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EOS

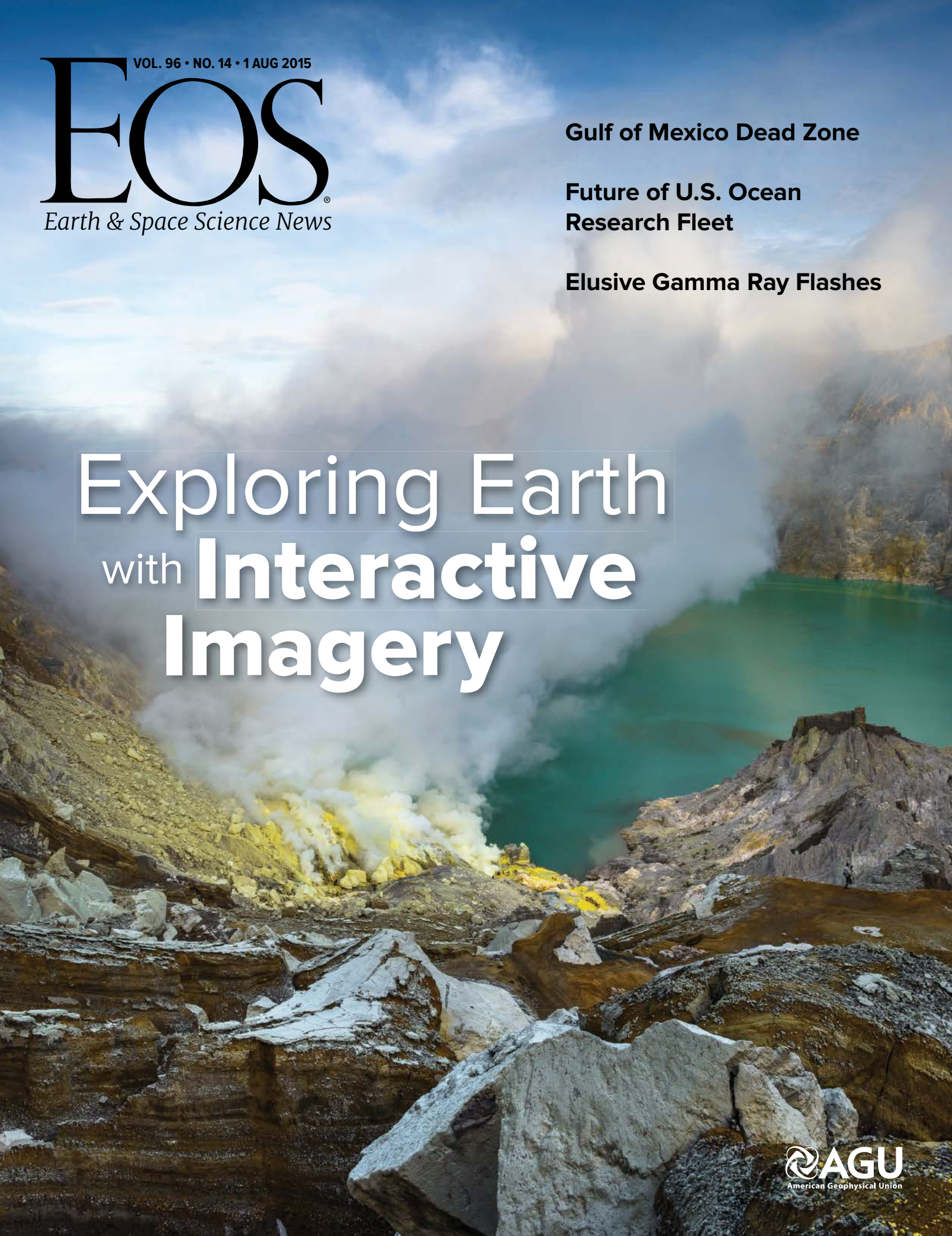
Earth & Space Science News

Gulf of Mexico Dead Zone

Future of U.S. Ocean Research Fleet

Elusive Gamma Ray Flashes

Exploring Earth with Interactive Imagery



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Puzzles Invite You to Explore Earth with Interactive Imagery

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Newly Discovered Properties of Elusive Gamma Ray Flashes

The properties of terrestrial gamma ray flashes have eluded scientists for years. A new study sheds light on how they originate.

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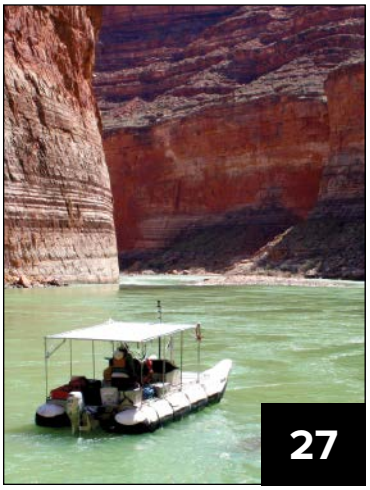

EOS.

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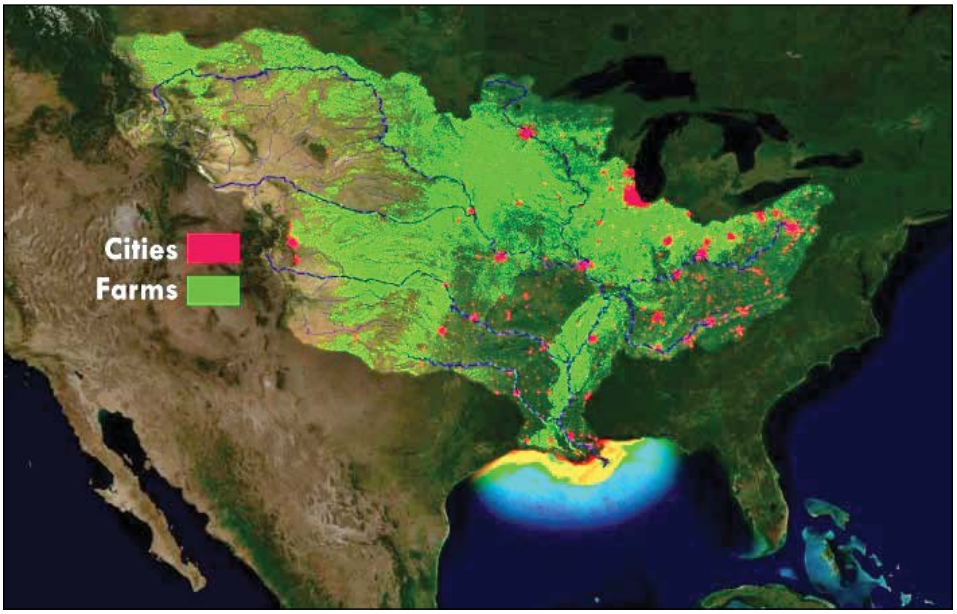
Connecticut-Sized Dead Zone Expected in Gulf of Mexico



NOAA

A visualization of how nutrient runoff from farms (green) and cities (red) in the Mississippi River Basin influences algal blooms in the Gulf of Mexico. The warmer colors represent a higher concentration of algae. National Oceanic and Atmospheric Administration scientists predict that the size of the 2015 Gulf of Mexico dead zone, which is caused by the decomposition of these blooms, will be about the size of Connecticut.

The National Oceanic and Atmospheric Administration (NOAA) recently released its prediction of the size of the annual Gulf of Mexico dead zone, which the agency forecasts to span about 14,200 square kilometers—about the area of the state of Connecticut. The actual size of this summer's dead zone will be studied and announced early this month.

This huge expanse of oxygen-depleted Gulf waters just beyond the Mississippi River Delta forms every summer after nutrients from wastewater and vast amounts of fertilizer used by farmers wash down the river and run off the Louisiana and Texas coasts during the rainy spring (see http://bit.ly/DZvideo). The extra nutrients—mainly chemical compounds containing nitrogen or phosphorus—nourish huge blooms of algae.

When the algal blooms eventually die, they fall to the sea bottom and decompose, soaking up the available dissolved oxygen. As oxygen levels fall too low to sustain most marine life, bottom-dwelling animals like crabs and shrimp cannot thrive and often flee the area, which can devastate the Gulf's seafood industry. Other, less mobile species may not survive.

"What we're trying to do is better understand the variability in size [of the dead zone] from year to year so we can better inform fisheries and management along the Gulf Coast" about where and when to expect potential shortages in their catch, said Dan Obenour, an environmental engineer at North Carolina State University in Raleigh.

Modeling the Dead Zone

In June, the U.S. Geological Survey estimated that 104,000 metric tons of nitrate and 19,300 metric tons of phosphorus had flowed into the Gulf of Mexico in May alone (see http://bit.ly/USGSflow). To predict the dead zone's expected size, NOAA combined results from four different computer models that weigh factors such as nutrient runoff, wind velocity, and other weather conditions. This is the first year that multiple models are being used. The predicted size of the 2015 dead zone, announced 17 June, is about the average it has been for the past several years.

One of the models, developed by Obenour and his colleagues, includes measurements of wind velocity over the continental shelf off Louisiana and Texas, where the dead zone occurs. Wind can affect the size of the nutrient load delivered to the shelf, fueling the formation of the dead zone, Obenour said.

Wind can also affect the amount of fresh water that flows into the shelf region, which causes the water column to separate into a colder, denser, saltier layer beneath a warmer, more buoyant, fresher layer. This stratification exacerbates the dead zone by preventing mixing of the layers, which would otherwise inject oxygen into the bottom layer.

Last year, a team of researchers analyzing a global database of more than 400 dead zones, including the one in the Gulf of Mexico, found that many of them could experience a sea surface temperature rise by the end of this century that could worsen stratification, increasing the size of dead zones (see http://bit.ly/DZdata).

By **JoAnna Wendel,** Staff Writer

Tailpipe Study: Newer Trucks Emit More Black Carbon

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A new pollution study in Europe using a van to chase other vehicles and measure their tailpipe emissions finds that newer, diesel-fueled, heavy trucks and buses emit, on average, 34% more of the health and climate hazard known as black carbon than older vehicles of the same types.

The unexpectedly dirty exhaust from heavy vehicles newer than 5 years old, compared with that from 5- to 10-year-old vehicles, may indicate that modifications by vehicle manufacturers to lessen other pollutants have had the undesirable side effect of boosting engines' black carbon output, the researchers suggest.

The new findings raise questions about truck and bus emissions at a time when the Obama administration is proposing stricter U.S. truck standards that would improve the fuel efficiency of an array of medium- and heavy-duty vehicles and cut their carbon dioxide emissions by an estimated 16%. The new standards, announced 19 June, do not explicitly address black carbon (see http://bit.ly/USrules).

Soot Happens, But Vehicle Sources Murky

Commonly known as soot, the combustion by-product black carbon is the second most important contributor to global warming. It has also been implicated in long-term human pulmonary and cardiovascular problems. Black carbon comes from many sources, but the Diesel Technology Forum, an industry group in Washington, D. C., estimates that diesel accounts for a quarter of worldwide black carbon emissions.

It has not been easy to link some pollutants from vehicles, such as black carbon, to emissions sources (see http://bit.ly/black_carb_sources). Governments seeking to regulate vehicle exhaust often depend on laboratory testing of preproduction models of new vehicles and computer simulations for assessing compliance to emissions standards. Once the preproduction models achieve certification, manufacturers are allowed to sell the production models to the public. Yet a growing number of studies are showing that such tests used to certify vehicles do not match real-world vehicle performance.

Sampling Black Carbon on the Run

Seeking on-the-road data for black carbon and several other pollutants, a team led by atmospheric chemist Griša Močnik of Aerosol, a company in Ljubljana, Slovenia, took to local highways with its instruments and recorded the first measurements of black carbon from a selection of cars, trucks, and buses representative of Europe's vehicle fleet.

The researchers installed several instruments in a passenger minivan: One device measured black carbon while others gauged nitrogen oxide and carbon dioxide. Another

Irena Ježek

Air intake tubes dangle from a side window of an instrument-laden minivan that researchers used to chase vehicles on Slovenian roads while measuring their tailpipe emissions. The tubes fed exhaust gases into separate instruments for measuring black carbon, nitrogen oxide, carbon dioxide, and particulates.

instrument captured tiny particles. The team taped air intake tubes to the outside of the van and drove Slovenian roads for a week.

In all, the scientists measured emissions from 139 diesel- or gasoline-fueled cars and diesel-fueled heavy vehicles (trucks and buses weightier than 1305 kilograms), allowing the researchers to analyze how emissions vary with vehicle type, age, and power-to-weight ratio.

A Mysterious Emission Upswing

Why black carbon from such vehicles may be on the rise in the face of tightening controls to cut back on pollution emissions remains a matter of speculation, Močnik said. But technological efforts to limit nitrogen oxide emissions might be a factor, he suggested.

Some manufacturers use selective catalytic reduction, a kind of chemical scrub, in heavy vehicles and diesel particulate filters—a mechanical system—in lighter ones, Močnik noted. The chemical scrub might be plucking out nitrogen oxide and letting through black carbon, he suggested. Engine operating temperatures also influence how much of each pollutant an engine produces.

