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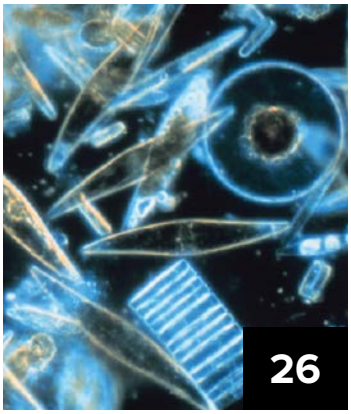

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Christine W. McEntee, Executive Director/CEO

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Dirty Water: Unintended Consequence of Climate Resiliency

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Floodwater full of debris inundates an intersection in Miami Beach, Fla. A pilot study last year found harmful bacteria in floodwater there after that city's climate resiliency system sucked up and pumped the water into an adjoining bay.

The city of Miami Beach, Fla., has made leaps and bounds in climate change resiliency by building an extensive pump system to rid its streets of ocean floodwater, but now the community faces a new problem: floodwaters contaminated by human and animal refuse that could one day be a threat to human health.

"By doing active pumping, they are concentrating some of these contaminants" in the water the city pumps into the local bay, said Maribeth Gidley, a research scientist at the National Oceanic and Atmospheric Administration's Atlantic Oceanographic and Meteorological Laboratory (NOAA AOML) in Miami.

Gidley presented the case study at a poster session on 23 February at the biennial Ocean Sciences meeting in New Orleans, La. (see http://bit.ly/OS-poster).

King Tide Floods, Microbes Tag Along

Historically, a perfect alignment of the Earth, Sun, and Moon—plus the seasonal high tide colloquially named the king tide—was needed to inundate Miami Beach with salty floodwaters. These days, however, the king tide alone brings about flooding multiple times per year, Gidley said.

Miami Beach officials hit this problem head on. In 2014, the city tested its first multimillion-dollar pumping system to reroute floodwater back into canals, where it would flush into Biscayne Bay. The system worked well, leaving streets that would normally be covered in ankle-deep water high and dry. The pumping systems, which are intended to replace old systems that relied on gravity alone to drain floodwaters, suck water up and deposit it into Biscayne Bay at a rate of 14,000 gallons per minute (equivalent to the contents of a large swimming pool each minute). A vortex system rids the water of large refuse and debris, Gidley said, but as of yet there is no system for chemically treating the water or removing potentially harmful microbes, which motivated her to investigate what could be lurking in the recaptured floodwater.

Gidley and her colleagues took samples of the water as it was pumped into local canals, as it was deposited in the bay via storm drains, and from the bay itself. Mostly in pumped waters, the researchers found surprisingly high levels of a type of live bacteria called *enterococci* that indicated the presence of fecal matter, Gidley said, not only from humans but probably also from dogs and birds. In a sample of water as it was pumped into a canal, the researchers found 21,000 colony-forming units (CFU) per 100 milliliters, whereas the acceptable level as determined by the U.S. Environmental Protection Agency is 35 CFU per 100 milliliters.

This level is extraordinarily high, "about one thousand times higher than the level allowed by water quality criteria for recreational water," said Chris Sinigalliano, director of the Molecular and Environmental Microbiology laboratory at NOAA AOML.

These microbes probably aren't all coming from the street, Gidley said. Miami Beach is an old community filled with old infrastructure that includes sewage systems that may be leaking, retired septic tanks, and potentially unidentified sanitary infrastructure from years past. Furthermore, the community sits on a bed of porous limestone, so as the tide rises, it doesn't just overtop canal borders—it soaks up through the soil, picking up bacteria on its way.

Although they didn't test directly for the presence of pathogens, Gidley noted that anytime there is fecal matter, "there is potential for pathogens."

Future Flooding Risks

Gidley and her colleagues' research is just beginning, she pointed out, but this pilot study will be a good reference for the city as it continues to improve its climate change resiliency systems.

Research on sea level rise has found that coastal cities in the United States are particularly vulnerable as anthropogenic climate change alters sea levels around the world (see http://bit.ly/Drown-Map). Other studies have found that flooding from storm surges and heavy rainfall is also getting worse (http://bit.ly/surge-rain), and newly published research shows that sea levels are rising the fastest they have in the past two millennia (see http://bit.ly/faster-rise).

Cities in the U.S. southeast, from Washington, D. C., to Miami, are filled with old infrastructure like that found in Miami Beach, said Sinigalliano, which could eventually contribute to future public health problems.

"One of the things that's hopefully going to come out of this is a more extensive monitoring study to better characterize how representative this is and how frequent and how chronic this [contamination] problem is" among U.S. coastal cities, Sinigalliano said.

By **JoAnna Wendel,** Staff Writer

Forensic Analysis of Landslide Reveals Rocky Secrets

Jeffrey Coe

On 25 May 2014, a huge rock avalanche cascaded down West Salt Creek valley and killed three people.

Early in the morning on 25 May 2014, Melvin "Slug" Hawkins heard a strange hissing noise coming from outside his home in Grand Mesa in western Colorado. Later that day, his son and two other men set out to figure out why water had stopped flowing into an irrigation ditch. By that evening, Hawkins's son and his two companions were dead—victims of a massive rockslide that careened without warning down the nearby West Salt Creek valley.

The West Salt Creek rock avalanche moved 54 million cubic meters of rock over a distance of 4 kilometers in less than 4 minutes. Its size and speed, as well as its tragic aftermath and remaining hazard, piqued the interest of scientists at the U.S. Geological Survey (USGS), who published a paper on 29 February in *Geosphere* detailing their forensic analysis of the deadly flow (see http://bit.ly/Slide-paper).

"There's this ongoing hazard that makes it important to understand what happened in the first event," said Jeffrey Coe, a research geologist at USGS in Denver, Colo., and lead author on the paper.

Cascade of Events

If you had been standing in the creek, Coe said, you would have seen a 40-meter-high wall of rock rushing at you from above.

Many people might imagine a rockslide as a single massive flow of rock and debris, but Coe and his team found that the West Salt Creek rock avalanche collapsed in a series of distinct events. The hissing noise that Slug Hawkins heard came from a smaller precursor debris flow that occurred several hours before the side of the valley came crashing down.

Using drones to build a detailed map of the aftermath, seismic data to study the rockslide's movement, and eyewitness accounts to corroborate the events, the researchers cobbled together a picture of the 3.5-minute slide.

Rain falling on snow was the definite trigger, Coe said. This kind of rock avalanche can be triggered by snowmelt alone, but when it rained, the snow melted faster. Water then mixed with more friable bits of rock and debris, which cascaded down the slope. Seismometers more than 100 kilometers away picked up the early morning debris flow, which the researchers call phase 1. Phase 2 occurred hours later, when a solid mass of rock slid suddenly, activating phase 3, the huge avalanche composed of loose pieces of rock and other debris that cascaded down 600 meters over a distance of about 4 kilometers into the valley below—stopping short of ranches and gas wells.

After this mass settled, eyewitnesses searching for the missing men say that its core along the valley bottom continued to flow. Sure enough, the researchers found mini strike-slip faults within the flow, confirming that its middle kept moving even though the edges stayed stationary. Another debris flow topped off the tumultuous events.

Seismic Analysis

Armed with seismic data from the event, the researchers then determined how fast the rockslide moved—between 15 and 36 meters per second (equivalent to 35–80 miles per hour). To calculate this, they worked backward from seismic data to determine the changes in magnitude and direction of the avalanche's force as it pinballed around kinks and curves in the valley.

The seismic waves tell us "what the landslide was doing, on average, at each moment in time," said Kate Allstadt, a research geophysicist at USGS in Golden, Colo., and a coauthor on the paper.

Coe and his colleagues suspect that the mass moved so fast because the underlying moist ground had liquefied, splitting the avalanche into two distinct layers.

Future of Landslides

The researchers hope that by studying this particular rock avalanche in detail, they can provide useful insights into landslides, which kill between 25 and 50 people each year in the United States. For instance, the precursor flow that occurred early in the morning was picked up by seismometers over 100 kilometers away—Coe wonders if more seismometers and more sensitive seismometers could help scientists tease apart how and if smaller landslides precede larger ones.

Although scientists can characterize landslides using seismic data, "we would not know for sure if a small landslide event was the main event or a precursor to a larger event until the larger event occurred—or didn't occur," Allstadt said.

The hazard at this particular slope isn't over yet—at the top of the creek, a depression formed following the avalanche that at its fullest holds 500,000 cubic meters of water. This "sag pond" could weaken the slope and cause another rock avalanche, or rock from the steep slope above it could fall, generating a small-scale tsunami that pushes water onto the unstable slope below, Coe said.

Even though a natural drainage pipe now helps to drain the pond, "there's this concern about what will happen during the spring snowmelt season," Coe said, so he and his colleagues are keeping an eye on the area for now.

By **JoAnna Wendel,** Staff Writer

Faster-Merging Snow Crystals Speed Greenland Ice Sheet Melting

A recent study has found that the warming of Greenland is speeding changes to the crystalline structure of the fallen snow there in such a way that the snowpack more readily absorbs solar energy. This transformation, in turn, contributes to more warming of Greenland's vast ice sheet, the researchers report, further propelling the transformation to more-heat-absorbent snow.

This vicious cycle is playing a major role in the growing losses of snow and ice from the region, said coauthor Sarah Doherty, an atmospheric scientist at the University of Washington in Seattle. She and her colleagues published their results in *The Cryosphere* on 3 March (see http://bit.ly/Cryo-Dark).

Although snow falls as the spiky ice crystals we call snowflakes, those tiny grains of ice tend to become rounded and merge together to form bigger grains once they've landed. As Greenland's climate warms, merging of grains happens quicker, Doherty explained. Because larger grains don't have as many crystal boundaries or as rough textures, they bounce sunlight back into space less effectively than finer-grained snow would, especially sunlight in invisible, near-infrared wavelengths (700 to 2500 nanometers) that make up half the solar energy Earth receives. Instead, the light gets absorbed as heat, melting the ice.

"You have a self-reinforcing mechanism," said Doherty. "When you have larger snow grains, you end up with a darker snowpack—it is actually absorbing more sunlight, which accelerates melting."

Melting of the Greenland ice sheet could threaten many of the world's major coastal cities because of the sea level rise it would cause globally. The deluge of fresh meltwater entering the sea could also disrupt ocean circulation patterns and harm marine organisms, members of this study's team added.

Black Carbon Decline

Scientists previously thought that much of recent high melting rates on Greenland's ice sheet stemmed from black carbon settling on the snow, blown in from countries farther south. This carbon—aerosolized pollution and soot from wildfires—would also limit snow's ability to reflect sunlight, causing melting. But, in fact, the amount of black carbon in the air—which is monitored by stations throughout the Arctic—has been slowly declining in recent decades after peaking in about 1910, according to a 2007 paper published in *Science* (http://bit.ly/Blk-Carbon).

Declines in black carbon reaching Greenland do not mean that particulates don't play a role, the researchers noted. As the top layer of snow melts, it leaves behind a deposit of tiny particles that were trapped inside it. This dark debris in the snow further reduces the reflectivity of the ice, increases warming, and causes more melting. Every layer that melts adds more particulates to the layer below it, compounding the issue.

Melting snow also exposes more dirt. That dirt can get picked up by the wind and deposited onto the ice, which also makes it melt faster, Doherty said.

As the snow gets dirtier, its reflectivity decreases and it melts faster, which causes a positive feedback loop, said the study's lead author, Marco Tedesco, a glaciologist at Columbia University's Lamont-Doherty Earth Observatory in Palisades, N.Y.

Another cause of reflectivity reduction is the exposure of bare ice once the snow melts. Snow's surface roughness, which scatters incoming light, gives it higher reflectivity than smooth ice.

Satellite Data Reveal Ice Sheet Darkening

Tedesco and his team analyzed satellite measurements of light reflecting off Greenland's surface, gathered from 1981 through 2012 by a NASA sensor called the Moderate Resolution Imaging Spectroradiometer (MODIS) and a National Oceanic and Atmospheric Administration advanced very high resolution radiometer. The researchers found that in Greenland between 1996 and 2012, the summertime reflectivity, or albedo, of the ice sheet surface decreased at the rate of about 2% per decade.

