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EOS

Earth & Space Science News

Finding the Pulse of Climate Change

Cyclists' Exposure to Air Pollution

Data Set for Land–Air Exchanges

NEW GULF OF MEXICO SEAFLOOR MAP

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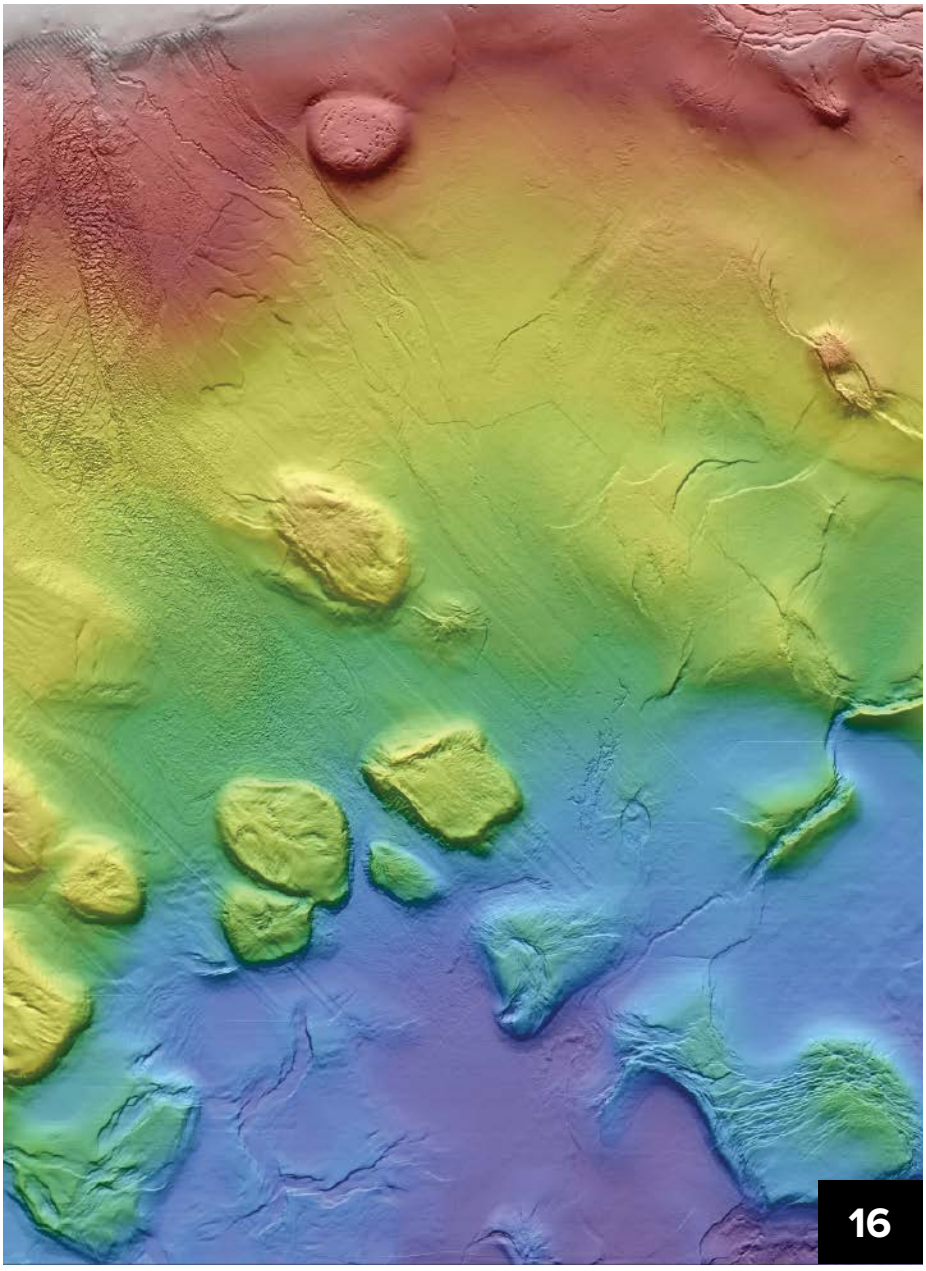

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The health, welfare, and livelihood of millions depend upon our elected officials' continued and robust support for hurricane research.

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Eos

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Christine W. McEntee, Executive Director/CEO

AGU American Geophysical Union

Innovative Postage Stamp Celebrates Upcoming Total Solar Eclipse

The total solar eclipse pictured on a postage stamp released 20 June is a remarkably good representation of what hordes of eclipse watchers will see with their own eyes this month. So says astrophysicist Fred Espenak, who snapped the photos of the Sun and the Moon featured on the new stamp.

The new stamp from the U.S. Postal Service (USPS) commemorates the 21 August total solar eclipse that will be viewable, weather permitting, along about a 110-kilometer-wide "path of totality" across the country from Oregon to South Carolina. This is the first time since 1979 that a total solar eclipse will be visible on the U.S. mainland. The postal service rolled out the 49-cent Forever stamp, always worth the 1-ounce price for first-class mail, on the cusp of the 2017 summer solstice.

To create the extraordinary stamp, its designer used a composite image provided by Espenak of an earlier eclipse. Espenak's image digitally stitched together 22 separate photographs that he took of a 2006 total solar eclipse in Libya. Combining exposures taken at different camera shutter speeds and fine-tuning and filtering them on a computer brought out details of the solar atmosphere that otherwise would not be visible on a stamp, according to Espenak, an eclipse expert, astrophysicist, and photographer. Espenak, who maintains NASA's official eclipse website, has been dubbed by some as "Mr. Eclipse."

The image that resulted from those sophisticated techniques shows exceptionally fine gradations of light and dark, so it comes close to representing what the Sun's corona looks like to the naked eye, explained Espenak, who retired from NASA's Goddard Space Flight Center in Greenbelt, Md., after working there as an astrophysicist for more than 30 years.

"The inner part of the corona is 1000 times brighter than the outer corona [that is] just a Sun's diameter away," Mr. Eclipse said. "The eye can see that beautifully, but photographs don't reveal that" unless they undergo special processing.

Pictured above are two views of a new stamp that when warmed by a person's finger, switches from showing the black disk of the Moon's silhouette covering the Sun to an illuminated view of the Moon in place of the black disk. A total solar eclipse occurs when the Moon comes between the Sun and viewers on Earth, briefly blocking out the observers' view of the disk of the Sun. Credit: ©2017 USPS; photos by Fred Espenak

Here's the Rub

But that's not all that's exceptional about this stamp.

If you touch the eclipse image on the stamp, the heat from your finger temporarily reveals an image of the full Moon (also shot by Espenak) covering the disk of the Sun. This effect is made possible with thermochromic ink, which changes the stamp's appearance in response to temperature, the first time USPS has used this technique.

USPS encourages postage stamp art directors to think of new approaches to subject matter that can enhance the stamp program, according to Antonio Alcalá, owner and creative director of Studio A in Alexandria, Va., who designed this stamp.

"I believe a primary experience of a solar eclipse is the rapid transition from daylight to darkness to daylight again," Alcalá told *Eos*. "Having seen thermochromic printing a few times in the past, I thought this technique might be suitable for conveying this general idea."

Contributing as well to the visual impact of these stamps, the postal service is printing them in a four-color process. This printing method achieves a richer black because less light reflects from the sheet of paper and allows for a greater range of tonality, Alcalá explained.

The reverse side of each pane of 16 of the new stamps shows a map of the United States crossed by the path of totality and gives the times of the total solar eclipse at each location specified on the map, from Salem, Ore., to Charleston, S.C.

USPS issued a much more traditional eclipse stamp in 2000. Other countries also have issued eclipse stamps in the past, including Mexico, Zimbabwe, and Libya.

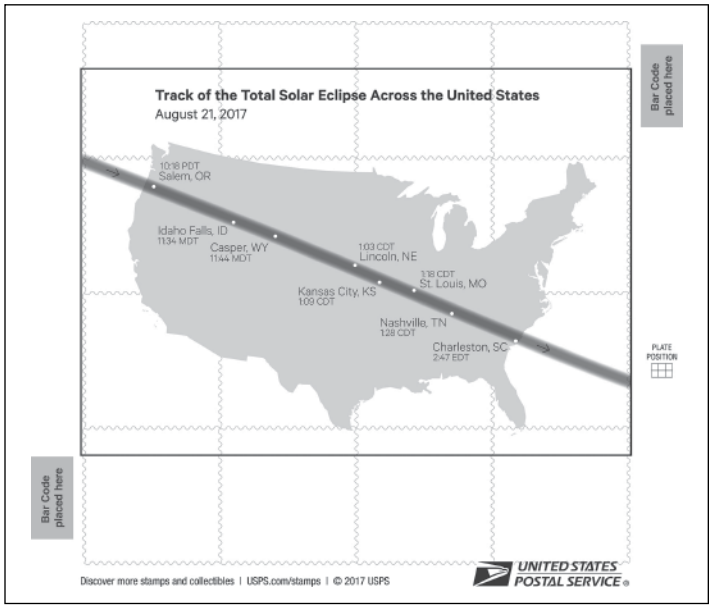
Reaching Millions of People

Espenak told *Eos* that, sure, he's thrilled about his images being used on the stamp, but he's also excited to inform and educate millions of people about an astronomical phenomenon. A solar eclipse is "one of the most spectacular ways" to reach out to the public and get them interested in science and technology, he said.

"The United States in particular is suffering from severe science illiteracy right now," Espenak said. "It's heartbreaking seeing the way the leadership in this country is taking us away from science."

Seeing a total solar eclipse "is a life-changing event," said Espenak, who looks forward to the August incident as his 28th such experience, noting that he has spent "only" about 70 minutes overall in ecliptic totality. Espenak said that nothing—not videos, books, or photos—can prepare someone for the sensation of witnessing a total eclipse in person.

"When that Moon shadow comes over the horizon and suddenly sweeps over [the Sun], you plunge from bright daylight into twilight in seconds," he said. "You feel this event in the pit of your stomach, you feel it on the hair



The back of the stamp pane features a map of the path of totality of the 21 August eclipse and the times that the total solar eclipse is predicted to be visible at some locations across the United States. Credit: USPS

on your arms and the back of your neck. You have a visceral reaction that something is very different, something is very wrong, even."

Because "it seems apocalyptic" with the Sun's bright disk briefly gone, "you can easily empathize with people thousands of years ago who didn't understand what was happening," he added.

Chasing Eclipses

Espenak caught his first total solar eclipse in 1970 when, at age 18 with a newly issued driver's license, his parents allowed him to drive the family's Chevy Biscayne, unchaperoned, about 750 kilometers from Staten Island, N.Y., to Windsor, N.C., to get in the path of the eclipse. He checked into a motel, and the next morning on eclipse day, the area behind the motel "was a field of tripods. Everybody was there in that motel to see the eclipse. It was like a big party there."

"I'm really wound up on eclipse day," said Espenak, who leads eclipse tours. There are so many cameras to set up and align that must be "coordinated almost like a ballet," he said. On eclipse day, he's not very social, cordoning off his staging area with police tape as a visual warning to others not to disturb him or his equipment.

"A number of TV stations have said they wanted to interview me during the eclipse, and I said, 'Are you out of your mind?'" Espenak recalled. "You can't pay me enough, not during the eclipse."

The August eclipse will be another nerve-racking time for Espenak. A few days prior, he'll talk about the eclipse at an astronomy convention in Casper, Wyo., which lies in the path of totality. However, if the forecast calls for clouds in Casper, he will be ready to drive an SUV full of photo equipment as far as he can along that path, the day before the eclipse, looking for better weather. That makes sense for Espenak, who said that seeing total eclipses "has been the biggest thrill of my life."

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

International Science Group Decries Trump Climate Pact Exit

The Arc de Triomphe in Paris glowed a celebratory green on 4 November 2016, the day the climate accord negotiated in that city took effect. On 12 June, the International Union of Geodesy and Geophysics issued a statement challenging U.S. president Donald Trump's 1 June decision to withdraw the United States from the accord. Credit: Chesnot/Getty Images

The fallout continues from U.S. president Donald Trump's decision in June to withdraw the country from the Paris climate change accord.

The International Union of Geodesy and Geophysics (IUGG) issued a statement on 12 June stating that the organization "is dismayed" that the United States seeks to renegotiate or withdraw from the accord.

"The world expects that scientific excellence and scientific knowledge will be incorporated into decision-making and that internationally binding decisions, once made, will be honored by governments and their successors," the IUGG statement reads (http://bit.ly/IUGG-2017). IUGG, established in 1919, is the oldest nongovernmental international scientific organization dealing with Earth and its environment.

By withdrawing from its leadership role in the Paris accord, the United States "has lost the opportunity to help reduce emissions," the statement continues. "IUGG therefore encourages the United States to continue to meet the aspirations of the Paris Agreement through the efforts of the states, cities, industries and citizens."

> IUGG "wanted to let the international scientific community know that we are against such political games related to our future."

The IUGG statement also notes that the decision by President Trump to terminate U.S. funding to the Green Climate Fund to assist developing nations with climate change–related investments is "as damaging, or more damaging than a potential US withdrawal" from the Paris accord.

Paris Withdrawal Causes "Serious Damage"

Trump's choice to withdraw from the Paris agreement "was not only a political decision, but a serious damage to international scientific cooperation," IUGG secretary-general Alik Ismail-Zadeh told *Eos*. "Hence IUGG could not stay silent and needed to issue a statement on this topic."

Ismail-Zadeh said the plan for IUGG to make a public statement was initiated on 3 June, a couple of days after Trump announced that he would withdraw the United States from the climate agreement.

"IUGG assesses soberly the situation and believes that this statement would not have a significant impact on the decision of the current U.S. government," he told *Eos*. "But IUGG wanted to let the international scientific community know that we are against such political games related to our future and the future of new generations."

On a personal note, Ismail-Zadeh said that everybody has the right to criticize any agreement. However, he added, "I think that it does not mean that the president of one of the world's greatest countries should ignore the opinion of the world's scientific and political communities and impose his own opinion on top of it."

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

Novel Air Pollution Study Gauges Individual Cyclists' Risks

Urban bicyclists and outdoor sports enthusiasts may soon learn more about the air pollution they breathe and its health risks as an unusual 3-year study gets under way. In mid-June, the project equipped its first cohort of volunteer bike commuters in New York with pollution sensors as well as a sophisticated array of health monitors. The equipment will ultimately track 150 riders' vital signs while they're on the move and, in a step beyond what prior similar studies have done, estimate each individual's pollution exposure.

The "traditional metrics" are just pollutant concentrations, said Steven Chillrud, a research professor at Columbia University's Lamont-Doherty Earth Observatory in Palisades, N.Y., who is one of the leaders of the research. Pollution is typically measured by how much of it is in the air, as micrograms per cubic meter, for example. But a jogger or cyclist breathes harder than someone sitting still, and that can drastically affect how much pollution that person actually inhales.

A more accurate way to look at exposure would be to consider dosage, said Chillrud, an environmental geochemist with an interest in public health. In a smaller pilot study of 40 individuals, the researchers found that their subjects' bike commutes "tend[ed] to dominate their overall air pollution exposure," said Darby Jack, a professor of environmental health at the Mailman School of Public Health in New York, also within Columbia University, who coleads the study with Chillrud.

Would the same hold true for a more statistically significant sample? Chillrud and Jack aim to find out.

Biking in traffic is thought to drastically increase exposure to fine particulate matter, especially black carbon. Credit: iStock.com/GibsonPictures

Focusing on Particulates

Although New York overall has cleaned up its air in recent years, its skies still rank among the dirtiest in the United States, according to the American Lung Association. This poor air quality makes the city a pollution laboratory, the researchers note.

The Columbia project focuses on fine particulate matter, called PM2.5 because it is smaller than 2.5 micrometers—about 1/20 the width of a human hair. It further focuses on black carbon, a subset of PM2.5 produced by burning organic matter. Most black carbon in cities comes from diesel exhaust. Long-term exposure to black carbon has been linked to an increased risk of heart failure and respiratory problems, but "looking at briefer exposures, the literature is thinner," Jack said. "I don't think anyone would say it's benign," but going from that to knowing exactly what the health effects are is a long step.

On 13 June, the researchers outfitted the first small group of volunteers with two sensors to measure PM2.5 and black carbon, a GPS device, a biometric shirt called a Hexoskin that measures breathing rates and heart rate variability, and an automatic blood pressure reader. These volunteers are to wear the shirt and blood pressure reader for six 24-hour periods over a 3-week window while the bike-mounted sensors collect data on their commute. The volunteers must return the equipment after 3 weeks for the researchers to collect the data, and then the devices will be given to a new set of volunteers, 150 in all over the course of the study.

Fine-Grained Measurements

Past air pollution monitoring studies often used expensive, bulky sensors mounted on buildings or poles. However, the recent advent of smaller, cheaper sensors is making it possible for pollution researchers to deploy many more sensors than before and to mount them on people or small vehicles like bicycles. As a result, scientists can measure concentrations at the street level at scales fine enough to look at individuals' exposures.

In studies similar to the new one starting up in New York, clean air activists in Pittsburgh's Group Against Smog and Pollution equip volunteer cyclists in the city with electronic air particle counters; a similar project is ongoing in Toronto, Ont., and nearby Hamilton, in Canada.

However, these projects don't take dosage into account, Chillrud said.

Early Results

Although the second phase of the study, launched 13 June, was more comprehensive, the pilot study of 40 riders has already revealed some key information, such as how unevenly pollution is distributed in space and time: "It turns out there are locations in the city that are fairly high pollution…and there are other places that are pretty clean, and there are times of day that are more polluted," Jack said.

The researchers, who say they're working with public radio station WNYC to help get the word out about the study and its results, have created an interactive online map from their pilot program data. With this map, other bike riders can upload a GPS file of a biking route to the interactive map and get an estimate of personal exposure to pollution on the ride. Jack and Chillrud hope to refine those estimates after the full study gets under way.

Jack said that he hopes the full study's data will ultimately help inform policy. "We're thinking of it as a message to city planners…that it's important that air pollution be one of several design criteria" considered when building new infrastructure. He speculates that their study might also serve as a call to cyclists to change their behavior by taking a different route, commuting at a different time, or even pedaling slower through the dirtiest part of their commute.

To Bike or Not to Bike

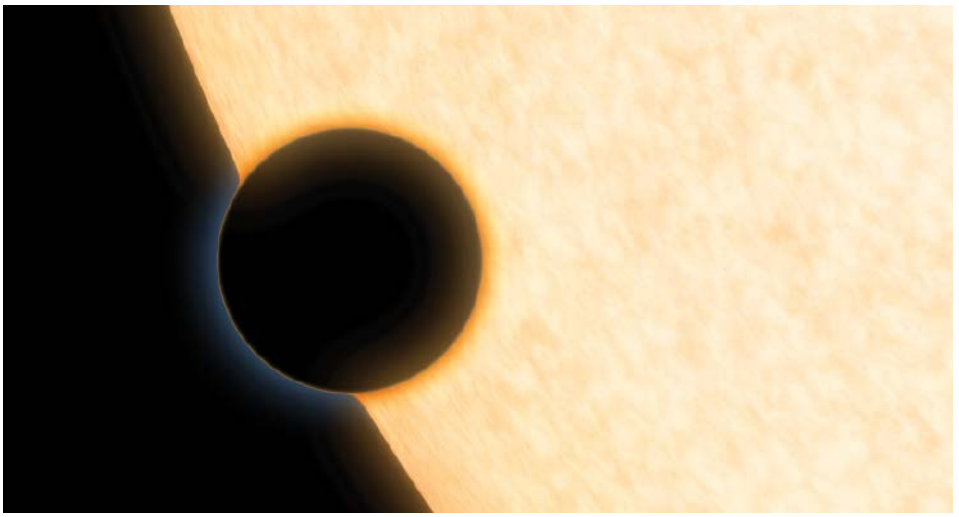
So far, the pollution data haven't caused any volunteers to stop biking, and Chillrud and Jack agree that the data shouldn't. The exercise benefits from biking almost certainly outweigh the pollution exposure, they said.

That view is supported by a study published last year in *Preventive Medicine* that modeled the relative trade-offs between active transportation and pollution exposure for a variety of concentration levels.

The study found that "even in the most polluted environments you're better off doing a little activity rather than no activity," said coauthor and public health modeler James Woodcock of the University of Cambridge in the United Kingdom.

By **Rachel Kaufman** (email: rk@readwriterachel.com; @rkaufman), Freelance Science Journalist

Ten Earth-Sized Planets Found by Exoplanet-Hunting Telescope



An artist's rendering of a Neptune-sized exoplanet. New research using Kepler data finds that the majority of exoplanets fall into two distinct size categories: similar to Earth or similar to Neptune but not in between. Credit: NASA/JPL-Caltech

NASA introduced 219 exoplanet candidates to the world this June. Ten of these are roughly Earth sized and orbit their stars in the so-called habitable zone, a distance from the star at which temperatures could be ripe for liquid water.

The candidate exoplanets appear in the eighth and newest catalog from the agency's exoplanet-hunting Kepler space telescope and the final catalog from Kepler's observations of the Cygnus constellation. The new catalog includes 4034 exoplanet candidates overall (http://bit.ly/exoplanet-archive).

Past "Kepler catalogs have shown us that small exoplanets are common," Susan Thompson, lead author on the catalog study and a research scientist at the SETI Institute in Mountain View, Calif., told *Eos*. "With this [latest] catalog, we can show whether this is also true for exoplanets that are in orbital periods similar to those of the Earth."

