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The forces exerted by glide avalances can be calculated fairly well.

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Christine W. McEntee, Executive Director/CEO

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# Space Dust Delivered Water During Earth's Formation

Although existing theories of where Earth's water comes from assume that ice-rich comets or asteroids hit the planet after it formed, new research leaves those ideas in the dust. A team of researchers has found evidence that "Earth has had water since the beginning of its formation," according to planetary scientist Lydia Hallis, who led the team.

A recent paper (http://bit.ly/water-origins-paper) about this evidence, published on 13 November 2015 in the journal *Science*, points to Earth's water coming from motes of space dust with water molecules attached getting incorporated into the planet during its formation.

Hallis and her colleagues tracked the water back to its dusty source by looking at 60-million-year-old lava flows from Baffin Island, Canada, that originated deep within Earth's mantle. Within these lava flow samples, which cooled into rock after erupting, the team found a low ratio of two isotopes of hydrogen—specifically, deuterium to ordinary hydrogen (D/H). The low value strongly indicates that Earth's water came from the solar nebula—a swirling disk of dust around the early Sun from which the planets and other bodies in our solar system formed.

### Heavy Water Holds the Answer

Deuterium is a neutron-containing hydrogen isotope; water containing deuterium is sometimes referred to as heavy water. Planetary scientists can use the ratio of deuterium to hydrogen within a planet's water reservoirs to determine the water's origin. "It's a signature for where that water came from in the solar system," said Hallis. Earth's water resides not just in such familiar locations as oceans, aquifers, and clouds but also in rock or magma permeated with water molecules and located deep within the planet.

Easily accessible reservoirs of water near Earth's surface, such as the oceans, contain deuterium but not at the same concentrations as when the planet first formed. The concentrations have changed due to contact with the atmosphere, crust, and upper mantle and exchanges of molecules and atoms between those different layers. Although portions of Earth's mantle do mix, Hallis thinks that the area of the deep mantle where the Baffin Island lava flows came from was an isolated region of the heterogeneous mantle. Therefore, those flows didn't mix with magma from the upper mantle or the crust before erupting, which allowed them to preserve their original D/H ratio, she and her team reported in their paper.

"I think the most important thing is that they've made a good attempt to measure Earth's original D/H ratio," said planetary scientist Benjamin Weiss of the Massachusetts Institute of Technology (MIT) in Cambridge, who was not involved in this research. He said that measurement marks the first step toward really understanding where our water came from.

### Comets and Meteorites Don't Match Up

Using the Sun as a proxy for the solar system-forming nebula, Hallis and her colleagues found that it is the only body in the solar system with as low a D/H ratio as the lava flows. However, when they compared their lava samples to meteorites, which are shards of comets or asteroids that landed and were found on Earth, all the meteorites had higher D/H ratios. The mismatch indicates that, most likely, neither the parent comets or asteroids nor the shards from such bodies are the source of Earth's water, Hallis told *Eos*.

A study (http://bit.ly/chondrites) published a little more than a year ago in *Science* also argued that Earth received its water as it was forming, but from really old meteors called carbonaceous chondrites. However, the D/H ratio that Hallis and her colleagues determined for the deep mantle is lower than that of the chondrites, Hallis said, suggesting that something that preceded those meteors—i.e., the nebula's dust—delivered the water.

Still, MIT's Weiss said we know too little about the D/H ratios of all asteroids and comets to rule them out as a source of Earth's water. "The trouble is, we don't know the full range of meteorites," he explained. "Our meteorites are just a tiny sample of the enormous diversity of asteroids that are out there."

In the future, meteorite specialists might discover some of the space rocks with D/H ratios closer to what Hallis and her colleagues found in the lava flows. In the meantime, their findings "definitely make it less probable that [asteroids] are the source," Weiss said.

### Other Planets Formed Similarly

Some scientists challenge the idea that water always existed on Earth because the extreme heat of the early solar system would evaporate any water. Hallis said that although the Earth probably did and still does lose hydrogen and therefore water, she believes the Earth kept most of its water. Earth's thick atmosphere and its magnetic field, which slows down atmospheric erosion by fending off the wind of charged particles from the Sun, help to reduce water losses. Other rocky planets probably formed with water in the same way as Earth but then lost their water—Mars lost its protective magnetic field and atmosphere, whereas conditions on Venus caused water molecules to break up and release hydrogen into space.

"There's no reason why, if Earth accreted in this way, that Venus, Mars, and Mercury, and maybe the other rocky bodies in the solar system, wouldn't have accreted in this way as well," said Hallis.



*Recent research points to all of Earth's water originating from water-laden dust particles present in the nebula from which the solar system formed.*

By **Cody Sullivan,** Writer Intern

# Laser Beams Brighten Prospects for Cave Science

David Black

*Ben Shinabery (right), a land surveyor in Louisville, Ky., stands in Big Bat Cave with a volunteer and a lidar scanner sitting atop a tripod.*

A compass, some measuring tape, a couple of waterproof notebooks, and a pencil or indelible pen: These are the bare minimum supplies a caver needs to create a map of a cave. While one person measures, sets compass headings, and calculates angles and true distances, another person slowly trails behind, making intricate hand-drawn sketches of the cave's geological features.

These days, cavers also employ handheld instruments that use laser beams to determine heights and distances. This is how Dave Field, a retired geophysicist and avid caver who heads the Mid-Atlantic Karst Conservancy, maps caves in Pennsylvania. However, these small instruments don't have the range needed to determine the size of large caverns where roofs and tunnel endings may be lost in darkness.

Several hundred miles away, in Breckenridge County, Ky., cave enthusiast and former state cartographer Ken Bailey, who is now the president of the Kentucky Karst Conservancy, deploys a much more powerful laser technology to map caves. The equipment, called a lidar terrestrial scanner, offers much greater range and data-gathering ability than handheld devices.

Bailey has teamed up with Ben Shinabery, a land surveyor with access to a scanner, to create three-dimensional (3-D) cave maps of Big Bat Cave—the world's 57th longest cave—near Custer, Ky. (see http://bit.ly/big-bat). Unlike Field's laser range finder, a lidar scanner pulses thousands of times per second, gathering thousands of data points per pulse. The data, when processed with powerful software, spit out a precise 3-D map of the cave, opening up whole worlds of information.

## First Maps, Then Science

Although people have explored caves since there have been people, the quest for scientific insights from caves remains a challenge. Scientists who work in caves say that ways to map caves more thoroughly and accurately could have a major influence on how that quest goes.

"I tell many cavers that [they're] the Lewis and Clarks" of cave science, said George Veni, a hydrogeologist and executive director of the National Cave and Karst Research Institute. "Without these maps, we can't do the science in any effective manner."

As a hydrogeologist, Veni looks at maps of caves that act as aquifers and can see how such caves function, right down to the permeability of the rocks, the structure, and the very plumbing of the terrain.

Mapping caves with the precision of lidar could also open up investigations to a wide range of scientists outside of hydrology, Veni said, from biologists studying bat populations, to archaeologists studying ancient societies, to geomorphologists studying how caves form, change, and erode. Caves also offer a multitude of localized paleoclimate data, Veni said, which could be revealed by 3-D maps.

## Lidar's Ups and Downs

Lidar has already proven itself a boon to science beyond the confines of caves. In the past couple of decades, scientists have used it to study Earth's surface and atmosphere and to investigate forests, ice sheets, mountains, and even coral reefs in high resolution.

Lidar works by shooting pulses of laser beams at a target, measuring how long it takes for the light to bounce back, and then calculating the distances. Some say that the technology's name derives from "light radar" because the technology works like radar but uses pulses of light instead of radio waves. Others identify LIDAR as an acronym, probably for "light detection and ranging."

In Pennsylvania, Dave Field relies on publicly available aerial lidar data of the state's topography to find sinkholes that might lead him to caves. Since the data became available, he said, the rate of discovering sinkholes has gone up significantly.

"It's been a real enlightenment just to see how much karst is out there," Field said, using a term for any landscape built on rocks, such as limestone, that water slowly dissolves—a process that creates such features as sinkholes and caves.

Below ground is another matter. The equipment isn't terribly portable, Veni said. Cave exploration often requires a person to squeeze through excruciatingly tight tunnels, navigate up and down sudden rises or drops, and sometimes even swim through water—with only 3 centimeters of breathing room underneath a tunnel's roof.

"It's a new tool, and, again, we're taking it into an environment that is hostile to electronics," Veni said.

Because the technology is so expensive—a good lidar scanner can cost more than a hundred thousand dollars—not many scientists have been able to take advantage of this valuable tool, Field noted.

## The Largest Caves

Andy Eavis, a self-described "cave fanatic" who has been exploring caves for more than 50 years and has mapped more than 500 kilometers of caves around the world, is currently using lidar technology to scan the world's

largest cave chambers. In preparation for the International Union of Speleology meeting in 2017, he and his team plan to produce 3-D-printed models of the vast caverns. The purpose, Eavis said, is to concretely define particular cave terminology like "passageway" or "chamber" because there is still some disagreement over what exactly these terms mean. For instance, how wide is a "passageway"? How high must the roof be to call an area a "chamber"?

Eavis and his team use a lidar scanner with a resolution of 1 centimeter and a range of up to 400 meters, which has suited their needs perfectly because one of the caves they scanned in November 2015—Cloud Ladder Hall in China—hosts a roof towering 365 meters (1197 feet).

"These roofs are bigger than any roofs man has ever made. Structurally, they shouldn't really stay up; they should have fallen down a long time ago," Eavis said.

In the past 2 years, Eavis and his team have mapped nine chambers in Malaysia, China, Spain, and France. Upcoming trips include visits to caves in Iran, Oman, Mexico, and Belize. A 3-D map produced by laser scanning of the Miao Room in China was recently documented in a *National Geographic* feature (http://bit.ly/Super-Cave).

After Eavis and his team are finished with their multicave scanning project, he says they'll sell the $150,000 scanner because they will have no more use for it.

### Conservation Efforts

Shinabery, the land surveyor, travels from Louisville, Ky., to Big Bat Cave once every 2 months to scan another leg and is often accompanied by a team of volunteers—students looking for research experience, members of the community who want to explore the cave, or local scientists. The karst conservancy has already put together videos of the scanned portions of the cave (see http://bit.ly/bbcave-flythru).

Bailey hopes that creating 3-D maps of Big Bat Cave and other Kentucky caves might lead to more conservation efforts. Caves not only provide homes to living things, including bat colonies that are currently being decimated by white-nose syndrome, but also provide water to millions of people across the nation.

However, if people can't see the caves, they might not care, Bailey said.

"We are protecting ourselves when we protect [caves]," he continued. "To be able to show people who will never go there why it's worth saving is what the lidar is for me."

By **JoAnna Wendel,** Staff Writer

# New Study Reveals How Much Groundwater Remains

Groundwater comprises a third of all freshwater on Earth and provides humans with a necessary source for irrigation and drinking water. However, until recently, the only groundwater supply estimates relied on rough calculations dating back to the mid-1970s. A new study provides the first data-driven calculations of the total supply and uncovers how much usable groundwater we have left.

To perform their calculations, researchers drew from a wealth of existing geochemical, geologic, and hydrologic data. "In the past, all of this data was kind of hidden in books and maps, and now it's much more readily available for these kinds of novel science questions," said Tom Gleeson, a hydrogeologist at the University of Victoria in British Columbia, Canada, and the lead researcher of the study, which was published on 16 November 2015 in *Nature Geoscience*.

> If the total volume of groundwater in the top 2 kilometers of crust were extracted and pooled across the continents, it would be about 180 meters deep.

The study (http://bit.ly/gwater-study) revealed that if the total volume of groundwater in the top 2 kilometers of crust were extracted and pooled across the continents, it would be about 180 meters deep. But the quantity of what the researchers call "young" groundwater is far smaller.

### Young Groundwater

Gleeson defines young groundwater as groundwater that has been recharged within the past 100 years. Although some regions—for instance, California—can use older groundwater, it is far too brackish in most places. So communities generally rely on young groundwater sources, he said. "If you take all that young groundwater out of the Earth, it would only be 3 meters high. So about the height of a stop sign," Gleeson said.

Of that young groundwater, he and his team have further focused on groundwater that accumulated in roughly the past 50 years, which they called "modern" groundwater. This analysis showed that very little—only 6%—of total groundwater gets replenished in roughly a human lifetime. "We're using our groundwater resources too fast—faster than they're being renewed," Gleeson said in a press release.

The researchers identified the modern groundwater by how much tritium, a radioactive isotope of hydrogen, the water contains. Modern groundwater contains higher concentrations of tritium than older groundwater because tritium fallout from thermonuclear tests in the mid-20th century spiked the water. Gleeson and his colleagues developed a database of tritium measurements, which they used with watershed models to estimate the volume of the modern groundwater.

The new study provides the first estimate of the volumes of young and modern groundwater and a map of the distribution of modern groundwater across the globe, Gleeson said. The team's estimate for total global groundwater closely matched the total groundwater calculations from the 1970s, he added.

### Going Deep

Gleeson said he hopes the team's new findings will enable policy makers to make more informed decisions about groundwater use in the future. "The depth of the groundwater is really important to know in terms of how deep we need to drill and how costly that would be," he said. The new maps might also prove useful for locating regions where industry and agriculture are putting usable groundwater at risk.

The team plans next to map the amount of time it will take before groundwater extraction around the world begins to affect the flow of the life-supporting rivers fed by groundwater, Gleeson said.

By **Shannon Kelleher,** Writer Intern

# What Is the Anthropocene?

Since Paul Crutzen and Eugene Stoermer introduced the word "Anthropocene" in 2000, scientists and nonscientists alike have used the word to highlight the concept that we are now living in a time when the global environment, at some level, is shaped by humankind rather than vice versa. Humans have significantly altered Earth's land surface, oceans, rivers, atmosphere, flora, and fauna. By its emphasis on the here and now and on what humans have done and can do in the future, the word "Anthropocene" has served as a call to action for environmental sustainability and responsibility [*Crutzen and Stoermer,* 2000; *Waters et al.,* 2014; *Ruddiman et al.,* 2015].

So far, however, the term "Anthropocene" has not been integrated into the official Geologic Time Scale, which geologists use to divide the past into named blocks based on the rock record. In 2016 or thereabouts, the International Commission on Stratigraphy—the scientific body that maintains the official Geologic Time Scale—will consider a proposal to formalize a definition of this term. It's a decision that has both semantic and scientific implications and may have legal implications as well.

## Multiple Meanings

Scientists generally agree on certain characteristics of the word "Anthropocene":

- It is here to stay, with more than 500,000 Google hits and growing.
- It carries connotations of human dominance of the environment.
- The Anthropocene is not currently a formal part of the Geologic Time Scale.

Underneath our agreements lies a major divergence in philosophy. Let's start with a simple test (Figure 1). The data shown on the left are abundances of corn pollen and corn smut spores in sediment layers in a lake in southern Ontario, Canada (although any proxy for anthropogenic influence could be used).

Can you relate your concept of the Anthropocene to a specific sedimentary record? Your answer likely reflects your views about making the Anthropocene a formal part of the Geologic Time Scale.

If you answered A, B, or C, you probably think you favor including the Anthropocene as a formal part of the Geologic Time Scale—especially if your particular choice of start date is selected. If your choice is not selected, you may not favor formalization at all.

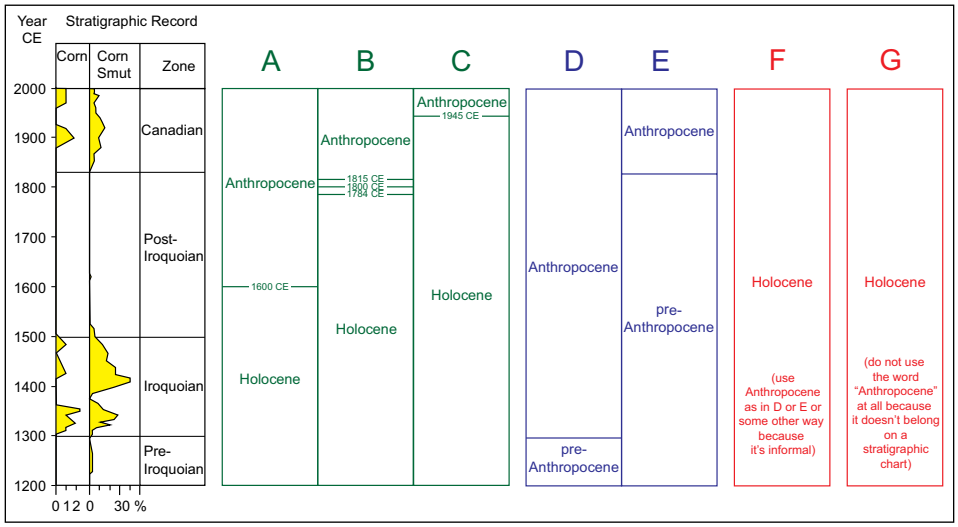


*Fig. 1. (left) A simplified pollen/spore diagram (redrawn from* McAndrews and Turton *[2010]) of the record from a lake sediment core with annual layers in southern Ontario, Canada. Variations in percentage of corn pollen (labeled "corn") and spores from a corn smut fungus serve as a proxy for human impact. Chronology comes from layer counts and radiocarbon dating. (right) Seven of the many concepts of the word "Anthropocene" (A–G) that divide this record. CE = Common Era. For additional discussion of various choices, see, for example,* Autin and Holbrook *[2012a, 2012b],* Edgeworth et al. *[2015],* Finney *[2014],* Gale and Hoare *[2012],* Gibbard and Walker *[2014],* Lewis and Maslin *[2015],* Ruddiman et al. *[2015],* Steffen et al. *[2015], and* Zalasiewicz et al. *[2014, 2015].*

If you answered D or E, you probably oppose formalization. The choice you made is based on cultural considerations—here with either a First Nation (D) or Eurocentric (E) emphasis. You probably don't want a subset of geologists to co-opt the word "Anthropocene" for their concepts.

