In Mocoa, many runout paths reached the channels of the river network. Landslide material accumulated in these channels and eventually was mobilized and caused destruction in the town (brown areas). (b) In Freetown, the landslide was transformed into debris flows that destroyed the part of the town at the bottom of the slope

main features of the real-world event, such as the concentration of landslides in a limited area in the eastern part of the catchment. Global deforestation maps show that several of the patches where landslides originated were deforested sometime between 2002 and 2016, suggesting a potential role of deforestation in promoting the onset of landslides in this region.

Outlook and Potential Applications

Inherent heterogeneity and the complexity of landslide-triggering processes preclude exact prediction of landslide release locations. Our simulations of the two 2017 landslide disasters were based entirely on remote sensing information and educated guesses of initial conditions, without local calibration. Nevertheless, STEP-TRAMM has been able to capture the salient features of landslide release events, including the numbers of individual slides, volumes of material, and approximate locations in the landscape.

The STEP-TRAMM platform offers a means for informed scenario generation, analyses of past events, and creating physically based risk mitigation strategies at the catchment scale. It could also be used to generate new science, for example, to systematically study how present and future rainfall characteristics and land use changes (e.g., deforestation) could affect landslide patterns.

Additional testing across regions and conditions clearly is required. Nonetheless, we hope that the natural hazards community will make use of this tool, which is publicly available at http://bit.ly/STEP-TRAMM, to advance process understanding.

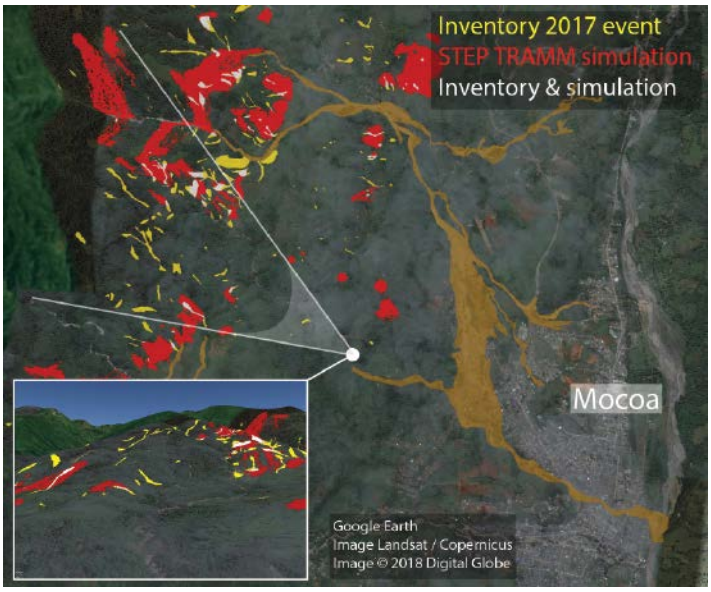


Fig. 4. Observed (yellow) and simulated (red) debris flow paths in Mocoa, with white polygons indicating overlap (inset shows a ground-level view of the area indicated). The complex processes occurring at various scales and the coarse resolution of the freely available data used to produce the model resulted in an inexact match between observed and simulated flow paths. However, the model accurately concentrated most of the landslides in the eastern region, which is also where the observed landslides were most concentrated. This region appears at top left in the main map and at right in the inset. Several areas within this region were previously deforested.

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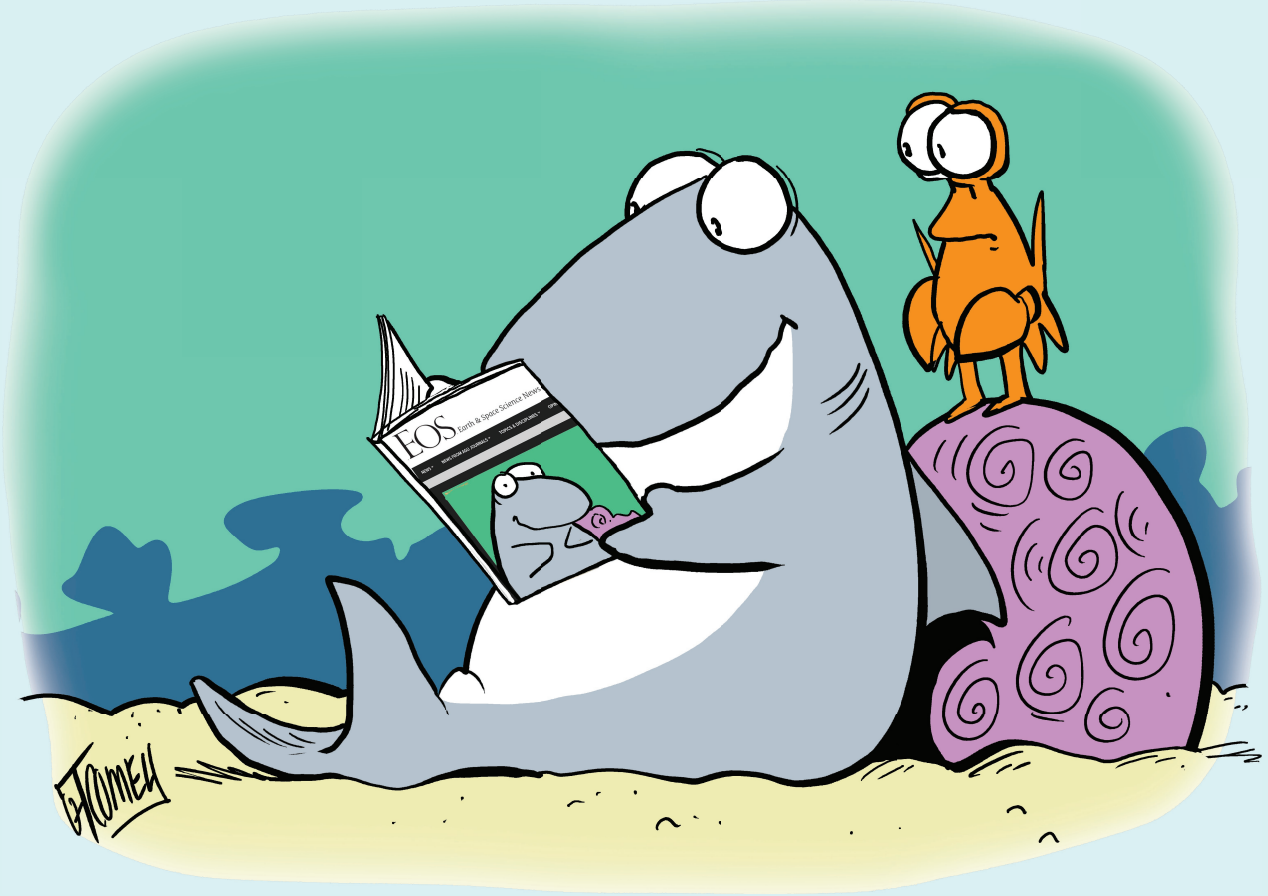
Dive into Ocean Issues with *Sherman's Lagoon*

By Randy Showstack



Sherman's Lagoon *is a popular comic strip that focuses on the everyday, all-too-human foibles of a cast of sea creatures while also sometimes tackling weighty issues about threats to the ocean. Above, Sherman, a shark, and Hawthorne, a hermit crab, read the latest issue of* Eos. *Credit: © Jim Toomey*

Who knew there was so much drama underwater?

Every day, the popular comic strip *Sherman's Lagoon* dishes up the goofy exploits of a happy-go-lucky shark, his wife, and their neighbors, who live in a fictitious and mostly friendly tropical lagoon.

They take on such seemingly weighty matters as silly sea-oriented business ideas, dating in the depths, computer hassles, and fulfilling bucket lists and grocery lists. And as they go about their lives, their antics display their all-too-human foibles.

But the comic strip often ventures into deeper waters. It mixes in real and important information about the ocean and about the serious environmental issues that the characters sometimes encounter.

Earlier this year, for instance, *Sherman's Lagoon* story lines not only revolved around schemes such as establishing a new underwater record for toppling dominoes but also drew attention to World Oceans Day and the March for

the Ocean. And in the past it has focused on marine debris, climate change, bottom trawling, overfishing, coral reefs under pressure, and other threats to the ocean and its creatures.

Sherman's Lagoon "is about trying to find that human connection while also sneaking a conservation message in or an ocean fact," cartoonist and strip creator Jim Toomey told *Eos.*

Entertainment and a Little Bit More

Sherman's Lagoon, which appears in more than 250 newspapers in North America, stars Sherman, the shark; Megan, who tries to keep her husband, Sherman, on a tight leash; Hawthorne, a party-pooping hermit crab; Filmore, a studious sea turtle; and Ernest, a nerdy fish driven to nefariousness.

"Fundamentally, I try to entertain. If I don't do that, then I get fired," Toomey mused. "So it's entertainment, it's storytelling, it's hopefully evoking a little bit of a laugh or a giggle or amusement. And then if I can accomplish all that, I oftentimes will try to weave in something a little bit more."

Toomey said that he tries to weave in those larger messages in a way that keeps the comic strip fun and apolitical. "Environmentalism has become a kind of partisan issue, and it's really important to keep [the strip] away from the politics," he said.

He noted that a few decades ago there was far less partisanship on environmental issues. Now, though, "I'll address an environmental issue, and people will email me and tell me to stop the liberal claptrap," he said. "My response is that it shouldn't really be a red or a blue issue. It should be about our kids and about our Earth. So I try not to take sides in the politics too much, at least not overtly. And that way, I can preserve a bigger audience, I think."

Toomey said that if he had a few minutes with President Donald Trump, he would tell him that "whether you're a hunter or religious, there is a lot of hidden environmentalism on the conservative side that you should pay attention to."

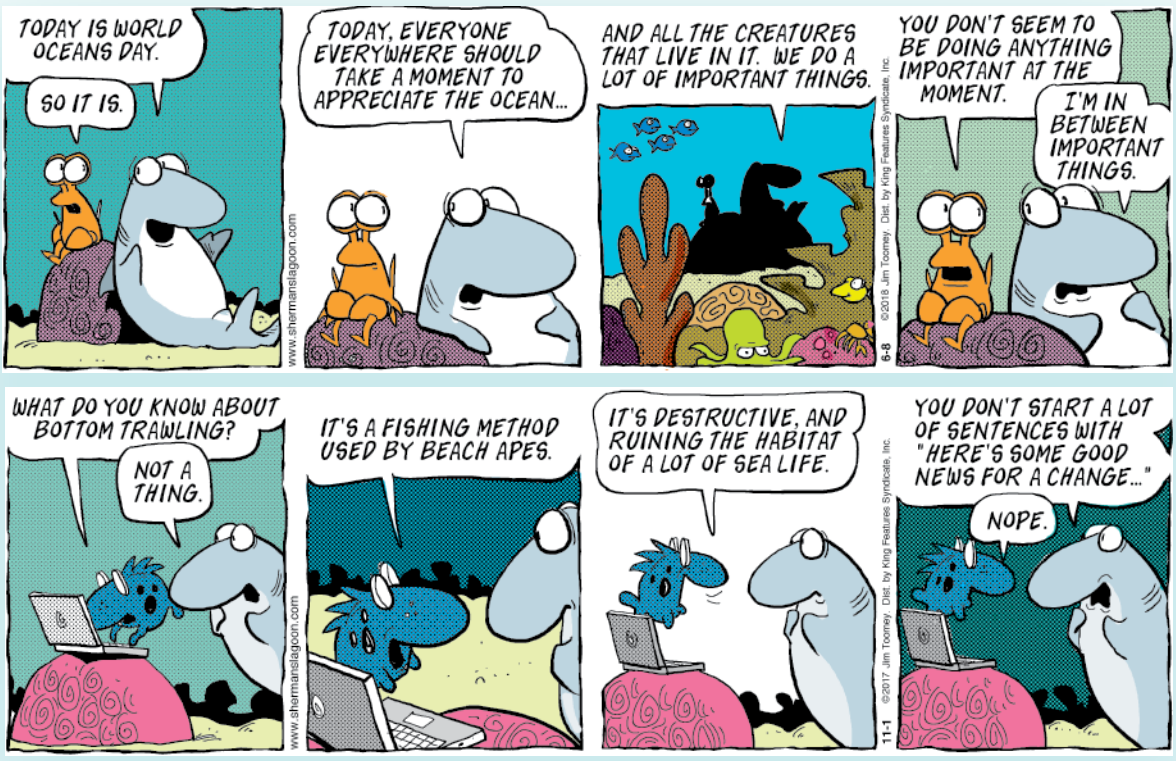
The Birth of the Comic Strip

The idea for the comic strip first took root when Toomey was about 12 years old. On a trip to the Caribbean, his father, a former U.S. Navy pilot, flew the family's six-seat Cessna 210 aircraft about 150 meters above the sea's clear waters. The ocean appeared as more than "the big gray veneer" that Toomey had been used to seeing from a beach. Instead, during that flight he noticed the underwater landscape with its hills and valleys and realized that the ocean world "is just as rich" as the world on land.