Simulating the variation of the ice sheet's albedo using a regional climate model indicated that increasing temperatures and melting accompanied by snow grain growth and greater bare ice exposure account for about half the decline, the scientists report. The rest of the decrease likely results from light-absorbing impurities in the snow and ice surface, which the model doesn't simulate, they noted.

"This [study] really improves our understanding of how ice melt happens in Greenland and potentially has implications for other glaciers as well," said Alexander Gershenson, a climate scientist at San José State University in San José, Calif., who is not affiliated with the research.

By **Mollie Bloudoff-Indelicato,** Freelance Science, Health, and Environmental Journalist; email: news@mbloudoff.com; Twitter: @mbloudoff

Editor's note: Marco Tedesco, Sarah Doherty, and other coauthors of the work described above urged the scientific community in a recent opinion piece on Eos.org (see http://bit.ly/darken-op) to quantify multiple factors in the darkening of the Greenland ice sheet's surface.

Sarah Doherty

As seen from an aircraft in 2010, a dusting of light-absorbing dirt, pollution, and algae and also a melt pool appear on the ice sheet's surface in a rapidly darkening region of southwest Greenland. New research indicates that larger snow grains resulting from warmer temperatures also contribute to increasing absorption of solar heat by Greenland's ice, accelerating its melting.

McNutt Breaks Barriers as Incoming Science Academy President

Peter Cutts for the National Science Foundation

Marcia McNutt, who was recently elected president of the U.S. National Academy of Sciences, spoke at an event in Washington, D. C., in 2012, when she was director of the U.S. Geological Survey.

Marine geophysicist Marcia McNutt will take office on 1 July as the first woman president of the U.S. National Academy of Sciences (NAS) since the academy's founding in 1863. McNutt's upcoming 6-year term will also break from the academy's normal selection of its president by placing a geoscientist for the second time in a row in a position that, according to McNutt, traditionally alternates between the life sciences and the physical sciences.

McNutt succeeds Ralph Cicerone, an atmospheric scientist, who will step down after nearly two terms heading the academy. Both McNutt and Cicerone previously served as president of AGU. The academy nominated McNutt in July 2015 (see http://bit.ly/McNutt-Nominated) and elected her on 16 February 2016.

In an interview with *Eos*, McNutt called the break from tradition by electing another geoscientist significant as a signal that "we have to confront globally" such issues in the geosciences as climate change, sustainability, energy, raw materials, and natural hazards.

"That's not to downplay the critical nature of other things that are in the news like Zika and Ebola and other pandemics," said McNutt, who is editor in chief of the *Science* family of journals and previously served as director of the U.S. Geological Survey. "As tragic as those are to the afflicted populations, they probably don't bear the same potential for global disruption as do some of the issues that we are facing in water security, in food security, in climate change destabilization."

> "What we don't want to do is give any excuse for politicizing the science."

An Auspicious Time

NAS dates from the Civil War when an act of Congress established the private nonprofit organization to advise the nation on science and technology issues. McNutt called the academy "the only distinguished body of scientists that has the charter to provide advice to governments." She told *Eos* that now is an "auspicious time" to serve as president of NAS. "It's hard to argue that there is any time in history when we could say that science isn't more needed to inform decisions," she explained.

McNutt said that she wants to promote good science and keep politics out of it. "My role is, first of all, to make sure that the academy continues to make it all about the science and not about the politics or not about anyone's interpretation of what one should therefore do with the science," she said. "What we don't want to do is give any excuse for politicizing the science."

In Congress, though, climate science is often a political football. For instance, at an 8 December hearing on climate change, Sen. Ted Cruz (R-Texas), who is running for president, said that some scientists are "global warming alarmists" (see http://bit.ly/Climate-Hearing).

McNutt said the purpose of that and similar hearings is "carefully controlled theater" for members of Congress to go on record for their supporters. She said that no amount of letters or complaints from the academy could do much in those situations. "What we really have to do is start with, I believe, the American public because these members of Congress are responsive to their electorate."

Woman at the Top

As the first woman to lead the academy, McNutt said that she feels a responsibility to be an advocate for women in science. "There are a number of women in the academy, including myself, who do feel an intense responsibility for this," she said. Being an advocate can include helping to elect more women to the academy itself and bringing more women into the science workforce, she said.

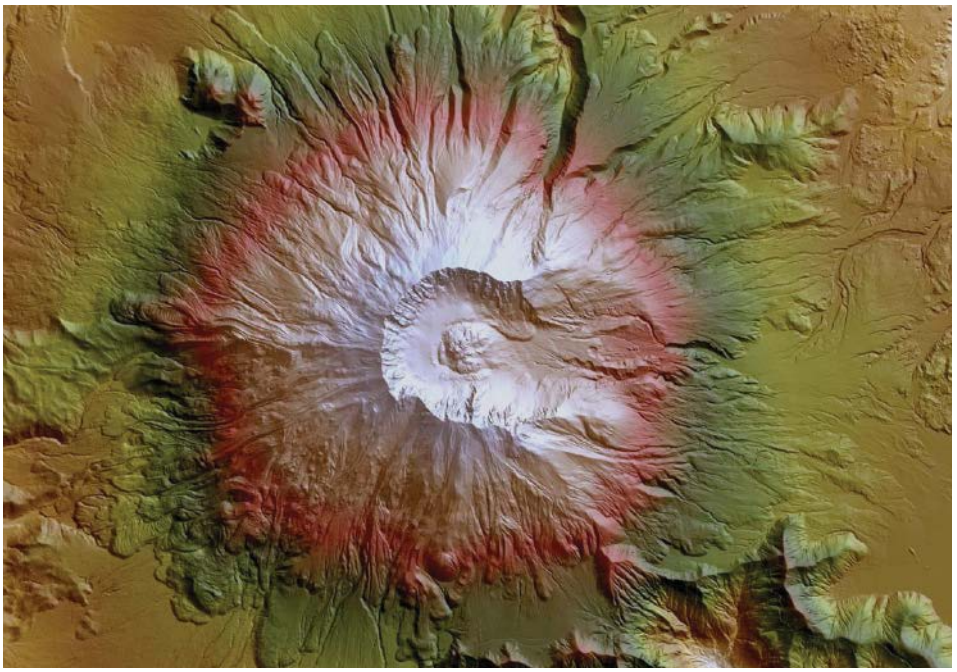
Setting the Tone

McNutt noted that her first priorities include getting to better know the organization and its efforts, including the many reports it issues on a range of topics. "How can we do the best job possible in terms of being responsive to the federal agencies by being cost-effective and timely without sacrificing the quality and the authoritative nature of those reports? That's going to be a very high priority for me," she said.

Another priority McNutt mentioned was setting the tone, saying that she wants to establish a sense of the academy president as "an approachable human who loves to discuss science" and who is "accessible to anyone who has a true interest in wanting to understand science."

By **Randy Showstack,** Staff Writer

USGS Budget Plan to Advance Earth Observations, Hazards Measures



USGS

High-resolution image of Mount St. Helens in Washington, produced from lidar. The 3D Elevation Program initiative, which is managed by the U.S. Geological Survey National Geospatial Program, collects high-quality lidar and interferometric synthetic aperture radar data over the United States to help with a range of societal uses.

In its latest budget proposal, the U.S. Geological Survey (USGS) aims for a significant boost to the nation's satellite Earth-observing capabilities, better protections for communities against the risks of earthquakes and geomagnetic storms, and major improvements to monitoring water use during droughts. These represent a few highlights of a proposed fiscal year (FY) 2017 budget of $1.169 billion (see Table 1) that would grow about 10% over the FY 2016 enacted level if Congress approves the agency's request.

To enhance Earth observation from space, USGS would increase funding for the Landsat 9 Earth-observing satellite to $19.7 million, an increase of $15.4 million, which would help move up the spacecraft's launch date to 2021 from 2023. A follow-on mission to Landsat 8, Landsat 9 will provide a direct but improved replacement for the still-orbiting Landsat 7 satellite, according to USGS.

"We are in lock step in planning with NASA and the Landsat science team to accelerate the launch date and design of the instruments and delivery of those for launch in 2021," said Virginia Burkett, USGS associate director for climate and land use change, at an 11 February briefing about the agency's FY 2017 funding proposal, which was released on 9 February.

Other budgeting related to Earth-viewing satellites includes $2.2 million in new funding to acquire data from the European Space Agency's Sentinel-2 satellites and $2.99 million in new funds to develop computing and online storage resources to produce and disseminate Landsat-based information products.

Increases for Hazards, Water Conservation, Mapping

To prepare for future hazards, the agency intends to maintain funding for an earthquake early warning system at the FY 2016 enacted level of $8.2 million. Also, $16.7 million (up $3.63 million) for unconventional oil and gas research includes funds to reduce the risk from induced seismicity. About $1.7 million in new funding to improve geomagnetic monitoring would support the administration's National Space Weather Strategy and assess the risk of geomagnetic storms to the power grid and electronic systems. Among other priorities, $6.24 million (up $2.11 million) would help with building landscape-level resilience to coastal hazards.

Aiming to better evaluate the effectiveness of water conservation measures, USGS is proposing $37.06 million (up $18.36 million) to spend on improved methods for near-real-time assessments of water use during droughts. "There has been a big push to up our game in understanding water use, monitoring it, and [in] how to estimate what's going on," said Don Cline, USGS associate director for water. He added that all of the pieces of the water initiative in the budget are aimed at strengthening programs focusing on water availability, water use, and water as a hazard.

Other significant funding includes $21.89 million (up $2.39 million) for the enhancement of landscape-scale three-dimensional maps that are used for a variety of applica-

Table 1. U.S. Geological Survey FY 2017 Budget Request[a]

APPROPRIATION CATEGORY	FY 2016 ENACTED[b]	FY 2017 REQUEST[b]	CHANGE[b]	PERCENTAGE CHANGE[c]
Ecosystems	160,232	173,938	13,706	8.6
Climate and Land Use Change	139,975	171,444	31,469	22.5
Energy and Minerals Resources and Environmental Health	94,511	99,483	4,972	5.3
Natural Hazards	139,013	149,701	10,688	7.7
Water Resources	210,687	227,992	17,305	8.2
Core Science Systems	111,550	118,395	6,845	6.1
Science Support	105,611	110,592	4,981	4.7
Facilities	100,421	117,258	16,837	16.8
Total appropriations	1,062,000	1,168,803	106,803	10.0

[a]Source: U.S. Geological Survey (see http://bit.ly/highlights, p. A-4).
[b]Budget authority in thousands of current dollars.
[c]Calculated from data.

tions, including aviation safety, precision agriculture, and managing infrastructure and construction, and $6.72 million (up $1.5 million) to accelerate map modernization for Alaska.

Increases Foreseen Across the Agency

On the whole, the FY 2017 budget proposal would provide funding hikes for all USGS mission areas.

The proposed budget "does a good job in forwarding our mission to protect and enhance the nation's communities, especially in regard to natural resource issues," USGS deputy director William Werkheiser said at the briefing. "We have a wide diversity of science to bring to the table. We're proud of that diversity, and we think this budget allows us to continue in that tradition."

The proposed budget "does a good job in forwarding our mission to protect and enhance the nation's communities."

Officials said they are optimistic about the budget proposal's prospects. Predicting bipartisan appeal for the plan in Congress, Barbara Wainman, USGS associate director for the Office of Communications and Publishing, noted that the agency has "the luxury of being nonpartisan and providing objective science." Among USGS areas typically supported on both sides of the aisle, officials mentioned coastal resilience, magnetic storms, and natural hazards.

However, some areas of the budget proposal could be tougher sells, including getting traction on Capitol Hill for requested increases in science support and infrastructure, said Kevin Gallagher, USGS associate director for core science systems. The FY 2017 plan includes $2.71 million for operations and maintenance, plus new funding of $10.9 million for the agency to continue reducing the footprint of its facilities, including consolidating operations and improving space utilization. "I think it's fair to say [that] at times our need for our facilities budget, our science support, has been underappreciated," said Gallagher.

By **Randy Showstack,** Staff Writer

NOAA's 2017 Budget Would Support Observational Infrastructure

The latest budget proposal for the National Oceanic and Atmospheric Administration (NOAA) calls for a 1.3% increase for fiscal year (FY) 2017 compared to FY 2016 enacted funding for the agency. The proposal includes increases for some NOAA divisions (see Table 1). Among plans that the budget would support, the agency intends to maintain and extend its observational infrastructure and beef up priority programs such as providing information and services to improve resilience of communities to natural hazards and "evolving" the National Weather Service (NWS).