Accompanying research also reveals that the majority of known exoplanets fall into two distinct sizes: rocky exoplanets up to 1.75 times the radius of Earth and Neptune-sized gassy exoplanets. The finding, which was accepted in The Astronomical Journal (http://bit.ly/ExoplanetClass), deepens scientists' understanding of exoplanet diversity.

> "These Kepler catalogs have shown us that small exoplanets are common."

Building Exoplanet Catalogs

In previous exoplanet catalogs, researchers focused on rocky planets with orbits like Mercury's, or less than about 100 Earth days, Thompson noted. In contrast, the new catalog is the first to feature enough potential near-Earth-sized planets orbiting in their habitable zones that scientists can start to fully understand just how abundant these bodies are in the galaxy, she continued.

Scientists build exoplanet catalogs by reprocessing the entirety of Kepler's data from the first 4 years of its mission, which ran from 2009 to 2013 until an onboard mechanical failure ended its campaign to observe more than 150,000 stars. Since then, researchers have combed through the data, finding more and more exoplanet candidates as their models became more accurate.

The analysis of Kepler data has revealed several types of exoplanets, including gassy "hot Jupiters" (bodies hotter than Jupiter) and smaller planets (from Neptune-sized gassy planets to rocky planets roughly the size of Earth). The majority of confirmed Kepler exoplanets have fallen into this smaller planet category.

New Branches of the Exoplanet Family Tree

The predominance of two distinct sizes in the new data add to our understanding of the exoplanet family tree, Kepler researchers noted. The differences observed are akin to the biological differences between reptiles and mammals, Benjamin Fulton said. Fulton is a graduate student and lead author on the soon-to-be-published paper. He splits his time between the California Institute of Technology (Caltech) in Pasadena and the University of Hawaii at Mānoa.

To better understand the size distribution of smaller exoplanets, Fulton and his colleagues turned to the W. M. Keck Observatory in Hawaii to take a closer look at 1300 stars hosting more than 2000 exoplanets. The researchers collected data about the stars' light, which dims periodically as their planets pass between them and Earth. The team used the observations of light from the stars—and how the planets affected that light—to determine the planets' sizes.

The team found that smaller exoplanets fall into two distinct size categories: rocky planets up to 1.75 times the radius of Earth and gassy planets 2–3.5 times the radius of Earth (or a touch shy of Neptune's size).

"Astronomers like to put things in buckets," Fulton said. "In this case, we have found two very distinct buckets for the majority of the Kepler planets."

These gassy mini-Neptunes could have rocky cores buried "beneath the crushing weight of a thick atmosphere" or no solid core at all, said Fulton, rendering them inhospitable to life as we know it. Few exoplanets exist between those two sizes.

The researchers speculate that these two categories could stem from the bodies' hydrogen and helium compositions when they first formed. Just enough gas, and the planet could balloon in size and "jump the gap" to become a mini-Neptune, said Andrew Howard, an astronomer at Caltech and principal investigator on the new research. But a small amount of gas would get blown away by radiation from the planet's host star.

The newly discovered size differences will help researchers home in on the more Earth-like exoplanets. "Our result sharpens up the dividing line between potentially habitable planets and those that are inhospitable to life as we know it," Fulton said.

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

Mining Ancient Texts Reveals Clues to Space Weather of Yore

An aurora glows above Tromsø, Norway, in 2010. Researchers searching ancient manuscripts for past observations of celestial events report that a sketch from an 8th-century manuscript may depict an aurora. Credit: Gunnar Hildonen, CC BY-SA 2.0 (http://bit.ly/ccbysa2-0)

Scientists use sophisticated instruments such as satellites to monitor space weather now, but watchers of the skies have been observing phenomena such as auroras for millennia. Japanese researchers recently identified what may be the earliest known, datable sketch of an aurora and say it can shed light on solar activity more than 1000 years ago.

The crude marginalia were found in the Zūqnīn Chronicle, a history of events from Creation to the late 8th century that is preserved in the Vatican Apostolic Library. Composed in 775 and 776 C.E., the manuscript is written in a dialect of Aramaic and attributed to a monk dubbed Joshua the Stylite, who lived in the monastery of Zūqnīn in what is now eastern Turkey. The manuscript yielded a total of 10 drawings of heavenly phenomena, including a sketch of horizontal bands from 771–772 C.E. The chronicle describes it thus:

> *It was seen at harvest time, occupying the entire northern side from the eastern corner to the western corner. Its form was as follows: a blood-red scepter, a green one, a black one, and a saffron-colored one. It was going from below to above. When one scepter was extinguished, another one went up. And when someone was looking at it, it was changed into seventy shapes.*

"One of the most obvious scientific merits for doing this research is that we can confirm past extreme events," said Hiroaki Isobe, an associate professor in the Graduate School of Advanced Integrated Studies in Human Survivability at Kyoto University in Kyoto, Japan. Isobe has collaborated with more than a dozen scientists and historians in searching and analyzing various archives for records of sightings in the heavens.

"For instance, in 775 and 994 there were sharp peaks in carbon-14 seen in tree rings, which is evidence of large amounts of cosmic rays in the atmosphere," Isobe told *Eos* on 22 May after he spoke at a joint conference of the Japan Geoscience Union (JpGU) and AGU in Chiba, Japan.

"This tells you that cosmic rays were there, but not their origin, such as whether they were from extreme space weather or gamma ray bursts or supernovas. If we can find evidence of low-latitude auroras in the same year as these peaks, it strongly supports the hypothesis that this carbon-14 is due to strong solar activity."

Stormy (Magnetic) Weather

That the circa 771–772 C.E. auroras were visible from the relatively low geomagnetic latitude of eastern Turkey suggests that they were associated with strong geomagnetic storms, according to Isobe. Although the Zūqnīn sketch was known to some historians, Isobe said his team is the first to investigate it in detail and confirm it was an aurora. Sketches are particularly useful in historical astronomy, he added, because words alone can be harder to interpret.

Written descriptions of auroras have been found in cuneiform clay tablets from Babylonia, whereas ancient Chinese and Japanese observers used terms such as "red vapor" or "white rainbow" to describe auroras. To determine whether a record really describes an aurora, features such as the time, Moon phase, color, size, and direction, as well as other contemporary observations, must be taken into account. If the report was made during a full Moon, for instance, it could be the result of atmospheric scattering of moonlight. But if it can be established that the phenomenon was an aurora, such reports are also a record of solar activity.

"You can actively mine these archives, and there's a huge treasure trove of information in them," said Martin Connors, Canada Research Chair in Space Science, Instrumentation and Networking at Athabasca University in Alberta. "I think they're being very careful about interpretation, such as using observations taken on a moonless night and correlating them with changing magnetic latitude."

Ryuho Kataoka of Japan's National Institute of Polar Research, one of Isobe's collaborators and a fellow speaker at a space weather session of the JpGU-AGU conference, shared the results of a study showing that aurora sightings in Japan in 1204 were likely caused by significant magnetic storms resulting from multiple coronal mass ejections. He noted that the observations were made at Kyoto during a time when the region was especially susceptible to geomagnetic effects because of the orientation of Earth's magnetic field. Kataoka showed attendees images of handwriting from the *Meigetsuki* (*The Record of the Clear Moon*), a diary written by Fujiwara no Teika, a poet-scholar who died around 1241.

"Their best events were when the northern latitude in Kyoto was most favorable for seeing them. That corroborates these reports being of aurora," Connors said.

"You can actively mine these archives, and there's a huge treasure trove of information in them."

Comet Tale

The Zūqnīn manuscript also contains a sketch of a comet plus a description that says the comet had two tails. The authors noted that the date coincides with the appearance of Halley's Comet in May 760 and that it is known to have also been observed by Chinese astronomers. A simulation using astronomy software led the researchers to conclude that the Zūqnīn Chronicle contains the earliest known description of two tails on a comet.

Isobe and his colleagues have published more than 10 papers about ancient records of celestial phenomena, including a January 2017 study (http://bit.ly/Hayakawa-2017) about the aurora sketches in *Publications of the Astronomical Society of Japan* and a February 2017 study (http://bit.ly/Kataoka-2017) in *Space Weather*.

By **Tim Hornyak** (@robotopia), Science and Technology Journalist

Merle Lee Allison (1948–2016)

Stephanie Mar

Merle Lee Allison

Merle Lee Allison, state geologist and director the Arizona Geological Survey, died on 16 August 2016 after suffering a head injury from a fall at his home on the previous Saturday.

Lee, as he was known to all, was a talented geologist who loved the outdoors, always seemed to have time for people big and small, and did not suffer fools gladly. He served as state geologist in three states and was a longtime active member of the Association of American State Geologists. In those roles, he never settled for business as usual but always championed the value of geological resources for national security and prosperity and the contribution that state geological surveys could make to the economic well-being of a state and its citizens.

Lee was born in 1948 in the Philadelphia area, where he spent his first 11 years before his family moved to Los Angeles. He received a B.A. in geology at the University of California, Riverside (1972), and was the first in his family to attend college. He pursued an M.S. from San Diego State University (1974) and worked for several years at Standard Oil Production Company in Texas before returning to academia to complete a Ph.D. at the University of Massachusetts Amherst (1986) on structural analysis of the Tensleep Fault in the Bighorn Basin of Wyoming. Following his Ph.D., Lee held positions as an exploration development geologist with Chevron and as a research geologist with the University of Utah Energy and Geoscience Institute.

From 1989 to 1999, Lee was the state geologist of Utah, before moving on to assume that same position in Kansas from 1999 to 2004. During his tenure in Kansas, he chaired the Kansas Energy Council from its inception in 2002 until 2005. In 2004–2005, he served as policy adviser for science and energy to Kansas governor Kathleen Sebelius. In December 2005, Lee was appointed Arizona state geologist, a position he held until his untimely death.

Myth Buster

Lee was a tireless organizer, a savvy political operative, and the possessor of a wicked sense of humor. While he was state geologist in Utah, he wanted to host the Geological Society of America (GSA) annual meeting in Salt Lake City, but the idea met with resistance from the beer-loving segment of the geoscience community based on the perception that the city was dry.

To overcome this, Lee convinced one of the Salt Lake City breweries to supply some kegs of beer, got an airline to fly it for free to the GSA annual meeting in San Diego, and then advertised that the Utah Geological Survey booth would be having free beer at 4:00 p.m. Several years later, the annual meeting was held in Salt Lake City.

When Kansas authorities tried to introduce creation science into school science standards, Lee played a key role in rallying opposition. Those efforts led to the founding of the Coalition on the Public Understanding of Science.

Glowing Recognition

Lee has been honored with numerous awards, both formal and informal. Among the latter, the *Hutchinson News* (Kansas) hailed Lee as a "Shining Light" for helping restore the city to safety after deadly natural gas explosions in 2001.

Author Sarah Andrews loosely based her murder mystery *Fault Line* on Lee's experiences during a controversy about the location of active faults in Salt Lake City. Being an inspiration for a book made Lee especially proud.

In 2002, the American Association of Petroleum Geologists recognized Lee with its Public Service Award. The next year, he received the Tanya Atwater "Encourage" Award from the Association for Women Geoscientists. The American Institute of Professional Geologists honored Lee with its John T. Galey Jr. Award for Public Service in 2008.

Geoinformatics Pioneer

Lee became a world leader in efforts to develop cyberinfrastructure for the Earth sciences. He recognized the field of geoinformatics early for its potential to accelerate discovery and bring science into policy decisions.

Knowing that state and federal geological surveys in the United States held enormous volumes of data, Lee convinced the National Science Foundation (NSF) to provide funding in 2007 for a workshop on data sharing.

An outcome of the workshop was the joint recommendation that "the nation's geological surveys develop a national geoscience information framework that is distributed, interoperable, uses open source standards and common protocols, respects and acknowledges data ownership, fosters communities of practice to grow, and develops new web services and clients."

Lee pursued this goal ceaselessly in the following years, and his activities became more national and international, as principal investigator of the Test Governance project for NSF's EarthCube initiative, cochair of the Belmont Forum e-Infrastructure and Data Management Secretariat and Steering Committee, North American member of the OneGeology board of directors, chair of the Geological Society's Geoinformatics Division, and a member of NSF's Advisory Committee for Cyberinfrastructure.

Pulling Big Data (and People) Together

Lee marshaled the resources of 48 state surveys to build the National Geothermal Data System in collaboration with the U.S. Department of Energy. A member of AGU since 1980, Lee was highly involved in recent years with the organization's geoinformatics efforts. In another AGU role, Lee was a member of the *Eos* Editorial Advisory Board since 2008.

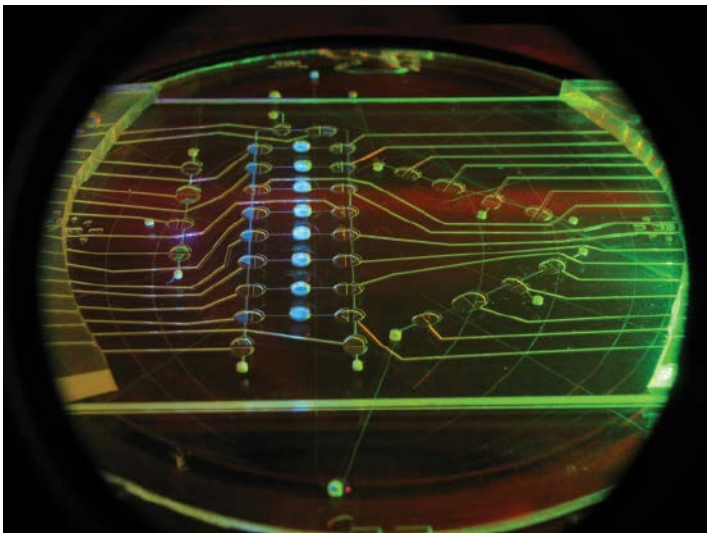
With his boundless energy and enthusiasm and his skill at bringing people together, Lee often served as the connector who enabled breakthroughs in geoinformatics. All of us will ultimately benefit from Lee Allison's legacy of promoting the development and accessibility of big data in the geosciences.

Lee is survived by his wife, Ann Becker; brother, Mark Allison, of Claremont, Calif.; and sister, Cathy Torrance, of Las Vegas, Nev.

By **Stephen M. Richard** (email: steve.richard@ldeo.columbia.edu), Lamont-Doherty Earth Observatory, Columbia University, Palisades, N.Y.; and **Denise J. Hills,** Geological Survey of Alabama, Tuscaloosa

Instrument Development Enables Planetary Exploration

Third International Workshop on Instrumentation for Planetary Missions
Pasadena, California, 24–27 October 2016



This laser-interrogated microfluidic chip (10 centimeters in diameter) is one of the new planetary instrument technologies that NASA and other space agencies are developing to search for chemical indicators of life on other planets. In this lab-on-a-chip device, a laser excites labeled amino acid molecules as they pass through a microchannel. Different amino acid types pass through the channel at well-defined speeds, enabling their identification. Credit: Fernanda Mora and Amanda Stockton, Microdevices Laboratory, JPL/Caltech

The scientific knowledge gained from future planetary exploration missions will depend critically on the capabilities of instruments (cameras, spectrometers, magnetometers, thermal sensors, seismometers, remote laboratories, and other robotic tools) rather than human explorers to acquire sensory information. The flight opportunities available to planetary instrument developers depend on a complex interplay among mission science requirements; technology capabilities; mass, power, and volume constraints; planetary geometries; and funding availability.

Last October, more than 195 engineers, scientists, technologists, and program managers representing 12 countries met in California for the third workshop in a series that began in 2012 at NASA Goddard Space Flight Center and has been held every 2 years since.

The workshop provided a forum for collaboration, team building, exchange of ideas and information, and presentation of status reports for instruments, subsystems, and other payload-related technologies needed to address planetary science questions. Oral and poster sessions were based on 136 submitted abstracts.

Panel sessions were organized around three themes:

- perspectives on the future of planetary exploration
- bridging the gap between planetary scientists and instrument developers
- lessons learned for instrument development at various technology readiness levels (TRL 1–9)

The perspectives panel addressed planetary science priorities and opportunities over the next several decades for planetary instruments on missions to Mars, the Moon, Mercury, Venus, small bodies, and the outer planets. Panel participants strongly supported existing technology development programs, including NASA's Planetary Instrument Concepts for the Advancement of Solar System Observations and Maturation of Instruments for Solar System Exploration (PICASSO and MatISSE; see https://go.nasa.gov/2tFCawJ).

The panel emphasized that innovative approaches enhance mission science return, but new technology development efforts must effectively address cost and technical risk concerns, provide clear advantages over currently existing capabilities, and take into account mission schedules. Panel members agreed that emerging low-cost demonstration platforms (e.g., planetary CubeSats and SmallSats) provide invaluable opportunities to help new planetary instrument technologies mature and reduce the development risk in transitioning them to larger missions.

The panel on bridging the gap emphasized the importance of scientists, technologists, and engineers connecting at meetings. These groups must be willing to consider partnerships with private industry, learn new roles, and become fluent in disciplines outside of their formal training.

The panel on lessons learned covered past instrument development efforts for technology readiness levels (TRLs) from stage 1 (conceptual) to stage 9 (flight proven). These lessons included the importance of development teams beginning to think early in the development process (TRLs 3–5) about planetary protection considerations, environmental and operational constraints, systems engineering, and data analysis and operational constraints. Instrument development teams at all TRL stages should include scientists (to provide the "why") and engineers (to provide the "how") on instruments and missions.

The panels also highlighted the value of strong teams with a mixture of backgrounds in science, technology, management, and components design, as well as experience with working on various types of teams. Mentoring programs are vital to passing this knowledge along to early-career scientists. Finally, the panels noted that instrument development is becoming more international; thus, researchers must learn to function within one another's cultures.

End-of-workshop feedback mentioned the difficulty in getting scientists and instrument engineers together at traditional conferences and recommended that the community seek ways to expand networking opportunities. For example, instrument talks could be incorporated into the annual Lunar and Planetary Science Conferences.

More details on the presentations are available in the workshop abstracts (see http://bit.ly/IPM-2016). The workshop also produced an open-source online instrument database (http://bit.ly/IPM-database) to facilitate ongoing input from developers.

The workshop was sponsored by the Lunar and Planetary Institute. The next workshop in this series is tentatively scheduled to take place in Berlin, Germany, in fall 2018.

By **Sabrina M. Feldman, David Beaty,** and **James W. Ashley** (email: james.w.ashley@jpl.nasa.gov), Jet Propulsion Laboratory, California Institute of Technology, Pasadena

Volcanic Ash Particles Hold Clues to Their History and Effects

Volcanic Ash as an Active Agent in the Earth System (VA3): Combining Models and Experiments
Hamburg, Germany, 12–13 September 2016

Volcanic ash is a spectacular companion of volcanic activity that carries valuable information about subsurface processes. It also poses a range of severe hazards to public health, infrastructure, aviation, and agriculture, and it plays a significant role in biogeochemical cycles.

Scientists can examine ash particles from volcanic eruptions for clues to the history of their journey from the lithosphere (Earth's crust and upper mantle) to the atmosphere, hydrosphere, and biosphere (Figure 1). These tephra particles are less than 2 millimeters in diameter, and they record most of their history on or near their surfaces. Understanding the physicochemical properties of the ash particle surfaces is essential to deciphering the underlying volcanic and atmospheric processes and to predicting the widespread effects and hazards posed by these small particles.

Leading volcanic ash research groups gathered in September 2016 for a workshop at the University of Hamburg organized by the university's Institute of Geophysics and Institute for Geology. Thirty experts, including 12 early-career scientists, discussed the life cycle, hazards, and environmental effects of volcanic ash to integrate the developments in this field and foster collaborations. Specialists in geochemistry, geology, volcanology, and atmospheric sciences brought experimental, observational, and modeling perspectives to the workshop. Discussions focused on the pros and cons of existing practices in fundamental and applied research, and participants elaborated on future best practices.

> Gaps remain in our understanding of the volcanic and atmospheric life cycle of ash.

For example, ash surface generation and alteration through processes occurring during eruption (e.g., fragmentation and recycling) and after eruption (e.g., aggregation, cloud chemistry, and microphysics) are not yet quantitatively well understood and thus are not fully implemented in the models. Therefore, gaps remain in our understanding of the volcanic and atmospheric life cycle of the ash and how this life cycle is linked to the surface properties and environmental effects of the ash.

This limitation hinders reliable estimation of far-field airborne ash concentrations, a central factor in assessing the ash hazard for aviation. Workshop participants agreed that tackling these issues would require combining recent experimental and observational data on rate parameters of physicochemical processes and ash surface characteristics with advanced atmospheric models that incorporate aerosol chemistry, microphysics, and interactions among aerosols, clouds, and solar radiation.

The workshop emphasized that addressing the challenges in volcanic ash surface characterization requires close collaboration of experts in laboratory experiments, in situ measurements, space-based observations, and numerical modeling to codevelop reliable assessment tools for fundamental research and operational purposes. Workshop participants made several suggestions on how to establish such an alliance:

- initiate a collaborative network with two working groups on the physical and geochemical life cycles of volcanic ash
- develop an integrated modeling, observational, and experimental data compilation on mid- to large-intensity eruptions to assist with benchmark modeling
- organize a joint session of the European Geosciences Union (EGU) and AGU to foster the coupling of modeling and experimental research on volcanic ash

These actions will be linked to existing activities within the International Association of Volcanology and Chemistry of the Earth's Interior, EGU, and AGU.

The workshop was supported by the Cluster of Excellence CliSAP (DFG EXE 177). For more details, visit the workshop's website (http://bit.ly/VA3workshop).

