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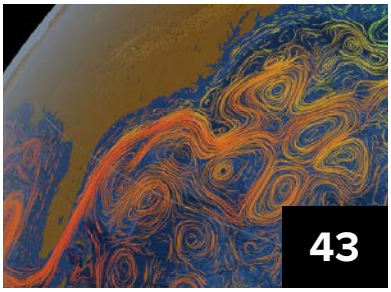

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Turquoise swirls of phytoplankton bloom in the Pacific Ocean off the coast of Chile. Credit: Aqua/MODIS, Suomi-NPP/VIIRS.

EOS.

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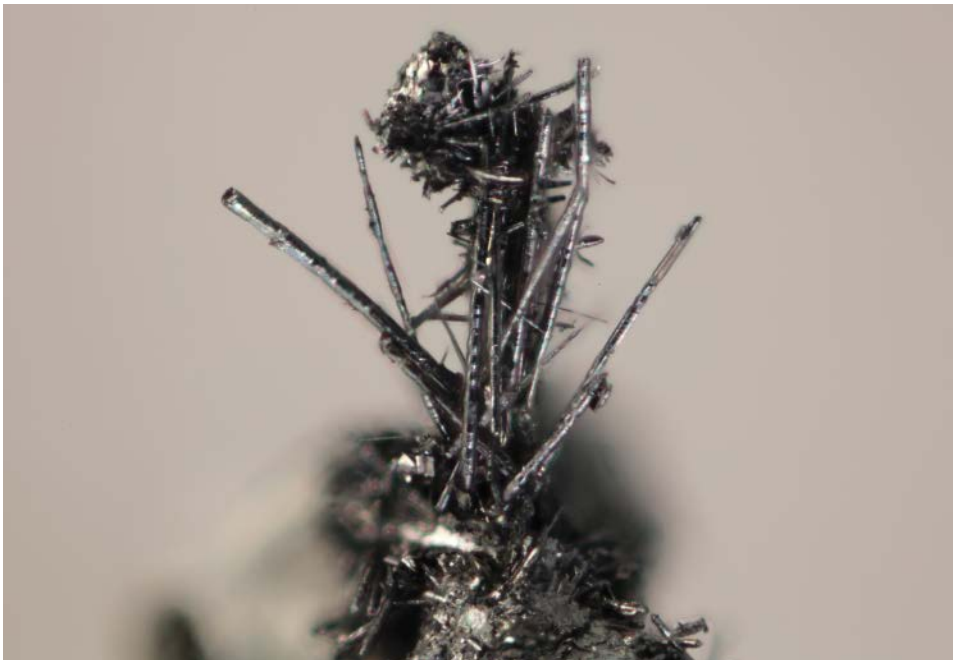
Whiskers on Familiar Crystal Revealed to Be New Mineral



John Jaszczak

The new mineral merelaniite, which to the naked eye looks like incredibly fine hairs. This particular sample stretches less than 2 millimeters tall. A chance discovery by a junior mineral enthusiast led to a new entry in the International Mineralogical Association's list of minerals.

Software engineer Bob Simonoff didn't realize that he was looking at a never-before-described mineral when he peered through his daughter's microscope at a sample of tanzanite one day in 2011. Covering the blue mineral were tiny, wirelike black structures, nothing like the senior Simonoff, a mineral enthusiast, had ever seen.

His daughter, fellow mineral buff Jessica Simonoff (then 14 years old), was studying the sample of tanzanite for an internship at the National Museum of Natural History in Washington, D. C., with mineralogist Mike Wise.

Wise didn't recognize the dark material either, so he and the younger Simonoff decided to look closer. In the lab, they found a high abundance of molybdenum in the wiry mineral, so they suspected it was an unusual form of molybdenite. Meanwhile, John Jaszczak, a solid-state physicist with a "serious interest in mineralogy," spotted a news item about this oddly shaped mineral from an issue of *Mineral News* and wondered whether it could be an undescribed mineral. He later requested a sample from Wise to study in his own lab at Michigan Technological University in Houghton.

Back at his lab, Jaszczak used Raman spectroscopy to analyze a sample of the mineral to investigate further. When light from a spectrometer bounces off a sample, the wavelengths of scattered photons reveal which kinds of atoms make up the material. The spectrum from this sample didn't match any known minerals, Jaszczak said.

Further investigation with an electron microscope revealed that the crystal structure of the millimeter-sized dark wires contained molybdenum and also sulfur, lead, and other elements, a combination never seen before, Jaszczak said. This result was a big clue that the mineral could be deemed entirely new.

And it was. Jaszczak recently published a paper in the journal *Minerals* (see http://bit.ly/merelaniite) describing the find, for which he proposed the name merelaniite after its hometown of Merelani, Tanzania.

Road to a Name

Every new mineral candidate must be approved by the International Mineralogical Association's (IMA) Commission on New Minerals, Nomenclature, and Classification (CNMNC). Scientists submit their candidate material to a battery of tests and build a case for its novelty. To do so for merelaniite, Jaszczak sought help from scientists all over the world to determine the mineral's crystal structure and properties such as density, opacity, and reflectiveness, among others.

The CNMNC receives about 120 new mineral proposals each year, of which it approves about 100, said Peter Burns, IMA president and an environmental chemist at the University of Notre Dame in Notre Dame, Ind. Currently, IMA lists 5179 unique minerals, but only a few boast a curved structure like merelaniite's, said Burns, including one called cylindrite.

As they investigated the new material, Jaszczak and his colleagues learned that its oddly curving shape resulted from a pattern of alternating layers: one of mostly molybdenum disulfide, then two layers of predominantly lead sulfide, then molybdenum disulfide again, and so on. A mismatch of bonding lengths between atoms across layers causes the curvature as atoms try to match up, warping the mineral structure, Jaszczak said.

After 4 years of testing and several months waiting for the CNMNC to deliberate, Jaszczak's team heard the news: Merelaniite was approved.

"I really wish that I had been given the opportunity to get in on the research," said now 18-year-old Jessica Simonoff, because she was studying the original sample of tanzanite on which the merelaniite was first spotted, albeit for different purposes. These days, she's a freshman in college, although she's not quite sure what she's going to study yet.

"I'm glad [the research] went somewhere and contributed to science," she continued.

New Minerals Matter

"The occurrence of minerals teaches us what kinds of combinations of elements are possible," Jaszczak said. Scientists can use what they learn from studying naturally occurring crystal structures and mineral properties to synthesize new materials.

For now, merelaniite remains just a new mineral. Like all minerals, it "provides new insights into the way elements fit together in geologic systems," Burns said.

"Whether this specific mineral would find an application in the future, who knows," he continued. "It's new knowledge that adds to the [scientific] understanding of how our planet works."

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

Former U.S. Science Academy President Ralph Cicerone Dies at 73

Ralph J. Cicerone, who served as president of the U.S. National Academy of Sciences (NAS) from 1 July 2005 through June of last year, died at his home in New Jersey on 5 November at age 73. A world authority on atmospheric chemistry and climate change, Cicerone was widely regarded as an authoritative, gentlemanly voice for science.

"The entire scientific community is mourning the sudden and untimely loss of this great leader who has been unexpectedly removed from the forefront of the scientific issues that matter most to the future well-being of society," Marcia McNutt, Cicerone's successor as NAS president, said in a statement from the academy on the day he died. Cicerone and McNutt both served as AGU presidents, Cicerone from 1992 to 1994 and McNutt from 2000 to 2002.

"Cicerone was a model for all of us of not only doing what counts, but doing it with honesty, integrity, and deep passion," McNutt said.

Rush Holt, CEO of the American Association for the Advancement of Science and executive publisher of the *Science* family of journals, remembered Cicerone in a 6 November statement as "a champion of science who helped scientists understand their obligations to society and helped non-scientists understand the importance of science to their lives, especially with respect to human-induced changes of Earth's climate."

Influenced Climate Science Policy

As head of the academy, Cicerone played an instrumental role in several prominent studies about climate change. Those included a series of 2011 reports, *America's Climate Choices*, which laid out motivations for action and outlined a comprehensive U.S. response to climate change, and a 2014 report, *Climate Change: Evidence and Causes*, released jointly with the Royal Society, the United Kingdom's science academy. Also, prior to becoming NAS president, Cicerone led an academy study about climate change that then president George W. Bush had requested.

In a June 2016 interview with *Eos* shortly before he retired from the academy presidency, Cicerone said that the biggest disappointment of his tenure as NAS head was the "rabid partisanship" surrounding climate change, which has included congressional grilling of climate experts and officials. "We are trashing our institutions. For example, the antigovernment feelings that anything the federal government touches is somehow dirty and wasteful and somehow morally wrong: this just drives me crazy," said Cicerone, who died the day after the Paris climate accord went into effect.

White House photo

Ralph Cicerone (left) shaking hands with President Barack Obama. White House science adviser John Holdren is pictured in the center in this photo taken on 27 April 2009 during the president's visit to the National Academy of Sciences to address its annual meeting.

Other Major Accomplishments

Among his other achievements while serving as the NAS president, Cicerone established a $500 million Gulf Research Program following the 2010 Deepwater Horizon oil spill in the Gulf of Mexico and hosted two visits to the academy by President Barack Obama.

He also helped increase gender diversity in the academy's ranks, seeing the number of women academy members rise from 9.5% (187 of 2062 members) in 2005 to 15.1% (354 of 2351 members) in 2016. Of new academy members elected in 2016, 28.6% (24 of 84) are women.

Cicerone pushed to maintain the quality of NAS's National Research Council reports despite a diminishment in federal reimbursements that help pay for those reports. He also spearheaded creation of the NAS Science and Entertainment Exchange, which connects Hollywood with scientists and engineers to bring more accurate science into popular films.

> He "was a model for all of us of not only doing what counts, but doing it with honesty, integrity, and deep passion."

Fields of Dreams: From Science to Sports

Immediately prior to serving as president of the academy, Cicerone was chancellor of the University of California (UC), Irvine, from 1998 to 2005. Cicerone did landmark research in atmospheric science. His research with Richard Stolarski in the 1970s was cited in the 1995 Nobel Prize in Chemistry that Paul Crutzen, Mario Molina, and F. Sherwood Rowland received for work about the formation and decomposition of ozone. Cicerone and Stolarski "had shown that free chlorine atoms in the atmosphere can decompose ozone catalytically in similar ways as nitrogen oxides do," the citation noted.

Cicerone received his M.S. and Ph.D. degrees in electrical engineering, with a minor in physics, from the University of Illinois at Urbana-Champaign. He earned a B.S. degree in electrical engineering from the Massachusetts Institute of Technology (MIT).

Alongside his enthusiasm for science and engineering, Cicerone loved sports. He told *Eos* that while at MIT studying engineering, he also played varsity baseball and enjoyed watching Boston Red Sox games. "My senior year at MIT, I was finally doing well enough as a student that I went to baseball games in the spring. One year, I went to 31 games," he recalled. Years later, UC Irvine named its baseball field for Cicerone, the driving force behind reviving the university's baseball program in the 1990s.

Cicerone is survived by his wife, Carol; their daughter; and two grandchildren.

By **Randy Showstack,** Staff Writer

New NASA Science Head Foresees Progress in Search for Alien Life

Randy Showstack

Thomas Zurbuchen, NASA's new associate administrator for the agency's science mission directorate, discussed his priorities during a 31 October briefing.

With the search for extraterrestrial life being one of the highest NASA science priorities, "major breakthroughs in this problem" could occur over the next 1–2 decades, space scientist Thomas Zurbuchen said recently. The newly appointed associate administrator for NASA's science mission directorate pointed to significant discoveries and advances in the search for extraterrestrial life since 1995 when astronomers discovered 51 Pegasi b, the first known planet orbiting a Sun-like star outside our solar system.

"Look how many planets we have right now, look where we found water, where we found organics. You can make a list of 10 things of that kind," he told reporters at a get-to-know-you briefing with them at NASA headquarters in Washington, D. C. "What we're after in planetary exploration in many ways is a part of the puzzle of finding extraterrestrial life," he said.

NASA's science directorate, which Zurbuchen has headed since 3 October, encompasses Earth and planetary science, heliophysics, and astrophysics and comprises more than 100 missions. These include the Hubble Space Telescope, the Juno mission to Jupiter, and Mars rovers. The James Webb Space Telescope (JWST) and the Wide Field Infrared Survey Telescope (WFIRST) are among future missions. Zurbuchen succeeds Geoffrey Yoder, who served as acting associate administrator for science since the retirement in April of John Grunsfeld.

> "What we're after in planetary exploration in many ways is a part of the puzzle of finding extraterrestrial life."

Swiss Roots

NASA is a long way from the small Swiss mountain village where Zurbuchen grew up in a family whose church rejected technology and education. His NASA position "is an extraordinary opportunity for impact in the world," said Zurbuchen, who became a U.S. citizen 12 years ago. He noted the importance of "enlarging the space of what we know and also making that space useful to humanity."

Zurbuchen received his Ph.D. in physics from the University of Bern in Switzerland in 1996. So far in his career, his research has spanned solar and heliospheric physics, experimental space research, space systems, and involvement with NASA missions, including the Mercury Surface, Space Environment, Geochemistry, and Ranging (MESSENGER) spacecraft to Mercury and the Ulysses heliosphere mission. Most recently, Zurbuchen was a professor of space science and aerospace engineering at the University of Michigan in Ann Arbor.

The new associate administrator, who held his get-acquainted briefing with reporters on 31 October, has demonstrated leadership skills that should serve him well in this new job, said William Swartz, a principal research scientist at the Johns Hopkins University Applied Physics Laboratory in Laurel, Md. Swartz told *Eos* about serving on a U.S. National Research Council committee chaired by Zurbuchen. According to Swartz, Zurbuchen helped ensure that all views were heard as the committee deliberated about achieving science goals with miniature satellites known as CubeSats (a keen interest of Zurbuchen's). Under Zurbuchen's leadership, "we reached consensus while not getting bogged down in arguments that ultimately could have led to gridlock," Swartz said.

Michael Liemohn, a professor of climate and space sciences and engineering at the University of Michigan and a former colleague of Zurbuchen, also spoke highly of him. "We can all get buried in the small details of our work lives, and it's good for somebody in a leadership position to be able to occasionally call everybody to attention and remind them of the big vision and the place that you're aiming at," said Liemohn, editor in chief of AGU's *Journal of Geophysical Research: Space Physics*. Zurbuchen "is good at not only listening to everybody to find out what those big-ticket items should be but honing those big-picture visions into tangible goals for an organization to head toward."

Top Priorities

Along with the search for extraterrestrial life, Zurbuchen spoke of understanding and protecting life on Earth as a top NASA science priority. Obtaining deeper insights into Earth includes tracking severe weather with satellites, monitoring potential disruptions from space weather, and better understanding climate change. Zurbuchen also noted that the search for the fundamentals of the universe, including dark energy and dark matter, is another of NASA's most important science goals.

Top management priorities for the new associate administrator include getting to know the science team at NASA and helping it succeed. "The team is already successful. I did not come to a whole bunch of broken glass. I walked in the door and I found a tremendously functional team," Zurbuchen said. Other priorities he noted are focusing on the agency's current operations and helping to make NASA a stronger organization strategically.

Navigating the Political Divide

In the political realm, NASA "has true bipartisan support," and many political leaders see value in NASA's mission, Zurbuchen said. "It's easy to see how [Earth science] affects us on a day-to-day basis. The business we're in here at NASA is taking measurements that affect our lives," he said. "Earth science is a really important part of the portfolio, for a variety of objectives."

He stressed the value of understanding that people may have different perspectives about issues. "Just because somebody doesn't agree the first time we open our mouths doesn't mean that they are stupid or we are smart or the other way around," he said.

Entrepreneurial Bent

In his prior tenure at the University of Michigan, Zurbuchen founded the College of Engineering's Center for Entrepreneurship. Now, in his new role, he questioned whether NASA, already an innovative agency, is "forward leaning" and sufficiently innovative. "I want to learn how to create the right environment" for that while also maintaining high overall standards, he commented.

Zurbuchen pointed to CubeSats as an example of a welcome, disruptive innovation that has a unique purpose—in this case, providing more and faster data gathering over locations on our planet or elsewhere. That and related technology have proven particularly useful for Earth science and heliophysics, he noted.

"This kind of disruption, that's what I'm looking for," he said. "How can we develop, invent a new technique, how can we invent new architectures of missions that can go in and really do science that we otherwise can't do?"

Nonetheless, NASA's approach can't be that "one size fits all," he said, emphasizing that NASA's missions and activities span a large range in terms of investments and size, from the Hubble telescope and the Earth science program to CubeSats. "The 'many flowers bloom' type of investment is absolutely critical for us as an agency and for humanity as a whole," he said.

By **Randy Showstack,** Staff Writer

Scientists Offer New Explanation for Island's Unexpected Uplift

Ricardo Ramalho

A deep, internally active magma system could be the reason that the Azores island of Santa Maria has been slowly uplifting for more than 3 million years. Outcroppings on the island like this one show different layers of ancient lava flows and marine sediments, which scientists used to trace ancient sea levels.

Islands in the middle of the ocean are supposed to sink. As they get older, the plate on which they sit cools, becomes denser, and sinks. Or the island's volcano gets so massive that it weighs down the entire island. Building on the expectation of island subsidence, Charles Darwin even penned a well-known theory about how sinking islands influence the growth of coral reefs.

A handful of oceanic islands, which don't sit on a continental shelf, break this rule. Most of them reside in the Atlantic Ocean. One in particular, Santa Maria, of the Azores Islands, located 1300 kilometers west of Portugal, slowly continues to rise above the sea, baffling scientists.

There are a few well-understood mechanisms for oceanic island uplift, said Ricardo Ramalho, a geologist at Portugal's University of Lisbon. Take Hawaii, for example. Hawaii is made up of volcanic islands, all formed from magma rising from a hot spot under the Pacific plate. As the plate moves over the hot spot, magma rises through the ocean floor, and the resulting volcanism forms an island. The plate continues to move, so older lithosphere cools and grows denser as it moves away from the magma source, causing the island to sink. But as that weight presses down on one part of the lithosphere, the lithosphere upstream, toward newer islands, rebounds, causing uplift in the younger islands.

But the Azores island cluster sits nowhere near a hot spot. In fact, these islands are 480 kilometers away from even the Mid-Atlantic Ridge, where new lithosphere forms. And Santa Maria, the oldest and southeasternmost island of the Azores, shows clear signs of uplift. Above the current sea level, cliffs contain evidence of lava flows that had encountered ocean water, and one side of the island boasts a wide, high-elevation rock staircase, eroded away long ago by waves and uplifted above the sea.

So Ramalho and a team of scientists decided to find out why. They recently published their findings in the *Geological Society of America Bulletin* (see http://bit.ly/gsa-paper).

History in the Cliffs

To figure out why the island continues to uplift, the scientists first had to reconstruct its history, which is written in the cliffs.

The researchers specifically looked for places on the cliff sides that showed where sea level once reached. Because lava that cools in

air forms different shapes than lava that cools in water, it's relatively simple to tell where flowing lava struck the cool ocean, Ramalho said. On land, lava cools in shapes called pāhoehoe and `a`a, but in the sea it forms structures called pillow basalts.

The team sailed all around the island, building a map of where they found transitions between the lava types, features that they call uplift tracers. By dating these marker lavas and comparing them to where sea level is now, they could build a basic history of the island's past.

The researchers found that Santa Maria Island first broke the ocean's surface 6 million years ago and then, through shield volcanism, grew steadily for about a million years. Then, 5.3 million years ago, the island subsided underneath the waves, most likely because of its own heavy weight pressing down on the lithosphere, Ramalho said. Later, the island reemerged because of renewed volcanism, while subsidence continued. Then, 3.5 million years ago, volcanism began to wane again, Ramalho said. It was also when new uplift began, the team's uplift markers showed.

> To figure out why the island continues to uplift, the scientists first had to reconstruct its history, which is written in the cliffs.

Why Uplift?

Because the nearest island, São Miguel, is much younger than 3.5 million years, its weight on the lithosphere couldn't have kicked off a teeter-totter-like rise in the lithosphere under Santa Maria, Ramalho said, which rules out that mechanism of uplift.

Another possible mechanism of uplift could be erosion, which would wear the island down and thus make it lighter and cause it to rise. But this mechanism is unlikely because eroded materials tend to accumulate at the base of the island edifice and slow down uplift. Sudden unloading of material is also unlikely, Ramalho said, because the uplift would be sudden, rather than long-lasting.

After ruling out those two possibilities, the researchers were left with a final mechanism. Because the beginning of uplift coincided with waning volcanism, they suspect that the magmatic activity didn't stop altogether but, rather, shifted from surface volcanism to intrusive activity deep in the crust.

This means that the "quietly active" magma has been intruding for millions of years into the crust beneath the island, causing the crust to bulge, which pushes the island upward, Ramalho said. Unfortunately, the exact mechanism of magma production is yet unknown, he continued. Some scientists argue that a mantle plume drives the melt, while others argue that water, or something else that creates an exceptionally volatile-rich mantle, could be causing the mantle to melt.

To test the plausibility of this new hypothesis, the research team determined a rough rate of past magma production by calculating the volume of the island and dividing it by how long Santa Maria took to form. They then calculated the approximate amount of magma that would have intruded into the crust beneath the island to explain the observed uplift, which started about the same time volcanism ended, 3.5 million years ago.

This hypothetical rate at which magma entered the crust matched the known rate of island formation. This supported the idea that uplift was driven by a shift from surface volcanism to a deep, intrusive system, the researchers report in their 21 October paper.

Quietly Active

The team's explanation for Santa Maria Island's uplift defies the conventional wisdom that "once an ocean island volcano has been carried away from its plume origin for several million years, it becomes extinct," said Karen Harpp, a geologist at Colgate University in Hamilton, N.Y. Ramalho's field observations and analysis of a possible mechanism of uplift at Santa Maria Island are "important support for similar observations [of uplift] elsewhere," she added.

Indeed, studies of other oceanic island chains in the eastern Atlantic, such as the Cape Verde Archipelago and the Madeira Archipelago, indicate that deep volcanism might have persisted under them as well, Ramalho said (see http://bit.ly/cape-verde). Other researchers also inferred that the same mechanism could be driving uplift in islands in the Canary Archipelago (see http://bit.ly/la-palma-canary).

These new findings "might help us to understand how magmatic systems behave in the long term," Ramalho suggested. They raised "questions about what is feeding [the magma] and what controls the transfer of magma from depth to surface." Perhaps, he added, this phenomenon "is more ubiquitous than previously thought."

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

Science Is Bipartisan Issue, White House Science Adviser Says

"Science has always to some extent been a bipartisan issue. It should continue to be a bipartisan issue," White House science adviser John Holdren told *Eos* in some of his first public remarks about the role of science after the election of Donald Trump as the next U.S. president.

"Science is good for the economy, it's good for the national security, it's good for the environment," the director of the White House Office of Science and Technology Policy since March 2009 told *Eos* after speaking at a recent workshop on ocean observations and understanding climate change. The way forward, he added, is for scientists to "keep being scientists and keep making the case for science and why it matters for society."

Holdren said that he could not comment on what he thinks will happen in the next administration because the 1939 Hatch Act prohibits federal employees from engaging in partisan political activity.

"We should not be deterred by any changes that might occur in the political climate. We still have to keep telling it like it is," Holdren told climate scientists and others at the workshop entitled "Sustaining Ocean Observations to Understand Future Changes in Earth's Climate," held at the National Academy of Sciences (NAS) in Washington, D. C., on 15 November. In those remarks, Holdren defended climate science and warned about the impacts of climate change.

Finding Win-Win Strategies

Several former federal officials at the workshop, including a former administrator of the National Oceanic and Atmospheric Administration (NOAA), told *Eos* that they worry about the future of U.S. leadership in climate change issues under the Trump administration. Trump, who has said that he considers himself to be "somewhat of an environmentalist," has referred to climate change as a hoax.

"A lot of what we need to do in this domain and others related to adaptation to climate change can fall under the heading of win-win strategies, things that would make sense even if the climate weren't changing," Holdren said at the workshop. He maintained that investments in climate research are good for the country.

Stating that there have always been storms, floods, and droughts, he added, "You don't need to accept that climate change is influencing the frequency and/or the severity of those events to accept that investing in being able to deal with them, in being better prepared, in being more resilient, is a good investment. I have been making that argument for years with people disinclined to put a lot of weight on climate change itself, and I'll keep making that argument."