If you answered F or G, you probably mildly (F) or strongly (G) oppose this inclusion.

In any case, no matter how you use the term "Anthropocene," others are using the same word with a very different meaning.

## Contrasting Philosophies

Throughout history, humans have divided time into named portions. Giving a name to something makes communication and analysis easier. For communicating time, two general philosophies are popular among various scientific disciplines.

One philosophy is to name time segments by some means of recognizing defined points in time. For example, the Victorian era can be defined precisely by the dates of the reign of Queen Victoria of England (20 June 1837 to 22 January 1901). Named intervals of time represent the same starting and ending points and are of the same duration everywhere. This precision is relatively easy when dealing with historical time; it becomes more difficult when dealing with the geologic record.

A second philosophy is to name time segments by stages in human cultural development, such as the Bronze Age and the Renaissance. The Bronze Age reflects neither a specific starting date nor a duration of a specific number of years. Rather, it begins and ends at different dates at different places on the basis of the presence or absence of specific features in the development of the civilization present in a particular place.

Geologists, like other scientists, have rules and precedents for formal nomenclature, and these are embodied in the Geologic Time Scale. The scale is tied to the rock record and took shape over centuries, often without strict definitions. Since the 1970s, however, the International Commission on Stratigraphy of the International Union of Geological Sciences has been the arbiter of the terms appearing on the Geologic Time Scale.

The Geologic Time Scale includes only those terms that, to the best of current knowledge, relate to the rock record of specific segments of geologic time. Each unit represents, conceptually, the same interval of time everywhere in the world. Although imprecision in recognizing the time signal in the rock record imposes limitations, no unit of the Geologic Time Scale is specified to have different durations in different parts of the world, and there is no geologic record of the future.

If the Anthropocene is to become a formal part of the Geologic Time Scale, a unique point in time must mark its beginning. Although it is tempting to examine at length the relative merits of various particular starting points, the real discussion should focus on a different question: Can any unique point in time coexist with current Anthropocene concepts and usage? In other words, does the Anthropocene have a beginning that is the same everywhere, or does it begin at different times in different places because it represents a holistic concept that involves time, place, human cultural attainment and dominance, and a variety of environmental effects [*Edgeworth et al.,* 2015; *Ruddiman et al.,* 2015]?

### Hierarchy

If the Anthropocene is to be incorporated into the Geologic Time Scale, the International Commission on Stratigraphy will have to deal with the question of rank. Each unit in the time scale has a rank. Eras are divided into periods, which are divided into epochs, which are divided into ages.

A quick search in the scientific and popular literature for the term "Anthropocene" reveals an obvious lack of consensus on its rank. Hundreds of citations refer to an Anthropocene era, an Anthropocene period, an Anthropocene epoch, and an Anthropocene age. In fact, the term "Anthropocene" is so widely employed that many users must be quite unaware of the formal rank terms of geologists.

Rank has consequences. If the rank of era is appropriate for the Anthropocene, the direct corollary is that the Cenozoic era, which began approximately 66 million years ago with the demise of the nonavian dinosaurs, has ended. If the Anthropocene is a period, then the Quaternary period, which began approximately 2.6 million years ago at a time of major glacial–interglacial fluctuation, has ended. If it is an epoch, then the Holocene epoch, the interglacial (warm) interval that began 11,800 years ago, has ended. If it is an age, then it is the current age within the Holocene epoch.

These consequences extend far beyond the scientific community. For instance, many building codes have strict legal definitions of what constitutes a "Holocene fault." If the Holocene epoch were to be over, perhaps a developer would try to build in an area of active ground movement because, technically, there is no Holocene fault. Or would "Holocene" have two meanings: one geological, one legal?

### Possible Outcomes

The International Commission on Stratigraphy has set a target date in 2016 for consideration of a proposal to formalize the Anthropocene. I see three possible outcomes:

- The word "Anthropocene" will be assigned a specific start time (which will not please everyone) and will be added to the formal Geologic Time Scale. In this case, the word "Anthropocene" will not have a 1:1 correspondence with any and all things anthropogenic. If the Anthropocene is assigned the rank of epoch, then the Holocene is over. Rigorously applied labels such as Holocene and Anthropocene will be used in all discussions of anthropogenic deposits or anthropogenic environmental effects that originate before the chosen start time.
- The word "Anthropocene" will be used in a cultural sense to indicate and call attention to the fact that humankind significantly influences the global environment. It will represent a holistic concept and may have different start times in different places in the world. It may depend on different features or environmental effects. Deposits of anthropogenic origin will be considered Anthropocene deposits. The Anthropocene can easily be depicted on the formal Geologic Time Scale but will not be a formal unit of it. Some people may consider the Anthropocene to be an informal unit of geologic time. Others may not consider it a time unit at all.
- The word "Anthropocene" will be assigned a specific start time and placed on the formal Geologic Time Scale, but a significant proportion of its use would be in direct contradiction of the basic tenets of stratigraphic correlation and terminology. Many scientists will now say that it is acceptable to have an Anthropocene epoch that is openly acknowledged to vary in age from place to place. These scientists will include those who in the past have recognized that chronostratigraphic correlation (although never perfect) strives to recognize time equivalence. The term will be used by all but strict-constructionist stratigraphers in a variety of ways to mean different things to different people, most of them thinking that their way is formal and correct.

In the next year or so, the International Commission on Stratigraphy will make a decision, and the rest of us will have to live with it. Is the Anthropocene a specific subdivision in the continuum of time, or is it a holistic concept that includes time but is not defined by it? Which decision will serve us best?

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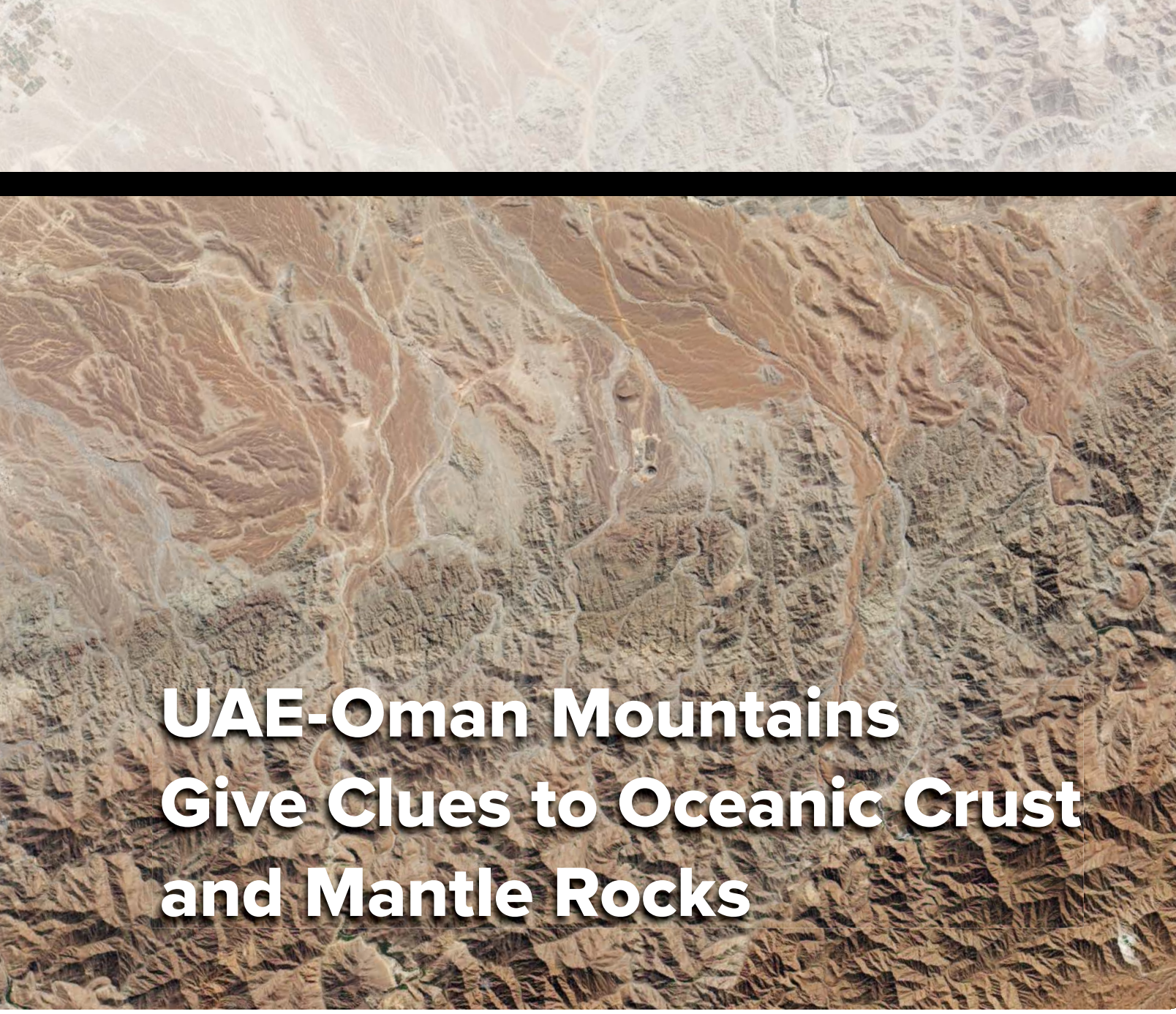


# UAE-Oman Mountains Give Clues to Oceanic Crust and Mantle Rocks

By Simone Pilia, Mohammed Y. Ali, Anthony B. Watts, and Michael P. Searle

When oceanic plates meet continental plates, the continental plates usually come out on top. Cases where this is reversed provide valuable access to oceanic crust and mantle materials.


As a rule, when tectonic plates made of dense oceanic crust material meet plates of more buoyant continental crust material, the oceanic plate moves beneath the continental plate and sinks into the mantle in a process known as subduction. Occasionally, however, a process called obduction thrusts sheets of oceanic crust and upper mantle rocks over the top of less dense continental material [*Coleman*, 1981]. Although obduction is regarded as a geodynamic anomaly [*Agard et al.*, 2014], it is not an uncommon occurrence.

*This aerial photo of the Semail ophiolite shows crustal basalt deposits (gray rocks at left, toward the north) that solidified in deep water in the ancient Tethys Ocean and peridotites from the Earth's mantle farther south (brown rocks at right).*

The evidence of such a process is contained in ophiolites, sequences of oceanic crust and upper mantle rocks found near the surfaces of continents. By far the largest, best exposed, and most studied ophiolite complex is the Semail ophiolite in the eastern corner of the Arabian Peninsula, spanning Oman and the United Arab Emirates (UAE) [*Glennie et al.*, 1973; *Lippard et al.*, 1986; *Searle and Cox*, 1999].

Although scientists have mapped and studied the surface geology of this region in detail, the middle to lower crustal structure of the UAE-Oman mountains remains an

enigma. Despite more than 40 years of detailed geological studies, a lack of high-resolution geophysical imaging beneath the UAE-Oman mountains remains.

In an attempt to unravel the structure beneath both the Semail ophiolite and the underlying crust of the UAE-Oman mountain range, scientists from the Petroleum Institute in Abu Dhabi, UAE, have teamed up with geologists and geophysicists from the University of Oxford in Oxford, U.K. Their detailed geophysical and geological observations represent significant progress toward solving the ongoing debates about the ophiolite emplacement processes.

## Evidence of Past Events

From middle Permian to mid-Cretaceous times (about 270 to 95 million years ago), the Arabian margin was a tectonically stable, passive, dominantly carbonate continental margin. During the Cenomanian–Turonian time (about 96 million years ago), the Semail ophiolite formed in the Tethyan region to the northeast as a result of a subduction-obduction process that thrust thin-skinned Tethyan oceanic sheets onto the collapsed continental margin. Flexural loading of the thrust sheets caused a foreland basin, the Aruma basin, to develop in front of the obducting ophiolite.

The UAE-Oman mountains are 150 kilometers wide and stretch for 700 kilometers, and they expose the Semail ophiolite thrust sheet, which is roughly 15–20 kilometers thick. Beneath the exceptionally well preserved Semail ophiolite, a series of thrust sheets of oceanic sedimentary and basaltic rocks, emplaced from northeast to southwest, separates the overlying ophiolite from the Arabian continental rocks beneath.

The structural fabric of these thrust sheets can be reconstructed to gain an understanding of the paleogeography of the Tethys Ocean that lay adjacent to the Arabian plate during Cretaceous times. The most distal thrust sheets (farthest from the areas of geologic activity) include deep-sea sediments, including cherts, radiolarian oozes, carbonate seamounts, and basalts, that immediately underlie the ophiolite. Restoration of thrust sheets between the ophiolite and the Arabian margin reveal more than 200 kilometers of horizontal shortening and thrusting [*Searle et al.*, 2015].

> The middle to lower crustal structure of the UAE-Oman mountains remains an enigma.

Along the base of the ophiolite thrust sheet, irregular occurrences of metamorphic rocks, amphibolites, and greenschists are termed the "metamorphic sole." Constraining the pressure, depth, temperature, and timing of metamorphism in these rocks enables us to reconstruct processes operating during oceanic subduction and ophiolite formation.

One unique thrust slice, the Bani Hamid thrust sheet in the northern Oman-UAE mountains, shows a 1-kilometer-thick sequence of extremely high grade marbles and quartzites (granulite facies). This sequence was formed during the latter part of the obduction process, when these buoyant rocks were jammed in the subduction zone and then thrust into the middle of the ophiolite [*Searle et al.*, 2015]. The thickness of the ophiolite thrust sheet and the structures in the underlying deeper part of the mountain belt, however, remain poorly known.

## Unanswered Questions

Two aspects of ophiolite research remain controversial: the tectonic setting of an ophiolite's origin (mid-ocean ridge, suprasubduction zone, transform fault) and the mechanism of their emplacement onto continental margins.

Detailed geochemical analyses of the crustal components provide information on the tectonic setting. Constraints on the geochronology of events are provided by uranium-lead isotopic ages from ophiolite crustal rocks and amphibolite minerals in the metamorphic sole. The mechanism of emplacement of large thrust sheets of dense ophiolite rocks onto more buoyant continental crust is determined from detailed structural mapping of the ophiolite and thrust sheets beneath combined with geochronological constraints.

Surface mapping can, however, examine only the upper crustal rocks that are exposed. We rely purely on geophysical methods to determine the structure of the deep, unexposed parts of the crust.

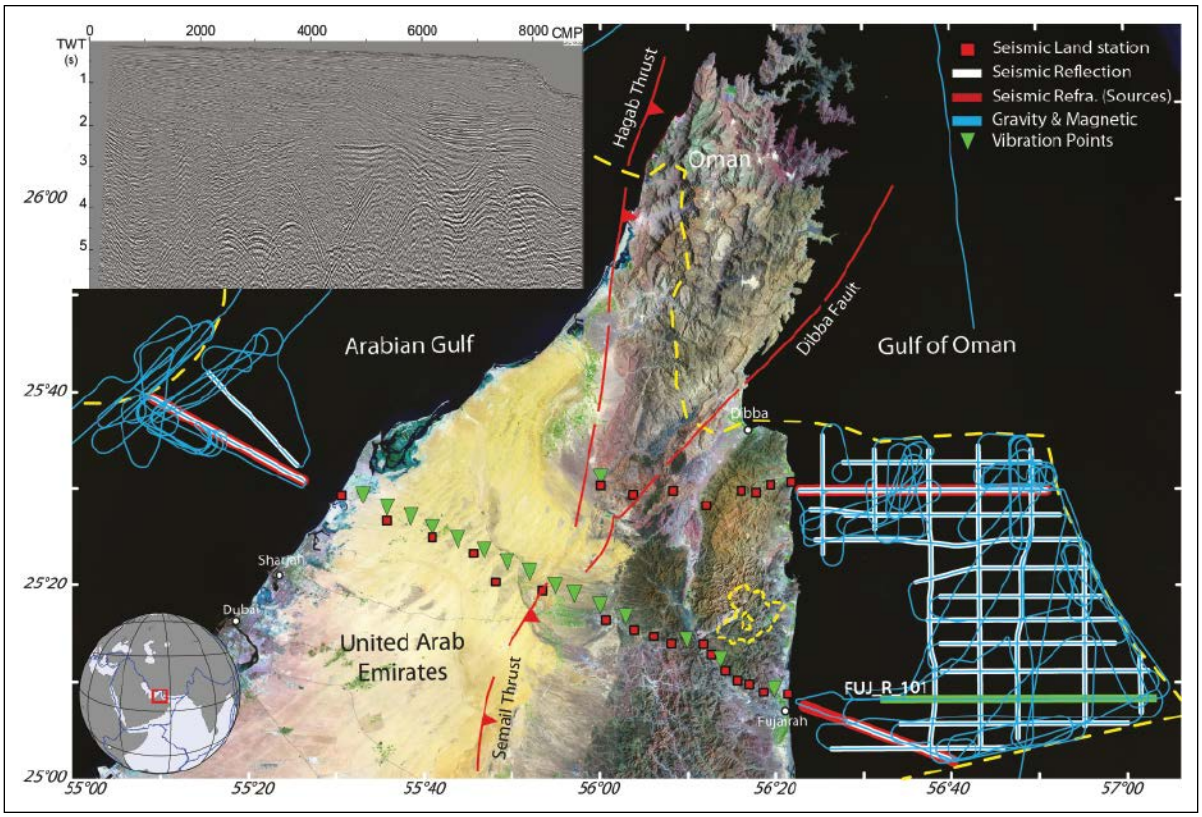
## Collecting Geophysical Data

To illuminate the crustal and upper mantle structure beneath the UAE-Oman mountains, the research team carried out the first integrated seismic reflection and refraction experiment in the UAE-Oman region in July 2014. Passive and active seismic techniques will be used to construct new images of the structure of the crust, which will be verified by potential field (gravity, magnetic) modeling. The scientists also plan to acquire vibroseis seismic data, in which a "thumper truck" generates vibrations in the ground, in early 2016 to complement the existing data set (Figure 1).