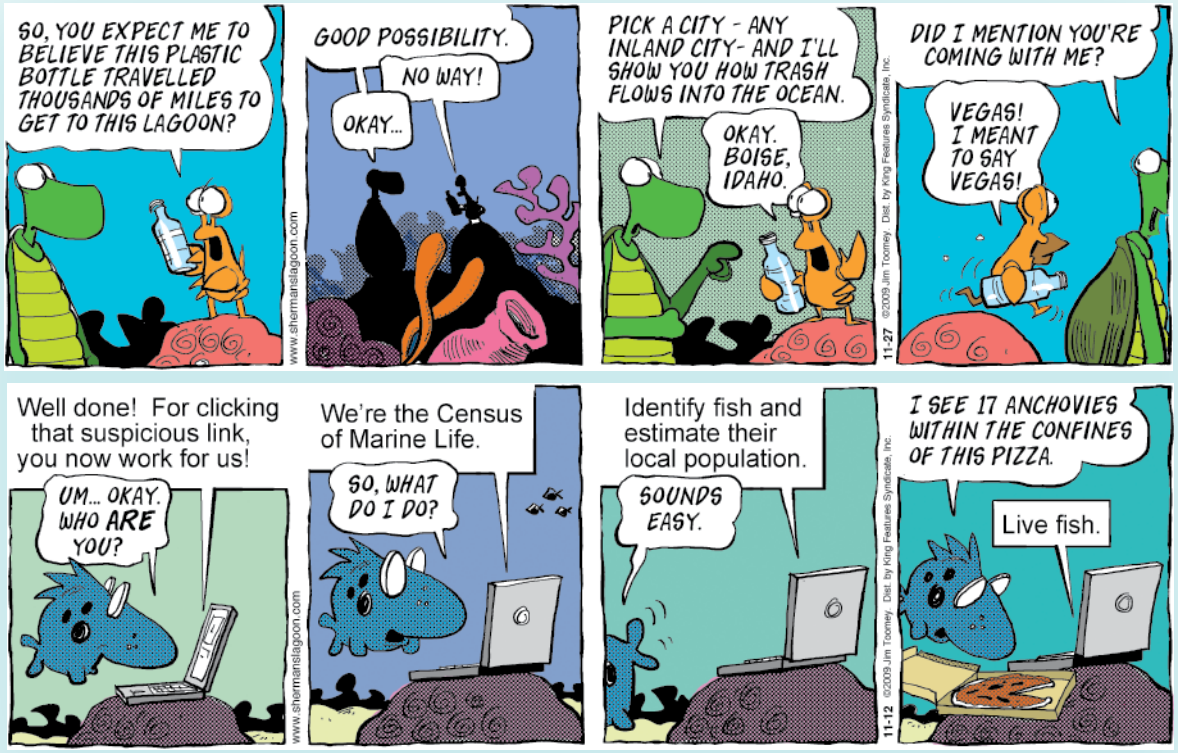
"I saw a shark in a small lagoon, and for me that was the birth of *Sherman's Lagoon,*" he said. "I was wondering what it would be like to get into the head of that shark."

Toomey recalled thinking "how cool it would be to be that shark in that lagoon and have that whole lagoon to yourself and be the master of this place."

It took him about 15 years to turn that initial inspiration into a comic strip. Toomey, who worked as a political cartoonist until he tired of the negativity and cynicism, remembers getting a book about sea life and thinking that "these characters are right out of central casting. Hollywood could not dream up a stranger cast of characters."



(Top) A panel of Sherman's Lagoon *that published on World Oceans Day, 8 June 2018, and (bottom) a comic strip from 1 November 2017 on bottom trawling, one of the many important ocean issues that Toomey has focused on in* Sherman's Lagoon. *© Jim Toomey*

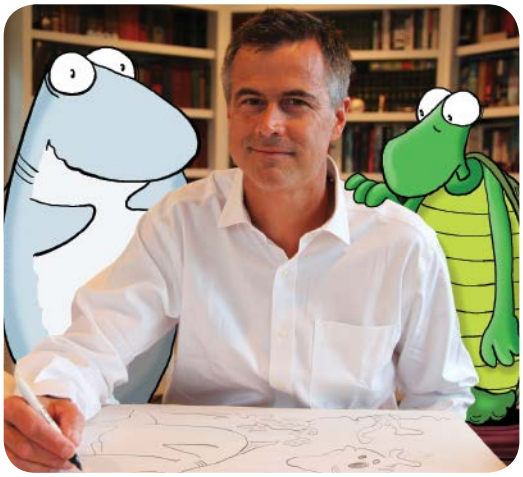


(Top) Sherman's Lagoon *comic strip from 27 November 2009, highlighting the issue of marine debris, and (bottom) one from 12 November 2009, referring to efforts to conduct a census of marine life. Credit: © Jim Toomey*

More Than a Creator of Comics

In addition to his comic strip and his many *Sherman's Lagoon* books, Toomey has also done a number of humorous and educational short videos with the Pew Charitable Trusts, United Nations Environment Programme, and others. To view one about ocean acidification, visit http://bit.ly/Toomey-video. Toomey has also given a TED talk about his work (see http://bit.ly/Toomey-TED).

Toomey earned a master's degree in environmental management in 2008 to help him better understand ocean issues "and how to wrap entertainment sweetness around a bitter pill of the environmental message." Twice, he has received environmental hero awards from the National Oceanic and Atmospheric Administration. In 2014, Toomey was the artist in residence on the DSV *Alvin,* a U.S. Navy deep-ocean submersible vehicle operated by the Woods Hole Oceanographic Institution.



Jim Toomey, creator of Sherman's Lagoon, *flanked by (left) Sherman and Filmore. Credit: © Jim Toomey*

Court Jester

The comic strip "is a little bit like a sitcom" because the story arc has to take you back to where you were at the beginning, Toomey said. "Everybody has to be the same, in the same place, the same status, unlike, say, a novel or a movie where there is a radical upheaval and things are very different in the end."

He maps out some of the story arc in advance, but not all of it. "You don't plan it all out in the beginning. You just kind of go with the flow. It's like improvising a bedtime story to a child," said Toomey.

Is he trying to make a difference with the comic strip by incorporating environmental issues? "Sometimes I am, and sometimes I'm just trying to entertain," he said. "I feel like there are other people who are actually doing the real work, and I'm kind of the court jester. I feel like the more I can tell the public, the better world we'll have. But I don't think everybody's waiting for me to do that."

Author Information

Randy Showstack (@RandyShowstack), Staff Writer

Celebrating the 2018 Class of Fellows

AGU has selected its new class of Fellows. The organization will recognize these esteemed scientists at Fall Meeting 2018 in Washington, D. C., during the Honors Tribute on Wednesday, 12 December 2018, at which President-elect Robin Bell will present the newly elected class. Please welcome our 62 colleagues who have joined our AGU College of Fellows!

A brief statement of the achievements for which each of the 62 Fellows was elected is provided below.

Jess F. Adkins

For pioneering new approaches and theories for the physical and chemical roles of the deep ocean in climate change.

Donald Francis Argus

For outstanding geophysical research in tectonic plate motions, terrestrial fluxes of ice and water, earthquake hazards, and geodetic reference frames.

Paul A. Baker

For fundamental contributions to our understanding of marine sedimentary geochemistry and the climate history of tropical South America.

Cecilia Bitz

For fundamental advances in high-latitude climate dynamics and the modeling of sea ice for climate applications.

Nina Buchmann

For her pioneering work to understand ecophysiological mechanisms regulating ecosystem carbon dynamics locally, regionally, and across diverse ecosystems.

Marc W. Caffee

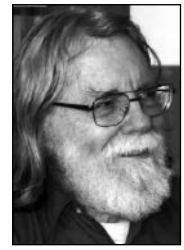
For his many contributions to highly precise measurement of isotopic abundances and applications to elucidating Earth's history.

Gregory R. Carmichael

For his seminal role in the development and application of atmospheric chemical transport models.

Andrew Cohen

For major contributions using modern and ancient lakes as archives of past climates and environmental change.



Patrick M. Crill

For deepening our understanding of the processes controlling methane emissions from the equator to the poles.

Thomas L. Delworth

For fundamental contributions to understanding Atlantic decadal climate variability, climate impact, and community service in model development.

Donna Eberhart-Phillips

For fundamental contributions to the seismotectonic analysis of subduction zones and fault zones and innovations in seismic tomography.

Kerry Emanuel

For the elucidation of fundamental dynamics and thermodynamics of moist processes in meteorology and climate.

Andrew T. Fisher

For breakthroughs and discoveries in marine and terrestrial hydrogeology, geothermics, method development, and modeling of coupled flows.

Marilyn L. Fogel

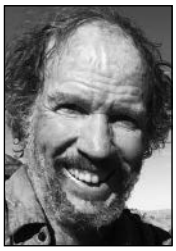
For pioneering breakthroughs and extensive achievement in isotopic biogeochemistry and leadership in establishing the field of biogeosciences.

Hayley J. Fowler

For major contributions to the prediction of hydrologic impacts of climate change.

S. Peter Gary

For fundamental advances in space plasma physics and sustained contribution to understanding the implications of plasma physics in space observations.

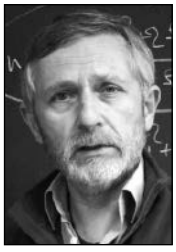


Steven Ghan

For pioneering contributions to the modeling and characterization of aerosols and clouds in the atmosphere and to innovative climate analysis methods.

Joris Gieskes

For his pioneering contributions to understanding chemical processes in the ocean, sediment, and basalt through pore water analyses and ocean drilling.



Karl-Heinz Glassmeier

For multiple fundamental transformational contributions to space and planetary physics.

Dorothy K. Hall

For pioneering, innovative, and sustained research for 44 years on global remote sensing of the Earth's cryosphere.

Charles Harvey

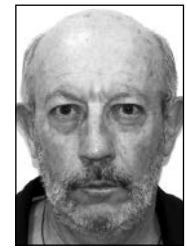
For breakthroughs in describing the fate and transport of arsenic in groundwater and bold field explorations of large-scale human–environment interactions.

Sidney R. Hemming

For major contributions using geochemical and isotopic tracers for sediments to reveal geological processes and events through Earth's history.

Benjamin P. Horton

For pioneering work on relative sea level proxies, which are transforming our understanding of Holocene sea level changes and coastal hazards.



Bruce Frank Houghton

For contributions to the nature, state, and kinematics of volcanic products and novel insights into volcanic eruption processes.

Catherine Jeandel

For major contributions on the marine biogeochemical cycles of trace elements and exploiting them and their isotopes as tracers in chemical oceanography.

Tomo Katsura

For fundamental contributions to high-pressure mineral physics and the structure and properties of Earth's mantle.

Kimitaka Kawamura

For his many pioneering and transformative contributions in understanding the origins, interactions, and fates of organic aerosols in the troposphere.

Simon L. Klemperer

For fundamental studies of the structure and evolution of oceans and continents and their margins.

