

VOL. 97 • NO. 19 • 1 OCT 2016  
**EOS**  
*Earth & Space Science News*

**Global Risks  
from Coastal Subsidence**

**Lessons from  
Dwarf Planets**

**AGU Expands  
into Geohealth**

# **Snapshots of Research in National Parks**



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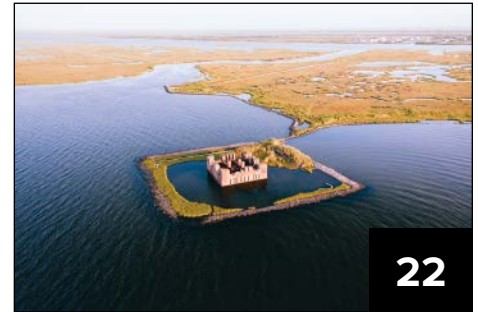


COVER

## Six Snapshots of Geoscience Research from National Parks

As the National Park Service celebrates its 100th anniversary this year, we celebrate ongoing Earth and atmospheric research made possible by conservation efforts.

### PROJECT UPDATE



### Global Risks and Research Priorities for Coastal Subsidence

Some of the world's largest cities are sinking faster than the oceans are rising. Humans are part of the problem, but we can also be part of the solution.

### NEWS



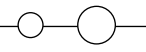
### What Have Dwarf Planets Taught Us About the Solar System?

It's been 10 years since Pluto was reclassified as a dwarf planet. But no matter the label, it and its dwarf planet cousins continue to stun researchers with their complexity.

### RESEARCH SPOTLIGHT

### 31 Tracking Down Elusive Origins of Kazakhstan's 1889 Chilik Quake

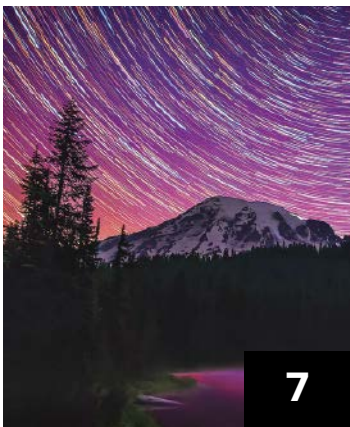
New fieldwork and satellite data suggest that three faults may have caused a large earthquake near Almaty, Kazakhstan, more than a century ago.



**DEPARTMENTS**



**32**



**7**

**3–11 News**  
 Closest Ever Terrestrial Exoplanet Found, Habitability Debated; Scientists Bittersweet as Australia Backtracks on Climate Cuts; U.S. Parks to Make Adaptation to “Continuous Change” a Top Goal; Stamps Celebrate National Parks During Agency’s Centennial; What Have Dwarf Planets Taught Us About the Solar System?

**12 Meeting Report**  
 Advancing Soil Carbon Cycle Science.

**28–29 AGU News**  
 AGU Journals: More Content and More Context; AGU Expands into Geohealth, Starting with New Journal.

**30–32 Research Spotlight**  
 Spotting the Source of Slow Solar Wind; Tracking Down Elusive Origins of Kazakhstan’s 1889 Chilik Quake; Scientists Map Temperature and Density in Earth’s Exosphere; How Do the Deep Waters of the Antarctic Form?

**33–40 Positions Available**  
 Current job openings in the Earth and space sciences.

**Inside Back Cover: Postcards from the Field**  
 The remotely operated vehicle *Jökull* investigates a massive, partly submarine landslide in Alaska’s Icy Bay.

**On the Cover**  
 Bison graze in Yellowstone National Park. Credit: istock.com/stellalevi.

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**Editor in Chief**  
**Barbara T. Richman:** AGU, Washington, D. C., USA; eos\_brichman@agu.org

**Editors**

<b>Christina M. S. Cohen</b> California Institute of Technology, Pasadena, Calif., USA; cohen@srl.caltech.edu	<b>Wendy S. Gordon</b> Ecologia Consulting, Austin, Texas, USA; wendy@ecologiaconsulting.com	<b>Carol A. Stein</b> Department of Earth and Environmental Sciences, University of Illinois at Chicago, Chicago, Ill., USA; cstein@uic.edu
<b>José D. Fuentes</b> Department of Meteorology, Pennsylvania State University, University Park, Pa., USA; juf15@meteo.psu.edu	<b>David Halpern</b> Jet Propulsion Laboratory, Pasadena, Calif., USA; davidhalpern29@gmail.com	

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# Closest Ever Terrestrial Exoplanet Found, Habitability Debated



ESO/M. Kornmesser

An artist's rendition of newly discovered terrestrial exoplanet Proxima b, which orbits 4.2 light-years away around our closest star neighbor, Proxima Centauri.

**T**here's a new, rocky exoplanet in the neighborhood: Proxima b.

Exoplanets may seem to be a dime a dozen these days—Kepler alone has racked up more than 2000 exoplanet detections—but there are some extra-special things about Proxima b. For one, it orbits our nearest stellar neighbor, Proxima Centauri, a red dwarf about 4.2 light-years away. It's also at least 1.3 times the mass of Earth and orbits in Proxima Centauri's "habitable zone," where liquid water could exist, according to a *Nature* paper published 24 August (<http://bit.ly/Proximab>).

Proxima b is not only the closest terrestrial planet known; "it's the closest planet outside our solar system that will ever be found, because there is no star closer to our solar system," said Ansgar Reiners, a coauthor on the new paper and an astrophysicist at Georg August Universität Göttingen in Germany.

## Planet Hunting

Using data from ground-based telescopes at the European Southern Observatory (ESO) in Chile, the team found Proxima b by looking at the subtle ways it affects the movement of its star, or the star's "Doppler wobble." This

effect occurs when an object projecting sound or light waves moves toward or away from its observer, affecting the way the observer perceives the sound or light waves. When the

**It might be more accurate to say that the exoplanet resides in the star's "temperate zone"—as in, it's the right temperature for hosting liquid water.**

object moves away from the observer, it seems to give off longer wavelengths, and the wavelengths seem shorter when it comes toward the observer.

While observing Proxima Centauri, the researchers noted that on a periodic basis, the star's light spectrum shifted toward red—or longer wavelengths—and then toward blue, or

shorter wavelengths. This Doppler wobble indicated that an exoplanet might be pulling on the star ever so slightly.

In fact, the team calculated that Proxima Centauri approaches Earth at 5 kilometers per hour and then recedes at the same speed over a period of 11.2 days. This 11-day cycle represents the exoplanet's short orbit around its star.

Guillem Anglada-Excludé, an astronomer at Queen Mary University of London and lead author on the paper, thought he had caught this planet several years ago after analyzing data collected from ESO's telescopes in 2000–2008, but he wasn't convinced. Further observations during the first half of 2016, using ESO's High Accuracy Radial Velocity Planet Searcher, convinced Anglada-Excludé and his team that they had an exoplanet. The research was part of the Pale Red Dot campaign, a program that searches for exoplanets around Proxima Centauri while connecting science to the public (see <https://palereddot.org/>).

## Habitable Zone Versus Temperate Zone

Earlier this month, rumors flew around the Web, based on an anonymous tip received by

the German weekly news magazine *Der Spiegel*, that the planet was Earth like and potentially habitable (see <http://bit.ly/exorumors>). Proxima Centauri is only 0.15% as bright as our Sun and only 14% as large, but because the exoplanet orbits so close—at 5% of the distance between Earth and the Sun, a tighter orbit than Mercury’s—it is smack-dab in the star’s habitable zone, the place where any existing water could be liquid.

Not only is the exoplanet’s size similar to Earth’s, but also it’s thought to be rocky like Earth, given its relatively small size. However, that’s where the comparisons end. Whereas Earth rotates and receives sunlight on all sides, the new exoplanet’s proximity to its host star suggests that it’s tidally locked—meaning that one side always faces the star, giving it a constant dayside and constant nightside. Although this doesn’t necessarily rule out habitability, the researchers aren’t even sure the planet has an atmosphere, much less one that could support life.

Further, because of its closeness, Proxima b is much more vulnerable to the star’s onslaught of solar flares and X-ray radiation. Although the paper notes that Proxima b

receives as much as 400 times the amount of X-ray flux from its star than we receive from ours, in a press conference on 23 August the researchers noted that a more typical flux could be only 100 times more—good news for potential habitability.

It might be more accurate to say that the exoplanet resides in the star’s “temperate zone”—that is, it’s the right temperature for hosting liquid water, explained Artie Hatzes, an astronomer at the Thuringian State Observatory in Tautenburg, Germany, in an accompanying *News and Views* article (see <http://bit.ly/NVProximab>). Hatzes was not involved in the research.

However, the existence of an atmosphere and liquid water depends on the system’s history, Reiners said, and many different formation scenarios lead to different outcomes. For instance, if the exoplanet formed out of material from far away, where it could have picked up ice, the planet could currently have water on its surface. Another scenario says that if Proxima Centauri was more active in its primitive years, its solar flares could have stripped the planet of an atmosphere.

Right now, these scenarios are all speculation, the researchers noted.

### Scratching the Surface

Despite the habitability debate, “the discovery proves that planets with certain characteristics similar to Earth are literally everywhere—including the nearest star to our solar system,” said Daniel Huber, an astrophysicist at the University of Sydney in Australia who wasn’t involved in the research.

Most of our understanding of exoplanets comes from those too far away to study in great detail, Huber said. For example, in 2015, scientists confirmed that another planet, Kepler-186f, also orbits its sun in the habitable zone. However, that planet is 500 light-years away.

The fact that scientists have “already found a near-Earth-mass planet orbiting the star closest to our Sun demonstrates that we have only started to scratch the surface of exploring planets in our solar neighborhood,” Huber said.

By **JoAnna Wendel**, Staff Writer



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# Scientists Bittersweet as Australia Backtracks on Climate Cuts



John Englart ("Takver"), CC BY-SA 2.0 (<http://bit.ly/ccbysa2-0>)

More than 100 climate scientists attending the Australian Meteorological and Oceanographic Society climate science conference in Melbourne staged a lunchtime protest on 8 February 2016 over restructuring and cuts to the Commonwealth Scientific and Industrial Research Organisation staff and climate research programs. This summer, some of these cuts were ordered to be scaled back.

Australia's scientific community expressed some measure of relief this summer after a top deputy to Prime Minister Malcolm Turnbull ordered the country's independent research agency to scale back further its plans to cut much of its basic climate research staff.

The directive from Science Minister Greg Hunt called for restoring 15 lost jobs and injecting \$37 million in new climate research funding over the next decade at the Commonwealth Scientific and Industrial Research Organisation (CSIRO), his office said on 8 August. That comes alongside a broader \$100 million, 3-year boost in funding across the board for CSIRO following federal elections in July.

Many scientists said they were pleased that Turnbull's government finally intervened after previously staying on the sidelines in the controversy over CSIRO, which dates back to early this year. Still, some argued that the intervention was too little too late and that details on its practical impact are still lacking.

"This is a good first step, but there are still a large number of very significant questions," Will Steffen, a climate researcher at Australian National University's Climate Change Institute, told *Eos* by phone.

## Another Partial About-Face

The development comes on top of a previous partial about-face by CSIRO leadership itself in April. CSIRO head Larry Marshall had announced the creation of a new Climate Science Centre (CSC) to oversee and coordinate much of CSIRO's remaining modeling and measurement projects. CSIRO leadership also said, at the time, that the agency had reduced its planned job reductions from roughly 70 to 40 of the agency's 140 climate research staffers.

The first job reductions plan came to light in February, when Australian media reported that CSIRO leadership told staff of its proposed cuts coupled with new hires in other areas. CSIRO leaders wanted to shift focus toward climate change mitigation and adaptation, arguing that Australia needed economically innovative research to stay globally competitive.

Scientists and scientific organizations around the world—along with leaders from the opposition Labor Party and the Australian Greens—called CSIRO's plans a blow to Australia's scientific reputation and said other Australian research institutions might not be able to compensate for the capacity reduction. They also argued against the research focus

shift, rejecting Marshall's assertions that scientists had gained sufficient understanding of Earth's climate system.

Now, with the 15 restored jobs, CSIRO's climate research staff will stand at about 115, Hunt told the Australian Broadcasting Corporation's *AM* show on 4 August. Moreover, in a speech on 8 August to the Australian Academy of Science (AAS), Hunt said that the new funding and jobs for CSIRO would help create a decadal climate monitoring and forecasting program within CSC.

Hunt's office directed questions from *Eos* to transcripts of the *AM* interview and AAS speech. CSIRO's press office didn't respond to requests for comment.

## Positive Step?

In a statement, AAS, which has been reviewing the country's climate science capabilities, called the job and funding boost a "positive step," as long as it "is effectively led and coordinated."

Steffen expressed hope that AAS's review would shed light on the net impact of the CSIRO cuts and the partial reversals on Australia's climate research capabilities. "The critical question is, What does this mean in reality, in the details?" Steffen said. "We still don't know for sure."

## Australia's Scientific Reputation

Steffen also argued that the additional funding and restored jobs—even if implemented properly—wouldn't undo the damage that the CSIRO cuts inflicted on a scientific reputation that Australia had taken "many, many years" to build.

Steffen cited the news that renowned CSIRO sea level researcher John Church was among the staffers who lost their jobs as symbolic of the damage the cuts have inflicted. "That can't be undone for a long time," Steffen said.

Hunt rejected the notion of significantly harmed scientific reputations in the *AM* interview. "Our job is to take where we are now and to strengthen the science and to strengthen our reputation, to attract great scientists from around the world," he said, adding that the "clear direction" that he and Turnbull were ushering in would aid in that endeavor.

By **Puneet Kollipara**, Freelance Writer; email: [puneet.kollipara@gmail.com](mailto:puneet.kollipara@gmail.com)

# U.S. Parks to Make Adaptation to “Continuous Change” a Top Goal

**P**rior to the U.S. National Park Service’s (NPS) centennial on 25 August, *Eos* spoke with Gary Machlis, science adviser to NPS director Jonathan Jarvis, about science and the national parks, climate change and other challenges facing the park system, and the Park Service’s plans for resource stewardship. The park system comprises 412 areas, including national parks, monuments, historic sites, seashores, recreation areas, and scenic rivers and trails.

Machlis, who is the first person to serve as science adviser to an NPS director, said that the Park Service plans to finalize on 15 December a new director’s order (number 100) that will update resource management and stewardship guiding principles and policies in the park system. This order incorporates an overarching goal from a 9 June NPS policy memorandum “to steward NPS resources for continuous change that is not yet fully understood.” The memorandum recognizes that climate change creates “dynamic environmental shifts that impact both natural and cultural resources.”

The memorandum grew out of a 2012 report by the National Park System Advisory Board Science Committee (see <http://bit.ly/2bAwMCd>). It updates a 1963 guiding document on resource management that said the goal of managing national parks and monuments “should be to preserve, or where necessary to recreate, the ecologic scene as viewed by the first European visitors.”

Machlis, who holds a Ph.D. in human ecology and is University Professor of Environmental Sustainability at Clemson University in Clemson, S.C., told *Eos*, “Now we must manage [parks] for what we know to be true: that they are not snapshots, they are films. I believe this new policy will lead to a new chapter [of] science in the national parks.”

The 9 June memorandum, which provides interim guidance to NPS during the development of the director’s order, also calls for basing NPS resource stewardship decision making on “the best available sound science and scholarship, accurate fidelity to the law, and long-term public interest.”

**Eos:** *Why is science important to the national parks and the Park Service?*

**Machlis:** Science is important for the national parks in two ways in my opinion, and they have to do with the guiding strategy of ours: parks for science and science for parks. Parks for science means these are important scientific assets, whether they are used to benchmark climate change [or] to discover, for example, bacteria cultures that could be used from the hot pools of Yellowstone to speed up and make [genetics advances] possible....

[For] all of that, the parks are an important national laboratory for science.

On the other hand, we need science to make good decisions on very complex problems, [such as] how to address siltation and sedimentation in the Colorado River and its effects on the hydrology and water regime of [the river’s] canyon. ... There is a whole realm of science that informs parks. That’s why our approach has to be both parks for science and science for parks. They are not separate. Often, science for parks—the operational applied science we do for

parks—discovers and contributes to new science. Often, new science and new scientific methods, such as remote monitoring, become critical tools for the operational science we are doing.

**Eos:** *What are some of the major challenges facing national parks right now?*

**Machlis:** One of the overarching ones is climate change. ...every young per-



Gary Machlis, science adviser to National Park Service (NPS) director Jonathan Jarvis.

son [who] joins the Park Service now [for] their entire careers will grapple with climate change because [it] is a fundamental transformation of very complex and sophisticated ecological systems. We don’t know the full extent of this, and it will take a generation to try to figure that out. We already see parks in continuous change. We see the effects of climate change in parks from coastal parks and sea level rise to parks [with] glacier retreat. And [climate change’s] impact on plants, animals, people is significant and ongoing. ... In some ways, climate change is a foundational challenge because it accelerates so many others. Examples would be biodiversity loss, habitat fragmentation, pollution, encroachment, [and] overdevelopment.

**Eos:** *What are the biggest opportunities you see for science and the national parks?*

**Machlis:** The biggest opportunity I see is a generation of incredibly smart young scientists who are creative, brilliant, well equipped with contemporary theory and with new forms of research, data collection, etc., who have broken down all kinds of barriers, who trust interdisciplinary research, who are open and curious, and who have a great love of science.

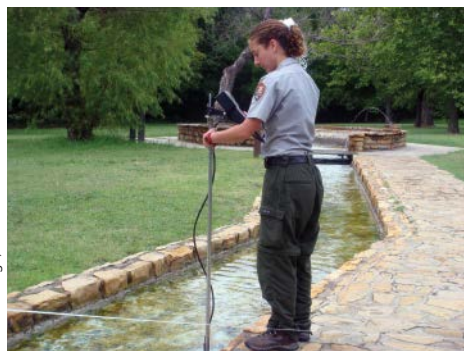
Another opportunity is the value of parks for science and science for parks as a guiding strategy. The more we do that, the more parks are seen not just as [places] that need science to operate but that also provide the scientific community with opportunities to advance basic knowledge. That’s an exciting opportunity. Who knows what will come from that, what discoveries will occur? Linking parks for



Oxbow Bend in Grand Teton National Park. The park was created by Congress in 1929.



## Stamps Celebrate National Parks During Agency's Centennial



Steve Blurrough, NPS

NPS stresses parks for science and science for parks, according to Gary Machlis, science adviser to the NPS director. Pictured, NPS hydrologic technician Emily Clark takes measurements to determine the rate of flow at Vendome Well in the Chickasaw National Recreation Area, Oklahoma.

science and science for parks, I think, has all kinds of future benefits.

**Eos:** *What is the future of citizen science in the parks?*

**Machlis:** There are now small affordable sensors that individuals can wear on their wrists that record atmospheric chemistry at [sufficient] levels of accuracy and data frequency to be useful to science. They are already being used by Chinese citizens to measure air quality in China's urban cores and to create independent data sets, independent of government.

Citizens can become more than just data collectors. Look at the popularity of the Audubon bird count. That's citizens trying to contribute to our body of knowledge. Add to that that [for] the generations after World War II... we have an educated citizenry about science at levels we've never had before. All of that bodes well, actually is hopeful, in terms of the public broadly engaging in science and for those that don't have it, rediscovering the public virtue of science.