Seismic reflection data were acquired along a grid of lines totaling 925 kilometers in the Arabian Gulf and Gulf of Oman (Figure 1) using the survey ship M/V *Hawk Explorer*. The ship towed an array of air guns (total volume of 7060 cubic inches, 116 liters) for generating seismic waves and a 5-kilometer-long multichannel streamer to record reflections from subseafloor sediments and basement rocks.

Seismic refraction data were acquired along selected reflection lines using 25 broadband land recording stations. The refraction data consisted of about 800 air gun shots fired at 50-second time intervals. Gravity and magnetic data were continuously collected throughout the cruise. Similar data will also be acquired along the east-west onshore refraction transects and will be integrated with existing onshore and offshore data.

Broadband seismometers are currently recording teleseismic earthquakes (more than 1000 kilometers from the measurement site). Analysis of three-component wave fronts and shear-wave splitting from these data will provide new insights into the deep lithospheric structure and degree of anisotropy, respectively.




Adapted from Landsat

*Fig. 1. This satellite image shows the site of the experiments. Shots for the refraction experiment were fired offshore (thick red lines) and recorded on land by broadband seismometers (red squares). Reflection transects are indicated by white lines. Gravity and magnetic data (light blue lines) were acquired throughout the cruise. We plan to deploy vibroseis trucks to several locations (green inverted triangles) to complement the existing data set. The yellow dashed line depicts the boundary between the United Arab Emirates (UAE) and other countries; the bottom left inset shows the location of the UAE. The top left inset shows a seismic record for reflection line FUJ_R_101 (highlighted in green).*

We anticipate that in the near future, the instruments will be moved to different locations within the UAE. This relocation will augment the existing national seismic network, and the resulting data set will be used to apply additional passive techniques (e.g., ambient noise tomography) and to study the earthquake hazards in the country. These sensors will extend the array coverage of the mountains, which, coupled with cutting-edge tomographic inversion techniques for analyzing seismic data, could potentially play a major role in deciphering the tectonics of the region. In addition, a detailed surface geology map of the ophiolite will be produced for the area across the two seismic refraction profiles.

### Applying the Data to Key Scientific Questions

As discussed above, much of the controversy surrounding ophiolites around the world concerns their origin, tectonic setting, and the mechanism of emplacement onto continental crust. The UAE-Oman mountains have proved critical to the general understanding of ophiolites because they have been mapped in great detail and have been subject to extensive high-precision geochemical and geochronological analyses that constrain the igneous history and metamorphic evolution of the sole amphibolites.

The rocks of the Bani Hamid thrust sheet in the northern UAE-Oman mountains constrain the metamorphic history of the subophiolite rocks that pin down both timing and depths of metamorphism [*Searle et al.,* 2015]. The thickness of the ophiolite thrust sheet and the structures in the underlying deeper part of the mountain belt, however, remain poorly understood. Part of the reason for this is the lack of high-resolution geophysical imaging.

Despite the abundance of recent geological and geochemical data interpretations, including those of the Semail ophiolite, project scientists believe that the ongoing debates about ophiolite formation and emplacement cannot be solved without further detailed geophysical and geological observations.

Moving forward, we will investigate various scenarios by combining new geophysical evidence, structural mapping, and geochemical analysis of rock sample data. We hope that the new data will shed light on critical structural questions and processes such as the following:

- the geometry of thrust sheets beneath the Semail ophiolite
- the structure of the Hagab thrust beneath the Musandam culmination that reflects the initial continental collision
- how the older obduction-related thrust sheets affect the Hagab-type thrusts

- the deep crustal structure of the northeastern margin of the Arabian plate
- the velocity structure of the crust and uppermost mantle beneath the orogenic belt and the flanking UAE foreland basin and Gulf of Oman rifted margin

The seismic refraction profiles will ensure that meaningful inferences can be made on the main structural elements of the crust and upper mantle beneath the mountain belts and adjacent regions. Together with evidence from active source seismology and gravity and magnetic anomalies, the data will determine the offshore extent of the ophiolite and inform assessments of resources, including oil and gas.

These results will also enable us to determine whether or not the ophiolite is detached from Tethyan oceanic lithosphere in the Gulf of Oman by a continental basement ridge, as postulated by *Ravaut et al.* [1997]. Passive seismic methodologies (e.g., seismic tomography and receiver function analysis) will provide relatively low resolution images of the crust, but they have the potential to provide insights into the deep structure of the subcrustal lithospheric mantle underlying the mountain belt and adjacent regions.

We strive to address major questions concerning the structure and emplacement of the Semail ophiolite and to contribute to the understanding of ophiolite complexes around the world. Early results are expected to be published in 2016.

> Project scientists believe that the ongoing debates about ophiolite formation and emplacement cannot be solved without further detailed geophysical and geological observations.


## Acknowledgments

The project is funded by the Petroleum Institute Research Centre (PIRC), with additional support from the UAE government and Schlumberger. The UAE Ministry of Energy provided logistical support and necessary approvals. The offshore data were acquired by Seabird Exploration on board M/V *Hawk Explorer*.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Katie Pratt/Deep Carbon Observatory

*In this close-up photo of ophiolite rocks from Wadi Fins, 88 kilometers southwest of Muscat, Oman, altered peridotites are interspersed with white magnesite veins, the product of olivine alteration. The field of view in this photo is about 15 centimeters across.*

# Sounding the Northern Seas

By Seth L. Danielson, Elizabeth L. Dobbins, Martin Jakobsson, Mark A. Johnson, Thomas J. Weingartner, William J. Williams, and Yulia Zarayskaya

Ocean, atmosphere, and ecosystem processes in the North Pacific and western (Pacific) Arctic are critical to determining climate both locally and globally. Yet up-to-date depictions of this region's seafloor depths have been lacking. Such information gaps can limit the effectiveness of oil spill responses, search and rescue missions, and scientific

*During the Arctic summer, the Sun barely dips below the horizon over the Beaufort Sea, north of Alaska and the Yukon Territory. This August 2015 photo, which depicts a region inside the Alaska Region Digital Elevation Model (ARDEM) grid region, was taken from the R/V* Norseman II *during a research expedition for the Arctic Marine Biodiversity Observation Network project.*

Seth Danielson

research projects, all of which rely on accurate information about ocean currents and the seafloor.

Specifically, oceanic circulation forecasts, geospatial mapping applications, and analyses of water column and seafloor environmental data require depictions of underwater terrain, or bathymetry. These depictions, represented as numerical matrices known as digital elevation models (DEMs), are ideally constructed with the most complete and up-to-date seafloor bottom sounding data available. Various DEMs are available; however, each has its own strengths and weaknesses, and not all data are publicly available. It is not surprising that bathymetric DEM resolution and quality are intimately tied to the accuracy of ocean circulation forecasts.

In the waters surrounding Alaska, many studies depend on adequately representing in ocean circulation models the passage of subarctic Pacific waters as they flow across the expansive and shallow Bering and Chukchi Sea continental shelves en route to the Arctic. The tightly interconnected nature of these shelves and their associated circulation systems and ecosystems require a single DEM that can be used by ongoing and future research projects.

## A New Model

To assist the mapping, response, and research applications noted above, our team developed the Alaska Region Digital Elevation Model (ARDEM; see http://bit.ly/ARDEM_model), which spans 130°E to 120°W and 45°N to 80°N with a horizontal grid spacing of 30″ in latitude and 60″ in longitude (Figure 1). The ARDEM grid provides both topographic elevation and bathymetric depth estimates for this entire region, with a horizontal resolution of approximately 1 kilometer.

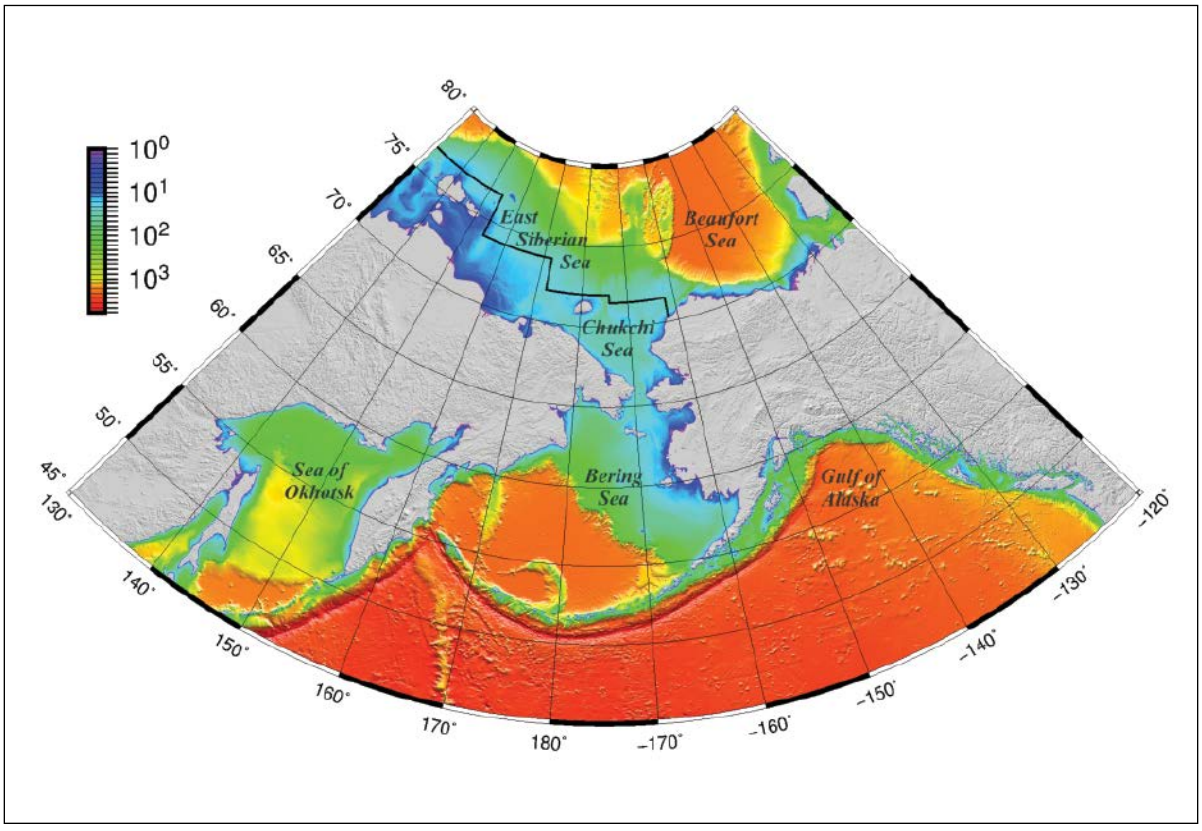
Three publicly available DEMs cover large portions or the entirety of the ARDEM region, but none fills the niche occupied by the ARDEM grid. The International Bathymetric Chart of the Arctic Ocean (IBCAO) [*Jakobsson et al.*, 2012] charts a grid across the entire Arctic with a southern boundary located at 64°N in the northern Bering Sea. The General Bathymetric Chart of the Oceans (GEBCO) world map [*Goodwillie and members of the informal Gridding Working Group of the GEBCO Sub-Committee on Digital Bathymetry*, 2011] and Smith and Sandwell's [*Smith and Sandwell*, 1997; *Becker et al.*, 2009] satellite-based bathymetry DEMs represent the premier global seafloor DEMs.

The organizations that make the global elevation models benefit from regional data compilations (such as IBCAO and now ARDEM) that are able to identify and assemble data within smaller regions. To facilitate collaboration with regional mapping efforts such as ARDEM, GEBCO formed the Sub-Committee on Regional Undersea Mapping.

## A Patchwork Quilt of Data

Vertical elevations and coastline locations are particularly prone to change along Alaska's coasts, where land masses

*Fig. 1. The Alaska Region Digital Elevation Model (ARDEM) grid, with ocean depths plotted on a logarithmic color scale. The International Bathymetric Chart of the Arctic Ocean (IBCAO) grid provides elevations located to the north of the black line that crosses the East Siberian and Chukchi Seas.*



NASA/Kathryn Hansen

*On a windless day in the Chukchi Sea, the water takes on a glassy appearance. Sea ice damps the ocean waves, transforming the water into a mirror for the clouds above.*

rise under the reduced weight of melting glaciers (isostatic rebound) and earthquakes alter land and ocean elevations by meters or even tens of meters in the case of the 1964 Alaska earthquake. Ice, waves, and melting permafrost can erode as much as 20 meters of Alaska's Arctic coast each year. Such rapid change means that scientists making DEMs of the region are always scrambling to stay up to date.

Adding to this complexity, compilation of large-scale bathymetric DEMs must contend with a patchwork quilt of data types, data quality, and vertical reference levels [*Smith*, 1993]. High-quality multibeam ship sounding data are desirable but sparse, particularly on the expansive high-latitude continental shelves [*Wessel and Chandler*, 2011]. Furthermore, many otherwise acceptable single-beam sounding data are degraded by poorly documented speed of sound and transducer depth equipment configurations. Soundings on nautical charts typically denote navigation hazards and so can be biased shallow with respect to the local mean water depth.

Regions such as large parts of the shallow shelves off the Arctic coast of Eurasia, where source data have not been readily accessible (e.g., because of government restrictions), often require grids to be constructed by digitizing latitude and longitude locations from contours on navigational charts. The contour lines on such grids can encompass large areas of the ocean, and they bias the gridded depths in a "terracing" effect [*Marks and Smith*, 2006].

A large fraction of the ARDEM region includes shallow sedimentary continental shelves. DEMs that employ satellite-based observations of gravity anomalies are imprecise over these regions because the measurements tend to represent subseafloor structure rather than the seafloor shape itself [*Lee et al.*, 2010].

> Such rapid change means that scientists making DEMs of the region are always scrambling to stay up to date.

For these reasons and against this backdrop, we constructed the ARDEM grid without digitized contour lines and satellite-based depth estimates. This approach required us to make an extensive digitization effort to capture point soundings from published navigational charts.

### Putting It All Together

We assembled ship-based depth sounding data from U.S. National Ocean Service and Canadian Hydrographic Service Electronic Navigation Chart point soundings, multibeam

swath data sets, miscellaneous single-beam tracklines, and point soundings digitized from paper nautical charts.

We also incorporated National Ocean Service seafloor survey data served by the National Geophysical Data Center's bathymetry database, along with other depth data from miscellaneous research cruises, including single-beam soundings from many Gulf of Alaska and Bering Sea expeditions aboard the R/V *Miller Freeman* and the R/V *Alpha Helix*. Other data include multibeam swaths from the Japan Agency for Marine-Earth Science and Technology R/V *Mirai* cruises.

An important set of data new to bathymetric DEM efforts that covers the ARDEM region came from our recent digitization of 315 historic Russian nautical charts and chart insets from the Laptev Sea, the East Siberian Sea, the Chukchi Sea, the Bering Sea, and the Sea of Okhotsk. These charts had scales ranging from 1:1000 to 1:2,000,000. We georeferenced and digitized the soundings, yielding more than $6 \times 10^5$ unique latitude-longitude-depth triplets.

Thirteen of the Russian charts were coarser than 1:500,000, and 110 were at a resolution of 1:50,000 or finer. We expect the maximum error in the location of each chart sounding to be on the order of approximately 1 centimeter (1 centimeter is equivalent to 500 meters on a 1:50,000 chart, and 1 centimeter is equivalent to 5 kilometers on a 1:500,000 scale chart). The nominal ARDEM grid spacing is 1 kilometer, so we believe that we were able to georeference data from charts with 1:50,000 resolution and higher into the appropriate ARDEM grid cells.

An important set of data came from our recent digitization of 315 historic Russian nautical charts.

Soundings acquired prior to modern satellite-based positioning methods may have location accuracies that are coarser than the approximately 1-kilometer grid resolution. Nonetheless, we find that these newly digitized soundings can provide appreciably more seafloor detail than digitized contours. Compare, for example, the panels in Figure 2. The differences between the older IBCAO and newer ARDEM panels show why we spent so much effort in digitizing the chart point soundings.