Black Carbon Boost Out of Step with Declines

Although the proposed new U.S. truck standards do not address black carbon emissions, they do include revised emissions certification methods to better reflect real-world vehicle performance.

Except for the black carbon rise in newer heavy vehicles, the measurements reported by Močnik and his colleagues in a study published 8 June in *Atmospheric Chemistry and Physics Discussions* confirm that nitrogen oxide and particulate emissions are dropping in most types of vehicles (http://bit.ly/ACPpaper). This broad emissions decline jives with similar reductions found by many different research teams and is a trend that the U.S. Environmental Protection Agency attributes to increasingly stringent regulation.

Still, another surprise that the on-road data revealed was a relatively high rate of emissions from diesel passenger cars versus heavy vehicles, Močnik said. Overall, diesel passenger cars produced more pollution per liter of fuel burned than heavy diesel vehicles such as buses and trucks. The discrepancy may stem from a greater demand in the commercial vehicle market for more fuel-efficient, and therefore cleaner, vehicles because fuel consumption inflates fleet expenses and eats into profits, Močnik speculates.

Evading True Emission Checks?

Black carbon is not a common target of vehicle pollution studies, said emissions researcher Vicente Franco of the International Council on Clean Transportation (ICCT), a mostly foundation-supported transport regulation think tank in Brussels, Belgium. Instead, researchers and regulators tend to focus on carbon dioxide, particulate matter, and nitrogen oxide.

Franco, for example, showed last year in a metastudy that the 15 new diesel cars he used as a sample emitted around 7 times the legal limit of nitrogen oxide (see http://bit.ly/ICCT_study). That study did not cover black carbon.

Franco added that the ICCT is concerned that manufacturers may be designing engines that cut emissions only during certification tests and emit more the rest of the time—a practice called "cycle beating." Measurements like those by Močnik's team, checking multiple types of vehicle fleet emissions throughout the entire driving cycle, could shed light on whether such suspicions are warranted.

By **Lucas Laursen,** Freelance Writer; Twitter: @lucaslaursen

A Case for Geology's Role in Policy Decisions

Anita Stein

Member of the European Parliament Carlos Zorrinho (third from left) and other officials discuss the roles of geoscience in policy making and Europe's economy. He and the other panelists pictured—(from left) European Commission Directorate General (EC DG) Internal Market representative Slavko Solar, European Federation of Geologists president Vitor Correia, and EC DG Energy representative Janis Folkmanis—spoke at a 2 June event at the European Parliament in Brussels, Belgium, highlighting a new report on geoscience and society.

A recent report on geology and society aims to convince European parliament members and other policy makers that geology can provide insights on a broad range of issues. Geology "underpins the provision of resources to Europe's population and industry, delivers a wide range of essential services, and helps us understand how we can live more sustainably on our planet," states the document, *Geology for Society* (http://bit.ly/georeport), issued by the Geological Society of London and the European Federation of Geologists.

The future security of Europe's energy supply "relies heavily on geological skills in a wide range of contexts, from resource extraction to renewable energy and use of the subsurface to store carbon dioxide and radioactive waste," according to the report. Geological understanding is essential also to managing Europe's water resources and to the region's economic health, the report adds.

Likewise, Europe needs a "skilled geoscience workforce and a strong research base" not only to compete economically but also to help provide for a burgeoning global population seeking higher living standards, the report notes.

Broad Relevance of Earth Sciences

Geosciences play a central role in a number of current policy arenas, including climate change, natural hazards, and hydraulic fracturing, Carlos Zorrinho, a member of the European Parliament from Portugal, told attendees at a 2 June event at the European Parliament in Brussels, Belgium, to launch the report.

Nic Bilham, director of policy and communications at the Geological Society, told *Eos* that the report builds on an earlier United Kingdom version of the document and on other work by the Geological Society "to raise awareness of the relevance of geology to a lot of the big challenges facing society now and in the future." The report, which aims to be a primer for policy makers to turn to as a resource, can be used broadly across Europe, he said. It has already has been translated into 14 languages.

By **Randy Showstack,** Staff Writer

Floods Fail in War, Win as Weapon Against Sea Level Rise

Scenes of flooding, from Colorado to Louisiana to Tbilisi, Georgia, captured international attention this spring. For some onlookers, the devastation wrought might make unleashing floods against an enemy seem like a good way to win a war.

A new study finds that in low-lying southwestern Netherlands, intentional flooding to gain the upper hand in war accounted for approximately a third of all floods in the area in the past 500 years. Despite the popularity of flooding as a weapon in the region, the tactic often did more harm than good to those who unleashed it, the research shows.

Deluge of War-Inspired Floods

Between the years 1500 and 2000 in southwestern Netherlands, Dutch troops or other combatants intentionally caused 11 of the 32 major floods of the period in an attempt to gain a military advantage, reports historical geographer Adriaan de Kraker of Vrije University in Amsterdam. His findings were published on 9 June in the journal *Hydrology and Earth System Sciences* (http://bit.ly/deKraker_study).

Military forces breached dikes and seawalls or opened sluices, allowing salt water to pour in and cover the landscape. In a later development, flood makers would leave defenses against seawater in place but route freshwater from rivers and channels into lowlands or prevent rainfall from draining off the land.

A Failed Strategy

The research shows that intentional flooding often flopped militarily, failing to halt or turn back the advances of enemies, although a notable flood defense by the Dutch starting in 1672 stopped a French army from occupying Amsterdam. Intentional inundation also forced inhabitants it was meant to protect off their lands and destroyed their property. It interfered with harvests, infused soil with harmful and long-lasting salinity when seawater was used, and reconfigured waterways through erosion and soil deposition, according to de Kraker.

The price of failure could be steep. For instance, during the Eighty Years' War, which began in 1568 and culminated with independence of the Netherlands from Spanish rule, the Dutch took elaborate measures to keep Spain from seizing control of the countryside. With surgical precision meant for maximum inundation, they flooded their own lands on the Flemish side of the Western Scheldt.

The maneuver failed on a massive scale. "The carefully chosen places to make breaches in the seawall or to simply take out a wooden sluice had a devastating impact on the landscape, but this strategy completely missed its directly anticipated goals," de Kraker reported. "Bruges, Ghent and Antwerp were subdued by the Spanish in the course of 1584 and 1585, leaving the rebel side [the Dutch] empty-handed."

Risky Business

Much of the risk of using floods for war in the Netherlands lay in controlling the water, de Kraker explained. Too much water, and enemy boats could easily cross; too little, and hostile armies pulling heavy cannons could cross on foot. What the Dutch needed was a flood of 50 centimeters—at that level, "it's one muddy mess," de Kraker said.

Also, small holes in dikes would lead to big trouble when not quickly repaired. With every high tide, the gaps would deepen and widen. "During the 16th and 17th century, things got beyond any form of control" de Kraker noted. Many flooded lands remained underwater, even after hostilities ceased. Others that were drained received inadequate repairs, later suffering deadly natural floods as a result.

Enter Deliberate Freshwater Floods

By the end of the 18th century, what had been mainly intentional saltwater flooding in the Netherlands expanded to include on-purpose freshwater inundations. The region encompasses the deltas of three major European rivers, so freshwater is abundant. Military planners devised ways to commandeer the network of channels, ditches, and sluices—usually used to keep the dike-protected lowlands, called polders, dry and productive—to fill them up, instead, with freshwater.

This freshwater tactic was meant to alleviate the salt stress on agriculture. Seawater-flooded polders could take years to return to preinundation agricultural production levels, sometimes hastened by growing salt-resistant rapeseed if flooding stopped

Ana, CC BY-NC-ND 2.0 (http://bit.ly/ccbyncnd2-0)

Military forces clashing in the Netherlands between the years 1500 and 2000 often flooded lowlands to hinder their opponents, a new study finds. Some flood makers tampered with networks of channels, sluices, and windmill-driven pumps—like those shown here in the village of Kinderdijk—meant to control water flow and keep the region's lowlands dry. Other forces breached sea walls or dikes to inundate lands. More often than not, the tactic failed to halt the enemy's advance and cost residents dearly in lives, property, and damage to the flooded lands.

Ministère de la Défense (France), Service Historique de la Défense

The Dutch fortress of Philippine, shown in this 18th century map, lay in the central part of a flood zone in Zeeland Flanders in southwestern Netherlands, an area the French invaded three times between 1702 and 1814, occupying it twice. The Dutch prepared an east-west corridor (beginning at the town of Sluis and ending east of the town of Hulst) to be flooded in case of warfare. During France's campaigns, French intelligence gathered information, including maps like this one, preserved in archives at Vincennes. When the Dutch flooded the lands around Philippine in 1747, the area silted up excessively, and French intelligence officers knew they only had to wait until low tide for their troops to be able to cross some areas.

early enough in late summer to fall. However, the freshwater approach relied heavily on spies to report enemy action well in advance of any attack.

For the Dutch, on-purpose freshwater and saltwater flooding was an especially risky tactic, commented U.S. Army Infantry Branch historian David Stieghan of Fort Benning, Ga., who did not participate in the study. This is because the low-lying lands relied on windmills to pump water out of the polders to the North Sea, he explained. Elsewhere, "you open a dam and the land dries out in days or weeks." Not so in the Netherlands, where many regions are below sea level, he added.

High and Dry

In his investigation of southwestern Netherlands flooding, de Kraker visited European museums and libraries, studied aerial photos of southwestern Netherlands, and investigated archaeological evidence, such as pottery and the remnants of old walls. He also pored over centuries-old correspondence of rebels, Spanish officials, and mayors of besieged towns, as well as other historical documents and maps related to ownership and use of lands in the region, maintenance of local sea walls, and changes to the area's landscape and soil.

Although intentional flooding in southwestern Netherlands largely failed militarily and harmed inhabitants and farms during the wars in which it was used, it brought silt into lowlands, so "the short-term loss could turn out to be a long-term gain," de Kraker told *Eos*.

Today, for example, some polders near Rotterdam and Amsterdam that avoided massive flooding for more than 800 years lie as deep as 6 meters below sea level. Yet 50,000 hectares that were flooded during the Eighty Years' War, with a thick layer of clay that the flooding deposited over time, now stand about a meter above sea level.

By **Christina Reed,** Freelance Writer

New Commission Aims to Protect Volcanic Geoheritage

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

Volcanologists have created a new commission to draw attention to the scientific and educational benefits of volcanic sites around the world and to foster sustainable geotourism to those areas. At the Fimmvörduháls in Iceland, tourists observe a shower of lava from the Eyjafjallajökull volcano in 2010.

Volcanoes are among the most dramatic landscapes on Earth and often are popular tourist destinations. A just-launched commission of a volcanology association wants to highlight the scientific and educational value of such landscapes and help protect them as a geological heritage.

The Commission on Volcano Geoheritage and Protected Volcanic Landscapes (VGPL), which launched on 29 June during a special session at the International Union of Geodesy and Geophysics (IUGG) general assembly in Prague, Czech Republic, has some big objectives. Among them are to identify the scientific value of protected volcano areas and to contribute scientific knowledge to managing these areas.

The commission, a new initiative of the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI), also aims to communicate the values of geological heritage through education and interpretation and emphasize volcano geotourism for economic and community sustainable development. IAVCEI is a semi-autonomous association of IUGG.

The Impetus to Protect and Manage Volcanic Regions

The commission plans to work with the United Nations Education, Scientific and Cultural Organization (UNESCO) World Heritage Committee and other bodies to protect volcanic regions. Several VGPL commission leaders spoke with *Eos* about the timely need for the new organization.

Increased geotourism, particularly to volcanic landscapes and active volcanoes, makes us "consider these volcanic landscapes and volcanic regions as critical areas to protect and conserve," Joan Martí, secretary general of IAVCEI, told *Eos*. The sites are important to the world's natural heritage because of the "unique geoscientific aspects they represent" and because they serve as "places to enjoy and learn about the science and history of our planet," he added.

"To contribute to this conservation, it is necessary to increase the scientific knowledge" about these volcanic landscapes as well as to "guarantee the security of their visitors by conducting accurate hazard assessments," Martí continued.

The IAVCEI executive committee approved the VGPL commission last November, explained Martí, a professor of research at the National Research Council of Spain (CSIS) and coordinator of CSIS's Group of Volcanology of Barcelona.

A Knowledge Hub

VGPL commission co-leader Karoly Nemeth, senior lecturer at the Institute of Agriculture and Environment at Massey University, in New Zealand, emphasized the need to properly communicate volcano science.

The commission could act as a "knowledge hub" and provide quality control for "the design of scientifically correct geoconservation, geoeducation, and geotouristic programs," he suggested. The commission also could help ensure stronger IAVCEI representation in various geoprotection programs, he added.

International Programs to Protect Geoheritage Sites

In a presentation during the IUGG special session, commission co-leader Thomas Casadevall, scientist emeritus with the U.S. Geological Survey, focused on international programs to protect geoheritage sites. Casadevall said that although there are more than 1000 UNESCO World Heritage sites, the majority are designated as cultural sites. Of the approximately 200 designated natural sites, about 17 are volcano sites, although some culturally designated sites, including Mount Fuji in Japan, have a strong volcanic focus.