Scientists "Have to Engage with Any Administration"

Workshop participant and speaker James Baker, who served as NOAA administrator from 1993 to 2001 during the Clinton administration, told *Eos* that he worries about Trump's statements about climate change. Baker said that Trump's potential policies could pose a threat to U.S. leadership in climate science and climate diplomacy and to the country's rapid growth and economic strength in renewable energy. He noted at the time of the workshop that Trump's science advisers were not known nor was who else "is going to be providing that kind of information."

"But all of the rhetoric up to now has been anticlimate," Baker said, referring to the president-elect's statements and positions that did not appear to take seriously the threat of climate change and that could encourage increased greenhouse gas emissions. "So I think we can see an additional and continuing attack on climate science and climate [change] mitigation activities."

Baker said that he is less concerned about Trump's vow to "end the war on coal" and prop up that energy sector. "It's going to be very hard to reinvigorate the coal industry, which has been declining the last few years" in the United States, Baker said, noting that natural gas has helped to reduce U.S. emissions.

> "We should not be deterred by any changes that might occur in the political climate. We still have to keep telling it like it is."

However, Baker said that scientists "have to engage with any administration" and make the case for climate science and for the Trump administration in particular to take the threat of climate change seriously. "The United States is such an important player, and the president and his team are the people who decide what happens" to a large extent, he said. "If we don't continue to make the case in a clear way to all sectors, I mean right and left, we are never going to actually progress things."

"Our Science Is Needed Now More Than Ever"

"I think our science is needed now more than ever to help inform adaptation decisions as well as how we continue to mitigate the impacts of climate change," Mary Glackin, cochair of the NAS committee that held the workshop, told *Eos* in personal comments separate from her official role.

Glackin is senior vice president for public-private partnerships and director of meteorological science and services at The Weather Company. She previously served as deputy undersecretary of commerce for NOAA operations.

The workshop was the fifth meeting held by the NAS committee as part of an 18-month study to examine ocean variables for climate research and prioritize the variables for which a long-term continuous record would be critical to understanding and modeling climate change.

REUTERS/Kevin Lamarque

Workers begin building the inaugural parade stands in front of the White House in Washington, D. C., in this 3 November photo. The White House science adviser has said that science is a bipartisan issue, and others have expressed concern about the incoming Trump administration's stance on climate change.

By **Randy Showstack,** Staff Writer

Challenges of Climate Change Adaptation

Practical and Methodological Challenges of Climate Change Adaptation
Oslo, Norway, 25–26 April 2016

Yorkman/Shutterstock.com

Attendees at an April 2016 workshop discussed adaptation challenges posed by urban flooding. More-frequent extreme precipitation events are currently occurring across Europe. One example, shown here, is the Boxing Day floods in North Yorkshire in the United Kingdom in December 2015.

Considerable challenges remain in understanding climate change, evaluating its associated effects on society, and identifying potential adaptation options. Implementing adaptation measures can increase the adaptive capacity and lessen the sensitivity of society as a whole, reducing its vulnerability to climate change effects.

To successfully adapt to climate change, society's leaders need to make decisions that reduce potential damage and take advantage of new opportunities. However, decision and policy makers do not always have the information they need to make necessary changes. Also, they often lack appropriate decision support tools to present information on a cost-loss level, which would enable them to explicitly include adaptation actions in city and state budgets.

The Center for International Climate and Environmental Research–Oslo (CICERO) and the Norwegian Computing Center convened a workshop in Oslo in April 2016 that brought together representatives from science and practice to discuss the practical and methodological challenges of climate change adaptation (see http://bit.ly/CCAdaptation). Climate scientists, environmental economists, statisticians, and those who provide and need distilled climate data to support decisions made by the public and private sector, mainly at the city and state levels, attended. The workshop was structured around three themes: adaptation, uncertainty, and visualization.

> Policy makers often lack appropriate decision support tools to present information on a cost-loss level.

The participants identified open access to available data as one of the main challenges of climate change adaptation. This holds, in particular, for economic and insurance data, in addition to the more traditional climate data. Such data sharing requires collaboration between governments, local authorities, the private sector, and public agencies. Compelling results from a pilot study presented at the meeting showed how local insurance loss data obtained from the insurance industry can enable informed decision making at the municipal level for reducing vulnerability to the effects of water-related natural hazards in cities.

Several recommendations emerged from the meeting, including that various data types must be coupled to assess climate change effects, the cost of these effects, and the cost of different adaptation options. In particular, attendees called for new modeling frameworks that can model the uncertainty of climate, risks to society, and costs and benefits of adaptation strategies in a joint fashion.

In addition, decision support tools must be able to deal with uncertainty. Meeting participants discussed how tools that combine real options analysis with a portfolio approach are flexible and appealing because they allow decision makers to ponder combined adaptation strategies and invest in adaptation on whatever schedule they choose, all while accounting for the uncertain effects of climate change.

Participants discussed visualization and presentation of information throughout the workshop. They agreed that there is a need for visualization tools for decision making and adaptation options that are user specific and simple without disguising the underlying uncertainty. The practitioners expressed a strong preference for uncertainty information that is presented in terms of risks and likelihoods.

In general, attendees agreed that scientists should interact with policy makers to co-produce stories. Storytelling—setting a scene—not only will help scientists convey information to policy makers but also will help both communicate costs and benefits of climate change adaptation strategies to the public.

The workshop was hosted by the Norwegian Computing Center with support from the Research Council of Norway through grants 249709/E10 and 243953/E10 and by NordForsk through project 744556.

By **Thordis L. Thorarinsdottir** (email: thordis@nr.no), Norwegian Computing Center, Oslo, Norway; and **Karianne de Bruin,** CICERO, Oslo, Norway; and Wageningen Environmental Research, Wageningen, Netherlands

Joint Aerosol Research Between Cuba and Spain Proves Fruitful

Optics Atmospheric Teams' Workshop
Camagüey, Cuba, 27–29 January 2016

iStock.com/debstheleo

A hazy dawn breaks over Havana, Cuba. A workshop last January documented the progress of a joint research project between Spain and Cuba, which since 2007 has provided valuable information on the characteristics of atmospheric aerosols over Cuba.

Spain and Cuba have conducted joint research on atmospheric aerosols since 2007, when an agreement was signed between the University of Valladolid (UVA) in Spain and the Institute of Meteorology (INSMET; http://bit.ly/Cuba-INSMET) in Cuba. Last January, we convened a workshop in Camagüey, Cuba, to evaluate the progress of this cooperation and to highlight the accomplishments that we have made so far.

Presentations at the workshop highlighted the progress made by three joint research projects conducted from 2008 to the present by the Grupo de Óptica Atmosférica from UVA (GOA-UVA) and the Grupo de Óptica Atmosférica de Camagüey (GOAC) from INSMET. These projects used an automated state-of-the-art Sun photometer to identify and measure the properties of optical and microphysical aerosols, which reflect and scatter solar radiation. This is the only Sun photometer of this type in Cuba, and we have contributed its measurements to NASA's Aerosol Robotic Network (AERONET; http://aeronet.gsfc.nasa.gov).

Speakers discussed the results of cloud optical depth (COD) statistics that AERONET calculated using 1 year's worth of measurements from our Sun photometer. They found a bimodal COD frequency distribution for all months. Coincident COD measurements from both the Sun photometer and Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) show the same frequency distributions for COD values lower than 5.

In addition, presentations focused on analysis of particles with aerodynamic diameters less than 10 micrometers (PM-10) and 1 micrometer (PM-1) over a 2-year period using a low-volume impactor to collect particles. Researchers have made gravimetrical measurements to quantify the concentration of the particles they collected at each range of aerodynamic diameters.

Other presentations focused on how, through aerosol optical depth (AOD) and Ångström exponent measurements, scientists have determined that maritime aerosols are the most prevalent at Camagüey year-round and Saharan dust particles increase from May to August. The researchers also reported that they studied several Saharan dust events. Specifically, they compared the AOD data derived from the Sun photometer and the Moderate Resolution Imaging Spectroradiometer (MODIS) during the transport of Saharan dust with the SKIRON/Eta model outputs for Camagüey, and they determined the biases in the data from both sources.

One goal of the program was to characterize PM-10 and PM-1 fractions and their chemical compositions at Camagüey. This has been done, and we found that during a Saharan dust event, the instruments measured a PM-10 maximum concentration of 73 milligrams per cubic meter. For aerosols, concentrations of sulfate and ammonium ions predominate in fine particles. For coarse particles, the main contributions are from sodium, chloride, and nitrate ions. These results were presented at the workshop.

The workshop featured six papers involving the joint studies that have been published in scientific journals with high impact factors (see http://www.goac.cu/uva). In addition, an optical bench for the angular calibration of solar radiation sensors, the first ever in Cuba, was inaugurated during the meeting. It was designed and built at GOA-UVA and installed at GOAC, and it began operating 2 weeks after the meeting. A proposal for automating the calibration process has been drafted in cooperation with Errico Armandillo of the European Space Agency, who attended the meeting.

Brent Holben, chair of AERONET and the first NASA scientist to visit Cuba, also attended the meeting. He discussed with the GOAC team the joint scientific interest for potential future official cooperation between GOAC-INSMET and NASA AERONET.

GOAC, the Camagüey Meteorological Province Center (CMPC), and the Province Delegation of the Ministry of Science, Technology and Environment of Cuba sponsored the workshop.

By **Juan Carlos Antuña-Marrero** (email: anadelia@caonao.cu), Grupo de Óptica Atmosférica de Camagüey, Meteorological Institute, Camagüey, Cuba; **Ángel De Frutos Baraja,** Grupo de Óptica Atmosférica, University of Valladolid, Valladolid, Spain; and **René Estevan Arredondo,** Grupo de Óptica Atmosférica de Camagüey, Meteorological Institute, Camagüey, Cuba

Academia and the Military Can Be Valuable Partners

Sailors use the old expression "All hands on deck!" to signal a ship's crew to meet, receive orders, and prepare for action. Usually, a ship's leadership uses this term only in times of crisis or stress because it involves every person not actively operating the ship. It is used when the ship's commanding officer requires the entire crew's knowledge, skill, and expertise.

However, instances can arise in which the collective experience of an entire ship lacks critical knowledge required for an operation. This situation requires looking beyond the traditional peer group to seek and give help.

We were involved with such a collaboration involving two cultures that can have a tenuous relationship: academia and the military. The interaction provided a valuable reminder that when they share a common purpose—in this case, protecting people and the environment from an oil spill—academics and military personnel can join forces.

Although academia and the military collaborate in some areas, the two communities leave work in the field, or, in military parlance, during "operations," as a military- or academia-only endeavor. However, if the two communities look beyond their cloisters, many opportunities for shared fieldwork arise that could jointly help society.

An Exchange of Business Cards

On 20 April 2010 in the northern Gulf of Mexico, the oil drilling platform Deepwater Horizon exploded and killed 11 people. The damaged Macondo well released an estimated 160 million gallons of oil into the ocean over 87 days, polluting the water, seafloor, sea surface, atmosphere, and coastal lands. The pervasive oil pollution threatened tourism and seafood industries as well as the ecology of the affected region.

During the Deepwater Horizon oil spill, Thad Allen, the former U.S. Coast Guard admiral and commandant who led the response to the disaster, often lamented that critical participants too frequently met for the first time at the onset of a crisis, as opposed to having met and interacted during advanced planning exercises. Adm. Allen frequently and famously stated, "You don't exchange business cards during a crisis."

As with so many aspects of life, different communities have different cultures with unique jargon, definitions of success, and experiences. Simply, it is better to exchange contact and information across these cultural boundaries in advance, when timing is not critical.

Two of us (Christopher Reddy and David Valentine) found ourselves in the thick of the Deepwater Horizon disaster because of our prior experiences studying the biogeochemistry of oil spills and natural oil seeps. We learned, through trial, to embrace Allen's mantra.

So in February 2016, long after the Deepwater Horizon crisis was over, our arms and ears were wide open when this article's third author, Lt. Cdr. Jason Ziebold of the U.S. Navy, asked to exchange business cards. At the time, he was part of a staff of military planners and operations managers for a large exercise in

Cpl. Rebecca Floto/U.S. Marine Corps

U.S. Marine Corps captain Justin Gaines uses binoculars to view the impact after a missile was fired as part of NATO exercise Cold Response 16 at Orland, Norway, on 24 February 2016. A portion of the exercise involved a partnership with academia.

Norway. He needed information that the collective knowledge of the staff lacked.

One of the greatest challenges of Deepwater Horizon was communicating and building trust with the diversity of stakeholders involved. These stakeholders ranged from government and industry responders to the media, nongovernmental organizations, local citizens, and academic researchers with expertise in the deep waters of the Gulf of Mexico. All of them had different responsibilities, goals, time frames, and cultures, and suddenly they were thrown together under duress.

These challenges have spawned efforts such as the Science Partnerships Enabling Rapid Response (SPERR). This is an ongoing effort to understand the obstacles facing effective scientific communication across government, industry, and academia during environmental crises such as large oil spills and to design new tools, protocols, and practices to enable engagement and collaboration.

But sometimes, as in our case, it takes just a little initiative and a simple gesture.

Deepwater Horizon Response, CC BY-ND 2.0 (http://bit.ly/ccbynd2-0)

Fire persists on 21 April 2010, a day after the explosion of the Deepwater Horizon oil drilling platform. The explosion killed 11, and the damaged Macondo well released upward of 160 million gallons of oil into the northern Gulf of Mexico over 87 days.

Oil Spills: Not Always an Accident

Oil spills are usually thought to be accidental, but releases also result from deliberate actions, such as the sinking of vessels during military conflicts. For example, hundreds of vessels that were deliberately sunk during World War II are leaking oil into the Pacific Ocean or are predicted to do so in the future. Environmental effects can also be used as weapons of war as exemplified during the first Gulf War when Saddam Hussein strategically chose to create an oil spill that leaked approximately 160 million gallons of crude oil.

Members of the military are aware that their strategic sinking of ships poses hazards long after conflicts end. An increasing trend in military circles is to take these effects, including environmental ones, into account during planning.

Cold Response 16

In 2015 and early 2016, U.S. forces were preparing a military exercise to conduct operations in cold-weather environments on land and at sea. The exercise, called Cold Response 16, placed fictional countries in the real-world geography of Norway.

An adversary country, Norlandia (northern Norway), invaded a North Atlantic Treaty Organization (NATO) ally, Highland (central Norway). NATO forces were charged with responding to the invasion and repelling Norlandian forces from Highland.

The intent of the military exercise was to defeat the enemy while limiting unnecessary human casualties and avoiding damage to allies' critical infrastructure, such as power plants, airports, and hospitals. But commanders and planners of Cold Response 16 also considered environmental, economic, and political impacts from damage to fisheries and aquaculture from the sinking of ships designed to refuel other ships at sea. Norway has the largest fishing industry in Europe and that is second by value in the world. An oil spill risked creating significant environmental damage with significant impact on local economies and the potential for negative publicity.

> If the military and academic communities look beyond their cloisters, many opportunities for shared fieldwork arise that could jointly help society.

Lt. Cdr. Ziebold was charged with researching the impacts of a spill and ways to minimize negative effects to both the NATO mission and nearby populations. He and his colleagues were concerned that they could create another Deepwater Horizon disaster.

An oil spill scientist would know that such a scenario would not happen in this case because of a variety of factors. But Ziebold's expertise is naval combat, not marine pollution science. He took the initiative of simply writing an email that eventually found its way to Reddy and Valentine.

Teaming Up to Reduce the Damage

Reddy and Valentine provided background knowledge on oil spills. They also helped to gather more information and expertise from colleagues in both U.S. government agencies and industry.

Armed with this information, the academic team briefed Cold Response 16 planners on various case studies of previous oil spills (including Deepwater Horizon), the different environmental fates and biological

effects of jet fuel versus diesel fuel, and the estimated concentrations of oil that would impact the environment in Cold Response 16.

The collective knowledge base resulted in advice to avoid sinking a ship in shallow waters near land and to take advantage of offshore winds and outgoing tides that would move oil away from shore. Thus, during the exercise, NATO forces were able to fictionally "sink" a Norlandia refueling ship at a time and in an area with near-ideal conditions to prevent and mitigate environmental damage. Furthermore, the information also provided the military planners knowledge of the environmental effects should a refueling ship need to be sunk in a shallow-water area.

A Mutually Beneficial Exercise

Beyond a successful military exercise, we see this as a successful, mutually beneficial exercise in communication between the military and academic researchers. This case exemplifies the value of stakeholders taking the simple, but often overlooked, step of "exchanging business cards" in the planning stages of events, rather than during active crises, when seeking to minimize damage from oil spills.

The military seeks advice from academia; however, it rarely seeks it during an ongoing operation. Once operations begin, military members do not typically think about incorporating elements of academia into rapid, life-versus-death decision making. Likewise, academics lack built-in incentives or rewards for having a willingness to develop or create more preexisting relationships outside the ivory tower. However, collaboration between the two communities can have great rewards. Reddy and Valentine have begun to enjoy this aspect of being scientists: providing clarity, information, and expertise to policy makers and other stakeholders before, during, and following oil spills.

> An increasing trend in military circles is to take environmental effects into account during planning.

In the wake of Deepwater Horizon, former National Oceanic and Atmospheric Administration (NOAA) administrator Jane Lubchenco stated that scientists who had preexisting relationships with federal agencies such as NOAA and the Coast Guard had the greatest success in helping to mitigate the crisis. In this case, a single email could perhaps one day protect untold lengths of coastline, people's livelihoods, and the country's relationships with allies.

Arguably, even such modest levels of engagement outside the ivory tower could have a greater impact than a highly cited publication.

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SPACE WEATHER from a Southern Point of View

By Michael D. Hartinger, C. Robert Clauer, and Zhonghua Xu

A recently completed instrument array in Antarctica provides a more complete understanding of the near-Earth space environment.

In 2008, during the International Polar Year campaign, a team of researchers and engineers traveled to a remote location high on the East Antarctic Plateau (EAP). There, they installed PG1, the first station in an autonomous six-station instrument array designed to monitor geospace, the near-Earth space environment.

Eight years later—despite frigid weather, the thin atmosphere at a pressure altitude of 3000–4000 meters above sea level, and various logisti-

Michael Hartinger

A team member prepares to dig an instrument pit near the newest station in a geospace monitoring array on the East Antarctic Plateau.

A temporary snow wall shields tents from the wind at the PG5 camp, roughly 800 kilometers from the South Pole Station on the windswept East Antarctic Plateau. PG5 is one of the most remote sites in the autonomous adaptive low-power instrument platform (AAL-PIP) array. In the background, the main instrument pit and solar panel tower are visible.

cal challenges inherent in positioning stations across the broad but desolate EAP—the array is now complete. The last station, PG5, was installed in January 2016.

The full array (Figure 1, red dots) currently spans roughly 10° of latitude, roughly 1000 kilometers, along the 40° longitude geomagnetic meridian. It is now returning data on high-latitude electrical current systems, plasma waves, and irregularities in the ionosphere (see http://bit.ly/VT-magnetic-data).

Observations from this array, when combined with those from an array in Greenland, enable researchers to monitor geospace above both hemispheres simultaneously in more detail than ever before.

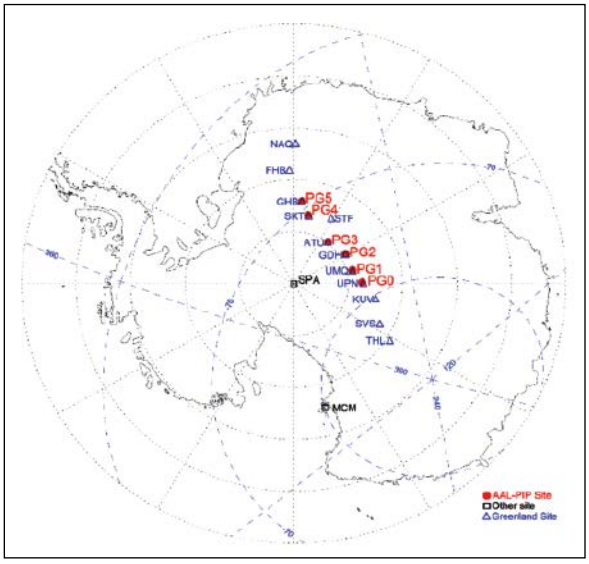

Fig. 1. Map of AAL-PIP sites (red dots), McMurdo Station (MCM), and South Pole Station (SPA). Tracing the Earth's magnetic field from Northern Hemisphere DTU Space Greenland sites, one arrives at magnetically conjugate locations in Antarctica (blue dots); these locations often overlap with AAL-PIP sites. These pairs of magnetic conjugate locations lie at each end of a geomagnetic field line, so that researchers can track current systems in each hemisphere simultaneously.

Dynamic electrical currents flow between different regions of geospace, heating Earth's upper atmosphere. These currents can affect human technology in undesirable ways: enhancing satellite drag, distorting radio communication, and inducing unwanted electrical currents in power grids. Understanding and predicting how these currents couple different parts of geospace is a major goal of the space plasma physics research community.

High-latitude current systems are particularly important, as they couple the solar wind to the geospace system. Ground-based instrument arrays can remotely sense such currents with high spatial and temporal resolution, exploring their properties on a range of scales and providing context for sparse satellite measurements.

Why Antarctica?

Because most ground observations come from the Northern Hemisphere, it is common to assume that such observations represent the overall geospace environment. However, the increasing availability of measurements in Antarctica shows that this assumption is not always correct. In fact, this assumption occasionally fails spectacularly when brilliant auroras are seen in the Southern Hemisphere but not the Northern Hemisphere, or vice versa. To get the complete picture, we need measurements in both hemispheres to characterize the geospace environment and understand what causes asymmetries between the north and south.

Earth's internally generated magnetic field organizes the high-latitude electrical currents that flow along the magnetic field. By tracing the field from preexisting Northern Hemisphere stations to the Southern Hemisphere, we can identify ideal "magnetically conjugate" locations, that is, pairs of locations that mark the beginning and end of a magnetic field line that enable us to track current systems in each hemisphere simultaneously.

As the solar wind distorts Earth's magnetic field, these stations will remain well situated for interhemispheric comparisons of high-latitude current systems under most conditions. A north–south array of magnetically conjugate instruments is a powerful tool for inter-

Zhonghua Xu

hemispheric comparisons because it allows researchers to investigate the spatial structure of current systems while constraining how interhemispheric comparisons are affected by latitude-dependent distortions in Earth's magnetic field.

Specially Designed Instrument Platforms

EAP and the west coast of Greenland are two of just a few high-latitude locations on Earth large enough for a conjugate instrument array. Through collaboration between Virginia Polytechnic Institute and State University (Virginia Tech), which operates Antarctic instruments (Figure 1, red dots; see http://mist.nianet.org), and the National Space Institute at the Technical University of Denmark (DTU Space), which operates Greenland's magnetometers (Figure 1, blue dots; see http://bit.ly/Greenland-magnetometers), it is now possible to observe large currents, plasma waves, and other phenomena in both hemispheres simultaneously.

However, the harsh EAP environment proved to be a challenging location in which to deploy and maintain instruments, with extreme winds, typical temperatures from −70°C to −14°C, and limited infrastructure. To help overcome this, the University of Michigan and Virginia Tech partnered to develop and deploy autonomous adaptive low-power instrument platforms (AAL-PIP; see http://bit.ly/autonomous-platforms).

These platforms provide a way of powering and communicating with multiple instruments in the harsh Antarctic environment. Each platform consists of a central pit with a battery box, an electronics box, and a solar panel tower. Wires connect the central pit to four different instruments at varying distances, which can be as far as 50 to 100 meters away.

The full instrument array is now returning data on high-latitude electrical current systems, plasma waves, and irregularities in the ionosphere.

Developing AAL-PIP leveraged many years of experience with similar instruments in Greenland and Antarctica. These AAL-PIPs are designed to be easily and quickly deployed during cold weather conditions, requiring few

Michael Hartinger

Team members work on the central pit of an AAL-PIP during testing near South Pole Station. The pit contains an insulated blue electronics box and a wooden battery box. A solar panel tower is in the foreground. From here, wires run to four instruments at varying distances. The flags mark the path of a wire to an induction magnetometer roughly 50 meters away from the pit.