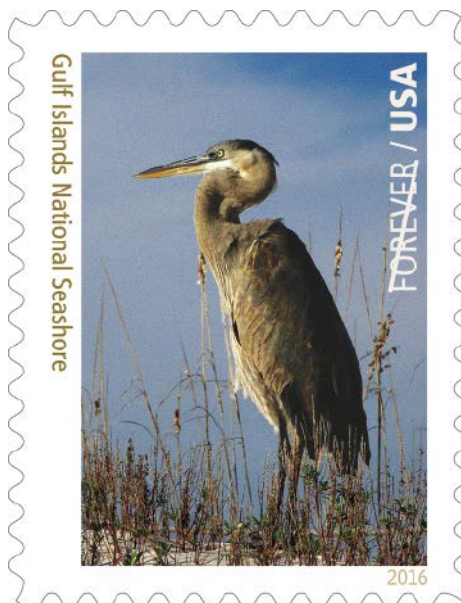
**Eos:** *What is the significance of the Park Service centennial?*

**Machlis:** The centennial is important because it is an achievement of the American people. It's not 100 years of a bureaucracy [or] 100 years of a government. It's that the American people created this extraordinary system of national parks. ... If we celebrate the achievement of the American people in the centennial and we keep our eyes focused on advancing science for parks and parks for science, I think that [the next] chapter in the history of science in the parks will get written and it will be very, very good.

Recently issued U.S. postage stamps provide a snapshot of the beauty and diversity of the vast system of national parks managed and maintained by the U.S. National Park Service (NPS), which celebrated its 100th birthday this summer.

A 16-stamp sheet, issued on 2 June by the U.S. Postal Service (USPS), includes stunning photographs and paintings of National Park Service lands, wildlife, and more from across the country. The sheet features imagery from some of the park system's most iconic treasures, including Yellowstone and Grand Canyon national parks.

In consultation with NPS, the postal service also included lesser known gems such as Theodore Roosevelt National Park in North Dakota and the small, urban Kenilworth Park and Aquatic Gardens in Washington, D. C. The stamps highlight the variety of park system locales, according to William Gicker, creative director and manager of the USPS stamp program.



A heron at the Gulf Islands National Seashore, which includes barrier islands in Florida and Mississippi. Photo by John Funderburk.



Mount Rainier National Park in Washington State. Matt Dieterich, who worked as an intern with the National Park Service's Geoscientists-In-the-Parks program, took 200 photographs between 2:00 a.m. and 4:00 a.m. on 22 June 2015 to make this "star trails" image.

"We think of stamps as miniature works of art that showcase the best of our country," Gicker said.

### One Hundredth Anniversary

The nation's first national park, Yellowstone, was established in 1872, prior to the creation of NPS in 1916. Today the century-old agency oversees 412 scenic lands, ocean sanctuaries, historic structures, and other sites, many of which have also served as settings for scientific discovery.

The arrangement of images on the commemorative stamp sheet roughly approximates their locations in the United States (see sheet image on next page). The top right corner of the sheet, for instance, features a David Muench photograph of the rocky shore of Acadia National Park in Maine; the bottom left corner showcases a rainbow-streaked image by Kevin Ebi of Haleakalā National Park in Hawaii.

### Nature Stamps Always Popular

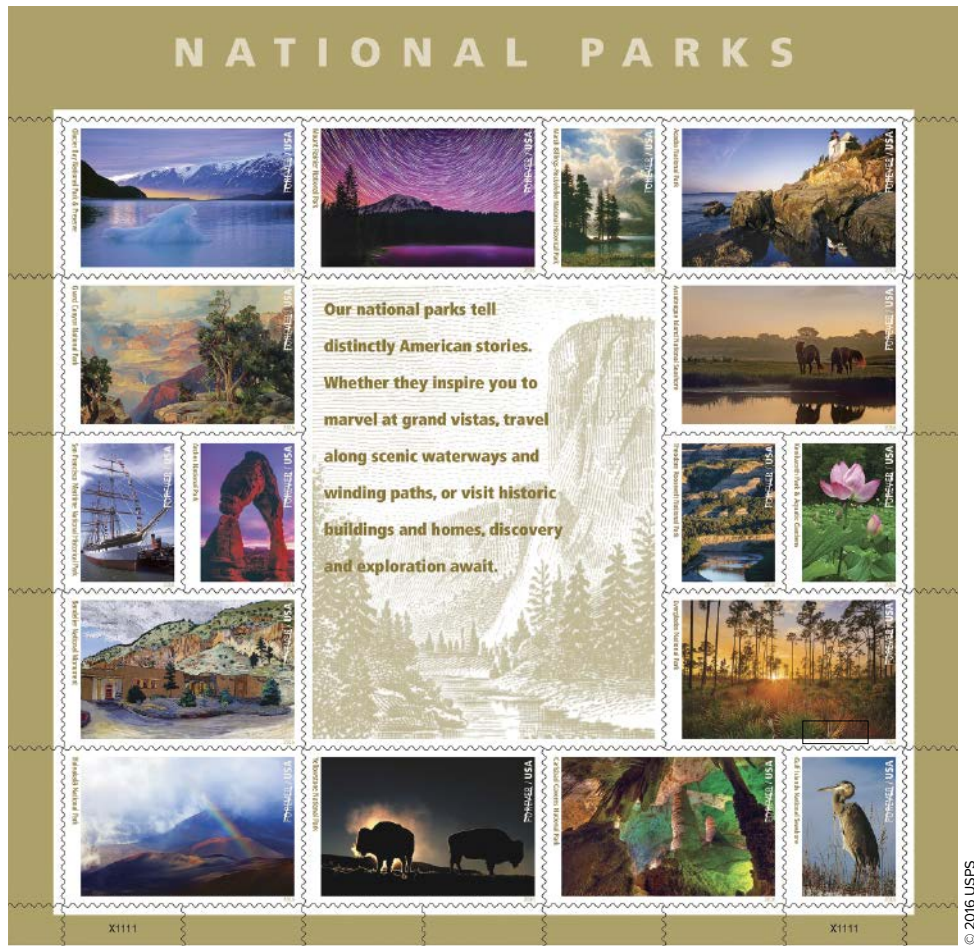
Nature stamps are always popular with the public, Gicker told *Eos*. The Citizens' Stamp Advisory Committee, appointed by the postmaster general, annually receives about 40,000 requests for new stamp designs, he said. USPS issues about 25 each year. Stamp selection criteria include honoring "extraordinary and enduring contributions to American society, history, culture or environment," according to USPS.

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The placement of stamps on the sheet commemorating the National Park Service centennial roughly approximates the locations of the pictured parks across the United States.

“Our goal is to always create stamps that are beautiful, interesting, and educational,” Gicker said.

**Visual and Textural Diversity**

Ethel Kessler, one of USPS’s four art directors for stamps, received the assignment to find and winnow down dramatic images of the national parks, then design a compelling set of stamps from them. The set, which could fill

just one sheet, needed to delight stamp buyers while also fitting into stamp collector books.

Kessler, who works on about 10 stamp projects at any given time, told *Eos* that for this project she sought visual and textural diversity in the images by including photographs and artwork from parks across the country. “I wanted a feeling of amazement, that each [image] gives you a completely different experience,” she said.

For every image used, Kessler said, she passed over about 10 or 20 outstanding options because they may not have worked so well when reduced to the size of a stamp. “Not only am I interested in gorgeous images, but [I wonder], ‘Do they reduce and hold up?’” she said.

The final product, she said, tries to “show something [that] people would be familiar with and, by the same token, something that was so dramatically gorgeous [that] you want to find out where the park is” and hope to go there.



Sunset through the pinelands and grasses of Everglades National Park in Florida. Photo by Paul Marcellini.

By **Randy Showstack**, Staff Writer

# What Have Dwarf Planets Taught Us About the Solar System?

**C**lassrooms across the world received some bad news on 24 August 2006. Pluto—the celestial body discovered in 1930 and named by an 11-year-old girl, the “pizzas” in the planet mnemonic “My very educated mother just served us nine pizzas”—had been officially stricken from the solar system’s family of planets and reclassified as a “dwarf planet.”

The discovery of the slightly more massive object Eris inspired the International Astronomical Union’s (IAU) decision. Proponents of the change insisted that if Pluto got to keep the label “planet,” so too should similarly sized objects—like Ceres, for instance, which was then considered a large asteroid.

A dwarf planet, by IAU’s new definition, must directly orbit the Sun. It must be massive enough for gravity to pull it into a roughly spherical shape. But unlike regular planets, dwarf planets haven’t cleared other smaller celestial debris out of their orbital paths.

As more objects got discovered, Pluto’s new label “dwarf planet” stuck. Then the jokes began.

Facebook group pages popped up, with snarky titles of “When I was your age, Pluto was a planet!” Angry Pluto enthusiasts wrote hate mail to astronomer Mike “Pluto Killer” Brown, one of the scientists who found Eris (see <http://bit.ly/PlutoKiller>). Astrophysicist Neil deGrasse Tyson, a strong proponent of the dwarf planet label, received his own stream of hate mail from crushed 6-year-olds (see <http://bit.ly/NDGTLetters>). To this day, Twitter users occasionally hurl insults at both.

Although some consider the reclassification a “demotion,” Pluto and its cousins Ceres, Makemake, Eris, Haumea, and others continue to dazzle scientists with their strange features and surprising geology. But perhaps more critical, these dwarf planets also trace a trail of scientific breadcrumbs that scientists can follow back in time to understand the origins of the solar system.

“I like to think of Pluto being the dwarf planet that showed us how the solar system’s architecture came to be,” said Renu Malhotra, a planetary scientist at University of Arizona’s Lunar and Planetary Laboratory.

Here are six such revelations about the solar system that we gained from studying dwarf planets.

**1 Dwarf Planets Are as Complex as Regular Planets.** When the New Horizons probe passed by Pluto more than a year ago, scientists found a complex system with areas of geologically young surface and evidence of active geology. Pluto, the images revealed, wasn’t just a chunk of rock orbiting in space. “Even I underestimated what we would find,” said Alan Stern, principal investigator of the New Horizons mission.

Pluto continues to stun scientists with its unexpected surface features, but its newly revealed complexity is just the beginning. Makemake has no atmosphere. Haumea spins faster than any other known large object in the solar system. Eris might have a thin, icy surface. Ceres hosts mysterious bright spots.

“The fact that these objects can be every bit as complicated as terrestrial planets is a headline,” Stern said. “It should be written in as big a point size as we can write it, because it was completely unexpected.”

**2 Dwarf Planets Reveal Neptune’s Orbital Origins.** By studying the particular orbital relationship between Pluto and Neptune, scientists figured out how Neptune got to its current position in the solar system. The two bodies are inextricably locked in an orbital resonance: Every time Neptune orbits the Sun three times, Pluto orbits twice, which means that even though Pluto may occasionally cross Neptune’s orbital path, they will never meet.

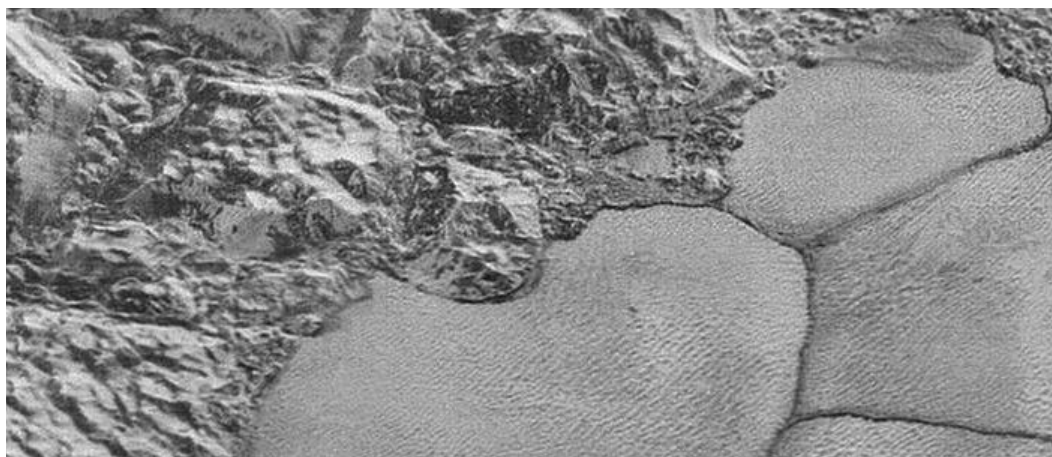


NASA/JHUAPL/SRI

On 14 July 2015, NASA’s New Horizons probe snapped the first ever close-up images of Pluto. Scientists continue to be stunned by its unexpectedly complex surface features.

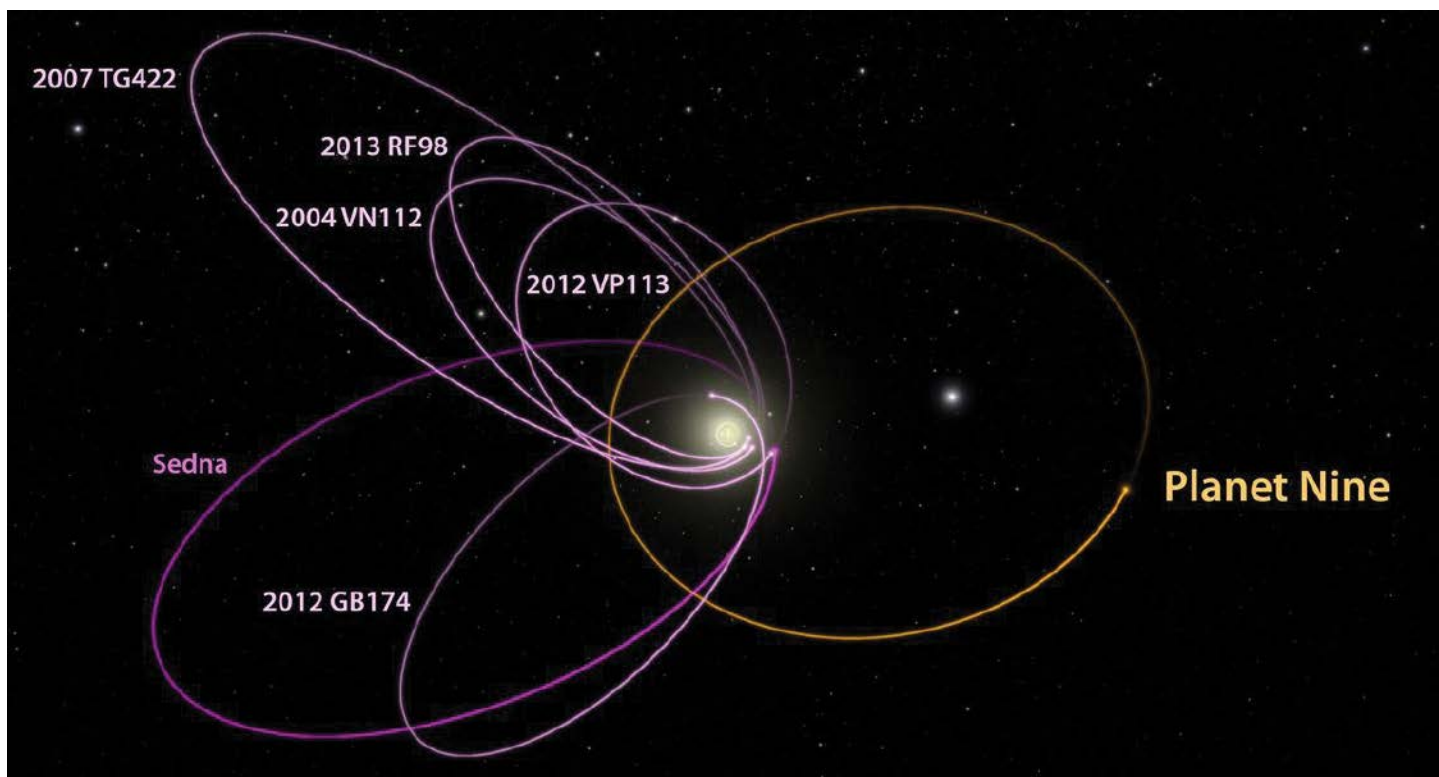
Scientists have always known about this resonance, but it was Malhotra who realized its significance. In a 1995 paper, Malhotra calculated that the only way Neptune and Pluto could have ended up in this resonance was if they both had formed closer to the Sun, then migrated outward (see <http://bit.ly/MalhotraPluto>).

Scientists theorize that in the early days of the solar system, the gas giants, Jupiter, Saturn, Neptune, and Uranus, migrated inward toward the Sun and knocked out leftover debris. This gravitational push on planetary debris ended up changing the planets’ orbits as well, sending Neptune farther out. Nep-



NASA/JHUAPL/SRI

A mosaic of Pluto’s complex surface taken by the New Horizons probe from about 15,000 kilometers away as it approached Pluto on 14 July 2015. Scientists are working to understand the origins of these unexpectedly diverse features.

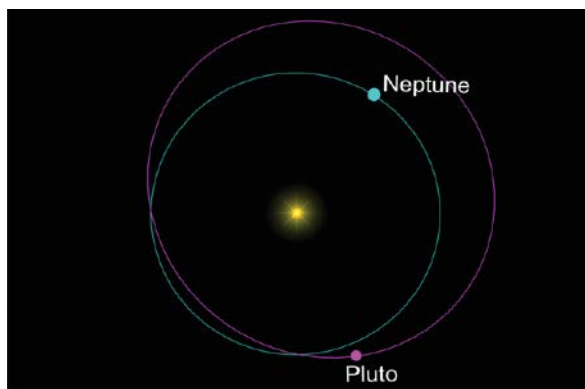


The orbits of Planet 9 and the dwarf planets it supposedly influences. Scientists calculated that only a Neptune-sized planet could keep these objects in their peculiar, angled orbits. The diagram was created using the WorldWide Telescope.

Caltech/R. Hurt (IPAC)

tune's gravitational force encountered Pluto's, and the two bodies pushed and pulled at each other until they fell into a resonance orbit. Astronomers detected the same effect in other bodies, including a new dwarf planet named 2015 RR245 announced to the world this year (see <http://bit.ly/new-dwarf-planet>).

**3 Dwarf Planets Give Us a Peek into the Early Solar System.** Dwarf planets are handy guides to the ancient solar system.



NASA/JPL

Scientists calculated that in the early solar system, Neptune migrated out to its current position and nudged Pluto into a resonance orbit. Although Pluto sometimes crosses Neptune's orbital path, the resonance prevents the two planets from colliding.

For instance, all the Kuiper belt dwarf planets—Pluto, Haumea, Makemake, and Eris—have moons that scientists suspect formed from high-impact collisions, said Scott Sheppard, an astronomer at the Carnegie Institution for Science in Washington, D. C. Haumea in particular is the only known Kuiper belt object to have a “family” that orbits along with Haumea and its moons, meaning that the debris kicked off by an impact long ago didn't have enough energy to escape Haumea's gravitational pull.

The presence of such moons is further evidence of an early period of “late heavy bombardment” of objects in the solar system. Scientists think that during this time, about 3.8–4 billion years ago, gravitational interactions among Jupiter, Saturn, and Neptune sent comets and asteroids sprawling across the solar system to collide with planets.

In the past 2 years, Ceres has also provided various windows into the past. In 2015, NASA's Dawn probe headed to the dwarf planet after visiting the asteroid

Vesta. There, scientists detected ammonia-rich clays in Ceres's surface.

Ammonia itself isn't stable at the temperatures found on Ceres (130–200 kelvins), but it is plentiful in the outer solar system. So how did the molecule get there? Scientists have formulated different hypotheses, said Carol Raymond, deputy principal investigator for Dawn. Either Ceres formed in the outer solar system, during its early days, and got kicked inward by a chaotic migration of the gas giants, or Ceres formed in the asteroid belt, and somehow ammonia-rich material from the outer solar system made its way inward.

Further study of Ceres will help clarify details of solar system formation, Raymond said.

**4 Dwarf Planet Candidates Helped Scientists “Find” Planet 9.** Thanks to a handful of debris orbiting farther away than Pluto, scientists this year found evidence that a rocky, Neptune-sized planet may lurk beyond the gaze of even our most powerful telescopes (see <http://bit.ly/Eos-Planet9>).

