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@AGU Eos

Satellite image of the July 2015 cyanobacteria bloom in Lake St. Clair. This bloom, which also affected Lake Erie, was the second worst on recent record. Credit: Joshua Stevens, NASA Earth Observatory, using USGS Landsat data.



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15 December 2015

New Spin on Pluto's Moons



NASA/JHUAPL/SwRI/Mark Showalter

A new analysis finds that the small moons of Pluto rotate remarkably quickly as they orbit the dwarf planet. Watch an animation—from which the above image came—of these Pluto system motions at http://bit.ly/four-tops. The animation shows Pluto and its relatively large moon Charon at the center with the smaller moons (from center outward) Styx, Nix, Kerberos and Hydra spinning as they orbit the larger bodies.

ike disobedient children, Pluto's four small outer moons are spinning at inexplicably high rates, apparently defying the steadying influence expected from Pluto and its large partner moon, Charon.

The small moons—Styx, Nix, Kerberos, and Hydra, in order of proximity to Pluto—all rotate much faster than the 20 to 38 Earth days the moons take to orbit the Pluto-Charon system, scientists reported last month. Kerberos spins the slowest, once every 5.33 Earth days, whereas Hydra is the whirling dervish of the quartet, rotating once every 10 hours 19 minutes.

These are fast rotation rates for moons, which usually keep one face pointed at their central planet, rotating just once per orbit of that planet. Earth's Moon, for instance, rotates once each 27 days 8 hours, the time it takes to orbit our planet once. Among Pluto's moons, Charon plays by the usual rules, rotating once per orbit of Pluto, but the other, smaller moons don't. The Four Tops

"These Pluto moons are essentially spinning tops, and that radically changes the way we understand the dynamics of how they operate," planetary scientist Mark Showalter of NASA's New Horizons mission and of the SETI Institute in Mountain View, Calif., told *Eos.*

"This is unlike anything we've seen elsewhere in the solar system," he added. "No one has ever seen a moon [like Hydra] that rotates 89 times during a single orbit."

Last July, the New Horizons mission carried out the first ever flyby of Pluto. Analyses of images recorded by the mission's spacecraft in

the weeks leading up to the flyby led to the discovery of the moon's surprising speeds, unveiled Monday, 9 November, at the annual meeting of the American Astronomical Society's Division for Planetary Sciences (http:// bit.ly/AAS-DPS) in National Harbor, Md.

Surprising Spin Rates

The fast spin rates are so surprising, said Showalter, because even if the moons formed as rapid rotators, the push and pull of the gravitational tides of Pluto and Charon ought to have slowed down that motion.

Instead, "it's just as if the moons picked some random rate of rotation and Pluto and Charon have no role with any of that," said Showalter. One possibility, he noted, is that the gravitational tides of Pluto and Charon work against each other, leaving the moons free to maintain a high spin. It may be like two parents who have given contradictory instructions, leaving their offspring to decide for themselves, Showalter mused. Among the solar system's panoply of so-called regular moons—those that form as the result of a collision between a planet and another body—Hydra ranks as the ninth fastest rotator, Showalter said.

First Take Revisited

Prior to the flyby, Showalter and Douglas Hamilton of the University of Maryland, College Park had come to a different understanding about the motions of Pluto's four small moons. Using Hubble Space Telescope images of the moons, they had concluded that the moons rotate chaotically, varying their spin rate and tumbling as they orbit Pluto and Charon. They published their moon motion study (http://bit.ly/moon-chaos) in the 4 June issue of *Nature*.

After examining data recorded by the New Horizons' Long Range Reconnaissance Imager camera, Showalter, Hamilton, and other colleagues realized that the preflyby explanation was not quite right.

The camera had observed variations in the brightness of the four moons during a 100-day interval that ended early last July. The brightness variations showed clear signs of periodicity, revealing that the moons were not so much tumbling as spinning in a regular fashion, just much faster than anyone expected. The images also reveal that Nix is rotating backward compared to the rest of the Pluto system, and on its side.

Fast Times in the Kuiper Belt

Showalter noted that the spin rates of these moons are similar to those of other objects in a vast reservoir of frozen bodies known as the Kuiper Belt, which lies beyond the orbit of Neptune and which includes the Pluto system. Kuiper Belt objects are thought to have acquired their rapid rotation through collisions with other icy debris in the reservoir. The same may be true of Pluto's small moons, Showalter suggested.

Because the fast-spinning Plutonian moons are tiny, ranging in diameter from 10 to a few tens of kilometers across, a collision with a large impactor could easily have imparted a lot of spin to the bodies, commented astronomer Scott Tremaine of the Institute for Advanced Study in Princeton, N.J., who is not part of the New Horizons team.

From the shapes of the moons revealed by the New Horizons camera, they appear to be mergers of several smaller pieces, indicating that Pluto once had many more moons in its retinue, Showalter said.

By **Ron Cowen,** Freelance Science Journalist; email: rcowen@msn.com

White House Plan Focuses on Hazards from Solar Storms

he White House is paying closer attention to the potential widespread damage that some powerful space weather storms emanating from the Sun can cause to electric power systems, satellite and aircraft operations, telecommunications, navigation, and other technology. On 29 October, the administration issued a new strategy and action plan to cope with space weather events.

Space weather is "a priority" for the Obama administration, White House science adviser John Holdren said at a 29 October White House forum to release the documents. "We absolutely need to ensure that our nation is appropriately prepared to respond to and recover from space weather events."

Space weather events occur when outbursts from the Sun, such as solar flares, solar energetic particles, and coronal mass ejections, collide with Earth's magnetic field. Although many of these events are harmless, some are powerful enough to cause havoc by disrupting critical technology. Speakers at the forum referred to a 1989 geomagnetic storm that cut electricity to 6 million Canadians for 9 hours and to the 1859 Carrington event, the largest documented series of geomagnetic storms from the Sun to have struck Earth.

Key Goals

The White House strategy (http://bit.ly/SW-Strategy) calls for improving efforts to protect against and mitigate space weather risks; improving the fundamental understanding of space weather; and increasing the accuracy, reliability, and timeliness of space



NASA's Solar Dynamics Observatory captured this image of a solar flare—as seen in the bright flash on the lower right limb of the Sun—at 8:12 p.m. Eastern Daylight Time on 1 October 2015. The image is a blend of three wavelengths of extreme ultraviolet light that have been colorized. weather observations and forecasts. The action plan includes specific federal agency and interagency measures to implement the strategy.

A panel established about a year ago—the interagency Space Weather Operations, Research and Mitigation (SWORM) task force—developed the strategy and action plan. This panel comprised representatives from 24 federal departments, agencies, and offices.

Bill Murtagh, assistant director for space weather at the White House Office of Science and Technology Policy, told *Eos* that a group was being formed to pick up where the SWORM task force left off to ensure implementation of the action plan (see http://bit.ly/SW -Plan). He noted that both sides of the aisle in Congress support taking action on space weather. "If it's controversial at all, it's 'Are we doing enough?" he said.

Vulnerability and Opportunity

During the late October forum, participants from government and industry agreed on the seriousness of the peril. "Although we have a lot to learn about the physics and phenomenology of space weather," said Kathryn Sullivan, administrator of the National

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Louis Lanzerotti, distinguished research professor of physics, New Jersey Institute of Technology, speaks at a 29 October White House forum on space weather.

Oceanic and Atmospheric Administration (NOAA), "there is no uncertainty" about society's vulnerability to its storms.