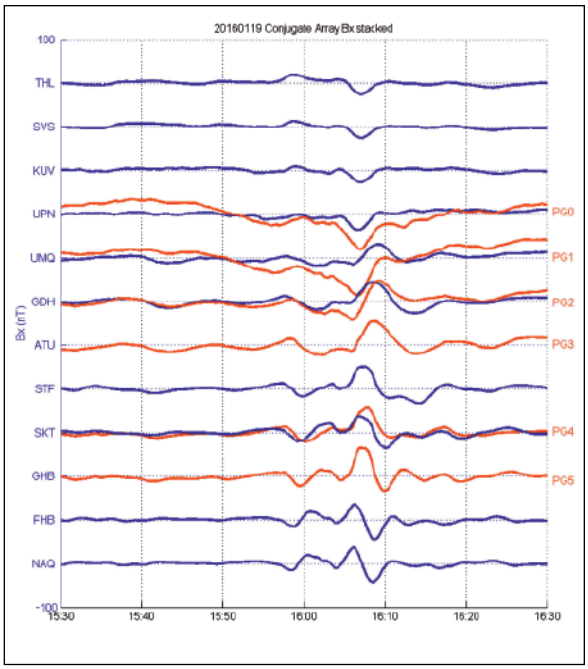

Fig. 2. A comparison of geomagnetic phenomena occurring in the Northern and Southern Hemispheres, measured at the stations shown in Figure 1, during a transient current event that passed over the stations at about 16:05 on 19 January 2016. The magnetic north–south components of the magnetic field variation measured by six AAL-PIP sites are shown as red lines, ordered according to magnetic latitude, with highest latitudes at the top. Blue lines are for all DTU Space Greenland west coast magnetometer stations available at the time. During this event, the amplitudes and phases of the corresponding magnetic perturbations varied rapidly with latitude and between hemispheres.

tools. The solar panel and battery-powered system are programmed for optimal power consumption.

As a result, high-resolution measurements from many instruments, including a fluxgate magnetometer, induction magnetometer, GPS receiver, and high-frequency radio experiment, are taken for most of the year [*Clauer et al.*, 2014]. The AAL-PIP station at PG1, for example, has operated continuously with few problems for 8 years.

A Challenging Deployment

The first and last stations to be deployed, PG1 in 2008 and PG5 in 2016, highlight the challenges of deploying instruments on EAP. PG1 and other locations in the chain are sited at pressure elevations of 3000–4000 meters; high elevations combine with cold, windy conditions to make camping and installation more difficult.

Because the cold weather rapidly discharged power drill and satellite phone batteries required for installation and communication, team members provided their own heat source: They constantly sheltered the batteries under their coats and in their sleeping bags. At the highest elevations, it took a very long time to boil snow to replenish drinking water supplies, and team members experienced shortness of breath while they were working.

All stations in the chain require LC-130 and Twin Otter airplane support to transport cargo, camping equipment, and the team. Flights to PG5 stop at New Zealand, McMurdo Station, the SPA South Pole Station, and a fuel cache before arriving at PG5. Flights from SPA to remote locations on EAP are available only a few weeks each year, and they are often canceled because of bad weather, sometimes stranding team members for weeks at a time. Our team overcame these challenges with considerable support from the U.S. Antarctic Program (https://www.usap.gov).

New Perspectives on the Geospace Environment

The spacing and sampling rates of AAL-PIP and DTU Space magnetometers are ideally suited for interhemispheric comparisons of mesoscale current dynamics: fluctuations spanning hundreds to thousands of kilometers occurring over timescales shorter than 10 minutes.

Kim et al. [2013] used this capability to compare the timing and amplitude of magnetic perturbations associated with such currents in each hemisphere. The same group further probed the structure of transient currents, using each array to confirm the presence or absence of uniquely structured vortices associated with localized currents aligned with Earth's magnetic field [*Kim et al.*, 2015]. A team at Virginia Tech is now comparing AAL-PIP data with numerical simulations and other data sets to explore the sources of these interhemispheric differences.

AAL-PIP data are also being used to explore the source of irregularities in the ionosphere—the charged plasma of Earth's upper atmosphere—that span about 10 kilometers; these phenomena can affect radio communication and the accuracy of GPS signals. Using instruments from this array, *Deshpande et al.* [2012] first demonstrated the capability of the Connected Autonomous Space Environment Sensor GPS receiver (http://bit.ly/CASES-sensor) for science-grade measurements, whereas *Kim et al.* [2014] used fluxgate magnetometers, induction magnetometers, and GPS receivers to show that plasma waves can modulate ionospheric irregularity dynamics.

We need measurements in both hemispheres to characterize the geospace environment and understand what causes asymmetries between the north and south.

The newly completed array makes it possible to compare magnetic perturbations between hemispheres (Figure 2). Such perturbations are seen at Northern Hemisphere Greenland stations (blue lines) and their Southern Hemisphere AAL-PIP counterparts (red lines) over a large spatial region. As in the transient current events discussed by *Kim et al.* [2013, 2015], the amplitude and phase of these perturbations vary rapidly with latitude and between hemispheres. Comparisons such as these can reveal how magnetic field topology and charged-particle precipitation, both of which vary with hemisphere and lat-

A Twin Otter plane arrives to bring the team back to South Pole Station after they deploy the PG4 AAL-PIP site.

itude, affect the properties of transient currents and other geospace phenomena.

A Powerful Combined Tool

The six closely spaced AAL-PIP stations are a powerful new tool for remote sensing of high-latitude current systems, plasma waves, and ionospheric irregularities on a wide range of temporal and spatial scales, providing a unique Southern Hemisphere perspective. When these observations are combined with satellite measurements and ground-based data from Greenland, they provide a truly global perspective of the geospace environment.

Acknowledgments

This project was supported by the National Science Foundation, which manages the U.S. Antarctic Program. AAL-PIP fluxgate magnetometer data are available via online databases: Magnetosphere-Ionosphere Science Team (MIST), Time History of Events and Macroscale Interactions During Substorms (THEMIS), Coordinated Data Analysis Web (CDAWeb), and SuperMAG. Other data are available by contacting MIST.

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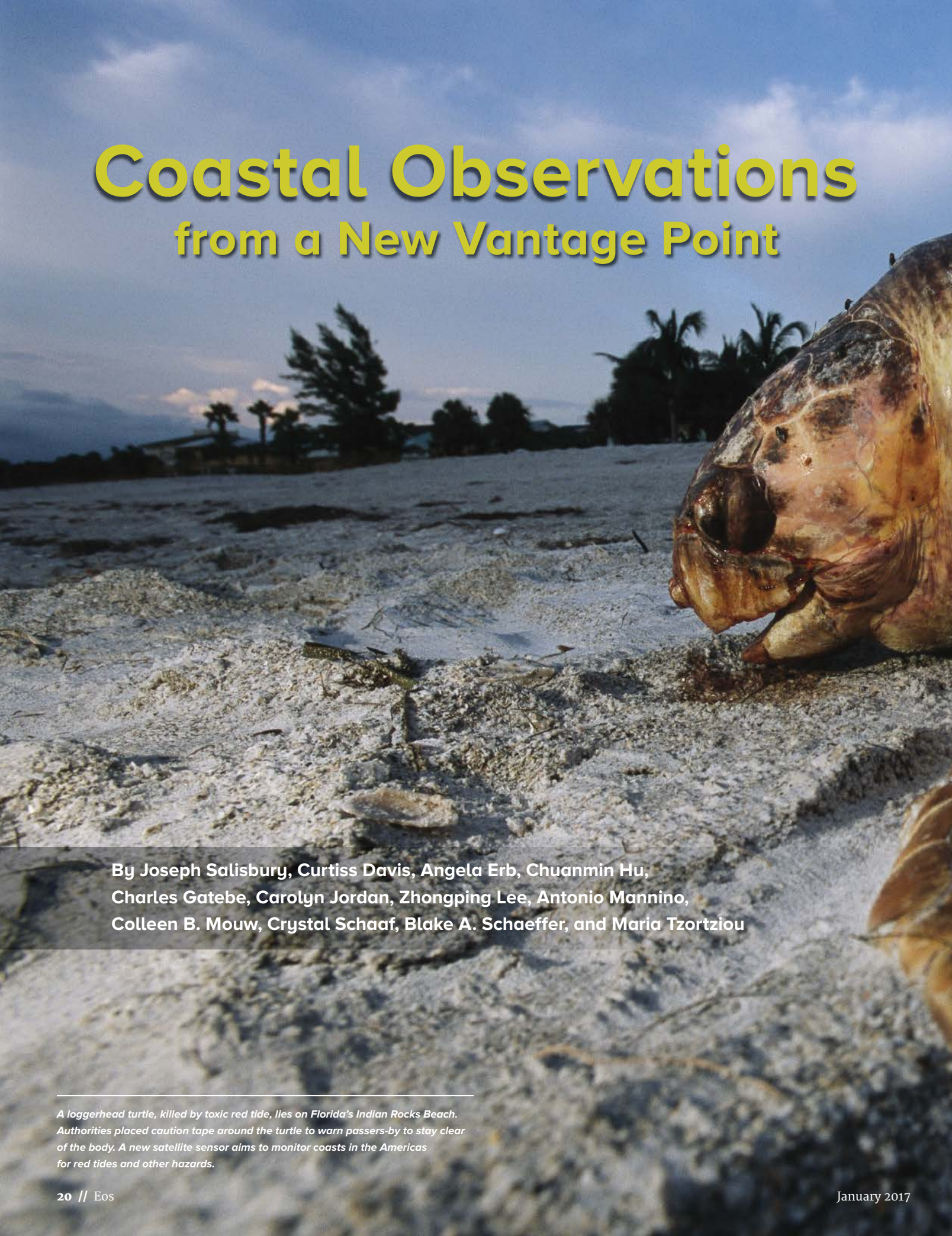
Coastal Observations
from a New Vantage Point



By Joseph Salisbury, Curtiss Davis, Angela Erb, Chuanmin Hu, Charles Gatebe, Carolyn Jordan, Zhongping Lee, Antonio Mannino, Colleen B. Mouw, Crystal Schaaf, Blake A. Schaeffer, and Maria Tzortziou

A loggerhead turtle, killed by toxic red tide, lies on Florida's Indian Rocks Beach. Authorities placed caution tape around the turtle to warn passers-by to stay clear of the body. A new satellite sensor aims to monitor coasts in the Americas for red tides and other hazards.

Tyrone Turner/National Geographic/Getty Images

World population was estimated at more than 7 billion people as of 2015, and roughly half of them live within 100 kilometers of a coastline [*United Nations Environment Program*, 2007]. Human population growth and climate change have put increasing pressure on coastal ecosystems. To ensure that humans can adapt to changes in these ecologically and economically important ecosystems, it is essential that we understand the factors that affect their water quality, ecological processes, and biogeochemical cycles.

Coastal ocean ecosystems are more complex than open-ocean ecosystems because currents, tides, surface winds, and light drive short-term variability in chemical and biological processes, including phytoplankton growth and migration. The waters of coastal ecosystems are also com-

Fish that suffocated from a red tide wash up on Florida's coast.

plex because of their proximity to land and, by extension, to the humans who inhabit the coastlines. This proximity subjects coastal ecosystems to variations in materials carried in river and groundwater flow, along with varying stress from human activities.

The value of coastal ecosystems and the pressures on them motivated, in part, the National Research Council [2007] to recommend in their Earth science decadal survey that NASA develop a satellite mission to monitor coastal stressors. In particular, the National Research Council recommended the Geostationary Coastal and Air Pollution Events (GEO-CAPE) satellite mission, which at the time was in its early planning stages and was formally initiated in 2008 (see http://bit.ly/GEO-CAPE). In addition to focusing on pollution events, GEO-CAPE would observe dynamic coastal ocean processes and variability in atmospheric composition across the United States.

Atmospheric objectives are described by *Fishman et al.* [2012]. Here we describe the coastal ecosystem part of the mission, which would investigate science questions centered on short-term biogeochemical processes, exchanges between land and ocean, the effects of climate change and human activity, the effects of airborne materials, and episodic pollution events and coastal hazards. By imaging the same regions repeatedly throughout the day, GEO-CAPE would offer an unprecedented look at these short-term phenomena.

The GEO-CAPE Mission

In 2008, two science working groups that focused separately on the ocean and the atmosphere convened to address land, ocean, and atmospheric processes and their interactions across terrestrial and aquatic interfaces. Members of these working groups, who were chosen from university experts and NASA personnel, began to formulate the specifics of GEO-CAPE.

GEO-CAPE has preformulation status. This means that NASA is funding efforts to create robust mission plans and instrument designs but is waiting on these plans and designs before setting a launch date, pending future funding. The original science working groups have defined scientific questions and continue to advise NASA on the spatial, spectral, temporal, and radiometric attributes for the GEO-CAPE mission.

Critically, GEO-CAPE would conduct remote sensing from a geostationary orbit, which would provide the necessary perspective for repeated observations of geographic regions of interest throughout the day. This orbit is a key factor in how GEO-CAPE would be different from the present suite of low-Earth-orbit ocean color satellites.

To reduce mission risk and cost, the working groups have endorsed the concept of phased implementation, or separate launches, of the ocean and atmospheric Earth-observing instruments, using hosting on commercial satellites. Although GEO-CAPE has an unspecified launch

date, NASA has invested nearly $20 million to advance the science and technology of the mission. GEO-CAPE would be a two- or three-instrument payload mission with a distributed architecture to reduce risk and cost.

GEO-CAPE's Ocean Color Sensor

Ocean color information can aid in identifying algal blooms, colored dissolved materials, particle loads, and oil spills. Ocean color can also provide information on land use and coastal features and reveal changes in response to storms and other disruptive phenomena. Thus, GEO-CAPE would track phytoplankton, water quality, and biogeochemical parameters across northern and southern latitudes in the Western Hemisphere.

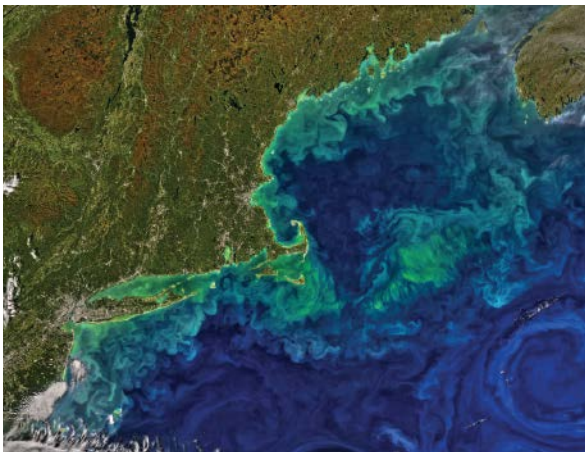
To achieve its scientific goals, the GEO-CAPE team developed the concept for an ocean color sensor uniquely designed to capture the evolution of algal blooms and monitor phytoplankton physiology, growth rates, and shifts in phytoplankton community composition. The sensor would also resolve coastal features, fronts, eddies, and upwelling and help to estimate biogeochemical fluxes and land-ocean-atmosphere exchanges at subdiurnal and multiday scales. The sensor would feature a hyperspectral ocean color radiometer that senses energy emanating from the coastal ocean in the ultraviolet, visible, and near- and shortwave-infrared spectral ranges.

Geostationary orbit would keep the sensor at a fixed location approximately 36,000 kilometers above the Earth (Figure 1). This would allow frequent imaging within its fixed field of view of North and South America's vast coastal regions and the Laurentian Great Lakes, providing frequent measurements that would revolutionize scientific understanding of coastal dynamics and dramatically increase the societal value of coastal observations from space.

Current ocean color sensors on polar orbiters can make measurements of the coastal ocean only once every 1–2 days. Because of cloud cover and other limitations, valid ocean color retrievals over coastal waters occur weekly, on average, which is inadequate to quantify coastal ocean dynamics. GEO-CAPE's high-frequency measurements (every 1 to 3 hours) would resolve rapidly changing conditions in coastal waters, making it possible to monitor and quantify ecosystem processes and to reduce measurement uncertainties (Figure 2).

Proposed applications include tracking harmful algal blooms, managing fisheries, assessing water quality, quantifying large oil spill thickness and extent, and improving disaster response.

By focusing on coastal environments, GEO-CAPE is poised to advance not only ocean science but also terrestrial ecosystem science, which would greatly increase the number of cloud-free observations of diurnal and seasonal changes in coastal vegetation. This improvement would enable new applications for studying agricultural productivity and stress, tidal inundation, disturbance of natural ecosystems, and responses to ephemeral phenomena such as storm events.



Aqua-MODIS

Phytoplankton swirls off the coast of New England in the eddy field between the Gulf Stream and the Gulf of Maine. This 7 October 2016 image is from the Aqua satellite's Moderate Resolution Imaging Spectroradiometer (MODIS); GEO-CAPE plans to collect similar images every 1–3 hours off all coasts along North America.

In addition, the spectral range and spatial resolution achievable with the sensor would provide data on atmospheric aerosols and potentially trace gases for studies of coastal emissions. These data would allow GEO-CAPE to study interdisciplinary science topics, including biogeochemical cycling in coastal ecosystems, carbon stocks and fluxes from coastal wetlands, coral reef health, coupled coastal air and water quality, the role of upwelling and bioaerosols in meteorology, and effects of anthropogenic disturbances in aquatic environments.

Enhanced Applications

Humans benefit from coastal ecosystems economically and in their quality of life [*Wheeler et al.*, 2012]. To sustain healthy coastal systems, economic prosperity, and quality of life, we will need the ability to monitor change, assess ecological conditions, and disseminate information to the people who need it most.

The GEO-CAPE Ocean Working Group and NASA's Applied Science Program work closely with the satellite user community, including the National Oceanic and Atmospheric Administration, the U.S. Environmental Protection Agency, the U.S. Navy, the U.S. Army Corps of Engineers, the Bureau of Ocean Energy Management, and the Gulf of Mexico Fishery Management Council. We have compiled metrics to assess user data needs and measurement requirements for specific applications concepts.

Following this assessment, proposed applications include tracking harmful algal blooms; managing fisheries; assessing water quality, surface currents, and underwater visibility; improving search and rescue and navigation; monitoring coastal and estuarine acidification; quantifying large oil spill thickness and extent; and improving carbon modeling, environmental forecasting, benthic habitat monitoring, and disaster response.

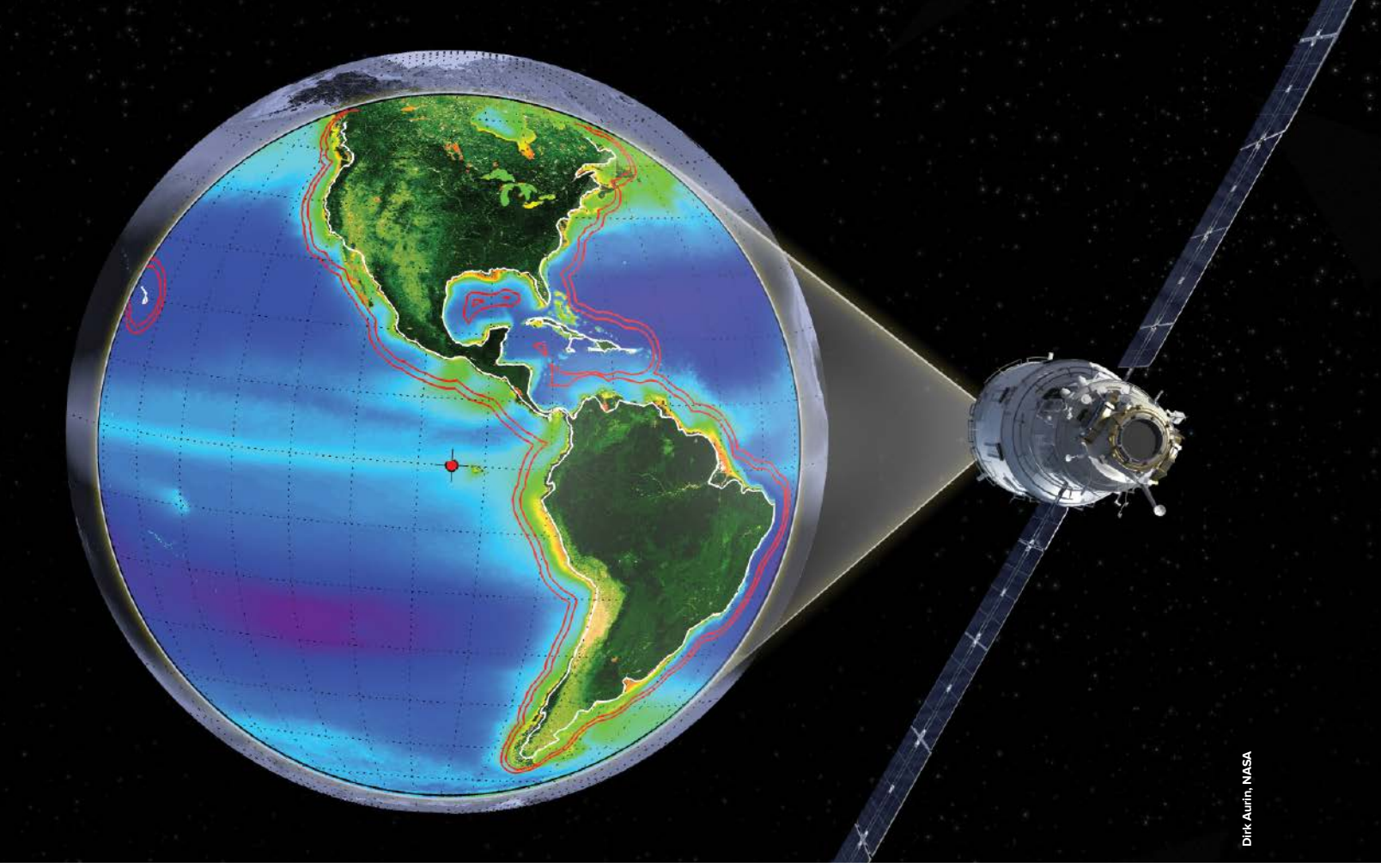


Fig. 1. The Geostationary Coastal and Air Pollution Events (GEO-CAPE) satellite's coverage is proposed to span North and South America. The satellite's geostationary view from 95°W at the equator (red dot) for the GEO-CAPE coastal ecosystem sensor is overlain on a color map from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) chlorophyll a/ biosphere mission composite. The black outer circle encompassing much of North and South America represents the 67° sensor viewing angle, which is the approximate limit to ocean color retrievals from 95°W. The red lines extending beyond the continental landmasses represent 375-kilometer (acceptable) and 500-kilometer (mission goal) distances away from the shore (white lines). Graphic development by the U.S. Environmental Protection Agency.

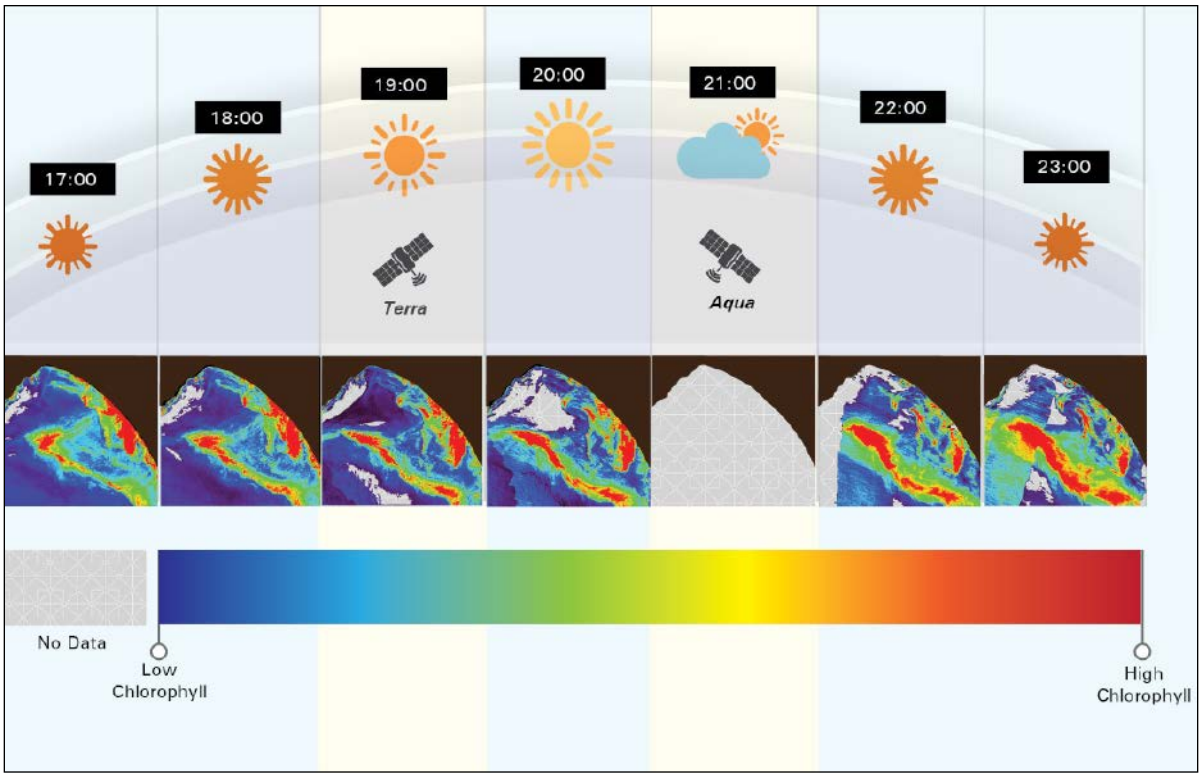
The ability of GEO-CAPE to monitor anthropogenic emissions and smoke plumes from fires on regional scales throughout the day would offer considerable potential for quantifying changes in coastal air quality, smoke plume evolution, and fire emissions, which have direct and significant effects on atmospheric and biogeochemical cycles, the Earth's radiation budget, and human lives. Access to information on other important abrupt disturbances—snowmelt and ice melt, river ice damming and spring flush, storm impacts, and coastal flooding—would also aid in resource monitoring and relief distribution. Improved temporal, spatial, and spectral resolution would contribute to coastal land monitoring, including rapid assessments of storm damage to coastal ecosystems, agriculture, human habitation, and businesses.