The $5.85 billion budget request provides funding increases for key infrastructure, including $12.25 million for an Integrated Water Prediction initiative that promises to raise from 4000 to 2.7 million the number of locations for measuring and forecasting river and stream properties, such as water flows and levels. The initiative would provide communities with the capability to better manage water resources and prepare for water-related hazards such as floods and droughts, according to NOAA officials. The increased coverage "will be almost like throwing a mesh down over the country," NOAA administrator Kathryn Sullivan said at a 4 March budget briefing, noting that the improved monitoring network would be 700 times denser than the current one.

Preserving Weather Radar and Sensor Networks

Additional funding for the Next Generation Weather Radar (NEXRAD; $25.26 million, up $8.54 million) would prolong by about 15 years the usefulness of this array with which NOAA meteorologists detect and track severe weather. Refurbishing NEXRAD is "the cost-efficient thing to do" for a system that is nearing the end of its life but remains viable and valuable, Sullivan said. So far, there is nothing on hand or on the horizon that could replace it, she said.

The agency is targeting $7.5 million to extend the life of the Automated Surface Observing System (ASOS), a network of ground-based, automated weather sensors at more than 900 airports nationwide serving aviation operations and meteorological, hydrological, and climatological research. The funding for NEXRAD and ASOS will help the agency continue to improve NWS, a process that has included reorganizing the weather service and upgrading its supercomputing capacity, according to NOAA.

Satellite Programs

Although some space-based infrastructure is slated for an increase, the budget trims other programs. Within NOAA's National Environmental Satellite, Data, and Information Service (NESDIS), the budget proposal provides $752.78 million for the Geostationary Operational Environmental Satellite R-Series, down by a planned reduction of $85.11 million. Funding for the Joint Polar Satellite System (JPSS) program would drop to $787.25 million (reduced by $21.72 million), which the agency says would allow for operating and sustaining the Suomi National Polar-orbiting Partnership satellite, launching and commissioning the JPSS-1 satellite, and continuing to develop the

Table 1. National Oceanic and Atmospheric Administration (NOAA) FY 2017 Budget Request[a]

PROGRAM	FY 2016 ENACTED[b]	FY 2017 REQUEST[b]	CHANGE[b,c]	PERCENTAGE CHANGE[c]
National Ocean Service (NOS)	601.85	569.92	(31.93)	–5.3
National Marine Fisheries Service (NMFS)	971.70	1015.93	44.23	4.6
Oceanic and Atmospheric Research (OAR)	481.98	519.79	37.81	7.8
National Weather Service (NWS)	1124.15	1119.29	(4.86)	–0.43
National Environmental Satellite, Data, and Information Service (NESDIS)	2349.36	2303.69	(45.67)	–1.9
Mission support	253.93	286.07	32.14	12.7
Office of Marine and Aviation Operations	334.19	289.30	(44.89)	–13.4
Total NOAA discretionary appropriations	5773.52	5850.59	77.07	1.3

[a]Source: National Oceanic and Atmospheric Administration (see http://bit.ly/noaa-doc).
[b]Budget authority in millions of current dollars.
[c]Calculated from data.

Ross Burgener, ET, NOAA/OAR/ESRL/GMD

Researchers launch an ozonesonde in 2013. These balloon-borne instruments provide information on ozone and meteorological quantities such as pressure, temperature, and humidity.

JPSS-2 spacecraft and its instruments. The budget would increase funding for the Polar Follow On satellite mission to $393 million (up $23 million).

"We have to continue investing in sustaining a robust array of observations because there is no such thing as viable and useful environmental intelligence unless you are keeping your fingers on the pulse of the planet in a very rich and robust way," Sullivan said.

Other Budget Highlights

The budget proposal also allocates funds to a major agency priority of replacing its aging fleet of regional-class and ocean-class vessels. With $24 million in the FY 2017 budget and $80.05 million available from 2016, NOAA plans to construct a regional survey vessel (RSV) as part of that process. RSVs can operate in shallow coastal waters and help with hydrography, fisheries sampling, and ocean sensing and monitoring.

The proposed NOAA budget also calls for $100 million to construct a second RSV. However, that money would come from so-called mandatory funding, unlike the "discretionary" money that makes up the bulk of funding for government agencies. This mandatory funding, which comprises an unusually large portion of some proposed science agency funding for FY 2017, requires additional congressional approval that's unlikely to come through in the current partisan political climate, budget analysts have said. The Obama administration's FY 2017 budget requests unveiled in February for NASA and the National Science Foundation include mandatory funding of $763 million and $400 million, respectively.

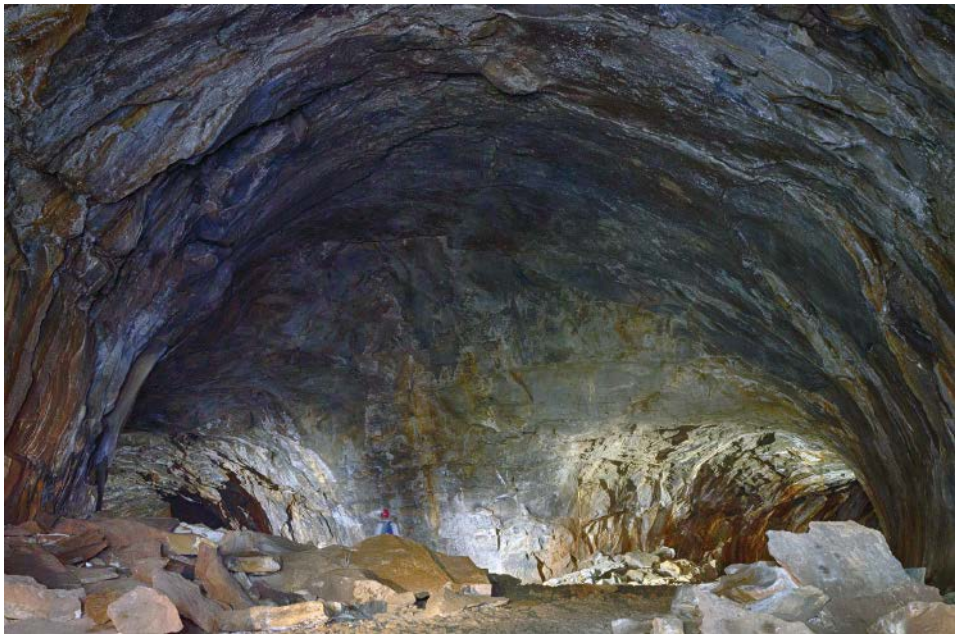
Under NOAA's plan, the Office of Oceanic and Atmospheric Research (OAR), which integrates research across NOAA, receives $493.41 million in the operations, research, and facilities (ORF) part of its funding, a net increase of $24.46 million. Within the ORF budget, the agency allocates $189.87 million for climate research (up $30.76 million). The budget provides $22.14 million for innovative research and technology (up $10 million) to create a new Research Transition Acceleration program to identify and fund the transition of promising research into operation, applications, and commercialization, according to NOAA budget documents. NOAA also plans some trimming of its OAR programs, for instance, to weather and air chemistry and to ocean, coastal, and Great Lakes research.

As part of the overall budget for the National Ocean Service (NOS), $528.4 million would support its ORF category, a net increase of $23.2 million. Slated for ocean and coastal management and services is $243.4 million, which includes an additional $4 million to respond to extreme events and an additional $5 million for ecosystem-based solutions for coastal resilience to extreme weather, climate hazards, and other threats. However, NOS funding for navigation, observations, and positioning would dip to $197.9 million. The $10 million decrease from FY 2016 includes a $2 million cut to discontinue single-year cooperative agreements with academic institutions for joint ocean and coastal mapping centers, a $6 million reduction to end the Regional Geospatial Modeling Grant program, and a $2 million decrease to reduce acquisition of hydrographic data from contract surveys.

By **Randy Showstack,** Staff Writer

Planetary Caves' Role in Astronaut Bases and the Search for Life

2nd International Planetary Caves Conference
Flagstaff, Arizona, 20–23 October 2015



Thomas Prettyman

During the conference, attendees explored a 1.6-kilometer-long lava tube cave, northwest of Flagstaff, Ariz. This cave, which is more than 700,000 years old, provided an ideal setting for discussions on formation processes, robotics requirements, and astrobiological potential within Martian caves.

Planetary caves are practically everywhere. Scientists have identified more than 200 lunar and more than 2000 Martian cave-related features. They've also found vents and fissures associated with water ice plumes on Saturnian, Jovian, and Neptunian moons. Recently, primary vents of two possible cryovolcanoes were identified on Pluto.

Caves on other planetary bodies and vents associated with plumes on icy moons offer high-priority targets for future habitability studies and robotic and human missions. Martian and lunar caves are ready-made sheltered environments for astronaut habitation or storage facilities. Additionally, Martian caves provide access to the subsurface without the need for Mars landers to bring a costly drilling payload. Such access facilitates the search for evidence of life and could reveal significant water ice deposits for human consumption and fuel.

To advance our understanding of planetary caves, an interdisciplinary group of about 40 researchers convened at the Lowell Observatory (see http://bit.ly/PlanetCaves2). Attendees discussed current research and pathways for future human and robotic missions to planetary caves. Scientists and engineers had the opportunity to discuss how to expand robotic planetary cave exploration capabilities. A local educational outreach component included a primary school "space caves" art contest and a presentation from the Coconino High School robotics team.

In addition to processes associated with volcanism and tidal forces, we discussed the potential for dissolution caves. On Titan, scientists used radar imaging to identify regions on the landscape indicative of dissolution. The study of how caves form on other planetary bodies will likely become an active area of research as higher-resolution imagery becomes available.

We also discussed new techniques for detecting planetary caves. For reliable remote cave detection, an approach that combines data from gravimetry, visible imaging, and thermal-infrared spectra shows considerable promise. Modeling cave entrance structure and genesis requires multiple images acquired from various viewing geometries and spectral wavelengths. Presently, researchers are limited by slightly off-nadir imaging and a limited ability to obtain multiple thermal and visible spectrum images of a given feature. For example, determining if a Martian pit crater wall is simply an overhanging rim or a possible cave entrance requires sideways-looking imagery with appropriate solar illumination.

Engineers reported on advances in cave explorer robotic technologies and prototype development. Any successful planetary cave robotic mission should include three-dimensional computer vision analysis of the entrance passageway and associated surface area to determine the cave access route, a data link from a rover deep within a cave to a surface rover or relay station, and a power supply for long-duration underground operations.

Astrobiologists discussed robotic payload requirements for detecting evidence of life in caves and techniques for detecting biosignatures, as well as Earth-analogue biosignatures of rock-consuming microorganisms. We suggested that such a payload should include mass spectroscopy, laser-induced breakdown spectroscopy, energy dispersive spectroscopy, and a visible spectrum camera. Cellular automation algorithms of visible spectrum imagery of the cave interior could assist in recognizing potential biosignatures.

NASA and private space companies have made recent statements concerning sending humans to Mars sometime in the 2030s. However, reaching technical readiness levels sufficient to support a crewed mission to Mars will require considerable work and substantial funding. The participants of this conference have helped elevate the importance of caves in this effort and will likely influence the direction we will take toward making robotic exploration and human habitation of planetary caves a reality.

By **J. Judson Wynne,** Carl Sagan Center, SETI Institute, Mountain View, Calif., and Department of Biological Sciences, Northern Arizona University, Flagstaff; email: jut.wynne@nau.edu; **Timothy Titus,** Astrogeology Science Center, U.S. Geological Survey, Flagstaff, Ariz.; and **Penelope J. Boston,** Cave and Karst Studies Program, Department of Earth and Environmental Sciences, New Mexico Institute of Mining and Technology, Socorro

Assessing Impacts of Climate Change on Food Security Worldwide

AgMIP Workshop on Coordinated Global and Regional Integrated Assessments of Climate Change and Food Security
Aspen, Colorado, 13–18 September 2015

The combination of a warming Earth and an increasing population will likely strain the world's food systems in the coming decades. Experts involved with the Agricultural Model Intercomparison and Improvement Project (AgMIP) focus on quantifying the changes through time. AgMIP, a program begun in 2010, involves about 800 climate scientists, economists, nutritionists, information technology specialists, and crop and livestock experts.