The story began in 2003, when Brown and his team at the California Institute of Technology (Caltech) discovered Sedna, a dwarf planet candidate that orbits far beyond the

Kuiper belt, Pluto's neighborhood of large, icy bodies 30 astronomical units (AU) away. Sedna maintains a steady orbit and comes within only 76 AU of the Sun at its closest approach.

Since then, scientists have spotted several more objects near Sedna, including 2012 VP113, found by Sheppard and colleague Chad Trujillo of Hawaii's Gemini Observatory. The pair noticed that their new object and the rest of these far-away objects had similar, steady orbits.

Back at Caltech, after reading Sheppard's and Trujillo's work, Brown and his colleagues set out to find the cause of such clustering, and after many hours of poring over models and simulations, they officially proposed that only a planet-sized body could exert enough gravitational pull to keep the far-away cluster of dwarf-planet-sized objects in steady orbits. This hypothesized planet was deemed Planet 9 (sometimes called Planet X).

"Right now we're doing surveys trying to find more dwarf planets," Sheppard said. "If we find more and more of these, they can lead us to the much bigger, major Planet X."

**5 Ceres (We Hope) Will Help Us Understand Icy Ocean Moons.** Kuiper belt dwarf planets aren't the only thing keeping scientists busy. Dawn mission scientists recently discovered that regions of Ceres contain higher concentrations of carbonate minerals than anywhere outside of the Earth's ocean floor. These minerals reveal that Ceres is like a "fossilized" ocean world, Raymond explained. They could be the



There may be only six officially designated dwarf planets (missing from the image is 2015 RR245, announced this year), but many more dwarf-planet-sized objects exist. They may even be the dominant class of objects in the solar system.

remnants of a vast ocean that once existed on the dwarf planet.

Scientists figured out that mysterious bright patches in Ceres's geologically young Occator crater come from sodium carbonate, a highly reflective mineral found in hydrothermal environments under Earth's oceans. This means that at some point in Ceres's history, hydrothermal processes must have pushed this material to the surface, Raymond said.

If hydrothermal processes are confirmed, Ceres's surface may be analogous to the current seafloors underneath the solar system's ice-covered moons. Astrobiologists yearn to

peek below the icy shells of Jupiter's and Saturn's moons Europa and Enceladus because there are vast oceans underneath, and life needs water to proliferate.

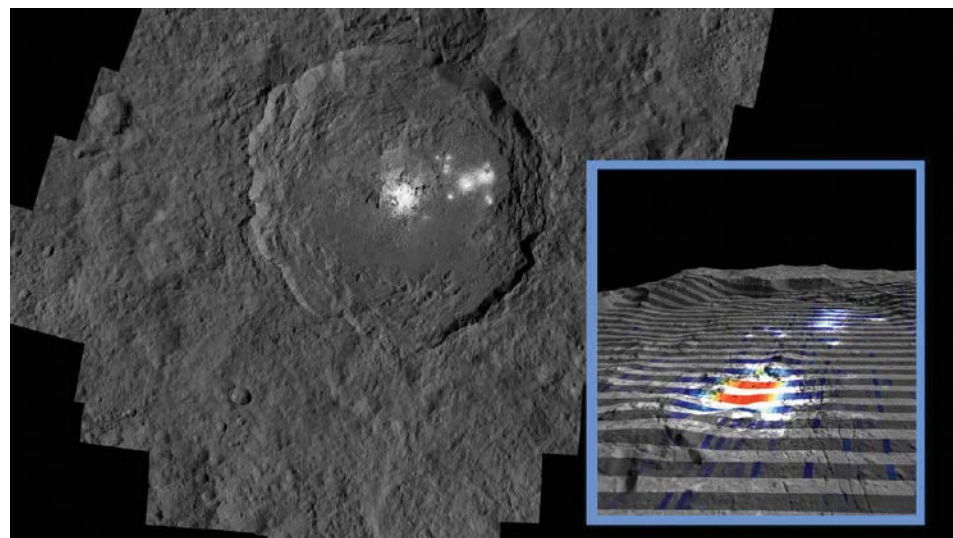
Ceres is similar to these moons because 25% of the dwarf planet is water ice. Plus, its seafloor-type conditions are "where all of the elements necessary for habitability occur together," Raymond said.

**6 Dwarf Planets Are Prolific.** Pluto holds a special place in the Internet's collective heart but may not be so special in the solar system. Currently, there are six dwarf planets officially designated by IAU: Pluto, Ceres, Eris, Makemake, Haumea, and 2015 RR245, discovered in July. Since scientists started looking deeper into the Kuiper belt, they have found at least 20 more similarly sized objects, Sheppard said.

And there may be dozens more out there. "We discovered that dwarf planets are the most populous class in the solar system," Stern said. Other solar systems may be like ours too, he added.

This population revelation, along with the surprising geological and atmospheric complexity found on dwarf planets, means that the field could be "at the very beginning of a paradigm shift and a revolution," Stern said. Perhaps, he continued, it's the classic large planets that are the "oddballs" of planetary formation.

He wonders, "Who's the misfit now?"



Scientists found evidence of carbonate minerals in the bright spots of dwarf planet Ceres's Occator crater. Stripes on the inset represent where the spectrometer frames lie, whereas red signifies a high abundance of carbonates and gray indicates a low abundance. These carbonate minerals mean that Ceres may have been covered once by an ocean.

By **JoAnna Wendel**, Staff Writer

# Advancing Soil Carbon Cycle Science

## International Decade of Soils Workshop

Boulder, Colorado, 14–16 March 2016



*This soil profile in East Fork Poplar Creek in Oak Ridge, Tenn., shows the physical and biological complexity of this critical system and the susceptibility of soils to erosion.*

Scott Brooks, ORNL

4p1000.org/). The White House Office of Science and Technology Policy called for a commitment to research and education in food and agriculture from all sectors (see <http://bit.ly/Food-Ag-21st-Cen>). Meeting these commitments requires a comprehensive understanding of factors influencing the resilience and vulnerability of soil carbon.

To address these needs, the Carbon Cycle Interagency Working Group (CCIWG) convened the International Decade of Soils (2015–2024) Workshop at the University Corporation for Atmospheric Research (UCAR) in Boulder, Colo., in March 2016 (see <http://bit.ly/Soils-2016>).

The workshop's primary goals were to improve understanding of the vulnerability and resilience of carbon in soils and to improve prediction of the critical role of soils in generating feedbacks to the climate. An additional goal was to inform the second State of the Carbon Cycle Report (SOCCR-2; <http://bit.ly/SOCCR-2>), a special report of the U.S. Sustained National Climate Assessment scheduled for release in 2018.

Breakout sessions were organized around three themes:

- vulnerability of soils to global change and the potential for restoration
- factors influencing soil carbon stabilization and destabilization
- new modeling frameworks for predicting soil carbon dynamics

Theme 1 participants discussed the importance to predictions of soil carbon vulnerability and resilience of such overarching processes as disturbance, land use, and erosion. Theme 2 participants affirmed that to represent these processes in models, it is necessary to identify the types and availability of experimental and observational data for model development and testing. Theme 3

participants discussed the growing set of microbe-enabled models and recognized that the benefits of different model frameworks and levels of biological complexity have not been as systematically evaluated as other approaches.

The workshop generated three frameworks for action:

- a method using soil order classifications for assessing and predicting soil vulnerability with respect to carbon loss and potential for mitigation;
- a synthesis of proxies for modeling carbon cycling, such as carbon use efficiency, mineral sorption, and microbial community assembly; and
- measurable compartments for soil carbon models that consider mineral protection, sorption of dissolved organic carbon, aggregate formation, and particulate organic matter.

Supporting framework 1, workshop participants generated a survey to seek input from soil scientists on the impacts of global change on soil carbon. All three frameworks are being developed into forward looking conceptual publications.

The named authors thank co-organizers Rose Abramoff and Margaret Torn of Lawrence Berkeley National Laboratory, Julie Jastrow of Argonne National Laboratory, and Gyami Shrestha of the U.S. Carbon Cycle Science Program. The organizers also thank the workshop participants for their contributions, UCAR for meeting space, and CCIWG for funding.

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By **Melanie A. Mayes**, Environmental Science Division and Climate Change Science Institute, Oak Ridge National Laboratory, Oak Ridge, Tenn.; email: [mayesma@ornl.gov](mailto:mayesma@ornl.gov); **Kate Lajtha**, Department of Crop and Soil Sciences, Oregon State University, Corvallis; and **Vanessa Bailey**, Biological Sciences Division, Pacific Northwest National Laboratory, Richland, Wash.

**S**oils play an important role in the world's carbon cycle by exchanging carbon with the atmosphere and hydrosphere. Soil carbon storage regulates our climate and provides the basis for ecosystem and agricultural productivity. Understanding the role of soils is vital to these essential ecosystem services.

The Conference of the Parties to the United Nations Framework Convention on Climate Change (November–December 2015; <http://bit.ly/UNFCCC-COP21>) focused attention on carbon stabilization and developed an initiative to increase carbon stored in soil by 4 parts per thousand each year (see <http://>



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Channel names are subject to change. The final program and AGU On-Demand channel listings will be published 3 October.



# Six Snapshots of Geoscience Research from National Parks

By Amy Coombs





Dave Soltau no. Images/Getty Images

**O**n 25 August 1916, President Woodrow Wilson signed an act designating the National Park Service as a new bureau in the Department of the Interior. The act aimed to protect America's most spectacular landscapes for future generations. Now, 100 years later, visitors from all over the world enjoy 34 million hectares of historic sites, geological formations, and habitat for rare and endangered species.

To geoscientists, however, this legacy of conservation means something more. It provides opportunities to study geological processes up close, to see how protected landscapes influence ecology, and to observe the effects of humankind in even the most remote places. More than 25,000 investigator permits were issued between 2011 and 2015, allowing researchers to collect data in some of the most ecologically and geologically rich repositories in the world.

Over the past 2 years, Eos.org has highlighted several snapshots of this research. At the towering

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*A view through Mesa Arch in Canyonlands National Park in Utah.*



Stock.com/Rocky Grimes

Margerie Glacier in Glacier Bay National Park and Preserve in Alaska.

cathedral cliffs of Yosemite, scientists discovered that in addition to seasonal freeze-thaw cycles, daily temperature fluctuations exfoliate rock faces, causing giant slabs of granite to fall. Excavations within the extinct continental rift preserved at Isle Royale National Park uncovered ancient copper mines dug by Native Americans. Carbon dioxide dissolved in hydrothermal waters may play a stronger role in triggering geyser eruptions at Yellowstone than previously thought. And at the Grand Canyon, researchers are learning about sediment deposition and erosion by restoring damaged banks and sandbars altered over many years by upstream dams. For more on these research projects, visit <http://bit.ly/Eos-NPSSnapshots>.

Here are six more snapshots of research, courtesy of the U.S. National Park Service.

## 1 A Massive Landslide Once Covered Bryce Canyon

Located in southwestern Utah, Bryce Canyon National Park straddles the rim of a high-elevation plateau and is full of oddly shaped red sandstone pillars called hoodoos—each the remnant of hundreds of thousands of years of erosion. According to new research, the northern part of this major tourist destination was once buried by debris from one of the world’s largest continental landslides.

Nearly 28 million years ago, a large volcanic field consisting of several calderas and volcanoes collapsed in a matter of minutes,

according to Utah Geological Survey scientist Robert Biek and his colleagues. The researchers discovered evidence for this massive event last summer and labeled it the Sevier gravity slide.

“The slide got hot enough to melt the rock to the consistency of taffy,” said Biek. Samples indicate that the falling rock moved fast enough to pulverize ultrahard volcanic rock into powder or fragments the size of rice grains. The findings were presented in September during a series of talks at the Geological Society of America meeting in Denver.



Brian Poicus, CC BY 2.0 (<http://bit.ly/ccby2-0>)

Hoodoos—oddly shaped sandstone pillars—in Bryce Canyon National Park in Utah.



Why such a big slide? “We don’t know what the immediate triggers were, but the volcanic field sat on weak clay,” said David Hacker, a geologist at Kent State University in Ohio who helped Biek map the area.

Scientists hypothesize that inflation from volcanic activity tilted the region, causing the weak clay underneath to collapse from the weight of the spreading volcanic field. Signs of this uplift and tilt can be seen in the park’s rich stratigraphy—the researchers point to a thrust fault that pushed bright orange bands of clay southward over younger rocks. Dating studies show that this lift occurred in the time period before the field is thought to have collapsed.

Remarkably, the Sevier gravity slide is the second catastrophic event Biek and Hacker found in the Bryce Canyon area. In 2014 the team identified the Markagunt gravity slide, which occurred about 22 million years ago outside the boundary of the park. That slide covered an area the size of Rhode Island, about the same area as the previous record holder for the world’s largest known deep history landslide—the Heart Mountain event that occurred outside Yellowstone National Park about 48 million years ago.

Given the stories of these landslides, researchers from around the world are beginning to reexamine other volcanic fields for evidence of large prehistoric landslides. “There are probably slides left unrecognized because they are so darn big,” said Biek.

## 2 Halibut Habitat in Glacier Bay Helps Supreme Court Case

In the 18th century, Alaska’s Glacier Bay was covered in a thick sheet of ice. As this glacier slowly receded, it left ice-

bergs that scraped gouges into the ocean floor. According to researchers, the discovery of these grooves and the species they support helped influence a 2006 U.S. Supreme Court decision that protected ocean life from commercial fishing.

In November 1999, “the state of Alaska had sued to limit federal jurisdiction over Glacier Bay waters—the National Park Service was embroiled in litigation that stood to limit management to land-based ecosystems,” said Glacier Bay National Park and Preserve superintendent Philip Hooe, who studied the grooves while a researcher with the U.S. Geological Survey (USGS). Fortuitously, when Hooe and collaborators first shared the discovery with park staff, the special master from the Supreme Court was visiting, on a trip to review evidence.

The suit, filed by the state of Alaska, stood to benefit commercial halibut and crab fishing operations, which the National Park Service had barred from using Glacier Bay in the 1990s. The ecological models put forward by commercial fisheries suggested that halibut and other fish commonly migrated long distances beyond the park boundary and spawned outside the park, which in turn suggested that restrictions in Glacier Bay would do little to protect fisheries.

If the suit were successful, National Park Service oversight would, by default, be limited to land-based species, said Hooe.

However, the researchers discovered that the iceberg gouges were teeming with halibut. Fish surveys conducted in the grooves showed that small halibut spent long periods of time in deeper grooves. Older, larger fish burrowed in the sediment layers found in shallower gouges that had partially filled with silt. “We found that halibut had more

localized ranges than previously thought and that the park played a key role in preserving marine habitat,” Hooge added.

Multibeam echo sounding sonar found a dense network of grooves that varied from 1 to 3 meters deep. Some stretched 20 meters wide and were as long as 1 to 5 kilometers. The grooves’ geometry revealed that they formed when massive icebergs ran aground many years ago and pushed boulders aside, said study coauthor Guy Cochrane of USGS in Santa Cruz, Calif.

The findings were published in the American Fisheries Society Symposium in September 2005 (see <http://bit.ly/AFSSGlacierBay>), just months after the Supreme Court delivered its opinion in favor of federal jurisdiction, and thus National Park Service management, of Glacier Bay waters on 6 June 2005.

According to Hooge, the paper became a symbolic piece. “We showed that the same glacier processes that motivated the initial protection of parkland extended well into marine areas,” said Hooge. “The land and marine system began as one unit and the ecosystem still reflected this history.”

### 3 Sulfuric Acid Carved Caves at Carlsbad

Hidden beneath the flowering cactus and shrubs of the Guadalupe Mountains of southeastern New Mexico lies a network of more than 119 fragile limestone caves protected by Carlsbad Caverns National Park. The unusual formation of the caves was at first hotly debated, but what

began as a far-fetched hypothesis is now used to explain cavern formation in several rare caves around the world.

It is now believed that the expansive hollow rooms in Carlsbad Caverns formed when hydrogen sulfide leaked upward along fractures from the underlying oil and gas deposits in the nearby Delaware Basin. After reaching oxygen-rich groundwater, sulfuric acid formed, dissolving large voids inside the mountain’s limestone rock.

“Only 5% of the caves in the world were dissolved by this method, so it’s rare,” said David Jagnow, who proposed the theory while he was a master’s student at the University of New Mexico in Albuquerque, before he launched a career as a petroleum geologist at Shell Oil Company in Houston, Texas. “In the early 1970s this was a new idea, so I was sticking my neck out pretty far.”

After finding 10-meter-thick deposits of calcium sulfate—gypsum—in Carlsbad Caverns, Jagnow was among the first to suggest that sulfuric acid had dissolved calcium carbonate in the limestone. “The calcium sulfate indicated that a sulfuric acid reaction had taken place,” said Jagnow. However, his idea of cave formation was contested while debates raged over the source of sulfuric acid.

The mystery was settled when a cavern called Lechuguilla Cave was finally explored in the late 1980s. Although the cavern had been known as a large bat habitat since at least 1914, the cavern itself was thought to have contained only a 30-meter entrance pit and about 120 meters of dry, dead-end passages. Over the next decades, cave explorers heard wind rumbling through the floor and believed that other caverns lay hidden, but it

Panorama of the 3.3-hectare “Big Room” in New Mexico’s Carlsbad Caverns National Park.



wasn't until 1986 that experts with an exploratory permit from the National Park Service dug an entrance to a staggering 220 kilometers of passages.

The discovery paved the way for a 1989 survey conducted by USGS scientist Kimberley Cunningham, who studied whole-rock sulfur isotope ratios and the concentration of gases and fluids in the cave. Hydrocarbons turned up in the samples, lending credence to the idea that the massive gypsum deposits formed after gas escaped from petroleum deposits located beneath the water table.

More than 300 caves are now thought to have been hollowed by sulfuric acid in the Guadalupe Mountains. The theory is also used to explain caverns in other parts of the world such as the Fiume-Vento Cave in Italy, Turkmenistan's Kugitangtou caves, and Las Brujas Cave in Argentina, as well as caves in the Grand Canyon and Wyoming. "It took about 20 years before the National Park Service hung signs saying that the caverns were formed by sulfuric acid," said Jagnow. "Nowadays it's a widely accepted theory."

## 4 Climate Change May Mismatch Bird Migration and Food Availability in Acadia

Located along the Atlantic shore of Maine, Acadia was the first national park established on the East Coast. The 19,020 hectares of woodland and granite peaks are home to many migratory songbirds. These birds are potentially under threat because climate change is affecting their migration routes at the same time that it alters the availability of food sources.



*Black-and-white warbler (Mniotilta varia).*

istock.com/MamaVonLemac

"We are concerned that fruits are ripening earlier while the birds are migrating later," said Abraham Miller-Rushing, science coordinator at Acadia National Park.

To understand the effects of climate change on migration and the availability of foods like berries and insects, researchers at the National Park Service recently launched a large-scale regional study of phenology—the



istock.com/William Haun

changes in ecological cycles from year to year. The study will include several songbirds identified as species of special concern by the state of Maine, such as the yellow-billed cuckoo (*Coccyzus americanus*), the American redstart (*Setophaga ruticilla*), and the black-and-white warbler (*Mniotilta varia*), among others.

Many of these species have a primary diet of insects in the spring and summer but may switch to fruit in the fall during their migration. The study is looking at the fruits these birds eat, including black huckleberry (*Gaylussacia baccata*), mountain holly (*Ilex mucronata*), wild raisin (*Viburnum nudum*), and others, in an effort to track when buds start to form and fruit starts to ripen.