William "Terry" Boston, chief executive officer emeritus of the largest power grid in North America, PJM Interconnection, agreed that geomagnetic disturbances pose "a clear and present threat to the [electrical] system."

To the academic community, the action plan offers an opportunity "to contribute importantly to the national effort" through basic and operational research, said Louis Lanzerotti, a distinguished research professor of physics at the New Jersey Institute of Technology in Newark. The community is "going to be thrilled" with the action plan, he said.

Cooperative Effort

The new strategy "is long overdue," and it partly makes up for "a very severe lack of regulation and appropriate standards for the U.S. electric grid," Thomas Popik, chairman of the Foundation for Resilient Societies, told *Eos.* The foundation is a nonprofit concerned about the protection of North America's electric grids and other critical infrastructure.

For Dan Baker, director of the Laboratory for Atmospheric and Space Physics at the University of Colorado Boulder, the cooperation between agencies inherent to the action plan suggests "we really have a chance for making this work."

There is "a golden opportunity" for collaboration between the academic, governmental, and commercial space weather sectors to improve forecasts and resilience to space weather events, agreed Conrad Lautenbacher, chief executive officer of the environmental data company GeoOptics and former NOAA administrator.

Baker, who chaired the National Research Council's 2012 Decadal Survey for Solar and Space Physics, expressed concern about continuity of implementation in future administrations and congressional support for the plan.

He told *Eos* that he hopes that the release of the space weather strategy and action plan "is a watershed moment [when] things are really going to change."





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By Randy Showstack, Staff Writer

Students with Disabilities Not Just Welcome but Expected

eoscience has long proved inaccessible for aspiring scientists with disabilities because of the rigorous nature of traditional field work. But starting next summer, a university in the western United States will offer a capstone summer study-abroad program based in Orvieto, Italy, that's designed to serve students of all physical abilities. It will be the first college geoscience study-abroad program in the nation with accommodations built into the curriculum for students who have disabilities.

Geoscience students with disabilities at the University of Arizona (UA) in Tucson previously worked with faculty to develop an alternative to the physically demanding capstone. However, substituting the usual capstone course with a different course exclusively for students with disabilities meant that those students were singled out from their classmates. This way of accommodating students "primarily views the problem with the individual," said Richard Bennett, a UA geosciences professor and lead instructor for the new capstone, named Accessible Earth. "The second view of teaching the curriculum says the problem is with the curriculum and it can be modified," he added.

According to Diedre Lamb, the senior access consultant with UA's Disability Resource Center, making alternative curricula available is a critical step in helping students with disabilities feel included. "What makes [Accessible Earth] unique is that when they apply for the program and if they're students with disabilities, they know that accessibility has been evaluated," she says. "They don't have to ask for access."

A different course exclusively for students with disabilities meant that those students were singled out from their classmates.

Embracing Tech

Beyond simply seeking to make the studyabroad experience more accessible, the program (http://bit.ly/Accessible-Earth) aims to refocus the emphasis of the trip from an arduous rite of passage to a learning experience rooted in technology and computational thinking, said Christopher Atchison, executive director of the International Association for Geoscience Diversity (IAGD) in Cincinnati, Ohio. Students in the Accessible Earth class will construct geologic maps using data they gather and analyze. Data will come from pub-

Class participants



body of the famously preserved Iceman (see http://bit.ly/Ice-Man).

Bennett believes the chance to explore Italian culture and scientific tradition will help put the course's tech-savvy take on geoscience in perspective. "Italy's a great place to look back on the history of science, from the Renaissance to the Space Age," he said. "One of the things we would like students to get from this is to understand that many of the techniques that were used by people like Galileo and Leonardo da Vinci are the same sort of concepts [used today]. We just now have tech that allows us to do these kinds of things bigger and better."

Compared to standard geoscience studyabroad experiences marketed on college websites, Accessible Earth offers a welcome departure, said Atchison. "The very first thing that people think of when we talk about fieldbased learning is that you have to be out climbing the mountains, and that's not really the way it is any longer."

A college will "promote this idea of being out in a rugged environment as a way of encouraging others to participate. But, by doing that, it's actually pushing people away from the diversity standpoint," Atchison explained. People with physical and sensory disabilities are more underrepresented in the geosciences than in any other field of science, engineering, or math, he noted.

Beyond Barriers

Concerns about barriers to diversity in the geosciences have led to some initial steps to encourage inclusivity. Since IAGD's establishment in 2008, it has been organizing field trips to give geoscience students with disabilities the chance to study abroad. In 2015, the American Geosciences Institute released the Disability Consensus Statement (http://bit.ly/ Disability-Consensus), which urges its signatories to be proactive in opening the field to diverse demographics.

There is still plenty of work to be done, Atchison said. "We're making great strides to promote that awareness first, but then opportunities need to be created to move it beyond just awareness," he added. "Opportunities like the Accessible Earth study-abroad course are going to make that happen."

By Shannon Kelleher, Writer Intern

Data for All: Using Satellite Observations for Social Good

atellite remote sensing offers a unique global observational platform for pursuing societal benefits in ways that are not feasible using only conventional groundbased approaches. Reaping these benefits requires an intimate engagement between the scientific community and a wide range of

stakeholders. This issue has taken on a new urgency, as the strong interplay between human activity and nature drives change on almost all continents, with rules set by human activities as well as nature.

The pursuit of a more sustainable, safer, and happier future drives the study of planet Earth, with its changing environmental conditions and natural resources. Observations from visible, laser, infrared, and microwave satellite sensors already provide information for managing land, water, agriculture, energy, disaster response, and ecosystem functions [Wood et al., 2011]. During the past few decades, we have been quite successful in taking advantage of the science and observations afforded by satellites to make spectacular societal impacts.

For example, the 1976 Big Thompson Flood in Colorado killed 144 people, whereas the 2013 Boulder/Lyons Flood, also in Colorado, was managed with eight casualties [*Hamill*, 2014]. Similarly, a cyclone off the coast of Bay of Bengal (Bangladesh) in 1991 took more than 65,000 lives and left 10 million homeless. The 2009 cyclone Aila in the same region killed a few hundred people and rendered 1 million homeless

[Chowdhury et al., 1993; Paul, 2009]. A significantly improved warning system facilitated by Earth-observing satellites arguably contributed to the savings in life and property in both instances.

We are gradually developing a plethora of more mature remote sensing technology missions for routine environmental monitoring. These include Landsat and altimetry missions, hydrologic missions like Global Precipitation Measurement, NASA's Gravity Recovery and Climate Experiment mission, and NASA's anticipated Surface Water and Ocean Topography mission. However, we lack much of the capacity required to handle the petabyte-scale influx of satellite environmental data that will become available.



Fig. 1. A coordinated constellation of satellites. Holistic use of the combined observational power of all of these satellites could serve a wide variety of societal purposes.

An Underused Resource

To take advantage of satellite observational capability to enhance and accelerate societal applications around the world, scientists and other stakeholders must collaborate to find answers in the coming decade. Time is of the essence, as long gestation periods, sometimes decades, are often necessary to transition from scientific research to real-world benefits for stakeholders. We are not yet taking complete advantage of the abundant scientific output and remote sensing data emerging rapidly from satellite missions, and we are failing to convert them to actionable products that improve decision making for users [*Hossain*, 2015].

Thus far, the benefits have mostly accrued

in the developed nations of Europe and North America. Global satellite observational coverage would be especially useful in the developing world because ground-based measurements are often largely absent here. However, programs to apply satellite observations to challenges in the developing world often struggle for longevity and continuity.