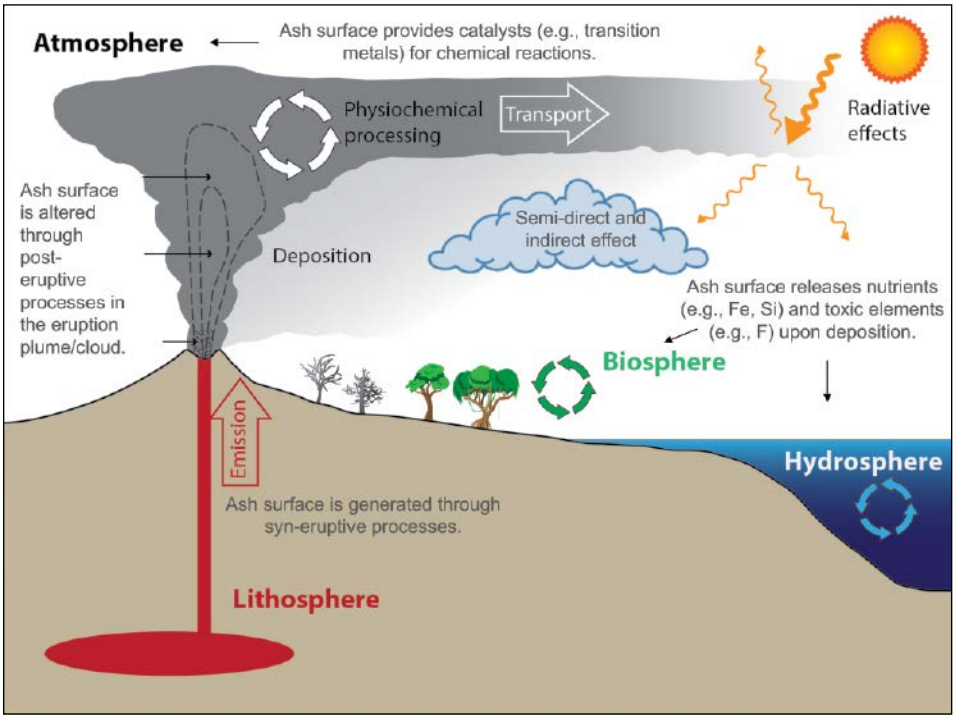


Fig. 1. Particle surface properties strongly affect the life cycle and effects of volcanic ash particles within the Earth system.

By **Gholam Ali Hoshyaripour** (email: gholamali.hoshyaripour@uni-hamburg.de), Institute of Geophysics, Research Centre for Earth System Research and Sustainability, Universität Hamburg, Hamburg, Germany

Proposed Federal Budget Heightens Hurricane Risk

Winds of more than 100 miles per hour stream through palm trees and kick up sand, creating whiteout conditions as Hurricane Wilma makes landfall at Miami Beach, Fla., in 2005. The storm was the most intense tropical cyclone ever recorded in the Atlantic basin. Credit: Mike Theiss/National Geographic/Getty Images

Summer, a season of warm temperatures and outdoor activities, is in full swing. So too is the Atlantic hurricane season, when the safety, security, and economies of many coastal communities are threatened by severe weather.

Thanks to scientists working at federal science agencies and offices—the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Society (USGS), NASA, and others—we are increasingly able to accurately predict and track severe storms, as well as deliver advance warning to communities in a storm's path. It is imperative that we continue to provide these agencies with the resources needed to ensure that vulnerable coastal communities remain secure, protected, and responsive to severe weather events.

Sadly, the Trump administration is failing in prioritizing important hurricane research and prediction efforts. This lack of emphasis will likely increase our nation's risk of hurricane damage in the years to come.

Scientists Provide a Watchful Eye

The impacts of hurricanes can be devastating. Since 1980, the United States has sustained 208 weather and climate disasters in which overall damages and costs reached or exceeded $1 billion. Hurricane Katrina alone, the costliest natural disaster in the history of the United States, resulted in more than $150 billion in losses and 1800 deaths (see http://bit.ly/NOAAdisasterstats). Some 123.3 million people—nearly 39% of the total U.S. population—and more than $10 trillion in coastal property are located less than 1.2 meters above local high-tide levels, making these communities particularly vulnerable to flooding, erosion, and destruction of critical infrastructure.

Scientists working for federal agencies and organizations supported through federal grants work collaboratively to provide timely, accurate research and resources to help protect communities and build resilience to extreme weather, including hurricanes. NOAA's National Weather Service plays a vital role in predicting, mitigating, and monitoring hurricanes and warning vulnerable communities through the National Hurricane Center. NOAA scientists also collaborate with USGS and regional weather offices to create detailed forecasts of wave-induced water levels. NASA Earth Science produces data that forecasters can use to improve their ability to predict and forecast hurricanes and other natural hazards. Research supported by the National Science Foundation (NSF) Geosciences Directorate enables preparation for, mitigation of, and adaptation to the effects of these and other disruptive natural events.

Thin Budgets for Hurricane Research and Preparedness

By failing to provide adequate resources for key programs in these agencies, the Trump administration's proposed budget for fiscal year 2018 (FY18) fails to prioritize the work these agencies conduct in protecting the U.S. population and overlooks the very real return on investment that these agencies provide.

For example, the FY18 budget calls for NOAA to zero out more than $250 million in grants and programs that support coastal and marine management, research, and education, cuts that would significantly damage our ability to prepare for and forecast hurricanes and tropical cyclones. Many of the programs funded by NASA Earth Science—including the innovative Global Hawk unmanned aerial vehicles that fly into the eyes of cyclones, which have helped push the boundaries of hurricane research and monitoring—are to be cut by $121 million, or 6.3%.

Lack of Funding Increases Risk

As history has shown us time and time again, the threats that hurricanes pose to the health and welfare of coastal communities are real, potentially devastating, and long lasting. The administration and Congress must act decisively to fund the life-saving work of scientists at federal agencies like NOAA, NSF, USGS, and NASA at levels that are strengthened, not diminished.

The health, welfare, and livelihood of millions depend upon our elected officials' continued and robust support for these critical agencies. Without this support, we effectively increase our risk of damage, destruction, and even death from hurricanes.

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

Central America and the Caribbean: The Pulse of Climate Change

Hurricane Matthew brought high winds and heavy rain to the Caribbean in October 2016. Such intense storms are part of the climate change equation in the Mesoamerican and Caribbean (MAC) region, where island and coastal nations are actively seeking to mitigate and adapt to the varied effects of changes in sea surface temperatures, rainfall patterns, and other environmental factors. Credit: NASA/NOAA GOES Project

Identified by some as a "hot spot" for its sensitivity to global climate change [*Giorgi,* 2006], the Gulf of Mexico and Caribbean region is uniquely positioned to serve as the world's climate change pulse. Events that play out here will be not only a warning signal of broader climate change to come but also a harbinger of social and economic responses to these changes.

The region could also be an exemplar of innovative responses to environmental change. This example, in turn, could function as a blueprint for similar mitigation and adaptation efforts elsewhere in the world.

A Region of Convergence

The Mesoamerican and Caribbean (MAC) region encompasses the coastal and island states abutting the western Atlantic Ocean, Caribbean Sea, Gulf of Mexico, eastern tropical Pacific adjacent to Central America, and northwestern South America. Multiple dynamic atmospheric and oceanic processes converge in the MAC region [*Gamble and Curtis,* 2008; *Zhang,* 2013], making it particularly sensitive to the effects of climate. The global trend of increasing sea surface temperatures, for example, may work with or against natural modes of climate variability in the region, highlighting the physical system's complexity and nonlinear nature.

The region could also be an exemplar of innovative responses to environmental change.

Hand in hand with these physical changes are the hazards they pose to people. More than 120 million people live in the area. Despite steady, albeit inequitable, economic growth during recent decades, the region has become increasingly exposed to climate-related pressures that threaten its social and economic well-being.

The region's extensive coastlines, relatively low capacity to adapt to changing conditions, scarce natural resources, and limited infrastructure further intensify the perception of risk [*Lane et al.,* 2013]. These factors also promote a sense of urgency toward action.

The Regional Climate Pulse

The convergence of atmospheric and oceanic interactions characteristic of the MAC region has been linked to several recent shifts in regional climate conditions.

From 1982 to 2012, the region experienced an accelerated seasonal warming trend in sea surface temperatures, ranging from 0.161°C to 0.209°C per decade. The rapidly increasing sea surface temperatures and associated decreases in total rainfall of the MAC region may be the most notable of such changes across the tropics and are consistent with climate predictions [*Taylor et al.,* 2013].

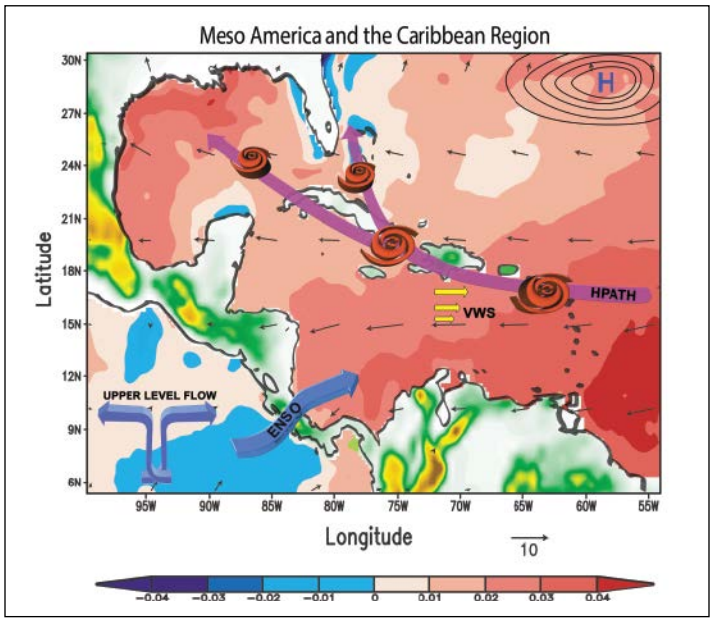
These increases accompanied an intensification of the Atlantic Warm Pool during the rainy season (August–November). Such intensification may accentuate tropical storm activity [*Glenn et al.,* 2015]. Excessive additional warming may lead to localized high-pressure ridges, which could produce heat waves, with potentially disastrous social and economic consequences.

Broader climate patterns also influence the region. Analysis of recent data suggests that a much drier than usual 2015 was caused by a combination of factors: the presence of a strong El Niño–Southern Oscillation (ENSO), intense Saharan dust episodes [*Angeles et al.,* 2010], and a positive North Atlantic Oscillation [*Angeles et al.,* 2007]. The net result was a historic drought, with sizable agricultural losses and water rationing in most of the large cities across the Caribbean.

The Local Pulse

The convergence of region-wide atmospheric and oceanic processes can also have a dramatic impact on local systems.

Since 2003, for example, the hypersaline Lake Enriquillo in the Dominican Republic has experienced a 50% increase in surface area, attributable in large part to greatly increased



Pertinent drivers for climate and weather in the MAC region. The landlocked shaded region represents topography, ocean shading represents sea surface temperature (SST) trends over the past 30 years (in °C per year), and the thin black arrows represent near-surface wind speeds and directions. "H" represents the North Atlantic High Pressure center, yellow arrows represent vertical wind shear (VWS), and the blue arrow represents the ENSO teleconnection in the MAC. The blue double arrows represent upper level flow in the Pacific Ocean, and the bifurcating pink arrows represent likely hurricane paths (HPATHs). The graphics in this figure are for visual purposes only and are not drawn to scale, except SSTs. Modified from Gamble and Curtis *[2008].*

mists and cloud cover. This moisture has reduced evaporation from the lakes and caused upstream cloud forests—forests that are continually blanketed by low-lying cloud cover—to shed excess water, which trickles down to the lake. Both effects are triggered by the warming Caribbean Sea [*Comarazamy et al.*, 2015].

The expansion of Lake Enriquillo, the largest lake and lowest location in the Caribbean, has inundated roadways, arable land, cattle pastures, and natural habitats and caused extensive property loss. On the other side of the border in Haiti, Lake Azuéi has experienced a 22% increase in surface area; community planners look to Enriquillo to anticipate what might happen during their resulting floods.

Sensitive Coastal Ecosystems

Climate change in the MAC region also affects sensitive coastal ecosystems, providing additional cases of local vulnerabilities.

Locally warming waters, combined with human exploitation via overfishing and urbanization of sensitive coastlines, have contributed to a significant decline in coral reefs during the past 30 years in the Caribbean. Runoff from rainstorms has helped to cause excessive annual sediment loads, resulting in harmful algal blooms [*Gardner et al.*, 2003], whereas sea level rise has reduced usable coastlines, affecting natural habitats and local economies [*Simpson et al.*, 2010].

The possible impact of climatic stresses on public health, such as their role in recent virus outbreaks, is largely unknown but could also contribute to a sense of vulnerability in the region.

Information at the Grassroots Level

The countries of the MAC region are acutely aware of the risks they face from climate change. They are beginning to shift the focus of regional efforts from education and building awareness of the threat to effective action to reduce vulnerabilities and adapt to new conditions.

> Broader local or indigenous knowledge networks could be used to enhance the utility of seasonal forecasts.

At the same time, an effective approach for attaining ecosystem sustainability while maintaining economic growth in the face of climate change [*Tompkins*, 2005] must take advantage of the region's rich tradition of local networks and indigenous knowledge. New joint initiatives by national and international organizations are focusing on obtaining usable environmental information and educating local communities in the use of this information for midrange and long-term planning at the grassroots level.

Such information can also be used to develop methods for quantifying the varied aspects of regional warming while taking into account local energy and water demands and food production needs.

A Research Agenda

Research to further inform mitigation and adaptation efforts could include a better understanding of the following:

- the interaction and synergy of regional processes, such as oceanic variability, atmospheric dust dispersal, sea level rise, and changes in land use, in the face of a globally changing climate;
- the impact of extreme weather events, such as tropical storms, storm surges, and extreme heat, on local infrastructure and on the security and health of community residents;
- socioeconomic interconnections and flexible economies as mitigation alternatives so that despite national borders, resources are strategically used to lessen regional environmental burdens (e.g., during droughts, shift of food production to western MAC countries while maximizing tourism in eastern Caribbean islands);
- how to foster local technological innovation under changing climate conditions, for example, to develop efficient energy systems, encourage crops that reduce water usage, and improve vector-borne disease tracking; and
- how to scale knowledge and experience gained at the local level to benefit global tropical communities.

We recommend that researchers and countries in the MAC region adopt programs that support the above agenda. We further recommend that MAC countries work together to build a program of study that will lead to mitigation of impacts of and adaptation to climate change.

Specific on-the-ground efforts could take many forms. For example, local communities could be linked with climate informatics to promote intense interaction between climate scientists, information brokers, and local users. Broader local or indigenous knowledge networks could be used to enhance the utility of seasonal forecasts. Scientists could be linked with community planners to improve infrastructure planning and emergency response strategies across agriculture, energy planning, and water management sectors.

An Example for the World

With such a research and mitigation program, the MAC region could serve as a template for studies of climate effects and their implications across society, demonstrating that well-designed, collective policies can have a positive impact on regional resilience.

A farmer looks out on his now submerged farmland, which became inundated in 2013 as the Dominican Republic's Lake Enriquillo expanded. The hypersaline lake is the largest lake in the Caribbean; it has grown by 50% in surface area since 2003. Credit: Mimi Sheller

We hope that such a program would help to shift the focus from climate change impacts to sustainability and resiliency.

At the same time, the relatively small size of most countries in the region and their diverse cultures, politics, and institutions allow for experimentation and implementation of different mitigation models and adaptation approaches. The rest of the world could learn from these examples.

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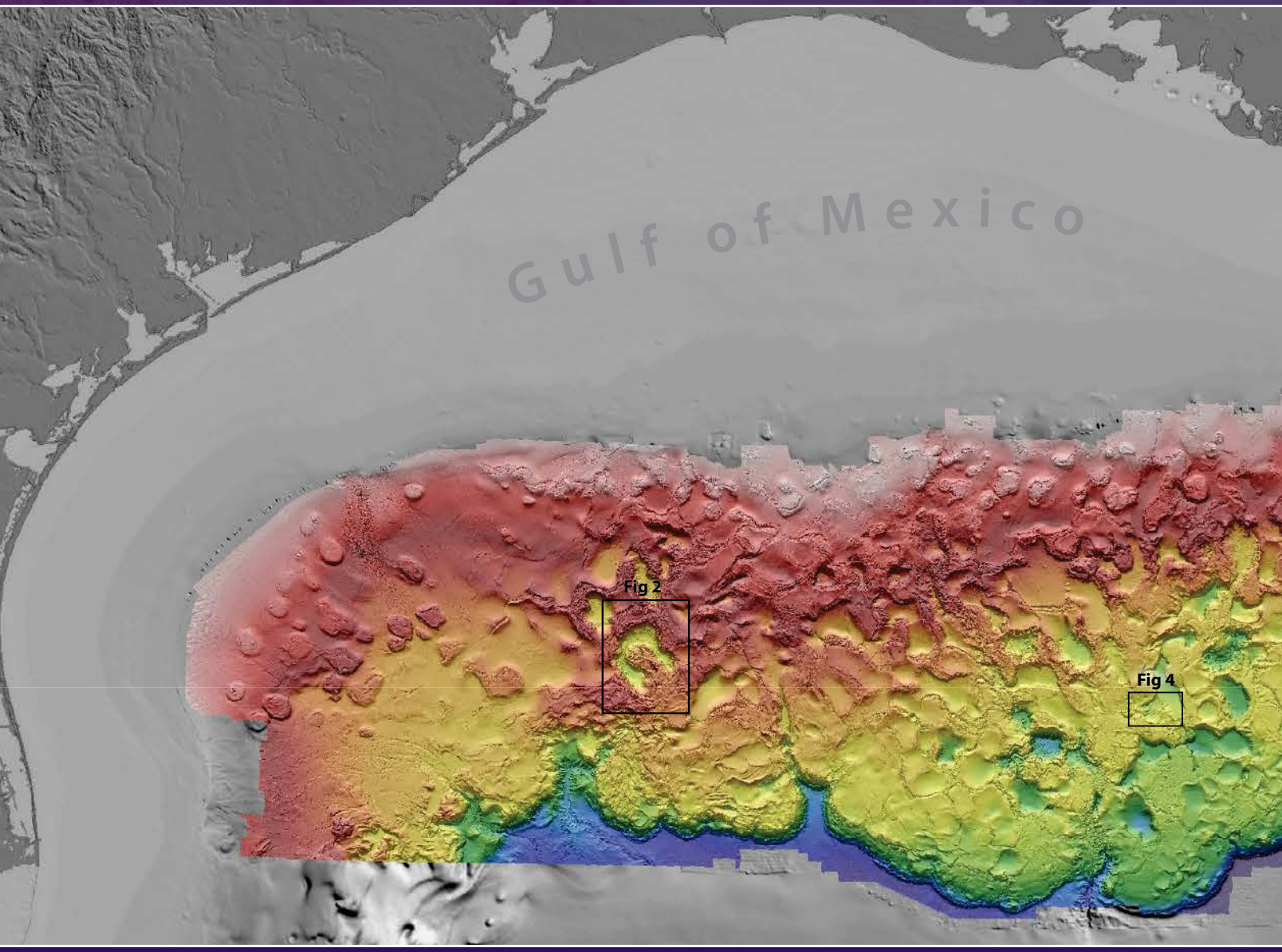
A 1.4-BILLION-PIXEL MAP OF THE GULF OF MEXICO SEAFLOOR

By K. V. Kramer and W. W. Shedd

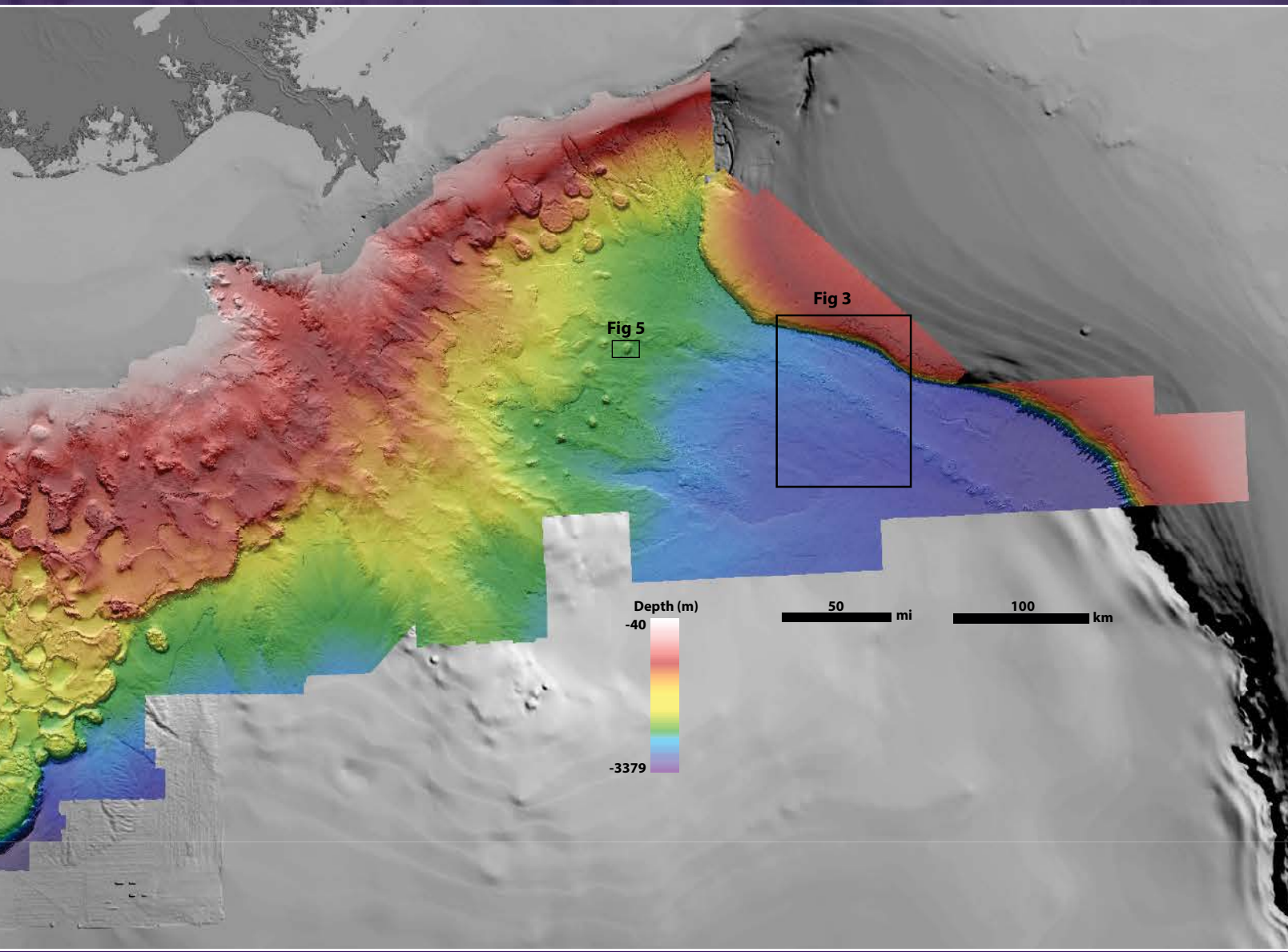


The geology of the Gulf of Mexico (GOM) is dynamic, driven not by plate tectonics but by the movement of subsurface bodies of salt. Salt deposits, a remnant of an ocean that existed some 200 million years ago, behave in a certain way when overlain by heavy sediments. They compact, deform, squeeze into cracks, and balloon into overlying material.