He urged scientists to use their expertise to help protect volcanic geoheritage areas. Casadevall specifically suggested that scientists could volunteer to evaluate World Heritage site nominations; attend the 2nd Volcandpark Conference in the Canary Islands, Spain, in November (see http://bit.ly/Volcandpark), for which IAVCEI is a sponsor; and assist with the revision of a global review of volcanic World Heritage properties.

Just visiting a volcanic property designated a World Heritage site, a geopark, or a biosphere reserve would be a way for scientists to become involved in the issue. Those sites, he said, "generally are that country's proudest expression of its Earth science heritage."

By **Randy Showstack,** Staff Writer

Alberto Behar (1967–2015)

Konrad Steffen

Alberto Behar

Scientist-engineer and adventurer Alberto Behar died on 9 January 2015 at the age of 47 when the plane he was flying crashed near his longtime workplace, NASA's Jet Propulsion Laboratory (JPL) in Pasadena, Calif.

Alberto concurrently worked as a research professor at Arizona State University's (ASU) School of Earth and Space Exploration beginning in 2009, where he operated the Extreme Environments Robotics and Instrumentation Laboratory. He was a researcher and educator who actively sought to bridge the gap between science and engineering. His career was dedicated to better understanding Earth and beyond by developing instruments that enabled exploration of regions too dangerous or inaccessible for human explorers.

Alberto was born and raised in Miami, Fla., after his parents emigrated from Cuba to the United States. He attended the University of Florida, majoring in computer and information engineering sciences. He went on to earn two graduate degrees: a Master of Engineering in electrical, computer, and systems engineering from Rensselaer Polytechnic Institute and a Master of Science in computer science, with a specialization in robotics, from the University of Southern California. In 1998, he obtained his doctorate in electrical engineering, with an astronautics minor, from the University of Southern California, Los Angeles (UCLA).

A Specialization in Robotics

During his 23-year career at JPL, Alberto specialized in robotics for exploring extreme environments on Earth and other planets. He once said that technological innovations are a way of overcoming the limits on our ability to explore: "Technology is how we get our senses to a remote location where we can't actually go ourselves."

He participated in the exploration of Mars, serving as the investigation scientist for the Dynamic Albedo of Neutrons instrument on the Curiosity rover. For the Mars Exploration rovers, he was a rover driver and a member of the system downlink analysis team. He was the investigation scientist on three of the Mars Odyssey orbiter instruments: the high-energy neutron detector, the gamma ray spectrometer, and the thermal imaging spectrometer.

In terrestrial research, his brilliant engineering creations reached deep into the oceans' hydrothermal vents, next to volcanoes, under thick ice sheets, and into the stratosphere. A promising new project with Diana Roman at Carnegie Institution's Department of Terrestrial Magnetism and Lindy Elkins-Tanton at ASU was building rapid-deploy, relatively inexpensive volcano sensors for sulfur, carbon, fluorine, and chlorine emissions accompanied by a simultaneously operating seismometer and weather station.

Instruments and Vehicles for Both Polar Regions

Alberto may be best remembered for the many instruments and vehicles he built that have expanded our understanding of both polar regions. His National Science Foundation–supported research included developing new devices that allowed researchers to safely and cleanly explore subglacial lakes and underwater vehicles that measure ocean and ice interactions in the Amundsen Sea, as well as the deployment of global positioning system sensors to measure ice mass loss in Antarctica.

"From his submarines that peeked under Antarctica to his boats that raced Greenland's rivers, Alberto's work enabled measurements of things we'd never known," said Thomas Wagner, the cryosphere program scientist at NASA headquarters. "His creativity knew few bounds."

A Greenland research paper that Alberto coauthored was released days after his death by *Proceedings of the National Academy of Science*. The lead author, Laurence Smith of UCLA, arranged to rewrite the acknowledgments section to begin with, "This research is dedicated to the memory of Dr. Alberto Behar, who tragically passed away January 9, 2015."

Alberto was a member of Sigma Xi, The Scientific Research Society, AGU, IEEE Autonomous Robotics, and the Association of Computing Machinery.

"Alberto Behar was a uniquely talented engineer, developing ways to measure changes in our natural world in the most challenging environments—the ocean depths or the Antarctic ice cap," said Elkins-Tanton, director of ASU's School of Earth and Space Exploration. "With those around him, he shared both a brilliant mind and a big heart. His students were full partners in a grand adventure. His colleagues quickly came to know his caring nature and irrepressible good humor."

An Inquisitive Mind

His inquisitive mind, inventiveness, and infectious enthusiasm inspired students, colleagues, and friends alike. He was passionate, driven, and widely known for his technical excellence. He brought optimism and an accompanying smile to every room he entered. To him, engineering was an enabling strategy for scientific research.

Alberto was devoted to exploration and discovery, and he was highly successful in his career, but he never lost sight of his true love: his family.

When he wasn't talking about work, he was talking about his wife and children. He absolutely adored them and took them along on many of his adventures. He is survived by his wife, Mary, and three children: his son, Indra, and his daughters, Isis and Athena.

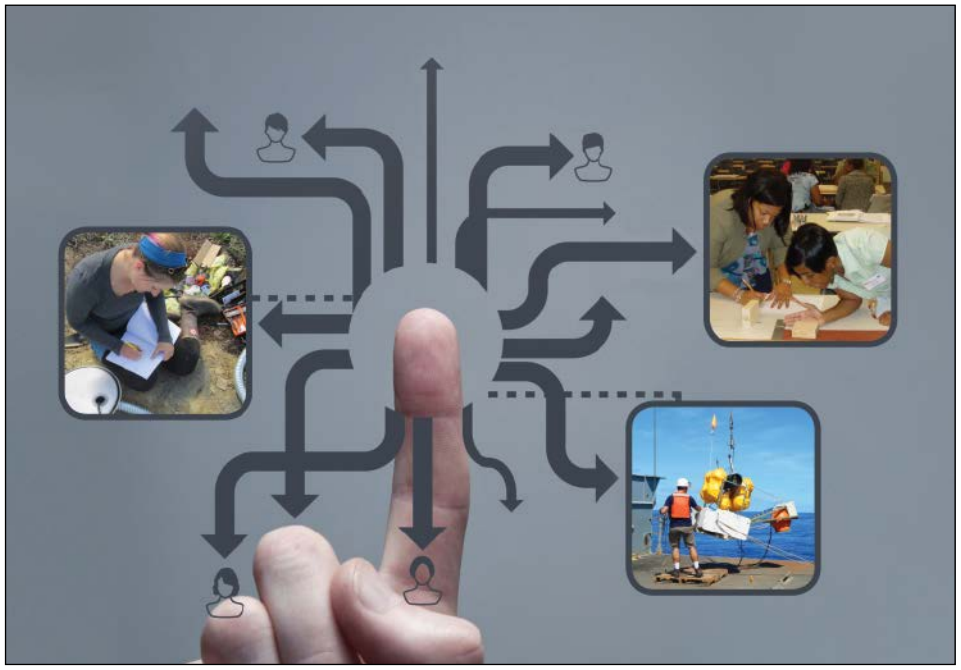
By **Nicole Cassis,** School of Earth and Space Exploration, Arizona State University, Tempe; email:ncassis@asu.edu

Laurence C. Smith, UCLA

Alberto Behar on the Greenland ice sheet in July 2012.

Promoting New Collaborations for Education Research in Geoscience

Encouraging Networks Between Geoscience and Geoscience Education (ENGAGE) Workshop
Arlington, Virginia, 18–20 January 2015



Johanna Adams

Networking between geoscientists and geoscience education researchers will broaden and strengthen research on how students learn as well as enhance the training received by college and graduate students.

The geoscience education community has made great strides in the study of teaching and learning at the undergraduate level, particularly with respect to solid Earth geology. For example, we now know that interactive strategies within lectures (such as single-concept assessments) improve students' tests scores and that the design of geoscience visuals can hinder students' understanding of geoscience concepts.

Nevertheless, the geosciences lag behind other science disciplines in the breadth of topics that have been studied and the application of this research to the classroom. In an effort to address these issues, early-career geoscientists and geoscience education researchers (GERs) gathered in mid-January in Arlington, Va., for the Encouraging Networks Between Geoscience and Geoscience Education (ENGAGE) Workshop.

The workshop focused on promoting greater use of education research in the geosciences and encouraging relationships between GERs and researchers in various disciplines such as the Earth, atmospheric, ocean, and polar sciences. Thirty-three participants were selected from more than 100 applications on the basis of disciplinary diversity and demonstrated interest in geoscience education research.

The workshop focused on promoting greater use of education research in the geosciences.

Participants discussed the nature of science and the challenges of training students in various geoscience disciplines. After a variety of activities designed to build a shared understanding of geoscience education research, participants began brainstorming projects that explore geoscience education research question such as how field-based learning impacts students' perception of space in remote sensing imagery. Invited speakers and panelists also provided examples of successful cross-disciplinary collaborations on such projects.

Attendees agreed that the workshop provided ample networking opportunities and prepared them for future collaborations. Specifically, the physical geoscientists valued the chance to collaborate on project development, whereas the GERs said they welcomed the discussion of the boundaries between outreach, evaluation, and research. GERs also found useful the discussions of potential next steps to advance geoscience education.

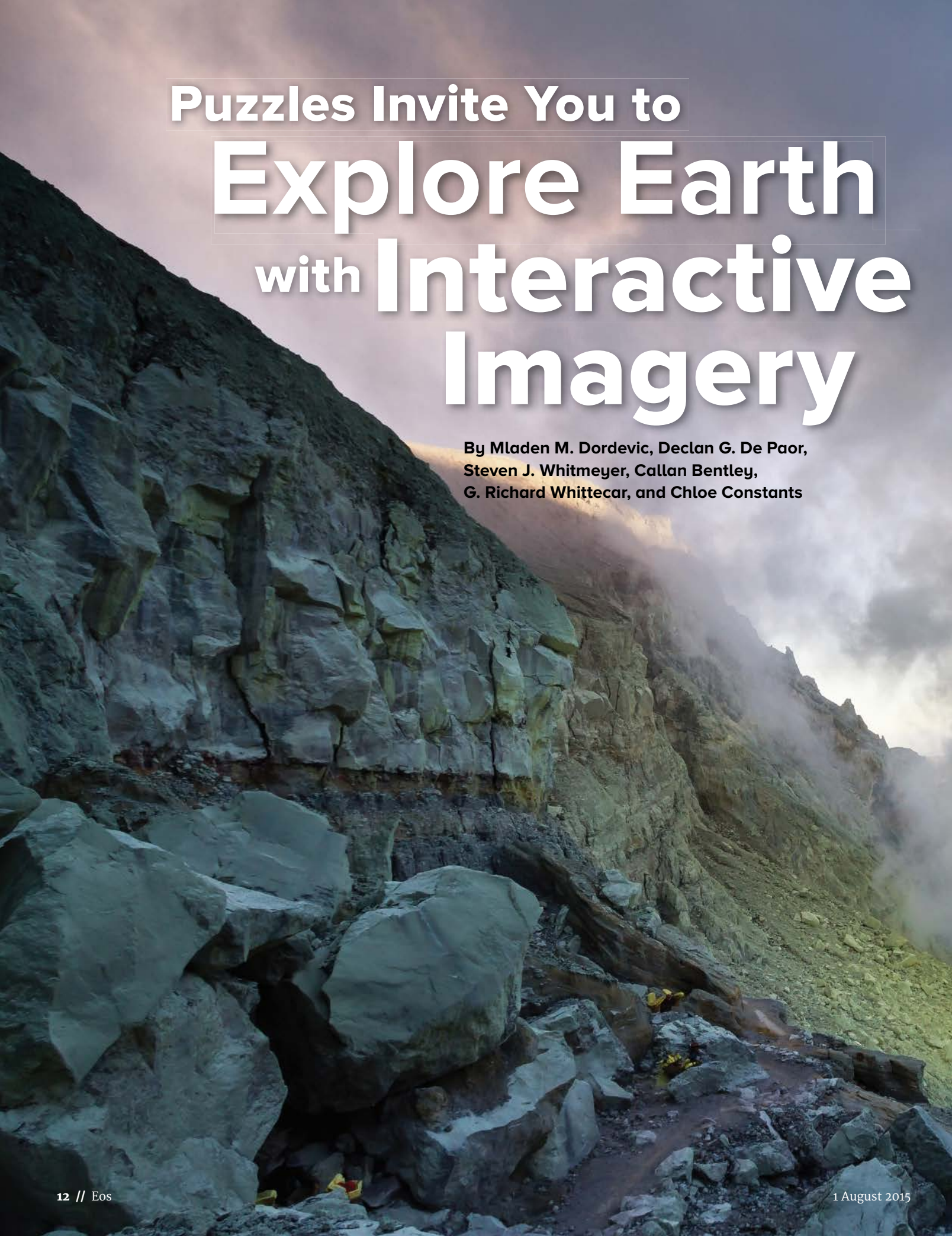
Workshop attendees developed a list of recommendations to advance geoscience education research. Key among those were the following:

- dedicated National Science Foundation funding mechanisms that could support geoscientists in their research and GERs in studying domain learning to enable both communities to dedicate time to advancing geoscience education; the participants envisioned a cross-directorate program that would build scholarship in both the disciplinary and education research domains
- future opportunities to further build collaborations between geoscientists and GERs to broaden the scope of topics receiving attention in geoscience education literature
- recognition of geoscience education research as a scholarly endeavor that contributes to the geosciences and is worthy of consideration in tenure and promotion evaluations; the early-career participants acknowledged the need for GERs in geology departments to both strengthen instructional practices and promote further scholarly work on how to best train geoscience students

The full ENGAGE Workshop report is available at http://bit.ly/ENGAGEWorkshop.