Recent GEO-CAPE Ocean Activities

GEO-CAPE is on track to join the global constellation of geostationary atmospheric chemistry and coastal ocean color sensors. The working group has carried out several engineering studies and field measurements over the past 5 years to ensure appropriate instrument designs that meet science requirements while maintaining reasonable cost and risk profiles of the GEO-CAPE ocean color sensor.

Satellite stability is a major challenge faced by a remote sensing instrument positioned far above Earth's surface. The GEO-CAPE instrument must be capable of capturing high-resolution (~250-meter) imagery each hour. To test stability and performance, engineering studies focused on how to keep the instrument stable enough to accomplish this task. These studies concluded that spacecraft disturbances affecting the ocean color instrument could be resolved using existing technologies. Oceanographic cruises in the Chesapeake Bay (July 2011) and the northern Gulf of Mexico (September 2013) obtained comprehensive high temporal, spectral, and spatial resolution data sets to capture patterns and scales of variability in coastal water ecosystems. These data sets are needed to evaluate the temporal, spatial, and spectral resolution requirements of the sensor.

Another field experiment (May–June 2016) was designed to collect additional measurements in the field of view of the Korean Geostationary Ocean Color Imager (GOCI), a pathfinder geostationary ocean color satellite currently in orbit. This collaborative field study with Korean scientists focused on diurnal dynamics of dissolved and suspended organic and inorganic materials, with special attention given to ocean color radiometry. These data would be used to evaluate what can be resolved with hourly data in complex coastal environments in preparation for algorithm development for GEO-CAPE.



Monterey Bay images courtesy of Paul Bissett (Eathon Intelligence), under NOAA and ONR funding, graphics by the Environmental Protection Agency

Fig. 2. Low-Earth-orbiting satellites, including Terra and Aqua, provide at best a single measurement per location per day. GEO-CAPE is expected to provide multiple views throughout the day to measure coastal dynamics, rendering the loss of information caused by cloud cover (e.g., at 21:00) less significant. Here GEO-CAPE data are simulated with frequent airborne hyperspectral data showing the movements of a potentially harmful algal bloom in Monterey Bay in California. Times are in Greenwich mean time (+8 hours local Pacific time). Graphic development by the U.S. Environmental Protection Agency.

A Leap Ahead for Coastal Science

With its unique imaging capabilities and vantage point, the GEO-CAPE ocean color sensor would do for coastal science and applications what the Geostationary Operational Environmental Satellite (GOES) system has done for weather prediction. GOES satellites, the most widely used environmental satellites in the world, have led to improved forecasts that save lives, preserve property, and benefit agriculture and have spawned new commercial ventures.

In a similar fashion, a quality geostationary ocean color satellite positioned over the Western Hemisphere would revolutionize the science of coastal processes, allow for more precise ecosystem modeling, and deliver products and information needed for societal health, coastal protection, businesses, and efficient use of Earth's resources.

Acknowledgments

We gratefully acknowledge the efforts of the GEO-CAPE Oceans, Atmospheric, and Interdisciplinary science working groups. The views expressed in this paper are those of the authors and do not represent the views or policies of the U.S. Environmental Protection Agency or NASA.

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Over this past summer, voters in Florida opted to provide property tax exemptions on renewable energy equipment like the solar panels shown here. In November they chose to protect the rights to own this equipment via existing state statutes, not constitutional law.

How Did Energy and Environmental Issues Fare on Five State Ballots?

By Elizabeth Jacobsen

A handful of states recently asked voters several questions that relate to energy and the environment. These questions ranged from local concerns, like state park funding, to laws addressing global climate change through carbon taxes and regulations on sustainable energy.

Here's how energy and environment ballot measures shook out in five states in the November election.

1 Florida Makes Decisions on Solar Power Regulation

Floridians decided that equipment used to harness renewable energy will be tax exempt. This means that the expensive equipment will not add to property taxes. Voters decided that the right to own the equipment and produce this energy will be protected only by existing state statutes, not by the constitution.

Florida mayors have been working for a while to elevate environmental issues such as climate change and sea level rise to the state and national level (see http://bit.ly/fla-mayors). Finally, in August, Florida voters approved Amendment 4, which provided tax exemptions for renewable energy equipment.

Opponents like Stop Playing Favorites argued that the amendment was unfair, favoring certain industries over others. However, the amendment received broad support; about 73% of voters approved, much more than the 60% minimum required for the amendment to pass. Supporters say that this new constitutional amendment will encourage investment in solar technology and help Florida take advantage of its renewable potential (see http://bit.ly/amend4-Aug16).

The discussion about solar energy regulation continued on 8 November with Amendment 1, which failed to pass. The amendment would have added to the state's constitution the right to own and lease solar energy equipment for personal use and would have created regulations to ensure that those who do not produce solar energy do not have to help subsidize it. Utility companies and Consumers for Smart Solar supported the amendment, claiming that it would have pro-

DeSoto Falls in DeSoto State Park in Alabama. Because a decision made in the 2016 election, the Alabama legislature will no longer be able to reallocate funds from the state parks budget to other purposes.

tected those who didn't choose solar energy and helped guard against scams (see http://bit.ly/fla-solar-amend1).

Opposition, however, was widespread. Floridians for Solar Choice led the campaign against the amendment and was supported by much of the solar industry, as well as environmental groups like Earthjustice. They argued that the amendment was a cleverly worded measure intended to confuse voters; rather than supporting solar energy, it would lay the groundwork for restrictions that would penalize solar users while promising rights that Floridians already held under state statutes.

Amendment 1 was able to win just over 50% of the votes but was far short of the 60% required to add it to the state's constitution. Thus, tax exemptions will encourage renewable energy generation, but generation and equipment use will not be subject to any new regulations at this time.

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Voters in California have chosen to uphold a ban on plastic bags. Voters across the country made decisions on environmental initiatives in last November's election.

2 California Upholds Its Ban on Plastic Bags

California voters navigated a confusing pair of propositions regarding disposable plastic bags. In 2014 the state passed Bill No. 270, which banned stores from distributing plastic bags and required them to charge for all other bags, such as paper or reusable bags.

Opponents to the bag law, including members of the bag industry, pushed to have it brought to a popular vote on the November ballot. Californians ratified the law by approving Proposition 67. This means that California can continue its plan to phase out plastic bags, a process already established in the state at the city and county levels (see http://bit.ly/prop67-calif).

On the same ballot, voters struck down Proposition 65, which would have required the revenue earned from bag sales to go to a new state government fund—the Environmental Protection and Enhancement Fund—rather than to the stores selling the bags.

Supporters of 67 like Californians Against Waste claimed that the bag industry, which supported 65 and opposed 67,


Jody Claborn

was working to confuse voters and stave off the bag ban. They argued that the bag industry supported 65 because it would have prevented grocers and retailers from receiving any funds from the bag charges, undermining their support for 67. Further, supporters of 67 insisted that a new government fund was unnecessary to handle the small amount of revenue that would be generated and that it would not be able to do much to help the environment because plastic bags would have to be eliminated entirely for a positive environmental outcome.

The results were close, especially for Proposition 67, which passed 52% to 48%. As a result, retailers across the state are now banned from distributing plastic bags to consumers, and any revenue from other bags will go directly to retailers to cover the costs of providing recyclable or reusable bags.

3 Alabama Addresses State Park Funding

Voters in Alabama chose to ratify an amendment that will protect the allocation of state park funds. The amendment, known as Amendment 2, passed with 80% of the vote (see http://bit.ly/alab-amend2).

In previous years, the Alabama State Legislature reallocated funds from the state parks budget (mainly from guest revenues, which make up about 90% of park funding) to other agencies. The lack of funding caused five parks to close and others to limit their services.

State parks balance the dual obligations of preserving natural resources and educating visitors about the value of these resources. Supporters said that this amendment was necessary to protect state parks for future generations.

Those who opposed the amendment point to a second stipulation, which allows private rather than state management of hotels, golf courses, and restaurants. They claim that these outside companies will increase entrance fees, restricting park access.

4 Nevada Opens Energy Markets

During the past election, Nevada voters took a first step toward adding an open energy market to their state's constitution. Nevadans were presented with Question 3, an amendment that would reduce energy market regulations and prohibit energy monopolies. Question 3 passed this round of voting 72% to 28% and must be approved by popular vote again in 2018 to be added to the constitution (see http://bit.ly/nev-q3).

Supporters such as Nevadans for Affordable Clean Energy Choices argued that the measure gives Nevadans options to choose more affordable energy or clean energy, allowing the state to keep up with technological and energy advances. Support was funded primarily by the Las Vegas Sands Corp.

Groups like No Handouts to Billionaires and the International Brotherhood of Electrical Workers opposed the measure, saying that it will cause energy rates to rise and fluctuate, hurting poorer families and cutting jobs. NV Energy, which controls 90% of the state energy market, has remained neutral and has expressed its willingness to adapt in the future.

If the amendment passes the second round of voting in 2018, it will open the energy market and eliminate

Kārlis Dambrāns

An electric car at a charging station. Washington State voters recommended that a cap on tax exemptions for alternative-fuel vehicles be repealed.

energy monopolies, which supporters say would allow Nevada residents more freedom in choosing an energy provider.

5 Washington Rejects Statewide Carbon Tax and Tax Exemption Cap on Alternative-Fuel Vehicles

Washington State voters cast an advisory vote on House Bill 2778, which set a cap on a tax exemption available to those leasing or buying alternative-fuel vehicles. The bill has already passed; this vote was an after-the-fact advisory that legislators are not bound to follow (see http://bit.ly/hbill-2778).

Those supporting House Bill 2778 claimed that it closes existing loopholes while creating incentive to sell and purchase electric vehicles, which are often cost prohibitive. Opponents argued that it would favor some companies over others and could drive business out of the state. Voters ultimately advised that the bill be repealed.

Washington voters also decided against enacting a statewide carbon tax. The proposal, Initiative 732, would have imposed a tax on carbon emissions that started at $15 per metric ton of emissions and increased by about 3.5% each year until it reached $100 per metric ton. To compensate for the tax increase, the state would have reduced sales tax and other taxes and increased the Working Families Tax Credit for low-income families. This, the initiative's authors said, would have resulted in a roughly revenue-neutral plan (see http://bit.ly/init-732).

The plan was designed to be revenue neutral to appeal to conservatives and increase its chances of being applied to other states. However, it instead caused debate among those with more liberal leanings.

The group Yes on I-732 led support efforts, arguing that the tax would reduce carbon emissions because potential emitters would have an incentive to reduce carbon output. Plus, it said, the tax funds would go back to Washington's citizens. Opposing groups, including No on 732 and the Washington State Democratic Party, said that the tax would make existing options more expensive without providing a route to new ones. Further, they argued, Washington already had low emissions, rendering the tax unnecessary.

Environmental groups were divided. Audubon Washington supported the measure, but other organizations like the Sierra Club chose a "Do Not Support" position because the initiative did not address the needs of low-income and minority communities, which would be most affected by climate change. The Sierra Club also noted that the revenue-neutral plan could actually become revenue negative, taking money away from other government efforts like schools and parks.

If the initiative had passed, Washington State would have been the first state to have levied a carbon tax on its residents. However, the initiative failed, 41% to 59%.

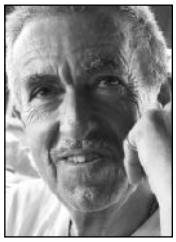
Author Information

Elizabeth Jacobsen, Staff Writer

Medalists Honored at 2016 AGU Fall Meeting

Stanley Robert Hart Receives 2016 William Bowie Medal

Stanley Robert Hart was awarded the 2016 William Bowie Medal at the AGU Fall Meeting Honors Ceremony, held on 14 December 2016 in San Francisco, Calif. The medal is for "outstanding contributions for fundamental geophysics and for unselfish cooperation in research."



Stanley Robert Hart

Citation

Stanley Hart's career began in the early 1960s with a focus on potassium-argon dating applied to continental materials. By the end of the decade, however, his attention was largely redirected to the mantle—and it is upon this critical region of our planet that he has left an indelible imprint that is uniquely his. The research activity stimulated by Stan's early (~1970) papers on lithophile element depletions in the ocean ridge basalt source blossomed into a subfield of geochemistry (chemical geodynamics) in which he played a leading role for many years and which has remained vigorous and vital up to the present day. His early insights opened the door for many others to follow, and the resulting vast database provides a dynamic picture of the Earth's interior that serves as an indispensable complement to geophysical models.

Stan Hart brings several extraordinary qualities to the practice of geochemistry. The first is the ability to reduce extremely complex processes to a simple essence that can be treated quantitatively. This has been a distinguishing characteristic of Stan's career, but he has also played important roles both in the development of geochemical mass spectrometry and in extracting physical and geological meaning from the high-quality measurements he helped make possible.

Stan moves with remarkable ease between pondering big scientific questions and the day-to-day challenges of analytical geochemistry. Perhaps most remarkable of all his scientific qualities is his extraordinarily adventuresome attitude toward research. He is undaunted by the need to develop new analytical techniques and fearless in moving out of his scientific comfort zone. Few geochemists have made major contributions across so diverse an array of topics—which span literally from mantle rocks to seawater to ore deposits.

Stan's readiness to move beyond his past experience has made it possible for him to bring new ideas and strategies to the study of a diversity of Earth's chemical systems. His influence upon our field is rooted in a combination of innovation, quantitative and integrative ability, and tenacity. Through the challenges of building and managing laboratories and leading sampling expeditions he has always remained a gracious colleague and a selfless teacher and mentor. For all he has given our science, perhaps we can forgive Stan for his role in the proliferation of the acronyms used to refer to the chemical reservoirs of the mantle.

—E. Bruce Watson, *Rensselaer Polytechnic Institute, Troy, N. Y.*

Response

I am touched and deeply honored to receive AGU's William Bowie Medal. And, Bruce, I read your citation with gratitude, and some amazement. You, so precise in your science, yet so flamboyant in your praise! I, the imposter, would meet this person! And abiding thanks to your cohorts: Don DePaolo, Al Hofmann, and Charlie Langmuir.

I have earlier thanked Pat Hurley at Massachusetts Institute of Technology (MIT) and Tom Aldrich at Department of Terrestrial Magnetism for trusting me, as a grad student and postdoc, with their mass spec labs. They fearlessly set me on the road that brings me here tonight. Innumerable fellow travelers had a hand in this as well. Students, colleagues, provocateurs—you all know who you are! I am so grateful for the companionship and excitement you all brought to these travels.

In this mélange, there are several who merit my special recognition for the simple fact that I could have done little without them. For 20 years, at MIT and Woods Hole Oceanographic Institution (WHOI), Jurek Blusztajn expertly managed my labs, and was a wise and gentle mentor to my students (and to their advisor). Jurek, I am so appreciative for those decades! And kudos to Sonia Esperanca, program director at National Science Foundation, both for her individual efforts on behalf of geochemistry-petrology and for her wise and professional representation of a truly remarkable government agency. Her support, judgment, and advice were vital through much of my career—even bleak words such as "Hart, no more 5-year umbrella grants." Sigh.

I would also thank geodesist William Bowie, who spent his career at the Coast and Geodetic Survey (1895–1936). He was an astute and highly respected leader in the scientific community and the author of some 250 publications. And he and I share a common thread. In 1929, he was on a National Academy of Sciences committee that recommended formation of an "Atlantic Oceanographic Institute"; just 49 days later, Massachusetts incorporated the WHOI, with Bowie on the first Board of Trustees. Where would I have spent the last 18 years of my career without Bowie's efforts some 59 years earlier?

Last, and most, my wife Pam always assured me that I could leap tall buildings. My children, Jolene, Elizabeth, and Nathaniel, treated my field travels and long lab nights with apparent equanimity. BTW, I concur with you, Bruce, that I am an incorrigible purveyor of acronyms: some universally acclaimed (MORB), one universally decried (FOZO).

—Stanley R. Hart, *Woods Hole Oceanographic Institution, Woods Hole, Mass.*

Hooper, Long, Nishimura, Sluijs, and Villarini Receive 2016 James B. Macelwane Medals

Andy Hooper, Maureen D. Long, Toshi Nishimura, Appy Sluijs, and Gabriele Villarini were awarded the 2016 James B. Macelwane Medal at the AGU Fall Meeting Honors Ceremony, held on 14 December 2016 in San Francisco, Calif. The medal is for "significant contributions to the geophysical sciences by an outstanding early-career scientist."

Andy Hooper

Citation for Andy Hooper

Andy Hooper is a specialist and innovator in geodetic imaging methods using interferometric analysis of satellite radar images (InSAR). At the same time, he has improved our understanding of magmatism and tectonics with geophysical models interpreting ground deformation. He is unusual in being at the top of his field in the technical aspects of geodetic data acquisition and processing, as well as being one of the leading modelers of geodetic data.

With InSAR analysis, the phases of radar echoes on multiple passes of a satellite over the same terrain are compared to reveal changes in the line-of-sight distance between the satellite and the ground. One approach to the problem is to identify those image pixels for which the radar echo is dominated by a single dominant scatterer. One of Andy's contributions was to develop an approach to identify such persistent scatterers using phase stability, the parameter of interest, rather than radar brightness as in earlier methods. He also made no assumptions about the temporal nature of the deformation, rather relying on the spatial coherence of the deformation signal. His algorithms offered several significant advances and are well suited for nonurban settings such as volcanoes. This work has had major impact, with his four papers on the subject attracting over 1500 citations to date.

Andy has unselfishly shared his advanced approaches to the analysis of InSAR time series by releasing his software (Stamps) to the community as open-source code, significantly

impacting the community of scientists using satellite geodesy. The software has been used in a wide range of applications spanning volcanic and tectonic deformation through to urban subsidence caused by water extraction. In 2015 alone, over 150 papers were published that used the Stamps software.

Andy's work on volcanic and tectonic processes has also had a major impact. In particular, he has led modeling efforts to understand magmatic processes in Iceland associated with recent eruptions, as well as demonstrating how ice cap retreat in Iceland can perturb the crustal stress state sufficiently to alter the tendency for magma to be trapped within the crust as opposed to erupting. His results have been published in several high-level journal articles. Since moving to the United Kingdom in 2013, Andy has helped establish Leeds as a world-leading research center for applied satellite geodesy.

—Freysteinn Sigmundsson, *University of Iceland, Reykjavik*

Response

Thank you to the medal committee for this award, which I am honored to receive, and thank you, Freysteinn, for those generous words. I do feel fortunate to be in a position where I can straddle two realms, working as both engineer and scientist.

Scientific endeavor is all about people, of course, and there are many exceptional individuals responsible for my being in this position today, although I can mention only a few here. My Ph.D. advisors at Stanford, Paul Segall, himself a former Macelwane Medal recipient, and Howard Zebker, mentored me through graduate school and taught me intellectual rigor and critical thinking. Their influence continues to very much shape my own approach to scientific problems.

My time spent during a postdoc in Iceland gave me the chance to live close to volcanoes. There, from Freysteinn Sigmundsson, I learned the importance of collaboration and working across disciplines, and I continue to work closely with colleagues there today.

Ramon Hanssen was instrumental then in getting me hired at Delft, where I spent several years in an engineering faculty, learning how to deal robustly with observations and errors. Ramon also taught me much about strategic thinking.

Now I am back in a geoscience-focused environment at Leeds, where I work with many talented individuals. Tim Wright, with whom I collaborate particularly closely, deserves special mention, and I have learned a great deal about leadership from him.

One of the most enjoyable aspects of my job has been working with graduate students. I have gained much from two former students, in particular, David Bekaert and Karsten Spaans, whom I had the pleasure of advising both during their master's degrees at Delft and then during their Ph.D. studies at Leeds.

There have been many others who have shaped the way I think about science and have contributed to this award. My wife, Julia, deserves special thanks for her advice on all aspects of scientific life, from dealing with colleagues to wrestling with gritty scientific problems. Last, I thank my children for keeping me grounded. When I told my 8-year-old son Tom, a keen runner, I had been awarded a medal, he was pretty impressed—until he found out that I had not actually won a race.

—Andy Hooper, *University of Leeds, Leeds, U.K.*

Maureen D. Long

Citation for Maureen D. Long

Maureen Long has made seminal contributions to our understanding of circulation in the Earth's mantle by combining seismology, mineral physics, and geodynamics. Much of Maureen's work concerns subduction zones, which are delineated by deep ocean trenches, where tectonic plates sink, or subduct into the Earth's mantle. The direction of mantle flow driven by convection, plate motion, and sinking slabs is best detected with seismic anisotropy that is caused by deformation-induced fabric in minerals. Maureen Long is a pioneer and leader in using seismic anisotropy to reveal how slabs subduct and the mantle circulates.

For her graduate work at the Massachusetts Institute of Technology, Maureen combined seismic observations with numerical models and mineralogical experiments to study anisotropy beneath Japan. With her multidisciplinary tool kit, she then began her major research thrust on subduction zones, first as a postdoctoral fellow at the Carnegie Institution of Washington's Department of Terrestrial Magnetism and later as a faculty member at Yale. Maureen led or co-led seismological field deployments in Oregon, the Appalachians, and Peru and an oceanographic survey over the U.S. Atlantic continental shelf. Her work resulted in key insights on subduction anisotropy and mantle flow near, for example, Japan, Tonga, Alaska, Oregon, Peru, and the Caribbean and Scotia Arcs.

Maureen's early studies showed that anisotropic fabric in the mantle beneath subduction zones is pervasively trench parallel, which suggests a component of flow perpendicular to plate motion. This discovery implied that slabs do not merely sink vertically but roll backward, squeezing the mantle out of the way and parallel to the trench. However, with new data, Maureen showed that while subduction zones attached to old plates have trench-parallel fabric, younger ones have trench-perpendicular fabric; this suggests that subducting plates transition from steadily subducting to foundering backward, depending on their age.

Maureen's contributions extend beyond studying subduction zone flow. She and colleagues used their Peru data to show that shallow slabs are weak and undergo extensive internal deformation. Her analysis of anisotropy in the lower mantle indicates flow deflected by chemically stable "piles" (large low shear velocity provinces) at the core-mantle boundary. Her recent work on anisotropy in the mantle transition zone and the lithosphere beneath continents has yielded new insights into deformation in these regions of the mantle.

Maureen Long is a rising star of mantle seismology and dynamics. With her field programs and interdisciplinary approach, she has made, and will continue to make, lasting discoveries about subduction zones and how the Earth's mantle convection engine works.

—David Bercovici, *Yale University, New Haven, Conn.*

Response

Thank you to AGU for this tremendous honor and to Dave Bercovici for the generous citation, for spearheading my nomination, and for years of mentorship and support. I am delighted to be named as a recipient of the Macelwane Medal, not least because I am grateful for the rare privilege of being able to thank my mentors, students, and collaborators in a public forum.

I decided that I wanted to become a geophysicist in middle school, after learning about plate tectonics in science class and realizing that it was the coolest thing I had ever heard of. Not many people see their career dreams at the age of 12 realized, and the fact that I have is due to my good fortune in having a string of extraordinary teachers and mentors. My professors at Rensselaer Polytechnic Institute treated me like a scientist from the day I walked in the door as a freshman, and two summers as a summer intern in Shun Karato's lab introduced me to seismic anisotropy—I've been hooked ever since. I pursued my Ph.D. in the fantastically rich environment of the Department of Earth, Atmospheric and Planetary Sciences at Massachusetts Institute of Technology; Rob van der Hilst was a consummate thesis advisor, and I'm grateful for his mentorship. My time in postdoc paradise at Carnegie was a joy, and working with David James and the late Paul Silver—whom I miss dearly—was a privilege. Since moving to Yale, I've been fortunate to be part of an outstanding department and an exceptional cohort of fellow junior faculty.