Such salt tectonics continue to sculpt the geologic strata and seafloor in the GOM like in few other places on Earth. Because of this salt tectonism and a steady supply of sediment delivered to the basin by rivers, the GOM's seafloor is a terrain continually in flux. Bathymetry is ripe with active faults and escarpments, slump blocks and slides, canyons and channels, sediment waves, pockmarks and mud volcanoes, and other natural oil and gas seeps.

A new regional seafloor data set created by the U.S. Department of the Interior's Bureau of Ocean Energy Management (BOEM) reveals that dynamic environment with stunning new clarity. The data include detailed seismic surveys originally shot by 15 different companies

Fig. 1. Northern Gulf of Mexico deepwater bathymetry grid created from 3-D seismic surveys. The grid defines water depth with 1.4 billion 12- × 12-meter cells and is available in feet and meters. BOEM grid coverage is limited to the area defined by rainbow colors. Shaded relief is vertically exaggerated by a factor of 5. Locations of Figures 2–5 are annotated. Credit: BOEM



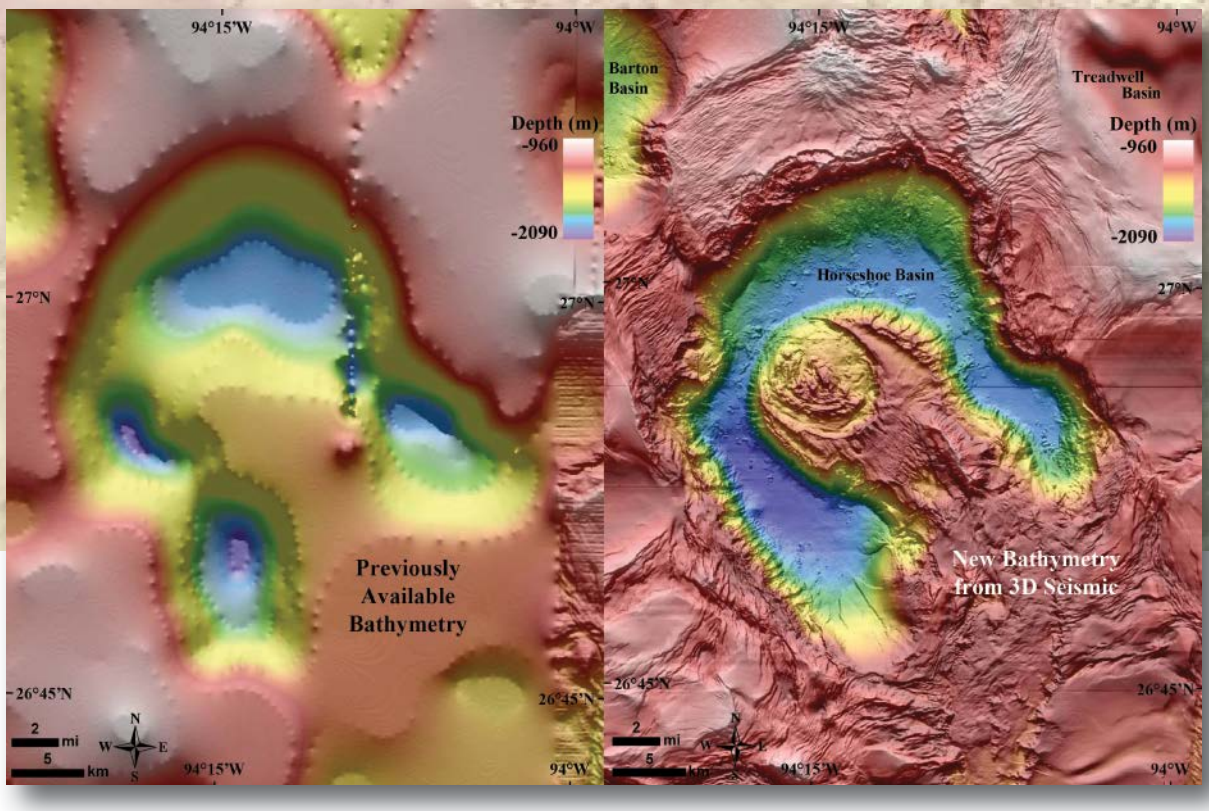


Fig. 2. Horseshoe Basin in the western Gulf of Mexico, as compared using (left) the historic NOAA bathymetry map and (right) BOEM's new map. The basin contains a salt dome at its center and is flanked by salt sheets. Movement of the salt is evident from the network of faults and rifts expressed on the seafloor around the basin, as well as from the sediment debris flows seen falling down the slopes of the basin and onto its floor. Credit: BOEM

involved in the oil and gas industry. BOEM gained permission to release the relevant proprietary data publicly in a freely downloadable aggregate map of the seafloor (http://bit.ly/BOEMGoMmap).

With a resolution as fine as 149 square meters per pixel, equal to about the areal footprint of an American single-family house, BOEM's bathymetry map is at least 16 times higher in resolution than the map historically used for the northern GOM. Most of those house-sized pixels in the new map are 1, 2, and 3 kilometers under the water, and the product contains 1.4 billion of them, making this a gigapixel map.

How Did the Salt Get There?

Scientists hypothesize that the salt precipitated out of hypersaline seawater when Africa and South America pulled away from North America during the Triassic and Jurassic, some 200 million years ago. The GOM was initially an enclosed, restricted basin into which seawater infiltrated and then evaporated in an arid climate, causing the hypersalinity (similar to what happened in the Great Salt Lake in Utah and the Dead Sea between Israel and Jordan).

Salt filled the basin to depths of thousands of meters until it was opened to the ancestral Atlantic Ocean and consequently regained open marine circulation and normal salinities. As geologic time progressed, river deltas and marine microfossils deposited thousands more meters of sediments into the basin, atop the thick layer of salt.

The salt, subjected to the immense pressure and heat of being buried kilometers deep, deformed like putty over time, oozing upward toward the seafloor. The moving salt fractured and faulted the overlying brittle sediments, in turn creating natural pathways for deep oil and gas to seep upward through the cracks and form reservoirs within shallower geologic layers [*Buffler and Sawyer,* 1985; *Hudec et al.,* 2013].

Out with the Old? Not So Fast!

The most popular bathymetry map of the northern Gulf of Mexico has been the version generated in the 1990s by the National Oceanic and Atmospheric Administration (NOAA), the National Geophysical Data Center (NGDC), and Texas A&M University's Gulf of Mexico Coastal Ocean

Our 3-D seismic database of confidential data covers 350,000 square kilometers of the Gulf of Mexico.

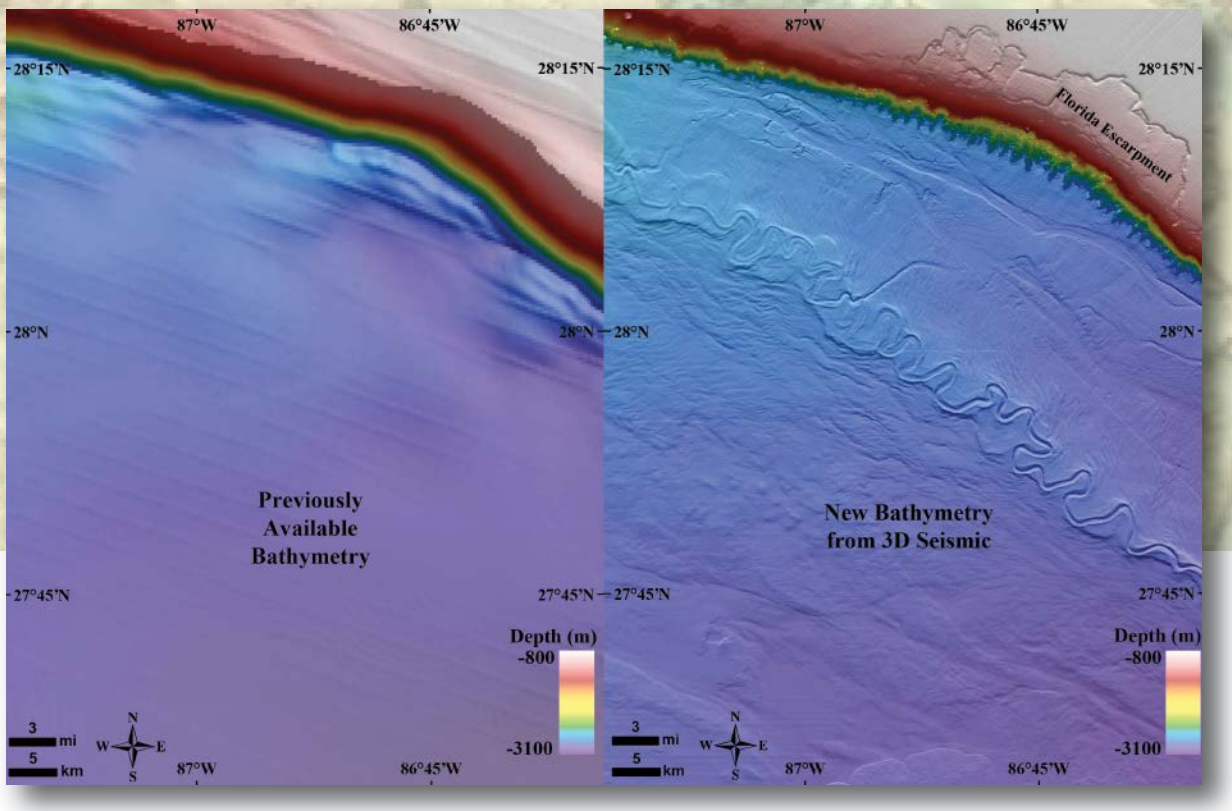


*Fig. 3. BOEM's new map extends by hundreds of kilometers the visualization of Joshua Channel on the eastern Gulf of Mexico abyssal plain [*Posamentier, *2003] compared with older data. The channel is visible on the seafloor for 280 kilometers, far beyond the bounds of this image, and an additional 240 kilometers is buried beneath younger sediment systems and muddy drape. BOEM research has established updip linkage with the ancestral Pearl River in Louisiana [*Frazier, *1974;* Mobley, *2005], and similar-scale channel–levee complexes have been observed in the Amazon Fan [*Lopez, *2001]. Credit: BOEM*

Observing System (GCOOS). The organizations compiled it using data from various multibeam sonar surveys and 2-D seismic lines spaced kilometers apart, providing a resolution of up to 2500 square meters per pixel. This is excellent resolution, geophysically speaking, and for the past 2 decades the map has been a respected and popular regional data set within science, academia, and the oil and gas industry.

BOEM's new map, derived exclusively from 3-D seismic data, doesn't cover as large an area as the NOAA/NGDC/GCOOS map, but its enhanced resolution and consistent pixel size reveal undiscovered and previously poorly resolved geologic features over the continental slope, salt minibasin province, abyssal plain, Mississippi Fan, and the Florida Shelf and Escarpment. However, because of the new map's smaller coverage, the historic map will continue to be very useful.

BOEM's Seismic Database

BOEM researchers constructed the map using BOEM's confidential database of 3-D seismic surveys, each of which was originally shot by the oil and gas industry in its search for hydrocarbons. As the bureau responsible for issuing geophysical survey permits in offshore federal waters, the U.S. Code of Federal Regulations reserves the right of BOEM to request a copy of each survey after it has been processed and cleaned up to meet specific quality standards.

After receiving a survey from a geophysical contractor or oil company, BOEM scientists use the data to assist with other important regulatory duties, such as assessing the geology for potential and discovered reservoirs of oil and gas. As of 2017, this 3-D seismic database of confidential data covers 350,000 square kilometers of the Gulf of Mexico, an area larger than the state of New Mexico. The oldest surveys in this database date back to the 1980s.

Deepwater Horizon and the First Integrated Map

In an ongoing effort since 1998, BOEM has used that database to map the seafloor across hundreds of surveys with the goal of identifying potential hard-ground substrates at naturally occurring oil and gas seeps suitable for benthic communities of corals and chemosynthetic organisms (e.g., mussels, clams, and tubeworms). These organisms consume the hydrocarbons and hydrogen sulfide released from those seeps.

When the disastrous Deepwater Horizon oil spill occurred in 2010, marine biologists of NOAA's Natural Resource Damage Assessment division needed a detailed map of the seafloor surrounding the incident to model how many of those benthic communities may have been affected. NOAA biologists, aware of BOEM's expansive seafloor database, requested that its geoscientists create a semiregional map that NOAA could use to model the area affected by the oil plume.

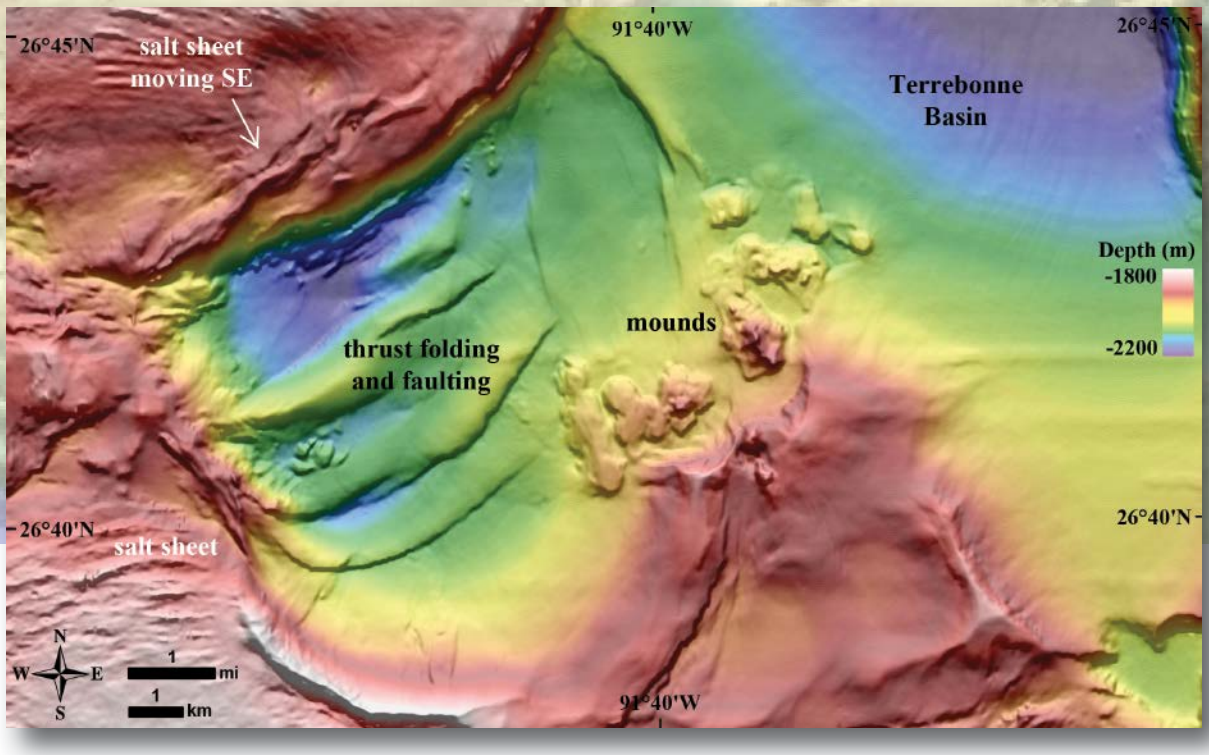


*Fig. 4. Gas expulsion mounds with adjacent thrust folding and faulting caused by lateral salt migration in the southern Terrebonne Basin in the central Gulf of Mexico. The image illustrates some of the features formed by the dynamic processes shaping the Gulf, specifically salt tectonics and natural hydrocarbon seepage. Thrust faulting and folding are due to southeast verging lateral movement of salt. Movement of salt is what gives the Gulf of Mexico seafloor its wrinkled nature, also creating faults and fracture networks that provide pathways for oil and gas seeps. These particular expulsion mounds were formed as a result of basin compaction and compression, resulting in upward gas migration [*McConnell and Kendall, *2002]. Credit: BOEM*

The effort required the researchers to devise a method for combining their multiple overlapping seafloor maps of the spill region, made using different 3-D seismic surveys, into a single gridded surface. Through that, the idea for an even broader gigapixel map was born.

Creating a Gigapixel Grid

Having developed the method and delivered the map to the biologists, the geoscientists realized the potential available to them: They could combine the rest of their seafloor maps to cover most of the northern GOM under deep water.

BOEM geoscientists used 3-D time-migrated surveys (in which depth is presented in milliseconds traveled by induced or passive seismics, not in feet or meters) to create the original grid. The researchers then assigned cells in the grid to depths using an algorithm developed by *Advocate and Hood* [1993]. They then compared the resulting depth grid with more than 300 well penetrations across the GOM to determine the time-depth conversion error, which averaged 1.3% of water depth.

The highest average error, 5%, occurs in water depths shallower than 150 meters because of the nature of conventional seismic acquisition in shallow water and the high variability of temperature and salinity in shallow water, which affect the velocity of sound in water. BOEM scientists decided that the seismic data acquired on the GOM's shallow shelf often contain too much noise for the seafloor interpreter to accurately determine where the water ends and the sediment begins. This meant that BOEM's map could not include certain areas of the shelf, making it smaller than the historic NOAA map, which does cover the shelf.

Within the depth range of 500 to 3300 meters (where the largest part of the grid exists), average error was calculated to be less than 0.5% of water depth. This low error meant that data from these depths would reveal the finest-resolution regional deepwater bathymetry ever created.

Making an Aggregate Map

The geoscientists began with more than 200 individual seafloor maps created from 3-D surveys dating from the late 1980s to the 2010s. In the U.S. portion of the Gulf of Mexico, few areas are covered by only a single survey

For additional high-resolution images from BOEM's gigapixel map, view the online version of this article at http://bit.ly/Eos-BOEMmap.