Also, the combined observational power of the multiple Earth-observing satellites too often places emphasis on the benefits from individual missions and observing systems. This observational power is currently not being harnessed to produce more durable societal benefits. The struggle for support and survival has often pitted various missions against each other. This competition ignores the synergistic power and benefits that combining data from the many Earthobserving satellites could provide, missing an opportunity to provide even more spectacular societal benefits.

A Fly's-Eye View

The scope of the opportunity and abundance of satellite observations confronting us in the nottoo-distant future is already

apparent. Figure 1 illustrates the basic concept behind using NASA's constellation of satellites for societal application. This concept is similar to the "A-Train," a series of coordinated satellites that passes over the same region in quick succession to monitor various aspects of Earth's atmosphere. The best use of such a system for applications requires a holistic use of the combined observational power of all of these satellites.

Our current and future satellite constellation for societal applications essentially provides us with a "compound eye" view of the world. Like the composite eye of a fly, coordinated satellites look with many eyes at the same time to see the world from many different angles, using an array of instruments (Figure 1).

To take advantage of this composite view is to make better decisions, using an application that is wired to expect and accept all the different observations across multiple platforms simultaneously. Such a capability could be used to address upcoming issues in water management [Maswood and Hossain, 2015, for example] or agricultural management.

The Way Ahead

Expanding the numbers and uses of satellite remote sensing instruments alone will not be sufficient to address society's needs. Availability of a satellite mission data portal does not necessarily imply universal access or easy applications [Hossain, 2012]. Uncertainty in measurements, scale, end user perception, operating constraints, data latency, mission interaction, scalability, and intuitiveness of

the application tool must also factor into the equation.

In anticipation of the coming era of plentiful Earth observations from satellites, the Earth science community must now put some thought into identifying key applications and key scientific issues. Now is the time for making connections between the regional stakeholder communities from around the world and the community that provides the science that fuels an application.

These connections will allow a meaningful discussion that has been largely uncoordinated but is necessary to globalize and accelerate societal applications of satellite data. The satellite and science communities must now engage with the stakeholder community to discuss what is possible and what is most urgent. These communities must set priorities to determine what must be left behind in order to scale up what is possible for the best societal applications.

Five upcoming challenges urgently need discussion, debate, and resolution as a longterm agenda:

1. What types of value-added products and information should we provide for resource-

> constrained public and national stake-

holder communities

2. What types of

industry or private

scientific research

leverage the com-

bined observational

power of our many

Earth-observing sat-

ellite missions (cur-

rent and future) in a

synergistic manner

to rapidly multiply

societal applications?

the scientific innova-

remote sensing data

robust applications

that do not require

long-term incuba-

port?

tion or external sup-

5. From an economic standpoint,

what is the optimal

business model to

to trigger durable and

tion from satellite

4. How can we use

etal needs? 3. How can we

sector partnerships

will most benefit the

needed to meet soci-

and agencies?

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support a sustainable partnership between scientific communities and the stakeholders?

One way to answer these questions is to take a regional and thematic approach, in order to map an agenda forward for Earth science applications of satellite remote sensing. For example, a community effort in 2013 focused on conservation biology and developed highly useful recommendations that could serve as inspiration for other areas and communities [Rose et al., 2014]. This effort brought together a group of remote sensing scientists and members of conservation organizations. They identified 10 conservation questions where the use and analysis of remote sensing data would greatly increase the potential for finding an answer.

Although societal benefits from space observations share common features, what works for region X may not necessarily apply to region Y, even when the problems are similar—thus, the need for regional solutions.

We need not confine ourselves to Earth observations from satellites. Airborne and ground-based measurement activities frequently aid in making decisions and improving applications. Also, microsatellites and unmanned aerial vehicles are becoming more widespread. Currently, the scientific community is divided about how these activities should be pursued in the coming years for the greater benefit of stakeholders.

Because it will take time and effort to reach consensus on these numerous issues, now is the time to get busy and build a well-mixed environment of scientific and application stakeholder communities.

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By Faisal Hossain, Department of Civil and Environmental Engineering, University of Washington, Seattle, Wash.; email: fhossain@uw.edu

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Geophysical Information for Teachers Workshop 7:30 A.M.–3:30 P.M., Golden Gate A

Getting Started in Undergraduate Research Workshop 8:00 A.M.–12:00 P.M., Golden Gate C3

How to Run an Effective and Inclusive REU Program 1:30 P.M.–4:30 P.M., Golden Gate C3

Games Arcade 6:00 P.M.–8:00 P.M., Golden Gate A

Tuesday, 15 December

Geophysical Information for Teachers Workshop 7:30 A.M.–3:30 P.M., Golden Gate A

Teaching Geoscience in Society: Building Relevance and Interest in Geosciences by Adding InTeGrate Resources to Your Class

9:00 A.M.-12:00 P.M., Golden Gate C3

Facilitating Classroom Innovation in the Geosciences: Taking Advantage of NSF Education Programs in the Division of Undergraduate Education 12:30 P.M.–1:30 P.M., Golden Gate C3 Measuring Impact of Education and Public Outreach: A Systematic Method for Planning and Evaluating Programs 2:00 P.M.–6:00 P.M., Golden Gate C3

Diversity Reception 6:30 P.M.–7:30 P.M., Club Room Sponsored by Scribendi

Networking Reception for Early Career Female Scientists and Students 7:00 P.M.–9:00 P.M., Golden Gate B Sponsored by Scribendi

Wednesday, 16 December

Navigating the NSF System 9:00 A.M.–12:00 P.M., Golden Gate A

Embedding Research in Undergraduate Classes Across the Geoscience Curriculum 1:00 P.M.–4:00 P.M., Golden Gate A

Opportunities Beyond Academia 4:15 P.M.–6:15 P.M., Golden Gate A

Thursday, 17 December

Preparing for Global Change: Increasing Climate Literacy through Collective Impact 9:00 A.M.–12:00 P.M., Golden Gate A

Climate Change Games Workshop 1:00 P.M.–4:00 P.M., Golden Gate A



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Nor

Better Forecasting for the Next Volcanic Eruption

By Valerio Acocella and Giovanni Chiodini

The Eruptive Precursors project in Campi Flegrei, Italy, seeks to understand conditions leading to caldera eruptions.

alderas are the most hazardous type of volcano. These depressions in the Earth's surface often form when a magma chamber empties suddenly after an explosive eruption. The hazard arises because of a caldera's large size, the long-lived magma systems that feed large explosive eruptions, and an overlying hydrothermal system that can either mask or amplify magmatic processes and make it difficult to predict these eruptions.

Periods of unrest, when the volcano undergoes abnormal changes in shape, structure, and chemistry, demonstrate calderas' complexity. Unrest may culminate in an eruption, or it may merely mark a stage in a more complex dynamic evolution of the volcano. A conceptual model of the unrest may sharpen scientists' understanding of the dynamics and lead to more reliable forecasts of impending eruptions.

Magmatic gas release has increased significantly over the past decade at Campi Flegrei, a restless caldera near Naples, Italy.

What can we learn about calderas by studying unrest? What should we expect from caldera unrest? What are the associated hazards? These were the central questions of the Eruptive Precursors project. After 2 years, this project has provided constraints on unrest, in the form of deviations from geophysical and geochemical baselines, at the Campi Flegrei caldera in southern Italy.