The IBCAO grid provides elevations to the ARDEM grid over the northern East Siberian Sea, the northern Chukchi Sea, and the Beaufort Sea (see Figure 1), allowing a seamless integration of the two compilations by users who require elevations in areas that overlap both of these two grids. The ARDEM grid also includes data from

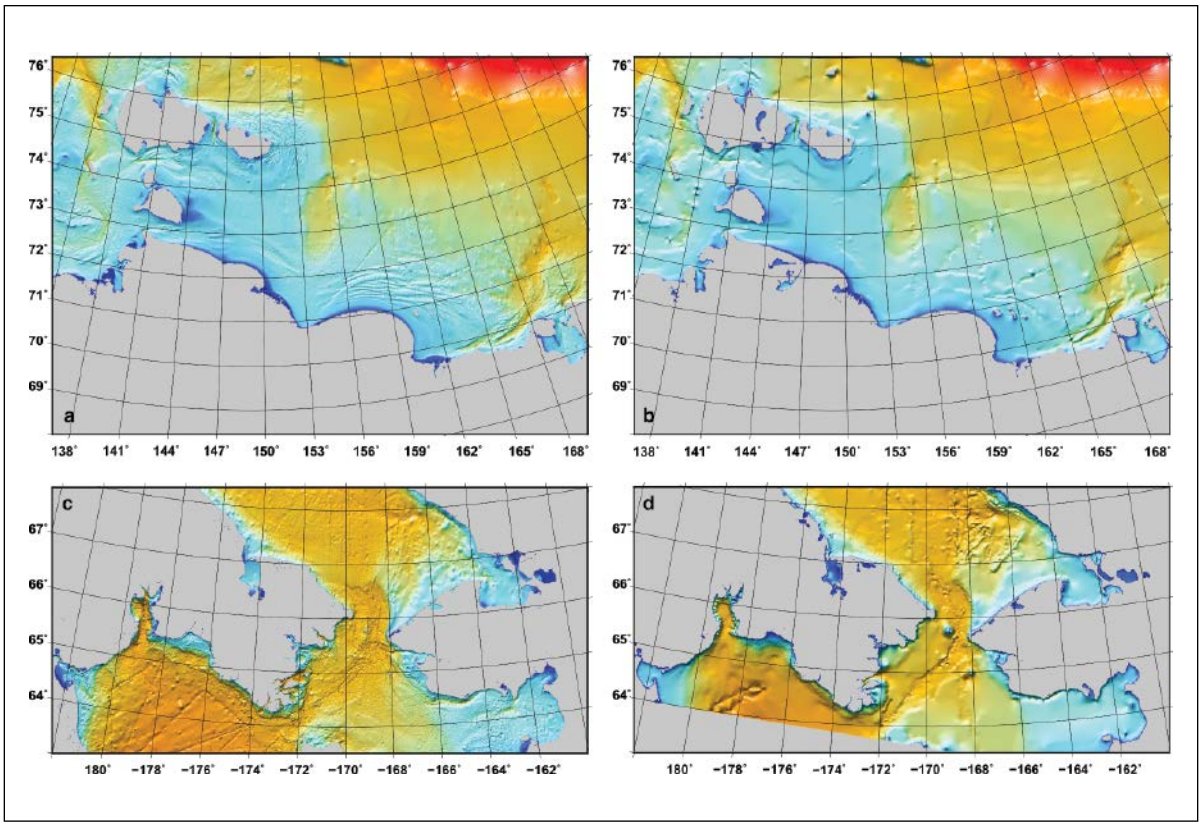



*Fig. 2. Comparison of (left) the new ARDEM grid with (right) the IBCAO grid (a and b) along the Siberian coast and (c and d) near Bering Strait.*

sounding-based grid cells in Smith and Sandwell's DEM (release version 14.1). Over land, elevations come from the National Geophysical Data Center's Global Land One-km Base Elevation Project (GLOBE) grid [*GLOBE Task Team et al.*, 1999].

The ARDEM grid provides a new research tool for the Pacific sector of the Arctic and subarctic shelf seas. The ARDEM grid itself and unrestricted data assembled for the ARDEM grid are available for other users through the Alaska Ocean Observing System (see http://www.aoos.org/). We anticipate that these data will help usher in a new era of precision Arctic modeling and mapping.


## Acknowledgments

We gratefully acknowledge the numerous organizations and individuals whose efforts have helped us assemble this soundings data set, including the National Oceanic and Atmospheric Administration, the National Ocean Survey, the National Geophysical Data Center, the Canadian Hydrographic Service, the Japan Agency for Marine-Earth Science and Technology, the creators of the GLOBE DEM, the creators of the Smith-Sandwell DEM, the Hawaii Mapping Research Group, the University of New Hampshire Center for Coastal and Ocean Mapping, the Lamont-Doherty Marine Geoscience Data System, Ned Cokelet, Bill Kopplin, Steve Okkonen, Will Perrie, and Steve Solomon. Russian charts were digitized by East View Geospatial of Minneapolis, Minn. We thank two anonymous reviewers for their improvements. This work was funded with support from the Oil Spill Research Institute (OSRI) and the North Pacific Research Board (NPRB), NPRB project 1225 (NPRB publication 574).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# Awardees and Prize Winners Honored at 2015 AGU Fall Meeting

## Chappell, Jones, and McBean Receive 2015 Ambassador Awards

*Charles R. Chappell, Lucile Jones, and Gordon McBean were awarded the 2015 Ambassador Award at the AGU Fall Meeting Honors Ceremony, held on 16 December 2015 in San Francisco, Calif. The award is in recognition for "outstanding contributions to the following area(s): societal impact, service to the Earth and space community, scientific leadership, and promotion of talent/career pool."*

Charles R. Chappell

### *Citation for Charles R. Chappell*

Throughout his nearly half century research career in solar-terrestrial physics Rick Chappell has continuously focused his energies on communication, outreach, mentoring, and creating innovative programs that enhance the public understanding, appreciation, and support of space and Earth science. These activities were originally focused on his own discipline of space physics but have spread to include Earth science and to address the broader issue of communicating science through the media to the public.

Rick began his outreach activities first with a major museum exhibit and then a movie about magnetospheric physics. He continued his public communications through being a media spokesperson for multiple Spacelab/shuttle missions.

Chappell's experience with the media led him to return to his alma mater, Vanderbilt University, in 1996 to conduct a study on the interaction between the science community and the media. This led to the book *Worlds Apart* and to the creation of a new undergraduate interdisciplinary major in the communication of science and technology. During this time he was a member of the AGU Committee on Public Outreach, being chairman for 1 year of his 3-year term.

Rick worked with colleagues to organize two cross-discipline collaborative AGU conferences, one in 1974 and one in 2014, which brought together scientists from different disciplines to understand the interaction between the ionosphere and magnetosphere.

Working with John Denver's Windstar Foundation in the late 1980s, Rick joined with scientists in Earth and space sciences to create the Aspen Global Change Institute (AGCI). AGCI has now been in operation for 25 years and has involved hundreds of Earth, space, and social scientists, who have carried out the cross-discipline study of global change. AGCI has also created education outreach programs such as ground truth study activities for students at the Science Olympiad.

The NASA administrator asked Rick to work with Vice President Gore to create the Global Learning and Observations to Benefit the Environment (GLOBE) program in 1994–1995. GLOBE involves K–12 students around the world in measuring their local environment and in reporting the results online. The program now involves tens of thousands of schools in more than 100 countries.

Rick has given talks to thousands of students of all ages and continues to be a leader in communications and educational outreach. I cannot think of anybody more deserving of the AGU Ambassador Award.

**—Andrew Nagy**, *University of Michigan, Ann Arbor*

### *Response*

I am honored and deeply grateful for being selected as an AGU Ambassador. My career has been about space exploration and communicating the results and importance of that exploration to the public, especially to the teachers and students. To be recognized for these communication and outreach activities is most meaningful to me.

As scientists, we all start our exploration journey in a limited area of study. As we grow in our understanding, the interdisciplinary nature of science leads us to work with explorers in other fields. Whether it is the relationship between the Sun and the Earth or the changing global environment, it is critically important to cross disciplines and interact with other scientists to piece together the big picture.

In my career I have worked to facilitate cross-discipline exploration through both planning interdisciplinary Chapman conferences and creating organizations such as the Aspen Global Change Institute. It is in this environment that sharing and learning take place and the broader research challenges are met through new partnerships.

For each of us explorers, taking time to communicate as individuals and as groups is critical, particularly in this time of the confusing politicization of science in areas such as global change. We owe a continued, understandable report to the public which funded our research, and we owe a period of giving back through teaching, interacting with teachers, and mentoring the young student explorers of the future. Programs such as GLOBE bring scientists, teachers, and K–12 students together to share knowledge while measuring their local environment. In this hands-on way, students become explorers who are sensitive to the changing environment around them. It was a great pleasure to work with Vice President Gore to help create this interagency program.

As scientists, we are given the great privilege of living the adventure of exploration and of doing and learning things that others have never done before. We are able to "live in the what might be" where our ideas that are born, honed, and realized through teamwork can become reality and can then be shared with others.

Thanks so much to all of the incredible people who explore our world and to AGU for creating this award, which recognizes the importance of our research and the need both to communicate to those who have invested in us and to pass the torch to the next generation of explorers.

**—Charles R. Chappell**, *Vanderbilt University, Destin, Fla.*

Lucile Jones

### *Citation for Lucile Jones*

Dr. Lucile "Lucy" Jones is an extraordinary public servant who has devoted her path-breaking career to reducing the threats of natural hazards in southern California, across the nation, and around the world. Since joining the U.S. Geological Survey (USGS) in 1983, Lucy has made outstanding research contributions and provided significant scientific leadership to the nation. She rose rapidly through the scientific ranks in recognition of her research on earthquake occurrence probability, which to this day forms the basis for all earthquake advisories issued by the state of California.

Since then, Lucy has expanded the scope of her research into the realm of risk and vulnerability studies to improve knowledge transfer across multiple natural hazards. She has led the development of scenarios that have made catastrophic hazards real to the people of California and in doing so sparked a science-based approach to earthquake preparedness that now involves tens of millions of people worldwide. She has successfully built strong partnerships with engineers, social scientists, biologists, geographers, public health doctors, emergency managers, and public officials to design scenarios that are among the most visible and highly used products to come out of the USGS.

Most recently, Lucy led a USGS cooperative project with the city of Los Angeles in which she served as the science adviser for seismic safety to Mayor Eric Garcetti. The results of this collaboration include a consensus approach to improving building safety, a comprehensive program to strengthen the water infrastructure in the city, and convening stakeholders in the state's utilities to address the vulnerabilities posed by utilities crossing the San Andreas Fault.

Lucy is widely recognized as an authoritative voice on natural hazards and disaster risk reduction. When earthquakes strike, the world's major media outlets turn to her for answers, and time and again, she has seized the teachable moment to the benefit of all. Lucy's skill in communicating with reporters and connecting with the public—including the many thousands who follow her on Twitter—has made her one of the most trusted scientists in America. Lucy Jones is truly an ambassador for science in service to society and a worthy recipient of this award.

**—David Applegate**, *U.S. Geological Survey, Reston, Va.*

### *Response*

I am honored to receive the Ambassador Award and am grateful to David Applegate and other colleagues at the USGS for nominating me. One cannot be an ambassador without a home country to represent and I am proud the

USGS has been my intellectual home for 32 years and of its commitment to science in the public service.

I began work in seismology while a graduate student at MIT, using my undergraduate degree in Chinese Language and Literature to study the Haicheng earthquake. I came to realize that the Chinese need for prediction to save lives was so large and the cost of a false alarm in an agrarian economy was so small that they could use the probability gain of an earthquake swarm to act at a much lower level of certainty than would be possible in the United States. In other words, the decision to act required economic and social information as well as seismologic information. This led to a career in earthquake statistics, to try to bring seismology to the people with the information to understand the impact of the predictions.

However, as we progressed in our ability to deliver probabilities, we discovered how few people actually understand them. I am grateful to the USGS for the opportunity to explore other approaches to explaining risk, including the ShakeOut, ARkStorm and SAFRR Tsunami Scenarios. That this path would eventually lead to a full year in Los Angeles City Hall is as astonishing to me as to anyone. Along the way, I have discovered that the scientist's boredom with solved problems and our need to express, quantify, and generally live in uncertainty often leads us to tell our potential partners what we don't know, rather than fulfill their need to understand what we do know. I also found that the stories of the scenarios and an understanding of the individual impacts of collective decisions helped bring our community together to finally address the risk.

Most support for our research comes from government, from the public purse, because people want the results. Especially as Earth scientists, much of our research could lead to a safer, more prosperous future, but only if it is used. I believe we have an obligation to ensure that the results of our research are not just heard, but understood by those who entrusted with the decisions that can protect our society and our environment.

**—Lucy Jones**, *U.S. Geological Survey, Pasadena, Calif.*

Gordon McBean

### *Citation for Gordon McBean*

Gordon's leadership roles in the community were propelled with his appointment in 1984 as a member of the Joint Scientific Committee (JSC) for the World Climate Research Programme (WCRP), mandated to plan and implement the major global climate research programs. He subsequently became the chair of JSC (1988–1994), and under his leadership WCRP implemented four major research programs in the areas of water/energy, variability/prediction, stratosphere, and Arctic/cryosphere.

While chairing WCRP and recognizing that there was little participation from the developing world in these major science programs, he helped in the creation of the Inter-American Institute for Global Change Research (IAI) and the System for Analysis Research and Training (START) for Africa and Asia. The success of both IAI and START programs in scientific capacity building in Latin America, Africa, and Asia is a testament to Gordon's vision and leadership.

Gordon also served as Canada's assistant deputy minister in Environment Canada, responsible for climate, weather, and air quality sciences and services and ministers' adviser on climate change science and policy, including at the Kyoto Protocol negotiations in 1997.

Gordon has also made significant contributions to the field of disaster risk reduction. After the Indian Ocean tsunami tragedy, he chaired the scoping and planning committee that led to the establishment of the Integrated Research on Disaster Risk program.

Gordon is the current president of the International Council for Science, the leading nongovernmental science organization in the world speaking on the issues of the freedom and responsibility of scientists around the globe.

Gordon's outstanding scientific contributions and his selfless efforts as a scientific ambassador to serve the profession and society make him an excellent recipient of this award.

**—Soroosh Sorooshian**, *University of California, Irvine*

### *Response*

I am very pleased and honored to have been selected for an AGU Ambassador Award for 2015. Throughout my career I have been inspired and motivated by mentors and colleagues to work together with scientists from around the world to understand and take action on the global geophysical issues of climate change, disaster risk reduction, and enhancement of research capacity around the globe. The development and implementation of these global programs, WCRP, IRDR, START, IAI, and others, were really the result of global team efforts and commitments, with all of us being motivated by our scientific interests to understand these complex issues and also to provide societies with the scientific information upon which actions can and should be made.

It has been very inspiring for me to work with many colleagues, including Professor Soroosh Sorooshian, who have contributed in many different ways to me being selected for this award. By working together, we have been able to make a much more substantial contribution to these issues—but we still have a long way to go with, for example, climate change. It is a continuing challenge for scientists to better communicate, clarify and, as appropriate, motivate our governments and societies to take action.

When writing this response, I knew that the global community will meet at the climate change Conference of the Parties 21 in Paris that is scheduled to end just before this AGU conference; but I could not really predict the outcome. As now president of the International Council for Science (ICSU), I think that it is important that we, collectively as a scientific community, speak out on these issues. We also need to address the issue of the freedom for all scientists to do science and have the support to enable their doing excellent science and connecting it to societal needs. We also need to, as a scientific community, emphasize our individual and collective responsibility of scientists.

I would like to thank AGU for this very important award and thank all my colleagues for their collective contributions to me being the recipient.

**—Gordon McBean**, *University of Western Ontario, Ontario, Canada*

## Sonia Esperança and Robin Reichlin Receive 2015 Edward A. Flinn III Award

*Sonia Esperança and Robin Reichlin received the 2015 Edward A. Flinn III Award at the AGU Fall Meeting Honors Ceremony, held on 16 December 2015 in San Francisco, Calif. The award honors "an individual or small group who personifies the Union's motto 'unselfish cooperation in research' through their facilitating, coordinating, and implementing activities."*

Sonia Esperança

Robin Reichlin

### *Citation*

As program directors at the National Science Foundation (NSF) in the Division of Earth Sciences for the last 20 years, Robin Reichlin and Sonia Esperança have played an exceptionally important role in advocating for, nurturing, and supporting the research community in solid Earth sciences, through combined efforts in their respective fields of specialty (geophysics and geochemistry and petrology). They have achieved an unprecedented level of respect and admiration, as well as confidence and trust, from a highly discerning and typically critical research community.

By carrying out their responsibilities as program directors with outstanding dedication, they have provided leadership for geochemistry and geophysics, exercising deep understanding of research quality and frontiers. Moreover, working as a team, Robin and Sonia have been instrumental in the development of key multidisciplinary infrastructure for geosciences that has changed the way in which we conduct our research. They have looked for ways to make new programs happen in the context of planning within NSF, often within a restricted fiscal climate, and have promoted workshops and meetings to refine the goals to make the cases convincing. In many situations, they have identified new research opportunities and laid the groundwork for new programs even before most of the research community was fully aware of them.

Examples of programs they have helped happen and sustain, among others, are Cooperative Studies of Earth's Deep Interior (CSEDI), Cooperative Institute for Dynamic Earth Research (CIDER), Computational Infrastructure in Geodynamics (CIG), Consortium for Materials Properties Research in Earth Sciences (COMPRES), and Meeting of Young Researchers in Earth Sciences (MYRES). Notably, they have played an important role in establishing the Frontiers in Earth System Dynamics program (FESD). The stewardship of these

important programs and their many other community activities have benefitted a large segment of the Earth science community. Clearly, many individuals at NSF and in the community have helped all these programs come to life and be sustained. However, Robin and Sonia's contributions stand out for their exceptional ability to communicate with the community and help researchers articulate their needs, as well as identify the highest and scientifically most worthy initiatives, embrace them, and advocate for them at NSF.

In summary, Robin and Sonia have sustained excellence in NSF's geoscience programs and tirelessly advocated on behalf of the Earth sciences research community to develop new programs and open up new research opportunities. The Flinn Award is a fully deserved and modest recognition of their contributions.

**—Barbara Romanowicz**, *University of California, Berkeley*

### *Response*

We are deeply honored to be the co-recipients of the 2015 Edward A. Flinn III Award, and wish to thank the AGU awards committee, and our Earth sciences community colleagues for this recognition. We are proud to join a group of outstanding awardees that has worked on behalf of the geosciences, including one of our mentors at NSF, Daniel Weill. Dan showed us how to be effective advocates for the novel research of the community within the NSF. We are also excited to share this award because early on we recognized that through a close partnership, we could best promote new facilities and research directions. The rapid advance of the frontiers of solid-Earth geosciences has sustained us through the many hurdles and setbacks along that path. We have shared a passion for the science, the people engaged in research, and a vision for a comprehensive, integrated understanding of the physical and chemical functioning of the Earth. We were lucky to be supported at home by our husbands, Steve Bohlen and Rick Carlson, who understood our determined minds and respected our devotion to promoting the health of our communities. We also shared being mothers to our children, Jesse, and Taylor, Hunter, Annie, and Sallie, and the tough decisions made to balance career and life, giving us an appreciation for similar issues faced by a new generation of scientists.