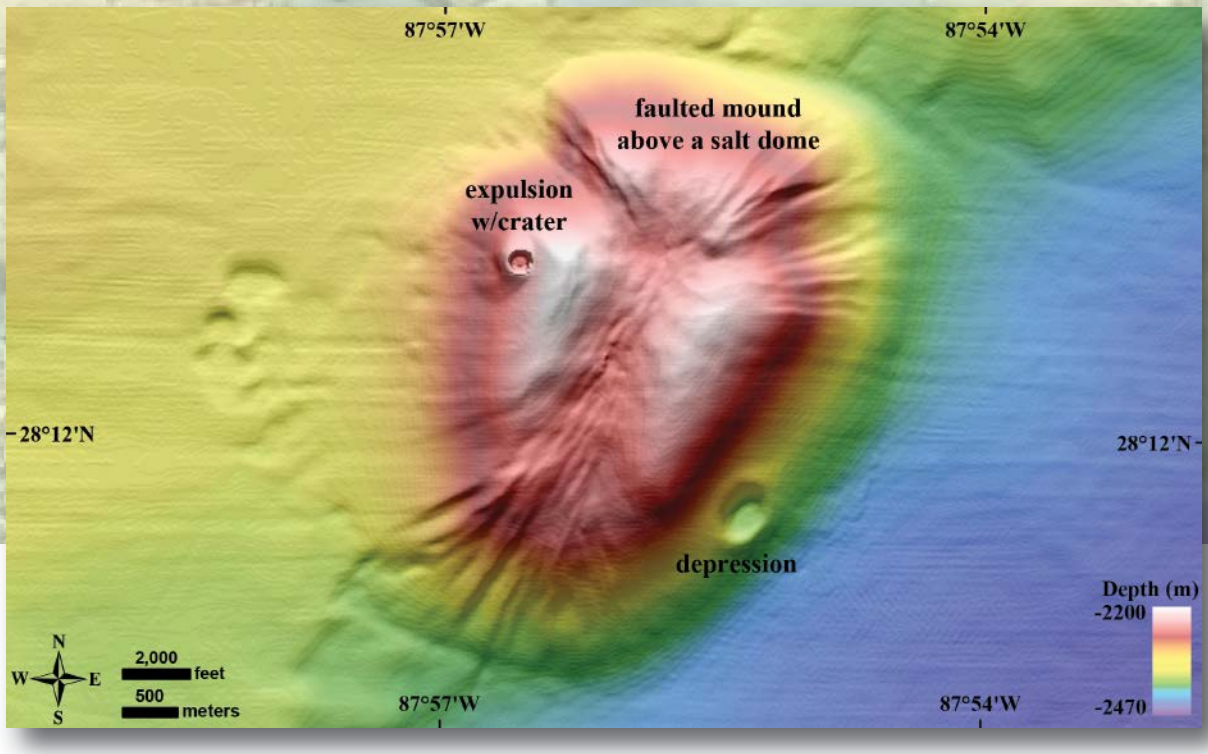


Fig. 5. A salt dome has uplifted shallow sediments in the eastern Gulf of Mexico's abyssal plain. Expulsion and depression features suggest ongoing natural fluid and/or gas seepage. As salt domes move shallower relative to the subsiding basins of sediment around them, sediments atop the domes are uplifted and form seafloor mounds. Over this dome, the movement created a network of extensional faults dividing the mound into three wedges. Faults can also provide pathways for fluid and/or gas migration, as indicated here by the circular depression, or pockmark, on the southeastern face of the mound, and an expulsion feature with a crater on the northwestern side. Credit: BOEM

(some are covered by four or more), and the interpreters needed to compare one with another to determine which was made using the best data. They created a mosaic of more than 100 of their highest-quality bathymetry maps, spanning water depths of 40 to 3379 meters and interpreted on seismic surveys originally shot by 15 different geophysical companies.

Even though BOEM maintains copies of all the seismic data, the original companies retain legal ownership for a period of 25 years. Mergers and acquisitions through the years meant that instead of being required to ask 15 companies for permission to publish, BOEM needed to request it from only seven: CGG Services (U.S.), Inc.; ExxonMobil Corporation; Petroleum Geo-Services (PGS); Seitel, Inc.; Spectrum USA; TGS-NOPEC Geophysical Company; and WesternGeco, LLC.

Obtaining permission from these seven companies took months, much longer than anticipated, but BOEM eventually received all necessary permissions and began the publication process. The new high-resolution grid is downloadable from the BOEM website. The site also offers GIS layers that classify more than 34,000 seafloor features such as pockmarks, channels, hard grounds, mud volcanoes, natural seeps, and others (see http://bit.ly/BOMmapGIS).

Figures 2–5 showcase the detail of BOEM's GOM gigapixel map, the payoff for 19 years of mapping efforts.

Acknowledgments

We thank CGG Services (U.S.), Inc.; ExxonMobil Corporation; PGS; Seitel, Inc.; Spectrum USA; TGS-NOPEC Geophysical Company; and WesternGeco, LLC for granting us permission to publish their data.

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UNDERSTANDING THE CAUSES AND EFFECTS OF RAPID WARMING IN THE ARCTIC

By Manfred Wendisch, Marlen Brückner, John P. Burrows, Susanne Crewell, Klaus Dethloff, Kerstin Ebell, Christof Lüpkes, Andreas Macke, Justus Notholt, Johannes Quaas, Annette Rinke, and Ina Tegen

For meteorologists and climate scientists, the Arctic is one of the most interesting regions on Earth. Climate changes there currently take place at an unprecedented pace and intensity, and the reported dramatic changes have not been completely anticipated. The Arctic is warming more rapidly than the rest of the world, a process referred to as Arctic amplification.

Over the past 25 years, scientists have observed a remarkable increase in near-surface air temperatures, which exceeds global warming by a factor of 2 to 3 (Figure 1). To find out why

Frozen and snow-covered meltwater ponds appear more frequently on the diminishing Arctic sea ice. A new research consortium is searching for the reasons behind unusually rapid warming in the Arctic, and they are working to improve models that simulate this effect. Credit: Stefan Hendricks, Helmholtz Center for Polar and Marine Research, Alfred Wegener Institute

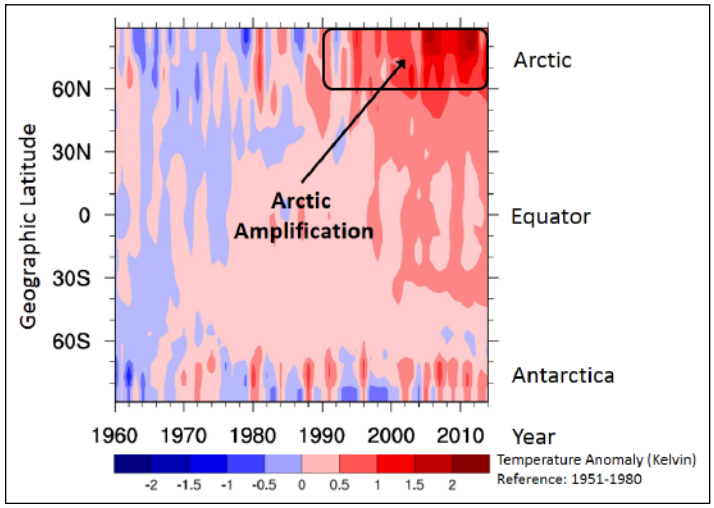

Fig. 1. Mean temperatures (by location and year, measured in kelvins), shown as variations from 1951–1980 mean temperatures. The increase in red areas in more recent years indicates global warming. The area inside the black box shows how this warming is amplified in the Arctic, particularly within the past 25 years. Data are provided by the NASA Goddard Institute for Space Studies.

this is happening, in January 2016 the German Research Foundation (Deutsche Forschungsgemeinschaft, or DFG) launched a new Transregional Collaborative Research Center (TR 172) called Arctic Amplification: Climate Relevant Atmospheric and Surface Processes, and Feedback Mechanisms.

This effort, known by the abbreviation (AC)³ (see http://www.ac3-tr.de), has as its overarching scientific objectives the identification, investigation, and evaluation of key processes involved in Arctic amplification; improving understanding of the major feedback mechanisms; and quantifying the relative importance of these mechanisms.

Our current understanding of the rapid changes in Arctic climate implies that atmospheric processes likely dominate the short-term warming mechanisms involved. Thus, research in (AC)³ has an atmospheric focus during Phase I, which was approved to obtain funding by DFG from January 2016 to December 2019. In Phases II and III (planned for January 2020 to December 2027) the researchers of TR 172 plan to investigate interactions between the oceanic and atmospheric components more thoroughly.

Recent Arctic Climate Changes

As a consequence of the recent drastic warming in the Arctic, other climate variables will also be affected dramatically [*Serreze and Barry*, 2011]. For example, routine satellite measurements have documented an enormous decline in the extent of Arctic sea ice that is even more than models predicted [*Stroeve et al.*, 2012; *Jeffries et al.*, 2013]. The past 9 years of satellite data have revealed the six smallest annual minima of sea ice extent since appropriate and reliable satellite observations began in 1979. The recent decline is larger than any observed in more than 1400 years [*Kinnard et al.*, 2011]. Climate models predict that summer Arctic sea ice may completely vanish by the end of the 21st century or earlier.

Not only is the Arctic sea ice extent shrinking, but so is its thickness [*Lindsay and Schweiger*, 2015]. The reduced summer sea ice in the Arctic results in larger areas of thinner first-year ice forming during subsequent winters. The average thinning of Arctic sea ice causes a higher transmission of solar radiation into the ocean and enhanced heat energy fluxes from the ocean to the atmosphere. It also accelerates transpolar ice drift, the migration of ice from Russia's Siberian coast across the Arctic basin, resulting in an increased export of sea ice into the North Atlantic Ocean off the eastern coast of Greenland. The thinner sea ice is also more vulnerable to storms like the major Arctic cyclone in summer 2012.

The extent of snow cover in both Eurasia and North America reached a record low in June 2012 [*Shi et al.*, 2013]. In contrast, snow cover over Eurasia has tended to increase in autumn in recent years, enhancing the strength of the Siberian high-pressure system during winter. This change in snow cover strongly affected the surface albedo of Arctic land areas, the length of the growing season, the timing and dynamics of spring river runoff, the thawing of permafrost, and the wildlife population.

A continued amplified warming in the Arctic is also expected to decrease the temperature gradient between the Arctic and midlatitudes, which is anticipated to influence the meandering of the polar jet stream and wind patterns [*Walsh*, 2014]. Consequently, this might increase the probability of extreme weather events in the midlatitudes, including colder winters and summer heat waves.

Models Have Room for Improvement

Unfortunately, coupled regional and global climate models do not yet unambiguously reproduce the recent drastic changes in Arctic climate parameters. For example, they systematically underestimate the decline of observed sea ice extent. These significant differences between models and observations imply that climate models do not adequately describe the underlying physical processes and feedback mechanisms in the Arctic. As a result, projections from these models are also likely to be inadequate and not yet fit for use.

As human influence on climate increases, more significant and potentially drastic climate changes in the Arctic are likely, although the accuracy of current projections is uncertain. These changes will have perceptible socioeconomic and ecological consequences for marine transportation, fisheries, ecosystems and ecosystem services, and tourism, as well as for oil, gas, and mineral exploration. It is thus a matter of urgency to qualitatively and quantitatively improve our knowledge of the Arctic climate system and the accuracy of its prediction.

How the Arctic Is Unusual

The Arctic climate exhibits many unique features. For example, the Sun does not rise high over the horizon, and seasonal variations in daylight are extreme (polar day and polar night). Bright ice and snow cover provide a highly

reflective surface, low-level mixed-phase (water and ice) clouds are quite frequent, and the prevailing atmospheric boundary layer is especially shallow in the Arctic. These special characteristics profoundly influence physical and biogeochemical processes and atmospheric composition, as well as meteorological and surface parameters in the Arctic.

Several feedback mechanisms are particularly effective in the Arctic, and these generally increase the sensitivity of the Arctic climate system (Figure 2). The most famous and already well studied feedback mechanism is the surface albedo effect, which reinforces warming over highly reflecting surfaces worldwide but is amplified even more in the Arctic. The increased near-surface air temperature causes a melting of the sea ice and snow cover. This reduced coverage, in turn, exposes less reflective surfaces, including open seawater, bare ground, and vegetated land. The less reflective surfaces absorb more solar radiation, which warms the land surface and the upper oceanic mixing layer, enhancing energy fluxes from the surface to the atmosphere, which increases the near-surface air temperature even further.

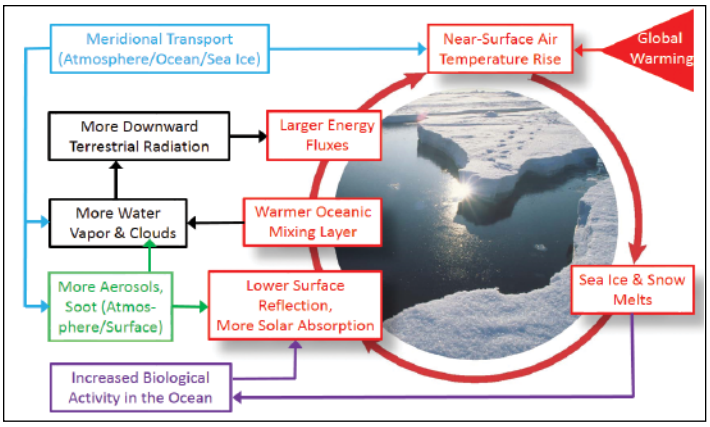

Fig. 2. Examples of feedback processes that amplify an initial near-surface air temperature rise caused by global warming. Red, surface albedo effect; blue, changes in north–south atmospheric and oceanic transport; black, effects of water vapor and clouds; green, effects of aerosol particles; purple, increased oceanic biological activity.

The surface albedo effect amplifies global warming in the Arctic, and other changes might intensify this warming even further. Such changes include meridional (north–south or vice versa) atmospheric and oceanic mass transport processes and related modifications of vertical turbulent exchange of energy between the ocean and the atmosphere. A warmer ocean surface could increase the atmospheric water vapor amount and enhance the occurrence of clouds in the atmosphere, which warm the lower atmosphere by radiating heat downward. An increase in the abundance of soot aerosol particles could enhance the absorption of solar radiation in the atmosphere and on snow or ice surfaces, further intensifying the warming effect. Biological activity changes in the ice-free ocean could increase the amounts of phytoplankton, which would also absorb more solar radiation.

The Arctic research community has not yet reached a consensus about the dominant mechanisms leading to Arctic amplification.

These changes will have an impact on the unique atmospheric chemical processes taking place at high latitudes, removing short-lived climate pollutants and toxic heavy metals from the troposphere and controlling the stratospheric ozone layer. In addition, algae and phytoplankton production depends on these processes and their modifications, and the organohalogens they release into the atmosphere will also change.

Although many individual consequences of changes in these Arctic climate parameters are known, their combined influence and relative importance for Arctic amplification are complicated to quantify and difficult to disentangle. As a result, there is not yet a consensus in the Arctic research community about the dominant mechanisms leading to the phenomenon of Arctic amplification.

Planned Observations and Modeling Studies

In the framework of $(AC)^3$, we will use campaign-based and continuous observations to establish consistent shorter- and longer-term measurements and data product records. These observations will be collected by instrumentation carried on aircraft, tethered balloons, research vessels, and satellites and from instruments at a selected set of ground-based sites. We will conduct field studies in different seasons and meteorological conditions, covering a suitably wide range of spatial and temporal scales (Figure 3).

The shorter-term intensive campaigns are embedded in longer-term data-sampling programs (i.e., the past 30 years), which aim to identify trends in the spatiotemporal variability of Arctic climate parameters. We will carry out this observational strategy in an international context and in close collaboration with modeling activities.

Modelers will use a hierarchy of process, regional, and global models to bridge the spatiotemporal scales, from local processes to appropriate global and long-term climate indicators (Figure 4). The models will serve several purposes. They will guide the planning and performance of field campaigns, assist in the interpretation of local measurements, serve as test beds to evaluate process parameterizations, quantify feedback mechanisms, and help researchers determine the origins of observed Arctic climate changes. The observations, in turn, will be used to evaluate the predictive skills of the models.

Fig. 3. Field observations within the framework of (AC)³. Results of these field observations will be compared with satellite data and predictions from climate models. Abbreviations are CONCORD, continuous characterization of the Ny-Ålesund/Spitsbergen column and radiative effects from ground-based remote sensing (ongoing project); ABEX, Arctic Balloon-borne profiling Experiment (May–June 2017); ACLOUD, Arctic Clouds–Characterization of Ice, aerosol Particles and Energy fluxes (May–June 2017); PAMARCMiP, Polar Airborne Measurements and Arctic Regional Climate Model Simulation Project (spring 2018); AFLUX, Arctic Amplification: Fluxes in the Cloudy Atmospheric Boundary Layer (spring 2019); PASCAL, Physical feedback of Arctic Atmospheric Boundary Layer, Sea ice, Cloud and Aerosol (May–June 2017); MOSAiC, Multidisciplinary drifting Observatory for the Study of Arctic Climate (2019–2020).

We will place particular emphasis on evaluating different parameterizations, analyzing and quantifying feedback mechanisms in sensitivity studies, and assessing the importance of processes for Arctic climate and their interaction with the global dynamics and climate change.

Moving Ahead This Year

We successfully performed a major observational campaign using R/V *Polarstern*, tethered balloon measurements from an ice floe camp, and research aircraft Polar 5 and Polar 6 (based in Longyearbyen, Svalbard) during May and June 2017. In particular, we investigated the coupling of sea ice, clouds, and aerosol in the transition zone between open ocean and sea ice.

The instrumentation on board R/V *Polarstern* provided standard and additional spectral radiation measurements to determine the surface energy budget and a detailed characterization of surface, cloud, and aerosol properties. A continuous ground-based measurement site at Svalbard, close to the open ocean, provided similar measurements.

Polar 5 and Polar 6 operated between Svalbard and the actual location of R/V *Polarstern* along the sea ice edge. The airborne observations were supplemented by measurements of the boundary layer structure (turbulent and radiative energy fluxes) from a tethered balloon. The campaign will be the basis for extended modeling efforts to improve our understanding of Arctic climate changes.

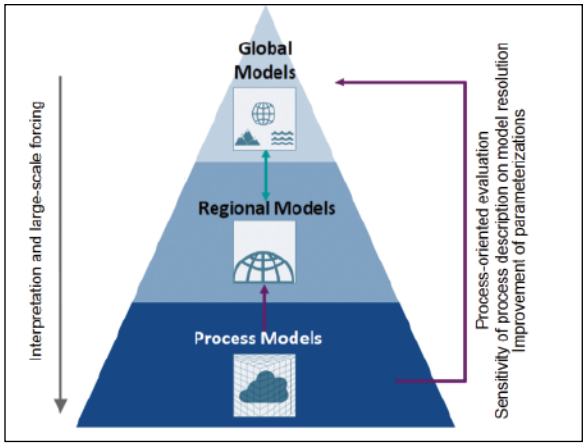

Fig. 4. The (AC)³ consortium will use a hierarchy of models covering a wide range of spatial and temporal scales to study Arctic amplification.

Acknowledgments

We gratefully acknowledge support from the DFG within TR 172 (AC)³.

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A NEW DATA SET MONITORS LAND-AIR EXCHANGES

By G. Z. Pastorello, D. Papale, H. Chu, C. Trotta, D. A. Agarwal, E. Canfora, D. D. Baldocchi, and M. S. Torn

FLUXNET2015, the latest update of the longest global record of ecosystem carbon, water, and energy fluxes, features improved data quality, new data products, and more open data-sharing policies.

The turn of the millennium marked a decade of systematic measurements of exchanges of carbon, water, and energy between the biosphere and the atmosphere, made by a few pioneering scientists at their own study sites. New knowledge was—and still is—generated from these data at individual sites. It quickly became clear, however, that pooling data from multiple sites would create a whole that is greater than the sum of its parts: a powerful tool not only for comparing and combining sites but also for studying land–air exchanges at regional and even global scales.

Scientists formed regional networks to foster sharing of data and methodologies, and FLUXNET was created, establishing a global "network of networks." But a challenge remained: Data sets were still too diverse, incompatible, and hard to compare. In June 2000, at the Marconi Conven-

The Southern Great Plains atmospheric observatory, a FLUXNET site near Lamont, Okla. (FLUXNET ID US-ARM), supports research on cloud, aerosol, and atmospheric processes. Credit: Sebastien Biraud

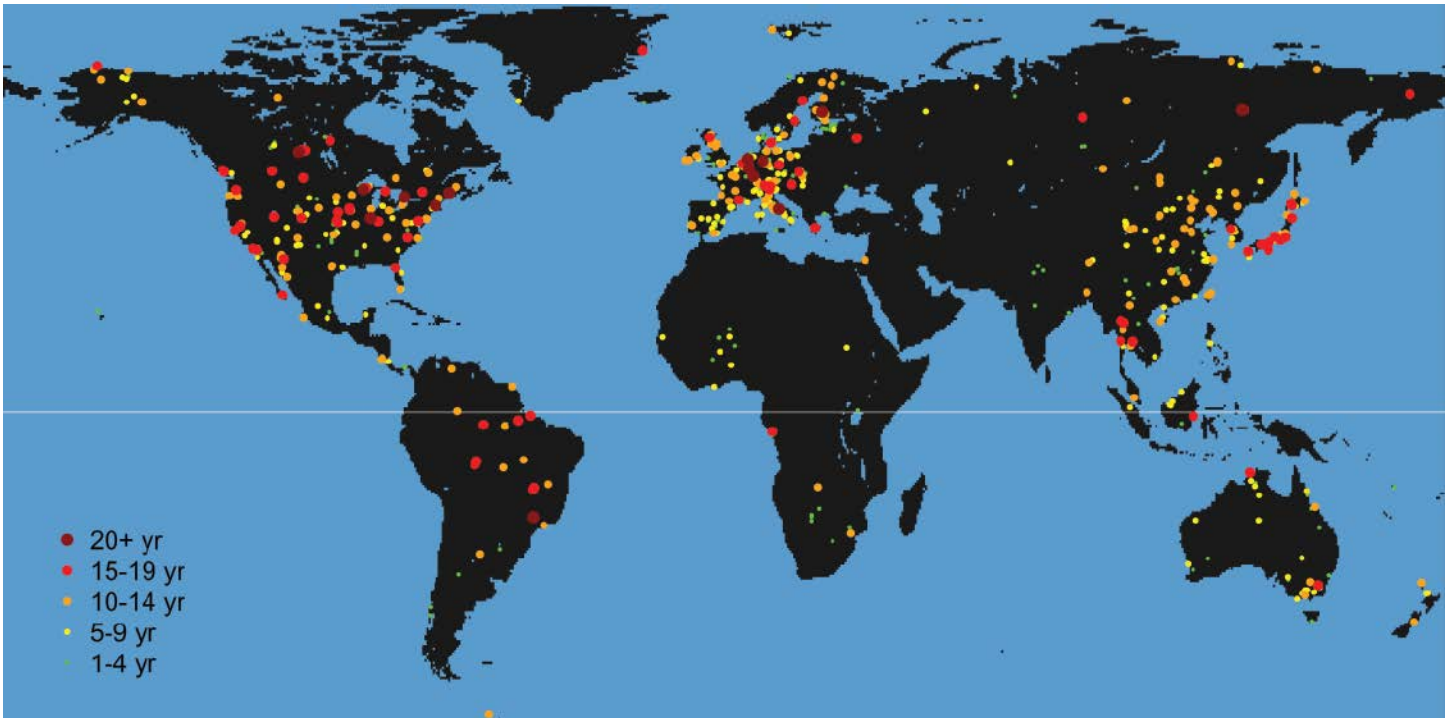

Fig. 1. This map shows the geographical extent of the FLUXNET tower site network, including active and historical sites. The FLUXNET2015 data set includes a subset of the sites shown in the map. The color and size of the circles indicate the length of measurements (as of December 2015).

tion Center on the northern California coast, a group of scientists resolved to change that. The first FLUXNET data set was born.