Cin-Ty Lee

For diverse contributions to understanding continent formation mechanisms and the interconnectedness of Earth's interior with the surface environment.

Jos Lelieveld

For outstanding contributions to the understanding of atmospheric chemical processes and the impact of air pollution on climate and human health.

Philippe Lognonné

For pioneering development of ionospheric seismology and unique contributions to the field of planetary seismology.

Timothy William Lyons

For exploring the evolution of Earth's oceans and atmosphere and their cause and effect relationships with the origins of life.

Trevor J. McDougall

For the discovery of new ocean mixing processes and pioneering new thermodynamic variables and concepts that have become standard tools in oceanography.

Bruno Merz

For groundbreaking contributions to integrating flood vulnerability and hazard research.

Stephen Montzka

For advances in detecting and understanding changes in atmospheric trace gases that affect stratospheric ozone, air quality, and climate.

Rumi Nakamura

For fundamental contributions to the understanding of plasma transport and acceleration in Earth's magnetotail.

Heidi Nepf

For seminal contributions to the theory, modeling, and environmental applications of flow and transport through aquatic vegetation.

Victor Pasko

For developing new understanding of lightning-driven electrical gas discharges in the upper regions of Earth's atmosphere.

Adina Paytan

For major contributions to ocean biogeochemistry and seawater chemical history.

Christa D. Peters-Lidard

For outstanding contributions to understanding land surface dynamics and for visionary leadership in coupled modeling and data assimilation.

Balaji Rajagopalan

For fundamental contributions in hydroclimatology and stochastic hydrology and in understanding the Indian monsoon rainfall variability.

César R. Ranero

For basic research on spreading ridges, bend faults fostering mantle serpentinization, and fluid flux in subduction zones affecting seismogenesis.

Geoffrey Reeves

For extraordinary leadership and fundamental scientific contributions in the field of the Earth's radiation belt and energetic particle dynamics.

Josh Roering

For innovative contributions to hillslope geomorphology, synthesizing the dynamic influences of weathering, sediment transport, and biotic activity.

David B. Rowley

For his groundbreaking work on plate tectonics and the evolution of its mountain belts.

Vincent J. M. Salters

For fundamental contributions to understanding mantle evolution and dynamics through hafnium isotope and trace element geochemistry.

Gavin A. Schmidt

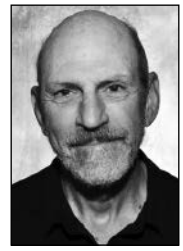
For sustained excellence in climate research; innovative use of diagnostic data; and clear communication of climate change, past, present, and future.

Richard Seager

For pioneering contributions in tropical climate dynamics and the dynamics of natural and human-induced sources of hydrologic variability and drought.

Nikolai Shapiro

For outstanding contributions in theoretical and observational seismology, notably in the development of Earth-imaging methods based on ambient noise.



Eli A. Silver

For fundamental contributions to the paradigm of plate tectonics and for wide-ranging work expanding understanding of subduction and collision processes.

Mark Simons

For seminal scientific advances and leadership of the community in the study of crustal deformation and gravity observations.

Brad Singer

For his pioneering applications of geochronology to understanding magmatic systems, geomagnetism, and climate.

Lee Slater

For visionary experimentation in near-surface geophysics that has advanced understanding of subsurface hydrogeological and biogeochemical processes.

David Tarboton

For fundamental contributions that have advanced hydrologic information systems and hydrologic modeling.

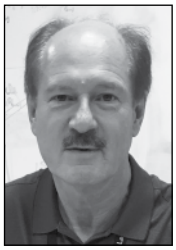
Visit https://eos.org/agu-news for more articles about AGU honors.

Doerthe Tetzlaff

For fundamental insights into physical processes controlling streamflow in headwaters and their influence on stream chemistry and aquatic ecology.

Friedhelm von Blanckenburg

For major contributions in applying isotope geochemistry to Earth's surface and crustal processes.



Christopher R. Webster

For development and application of tunable laser spectroscopy investigations to address fundamental questions in Earth and planetary science.

Naohiro Yoshida

For being the world's leading biogeochemist and atmospheric chemist studying bioelement cycles through innovative isotope exchanged molecule tracers.

Vladimir E. Zakharov

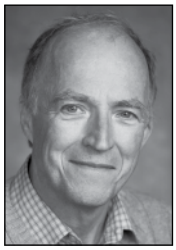
For seminal, pioneering contributions, particularly on solitons and wave turbulence, with applications to oceans, plasmas, and nonlinear geophysics.

Fuqing Zhang

For fundamental understanding of multiscale predictability and dynamics and for breakthroughs in hurricane prediction through ensemble data assimilation.

Pei-zhen Zhang

For his profound work on tectonics and seismic hazard in Asia and for his leadership in establishing and analyzing one of the world's great GPS networks.



Francis W. Zwiers

For leading contributions to climate science, pioneering the use of advanced statistical techniques from evaluating predictions to extreme event analysis.

Yellow Detritus in the Oceans May Help Reduce Warming

In this image of of the Mackenzie River Delta flowing into the Beaufort Sea in July 2017, captured by NASA's Landsat 8 Operational Land Imager instrument, the yellow-tinted swirls are caused by phytoplankton, along with dissolved organic matter and water molecules. Credit: Norman Kuring, NASA/GSFC/OBPG

A quick glance from an airplane window shows that the ocean looks kind of blue, whereas a satellite view reveals varying shades that reflect the water depth and the amount of material floating near the surface. Waters thick with phytoplankton and dissolved organic matter absorb and scatter light near the surface, shifting the visual properties of the water and changing its appearance.

One variation of light-attenuating material in the water is known as colored detrital matter (CDM), which tints the water yellow. CDM is an agglomeration of dissolved organic molecules and detritus; most of it is material washed from the land into the ocean during storms, but it can also form in situ or be seafloor lifted to the surface by vertical ocean currents. Scientists predict that increasing precipitation in the Northern Hemisphere in the future will deposit more of this yellow material in the coastal aquatic environment.

Kim et al. explored how outwash affects ocean heating and temperature. The research offers insights into how inputs from coastal environments may alter oceans and how those alterations could influence global climate change.

The researchers ran two Earth system model simulations for 300-year time spans, with CDM data collected by NASA's Moderate Resolution Imaging Spectroradiometer instrument. The models contained fully coupled land-ocean-atmosphere-ice components. In the "green ocean" control simulation, only phytoplankton attenuated light; in the "yellow ocean" experimental simulation, both phytoplankton and CDM attenuated light.

In the model simulations, the yellow ocean was more opaque than the green ocean, and the conditions in the yellow ocean resulted in lower sea surface temperatures, reduced ocean heat content, and decreased sea surface height after 300 years. Globally, the temperature of the upper 700 meters in the yellow ocean simulation was colder than in the green ocean simulation, which triggered a thermal contraction of ocean waters and a 6-centimeter reduction in sea surface height.

At the surface, the yellow ocean simulation indicated increased solar heating at 0- to 10-meter depth but less sunlight (and cooler waters) at 20- to 30-meter depth. This result suggests that detritus leads to shallower light absorption, preferentially heating water close to the surface.

The results run counter to recent observations of ocean warming and suggest that an influx of CDM may mitigate the effects of a warming climate. Although the simulations may not match the actual magnitude of changing light conditions in the future ocean, they do highlight how dissolved organic matter can influence ocean heating and circulation. The study illuminates a path to future work exploring the links between land and ocean processes, particularly at high latitudes. (*Geophysical Research Letters*, https://doi.org/10.1029/2018GL077297, 2018) **—Aaron Sidder, Freelance Writer**

Conserving Riverside Habitat Could Bolster Bottom Lines

The global production of palm oil has more than doubled since the turn of the century. The oil accounts for nearly a third of the world's vegetable oil use and appears in commercial products ranging from shampoo to biodiesel.

The tropics support the growth of the palm oil industry, much to the detriment of tropical forest ecosystems. In Malaysia and Indonesia alone, 9.5 million forested hectares were converted into oil palm plantations between 1990 and 2010. This land conversion spurs drastic environmental change and reduces the natural benefits that humans gain from the land, especially in riparian ecosystems that border streams and rivers. Pollination, water filtration, and erosion control are some of the ecosystem services that suffer when forests become oil palm plantations.

This photograph, shot from a drone, shows an oil palm plantation planted right up to the river's bank. Credit: ConservationDrones .org, CC BY 2.0 (http://bit.ly/ccby2-0)

According to new research by *Horton et al.,* however, many of these services could be retained if plantations implemented riparian buffers—protected habitat along riverbanks—instead of planting crops right up to the water's edge. There are benefits for farmers too: The study suggests that over time the riparian buffers could actually increase crop yield.

The researchers simulated river channel migration and bank erosion over 25-year intervals for 100 years. Drawing on remote sensing imagery and estimates of plantation productivity, they used a numerical model to estimate how physical changes in the river's position affected economic returns from oil palm crops on the floodplain. Each model ran under two scenarios: with a habitat buffer and without one.

The results of the river channel migration simulations suggest that the removal of riverbank vegetation could cause the river to shift course when it otherwise might not, especially over longer timescales. Over 100 simulated years, the amount of land lost under the no-buffer scenario was significantly greater than the losses with a riparian buffer. Along reaches where modeled erosion rates were particularly high, the absence of a forested buffer cost a plantation the equivalent of three rows of oil palms beside the river.

The results indicate that on timescales longer than a decade, plantation returns may increase in response to the habitat buffer. Although yields may initially suffer because of reduced planting space along the water, native vegetation stretching 10–30 meters from the bank can ultimately prevent erosion and help protect the plantation from flood damage.

Farmers will likely always struggle to balance conservation and profitability, but this research suggests that in the long term, adding a dose of river management to oil palm agriculture could have significant economic and environmental impacts. (*Earth's Future,* https://doi.org/10.1029/2018EF000874, 2018) **—Aaron Sidder, Freelance Writer**

Increasing Radiation Levels May Challenge Space Exploration

The Sun's magnetic activity oscillates on a roughly 11-year cycle, but our star has been pretty magnetically mellow lately. After an average peak in 2001, magnetic activity from the Sun declined during the longest solar minimum period in the past 80 years, bottoming out around 2009. The following "minipeak" in 2014 was far smaller than average, and the Sun's magnetic activity is again in a declining phase expected to last until around 2020.

Although lower magnetic activity from the Sun is generally associated with fewer and less severe space weather events, another threat can emerge when the Sun goes quiet: cosmic rays zipping through the galaxy. Periods of lower solar magnetic activity can still pose a high risk for space exploration, as cosmic rays can move more freely through the solar system with less magnetic interference from the Sun. Over this latest period of anomalously low magnetic field strength, the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) on the Lunar Reconnaissance Orbiter (LRO) gave *Schwadron et al.* a chance to measure solar radiation directly.

Prior to the recent analysis of CRaTER data, studies in 2014 showed that radiation between Earth and the Sun was increasing over time and that an unshielded astronaut could be exposed to as much as 20% more radiation with each passing cycle. The new results indicate that the radiation environment is even worse than predicted—by about 10%.

The scientists suggest that most of the extra radiation exposure comes from low-energy cosmic ray particles. Although lower-energy particles are easier to shield against, the scientists suggest that the extra 10% may still impose limits on space exploration in the future.

In the course of evaluating the radiation environment, CRaTER also got a chance to observe one of the largest solar energetic particle events of the past solar cycle, which occurred in September 2017. The authors' data suggest that a series of magnetically well connected coronal mass ejections is responsible for the uptick in radiation. As the future of space exploration progresses, understanding events like these and the risks that the worsening radiation environment pose to both crew and spacecraft will become increasingly important. (*Space Weather,* https://doi.org/10.1002/2017SW001803, 2018) **—David Shultz, Freelance Writer**

Biogeosciences

Post Doctoral Opportunity for Soil Moisture and Microwave Remote Sensing

The Microwave Remote Sensing Laboratory (MIRSL) at the University of Massachusetts is looking for a Post-Doctoral scholar in the field of Microwave Remote Sensing to work on the topics of remote sensing of agricultural and natural ecosystems, and in the measuring soil moisture beneath forested canopies. The interested candidate will be able to perform field work and analysis of active and passive L-band microwave data collected by airborne and spaceborne platforms. Skills should include the ability to work in a Unix environment with Python, Matlab, QGIS and a lower level programming language such as C or FORTRAN. The successful applicant will work on the SMAPVEX19 field campaign, SAR time series analysis from UAVSAR, ALOS and Sentinel-1, and on algorithm development for the upcoming NISAR satellite mission.