A History of Unrest

Campi Flegrei is a restless caldera in a densely inhabited area; it lies immediately to the west of central Naples. After major eruptions 39,000 and 15,000 years ago, there was a marked uplift, which produced a resurgent dome, in the past 5000 years, during which several minor eruptions occurred (most recently in 1538).

In the past century, at least three periods of unrest occurred, from 1950 to 1952, 1969 to 1972, and 1982 to 1984. This unrest led to the caldera's surface rising as much as ~0.7, ~1.7, and ~1.8 meters, respectively (Figure 1).

The best monitored and most dramatic unrest, which took place in 1982–1984, was accompanied by earthquakes of magnitude less than 4.2 on the Richter scale at a depth less than 3 to 4 kilometers and by surface fracturing. Campi Flegrei caldera then relaxed, and its surface subsided by almost 1 meter between 1984 and 2004. Since 2005, the caldera has been rising again, with a cumulative total of approximately 30 centimeters as of early 2015. This uplift has been accompanied by minor seismicity and a marked increase in the flux of the magmatic gases coming out of the volcanoes' fumaroles [*Chiodini et al.*, 2015].

A Multiagency Effort

The 2012–2015 Eruptive Precursors project (which has now ended) was launched to better understand the unrest behavior of Campi Flegrei and to assess the associated hazards. This project was a collaboration among the Italian Department of Civil Defense; the Napoli, Palermo, Pisa, and Bologna branches of the National Institute of Geophysics and Volcanology; and five Italian universities (Roma Tre, Napoli, Perugia, Salerno, and Firenze). The project embraces geological, geochemical, geophysical, petrological, statistical, modeling, and hazard studies of the onshore and offshore portions of Campi Flegrei.

Eruptive Precursors had three goals: to define how the shallow Campi Flegrei hydrothermal system works; to match this knowledge with that acquired about the caldera's magmatic system, allowing scientists to propose a conceptual model of the restless Campi Flegrei caldera; and to evaluate magmatic and nonmagmatic hazards using a statistical technique known as a Bayesian event tree.

The project was thus not directly aimed at defining the conditions causing an eruption at Campi Flegrei specifi-



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cally, an objective still difficult to achieve. Rather, the aim was to understand what happens within a restless caldera and what processes control unrest.

Understanding Caldera Processes

With its completion in 2015, Eruptive Precursors has significantly improved our knowledge of caldera-related processes and contributed to the accomplishment of the three goals. We are now disseminating the results through publications and technical reports. Some of our successes related to the above goals include the following:

• We produced a database of global caldera unrest from 1988 to 2014, which defines major types of unrest, including that at Campi Flegrei [*Acocella et al.*, 2015]. We include statistical analyses of the unrest events.

• We incorporated the solubility of nitrogen gas in Campi Flegrei magmas into a model of volcano degassing. This helps connect measurements of the composition of the fumarolic gases to pressure variations controlling fluid-melt separation processes within the caldera [*Caliro et al.*, 2014].

• We highlighted the persistent activity of two sources (a magmatic reservoir at 4 kilometers depth, centered

Fig. 1. (a) Simplified structural map of Campi Flegrei caldera (Italy), including the map view location of the magmatic source (green ellipse, 4 kilometers deep) and hydrothermal source (blue circle, 2 kilometers below the Solfatara volcanic crater) responsible for the post-1980 deformation [Amoruso et al., 2014]. (b) Elevation changes of benchmark 25a (shown in Figure 1a) from 1905 to 2009 [after Del Gaudio et al., 2010] merged with more recent (2009–2012) GPS data [De Martino et al., 2014]; m a.s.l. = meters above sea level. (c) Measured and simulated fumarolic carbon dioxide:water (CO₂/H₂O) ratio (top), ground deformation (middle), and earthquake magnitudes (bottom); dashed lines refer to times of injection of magmatic fluids into the hydrothermal aquifer [after Chiodini et al., 2012].

below Pozzuoli, and a hydrothermal reservoir at 2 kilometers depth, centered below Solfatara; Figure 1) to explain the surface deformation of the past 35 years. We also included a viscoelastic component of this deformation in our model [*Amoruso et al.*, 2014].

• We produced onshore and offshore monitoring data, including geophysical (infrared, GPS, tiltmeter, gravity, and seismicity) and geochemical (composition, fluxes and temperature of fumaroles, soils, thermal waters, and groundwater table) sources. We have organized many of



these data and merged them into databases available to the scientific community [e.g., *De Martino et al.*, 2014].

• We produced a conceptual model that provides a first working hypothesis, shared with the scientific community, for the functioning and coupling of magmatic and hydrothermal systems. According to our model, the 4-kilometer-deep magmatic reservoir repeatedly releases magmatic gases into the shallower hydrothermal reservoir. These gases interact with meteoric fluids (derived from precipitation), feeding the gas plume beneath Solfatara (Figure 2) [Chiodini et al., 2015]. This discontinuous

but repeated discharge of magmatic fluids has depressurized the shallow magmatic system and heated the hydrothermal system by about 20°C to 100°C. The resulting changes in temperature and pressure suggest variations in the strength of the upper crustal rocks, raising concern about the specific risks and most likely locations for eruptions.

We produced a conceptual model that provides a first working hypothesis, shared with the scientific community, for the functioning and coupling of magmatic and hydrothermal systems.

• This information will be included within the updated version of the Bayesian event tree for Campi Flegrei. We have also issued an elicitation (the first in 5 years) for

A new fumarolic vent that appeared at the Pisciarelli site (external slopes of Solfatara crater) in December 2009. Since 2005, evident signs of increased hydrothermal activity (opening of mud pools, fumarolic vents, localized seismic activity) affected this area.

experts to implement this model and use it to evaluate magmatic and nonmagmatic hazards.

The Current Unrest

The current unrest phase at Campi Flegrei has lasted for

10 years. In contrast, the major unrest of 1982–1984 had shorter duration but was accompanied by intense seismicity and deformation.

In this project we highlighted a possible reason for this difference. In addition to more recent (2012–2013) possible input of magma from the deep magma reservoir into the shallow thermal reservoir [D'Auria et al., 2015], the current unrest may have been

driven largely by a relatively slow process that has heated the hydrothermal system. This process was a result of repeated events of fluid expulsion from a depressurizing



Fig. 2. Conceptual model depicting the release of magmatic fluids from the shallow magmatic source (red) toward the hydrothermal system (yellow) below the Solfatara volcanic crater, where these fluids mix with meteoric liquid (i.e., groundwater from rain; modified from Chiodini et al. [2015], used with permission). PTE (pressurized finite triaxial ellipsoid) and PS (pressurized oblate spheroid) are the deformation sources active at Campi Flegrei at least since 1980 [Amoruso et al., 2014].

magmatic source (Figure 2). Long-term heating may also promote persistent weakening below the caldera, creating more favorable conditions for a future eruption. Eruptive Precursors has provided a robust scientific basis to better understand the Campi Flegrei caldera, capturing the relationships between magmatic and hydrothermal systems. These processes may be representative of many similar restless calderas, including Long Valley (California), Yellowstone (Wyoming), and Rabaul (Papua New Guinea), thus providing an important reference for geologists studying calderas around the world.

Our improved understanding of Campi Flegrei will be included in hazard assessment models, which will help scientists and government agency representatives mitigate the risks of the most dangerous volcanoes on Earth.

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Agencies Collaborate, Develop a Cyanobacteria Assessment Network

By Blake A. Schaeffer, Keith Loftin, Richard P. Stumpf, and P. Jeremy Werdell

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An integrated, holistic approach to detecting and characterizing cyanobacteria blooms could reduce human health risks and better direct field resources.