In mid-September 2015, the Aspen Global Change Institute convened an AgMIP workshop (see http://bit.ly/AgMIPwkshp) to draft plans and protocols for assessing global- and regional-scale modeling of crops, livestock, economics, and nutrition across major agricultural regions worldwide. The goal of this Coordinated Global and Regional Integrated Assessments (CGRA) project is to characterize climate effects on large- and small-scale farming systems (see http://bit.ly/AgMIPCGRA).

Three outcomes stemmed from discussions among workshop participants. First, workshop attendees agreed that global agricultural models should be used to address extreme events and shocks, such as how to respond to simultaneous severe droughts and floods occurring across multiple breadbasket regions, as well as other shocks, such as economic crises and conflicts. Second, participants agreed to expand the scope of AgMIP to include near-term forecasts, ranging from within-season and interannual timescales to decadal timescales. Finally, participants agreed that nutrition metrics for agricultural production must go beyond calories to include dietary intake and nutrients. These conclusions will inform the CGRA simulations on adaptation, mitigation, food security, and food policy.

Because CGRA will be based on simulation protocols agreed on by the participating scientists, it represents a quantum step forward in producing consistent multimodel, multidiscipline, and multiscale assessments of agricultural and food security impacts, including robust characterizations of uncertainty and risk. Simulations will be rooted in historical observations and climate projections from the two recent versions of the Coupled Model Intercomparison Project (CMIP5 and CMIP6) and will be driven by scenarios that link to the Representative Concentration Pathways (RCPs) and Shared Socioeconomic Pathways (SSPs) used in the Intergovernmental Panel on Climate Change's assessment reports. Participants discussed how CGRA will be coordinated through the development of detailed new Representative Agricultural Pathways (RAPs)—a logically consistent set of drivers and outcomes—at both global and regional scales.

CGRA results will have direct implications for international climate policy, national adaptation and mitigation planning, and development aid. Meeting participants affirmed that CGRA outputs will be available to inform and improve integrated assessment modeling, nitrogen and carbon cycle simulations, and projections of impacts on land use, water resources, ecosystems, and urban food supply.

Draft protocols for CGRA will be developed and posted on the AgMIP website (http://www.agmip.org) for public comment by the agricultural modeling community. The next CGRA workshop will take place at the 6th AgMIP Global Workshop in Montpellier, France, in June 2016 (see http://bit.ly/AgMIPwkshp6).

Shari Lifson

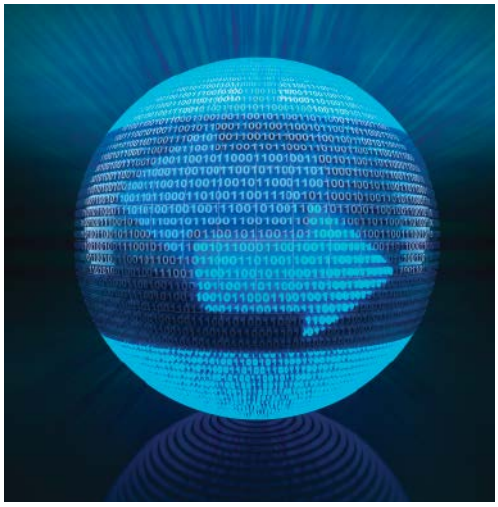
A workshop gathered experts committed to forging links between global and regional assessments of agriculture and the people impacted by food insecurity.

By **Cynthia Rosenzweig,** NASA Goddard Institute for Space Studies, New York, N.Y.; email: cynthia.rosenzweig@nasa.gov; **John Antle,** Oregon State University, Corvallis; and **Joshua Elliott,** University of Chicago, Chicago, Ill.

Embracing Open Data in Field-Driven Sciences

Climate change and the other complex issues facing our planet require the application of vast amounts of data, information, and knowledge to be fully understood. No single scientist or organization has all of the data, tools, or capabilities to do this work; only by bringing diverse research communities together around shared data and information will these problems be addressed.

However, ecology, geology, and the other sciences that depend on field observations pose special challenges for data and sample sharing. These disciplines often rely on time-sensitive, perishable data and samples that are temporally and spatially unique: the observations of an ash plume evolving, for example, or the samples amassed during a research cruise to assess the impacts of an oil spill.



iStock.com/ymgerman

These challenges have caused field-driven sciences to be slow in making data accessible and reproducible. To keep research on the leading edge of discovery, data and sample sharing in the field sciences must evolve to become common practice.

The Value of Open Field Data

A recent policy forum article published in *Science* (see http://bit.ly/ScienceOpenData) argues that open access to data and samples is fundamental for verifiable progress in the field sciences. According to the article, making data and samples freely available fosters transparency, enhances the value of data by opening it up to further analysis, and fosters integrity in research results and public trust in science.

A world with publicly available data and samples is one where scientists can achieve greater impact through collaboration while expanding global research. Take, for example, the Past Global Changes (PAGES) project. The data generated by PAGES-coordinated research projects are available in publicly accessible databases, including those of the National Centers of Environmental Information (formerly the National Geophysical Data Center), which is operated by the National Oceanic and Atmospheric Administration (NOAA).

Through PAGES, members of the international paleoclimate community assembled existing climate records, such as tree rings, fossil pollen, and other proxy data, of the past 2000 years. These data will also be open access, allowing others to use them to improve projections of future climate and help society prepare for climate-related hazards. Efforts like PAGES further scientific inquiry by enabling disparate research endeavors to examine deep pools of data already in existence.

Sharing data and samples also contributes to the health of humans and society. This was readily demonstrated years ago when NOAA released weather data to the public. Other groups used these data to generate more accurate forecasts, which lowered the costs of weather-related damage (see http://bit.ly/NOAAWeatherData). In addition, a billion-dollar weather industry that relies on NOAA's real-time data emerged; both Weather.com and Weather Underground are built on open government raw weather and climate data.

To further critical research efforts and expand the use of its reams of climate, weather, and environmental data resources, NOAA launched the Big Data Project in 2015. The initiative aims to more effectively and efficiently distribute these data to scientists, decision makers, and industries and enable the development of new products and services that will further understanding of our planet. In short, releasing data benefits everyone.

Open data can also be an important tool for education and outreach. The *Science* article mentions the National Science Foundation's Ocean Observatories Initiative, whose unifying cyberinfrastructure acquires, processes, and distributes data from more than 700 oceanographic instruments, not only to researchers but also to educators and the public. Anyone can plot or download the data. Such publicly available resources can encourage citizen science and public involvement in science.

Overcoming Data Hoarding

As the authors of the *Science* article acknowledge, sharing field sciences data and samples can be time-consuming and resource intensive. The cultural, financial, and technical barriers to making data open and research reproducible are, indeed, numerous.

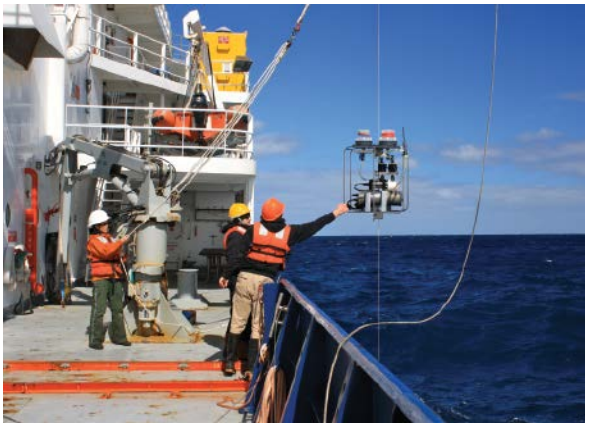
The cultural, financial, and technical barriers to making data open and research reproducible are numerous.

Scientists may guard their data, fearing that sharing their data might allow another research group to scoop them and publish results first. Productivity in science is traditionally measured by the number of papers a researcher publishes in traditional journals with high impact factors. Massive amounts of time, money, and energy are behind scientific data—these published papers represent a return on this investment.

The *Science* article maintains that bottom-up approaches are more likely to effect change than top-down mandates. Research institutions, funding agencies, and other stakeholders need to develop new ways to change research incentives to recognize the value of data sharing to science. In the current culture, those who create data sets and software or share their data often receive little acknowledgment for doing so. Data journals with citable output are one means of recognizing the contributions of data wranglers and the value of open data to science.

Other approaches could involve giving researchers who put data online an edge, with unique funding opportunities or insti-

tutional awards. Ultimately, new approaches will stand a better chance of success if they take into account the traditional culture of scientific research, where data are often seen as proprietary and long-term preservation of data is a low priority.



Rebecca Fowler

Increasing access to field sciences data and samples, such as those collected during a 2012 research cruise to explore the biological, chemical, and physical properties of a Southern Ocean phytoplankton bloom, will move science forward by facilitating reproducibility of results and reuse of data.

Digitizing and Archiving Data

Digitizing and integrating data are another challenge for the field sciences community. Data management and storage were not always factored into research projects—not to mention that much of the field sciences involves observations that are not repeatable—thus valuable historical records are often missing from repositories.

Despite the resources required to formally archive and make the vast amount of data in existence accessible, it is still more cost-effective to preserve these data than it is to try to fill gaps in records through new studies. To make this process easier, data repositories could help researchers properly cite, share, and secure their data by providing training and technical support.

The Challenge

Making data accessible and reproducible calls for a massive cultural shift in science, one that requires changes in funding strategies, community values, and how science is done. For this shift to happen, everyone must be invested in it—funding agencies, researchers, data repositories, and journals.

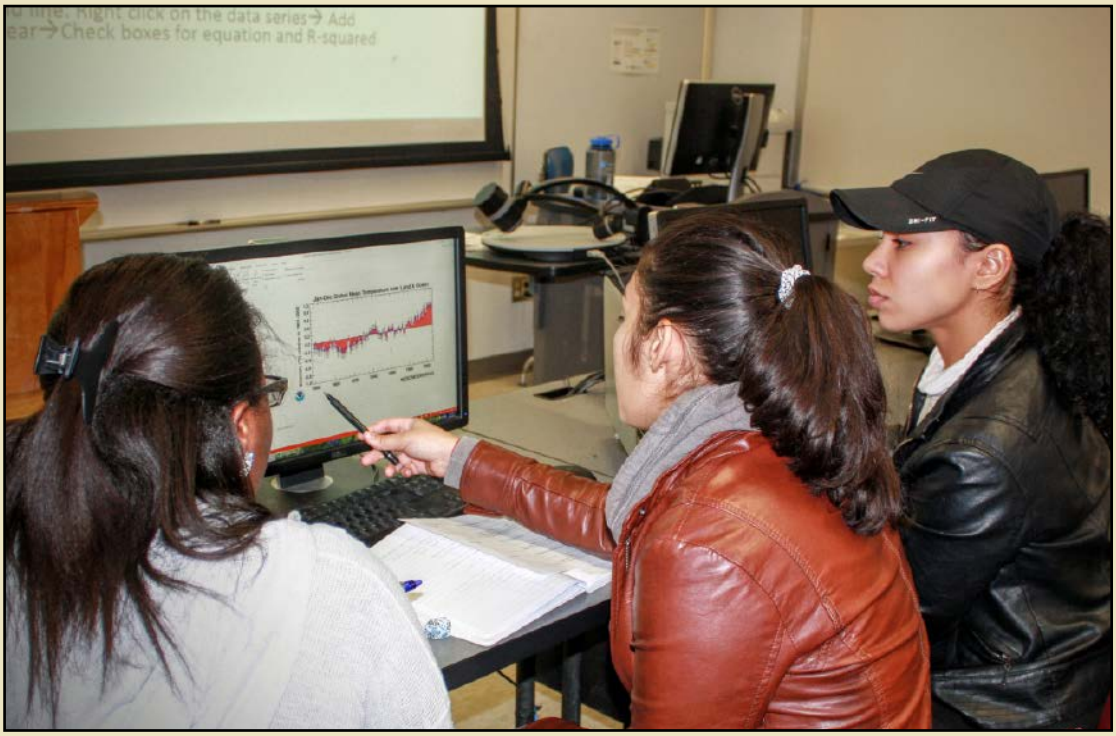
We need new initiatives and approaches to facilitate data deposition and recognize the creators of data sets and software. Critically, we need these new initiatives funded. The barriers to opening field sciences data are large, but those involved with the field-based sciences are adept at solving difficult problems through creativity, collaboration, and development of new technologies.