The study questions whether changes to the onset of ripening influence food availability during new migration time periods. Data must be collected over many years and at large spatial scales in numerous habitats to conclusively demonstrate phenological mismatches between, say, when berries ripen and when birds migrate overhead.

Yet some broader phenological results have already been firmly established. According to Katharine Gerst, a scientist with the USA National Phenology Network in Tucson, Ariz., research conducted over recent years shows extremely early springs in many East Coast national parks compared with the historical range of variation.

The network has archived more than 1.8 million records from national parks and open-space preserves across the nation, including data from Miller-Rushing's team. These records facilitate studies of numerous phenology variables, including nutrient cycling, the timing

of pollinator and flower availability, and the migration patterns of predators and prey.

## 5 Magma Supply Affects Eruption Rates at Hawaii Volcanoes

Kilauea Volcano is one of the most active volcanoes in the world and a feature attraction at Hawai'i Volcanoes National Park. It is also a public nuisance—communities continually face threats from lava flows and volcanic smog.

These problems motivated several studies designed to better understand and predict eruption activity, including a recent survey of magma supply from the hot spot that feeds Hawaii. "Sometimes the magma supply increases, and this causes the eruption rate to increase, and even results in new eruptive activity," said Michael Poland, a volcanologist with USGS who conducts research in Hawai'i Volcanoes National Park.

In a study of magma supply to Kilauea, published in 2012 in *Nature Geoscience*, Poland and his colleagues used GPS receivers placed in numerous locations around the volcano, as well as satellite radar data, to trace the degree of swelling caused by a magma influx (see <http://bit.ly/PolandHI>).

The readings from the instruments indicated that magma supply began increasing in 2003 and peaked in 2006. It remained high through 2007. This pattern correlated with an increase in volcanic activity that began in 2005, when the eruption rate nearly doubled.



Steam rises as lava from Kilauea Volcano in Hawaii Volcanoes National Park flows into the ocean.

istock.com/Justmeznick



Marjorie Chan

Iron concretions are found in many locations in southern Utah's red rock desert.

By 16 June 2007, the volcano had swelled with so much magma that it burst along the East Rift Zone, where a new eruption site formed and spewed lava for a few hours. A new summit eruption—the first since 1982—occurred in 2008 and continues to this day. “A lot of this activity is due to the increase in magma supply that we saw in the early 2000s,” said Poland.

Poland and his colleagues also found that carbon dioxide (CO<sub>2</sub>) emissions peaked years before the surge in magma supply itself, suggesting that the CO<sub>2</sub> ascended faster than the magma from which it was released. “We hope to be able to anticipate changes in the magma supply by tracking CO<sub>2</sub>,” said Poland.

## 6 Rock Colors at Zion, Capitol Reef, and Canyonlands Help Scientists Search for Water on Mars

Not all sandstone is the same color even within a single formation—in fact, some of the Jurassic Navajo Sandstone exposed in Zion, Capitol Reef, and Canyonlands national parks in southern Utah is richly hued with bright red, pink-orange, and even white colors. According to recent findings, color variations are likely due to the movement of fluids through the rock over time.

“Mother Nature’s artistry is based on iron as the pigment of the color palette. Iron is cycling through the Earth’s sedimentary crust via fluid flow, and the coloration left behind is a record of this process,” said Marjorie Chan, a geologist at the University of Utah who outlined the basic chemistry of red rock color in a series of papers (<http://bit.ly/UofUChan>).

First, Chan and colleagues collected representative samples of visually distinctive Navajo Sandstone colors. Then the researchers used microscope techniques, X-ray diffraction, and mass spectrometry technology to identify the mineral and pigment compositions of each sample.

Their findings painted a rich picture. The porosity of sandstones varied; highly porous rock indicated early water infiltration, and cements gave indications of where water couldn’t permeate. In addition, coatings of iron oxide residues encapsulated grains of sandstone and were found in a higher concentration in dusky brown to red colored sandstone but in lower levels in yellow-orange rock.

White rock was porous and largely missing iron-rich grain coatings, suggesting that chemicals in paleogroundwater “bleached” the sandstone over time. “Hydrocarbons, acidic fluids, or carbon dioxide are chemically capable of bleaching the sandstone white,” said Chan.

The findings have been cited by researchers interested in the Martian environment, where concentrated iron oxide minerals might indicate the presence of water long ago. The Mars rover Opportunity imaged small round “blueberries” similar in structure and formation to the circular concretions of iron oxide commonly found in Utah’s red rock desert.

“You can imagine our delight when we saw the pictures of blueberries,” said Chan. “This suggested to us that there was indeed past water on Mars that had moved through the subsurface. Here the Earth analogues from public lands provided valuable insight into the Mars geology.”

### Author Information

Author: **Amy Coombs**, Editorial Intern

An aerial photograph of a coastal wetland. The foreground is dominated by a large, dark blue body of water with visible ripples. In the middle ground, there's a smaller, lighter blue pond surrounded by green and yellowish vegetation. To the right of this pond, there's a large, rectangular stone structure, possibly a dam or a breakwater, with several vertical pillars. The background shows a vast, flat landscape with patches of water and land, extending to a distant horizon under a clear sky.

# Global Risks and Research Priorities for Coastal Subsidence

By Mead Allison, Brendan Yuill, Torbjörn Törnqvist,  
Falk Amelung, Timothy H. Dixon, Gilles Erkens,  
Roelof Stuurman, Cathleen Jones, Glenn Milne,  
Michael Steckler, James Syvitski, and Pietro Teatini





Coastal lowlands, which rise less than 10 meters above sea level, are particularly vulnerable to the climate change effects forecast for the 21st century. Threats include inundation by accelerating sea level rise and increases in severity and frequency of tropical storm surges. These threats coincide with a world-wide surge in human population in

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*The ruins of Fort Beauregard (also known as Fort Proctor) are partly submerged in Lake Borgne, east of New Orleans, La. Many coastal areas are sinking even faster than sea level is rising.*

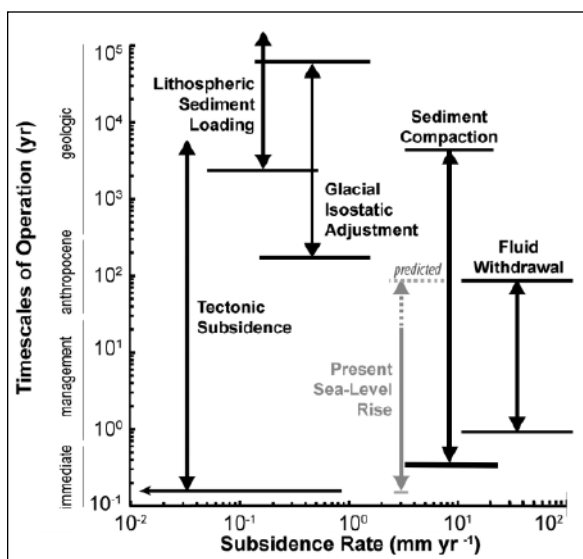


Fig. 1. Plot of major coastal subsidence mechanisms and their rates and timescales of operation. The present eustatic sea level rise and the predicted eustatic sea level rise by 2100 (possible range shown by dotted line) are also plotted, demonstrating the important contribution of subsidence to relative sea level rise in coastal areas. (Eustatic sea level changes are driven by changes in the volume of water in the ocean or changes in the shape of ocean basins rather than by land elevation changes.)

coastal areas. Coastal population centers include several megacities, whose populations exceed 10 million. Many of these coastal megacities are located on river deltas that are also major centers for agriculture, fisheries, and hydrocarbon production.

To make matters worse, many coastal areas are sinking even faster than the waters are rising: Natural and human-driven subsidence rates arising from shallow processes can be 1–2 orders of magnitude greater than the rate of climate-driven sea level rise predicted for the remainder of the 21st century (Figure 1).

The risk of rapid coastal subsidence to infrastructure and economies, as well as to the natural environment in coastal lowlands, is global and is most acute in large river deltas, which are home to about 500 million people.

Thus we have a pressing need to understand what drives coastal subsidence. We must develop better measurements and modeling, and we must link this science with its socioeconomic implications. In response to this need, an international community of researchers organized a series of workshops—one in New Orleans, La., in 2013 (see <http://bit.ly/subsidence-2013>), and another in Venice, Italy, in 2016 (see <http://bit.ly/subsidence-2016>).

As a result of this effort, a working group strategy has emerged that uses key geographic sites to design and test measurement and monitoring methods. Here we report our progress on research in the Mississippi Delta in Louisiana, and we summarize recent efforts to expand this research into other coastal areas. However, the larger goal of the coastal subsidence working group is to initiate global research and monitoring initiatives to address the critical knowledge gaps we must fill to pro-

tect coastal populations, infrastructure, and natural resources.

### Subsidence Drivers

Human modifications, mainly concentrated in a zone as much as a few hundred meters below the land surface, are responsible for the largest contributions to the subsidence that appears at the ground surface, although other factors contribute as well [Syvitski *et al.*, 2009]. Compaction of high-porosity near-surface sediments often dominates land subsidence [Törnqvist *et al.*, 2008]. The risk is compounded when flood control levees and embankments prevent the deposition of sediment that could compensate for this compaction. Thus the potential exists for humans to mitigate these types of risks and effects.

Deeper, often poorly understood, processes also contribute to coastal subsidence, including thermal subsidence and fault motion. However, these deeper processes typically contribute less than a few millimeters per year (Figure 1) to the overall loss in elevation in most coastal areas, in contrast to human-caused effects like water withdrawal, which can contribute as much as a meter of subsidence annually.

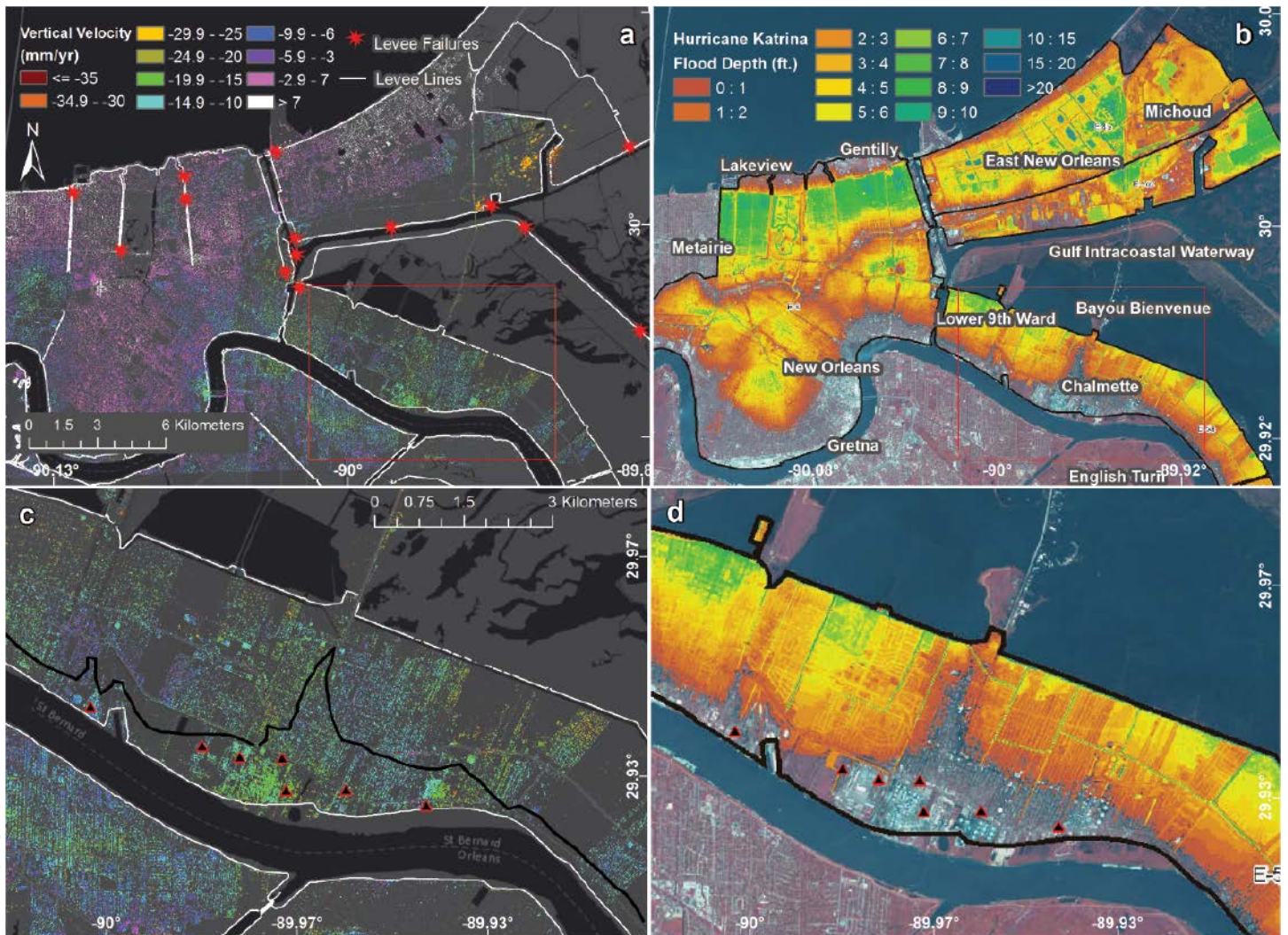
These deep processes can add to the sum of risk factors, but their contributions are commonly amplified in the deepest deposits of a sedimentary basin because of the response of Earth's lithosphere to changes in loads (isostatic adjustment), including sediment loading. For example, past ice sheets, like those that once covered large parts of North America and Europe, depressed the Earth's surface underneath, causing adjacent landmasses to rise. Now that these ice sheets have retreated, the surface underneath is gradually rebounding (isostatic adjustment). In response, the surrounding areas now experience annual subsidence rates of as much as 2 millimeters.

Humans also contribute to these deeper processes. Many deltas are major production zones for petroleum and other hydrocarbons, processes that extract fluids from deeper levels, as much as a few kilometers. Extracting these fluids can accelerate subsidence for as long as several decades afterward [Kolker *et al.*, 2011]. Burgeoning coastal lowland demand for groundwater for potable, industrial, and agriculture uses also accelerates subsidence by reducing aquifer fluid pore pressure. A dramatic example can be found in China's Huanghe Delta, where groundwater removal for coastal aquaculture has produced subsidence hot spots of 250 millimeters annually [Higgins *et al.*, 2013].

Deltas often contain extensive Holocene peat beds that are exposed to oxidation and rapid collapse as shallow aquifers are deflated. In Southeast Asia, deforestation and drainage for agriculture may reduce these peatlands from 90% to 20% intact between 1990 and 2020, resulting in annual subsidence rates of as much as 30–60 millimeters [Hooijer *et al.*, 2012].

### Measurements and Monitoring Strategies

Developing subsidence mitigation plans requires a combination of measurement and monitoring strategies. The spatial and temporal changes in elevation associated with subsidence must be measured accurately. Also, the contributions from various driving factors must be separated out,



Jones et al. (2016)

and their respective contributions to the total subsidence rate expressed at the land surface must be quantified.

Measurement strategies must be tailored for individual settings and availability of funds, but any unified, international effort must focus on deltaic areas and coastal megacity “supersites.” These areas are characterized by extreme subsidence rates, and large human populations and supporting infrastructure are at risk.

New Orleans, La., is not a megacity in population, but it is a suitable supersite for concentrating mapping and monitoring of total subsidence because it lies within the subsiding Mississippi Delta. Subsidence in this delta has been identified as a major cause of rapid wetland loss and barrier island degradation, which threaten the viability of the coastal ecosystem [Louisiana Coastal Protection and Restoration Authority (LACPR), 2012]. This region also experiences subsidence issues related to groundwater extraction and drainage of peat-rich soils [Dixon et al., 2006].

The integrated strategy implemented in metropolitan New Orleans combines a terrestrial network of site-specific measurement stations with remote sensing. We believe that this strategy can be used as a guide for other high-risk coastal cities and deltas.

New Orleans, La., is the site of coastal subsidence and hurricane-induced flooding. (a) Red asterisks indicate the locations of levee failures during Hurricane Katrina in 2005. Pinkish and white shades on the map indicate the highest subsidence rates, as millimeters per year of vertical velocity. (b) Flood depths (in feet; 1 foot = ~0.3 meter) are shown for 3 September 2005, shortly after Hurricane Katrina dissipated. Green indicates the deepest flooding. (c) Thick peat layers near Bayou Bienvenue are associated with high subsidence rates at nearby Chalmette, La. There is little to no peat under several industrial areas (red triangles). (d) Chalmette flood depths for 3 September 2005.

Our group is addressing the measurement challenge using data from the interferometric synthetic aperture radar (InSAR; <http://go.nasa.gov/2bwYkro>) instrument aboard NASA Jet Propulsion Laboratory’s Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR; <http://go.nasa.gov/2bMsvMr>) aircraft to produce spatially continuous total subsidence maps of metropolitan New Orleans [Jones et al., 2016]. This aircraft has gathered L band (1–2 gigahertz) SAR data during semiannual overflights since June 2009. Continuously operating GPS reference stations (CORS) fix these remotely sensed, relative dis-

placement measurements within a global reference frame. Additional CORS stations are being installed at strategic locations in 2016, which will enable more frequent and precise point monitoring of total subsidence.

The second main challenge is to separate out, or deconvolve, the processes that contribute to total subsidence over large urban and deltaic areas. Our strategy is to develop a network of “superstations” in critical, rapidly subsiding areas where multiple subsidence measurement methods can be applied at a single site to examine past and present subsidence. The superstation methodology is motivated by the fact that previous studies, commonly relying on just one method, have often produced conflicting results.

One such superstation, funded by the U.S. Army Corps of Engineers and the first of a planned network, has been installed at a wetland site in the Mississippi Delta. Work began in January 2016. The superstation came online in August 2016, and the instruments are sending data through the uplink. A continuous sediment drill core extends throughout the Holocene succession into the top of the Pleistocene, enabling us to reconstruct the subsidence history at the site. The superstation is located at a site operated by the Coastwide Reference Monitoring System (CRMS; <http://bit.ly/USGS-CRMS>) network, which monitors, among other things, surface elevation change and vertical accretion (deposit accumulation on the delta plain) by means of the rod surface elevation table-marker horizon (RSET-MH) technique [Webb *et al.*, 2013].

The superstation (colocated with the CRMS0276 site) is being equipped with recently developed low-power interferometric optical fiber strainmeters in multiple wells, which are capable of continuous, micrometer-resolution strain monitoring [DeWolf *et al.*, 2013]. Strainmeters will be installed at three depths (about 39, 26, and 10 meters). The deepest of these will penetrate into the Pleistocene basement, allowing us to monitor vertical motions over different depth-integrated strata. GPS antennas will be attached to either the base or the top of the strainmeters and tied in to the CORS network (see <http://bit.ly/NOAA-CORS>) that is operated by the National Geodetic Survey.

The site will be outfitted with enhanced backscatter hardware, including transponders or corner reflectors [Fujita, 2003; Strozzi *et al.*, 2013] to test various radar reflector designs to optimize use with L band SAR. We will use SAR to derive the regional pattern of total elevation change in deltaic wetland areas, using radar scattering benchmarks as a reference. Subsidence rates can also vary substantially over time, so we anticipate that we will monitor at this and future Mississippi Delta superstations for many years.

### Beyond the Mississippi

Team members have allied efforts in other systems, using multiple measurement methodologies to examine the diverse causes of coastal subsidence. For example, in the Ganges-Brahmaputra Delta in Bangladesh, L band InSAR

instruments, calibrated with CORS, are measuring land subsidence rates of as much as 18 millimeters per year, with the lowest rates appearing primarily in exposed Pleistocene terraces and the highest rates in Holocene organic-rich muds [Higgins *et al.*, 2014].