Satellite technology

allows us to develop

early-warning indicators

of cyanobacteria blooms

at the local scale while

maintaining continuous

national coverage.

yanobacteria are a genetically diverse group of photosynthetic microorganisms that occupy a broad range of habitats on land and water all over the world. They release toxins that can cause lung and skin irritation, alter the taste and odor of potable water, and cause human and animal illness. Cyanobacteria blooms occur worldwide, and climate change may increase the frequency, duration, and extent of these bloom events. Rapid detection of potentially harmful blooms is essential to protect humans and animals from exposure. Information about potential for exposure, such as bloom duration, frequency, and extent, is especially critical for developing environmental management decisions during periods of limited resources and funding.

The National Research Council (NRC) report *Exposure Science in the 21st Century* suggested that effectively assessing

and mitigating exposures requires techniques for rapid measurement of a stressor, such as an algal bloom, across diverse geographic, temporal, and biologic scales (e.g., various bloom concentrations) and an enhanced infrastructure to address threats [National Research Council (NRC), 2012]. The report specifically calls for approaches that use diverse information, such as satellite remote sensing, to identify and understand exposures that may pose a threat to ecosystems or human health.

A collaborative effort integrates the work of the U.S. Environmental Protection Agency (EPA), NASA, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Geological Survey (USGS) to provide an approach for using satellite ocean color capabilities in U.S. fresh and brackish water quality management decisions. The overarching goal of this collaborative project is to detect and quantify cyanobacteria blooms using satellite data records in order to support the environmental management and public use of U.S. lakes and reservoirs.

Satellite image of the October 2011 cyanobacteria bloom in Lake Erie, the worst bloom in decades. Such blooms were common in the 1950s and 1960s, before current regulations on agricultural and sewage runoff were in place. Satellite remote sensing tools may enable policy makers and environmental managers to assess the sustainability of watershed ecosystems and the services they provide, now and in the future. Satellite technology allows us to develop early-warning indicators of cyanobacteria blooms at the local scale while maintaining continuous national coverage.

An Integrated, Holistic Approach

Cyanobacteria and their toxins are addressed differently by each state within the United States. Some states have monitoring programs in place or event-based response strategies or provide public education. One of the significant issues for management is access to timely and consistent data. Methods for disseminating satellite data to managers have typically been cumbersome because the data are often provided in a form that makes it difficult for

a nonspecialist to extract information that can be acted upon. Managers will substantially benefit from user-friendly data structures that improve our ability to flag water bodies for cyanobacteria blooms and evaluate interannual and seasonal patterns.

In all cases, timely distribution of data is necessary to provide warnings within days of an observation and seasonal assessments in the same calendar year. If satellites are going to help managers respond to the immediate impacts of cyanobacteria blooms,

then timely, useful, and cost-effective delivery of information from the satellite data is needed.

The project will disseminate information derived from ocean color instruments on board the Aqua, Sentinel-3, Sentinel-2, and Landsat satellites. We will also develop a strategy for evaluation, validation, and refinement of algorithms for use with other satellite instruments, such as the existing Suomi National Polar-orbiting Partnership and upcoming Pre-Aerosol, Clouds, and ocean Ecosystem (PACE) missions.

The project is structured within a sustainability framework for a more holistic approach including environmental, human health, and economic considerations. The four federal agencies embrace research on sustainability by supporting work focused on making, building, and finding connections between environmental, economic, and social problems [*NRC*, 2013].

Linking Color Data with Cyanobacteria

Achieving a national standard for bloom monitoring in fresh and brackish waters requires an approach analogous to open ocean remote sensing. Current ocean color satellites measure the spectral reflectance emanating from the top of the atmosphere at discrete visible and near-infrared wavelengths. Measures of cyanobacteria abundance will be derived from algorithms that use top-of-atmosphere reflectance. This method uses chlorophyllinduced differences in reflectance that distinguish prokaryotic cyanobacteria from most eukaryotic algae (Figure 1).

Unlike approaches for the open ocean, this approach does not rely on standard correction algorithms to remove contributions from atmospheric aerosols from the total signal the estimation of which can be unreliable in excessively turbid water or in the presence of anthropogenic aerosols.

The cyanobacteria algorithm has been successfully applied to time series data from the Medium Resolution Imaging Spectrometers on board the European satellite Envisat and the NASA satellite Aqua [*Lunetta et al.*, 2015; *Wynne et al.*, 2013]. The algorithm will also be implemented into standard NASA ocean color data processing software and made publicly available through the NASA Sea-viewing Wide Field-of-view Sensor (SeaWiFS) Data Analysis System.

For comparison, the Council for Scientific and Industrial Research has applied a similar algorithm in South Africa, whereas the Global Observatory of Lake Responses to Environmental Change program uses a somewhat different mathematical approach (semianalytical algorithms).

Other satellites will be incorporated into the effort to provide data from smaller bodies of water. Landsat may provide estimates of blooms in smaller water bodies as frequently as every 8–16 days. With Sentinel-2 now operational, smaller water bodies will have more frequent coverage.

As management needs change and biooptical algorithms improve, strategies will be needed to determine when to introduce new or refined algorithms for analyzing satellite data. This requires continual assessment of algorithm accuracy, consistency, and robustness. The assessment becomes particularly chal-

lenging in areas where complex environmental variations across space and time make it impractical to use the same conditions and assumptions used to evaluate ocean color products in the open ocean.

Using reference data from the National Aquatic Resources Surveys and the National Water Quality Monitoring Council's Water Quality Portal, we will compare satellite-derived products with data taken on site, as well as model outputs from multiple satellite instruments. Val-



Fig. 1. (top) True-color image cyanobacteria concentrations for Florida from the Medium Resolution Imaging Spectrometer (MERIS) sensor on Envisat, taken 1 October 2011. (bottom) Satellite-derived quantitative values of cyanobacteria concentrations for the area within the box above. Concentrations are represented using a color scale ranging from blue (low concentrations) to red (high concentrations).

idation will also include verification that products are consistent across both time and space. For instance, we will evaluate the stability of the product from day to day under uniform environmental conditions and determine conditions that lead to increased error or failure.

Human land use activities in watershed areas are continually changing, but little is known concerning the effects of landscape changes and linkages to bloom events. No large-scale, systematic effort has been undertaken to use remote sensing data to monitor chlorophyll *a*, the ubiquitous photosynthetic pigment of all phytoplankton, and cyanobacteria concentrations for smaller inland lakes used for potable water sources.

We will perform analyses to determine relationships between land cover, land use, and bloom occurrences. We

will focus on identifying specific land use activities that may be linked to changes in nutrient loadings and other controlling factors by determining the optimal land development intensity index to better understand occurrence of bloom events.

Human Health and Economic Effects

The World Health Organization has developed "action level" recommendations for levels of human exposure to cyanotoxins [World Health Organization, 1999]. However, the actual extent of the p

However, the actual extent of the potential human exposure to these toxins is unknown.

This project will detect health effects associated with cyanobacteria by building upon a combination of retro-

spective assessment of remotely sensed images and human health data analysis. Thus, we hope to identify health effects associated with cyanobacteria blooms across geographic locations and with the passage of time.