Embracing open science improves discovery, access, integration, use, and value of field sciences data and samples. There may always be data hoarders and those who value opacity over transparency, but the acceptance of open data comes at a price only to those who do not want to confront the changing nature of science.

By **Rebecca Fowler,** Federation of Earth Science Information Partners, Boulder, Colo.; email: rebeccafowler@esipfed.org

STUDENTS, MEET DATA

By Nicholas E. Bader, Dax Soule, Devin Castendyk, Thomas Meixner, Catherine O'Reilly, and Rebekka Darner Gougis



Jannett Dinsmore

Undergraduate students at the State University of New York at New Paltz work with long-term temperature data in the Project Environmental Data-Driven Inquiry and Exploration (EDDIE) Climate Change module.

Lessons that incorporate publicly available data from Earth-observing sensors can expose students to the thrill of scientific discovery.

It is almost too obvious to state: Proficiency requires practice. As educators, if we want our students to excel at a task, we must design experiences that allow them to practice. If we want our students to learn to "do science," then they should practice asking and answering real scientific questions, using real data.

Our team developed Project Environmental Data-Driven Inquiry and Exploration (Project EDDIE; see http://www.projecteddie.org) to provide college educators with adaptable, modular, and pedagogically sound activities that get students working with large data sets. Project EDDIE focuses on sensor-based data sets—those collected by instruments that sense environmental variables such as

streamflow and soil respiration—because students and educators can tap into publicly available data sets without needing to conduct their own lengthy observation campaigns.

The Project EDDIE team includes scientists in the Earth, environmental, and biological sciences, working together with science education specialists. Together, we have created 10 groups of classroom activities, leveraging different data sources that engage students in the process of answering scientific questions with data.

Why Sensor-Based Data Sets?

Educators face significant challenges if they wish to assign data-driven exercises to students. Gathering real data requires a large investment of time and resources—for example, training students in the technical skills needed to gather unbiased data. Although these technical skills are valuable, their cost–benefit calculation may not be favorable for an educator faced with a large introductory class or a limited budget for research-grade equipment. Moreover, it can be easy for students to get bogged down in the methodological details of data collection and lose sight of the big scientific questions that drive data collection in the first place.

In the past few decades, the Internet has provided anyone interested with a wealth of new data from a variety of environmental sensors, such as the real-time streamflow data available from the U.S. Geological Survey (USGS). In fact, the availability of data may be expanding more rapidly than the preparation of a workforce able to use this technology [*Benson et al.*, 2010]. These continuous, sensor-based records provide an unprecedented opportunity for students to ask real scientific questions and to answer those questions with real data.

Educators have begun to use these data sets in undergraduate classrooms to teach both fundamental and cutting-edge concepts in geology, ecology, and environmental sciences. Because the analysis of these data sets requires only a computer and basic software, students enrolled in online or distance-learning courses could, in theory, be able to engage with the data too.

Big Data, Big Challenges

Even though data sets may be publicly available, they can be challenging to use in the classroom. Simply learning to manipulate data can be challenging for students who may have minimal prior experience with spreadsheets or databases. Furthermore, *Ledley et al.* [2008] note that online data sets are typically compiled by scientists for other scientists; nonspecialists may have difficulty working with the data or even finding it.

However, simplifying the data is not necessarily a good approach for instructors because providing prepackaged, simulated data sets to students can sacrifice some of the excitement of working with real data and fails to teach the skills students need to find and process data. Moreover, the "messiness" of working with real data brings crucial statistical concepts of variability and randomness to the forefront, as it does in real scientific studies.

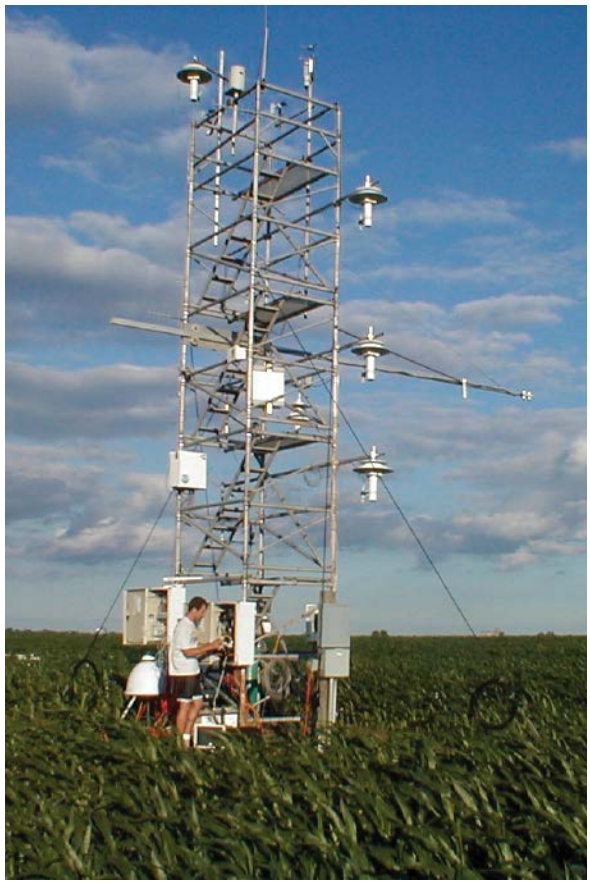
What educators need, then, is a flexible approach for getting students working with data as quickly as possible, in a way that minimizes student frustration while still

NOAA

U.S. Climate Reference Network weather station, Capitol Reef National Park, Utah.

U.S. Geological Survey stream gauge near Augusta, Maine.

Nick Stasulis/USGS



ORNL/FLUXNET

AmeriFlux gas flux sensor near Bondville, Ill.

exposing them to the real-world challenges of manipulating sensor-based data sets. As *Langen et al.* [2014] suggest, effective activities should be carefully scaffolded to introduce new challenges one at a time to keep students from becoming too frustrated.

However, activities should not be "cookbook" exercises that can be followed step by step. Instead, useful activities promote student-centered learning coupled with scientific discourse, making student tasks closely resemble the work of scientists. Of course, developing such activities requires significant investments of time and energy, which may deter educators from making the attempt.

Project EDDIE's Strategy

Project EDDIE emerged from conversations among early-career faculty at meetings of the Global Lake Ecological Observatory Network (GLEON); the group later expanded to include additional hydrologists and biogeochemists. Participants wanted to develop effective classroom activities using authentic, large data sets that are freely available online. These activities would be grouped into independent self-contained "modules" that could be used in a classroom with minimal prior student knowledge.

During summer meetings in 2014 and 2015, team members developed 10 different modules, each containing several classroom activities (Table 1). Although each module uses different sensor-based and long-term data sets to address different research questions, all of the modules are designed with four goals for student learning outcomes:

- Students should be able to manipulate large data sets at different scales in order to conduct inquiry-based investigations.
- Students should improve their ability to reason about statistical variation.
- Students should engage in authentic and productive scientific discourse.
- Students should gain insight into the nature of scientific inquiry in the natural sciences.

To support active learning, the modules use the 5Es learning cycle (engagement, exploration, explanation, extension, and evaluation), which has been shown by *Bybee et al.* [2006] to increase student interest in science, as well as to increase student mastery of sophisticated aspects of scientific reasoning.

Useful activities promote student-centered learning coupled with scientific discourse, making student tasks closely resemble the work of scientists.

Supporting Different Levels of Learning

Project EDDIE modules are divided into individual activities so that they can be used in a range of potential teaching environments and completed by students at different levels. Single activities can be assigned during a lecture period in an introductory course, whereas a series of activities may require a full laboratory session in an upper level course. In the Stream Discharge module, for example, students might begin by examining discharge patterns in natural streams, using data in the USGS's Hydrologic Benchmark Network. Because students have access to discharge measurements spanning many decades, they can look for patterns on daily, monthly, and annual time scales. Students must then grapple with the difficult task of identifying changes in discharge, through time or across sites, against this background of natural variability. This part of the activity might be sufficient for an hour-long class.

Alternatively, students in a 3-hour lab period might complete the first activity and move on to work on peak discharge and flood frequency. More advanced students might skip the first part entirely and go straight to an analysis of urbanization and flood frequency.

The Project EDDIE team has developed and tested modules using a variety of other sensor-based or long-term data sets. For instance, students working on the Climate Change module use the Mauna Loa carbon dioxide record and the Vostok ice core record to address questions about

Table 1. Current Project EDDIE Modules and Some of the Data Sets

MODULE	DATA SET(S)[a]	STATUS
Lake Ice-off Phenology	NSIDC Global Lake and River Ice Phenology Database	Complete
Lake Metabolism	Respiration calculated from GLEON lake data	Complete
Lake Mixing	Buoy thermistor data from GLEON	Complete
Lake Modeling	GLEON	In testing 2016
Stream Discharge	USGS Hydrologic Benchmark Network; USGS Real-Time Water Data	Complete
Water Quality	USGS Water Quality Watch Data	Finished testing
Nutrient Loading	USGS Water Quality Watch Data	Finished testing
Climate Change	NASA GISS; NOAA ESRL; NOAA NCDC	Finished testing
Soil Respiration	ORNL Carbon Dioxide Information Analysis Center; AmeriFlux	In testing 2016
Seismology	IRIS	In testing 2016

[a]ESRL, Earth System Research Laboratory; GISS, Goddard Institute for Space Studies; GLEON, Global Lake Ecological Observatory Network; IRIS, Incorporated Research Institutions for Seismology; NCDC, National Climatic Data Center; NOAA, National Oceanic and Atmospheric Administration; NSIDC, National Snow and Ice Data Center; ORNL, Oak Ridge National Laboratory; USGS, U.S. Geological Survey.

rates of change. The Soil Respiration module points students to ecosystem carbon dioxide flux data available from the University of Michigan Biological Station's Ameriflux site and the Oak Ridge National Laboratory Carbon Dioxide Information Analysis Center. The Seismology module gives students practice with data from the Incorporated Research Institutions for Seismology. Several limnology modules use lake data available from the Global Lake Ecological Observatory Network and other sources (Table 1).

Does Project EDDIE Work?

Assessment of student learning is a critical component of Project EDDIE's strategy. Careful assessment tells us whether our students are learning the skills necessary to manage and interpret large data sets. Beginning during the 2014–2015 academic year, participating students at eight different U.S. colleges completed premodule and postmodule surveys to measure how their understanding of concepts such as data variability, random processes, and data interpretation changed after working on a Project EDDIE module.

Although assessment is not yet complete, preliminary results indicate that students felt more comfortable dealing with large data sets on a computer and more competent at manipulating data in spreadsheets after completing a module. In addition, students were more likely to use large sensor-based data sets to solve a scientific problem after engaging in a module, and their intuitive understanding of natural variation improved. A pilot study reported by *Carey et al.* [2015] indicates that working on modules improved students' quantitative literacy and enabled them to grapple with difficult concepts such as data visualization and how resolution affects our ability to detect environmental changes.

Project team members continue to test and finalize existing modules and develop new ones. We are now beginning to focus on making Project EDDIE modules publicly available by posting modules in an online repository linked to the National Association of Geoscience Teachers' Science Education Resource Center at Carleton College (see http://serc.carleton.edu). We hope that access to these activities will help to overcome the "activation energy" of introducing students to sensor-based data.

Acknowledgments

Project EDDIE was made possible by a Transforming Undergraduate Education in Science (TUES) grant from the National Science Foundation (NSF DEB 1245707). Other members of the EDDIE team developed some of the modules discussed in this article, including Cayelan Carey (Virginia Polytechnic Institute and State University), Randy Fuller (Colgate University), Cathy Gibson (Waterworks Analytics), Jennifer Klug (Fairfield University), Lucas Nave (University of Michigan Biological Station), David Richardson (State University of New York at New Paltz), and Janet Stomberg (Illinois State University). Project EDDIE is a sponsored program of the National Association of Geoscience Teachers and is supported by the Center for Mathematics, Sciences, and Technology at Illinois State University.