FLUXNET2015 is the third data set in the series, following the original Marconi data set from 2000 and the widely used 2007 version produced after a workshop in La Thuile, Italy. Released in December 2015, with two augmentations in 2016, the FLUXNET2015 data set includes more than 1500 site years of data at 30-minute intervals from 212 sites, ranging from the Norwegian tundra in Svalbard to the South African savanna in Kruger National Park, from the birch forests of Hokkaido, Japan, to the scrub oak near the launchpads of the Kennedy Space Center in Florida. Each site has records of fluxes of carbon, water, and energy and other ecosystem and biometeorological variables.

The fidelity of these flux measurements and their singular spatial and temporal coverage uniquely position them not only to help answer a broad range of questions about ecosystems, climate, and land use but also to bridge gaps between field observations and larger-scale tools like climate models and remote sensing. If past usage of FLUXNET data sets is any guide, we expect that scientists will use these data to validate satellite measurements, inform Earth system models, provide insight into a host of questions in ecology and hydrology, and fuel novel applications, many harnessing big data tools, on scales ranging from microbes to continents.

Updating FLUXNET Data Sets

FLUXNET sites span all continents and all major climate zones (Figure 1). Some regions of the globe and ecosystem types are still underrepresented, but this newest release has improved coverage (see Figure 2 at http://bit.ly/FLUXNET-Fig2). Increased data contributions from regional networks in the Americas, Asia, Europe, and Oceania helped expand the geographic and temporal coverage of the data set.

The longest continuous flux data records now exceed 25 years. AmeriFlux and the European networks reached 20 years of age in 2016, and other networks host records nearly as long. This combination of longer time series and new sites from undersampled regions makes the FLUXNET2015 data set the state of the art for understanding long-term interactions between the atmosphere and the biosphere and for addressing questions about year-to-year variability and trends in fluxes.

Such long flux records are also essential for gaining insight into extreme events and the ways that disturbed ecosystems respond over time. They can also help address emerging science questions, such as identifying the causes and effects of the greening of the Arctic, detected by nearly 30 years of remote sensing, or finding what drives the increasing amplitude of seasonal variability of atmospheric carbon dioxide (CO_2), observed in nearly 60 years of records from the Mauna Loa Observatory in Hawaii.

This update was also motivated by the opportunity for higher-quality data. The FLUXNET data team and site teams collaborated on extensive data quality control that allowed us to avoid or correct many of the data issues that are common in observed data such as missing sensor calibrations or inconsistent processing of a measured variable. Advances in the science and the availability of complementary data sets also allowed for the creation of new data products, such as uncertainty estimates and better methods for filling long gaps in micrometeorological data.

Earlier FLUXNET data sets were used in hundreds of peer-reviewed papers, for studies ranging from soil microbiology to effects of climate change at a global scale. As a simple metric, a Web of Science keyword search for FLUXNET now yields more than 400 papers. Stimulating new science with useful data products is a main motivation behind the work to create FLUXNET data sets.

What's Inside

Data collection at FLUXNET sites engenders only minimal disturbance to the ecosystem and produces flux estimates representative of spatial scales of hundreds of meters and

multiple temporal scales, from hours to years, and now decades. To make the data simple to use by scientists from many disciplines, data included in FLUXNET2015 were consistently quality controlled and gap filled. Also, ecosystem exchange of CO_2 was partitioned into ecosystem respiration (as CO_2 released into the atmosphere) and gross primary production (as CO_2 uptake by the ecosystem).

The FLUXNET2015 data set includes a number of new features. One is the revised and extended data quality checks, which not only increase data quality for individual sites but also help harmonize quality levels among all sites. This uniformity in the data is important for synthesis analyses, which require sites to be comparable.

Also included for the first time are estimates of uncertainties for key steps in the processing. Some of the steps, such as filtering for low wind conditions and partitioning of CO_2 fluxes, were implemented with multiple methods, resulting in more thorough estimates of uncertainties. These uncertainty estimates have been a long-standing request from ecosystem and Earth system modelers and make this data set especially useful for applications like model validation and constraining.

FLUXNET2015 also includes estimated energy corrections that were applied to achieve energy balance closure (between storage and incoming and outgoing energy), which makes the data more useful to climate and ecosystem models that require closed energy budgets when using flux data.

To fill long gaps in meteorological data, FLUXNET2015 used downscaled data based on the ERA-Interim global reanalysis data set, which provides a gridded and uninterrupted record derived using a data-informed model. This approach improved the accuracy of gap-filled micrometeorology data points and of temporally aggregated products such as those at daily or yearly resolutions.

Some of these data products and processing steps, especially the data quality checks, prevented some sites from being included in the data set. As a result, not all sites that contributed data or were part of the La Thuile data set were included in FLUXNET2015. The FLUXNET data team continues to work with these site teams to include data from their sites in future FLUXNET data sets.

Data collection at FLUXNET sites engenders only minimal disturbance to the ecosystem and produces flux estimates on temporal scales from hours to years, and now decades.

Embracing the Benefits—and Challenges—of Open Data

Open data sharing has gained momentum and is becoming a cornerstone of scientific research. In principle, open data sharing benefits not just users—it also benefits the teams collecting the data by enhancing community integration, collaboration opportunities, data collection protocols, recognition for the data collection and curation work, and fulfilling funding agency requirements on data availability.

In practice, however, sharing data remains complicated. The extra work and the logistics of supporting open sharing are beyond the reach of many scientists. FLUXNET data sets are based on field data collected by many independent teams from many countries. The multisource nature of the data set brings the added challenge of ensuring that the various data collectors receive proper credit when their data are used. Proper attribution is also necessary for site teams to get a better measure of the impact of their work and opportunities to participate in the science using their data. Data policies aimed at addressing these requirements have been put in place to enable data sharing via the services provided by regional networks and FLUXNET.

Data policies have evolved at least as much as the FLUXNET data sets themselves. For the Marconi data set, the policy stated that site teams had to be informed of the data usage and could request that work on conflicting topics be postponed. For the La Thuile data set, each site team classified its data into one of three data policy tiers. The most lenient required only acknowledgment of the data source. A middle tier required

Twitchell Island, in the Sacramento–San Joaquin River Delta in Sacramento County in California, is a wetland flux site (FLUXNET ID US-Twt) in the FLUXNET network. It provides data to FLUXNET2015, the latest iteration of the FLUXNET data sets, that include measurements of exchanges of carbon, water, and energy between land and atmosphere at sites around the world. Credit: Kyle Hemes

Tonzi Ranch, in the lower foothills of the Sierra Nevada Mountains in California, is one example of an oak savanna flux site (FLUXNET ID US-Ton). Credit: Dennis Baldocchi

users to submit proposals, which needed approval by a committee with representatives from each regional network and FLUXNET. In the strictest tier, data access was limited to the teams that contributed data.

The FLUXNET2015 data policy has matured to allow access to all interested users, with two tiers differing only in the terms for using the data, for example, for publications or class assignments. One tier requires acknowledgments, and the other requires that data providers be given the opportunity to add intellectual contributions and potentially become coauthors. This policy approach allows much broader access to the data and more opportunities to experiment with them.

Over the past decade, many FLUXNET site teams moved from being cautious about data sharing to being advocates for increased openness. FLUXNET's track record of more than 20 years of sharing data helps pave the way toward reproducible science and should encourage other communities to tackle the challenges of sharing data sets with many sources and users.

Where We Go from Here

The FLUXNET2015 data set can be downloaded from the FLUXNET-Fluxdata website (http://bit.ly/FLUXNET2015data). Download it, use it, discover—have fun! And let us know: Questions, suggestions, and comments can be sent to fluxdata-support@fluxdata.org. Site teams interested in contributing data to future FLUXNET data sets are encouraged to contact their regional networks.

There is still much room for improving the spatial coverage and representativeness of future data sets, considering all the existing sites that are potential new data contributors. We thank the site teams that helped us prepare their site data for inclusion in this data set and urge teams from sites that were not ready in time for this release to work with us to add their sites to upcoming data sets.

Acknowledgments

Site teams are the true engine of all FLUXNET data sets. Their extensive effort in collecting data, often under harsh conditions, generating quality data products, and providing their data for use by a broad community is invaluable and irreplaceable. The FLUXNET2015 data set is truly a community achievement!

This work used eddy covariance data acquired and shared by the FLUXNET community, including these networks: AmeriFlux, AfriFlux, AsiaFlux, CarboAfrica, CarboEuropeIP, CarboItaly, CarboMont, ChinaFlux, Fluxnet-Canada, GreenGrass, ICOS, KoFlux, LBA, NECC, OzFlux-TERN, TCOS-Siberia, and USCCC. The ERA-Interim reanalysis data are provided by the European Centre for Medium-Range Weather Forecasts and processed by Laboratoire des Sciences du Climat et de l'Environnement. The FLUXNET eddy covariance data processing and harmonization were carried out by the European Fluxes Database Cluster, the AmeriFlux Management Project, and the Fluxdata project of FLUXNET, with the support of the Carbon Dioxide Information Analysis Center (CDIAC) and the Integrated Carbon Observation System (ICOS) Ecosystem Thematic Centre, and the OzFlux, ChinaFlux, and AsiaFlux offices.

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2017 AGU Section and Focus Group Awardees and Named Lecturers

We are very pleased to announce the 2017 section and focus group awardees and named lecturers!

On behalf of the leaders, staff, and selection committees of AGU and the entire AGU community, we congratulate these honorees. Their colleagues have chosen them for this recognition for their innovative research, important contributions to promoting better understanding of their scientific fields, and meritorious work and service to their communities. We acknowledge our esteemed lecturers by inviting them to present under the annual Bowie Lecture Series as well as the Section and Focus Group Named Lecture Series.

AGU inaugurated the Bowie Lecture in 1989 to commemorate the fiftieth presentation of the William Bowie Medal, which is named for AGU's first president and is the highest honor given by the organization. In the list below, asterisks denote Bowie lecturers. Named lectures offered by AGU sections and focus groups recognize distinguished scientists with proven leadership in their fields of study.

We appreciate the efforts of all nominators, nomination supporters, selection committees, and sections and focus groups in bestowing these honors on their well-deserving colleagues and for their continued commitment to the AGU Honors Program. We look forward to recognizing this year's section and focus group honorees and their achievements at the 2017 Fall Meeting.

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

Atmospheric and Space Electricity Focus Group

Benjamin Franklin Lecture
Hugh J. Christian Jr., University of Alabama in Huntsville

Atmospheric Sciences Section

Atmospheric Sciences Ascent Award
Annmarie Carlton, University of California, Irvine
Larry W. Horowitz, Geophysical Fluid Dynamics Laboratory, National Oceanic and Atmospheric Administration
Gabriel Andrés Vecchi, Princeton University
Robert Wood, University of Washington

James R. Holton Award
Jianfei Peng, Texas A&M University
Karin van der Wiel, Royal Netherlands Meteorological Institute

Yoram J. Kaufman Unselfish Cooperation in Research Award
Teruyuki Nakajima, Japan Aerospace Exploration Agency

*Jacob Bjerknes Lecture**
Clara Deser, National Center for Atmospheric Research

*Jule Gregory Charney Lecture**
Bjorn Stevens, Max Planck Institute for Meteorology

Biogeosciences Section

Sulzman Award for Excellence in Education and Mentoring
Claudia Czimczik, University of California, Irvine

William S. and Carelyn Y. Reeburgh Lecture
Katherine H. Freeman, Pennsylvania State University

Cryosphere Focus Group

Cryosphere Early Career Award
Jan Lenaerts, Utrecht University

John F. Nye Lecture
Roger C. Bales, University of California, Merced

Earth and Planetary Surface Processes Focus Group

G. K. Gilbert Award in Surface Processes
Michael Church, University of British Columbia

Luna B. Leopold Young Scientist Award
Isaac J. Larsen, University of Massachusetts

Ralph Sharp Lecture
Isaac J. Larsen, University of Massachusetts

Earth and Space Science Informatics Focus Group

Greg Leptoukh Lecture
Kirk Martinez, University of Southampton

Geodesy Section

Geodesy Section Award
Juliet Biggs, University of Bristol

Ivan I. Mueller Award for Distinguished Service and Leadership
Kenneth W. Hudnut, U.S. Geological Survey

*William Bowie Lecture**
Tonie M. van Dam, University of Luxembourg

Geomagnetism, Paleomagnetism, and Electromagnetism Section

William Gilbert Award
John Booker, University of Washington

*Edward Bullard Lecture**
Kenneth P. Kodama, Lehigh University

Global Environmental Change Focus Group

Bert Bolin Global Environmental Change Award/Lecture
J. David Neelin, University of California, Los Angeles

Global Environmental Change Early Career Award
Jennifer A. Burney, University of California, San Diego
J. Elliott Campbell, University of California, Merced
Pierre Gentine, Columbia University
Jintai Lin, Peking University

Piers J. Sellers Global Environmental Change Mid-Career Award
James T. Randerson, University of California, Irvine

Stephen Schneider Lecture
Linda O. Mearns, National Center for Atmospheric Research

Tyndall History of Global Environmental Change Lecture
James Rodger Fleming, Colby College

Hydrology Section

Hydrologic Sciences Early Career Award
Amir AghaKouchak, University of California, Irvine

Hydrologic Sciences Award
Elfatih A. B. Eltahir, Massachusetts Institute of Technology

*Walter B. Langbein Lecture**
Robert M. Hirsch, U.S. Geological Survey

Paul Witherspoon Lecture
Thorsten Wagener, University of Bristol

Horton Research Grant
Ravindra Dwivedi, University of Arizona
James Knighton, Cornell University
Michael O'Connor, University of Texas at Austin

Mineral and Rock Physics Focus Group

Mineral and Rock Physics Early Career Award
Lowell Miyagi, University of Utah

Mineral and Rock Physics Graduate Research Award
Harrison Lisabeth, University of Maryland
Joshua P. Townsend, Sandia National Laboratories

John C. Jamieson Student Paper Award
Christopher Langrand, Unité Matériaux et Transformations, Université de Lille

Natural Hazards Focus Group

Natural Hazards Focus Group Award for Graduate Research
Lauren N. Schaefer, University of Canterbury

Gilbert F. White Distinguished Lecture
John L. LaBrecque, Geohazards Focus Area, Global Geodetic Observing System

Near-Surface Geophysics Focus Group

GSSI Near-Surface Geophysics Student Grant
Wilhelm Fraundorfer, University of Nebraska–Lincoln

Nonlinear Geophysics Focus Group

Donald L. Turcotte Award
Prachanda Subedi, University of Delaware

Ed Lorenz Lecture
William Klein, Boston University

Ocean Sciences Section

Ocean Sciences Award
Douglas Chester Webb, Falmouth, Massachusetts

Ocean Sciences Early Carever Award
Kristopher Karnauskas, University of Colorado Boulder

Rachel Carson Lecture
Paola Malanotte-Rizzoli, Massachusetts Institute of Technology

Harald Sverdrup Lecture
Sybil Seitzinger, University of Victoria

Paleoceanography and Paleoclimatology Focus Group

Willi Dansgaard Award
Hubertus Fischer, University of Bern

Planetary Sciences Section

Ronald Greeley Early Career Award in Planetary Sciences
Seth Jacobson, Northwestern University

Fred Whipple Award and Lecture
Michael C. Malin, Malin Space Science Systems

*Eugene Shoemaker Lecture**
Scott Bolton, Southwest Research Institute

Seismology Section

Keiiti Aki Young Scientist Award
Lucia Gualtieri, Lamont-Doherty Earth Observatory of Columbia University

*Beno Gutenberg Lecture**
Shuichi Kodaira, Japan Agency for Marine-Earth Science and Technology

Space Physics and Aeronomy Section

Basu United States Early Career Award for Research in Sun-Earth Systems Science
Lauren W. Blum, NASA Goddard Space Flight Center

Fred L. Scarf Award
Hong Zhao, University of Colorado Boulder

Space Physics and Aeronomy Richard Carrington Education and Public Outreach Award
Sigrid Close, Stanford University

Sunanda and Santimay Basu (International) Early Career Award in Sun-Earth Systems Science
Quanqi Shi, Shandong University, Weihai

*Marcel Nicolet Lecture**
Joseph Huba, U.S. Naval Research Laboratory

*James Van Allen Lecture**
Tamas I. Gombosi, University of Michigan

Study of the Earth's Deep Interior Focus Group

Study of the Earth's Deep Interior Graduate Research Award
Lorenzo Colli, Ludwig-Maximilians-Universität München
Timothy D. Jones, Australian National University

Tectonophysics Section

Jason Morgan Early Career Award
Romain Jolivet, École Normale Supérieure

*Francis Birch Lecture**
Greg Hirth, Brown University

Volcanology, Geochemistry, and Petrology Section

Hisashi Kuno Award
Matthew Steele-MacInnis, University of Arizona
James M. Watkins, University of Oregon

Norman L. Bowen Award and Lecture
Craig Manning, University of California, Los Angeles
Bernard Marty, Centre de Recherches Pétrographiques et Géochimiques

*Reginald Daly Lecture**
Catherine Chauvel, Institute of Earth Sciences, Grenoble

Joint Award: Geodesy, Seismology, and Tectonophysics Sections

Paul G. Silver Award
David Mainprice, Université de Montpellier and Géosciences Montpellier

Joint Prize: Nonlinear Geophysics Focus Group and Space Physics and Aeronomy Section

Space Weather and Nonlinear Waves and Processes Prize
Walter Gonzalez, Instituto Nacional de Pesquisas Espaciais

Joint Lecture: Biogeosciences and Planetary Sciences Sections

Carl Sagan Lecture
Jonathan I. Lunine, Cornell University

Joint Lecture: Paleoceanography and Paleoclimatology Focus Group and Ocean Sciences Section

Cesare Emiliani Lecture
Thomas F. Stocker, University of Bern

AGU Honors Program Makes Strides in Diversity

During the past few years, AGU has been committed to growing, diversifying, and building a more transparent culture around its Honors Program and the nomination process for its various forms of recognition. The Honors and Recognition Committee, along with engaged volunteer members and AGU staff, has done an admirable job of improving the program and better aligning its awards with AGU's vision and core values.

The AGU Honors Program promotes scientific leadership and collaboration, recognizes efforts to inform society about Earth and space science, and builds the global talent pool. The program extends beyond Union-level honors to yearly fellowships and numerous honors within AGU's 23 sections and focus groups.

Highlights and accomplishments for 2016 include the following:

- A new Union medal, the Devendra Lal Memorial Medal, will be awarded for the first time in 2017 in recognition of "outstanding Earth and/or space sciences research by a scientist belonging to and working in a developing nation."
- Two Africa Awards for Research Excellence in Earth and Space Science were given for the first time at the 2016 Honors Ceremony in recognition of two early-career scientists who are citizens or permanent residents of countries on the African continent.
- The Kaula Award, recently elevated in status, was given for the first time as a Union-level award at the 2016 Honors Ceremony in recognition for "unselfish service to the scientific community through extraordinary dedication to, and exceptional efforts on behalf of, the Union's publications program."

In addition to our highlights and accomplishments in 2016, the AGU Honors and Recognition Committee, as well as AGU staff, implemented strategies and initiatives to improve diversity and increase the number of nominations. In the spirit of transparency, we're sharing the 2016 Honors Program demographic information to demonstrate our progress and areas for improvement.

Table 1. AGU Membership

	1975	2000	2005	2010	2014	2015
Approximate total AGU membership	12,000	39,000	45,000	60,000	60,000	60,000
Women members, %	unrecorded	15	17	20	26	27
Non-U.S. members, %	20	32	34	39	39	39

Table 2. Demographic Information on 2016 AGU Medal, Award, and Prize Nominations

HONOR TYPE	MALE[a]	FEMALE[a]	U.S. MEMBERS	NON-U.S. MEMBERS
Union award	80 (60%)	57 (40%)	96 (70%)	50 (30%)
Union medal	68 (80%)	14 (20%)	57 (70%)	25 (30%)
Union prize	6 (90%)	1 (10%)	2 (30%)	5 (70%)
Total	154 (68%)	72 (32%)	155 (70%)	80 (30%)

[a]Group/program/team nominations for the Education Award omit gender demographic information.