I share this recognition with a large group of collaborators with whom I've worked and adventured—thanks to all of you for your brilliance, your friendship, and for making my science better. It has been an honor to work with my extraordinary students and postdocs, especially Juan Aragon, Neala Creasy, Caroline Eakin, Heather Ford, Xiaobo He, Colton Lynner, Karen Paczkowski, and Erin Wirth. As a seismologist, I feel fortunate to be part of a scientific community that encourages early-career scientists, fosters collaboration and cooperation, and increasingly values diversity.

Most important, I am grateful to my parents, siblings, and family for their love and support over the years. Above all, a huge thank you to my husband, Tony, and our children, Patrick and Caroline; you are the light of my life and I would never be able to do the work I do without you.

—Maureen D. Long, *Yale University, New Haven, Conn.*

Yukitoshi Nishimura

Citation for Yukitoshi Nishimura

Yukitoshi "Toshi" Nishimura has transformed our understanding of plasma processes in near-Earth space. His research into substorms led the geospace research community to see this dynamic process as system-wide, wherein plasma is transported hundreds of thousands of kilometers from the dayside magnetopause to the magnetotail and then the inner magnetosphere, leading to an instability that creates beautiful auroras and changes Earth's plasma environment. Using NASA Time History of Events and Macroscale Interactions during Substorms (THEMIS) satellite plasma observations, together with images from ground-based auroral cameras, Toshi made the first

unequivocal causal connection between a space plasma process and a specific type of aurora. With that same research, Toshi also made the first testable magnetic mapping between deep in the magnetosphere and the auroral ionosphere. I will limit my citation to the substorm work, but suffice it to say that I consider his auroral and mapping results to be equally important.

At the heart of Toshi's research is innovative use of data from multiple observational platforms. He has combined plasma and wave observations from an international fleet of satellites with ground-based observations from auroral imagers, radars, and magnetometers to "see" geospace in fundamentally new ways. Where the rest of our field looked at the data from the perspective of the leading paradigms, Toshi found something new that did not fit existing ideas. What Toshi had found were north–south auroral forms stretching from the poleward to the equatorward edge of the auroral oval during, he argued, *every* substorm. This was perplexing, as neither dominant paradigm required anything that might correspond to these streamers.

Toshi faced a tough crowd not at all receptive to his ideas. He had to explain what the streamer signified in terms of magnetospheric dynamics, and so he did. He had to discover what the arrival of the streamer at the equatorward edge of the oval signified in terms of stability of the system, and so he did. Throughout, Toshi did the necessary work and injected his judicious creativity.

The influence of Toshi's substorm research has been profound. Now substorm onset is seen as part of a larger process, where flux tubes move from the dayside, across the polar cap and the inner edge of the plasma sheet, carrying plasma with different physical properties that pushes a stable magnetotail into instability. Toshi brought open-mindedness and creativity to the problem and opened our eyes to a more comprehensive and self-consistent picture. In a very real sense, his work on the substorm has been paradigm shifting.

—Eric Donovan, *University of Calgary, Calgary, Alb., Canada*

Response

Thank you, Eric, for your generous citation and nomination. I am truly grateful to the members of AGU for this honor, and I am humbled to join the company of the many prestigious scientists who have received the Macelwane Medal. This could not have happened without strong support and encouragement from my close colleagues, and I would like to take this opportunity to express my deep gratitude to them.

Unlike many of the past recipients in space physics and possibly in other fields, I did not build any instruments or large simulation codes by myself. My research almost always relies on hard work from my kind collaborators who invest a countless amount of time and effort making data available. My postdoctoral research at University of California, Los Angeles started when new science from NASA's THEMIS mission led by Vassilis Angelopoulos was blooming. Eric Donovan and colleagues at University of Calgary and University of California, Berkeley built world-class imaging networks, and my postdoctoral advisor, Larry Lyons, shared with me his enthusiasm and ambition to solve the substorm problem. My part of the work was just to make things happen by cooking data. It was, of course, not easy, but I have been extremely fortunate to interact with the experts in the field who have paved the way for my research. I am also thankful to strong supporters in the community, particularly Bob Lysak.

Back when I worked in Japan, my advisors, Takayuki Ono and Takashi Kikuchi, as well as their lab members, opened the door for me to the exciting science of space physics. Their enthusiasm for science, deep knowledge, and dedication to education made me think that I wanted to be such a professional scientist. Sometimes they were a bit intense; we spent hours just to discuss a figure, and group meetings lasted until midnight. But all those became precious memories and still influence me.

I have also been privileged to work with talented students, most recently with Ying Zou, Bea Gallardo-Lacourt, Boyi Wang, and Cheng Zhen. I am grateful for their hard work, and it has been a great pleasure to witness their tremendous growth both academically and personally; I believe more is yet to come.

Finally, I wish to thank my family, in particular, my wife and fellow space physicist, Wen Li, for her kind support and sharing joy in life and science.

—Toshi Nishimura, *University of California, Los Angeles*

Appy Sluijs

Citation for Appy Sluijs

It is my honor to introduce Appy Sluijs, a recipient of the 2016 James B. Macelwane Medal. Appy, a geobiologist, is being recognized for his prolific and leading-edge contributions to resolving the nature of extreme climate change and impacts on marine biota in Earth's past.

Appy's scientific achievements come as no surprise. His deep passion and aptitude for his craft were evident early on when, as an undergraduate at Utrecht, he participated in Ocean Drilling Program (ODP) Leg 208 to the South Atlantic. Despite his inexperience, he made the most of the opportunity, becoming a valued member of the scientific party and eventually contributing to several seminal publications that defined the scale and timing of Eocene hyperthermals and ocean acidification, including the Paleocene-Eocene Thermal Maximum (PETM). Building on this foundation, as a graduate student under the tutelage of Henk Brinkhuis and later as a postdoc, he produced a series of landmark papers involving dinoflagellate taxonomy and geochemical proxies to constrain changes in ocean temperatures, salinity, and ecology of the Arctic and lower-latitude coastal oceans. Key to this effort was his creative use of organic biomarker proxies which he and colleagues at the Royal Netherlands Institute for Sea Research, J. Sinninghe Damsté and S. Schouten, began to apply to Paleogene archives across the globe. This work not only established the extreme warmth and stratification of the Arctic during the PETM but also served as a cornerstone for subsequent reconstructions of global meridional temperature gradients for the Paleogene. In addition to the landmark work on Eocene hyperthermals, Appy contributed to high-impact studies of several other key climate events of the Paleogene, including the middle Eocene Climatic Optimum and the Eocene-Oligocene transition.

Not long after these very early career accomplishments, Appy was appointed full professor, one of the youngest to achieve the rank at Utrecht University. He has since established a major research program and continues to address fundamental issues on the character and impacts of major changes in climate during the Cenozoic. He is also recognized for his extensive service to the scientific community and for exceptional public outreach and education, particularly his work with students in the Young Academy of the Royal Society of the Netherlands.

—James C. Zachos, *University of California, Santa Cruz*

Response

Thank you, Jim, for this generous citation. I also thank you and my colleagues who wrote letters for the nomination. I thank the members of the Macelwane Medal Committee and AGU for this great honor.

Similar to many of us, my story is one of remarkable serendipity. Coming from a nature-loving family and focusing on biology during my undergraduate studies, I miraculously ran into Henk Brinkhuis at Utrecht University, who introduced me to the wonderful world of dinoflagellates, micropaleontology, and paleoceanography. I would not be where I am without his generosity and inspiration. After my first micropaleontological work, Henk sent me to University of California, Santa Cruz to work with Jim and Stephen Schellenberg, who introduced me to geochemistry. During my graduate work I had the pleasure to collaborate with a set of truly unique, diverse, and creative scientific innovators. Along with Henk and Jim, these were Jerry Dickens, Jaap Sinninghe Damsté, Stefan Schouten, Lucas Lourens, Matt Huber, Ellen Thomas, and many others, discovering, describing, and understanding Paleocene-Eocene transient global warming events. Later on, Gert-Jan Reichart helped me design biogeochemical culturing experiments for dinoflagellate proxy development. I consider all of these people to be incredible scientists and great friends. I also thank my parents and the rest of my family and friends for their unconditional support and Margriet for being who she is.

I cannot name all colleagues who inspired me and with whom I have had the pleasure to work (even Scopus stops counting at 150 collaborators). I would, however, like to mention that much of my work was driven by two institutes: the International Ocean Discovery Program and the Urbino Summer School on Paleoclimatology, dominantly initiated by Henk and Simone Galeotti, which by now has taught over 800 international graduate students.

Our field of science, multidisciplinary paleoclimatology and paleoceanography, had barely started when Father James Macelwane was the AGU president. Now it is a crucial field in improving projections of future change. The rapid progress over the past decades is the accomplishment of a critical but constructive community with excellent leadership in the past and the present. I therefore feel that this medal, although awarded to me, rather marks the success of this research community as a whole, which includes students, postdocs, and faculty, all standing on the shoulders of past giants. And as many grand scientific and societal challenges lie ahead of us, I'm proud to be part of it.

—Appy Sluijs, *Utrecht University, Netherlands*

Gabriele Villarini

Citation for Gabriele Villarini

Gabriele Villarini bridges hydrometeorology, climate dynamics, and disaster science in an innovative way. He has explored the meteorological context of floods as it relates to storm tracks, atmospheric rivers, and tropical cyclones, developing consistent and insightful diagnoses and a fundamental building block for understanding how future climate changes may lead to changed event frequency and spatial structure of floods. His work has also led to a better understanding of storm structure, inferences from radar, and the hydrologic response associated with floods. Collectively, he provides the seminal contribution of his generation to this subject area that is worthy of the Macelwane Medal.

His contributions are diverse and impressive. His graduate work laid the foundation of uncertainty analysis of radar-based rainfall fields and was perhaps the most comprehensive such work. His postdoctoral work on flood hydrology extended his contributions in hydrometeorology by developing and applying tools to identify different forms of nonstationarity in extreme rainfall and flood fields and relating these to specific forms of changes in the driving hydrometeorological mechanisms. This work represents a significant departure from his earlier work and demonstrates considerable dedication to working on an important topic and addressing it in depth. One of his colleagues at the time mentioned that she does not believe that Gabriele ever sleeps. His tenure as a faculty member at the University of Iowa has been equally impressive. He has built a wide array of collaborations with practicing and academic hydrologists, meteorologists, climate modelers, and statisticians. These collaborations have led to a series of interesting papers that connect large-scale atmospheric dynamics and their predictability to local and regional extremes. He has become extremely influential in this area and has been a leading contributor to the U.S. Army Corps of Engineers study on how future flood frequency changes can be diagnosed and risk profiled.

I especially like the humility and dedication with which Gabriele approaches the profession and scholarship. He is an outstanding role model for the future of our interdisciplinary field. I fully expect him to shape the directions of research and practice in the field, as he continues to grow and embrace new topics.

—Upmanu Lall, *International Research Institute for Climate and Society, Palisades, N. Y.*

Response

Thank you, Manu, for your kind words in the citation, and thanks to AGU and to the colleagues who have supported my nomination. This award arguably represents the highest honor for an early-career scientist in the geophysical sciences, and I am thrilled to have been selected to receive it; it is also very humbling given the caliber of scientists who received it before me. Being selected has given me the opportunity to look back at my career so far and to acknowledge how fortunate I have been.

My career wouldn't have been the same if I hadn't had the good fortune to work with my Ph.D. adviser at the University of Iowa, Prof. Witold Krajewski. Witek was the best adviser I could have asked for, and has always been there for me, during my graduate work and afterward. He supported and challenged me at every step, allowing me to develop into the scientist I have become. He taught me never to cut corners or take the easy way out. I take pride in considering Witek a lifelong mentor and colleague, but more important a friend.

After completing my Ph.D., I was once again really fortunate to be able to work with Prof. James Smith at Princeton University. Jim was a fantastic mentor, who provided me with great guidance and exposed me to a large number of research topics that I probably wouldn't have dealt with otherwise. Learning from him was instrumental in shaping my current research interests. Overall, I wish everybody could be as lucky as I have been to work with mentors like Witek and Jim.

During my career, I have met and befriended many great scientists. Enrico Scoccimarro, Gabriel Vecchi, and Rhawn Denniston deserve a special mention for their support and friendship over the years and for making our collaborative research fun, exciting, and enriching.

None of this would have been possible, though, without the continued support from my family. My parents and brother have always given me endless love, and they have taught me never to give up and that hard work always pays off. My wife, Amie, is my rock, and she has always been my number-one supporter. And nothing compares to coming home to my daughters, Eleonora and Camilla, after a long day at work, and being asked "How was work, Papá?" followed by hugs and kisses. Thank you!

—Gabriele Villarini, *University of Iowa, Iowa City*

Robert Coe Receives 2016 John Adam Fleming Medal

Robert Coe was awarded the 2016 John Adam Fleming Medal at the AGU Fall Meeting Honors Ceremony, held on 14 December 2016 in San Francisco, Calif. The medal is for "original research and technical leadership in geomagnetism, atmospheric electricity, aeronomy, space physics, and/or related sciences."

Robert Coe

Citation

Robert Coe is a world-renowned scientist who has made significant contributions to several broad areas of geomagnetism and paleomagnetism. His scientific accomplishments have illuminated the research of many who work in areas ranging from geomagnetism and paleomagnetism to volcanology, geochemistry and petrology, and tectonophysics.

Coe is one of the pioneers in paleointensity determination. In the 1960–1970s Coe singularly developed a means of more accurately measuring the intensity of the ancient field recorded in rocks. This method, which bears his name, is now the gold standard of all paleointensity methods. Along the way he has produced many of the most reliable paleointensity values that we have. His most cited *Journal of Geophysical Research* (*JGR*) papers are still the bedrock references for anyone attempting to do the paleointensity work.

Coe has made significant contributions to the understanding of geomagnetic secular variation, including magnetic field reversals. Coe was one of the first paleomagnetists to use and realize the potential of geodynamo models as a tool to better understand observations of geomagnetic field behavior. He has teamed up with other world-class scientists, such as Gary Glatzmaier and Peter Olsen, to combine paleomagnetic results with dynamo theory. For example, he and his colleagues have shown that the reversal rate of the geomagnetic field can be significantly affected by lateral changes in the heat flux through the core-mantle boundary.

Coe has also made seminal contributions to the studies of tectonics. He and his students have carried out paleomagnetic projects in various tectonic settings, over scales ranging from small fault blocks to cratons. These works have led to new ideas about how large-scale continental collisions occur.

In the area of service, Coe's record is every bit as exemplary as it is in research and teaching. He has served as editor for *JGR* and the *Journal of Geomagnetism and Geoelectricity*, as president of AGU's Geomagnetism and Paleomagnetism section, and as a member of numerous national and international science panels and advisory boards.

Coe's unwavering generosity in sharing his time, knowledge, and other resources extends to both colleagues and students. He has set a standard of integrity and professional commitment that is well respected in our community. In recognition of his outstanding contributions to the development of paleointensity methodology and scientific achievements in tectonophysics and geodynamo research, Coe is thoroughly deserving of the John Adam Fleming Medal.

—Rixiang Zhu, *Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China*

Response

Many thanks to AGU for this honor, to my students and many colleagues around the world for their friendship and collaboration, and to my wife and children for their support and inspiration. Looking back 60 years to when I first entered college, I realize that I've been very fortunate. I had no idea I would become a scientist, only that I was searching for understanding and meaning deeper than myself. After a year's sampling of general education requirements, I was drawn toward the demonstrable truth found in the natural sciences. Eventually my love of the outdoors, mountaineering, and long discussions with my roommate about geologic time led to geophysics. I was privileged to have some truly inspiring teachers and mentors, including William Lipscomb in chemistry and Francis Birch in geophysics as an undergraduate and John Verhoogen, Allan Cox, and Mervyn Paterson as a doctoral student and postdoc. Given license to choose whatever interested me for my thesis, I hit on the little-studied problem of deciphering the ancient magnetic field intensity hidden in the paleomagnetism of rocks. I managed to make significant progress, but even more satisfying has been to witness the huge strides made since by many younger colleagues. After a formative postdoctoral year in

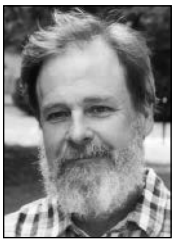
Australia, I again met with great fortune by being offered a job at the new University of California campus in Santa Cruz. With it came the opportunity to help start a department of Earth sciences from scratch in an amazingly beautiful setting, in a culture that emphasized equally the instruction of undergraduate and graduate students, and with complete free rein to pursue my intellectual interests. I made some rewarding excursions into deformation experiments and phase changes in minerals, but once again the many varied aspects of paleomagnetism eventually captured most of my attention, with its combination of fieldwork, lab measurements, and theory. For my entire career, and now into retirement, I've been able to investigate the paleointensity, secular variation, excursions, and reversals of the geomagnetic field and tectonics and magnetostratigraphy in regions around the world including North America, Alaska, China, Siberia, and Papua New Guinea. What an incredible privilege it has been to be given the freedom to search for truth and beauty in the natural world, wherever my curiosity led me.

Beauty is truth, truth beauty—that is all
Ye know on earth, and all ye need to know.
—Keats, 1819

—Robert Coe, *Earth and Planetary Sciences Department, University of California, Santa Cruz*

Samuel A. Bowring Receives 2016 Walter H. Bucher Medal

Samuel A. Bowring was awarded the 2016 Walter H. Bucher Medal at the AGU Fall Meeting Honors Ceremony, held on 14 December 2016 in San Francisco, Calif. The medal is for "original contributions to the basic knowledge of crust and lithosphere."



Samuel A. Bowring

Citation

Sam Bowring's expertise as a field geologist, his enormous breadth of knowledge, and his unwavering pursuit of the highest possible precision and accuracy in uranium-lead geochronology has transformed our understanding of the time when life began, the timing and triggers of the great mass extinctions, and the manner in which the Earth's earliest crust evolved.

Sam determined the duration and rate of biological evolution at the Pre-Cambrian/Cambrian boundary—the so-called explosion of life that is the single most important evolutionary event in Earth history. Sam dated key volcanic strata within the sedimentary layers that record the Early Cambrian evolution of life and showed that the Cambrian period began 541 million years ago and that the Early Cambrian interval spanning the explosion of life lasted only 5 million to 6 million years. Sam showed that during this brief time interval more phyla than have ever since existed on Earth came into existence. This represents a truly profound and astonishing new discovery about how life evolved on Earth.

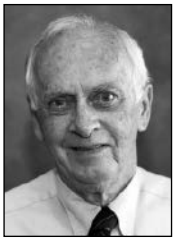
Sam has also established the timing and duration of the most significant biological extinction event in Earth history—the one defining the end of the Permian. Sam and colleagues have demonstrated that the extinction occurred in a time interval of less than 60,000 years and that the surge in light carbon predates the extinction by only 10,000 years. Having now established the precise timing of the extinction event and the global environmental crisis that preceded it, Sam has provided fundamental constraints on the forces that led to the environmental crisis resulting in the greatest extinction in Earth's history.

Sam's work on the world's oldest rocks, the Acasta gneisses, has led to a new understanding of the processes leading to the early growth of continental crust. Through his rigorous field efforts in the Northwest Territories of Canada and his geochronological studies, Sam established that the Acasta gneisses were Priscoan in age (>4 billion years old). His geochemical studies of these early crustal remnants showed that these rocks were similar to today's arc-derived continental crustal rocks, supporting the notion that crustal recycling started early on in Earth history and has continued to the present.

—Tim Grove, *Massachusetts Institute of Technology, Cambridge*

Peter George Brewer Receives 2016 Maurice Ewing Medal

Peter George Brewer was awarded the 2016 Maurice Ewing Medal at the AGU Fall Meeting Honors Ceremony, held on 14 December 2016 in San Francisco, Calif. The medal is for "significant original contributions to the ocean sciences."



Peter George Brewer

Citation

Peter Brewer has been one of the world's leaders for studying the ocean carbon cycle, global ocean change, and the fate of fossil fuel carbon dioxide (CO_2). He has been a role model for scientific vision, leadership, courage, and integrity. I have known Peter for almost 48 years. We worked together on several projects, and I can confirm that Peter is remarkably inclusive in mentoring of other scientists due to his extraordinary talent for asking key questions.

His primary research interests are in the ocean geochemistry of the greenhouse gases, and he has repeatedly made fundamental discoveries on topics before others even recognized them as important areas to study. Peter's greatest research accomplishments have been regarding the uptake and distributions of CO_2 in the ocean. During the Transient Tracers in the Ocean (TTO) and Joint Global Ocean Flux Study (JGOFS) era, he led the acquisition of ocean basin-scale sections of alkalinity and dissolved inorganic carbon. In the 1970s he used such data from the South Atlantic to first determine the distributions of anthropogenic CO_2 in the ocean. Along the way he identified that nitrate concentrations were needed for the accurate interpretation of alkalinity distributions and alkalinity-calcium relationships. He subsequently was one of the first to identify the extent and implications of this anthropogenic CO_2 for ocean acidification, "the other CO_2 problem."

As director and CEO, he led the Monterey Bay Aquarium Research Institute (MBARI) during a period of intensive growth. Brewer then moved on to reinvent himself as a research scientist and developed new directions of study that combined the unique scientific and engineering capabilities available at MBARI. He developed concepts and tools for studying the evolution of the oceanic fossil fuel signal of CO_2, the geochemistry of methane hydrates, and evaluation of strategies for sequestration of fossil fuel CO_2. Brewer's approach is typified by a quote from his 1999 Revelle Lecture: "If all we do as scientists is measure, model and warn, then our value to society will be limited. Can we also provide solutions as well as define the problems?"

In addition to his outstanding scientific accomplishments, Peter has led development of interdisciplinary research programs to attack these problems on a global scale. JGOFS is Brewer's greatest legacy. As the first chair of the U.S. JGOFS program, he led the community studying the carbon cycle in the global ocean and its link to climate.

Peter Brewer's scientific accomplishments and leadership in the field of ocean sciences have been extraordinary, and we honor that by bestowing on him the Maurice Ewing Medal.

—James W. Murray, *University of Washington, Seattle*

Response

I thank Jim Murray for his kind citation. We have been friends and colleagues for almost 50 years, and even as a student, Jim possessed the scientific gifts that pulled me in. John Riley at Liverpool, and Derek Spencer at Woods Hole, had enormous influence on me, as also did David Packard some 25 years later. I thank too Charlie Paull, Marcia McNutt, and Rita Colwell for their splendid examples of common sense in great science, and the MBARI team for their amazing skills and sustained friendship.

In retrospect, a key turning point was the 1968 request that I teach the marine chemistry course on the opening day of the now legendary MIT-WHOI Joint Program. That experience forced me to look at the fundamentals behind what then was only a happenstance collection of modest chemical observations in the ocean. It also put me in contact with a series of marvelous students. That lesson has stayed with me throughout my career, and I have been fortunate in being able to apply very basic and fundamental chemical rules to open up important problems. The earliest examples were in the accurate representation of the oceanic CO_2 system, and

today we are applying similar rigor to the insidious problem of declining ocean oxygen levels.

Jim mentions leadership in building the JGOFS program in the mid-1980s that successfully laid the basis for modern biogeochemical knowledge of the ocean. Today the precarious pH balance of the ocean is changing rapidly with threats to coral reefs in the tropics and calcareous organisms at the poles. And ocean warming is driving reduced ventilation and increased microbial oxygen consumption rates with huge consequences for marine life. A young scientist listening today must barely comprehend how rapid these changes are and that we still are only seeing glimmerings of Earth's future.

It has been a privilege to take part in these discoveries, and deeply concerning too as we see with increasing clarity the power of the chemical physics we are unleashing, biting down on our Earth.

I have been attending AGU meetings now since 1968, and the Union offers a welcoming home for scientists from around the world. I thank you all for the marvelous questions you ask about our Earth and its place in space. And most of all I thank my wife, Hilary, who is a far better judge of the character of scientists than am I.

—Peter G. Brewer, *Monterey Bay Aquarium Research Institute, Moss Landing, Calif.*

Thomas Dunne Receives 2016 Robert E. Horton Medal

Thomas Dunne was awarded the 2016 Robert E. Horton Medal at the AGU Fall Meeting Honors Ceremony, held on 14 December 2016 in San Francisco, Calif. The medal is for "outstanding contributions to hydrology."