Support for the ENGAGE workshop was provided by National Science Foundation awards EAR-1425893 and EAR-1425927.

By **Nicole D. LaDue,** Department of Geology and Environmental Geosciences, Northern Illinois University, DeKalb, Ill.; email: nladue@niu.edu; and **John Taber** and **Michael Hubenthal,** Incorporated Research Institutions for Seismology, Washington, D. C.



Puzzles Invite You to Explore Earth with Interactive Imagery

By Mladen M. Dordevic, Declan G. De Paor, Steven J. Whitmeyer, Callan Bentley, G. Richard Whittecar, and Chloe Constants

Decades of geoscience field trip reports bear witness to the importance of field-based learning experiences, but most instructors can take students to only a handful of field sites in person. In addition, students with mobility constraints, as well as those with childcare, eldercare, or work responsibilities outside of classroom hours, may find physical fieldwork impractical if not impossible.

Even students who are able to attend field classes may be distracted and miss their instructor's comments in the outdoor environment. Furthermore, K–12 students and those in community colleges, historically black colleges, and tribal colleges or students pursuing degrees via distance education have very limited opportunities for in-person field experiences.

A worldwide digital geoscience field experience can provide access for people at all educational levels and life stages, from elementary school through graduate school and from informal education settings such as museums, planetariums, and aquariums to assisted living communities. To make this virtual geologic experience more effec-

Monthon Wa/Getty Images

The acid crater lake in Indonesia's Ijen volcano.

tive for formal and informal lifelong learning, we have created EarthQuiz (see http://www.earthquiz.net/).

Integrating Existing Resources

EarthQuiz leverages Google Street View™, Photo Spheres, GigaPans, and Google Maps™ satellite view imagery to enable crowdsourced creation, Web-based delivery, and autoscoring of interactive geoscientific exercises. Viewers are challenged to identify and locate geologic features around the globe through a series of game-like questions.

To make the virtual geologic experience more effective for formal and informal lifelong learning, we have created EarthQuiz.

The concept originated when we noticed that Google Street View™ and satellite view scenes often showed geologically relevant content: rocks and structures exposed in road cuts or other outcrops; landscape features, including mountains, lakes, and coastlines; surface processes such as landslides, glaciation, and erosion; and even underwater scenes of marine environments.

Instructors can organize EarthQuiz questions into regional or topical collections, create course modules, and assign homework that is autoscored by the computer, which also gives automatic feedback written by the instructor. These are "learning objects" as defined in the education research literature [*McGreal*, 2004]—small chunks of digital data and metadata that are extensible, malleable, and reusable and have built-in assessment and feedback.

Google Street View™ imagery is amazingly pervasive around the globe. Street View™ cars document innumerable roads. Bikers, hikers, and snowboarders record off-road tracks; Street View™ even goes underwater in photos captured by scuba divers. Nevertheless, Street View™ is not available for many locations of great geologic interest, including countries where Google has not been allowed to record views. Additionally, some Street View™ imagery is of insufficient quality for outcrop-scale identification of features. Fortunately, there is an abundance of other digital imagery, including Photo Spheres (360° panoramic photographs), GigaPans (deeply zoomable gigapixel images [*Piatek et al.*, 2012]), and Google Maps™ satellite views.

Google Maps™ satellite view provides images of many types of geologic structures (Figure 1). Fractures in Utah's Zion National Park and vertical dikes around Shiprock, N.M., are best viewed from an elevated vertical perspective. Spectacular fold examples near Alice Springs, Australia, and oceanic fracture zones and transform faults west of Mendocino Point, Calif., also appear clearly from this perspective.

These and countless other locations are even better viewed in Google Earth™, with its ability to incline the camera angle (see, e.g., http://bit.ly/SERCGEarth, a guide from Carleton College's Science Education Resource Center). We did not include in EarthQuiz a Google Earth™ option, however, because the Google Earth™ browser plug-in and application programs interface (API) is deprecated—the existing plug-in will no longer be supported for any Web browser after December 2015. However, Google has promised a plug-in-free API in the future, at which point we will explore a Google Earth™ views option.

The EarthQuiz Experience

EarthQuiz challenges website visitors to answer multiple-choice geoscientific quiz questions and to estimate image locations (the locational part was inspired by Anton Wallén's GeoGuessr.com). Activities emphasize exploration, adventure, and interpretation. The EarthQuiz user manual (http://earthquiz.net/help.pdf) and video tutorials (http://bit.ly/EQTutorial1 and http://bit.ly/EQTutorial2) are provided on the Web.

In the sample question in Figure 2, users are presented with an image of an actively erupting volcano on the Kamchatka peninsula in Russia and a two-part challenge: Evaluate the temperature of the erupting lava and pinpoint the location of the volcano. Users can pan and zoom but cannot exit the image and see the map view until they submit an answer. The computer autoscores submitted answers, offers feedback, and loads the next question.

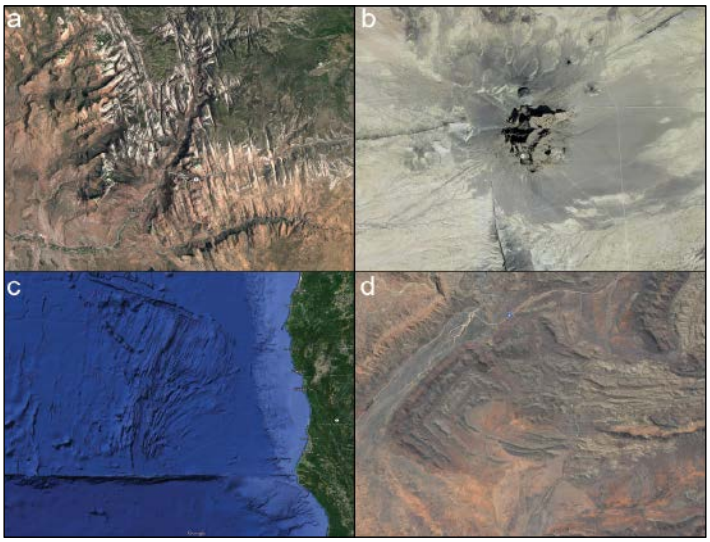


Fig. 1. Geologic features as seen with the satellite view of Google Maps™. (a) Fracture patterns in Zion National Park (37.2500215, -112.9473522); Imagery © 2015 Google, USDA Farm Service Agency, Map data © 2015 Google. (b) Shiprock, N.M., volcanic plug with radial dikes (36.6884074, -108.8336981); Imagery and Map data © 2015 Google. (c) Oceanic transforms and fractures just northwest of Mendocino, Calif. (42.0232886, -126.9627148); Imagery © 2015 SIO, NOAA, U.S. Navy, NGA, GEBCO, LDEO-Columbia, NSF, Landsat, Map data © 2015 Google. (d) Spectacular fold patterns east of Alice Springs, Australia (-23.7204051, 134.2455588); Imagery © 2015 CNES / Astrium, DigitalGlobe, Map data © 2015 Google.

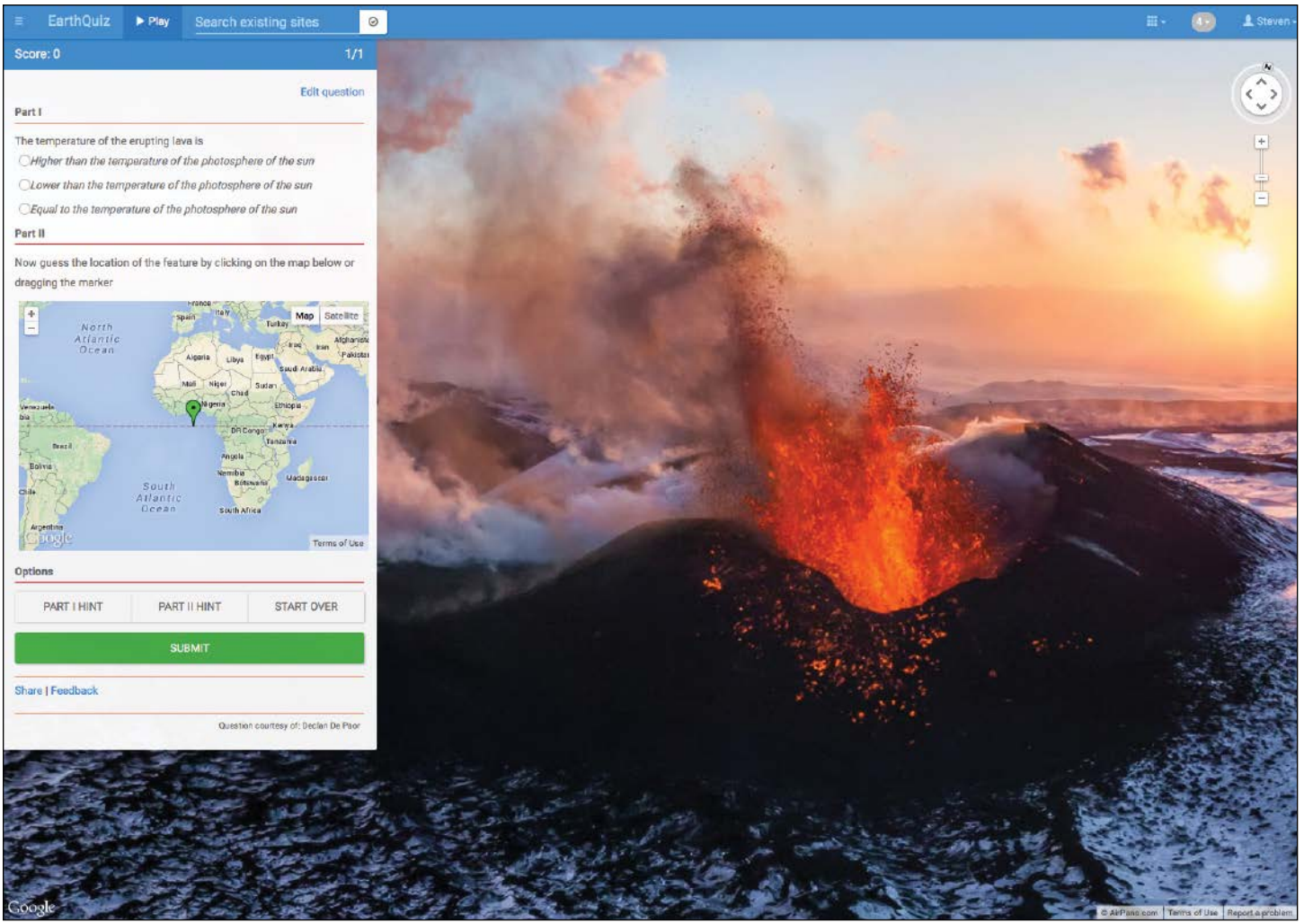


Fig. 2. EarthQuiz question featuring Photo Sphere imagery of a volcano on the Kamchatka peninsula in Russia. The box at the left shows the associated multiple-choice question (Part I) and a world map with a placemark for guessing the real-world location of the image (Part II). Background photo: AirPano.com

At the K–8 student level, instructors may want students to learn important locations such as the Grand Canyon using an inverse scavenger hunt approach that could be fun and educational for younger students. In a scavenger hunt, students search for prizes hidden in unknown places, whereas we show students the places and ask them what they are.

At the college level, however, the exact location of a site may be less important than its geologic province or provenance. Recently erupted basaltic lava looks pretty much the same in Hawaii or Iceland, for example, but is not likely to be found in Florida. Students at this level ought to be rewarded for identifying a provenance and not penalized for selecting a distant, geologically near-identical place. Therefore, instructors have the option to invite students to choose among predefined regions or to make locations part of the quiz, for example, "Is this an image of (a) Granite from the Sierra Nevada, (b) Limestone from Bermuda," etc.

The Instructor Interface

Professors, schoolteachers, and other credentialed geoscientists can create sites and group them in collections for use in course modules. Instructors can choose from Google Street View™, Photo Sphere, GigaPan, or Google Maps™ satellite view imagery. They compose questions and tag them with an educational level. They can also evaluate and comment on colleagues' creations. A course module management system allows instructors to enroll students, assign homework, and view autograded assignments.

A curatorial board of credentialed professionals manages the collections to ensure quality control and make sure that questions address appropriate geoscience themes without rewarding invalid responses (e.g., Atlantis, the Bermuda Triangle, etc.). This is a necessary precaution in any crowdsourced system. Curators do not have access to student work to maintain the students' privacy.