Remote sensing of cyanobacteria blooms offers a unique opportunity to estimate human exposure to cyanotoxins

estimates.

over specific geographic areas.

cyanobacteria concentrations

Probability-based assessment of

over time may allow us to develop

spatially and temporally explicit

occurrence models for exposure

During bloom events, public

change to more extensive treat-

water supplies, not only for toxin

removal but also for the removal

of nuisance taste and odor com-

pounds. In some areas, severe

blooms can lead to decreases in

water suppliers often need to

ment approaches or alternate

Remote sensing of cyanobacteria blooms offers a unique opportunity to estimate human exposure to cyanotoxins over specific geographic areas.

tourism and property values.

In addition, monitoring costs money and takes time, and results are often not available in a time frame that is relevant to management decisions. Automated detection of



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Beach notice sign warns recreational users to avoid direct contact with cyanobacteria.

events based on remote sensing data has the potential to improve the quality and timing of data delivered to resource managers and the public.

Automated monitoring may lead to substantial cost savings. This project will identify costs associated with monitoring and potential savings with automated detection.

These risk reductions and cost savings can be realized only if the data are easily available in an easily understandable form for stakeholders entrusted with making environmental decisions. Ocean color satellite data are accessible to scientists but are not routinely processed and delivered to stakeholders or official users in a manner that is practical to daily life. Satellite data pushed from NOAA, NASA, and USGS to EPA will be made available for stakeholders through a mobile device platform and Web portals.

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Specific stakeholders have already been identified as project partners and will be involved in the project from the beginning for feedback and guidance.

Protecting the Public

At the conclusion of this project, we anticipate an increase in the applied use of remotely sensed water quality data for water quality management. We anticipate that environmental managers will be able to make better decisions using uniform satellite data products. In addition, satellite data products may augment federal, state, tribal, and municipal monitoring and research efforts.

The use of this technology has tremendous potential because the temporal and spatial coverage of the imagery can rectify the current lack of data available for many systems. Using satellite data to monitor and report blooms throughout a region or state

would provide a new and powerful tool to assist in the holistic management of events that may involve significant risk to the public. Ultimately, this project will lead to more informed resource allocation decisions (e.g., focusing efforts more directly on problem areas identified by the satellites), improving preparedness for cyanobacteria blooms, helping the public become better informed, and reducing the potential for public exposure to cyanobacteria.

Acknowledgments

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Water Resources Research at 50: Lasting Impact Expected to Grow

n 1965, AGU launched a new platform for communicating the work of hydrologists. Since then, *Water Resources Research (WRR)* has grown into a preeminent source of new scientific insights regarding water systems. The journal covers a range of important aspects of those systems, from technological advancements and research breakthroughs to balancing the competing requirements of water management, societal needs, and sustainability.

To celebrate the fiftieth anniversary, the journal's editorial board has organized a special section that "looks back on 50 years of research activity and provides a perspective for future research focusing on water systems for the development and benefit of society," the section's introduction states (see http://bit.ly/WRR50-special).

To mark this major milestone, *Eos* spoke with current editor in chief Alberto Montanari (University of Bologna), AGU publications director Brooks Hanson, and other members of the *WRR* editorial board: Jean Bahr (University of Wisconsin–Madison), Scott Mackay (University at Buffalo), and Harihar Rajaram (University of Colorado Boulder).

Eos: What are the most important contributions that WRR has made to hydrology and the scientific community in the past 50 years?

Montanari: I would say the main contribution has been to promote an understanding of the links between hydrology, water, and human populations. Humans have an impact on the environment and therefore water—and water impacts us. WRR has always promoted the assessment of this feedback between water, politics, economics, social tensions, societal development, and human well-being. I think WRR has always been an ideal publication outlet, for both young and established scientists.

Eos: What sets WRR apart from other hydrology journals, and how does the journal reflect the broader mission of AGU?

Bahr: I think that what distinguishes WRR, in addition to the high standards it sets for significance of contributions, is the breadth of topics—not only natural science and engineering aspects of water resources but also economics, policy, and management.

Hanson: The Hydrology section (http://bit .ly/AGU-hydrology) is now one of AGU's largest, and WRR is now one of our largest journals. The journal has grown—and its breadth and scope have grown—as the hydrologic sciences have grown, both in basic research and in covering important and complex issues in society. This intersection is exactly AGU's mission.

Eos: How do you see the journal contributing to AGU's mission to nurture the next generation of scientists?

Bahr: The rigorous review process employed by WRR provides these younger scientists with constructive feedback that is designed to help them sharpen their arguments and improve their analytical and communications skills. In my role as an educator of the next generation of hydrogeologists, I use articles from WRR regularly as assigned readings for my students.

Mackay: A very large number of papers published in WRR every year have graduate students, postdocs, and early-career scientists as lead authors. I believe the journal is widely recognized within the field of hydrology as *the* place to publish early to land good postdoc or tenure track positions. Also, as editors, we strongly encourage early-career researchers to publish in WRR. We have held open forums at the AGU Fall Meeting so that young scientists can ask the editors questions about how to get published, how the review process is conducted, etc. We welcome queries from authors on ideas for papers, as we can advise them on any dos and don'ts.

Hanson: The Hydrology section has helped start a student conference immediately before the Fall Meeting and developed an "AGU Water" Facebook page (http://bit .ly/Water-Facebook). WRR editors and AGU staff are actively engaged in those initiatives. Our surveys have shown that students, in particular, value AGU publications for their quality and reach. We are working to expand the diversity of our editorial teams and have that as a priority, and we're also starting a series of author and reviewer workshops and webinars and other educational efforts—for example, around data management—to help engage early-career and international scientists.

Eos: As the journal evolves, what excites you about being an editor?

Rajaram: Just the breadth of new themes reflected in the papers we're getting. *WRR* is coming back to its roots, where we're trying



A hydrologist collects a water sample from a stream in Antarctica to use in studying biogeochemical exchanges in the streambed and margins and how those influence weathering, microbial nitrogen cycling, and stream temperature. Water Resources Research has included a paper on this research (see http://bit.ly/coupled-hydro-biogeochem) in a special section commemorating 50 years of the journal's publication.

to integrate the science side and the management side, [as well as the] society and social development side. It's a pretty exciting time.

Montanari: In 2015, we are going to get about 1700 papers. It really is a privilege—I have the opportunity to gain a very broad picture. And this special section is really exciting—this is the second special section celebrating an anniversary. The first was in 1986 to celebrate the twentieth anniversary [actually celebrated in the journal's 21st year], and it was a milestone; people are still reading those papers (see http://bit.ly/ WRR20-special). I have the ambition that this special section will be a milestone like



A special section of Water Resources Research celebrates the fiftieth anniversary of the journal, whose first issue was published in March 1965.

tions, and they are all new discoveries, new papers, giving an exciting picture for the future of scientific research. Eos: What do you see as the main goals

the previous one.

impressive collec-

tion of contribu-

You can see an

for WRR looking ahead for the next 50 years? How do you define or envision succoss?

Hanson: I think WRR is already

extremely successful. It is one of our largest journals, and submissions continue to increase at about 10% per year. The editors have also started a "Debates" series to further highlight some of the complex scientific and societal issues touched on by the research papers it publishes. We expect that the journal will continue to grow and present important research in the hydrological sciences.

Montanari: This special section is entitled "Legacy and Perspectives." The idea of giving it this title was to emphasize that on the one end, we have this legacy, this tradition, and, on the other end, we need a new vision. I think the legacy is extremely important, but at the same time, we need to work from a local perspective to a global perspective. In the past, water management took place at the catchment scale; nowadays, our hydrology needs to look at the big picture. I think this is the challenge for the next 50 yearsour perspective should be global.