Thomas Dunne

Citation

This is an award that is long overdue. Tom Dunne has been a major influence in hydrology and geomorphology for the past 40 years in a variety of environments, from Vermont to East Africa, the Andes, and the Amazon. Tom's methodology has been instructive regardless of the domain of his research. During a period when there has been a tendency for researchers to concentrate either on experiments or on computer models, he has always, like Robert Horton, aimed to transfer the knowledge obtained from careful field experiments to the appropriate representation of processes in models. Tom has done this in an exemplary way: runoff generation mechanisms (from hillslopes to the entire Amazon); channel networks (landscape evolution and river habitat); weathering, hillslope erosion, sediment routing, and sediment budgets; river mechanics, meandering, and floodplain depositional processes; and watershed management and river restoration. He has done so at scales from small plots to the Amazon. At times his methods have been unorthodox, such as his approach to simulating the effects of cattle on infiltration rates in East Africa (which makes for a highly entertaining seminar that inspires students).

Tom is a true research scientist, but that has not meant that he has neglected the application of the science to practical problems—that is essentially what his book with Luna Leopold, *Water in Environmental Planning*, is all about. He has also been prepared to devote time to the wider interests of the hydrological and geomorphological communities, serving on numerous national and international committees, including working for the United Nations.

All of the supporting letters refer to Tom's inspiring influence on his students and younger colleagues. In his case, it can really be said that he has nurtured them through his intellectual curiosity, by his active contribution to their fieldwork, and via the weekly paper discussion (or dissection) sessions at his home. Many of those students have, of course, gone on to be outstanding hydrologists, geomorphologists, and ecohydrologists in their own right.

Tom's name is already linked to that of Horton through the descriptions of Horton and Dunne overland flow mechanisms in hydrological textbooks. As Bill Dietrich expressed in his supporting letter, "He took up the charge of Horton's 'hydrophysical' approach and contributed many fundamental insights about surface processes and landscapes. Our understanding of hydrology and geomorphology has been greatly advanced by both his scholarly publications and his intellectual leadership."

—Keith Bevin, *Lancaster University, Lancaster, U.K.*

Response

Thank you to Keith Beven and the other supporters of this nomination for providing me with such an honor, and to the audience for letting me enjoy it with you. The heartwarming aspect of the award is that it reminds me of the influences of the communities and institutions in which I have been fortunate to participate. The geography departments at Cambridge and Johns Hopkins impressed on me the importance of constructing theory based on field investigations (working on what Keith frequently emphasizes are our epistemic uncertainties about how landscapes function), and of spending at least a portion of one's research efforts on topics of societal value. Nairobi and McGill Universities exposed me to the subarctic and tropics, expanding my appreciation of the environmental range of Earth. And in the multidepartmental communities at the Universities of Washington and of California, Santa Barbara colleagues strengthened my geophysical education and expanded the geographical range and time depth of my studies and also my interest in hydrologic and geomorphic contributions to environmental conservation and restoration from the Pacific Northwest to the Amazon Basin. I am mindful that it was possible to learn new things in all the roles I had in these institutions from undergraduate to aging professor. I learned that diversity of scientific approaches and of geographical exposure is valuable and enriching.

But this is also a night to reflect on Robert Horton. He has guided me since my undergraduate days when I was taught that his hydrophysical approach was the key to understanding the fluid mechanical processes driving the formation and hydrological functioning of landscapes. I had to be informed later of the roles that Earth plays in providing the material properties, boundary conditions, and time frames in which those landforms and those functions evolve. But Horton has broader lessons for all of us. He distilled his working engineer's experience as an observer of nature and his multilingual reading into foundational studies across the processes and scales of the hydrologic cycle. In the 1930s, he published a scientific agenda for hydrology and was a cofounder of the Hydrology section of AGU in the face of considerable early skepticism about whether hydrology was truly a scientific field. For that, we should be particularly grateful to Robert Horton for providing us with this community and with an opportunity to ask continually whether our own work supports his optimistic vision of what we might accomplish.

—Thomas Dunne, *Bren School of Environmental Science and Management, University of California, Santa Barbara*

Alex Halliday Receives 2016 Harry H. Hess Medal

Alex Halliday was awarded the 2016 Harry H. Hess Medal at the AGU Fall Meeting Honors Ceremony, held on 14 December 2016 in San Francisco, Calif. The medal is for "outstanding achievements in research on the constitution and evolution of the Earth and other planets."

Alex Halliday

Citation

Alex Halliday is a pioneer in the application of isotopic techniques in geochemistry. The past few decades have seen remarkable developments that constrain the timing and nature of events in the early history of the solar system, and Alex has been one of the principal leaders in this effort. His wide-ranging efforts have also contributed to our understanding of weathering, paleoclimatology, mantle geochemistry, and basalt and granite petrogenesis.

Leadership can come from pioneering new measurements and from putting together a story. Alex has done both. He was a major player in the development and use of multicollector inductively coupled plasma mass spectrometry (ICPMS) for isotope geochemistry. Most significant, working with Der-Chuen Lee, he recognized and developed use of the hafnium-tungsten system. This made it possible to say something about the timing of core formation, a centrally important process in planetary formation and evolution. The relevant half-life, 9 million years, is conveniently similar to the timescale of planet and core formation, and the measurement can be done to sufficient precision to see the small amount that results from decays after multiple half-lives. In proposing the big picture, Alex sought to place his results in the context of

our evolving view of how planets (and Earth in particular) formed. Core formation is contemporaneous with accretion, with some (perhaps most) taking place in the first few million years, but with a substantial tail extending out to as much as 100 million years. Alex placed his results in the context of the giant impact, the prevailing view of lunar formation. He named the impactor Theia. This singular event and its isotopic consequences are widely accepted, although several aspects remain imperfectly understood. The story embraces Earth formation, the origin of the Moon, the relative timing of Mars, and the context provided by meteorites.

Alex also led the way with high-precision silicon isotope measurements; these have had multiple applications, including the isotopic similarity of Earth and the Moon. Alex has made other important contributions, including influential earlier work that interprets the incompatible trace elements in oceanic island basalt and mid-ocean ridge basalt. He has had many successful students, and he has also contributed great service to the scientific community, including leadership at Oxford and the Royal Society of London, and as a section president (Volcanology, Geochemistry and Petrology) at AGU. He is an outstanding recipient of the Hess Medal.

—David Stevenson, *California Institute of Technology, Pasadena*

Response

I should start by thanking Dave and others who were involved in my nomination, and AGU, for this great honor.

The Hess Medal is not special just because of the previous recipients and the science it recognizes. Hess himself was special. Ron Oxburgh, a former Hess student, who opened my labs in Michigan, describes him as one of the most relaxed, courteous, and considerate heads of department ever. He was highly entrepreneurial. Apparently, during World War II he commanded a troop transporter in the Pacific and, while under fire, the devoted coxswains of the landing craft would leap out of the boat and grab rocks for him! He also left his echo-sounder running continuously, which was not "normal" but facilitated the modern bathymetric chart of the Pacific, delineating deep ocean trenches associated with subduction.

My Ph.D. had little to do with deep planetary interiors. However, at Newcastle I got to hear talks by several big thinkers in the field, such as a younger Dave Stevenson. It was later, at Scottish Universities Research and Reactor Centre and then at the University of Michigan, that I was able to pursue my fascination first with the deep Earth and then cosmochemistry. Like Hess, I have had excellent postdocs and students including Der-Chuen Lee mentioned by Dave, but also many others. There is one in particular I should mention who helped me get started at Michigan; Jon Davidson is being made an AGU Fellow this year but sadly died of leukemia at the end of September. Jon, like Hess, was an inspiration to many.

In the spirit of Hess, isotope geochemistry has benefited from innovative approaches to big problems like the origins of the Earth and Moon. When I saw the prototype MC-ICPMS it was clear what it could achieve, but it has required the support of program directors and university leaders at Michigan, ETH, and Oxford. As we developed tungsten and other systems, and explored new archives, there were also many supportive colleagues such as Claude Allègre, Keith O'Nions, and the late Jerry Wasserburg. We have all had the privilege of working at times of great scientific discoveries. It's brilliant. However, my biggest thank you has to be to Christine and our boys, Jamie and Ross, who have put up with a busy Alex and three major relocations while I have fun being paid to do something I love.

Thank you all so much.

—Alex Halliday, *University of Oxford, U.K.*

Ellen R. M. Druffel Receives 2016 Roger Revelle Medal

Ellen R. M. Druffel was awarded the 2016 Roger Revelle Medal at the AGU Fall Meeting Honors Ceremony, held on 14 December 2016 in San Francisco, Calif. The medal is for "outstanding contributions in atmospheric sciences, atmosphere-ocean coupling, atmosphere-land coupling, biogeochemical cycles, climate or related aspects of the Earth system."

Ellen R. M. Druffel

Citation

Ellen Druffel is an explorer and scientific pioneer. Over her career, she has developed the measurement of radiocarbon (^{14}C) as a tool for studying timescales of ocean carbon cycling. Her research has paralleled a technological revolution allowing a shift from detecting the occasional flash of radioactive decay in bulk samples to counting individual ^{14}C atoms in single compounds extracted from water or sediments. In both cases, her laboratory's meticulous attention to detail and development of new methods mean that Ellen's results are not only trusted for their accuracy but often the first observations of their kind.

Ellen's early work with Pete Williams at Scripps Institution of Oceanography required painstaking field and laboratory work to document profiles of radiocarbon in the open ocean, including both dissolved and particulate organic matter. Surprisingly, the mean radiocarbon age of dissolved organic carbon was thousands of years, even though its ultimate source is newly photosynthesized carbon. In attempting to explain this mystery, Ellen and her group have fundamentally altered our understanding of ocean organic matter through the recognition that dissolved and particulate matter consist of many distinct, differently aged components. Recent work investigates the roles of black carbon and recycling of sedimentary carbon in explaining old organic carbon.

Another of Ellen's major contributions is the use of ^{14}C in corals as recorders of past change in ocean ventilation and mixing. The amassed data from her global coral archive provide unique, continuous records of tropical ocean circulation and reveal temporal variations in phenomena such as the El Niño–Southern Oscillation over the past millennium. They also record patterns of uptake of bomb-produced radiocarbon in the surface oceans that constrain estimates of ocean-atmosphere exchange CO_2 used in global climate models.

Ellen has made major contributions to AGU and its community through her leadership and deportment. Her sense of adventure has led her to explore the oceans, from scuba diving to ocean vessels and deep submersibles, and inspires a new generation of students. Her commitment to the advancement of oceanographic research and to forwarding women's careers in science has impact far beyond her scientific discoveries.

As a longtime colleague in the Earth System Science Department at the University of California, Irvine, we salute Ellen as a kind and conscientious coworker with a wicked sense of humor. We think she is an adventurous, courageous researcher, like Roger Revelle, and are thrilled that she is this year's Revelle Medal winner.

—Susan Trumbore, *Max Planck Institute of Biogeochemistry, Jena, Germany; and* **Michael Prather**, *University of California, Irvine*

Response

I am humbled by this honor and am very grateful to AGU and to Michael Prather and Sue Trumbore for their generous citation. It is important to emphasize that our research has relied heavily on collaborations with many colleagues over the past years. I share this honor with them.

Most important is my colleague, Sheila Griffin. Sheila and I have worked together for 38 years, since our time at University of California, San Diego. Sheila has trained our students in laboratory and vacuum line techniques, made high-precision isotopic measurements, planned and participated in many cruises, designed equipment, run our lab, and is a dear friend. Without Sheila's contributions, I would not be here tonight.

To my husband, Steve, who has always supported and believed in me, I thank you. You are a terrific husband and a wonderful father to our children, Kevin and Rachel. You fill our lives with inspiration, laughter, and love and put up with my occasional absentmindedness.

To our students and postdocs, it is your contributions, your blood, sweat, and tears, that have made our research program move forward. And your good-natured banter, which includes rubber chickens and rats, has been particularly heartwarming.

In the early 1990s, I was welcomed into the new Earth System Science group at University of California, Irvine, pioneered by Ralph Cicerone. They provided a fertile, supportive atmosphere for us to learn, to dream, to build, and to grow. I am so grateful to Peter M. Williams, my mentor who taught me how to ask important questions, and to work like the dickens to make difficult measurements. I remember his words, "If this was easy, someone would have done it a long time ago." I still miss you, Pete. My colleagues Cindy Lee, Lihini Aluwihare, Ann McNichol, Robbie Toggweiler, Rob Dunbar, Brett Walker, Sue Trumbore, John Southon, and Bill Cain have provided inspiration and friendship along the way. Thanks to my parents, who encouraged me to achieve my dream of becoming a scientist.

In 1957, Roger Revelle and Hans Suess published a paper in *Tellus* wherein they made initial estimates of the buildup of excess CO_2 in the atmosphere and ocean by the early 21st century. My group has worked on a small part of this big problem. We are truly fortunate to be able to ask scientific questions and spend time, sometimes lots of time, trying to answer them. Thank you, again, for this honor.

—Ellen R. M. Druffel, *University of California, Irvine*

Shun-ichiro Karato Receives 2016 Inge Lehmann Medal

Shun-ichiro Karato was awarded the 2016 Inge Lehmann Medal at the AGU Fall Meeting Honors Ceremony, held on 14 December 2016 in San Francisco, Calif. The medal is for "outstanding contributions to the understanding of the structure, composition, and dynamics of the Earth's mantle and core."

Shun-ichiro Karato

Citation

Prof. Shun-ichiro Karato is a thoroughly deserving recipient of AGU's 2016 Inge Lehmann Medal for his seminal research in mineral and rock physics and its implications for our understanding of the structure and dynamical processes of the Earth's mantle and core. Shun has built a formidable reputation as one of the foremost mineral/rock physicists of his generation by always choosing interesting and rewarding research problems and tackling them with a mix of creative experiments and original analysis and interpretation.

It is a characteristic of his work that experimental results are always placed in a wider context. This involves the use of appropriate models for material behavior, often drawn from the field of materials science, and a typically bold and provocative discussion of the application of the new insights to the behavior of the Earth. He has made multiple important contributions to our understanding of the deformation of Earth materials by developing and applying new experimental approaches for the study of the rheology of the high-pressure minerals of the transition zone and lower mantle, culminating in an opposed-anvil "rotational Drickamer" apparatus capable of high-strain deformation in torsion at pressures reaching those of the uppermost lower mantle. This technique has recently allowed the first large-strain deformation experiments on the wadsleyite and ringwoodite phases of the transition zone and the bridgmanite + ferropericlase mixture of the lower mantle, within their high-pressure stability fields, providing new insights into dislocation slip systems and rheology.

Shun has had a sustained interest in the influence of grain size, water, and partial melting upon rheology ever since his pioneering work in the 1980s delineating the boundary between the dislocation and diffusional creep regimes in fine-grained olivine aggregates. The capacity of phase transformations occurring under conditions far from thermodynamic equilibrium to drastically reduce grain size and thus influence the rheology of the cool interiors of subducting slabs has also been emphasized. He first suggested that partial melting of the mantle might strengthen it by removing water from minerals into the melt. He has also actively explored the link between deformation and the development of fabric with important implications for seismic anisotropy in the upper mantle and in the inner core, where he has suggested a role for the magnetic field. Shun has been an influential thinker about seismic wave attenuation and dispersion. In recent years, he has led studies of the effect of water in nominally anhydrous minerals on their electrical conductivity, rheology, and deformation fabrics.

The breadth and depth of Prof. Karato's contribution to our understanding of the mechanical behavior of geological materials are well illustrated by his powerful synthesis *Deformation of Earth Materials,* published by Cambridge University Press.

—Eiji Ohtani, *Tohoku Univ ersity, Sendai, Japan; and* **Ian Jackson,** *Australian National University, Canberra, ACT, Australia*

Response

Thank you Eiji and Ian for your kind nomination of me for the Lehmann Medal. Thank you also to those who supported this nomination and the committee members. It is my great pleasure to receive this honor for what I have done during the last ~40 years of my life.

I was born in Fukuoka, Japan, 4 years after the end of the Second World War and became a student of the University of Tokyo in 1968. That was a special year. In 1968, the model of plate tectonics was established, and the student rebellion spread throughout the world and there was no lecture at the University of Tokyo for more than a year. But this was the year in which I learned the most. I became an independent student and finished my Ph.D. without a supervisor. When I was struggling to become a scientist, luckily enough I had a chance to spend a few years at Australian National University (ANU) in Canberra. The time in Canberra was just so wonderful both scientifically and personally. In a very relaxed atmosphere, people there conducted world-class scientific studies. For the first time in my life, I got rigorous training as an experimentalist. I also learned that there are different styles of conducting scientific studies. Developing "bold" hypotheses and testing them with rigorous approaches is one way of doing science that I learned at ANU.

When I was a student, I got fascinated by geodynamics but soon realized that understanding materials properties is a key to putting a strong physical basis on geodynamics. Among various physical properties connected to geodynamics, I chose rheological properties and the role of water on various properties as the topics of my studies. These are the problems in "mineral physics," but I have been trying to go beyond conventional mineral physics. I focused on issues that are closely connected to geophysical observations.

In studying these problems new approaches are sometimes needed, including technical developments. Developing a new technique is essential but challenging in the busy recent scientific community. I was fortunate to enjoy much support from colleagues including students and postdocs that made this challenge sometimes successful. In particular, I should mention colleagues in Tokyo, Canberra, Minnesota, and New Haven. And, last but not least, I thank my family (my wife Yoko and each of our parents). Without their selfless support I would not be here today. Thank you all.

—Shun-ichiro Karato, *Yale University, New Haven, Conn.*

Veronique Dehant Receives 2016 Charles A. Whitten Medal

Veronique Dehant was awarded the 2016 Charles A. Whitten Medal at the AGU Fall Meeting Honors Ceremony, held on 14 December 2016 in San Francisco, Calif. The medal is for "outstanding achievement in research on the form and dynamics of the Earth and planets."

Veronique Dehant

Citation

Veronique Dehant's research area is the modeling of the deformable Earth's interior in response to external forcing factors such as the gravitational attraction of the Sun and Moon and the rotational forces associated with the motion of its axis of rotation in space. She extended this research to the solid planets of the inner solar system as well as to the icy satellites of the outer planets. She and her team made groundbreaking contributions in these domains over the past decades.

Firstly, Veronique's research was centered on the rotation of the Earth in space (precession and nutation) and its strong link with the global structure of our planet. She developed a model of deformable rotating Earth, taking into account all components of the solid Earth and their interfaces. Veronique also studied the effects of mantle anelasticity on Earth tides, the resonances between the liquid and solid inner cores, which led to better understanding of the free oscillations of the Earth and the influence of the geophysical fluids on its deformation and rotation. Further to her work on atmospheric effects on Earth's rotation she led research within working groups and commissions of the International Astronomical Union (IAU) with the aim of improving knowledge of each component of the deformable Earth system impacted by or impacting the Earth's rotation. A major outcome of her efforts was the definition of a new nutation model adopted by IAU in 2000. The culmination of decades of work in this area is her book with P. M. Mathews, *Precession, Nutation, and Wobble of the Earth* (2015).

Veronique has also been very active in making and leading research in planetary geophysics: modeling the interior of Mars, the processes of sublimation and condensation of its polar caps, and its gravity field temporal variations. She applied this approach to Venus and Mercury and to the icy satellites of the outer planets. She proposed a radio science instrument on the ExoMars space mission and was selected as principal investigator. She is an investigator of several missions of the European Space Agency to Mars and Venus (Mars Express and Venus Express), as well as to Mercury (BepiColombo).

For her remarkable scientific achievements Veronique has received several prestigious prizes and is member of several

academies. Considering all these and her creativity, her outstanding leadership and services to the community, and her enormous influence in mentoring many junior colleagues, Veronique highly deserves the 2016 Whitten Medal of AGU.

—Georges Balmino, *Centre National d'Études Spatiales Paris, France*

Response

Thank you so much, Georges, for the very generous citation! Thanks also to the colleagues who have proposed me to the Whitten Medal Committee, and its chair, Anny Cazenave, in particular. I am extremely honored and grateful to receive the prestigious Whitten Medal!

I studied mathematics and physics, and I did not anticipate that I would be a researcher in the field of dynamics of the Earth and planets, recognized by the Whitten Medal. I came into the field of Earth dynamics after my master's degrees in mathematics and physics and thanks to the heartfelt and appreciated mentorship and guidance of Paul Melchior, Paul Paquet, and André Berger from Belgium. Research rapidly became a passion. John Wahr, with whom I had the opportunity to work at the beginning of my career, was a great inspiration to my work.

I then came into the field of planetary science about 15 years ago. This happened when space missions were more and more aiming at understanding internal dynamics of planets. Understanding the evolution of planets has become fascinating to me as well, and I am now preparing an instrument for a mission to Mars, Lander Radioscience (LaRa), aiming at obtaining Mars rotation dynamics and to learn about its deep interior.

More than 10 years ago, I decided to write a book, *Precession, Nutation, and Wobble of the Earth,* coauthored by Sonny Mathews. This was a very nice experience, which allowed me to have the necessary distance to understand where efforts have to be put for the next generation of Earth rotation and orientation models. I decided then to propose the idea of working on coupling mechanisms at the core-mantle boundary for a European Research Council Advanced Grant, which I got. This is very exciting as I am now back to studying Earth in parallel with being principal investigator of a selected space mission, which is very challenging and exciting.

This award wouldn't be possible without the constant support of the Royal Observatory of Belgium and the great team that I have had the good fortune to work with at the various stages of my career. An invaluable treasure in my life was and is the ongoing support from my beloved family and friends. I praise them for all the good things they have provided for me, and, in particular, Guy, my husband, who transformed my dreams into reality, supporting me over my entire career.

—Veronique Dehant, *Royal Observatory of Belgium and Université Catholique de Louvain*

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Devendra Lal Medal Fosters Diversity and Inclusion in AGU Honors

A recently approved medal of AGU aims to promote excellence in the Earth and space sciences in developing nations by recognizing outstanding research accomplishments in those countries. The medal also furthers AGU's strategic objective of decreasing barriers to gender and ethnic diversity and inclusiveness in the organization's honors program to increase participation of underrepresented groups (see http://bit.ly/Tier1-Tier2 for a list of developing nations).

With this new medal, AGU will strengthen its recognition and engagement in the international community and establish a mechanism to support international collaboration, particularly by underrepresented groups. Recipients of this medal may be at any stage of their professional careers, but preference will be given to the recognition of early-career research accomplishments.

With this new medal, AGU will strengthen its recognition and engagement in the international community.

Obligation and Commitment

The Devendra Lal Medal not only aligns well with AGU's vision and mission, but it also addresses the organization's obligation and strengthens its commitment to ensure a workplace climate for Earth and space scientists that is inclusive, respectful, and free from bias and discrimination. In a recently published *From the Prow* blog post, AGU president Margaret Leinen called on AGU members to share ideas (see http://bit.ly/diversity-foundation): How would they develop and improve areas and programs of AGU to increase diversity and inclusion among all AGU members and peers in the Earth and space science community, regardless of race, gender, religion, ethnicity, sexuality, cultural identity, disability, or socioeconomic status? The establishment of the Devendra Lal Medal strengthens this message and outreach.

AGU extends its gratitude to a group of esteemed AGU members who worked closely with the Honors and Recognition Committee, in discussion with the AGU Board and Council, to establish this medal. It honors an innovative and highly acclaimed scientist, Prof. Devendra Lal, whose life and work continue to inspire and motivate new generations of Earth and space scientists.

Nominations for the Devendra Lal Medal will open on 15 January.

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

Ancient Ocean Floor Seashells Improve Model of Past Glaciers

Martin St-Amant, CC BY-SA 3.0 (http://bit.ly/ccbysa3-0)

A new, more accurate model of glacial cycles over the past 150,000 years could help predict the fate of existing glaciers.

Every 100,000 or so years over the past million years, relatively small changes in the amount of sunlight that reaches the Arctic region in summer have spurred dramatic shifts in the proportion of Earth's surface that is covered in ice. During the most recent of these massive transformations, up to 30% of the planet's surface was covered in glaciers, including an ice sheet over Canada and the northern United States that at places reached more than a kilometer and a half thick.

Now researchers have produced a new, more detailed model of this latest glacial cycle, spanning from 150,000 years ago to the present. To reconstruct the volume of ice covering the globe, *Lisiecki and Stern* analyzed the shells of single-celled ocean floor creatures called foraminifera, which capture two different isotopes of oxygen in their shells. In the environment, the lighter isotope, ^{16}O, evaporates easily from the ocean and falls on land as rain or snow. When the climate cools, it becomes trapped in ice sheets as snow freezes to the ground. Meanwhile, the heavier isotope, ^{18}O, stays in the ocean. As they get buried in layers of ocean sediment over time, foraminifera shells provide a snapshot of the isotope ratio left in the ocean, which can be used to calculate the volume of global ice sheets and changing deep-sea temperatures.