The Google Earth for Onsite and Distance Education (GEODE) research team currently serves as EarthQuiz's

EarthQuiz greatly broadens the range of field settings that students can experience beyond in-person class trips.

curatorial board. However, we are looking for qualified instructors with expertise in other subdisciplines to serve as curators.

Implementation and Results

EarthQuiz is a potentially transformative vehicle for educational instruction and research. Field instructors could use the website's collections for formative assessment of pre-field trip preparation and posttrip reinforcement. This resource greatly broadens the range of field settings that students can experience beyond in-person class trips. Virtual sites cannot fully replace physical presence in the field, but they offer opportunities to develop global awareness in asynchronous, distance education, and informal education settings.

Coba et al. [2015] found that in large general education classes, virtual Google Earth™ tours produced more learning gains than plain text and images. However, further studies are needed to assess long-term learning outcomes. Anecdotally, our experience shows that a coordinated series of exercises (a "learning progression" from one topic to the next so that students gain practice with the interface and with geoscience concepts) is likely to yield the best outcomes.

Our interests are mainly in hard rock geology, and many of the existing 700 or so sites fall within that category. However, there is significant content overlap, such that a structural geology collection might inspire geomorphology instructors to create questions using the same locations. EarthQuiz content is mostly crowdsourced, where the "crowd" consists of geoscience educators with a vast range of expertise [*Whitmeyer and De Paor,* 2014]. Thus, future collections could include such disciplines as biogeography, phenology, and marine ecology.

We envision EarthQuiz contributing to the development of "inverse massive open online courses"—small classes or even individual students who benefit from the wisdom of massive numbers of instructors [*De Paor et al.,* 2013].

Generating EarthQuiz content has been not just an exercise in building teaching resources but also a personal learning experience for all of us. We anticipate that future EarthQuiz contributors and users will find it to be a learning experience too.

Acknowledgments

We thank the editors and anonymous reviewers for excellent comments. This work was supported by National Science Foundation DUE-1323419: "Google Earth for Onsite and Distance Education (GEODE)" and by Google GEO Curriculum awards to D. G. De Paor and S. J. Whitmeyer.

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A University-Government Partnership for

Oceanographic Research

By Deborah K. Smith, Jon Alberts, Annette DeSilva, and Christopher Measures

LDEO

After 44 years of coordinating the U.S. academic research fleet and facilities, the University-National Oceanographic Laboratory System (UNOLS) gears for the future.

Understanding the global environment and predicting its future require that scientists arm themselves with solid working knowledge of the oceans. Researchers from institutions large and small devote their careers to examining oceanic nutrient cycles, the formation of currents, and the evolution of ocean basins through time.

Collecting data from the oceans, their basins, and their subseafloors, particularly in remote locations or on global scales, proves very expensive and far beyond the means of a typical lab or academic science department. How do scientists from the hundreds of universities and research institutions in the United States gain access to the equipment they need?

Since 1971, one answer has been the University-National Oceanographic Laboratory System (UNOLS), an organization with membership of 62 U.S. academic institutions and national laboratories. UNOLS is governed by ocean scientists who form an elected council and nine standing committees that collectively comprise more than 60 volunteers. Together, these volunteers manage the operations of 16 ocean-going research vessels and other critical facilities.

At age 44, UNOLS is still going strong, but to continue providing the highest-quality facilities vital for conducting oceanographic research, we need ongoing community input and active engagement.

A Need to Better Understand the Sea

In the decades after World War II, U.S. government officials recognized that meeting national needs—from basic science to defense to food security—required an understanding of

The R/V Marcus G. Langseth, 1 of 16 ocean-going research facilities in the University-National Oceanographic Laboratory System (UNOLS) research fleet. The Langseth serves as the UNOLS National Oceanographic Seismic Facility.

R/V *ATLANTIS and ALVIN*

R/V *SIKULIAQ*

R/V *SHARP*

R/V *PELICAN*

AUV *SENTRY*

UNOLS Facilities

Global Class Vessels	Operator	Length (m)	Year built/refit
THOMAS G. THOMPSON	University of Washington	83.5	1991
ROGER REVELLE	University of California San Diego	83.5	1996
ATLANTIS	Woods Hole Oceanographic Institution	83.5	1997
SIKULIAQ	University of Alaska Fairbanks	80	2014
*MARCUS G. LANGSETH**	Lamont Doherty Earth Observatory	72	1996/2007
Ocean/Intermediate Class Vessels			
*NEIL ARMSTRONG***	Woods Hole Oceanographic Institution	72.5	2014
*SALLY RIDE***	University of California San Diego	72.5	2014
KILO MOANA	University of Hawaii	57	2002
ENDEAVOR	University of Rhode Island	56	1976/93
OCEANUS	Oregon State University	54	1976/94
ATLANTIC EXPLORER	Bermuda Institute of Ocean Science	51	1982/2006
Regional Class Vessels			
HUGH R. SHARP	University of Delaware	44.5	2005
Coastal/Local Class Vessels			
ROBERT G. SPROUL	University of California San Diego	38	1981/85
PELICAN	Louisiana Universities Marine Consortium	35	1985/2003
F. G. WALTON SMITH	University of Miami	29	2000
SAVANNAH	Skidaway Institute of Oceanography	28	2001
BLUE HERON	University of Minnesota	26	1985/99
CLIFFORD A. BARNES	University of Washington	20	1966/84
National Deep Submergence Facility			
ALVIN, ROV *JASON/MEDEA*, AUV *SENTRY*	Woods Hole Oceanographic Institution		
Center for Interdisciplinary Remotely-Piloted Aircraft Studies			
TWIN OTTER, UNMANNED AIRCRAFT SYSTEMS	Naval Postgraduate School		

* National Oceanographic Seismic Facility
** Expected to enter UNOLS service in 2016

Fig. 1. University-National Oceanographic Laboratories System (UNOLS) facilities and their operators. Facility details and the current UNOLS membership list can be found at https://www.unols.org/.

marine processes (e.g., see Panel Reports of the Commission on Marine Science from 1969; http://bit.ly/PRCMS1969). This recognition, and associated funding increases, spurred rapid growth within marine science research.

This research showed that Earth's vast oceans influenced the rest of the Earth system through a myriad of Earth-ocean-atmosphere system processes. These involve nearshore and open-ocean processes, including ocean circulation, biogeochemistry, ecosystem structure, continental slope failure, tsunami and earthquake potential, ecosystems and venting fluids, and deep-sea mineral deposition.

Furthermore, the government and the public began to realize—prompted by a nascent environmental movement—how strongly humans could affect the Earth system, including the oceans.

By the 1960s, academic and government institutions were operating an unprecedented number of ocean-going research ships, and the sizes of these ships were increasing. By 1970, the nation boasted 17 laboratories operating 33 research vessels. Twelve of the ships were large enough to require regulatory inspection.

Growth Creates Challenges

Although the explosion in marine research generated important new knowledge, several major challenges became apparent. Investigators from non-ship-operating institutions needed ship access, but there was no organized way of accommodating them. Federal funding agencies also grew concerned about the increasing costs of the vessels and their different modes of operation. And as time progressed, the operating costs of ships rapidly became unsustainable within institutional operating budgets.

In 1969, the President's Commission on Marine Science Engineering and Resources recommended that a National Oceanographic Laboratories System (NOLS) be established to provide a full range of facilities to the marine science community. Universities agreed with the goals of NOLS but were concerned about excessive federal control. Thus, a group of academic and NSF representatives proposed University-NOLS, which would be coordinated by an association of university laboratories.

UNOLS launched in 1971 with members from ship- and non-ship-operating institutions. Ship operations remained the responsibility of individual operators but were unified and reviewed under the UNOLS umbrella.

UNOLS has evolved over the years, adapting to the needs of the scientific community, the funding agencies, and the expanded types of research platforms available. But its role has remained largely the same: to coordinate and facilitate access to the facilities upon which the national oceanographic research and education enterprise depends.

A Fleet of Research Facilities

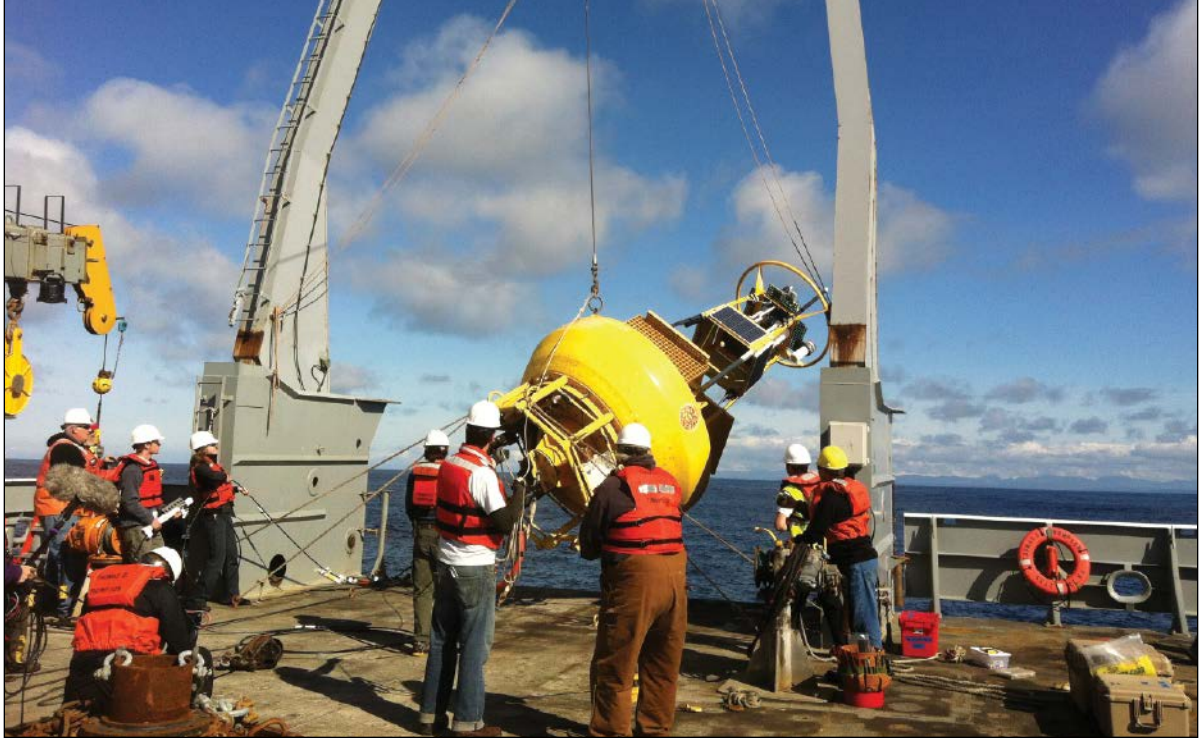
Current UNOLS facilities include 16 research vessels, the National Deep Submergence Facility (NDSF), the National Oceanographic Aircraft Facility, and the National Oceanographic Seismic Facility (Figure 1). The UNOLS Fleet Improvement Committee oversees long-range planning to supervise the design and acquisition of ships and to ensure the right mix and composition of the fleet. The process leading from initial design to ship acquisition can last more than a decade.

R/V *Sikuliaq* is the newest vessel to join the fleet (Figure 1). This 80-meter-long, ice-capable vessel is owned by the National Science Foundation (NSF) and is operated by the University of Alaska Fairbanks. R/V *Sikuliaq* can break ice up to three-quarters of a meter thick, enabling scientists to work in the seasonal ice of the Arctic and Antarctic.

Two other new ships, both owned by the U.S. Navy, will begin science operations in 2016: R/V *Neil Armstrong*, operated by Woods Hole Oceanographic Institution, and R/V *Sally Ride*, operated by Scripps Institution of Oceanography. These general-purpose vessels (both 72.5 meters long) will support a wide suite of multidisciplinary research, including mapping, sampling, and deploying and retrieving over-the-side instruments and vehicles in coastal and deepwater environments.

The 72-meter-long R/V *Marcus G. Langseth*, operated by the Lamont-Doherty Earth Observatory, serves as the National Oceanographic Seismic Facility. Its air guns and 6- and 8-kilometer-long streamers acquire the data that allow researchers to map Earth's structure kilometers below the seafloor.

Other UNOLS facilities include NDSF, which manages and operates the submersible *Alvin*, the remotely operated vehicle *Jason/Medea*, and the autonomous underwater vehicle *Sentry*. The Center for Interdisciplinary Remotely-



Dough Russell/UW

R/V Thomas G. Thompson *prepares to complete deployment of the Chá bă mooring off of La Push, Wash., in 2010. Chá bă is an important part of the Northwest Enhanced Moorings Observatory; it monitors meteorology (winds, air temperature, rainfall) and ocean properties (salinity, temperature, acidity, currents, nutrient concentrations, etc.).*

Piloted Aircraft Studies supports the ocean sciences with a Twin Otter aircraft and five unmanned aircraft systems.

Finally, UNOLS has established pools of frequently used scientific equipment, any item of which can be used by researchers on a cruise-by-cruise basis. These include the U.S. National Ocean Bottom Seismograph Instrument Pool, Potential Fields Pool Equipment, and the Van, Winch, and Wire pools. For more, see http://bit.ly/UNOLSpools.