The Microwave Remote Sensing Laboratory at UMass has a 40-year history in the development of sensors and algorithms for environmental applications. The lab itself supports airborne interferometric SARs at S-, Ku- and Ka-band that are used in support of satellite missions and land-surface imaging. Interested candidates should send a CV and letter of interest to Paul Siqueira (siqueira@umass.edu) with "MIRSL Post Doc Application" in the subject heading. All interested candidates should submit their materials prior to January 15. The position will remain open until filled.

Geochemistry

Assistant Professor-Chemistry & Geochemistry

The Chemistry and Geochemistry Department at Montana Tech is seeking a tenure-track assistant professor with expertise in Analytical Chemistry or another closely related discipline. This position requires an earned Ph.D. by the job start date of August 15, 2019 and is contingent on funding. Primary teaching responsibilities will be in Quantitative Chemical Analysis, Advanced Instrumental Analysis, the General Chemistry series, and other areas as needed. Development of an active, funded research program is expected using both undergraduate and graduate students. Research areas including, but not limited to, analytical chemistry, bioanalytical chemistry, and environmental chemistry are targeted for strategic development within the department as is supporting the newly proposed Earth Science and Engineering PhD program. Other duties as required may be assigned.

For more information and to apply visit https://montanatechuniversity.applytojob.com/apply

FACULTY POSITION IN ISOTOPE GEOCHEMISTRY AND GEOCHEMISTRY

The Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, invites applications for a nine-month, tenure-line position in Isotope Geochemistry and Geochemistry to be hired at the rank of Associate Professor. The successful candidate will develop a successful program of externally funded research in isotope geochemistry and geochemistry that includes supervision of undergraduate and graduate students, post-doctoral researchers, and technical staff. The candidate will provide primary oversight of a newly created ICP-MS core facility, which will include quadrupole and multi-collector ICP-MS instruments, a laser ablation system, and a clean laboratory housed in the Department of Earth and Planetary Sciences, located within the newly constructed Strong Hall. All laboratory spaces are new and purpose-built for the core facility, with significant university resources available for equipment purchase. Associated responsibilities include financial oversight and subsequent set-up, operation, and maintenance of a recharge-based, multi-instrument facility available for department, university, and external users. In addition, the candidate is expected to perform rank-appropriate departmental and university service. The successful candidate will instruct undergraduate courses, as well as graduate courses in the candidate's specialty.

Applicants must hold a Ph.D. (or equivalent) degree in solid-earth geoscience or a related discipline, and demonstrate excellence and innovation through publications and grants/contracts in isotope geochemistry (radiogenic and/or non-traditional stable isotope) or geochemistry, with the capacity to lead research in isotope geochemistry. The specific research specialty is open. The candidate must have a minimum of 7 years of research experience beyond the Ph.D. degree, and must have first-hand experience in setting up, running, and maintaining a multiple instrument ICP-MS facility and clean laboratory.

To apply, please email the following to epsicpms@utk.edu, with the subject line 'Isotope geochemistry search:' full curriculum vitae, cover letter describing research and teaching experience, philosophy, and plans, and names of 4 references with contact information. Applications received by 7 January, 2019, are ensured review, but earlier submission is highly encouraged. The position will remain open until filled. Questions about the position should be directed to Dr. Chris Fedo (cfedo@utk.edu). For those attending, we will meet with selected candidates at the 2018 GSA Annual Meeting in Indianapolis and the 2018 AGU Fall Meeting in Washington DC. Please contact Dr. Chris Fedo, chair, with any questions at cfedo@utk.edu

The University of Tennessee is seeking candidates who have the ability to contribute in meaningful ways to the diversity and intercultural goals of the University. The University is an EEO/AA/Title VI/Section 504/ADA/ADEA institution in the provision of its education and employment programs and services. All qualified applicants will receive equal consideration for employment without regard to race, color, national origin, religion, sex, pregnancy, marital status, sexual orientation, gender identity, age, physical or mental disability, or covered veteran status.

Tenure Track Scientist – Marine Chemistry & Geochemistry

The Marine Chemistry & Geochemistry Department at the Woods Hole Oceanographic Institution (WHOI) – www.whoi.edu–invites exceptional candidates to apply to one or more of our tenure track positions on our scientific staff. The successful candidate(s) will conduct research in any area of marine chemistry and geochemistry that complements existing programs on the chemistry of the ocean and its interactions with the Earth as a whole. Core departmental strengths include: biogeochemistry and organic geochemistry; microbial ecology and molecular biology; carbon, nutrient, and trace element cycling; environmental change including climate change, air sea exchange; photochemistry; coastal, estuarine, wetland and river geochemistry & biogeochemistry; sediment geochemistry; fluid-rock interactions; igneous geochemistry; noble gas geochemistry; and isotope systematics, including radiochemistry. MC&G scientific staff conducts research throughout the world's open-ocean, deep-sea, coastal and inland environments, develops sensors for in-situ measurements, analyzes samples using state-of-the-art analytical techniques, carries out laboratory-based experimental studies, and applies computer models and remote sensing techniques. For more information about this job and to apply online, please visit http://careers.whoi.edu, navigate to 'Current Opportunities' and respond to Job Reference 18-10-06. Review of applications will begin on 12/17/2018.

Interdisciplinary

Assistant/Associate Professor, Geodesy or Remote Sensing

The Department of Geology & Geophysics at the University of Utah seeks applications for a tenure track position at the Assistant or Associate Professor level in geodesy or remote sensing beginning fall 2019. The successful candidate will be expected to develop an internationally visible, externally funded research program and teach departmental courses at the undergraduate and graduate levels. A Ph.D. is required at the time of appointment. We will consider candidates in a broad range of specialties in geodesy and remote sensing. Example specialties include: GPS, InSAR, gravity, Lidar, multi-band and hyperspectral imaging. We particularly welcome candidates who contribute to the existing departmental strengths, especially in one or more of three broad topical areas in which future growth is envisioned: (1) Surface Processes and Hazards, (2) Sustainable Resource Science and Engineering, and (3) Earth and Planetary Evolution. The Department of Geology & Geophysics is housed in the state-of-the-art Sutton Building, a sustainably-designed building with modern research and teaching facilities. Related campus research infrastructure includes the University of Utah Seismograph Stations, the Global Change and Sustainability Center, the Center for High Performance Computing, the Scientific Computing and Imaging Institute, and the Department of Geography. Opportunities also exist within the college for collaboration with the Departments of Mining Engineering, Atmospheric Sciences, and Metallurgical Engineering. Evaluation of applications will begin on December 1, 2018, and continue until the position is filled.

To apply, candidates should submit (1) statement of interest, (2) summary of current research activi-

ties and future research and funding plans, (3) teaching statement describing teaching philosophy and proposed courses at the graduate and undergraduate levels for the University of Utah, (4) diversity statement describing commitment to diversity, equity, and inclusion and the mentoring of diverse students and junior colleagues, (5) curriculum vitae, and (6) names and contact information for five referees. Research and teaching statements should be limited to four pages each. Upload application materials to: https://employment.utah.edu/salt-lake-city-ut/assistant-or-associate-professor/A3F66F295408479797DA8B172A1A2E3F/job/.

Specific questions about the position should be directed to M. Thorne [michael.thorne@utah.edu]. More Information about the Department of Geology and Geophysics can be found at: http://www.earth.utah.edu.

EEO/Diversity Information

The University of Utah is an Affirmative Action/Equal Opportunity employer and does not discriminate based upon race, national origin, color, religion, sex, age, sexual orientation, gender identity/expression, status as a person with a disability, genetic information, or Protected Veteran status. Individuals from historically underrepresented groups, such as minorities, women, qualified persons with disabilities and protected veterans are encouraged to apply. Veterans' preference is extended to qualified applicants, upon request and consistent with University policy and Utah state law. Upon request, reasonable accommodations in the application process will be provided to individuals with disabilities. To inquire about the University's nondiscrimination or affirmative action policies or to request disability accommodation, please contact: Director, Office of Equal Opportunity and Affirmative Action, 201 S. Presidents Circle, Rm 135, (801) 581-8365.

The University of Utah values candidates who have experience working in settings with students from diverse backgrounds, and possess a strong commitment to improving access to higher education for historically underrepresented students.

Assistant Professor Faculty Position

The Department of Atmospheric and Oceanic Science at the University of Maryland, College Park invites applications for a tenure track position at the Assistant Professor level. We seek a candidate who will develop an active, externally funded research effort that will complement existing areas of expertise within our Department, teach at both the graduate and undergraduate levels, and is able to make use of the unique resources provided by the Earth System Science Interdisciplinary Center, the state of Maryland, as well as the rest of the greater Washington DC region. Research areas of interest include, but are not limited to biogeochemical cycles, Chesapeake Bay, modeling the interaction between human and natural systems, the oceans and polar science.

Applicants should submit the following: (1) one-page cover letter describing their interest in the position; (2) curriculum vitae; (3) teaching statement; (4) research statement; (5) diversity and inclusion statement; (6) the names and contact information of three persons who can provide letters of recommendation. Position will remain open until filled and best consideration will be given to applications submitted by 12/31/2018.

The Department of Atmospheric & Oceanic Science especially encourages applications from women, underrepresented minorities and those who can contribute to a climate of inclusivity. Candidates who have experience working with a diverse range of faculty, students and groups are encouraged to identify their experiences in these areas.

The University of Maryland, College Park, an equal opportunity/affirmative action employer, complies with all applicable federal and state laws and regulations regarding nondiscrimination and affirmative action; all qualified applicants will receive consideration for employment. The University is committed to a policy of equal opportunity for all persons and does not discriminate on the basis of race, color, religion, sex, national origin, physical or mental disability, protected veteran status, age, gender identity or expression, sexual orientation, creed, marital status, political affiliation, personal appearance, or on the basis of rights secured by the First amendment, in all aspects of employment, educational programs and activities, and admissions.

To apply: http://ejobs.umd.edu/postings/64554

Assistant Professor in Ecosystem Science – Biogeochemistry, Department of Ecosystem Science and Sustainability, Colorado State University, Fort Collins, CO 80523

Description: Tenure track, 9-month academic faculty position

The Department of Ecosystem Science and Sustainability at Colorado State University (Fort Collins, Colorado) is recruiting a new tenure-track faculty member at the rank of ASSISTANT PROFESSOR in ecosystem science with biogeochemistry and sustainability expertise. The position is expected to start at the beginning of fall 2019 Semester. We seek candidates with expertise related to (but not restricted to) land-use change and ecosystem services of global systems, human-modified and managed landscapes, or social-ecological systems. The research foci can encompass small-scale mechanism to larger, integrative global processes. Research approaches could include (but are not limited to) trace

Department of Geosciences
PRINCETON UNIVERSITY
HARRY HESS FELLOWS PROGRAM

The Department of Geosciences at Princeton University announces competition for the **2019-2020 Harry Hess Fellows Program**. This honorific postdoctoral fellowship program provides opportunities for outstanding geoscientists to work in the field of their choice. Research may be carried out independently or in collaboration with members of the Geosciences Department. One or more Hess Fellows may be appointed. Applications are welcome from candidates who have earned a Ph.D. in the last five years or expect to have a Ph.D. by the start of the fellowship. Current areas of research include:

- Biogeochemical Cycles
- Environmental Chemistry
- Geochemistry
- Glaciology
- Geomicrobiology
- Mineral Physics
- Oceanography
- Geochronology
- Paleoclimatology
- Paleontology
- Petrology
- Seismology
- Tectonics
- Atmospheric Science
- Planetary Science
- Earth History

Applications are due on **January 1, 2019**, but evaluation of applications and interviews of candidates will begin immediately. Applicants should include a cover letter, a curriculum vitae including a publication list, a 1-2 page statement of research interests and goals, and name, address and email address of three referees familiar with their work by applying on the Princeton University jobsite **https://www.princeton.edu/acad-positions/position/9602.**

Hess Fellowships provide a competitive annual salary, depending upon experience, along with a significant allowance for travel to meetings and for research support. Initial awards are for one year, with the possibility of renewal for additional years depending upon satisfactory performance and available funding. A preferred starting date is on or before **September 1st, 2019.**

This position is subject to the University's background check policy. Princeton University is an equal opportunity employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability status, protected veteran status, or any other characteristic protected by law.