Although regional subsidence in this delta is primarily controlled by local stratigraphy, with rates varying by more than an order of magnitude depending on lithology, dewatering and tidal sediment exclusion induced by coastal poldering in the 1960s have generated 1–1.5 meters of elevation loss relative to surrounding natural mangrove forest [Auerbach *et al.*, 2015].

In the Venice Lagoon (Italy), a comprehensive monitoring program has been ongoing since 2007, using SAR and an innovative network of more than 50 artificial corner reflectors placed in marshes and tidal flats [Strozzi *et al.*, 2013]. Subsidence rates have declined lagoon-wide since

the cessation of groundwater pumping in the 1970s. However, ongoing monitoring with a new generation of SAR satellites (e.g., ALOS PALSAR, COSMOS-SkyMed, Sentinel-1) has recently identified rapid (up to 40 millimeters per year) local subsidence associated with renovation of historical structures and the construc-

tion of structures for the Modulo Sperimentale Elettromeccanico (or Experimental Electromechanical Module, MoSE) tidal barrier to protect the lagoon from high-water (acqua alta) events [Tosi *et al.*, 2016].

### From Measurements to Modeling

The frontier in subsidence modeling is finding a way to couple individual drivers to provide an integrated simulation of ground motion within a study area that accounts for their interaction. To date, data availability has been a major obstacle in creating such coupled models. Hence our proposed supersite/superstation network methodology will provide direct observational control on active subsidence drivers in key localities and should be part of an international effort that will also catalog, manage, and disseminate the data to the modeling community.

Predicting future elevation loss in coastal lowlands will ultimately require the use of multiple modeling strategies. Future coupled model advances are necessary to address the complexity induced by multidriver subsidence and interactions between drivers.

Researchers have developed numerical models to simulate a variety of independent subsidence drivers. These include deep natural processes such as isostatic subsidence [Wolstencroft *et al.*, 2014], geomechanical subsidence at the regional scale due to fluid withdrawal [Gambolati and Teatini, 2015], and local-scale processes such as peat oxidation or shallow consolidation caused by surface loading in newly urbanized zones or recently formed deltaic areas [Meckel *et al.*, 2006].

The world of complex research models that simulate underlying subsidence processes is distinct from the need for simple kinematic, planning-level models of

## The master plan to restore the Mississippi Delta and adjacent coastal Louisiana is the most expensive restoration plan conceived to date globally.

reduced complexity that can be used by policy makers. What we need, in addition to the research models, are simple models that simulate ground motion over timescales (years to decades) and spatial areas (tens to hundreds of square kilometers) that are relevant to decision makers. To assess coastal subsidence as part of a larger risk assessment analysis, these models will need to be used in conjunction with other models that predict coastal hazards associated with such phenomena as storm surges, climate-driven sea level rise, and river flooding.

In the Mississippi Delta, where Louisiana's modeling team is using reduced complexity models to guide project selection and the overall coastal restoration effort, coupling various reduced complexity subsidence models would be a major advance.

### Implications for the Mississippi Delta

The master plan to restore the Mississippi Delta and adjacent coastal Louisiana [LACPRO, 2012], the most expensive restoration plan conceived to date globally, presently uses a map, differentiated into 17 geographical regions derived by an expert team, of plausible subsidence rates (0 to 35 millimeters per year). These rates play a much larger role than predicted eustatic sea level rise rates in acreages of wetlands built and preserved and the sustainability of these wetlands over 50-year model simulations for proposed projects [Couvillion *et al.*, 2013].

The integrated program under way by our expert team and others combines satellite and aerial SAR, point ground measurements (CORS, leveling), and subsurface monitoring instrumentation (strainmeters) to better understand the rates and drivers of coastal subsidence. This program will dramatically improve decision makers' ability to gauge the cost-benefit ratio of individual restoration and protection projects, particularly with regard to their postconstruction evolution.

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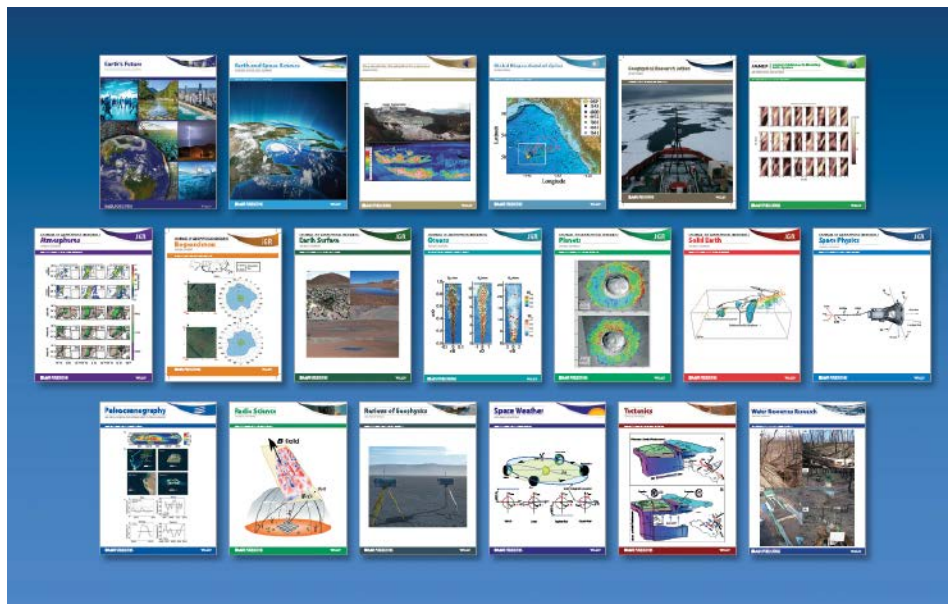
**Mead Allison** and **Brendan Yuill**, The Water Institute of the Gulf, Baton Rouge, La.; email: meadallison@thewaterinstitute.org; **Torbjörn Törnqvist**, Tulane University, New Orleans, La.; **Falk Amelung**, University of Miami, Miami, Fla.; **Timothy H. Dixon**, University of South Florida, Tampa; **Gilles Erkens** and **Roelof Stuurman**, Deltares/Utrecht University, Utrecht, Netherlands; **Cathleen Jones**, Jet Propulsion Laboratory, California Institute of Technology, Pasadena; **Glenn Milne**, University of Ottawa, Ottawa, Ont., Canada; **Michael Steckler**, Lamont-Doherty Earth Observatory, Columbia University, Palisades, N.Y.; **James Syvitski**, Community Surface Dynamics Modeling System, University of Colorado, Boulder; and **Pietro Teatini**, Dipartimento di Ingegneria Civile Edile e Ambientale, University of Padua, Padua, Italy

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# AGU Journals: More Content and More Context



Recent covers of the 19 journals that AGU currently publishes.

**A**GU's journals have grown recently in a variety of ways that provide more content and context for readers and better visibility for authors. First, as noted in a 7 August *From the Prow* post (<http://bit.ly/2cneWit>), submissions to AGU journals grew 16% in 2015 (to a total of 13,021), and year-to-date submissions were up an additional 8% in 2016 (to a total of 8192 through 31 July 2016).

The number of published articles has correspondingly increased; AGU published 5761 papers in 2015 in 19 journals. Although the increase was seen across nearly all titles, submissions have risen most in *Geophysical Research Letters* (GRL), AGU's largest journal; the *Journal of Geophysical Research: Biogeochemistry* (JGR: Biogeochemistry); and the *Journal of Advances in Modeling Earth Systems* (JAMES).

One of AGU's newest open-access journals, *Earth's Future* (EF), is also seeing a surge in submissions following its indexing in Journal Citation Reports last year and receipt of its first impact factor, 5.62. Compared with the impact factors of other AGU journals that publish new research, the impact factor of *Earth's Future* ranks just below that of JAMES, which is also open-access. *Global Biogeochemical Cycles* (4.5) and GRL (4.2) closely follow EF. (*Reviews of Geophysics* has the highest impact factor, 11.4.) *Earth's Future* has recently added an edi-

tor focusing on natural hazards and is seeking submissions for special issues on energy and on the food-water interface.

Even with the broad growth in submissions, AGU editors have improved upon our journals' average times to first decision.

Most journals are now returning papers that have been through peer review to authors in less than 2 months after submission, led by GRL (at just under 1 month, on average); JGR: *Space Physics*; *Space Weather*; and *Geochemistry*,

**Even with the broad growth in submissions, AGU editors have improved upon our journals' average times to first decision.**

*Geophysics*, *Geosystems*. Data for all AGU journals are available on the AGU Publications website at <http://bit.ly/2bxGcmi>. Although remaining committed to prompt decisions, GRL editors are now using a "major revisions"

option for the journal's manuscripts to encourage better papers that fit GRL's criteria for timeliness and impact.

## More Scientific Context

As AGU journals grow in quantity and quality, AGU Publications and Eos.org are also providing more context around the science that we disseminate. Online, AGU is providing resources and links to our journals' content, as well as related discussions elsewhere.

All AGU journals are producing more special issues than before, with a focus on providing broad views of Earth and space science.

- *Water Resources Research* celebrated its 50th anniversary last year with a special issue (see <http://bit.ly/1XfSbmt>) that included papers looking toward the future of the field, particularly those on the interface between hydrology and society.

- JGR: *Planets* is celebrating its 25th anniversary later this year with a collection of overviews written to be accessible to a broad audience.

- JGR: *Space Physics* is publishing a special issue exploring "Unsolved Problems in the Magnetosphere" (see <http://bit.ly/2bxPUA2>).

- *Earth and Space Science* is featuring a special issue entitled "Geoscience Papers of the Future," highlighting and demonstrating how to practice reproducibility for figures, open codes, and open data (see <http://bit.ly/2bVYNHU>).

Most of our journals are also contributing to a special issue on integrative Arctic science.

Many AGU journals are also expanding invited commentaries covering particularly notable research topics and results as well as the interface between science and society. *Space Weather* has long included commentaries, as has *Earth's Future* since its launch in 2013. *Water Resources Research* has been publishing a series of commentaries, called "Debates," that explore areas in hydrology of broad and active discussion. These commentaries are all provided as open-access for readers and without any fees for authors. What's more, all commentaries discussing recent research are organized together in a collection (see <http://bit.ly/2bxHDDRO>) that can be accessed from any journal home page.

For some time, Eos.org has been featuring AGU papers, selected by the editors of each journal, in Research Spotlights written by journalists. Research Spotlights are among the

## AGU Expands into Geohealth, Starting with New Journal

most widely read items on Eos.org. AGU's journal editors now complement these spotlights with short "Editors' Highlights" about other selected papers. *Editors' Vox*, part of the opinion section on Eos.org, discusses still more papers. For example, the *Reviews of Geophysics* editors frequently feature in this section question-and-answer interviews with journal authors as a way to provide a broad introduction to important comprehensive reviews.

### Linking Related Content

Readers can discover these types of paper-specific content, as well as related AGU press releases, news stories in Eos.org, and posts on AGU's blogs by means of a paper's "related content" section, which follows the references online. An orange, keyhole-shaped icon marks any paper listed on the journal home page that has one or more pieces of such related content. Each journal home page also offers a feed of all recent enhanced content. We plan to expand the related content to include other AGU content, for example, journal covers and related, recorded meeting presentations on AGU On-Demand. Altmetric ratings and listings also add context to AGU journal content by linking to other news stories, blogs, and social media posts that reference the article.

In addition, the related content section of every AGU paper now lists papers across all journals in Wiley's library that are most similar in content (this list is updated as new content is published).

*JGR: Planets* is now asking authors, if they so choose, to provide plain-language summaries of their papers. The journal will include these summaries in the online and PDF versions of articles below the formal abstracts and use them increasingly for social media and other outreach. Although such summaries remain optional, we hope that many authors will provide them. We will soon extend this plain-language option to the other AGU journals.

These many efforts to enhance content and context for AGU journal articles complement the already free availability of all new AGU content 24 months after publication and the expansion of open-access across AGU journals.

AGU journals collectively represent a wide and rich view of Earth and space science, which forms a foundation for addressing many relevant issues in society, extending from small scales to global. Expanding access to and understanding of this science not only fosters new interdisciplinary research but also helps increase public understanding of science and awareness of its important role in society.

By **Brooks Hanson**, Director of Publications, AGU; email: bhanson@agu.org

I'm so pleased to share news of a project that has finally come to fruition after much hard work and support from the leaders of AGU. This summer, our organization formally embraced the emerging field of geohealth, which encompasses Earth, atmospheric, ocean, and environmental sciences; ecology; agriculture; and health.

AGU entered into this emerging field with the 11 August launch of a new journal, entitled *GeoHealth* (see <http://geohealth.agu.org/>)—a step taken together with our longtime publishing partner Wiley.

The new journal will provide an outlet for members of the scientific community who conduct research that relates Earth and environmental sciences to human, agricultural, and environmental health. Content will include original research, reviews, policy discussions, and commentaries about this new discipline.

### Protecting the Public and Environment

As I noted in a *From the Prow* post last year (see <http://bit.ly/2bNyALc>), since 2009 we've seen almost a 37% increase in published geohealth research as our understanding has grown regarding how Earth and space science provides deeper insight into health and disease in both people and ecosystems. Geohealth research and the collaboration of geoscientists, ecologists, health professionals, and other allied researchers play a critical role in protecting both public and environmental health and safety.

I'm excited to announce that the distinguished Rita R. Colwell will serve as founding

editor of *GeoHealth*. Colwell previously served as the eleventh director of the National Science Foundation and is a former president of the American Association for the Advancement of Science and the American Society for Microbiology. She will lead the launch of the journal. We will also start the search for two editors in chief to serve 4-year terms; one editor will focus on the geosciences, and the other will focus on health. We expect to start accepting submissions later this fall, and the journal's first articles will publish around the time of Fall Meeting.

### Just the First Step

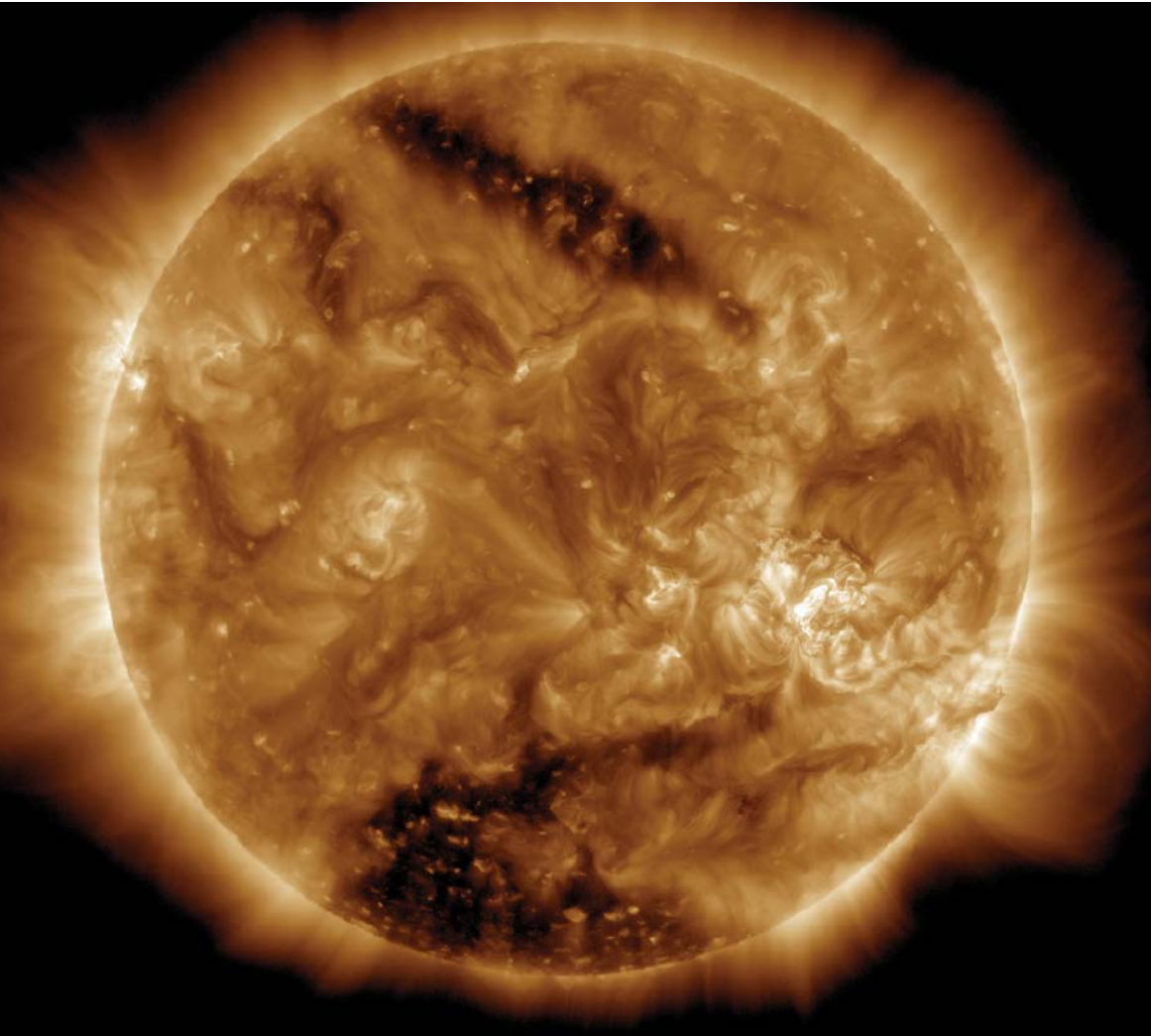
Fostering and facilitating new geohealth research and partnerships among scientists are something we feel will be incredibly beneficial to society worldwide. This new journal is just the first step for AGU as we expand the breadth of our science to formally include geohealth. Expect to see future AGU programing around how Earth and space sciences contribute to human, agricultural, and environmental health.

I want to personally thank those on the Board of Directors, Council, and Publications Committee who helped make this vision a reality. I hope the Earth and space science community will join me in embracing geohealth and demonstrating our sciences' contributions to the health of our planet and society.

By **Chris McEntee**, Executive Director/CEO, AGU; email: [agu\\_execdirector@agu.org](mailto:agu_execdirector@agu.org)



## Spotting the Source of Slow Solar Wind



NASA/Goddard/SDO

Coronal holes, like the one pictured here at the southern pole of the Sun, are a source of fast solar wind; the source of slow solar wind has been harder to trace.

The surface of the Sun is a hotbed of activity. The outer layer of the Sun, known as the corona, can reach a few million degrees Celsius, spewing a hot gas of protons, electrons, and other trace elements out into space. The escaping plasma and particles are called solar wind. Fast solar wind, which can reach speeds in excess of 500 kilometers per second, emerges from the center of coronal holes—dark spots on the surface where the Sun’s magnetic field lines open up and extend out into space, providing an escape route for the hot gas. The origin of slow solar wind, however, has proven more difficult to uncover. To help zero in on its source, *Keplek et al.* took a

look at data gathered as slow solar wind swept past several near-Earth spacecraft.

Previous research has given rise to three general models for slow solar wind: The expansion factor model predicts that slow wind emanates from the tubelike stretch of space containing the magnetic field as it peels off into space away from the Sun at the edges of coronal holes; the interchange model suggests that the wind comes from the intact corona, spurred by the collision and realignment of magnetic field lines, or magnetic reconnection; and the S-Web model is somewhere between the two, with the solar wind fueled by magnetic reconnection and

emanating from the boundaries of coronal holes.

To trace the wind’s origin, the scientists looked at its charge state ratios and elemental composition, which can serve as a fingerprint for the conditions that produce solar wind. Using measurements of charge state abundance and composition measurements at 12-minute intervals made by the Advanced Composition Explorer (ACE) and Wind spacecraft, the team found that the plasma measurements fluctuated on roughly 90-minute cycles, a finding in agreement with previous research on charge state and composition variability.