Among the many rewards of fighting for new science and the funding to support it are the opportunities to work closely with many of the greatest minds and visionaries in the field, and to watch the development of students who have grown and emerged as new leaders in the geosciences. We are fortunate to have had the opportunity to nurture emerging ideas and technologies that have paved the path to new understanding, and to view the research community and their science from a synoptic viewpoint. The joy is in looking back over 20-plus years to see the enormous growth in the breadth, sophistication, and integration of solid-Earth science and how every discovery benefits knowledge and society.

Though recognized as individuals, we know that it is the concerted and persistent efforts of many that bring success. We are but two members of a team of program directors united in a passionate desire to facilitate understanding of the beautiful mysteries of the Earth. We feel deeply fortunate to have played a part. Thank you.

**—Sonia Esperança** *and* **Robin Reichlin**, *National Science Foundation, Arlington, Va.*

## Benjamin Lee Preston Receives 2015 Charles S. Falkenberg Award

*Benjamin Lee Preston received the 2015 Charles S. Falkenberg Award at the AGU Fall Meeting Honors Ceremony, held on 16 December 2015 in San Francisco, Calif. The award honors an "early- to middle-career scientist who has contributed to the quality of life, economic opportunities, and stewardship of the planet through the use of Earth science information and to the public awareness of the importance of understanding our planet."*

*Benjamin Lee Preston*

### *Citation*

Dr. Benjamin Preston fully embodies the spirit and focus of the Charles S. Falkenberg Award. Ben has been a tireless leader in climate change research and raising societal awareness of the challenges posed by climate change. He has published research that spans experimentation, analysis of Earth system observations, and physical/ecosystem modeling. His research leadership also extends into the social sciences. This depth has enabled Ben to become an internationally recognized innovator in both fundamental and applied research regarding the assessment of climate change vulnerability and risk, including probabilistic analysis of climate projection ensembles, evaluation of exceeding climate thresholds in natural and human systems, and the use of risk management in guiding climate adaptation decision making.

For over the past decade, Ben has been working on the analysis of the spatial and temporal dynamics of climate risk to human settlements, including spatial integration of heterogeneous biophysical data on climate, topography, and land use from Earth system models and remote sensing. He has integrated these data with socioeconomic data such as land values, population, and infrastructure in order to translate changes in the Earth system into societal vulnerability and adaptive capacity to climate and global change. It is this commitment to understanding how climate risk research is used by society that really sets Ben apart from others.

Ben is well known for his skills in communicating with various audiences about climate change, the underlying science, and ways in which society can manage climate risk; he has participated in congressional Climate Science Day, met with Tennessee and Virginia congressional staff, given invited talks at the Chattanooga Engineers Club and Knoxville Rotary Club, participated in a discussion of climate change on local public radio, and talked to high school students about climate change and the rewards of a career in science. He has also been the Intergovernmental Panel on Climate Change (IPCC) *Fifth Assessment Report* coordinating lead author on Working Group II's "Adaptation, Opportunities, Constraints, and Limits" chapter and lead author on the IPCC *Synthesis Report* and was highlighted in the video accompanying the release of the IPCC Working Group II report.

I believe that Ben is emerging as an exceptional and important leader in the AGU and climate community and fully embodies the personal and professional qualities represented by the Falkenberg Award.

**—Jack D. Fellows**, *Oak Ridge National Laboratory, Oak Ridge, Tenn.*

### *Response*

Almost 20 years have elapsed since I first began my graduate studies in environmental science. Throughout that time, I have sought to identify ways in which science can be applied to address practical environmental challenges. Despite being warned by multiple advisers about the potential pitfalls of dabbling in policy or public engagement, I believe there is a growing demand for scientists who, regardless of the stage of their career, are committed to pursuing quality science with direct social impacts.

Therefore, it is indeed an honor to receive the Charles S. Falkenberg Award. I am grateful to both AGU and the Earth Science Information Partnership, not only for this individual recognition but also for their support of the Falkenberg Award, which acknowledges the value of public engagement and science communication. I also owe much to a long list of mentors—Vicki Arroyo, Jack Fellows, Bill Glaze, Gary Jacobs, Jay Gulledge, Bill Hooke, Tony Janetos, Roger Jones, and Terry Snell, to name but a few—who have helped me along what has so far been a rewarding career path.

The advances I have witnessed over the past 2 decades in computing, remote sensing, visualization, and understanding of Earth system processes are clear indicators of the benefits generated from investments in science. Nevertheless, challenges remain in making Earth science information accessible, interoperable, and useful for society. We must constantly reevaluate how we can do a better job of putting that information to work for societal benefit. In so doing, we will likely discover a need to better understand humans as the dominant agent of global change. We are extensively documenting how, when, and where we are affecting our planet, but questions of why are more elusive. By coupling our knowledge of Earth system dynamics with knowledge of human system dynamics generated by social, behavioral, and policy sciences, we can accelerate our capacity to use science to enhance the well-being of human and natural systems alike.

The Earth scientists of the future may therefore be trained quite differently than those of the past. We are already seeing opportunities for interdisciplinary education and careers expanding rapidly. Research organizations, including my own, are actively integrating knowledge and capabilities to address questions at the forefront of Earth science but also relevant to different stakeholder communities and their objectives. These trends are part of the legacy of Charles Falkenberg. Hopefully, that legacy inspires us all.

**—Benjamin Lee Preston**, *Oak Ridge National Laboratory, Oak Ridge, Tenn.*

## Holly Gilbert Receives 2015 Athelstan Spilhaus Award

*Holly Gilbert received the Athelstan Spilhaus Award at the 2015 AGU Fall Meeting Honors Ceremony, held on 16 December 2015 in San Francisco, Calif. The award honors an individual "for their enhancement of the public engagement with Earth and space sciences."*

Holly Gilbert

### *Citation*

The Athelstan Spilhaus Award recognizes exceptional skill, dedication, and success in informing the public of the value, beauty, and excitement of Earth and space science research. Dr. Holly Gilbert embodies these virtues like few others.

Holly has made extraordinary contributions to enhancing the public's understanding of heliophysics and space science while also becoming an effective leader in a major research organization. Her highly successful research career has provided her with the deep scientific understanding that conveys authenticity and genuine excitement, and her exceptional communication talent provides her with a unique skill set to interact with the public.

I had the pleasure of experiencing Holly's capabilities starting in 2008, when she joined the Goddard Space Flight Center to dedicate herself not only to managing all of the outreach activities of her organization but also to finding innovative ways to show to the public the fascination and importance of heliophysics science. With characteristic energy and dedication, she translates scientific discoveries into captivating information for the public. Her excellence in building relationships between researcher and outreach communities is recognized widely.

Holly understood early on the tremendous outreach potential inherent in public media. Unlike anybody I have ever met, she took action—with tremendous success. She appeared and continues to appear on numerous radio and television shows, and she played key roles in Discovery Channel (*2012 Apocalypse*), History Channel (*The Universe*), PBS (*Earth from Space*), and Weather Channel (*Space Tornadoes*) documentaries. It is a mark of her standing with the media that she was invited to join a brainstorming session with Morgan Freeman for his Science Channel series *Through the Wormhole*, where she helped formulate ideas for topics at its inception.

Holly also routinely provides lectures for high-profile events like keynotes at two recent NASA at the Smithsonian events, which were attended by national policy makers, and talks at schools and other educational venues. For example, she taught an astronomy course at a community college in Houston, Texas, and she was the guest lecturer at the St. George Observatory (Schriever, La.), where a solar telescope was dedicated in her name to recognize her commitment to teaching the public. Holly receives hundreds of emails from people she has touched personally, many from parents complimenting her ability to inspire their children. Space physics and aeronomy research owes much of its public recognition to her.

Dr. Holly Gilbert is a most deserving recipient of AGU's 2015 Athelstan Spilhaus Award.

**—Michael Hesse,** *NASA Goddard Space Flight Center, Greenbelt, Md.*

### *Response*

I am deeply honored to be recognized with this award and feel extremely lucky for so many opportunities to interact with the public, allowing me to share my excitement about heliophysics science. Communicating and promoting science in the context of sharing independent research results at conferences is part of being a scientist. I've been privileged with opportunities to extend my communication skills to reach large, diverse groups of people, whether in classrooms, on cable TV, or on cruise ships. The most rewarding part of doing this type of outreach is seeing children get inspired as I'm talking to them. Exploring the domain of the Sun has awed us with scientific complexity and beauty. Sharing our enthusiasm and knowledge with the general public provides them with a glimpse of that fundamental beauty, benefiting scientists and society alike.

I'd like to thank Michael Hesse for his continued support and recognition of the importance of communicating science to the public. I'll be forever indebted to Tom Holzer, my thesis adviser and mentor, who taught me the importance of presenting complex physics concepts in a simple way. Outreach is meaningless without the hard work and dedication of the scientific community, so I thank my heliophysics colleagues for conducting world class scientific research that continually provides the content to help educate the world. Lastly, I'd like to thank AGU for recognizing and appreciating scientists who take time away from their normal work to conduct vitally important outreach.

**—Holly Gilbert,** *NASA Goddard Space Flight Center, Greenbelt, Md.*

The version of "Holly Gilbert Receives 2015 Athelstan Spilhaus Award" printed in the 15 January magazine contained the wrong response. This PDF version has been updated to present the correct response by Holly Gilbert.

## Peter J. Webster Receives 2015 International Award

*Peter J. Webster received the 2015 International Award at the AGU Fall Meeting Honors Ceremony, held on 16 December 2015 in San Francisco, Calif. The award honors "an individual scientist, group, or a small team for making an outstanding contribution to furthering the Earth and space sciences and using science for the benefit of society in developing nations."*

Peter J. Webster

### *Citation*

Peter Webster has made landmark contributions to the understanding of the dynamics of the tropical atmosphere and especially to the workings of the south Asian monsoon, which affects the billions of people living in the subtropics. Webster's vision and insight led to one of the grandest international field campaigns in the history of atmospheric sciences—the Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere Response Experiment (TOGA COARE)—which employed numerous ships and aircraft in a logistically complex array over the remote tropical Pacific Ocean "warm pool," which hosts an interacting set of cloud systems, atmospheric waves, and ocean-atmospheric fluxes that affect weather and climate over the globe. TOGA COARE provided an observational data set that continues to stand as a cornerstone for advancing understanding of tropical dynamics and improving weather and climate models.

Webster's preacademic career was as a weather forecaster in Australia. In the past decade he has returned to forecasting, turning theoretical insights into monsoonal dynamics toward improving monsoon predictions for south Asian countries. He has focused on the 1–2 week warning time frame, which, as known from his own research, is the typical time scale of the somewhat erratic but "active" and "break" periods of the monsoon. From his work on the fundamentals of active/break cycles, he recognized how the European Centre for Medium-Range Weather Forecasts (ECMWF) global model handles these cycles and has developed a method for forecasting upcoming dry and wet spells based on statistical rendering of the ECMWF output. He has combined this model forecast framework with a river runoff model to be able to predict with remarkable acuity the probability of disasters such as the floods that have devastated Pakistan in the last several years. These forecasts aim also to help prevent crop failures from either flood or excessive dryness on 1–2 week time scales.

Webster has worked tirelessly with agencies and governments concerned with disaster mitigation and regional forecasting. In some 20 journeys to south Asia in the past decade and a half he has organized a project called Climate Forecast Applications in Bangladesh, which proved that storm and flood forecasts were practicable with 1–2 week lead times, and now has formed a company to bring these methods to the various countries of south Asia. In the January 2013 issue of *Nature*, Webster laid out a plan in which these methods can contribute to disaster mitigation in south Asia if only the correct combination of governmental and private sector participants can be realized.

**—Robert Houze,** *University of Washington, Seattle*

### *Response*

I am deeply honored to receive the AGU International Award. Thank you to the Union and my nominators. Any contribution

to international research has been achieved in tandem with many people over a long period of time.

I became interested in the tropics. Forty years ago, forecasting variations in the monsoon was a rather haphazard empirical affair. But we had started to understand some of the basic dynamics that set the tropics apart. Not only was it an almost untouched field, it provided an opportunity to do something socially useful. With the growing power of numerical weather prediction, there seemed to be a hope that we could move from qualitative forecasting efforts to something more quantitative. But to achieve this goal, we needed to understand the elementary physics of the basic phenomena we were trying to predict. This requirement led to a series of low-latitude field experiments: MONEX, describing basic monsoon behavior, EMEX documenting the involvement of smaller scale elements in monsoon dynamics, TOGA in which was developed a real-time operational ENSO monitoring, TOGA COARE that provided new insights into ocean-atmosphere interaction, and JASMINE investigating intraseasonal variability of the monsoon. My involvement in these international experiments has forged valued and lasting relationships across many communities around the world.

Perhaps the deepest gratification has come from working with many talented graduate students, many of whom are from overseas. I have mentored seven doctoral students from South America and seven from Asia. I have learnt so much from each of them about different approaches to life, research, and social interactions. This introduction to social differences has proven extremely useful as we endeavored to use our hazard forecasting techniques in Bangladesh, India, and Pakistan. Merely transferring technology turns out to be insufficient and, without due deference to different social norms, international projects often wither in the "Valley of Death." We are still learning how to become more effective.

Finally, I would like to acknowledge partners with whom I have worked, in particular, Robert Houze Jr., Roger Lukas, Timothy Palmer, Sri A. Subbiah, Tom Brennan, and Ernesto Sánchez-Triana. In addition, I thank members of my research group, many of whom have accompanied me on this interesting journey over the last few decades. To a large degree, Georgia Tech has made possible many of our international projects. Also, special thanks and gratitude for the steadfast support of my partner, Judith Curry.

**—Peter J. Webster**, *Georgia Institute of Technology, Atlanta*

## Andrew C. Revkin Receives 2015 Robert C. Cowen Award for Sustained Achievement in Science Journalism

*Andrew C. Revkin received the 2015 Robert C. Cowen Award for Sustained Achievement in Science Journalism at the AGU Fall Meeting Honors Ceremony, held on 16 December 2015 in San Francisco, Calif. The award recognizes "a journalist or team of journalists who have made significant, lasting, and consistent contributions to accurate reporting on the Earth and space sciences for the general public."*

*Andrew C. Revkin*

### *Citation*

Roaming from the North Pole to the White House to the Amazon rain forest, Andrew C. Revkin has devoted his career to conveying consequential Earth and environmental science and related policy issues to the widest possible audiences—through magazine stories, thousands of *New York Times* articles and blog posts, prize-winning photography and documentaries, and three lauded books aimed at both adults and young readers.

Those achievements alone might make him an outstanding recipient of the AGU Robert C. Cowen Award for Sustained Achievement in Science Journalism. But early on, Revkin's broad interdisciplinary awareness of science and human development led him beyond the conventional role of the journalist. In a 1992 climate book written for the American Museum of Natural History, he proposed that humanity had entered a post-Holocene "geological age of our own making." His proposed name, the Anthrocene, did not catch on, but he is among those credited with laying the foundation for the concept of the Anthropocene.

In 14 years as a news reporter at the *Times*, Andy conceived of or helped lead a string of special reports and series on climate and energy. In 2005 and 2006, he exclusively uncovered the suppression of climate science by political appointees. In 2007, he conceived of and launched his *Times* blog *Dot Earth,* exploring all facets of the evolving human relationship with our finite planet.

After he left the *Times* staff in 2010 to teach courses in environmental communication at Pace University, his blog moved to the opinion side of the paper. But even as a commentator, as Andy likes to say, his advocacy is for reality, not some agenda.

He has worked to foster scientists' communication skills and has written three book chapters on science and environmental communication.

Andy has even told the story of climate change through song. Several of his songs with environmental themes have been receiving increased attention, particularly "Liberated Carbon," on the history of humanity's relationship with fossil fuels.

**—Walter Munk**, *Scripps Institution of Oceanography, San Diego, Calif.*

### *Response*

I am deeply grateful to AGU for this recognition of 32 years (and counting!) spent trying to convey what humans have learned about how this wondrous planet works and how we've learned it. I especially thank my nominator, the extraordinary Walter Munk, and those who signed supporting letters: William H. Hooke of the American Meteorological Society, Jamie Morison of the University of Washington, J. Marshall Shepherd of the University of Georgia, James P. M. Syvitski of the University of Colorado, and Apollo astronaut Russell L. Schweickart. They have all been generous and trusted guides and tutors in the face of complex and consequential questions.

It's particularly gratifying to be recognized by scientists because I almost became one. As a boy in Rhode Island, my passion for fishing and Jacques-Yves Cousteau tugged me to the water. A bar mitzvah gift of a snorkeling set got me under the surface. A science teacher, Joe Ferretti, fueled my curiosity, letting me design a fan-driven wave tank in place of writing a pro-forma paper.

But the rigorous focus required to pursue a Ph.D. was a bad fit for my temperament. I found fascination in the widest field of view. In examining the ultimate transdisciplinary issue, humanity's evolving two-way relationship with the climate, I've had the rare privilege of studying the whole picture, from the climate models running on supercomputers in Boulder in 1985 to the burning rain forests of the western Amazon in 1989 to the shifting sea ice around the North Pole in 2003 to the contentious climate treaty talks in one city after another.

Even as I've been chronicling this extraordinary period of environmental and social change, I've also been navigating equally momentous changes in how ideas are shared and shaped. The shift from knowledge gatekeepers to networked communities—from Walter Cronkite to Wikipedia—is in its earliest stages, with profound changes in the works both for journalism and science.

In many ways, I feel like I'm just beginning. That's a good thing. When I look at Walter Munk's unrelenting zest for inquiry at age 98, I realize that—with luck—I might have another 32 years of communicating ahead of me.

Let's get together in 2047 and see how things have gone.