Information about the research activities of the Department of Geosciences may be viewed at **https://www.princeton.edu/geosciences/research/**

Department of Geosciences
PRINCETON UNIVERSITY
ASSISTANT PROFESSOR

The Department of Geosciences at Princeton University is seeking applications for a tenure-track assistant professor faculty position in geology, broadly defined. We are particularly interested in interdisciplinary scientists who could interact productively with existing faculty working in geophysics and/or climate. Possible fields of specialty include, but are not limited to, petrology, volcanology, tectonics, glaciology, rock deformation, earth surface processes, and paleontology.

Applicants should send a curriculum vitae, including a publication list, a statement of research and teaching interests, and contact information for three references to **https://www.princeton.edu/acad-positions/position/9581.** Evaluation of applications will begin as they arrive; for fullest consideration, apply by **December 21, 2018**, but applications will be accepted until the position is filled.

Princeton is especially interested in candidates who can contribute to the diversity and excellence of our academic community. For general information about applying to Princeton and how to self-identify, please link to **http://web.princeton.edu/sites/dof/ApplicantsInfo.htm.**

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

This position is subject to the University's background check policy. Information about the research activities of the Department of Geosciences may be viewed at **https://www.princeton.edu/geosciences/research/.**

gas and/or biogeochemical processes, the use of stable isotopes, use of large data sets, molecular microbial tools, modeling, experiments, and inter- or trans-disciplinary studies. Applicants should be interested in working in a highly collaborative department and enthusiastic about teaching at both the undergraduate and graduate levels, while contributing to the land grant mission of Colorado State University. Teaching responsibilities will include courses in ecosystem ecology and biogeochemistry. We envision an independent researcher who will develop a strong, extramurally-funded research program. The department of ESS has a commitment to actively contributing to developing a diverse and inclusive environment within the department, college, and university, and will expect the candidate to contribute to this vision.

To apply and view a full announcement please visit http://jobs.colostate.edu/postings/61686 by January 4, 2019 for full consideration.

CSU is an EO/EA/AA employer and conducts background checks on all final candidates.

Assistant Professor in Environmental Science

Barnard College seeks a full time tenure track Assistant Professor in Environmental Science, starting July 2019. The successful candidate will demonstrate a commitment to and experience in teaching undergraduates along with establishing an active and externally funded research program involving undergraduates. Candidates should be engaged in laboratory and/or field based research that is accessible to undergraduate students and potentially utilizes the local environment in the broadly defined areas of atmospheric science/air quality, ecosystems, or resilience to environmental change. Teaching responsibilities could include courses supporting undergraduate research, client based service learning, field methods, GIS, and electives in their research area.

Barnard is an independent liberal arts undergraduate college for women in New York City affiliated with Columbia University. There are many opportunities to collaborate with faculty in the larger research community at Barnard College as well as with researchers at Columbia's Earth Institute, School of Engineering and Applied Science, Lamont-Doherty Earth Observatory, Mailman School of Public Health, and Department of Ecology, Evolution, and Environmental Biology.

Barnard College is an Equal Opportunity Employer. Barnard does not discriminate due to race, color, creed, religion, sex, sexual orientation, gender and/or gender identity or expression, marital or parental status, national origin, ethnicity, citizenship status, veteran or military status, age, disability, or any other legally protected basis, and to the extent permitted by law. Qualified candidates of diverse ethnic and racial backgrounds are encouraged to apply for vacant positions at all levels.

Applications should be submitted electronically and include the following: a cover letter, curriculum-vitae including a publication list, separate research and teaching statements highlighting past experiences and future plans, contact information for three references, and up to three pre/reprints of scholarly work. We are currently hiring two positions in the Environmental Science Department with the second position in Environmental Sustainability. Reviews of material will begin December 18, 2018. Please submit materials to http://careers.barnard.edu/postings/3923. Please direct inquiries to bmaillou@barnard.edu.

Assistant Professor in Environmental Sustainability

Barnard College seeks a full time tenure track Assistant Professor in Environmental Sustainability, starting July 2019. The successful candidate will demonstrate a commitment to and experience in teaching undergraduates along with establishing an active and externally funded research program involving undergraduates. Candidates in any field related to environmental sustainability, resilience, or environmental justice who use spatial-temporal data analysis, spatial simulation and modeling, Geographic Information Systems (GIS), high performance computing, or visualization in research, are invited to apply. Teaching responsibilities could include courses in Environmental Data Analysis, GIS, Senior Seminar, and an elective in their research area.

Barnard is an independent undergraduate liberal arts college for women in New York City affiliated with Columbia University. There are many opportunities to collaborate with faculty at Barnard in Anthropology, Economics, Urban Studies as well as with researchers at Columbia's Earth Institute, Lamont-Doherty Earth Observatory, Mailman School of Public Health, Center for International Earth Science Information Network (CIESIN), the International Research Institute for Climate and Society (IRI), and the National Center for Disaster Preparedness (NCDP).

Barnard College is an Equal Opportunity Employer. Barnard does not discriminate due to race, color, creed, religion, sex, sexual orientation, gender and/or gender identity or expression, marital or parental status, national origin, ethnicity, citizenship status, veteran or military status, age, disability, or any other legally protected basis, and to the extent permitted by law. Qualified candidates of diverse ethnic and racial backgrounds are encouraged to apply for vacant positions at all levels.

Applications should be submitted electronically and include the follow-

ing: a cover letter, curriculum-vitae including a publication list, separate research and teaching statements highlighting past experiences and future plans, contact information for three references, and up to three pre/reprints of scholarly work. We are currently hiring two positions in the Environmental Science Department with the second position in Environmental Science. Reviews of material will begin December 18, 2018. Please submit materials to http://careers.barnard.edu/postings/3919 and direct inquiries to mstute@barnard.edu.

Assistant Professor of Earth System Science (tenure track): Global change impacts on terrestrial ecosystems

The Department of Earth System Science (ESS) at the University of California, Irvine, invites applications for a tenure-track faculty position focused on the effects of global environmental change on natural or managed terrestrial ecosystems. We are particularly interested in applicants who are working to quantify, understand and predict the impacts on land surface structure and function, including vegetation dynamics, hydrology or biogeochemistry. We welcome applications from researchers who are using a range of approaches, such as manipulations, in-situ or remotely-sensed observations, or process modeling. The successful applicant will have a strong research agenda, a commitment to excellence in teaching, and enthusiasm for joining a collegial, cross-disciplinary department.

UC Irvine's ESS department was founded to explore the global environmental changes that occur on human time scales. The department has 24 full time faculty from diverse backgrounds and a goal of understanding how human society is changing the land, atmosphere, oceans and cryosphere (http://www.ess.uci.edu/). UCI is a Minority Serving Institution (MSI), a Hispanic-Serving Institution (HSI) and an Asian American and Native American Pacific Islander-Serving Institution (AANAPISI). These federal designations align with UCI's aspiration to be a national leader and global model of inclusive excellence.

Candidates must have a doctoral degree. Apply online at https://recruit.ap.uci.edu/apply/JPF04979 or contact facultysearch@ess.uci.edu. Review of applications will begin December 21, 2018.

The University of California, Irvine is an Equal Opportunity /Affirmative Action Employer advancing inclusive excellence. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability, age, protected veteran status, or other protected categories covered by the UC nondiscrimination policy. A recipient of an NSF ADVANCE award for gender equity, UCI is responsive to the needs of dual career couples, supports work-life balance through an array of family-friendly policies, and is dedicated to broadening participation in higher education.

Matthews Endowed Professor in Earth Sciences

Position No. 50601. The Roy M. Huffington Department of Earth Sciences announces a search to fill a named tenured professorship honoring C.W. Matthews. We are seeking mid-career applicants with active research programs in the area of the dynamics of fluid-rock interaction. The cross-disciplinary nature of fluid-rock interaction is such that the successful candidate may apply techniques from petrology, hydrology, general geochemistry, isotope geochemistry, or economic geology. The successful applicant will exhibit the ability to (1) maintain programs with external funds obtained from a diverse portfolio of funding agencies, (2) oversee professional staff, and (3) mentor students at both the undergraduate and graduate level. The successful applicant will have a commitment to full participation in the educational mission of the department, which is to provide professional training in the Earth Sciences in a liberal arts environment. As the third holder of the Chair, which was established in 1979, the successful candidate must demonstrate strong potential to strengthen and expand the existing departmental research focus. The current focus includes research on problems in the national interest such as natural hazards, earthquake seismology – including induced seismicity, nuclear test ban treaty monitoring, natural resources such as geothermal energy and problems in global environmental change. Applications can be submitted electronically to https://apply.interfolio.com/55725.

Applicants should include a curriculum vitae, statements of teaching and research interests, and contact information for three references. To insure full consideration, applications must be received by January 15, 2019, but the committee will continue to accept applications until the position is filled. The committee will notify applicants of its decisions after the position is filled. Ph.D. is required at the time of appointment.

Southern Methodist University will not discriminate in any program or activity on the basis of race, color, religion, national origin, sex, age, disability, genetic information, veteran status, sexual orientation, or gender identity or expression. The Executive Director for Access and Equity/Title IX Coordinator is designated to handle inquiries regarding nondiscrimination policies and may be reached at the Perkins Administration Building, Room 204, 6425 Boaz Lane, Dallas TX 75205, 214-768-3601, accessequity@smu.edu

Hiring is contingent upon the satisfactory completion of a background check.

Ph.D. Positions in Earth System Science

https://vimeo.com/260928738

www.clarku.edu/departments/geography/graduate/apply.cfm

Applications are invited for Ph.D. assistantships within the Graduate School of Geography at Clark University. Assistantships cover tuition, provide an annual stipend, and include eligibility for a competitive fellowship. Clark's Earth System Science program features expertise in terrestrial ecosystems and global change, hydrology, forest ecology, biogeography, polar science, terrestrial and marine biogeochemistry, disturbance and landscape ecology, GIScience, and remote sensing. For complete details see our website (www.clarku.edu/departments/geography), or contact Rachel Levitt (Program Administrator) at RLevitt@clarku.edu / 508-793-7282. Applicants are also encouraged to communicate with prospective advisors (www.clarku.edu/departments/geography/faculty.cfm).

Clark Geography Ph.D. Program: All accepted Ph.D. applicants receive guaranteed TA/RA stipends

The Graduate School of Geography at Clark University is internationally renowned for innovative scholarships and is an acknowledged leader in the field. Consistently ranked as one of the top-ten graduate programs by the National Research Council, Clark Geography enables graduate students to train with top professionals and participate in a world-class research community. Students are guaranteed tuition remission and Graduate Assistantships for a minimum of four years, fostering a tight-knit, support-

ive intellectual community. Having awarded more Ph.D.s than any other geography program in the U.S., Clark Geography has a reputation for training future leaders in the field.

Postdoctoral Research Associate, Biogeochemical Reactive Transport Modeling

Purpose: The Environmental Sciences Division at Oak Ridge National Laboratory is seeking a postdoctoral researcher to develop and evaluate novel multiscale models for reactive transport in stream corridors.