Support for the UNOLS fleet and major facilities comes primarily from NSF, which provides around 65% of the fleet's budget. Other major supporting agencies include the Office of Naval Research (~15%) and the National Oceanic and Atmospheric Administration (~10%). Remaining support comes from states, institutions, the Bureau of Ocean Energy Management, the U.S. Geological Survey, the Environmental Protection Agency, and others.

Meeting Future Needs

To plan for the future fleet, the UNOLS Council recently surveyed the research community and received more than 350 survey responses. The vast majority (90%) of respondents indicated that the need for the fleet will remain constant or increase in the future.

But respondents also indicated that tight fiscal budgets were taking a toll. Specifically, 62% had at some point been reluctant to submit a ship proposal because of the perception of low award rates for these proposals. And 92% of respondents indicated that availability of funding limited the types of science questions they could address. Full results can be found on the UNOLS website (http://bit.ly/UNOLSSurvey).

Bringing in the Next Generation

UNOLS runs programs to engage and train the next generation of oceanographic scientists and to help them make full use of the research fleet. During a short course and cruise, researchers instruct early-career scientists on how to be chief scientists on projects that use UNOLS facilities. Since 2011, 99 participants have taken part in this program and have collectively submitted 31 requests to use a U.S. research vessel.

The new-users program run by the Deep Submergence Science Committee (DeSSC) consists of a workshop held prior to the DeSSC meeting at the AGU Fall Meeting. Experienced scientists and NDSF operators provide instruction during the workshop. This program has had 123 participants since 2011, some of whom now serve as members of the DeSSC committee.

Get Involved

UNOLS makes recommendations for replacing, modifying, or improving the number and mix of facilities, and it is important for the science community to provide input into these recommendations. You can get involved in a number of ways. One is to join the UNOLS listserv (http://bit.ly/UNOLSlistserv) to receive announcements of activities and requests for input. Requests for nominations to serve on a committee are sent out through the UNOLS listserv, and nominations and self-nominations are welcome. You can also contact a member of a committee to comment on a specific issue.

There are also several community meetings related to UNOLS during the year (e.g., the UNOLS Annual Meeting and the DeSSC and the Marcus Langseth Oversight Committee meetings).

UNOLS facilities are a vital part of the infrastructure necessary to do ocean science. The system relies on the research community to help set its course to ensure and enhance the excellence of oceanographic programs. With this help, UNOLS will continue to serve the ocean science community as a key resource for collecting oceanic data.

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Praveen Kumar, University of Illinois at Urbana-Champaign
Glen M. MacDonald, University of California, Los Angeles
Hugh S. O'Neill, Australian National University*
Bette L. Otto-Bliesner, National Center for Atmospheric Research
Jonathan T. Overpeck, University of Arizona
Hans W. Paerl, University of North Carolina at Chapel Hill
William K. Peterson, University of Colorado Boulder
Robert Pinkel, University of California, San Diego
Fred F. Pollitz, U.S. Geological Survey, Earthquake Science Center*
Jay Quade, University of Arizona
William J. Randel, National Center for Atmospheric Research*
Philip J. Rasch, Pacific Northwest National Laboratory
Lorraine A. Remer, University of Maryland, Baltimore County*
Michael L. Roderick, Australian National University*
Daniel Rosenfeld, Hebrew University of Jerusalem
Cynthia Rosenzweig, NASA Goddard Institute for Space Studies
Roger M. Samelson, Oregon State University
Martha K. Savage, Victoria University of Wellington*
Barbara Sherwood Lollar, University of Toronto
Laurence C. Smith, University of California, Los Angeles
Michael J. Thompson, University Corporation for Atmospheric Research
Axel Timmermann, University of Hawaii*
Larry D. Travis, NASA Goddard Institute for Space Studies*
Peter A. Troch, University of Arizona
Scott W. Tyler, University of Nevada, Reno
Jean-Pierre Vilotte, Institut de Physique du Globe de Paris
Martin Visbeck, GEOMAR Helmholtz Centre for Ocean Research Kiel
Yanbin Wang, University of Chicago
Guoxiong Wu, Institute of Atmospheric Physics, Chinese Academy of Sciences*
Ping Yang, Texas A&M University

Awards

Ambassador Award
Charles R. Chappell, Vanderbilt University
Lucile Jones, U.S. Geological Survey*
Gordon McBean, University of Western Ontario

Edward A. Flinn III Award
Sonia Esperanca and Robin L. Reichlin, National Science Foundation

Charles S. Falkenberg Award
Benjamin L. Preston, Oak Ridge National Laboratory

Athelstan Spilhaus Award
Holly R. Gilbert, NASA Goddard Space Flight Center*

International Award
Peter J. Webster, Georgia Institute of Technology*

Robert C. Cowen Award for Sustained Achievement in Science Journalism
Andrew Revkin, *The New York Times*

Walter Sullivan Award for Excellence in Science Journalism–Features
Douglas Fox, Freelance Writer

David Perlman Award for Excellence in Science Journalism–News
Sandi Doughton, *The Seattle Times*

Prizes

The Asahiko Taira International Scientific Ocean Drilling Research Prize
Fumio Inagaki, Japan Agency for Marine-Earth Science and Technology

Climate Communications Prize
Richard C. J. Somerville, Scripps Institution of Oceanography

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G-Cubed: Building on 15 Years of Publishing Process-Level Science

Geochemistry, Geophysics, Geosystems (or *G-Cubed*) is the premier interdisciplinary journal of AGU and has been published since 2000 in collaboration with the Geochemical Society. The journal hosts intermediate-length articles (~10,000 words, ~10 figures) of broad community interest, covering Earth and planetary processes with a focus on understanding planets as a system. The journal's editors welcome observational, experimental, and theoretical investigations of the solid Earth and planets, their hydrospheres and atmospheres, Earth's biosphere, and the solar system at all spatial and temporal scales.

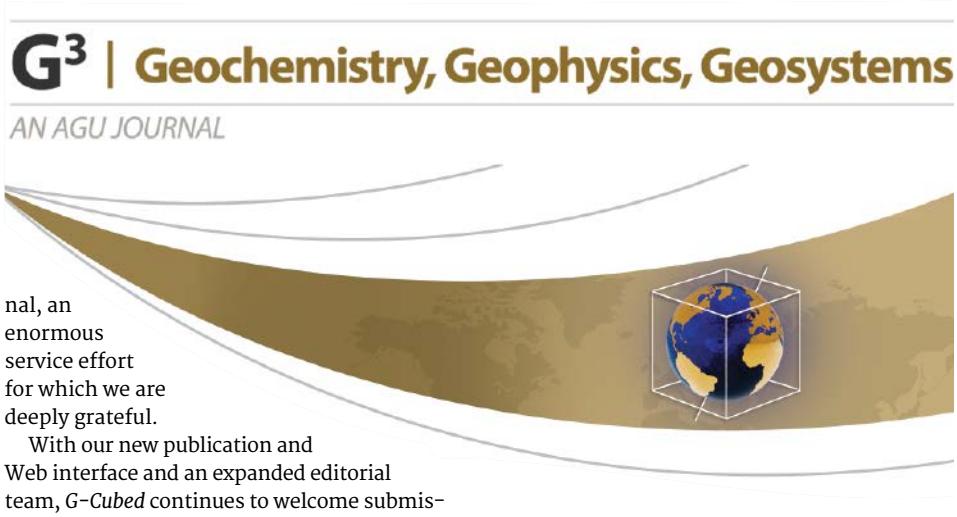
G-Cubed defines itself by its mission to publish the best process-level science. The journal has also led the transformation to online publication since its inception. We remain committed to exploring new ways of electronic publishing in an open and collaborative approach, working with authors; AGU; and John Wiley, our publisher, to help make complex, data-rich scientific studies widely accessible.

G-Cubed papers reach a wide readership whose residence is split roughly evenly between Europe, Asia, and the Americas, with a growing usage in Africa. In 2014, *G-Cubed*'s impact factor was 3.054, and we published about 300 articles.

The Editorial Team

The journal's team has always been proud of shepherding fair, fast, and detailed reviews. The current median time to first decision is very close to our target of 6 weeks. To achieve this efficiency, *G-Cubed* has recently expanded its editorial board. The current board of editors reflects the disciplinary breadth and geographic diversity of our readership; it consists of Janne Blichert-Toft (Ecole Normale Supérieure de Lyon), Ulrich Faul (Massachusetts Institute of Technology), Cin-Ty Lee (Rice University), Adina Paytan (University of California, Santa Cruz), Yusuke Yokoyama (University of Tokyo), and Thorsten W. Becker (University of Southern California), who also serves as editor in chief.

Editors now handle approximately 80% of all papers, but we also rely on the support of a team of about 15 associate editors when needed. This success builds, of course, on the continued support of our international group of experts who serve as reviewers for the journal, an enormous service effort for which we are deeply grateful.



With our new publication and Web interface and an expanded editorial team, *G-Cubed* continues to welcome submissions of articles that discuss—and technical reports that empower—cutting-edge science. We are particularly keen to receive more papers that speak to the connections between parts of the Earth systems, for example, pertaining to the interface between the solid Earth and the exosphere; Earth and planetary evolution, including volatile cycles; the interactions between lithospheric and deep mantle dynamics; fault systems; and fault constitutive laws.

Crosscutting Themes

G-Cubed also hosts "themes," which are collections of articles on particular topics. Unlike regular special sections, all papers within themes are published immediately after review, and the coherence of content is ensured by cross-linking and special associate editorial teams. We are currently seeking submissions for active themes on oceanic detachment faults; subduction processes in Central America; magnetism from atomic to planetary scales; the lithosphere-asthenosphere boundary; and magmatic, neovolcanic, hydrothermal, and biological processes along intraoceanic arcs and back arcs. We also welcome suggestions for new themes, and we look forward to working with authors to make sure that the journal serves the community's science needs.

To highlight new advances in science such as those arising currently through several National Science Foundation Frontiers in Earth System Dynamics projects and to reaffirm our commitment to facilitate discourse between the disciplines, we are now also initiating a new series on frontiers in Earth systems with the inaugural theme on deep Earth–surface interactions.

This theme will host a range of cutting-edge and sometimes provocative overview papers, covering Earth evolution as reflected in topics such as oxygenation; weathering and the carbon cycle; mass extinctions; convective interactions between the core, mantle, and the magnetic field; extreme climatic events; and solid Earth–climate interactions. The first set of these papers will be published in fall 2015. In addition, *G-Cubed* editors will be conveners, contributing authors, and invited speakers within a Union session on the same topic at the 2015 AGU Fall Meeting. This will further facilitate the debate of inherent scientific issues of Earth system science, within and outside of the journal.

How to Contact Us

More information about *G-Cubed* can be found on the journal website (http://bit.ly/AGU_GCubed), and our AGU team and editors can be reached at g-cubed@agu.org.

In addition, feel free to contact me directly with comments, questions, or suggestions. We look forward to continuing to work with the community to facilitate Earth systems science discourse and strive to have the journal meet the demands of a changing research landscape.

By **Thorsten W. Becker,** Editor in Chief, *Geochemistry, Geophysics, Geosystems;* University of Southern California, Los Angeles; email: twb@usc.edu

Outstanding Student Paper Awards

The following AGU members received Outstanding Student Paper Awards at the 2015 Joint Assembly in Montreal, Quebec, Canada. Winners have individual pages on AGU's website (see http://membership.agu.org/ospa-winners/).

Atmospheric Sciences

Coordinators: Roya Mortazavi, Daniel Nadeau

Jean-Sebastien Landry, McGill University, *Global carbon cycle and temperature impacts of future changes in fire regime*

Bernardo Teufel, University of Quebec at Montreal, *Impact of interactive vegetation phenology on the simulated pan-Arctic land surface state*

Biogeosciences

Coordinators: Ru Chen, Susan Natali

Azadeh Joshani, Concordia University, *Investigating preservation of organic matter through complexation with iron oxides*

Earth Surface Processes

Coordinators: James Brenan, Hao Ferrier

Camille Ouellet Dallaire, McGill University, *River reach classification at high spatial resolution to support the assessment of environmental flow requirements in Canada*

Hydrology

Coordinators: Terri Hogue, Tara Troy

Offer Rozenstein, Ben-Gurion University of the Negev, *Diurnal emissivity dynamics in bare versus biocrusted sand dunes*

Sarah Scarlett, University of Waterloo, *Controls on plot-scale evapotranspiration from a constructed fen in a post-mined oil sands landscape, Fort McMurray, Alberta*

Seismology

Coordinator: Sandeep Mahajan

Yelena Kropivnitskaya, Western University, *Sensitivity analysis of eastern Canada high resolution seismic hazard maps to the ground motion prediction equations*

Solid Earth

Coordinator: Heather Watson

Evan Eshelman, York University, *Stand-off detection and mapping of mineral and organic compounds using ultraviolet Raman spectroscopy*

Tectonophysics

Coordinator: Julia Morgan

Renaud Soucy La Roche, Queen's University, *Syn-compression normal-sense low-angle detachment in the Himalayan foreland, Western Nepal: Implications for orogenic models*

Volcanology, Geochemistry, and Petrology

Coordinators: Michael Bizimis, Eric Brown, Sarah Brownlee, Michelle Coombs, Brian Dreyer, Qi Fu, Sarah Lambart, Noah McClean, Sean Mulcahy, Tyrone Rooney, Fang-Zhen Teng

Patrick Beaudry, Queens College, City University of New York, *Sulphur isotope fractionation during degassing of Canary Island magmas*

Jennifer Blanchard, Carleton University, *Modelling the structure and composition of layered intrusions in plume center regions using potential field data*

Amazon Rain Forest Nourished by African Dust

Aerial view of the Amazon rain forest, which is nourished by phosphorus from African dust.