The authors' prior work averaged this ratio (known as $\delta^{18}O$) from 57 sediment cores from oceans across the globe to reconstruct the evolution of glacial ice sheets over the past 5 million years. Because of the small number of samples and certain assumptions built into this model, however, the margin of error for the timing of events such as sea level rise could be as much as 4000 years.

By including 5 times as many records as in the previous version, the authors have reduced that error rate to approximately 1000 years over the past glacial cycle. First, the team took $\delta^{18}O$ data from 263 cores from eight regions in the North and South Atlantic, Pacific, and Indian Oceans. Then they correlated ice-rafted debris and temperature data from North Atlantic cores with independent data on temperature from an ice core in Greenland and stalagmites from China and the Alps.

The new, more accurate model suggests that sea levels rose more rapidly than previously thought in response to increases in solar energy. This finding could improve future predictions of how quickly glaciers will respond to future solar radiation and other factors that drive climate change, such as the buildup of greenhouse gases in the atmosphere. (*Paleoceanography*, doi:10.1002/2016PA003002, 2016) **—Emily Underwood, Freelance Writer**

Switching to Drought-Tolerant Plants Could Alter Urban Climates

Drought conditions have persisted in California since 2012, prompting Los Angeles and other cities throughout the state to encourage the replacement of thirsty lawns with plants that require less water. This switch could significantly affect local urban temperatures, according to a new study by *Vahmani and Ban-Weiss.*

In Los Angeles, programs such as Cash for Grass offer incentives to residents willing to pull up their lawns and lay down native plants, which thrive with less irrigation. Despite the success of similar programs already in place in dry cities in other states—including Phoenix, Ariz., and Las Vegas, Nev.—little is known about how such efforts affect the urban climate.

The researchers used a climate model described in a previous study that accounts for the region's complex mix of varying urban land cover, coastal sea breezes, and surrounding mountains to investigate the effects of replacing lawns in the megacity of Los Angeles. Using the model, the team simulated scenarios in which existing vegetation was replaced with native plants and irrigation was stopped completely.

The scientists found that replacing lawns with drought-tolerant vegetation raised summer daytime temperatures by up to 1.9°C in their models. This rise was mostly due to decreases in irrigation and subsequent reductions in evaporation of water, which acts as an air conditioner to keep temperatures down.

However, the model also showed that hotter daytime temperatures were balanced out by cooler summer nights. A switch from lawns to drought-resistant vegetation lowered nighttime temperatures by an average of about 3°C because of changes in soil moisture that altered ground heat fluxes. The nighttime cooling effects of decreased irrigation could help the Los Angeles region's 13 million residents recover from the heat of the day during extreme heat events—an important public health consideration.

The authors note that their study reflects an extreme scenario in which irrigation stops completely. Nonetheless, the findings could help scientists better predict the effects of lawn replacement efforts in Los Angeles and ensure that such programs will actually help, and not harm, the region's climate. (*Geophysical Research Letters,* doi:10.1002/2016GL069658, 2016) **—Sarah Stanley, Freelance Writer**

George Ban-Weiss

More Los Angeles gardens like this one—with drought-resistant plants—could make summer nights cooler and summer days hotter.

Modeling Rainfall Runoff

U.S. Department of Agriculture, CC BY 2.0 (http://bit.ly/ccby2-0)

An aerial view of the flooding near Baton Rouge, La., in 2016.

Flowing water has tremendous power. It can carry heavy boulders and carve massive canyons. Scientists continually work on understanding the specifics of one of the most common types of flowing water: runoff that occurs from a rainstorm. In a warming world where rainfall is becoming concentrated in heavy precipitation events, this is more crucial than ever before. The recent floods in Louisiana bear testament to this reality.

Although there are plenty of rainfall-runoff models—computer simulations that convert rainfall into runoff predictions—these models often lack analytical expressions for converting storm event rainfall into runoff. An exception is the Soil Conservation Service (now the Natural Resources Conservation Service) curve number method, which consists of a simple expression for converting storm event rainfall into runoff. Graphically, this expression is a curve, and the shape of this curve is controlled by one water storage parameter that is referenced with a curve number (CN) index. Runoff CNs are based on factors such as soil type, land use, and topography. Rainfall-runoff curve expressions are not found in most existing models.

Here *Bartlett et al.* present a rainfall-runoff curve with a general form that unifies the Soil Conservation Service CN method with many existing rainfall-runoff models. With this expression, users can quickly compare these different models and rainfall-runoff data without the need for numerical simulations of the rainfall event. In other words, users can get a well-defined estimate of the runoff amount at a location on a river given any hypothetical rainfall amount by using just a water retention index like the local CN.

Although the models are mathematically derived, the authors analyzed their results by using data from the Davidson River watershed, an area of approximately 104 square kilometers in North Carolina. The U.S. Geological Survey has recorded streamflow at the watershed outlet and rainfall at Lake Logan, a man-made reservoir in the watershed, since 1998. With the rainfall and streamflow data, the team estimated what the rainfall-runoff curve should have looked like and then compared this data-derived curve with the analytical expressions specific to each model.

In addition, the authors' method extends the general rainfall-runoff curve to represent different types of runoff, be it water seeping within the soil near the stream or gushing down a hillslope. Like the quintessential event-based model—the Soil Conservation Service CN method—this general rainfall-runoff curve may then be related to land use, climate, geology, and other characteristics. (*Water Resources Research,* doi:10.1002/2016WR019084, 2016) **—Shannon Hall, Freelance Writer**

Mars's Atmosphere Matches Earth's Turbulent Nature

As anyone who's flown on an airplane can attest to, in Earth's atmosphere, turbulence is everywhere. On sunny days, pockets of hot air churn up through the sky. Mountains act like rocks in rivers of air, leaving swirling eddies downwind. And high above, air currents shed vortices as they race around the Earth.

We accept this behavior as normal, albeit annoying when trying to sip weak drinks at 35,000 feet. Turbulence is a general property of gases and liquids that occurs when they are strongly stirred, and it is expected to be present in all planetary atmospheres, in the case of Earth and Mars, at scales greater than about 1 millimeter and 1 centimeter, respectively. Below this, the atmospheres are like molasses, so smaller whirls don't exist.

Until now, scientists have concentrated on understanding the ways that solar energy stirs terrestrial and Martian atmospheres, focusing on structures that cover thousands of kilometers or more in size; they have neglected the scales from this size down to the dissipation scale. Theorists have proposed that over these scales the atmospheres should follow statistical (turbulent) laws that are not sensitive to the details of the stirring mechanism. Until now, we have been able to quantify these laws only on Earth. But to fully verify the roles that these scales play, we need a new point of comparison. Now a new study from *Chen et al.* reports that the properties of turbulence in Mars's atmosphere are remarkably similar to Earth's.

Decades of observations and simulations have given scientists a good look at the dynamics of the Martian atmosphere on a global scale, including cells of circulation from equator to pole that resemble Earth's. This behavior is driven by global factors like the warmth of the Sun and the planet's rotation, and they can be predicted from physical laws. But unlike the classical laws of fluids, turbulent laws describe the chaos, the randomness, of strongly stirred fluids. Patterns here are stochastic: They can be scrutinized statistically but not precisely predicted. Therefore, the dynamics of the atmosphere on more graspable scales—for example, scales on Earth the size of mountains, buildings, trees, and other things that influence turbulence—can only be dealt with statistically. In currents of air, nobody can reliably predict whether a particular eddy will form, but we can calculate quantities like the spectrum of sizes, how often eddies are likely to form, and how far apart they are likely to be.

To that end, the authors have produced the most detailed statistical analysis yet of Mars's atmosphere. They used a public data set called the Mars Analysis Correction Data Assimilation (MACDA), which includes 5 years of measurements from NASA's Mars Global Surveyor orbiter and also uses a model of global atmospheric circulation to fill in gaps.

The authors find that statistically, the spectrum of how parameters like temperature, pressure, and wind speed behave on Mars is remarkably similar to Earth's. In fact, mathematically, the exponents of the power laws that govern their behavior are virtually identical.

The finding suggests something profound about the underlying physics: Certain patterns likely emerge in all planetary atmospheres. And even though physics still can't predict the exact state of a turbulent atmosphere, the classical laws that attempt to define the statistics of those patterns do hold.

In this way, the authors note, the study tells us as much about Earth as it does about Mars. It demonstrates that the laws that spill our in-flight drinks across our tray tables aren't unique but hold across Mars and Venus, the other terrestrial planets with robust atmospheres. (*Journal of Geophysical Research: Atmospheres,* doi:10.1002/2016JD025211, 2016) **—Mark Zastrow, Freelance Writer**

Eliminating Uncertainty One Cloud at a Time

When it comes to forecasting climate change, there's one huge wild card: clouds. By reflecting, absorbing, and emitting radiation, clouds (and fine particles known as aerosols) play a major role in the planet's energy balance and thus in setting Earth's temperature. And yet whether an individual cloud warms the planet or cools it depends on its size, latitude, altitude, albedo, and other physical parameters. For decades, climate models have strongly disagreed on how cloud properties—and their effects on Earth's energy budget—will change with global warming, making clouds the biggest source of uncertainty in climate model predictions.

Thus, climate scientists will be able to narrow uncertainty in forecasting climate change only if they can better constrain the feedbacks from clouds. With that in mind, *Zelinka et al.* decompose cloud feedbacks to better connect them to specific physical processes.

To do this, the team used so-called cloud radiative kernels along with detailed model cloud information provided by the International Satellite Cloud Climatology Project simulator. They calculated the feedback due to 49 different types of clouds, which were divided into seven altitude categories and seven optical depth categories. Over the past few years, kernels have become a common tool for comparing cloud feedbacks among climate models.

In this case, the authors refined the technique to compute amount, altitude, and optical depth feedbacks separately for upper level and low-level clouds. Low-level clouds are those that reside in the boundary layer, the layer of Earth's atmosphere directly influenced by its surface. Upper level clouds reside above the boundary layer and are affected by different processes.

The team discovered that all climate models agree on the direction of three main feedbacks that accompany global warming. First, upper level clouds rise to higher altitudes in all models, warming the planet by trapping more heat. Although this was previously known, the positive feedback is actually smaller and better constrained than past research has suggested. Second, low-level cloud cover decreases in all models, warming the planet by reflecting less incoming sunlight back to space. And third, the optical depth of low-level clouds increases in all models, cooling the planet by reflecting more sunlight.

Decomposing cloud feedbacks into individual components provides valuable insights into the individual mechanisms at play. This is crucial if we want to understand and constrain cloud feedbacks and to forecast how the planet will react to climate change. (*Geophysical Research Letters,* doi:10.1002/2016GL069917, 2016) **—Shannon Hall, Freelance Writer**

Isotopes Track Carbon Cycle in Northern Wisconsin Wilderness

In the face of global climate change, scientists are always in search of better models to accurately measure carbon in an ecosystem. In particular, they look to determine how quickly carbon can cycle through plants and soil until it reaches the atmosphere again.

This rate helps them to project global climates in both the near and distant future and the regional effects that these changes may have on temperature, sea levels, rainfall, and crop growth. The closer scientists get to accurately measuring carbon and its sources and sinks, the closer they get to forecasting the future.

Carbon-14, or radiocarbon, is one isotope used to track the movement of carbon from the atmosphere. Radiocarbon is sequestered by trees via photosynthesis, moved to the ground, and finally released again into the atmosphere. Nuclear weapons testing during the middle of the 20th century temporarily elevated radiocarbon in the atmosphere, and consequently, carbon stored in terrestrial ecosystems on timescales of decades has elevated levels of radiocarbon compared with the radiocarbon levels in the present-day atmosphere. Because of this difference, scientists can use radiocarbon to determine how long it takes carbon to cycle through vegetation, into soils, and back to the atmosphere.

In a recent study, *LaFranchi et al.* collected air samples at the WLEF tall tower in northern Wisconsin, an area surrounded by forest and wetland ecosystems with a relatively sparse human population. The authors took the samples at a height of 369 meters above the ground from 2010 through the end of 2012. From this, they gathered 114 radiocarbon observations over the 3 years of sampling.

After collecting the radiocarbon data from the tower, the researchers ran it through a series of atmospheric carbon simulations to retrace the origins of the carbon samples. These simulations combined weather models, fossil fuel and nuclear emissions data, a global fire emissions database, and a terrestrial biosphere model (modeling the amount of carbon that is released from soils and vegetation). These simulations created a full picture of where the radiocarbon in the atmosphere was coming from.

The measurements showed a seasonal increase in radiocarbon abundance in the summers and declines in the winters, particularly in the first year of sampling (2010). Although fossil fuel, which is devoid of radiocarbon and thus lessens its fraction in the atmosphere, had the largest effect on radiocarbon abundance in the atmosphere throughout the year, the researchers were surprised to find that forests and vegetation respiration made a larger contribution than expected.

Their results indicate that the radiocarbon input to the atmosphere from soils and vegetation was 2 to 3 times higher than predicted by their ecosystem model. The likely source for this overabundance is the boreal forests of central and northwestern Canada. These massive forests are globally significant for their large carbon storage but are vulnerable to climate change, which could cause more carbon to be released in the future.

The authors hope that the radiocarbon approach used in the study could help home in on the intricacies of the carbon cycle for future research, in particular, how the natural carbon cycle responds to human-caused climate change. They also hope that their study will help lead to a better understanding of the short-term feedbacks of carbon released into the atmosphere. (*Journal of Geophysical Research: Biogeosciences*, doi:10.1002/2015JG003271, 2016) **—Alexandra Branscombe, Freelance Writer**

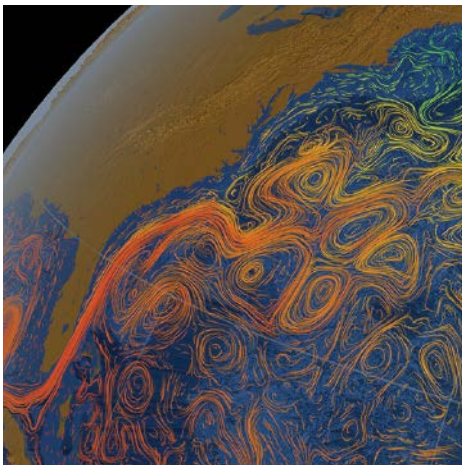
Gulf Stream Destabilization Point Is on the Move

The mighty Gulf Stream current transports warm water out of the Gulf of Mexico and along the U.S. East Coast from Florida to North Carolina before it begins its arc across the deep Atlantic. After the Gulf Stream passes Cape Hatteras, N.C., it gradually forms distinctive patterns called meanders, wavelike crests and troughs that look like curves in a huge, winding river.

In a new study, *Andres* reports that the location where the Gulf Stream meanders begin to amplify has migrated westward over the past 2 decades. Satellite, mooring, and shipboard observations of the current's flow from 1993 to 2014 show that this "destabilization point" has shifted west at a rate of about 25 kilometers per year.

Gulf Stream meanders can create underwater cyclones and other features that disrupt and stir nearby currents. The author's analysis suggests that the migration of the destabilization point has boosted the frequency of deep stirring events since 2008. The westward movement may also be related to recent warming of shallower water above the continental shelf in the Mid-Atlantic Bight.

The author hypothesizes that the cause of the migration could be related to interactions between the Gulf Stream and the Deep Western Boundary Current, which flows toward the equator and crosses beneath the Gulf Stream near Cape Hatteras. Future research could determine why the destabilization point is on the move and what its full implications, such as potential effects on marine ecosystems, will be. (*Geophysical Research Letters*, doi:10.1002/2016GL069966, 2016) **—Sarah Stanley, Freelance Writer**



NASA/Goddard Space Flight Center Scientific Visualization Studio

East of North Carolina, the warm Gulf Stream current begins to meander. New research reveals that the point where meandering begins is moving steadily westward.

Corals Reveal Ancient Ocean Temperatures in Great Barrier Reef

As rising ocean temperatures bleach corals in the Great Barrier Reef, scientists seek better insight into climate trends in the region. However, climate models do not yet adequately reflect trends in southern tropical and subtropical oceans. To collect new data that could improve these models, *Sadler et al.* turned to records captured in ancient coral beds.

As stony corals grow, they build their skeletons from calcium (Ca) in the surrounding seawater. Strontium (Sr) atoms are sized similarly to calcium and have the same ionic charge, so they also get incorporated into coral skeletons. The abundance of strontium in newly forming coral depends on the temperature of the seawater that bathes it—the colder the temperatures are, the more strontium infiltrates coral skeletons as they form. In this way, corals can serve as archives of past climate conditions.

National Park Service

New research demonstrates that Porites *corals can reveal ancient climate trends in the Great Barrier Reef region.*

To build this archive, scientists first had to examine how Sr/Ca ratios behaved during modern times, when sea temperatures were known. In February 2014, the researchers visited massive *Porites* coral colonies at Heron Reef in the southern Great Barrier Reef, located off the northeastern coast of Australia. The authors used scuba and pneumatic drills to penetrate the growing coral colonies and retrieve core samples.

Porites coral grows by building new layers of skeleton on its surface. Therefore, over time, the coral skeletal layers served as a timeline, with deeper layers corresponding to earlier periods, similar to tree rings. At various points along the cores, the researchers measured Ca and Sr levels and matched them to known ocean temperature data for the corresponding time periods. This gave an equation that related Sr/Ca ratios to ocean temperature.

The scientists then applied the equation to ancient corals from the mid-Holocene, which they later collected using a small, portable drilling platform at a site about 2 kilometers away from the modern coral site. Radioactive dating revealed the ages of coral tissue along the length of each core. After determining Sr/Ca ratios, the team used the equation derived from the modern coral to determine prehistoric ocean temperatures.

The ancient corals revealed that about 5200 years ago, ocean temperatures at Heron Reef were 1.3°C–2.8°C cooler than present, and about 7000 years ago they were 1.3°C cooler than present. The results also suggest that a warm period known as the mid-Holocene Thermal Maximum occurred between 6000 and 6800 years ago, earlier than previous estimates that placed it between 5350 and 4480 years ago.

The authors say that more research is needed to confirm the earlier dates for the mid-Holocene Thermal Maximum in the subtropical western Pacific, but their findings demonstrate that ancient *Porites* corals could provide the necessary data for these ongoing efforts. (*Paleoceanography*, doi:10.1002/2016PA002943, 2016) **—Sarah Stanley, Freelance Writer**

High-Resolution Ocean Model Captures Large-Scale Heat Transport

The atmosphere and ocean constantly interact by exchanging heat, moisture, and momentum in the form of wind and currents. This air-sea flux has a major impact on global climate, and ocean models that accurately capture it are important for improving weather forecasts and predictions of future climate conditions.

In a recent study, *Roberts et al.* investigated two ocean models with different levels of resolution to determine how well they capture small-scale air-sea flux and large-scale heat transport. They found that a lower-resolution model is sufficient for capturing air-sea flux in some cases, but a higher-resolution model more accurately simulates large-scale heat transport in the North Atlantic.

The lower-resolution model is known as an "eddy-permitting" model because it can roughly capture ocean storms, which it does at a resolution of 0.25° latitude and longitude. The higher-resolution "eddy-resolving" model captures ocean storms more realistically, at a resolution of 1/12 of a degree.

The researchers paired each ocean model with an atmospheric model to simulate air-sea flux across the globe over the course of 20 years. When they compared the model results with observational data for the same time frame, they found that the eddy-permitting model was nearly as effective as the eddy-resolving model in capturing air-sea flux interactions.

Most previous studies have compared eddy-resolving models of 0.1° resolution with 1° resolution models (more typically used for long climate simulations), finding the lower resolution to be inadequate. The new findings show that a 0.25° resolution eddy-permitting model may be sufficient and more affordable for some researchers who might otherwise have considered an eddy-resolving model.

However, the team found that the eddy-resolving model did a much better job of capturing average sea surface temperatures and therefore heat exchange with the atmosphere in the North Atlantic. The resulting simulation of ocean heat transport in the region more closely matched actual observations.

If supported by further research, these findings could help researchers refine climate models and improve future climate projections. (*Geophysical Research Letters*, doi:10.1002/2016GL070559, 2016) **—Sarah Stanley, Freelance Writer**

Mapping Geoelectric Hazards Across the United States

NASA Earth Observatory/NOAA NGDC

Nighttime photograph of the continental United States.

Variations in the Earth's space environment can disturb our planet's geomagnetic field, inducing electric fields in the conducting crust, mantle, and oceans. If space weather is stormy, these geoelectric fields can drive uncontrolled current through power grids sufficient to cause blackouts and even wreak permanent damage.

It has happened in the past, and we can expect it to happen again in the future—an extremely intense magnetic storm could cause continental-scale failure of electric power grids. Such an event would have long-lasting negative consequences on society.

New research by *Love et al.* provides some clues on what might happen to electric grids during a large geomagnetic storm. The work is part of the U.S. Geological Survey's (USGS) contributions to an interagency project called Space Weather Operations, Research, and Mitigation (SWORM), initiated by the White House's National Science and Technology Council in 2015.

Specifically, the researchers created maps of geoelectric fields that estimate what would be generated by a magnetic superstorm. The researchers used two kinds of data to create the new maps.

First, they used monitoring data collected at magnetic observatories operated by USGS and in other countries within the International Real-time Magnetic Observatory Network (INTERMAGNET) consortium. From these data, the team constructed a latitude-dependent statistical function of geomagnetic activity. Second, they used magnetotelluric survey data acquired by the National Science Foundation's EarthScope program and a smaller set of data collected by USGS. These data measure the relationship between induced geoelectric fields and the inducing geomagnetic field at different locations across the continental United States.

By putting those two sets of data together, the researchers were able to create a hazard map, showing the strength of induced geoelectric fields during strong magnetic storms—storms with strengths that are likely to occur only once per century. They found that the strength of these fields can depend significantly on location, by more than 2 orders of magnitude. The authors also found that Minnesota and Wisconsin have some of the highest areas of geoelectric hazard, whereas Florida has some of the lowest.

Magnetotelluric data are not yet available for the whole United States, so a country-wide assessment is not yet possible. However, the authors expect that dense power networks in the Northeast, which has complicated underground structures, would experience large hazards from induced geoelectric fields.

A disruption of electrical power could be disastrous in highly populated metropolitan centers, so predicting possible geoelectric hazards across the rest of the United States is an important ongoing project. (*Geophysical Research Letters*, doi:10.1002/2016GL070469, 2016) **—Leah Crane, Freelance Writer**

NEW in Fall 2016

GeoHealth

AN OPEN ACCESS AGU JOURNAL

GeoHealth will foster the intersection of Earth science disciplines (Earth processes, climate change, atmospheric and ocean sciences, hydrology, among others), with those of the health sciences, defined broadly (environmental and ecosystem health and services, human and agricultural health, geomedicine, and the impact of natural hazards). This is an important opportunity to help shape and lead this increasing important, cross-cutting discipline.

Now Accepting Applications for Two Founding Editors in Chief of *GeoHealth*

AGU is looking for two dynamic, well-organized scientists with high editorial standards and strong leadership skills to serve 4-year terms as the editors in chief (EICs) for this exciting journal. One editor's main area of focus will be on the geosciences, while the other editor's main area of focus will be on health.

The EICs will be the principal architects of the scientific content of the journal. They are active scientists, well-known and well-regarded in their respective discipline. The EICs must be active in soliciting the best science from the best scientists to be published in the journal. Working with the other editors and AGU staff, EICs are the arbiter of the content of the journal. Among other functions, EICs will be responsible for:

- **Acting as an ambassador to the author/editor/reviewer/scientist community.**
- **Setting the strategy for the journal.**
- **Leading the editor selection process.**
- **Assigning and balancing review work load.**
- **Making decisions related to scientific ethics.**
- **Reviewing and contributing to periodic monitoring reports.**
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If you would like to be considered for one of the Editor in Chief positions of *GeoHealth,* send your curriculum vitae with a letter of interest via email to pubmatters@agu.org. If you would like to nominate a highly qualified colleague, send a letter of recommendation to the same email address. **Please make sure that you specify *GeoHealth* in the subject line of the email.**

geohealth.agu.org

AGU PUBLICATIONS

ATMOSPHERIC SCIENCES

Tenure-Track Assistant Professor of Physics (Atmospheric), New Mexico Tech

The Department of Physics at New Mexico Tech invites applications for a tenure-track position in Atmospheric Physics. Current atmospheric research interests in our department include lightning and atmospheric electricity, instrumentation, cloud physics and thunderstorm structure, interaction of clouds and climate, Earth's upper atmosphere, and planetary atmospheres. Candidates with backgrounds in experimental areas of atmospheric physics, atmospheric electricity, or custom instrumentation are particularly encouraged to apply. On-campus facilities and collaborating institutions include the Langmuir Laboratory for Atmospheric Research, Sandia National Laboratory, and Los Alamos National Laboratory. The department also maintains a model shop with a master machinist for fabrications and a Beowulf cluster for atmospheric simulations as well as several other small laboratories and a maker space.