The authors discovered that the charge state and composition properties of the slow wind oscillated in regular, nonrandom patterns between measures typical of slow wind and those typical of fast wind. Proton density within the plasma became 3 times higher by the midpoint of the cycle before dropping down again, whereas the helium, carbon, and oxygen abundances peaked late in the 90-minute cycle. This pattern of variability suggested that the charge state and composition of slow wind are imbued in the wind as it originates in the solar atmosphere and not in transit.

These findings hint at a potential slow solar wind source. Only magnetic reconnection at the Sun’s surface could cause the wind to have charge state and compositional properties characteristic of both fast and slow wind. The lack of relationship between the velocity of the wind and its composition revealed in the study would not be predicted by the expansion and interchange models.

The results provide strong evidence for a magnetically driven slow wind source, which could eventually help researchers better predict solar wind phenomena and protect infrastructure and operations on Earth from the effects of space weather. (*Geophysical Research Letters*, doi:10.1002/2016GL068607, 2016)

—Kate Wheeling, Freelance Writer



## Tracking Down Elusive Origins of Kazakhstan's 1889 Chilik Quake

On 11 July 1889, a magnitude 8.0–8.3 earthquake rocked what is now south-eastern Kazakhstan. It originated near the Chilik River and wreaked havoc on the nearby city of Almaty. The Chilik event is one of the largest documented earthquakes occurring far from a tectonic plate boundary. Despite its size, researchers have puzzled for years over what might have triggered the tremor.

Now, 126 years after it struck, *Abdrakhmatov et al.* have uncovered important new clues to the mystery of the quake's origins. Using fieldwork and satellite data, they propose that ground surface ruptures along three separate faults occurred during the 1889 Chilik earthquake.

The Chilik quake was actually one of several that hit the northern part of the Tien Shan region between 1885 and 1911, shaking Almaty and the nearby city of Bishkek. The mountainous area is crisscrossed with faults, with at least one potentially passing straight through Almaty. From historical reports of damage, the epicenter of the quake is thought to have been located about 100 kilometers southeast of Almaty at a depth of 40 kilometers.

The 1889 earthquake should have produced visible ruptures in the landscape, like a major 1911 tremor in the area did. However, scientists couldn't find any visible fault scarps long enough to be associated with the event. The

team reexamined three visible ruptures that other scientists had previously linked to the quake, despite their relatively short lengths.

The researchers used a variety of techniques to explore the ruptures, which occurred along three different faults. Satellite imagery, aerial photography, GPS data, radiocarbon dating, examination of materials in dug trenches, and infrared stimulated luminescence dating all suggested that all three rupture features may have formed during the 1889 Chilik earthquake.

Together, the ruptured distances add up to at least 175 kilometers, close to the 200- to 300-kilometer rupture length expected for magnitude 8 earthquakes. The authors say that additional rupture segments may remain undiscovered.

Dating materials at one of the faults suggested that no other earthquake had produced a surface rupture there for at least 5000 years before the 1889 tremor. Such a long time between quakes is consistent with other studies of large quakes within continental interiors, far from any tectonic plate boundaries.



Richard Walker

Coauthor David Mackenzie winds out a balloon equipped with a camera to produce a low-altitude photogrammetry survey of the 1889 earthquake ruptures in Kazakhstan. He is kneeling on top of the fault scarp.

The potentially long interval between earthquakes along hard-to-identify faults raises concerns about pinpointing potential hazards in the area. Earthquakes similar to the Chilik event would pose a serious threat to nearby structures and communities, including the 2 million residents of Almaty. (*Journal of Geophysical Research: Solid Earth*, doi:10.1002/2015JB012763, 2016) —Sarah Stanley, Freelance Writer

## Scientists Map Temperature and Density in Earth's Exosphere

If it weren't for the exosphere—Earth's outermost layer of atmosphere—we might all be at the mercy of the Sun's blinding rays and other objects hurtling toward us from outer space. In the exosphere, the air becomes very thin, almost vacuum-like, with very few particles, as many atoms and molecules from Earth's atmosphere begin to escape into space.

Another consequence of the near-vacuum conditions is that there is very little friction, which makes this region of the atmosphere ideal for satellites. However, regions of the exosphere can differ greatly in terms of temperature and density, which can affect the orbits of spacecraft placed in this region. Incoming radiation, particularly from the Sun, can also influence the density of gases in the exosphere. Therefore understanding the

variation in temperature and density of the exosphere can provide valuable information for scientists when they are considering where to place satellites.

In this new study, *Weimer et al.* analyze density data from two satellites, Challenging Mini-satellite Payload (CHAMP) and Gravity Recovery and Climate Experiment (GRACE), measured by accelerometers found on board. The measured densities can then be converted to temperatures using the Naval Research Laboratory's Mass Spectrometer, Incoherent Scatter Radar Extended Model.

The researchers found that the densities in the exosphere—which, in turn, correlated to differences in temperature—varied on the basis of solar cycles and other geomagnetic fluctuations. The scientists then averaged out

these temperatures in grids such that the cells would have equal areas using NASA Jet Propulsion Laboratory's Hierarchical Equal Area Iso-latitude Pixelization of a Sphere (HEALPix). Typically, grid cells constructed by latitude and longitude lines get smaller and smaller near the poles and do not have equivalent areas. HEALPix rectifies this issue, however, allowing researchers to more easily compare averages from different regions of the exosphere.

With the methods used here, the authors propose a new way to create more accurate models of the exosphere. Those models could help researchers understand variations in exospheric temperatures or determine where to place certain spacecraft. (*Journal of Geophysical Research: Space Physics*, doi:10.1002/2016JA022691, 2016) —Wudan Yan, Freelance Writer

# How Do the Deep Waters of the Antarctic Form?



Christopher Michel, CC BY 2.0 (<http://bit.ly/ccby2-0>)

Emperor penguins cluster on the ice of Antarctica's Weddell Sea, which is responsible for recharging the deep waters of the Southern Ocean.

For many, Antarctica is out of sight, out of mind. However, the waters that surround the landmass play a major role in global climate.

The Southern Ocean absorbs and stores a large amount of carbon dioxide, acting as a buffer to slow the rate of climate change. The way these waters form and circulate in the deepest reaches of the ocean is an important control on the ability of these waters to store carbon and act as a climate safeguard.

Here *Loose et al.* use a new technique to understand how the deepest waters in the oceans form. The researchers investigated deepwater formation in the Antarctic but also extended these methods to look at the formation of deep waters worldwide.

The authors examined the physical processes that are recorded in noble gases as surface water becomes deep water. These physical processes provide information on sea ice formation, subsurface ice melt of glaciers, and the exchanges between air and sea.

The noble gases neon, argon, krypton, and xenon are unique because they are found primarily in Earth's atmosphere, whereas helium and radon are naturally produced by radioactive decay in the crust and outer man-

tle. The helium-3 isotope is also ordinarily found in the mantle and in seawater that emanates from the ocean spreading centers. Therefore tracing the noble gases and their isotopes can provide insight into water mass origin and past contact with the lithosphere and with sources of geothermal heat.

The concentration of these gases can also provide a record of air-sea interactions. For example, the abundance of noble gases originating in the atmosphere gives insight into wind speed at the time of deepwater formation, or the role of air bubbles, which can supersaturate the water. Noble gas concentrations can also provide information on water temperature at the ocean surface—

because warmer waters can hold less dissolved gases—or on how much sea ice formation and brine rejection occurred at the time of deepwater formation.

The scientists focused on the Weddell Sea, a prime location where Antarctic bottom water is known to form. They analyzed samples collected aboard the RRS *James Cook* in January 2009 and the RRS *James Clark Ross* in March and April 2010. The concentrations of noble gases (specifically, helium, neon, argon, krypton, and xenon) were determined using a dual mass spectrometer system.

The researchers found that both glacial ice and sea ice govern gas concentrations in these deepwater masses. It was already known that salty brine rejection during sea ice formation around Antarctica dramatically alters the density of these deepest waters. This study demonstrates that the same is true for gas concentrations.

The noble gas content found in bottom water, the scientists found, tells a story specific to how this water formed and where it traveled. After it leaves the surface, the water picks up a small fraction of ice melt from glaciers, icebergs, and ice shelves, which further modifies the water's noble gas concentrations, forming a unique "fingerprint." Using such fingerprints collected across space and time, it may be possible to reconstruct glacial melt and sea ice production in the past, including during the last major ice age, when ocean properties were distinct from today. (*Journal of Geophysical Research: Oceans*, doi:10.1002/2016JC011809, 2016) —**Wudan Yan**, Freelance Writer

## Correction

The photograph featured in Postcards from the Field in the 15 September 2016 issue of *Eos* magazine was incorrectly attributed. The photo was taken by the submitter, Katie Pratt. In addition, Pratt's affiliation information was unclear. She is the communications director for the Deep Carbon Observatory, an international research program that connects scientists from around the world.

### AGU's Career Center is the main resource for recruitment advertising.

All Positions Available and additional job postings can be viewed at <https://eos.org/jobs-support>.

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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

### Postdoctoral Research Scientist

The Department of Applied Physics and Applied Mathematics at Columbia University in New York seeks applicants for a Postdoctoral Research Scientist appointment to conduct satellite- and surface-based remote sensing data analyses that will help constrain global climate model predictions of low cloud feedbacks and climate sensitivity. The appointment is for a 2-year period.

The successful candidate will use active remote sensing data from the CloudSat and CALIPSO satellites, along with ancillary data from other A-Train instruments and from the ARM Eastern North Atlantic site, to study the properties of subtropical shallow cumulus and stratocumulus clouds in a variety of large-scale environments. The goal is to use these analyses to evaluate simulations of low clouds in the GISS global climate model and to assess the fidelity of the model's projections of low cloud changes in climate warming scenarios. The candidate will be expected to perform original research, present the results of the research at scientific meetings, and publish first-author papers in peer-reviewed journals. The candidate will be resident at NASA GISS, located in New York City near the Morningside Campus of Columbia University.

Successful applicants will have a Ph.D. in atmospheric science or a similar field. Expertise in cloud physics and remote sensing and a willingness to become involved in cloud parameterization evaluation are required. Strong mathematics and programming skills are also a requirement. Strong candidates will be aware of the current status of cloud parameterization and emerging issues in the science of cloud feedback and will be interested in bridging the gap between observations and modeling in meaningful ways.

Columbia University is an Equal Opportunity/Affirmative Action employer. Applications will be accepted until the position is filled. For application requirements and instructions please visit: [academicjobs.columbia.edu/applicants/Central?quickFind=63338](http://academicjobs.columbia.edu/applicants/Central?quickFind=63338).

### Postdoctoral Research Scientist

The Department of Applied Physics and Applied Mathematics at The Fu Foundation School of Engineering and Applied Science of Columbia University in the City of New York invites applications for a Postdoctoral Research Scientist position in the area of modeling atmospheric chemistry and aerosol processes over a wide range of oxidation-reduction states and their interactions with the climates of Solar System rocky planets and rocky exoplanets in a three-dimensional general circulation model. This is a full-time position for a 2-year period.

The successful candidate will participate in a groundbreaking NASA research initiative, the Nexus for Exoplanet System Science (NExSS; <https://nexss.info>), with an interdisciplinary team of scientists from the Goddard Institute for Space Studies (GISS), the Goddard Space Flight Center, Columbia University, and other institutions. The broad goals of the team's research are to address questions about the habitability of the past climates of Earth, Mars, and Venus, to use these insights to assess the habitability of exoplanet climates, and to inform the design of future spacecraft missions for detecting and characterizing habitable exoplanets. The candidate will be expected to perform original research, present the results of the research at scientific meetings, and publish first-author papers in peer-reviewed journals. The candidate will be resident at NASA GISS, located in New York City near the Morningside Campus of Columbia University.

## BIOGEOSCIENCES

### Tenure-Track Assistant Professor in Geomicrobiology

Baylor University is a private Christian university and a nationally ranked research institution, consistently listed with highest honors among The Chronicle of Higher Education's "Great Colleges to Work For." Chartered in 1845 by the Republic of Texas through

the efforts of Baptist pioneers, Baylor is the oldest continuously operating university in Texas. The university provides a vibrant campus community for over 15,000 students from all 50 states and more than 80 countries by blending interdisciplinary research with an international reputation for educational excellence and a faculty commitment to teaching and scholarship. Baylor is actively recruiting new faculty with a strong commitment to the classroom and an equally strong commitment to discovering new knowledge as we pursue our bold vision, Pro Futuris ([www.baylor.edu/profuturis/](http://www.baylor.edu/profuturis/)). Tenure-Track Assistant Professor, Geomicrobiology The Baylor University Department of Geosciences (<http://www.baylor.edu/Geology/>) seeks a dynamic scholar to fill this position beginning August, 2017. Candidates should have a Ph.D. in Geology, Microbiology, or a closely related discipline with a strong emphasis on microbial mediation of biogeochemical and hydrological processes within the vadose and shallow saturated zones. Utilization of unique analytical techniques or conceptual modeling coupled with field-based measurements is desired. Research areas may range in scope from the Critical Zone to global biogeochemistry with relevance to hydrologic cycles. Regardless of research focus area, enthusiasm for interdisciplinary research and cultivation of new collaborations is essential.

### Assistant Professor of Earth Sciences

The Ohio State University at Newark is seeking applications for a 9-month, full-time tenure-track position as Assistant Professor of Earth Sciences beginning fall, 2017.

**Summary of Duties:** Teaching duties include delivering approximately 18 credit hours of instruction per year (semester calendar), primarily in lower-level courses. Research duties include conducting research in accordance with the expectations of the School of Earth Sciences. Service duties encompass contributions to the campus, department, university, and communities in the region.

**Qualifications:** PhD in earth sciences, a culturally responsive pedagogy appropriate for a racially and ethnically diverse student population, the ability to produce research publishable in scholarly journals, and a documented record of excellence in teaching at the undergraduate level.

**Application Procedures:** To assure consideration, submit a letter of application, curriculum vitae, three letters of reference (with phone numbers), and a statement of teaching philosophy to: The Ohio State University at Newark, Office of Human Resources, Assistant Professor Earth Sciences, #420687, 1179 University Drive, Newark, OH 43055. To ensure full consideration, application materials must be received by December 5, 2016. Ohio State Newark is an Equal Opportunity/Affirmative Action Employer and is committed to fostering a culturally and intellectually diverse environment and encouraging all members of our learning community to reach their full potential. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, or protected veteran status.

The Department of Geology and Geophysics at Texas A&M University invites applications for a tenure-track faculty position in paleontology. Areas of interest include marine micropaleontology, marine invertebrate paleontology, paleoecology, paleoclimatology and biostratigraphy. Successful applicants are expected to develop and maintain a vigorous, externally funded research program and demonstrate a commitment to exceptional undergraduate and graduate teaching through effective pedagogical techniques. We are a collaborative, broad-based Department within the College of Geosciences, which includes the Departments of Oceanography, Atmospheric Science, Geography, Texas Sea Grant, the Geochemical and Environmental Research Group (GERG), and the International Ocean Discovery Program. Opportunities for collaboration also exist within the Faculty of Ecology and Evolutionary Biology, which brings together faculty interested in Ecology and Evolutionary Biology from across the campus.

Interested candidates should submit electronic versions of a curriculum vita, statement of research interests and teaching philosophy, the names and addresses of at least three references and up to four reprints to <https://apply.interfolio.com/36752>. Screening of applications will begin October 1, 2016, and will continue until the position is filled. A Ph.D. is required at the time of employment.

Texas A&M University, a land-, sea-, and space-grant university, is located in a metropolitan area with a dynamic and international community of 255,000 people. Texas A&M University is an affirmative action/equal opportunity employer committed to excellence through the recruitment and retention of a diverse faculty and student body and compliance with the American with Disabilities Act. The University is dedicated to the goal of building a culturally diverse and pluralistic faculty and staff committed to teaching and working in a multicultural environment. We strongly encourage applications from women, underrepresented ethnic groups, veterans, and persons with disabilities. Texas A&M University also has a policy to address the needs of dual-career partners (<https://advance.tamu.edu/dual-career-program-information/>)

to this position. The successful candidate may teach courses in geomicrobiology, soil hydrology, or biogeochemistry, establish and participate in externally-funded research, and successfully mentor M.S. and Ph.D. candidates to graduation. The Department currently consists of 17 tenured and tenure-track geoscientists, and supports the Baylor Center for Reservoir and Aquatic Systems Research (CRASR at <http://www.baylor.edu/crasr/> for further information). Research space is available in the 500,000 ft<sup>2</sup> "state-of-the-art" Baylor Sciences Building. Applications for the position will be accepted until the position is filled. Please submit a letter of application, current curriculum vitae, official transcript showing highest degree conferred (if ABD, also send official transcript of completed Ph.D. hours), and a description of your research plan and teaching philosophy. Include names, addresses, and phone numbers of three individuals from whom you have requested letters of recommendation to: Dr. Steven G. Driese, Search Committee Chair, Department of Geosciences, One Bear Place #97354, Baylor University, Waco, TX 76798-7354 USA; +1-254-710-2194; please submit all applications electronically to [Steven\\_Driese@baylor.edu](mailto:Steven_Driese@baylor.edu). Salary is commensurate with experience and qualifications. Applications will be reviewed beginning 11/01/2016 and will be accepted until the position is filled. To

ensure full consideration, complete applications must be submitted by 11/15/2016. Baylor University is a private not-for-profit university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Opportunity employer, Baylor is committed to compliance with all applicable anti-discrimination laws, including those regarding age, race, color, sex, national origin, marital status, pregnancy status, military service, genetic information, and disability. As a religious educational institution, Baylor is lawfully permitted to consider an applicant's religion as a selection criterion. Baylor encourages women, minorities, veterans and individuals with disabilities to apply.

#### CRYOSPHERE SCIENCES

##### Research Scientist in Lagrangian Sea-Ice Modelling

The Atmospheric and Oceanic Sciences Program at Princeton University, in association with NOAA's Geophysical Fluid Dynamics Laboratory (GFDL), and the Andlinger Center for Energy and the Environment, seeks a postdoctoral or more senior research associate to explore the use of the smoothed particle hydrodynamics method for simulating sea-ice dynamics.

This work will involve exploring innovative approaches to modeling sea ice, with a focus on representing sea ice as a granular media. The project aims

## Lamont-Doherty Earth Observatory COLUMBIA UNIVERSITY | EARTH INSTITUTE

### Postdoctoral Fellowships: Earth and Environmental Sciences

Lamont-Doherty Earth Observatory (LDEO) invites applications for Postdoctoral Fellowships in the fields of Earth and environmental sciences. Our researchers work to understand the dynamics of the Earth's chemical, physical, and biological systems, from the core to the upper atmosphere. Our scientists lead research in the fields of solid Earth dynamics; ocean, atmospheric, and climate systems; cryospheric dynamics; paleoclimate; and biogeoscience.

The principal selection criteria for Fellows are scientific excellence and a clearly expressed plan to investigate problems at the forefront of Earth science. Candidates should have recently completed their Ph.D. or should expect to complete their degree requirements by September 2017. Applications from all related fields are welcomed. Fellowships are supported institutionally for 24 months, include a \$7,500 research allowance, and carry an annual salary of \$64,000. LDEO is especially interested in qualified candidates whose record of achievement will contribute to the diversity of the Observatory's scientific personnel.

**The deadline for applications is November 14, 2016.**

For more information and to apply for the fellowship, please visit:

<http://www.ldeo.columbia.edu/postdoc>

LDEO is committed to diversity. Columbia University is an Equal Opportunity/Affirmative Action – Race/Gender/Disability/Veterans Employer.

to construct an operational Lagrangian sea-ice model, which can be tested against existing numerical models. The particle-based sea-ice model will be used to study the large scale properties of sea ice, which are emergent from individual particle interactions.