By Lily Strelich, Freelance Writer

How Your Gift Can Keep On Giving



magine if only 17 out of 250 registered guests showed up at an event you were hosting or if only 7 out of 100 available chairs were filled during one of your scientific presentations. Chances are that you would feel tense, awkward, or dejected.

Although this isn't likely to happen at your personal events or scientific presentations, the truth is that AGU's fundraising appeals regularly attract far fewer positive responses than they should. Less than 7% of AGU members make financial contributions to our organization. Of that 7%, only 2.3% (1400 of more than 62,000) of those members make contributions of \$50 or greater.

As the director of development, I understand that AGU members must choose among many needs and options regarding where to allocate their disposable income. Some members make AGU a high priority. Others choose to make gifts elsewhere. It wouldn't be fair, or realistic, to expect all AGU members to make financial contributions to AGU beyond their annual dues. However, something should be done to encourage more individuals to give to AGU at modest levels. To that end, AGU is offering an incentive program that can positively impact all AGU sections and focus groups.

The incentive program will provide unrestricted funding of up to \$5000 to sections or focus groups that meet the minimum requirements. Section and focus group leaders maintain complete discretion as to how the funds are used.

How It Works

AGU members who make contributions this year of \$50 or more to any AGU fund will be considered qualifying donors toward the incentive program. Sections and focus groups with high enough percentages of qualifying donors will receive funding awards. Each qualifying donor's contribution will count as participation for only the one section or focus group that is the donor's primary affiliation.

The incentive program will award unrestricted funding according to the minimum participation thresholds below, starting at a 5% rate of participation. All gifts must be made by 31 December 2015 to qualify for the 2015 incentive program. AGU will calculate rates of participation using primary affiliation figures—excluding student members—as of 31 December 2015.

The unrestricted funding will be awarded in 2016 as follows:

- 5% participation = \$1000
- 7% participation = \$2000
- 10% participation = \$3000
- 12% participation = \$4000
- 15% participation = \$5000

A rate-of-participation system puts all sections and focus groups on an even playing field. AGU development staff encourage all AGU members to participate in this program.

Significant Changes

The year 2015 has brought about significant changes to AGU's development efforts. During the past 12 months, AGU has introduced a new organizational partnership program, revamped the benefits related to our individual giving program, enhanced the section and focus group sponsorship program, and made significant efforts to increase awareness among our members and industry constituents of the importance of development. Although all of these steps will increase development revenues over time, the incentive program can offer immediate financial rewards.

With dues renewal in full swing, Fall Meeting under way the week of 14 December, and year end approaching, please consider making a qualifying donation of \$50 or greater to an AGU fund of your choice. This could ultimately benefit your primary section or focus group.

By Jeff Borchardt, Development Director, AGU; email: jborchardt@agu.org

Great Lakes Hold Sway over Water and Carbon Cycling

NASA's Aqua satellite catches a rare glimpse of a cloudless summer day over the Great Lakes. Together, Lakes Superior, Huron, Michigan, Ontario, and Erie make up the largest body of fresh water on Earth.

A convoluted combination of biological, physical, and chemical exchanges gives lakes significant sway over climate. Their influence on local temperatures and carbon cycling can translate to climatic variations on local, regional, and even global scales.

The Great Lakes contain roughly 20% of the Earth's surface fresh water, and variables like albedo, heat capacity, surface roughness, evaporation, and greenhouse gas exchange exert a measurable influence on the surrounding environment. The movement, or flux, of carbon and water through lake systems has been harder to track, however.

The lack of observational data on the open water has so far prevented scientists from examining carbon and water fluxes over long time scales ranging from months to years. However, a new study tackles this problem, using direction measurements of latent heat and carbon dioxide to identify exchanges between the lake surface and the atmosphere.

Between October 2011 and September 2013, *Shao et al.* collected data from the Western Basin of Lake Erie using the eddy covariance technique, which calculates atmospheric fluxes by measuring the turbulent flow of gases. Their instruments were mounted to a buoy roughly 12 kilometers from shore, and a radio system transmitted data every 5 minutes for near-real-time observations.

The team also collected water samples up to 1 meter deep to analyze water quality, temperature, pH, and chlorophyll levels. They towed nets to measure the population of the cyanobacterium *Microcystis aeruginosa*, responsible for noxious algal blooms like the one that contaminated the drinking water of 500,000 Toledo residents in 2014.

The team found that carbon flux was closely linked to chlorophyll levels on the monthly scale, with western Lake Erie acting as a carbon sink during summer months. However, on average, the lake was a net carbon source over the 2-year study period. The total amount of carbon released from the lake was equivalent to one quarter of the carbon absorbed by the surrounding forests.

The study also showed that evaporation sent 90% of the annual rainfall back into the atmosphere. The scale of these exchanges demonstrates the importance of lakes in regional water and carbon cycling and environmental conditions both locally and globally. (*Journal of Geophysical Research: Biogeosciences*, doi:10.1002/2015JG003025, 2015) —Lily Strelich, Freelance Writer

Sea Level Rise Due to Warming, Weakening of Greenland Glaciers

The melting of glaciers is one of the most dramatic and palpable symptoms of climate change. Roughly half of the total sea level rise between 1993 and 2007—approximately 46 millimeters can be attributed to terrestrial ice melting or calving into the sea.

of energy when it transitions from liquid to solid, and over time, that energy can raise the average temperature of Greenland glaciers. The authors calculate that 1 kilogram of refreezing meltwater releases enough energy to decrease the viscosity of 100 kilograms of ice

In a recent study, Colgan et al. use a mathematical model to predict how much ice will be lost from Greenland over the next 500 years and the amount of sea level rise expected as a result due to a mechanism they call "thermal-viscous collapse." The authors' model focuses on increasing ice temperatures and resulting changes in ice viscosity. These variables are closely related: As ice heats up, its viscosity decreases, resulting in faster flow and iceberg production.

Using an ensemble of 50 computer simulations, the team predicts that within 500 years a thermal-viscous collapse could begin to warm the

Meltwater flows across the surface of the Greenland ice sheet.

deepest portions of the ice sheet to their melting point. According to the authors, a thermal-viscous collapse occurs when ice that is significantly colder than the freezing temperature—as it is in most of Greenland today—warms to the melting point.

Counterintuitively, such a collapse could be caused by meltwater refreezing within the ice sheet. One gram of water releases 335 joules by 11%. When this enhanced ice flow is extrapolated to the entire

ice sheet, the calculations reveal that Greenland could lose 5% ± 2% of its ice by 2500. vith According to the models, that Used loss could translate to a cumulative sea level rise contribution of York University). 33 ± 18 centimeters. The authors are careful to point out that their model represents an analysis of only one Colgan mechanism and one possible future and that they did not account for factors that might

> loops or other mechanisms associated with ice loss that could stabilize the ice sheet and prevent thermal-viscous collapse from occurring. However, the study indicates that such an event appears both thermodynamically and thermomechanically possible within the next few hundred years. (Earth's Future, doi:10.1002/2015EF000301, 2015) - David Shultz, Freelance Writer

prevent the thermal-viscous

collapse. There may be feedback

Hydraulic Fracturing Water Use Is Tied to Environmental Impact

The increasing number of hydraulic fracturing operations around the United States has prompted concerns about its impact on the environment. Assessing these impacts has been difficult, partly because of a lack of timely, comprehensive data on hydraulic fracturing in general and on injected water volumes in particular. To track variation in water volumes across well types and geography, researchers from the U.S. Geological Survey created a national-scale map of injected water usage, a crucial step in assessing the potential environmental impact of hydraulic fracturing.