The productivity of the Amazon rain forest, which plays a crucial role in regulating Earth's climate, is limited by the availability of nutrients, especially phosphorus. Because water runoff keeps depleting this key nutrient from the basin's old and low-phosphorus soils, previous studies have suggested the Amazon's long-term productivity must depend upon dust transported from a distance source such as the Sahara. This foreign source of phosphorus, however, is not well quantified, and large discrepancies exist between current measurements and model estimates.

To resolve these discrepancies, *Yu et al.* published the first multiyear (2007–2013) satellite-based estimate of dust deposition in the Amazon Basin using three-dimensional (3-D) aerosol measurements from the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) instrument on board the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite. The researchers calculate that an average of 28 teragrams of dust was deposited in the basin during the annual wet season. In addition, the researchers conclude that dust deposition in the Amazon Basin is largely associated with rainfall conditions in the Sahel region during the previous year.

Compared with previous satellite results, the multiyear CALIOP-based estimates more closely match measurements and model simulations. The team suggests that this is due to the inclusion of meridional (north–south) dust transport, the 3-D nature of CALIOP's measurements, and a revised geographic definition of the Amazon Basin itself.

Although the amount of phosphorus deposition associated with the imported dust is relatively small, accounting for no more than 13% of the total, its contribution is comparable to the nutrient's estimated hydrological loss. Because rains and floods would severely deplete the phosphorus in the soil over a time frame of decades to centuries, the team concludes that African dust plays an important role in maintaining the Amazon rain forest's long-term health. (*Geophysical Research Letters,* doi:10.1002/2015GL063040, 2015) **—Terri Cook, Freelance Writer**

Newly Discovered Properties of Elusive Gamma Ray Flashes

Thunderstorms are composed of multiple layers of electric charge. This charge separation creates a strong electric field, which in turn produces regular lightning.

But sometimes, thunderstorms also generate short bursts of high-energy radiation called terrestrial gamma ray flashes (TGFs). These flashes occur when the storms act like giant particle accelerators, allowing accelerated high-energy electrons to slam into air molecules and produce gamma rays, more electrons, and positrons.

Scientists remain unsure of the exact mechanisms that produce TGFs. Previous studies have uncovered some details about how TGFs are formed but have not yet measured where inside thunderstorms they are produced. However, knowing their source altitude would help determine how bright TGFs are and would shed further light on the physics of how they are made.

Cummer et al. conducted a study to directly measure the TGF source altitude. The team combined TGF measurements collected by the Gamma-ray Burst Motor (GBM) instrument on NASA's Fermi Gamma-ray Space Telescope with ground-based measurements of the associated radio emissions.

Using the relative timing to determine which radio emissions were produced during the TGF generation and exploiting reflections of these radio emissions from the ionosphere, the authors determined that the TGFs observed were produced near 12 kilometers in altitude. This shows that TGFs are produced in the very center of thunderstorms, between the electrically charged layers. The team also found that the electromagnetic pulse produced by TGFs can be strong enough to affect the ionosphere. (*Geophysical Research Letters*, doi:10.1002/2014GL062196, 2014) **—Catherine Minnehan, Freelance Writer**

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Researchers observe thunderstorms to investigate how they create terrestrial gamma ray flashes.

Using Sound Waves to Study Grand Canyon Sediment

More than half a century ago, the Glen Canyon Dam was built to hold back the mighty Colorado River above Lees Ferry, stopping sediment from flowing naturally into the Grand Canyon. Researchers are still working to understand the dam's subsequent impact on downstream sandbars. These beaches are a fundamental aspect of the predam landscape and crucial to endangered species and river sports alike.

In recent years, the Bureau of Reclamation has unleashed experimental floods in an attempt to restore sand to eroded banks. Understanding the effects of such experiments requires detailed monitoring of the riverbed elevation and grain size, but dredging sediment and collecting cores is both pricy and time-consuming.

In recent years, geologists have turned to more efficient photo sampling—time-lapsed images that reveal visual effects of experiments. However, to understand the complete environment of sand, gravel, and boulders, a more sweeping approach is needed.

Accordingly, *Buscombe et al.,* tested an increasingly popular technique called high-frequency acoustic backscattering to classify the Colorado River bottom. The approach bounces sound waves off sediment to determine its grain size. In the past, geologists have used this technique to successfully survey large, homogeneous areas, but the Grand Canyon's dynamic riverbed, composed of a patchwork of sediment types, presented a unique challenge.

The authors used a machine-learning approach to arrive at the best way to calibrate a model of riverbed backscattering to classify sediments at very fine spatial resolution. As a result, they were able to classify patches of sand, gravel, and boulders with up to 95% accuracy.

Tracking how these patches grow or shrink over time could help document how events such as dam removal, experimental water releases, and natural floods influence sediment distribution. The team believes the technique should hold up away from the Grand Canyon calibration sites where it was tested, allowing for more accurate analysis of riverbeds around the world. (*Journal of Geophysical Research: Earth Surface*, doi:10.1002/2014JF003191, 2014) **—Eric Betz, Freelance Writer**

Joseph E. Hazel Jr., Northern Arizona University

Scientists survey from a boat at a study site along the Colorado River within the Grand Canyon, collecting high-frequency acoustic backscatter data with a multibeam echosounder to determine riverbed grain size.

Eos Positions Available ads can be viewed on Eos.org at **https://eos.org/jobs-support.**

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Atmospheric Sciences

California Institute of Technology Division of Geological and Planetary Science Assistant Professor in the fields of Atmosphere, Ocean, and Climate Dynamics

The Division of Geological and Planetary Sciences at the California Institute of Technology is seeking applicants for a tenure-track position at the assistant professor level. We seek applicants for a position in the broad area of the dynamics of the atmosphere, ocean, and climate. A strong commitment to both teaching and research is expected.

Initial appointments at the assistant professor level are for four years, and are contingent upon completion of the Ph.D. degree in a relevant field. Interested applicants should submit an electronic application at https://applications.caltech.edu/job/climate and include a brief cover letter, curriculum vitae, relevant publications, a description of proposed research, and a statement of teaching interests. Applications will be accepted until the position is filled.

Questions about the application process may be directed to marcia@gps.caltech.edu

EOE of Minorities/Females/Protected Vets/Disability

Ocean Sciences

Assistant Professor with focus on applications of tracers to resolving ocean biogeochemical processes. The College of Earth, Ocean, and Atmospheric Sciences at Oregon State University located in Corvallis, Oregon invites applications full-time (1.0 FTE) 12 month tenure-track position. We seek a colleague to develop and maintain a vigorous, externally funded research program in the observation of trace species in the ocean, and interpretation of distributions in the context of resolving ocean processes.

This position will complement and expand upon CEOAS research programs in Ocean Ecology and Biogeochemistry. Will teach undergraduate and graduate courses, which may include core ocean biogeochemistry and/or ecology; transition element, isotope, or transient tracer cycling; and analytical methodology. Advising and mentoring students and/or postdocs is expected. Requires: Ph.D. Ph.D. in oceanography, geochemistry, or a closely related field by the start of employment; scholarly potential demonstrated by a record of peer-reviewed publications and a clearly defined research agenda; potential for establishing a funded research program; potential for teaching excellence, student success, mentoring students/postdocs. For CEOAS information see: http://ceoas.oregonstate.edu To apply go to: http//oregonstate.edu/jobs posting #0015240. For full consideration, apply by 08/15/2015. Closing date: 09/30/2015.

Post-doctoral position in ocean ensemble prediction

A Post-doctoral research position in oceanography is available at NRL, Stennis Space Center. The objective of this project is to develop a state of the art global ensemble forecast system based on the Navy's operational HYbrid Coordinate Ocean Model (HYCOM) model. The system is expected to provide ocean forecasts and the associated uncertainty estimates that are critical to the US Navy's future missions. The technology to be used is based on the ensemble Kalman filter (EnKF) theory. The ensemble system is expected to be implemented for operation in the future. It will adequately represent the initial state uncertainties and accurately predict the ocean state and probabilistic information up to months. A stochastic forcing model is expected to be developed to account for the model-related uncertainties. This position is full time with a duration of one year initially and can be extended for further years. Applications will be reviewed immediately until the position is filled. Salary and benefits are highly competitive, relocation will be paid. Please email a resume and description of interest to Mozheng Wei (Mozheng.Wei@nrlssc.navy.mil; 228-688-4493).

Solid Earth Geophysics

2 Tenure-track positions (Seismology and Environmental Geosciences)

For the Seismology Department position we are looking for a young and enthusiastic scientist with a strong background in either: 1) Seismotectonics and Seismic Risk, or 2) Soil Response and Microzonation. All applicants must have experience with the use of large seismic and geodetic databases and with the application of geodetic techniques like InSAR, DinSAR, SAR, LIDAR and GPS to monitor land deformation. The proposed research plan must take advantage of the seismic and geodetic databases already existing at CICESE, aiming to address issues of local interest as well as increase our understanding of the seismotectonics of active faults and the broader field of deformation of active plate boundaries.

For the Geology Department position we are looking for a young and enthusiastic scientist with a strong background in the broad field of Environmental Geosciences. Areas of expertise include, but are not limited to, biogeochemistry, remote sensing, transport processes by land, air and water, and scaling of processes in time and space. Applicants must have completed a doctoral degree in Earth Sciences, Environmental Sciences, Soil Science or a related discipline. They must have a strong academic and publication record, a commitment to graduate instruction and thesis advising, disposition and ability for interdisciplinary and team research, as well as leadership and communication abilities. Postdoctoral experience in teaching and research is desirable, as well as success in attracting external funding, international experience, and linkages to non-academic sectors.

The successful candidates will have a strong academic and publication record, a commitment to graduate instruction and thesis advising, disposition and ability for interdisciplinary and team research, as well as leadership and communication abilities. Postdoctoral experience in teaching and research is desirable, as well as success in attracting external funding, international experience, and linkages to non-academic sectors. Duties also include participation in the M.S. and PhD. programs in Earth Sciences, offering courses, supervising graduate student research projects and promoting interdisciplinary thesis. Initially, teaching in English is acceptable, but the successful candidate should be able to switch to Spanish in a reasonable time frame.

CICESE is located in Ensenada, Baja California, Mexico, which also hosts a growing cluster of research institutions. It is the largest of 27 research centers coordinated by Mexico's National Council for Science and Technology (CONACYT), and includes Oceanography, Earth Sciences, Biotechnology and Applied Physics Divisions. More information about current research lines and infrastructure at the Seismology and Geology Departments, and CICESE in general can be found at http://www.cicese.mx.

Both positions are tenure-track but contracts are initially annual. The level of hiring depends on qualifications. Applications must include: a) cover letter, b) proposal of research and teaching objectives, c) curriculum vitae including publications, teaching experience and projects in which the candidate has been the PI or has participated, d) three reference letters, and e) three recent relevant scientific products.

Applications and questions regarding the positions must be addressed either to: Dr. Antonio Vidal-Villegas (Head, Seismology Department), vidalv@cicese.mx or Dr. Thomas Kretzschmar (Head, Geology Department), tkretzsc@cicese.mx (both with copy to Dr. Edgardo Cañón-Tapia (Director, Earth Sciences Division)), dir-ct@cicese.mx. Review of

applications will begin immediately and continue until the position is filled.

UC SANTA BARBARA, DEPARTMENT OF EARTH SCIENCE GEOPHYSICS

The Department of Earth Science at the University of California, Santa Barbara, invites applications for a tenure-track Assistant Professor position in Geophysics, starting July 1, 2016. We seek an innovative geophysicist who investigates solid Earth processes with modern geophysical data and/or simulation methods. All areas of technical expertise will be considered, with preference for seismology, geodesy, and/or numerical modeling. We seek candidates who complement our current research program and integrate tectonics and geophysics.

The successful candidate is expected to develop a vigorous, externally funded research program and to advise graduate and undergraduate students. A Ph.D. or an equivalent degree is required at the time of appointment.

Applicants should submit a PDF containing a letter of application, their curriculum vitae, a description of teaching and research objectives and accomplishments, and the contact information of three referees who will provide letters. Applicants should request that the three referees send letters of evaluation by October 1st, 2015. The application file and letters of reference should be submitted to https://recruit.ap.ucsb.edu.

Review of applications will begin October 1st, 2015. The position will remain open until filled, but to ensure full consideration, application materials should be submitted by this date.