Table 3. Demographic Information on 2016 AGU Medal, Award, and Prize Honorees

HONOR TYPE	MALE	FEMALE	U.S. MEMBERS	NON-U.S. MEMBERS
Union award	8 (50%)	8 (50%)	13 (80%)	3 (20%)
Union medal	11 (80%)	3 (20%)	10 (70%)	4 (30%)
Union prize	2 (100%)	0 (0%)	1 (50%)	1 (50%)
Total	21 (70%)	11 (30%)	24 (80%)	8 (20%)

Gender and International Diversity in the 2016 Honors Cycle

AGU has grown more diverse, with the percentage of women and non-U.S. members having increased dramatically over time. Table 1 shows that the percentage of non-U.S. members nearly doubled from 1975 to 2015 and expanded from 32% to 39% during the past 15 years. Since the year 2000, the percentage of women members also rose, from 15% to 27%.

Overall, the data show that gender diversity in AGU honors is approaching parity with the overall membership demographic; the international diversity performance in AGU Honors has improved by more than 10% across all AGU honors. Tables 2 and 3 show gender and international diversity data for 2016 nominees and honorees, respectively.

Using data from the past 3 years, we have compared percentages of Union medals, awards, and prizes received by women and men. In Figure 1, bar graphs show this gender comparison from 2014 to 2016 and compare percentages of honors received by AGU members in the United States with percentages received by members in other countries during the same time period.

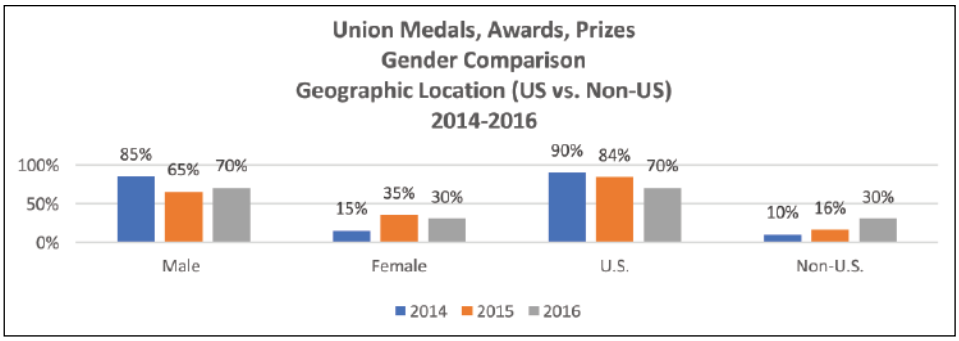


Fig. 1. Comparative data on gender and geographic location for AGU Union medals, awards, and prizes (2014–2016).

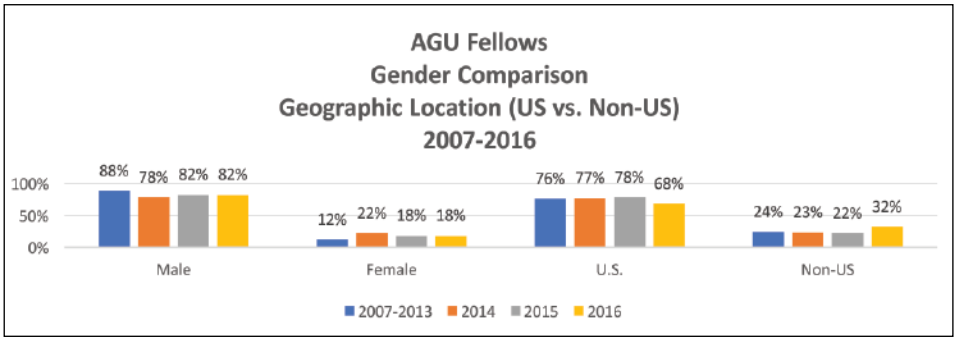


Fig. 2. Comparative data on gender and geographic location for the AGU Fellows program (2007–2016).

Table 4. Demographic Information on 2016 AGU Fellows

	INITIAL STAGE: NOMINEES	SECOND STAGE: SECTION/FOCUS GROUP RANKED NOMINEES	THIRD STAGE: ELECTION OF FELLOWS BY THE UNION FELLOWS COMMITTEE
Men	190 (84%)	98 (83%)	49 (82%)
Women	36 (16%)	20 (17%)	11 (18%)
U.S. members	160 (71%)	80 (68%)	41 (68%)
Non-U.S. members	66 (29%)	38 (32%)	19 (32%)
Total	226	118	60

Diversity of AGU Fellows

In 2016, a total of 226 Fellows nominations were received. From these, 118 candidates advanced to the Union Fellows Committee for consideration, and 60 new Fellows were elected and announced in July 2016. Ultimately, the class of elected Fellows was 18% female and 32% international, as indicated in Table 4.

Bar graphs in Figure 2 show the variations in percentages of AGU Fellows by gender and by members' locations within and outside the United States from 2007 through 2016.

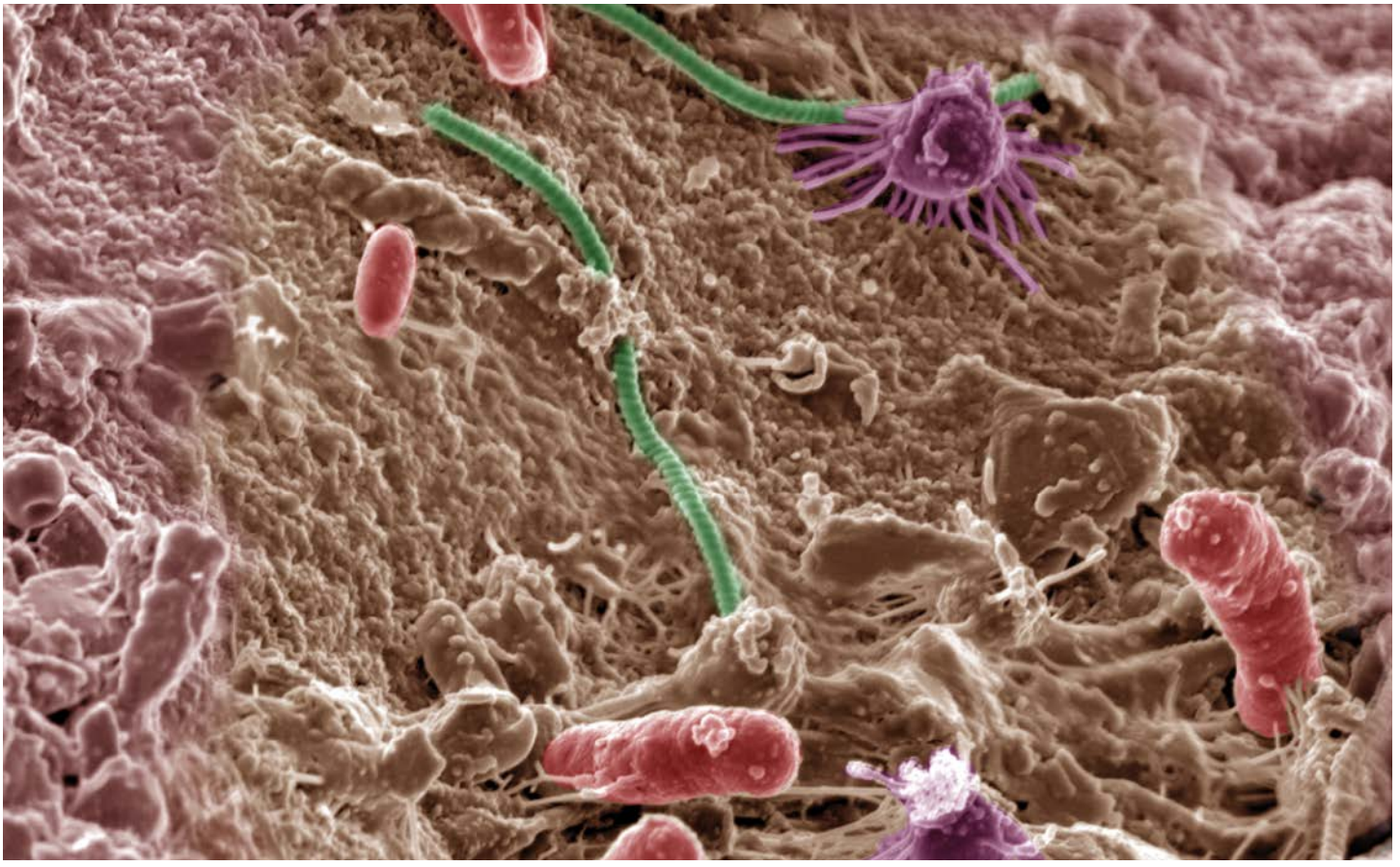
Honors Excellence: The Importance of Honors Nominations

Nominating a colleague for an AGU honor is the best way to recognize professional efforts. Doing so also furthers our organization's stated goals of rewarding outstanding contributions to research and advancing the Earth and space sciences through engagement and awareness.

AGU recognizes its vital role and obligation not only to ensure a workplace climate for Earth and space scientists that is inclusive, respectful, and free from bias and discrimination but also to foster a community that reflects the diverse public it serves. May this article act as a reminder of the importance of nominating worthy candidates and taking notice of our underrepresented colleagues. As AGU president Eric Davidson and past president Margaret Leinen said in a *From the Prow* post (see http://bit.ly/prow-diversity), "We cannot live up to all that our mission promises if the Earth and space science community is not representative of humanity."

By **Sam Mukasa** (email: unionhonors@agu.org), Chair, Honors and Recognition Committee, AGU

How Do Microbial Ecosystems and Climate Change Interact?



Microbes in the soil are central players in converting carbon into greenhouse gases. Credit: Pacific Northwest National Laboratory, CC BY-NC-SA 2.0 (http://bit.ly/ccbyncsa2-0)

Microorganisms have been changing the climate and have been changed by the climate throughout most of Earth's history. A new joint report, "Microbes and Climate Change," from AGU and the American Society for Microbiology (ASM), explores these dynamics and provides insights for better understanding and future work (see http://bit.ly/microbes-cc).

The April 2017 report is the output of a 1-day research colloquium last year, jointly sponsored by ASM and AGU. It highlights how microorganisms respond to, adapt to, and evolve in their surroundings at higher rates than most other organisms. This accelerated pace allows scientists to study the effects of climate change on microbes to understand and perhaps predict the future effects of climate change on all forms of life.

The 3 March 2016 colloquium brought together experts from multiple scientific disciplines to discuss current understanding of microbes and our changing climate, as well as gaps and priorities for future study. Thirty invited scientists of various backgrounds, about half from each of the two scientific societies, participated in the meeting and coauthored the report. Colloquium steering committee members Stanley Maloy, Mary Ann Moran, Margaret Mulholland, Heidi Sosik, and John Spear facilitated the work of the authoring committee.

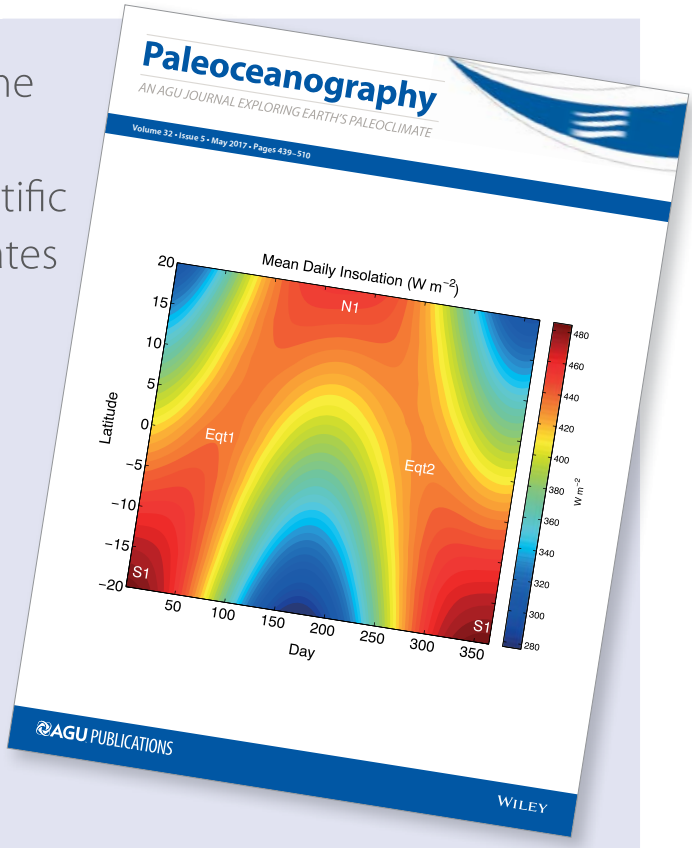
The 24-page document provides a primer on biogeochemical processes and climate change, then addresses impacts in three areas: terrestrial polar regions; soil, agriculture, and freshwater; and oceans. It also explores ecological communities of microorganisms (i.e., microbiomes), effects of climate change on these communities, and how they adapt. The report is written for public audiences, including policy makers, educators, and scientists and science-interested students.

"There is much more to learn and understand about how shifts in the Earth's climate affect complex and interconnected microbial functions and the biogeochemical cycles they mediate," said Eric Davidson, AGU president and a biogeochemist. "The information in this joint report lays out the current understanding of microbial ecosystem feedbacks that accelerate or mitigate climate change, as well as gaps and priorities for future study. This collaborative effort between ASM and AGU is a model for future joint society activities."

By **Billy M. Williams** (email: bwilliams@agu.org), Vice President, Science, AGU

Paleoceanography will be renamed to *Paleoceanography and Paleoclimatology* in January 2018

"Inserting the word 'climate' into the name allows us to celebrate the growth and evolution of our scientific undertaking. Understanding climates of the past has been an integral part of Earth sciences since their early days...In our present time of environmental change, it is, more than ever, important to use proxy data on Earth's past in order to evaluate Earth's future, thus making our past a key guide to our future."



Ellen Thomas

Editor in Chief,
Paleoceanography and Paleoclimatology

Submit your paleoceanography and paleoclimatology papers at
paleoceanography.agu.org

AGU PUBLICATIONS

An Improved Model of How Magma Moves Through Earth's Crust

A new model that simulates the speed and path of magma spreading through Earth's crust may help scientists predict when and where eruptions may occur on Italy's Mount Etna (pictured) and other active volcanoes. Credit: gnuckx

Volcanic eruptions of basalt are fed by intrusions of magma, called dikes, which advance through Earth's crust for a few hours or days before reaching the surface. Although many never make it that far, those that do can pose a serious threat to people and infrastructure, so forecasting when and where a dike will erupt is important to assessing volcanic hazards.

However, the migration of magma below a volcano is complex, and its simulation is numerically demanding, meaning that efforts to model dike propagation so far have been limited to models that can quantify either a dike's velocity or its trajectory but not both simultaneously. To overcome this limitation, *Pinel et al.* have developed a hybrid numerical model that quantifies both by dividing the simulations into two separate steps, one that calculates a two-dimensional trajectory and a second that runs a one-dimensional propagation model along that path.

The results indicate that the migration of magma is heavily influenced by surface loading—the addition or removal of weight on Earth's surface—such as that caused by the development of a volcano or its partial removal via a massive landslide or caldera eruption. The team confirmed previous research that showed that increasing surface load attracts magma while also reducing its velocity, whereas unloading diverts much of the magma.

To test its approach, the team applied their model to a lateral eruption that occurred on Italy's Mount Etna in July 2001. The eruption was fed by two dikes, including one that in its final stages clearly slowed down and bent toward the west while still 1–2 kilometers below the surface. The results showed that the two-step model was capable of simulating that dike's velocity and trajectory and thus offers a new means of constraining the local stress field, which partially controls these properties.

The authors report that in the future, more complex versions of this model that incorporate information on local topography and magmatic properties could be integrated with real-time geophysical data to improve forecasts of when and where a propagating dike could erupt at the surface. (*Journal of Geophysical Research: Solid Earth*, https://doi.org/10.1002/2016JB013630, 2017) **—Terri Cook, Freelance Writer**

Can Tree Planting Really Help Mitigate Climate Change?

Researchers examine whether reforestation can help mitigate climate change. Credit: iStock.com/ufokim

For centuries, nature enthusiasts around the world have hosted events to plant and care for trees. At the first U.S. Arbor Day, held in 1872, Nebraska residents planted an estimated 1 million trees. In more recent years, some groups have called for reforestation (planting trees in areas where they had formerly grown but were cut down, burned, or otherwise destroyed) and afforestation (planting trees in areas where they have not historically grown, such as in grasslands) with a new goal in mind: to help mitigate climate change.

When a tree takes in carbon from the atmosphere, it stores it throughout its lifetime through a process called carbon sequestration. The surrounding soil can sequester carbon for even longer periods, for hundreds, sometimes thousands, of years.

Still, scientists have questioned whether tree planting is a good way to mitigate humanity's effect on climate. In particular, a landmark study in 2000 found that for most of the world's forests, the cons can outweigh the pros. Trees that are planted in high-latitude (near the poles) regions often reflect less sunlight than the natural formations they replace, such as snowdrifts or grasses. When this happens, more radiation is absorbed at Earth's surface, warming the ground and the layer of air just above it. So the study found that although it might be beneficial to plant trees in low-latitude (near the equator) regions, planting trees elsewhere could actually produce more warming.

A new study conducted by *Mykleby et al.* generally supports this conclusion and provides additional recommendations for afforestation efforts.

In light of the deforestation occurring in many tropical forests nearest the equator, the researchers chose to focus on midlatitude and high-latitude regions where afforestation might be more effective. They used a land surface model to simulate the different types of conifer evergreen trees that grow in temperate and boreal regions of North America.

Then they checked the results of their model against data collected at field sites in the humid Pacific Northwest, the alpine Rocky Mountains, the eastern coast of North America, and boreal regions of Canada.

Overall, the researchers found that afforestation would be most effective in these regions of the United States (except for mountainous regions in the West) and coastal provinces of Canada (including Nova Scotia, New Brunswick, and British Columbia). Furthermore, they found two ways to maximize the benefits of afforestation: planting trees as densely as possible and harvesting trees once they surpass their peak rate of carbon sequestration. In most forests they studied, this time frame would be about every 35–45 years, but in the American Rockies it could be as many as 90 years.

The team hopes that by painting a clearer picture of forest-climate interactions, this study will help inform policy makers. They note that altering land use may help countries in their efforts to achieve climate goals set forth by the Paris Agreement, a worldwide effort to combat climate change. (*Geophysical Research Letters*, https://doi.org/10.1002/2016GL071459, 2017) **—Sarah Witman, Freelance Writer**

Mysterious Intraseasonal Oscillations in Monsoons

India's summer monsoon is a major event, single-handedly supplying water for agriculture across all of southern Asia. Because of its widespread effect on the region's environmental and socioeconomic health, the monsoon has long been studied by meteorologists, climatologists, and oceanographers hoping to understand and forecast its behavior.

One phenomenon in particular, the monsoon intraseasonal oscillations (MISOs), has captured scientists' interest. MISOs are alternating periods of heavy and minimal rainfall, each lasting for about a month or so and tending to follow a cyclical, northward shifting pattern from the equator to southern Asia. Although they were once believed to be a function of the tropical atmosphere, more recent studies have suggested that MISOs come from some kind of powerful atmosphere-ocean interaction.

In one such study, *Li et al.* examined the pathways of MISOs traveling across the Bay of Bengal, a region where the monsoon undergoes changes in intensity and frequency.

The same team previously examined the role of ocean salinity stratification (layering of seawater with different salt contents) in variations in sea surface temperature and the atmospheric processes that produce rainfall. Here, however, they addressed the contribution from two other variables: the depth of the mixed layer, which lies just below the sea surface, and the thickness of the barrier layer, which forms the bottom of the mixed layer.

Using an ocean model with data from 2000 to 2014, the researchers investigated how these upper ocean processes affect sea surface temperature (and how variations in sea surface temperature, in turn, affect rain formation in the MISOs).

An influx of freshwater from the monsoon, the researchers found, creates a shallow mixed layer and a thick barrier layer, causing dramatic fluctuations in sea surface temperature over the course of the season. What's more, these air-sea interactions lead to the highly irregular rainfall patterns seen as the MISOs reach Asia.

Using advanced models and checking them against satellite data allowed the researchers to pinpoint these driving forces behind MISOs with more precision than in previous studies. Their efforts promise to improve the accuracy of future simulations and forecasts of the MISOs that occur during India's summer monsoon. (*Journal of Geophysical Research: Oceans*, https://doi.org/10.1002/2017JC012692, 2017) **—Sarah Witman, Freelance Writer**

Spacecraft Returns Its First Data on Martian Solar Irradiance

Since it began orbiting Mars in late 2014, NASA's MAVEN spacecraft has explored the Red Planet's upper atmosphere and its interactions with the Sun. Now scientists present the first measurements of solar irradiance made using data from a MAVEN-mounted sensor. Credit: NASA Goddard Space Flight Center

Ancient riverbeds, mineral deposits, and abundant additional evidence suggest that water once flowed plentifully on Mars. However, the lack of a protective magnetic field like Earth's may have made Mars's atmosphere more vulnerable to the solar wind, which stripped away air and water over time, leaving the planet cold and arid.

In a new study, *Thiemann et al.* highlight one line of evidence that could help clarify what happened to Mars's atmosphere, which is now thin. They used data from NASA's Mars Atmosphere and Volatile Evolution (MAVEN) mission to calculate solar irradiance, the amount of power delivered by solar electromagnetic waves over a given area of the Martian atmosphere. Such measurements are important for understanding the Sun's influence on Mars.

The researchers worked with data collected by a sensor on the MAVEN spacecraft that measures certain wavelengths of radiation known as solar extreme ultraviolet (EUV) radiation. With wavelengths ranging from 6 to 120 nanometers, solar EUV radiation is known to heat the upper atmospheres of both Earth and Mars, and its interactions with gases have an impact on atmospheric composition.