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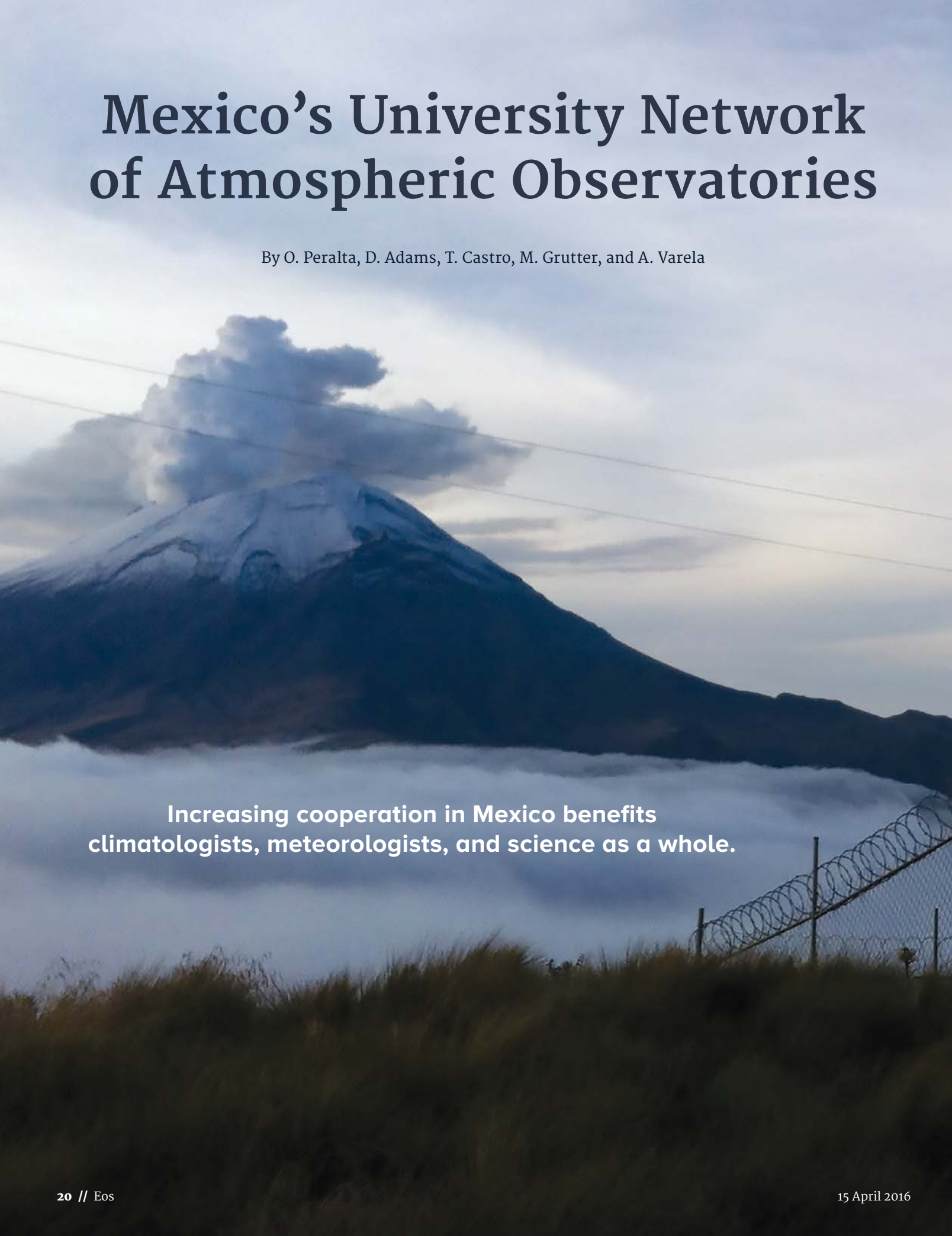
Mexico's University Network of Atmospheric Observatories

By O. Peralta, D. Adams, T. Castro, M. Grutter, and A. Varela



Increasing cooperation in Mexico benefits climatologists, meteorologists, and science as a whole.

Three Red Universitaria de Observatorios Atmosféricos (RUOA) observatories operate in unique natural protected zones in Mexico, including this one, located 4 kilometers above sea level on the volcanic peak Altzomoni, near Popocatépetl (in the background) in the State of Mexico.

Red Universitaria de Observatorios Atmosféricos

Mexico is one of the most diverse countries in the world in terms of its climate and meteorology. With its great latitudinal range and diverse topography, climates range from Mediterranean in Baja California in the northwest to the tropical rain forest of Chiapas in the southeast. The scorching aridity of the Sonoran Desert contrasts with the frigid glacial barrens of the volcanic peaks of Popocatépetl (5400 meters elevation) and the Pico de Orizaba (5700 meters) as well as the thousands of kilometers of tropical beaches.

Diversity is not the only defining characteristic of Mexico's weather and climate. Hurricanes batter both coasts, and tornadoes can even wreak havoc in the northeast. Anthropogenic influences are also striking: Mexico City's air quality problems are typical of one of Earth's most populous urban clusters. Desertification and conflicts over water usage threaten many of the arid regions in the north. Surprisingly, Mexican academic programs and scientific investigation in the atmospheric sciences are not commensurate with this diversity of atmospheric phenomena available for study.

Observational networks—meteorological, hydrological, and maritime—do exist; however, they are used primarily for weather and hydrological forecasting and/or hazard warnings. For instance, the Servicio Meteorológico Nacional (Mexican Weather Service) has numerous automatic weather stations, radars, and atmospheric soundings principally for weather prediction. Research-based observational networks for the atmospheric sciences, however, have been lacking. Fortunately, in recent years, this has begun to change.

A New Network

To motivate the expansion of long-term research on climatology, meteorology, air chemistry, and air quality, as well as

Red Universitaria de Observatorios Atmosféricos

The University Network of Atmospheric Observatories, including this one at the Mexico City campus, is a project of the National Autonomous University of Mexico's Atmospheric Sciences Center.

training students and researchers, the Universidad Nacional Autónoma de México (UNAM) has created the University Network of Atmospheric Observatories (Red Universitaria de Observatorios Atmosféricos (RUOA)). These observatories, located in a variety of urban and natural settings, will provide research-quality data in areas ranging from atmospheric chemistry, aerobiology, and greenhouse gases to tropospheric water vapor, cloud physics, and electric fields.

These sites also serve as a basis for technological development. For example, a multiaxis differential optical absorption spectrometer (MAX-DOAS) system, which uses scattered solar radiation for gas column measurements, was designed and constructed at UNAM. Long-term measures of air quality and greenhouse gas concentrations will help scientists understand their spatial and temporal variability and inform policy makers in the areas of public health, ecological conservation, and climate change. Also, RUOA will be an educational and training space for technicians and operators from other meteorological and air quality networks in Mexico.

RUOA Observatories

At present, RUOA consists of six atmospheric observatories in urban zones:

- the UNAM campus site in Mexico City
- Juriquilla, Querétaro
- Aguascalientes, Aguascalientes
- Saltillo, Coahuila
- Hermosillo, Sonora
- Morelia, Michoacán

In addition, three observatories operate in unique natural protected zones: the deciduous forest on the Pacific coast of Jalisco in Chamela; the rain forest of Los Tuxtlas, Veracruz; and the high-altitude (4 kilometers above sea level) volcanic environment of Altzomoni, State of Mexico.

The permanent maintenance of the RUOA observatories, which includes the calibration, validation, and publication of the data produced, is the responsibility of the participating research groups at UNAM's Centro de Ciencias de la Atmósfera (see http://bit.ly/Mexico_UNAM). Many of these groups have experience developing, analyzing, or correcting data from other meteorological or air quality networks in Mexico. All data will be freely available, a large portion of them in real time at the RUOA website (http://bit.ly/Mexico_Atmos).

Related Projects

RUOA is linked to several national and international projects. The Mexico City Air Quality Network has instruments in two RUOA observatories and measures the air quality in close collaboration with UNAM. The Mexican Weather Service has meteorological instruments in two RUOA observatories located in natural protected areas. In addition, the Mexican Aerobiology Network shares infrastructure and information with RUOA so that both networks can identify and classify a wide variety of pollen types. Also, carbon dioxide (CO_2) and methane (CH_4) monitors installed in RUOA support a funded project named "Temporal and Spatial Variability of CO_2 and CH_4 in Mexico" to evaluate changes in greenhouse gases.

A plan for a high-altitude site (Altzomoni) to contribute to the World Meteorological Organization's Global Atmosphere Watch program is already in progress. The Altzomoni Observatory has recently been accepted to be part of the international Network for the Detection of Atmospheric Composition Change.

Finally, the recently formed Black Carbon Network (RCN) is a system for measuring black carbon nationwide, and with support from RUOA it covers four cities and a pristine background site. RCN and RUOA have been comparing information in order to evaluate Mexico's contribution to global warming with short-lived climate forcers.

Five RUOA observatories are also hosts for TlalocNet, a national network of GPS meteorology stations for continuously measuring water vapor columns.

Available Instrumentation and Data

Each of the RUOA measuring sites observes a diverse array of surface and atmospheric variables. Urban observatories have sensors that measure the absorption and scattering aerosols and black carbon. There are also technologies to measure ion concentrations in real time for particles smaller than 1 micrometer. In addition, observatories have ceilometers to detect and range clouds, hydrometeors, or air masses that have a substantial amount of particles. Those instruments also serve to estimate the height and thickness of clouds and the evolution of the planetary boundary layer.

The RUOA observatories offer new data to fill a need for atmospheric information on the Tropic of Cancer, which is relatively unstudied in America.

At some stations, samples are regularly collected to distinguish allergens from other biological particulate matter, to identify volatile organic compounds, and to analyze the chemical composition of wet deposition. The analysis of heavy metals, organic acids, and acid rain precursors (nitrogen oxides and sulfur), as well as nine inorganic ions, is important in understanding the incorporation of air pollutants in rainwater and how it is associated with atmospheric dispersion of pollutants over a large region.

Wind data (speed and direction), temperature, humidity, pressure, solar radiation, and precipitation will also be measured at the observatories. All of the variables are registered in an acquisition system. A field mill monitor detects atmospheric electric field variation and the presence of lightning within a 50-kilometer radius. Additionally, disdrometers measure the amount of precipitation and provide detailed information on raindrops, discriminating between different types of hydrometeors (liquid or solid). The sensors also indicate the range of visibility of fog events. Moreover, data from GPS receivers at the observatories, together with surface pressure and temperature measurements, are used to estimate precipitable water vapor for both meteorological research and long-term climate studies.

UNAM has designed instruments for determining the concentrations of several gases (nitrogen dioxide, formaldehyde, and sulfur dioxide) by measuring ultraviolet/visible light absorption at different elevation angles in an atmospheric column. These MAX-DOAS instruments have been installed at five sites to assess the distribution of pollution at several altitudes as well as to validate satellite data.

Furthermore, RUOA observatories have analyzers that continuously measure concentrations of carbon dioxide, methane, carbon monoxide, and water in air because continuous measurement of gases that participate in the radiative balance has become increasingly important for understanding their effects on the global climate. Observatories in urban zones have standard air quality gas (ozone, sulfur dioxide, carbon monoxide, nitrogen dioxide) and particle (PM_{10} and $PM_{2.5}$) monitors. They also have passive samplers that collect atmospheric aerosols used to study organic compounds that persist in the environment.

UNAM is the most important university in Mexico, as well as the largest university in Latin America. Its RUOA observatories offer new data to fill a need for atmospheric information on the Tropic of Cancer, which is relatively unstudied in America. This information is relevant to the scientific and other communities interested in atmospheric phenomena related to the diversity of climate, weather, and chemistry of the atmosphere.