Major Duties and Responsibilities: You will work as part of a multidisciplinary team studying mercury transport and transformation processes in low-order streams. You will develop models for nutrient and contaminant dynamics in low-order streams, taking into account rate-limited mass transfer between the flowing streams and biogeochemically active transient storage zones. Working as part of a team, you will implement those models in advanced community software running on high-performance computing resources. A significant focus will be on comparing the models to column and flume experiments and to field observations in low-order streams.

Required Qualifications: A Ph.D. in hydrology, environmental sciences, geosciences, environmental or chemical engineering or a related field is required. Basic understanding of mass transfer processes in the stream corridor and working knowledge of geochemical speciation modeling are required. Experience with multicomponent reactive transport modeling would be a distinct advantage, as would experience with modeling solute transport in the hyporheic zones of streams or rivers. Experience and demonstrated productivity with numerical models of complex phenomena in C/C++ or modern versions of Fortran is required, as is willingness to learn Python or similar scripting tools. You must work independently and collaboratively as part of a dynamic, multidisciplinary team.

Applicants must have received their most recent degree less than five years prior to the date of application and must complete all degree requirements before starting their appointment.

The appointment length will be up to 24 months with the possibility of an extension of up to 12 months. Initial appointments and extensions are subject to performance and availability of funding.

For additional information please contact Scott Painter (paintersl@ornl.gov) or visit jobs.ornl.gov

Tenure-Track Faculty Position in Environmental Biogeochemistry

The Department of Earth and Environmental Sciences at The University of Texas Arlington invites applications for a tenure-track faculty position in broadly construed areas related to environmental biogeochemistry at the level of Assistant Professor. Faculty candidates for higher ranks with exceptional track records will also be considered. We seek a broadly-trained biogeochemist who complements the interdisciplinary nature of our geology and environmental science programs. While candidates from all subdisciplines of earth and environmental sciences are encouraged to apply, we are particularly interested in candidates with expertise in analytical biogeochemistry, biogeochemical data mining, climate and biogeochemical dynamical or statistical modeling, or the exposome. Opportunities for collaboration exist with departmental research groups (https://www.uta.edu/ees/) and other research groups of data science, analytical chemistry, ecology, and genomics in the College of Science. Our geochemistry analytical strengths include the on-campus Shimadzu Institute for Research Technologies (http://www.uta.edu/sirt/).

Applicants should have a doctoral degree in earth and environmental sciences or a related field. Successful candidates are expected to demonstrate a commitment to diversity and equity in education through their scholarship, teaching, and/or service. We are deeply committed to increasing diversity and especially encourage applications from women and minority scholars.

Review of applications will begin immediately and continue until the position is filled. For full consideration, applications should be submitted by November 16th, 2018. Applicants must apply online at https://uta.peopleadmin.com/postings/7068.A complete application includes: 1) curriculum vitae, 2) summary of current and proposed research (max. two pages), 3) statement of teaching interests (max. one page), and 4) names and email addresses of three references.

Question regarding this position may be directed via email to Dr. Max Hu, Search Committee Chair (maxhu@uta.edu) or Dr. Arne Winguth, Department Chair (awinguth@uta.edu).

As an equal employment opportunity and affirmative action employer, it is the policy of The University of Texas Arlington to promote and ensure equal employment opportunity for all individuals without regard to race, color, religion, sex, national origin, age, sexual orientation, gender identity, disability, or veteran status.

Tenure Track Position in Solid Earth Geosciences or Engineering Seismology

The Center for Earthquake Research and Information (CERI) at the University of Memphis invites applications for a tenure-track faculty position at the Assistant Professor level to begin in August 2019. We are searching broadly and seeking an individual to complement our existing strengths in seismology, geodesy, computational tectonics, earthquake physics and seismic hazard. We particularly encourage applicants with research interests related to Active tectonics, Continental/Lithospheric dynamics, Computational Geophysics, Exploration Geophysics, or Engineering Seismology. Applicants must have a Ph.D. at the time of employment, and show a demonstrated record or strong promise of research productivity. The successful candidate is expected to build a vigorous, externally funded research program, mentor M.S. and Ph.D. graduate students, and teach graduate courses in her or his specialty. As part of a University interdisciplinary research center, CERI faculty are engaged in a variety of regional, national, and international research projects (https://www.memphis.edu/ceri/). More information about this position can be obtained by contacting the chair of the search committee, Eunseo Choi (echoi2@memphis.edu).

Applicants should submit an application letter, full curriculum vitae, statements of research and teaching interests, and the names and addresses (with phone numbers and email) of at least three references. To receive full consideration, applications must be submitted through the University of Memphis WorkForUM online application system (https://workforum.memphis.edu) by December 17, 2018. The University of Memphis is an Equal Opportunity/Affirmative Action employer.

Tenure Track Scientist–Biology

The Biology Department at the Woods Hole Oceanographic Institution (WHOI) – www.whoi.edu–invites exceptional candidates to apply for our tenure track position on our scientific staff. The successful candidate will complement our existing interdisciplinary strengths in biology, biological oceanography, and marine ecology. We are particularly interested in applicants who conduct research in marine zooplankton ecology using novel observational, experimental and/or modeling approaches. Expertise may include (but is not limited to) physiology, behavior, trophic interactions, or the impacts of climate change. For more information about this job and to apply online, please visit http://careers.whoi.edu, navigate to 'Current Opportunities' and respond to Job Reference 18-10-01. Application deadline is 12/17/2018.

Positions in Physical Hydrogeology and Paleontology: University of Wisconsin–Milwaukee

The Department of Geosciences at the University of Wisconsin–Milwaukee seeks to fill two positions beginning August 19, 2019: one in Physical Hydrogeology and the other in Paleontology/Paleobiology.

The first position is for a tenure-track faculty position in Physical Hydrogeology (http://jobs.uwm.edu/postings/28007) (position # 02206838) at the rank of Assistant Professor.

UNIVERSITY OF MIAMI

FACULTY POSITION IN INTEGRATED COASTAL ZONE PROCESSES AND MANAGEMENT

University of Miami
Rosenstiel School of Marine and Atmospheric Science

The Department of Marine Ecosystems and Society at UM RSMAS is recruiting a tenure track or tenured faculty member in **Integrated Coastal Zone Processes and Management**. We seek expertise in analytical, statistical and computer modeling research addressing coastal processes, hydrodynamics and sustainability of human-natural coastal ecosystems. Candidates from the natural, physical, and social science fields with high scholarly productivity and excellent teaching and communication skills are encouraged to apply. Individual is expected to work on policy relevant challenges in an interdisciplinary setting with groups from across the university and will be expected to enhance the School's undergraduate, masters and Ph.D. programs.

The position is open to any rank and the salary is commensurate with rank/experience. A Ph.D. in a related field is required. Females, Minorities, Veterans and those with Disabilities are encouraged to apply.

Applications should include a statement of research interests, research sample, curriculum vitae, and names and contact information for five references. Candidates may submit their application to **www.miami.edu/careers** (**position #R100026154**) or request for more information to: **messearch@rsmas.miami.edu**. We anticipate conducting interviews for the position in **Fall 2018**. Position will remain open until filled.

The Faculty Mathematics and Natural Sciences invites in cooperation with
the Leibniz Institute of Atmospheric Physics Kühlungsborn (IAP) applications for a

W3-PROFESSORSHIP IN ATMOSPHERIC PHYSICS

at the IAP and the Institute of Physics, starting **1st of October 2020** (within budget considerations).

We are looking for an outstanding scientist in the field of atmospheric physics. Emphasis should be on the experimental exploration of the middle atmosphere. The main task is leading the Leibniz Institute of Atmospheric Physics (IAP) and, if applicable, the department "Optical Soundings" at IAP. In addition, the candidate is expected to collaborate with the Institute of Physics of the University, to participate in joint projects and to contribute to the activities of the Interdisciplinary Faculty. The teaching duties comprise courses and seminars in atmospheric physics for master and PhD programs.
Additional Information: Prof. Dr. Stefan Lochbrunner 0381/498-6960 email: stefan.lochbrunner@uni-rostock.de

Qualifications are as per § 58 of the Higher Education Act of the State of Mecklenburg-Vorpommern (LHG M-V): completed university studies, doctoral degree, post-doctoral thesis ("Habilitation"), teaching experience or equivalent qualifications, usually earned within the context of junior professorship.

A special focus is placed on academic achievement and teaching qualifications as well scientific organization and academic administration. For this reason candidates should describe previous teaching results, ideas regarding future teaching (including didactic lesson planning) and their prior experience in academic and scientific management. In addition, candidates are expected to have experience and interest in developing programs that can attract and maintain external funding.

The professorship is to be filled according to § 61 LHG M-V as a position with civil servant status for life, or, if applicable, for 5 years. It is also possible to fill the position as a regular state employee.

The University of Rostock is committed to their university management guidelines.

The University of Rostock is especially interested in promoting women within the context of § 7 (3) of the Gender Equality Act, and therefore specifically encourages applications from qualified women. Disabled applicants will be given preference if all other qualifications are essentially equal.

Applications with the usual documents (full CV, a complete list of academic and professional background, publications, teaching experience, any additional qualifications, a summary of grants and sponsored research activities and a description of future research plans) should be sent no later than **31 January 2019** to the University of Rostock, Dean of the Faculty of Natural Sciences, Wismarsche Straße 45, 18051 Rostock, Germany or by email to **dekan.mnf@uni-rostock.de.**

Application costs cannot be reimbursed by the state of Mecklenburg-Vorpommern. We ask you to submit applications only in copy, as they will not be retumed after the procedure has been completed.

Applicants must hold a Ph.D. in hydrogeology (or appropriate related field) at the time of appointment, and have demonstrated research experience in physical hydrogeology. Post-doctoral experience is desirable. The successful candidate is expected to conduct an active, internationally recognized, externally funded research program that will attract and support graduate students. The successful candidate will teach an undergraduate/graduate course in physical hydrogeology, an introductory course, upper level undergraduate and graduate level courses in their field of expertise, and advise graduate student thesis projects.

The second position is for a visiting assistant professor position in Paleontology/Paleobiology (http://jobs.uwm.edu/postings/28018) (position # 02210472). The position is for 2019–2020 but may be renewed for up to two more years. The successful candidate is expected to develop a vigorous, externally funded research program, teach three courses per year at multiple levels within our curriculum, and supervise research by graduate and undergraduate students. Minimum qualifications for the position are a PhD in Paleontology (or appropriate related field) at the time of appointment and research experience in paleontology/paleobiology. Postdoctoral experience, publications and published abstracts, funding experience, and teaching experience, though not required, are viewed as an asset.

Review of applications will begin December 11, 2018. Priority will be given to applications received by this date, but the position remains open until filled. Candidates will upload a cover letter, curriculum vitae, and statement of teaching philosophy and research interests. They will also submit three e-mail addresses for letters of recommendation online. Candidates should also submit three examples of published work uploaded with the application in the following Application Document areas: Publication 1 in 'Other Document 1', Publication 2 in 'Other Document 2', and Publication 3 in 'Other Document 3'. Any applicant wishing to submit additional documents for consideration, including additional published works, should upload those submissions to Application Document areas 'Reference Letter 1' and 'Reference Letter 2'.

The University of Wisconsin-Milwaukee is a Research 1 institution located on the north side of Milwaukee. The department of Geosciences offers B.S./B.A., M.S., and Ph.D. degree programs and is staffed by 10 full-time faculty. The University of Wisconsin-Milwaukee is an Equal Opportunity/Affirmative Action Employer.

For more details on how to apply, please visit http://jobs.uwm.edu/ (position #'s 02206838 and 02210472). If you have any questions, please contact Shangping Xu (xus@uwm.edu), Physical Hydrogeology Position Primary Contact; Lindsay McHenry (lmchenry@uwm.edu), Paleontology Position Primary Contact; or John L. Isbell, Department of Geosciences Chair (jisbell@uwm.edu).