**—Andrew C. Revkin**, *Pace University, Pleasantville, N.Y.*

## Douglas Fox Receives 2015 Walter Sullivan Award for Excellence in Science Journalism – Features

*Douglas Fox received the 2015 Walter Sullivan Award for Excellence in Science Journalism – Features at the AGU Fall Meeting Honors Ceremony, held on 16 December 2015 in San Francisco, Calif. The award recognizes "a journalist for a feature story or series in any medium except books that makes information about the Earth and space sciences accessible and interesting to the general public."*

Douglas Fox

### *Citation*

Douglas Fox spent the first 8 years of his journalism career writing about biology before turning to Earth science in 2007, during a 7-week reporting trip to West Antarctica. He hadn't been formally exposed to the Earth sciences, but that trip reawakened his old interests, nurtured as a youngster roaming the naked landscapes of Arizona, Colorado, and the Baja California Peninsula in Mexico.

Doug strives to spend time immersed with researchers in the field—whether on a ship at sea, in a tent on a polar ice sheet, or traversing the Basin and Range in the American West—gathering hundreds of pages of notes on the tiny, telling details that can bring a story to life: the cream cheese texture of deep-sea mud, the rotten-egg stench of petroleum in stone, or the way that a rock hammer serves as the sensory proboscis of a geologist. Doug often writes about things that seem mundane—dust or ice or precariously balanced rocks—but hidden in these minutiae, he somehow finds expansive stories that change how we see the world around us.

The feature for which Doug won the Walter Sullivan Award, "The Dust Detectives" (*High Country News*, 22 December 2014), grew out of an interest that germinated over a period of years. Doug first spent time with dust researchers in 2011, exploring the unseen biosphere of airborne microbes and their possible role in rainfall. He published a pair of stories with *Discover* and *Science News for Students* in 2012 but felt that there remained something larger to be explored: the connection between the microcosm of a single dust speck and the great, global commerce of these invisible particles that shapes our world.

With his painstakingly precise and thorough reporting and artist's eye for detail, Doug performed a sort of journalistic alchemy. In his hands, dust is no longer the idle bits drifting in beams of light, but a powerful, almost magic-seeming force that shapes ecosystems in ways that scientists are just beginning to understand. Conveying the importance of microscopic and macroscopic worlds beyond our senses is no easy task, and yet Doug manages to bring it all into solid, intricate focus, enticing readers with a story that ranges from Kurt Vonnegut to the Silk Road and with vivid portraits of the far-off places that shape our own, including mountain ranges that themselves seem almost alive in their animation through geologic time.

**—Jodi Peterson**, High Country News, *Paonia, Colo.*

### *Response*

I'm honored to receive the Walter Sullivan award, and happy, for many reasons, to see this particular story garner that recognition ("The Dust Detectives," *High Country News*, 22 December 2014).

I had envisioned writing this story for 2 years—and had a sense that there was something large to be said. But that alone does not guarantee that a story will turn out well. The distance from an idea to words printed on the page is long, and making that journey requires that you depend on others.

I'm grateful for the generosity of those people whom I interviewed and visited while working on this story between 2011 and 2014. You were probably surprised by the number of conversations this entailed, and the sheer number of hours spent talking. It might have felt excessive and exhausting. But those long hours almost always make a story better. In the case of this story, I recall one tired conversation that happened at 8:00 p.m. in a hotel bar, after a long day in the lab. That conversation transpired in November 2011—and spawned what would become an entire section in the story published in December 2014, tracing an important thread of history from Kurt and Bernard Vonnegut in the 1940s through to the present day.

I want to thank *High Country News* not just for giving me the chance to write this story but simply for being the magazine, the organization, and the people that you are. I enjoy working with you. And I deeply respect your commitment to storytelling, and to providing the resources, the patient thought, and the space on a page that this requires.

And I want to thank Sarah Gilman, who edited me from beginning to end. Some stories come out well-crystallized the first time around, and the editing is straightforward. This was not one of those stories. The idea was there but required plenty of chiseling, honing, and generous use of the delete key to bring it out. It was Sarah who took a patient interest in the story and worked with me for 6 months, through countless rounds of suggestions and questions. That process can be exhausting, grating, and painful. But in this rare case it was painless—a partnership with someone whom I'd never met face to face but came to trust and respect. Thank you, Sarah! I enjoyed working with you.

**—Douglas Fox**, *Freelance Writer, Alameda, Calif.*

## Sandi Doughton Receives 2015 David Perlman Award for Excellence in Science Journalism – News

*Sandi Doughton received the 2015 David Perlman Award for Excellence in Science Journalism – News at the AGU Fall Meeting Honors Ceremony, held on 16 December 2015 in San Francisco, Calif. The award recognizes "a journalist for a news story or series in any medium except books that makes information about the Earth and space sciences accessible and interesting to the general public."*

Sandi Doughton

### *Citation*

Sandi Doughton first wrote about the laser surveying system called lidar years ago.

In 2009, she reported on how scientists used lidar to study mysterious mounds in the lowlands of southwest Washington. It was a classic story by our top-notch science reporter: lots of details for the science geeks written in an engaging fashion for our broader audience. The crisp lidar images showed the mounds formed at the edges of retreating glaciers, supporting a theory about their origin proposed 100 years ago.

Later that same year she reported on the experts who were using lidar to monitor movement in a large landslide that buried a quarter mile of highway in Yakima County in central Washington.

So when last year's catastrophic landslide buried a rural, riverfront community in Snohomish County, north of Seattle, Sandi immediately wondered what lidar images of the terrain would show. She dug around and found that Snohomish County had conducted lidar surveys of the slide area and extended river valley in 2013.

The images revealed scars left by a series of huge landslides up and down the valley that are now hidden by time and thick vegetation. At least one of these ancient slides was twice as big as the one that struck on 22 March 2014, killing 43 people in Oso.

Seeing these images left no doubt about the danger along the Stillaguamish River.

Sandi's story, though, did more than report the results of those surveys. She took the time to explain how the technology works. She then switched to watchdog mode and reported how many of these valuable images aren't easily accessed by homeowners, builders, and buyers wanting to better understand the risks associated with a piece of property.

All this discussion of lidar and its benefits led the Washington State Legislature this past spring to pass legislation that will expand lidar mapping of geologic hazards and make that information more available. The legislation, signed by the governor in April, was the first major public policy initiative in response to the Oso landslide.

**—Richard Wagoner**, The Seattle Times, *Seattle, Wash.*

### *Response*

For a science writer, it's a thrill to be mentioned in the same sentence as David Perlman. To receive an award named for one of the best and hardest-working reporters in the business is an honor.

Like David, I work for a daily newspaper. It's unusual for scientific organizations to recognize the distinction between feature stories and journalism produced on tight deadlines—sometimes within hours, at most over a few days.

I'm grateful to AGU for acknowledging the value of that kind of coverage, and to David for setting the standard as to how it should be done. And since a journalist is only as good as her sources, I'd also like to thank the many geoscientists who have so freely shared their time and expertise with me over the years.

This story grew out of the horrific landslide that roared off a slope near the Western Washington town of Oso. Within minutes, an entire neighborhood along the Stillaguamish River was obliterated. Forty-three people, who had been going about their business on a Saturday morning, were killed.

An emergency manager described the disaster as "completely unforeseen."

Geoscientists knew better.

As my colleagues at the *Seattle Times* quickly determined, the hillside had collapsed repeatedly in the past. Geologists had warned it would happen again.

That history made me wonder what lidar images of the slide area might show. The technique has fascinated me ever since I learned about its power to reveal hidden features on the landscape, so I turned to Ralph Haugerud. One of the U.S. Geological Survey's most accomplished "lidar whisperers," Haugerud was already working up a quick report on the Stillaguamish valley.

That report documented dozens of previous slides, some even bigger than the one that obliterated the community near Oso. But the people who lived there never saw those lidar images, nor was the lidar data incorporated into state databases or land use policies.

In the Pacific Northwest, there are many examples of the Earth sciences nudging society toward positive change. Field geologists and seismologists revolutionized our understanding of earthquake risk—and the region is much better prepared as a result. The same is true of volcanic hazards.

Those examples make me optimistic that contributions from the geosciences, including lidar, will eventually lead to better understanding of landslide hazard and better public policy. I just hope we don't have to experience another tragedy like Oso before we get there.

**—Sandi Doughton**, The Seattle Times, *Seattle, Wash.*

## Fumio Inagaki Receives 2015 Asahiko Taira International Scientific Ocean Drilling Research Prize

*Fumio Inagaki was awarded the 2015 Asahiko Taira International Scientific Ocean Drilling Research Prize at the AGU Fall Meeting Honors Ceremony, held on 16 December 2015 in San Francisco, Calif. The Taira Prize is a partnership between AGU and the Japan Geoscience Union (JpGU), and is made possible through a generous donation from the Integrated Ocean Drilling Program Management International (IOPD-MI). The prize honors an individual for "outstanding transdisciplinary research accomplishment in ocean drilling."*

*Fumio Inagaki*

### *Citation*

Fumio Inagaki is one of the most influential leaders in the science and technology of exploring life through ocean drilling. He has significantly advanced the study of microbial life in deeply buried sediment. He is internationally recognized as an innovator of techniques, standards, and instrumentation in ocean drilling geomicrobiological research. Fumio has published over 100 articles in renowned international journals and textbooks on life below the ocean floor. His truly interdisciplinary work combines microbiology, geochemistry, and geology with ocean drilling science and technology to understand the limits of life on Earth. His studies of the biogeochemical functions of deep-ocean microorganisms include transdisciplinary contributions to important societal challenges, such as the fate of Earth's deep carbon, subseafloor carbon dioxide storage, and the microbial potential for converting carbon dioxide to methane in deeply buried coal beds.

Among his major scientific contributions through ocean drilling are the first demonstration of subseafloor biogeography of microbial life, the proof by stable-isotope tracing experiments that cells in deep subseafloor sediment are capable of metabolic activity, and the recent discovery of microbial life in deeply buried subseafloor coal by ultradeep ocean drilling. His achievements have not only pushed the frontiers of ocean drilling for deep biosphere research but also been influential in a broad range of other fields, such as extreme environment research, microbial ecology, geobiology, and astrobiology.

Fumio Inagaki's exceptional leadership in the science and technology of ocean drilling include his outstanding support of young scientists and his engagement in design of the *Chikyu*, the most modern scientific drilling vessel. He has co-led or participated in 10 ocean drilling expeditions focused on exploration and understanding of subsurface life. In all of his work, Fumio has shown exceptional generosity, dedication to international collaboration beyond any frontier, and amazing integrity as a person in a highly competitive field. He has a great sensibility for the achievements of others, which he is always ready to put before his own. He opens his lab at the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) to any international student or postdoc in need of advice or equipment. He has dedicated a lot of time to service on scientific boards and committees for the advancement of ocean drilling science. As the first recipient of the Taira Prize, Fumio Inagaki is honored for his exceptional scientific and technological leadership in international ocean drilling research.

**—Antje Boetius,** *Max Planck Institute for Marine Microbiology, Bremen, Germany; and* **Steven D'Hondt,** *University of Rhode Island, Narragansett*

### *Response*

It is a tremendous honor for me to receive the prestigious Taira Prize. I would like to express my deepest thanks to Antje Boetius and Steve D'Hondt for their gracious citation, and AGU, Japan Geoscience Union (JpGU), and Integrated Ocean Drilling Program (IODP) for establishing the Taira Prize to recognize international scientific ocean drilling research.

My first participation in ocean drilling was on the U.S. drilling vessel *JOIDES Resolution* (JR) during the Ocean Drilling Program (ODP) Leg 201 off Peru and in the East Equatorial Pacific in 2002, which was the pioneering project dedicated to the study of subseafloor life and the deep biosphere. I had the good fortune to work with fantastic international colleagues during Leg 201, including the co-chief scientists Steve D'Hondt and Bo Barker Jørgensen. I still remember the electric blitz I felt when numerous geochemical and microbiological profiles were posted on the shipboard wall, which systematically showed the beautiful nature of the subsurface microbial ecosystems that we had explored with drilling. In 2010, I had the opportunity to sail as co-chief scientist with Steve on IODP Expedition 329 to explore the ultra-oligotrophic South Pacific Gyre. This challenging adventure on the JR confirmed the deep penetration of dissolved oxygen into the deep-sea sediments from the seafloor to the basement and, for the first time, demonstrated that there are no limits to the aerobic sedimentary biosphere. In 2012, onboard the Japanese riser-drilling vessel *Chikyu,* I had the unprecedented second opportunity to sail as co-chief scientist, this time with Kai-Uwe Hinrichs, to explore the limits of deep life down to ~2.5 kilometers below the seafloor. During the *Chikyu*'s Expedition 337, it was an unforgettable moment with Kai and colleagues when we extended the previous scientific ocean drilling world record to a depth of 2466 meters and observed ultra-deep microbial life in ~20 million-year-old coal horizons.

I am particularly proud to have had the opportunity to explore the deep-biosphere frontiers working with many excellent teams and friends, not only in my geomicrobiology laboratory at JAMSTEC, but also during the drilling expeditions. Indeed, this first Taira Prize recognizes the efforts of the entire deep-biosphere ocean-drilling community. Finally, most importantly, I would like to especially thank my wife and family, who have always supported my scientific ventures. In 2011, Bo mentioned that "deep-biosphere research is still a young science with exciting challenges ahead"—where nobody has gone before.

**—Fumio Inagaki,** *Japan Agency for Marine-Earth Science and Technology, Nankoku, Kochi, Japan*

## Richard C. J. Somerville Receives 2015 Climate Communication Prize

*Richard C.J. Somerville was awarded the 2015 Climate Communication Prize at the AGU Fall Meeting Honors Ceremony, held on 16 December 2015 in San Francisco, Calif. The Climate Communication Prize is funded by Nature's Own, a purveyor of fossils, minerals, and handcrafted jewelry in Boulder, Colo. The prize honors an "AGU member-scientist for the communication of climate science, and highlights the importance of promoting scientific literacy, clarity of message, and efforts to foster respected and understanding of science-based values as they relate to the implications of climate change."*

Richard C. J Somerville

### *Citation*

Richard Somerville has made monumental contributions to the collective effort to communicate climate change to the public. These efforts include contributions to AGU's own communication and outreach mission. At the AGU Fall Meeting 3 years ago in San Francisco, Richard, working with Susan Joy Hassol and the newly formed Climate Science Rapid Response Team, jointly conducted a series of workshops for climate scientists, providing critical training to these scientists, including the next generation of climate science communicators.

Richard coauthored with Susan Joy Hassol an influential article "Communicating the Science of Climate Change" in *Physics Today*. In this article, he presented a number of key science communication concepts to the community. For example, the article showed how emissions would have to be ramped down rapidly as the timing of peak emissions is increasingly delayed. The diagram communicates the urgency of climate change mitigation in a compelling manner.

Richard has also played a critical role in organizing the scientific community to more effectively combat the misinformation and disinformation that is sadly so omnipresent in today's media coverage of climate change. He played an influential role, for example, in drafting a letter from 38 climate scientists to counter a particularly misleading op-ed published in the *Wall Street Journal*. The letter of response began with Richard's very effective rhetorical question: "Do you consult your dentist about your heart condition?"

One of the tougher things for climate scientists to talk about effectively is the relationship between climate change and extreme weather. Too often, scientists, as Richard has noted, lead with what is not known, rather than what is known—a fatal communication blunder. Richard has been out front in talking about the conundrum, coaching a whole generation of climate scientists in how to communicate the actual connections in ways that are effective and accurate.

Richard continues to do all of these things even as he has, along with other University of California, San Diego (UCSD) faculty, developed and begun to teach a new massive open online course (MOOC) on climate change. Entitled "Change in Four Dimensions," the course covers the physical, sociological, technological, and humanistic aspects of climate change.

Richard is currently the primary scientific adviser for Susan Joy Hassol's Climate Communication group while also serving as distinguished professor emeritus and research professor at the Scripps Institution of Oceanography/UCSD.

**—Michael E. Mann,** *Pennsylvania State University, University Park; and* **Jeffrey T. Kiehl,** *National Center for Atmospheric Research, Boulder, Colo.*

### *Response*

With great humility, I profoundly thank AGU for awarding me its Climate Communication Prize. I thank Jeff Kiehl and Mike Mann for nominating me, and I thank Nature's Own for the cash award that accompanies this great honor. All the previous winners of this prize, Gavin Schmidt, Jeff Kiehl, Kevin Trenberth, and Katharine Hayhoe are my friends and colleagues. I have learned much from them about communicating the science of climate change. I also gratefully acknowledge the late Steve Schneider, who taught all of us. I agree with Steve's wise advice to everyone who communicates science: Know thy audience; know thyself; know thy stuff.

I have also learned much from scientists who have mastered the art of communicating science with the broad public through television, notably Neil deGrasse Tyson and the late Carl Sagan. Many fine scientists have excelled at speaking and writing for the general public, including John Tyndall, who put the greenhouse effect on a firm physical foundation in 1861. Elizabeth Kolbert is a superb science writer who writes often and powerfully about climate change. All these people have inspired me.

I must single out the immense benefit I have had from working on climate communication for more than 25 years with Susan Joy Hassol. Our partnership is unusual. Susan is a professional communicator, not a scientist, but she has acquired a deep understanding of climate science, and she has an uncanny ability to explain complex scientific topics in clear, compelling English. The website climatecommunication.org showcases many products of our collaboration and is a one-stop shop for anybody who wants to do better at communicating climate science.

There are many obstacles to communicating climate science clearly. Communicating well is like skiing well. Nobody is born an expert skier, but it can be learned, and a good way of learning is taking lessons from experts. We know that excellent science can inform wise policy and that communicating the science effectively can help the world cope intelligently with the challenge of climate change. I hope that many more climate scientists will make the effort to improve their ability to communicate science with the wider world. I thank Sylvia Bal, my wife of 50 years, for her unwavering support. I thank the many colleagues who have worked with me. I thank AGU and Nature's Own for establishing this prize in climate communication and for honoring me with it.

**—Richard C. J. Somerville,** *Scripps Institution of Oceanography, University of California, San Diego, La Jolla*

# Slow-Moving Glide Avalanches Still Pack a Punch

Christopher Ancey. Used with permission.