Acknowledgments

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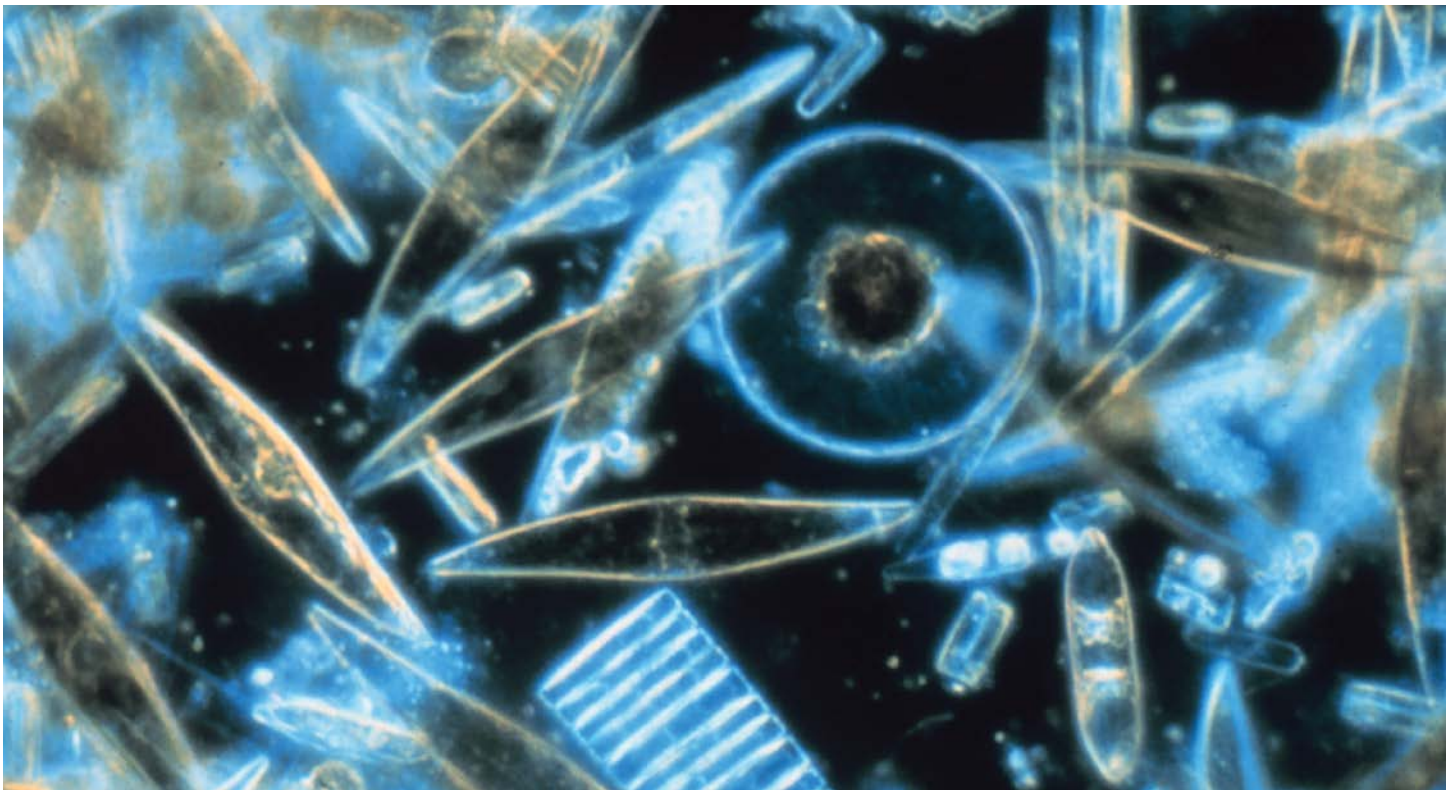
How Oceans Could Change If We Reverse Anthropogenic Warming



Gordon T. Taylor, Stony Brook University, NOAA Corps Collection

Diatoms from McMurdo Sound, as seen through a microscope.

It is well established at this point that anthropogenic factors are warming the planet at an unprecedented rate. Reducing and eventually eliminating our role in climate change is a lofty and necessary goal, but the planet's climate—especially the oceans—carries an enormous amount of inertia. Here, using computer models, *John et al.* investigate how the oceans and the microscopic organisms that inhabit them would respond to a mitigation of anthropogenic warming over the course of about 100 years.

The properties of Earth's oceans are the product of a complex balance of surface temperature, currents, biogeochemical processes, and numerous other factors. Warming and cooling of the climate influence each variable in unique ways, with some reacting quite quickly and others experiencing long lag times before any measurable response. These differences in inertia could lead to scenarios where the oceans' properties continue to change for centuries or even millennia, even if anthropogenic warming could be mitigated entirely. To examine such a scenario and attempt to parse out these "legacy effects," scientists simulated a 95-year period of warming (2006–2100) followed by a symmetrical period of cooling (2101–2195) and looked at how the oceans differed at the start and end point of the experiment period.

Overall, the team's results show that net primary production by phytoplankton in the ocean is likely to rise in such a scenario. This increase in productivity is caused by increased mixing between layers of ocean water: As the planet cools, ocean waters near the surface respond faster than those deeper down. This results in a cooler top layer and relatively warmer waters between 400 and 800 meters deep. This, in turn, brings the density of the ocean's layers closer together and allows for easier mixing. As the deep waters circulate more freely toward the surface, they carry new supplies of nitrate along with them, replenishing the vital nutrient that allows the phytoplankton to thrive. The magnitude of this effect varied considerably by geographic location, with the most extreme production increases occurring in the subtropics and the Arctic.

The makeup of these phytoplankton populations, however, was quite different from contemporary norms. The models predicted a persistent depletion of silicates in the ocean waters, which allowed larger phytoplankton, especially the nondiatoms—which do not require silicates—to dominate.

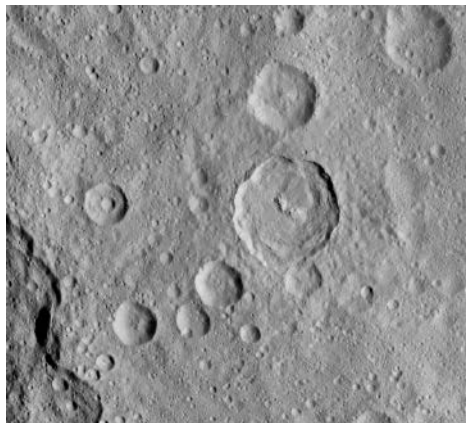
The simulation results show that anthropogenic forcing will continue to influence Earth's climate for a long time, even if it can be mitigated within the next hundred years. Understanding and predicting the future state of the planet should both prepare us for the future and serve as a reminder of the long-lasting impact our action today may have on the planet. Even if we find a way to completely stop anthropogenic warming today, the legacy effects of the change we've already caused would continue to echo many years into the future. (*Geophysical Research Letters*, doi:10.1002/2015GL066160, 2015)

—David Shultz, Freelance Writer

Objects That Slam into Ceres Remain on Its Surface

The origin and composition of the dwarf planet Ceres, the most massive body in the asteroid belt, have long been the subject of debate. As wide as the state of Texas, the nearly spherical body has a density less than half that of Earth's, suggesting either that Ceres could host large volumes of ice in its mantle or that it may be composed of very porous silicate minerals. The potential presence—or absence—of ice on Ceres, as well as on other small planetary bodies, may also affect whether the remnants of asteroids and other cosmic impactors remain on the surface or bounce off into space, according to a new study by *Daly and Schultz.*

Since previous estimates of how much impactor material remains on the surface have focused on rocky targets denser than Ceres, the researchers conducted a series of experiments at the NASA Ames Vertical Gun Range to examine the effects of high-speed collisions on more porous, Ceres-like targets. Using a 4-meter-long cannon that can launch projectiles at speeds of up to 22,000 kilometers per hour, the scientists simulated impacts of both metallic and stony meteorites into frozen surfaces whose properties represented the two possibilities for Ceres's surface: ice rich or porous silicate.



NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

Impact craters on the surface of the dwarf planet Ceres as seen from the Dawn spacecraft on 2 October 2015 at an altitude of 1470 kilometers.

The results show that regardless of the angle of impact, the type of impactor, or the composition of the surface, a large proportion of the projectiles remained in and near the impact craters, providing strong experimental evidence that Ceres's surface is extensively contaminated with cosmic debris. Because the team observed that more of the projectile remained in and near the crater when it impacted the snowy targets, they concluded that an ice-rich surface will accumulate cosmic debris even more efficiently than one composed of porous silicates.

The findings also have implications for understanding the evolution of Ceres's surface. If high-speed impactors excavate ice, it could rapidly sublimate, a process that would concentrate impactor material on the body's surface, according to the researchers. If, however, there is minimal ice present, the team predicts the impact debris will be more evenly distributed throughout the depth of the unconsolidated surface layer. High-resolution images scheduled to be taken by the Dawn spacecraft after it drops into its final orbit around the dwarf planet later this year should provide the first visual evidence that will help to determine the extent to which Ceres's surface is dominated by exotic or locally derived material. (*Geophysical Research Letters,* doi:10.1002/2015GL065601, 2015) **—Terri Cook, Freelance Writer**

Tracking Radioactive Cesium Released During Fukushima Disaster

On 11 March 2011, a tsunami struck the east coast of Japan, damaging the Fukushima nuclear power plant and precipitating the second-largest series of nuclear meltdowns in history. The majority of the fallout was deposited into the Pacific Ocean, and scientists have scrambled to track the position of the harmful radioactive atoms ever since.

Between 2012 and 2014, *Yoshida et al.* analyzed the abundance of two cesium (Cs) isotopes—^{134}Cs and ^{137}Cs—at various locations throughout the North Pacific Ocean. These radioactive elements were released in relatively equal abundance during the Fukushima disaster, but ^{137}Cs already existed in low levels in the Pacific Ocean as a leftover product of nuclear weapons testing over the years. Any discovery of ^{134}Cs, however, could be directly attributed to the Fukushima disaster.

At the end of 2012, samples of surface water taken along the 30°N parallel—which runs approximately from San Diego to southern Japan—showed ^{134}Cs had migrated as far east as 174.3°W longitude. (For reference, Hawaii is located at 157.8°W.) Similar measurements taken in 2013 show that the cesium appeared to be traveling about 5 centimeters per second: It had migrated to 160.6°W—approximately 1580 kilometers closer to North America.

The team also took depth measurements to track how deep the cesium was penetrating the water. Again, no ^{134}Cs was found farther east than 160.6°W, but closer to Japan the radioactive isotopes were observed as far down as 600 meters—a surprising finding that showed the rapid and deep progression only 2 years after the accident. Physical processes responsible for the deep signal could be explained by the distinct water mass formation or deep wintertime mixing; however, it has yet to be clarified.

Although the full environmental impact of the Fukushima disaster may not be fully understood for years to come, the ^{134}Cs present in the oceans won't stay there for long; its half-life is only about 2 years, meaning that since the 2012 measurements, more than half of the isotopes have decayed. However, the radioactive ^{137}Cs released from the plant won't see a similar 50% reduction until around the year 2040.

The team says their findings are mostly consistent with models that aimed to predict the spread of the fallout and that the cesium might even be advancing slightly slower than predicted. (*Geophysical Research Letters,* doi:10.1002/2015GL065259, 2015) **—David Shultz, Freelance Writer**

The High Cost of Switching Power Sources

As global temperatures continue to rise, many countries have turned to nuclear power as an alternative to carbon dioxide–emitting fuel sources like coal. However, many leaders and policy makers question whether the benefits of nuclear power offset the risk of radioactive contamination. Some nations—like Germany—have abandoned nuclear power as an alternative energy source. Here *Mielonen et al.* simulated a scenario in which the rest of the world followed suit and reverted to coal power.

The team used a global three-dimensional climate model to simulate what would happen if every nuclear power plant on Earth were swapped for a coal plant. They assessed the impacts of carbon dioxide emissions and particulate matter on the environment, as well as the human health effects of particulate matter smaller than 2.5 micrometers in diameter.

The results of the team's all-coal scenario paint a grim picture. Their models reveal that increased aerosol emissions from coal power plants would actually cool the climate at first because atmospheric aerosols reflect sunlight back into space. However, after 37 years, enough carbon dioxide would accumulate in the atmosphere to reverse this cooling effect and even accelerate global warming. They estimated that long-term exposure to these same aerosols would contribute to a worldwide increase in cardiopulmonary diseases and lung cancer, causing 150,000 premature deaths each year. Two thirds of these deaths would occur in Europe.

The researchers recognize that the study does not provide a complete assessment of the factors involved in choosing an energy source. They did not include an analysis of the risks inherent in nuclear energy, like accidents from nuclear waste or the potential for developing nuclear weapons. The team also acknowledges that the likelihood of their worst-case scenario turning into reality is slim—but the study still serves a practical purpose by emphasizing the detrimental consequences of fossil fuel reliance.

Mario Goebbels, CC BY-SA 2.0 (http://bit.ly/ccbysa2-0)

Data from global three-dimensional climate modeling show that a mass switch from nuclear power to coal would increase deaths from exposure to harmful aerosols and accelerate climate change.