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

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

Interdisciplinary/Other

Faculty Position in Earth and Planetary Science At Rice University Department of Earth Science

We seek creative and promising candidates across the broad spectrum of earth and planetary science who complement the disciplines represented in our department.

Successful candidates are expected to direct an active research program, supervise graduate research, and teach courses for undergraduate and graduate students. Details about the department and its facilities can be found at http://earthscience.rice.edu

Please send a CV, research and teaching statements, and names of four or more references to esci-search@rice.edu.

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Faculty Position in Geology or Geophysics at the University of Michigan

The Department of Earth and Environmental Sciences at the University of Michigan anticipates an opening for a tenure-track assistant professor in the areas of geology or geophysics for a university-year appointment starting September 1, 2016. The Department intends to pursue additional hires in this direction in future years, and we are particularly interested in candidates whose strengths will complement existing research programs within the Department.

Geology: We encourage applications from candidates whose research interests encompass the origin, evolution, or dynamics of the continents. The successful candidate will develop a strong field-based research program, complemented by expertise in modern analytical techniques or in numerical or analogue modeling. Candidates with an interest in understanding continental evolution in deep geologic time are particularly encouraged to apply.

Geophysics: We encourage applications from candidates who will develop an observationally based research program using geophysical methods (e.g. seismology, geodesy, or potential fields) to study the Earth at the crustal or continental scale. We are particularly interested in those applicants whose work is relevant to societal concerns including natural hazards, such as earthquakes, volcanism, and associated hazards, or environmental change to the hydrosphere or cryosphere.

The successful candidate is expected to establish an independent research program and contribute to both undergraduate and graduate teaching. Applicants must have a Ph.D. at the time of appointment, and should submit a CV, statement of current and future research plans, statement of teaching philosophy and experience, evidence of teaching excellence (if any), and names and contact information of at least four persons who can provide letters of recommendation.

Information about the Department and instructions for submitting an application can be found at www.lsa.umich.edu/earth.

To apply please go to http://www.earth.lsa.umich.edu/facultysearch/newapplicant, complete the online form and upload the required application documents as a single PDF file. If you have any questions or comments, please send an email message to Michigan-Earth-Search@umich.edu.

The application deadline is September 15, 2015 for full consideration, but applications will continue to be reviewed until the position is filled. Women and minorities are encouraged to apply. The University of Michigan is supportive of the needs of dual career couples and is an equal opportunity/affirmative action employer.

Two Positions: Stratigraphy/Sedimentology and Geomorphology/Climatology Denison University

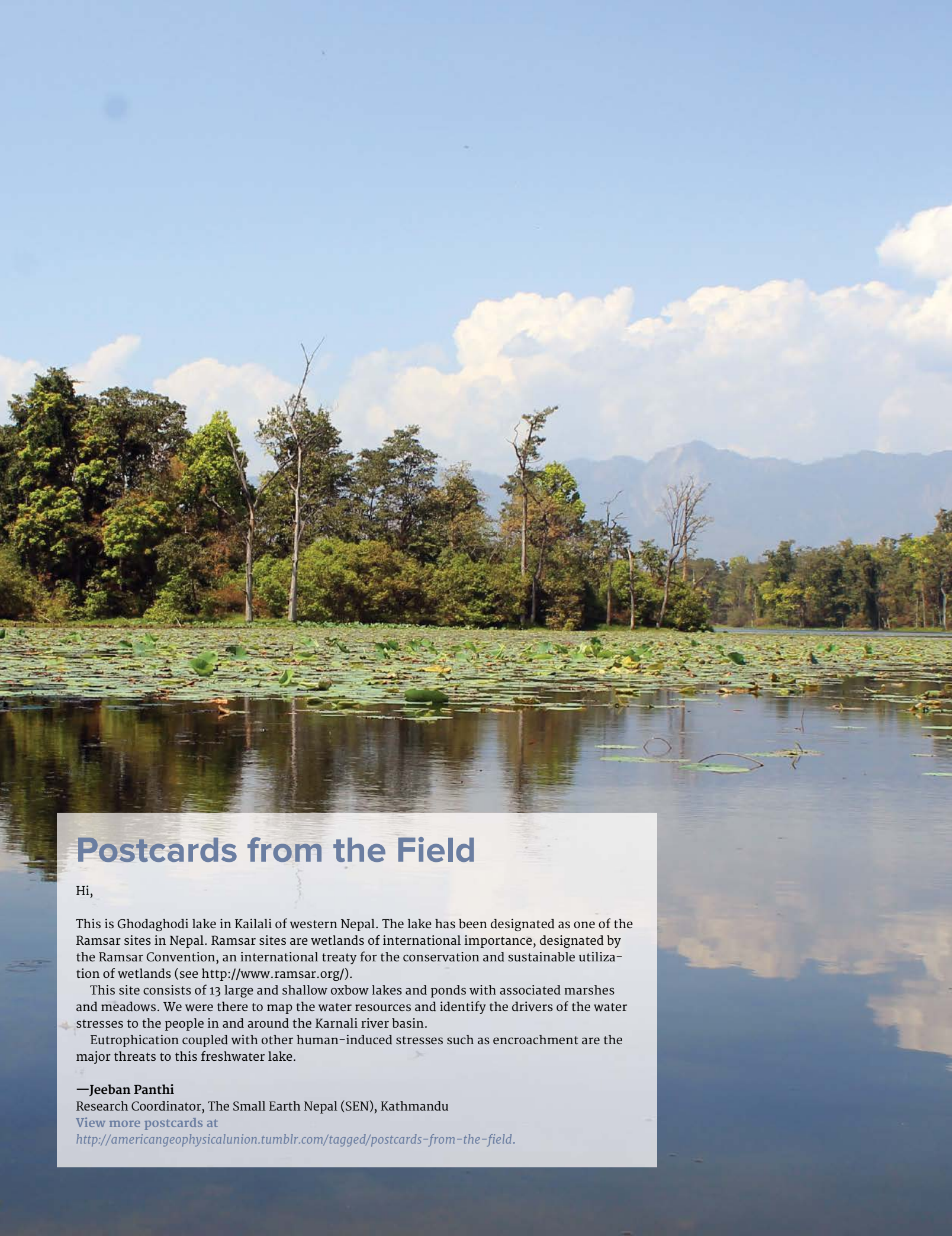
Denison University invites applications for two tenure track positions in the Department of Geosciences, to begin in August 2016. We seek broadly trained scientists engaged in the study of (1) Sedimentology and/or Stratigraphy, and (2) Geomorphology and/or Climatology. We welcome candidates that combine these specialties in innovative ways, and are willing to consider joint applications. Successful candidates should demonstrate potential to be outstanding teachers, active scholars, and contributors to the continued growth of the Department and College. Candidates must have a Ph.D. at the time of appointment.

We seek colleagues who are committed to teaching excellence in the liberal arts tradition, are field-based, have broad interests beyond their individual specialties, and will provide a balance of classroom, field, and laboratory experiences for our students. Candidates must have the desire and ability to teach courses at all levels of the curriculum. The typical teaching load is three lab courses per year. In addition, successful candidates are expected to maintain vibrant and productive research programs that actively incorporate undergraduate students.

Denison University is a highly selective, private residential liberal arts college enrolling approximately 2100 undergraduate students from across the country and around the world. The college is located in the village of Granville, Ohio, 25 miles east of Columbus. For more information about Denison, visit our website at www.denison.edu.

All application materials will be handled electronically at https://employment.denison.edu. (Please clearly indicate the desired position.) Applications must include: 1) a letter of application addressing the position requirements listed above; 2) a current curriculum vita; 3) academic transcripts of undergraduate and graduate course work (unofficial acceptable); 4) a statement of teaching philosophy and experience; and, 5) a statement of your research program in a liberal arts context. In addition, please include the contact information for three persons who know your teaching and scholarship well, who will then be requested to upload reference letters. Completed application materials submitted by October 15, 2015 will receive full consideration, and evaluation will continue until the position is filled. For those attending, we plan to meet with selected candidates at the 2015 GSA Annual Meeting in Baltimore, MD.

To achieve our mission as a liberal arts college, we continually strive to foster a diverse campus community, which recognizes the value of all persons regardless of religion, race, ethnicity, gender, sexual orientation, disability, or socioeconomic background. For additional information and resources about diversity at Denison please see our Diversity Guide at http://denison.edu/forms/diversity-guide. Denison University is an Affirmative Action, Equal Opportunity Employer.



Postcards from the Field

Hi,

This is Ghodaghodi lake in Kailali of western Nepal. The lake has been designated as one of the Ramsar sites in Nepal. Ramsar sites are wetlands of international importance, designated by the Ramsar Convention, an international treaty for the conservation and sustainable utilization of wetlands (see http://www.ramsar.org/).

This site consists of 13 large and shallow oxbow lakes and ponds with associated marshes and meadows. We were there to map the water resources and identify the drivers of the water stresses to the people in and around the Karnali river basin.

Eutrophication coupled with other human-induced stresses such as encroachment are the major threats to this freshwater lake.

—Jeeban Panthi
Research Coordinator, The Small Earth Nepal (SEN), Kathmandu
View more postcards at
http://americangeophysicalunion.tumblr.com/tagged/postcards-from-the-field.

AGU FALL MEETING

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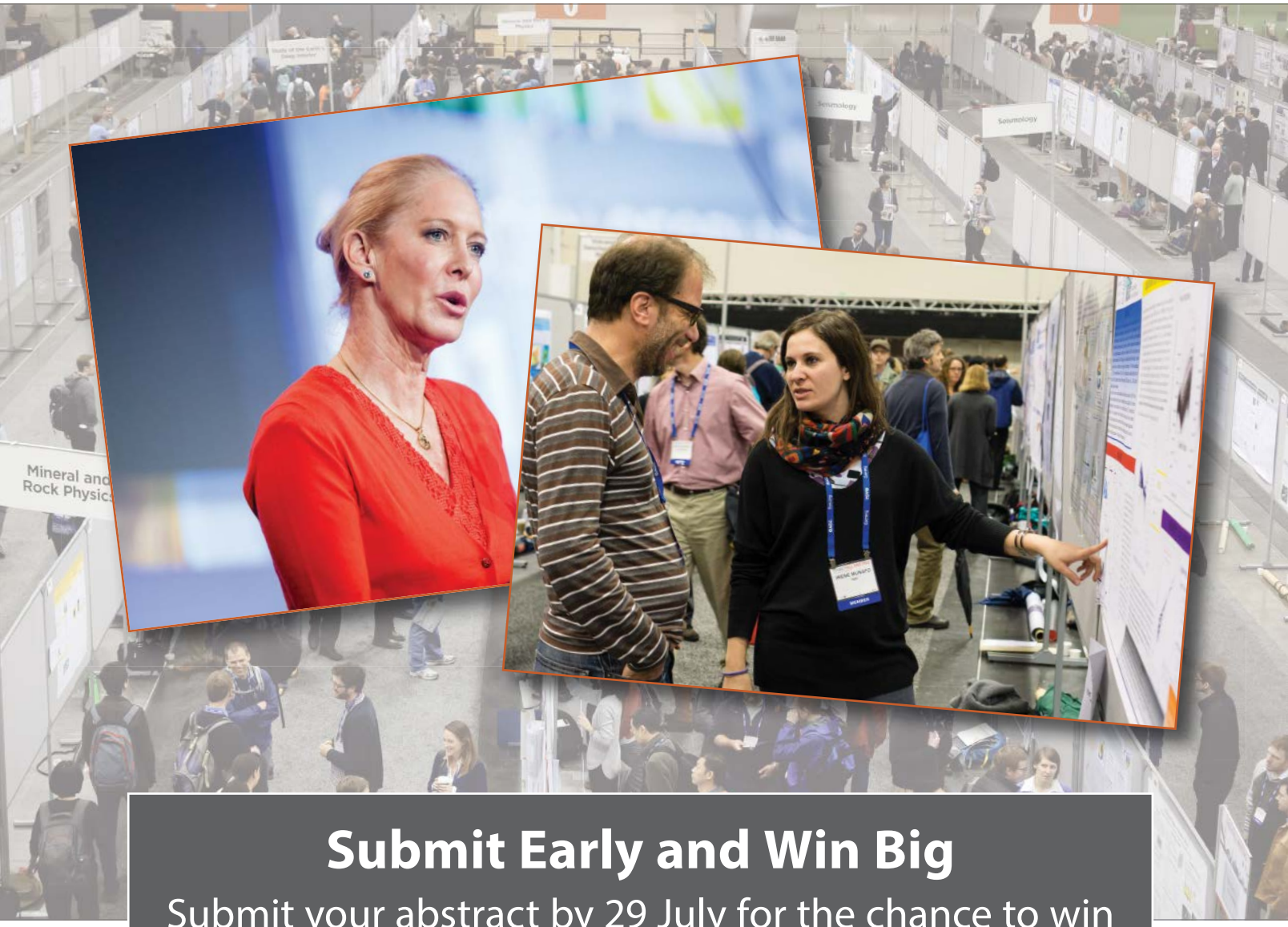

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