The ideal candidate has a strong background in one or more areas among material science, soft-matter science (granular materials), numerical methods, sea-ice dynamics and geophysical fluid dynamics. Experience with smoothed particle hydrodynamics solvers or the discrete element method will be advantageous in this research.

Candidates must have a Ph.D. in either applied mathematics, physics, cryosphere, or a related field. Initial appointment is for one year with the possibility of renewal subject to satisfactory performance and available funding.

Complete applications, including a CV, a statement of research interests, and contact information of 3 references should be submitted by October 1, 2016 for full consideration. Applicants should apply online to <http://jobs.princeton.edu>, Requisition #1600731. For more information about the research project and application process, please contact Alistair Adcroft ([aadcroft@princeton.edu](mailto:aadcroft@princeton.edu)), Olga Sergienko ([osergien@princeton.edu](mailto:osergien@princeton.edu)) and Alon Stern ([as42@princeton.edu](mailto:as42@princeton.edu)). This position is subject to the University's background check policy.

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

#### EARTH AND SPACE SCIENCE INFORMATICS

##### Tenure-line Position in Energy Resources Engineering at Stanford University

The Department of Energy Resources Engineering at Stanford University invites applications for a tenure-line faculty appointment. The position is at the assistant professor level. It is desired that the selected candidate be able to start no later than Autumn 2017. For more information about the Energy Resources Engineering Department, see the Stanford ERE web page at <http://pangea.stanford.edu/ERE/>.

The Department of Energy Resources Engineering focuses on a wide range of activities related to the recovery of the Earth's energy resources (e.g., hydrocarbons, geothermal, and other renewables). The department has core areas of expertise in computational (simulation and optimization) and experimental approaches to energy production. ERE offers degrees in both energy resources

Director of the Berg-Hughes Center for Petroleum and Sedimentary Systems

The Department of Geology and Geophysics at Texas A&M University invites applications for the position of Director of the Berg-Hughes Center for Petroleum and Sedimentary Systems. The Berg-Hughes Center integrates geosciences, engineering and other disciplines to collaborate with industry and others to advance research and education in petroleum studies.

We seek dynamic, innovative, geoscientists with demonstrated experience in leading large, multi-disciplinary teams and in obtaining funding from both industry and government to become the Director of the Berg-Hughes Center (<http://berg-hughes.tamu.edu>). This is a senior-level faculty position (Professor, or Executive Professor) in sedimentary or petroleum geology.

We are seeking candidates with strong accomplishments in applying fundamental concepts in petroleum geosciences and engineering to grand challenges in energy and natural-resource sciences, ranging from the pore to basin scale. Areas of expertise may include, but are not limited to, sedimentary processes, depositional environments, sequence stratigraphy, basin architecture, basin modeling, geologic modeling, and energy and natural-resource science. The successful applicant will be expected to provide enlightened leadership, and effective management of the center activities. The Berg-Hughes Center Director must possess the ability to engage industry other colleges and government entities in initiatives that advance scientific and technical frontiers. The Director must have working knowledge of petroleum engineering and the ability to bridge geosciences with engineering disciplines. This position will also engage faculty and industrial leaders to ensure that students participating in center activities become tomorrow's leaders. The Director will be expected to establish a vigorous and externally-funded research program in collaboration with faculty in the Department of Geology & Geophysics, other research units in the College of Geosciences, the Department of Petroleum Engineering, the Texas A&M Energy Institute and the petroleum industry. The successful candidate will also be expected to mentor junior faculty and graduate students and contribute to graduate teaching and research.

Interested candidates should submit electronic versions of a curriculum vita, statements of research interest and teaching philosophy, leadership philosophy, funding history, and the names and email addresses of at least three references, and up to four reprints at <https://apply.interfolio.com/36755>. Screening of applications will begin October 1, 2016 and will continue until the position is filled. A Ph.D. or a M.S. with greater than 20 years industry experience, or industry engagement is required at the time of employment.

The Berg-Hughes Center for Petroleum and Sedimentary Systems is a comprehensive program that integrates geosciences, engineering and related disciplines, including the Department of Geology and Geophysics and the Crisman Institute for Petroleum Research in the Harold Vance Department of Petroleum Engineering. The Department of Geology and Geophysics ([geoweb.tamu.edu](http://geoweb.tamu.edu)) is part of the College of Geosciences, which also includes the Departments of Atmospheric Sciences, Geography, Oceanography, as well as Sea Grant, the Geochemical and Environmental Research Group (GERG), and the Integrated Ocean Discovery Program (IODP).

Texas A&M University, a land-, sea-, and space-grant university is located in a metropolitan area with a dynamic and international community of 255,000 people. Texas A&M University is an affirmative action/equal opportunity employer committed to excellence through the recruitment and retention of a diverse faculty and student body and compliance with the American with Disabilities Act. The University is dedicated to the goal of building a culturally diverse and pluralistic faculty and staff committed to teaching and working in a multicultural environment. We strongly encourage applications from women, underrepresented ethnic groups, veterans, and persons with disabilities. Texas A&M University also has a policy to address the needs of dual-career partners (<https://advance.tamu.edu/dual-career-program-information/>)



TRINITY  
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## IMOGENE AND HAROLD HERNDON PROFESSORSHIP IN GEOSCIENCES

The Department of Geosciences at Trinity University invites applications for the Imogene and Harold Herndon Professorship in Geosciences. Appointment to this endowed position is at the rank of Professor with tenure. A Ph.D. in Geosciences or a closely aligned field is required. The position includes a reduced teaching load and a yearly discretionary budget. We seek candidates whose research program is widely recognized, externally funded, and provides opportunities for meaningful involvement of undergraduates. Demonstrated dedication to and success in undergraduate education are required. We are open to a wide range of research specialties, including but not limited to hydrogeology, aqueous geochemistry, soil science, climate science, and oceanography.

Trinity University is an independent, coeducational, selective, primarily undergraduate institution with high-quality science, liberal arts, and pre-professional programs. Trinity is among the national leaders in percentage of graduates who earn doctorates in the sciences. Further information about the department and this search can be found at <http://www.trinity.edu/departments/geosciences/>.

Applications or letters of nomination should be sent to [herndonsearch@trinity.edu](mailto:herndonsearch@trinity.edu). Complete applications must include a cover letter, curriculum vitae, a detailed statement of undergraduate teaching experience and philosophy, documentation of teaching effectiveness, a description of research plans, and the names and contact information of four professional references. Review of completed applications will begin on December 1, 2016. Questions about the search can be directed to Dr. Glenn Kroeger [[gkroeger@trinity.edu](mailto:gkroeger@trinity.edu)]. *Minority and women candidates are strongly encouraged to apply. Trinity University is an Equal Opportunity Employer.*

**Applied Geoinformatics—Dartmouth College**

The Department of Earth Sciences at Dartmouth College invites applications for a junior rank tenure-track position in the area of geoinformatics with application to one or more of our core research areas including i) ice and climate systems, ii) water and environmental biogeochemistry, and iii) planetary evolution and surface processes. We especially welcome applications from candidates who link traditional geologic approaches and state-of-the-art computational geoinformatics in their research. Particular attention will be given to candidates who combine a focus on understanding fundamental processes with laboratory and/or field research programs that complement and contribute to ongoing research activities in the Departments of Earth Sciences, Mathematics, and Computer Sciences, as well as the Thayer School of Engineering. The successful candidate will continue Dartmouth's strong traditions in graduate and undergraduate research and teaching. Teaching responsibilities consist of three courses spread over three of four ten-week terms.

The Department of Earth Sciences is home to 11 tenured and tenure-track faculty members in the School of Arts and Sciences, and enjoys strong Ph.D. and M.S. programs and outstanding undergraduate majors. To create an atmosphere supportive of research, Dartmouth College offers new faculty members grants for research-related expenses, a quarter of sabbatical leave for each three academic years in residence, and flexible scheduling of teaching responsibilities.

Dartmouth College has undergraduate and graduate student populations that are diverse by many measures. We seek applicants with a record of successful teaching and mentoring of students from all backgrounds (including first-generation college students, low-income students, racial and ethnic minorities, women, LGBTQ, etc.). Dartmouth provides opportunities to participate in undergraduate diversity initiatives in STEM research, such as our Women in Science Program, E. E. Just STEM Scholars Program, Academic Summer Undergraduate Research Experience (ASURE), and the Mellon Mays Undergraduate Fellowship.

Dartmouth, a member of the Ivy League, is located in Hanover, New Hampshire (on the Vermont border). Dartmouth has a beautiful, historic campus located in a scenic area on the Connecticut River. Recreational opportunities abound all year round.

To learn more about Dartmouth College and the Department of Earth Sciences, visit <http://www.dartmouth.edu/~earthsci>.

To submit an application, upload a cover letter, curriculum vitae, statements of teaching and research interests and objectives, reprints or preprints of up to three of your most significant publications, and the name, address (including street address), e-mail address and fax/phone numbers of at least three references to: <https://apply.interfolio.com/37126>

Application review will begin November 1, 2016, and continue until the position is filled. The appointment will be effective July 1, 2017.

Dartmouth College is an equal opportunity/affirmative action employer with a strong commitment to diversity. In that spirit, we are particularly interested in receiving applications from a broad spectrum of people, including women, minorities, individuals with disabilities, veterans or any other legally protected group.

engineering (B.S., M.S., Ph.D.) and petroleum engineering (M.S., Ph.D.).

We seek scholars with a Ph.D. in an engineering or computational discipline who possess novel and innovative research capabilities in energy transitions engineering, renewable energy integration and optimization, and renewable resource planning and optimization. We envision intellectual engagement in one or more of the following areas:

Computational approaches for the design and dispatch of renewable or hybrid renewable-fossil energy systems

Optimal control of renewable- and flexible-power systems operation

Energy storage system design, including optimization, valuation, and novel technology evaluation

Multi-criteria optimization focusing on challenges associated with novel energy technologies including energy generation, land use, water consumption, materials abundance, and scalability

Analysis of technological change, including rigorous modeling of innovation, technology scale-up and deployment

We will begin reviewing applications on September 1, 2016 and will continue until a suitable candidate is identified. To apply, please submit the following application materials: cover letter, curriculum vitae with a complete list of publications, a statement outlining research and teaching interests, the

names of three references including e-mail addresses, and copies of up to five selected papers published in refereed journals over the past three years. Please apply online at <https://academicjobsonline.org/ajo/jobs/7416> in electronic format (pdf only).

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

**GEOCHEMISTRY**

**Tenure-track Assistant Professor**

The University of Oklahoma invites applications and nominations for a tenure-track Assistant Professor faculty position in Structural Geology/Tectonics. Exceptional candidates at the Associate Professor level will also be considered. We seek a dynamic colleague who will teach and supervise students at all levels, while conducting an independent, externally funded research program in his/her field of expertise. The holder of this position is expected to (1) conduct research in structural analysis using any combination of theoretical, experimental, field and geophysical approaches; and (2) educate students in the area of struc-

*The National Academies of*  
SCIENCES • ENGINEERING • MEDICINE

**NRC Research Associateship Programs**  
Postdoctoral, Senior and Graduate Research Awards  
offered for research at  
U.S. federal laboratories

The National Academy of Sciences offers graduate, postdoctoral and senior research awards on behalf of 26 U.S. federal research agencies and affiliated institutions with facilities at over 100 locations throughout the U.S. and abroad.

We are seeking highly qualified candidates including recent doctoral recipients and senior researchers. Applicants should hold, or anticipate receiving, an earned doctorate in science or engineering. Degrees from universities abroad should be equivalent in training and research experience to a degree from a U.S. institution.

**Benefits of an NRC Research Associateship award include:**

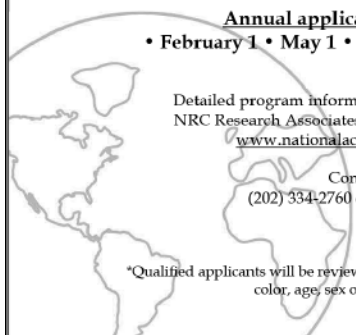
- Postdoctoral stipends from \$45,000 to \$80,000 – higher for senior researchers •
- Relocation, professional travel, health insurance •
- Open to U.S. and non-U.S. citizens •

**Annual application deadlines**  
• February 1 • May 1 • August 1 • November 1

Detailed program information can be found on the  
NRC Research Associateship Programs website at:  
[www.nationalacademies.org/rap](http://www.nationalacademies.org/rap)

Contact:  
(202) 334-2760 or [rap@nas.edu](mailto:rap@nas.edu)

\*Qualified applicants will be reviewed without regard to race, religion, color, age, sex or national origin



tural concepts and techniques. The area of research experience and expertise is open. We expect the candidate to teach undergraduate Structural Geology and graduate courses in Advanced Structural Geology, and participate in the Introductory Field Geology course and Field camp.

The candidate must hold a Ph.D. at the time of appointment, have a research record, and an interest in teaching undergraduates and mentoring graduate students. Salary, benefits, and start-up funds will be competitive and commensurate with experience. The ConocoPhillips School of Geology and Geophysics has a large, vibrant faculty with a broad range of research activities, from fundamental to applied, and strong ties to the petroleum industry. The student body currently includes 180 undergraduates and 95 M.S. and Ph.D. students.

Screening of applicants will begin in November 2016. Interviews will take place in January and February 2017. The position will be available at the beginning of 2017 academic year (Fall 2017 semester), and the search will remain open until the position is filled. Applicants are encouraged to apply at [apply.interfolio.com/37030](http://apply.interfolio.com/37030). Submissions should include a complete vita/resume, statement of research and teaching interests, and a list of three references (including names, phone numbers, e-mail addresses, and complete mailing addresses). Questions or

requests for additional information may be addressed to Chair of the Structural Geology/Tectonics Search Committee, at (405) 325-3253, or [oustructuresearchchair@ou.edu](mailto:oustructuresearchchair@ou.edu).

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

#### Tenure-Track Faculty Position

The Geology Department at Washington and Lee University, Lexington, VA seeks applications for a tenure-track assistant professor in environmental geochemistry starting in fall 2017. PhD required at the time of appointment. Courses taught by the successful candidate will include hydrology, geochemistry, and environmental field methods at the majors level, and physical geology at the introductory level. We seek a dynamic, creative teacher/scholar, dedicated to diverse teaching approaches, enthusiastic about teaching intensive field-based geology courses, and able to develop a strong research program including collaboration with undergraduates. W&L and the Geology Department value excellence in scholarship, meaningful engagement in professional activities, sustainability,

Sedimentary Basin Analysis and Modeling Position, Berg-Hughes Center and Department of Geology and Geophysics, Texas A&M University

The Berg--Hughes Center for Petroleum and Sedimentary Systems (BHC) and the Department of Geology and Geophysics at Texas A&M University invite applications from individuals for a non-tenure track, three-year renewable contract position as a Research Professor in Sedimentary Basin Analysis and Modeling beginning January 16, 2017. This position will be a joint appointment with teaching, research and service responsibilities in the Berg--Hughes Center and Department of Geology and Geophysics. This is a 9-month annual appointment.

The principal responsibility of this position is to lead the collaborative research and teaching programs in the Chevron--TAMU/BHC Basin Modeling Center of Research Excellence in the BHC and Department of Geology and Geophysics. This responsibility includes leading in the development of a robust externally funded research program in basin analysis and modeling that includes research collaboration with researchers in the petroleum industry; teaching integrative courses that introduce advanced concepts and technologies needed for unraveling the geo-history of sedimentary basins and the origin and location of unconventional and conventional petroleum resources inherent to sedimentary basins, and supervising graduate students and mentoring faculty in the use of sophisticated computational and applied research approaches and techniques to solve complex geologic problems.

We seek candidates who have had extensive experience in sedimentary basin analysis and modeling and in serving as a team leader on multi-disciplinary research projects, and who have demonstrated the ability to develop and maintain an externally funded research program. Applicants must have a record of success in working collaboratively with researchers in academia and the petroleum industry and be enthusiastic about teaching integrative courses and supervising graduate students in basin analysis, basin architecture, basin modeling, basin geodynamics, and related areas.

Applicants must have an earned Ph.D. at the time of appointment. Successful applicants will be expected to teach effectively at the graduate level in basin analysis and modeling and related fields and in team taught courses, including classes in the Petroleum Certificate curriculum and to supervise undergraduate, M.S. and Ph.D. research, including students who are interested in pursuing careers in the petroleum industry. Applicants are expected to build and maintain a collaborative research program with colleagues in the College of Geosciences, the Berg--Hughes Center, the Department of Geology and Geophysics, the Department of Petroleum

Engineering, and other energy related groups at Texas A&M University and the Texas A&M University System and with geoscientists and petroleum engineers in the oil and gas industry and national and international research institutions.

Interested candidates should submit electronic versions of a letter of application, curriculum vita, teaching philosophy, statement of research vision, strategies to implement that vision, and accomplishments, and the names and email addresses of at least three references to the Chair of the Basin Analysis and Modeling Search Committee at <https://apply.interfolio.com/36545>. Screening of applications for the position will begin immediately and will continue until the position is filled. The Berg--Hughes Center ([berg-hughes.tamu.edu](http://berg-hughes.tamu.edu)) and the Department of Geology and Geophysics ([geoweb.tamu.edu](http://geoweb.tamu.edu)) are part of the College of Geosciences, which also includes the Departments of Atmospheric Sciences, Geography, and Oceanography; the Geochemical and Environmental Research Group (GERG); and the Integrated Ocean Drilling Program (IODP). Texas A&M University, a land-, sea-, and space-grant university, is located in a metropolitan area with a dynamic and international community of 227,000 people. Texas A&M University is an affirmative action/equal opportunity employer committed to excellence through the recruitment and retention of a diverse faculty and student body and compliance with the American with Disabilities Act. The University is dedicated to the goal of building a culturally diverse and pluralistic faculty and staff committed to teaching and working in a multicultural environment. We strongly encourage applications from women, underrepresented ethnic groups, veterans, and persons with disabilities. Texas A&M University also has a policy to address the needs of dual-career partners (<https://advance.tamu.edu/dual-career-program-information/>)



#### University of Maryland, College Park

Director: Earth System Science Interdisciplinary Center (ESSIC)

Leading a significantly expanded vision for ESSIC, the Director will leverage excellence across the campus relevant to the Earth system to build co-operative partnerships with the natural sciences and departments in a wide range of colleges, including but not limited to Agriculture and Natural Resources, Engineering, Public Health, and Public Policy. S/he will be a scientist of the highest quality in any of the disciplines essential to understanding the Earth system and must be a recognized player in the Earth system community, with a strong record of strategic leadership and a demonstrated ability to work collaboratively and successfully, nationally and internationally, inside and beyond academia. ESSIC has 11 academic faculty and 150 research scientists, with an annual research income of approximately \$35M, and the Director must have a strong commitment to faculty and staff development. Appointed for a five year (renewable) term reporting to the Dean of the College of Computer, Mathematical and Natural Sciences s/he will also hold a tenured Full Professorship in an appropriate department on the campus. Ph.D. or equivalent required.

Applicants should submit as a SINGLE document a Curriculum Vitae including publications, a description of how their research and their experience qualify them for this position and the names and contact information for five referees. For more detail see <http://essic.umd.edu>

Please apply at: <http://go.umd.edu/essicdir>

The position will remain open until filled, but for best consideration applications should be received by December 31, 2016. Inquiries may be sent to: Professor Steve Halperin at [shalper@umd.edu](mailto:shalper@umd.edu).