The study isn't merely a question of nuclear versus coal, however; rather, the authors caution that nations abandoning nuclear power should carefully consider the health and climate effects of energy sources that might take its place. For example, coal has clearly adverse health effects, and biomass burning may not be a good option either. Ultimately, further research is necessary to determine which fuel source will have the smallest unfavorable impact on health and/or climate. (*Journal of Geophysical Research: Atmospheres*, doi:10.1002/2015JD024183, 2015) **—Shannon Kelleher, Writer Intern**

Soil Loses Pyrogenic Carbon by an Unexpected Pathway

Pyrogenic carbon—also known as black carbon—is charred carbon deposited by vegetation and grassland fires. In the agricultural community, the pyrogenic carbon–rich biochar is known as a soil enhancer, improving soil fertility and boosting the land's carbon storage. Despite the fact that it is a common component of the global biogeochemical carbon cycle, little is known about what happens to pyrogenic carbon after it is deposited. Relatively low concentrations suggest that it must be disappearing from the soil, yet the pathway by which this carbon is transported out of the soil has remained somewhat of a mystery.

In a recent study, *Güereña et al.* sought to uncover the pathways by which pyrogenic carbon is removed from soil at the headwaters of the White Nile watershed of Lake Victoria in East Africa, where forest has been converted to farmland. The team expected to identify erosion as the primary transporter of pyrogenic carbon and to find pyrogenic carbon eroding faster than nonpyrogenic carbon—but their results were a bit of a surprise.

Over the course of a year, the team sampled soil and water from different land gradient angles in catchments—natural areas where water accumulates—at all major tributaries of the White Nile watershed and measured concentrations of organic carbon and pyrogenic carbon.

They found that pyrogenic carbon was not transported by erosion and surface water flow more than nonpyrogenic carbon—suggesting that the charred carbon deposited by forest fires is no more susceptible to erosion than the organic carbon already stored in the soil. However, the researchers found that concentrations of pyrogenic carbon increased with soil depth. Since the concentration of pyrogenic carbon in underground base flow water corresponded to these higher concentrations below the surface, they concluded that the trick to pyrogenic carbon's vanishing act lies in transportation processes happening deep in the soil, rather than on the surface. (*Global Biogeochemical Cycles*, doi:10.1002/2015GB005095, 2015) **—Shannon Kelleher, Writer Intern**

What Causes the Strange Pulses in Saturn's Magnetosphere?

In addition to its signature rings and many moons, Saturn is surrounded by its own magnetosphere—the bubble of space influenced by the planet's magnetic field. The behaviors of various phenomena within the magnetosphere, including charged particles, magnetic fields, the aurora, radio emissions, and even the rings themselves, undergo periodic cycles that last about 10.7 hours.

For the past decade, scientists have puzzled over what could cause these pulses. The periodic cycles of the magnetospheres of Earth and Jupiter are caused by the misalignment of each planet's spin axis and magnetic field axis. However, Saturn has no such mismatch.

A new model by *Carbary* provides new evidence for a potential mechanism that has been previously explored by several scientists: a rotating spiral wave of increased particle density that travels outward from the planet. As the spiral turns, regions of higher plasma density and magnetic field strength periodically sweep through Saturn's magnetosphere, giving rise to the observed cyclical behavior.

To construct the new model, Carbary used observations made by NASA's Cassini spacecraft during the first 200 days of 2010. As it swung around Saturn—well within the magnetosphere—Cassini measured magnetic field strength and plasma density. Carbary used these data to calculate the wave speed of the hypothetical spiral.

An observer looking down at the north pole of Saturn from above would see that the spiral travels outward from the planet and rotates counterclockwise. It appears stiff near the planet where the wave speed is high, like the spokes of a wheel. However, the spiral takes shape as the wave speed slows toward the outer magnetosphere.

Carbary tested the new model's predictions against other Cassini observations from 2010. The model accurately predicted the 10.7-hour periodic signature. However, it also predicted smaller secondary signals approximately 20 minutes before and after the main signal, which were not observed by Cassini. Future studies are needed to refine the model and identify the underlying mechanism that drives the spiral. (*Geophysical Research Letters*, doi:10.1002/2015GL067292, 2016) **—Sarah Stanley, Freelance Writer**

Unknown Tsunami Trigger Hides Along a Creeping Aleutian Fault

When we think about what causes an earthquake, the first thing that usually comes to mind is a fault that slips suddenly—the kind of sudden quakes that can generate tsunamis. But a fault line that creeps—when two tectonic plates slide against each other smoothly—probably wouldn't be considered a major suspect for tsunami-causing earthquakes. Far north off the Aleutian Islands, however, a creeping section of the Aleutian Subduction Zone might be the source of past and future tsunamis that could impact coastal areas around the Pacific Ocean.

Witter et al. explored the coastal geology at Stardust Bay on Sedanka Island, Alaska, above a creeping part of the Aleutian Subduction Zone and identified six tsunami events recorded in distinct marine sand layers. Drift logs and other landforms near the beach also provide clues that tsunamis historically hit the shores of Sedanka Island. These included shallow ponds, a swale just behind the current beach berm, an apparent tsunami terrace, and unusual stream channels most likely caused by post-tsunami backflow.

The researchers used radioactive cesium to date the first layer of sand, which most likely was deposited by the 1957 Aleutian tsunami.

Robert Witter

Geologists examine drift logs stranded up to 18.5 meters above sea level and 900 meters from the shoreline of Stardust Bay on the remote Pacific coast of Sedanka Island, Alaska. The logs were carried inland and deposited in 1957 by a large tsunami generated by the magnitude 8.6 Andreanof Islands earthquake. The elevations of the drift logs provide estimates of the minimum run-up of tsunami waves.

They used carbon-14 dating for the second through sixth sand layers and found that that second sand bed was laid down by a tsunami that inundated Stardust Bay between 300 and 175 years B.P. (before present, measured from 1 January 1950 to reflect when radiocarbon dating was first used). The third through sixth sand layers came from tsunamis that occurred from 660 to 560, 1170 to 1010, 1380 to 1280, and 1680 to 1510 years B.P., respectively. On average, a tsunami hit Sedanka Island every 300–340 years.

The causes of these tsunamis remain somewhat unclear, as the nearby fault presently creeps and appears not to be storing energy to release in a big seismic event. The researchers simulated the 1957 tsunami and found that the Aleutian Subduction Zone fault would need to have slipped by at least 10 meters in order to generate waves large enough to leave the evidence for inundation that they found in Stardust Bay. Because the subduction fault isn't currently locked, the team also considered alternative sources for the tsunami—but each potential source relies on rupture of some kind of fault offshore. They even investigated whether an underwater landslide triggered the tsunami but couldn't find any conclusive evidence for or against such an event. These findings suggest that an unknown tsunami source still lurks within this creeping part of the Aleutian Subduction Zone. (*Geophysical Research Letters*, doi:10.1002/2015GL066083, 2016) **—Cody Sullivan, Writer Intern**

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Naval Research Laboratory,
Stennis Space Center, MS

The Naval Research Laboratory is seeking postdoctoral researchers to push forward the frontiers of ocean forecasting, covering a wide scope of physics including surface waves, thermohaline circulation, nearshore circulation, and ocean/atmosphere coupling from global to nearshore scales. This challenging work includes processing and analysis of satellite and in water observations, construction of numerical model systems on high performance computing and assimilation for predicting the ocean environment. For a quick overview of some of the research projects within the NRL oceanography division at Stennis Space Center, visit the web site: **http://www7320.nrlssc.navy.mil/projects.php**

Applicants must be a US citizen or Permanent Resident at time of application. NRL is an Equal Opportunity Employer. Applications will be accepted until positions are filled. Please e-mail a resume and description of research interests:

Gregg Jacobs: jacobs@nrlssc.navy.mil

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 April 30, 2016 for full consideration. Applicants should apply online to http://jobs.princeton.edu, Requisition #1600132. 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 race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law.

Postcards from the Field

Dear AGU,

Here's an autumn view of two of 10 whole-ecosystem warming enclosures being operated as the Spruce and Peatland Responses Under Climatic and Environmental change (SPRUCE) experiment on the U.S. Department of Agriculture Forest Service's Marcell Experimental Forest in northern Minnesota. We have initiated a decadal study of the effects of warming by elevated carbon dioxide effects in a high carbon peatland to study the fate of ancient peatland carbon and greenhouse gas emissions, organism responses, and ecosystem hydrology. Let us know if you would like to participate. More details are available at http://mnspruce.ornl.gov.

—Paul J. Hanson, SPRUCE Principal Investigator and Coordinating Investigator, Climate Change Science Institute, Oak Ridge National Laboratory, Oak Ridge, Tenn.

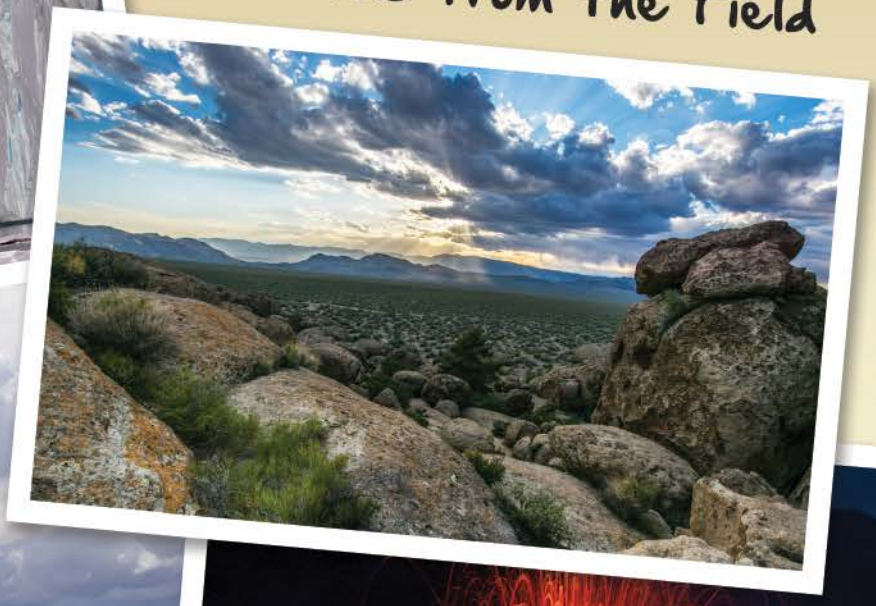
View more postcards at
http://americangeophysicalunion.tumblr.com/tagged/postcards-from-the-field.

SHARING SCIENCE

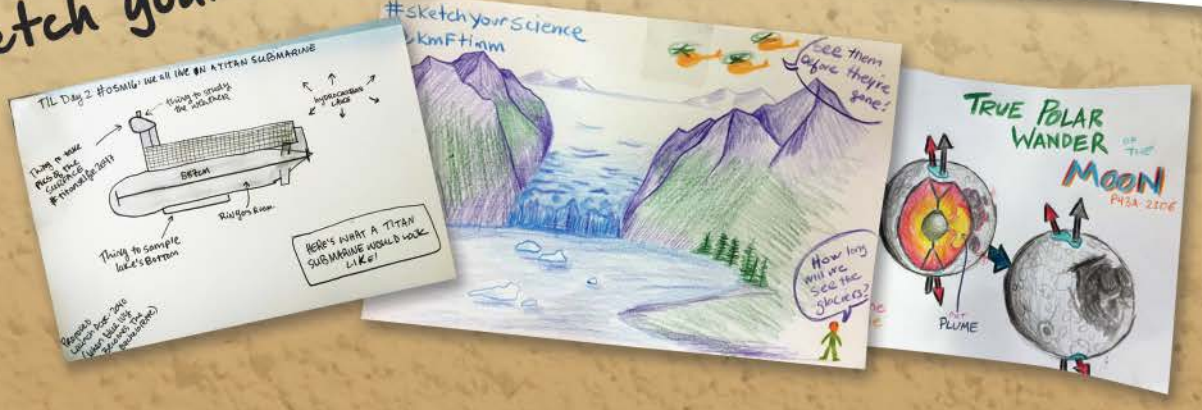
Learn, Engage, Be Inspired!

Two Great Ways to Share Your Science with AGU

Postcards from the Field



Sketch your Science



View postcards and sketches as well as submission guidelines at

americangeophysicalunion.tumblr.com

AGU