As it orbits Mars in the upper atmosphere, MAVEN's EUV monitor takes solar EUV measurements every second that the Sun is in the instrument's field of view, which is approximately 60% of the time. A mathematical model called the Flare Irradiance Spectral Model–Mars (FISM-M) uses the EUV measurements to calculate spectral irradiance, the solar irradiance received by the Martian atmosphere for a specific wavelength.

In their study, the team outlines the capabilities and limitations of the FISM-M model. The algorithms used in FISM-M incorporate concurrent solar EUV data collected in Earth's upper atmosphere by NASA's Solar Dynamics Observatory (SDO). SDO data help calibrate MAVEN data and enable calculation of Martian solar irradiance, not only on a daily basis but also after explosive solar flares.

The researchers present solar irradiance measurements calculated using FISM-M between October 2015 and November 2016. These measurements varied due to fluctuations in EUV radiation caused by solar flares, the rotation of the Sun, Mars's elliptical orbit around the Sun, and the progression of the Sun's 11-year cycle.

The EUV monitor is just one of an array of instruments and sensors that MAVEN uses to study Mars's upper atmosphere as it seeks clues to the atmospheric history of the Red Planet. The information presented by the team will help inform future research with FISM-M, as well as allow improvements to the model itself. (*Journal of Geophysical Research: Space Physics*, https://doi.org/10.1002/2016JA023512, 2017)

—Sarah Stanley, Freelance Writer

When Ocean and Atmosphere Couple, the Climate Wobbles

In the atmosphere above the North Atlantic Ocean, a large zone of high pressure near the Azores called the Azores High and a zone of low pressure near Iceland and southern Greenland called the Icelandic Low help to funnel winds and fuel a storm track. This storm track has profound effects on weather patterns across the Northern Hemisphere.

These effects intensify and weaken as the storm track gains and loses strength every 25–30 years or so, a wobbling called the North Atlantic Oscillation (NAO). A strong NAO may dole out harsher winters to Canada and milder ones to northern Europe, for example, as well as make the Middle East even drier.

Understanding what drives such oscillations—not just in the NAO but also in similar systems across the globe—is crucial if scientists are to improve predictions of future climate. Does an atmospheric jet weaken because of changes in ocean current or temperature, for example, or does it work the other way around, with the ocean responding to changes in the atmosphere? Or is it some of both? In a new study, *Vannitsem and Ghil* present a new mathematical tool for determining what drives the system: ocean, atmosphere, or the two combined.

The team used the NAO as a test case. They compared data sets from several previous studies with earlier theoretical models of the NAO to tease out the phenomenon's most important drivers.

They found that the oscillations were driven by the confluence of ocean and atmospheric factors: ocean temperatures, atmospheric pressures, and ocean currents. The effects were particularly strong during winter, implying that the effects of this genuine coupling between oceanic and atmospheric processes vary with the season, the authors say. (*Geophysical Research Letters*, https://doi.org/10.1002/2016GL072229, 2017) **—Emily Underwood, Freelance Writer**

Diagnosing Cryptic Remagnetization in Sedimentary Rocks

Mount Everest (Qomolangma), in Tibet. Samples collected from sites near here show that sedimentary rocks from southern Tibet exhibit widespread chemical remagnetization. Correcting for this now allows reconciliation of paleomagnetic and geological reconstructions of plate tectonic history prior to the collision that formed the Himalayas. Credit: Wentao Huang

After being exposed to Earth's magnetic field, some minerals within rocks acquire a magnetic signal that can be used to measure how this field has changed or even reversed through time. More important, these signals are frequently used to trace where the rocks formed.

Frequently, however, the migration of fluids and other processes can remagnetize, or overprint, the original signal. Because this overprinting is often difficult to detect, especially in carbonates and other sedimentary rocks, remagnetization can lead to flawed reconstructions of the ancient locations and motions of Earth's tectonic plates.

Sedimentary rocks play a key role in reconstructing the wanderings of the Tibetan Himalaya prior to its collision with Asia. To evaluate the extent of the remagnetization in these rocks, *Huang et al.* magnetically, chemically, and visually characterized 72 carbonate and volcaniclastic sandstone samples collected from Jurassic to Paleogene Himalayan strata in the Gamba and Tingri regions of southern Tibet.

Using a series of magnetic and petrographic techniques, including scanning electron microscopy, the team determined that although magnetite is the predominant magnetic material in both types of rocks, its characteristics vary noticeably between the two. The sandstones, for example, contain fragments of chemically unaltered magnetite and show little evidence of pyrite oxidation, whereas the carbonates host predominantly authigenic forms of magnetite that have replaced other minerals, particularly pyrite.

The authors conclude that although the sandstones retained their initial magnetic signal, the carbonates had been extensively remagnetized, most likely because of chemical reactions instigated by fluids circulating before and after the onset of the Himalayan collision. Paleomagnetic estimates of the tectonic evolution of the Tibetan Himalaya and India prior to collision can now be reconciled with geological evidence that the onset of collision occurred 58 million years ago. This evidence demonstrates the importance of using a combination of techniques to thoroughly evaluate a sedimentary rock's magnetism prior to applying paleomagnetic data to tectonic interpretations. (*Journal of Geophysical Research: Solid Earth*, https://doi.org/10.1002/2017JB013987, 2017) **—Terri Cook, Freelance Writer**

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∗ Print-only recruitment ads will only be allowed for those whose requirements include that positions must be advertised in a printed/paper medium.

ATMOSPHERIC SCIENCES

Assistant Professor (Probationary Tenure-Track)–Atmospheric Science, Department of Physics and Atmospheric Science, Dalhousie University

Dalhousie University invites applications from outstanding candidates for a faculty position in atmospheric science. This is a probationary tenure track position with the rank of assistant professor. Candidates will have a PhD in a related discipline, proven teaching ability or potential at the university level, and must demonstrate the ability or potential to establish a successful research program. The successful candidate will be expected to enhance and complement the existing activities of the atmospheric science group in both teaching and research.

The atmospheric science group (www.atm.dal.ca) and the broader department have an active research program with connections to many major national and international programs. Dalhousie is one of the top universities in Canada. For example, three of the last four recipients of the NSERC Herzberg Gold Medal, Canada's highest prize in science and engineering, have been Dalhousie faculty. Halifax offers an outstanding quality of life.

Applications should be submitted by September 4, 2017 and consist of a curriculum vitae, a research proposal (max 3 pages), a statement of teaching interests and experience, contact information for at least three referees, and a completed Self-Identification Questionnaire (available at: http://www.dal.ca/becounted/selfid). Please send application materials to:

Chair, Atmospheric Science Search
c/o Jennifer.Currie@Dal.Ca
Department of Physics and Atmospheric Science
Dalhousie University
6310 Coburg Street, Room 218
Halifax, Nova Scotia, B3H 4R2
Canada

Consideration of candidates will begin in September 2017 and continue until the position is filled. While it is intended for the position to commence on July 1, 2018, the start date can be negotiated at the time of offer.

Dalhousie University is committed to fostering a collegial culture grounded in diversity and inclusiveness. The University encourages applications from Aboriginal people, persons with a disability, racially visible persons, women, persons of minority sexual orientations and gender identities, and all candidates who would contribute to the diversity of our community. All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority.

Postdoctoral Research Associate, Purdue University

The Shepson Tropospheric Chemistry Research Group at Purdue University has an opening for a Postdoctoral Research Associate. The position involves an opportunity to lead, and to work on a number of other problems in atmospheric chemistry, but focusing on development and application of methods for quantitative determination of greenhouse gas fluxes in a variety of natural and anthropogenically impacted environments. Expertise in atmospheric science, quantitative measurements and error analysis, chemical instrumentation, statistical data analysis, and good computational skills is essential. The position is for one year, but potentially renewable annually. The position will be open until filled. Interested candidates should send a CV with a list of 3 references to:

Prof. Paul B. Shepson
Purdue University
560 Oval Dr.
West Lafayette, IN 47907
765-494-7441
pshepson@purdue.edu

Purdue University is an ADVANCE Institution. Purdue University is an EEO/AA employer fully committed to achieving a diverse work force. A background check will be required for employment in this position.

CRYOSPHERE SCIENCES

Assistant/Associate Professor of Physical Glaciology Climate Change Institute and School of Earth and Climate Sciences, University of Maine

The University of Maine Climate Change Institute (CCI) and School of Earth and Climate Sciences (SECS) invite applicants for a full-time tenure-track Assistant/Associate Professor position in Physical Glaciology. The successful applicant will have a joint appointment salaried through the two units (55% CCI/45% SECS) with tenure home in SECS, and position responsibilities distributed as 60% research and 40% teaching. We seek an individual who integrates observations from field study and remote sensing of critical cryosphere phenomena into a physical framework that joins glacier dynamics to Earth's climate on short and long periods. The individual will be expected to develop and carry out glaciological field investigations with an emphasis on ice sheet dynamics, and to establish and maintain collaborations with UMaine, national, and international research programs. Potential research collaboration areas include those related but not restricted to: ice-ocean interactions and sea-level rise; understanding the tempo and causes of global climate change through geological observations; interpretation of ice core records with the larger Earth/climate system; ice sheets and mountain gla-

HEAD OF RESEARCH UNIT "SNOW AND PERMAFROST"

The WSL Institute for Snow and Avalanche Research SLF is part of the Swiss Federal Institute for Forest, Snow and Landscape Research WSL and thus of the ETH Domain. WSL focuses on the sustainable use and protection of landscapes and habitats, and a responsible approach to natural hazards. WSL employs approximately 500 people, of whom 140 work at SLF in Davos.

The Research Unit "Snow and Permafrost" investigates the physical properties of snow, soil and permafrost and the surface exchange with the atmosphere in order to understand the formation of natural hazards such as avalanches, floods and slope instabilities and the interaction of the cryosphere with climate change.
The directorate of WSL wishes to recruit a **HEAD OF RESEARCH UNIT "SNOW AND PERMAFROST"**

As a researcher with an international reputation, you will manage the research unit, which has some 40 staff members, in cooperation with the group leaders. Coordinating and promoting the research within the unit as well as leading your own projects are part of your responsibilities. Your diverse activities involve supporting the implementation of the scientific results into practice. Furthermore, you will acquire third party funding for research projects and promote cooperation with public authorities and organizations at both national and international level.

You are at an advanced stage of your scientific career with several years of independent research and have a strong performance record in the area of interaction between subsoil, snow cover and the atmosphere as well as their impact on the environment. You have experience in managing large research groups and/or in leading interdisciplinary research projects. You have an integrative personality with negotiating skills and a good command of one of the Swiss national languages as well as English.

Please send your complete application to:
Jasmine Zimmermann, Human Resources WSL/SLF.
Prof. Dr. Konrad Steffen, Director, phone +41 (0)44 739 24 55, will be happy to answer any questions or offer further information.

The WSL strives to increase the proportion of women in its employment, which is why qualified women are particularly called upon to apply for this position.

Link for your application:
https://apply.refline.ch/273855/0716/pub/4/index.html

ciers as indicators of past and future climate change; ice rheology; and coupled ice mechanics and geochemical evolution of glaciers. A PhD in glaciology or closely related field is required. For more information about CCI and SECS, visit http://climatechange.umaine.edu and https://umaine.edu/earthclimate/.

Go here to see complete job advertisement and submit an application: https://umaine.hiretouch.com/job-details?jobID=40766&job=assistant-associate-professor-of-physical-glaciology. Applicants must create a profile and application; upload a cover letter, a CV which fully describes their experience with specific reference to the required and desirable qualifications, statement of teaching philosophy and interests, statement of research vision, and contact information for three professional references. Review of applications will begin July 17, 2017 and will continue until the position is filled. Anticipated start date is January 2018. For questions about the position, please contact um.glaciologysearch@maine.edu.

The University of Maine is an EEO/AA Employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, sexual orientation, age, disability, protected veteran status, or any other characteristic protected by law.

GLOBAL ENVIRONMENTAL CHANGE

Associate Director, Pacific Institute for Climate Solutions – Victoria, BC

The Pacific Institute for Climate Solutions (PICS) is a collaborative initiative between the four research intensive universities in British Columbia. The mandate of PICS is to partner with governments, the private sector, other researchers and civil society, to undertake research on, monitor, and assess the potential impacts of climate change and to assess, develop and promote viable mitigation and adaptation options to better inform climate change policies and actions. The principal lines of communication between the partner universities are through the Executive Committee (on which sit the Vice- Presidents, Research from each university), the Program Committee, and a PICS campus manager at each university.

The PICS Associate Director is responsible for a number of key PICS programs, and will be instrumental in developing and managing the institutes research projects and other outreach activities that promote the goals of PICS. The Associate Director is second in command at PICS and will stand in for the Executive Director as required. The successful candidate will take a leading role in the development and implementation of the Institute's new strategic objectives.

Minimum Qualifications include a PhD or equivalent professional experience, with a solid understanding of climate change and the ability to understand conceptually the objectives and focus areas of the PICS mandate. Four years' experience in managing research teams, or an equivalent combination of education and experience is essential.

Deadline for applications is 4:00 pm (PDT), July 28, 2017.

Please submit your CV to picsadmn@uvic.ca.

HYDROLOGY

Assistant Professor of Earth and Planetary Sciences, Washington University in St. Louis

The Department of Earth and Planetary Sciences at Washington University in St. Louis invites applications for a tenure-track Assistant Professor position in the field of surface hydrology. The candidate is expected to perform basic research in hydrologic processes at or near Earth's surface. Areas of interest include but are not limited to fluvial, lacustrine, and/or estuarine systems, fluvial geomorphology and sediment transport, flooding, and relationships to ecological and climate systems. The ideal candidate will employ quantitative tools and will integrate computational approaches with direct and remotely sensed observations.

The successful candidate is expected to develop a vigorous, externally funded research program, maintain a strong publication record, advise students, provide outstanding teaching over a broad range of undergraduate and graduate courses, and participate actively in departmental governance and university service. We seek candidates who will strengthen existing research programs in geology, climate science, and remote sensing, as well as foster collaboration with scholars across the Washington University community.

Candidates must have a Ph.D. in Earth science, or a related field, at the time of appointment. Complete applications include a cover letter, curriculum vitae, statements of teaching and research interests, and the names and contact information of at least four references as a single PDF, and should be sent to Professor Philip Skemer, Hydrology Search Committee Chair, Department of Earth and Planetary Sciences, Washington University, Campus Box 1169, 1 Brookings Drive, St. Louis, MO 63130, or via e-mail: hydrologysearch@eps.wustl.edu. Applications must be received by October 15, 2017 to ensure full consideration. Washington University is an Equal Opportunity Employer.

All qualified applicants will receive consideration for employment without regard to race, color, religion, age, sex, sexual orientation, gender iden-

tity or expression, national origin, genetic information, disability, or protected veteran status.

OCEAN SCIENCES

Postdoctoral Fellow–Storm Surge and Wave Modeling, Florida International University

The Extreme Events Institute (EEI) at Florida International University (FIU), Miami has one postdoctoral opening to support storm surge and wave modeling for quantifying the impacts on the built and natural coastal environments. The EEI (eei.fiu.edu) is a multi-disciplinary research and education organization focused on reducing hurricane damage and loss of life, and collaborates actively with NOAA's National Hurricane Center, co-located on the FIU Campus.

The fellow will conduct storm surge and wave simulations, develop the real-time forecast capacity of storm surge models, and integrate freshwater flooding and storm surge models. The position will be renewed on an annual basis, for a minimum of 2 years, based on satisfactory performance. With strong performance, there is potential for advancement.

Candidates should have a doctoral degree from an accredited institution in a relevant science or engineering discipline and have an interest in disaster preparedness, resilience, and hazard insurance. Advanced knowledge of numerical modeling is required and experience of storm surge and wave modeling is preferred. A successful candidate will have: (1) a strong quantitative and analytic background, (2) strong programming skills in Fortran or C/C++ and Python or Matlab, and (3) effective communication skills with an ability to work within a multi-disciplinary research team.

Applicants should send a curriculum vitae, cover letter, 1–2 representative publications, and the contact information of two references to Dr. Keqi Zhang (zhangk@fiu.edu) and Mrs. Carolyn Robertson (crober@fiu.edu). Review of applications will begin on July 17, 2017 and will continue until the position is filled.

Professor of Atmosphere Ocean Science and Mathematics (open rank, tenured/tenure track), The Courant Institute of Mathematical Sciences at New York University

The Center for Atmosphere Ocean Science (CAOS), a unit of the Department of Mathematics within the Courant Institute of Mathematical Sciences at New York University, seeks candidates for an open rank faculty position, anticipated to begin in September 2018. Appointments may be made at either a junior or senior level. The CAOS group focuses on the intersection between applied mathematics and atmosphere ocean science (including the cryosphere), and hosts a distinct interdisciplinary PhD program within the Courant Institute. The ideal candidate will leverage existing strengths of the Courant Institute in applied mathematics to atmosphere-ocean-climate research. A research focus in multi-scale dynamics, high-performance simulation, or physical oceanography would be especially attractive, but exceptional candidates from any relevant area will be considered.

Please include a CV, a short statement of your research and teaching interests, and a list of at least three references who could provide a letter on your behalf upon request.

A PhD in Atmospheric Science, Oceanic Science, Mathematics, or a related field is required.

Applications can be submitted through Interfolio.com via the direct link https://apply.interfolio.com/42829.

Applications and supporting documents received by September 30th, 2017 will receive full consideration.

The Courant Institute/New York University is an Equal Opportunity/Affirmative Action Employer. Applications from women and underrepresented groups are particularly encouraged.

New York University is situated in Greenwich Village, one of the most vibrant and family friendly neighborhoods in the City of New York.

Postcards from the Field

Greetings, All!

Here's a double rainbow that occurred during a frontal shower near the Lincoln, Neb., airport, captured during the NASA-funded Atmospheric Carbon and Transport-America (ACT-America) campaign in summer 2016. For more information, visit http://bit.ly/Act-America.

—Sandip Pal, Department of Meteorology and Atmospheric Science, Pennsylvania State University, University Park

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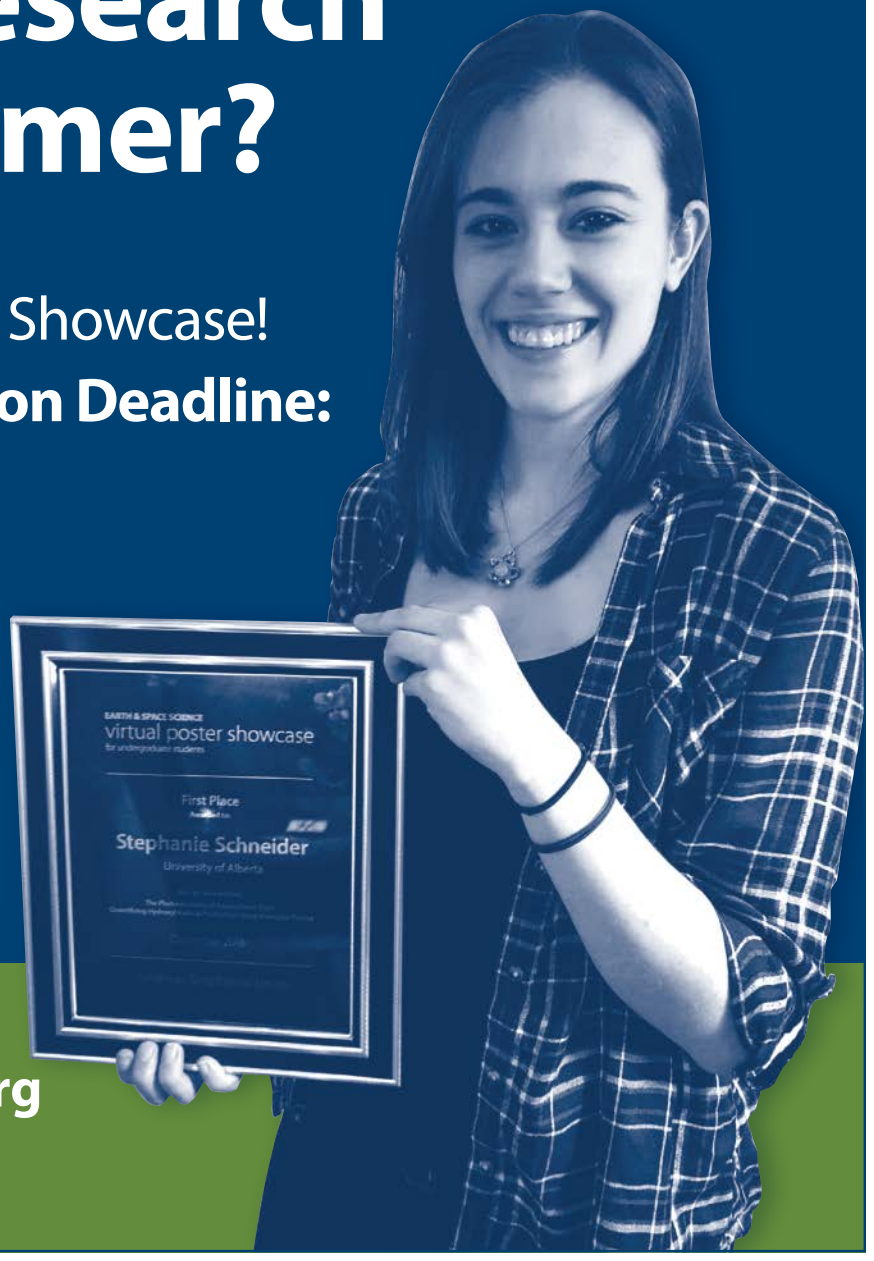

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