Assistant Professor, Hydrogeoscientist – West Virginia University Department of Geology and Geography (Job No. 09825)

The West Virginia University Department of Geology & Geography invites applications for a tenure-track position in geology at the Assistant Professor level starting in August 2019. A Ph.D. or equivalent degree in Geoscience or a broadly related field is required at the time of appointment. We seek applications from individuals with interests in basic and applied aspects of water science. The successful applicant will possess demonstrable expertise applicable to competitively funded research problems. Relevant specialties might include physical hydrogeology; fluid flow modeling; hyporheic or vadose zone processes; groundwater-surface water interaction; flow in fractured media; hydrogeology of energy-related activities; groundwater supply and sustainability; contaminant transport; watershed dynamics; ecohydrology; or karst hydrogeology.

Candidates will be evaluated based on their potential to establish a vigorous externally funded research program, publish scholarly work, mentor graduate students, and to teach at the undergraduate and graduate levels, including a junior-senior level physical hydrogeology course.

Research on fresh water resources is a strategic focus at WVU, as demonstrated by a newly established interdisciplinary Institute of Water Security and Science (https://iwss.wvu.edu/), a National Science Foundation funded multi-state Appalachian Freshwater Initiative (https://iwss.wvu.edu/projects/appalachian-freshwater-initiative), and many other water focus areas located in WVU colleges and centers.

WVU (http://www.wvu.edu) is a comprehensive land-grant university that enrolls 29,000 students. It is classified as 'highest research activity' by the Carnegie Foundation. WVU is located in Morgantown (https://www.morgantownwv.gov/), ranked as a most preferred small city in America. The immediate region has a diverse population of about 200,000 residents. The community lies within a high technology corridor that includes several federal research facilities, as well

TEXAS Geosciences
The University of Texas at Austin
Jackson School of Geosciences

DIRECTOR OF THE UNIVERSITY OF TEXAS AT AUSTIN INSTITUTE FOR GEOPHYSICS

The Institute for Geophysics at The University of Texas at Austin (UTIG), one of the three principal units in the Jackson School of Geosciences, seeks applications for the position of **Director**, which may include a concurrent faculty appointment in the Department of Geological Sciences (qualifications for faculty position must be commensurate with rank). UTIG is a world leader in expeditionary-scale geophysical research, numerical modeling and computational-enabled discovery, conducting research in four broad themes: climate; energy; marine geosciences, seismology and tectonophysics; and polar and planetary geophysics. It has a staff of about 75 research scientists and support staff. Both graduate and undergraduate students play important roles in the UTIG research mission. The science vision of the Institute is described in more detail at **http://ig.utexas.edu/utig-science-vision-plan/**.

An accomplished leader is sought to provide strategic vision and outstanding operational management, to foster high-quality research programs, and to guide the UTIG community to the next level of accomplishment and impact. The UTIG Director will maintain and strengthen the culture of collaboration and innovation in the Jackson School of Geosciences, expand the reputation of the institute, promote diversity within the institute and demonstrate commitment to a high-quality student experience.

The ideal candidate will possess a Ph.D. in a relevant scientific field (e.g., geology, geophysics, oceanography, planetary sciences, etc.), and will have experience in the administration of complex organizations and research programs, a demonstrated record of high-quality research and publications, and excellence in people management and communication skills. Involvement in international and/or large federal programs, and leadership in academic and professional activities is desired.

An applicant should submit a letter of interest, a vision statement (including your perspectives on how to advance both scholarly excellence and diversity in the workplace at UTIG), CV, and list of four references (with titles and email addresses) electronically to **https://apply.interfolio.com/56029**. Additionally a resume must be submitted at the UT Austin Jobs website: **https://utdirect.utexas.edu/apps/hr/jobs/nlogon/180920010382**. Questions should be directed to Dr. Gail Christeson or Dr. Sean Gulick, co-chairs, UTIG Director Search Committee at **gail@ig.utexas.edu** and **sean@ig.utexas.edu**. References will only be contacted with permission of the candidates.

Review of applications will commence on **Jan. 15, 2019**; however, applications will be accepted until the position is filled. The desired target date for the new director to assume duties is **Sept. 1, 2019**.

as resource-based industries. The city is readily accessible to Pittsburgh and Washington, DC.

To apply for this position, visit https://careers.wvu.edu, navigate to the position title listed above, and submit (1) a single PDF file including a statement of research interests, a statement of teaching philosophy, and a current curriculum vitae; (2) a list of names and e-mail addresses for at least three individuals who can provide prompt letters of recommendation; and (3) pdf files of up to four publications.

Review of applications will commence on December 3, 2018 and continue until the position is filled. For additional information, please see http://pages.geo.wvu.edu/hydrogeo or contact search chair Steve Kite at steve.kite@mail.wvu.edu. WVU is an EEO/Affirmative Action Employer and welcomes applications from all qualified individuals, including minorities, females, individuals with disabilities, and veterans.

Ocean Science

Post doctoral research associate

Applications are invited for a postdoctoral research associate as a part of the 'Wave-Ice-Ocean Interactions along the Arctic Coast' project funded by the National Science Foundation. The project is a collaborative effort of the Applied Physical Laboratory (APL) and the Department of Civil/Environmental Engineering (CEE) at the University of Washington (UW). The project combines field observations and numerical modeling of wave-ice interactions, coastal circulation, and water temperatures under changing Arctic ice conditions.

Requirements

The postdoc for this position will synthesize field data and model results from three case study sites, followed by application of the results in a hindcast of the larger domain. They will participate in field data collection in autumn 2019 and 2020. Demonstrated expertise related to sea ice and/or wave measurements in the polar regions is required. Prior modeling and coding experience is desired. Candidates with a PhD degree in Physical Oceanography, Earth and Atmospheric Sciences, or related fields are encouraged to apply.

Terms

The initial appointment will be for one year, with a flexible start date in the spring of 2019. Extension of the appointment to a total 2.5 years will be made subject to satisfactory work on the project.

How to Apply

Candidates interested in the postdoctoral position should email both Dr. Jim Thomson (jthomson@apl.washington.edu) and Dr. Nirnimesh Kumar (nirni@uw.edu). Please provide a complete CV with your email. Review of applicants will begin on 1 November 2018.

Professional Specialist in Climate Prediction, Princeton University

The Atmospheric and Oceanic Sciences Program at Princeton University in cooperation with NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) seeks a motivated individual to join a team conducting experimental real-time seasonal to interannual climate prediction and related research. The incumbent will be part of a team that is responsible for gathering observations and running real-time experimental seasonal to interannual predictions using state of the art climate models. The incumbent will (a) perform climate model simulations, (b) obtain observational data needed for the predictions and perform quality control on that data, and (c) conduct directed research towards improving our understanding of seasonal to decadal climate variability and predictability, as well as towards improving our prediction system.

The selected candidate will have a graduate degree in meteorology, oceanography, or in a related field, and will possess one or more of the following attributes: (a) strong background in climate dynamics, (b) strong computational skills, including experience using coupled climate models and (c) strong diagnostic skills in analyzing simulated and observed data sets. Appointments are initially for one year with renewal contingent upon satisfactory performance and continued funding.

Successful candidates will be based at the Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, New Jersey. For further information, please contact Tom Delworth (Tom.Delworth@noaa.gov) or Nat Johnson (Nathaniel.Johnson@noaa.gov). Complete applications, including a CV, three references in order to solicit letters of recommendation, and a one-to-two page statement of professional interests must be submitted to https://www.princeton.edu/acad-positions/position/9461 by December 15, 2018 to ensure full consideration. Review of applications will begin as soon as they are received, and continue until the position is filled. This position is subject to the University's background check policy.

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

Tenure-Track Assistant Professor in Coastal Ecosystem Modeling

School of Marine Science and Policy
The University of Delaware
Newark, Delaware

The School of Marine Science and Policy (SMSP) at the University of Delaware (UD) is seeking an ecosystem modeler with research interests in estuarine and coastal marine environments for a tenure-track assistant professor position to start by Fall 2019. A Ph.D. in marine science, ecology, oceanography, or a related field is required.

We seek a dynamic individual who will establish an internationally recognized, extramurally funded, applied research program on the natural systems in the coastal zone with a quantitative modeling approach. The ideal candidate has experience in, or a concrete pathway towards, collaborating on policy, social, or economic questions. Research areas include: human and natural ecosystem coupling; modeling the effects of climate change on coastal ecosystems; and coupling physical oceanography models with biological and/or chemical models in the coastal zone. It is expected that the new hire will utilize and integrate a variety of observational datasets and will crossover into synergistic big data and data science University-wide initiatives.

Questions regarding this position (but not applications) may be addressed to the committee chair Cristina Archer (carcher@udel.edu). Review of applications will begin on December 1, 2018, and will continue until the position is filled.

To Apply:

To be considered for this position, apply at http://apply.interfolio.com/57116

Equal Employment Opportunity

The University's Notice of Non-Discrimination can be found at http://www.udel.edu/aboutus/legalnotices.html.

Tenure Track Scientist–Physical Oceanography

The Physical Oceanography Department at the Woods Hole Oceanographic Institution (WHOI)– www.whoi.edu–invites exceptional candidates to apply to one or more a tenure track positions on our scientific staff. The successful candidate will join a collaborative group of scientists who address a wide range of fundamental problems in ocean and climate dynamics, as well as interdisciplinary research questions, using observations, modeling, theory, and laboratory experiments. We welcome applicants regardless of approach (observational, modeling, and theory) and especially encourage those with a theoretical/dynamical focus. We seek, but not exclusively, individuals with expertise in: 1) coastal dynamics, 2) high-latitude processes, 3) climate variability, and 4) submesoscale processes and mixing. Candidates with interdisciplinary interests in the interplay between ocean dynamics and biological or geochemical processes, or in the interaction of the ocean with the atmosphere, the land, and the cryosphere are encouraged. For more information about this job and to apply online, please visit http://careers.whoi.edu, navigate to 'Current Opportunities' and respond to Job Reference 18-10-03. Review of applications will begin on 12/17/2018.

Tenure Track Scientists – Applied Ocean Physics & Engineering

The Department of Applied Ocean Physics & Engineering at the Woods Hole Oceanographic Institution–www.whoi.edu/aope–invites exceptional candidates to apply for one or more tenure track or tenured scientific-staff positions. We have two different opportunities for which we are seeking candidates, both of which are explained below.

Applied Ocean Physics & Engineering is looking to complement and expand existing programs in coastal & ocean fluid dynamics, ocean acoustics, and deep submergence, with core strengths in nearshore, estuarine, and coastal fluid dynamics, sediment transport, and morphodynamics; biophysical interactions; mixing; acoustical propagation and scattering; vehicles, sensors, and autonomy; and polar processes. Applicants are sought in all supported areas, with particular opportunities in robotics, sensors, coastal remote sensing, and surf zone processes.

We are also looking for qualified candidates to initiate new and expand existing programs in field robotics and machine learning with applications to marine environments. Areas of particular interest include but are not restricted to: marine robotics; machine learning; simultaneous localization and mapping; multi-robot coordination and path planning; adaptive exploration and sampling; data exploration and visualization; underwater manipulation; novel actuation techniques; computer vision; life-long learning and autonomy; and scene understanding.

For more information about these jobs and to apply online, please visit http://careers.whoi.edu, navigate to 'Current Opportunities' and respond to Job Reference 18-10-10 (Robotics) or 18-10-11. Review of applications will begin on 12/15/2018.

Paleoceanography and Paleoclimatology

Tenure Track Scientists – Geology & Geophysics

The Geology & Geophysics Department at the Woods Hole Oceanographic Institution (WHOI) – www.whoi.edu–has tenure track science position openings for exceptional candidates in two disciplinary areas: Paleoclimatology and Marine Geophysics.

In Paleoclimatology, we seek an innovative, highly collaborative individual with interest and expertise in

the generation of proxy records to enhance understanding of Earth's climate on time scales relevant to present day and future climate change. Interest in development and/or application of new proxies, proxy system models, and the use of paleoceanographic and climate data to explore impacts of past climate changes on human societies and ecosystems would be welcome. The successful candidate will complement and enhance existing departmental strengths including past and present ocean and climate dynamics, paleoceanography, climate modelling, proxy development, climate impacts, ice-sheet dynamics, coastal processes and hazards, and to utilize WHOI's exceptional analytical and sea-going facilities.