The University of Maryland, College Park, is an equal opportunity/affirmative action employer.

and the development of a campus climate that supports equality and diversity among its faculty, staff, and students. W&L is a nationally ranked, highly selective liberal arts college. The Department (geology.wlu.edu) has excellent facilities and resources, makes great use of the Appalachians in field courses and labs, and belongs to the Keck Geology Consortium. Applications should include: curriculum vitae; teaching statement including teaching interests/experience; research statement; and contact information for 3 referees. Apply via email to wilsons@wlu.edu. Please address to Lisa Greer, Chair, Geology Department, Washington and Lee University. Initial review of applications will begin Sept. 1; we will be available to meet with potential candidates at the fall GSA meeting in Denver. Review will continue until the position is filled. The University is an Equal Opportunity Employer.

#### GLOBAL ENVIRONMENTAL CHANGE

##### Applied Geophysics

The Department of Earth and Atmospheric Sciences at Central Michigan University invites applications for a tenure-track position in applied geophysics at the Assistant Professor level, beginning Fall 2017. We seek candidates who use a combination of field-based geophysical methods and quan-

titative methods to examine crustal or lithosphere dynamics; earthquake processes; petroleum or metal exploration geophysics; subsurface fracturing and fluid flow; or environmental geophysics. The selected candidate will support the department's programs through engaging, student-centered teaching, develop an externally-funded research program that involves students, and actively contribute to service initiatives that advance the department, college, and university.

The Department of Earth and Atmospheric Sciences, housed in the College of Science and Engineering, offers B.S. degrees in Geology, Environmental Science, and Meteorology, and participates in an interdisciplinary Ph.D. program in Earth and Ecosystems Science. The expertise of faculty members spans research areas across the geosciences, including hydrogeology, environmental modeling, Earth surface processes, climatology, and geochemistry. Further information about the department can be found at <http://www.eas.cmich.edu>.

Candidates must hold a Ph.D. in geophysics, geological sciences, or a related field. In addition, candidates must demonstrate (1) the potential for outstanding teaching, (2) the potential to develop a vigorous research program that involves students and attracts external funding, and (3) strong oral and written communication skills.

Preference will be given to candidates who have postdoctoral experience (academic or industry), a demonstrated record of receiving external funding, and teaching experience.

Review of applications will begin October 15th, and continue until the position is filled. Applicants should submit a CV, cover letter, statement of research interests, statement of teaching philosophy, and the names and contact information for 3 referees through an online process at <http://www.jobs.cmich.edu>. Requests for further information may be addressed to Dr. Lawrence Lemke at [L.D.Lemke@cmich.edu](mailto:L.D.Lemke@cmich.edu).

Classified by the Carnegie Foundation as a research high (R2) doctoral university, CMU is recognized for strong undergraduate education and a range of focused graduate and research programs. CMU is a student-focused university with opportunities for leadership, internships, and off-campus volunteer programs. CMU, an AA/EO institution, strongly and actively strives to increase diversity within its community (see [www.cmich.edu/aaeo/](http://www.cmich.edu/aaeo/)).

#### HYDROGEOLOGY

##### ASSISTANT PROFESSOR OF EARTH AND ATMOSPHERIC SCIENCES (Hydrogeology/Groundwater Modeling)

Applications are invited for a tenure track position as Assistant Professor in

the Department of Earth and Atmospheric Sciences at the University of Nebraska-Lincoln. The successful candidate will be expected to participate in teaching and curricular development of undergraduate and graduate courses, to advise and direct graduate students, and to develop a rigorous research program that is supported by external funding. It is expected that the research program will focus on the responses of groundwater systems to climate change. Candidates must hold a Ph.D. in Geology, Hydrogeology, or a related field at the time of appointment. Ability to contribute to multidisciplinary water and climate research efforts within Department of Earth & Atmospheric Sciences and across the university will be considered as an advantage. The preferred candidate will also demonstrate strong potential for research and teaching.

The Department of Earth and Atmospheric Sciences offers B.S. degrees in Geology and Meteorology-Climatology, as well as M.S. and Ph.D. degrees in Earth and Atmospheric Sciences. Primary research areas within the geological sciences include sedimentary geology, paleontology and paleobiology, petroleum geosciences, hydrogeological sciences, and geobiology. Research in atmospheric sciences is focused on meteorological hazards, climate change, and remote sensing. Additional information about our depart-



FACULTY POSITION IN ATMOSPHERIC SCIENCES (DYNAMICS)  
Stanford University

## FACULTY POSITION IN ATMOSPHERIC SCIENCES (DYNAMICS) Stanford University

The Department of Earth System Science at Stanford University invites applications for a tenure-track faculty appointment in the area of Atmospheric Sciences. The primary focus of the search is in atmospheric dynamics, although candidates with interests in the broader atmospheric sciences are also encouraged to apply. We are searching for a creative and innovative scholar with a demonstrated research record who is also committed to high-quality undergraduate and graduate teaching, including a demonstrated ability or potential in teaching and mentoring a diverse student body (such as women, minorities, and others from underrepresented backgrounds). The level of the appointment is open, with a preference for candidates at the junior rank.

We seek an expert who studies the role of atmospheric dynamics in shaping climate system variability and change. Although we are open to a broad range of specific expertise and research topics, we are seeking to add expertise in understanding the fluid dynamics of the atmosphere within the context of the Earth System. Particular areas of emphasis could include the hydrological cycle, atmosphere-ocean and/or atmosphere-sea ice coupling, tropical meteorology, eddy-mean flow dynamics, stratospheric dynamics, the dynamics of extreme weather and climate events, and feedbacks between the atmospheric circulation and atmospheric constituents such as trace gases and aerosols.

A candidate's tools and methods may be theoretical, computational and/or observational, with potential to establish a vigorous research program, preferably grounded in geophysical fluid dynamics. In addition, because a wide range of scientific challenges offer compelling prospects for future breakthroughs, the successful applicant will also have demonstrated interests in interacting effectively with a broad range of colleagues, such as in the School of Earth, Energy and Environmental Sciences, the Stanford Woods Institute for the Environment, or outside institutions. The successful applicant is also expected to teach classes and mentor graduate students in the Department of Earth System Science, and to teach in the Earth Systems undergraduate program.

Please apply online with the following application materials: cover letter, curriculum vitae, a statement outlining research and teaching experience and interests, and the names and addresses of three or more referees, at <https://academicjobsonline.org/ajojobs/7555>. The search committee will request letters of recommendation for a subset of applicants following review of these materials. Review of applications will begin October 1, 2016. Applications will continue to be accepted until the position is filled.

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



ment can be found on our web site: <http://eas.unl.edu>.

To apply, go to <http://employment.unl.edu/postings/51081> and complete the “faculty/administrative form.” Applicants must attach a cover letter, curriculum vitae, statements of research and teaching interests, and names of at least three references via the above website. We will begin to review applications on November 23, but the position will remain open until it is filled.

The University of Nebraska–Lincoln is committed to a pluralistic campus community through affirmative action, equal opportunity, work–life balance, and dual careers. See <http://www.unl.edu/equity/notice-nondiscrimination>.

For further information, contact Dr. Richard Kettler, Search Committee Chair by email, phone, or mail at: [rkettler1@unl.edu](mailto:rkettler1@unl.edu), 1-402-472-0882; Department of Earth & Atmospheric Sciences, University of Nebraska–Lincoln, 214 Bessey Hall, Lincoln NE 68588-0340.

#### INTERDISCIPLINARY

##### Research Scientist Position Available

The Crustal Geophysics and Geochemistry Science Center (CGGSC) has an open position for a capable, established research scientist able to join and enhance our team of remote sensing experts. The CGGSC invites appli-

cations for a permanent Research Geophysicist/Physical Scientist/Geologist position that is supported by the Mineral Resources Program. We seek candidates that combine a broad expertise in remote sensing, with an emphasis on the use of imaging spectroscopy techniques (laboratory, theoretical and field), that may be applied to such topics as mineral resource and disaster/hazard assessments, geoenvironmental and planetary investigations, and human health issues.

The position will be filled at the GS-14 level (salary is \$107,272 to \$139,457 per annum). The successful candidate will have a demonstrated publication record and will have developed, or show the potential to devise and lead a nationally recognized research program in earth sciences. Detailed vacancy requirements and applications procedures for the Research Scientist position can be found at [www.usajobs.gov](http://www.usajobs.gov) under vacancy announcement #DEN-2016-0481. This recruitment will open on October 1, 2016 and applications must be submitted by midnight MST on October 31, 2016 in order to be considered.

The U.S. Geological Survey is an Affirmative Action/Equal Opportunity employer that values diversity. Women, persons with disabilities, and members of other under-represented groups are encouraged to apply. Additional details of the CGGSC (research

scientists, support staff, and facilities) and the U.S. Geological Survey’s Mineral Resources Program may be viewed at our web pages <http://crustal.cr.usgs.gov/index.html> and <http://minerals.usgs.gov/>.

##### Wiess Post-Doctoral Research Fellowship

The Department of Earth Science at Rice University is inviting applications for the Wiess Post-Doctoral Research Fellowship in the broad fields of Earth, atmospheric, and planetary sciences.

Applicants must have a Ph.D. awarded within three years of the time of appointment.

The research fellowship will be supported by the Department of Earth Science for two years pending satisfactory progress in their first year. The fellowship covers an annual stipend of \$60,000 with a benefits package and an additional annual discretionary research allowance of \$3,500.

Applicants are requested to develop a proposal of research to be undertaken during the fellowship period. The principal selection criteria are scientific excellence and a clearly expressed research plan to address questions at the forefront of Earth science, broadly defined. Applicants are encouraged to explore possible research synergies with faculty in the Department of Earth Science (<http://earthscience.rice.edu>), but the proposed research should

encompass independent research ideas and explore new directions beyond the applicant’s Ph.D. Preference will be given to candidates whose proposals demonstrate independence and originality, and also the potential for collaboration with one or more faculty in the Department of Earth Science.

Candidates are required to submit:

1. A cover letter addressed to the search committee chair
2. A research proposal of no more than 3 pages (single-spaced) including figures
3. A current CV, including a list of publications

All documents should be submitted as a single PDF file by 15 November, 2016, to the chair of the fellowship search committee ([esci-postdoc@rice.edu](mailto:esci-postdoc@rice.edu)). In addition, three letters of reference should be submitted separately by each referee to the chair of the fellowship chair committee ([esci-postdoc@rice.edu](mailto:esci-postdoc@rice.edu)) by 15 November, 2016.

The highest ranked candidates will be invited to visit Rice in early 2017. Following acceptance, the appointment may begin anytime before January 1st 2018. For further information or questions contact the chair of the search committee at [esci-postdoc@rice.edu](mailto:esci-postdoc@rice.edu).

Rice University, located in Houston, Texas, is a private, coeducational, non-sectarian university that aspires to path-breaking research, unsurpassed teaching, and contributions to the bet-

### Faculty Cluster Hire in Earth Surface Processes University of California Santa Barbara Tenure-Track Assistant Professor Positions

The University of California Santa Barbara announces a multidisciplinary cluster hire of four outstanding scientists, to further strengthen its world class Earth surface process teaching and research mission. We seek dynamic researchers who are at the forefront of advancing theory, measurements and understanding in terrestrial Earth Surface Processes from disciplines including climatology, geochemistry, geology, geomorphology, hydrology and soil science. The cluster hire will build on UC Santa Barbara’s foundation strengths in physical geography and Earth and environmental sciences. Successful hires will contribute to improving our understanding of the characteristics and functioning of the entire planet, and especially its terrestrial surface through the study of the complex interactions among atmosphere, geosphere, hydrosphere, biosphere, cryosphere, including their alteration by, and impact on, human activity. We will give preference to candidates with demonstrated expertise in one or more quantitative techniques including field measurement, remote sensing, modeling, and theory and candidates who, based on research and teaching proficiency, would fit into one of the following: the Bren School of Environmental Science and Management, the Department of Earth Science, and the Department of Geography. Applications will be reviewed starting October 31, 2016 with expected appointments on July 1, 2017. Please see the following website for a more complete description of the positions <http://www.eri.ucsb.edu/escluster>. To be considered for one of the four available positions, apply electronically at: <https://recruit.ap.ucsb.edu/>. Applications completed by October 31st, 2016 will receive fullest consideration, but each department will continue reviewing applicant files until that position is filled.

*The Department is especially interested in candidates who can contribute to the diversity and excellence of the academic community through research, teaching and service.*

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

terment of our world. Rice fulfills this mission by cultivating a diverse community of learning and discovery that produces leaders across the spectrum of human endeavor.

Rice University is an Equal Opportunity Employer with commitment to diversity at all levels, and considers for employment qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national or ethnic origin, genetic information, disability or protected veteran status.

**OCEAN SCIENCE**

**Executive Director of the CLIVAR International Project Office**

The First Institute of Oceanography (FIO) and the World Climate Research Programme (WCRP) invite applications for the post of Executive Director of the International CLIVAR (Climate and

Ocean - Variability, Predictability, and Change) Project Office.

The goal of CLIVAR is to improve understanding and prediction of ocean-atmosphere interactions and their influence on climate variability and change, to the benefit of society and the environment (<http://www.clivar.org>). CLIVAR is a core project of the WCRP (<http://wcrp-climate.org>).

The Executive Director will be responsible for a range of activities including managing the Project Office, participating in relevant meetings, promoting CLIVAR objectives, and seeking sources of additional funding.

Candidates should hold at least an MSc in oceanography, climate or closely related field. Required skills include a broad knowledge of oceanography and climate science, ability to communicate to a range of stakeholders, and demonstrated team leadership. Excellent written and spoken

communication skills in English are essential.

The work place is the First Institute of Oceanography of the State Oceanographic Administration of China, located in Qingdao, China. The position is available from 1st October 2016.

For additional information see Further Details ([http://wcrp-climate.org/News-Highlights/2016/Documents/CLIVAR\\_ED\\_Further%20details%20final.pdf](http://wcrp-climate.org/News-Highlights/2016/Documents/CLIVAR_ED_Further%20details%20final.pdf)).

Inquiries about the position may be directed to Mike Sparrow, e-mail: [msparrow@wmo.int](mailto:msparrow@wmo.int).

The position will remain open until filled by a suitable candidate. The application must include a covering letter summarizing details of your relevant qualifications and experience, a CV and the names and contact information of three references and should be sent to Ms. Lina Kang ([lina.kang@clivar.org](mailto:lina.kang@clivar.org)).

# PLACE YOUR AD HERE

Visit [Careers.agu.org](http://careers.agu.org) to learn more about employment advertising with AGU

The atmospheric sciences group (Prof. Fueglistaler) seeks an outstanding postdoctoral or more senior researcher to work on numerical modeling of cirrus clouds with a focus on the tropical tropopause layer. Candidates must have received a Ph.D. in physical sciences or mathematics, and should have some experience in numerical cloud modeling. Ideally, the candidate will have worked on problems related to cirrus clouds in the tropical tropopause layer before, and will have an understanding of not only numerical modeling, but also of observational data from both remote sensing and in-situ instruments. The position requires the ability and interest to work across disciplines, and the proven ability to work independently.

The term of the appointment is for one year with the possibility of renewal based on satisfactory performance and continued funding. Applicants are asked to submit a vitae, a brief statement of research experience and interests, and names of 2-3 references to <http://jobs.princeton.edu>, Requisition #1600719. Review of applications is immediate and will continue until the positions are filled. This position is subject to the University's background check policy. Princeton University is an equal opportunity/affirmative action employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law.

The atmospheric sciences group (Prof. Fueglistaler) seeks an outstanding postdoctoral or more senior researcher to work on the role of the distribution of radiatively active species for the atmospheric general circulation. The candidate will enjoy a great degree of freedom, and specific projects will be developed based on the candidate's interests and strengths. Candidates must have received a Ph.D. in physical sciences or mathematics. Ideally, candidates will have a very strong background in radiative transfer, but candidates with the self-motivation and necessary background in mathematics and/or physics will be given full consideration.

The position requires the ability and interest to work across disciplines, and the proven ability to work independently. The term of the appointment is for one year with the possibility of renewal based on satisfactory performance and continued funding. Applicants are asked to submit a vitae, a brief statement of research experience and interests, and names of 2-3 references to <http://jobs.princeton.edu>, Requisition #1600720. Review of applications is immediate and will continue until the positions are filled. These positions are subject to the University's background check policy. Princeton University is an equal opportunity/affirmative action employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law.

**COLORADO STATE UNIVERSITY  
ATMOSPHERIC SCIENCE TENURE TRACK FACULTY POSITIONS**

The Department of Atmospheric Science at Colorado State University invites applications for two tenure-track faculty positions at the assistant or associate professor level. We solicit candidates in the areas of atmospheric radiation and remote sensing.

The new faculty members will be expected to build and maintain a strong, internationally recognized research program supported through external funding, complement and expand upon the current research and teaching activities, and provide service to the University and broader community. They will also contribute to teaching and intellectual leadership in our atmospheric science curriculum at the M.S. and Ph.D. levels by teaching courses in the Department's core graduate curriculum, advising graduate students, and developing advanced courses in his or her areas of expertise. Further information about the Department can be found at <http://www.atmos.colostate.edu>.

A Ph.D. in atmospheric science or a closely related field is required by the position start date. Candidates should have an outstanding research record commensurate with experience and should demonstrate potential for continued extraordinary scholarship. Candidates must exhibit ability and enthusiasm to teach courses in the department's graduate curriculum.

Applications and nominations will be considered until the positions are filled; however, applications should be received by October 24, 2016 to ensure full consideration. Search will remain open until the positions are filled. Application materials of candidates, including letters of recommendation, will only be made available for review by the broader faculty of the Department of Atmospheric Science if the applicant reaches the semifinalist stage. Applicants should submit a cover letter, one to two page statements on research and teaching interests, curriculum vitae, and the names of four references (who will not be contacted without prior approval of the candidate) at the following link: <http://jobs.colostate.edu/postings/37297>.

Please address inquiries about the position to:

Professor Christian Kummerow, Search Chair  
Department of Atmospheric Science  
Colorado State University  
Fort Collins, CO  
80523-1371  
[kummerow@atmos.colostate.edu](mailto:kummerow@atmos.colostate.edu)

Located 60 miles north of Denver, at the base of the Rocky Mountain foothills, Fort Collins is often ranked among the top places to live in the United States. The City offers a pleasant climate with excellent schools and abundant cultural and recreational opportunities nearby. More information on Fort Collins is available at [www.visitfortcollins.com](http://www.visitfortcollins.com).

**Condition for Employment:**  
Colorado State University is committed to providing a safe and productive learning and living community. To achieve that goal, we conduct background investigations for all final candidates being considered for employment. Background checks may include, but are not limited to, criminal history, national sex offender search and motor vehicle history.

**Commitment to Diversity and Inclusion:**  
Reflecting departmental and institutional values, candidates are expected to have the ability to advance the Department's commitment to diversity and inclusion.

Colorado State University does not discriminate on the basis of race, age, creed, color, religion, national origin or ancestry, sex, gender, disability, veteran status, genetic information, sexual orientation, gender identity or expression, or pregnancy. Colorado State University is an equal opportunity/equal access/affirmative action employer fully committed to achieving a diverse workforce and complies with all Federal and Colorado State laws, regulations, and executive orders regarding non-discrimination and affirmative action. The Office of Equal Opportunity is located in 101 Student Services.

# Postcards from the Field

Hi, Everyone.

Collecting high-resolution multibeam bathymetry of a massive partly supraglacial, partly submarine tsunamigenic landslide in Taan Fiord, Icy Bay, Southeast Alaska. We are using the @waterSHEDlab @UWTacoma @OceanSciGroup ZBoat Jökull to map near the ice face.

—**Dan Shugar**, School of Interdisciplinary Arts and Sciences, University of Washington Tacoma

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



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