A PhD is required in physics, atmospheric science, or a related field. The successful candidate should expect to teach at the undergraduate and graduate level. They will further contribute to the health of the department by obtaining external funding to support graduate and undergraduate research assistants.

Candidates should thus have a demonstrated record of research normally achieved through postdoctoral experiences, or the equivalent. Applicants shall submit a curriculum vitae along with a statement of research interests and teaching philosophy to: New Mexico Tech, Human Resources Office 801 Leroy Pl, Socorro, NM 87801-4796. Please also arrange for three letters of recommendation to be sent with your application packet. For additional information see the department's web page at physics.nmt.edu, the institute web page at www.nmt.edu, or contact the search committee chair Dr. Kenneth Eack at ken.eack@nmt.edu. Review of applications will begin February 1, 2016, with an expected start date of August 2017.

BIOGEOSCIENCES

Tenure Track Faculty Position in Geology, Wayne State University

The Department of Geology at Wayne State University invites applications for a tenure-track position in Hydrogeology or Geophysics at the rank of assistant or associate professor beginning in August 2017. Preference will be given to candidates who use innovative approaches to study complex problems in fields such as: groundwater flow and contaminant transport, surface-groundwater exchange, environmental geophysics, and solid earth geophysics. Applicants

Michel T. Halbouty '30 Visiting Chair in Geology and Geophysics

The Department of Geology and Geophysics at Texas A&M University is pleased to announce the Michel T. Halbouty '30 Visiting Chair in Geology and Geophysics. The purpose of Mr. Halbouty's generous gift is to "Promote excellence in the teaching and research of the Department of Geology and Geophysics." We expect to appoint 4 to 5 distinguished scholars to the Visiting Chair over the next few years and provide them the opportunity to visit our campus and interact with department faculty and students for up to twelve months duration. The appointment provides partial salary support and additional funds to cover lodging and travel, as well as proposed engagement activities.

Applications should be submitted by March 20, 2017, to be considered for awards in 2017 and 2018. Interested persons are encouraged to contact faculty members in the Department of Geology and Geophysics (http://geoweb.tamu.edu/). Applications should identify potential faculty proponents, include a CV, a 2-page proposal identifying research, teaching and engagement activities as a Visiting Chair holder, availability for visiting the department in the upcoming academic year, and tabulation of desired funds needed for salary and other expenses.

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 Americans 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 individuals with disabilities. Texas A&M University also has a policy of being responsive to the needs of dual-career partners (hr.tamu.edu/employment/dual-career.html).

Please send your application materials to F.M. Chester, chair of the Halbouty Visiting Chair Committee (chesterf@tamu.edu). For further information, contact F.M. Chester or other faculty members of the department (http://geoweb.tamu.edu/).

must have a Ph.D., postdoctoral experience, and an outstanding record of research achievement. Successful applicants are expected to establish and maintain vigorous, externally funded research programs and to participate in graduate and undergraduate education in geology and environmental science.

Wayne State University is a large, comprehensive, nationally ranked research institution that offers state-of-the-art research facilities and highly competitive start-up packages. WSU is located in midtown Detroit, which enjoys vibrant cultural and educational amenities amidst the rich natural environment of the Great Lakes. Wayne State is also ideally situated to explore the multifaceted legacy of environmental concerns common to post-industrial urban regions.

Please apply on-line at jobs.wayne.edu (posting #042344) by January 3, 2017 for full consideration. In addition to an online application that includes cover letter and curriculum vitae, applicants must submit a 2-page statement of their research plans and have three letters of reference sent to: Faculty Search Committee, Department of Geology, Wayne State University, Detroit, MI 48202 or to Dr. David Njus, Chair at (ad5348@wayne.edu). Applications will be considered only when all materials have been received.

Wayne State University is an affirmative action/equal opportunity employer.

Women and members of minority groups are especially encouraged to apply.

GEOCHEMISTRY

Assistant–Associate Professor, Arizona State University

The School of Earth and Space Exploration (SESE) and the School of Molecular Sciences (SMS) at Arizona State University invite applications for a jointly-appointed, tenure-track Assistant or Associate Professor in Isotope Geochemistry, with an anticipated start date of August 2017. Rank and tenure status will depend on experience. We seek diverse applicants with expertise in radiogenic or light stable isotope geochemistry. We especially encourage applicants who: 1) employ analytical isotope geochemistry to study the tempo and dynamics of chemical, physical, or biological processes on Earth and elsewhere in our solar system; 2) have interests in developing analytical protocols and instrumentation; 3) are enthusiastic about collaborative research spanning traditional disciplinary boundaries; and 4) complement ASU's existing strengths in geochemistry.

The successful candidate will explore problems at the leading edge of their field, teach at the undergraduate

Assistant/Associate/Full Professors - Physical and Biological Oceanography, Marine Geophysics/Geology, and Ocean Engineering

South University of Science and Technology of China

The school of oceanography at the South University of Science and Technology of China (SUSTC) invites applications for several tenure-track (or tenured) faculty positions at the ranks of Assistant, Associate, and Full Professor. Applicants must have earned Doctoral degrees in marine geophysics/geology, physical oceanography, biological oceanography, ocean engineering or closely related field. Successful applicants will be expected to establish a robust, externally funded research program and demonstrate a strong commitment to undergraduate and graduate teaching, student mentoring, and professional service. These positions will be open until filled.

SUSTC is a young university at Shenzhen in southern China since 2010 which is set to become a world-leading research university, to lead the higher education reform in China, to serve the needs of innovation-oriented national development and the needs of building Shenzhen into a modern, international and innovative metropolitan. These positions are created with a significant development to establish a vigorous research program in oceanography at SUSTC to serve the national call for China's important role in deep sea research and resource-oriented exploration in the world oceans.

To apply submit a cover letter, complete vitae with list of publications, and three names of references via http://talent.sustc.edu.cn/en/, or to Dr. Y. John Chen, Chair Professor at School of Oceanography, South University of Science and Technology of China, No 1088, Xueyuan Rd., Xili, Nanshan District, Shenzhen, Guangdong, China 518055.

and graduate levels, conduct research publishable in top-tier journals, and participate in service to the institution and profession as appropriate.

SESE and SMS have a history of successful joint faculty appointments. SESE unites Earth and space science in one school, combining science, engineering, and education to investigate the biggest questions of our time. SMS transcends traditional boundaries of chemistry and biochemistry to conduct solutions-oriented research and train a new generation of molecular scientists. SESE and SMS faculty benefit from state-of-the-art facilities on the Tempe AZ campus including: new clean laboratories and instrumentation space, and centers of excellence in geochronology, aqueous and environmental geochemistry, and non-traditional isotope geochemistry. The SESE and SMS faculty also have access to ASU's Secondary Ion Mass Spectrometry (SIMS/NanoSIMS) facilities, and world-class microbeam instrumentation in ASU's LeRoy Eyring Center for Solid-State Science.

Minimum Qualifications:

• Ph.D. in a relevant discipline by the time of appointment

• Experience in isotope geochemistry commensurate with rank

• Demonstrated potential to establish a vigorous, externally-funded research program with national and international impact

• Evidence of scholarly contributions in isotope geochemistry commensurate with rank

• A commitment to quality teaching at the graduate and undergraduate levels.

Desired Qualifications:

• Research expertise as noted above

• Demonstrated success meeting the educational needs of diverse student populations and/or engaging in scientific outreach to diverse communities.

To apply, submit the following as one pdf file via email to sesenewfac@asu.edu: 1) a cover letter describing the applicant's experience, research, and teaching interests; 2) a current CV; and 3) names, email addresses, and telephone numbers of three references who may be contacted at a later stage of the search. Please indicate Job #11789 in your letter and email.

Initial deadline for receipt of complete applications is December 20, 2016; if not filled, reviews will continue every two weeks thereafter until search is closed. A background check is required for employment.

For more information, see: https://sese.asu.edu/about/opportunities/faculty-positions; https://sms.asu.edu/about/employment-opportunities

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HYDROLOGY

Assistant Professor in Water Quality, Colorado State University

The Department of Ecosystem Science and Sustainability at Colorado State University is seeking an Assistant Professor in Water Quality (full time, tenure-track). We seek applications from candidates who have expertise in water quality laboratory analyses, field sampling techniques, water quality regulations, and the effects of land use and land management on water quality. Teaching expectations include lecture and lab-based undergraduate courses in land use and water quality. This position teaches WR418 and WR419 (Land Use and Water Quality and Water Quality Lab) and contributes to other undergraduate and graduate courses in Watershed Science and Ecosystem Science and Sustainability. This position advises undergraduate and graduate students in the department, conducts research related to water quality and contributes to service and outreach activities.

Required Job Qualifications:

1. A PhD in a related field completed by start date (anticipated to be August 16, 2017).
2. Experience with field and laboratory-based water quality measurements.

Preferred Job Qualifications:

1. Experience in applied land use and water quality research.
2. Expertise in water chemistry.
3. Strong publication record.
4. Demonstrated ability or potential for generating external funding.
5. Commitment to excellence in teaching.
6. Ability to communicate scientific knowledge to practitioners, managers, and policy makers.
7. Experience and interest in working on interdisciplinary teams.

Desired start date of August 2017. Questions? Contact Stephanie.Kampf@colostate.edu. Please visit https://jobs.colostate.edu/postings/40030 for full job details and application instructions. Application closes January 9, 2017.

Multiple Faculty Positions in Water Sciences, Hohai University

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

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

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

Positions:

(1) 2-3 Professors

CHWR seeks 2-3 faculty positions at the rank of full professor in the fields of water resources management, water resource policy, hydrometeorology, urban hydrology or water-food-energy nexus.

(2) 4-5 Associate Professors

CHWR also seeks 4-5 faculty positions at the rank of associate professor in the fields of water resources management, water resources policy, eco-hydrology, urban hydrology, hydrometeorology, water informatics, and other fields of hydrological sciences.

(3) 2-3 Lecturers (Equivalent to Assistant Professors)

The study fields of the early-career faculties can span all above fields.

Primary Duties & Responsibilities

The successful candidates will teach and supervise students at all levels, while conducting independent, externally funded research programs in their fields of expertise. Support for developing an active research agenda is provided through start-up funds and departmental support. CHWR will provide strong supports to the successful candidates to apply for national and provincial research grants and talent programs (e.g. Thousand Talents Plan and Thousand Youth Talents Plan).

Experience & Qualifications
All candidates must hold a Ph.D. in hydrology, water resources, and other related fields.
Senior candidates must be established leaders in their field with developed excellent research programs and demonstrate strong research and teaching experience.
Mid-career candidates should demonstrate strong records of publication and funded research, and participation in collaborations.
Early-career candidates with postdoctoral training are preferred and should demonstrate excellent academic credentials, strong research plan, and good ability to teach effectively.
Application Instructions
Applications should be submitted electronically as a single PDF file, and should include:
A cover letter that addresses your interests, qualifications and experience;
A curriculum vitae;
A statement of research interests;
A statement of teaching philosophy;
A copy of undergraduate and graduate transcripts.
Three letters of recommendation should be sent separately as a PDF by the recommenders. Review of applications will begin upon receipt until the position is filled. Materials should be sent to: kzhang@hhu.edu.cn.

INTERDISCIPLINARY

Faculty Position in Geophysics at the University of Houston

The Department of Earth and Atmospheric Sciences at the University of Houston invites applicants for a tenure-track faculty position in geophysics at the level of Assistant Professor or Associate Professor (untenured). The department is seeking outstanding candidates with the potential for exceptional research, excellence in teaching, and a clear commitment to enhancing the diversity of the faculty, graduate, and undergraduate student population. We seek candidates of outstanding ability in potential fields (gravity, magnetics, electricity, and electromagnetism), including data acquisition, processing, and interpretation, with research interests in near-surface, exploration, environmental, and solid-earth geophysics. Outstanding candidates will be considered from other fields of geophysics that build on department strengths, which include seismology, remote sensing, geodynamics, rock physics, and tectonics. The successful candidate will participate with an enthusiastic team of geoscience faculty and students, in a department with a broad range of geophysical capabilities located in a vibrant city and one of the leading energy capitals of the world.
Information for Applicants
Candidates must have completed their PhD at the time of appointment. Successful candidates will be expected to build a vigorous, externally funded research program and demonstrate productivity via peer-reviewed publications. Candidates will also be expected to teach at both the undergraduate and graduate levels and will mentor MS and PhD students. We expect to fill the position by August 2017. Candidate evaluation will begin on December 1, 2016 and continue until the position is filled.
Candidates for the position should submit: 1) a letter of application including statements of teaching and research interests, 2) a curriculum vitae, 3) graduate student transcripts, and 4) names and contacts of at least three referees. Applications should be submitted electronically, via the university web portal: http://jobs.uh.edu/postings/32813.
Queries may be addressed to:
Dr. Hua-Wei Zhou, Chair,
Department of Earth and Atmospheric Sciences
University of Houston
hzhou@uh.edu
Further information can be obtained by viewing the departmental web page at http://www.eas.uh.edu/ or by calling the department at (713) 743-3399.
The University of Houston is an Equal Opportunity/Affirmative Action Employer. Minorities, women, veterans, and persons with disabilities are encouraged to apply. The University of Houston is responsive to the needs of dual career couples.

Interdisciplinary - The Jonathan O. Davis Scholarship

The Jonathan O. Davis Scholarship supports graduate students working on the Quaternary geology of the Great Basin. The national scholarship is $7,500 and the University of Nevada, Reno stipend is $7,500. The national scholarship is open to graduate students enrolled in an M.S. or Ph.D. program at any university in the United States. The Nevada stipend is open to graduate students enrolled in an M.S. or Ph.D. program at the University of Nevada, Reno. Applications must be post-marked or submitted electronically by February 17, 2017. Details on application and submission requirements can be found at: http://www.dri.edu/GradPrograms/Opportunities/JonathanDavis. Proposals will not be returned.

Transportation Modeling, The University of Alabama

ALABAMA, TUSCALOOSA 35487-0322. The University of Alabama, Department of Geography invites applications for a position in the area of Transportation Modeling, starting August 16, 2017 at the rank of Professor with tenure. This new position will support the expansion of our Department and the initiation of our new Ph.D. program, tentatively scheduled to begin fall 2017. Successful candidates will demonstrate sustained accomplishments including a research program that is widely recognized and externally funded as well as a proven track record of graduate and undergraduate mentoring. It is expected that the candidate hired would significantly enhance the University of Alabama's visibility and impact in transportation research and scholarship. Preference will be given to candidates whose research complements the University's designation as a National Geospatial-Intelligence Agency Center of Academic Excellence in Geospatial Sciences and one or more of the department's broader research foci including: water resources, human-environment systems, environmental management and change, and human impacts on the environment (see geography.ua.edu). A Ph.D. in Geography or closely related discipline is required.
The University of Alabama is rapidly growing (37,665 students) and provides excellent faculty support and many opportunities to collaborate with scientists on the Tuscaloosa campus, including the new Alabama Transportation Institute, Center for Advanced Public Safety, Alabama Center for Insurance Information and Research, and the Center for Advanced Vehicle Technologies. This position is part of a University initiative to enhance its research productivity, and is one of two Full Professor appointments granted to the department of Geography this year. Formal review of applications will begin February 6, 2017 and will continue until the positions are filled. Apply online at https://facultyjobs.ua.edu/postings/39867. Applicants must attach a cover letter, CV (including contact information for at least three references), and two separate statements of research and teaching interests. For additional information, contact Search Committee Co-Chairs, Sagy Cohen (sagy.cohen@ua.edu) or Joe Weber (jweber2@ua.edu).
The University of Alabama is an Equal Employment/Equal Educational Opportunity Institution. All qualified applicants will receive consideration for employment without regard to race, color, religion, national origin, sex, sexual orientation, gender identity, gender expression, age, genetic information, disability, or protected veteran status, and will not be discriminated against because of their protected status. Applicants to and employees of this institution are protected under federal law from discrimination on several bases. Follow the link below to find out more.
"EEO is the Law" http://www1.eeoc.gov/employers/upload/eeoc_self_print_poster.pdf.

SOLID EARTH GEOPHYSICS

Assistant–Associate Professor of Geophysics, The University of Tulsa

The Department of Geosciences at The University of Tulsa invites applications for a tenure-track faculty position in Geophysics at the Assistant or Associate Professor level. Distinguished candidates may be considered at a higher level. A Ph.D. in Geophysics or a related field is required; preference will be given to candidates with specialty in Exploration or Applied Geophysics. The successful candidate will be expected to teach courses at the undergraduate and graduate levels, and establish an externally funded research program involving students. Interdisciplinary, international and industrial collaborative research is encouraged, and is very common between departments in the College. The University of Tulsa is a premier private, doctoral-granting research institution committed to excellence in teaching, creative scholarship, and service. The University offers competitive salary and benefits packages. Minorities and women are encouraged to apply. The Department of Geosciences has strengths in petroleum-related geology and geophysics, tectonics, reservoir characterization and environmental geology. The Department offers a BS and MS in Geoscience and in Geophysics, as well as BA degrees. The Department also offers a PhD in Geosciences. Students in the Department are generally high achieving and eager to participate in research.

The city of Tulsa has a vibrant geological and geophysical community. Tulsa is home to the international headquarters of the American Association of Petroleum Geology, Society of Exploration Geophysics, and the Society for Sedimentary Geology. The Department of Geosciences has an excellent array of geophysical surveying equipment and associated processing/visualization software, including seismic, GPR, well-logs and various electrical and magnetic methods (also see: https://engineering.utulsa.edu/academics/geosciences/facilities/).

Send a letter of application stating research and teaching interests, curriculum vita, and name and contact information for three references to Dr. Peter Michael, Chair, Department of Geosciences, The University of Tulsa, 800 South Tucker Drive, Tulsa, OK 74104-9700. Applications may also be sent electronically to: pjm@utulsa.edu. Application review will begin immediately and continue until the position is filled. The University of Tulsa does not discriminate on the basis of personal status and group characteristics including but not limited to the classes protected under federal and state law. The University of Tulsa is an Equal Opportunity Employer F/M/Disabled/Veteran.

POSTDOCTORAL RESEARCH AND VISITING RESEARCH SCIENTISTS
ATMOSPHERIC AND OCEANIC SCIENCES
PRINCETON UNIVERSITY/GFDL

In collaboration with NOAA's Geophysical Fluid Dynamics Laboratory (GFDL), the Atmospheric and Oceanic Sciences Program at Princeton University solicits applications to its Postdoctoral and Visiting Research Scientist Program.

The AOS Program and GFDL offer a stimulating environment with significant computational and intellectual resources in which to conduct collaborative or independent research. We primarily seek applications from recent Ph.D.s for postdoctoral positions but will accept applications from more experienced researchers. Applications from independent researchers and more senior scientists who may need partial support for sabbatical or short visits may also be considered. Postdoctoral or more senior appointments are initially for one year with the possibility of renewal for a second year based on satisfactory performance and continued funding. A competitive salary is offered commensurate with experience and qualifications.

We seek applications in all areas of the climate sciences. This includes research in basic processes in atmospheric and oceanic dynamics; climate dynamics, variability and prediction; atmospheric physics and chemistry; cloud dynamics and convection; boundary layer processes; land-sea-ice dynamics; continental hydrology and land processes; physical oceanography; ocean-atmosphere interaction; climate diagnostics and analysis. Applicants must have a Ph.D. in a relevant discipline.

Further information about the Program may be obtained from: http://www.princeton.edu/aos/. Applicants are strongly encouraged to contact potential hosts at GFDL and Princeton University prior to application to discuss areas of possible research.

Complete applications, including a CV, copies of recent publications, at least 3 letters of recommendation, and a titled research proposal should be submitted by January 15, 2017 for full consideration. Applicants should apply online to http://jobs.princeton.edu, Requisition #1600924. We encourage applications from women, under-represented minorities, veterans and those with disabilities. These positions are 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 age, race, color, religion, sex, sexual orientation, gender identity, or expression, national origin, disability status, protected veteran status, or any other characteristic protected by law.

Postcards from the Field

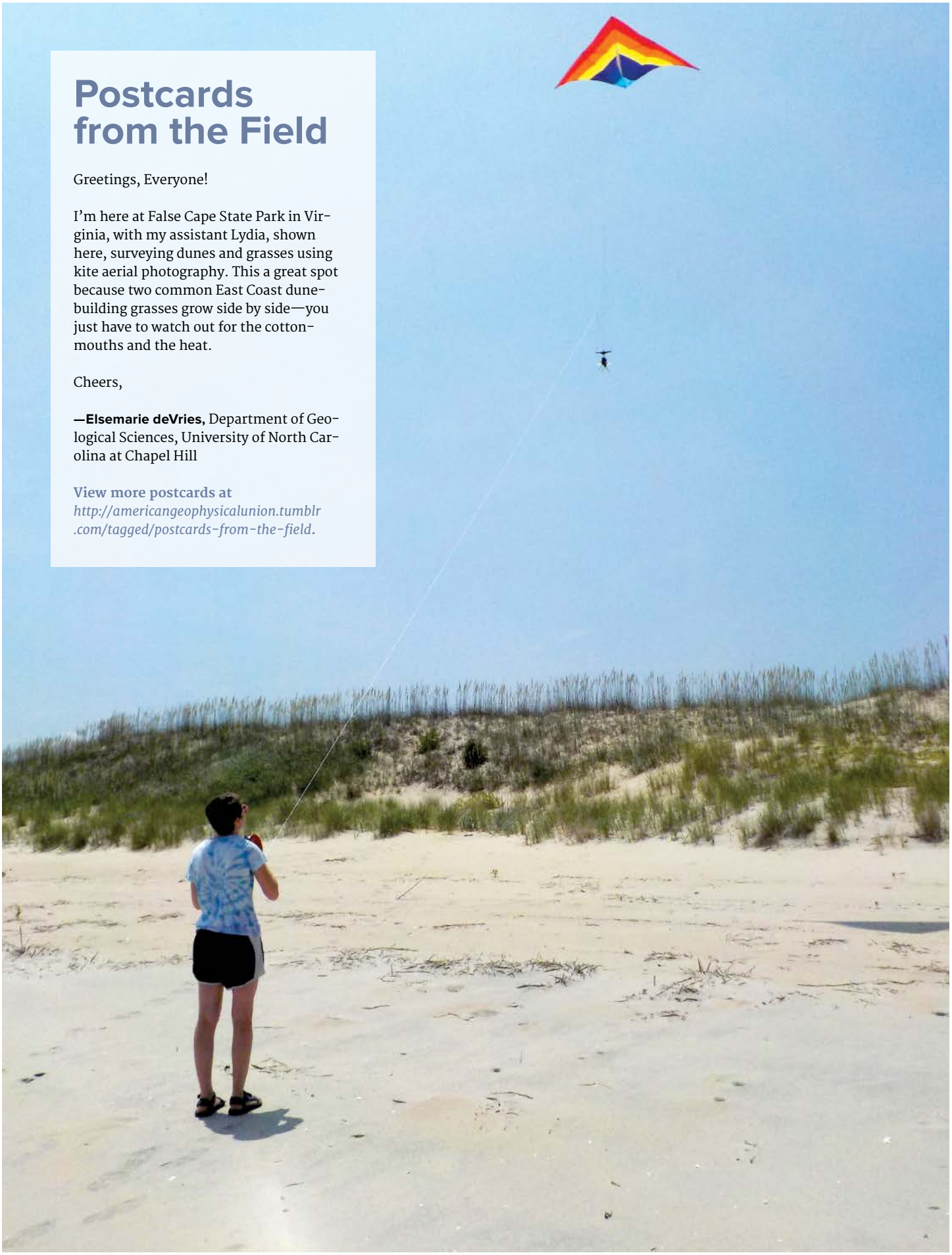
Greetings, Everyone!

I'm here at False Cape State Park in Virginia, with my assistant Lydia, shown here, surveying dunes and grasses using kite aerial photography. This a great spot because two common East Coast dune-building grasses grow side by side—you just have to watch out for the cottonmouths and the heat.

Cheers,

—Elsemarie deVries, Department of Geological Sciences, University of North Carolina at Chapel Hill

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



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