In Marine Geophysics, we are seeking candidates in one of two broad disciplinary areas of seismology or geodynamics as applied to the marine environment. Strong candidates in related geophysical fields may also be considered. Candidates whose field or laboratory-based research complements and/or bridges existing strengths, including WHOI's considerable facilities and expertise for the design and implementation of sea-going experiments, are especially encouraged to apply. Existing departmental strengths and interests include geophysics (active and passive seismology, electromagnetic methods, magnetics, potential fields, and geodynamics), tectonics, ice-sheet dynamics, volcanology, geochemistry, coastal processes, past and present climate dynamics and biogeochemistry.

For more information about these jobs and to apply online, please visit http://careers.whoi.edu, navigate to 'Current Opportunities' and respond to Job Reference 18-10-08 (Paleoclimatology) or 18-10-09 (Marine Geophysics). Review of applications will begin on 12/07/2018.

Planetary Sciences

Research Space Scientist–AST, Planetary Studies, NASA

The Science & Exploration Directorate, Solar System Exploration Division, Planetary Environments Laboratory (Code 699) is seeking a scientist to conduct research into the geochemistry and astrobiology of Ocean Worlds and Icy Worlds in our solar system and beyond. The research involves studying the origin, evolution, chemical composition, and astrobiological potential of planets (including exoplanets), planetary satellites, asteroids, meteorites, and comets, incorporating comparisons with terrestrial analogs where appropriate. Duties include playing a leading role in mission and instrument development for future ocean worlds exploration.

The applicant will formulate research plans and hypotheses and develop a novel or complex research approaches for studies of the past evolution, current state, environmental processing, and astrobiological potential of the chemical/molecular composition of tidally active ocean worlds (Enceladus, Europa, Ganymede, Callisto, and Titan) as well as potential ocean worlds (e.g., Triton, Pluto, Ceres) and other bodies. The applicant will formulate approaches to explore, analyze, and quantify the habitability and potential biology of these environments, including development, test, and potential flight mission deployment of experiments to seek chemical/molecular biosignatures on selected targets. Instrument development for research, prototyping, and flight deployment opportunities would include a focus on advanced mass spectrometry, chemical separation, and other sensitive analytical techniques and associated technologies. This work may include modeling and laboratory work to validate such approaches through comparison with terrestrial and non-terrestrial controlled analogs, chemicals, and/or processes.

The applicant will plan and conduct research that represents a systematic attack on problems recognized as difficult and unyielding to investigation and will independently conceive and propose for research support to address problems of broad scope and complexity requiring subdivision into separate phases of conceptualization/definition, design, development, test and optimization, data analysis, and interpretation of results. The science research results will be shared through publication in peer-reviewed publications, requirements documents, white papers, invited talks and seminars, and presentations at scientific conferences.

The applicant will additionally support the broader development of approaches for conducting investigations of planetary bodies, where geochemical processes can be linked to ocean worlds or icy worlds; the submission of proposals for development funding; and advocacy for their implementation in the scientific community and the public.

For additional information please contact: Dr. William Brinckerhoff at: William.B.Brinckerhoff@nasa.gov

Tenure Track Positions(s) in Planetary Science

The Department of Earth, Atmospheric, and Planetary Sciences (EAPS), within the College of Science at Purdue University, invites applications for one or more tenure-track faculty positions in planetary atmospheres and/or planetary physics. These appointments will be at the level of Assistant or Associate Professor. Growth in planetary science is part of large-scale interdisciplinary hiring effort across key strategic areas in the College of Science. This position comes at a time when the College is under new leadership and with multiple commitments of significant investment.

Candidates should be able to develop a vigorous, externally funded, internationally recognized theoretical, experimental, and/or observational research program that addresses research questions of fundamental importance. Possible areas of study in planetary atmospheres could include observing and/or modeling of the atmospheres of jovian, terrestrial, exosolar planets or small bodies, and/or the origin of life and habitability. Possible areas of study in planetary physics could include computer modeling of impact processes, planetary origins, or planetary interiors.

Candidates are expected to develop a program that is complementary to existing research within the department and teaching needs at the undergraduate and graduate levels. The potential to develop interdisciplinary, collaborative research that cuts across specialty areas within the department, the College of Science, and Purdue's research community is desirable. Candidates must have completed their Ph.D. in Planetary Sciences or related field at the time of employment. Within EAPS and Purdue, candidates will find supportive colleagues, a diverse and vibrant academic community, with ample opportunities for professional and personal growth.

Purdue University's Department of Earth, Atmospheric, and Planetary Sciences is committed to advancing diversity in all areas of faculty effort, including scholarship, instruction, and engagement. Candidates should address at least one of these areas in their cover letter, indicating their past experiences, current interests or activities, and/or future goals to promote a climate that values diversity and inclusion.

Interested applicants should visit https://hiring.science.purdue.edu, submit a curriculum vitae, a research statement, a teaching statement, and complete contact information for at least 3 references. Review of applications will begin January 2, 2019, and will continue until the position is filled. Questions related to this position should be sent to David Minton (daminton@purdue.edu). Applications will be accepted until the position is filled. A background check will be required for employment in this position. Purdue University is an ADVANCE institution.

Purdue University is an EOE/AA employer. All individuals, including minorities, women, individuals with disabilities, and veterans are encouraged to apply.

Seismology

Assistant Professor of Seismology, Purdue University

The Department of Earth, Atmospheric, and Planetary Sciences (EAPS), within the College of Science at Purdue University, invites applications for a tenure-track faculty position at the rank of Assistant Professor in the area of seismology. As part of a large-scale interdisciplinary hiring effort across key strategic areas in the College of Science—Purdue's second-largest college, comprising the physical, life, and computing sciences—this position comes at a time when the College is under new leadership and with multiple commitments of significant investment.

EAPS has strengths in exploration geophysics, seismic imaging, geophysical modeling, earth material properties, geodesy, and tectonics. We seek to add a quantitative seismologist interested in addressing questions on the solid earth at a range of scales. Areas of specialization could include earthquake geophysics, and/or natural/active source seismic imaging. Candidates are expected to develop a vigorous, externally funded, internationally recognized research program, that is complementary to existing research and teaching needs at the undergraduate and graduate levels. The potential to develop interdisciplinary research that cuts across specialty areas within the department, the College of Science, and Purdue's research community is desirable. Candidates must have completed their Ph.D. in the area of Geophysics or a related field by the time of employment. Within EAPS and Purdue, candidates will find supportive colleagues, a diverse and vibrant academic community, with ample opportunities for professional and personal growth.

Purdue University's Department of Earth, Atmospheric, and Planetary Sciences is committed to advancing diversity in all areas of faculty effort, including scholarship, instruction, and engagement. Candidates should address at least one of these areas in their cover letter, indicating their past experiences, current interests or activities, and/or future goals to promote a climate that values diversity and inclusion.

Interested applicants should visit https://hiring.science.purdue.edu, submit a curriculum vitae, a research statement, a teaching statement, and complete contact information for at least 3 references. Review of applications will begin December 20, 2018, and will continue until the position is filled. Questions related to this position should be sent to Douglas Schmitt (schmitt@purdue.edu) or Christopher Andronicos (candroni@purdue.edu). Applications will be accepted until the position is filled. A background check will be required for employment in this position. Purdue University is an ADVANCE institution.

Purdue University is an EOE/AA employer. All individuals, including minorities, women, individuals with disabilities, and veterans are encouraged to apply.

Postcards from the Field

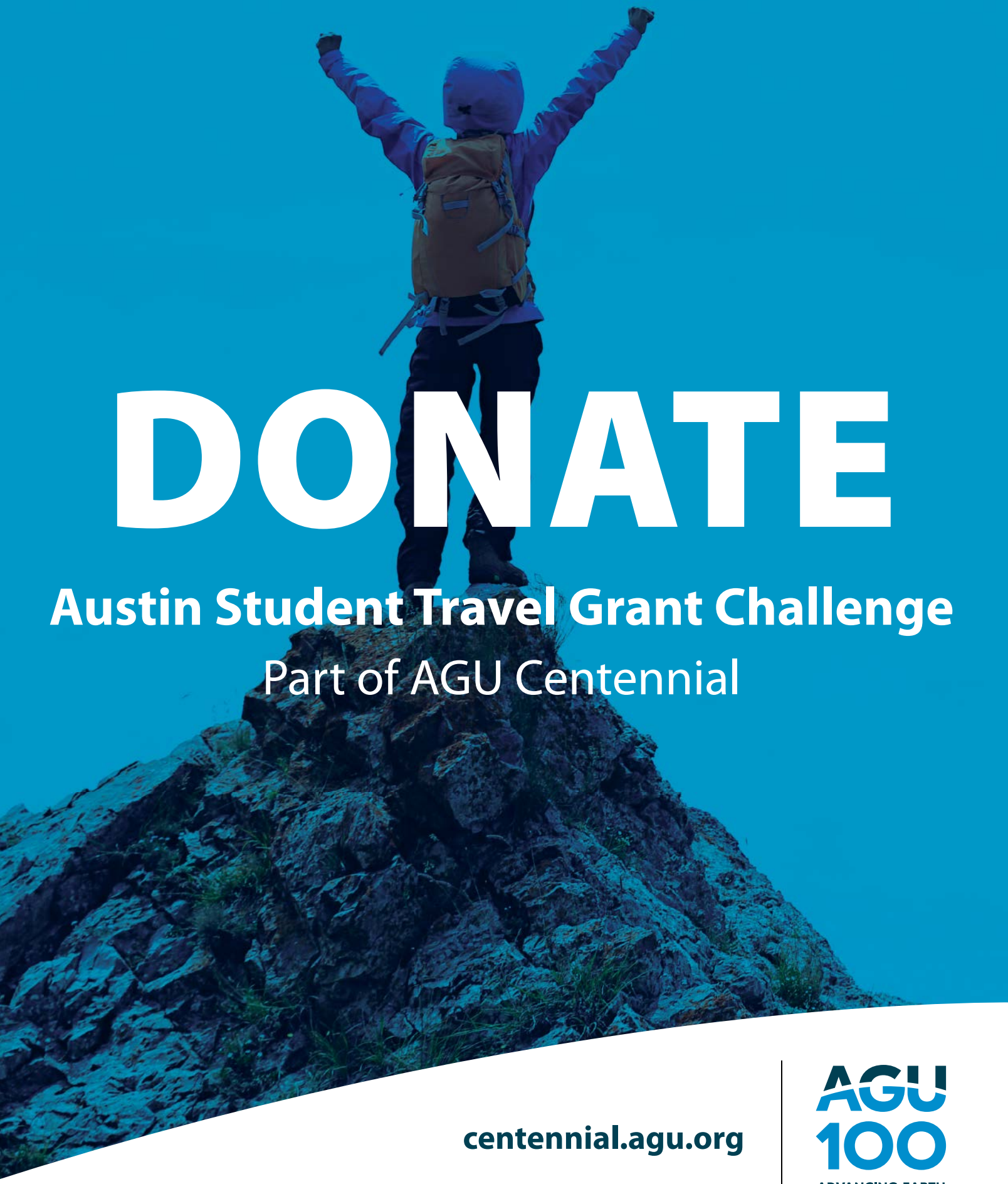
Hello from the shore of the Chukchi Sea!

This photo is from an Arctic geophysics research class that I teach every other spring. My group was in Utqiaġvik (formerly Barrow), Alaska, at the end of February working on a new method for quickly determining the thickness of sea ice.

One night we saw that the aurorae were out, and we put on our gear (it was −40°F with the wind) to go out and see them. We got to the beach and this rise at the edge of the shore ice, and the students were amazed. I quietly moved back and put my camera on a 30-second exposure, hoping that the students wouldn't move. I shouldn't have worried about that because they were mesmerized by this once-in-their-lifetime event. They were astounded by the beauty of the deadly particle flux from our Sun being caught by Earth's magnetic field and then turned into this amazing, living exhibition of now benign color.

—Rhett Herman, Department of Physics, Radford University, Radford, Va.

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



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