*A chairlift station in St. François Longchamps, France, damaged by a wet-snow glide avalanche in March 2012.*

Avalanches pose a dramatic threat to human lives and infrastructure in snowy regions around the world. Rising global temperatures have increased the frequency and impact of gravity-driven flows, in which mechanical failures trigger snow avalanches and debris flows. A type of wet-snow avalanche known as glide avalanches has caused increasing damage as well, but scientists still struggle to understand the precise physics behind these hazards.

When meltwater is under pressure from the snowpack above and warmed by the ground below, it acts as a lubricant, which causes a large solid mass of wet snow to glide slowly down a slope. These avalanches are most common on fairly steep slopes with a smooth surface like grass or bare rock. Adjacent areas of snow glide at different speeds, generating stress within the snowpack. Once the stress reaches a critical level, the snowpack can crack all the way through, cascading snow down the slope. Glide avalanches can cause serious damage to infrastructure, such as chair lift towers, and calculating their potential impact is vital to better protecting mountain communities.

## Correction

In the 15 December 2015 issue of *Eos,* the affiliation of Postcards from the Field contributor Allen Pope should have been listed as the University of Colorado, Boulder.

One such glide avalanche occurred on 2 March 2012 at the St. François Longchamps resort in France. Seventy skiers were riding the chairlift when it was hit, but they were evacuated unharmed. This was the first avalanche to hit this 28-year-old chairlift, which was damaged again by a 2015 glide avalanche.

Using mathematical models and laboratory simulations, *Ancey and Bain* reviewed the physics of glide avalanches and the forces they exert on simple structures such as chair lift towers. They also used two case studies of glide avalanche damage to chair lift towers to back calculate the forces involved. Although the precise physical mechanisms behind glide avalanches remain elusive, when the snow depth and density are known, the force exerted on simple structures can be calculated. The team also reports that gliding snowpacks can produce the same force as high-speed flows.

The studies the authors reviewed also differ in predictions of wet-snow avalanche frequency in response to global climate change. Field surveys show considerable variability in the nature of avalanche activity in recent decades, and the researchers reported no clear correlation between global warming and the frequency of wet-snow avalanches. Despite this ambiguity, the study is an important step toward a better scientific understanding of avalanche physics and prediction, vital to cold climate regions where communities and economies rely on snow safety. (*Reviews of Geophysics,* doi:10.1002/2015RG000491, 2015) **—Nancy McGuire, Freelance Writer**

# Improving Indian Summer Monsoon Prediction

The Indian summer monsoon brings torrential rains to Southeast Asia from June through September every year in a weather event with massive impacts on local economics, infrastructure, and culture. In summer, winds from the southwest carry moisture from the Indian Ocean and deposit it over the Indian subcontinent. Around October, the winds reverse direction, and only certain regions receive the remaining moisture.

The topography of the subcontinent further contributes to the intensity of the monsoon, with the Himalayas and the Western Ghats acting as barriers that trap severe weather above India. Despite its seasonality, the timing, duration, and intensity of the Indian Summer Monsoon vary widely, and scientists are keen to improve modeling and prediction methods to account for this kind of variability.

Using observations from an instrument called the Atmospheric Infrared Sounder (AIRS) aboard NASA's Aqua satellite, *Raju et al.* evaluated how changes in temperature and moisture with respect to altitude influence monsoon development. They used the data to model monsoon characteristics, including precipitation, easterly wind shear, low-level moisture distribution, and the temperature of the troposphere (the lowest layer of Earth's atmosphere).

By combining observations and a regional model, the team was able to more accurately forecast patterns of precipitation across the region. The forecast monsoon features are highly correlated with observations, indicating their potential value for future predictions of the Indian summer monsoon. The AIRS data may be the key to more realistic models of temperature and moisture processes that drive monsoon development and behavior. Seasonal forecast improvements would have tremendous implications for lives and livelihoods throughout the region, especially during the extremes (drought or flood). (*Journal of Geophysical Research: Atmospheres*, doi:10.1002/2014JD023024, 2015) **—Lily Strelich, Freelance Writer**

Caisii Mao/demotix.com

*Indian cycle rickshaw drivers battle the high water to get commuters through the flooded areas of Dhobinala during heavy monsoon rains in Dimapur, Nagaland, India.*

# Forecast Versus Reality: High-Resolution Weather Prediction

Flickr user Kelly DeLay, CC BY-NC 2.0 (http://bit.ly/ccbync2-0)

*A storm cell in Groom, Texas, produces a brief tornado.*

The storm systems that sweep across the central United States drive flooding, drought, and environmental changes that affect communities and economies across the country. People in the path of these storms rely on quantitative precipitation forecasts from numerical weather prediction models, which offer estimates of rainfall hours to days in advance. High-resolution models can be combined with hydrologic models to project broader effects like streamflow and flooding, but model accuracy can fluctuate depending on the season, grid resolution, and available observational data.

The High-Resolution Rapid Refresh (HRRR) model was developed to resolve some of this uncertainty. It uses latent heat profiles derived from radar observations to provide hourly forecasts of convective storms on the scale of 3 kilometers. Because of this precision, honing the HRRR model accuracy has far-reaching benefits for infrastructure and industry across the country. Here *Bytheway and Kummerow* use observational data to evaluate HRRR forecast performance.

The team developed a verification process based on data collected during the 2013 warm season by the National Centers for Environmental Prediction Stage IV radar rainfall product, comparing 467 convective precipitation features with HRRR forecast precipitation features. They found that the correlation between modeled and observed features fluctuated over the forecast period, with the closest correlation around hour 3 of any given forecast.

Overall, HRRR forecasted rainfall within 30 kilometers of the observed rainfall throughout the forecast period. It was also relatively good at predicting the location of the storm center of mass, although it tended to skew slightly west. In general, the model predicted smaller storms with rainfall concentrated in more intense cores than were actually observed. The distribution of rainfall within the storms was related to the model's ability to produce deep convection relative to atmospheric moisture content. The researchers shared these results with HRRR developers, and the updated version of the model attempts to mitigate the biases they identified. (*Journal of Advances in Modeling Earth Systems* (*JAMES*), doi:10.1002/2015MS000497, 2015) **—Lily Strelich, Freelance Writer**

# Convection Cycles, Atmosphere, and Ocean Work Symbiotically

Fluctuations in Earth's climate reflect the complex interactions of the atmosphere and oceans, a dynamic dance that changes with the seasons. One such interaction is the Madden-Julian Oscillation (MJO), a marriage of atmospheric circulation and tropical convection that propagates eastward above the warm regions of the Indian and Pacific Oceans.

The circulation cells are large—about 10,000 kilometers wide along the equator—and occur intraseasonally, roughly every 30 to 70 days. Because of this scale and frequency, the MJO has a big impact on global weather.

The rising and sinking motions within the MJO circulation cells produce a pattern of enhanced and suppressed convection. This convection pattern brings rainfall and induces changes in clouds and wind, which translates to variations in heat, salinity, and momentum at the ocean surface where water and atmosphere interact. The associated changes in sea surface temperature can have global consequences, but the MJO is difficult to explain theoretically or simulate in atmospheric general circulation models, and its relationship with sea surface temperature is poorly understood.

Here *DeMott et al.* work to fill in these knowledge gaps by reviewing published studies dealing with observations of MJO processes, theories of air-sea interactions within the MJO, and modeling studies of these feedbacks. Their review article aims to develop better insight into how air-sea interactions influence the MJO and, ultimately, how these exchanges shape weather patterns.

When the MJO inhibits convection, light winds and clear skies allow the upper few meters of the ocean to warm and separate into stable layers stratified by temperature and salinity. As MJO convection develops, windy conditions at the surface mix these layers and transfer energy stored in the upper ocean to the atmosphere.

As the MJO propagates eastward, this mixing action increases, driving currents and upsetting the stratified layers. Scientists discovered the phenomenon in the 1970s, but a comprehensive theory for the MJO and a clear understanding of the role of the ocean in the disturbance have been elusive. The researchers summarize the current understanding of these processes by analyzing results of more than 300 papers focused on the problem.

Charlotte A. DeMott. Used with permission.

*Cloudiness within the Madden-Julian Oscillation (MJO), shown here in the west Pacific, regulates radiative, freshwater, and momentum forcing of the upper ocean. The ocean adjustment to the forcing regulates sea surface warming or cooling, which can, in turn, affect MJO cloudiness.*

The review study found that high-resolution mixed layer ocean models can represent some of the complicated air-sea interactions and recommended that scientists use coupled simulations and evaluate them in terms of the observed relationship between convection and sea surface temperature and associated variables.

A full assessment of air-sea interactions within the MJO requires a combination of methods, including modeling studies, process-oriented diagnostics, and careful measures of the environmental moisture profile and heat budget of the MJO. A comprehensive approach is central to improving our knowledge of ocean-atmospheric coupled feedbacks. (*Reviews of Geophysics,* doi:10.1002/2014RG000478, 2015) **—Lily Strelich, Freelance Writer**

# Aerosols May Play a Big Part in Atmospheric Absorption

Life on Earth is supported by a thin layer of gases held to the planet's surface by gravity. Our atmosphere provides the breath of life and regulates global temperature in the face of a constant onslaught of solar radiation. Aerosol particles—including smoke, ash, soot, mineral dust, and sea salt—play a key role in regulating atmospheric energy exchanges. The particles can directly drive effects in the energy budget by raising the Earth's albedo, scattering and reflecting solar radiation back into space and ultimately cooling the planet. Indirect effects of aerosols are more complex, like the uncertainties of particle interaction with clouds. A better scientific understanding of the role of aerosols in the atmosphere could give communities a vital tool to adapt to the Earth's changing climate.

Here *Lacagnina et al.* evaluate the single-scattering albedo of the atmosphere with measurements from the Polarization and Anisotropy of Reflectances for Atmospheric Sciences Coupled with Observations from a Lidar (PARASOL) satellite and compare their measures with observations from the Ozone Monitoring Instrument and the ground-based Aerosol Robotic Network. This study is the first time PARASOL data have been compared alongside other observations, and the data cover almost the entire globe, offering valuable insight into aerosol influence.

The scientists found that the data sets usually reflect real-world observations quite nicely but that the models slightly overestimate aerosol scattering, as opposed to absorption. In other words, the models predicted an outsize role for aerosol, scattering solar radiation and cooling the upper atmosphere. The researchers suggest this bias implies that the direct and indirect effects of aerosols within the atmosphere may be bigger than previously simulated.

The researchers hope their work highlights the potential and the importance of aerosols and the single-scattering albedo effect in evaluating the Earth's energy exchange. The success of this comparison between PARASOL data, observations, and model simulations may help open the door to more cohesive analyses of the atmosphere. (*Journal of Geophysical Research: Atmospheres*, doi:10.1002/2015JD023501, 2015) **—Lily Strelich, Freelance Writer**

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## Hydrology

**Tenure-Track Assistant Professor Position GROUNDWATER HYDROLOGIST University of Wyoming**

The Department of Civil and Architectural Engineering at the University of Wyoming invites applications for a tenure-track faculty position in Groundwater Hydrology at the Assistant Professor level. We seek a candidate with the interest and abilit y to develop and sustain a nationally competitive research program. The successful candidate must hold an earned doctoral degree in Civil Engineering or in a closely related discipline by the position start date. Registration as a professional engineer or professional hydrologist are desirable but not required. The successful candidate must be able to teach courses in fluid mechanics, hydraulics, hydrology, and water resources engineering. Also, the successful candidate must have the demonstrated ability to develop an externally funded research program in groundwater hydrology.

This position will become part of a major research thrust in water resources at the University of Wyoming. Groundwater resources are of immense impo11ance to societal and ecological needs. Approximately half of Wyoming water resources are from groundwater, and subsurface resources provide critical water to agriculture, oil and gas development, and municipalities. There are tremendous research challenges in groundwater resulting from changing climate signals and human population patterns, and emerging techniques provide outstanding opportunities for groundwater hydrologists to better quantify the fate and transport of water in a changing west. We seek a groundwater hydrologist with experience in laboratory and field approaches for describing complex subsurface processes. Areas of specific interest include, but are not limited to, surface-groundwater interaction, unsaturated flow and contaminant transport.

As a member of the faculty of the Department of Civil and Architectural Engineering, the successful candidate will integrate his or her research with the goals of the new Wyoming Center for Environmental Hydrology and Geophysics (http://www.uwyo.edu/epscor/wycehg/) and provide academic support to the PhD program in Water Resources, Environmental Science and Engineering (http://www.uwyo.edu/wrese/).

UW faculty have access to world-class computational resources as described at: https://arcc.uwyo.edu/. The depat1ment is supported by 22 tenured or tenure-track faculty and offers ABET-accredited baccalaureate programs in both civil engineering and architectural engineering to approximately 300 undergraduate students. The department also offers graduate programs at the Masters and PhD levels to roughly 60 graduate students.

Laramie is a picturesque and friendly town offering a reasonable cost ofliving, good K-12 public schools and easy access to outdoor activities in the Rocky Mountain region. Additional information on the Department, College, and Laramie is available at: http://www.uwyo.edu/civil , http://ceas.uwyo.edu and http://www.laramie.org.

Applications must include: 1) a letter of application, 2) a curriculum vitae including a list of publications, 3) a statement of research interests, 4) a statement ofteaching interests, and 5) contact information for at least three references. Do not include supplemental information such as off-prints of papers, reference letters, or transcripts. Review of applications will begin 1 5

September 2015 and continue until the position is filled. The preferred start date for the position is January 2016. Submit applications in a single PDF file to: water_search@uwyo.edu.

The University ofWyoming is an Equal Employment Opportunity/Affirmative Action employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, disability or protected veteran status or any other characteristic protected by law and University policy. Please see: http://www.uwyo.edu/diversity/faimess. We conduct background investigations for all final candidates being considered for employment. Offers of employment are contingent upon the completion of the background check.

**Tenure-Track Faculty Position, Civil and Environmental Engineering, Utah State University**

The Department of Civil and Environmental Engineering at Utah State University is searching to fill a tenure-track faculty position in water management of irrigated systems (complete description go to https://usu.hiretouch.com/job-details?jobid=937) as part of a water-focused cluster hire involving multiple colleges within the University (https://caas.usu.edu/cwi/). All ranks (Assistant/Associate/Full Professor level) will be considered for this position. Applications will begin being reviewed on 12/2/15, but the position will remain open until filled.

## Ocean Sciences

**Assistant Professor, Tenure Track.**

The University of Washington School of Oceanography invites applications for a full-time (100% FTE), 9-month, multi-year tenure-track Assistant Professor (0116) position. A Ph.D. or foreign equivalent is required on the date of appointment. We seek to hire a physical oceanographer with strong dynamical and/or observational interests. The applicant's research focus may be at any scale, from coastal to global, from

mixing to climate. Applicants should demonstrate interest in interdisciplinary collaboration, and complement the research of our current faculty. University of Washington faculty engage in teaching, research and service. The successful applicant will be expected to contribute to the teaching mission of the department at the graduate and undergraduate levels. The University of Washington and the School of Oceanography promote diversity and inclusivity among our students, faculty, staff, and public. Thus, we seek candidates whose research, teaching, and/or service have prepared them to fulfill our commitment to inclusion, and have given them the confidence to fully engage audiences in higher education from a wide spectrum of backgrounds.

The University of Washington (UW) is located in the greater Seattle metropolitan area, with a dynamic, multicultural community of 3.7 million people and a range of ecosystems from mountains to ocean. The UW serves a diverse population of 80,000 students, faculty and staff, including 25% first-generation college students, over 25% Pell Grant students, and faculty from over 70 countries. A recipient of the 2006 Alfred P. Sloan Award for Faculty Career Flexibility and a National Science Foundation ADVANCE Institutional Transformation Award to increase the advancement of women faculty in science, engineering, and math (see www.engr.washington.edu/advance), the UW provides a wide range of networking, mentoring and development opportunities for junior faculty.

Questions pertaining to this search can be addressed to Dr. Parker MacCready, Search Committee Chair (pmacc@uw.edu). More information on the School of Oceanography can be found at http://ocean.washington.edu.

Applicants should submit a cover letter, curriculum vitae with publication list, statements of research and teaching interests with reference to how their teaching and/or research demonstrate a commitment to diversity and inclusion through scholarship or by improving access to higher education for underrepresented individuals or groups, and the names and contact information of four references. We request letters of recommendation from these references to be sent separately. Electronic materials are preferred; send to oceanjob@uw.edu with Assistant Professor PO Position in the subject line. If you are only able to send a hard copy, please address it to Ms. Su Tipple, School of Oceanography, University of Washington, Box 357940, Seattle, WA, 98195, USA. Individuals with disabilities desiring accommodations in the application process should notify Su Tipple at 206-543-5060. Applications, including letters of recommendation, should be received prior to February 1, 2016, to ensure full consideration.

University of Washington is an affirmative action and equal opportunity employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, age, protected veteran or disabled status, or genetic information. The University of Washington is recognized for supporting the work-life balance of its faculty and offers a wide range of professional development and networking opportunities for junior faculty and a comprehensive benefits package, including access to campus child-care and health/vision/dental plans for spouse, domestic partner, and/or dependents. Details can be found at http://www.washington.edu/admin/hr/benefits/forms/ben-summaries/faculty.pdf

**Post Doctoral Research Associate, Marine Sciences, Stennis Space Center**

A postdoctoral position in physical oceanography is available in the Department of Marine Science at The University of Southern Mississippi. The successful candidate will work on various problems related to tide and internal tide generation, propagation and dissipation in the realistically forced global HYCOM model. In particular, a better parameterization of internal tide wave drag will be explored. The candidate is expected to perform idealized 2D and realistic global 3D HYCOM simulations. This position allows for ample collaboration opportunities with science partners of the ONR NOPP project Topic 3 "Seamless Forecasting from the Deep Ocean to the Coast." A PhD in physical oceanography or other related field is required at the time of the appointment. A qualified applicant is anticipated to have experience in numerical modeling and knowledge of internal wave processes in the ocean.

This position is initially for one year but is renewable based on satisfactory performance. Interested candidates please contact Maarten.Buijsman@usm.edu or see online posting at: jobs.usm.edu/applicants/Central?quickFind=55843

The USM is an equal opportunity action employer.

**The Marine Science Institute (University of California, Santa Barbara) seeks a PhD level postdoctoral fellow to contribute to studies of nutrient fluxes and exchanges from sediments into coastal waters near kelp forest ecosystems.**

The position will involve hydrodynamic and biogeochemical field measurements and associated data analysis and modeling. The research is associated with an on-going NSF funded Long-Term Ecological Research (LTER) project and related work on coastal ecosystems (http://sbc.lternet.edu/). Salary and benefits will depend on aca-

demic background and experience. 100% time appointment for one year from start date with possibility for second year renewal. Start date is negotiable, but is anticipated by April 2016. Electronic applications (including a full CV, description of research interests and names and addresses of three references) should be sent to: https://recruit.ap.ucsb.edu/apply/JPF00623. Application review will begin January 15, 2016 and continue until position is filled. The department is especially interested in candidates who can contribute to the diversity and excellence of the academic community. The University of California is an Equal Opportunity/Affirmative Action Employer. All qualified applicants will receive consideration for employment without regard to race, color, religion, sex, national origin, or any other characteristic protected by law including protected Veterans and individuals with disabilities.

**The NSF is seeking a qualified candidate to fill the position of Program Director in the Marine Geology and Geophysics (MGG) Program in the Division of Ocean Sciences (OCE), Directorate for Geosciences (GEO) in Arlington, VA.**

The successful candidate will manage a portfolio of research in marine geophysics, including research relating to: the structure and tectonic evolution of the oceanic lithosphere and its associated volcanic, magmatic, hydrothermal, and earthquake activity; the tectonics and morphology of the seafloor and the geodynamic processes that create it; and subseafloor fluid flow that controls the exchange of heat and chemical species between seawater, abyssal ecosystems, and ocean crust. The individual selected for this position will also oversee NSF-funded marine geophysical infrastructure and data centers, coordinating with the Division of Ocean Sciences facilities group to facilitate access to marine seismic facilities (e.g., the Ocean Bottom Seismometer Instrument Pool and 2D/3D seismic data acquisition platforms), as the Division of Ocean Sciences continues to implement community recommendations (e.g., the National Academy of Sciences report Sea Change: Decadal Survey of Ocean Sciences 2015-2025).

Specific details regarding the duties, qualifications, benefits and how to apply are found on the USAJOBS website (https://www.usajobs.gov/).

Applicants wishing to apply for a Permanent Appointment should see Job Announcement OCE-2016-0002 at: https://www.usajobs.gov/GetJob/ViewDetails/423526200

Applicants wishing to apply for a Federal Temporary, IPA or VSEE Appointment should see Job Announcement OCE-2016-0003 at:

https://www.usajobs.gov/GetJob/ViewDetails/423526700

Please contact Candace Major, MGG Program Lead (cmajor@nsf.gov; 703-292-7597), with any questions about this position.

**YALE UNIVERSITY: Postdoctoral Positions in Ocean, Atmosphere and Climate Dynamics**

One or two postdoctoral positions in Ocean, Atmosphere and Climate Dynamics will be available at Yale University, Department of Geology and Geophysics (http://people.earth.yale.edu/profile/alexey-fedorov/about). General fields of research include ocean and atmosphere circulation, ocean-atmosphere interactions, the role of ocean in climate, climate variability and change, paleoclimate. Particular projects: El NiÒo and mean tropical climate in the past, present and future; ITCZ in different climates; biases in GCMs; stability, variability and predictability of the Atlantic meridional overturning circulation (AMOC). The work will involve numerical modeling, analyses of observational and GCM data, and analytical approaches. A PhD in physical oceanography, atmospheric sciences or related disciplines is required. Experience with ocean or climate GCM is a big advantage. Funding is currently available for two to three years. Successful candidates can begin their program at Yale between April - September, 2016. The applicants should email his or her CV, a statement of research interests, one reprint or preprint, and the names of three referees to Professor Alexey Fedorov (alexey.fedorov@yale.edu; Subject: postdoctoral search). Short-listed candidates will be contacted. Yale University is an affirmative action/equal opportunity employer. Yale values diversity in its faculty, staff, and students and strongly encourages applications from women and members of underrepresented minority groups.

## Solid Earth Geophysics

**Tenure-Track Faculty Position in Geophysics**

(position number 198994, requisition number 1500158F)

The Department of Physics at New Mexico State University invites applications for a tenure-track faculty appointment in Computational Geophysics. Candidates with computational skills in seismology, crustal and mantle dynamics, and thermo-mechanical properties of rock systems are invited. A strong computational and physics background is required. The NMSU Physics Dept. offers Bachelor's degrees in Physics and Engineering Physics and Master's and Doctoral degrees in Physics and Geophysics. Current research areas in the department include high-energy nuclear and particle physics, solid-state/condensed-matter physics and materials science, optics, and geophysics. There are additional university strengths in Astronomy (helioseismology and planetary physics), Electrical and Computer Engineering, and Mechanical Engineering. The successful candidate is expected to initiate and maintain an active, externally funded research program, supervise graduate students, and to teach at both undergraduate and graduate levels. Appointment will be at the Assistant Professor level. A Ph.D. degree in Physics, Geophysics, or related field is required, and postdoctoral experience is highly desired.

Applications must be filed electronically at (http://jobs.nmsu.edu) and the deadline for applications is February 15, 2016. Applicants should attach a resume, a statement of research interests, a short description of the candidate's teaching philosophy and the names and addresses of at least three persons familiar with the candidate who are willing to provide letters of reference. The position is anticipated to start in Fall, 2016.

For further information or questions please contact the Head of the Search Committee, Prof. Tom Hearn, at thearn@physics.nmsu.edu . NMSU is an Equal-Opportunity/Affirmative-Action employer; Minorities, Females, Veterans, and those with a Disability are particularly encouraged to apply.

## Interdisciplinary/Other

**Assistant Professor in Tectonics/Structural Geology, Department of Geology, University of Maryland, College Park.**

The Department of Geology at the University of Maryland invites applications for a tenure-track assistant professor in Tectonics/Structural Geology, broadly defined. Possible research areas of interest include, but are not limited to: active tectonics and natural hazards, basin analysis, climate-tectonics interactions, crustal evolution, geodesy, microtectonics, orogenesis, planetary geology, and tectonophysics. The appointee will be expected to develop and maintain an active, externally funded research program that will involve both graduate and undergraduate students, and to participate fully in teaching at all levels, including structural geology. We particularly encourage applications from those who integrate across traditional disciplinary boundaries both within the Department of Geology (http://www.geology.umd.edu) and throughout the College of Computer, Mathematics, and Natural Sciences (http://www.cmns.umd.edu). Candidates from underrepresented groups are encouraged to apply.

A Ph.D. in Geology or a related discipline is required at the time of appointment. The appointment may begin as early as August 1, 2016. Applications should be submitted online at http://ejobs.umd.edu/postings/38311 and should include the following: a letter of application stating research and teaching goals; a complete CV; and contact information for three (3) professional references. Review of applications will begin in January 2016, and will be ongoing until the position is filled.

The University of Maryland, College Park, an equal opportunity/affirmative action employer, complies with all applicable federal and state laws and regulations regarding nondiscrimination and affirmative action; all qualified applicants will receive consideration for employment. The University is committed to a policy of equal opportunity for all persons and does not discriminate on the basis of race, color, religion, sex, national origin, physical or mental disability, protected veteran status, age, gender identity or expression, sexual orientation, creed, marital status, political affiliation, personal appearance, or on the basis of rights secured by the First Amendment, in all aspects of employment, educational programs and activities, and admissions.

**Assistant/Associate Professor of Microbial Biogeochemistry**

The Department of Soil, Water and Environmental Science (SWES) at the University of Arizona seeks a dynamic individual to initiate a research and teaching program at the interface of soil microbial ecology and biogeochemistry. Applicants are sought who use contemporary techniques such as genomics, bioinformatics, isotope geochemistry, or high resolution imaging and spectroscopy, to study microbial communities and activities, and their interactions with biogeochemical processes in earth surface systems (ecosystems, soil, rock, water). Potential research foci may include (but are not limited to): plant-soil-microbe relations; nutrient dynamics and rhizosphere processes; mineral and organic matter transformations; and coupled microbial-biogeochemical processes, ranging from molecular to watershed scales. The candidate will teach an undergraduate course each year and a graduate course in a related area of specialization, contribute to student mentoring, and help to develop innovative approaches to enhance student engagement, increase diversity, and expand collaborations with community and business partners.

The SWES department comprises a cross-section of faculty, staff, and students with unparalleled capacity to address emerging environmental issues of local to global significance, including climate change, contaminant remediation, and the sustainable management of land and water resources. Outstanding research opportunities exist at the University of Arizona, with a strong culture of

interdisciplinary scholarship among faculty in the School of Earth and Environmental Sciences (http://www.sees.arizona.edu/), the School of Plant Sciences, the Department of Ecology and Evolutionary Biology, the Mel and Enid Zuckerman School of Public Health, and Biosphere 2.

Qualifications:

Minimum qualifications include a Ph.D. in microbiology, soil science or geoscience, biogeochemistry, or a closely related field. Postdoctoral experience is preferred. Applications from candidates with an interest in collaborative research are preferred, as are those from individuals who would bring novel microbial and/or biogeochemical approaches and techniques to bear on environmental systems. This is a tenure/tenure-eligible position and will have a 70/30 split between research and teaching. As an equal opportunity and affirmative action employer, the University of Arizona recognizes the power of a diverse community and encourages applications from individuals with varied experiences, perspectives and backgrounds, and who have experience with a variety of teaching methods and curricular perspectives.

About the University of Arizona:

The University of Arizona is the state's land-grant university and the Agricultural Experiment Station and Extension programs are housed in the College of Agriculture and Life Sciences (http://cals.arizona.edu/main/), which SWES is a part of. The UA is recognized as a global leader for research with a diverse working environment, nationally recognized work/life program, and a competitive benefits package. The UA is located in the heart of Tucson, a diverse and vibrant community, with a growing population, excellent recreational opportunities, and favorable economic climate. Explore Tucson and UA at http://whyua.arizona.edu/.

Application Instructions:

More information on the position and complete application instructions may be found at the UA Human Resources link: https://uacareers.com/postings/6969. Formal review of applications will begin 2/15/16 and continue until the position is filled

**Post-Doctoral Fellowships: Dept. of Earth, Ocean and Atmospheric Science, Florida State University**

The Department of Earth, Ocean & Atmospheric Science (EOAS) at Florida State University seeks candidates for two postdoctoral positions to conduct supervised research and teaching duties in the areas of solid Earth dynamics, isotope geochemistry, or arctic carbon cycling. These two-year positions are jointly supported by the College of Arts & Sciences and by faculty research grants. The positions are intended to better prepare future faculty by combining state-of-the-art research programs with classroom teaching experience for the candidates, and will involve two semesters of teaching, including one semester where the candidate will serve as the instructor of record for an undergraduate course. Fellows will work under direction of FSU faculty to support funded research programs (see below). Additionally, they will develop classroom teaching skills during one semester of each year, first under supervision and, during the second year, as instructors of record for an undergraduate class details of which are provided below. Fellows will be eligible to participate in the Preparing Future Faculty program at FSU (PFF). Research programs and instructional mentors seeking fellows include the following:

• Insights into the volatile budget in the Earth's interior using high pressure experiments, geochemical analysis, and numerical simulations. [see online info].

• Applying novel geochemical methods (e.g. novel stable metal isotopes) to the sedimentary record to trace the redox evolution throughout Earth history. [see online info].

• Researching carbon storage and flux in Arctic permafrost soils and peatlands from the arctic to the tropics [see online info].

Eligible candidates must hold a PhD in chemical oceanography, geochemistry or mineral physics related to the three areas of interest described above, at the time of appointment. Salary is $45,000 per annum, participation in state health plans is covered and $1,500 towards the purchase of a computer may be requested. The Florida State University is an equal opportunity, affirmative action employer and women, minorities, and individuals with disabilities, are strongly encouraged to apply. To apply, respond to the listing for Postdoctoral Associate, Earth, Ocean and Atmospheric Science at http://jobs.fsu.edu. Additional inquiries may be addressed to EOAS-PostDoc@ocean.fsu.edu. Review of applications will begin February 26, 2016, and appointment terms will begin for the fall semester 2016.

**Visiting Faculty Position /Volcanology and Geothermal Sciences /Kyoto University, Japan**

Kyoto University invites applications for a visiting Professor or Associate Professor in volcanology, geothermal sciences and related disciplines. The successful applicant is expected to work at Aso Volcanological Laboratory or Beppu Geothermal Research Laboratory, Kyushu, Japan. Attractive salary and traveling expenses are provided from the university. The position is opened on October 1, 2016, and the tenure is 3 to 12 months. The applicant should be 65 years old or younger when his/her term in this position has terminated. Send (1) CV including date of birth, nationality and publication list, (2) statement of research interests, (3) pdf files of 3 significant publications, (4) names and e-mail addresses of three references and (5) desired arrival date and place of assignment (Beppu or Aso) to Prof. Takahiro Ohkura through e-mail to VFP16@aso.vgs.kyoto-u.ac.jp by March 1, 2016. For the details, please look at http://www.vgs.kyoto-u.ac.jp/igse/.

## Student Opportunities

**PhD Fellowships in Remote Sensing are available immediately in Virginia Tech's Interdisciplinary Graduate Program.**

Remote Sensing is an interdisciplinary field which is evolving rapidly to address a wide range of scientific and societal problems. Virginia Tech's Remote Sensing graduate program spans nine departments in five separate colleges and covers all aspects of Remote Sensing, including engineering, theory, data analysis, applications, and policy. Students in the program pursue a Ph.D. in a core discipline in their home department while taking additional interdisciplinary courses which count toward a Remote Sensing Certificate. Interested applicants are encouraged to visit our website (http://rsigep.frec.vt.edu/) to learn more about the curriculum, specific research themes, the application process, and how to communicate with prospective advisors. General questions can be directed to rs_igep@vt.edu.

**PhD in Climate Decision Making through EPP at Carnegie Mellon.**

We seek PhD students with technical backgrounds to address 1) public understand and perceptions of GHGs, climate and low emission energy portfolios; 2) decarbonizing the energy system; 3) future of nuclear; and 4) risks of dead ends in scaling up climate policies. See: www.epp.cmu.edu and http://CEDMcenter.org. Contact: ebass@cmu.edu.

**PhD Student Opportunity in Hydrology, Washington State University**

Four year RA available for student to work with an interdisciplinary team to understand the interactions between drought, forest management, and wildfire on forest ecosystem resilience. Students experienced with Linux/programming and/or ecohydrology will be competitive. The student will be co-advised by Jennifer Adam (WSU} and Christina Tague {UCSB}. Interested students should contact jcadam@wsu.edu for more information. Fall semester applications to WSU are due on 10 January for priority consideration.

Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE

**Two Faculty Positions in Solid Earth Dynamics, Structure, and Evolution and/or Ocean, Atmosphere and/or Climate**

The Department of Earth and Environmental Sciences (DEES) is seeking outstanding scientists to fill two open-rank faculty positions, in the areas of solid earth dynamics, structure and evolution and/or ocean, atmosphere and/or climate. Appointment can be at any rank from tenure-track assistant professor to tenured full professor.

Columbia University's vibrant program in these fields is one of the most highly rated in the United States and includes a world-class research and graduate training program, mostly based at Lamont-Doherty Earth Observatory (LDEO) in Palisades NY, and involving 100+ scientists and 90+ graduate students, as well as an undergraduate program on the Manhattan campus. Primary appointments are within DEES with 9 months of institutional salary support. The positions are based at, and will include affiliation with, LDEO. Secondary affiliation with Columbia's International Research Institute for Climate and Society (IRI) and Department of Applied Physics and Applied Mathematics are possible, as is close collaboration with the American Museum of Natural History and NASA's Goddard Institute for Space Studies.

The successful candidates will develop high-impact research programs focused on problems of global significance and have demonstrated excellence in teaching or potential for such in the case of entry level appointments. Applicants should address the specific ways they would contribute to the research and teaching mission of DEES/LDEO. Minimum requirements for the position are demonstrated scientific creativity and a Ph.D. in a related field. Early-career scientists are especially invited to apply. Application review will commence on January 20, 2016 and continue until the positions are filled. For more information and to apply for either position please visit our online site at:

**https://academicjobs.columbia.edu/applicants/Central?quickFind=61767**

Columbia University is an Equal Opportunity/Affirmative Action employer -- Race/Gender/Disability/Veteran.

# Postcards from the Field

Installing seismometers in Bavaria, Germany, to extend the coverage of AlpArray. This experiment is a European initiative to advance our understanding of orogenesis and its relationship to mantle dynamics, plate reorganizations, surface processes and seismic hazard in the Alps–Apennines–Carpathians–Dinarides orogenic system. In this photo, seismologists Angelo Pisconti and Januka Attanayake from the Institut für Geophysik at Westfälische Wilhelms-Universität Münster in Germany are seen installing broadband seismometers in Todtenweis, Germany. During this trip, one of the seismometers was installed in a 900-year-old wine cellar beneath Kloster Scheyern (Scheyern Abbey). This particular phase of seismometer installation in Germany is led by Professor Christine Thomas. For further details, visit http://www.seismo.ethz.ch/research/groups/alrt/projects/alparray/.

**—Stefan Ueding**
State Certified Technician, Institute of Geophysics, University of Münster

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

# UNION HONORS PROGRAM

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**New Union Awards for 2016**

Africa Award for Research Excellence in Earth and Space Science

William Kaula Award

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