Hydraulic fracturing, or fracking, is a method used to extract oil and gas from petroleum reservoirs that can't be tapped with traditional drilling techniques. The type of reservoir influences the type of fluids used and whether wells are drilled horizontally, vertically, or directionally (otherwise known as "slant" drilling). Many basins are developed using a combination of drilling directions.

Gallegos et al. examined data from more than 263,800 oil and gas wells of all types, hydraulically fractured between 2000 and 2014. They found that water usage varied depending on the type of reservoir. On average, the highest volumes of water were injected into wells in shale gas areas, as opposed to coal bed methane, tight oil, or tight gas areas. ("Tight" oil and gas are contained in rock formations with low permeability.)

Drilling direction also had an effect on water volume: Average water use in horizontal wells increased between 2000 and 2014, whereas the volume of water injected into vertical and directional wells remained steady. This helps to explain why water use is so variable across the nation and indicates that environmental impacts may be highly variable as well, depending on drilling operation methods and local factors.

Hydraulic fracturing draws water from local resources, so it can affect water availability, agricultural practices, and the behavior of waterways and the wildlife that depend on them. These effects are amplified in drought-prone regions. Hydraulic fracturing has also caused concern over potential contamination of drinking water by wastewater and fluids that can flow back to the surface after injection. Although wastewater is often disposed of in deep wells, this practice has become more contentious after being tied to induced seismicity in some areas.

This study contributes to a more complete knowledge of hydraulic fracturing. Understanding how drilling operations and opportunities for recycling affect the local environment is critical for local decision makers responsible for oil, gas, and water resources, wastewater disposal and treatment, and environmental management. (Water Resources Research, doi:10.1002/2015WR017278, 2015) -Lily Strelich, Freelance Writer

New Clues to Mysterious Hiss in Earth's Plasmasphere

n space, no one can hear you scream—but if you have the right radio equipment, you can "hear" the electromagnetic waves undu-L lating through the void. Now scientists have found previously unheard signals in this static that might help them uncover the source of a particular kind of hiss.

All of the waves examined in this study were generated by the particles of plasma trapped in Earth's magnetic field. They spiral, gyrate, resonate, and stock up energy and release it—which creates tiny ripples in the electric and magnetic field surrounding Earth. When these waves are converted to sound—like a radio playing FM broadcasts the space around Earth sounds like a jungle filled with different species of particles and electromagnetic behaviors, all emitting distinctive calls. For example, lightning can trigger waves called whistlers, which, as the name suggests, sound like whistling falling tones. Spectacular auroral displays amplify the so-called dawn chorus—chirpy waves that sound similar to birds in the morning.

One of the most mysterious of these noises is plasmaspheric hissan ever-present sibilance in the inner regions of Earth's magnetic field. It sounds like pure static spanning 100 Hz to several kilohertz, a frequency range roughly equivalent to that produced by the middle third of a piano. Scientists know that plasmaspheric hiss plays a crucial role in shaping the structure of Earth's radiation belts, disrupting them by knocking their energetic particles out into the atmosphere.

However, the source of the hiss is unknown. One theory says that it is the direct result of spiraling electrons high over Earth's equator.

Others propose that it consists of the remnants of distant whistlers or chorus waves that devolve into incoherence, like the expressionless chop far out at sea. Previously, scien-

An artist's impression of the twin Van Allen Probes in orbit within Earth's magnetic field.

tists assumed that this hiss was random white noise with no coherent features.

However, when Summers et al. analyzed NASA satellite measurements of the hiss from 2013, they found something quite different. After breaking down the noise into its spectrum of frequencies, they discovered barely detectable rising and falling tones similar to the whistlers, at frequencies rising to roughly middle C and falling for about two octaves. The authors say that this detection was made possible by the high resolution of the instruments on the satellites, NASA's Van Allen Probes, and their particularly useful orbit, which keeps them mostly within Earth's radiation belts.

Although the waves within plasmaspheric hiss resemble whistler tones and may share similarities in mathematical wave theory, the physical mechanism that generates the hiss is still wide open for debate. The authors expect that this fine structure will renew interest in the subject and may contain the clues to pin down its source. (Journal of Geophysical Research: Space Physics, doi:10.1002/2014JA020437, 2014) -- Mark Zastrow, Freelance Writer

Water Waves Provide **Insight into Landslides** and Avalanche Models

Scientists have long been interested in understanding and predicting landslides, like this one in Haiti triggered by the 7.0 magnitude guake that struck the country in 2010.

he ground beneath our feet usually feels solid, but Earth's land masses rest atop shifting tectonic plates that float on magma like colossal rafts on viscous seas. The plates are constantly moving, settling, and grinding against one another, causing earthquakes and volcanic eruptions, forming new mountains, and opening up new valleys. Landslides are powerful and potentially dangerous consequences of all this subterranean turbulence, and scientists are interested in predicting and modeling these events.

A plethora of mathematical formulas incorporating elements such as grain size, topography, gravity, and innumerable other factors has been created to describe the flow of solid particles in three dimensions, and researchers are constantly seeking to refine these models to match observations taken from real life events. Recently, researchers have recognized the importance of creating nonhydrostatic models, which do not rely on incorporating the interplay of gravity and pressure. Here Castro-Orgaz et al. add to this body of research by testing a group of equations known as Boussinesq-type gravity waves, which are used to describe waves of water, to analyze whether waves of solid materials can be described in the same way.

The team concludes that the Boussinesq-type gravity waves do, in fact, help describe the way avalanches and landslides propagate over time. In addition to refining their models, the scientists also suggest that this approach helps to describe the vertical motion of solids in a way that eliminates the need for many nongeneralizable assumptions previously used in models of granular flow. Instead, the assumptions are replaced with mathematics, opening a new framework for how researchers think about the flow of solids in three dimensions. (Journal of Geophysical Research: Earth Surface, doi:10.1002/2014JF003279, 2015). — David Shultz, Freelance Writer

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Atmospheric Sciences

Assistant Professor at Texas A&M University

The Department of Atmospheric Sciences at Texas A&M University is seeking applications for a tenure-track position at the assistant professor level in the field of physical meteorology, with an emphasis on radiative transfer and atmospheric remote sensing. Candidates are sought with research expertise in one or more of the following areas: radiative transfer, atmospheric remote sensing, and applications of remote sensing observations to broader areas such as climate study, physical meteorology, and atmospheric chemistry. A Ph.D. in atmospheric sciences or a related field is required at the time of appointment. Postdoctoral experience is desirable but is not required. The successful candidate will be expected to maintain a prominent research program and to teach courses at the undergradu ate and graduate levels.

The Department of Atmospheric Sciences is one of the largest such departments in the U.S., offering degree programs at all levels and research activities across the full spectrum of the atmospheric sciences. Resources available for teaching and research include the Texas A&M Supercomputing Center; the Center for Geospatial Sciences, Applications, and Technology; the Texas Center for Climate Studies; and the Center for Atmospheric Chemistry and the Environ ment.

The Department of Atmospheric Sciences is part of the College of Geosciences, which also includes the Departments of Geology and Geophysics, Geography, and Oceanography. Texas Sea Grant, the Geochemical and Environmental Research Group, and the International Ocean Discovery Program are also part of the College of Geosciences. Texas A&M University, a land-, sea-, and space-grant university, is located in a metropolitan area with a dynamic and international community of over 250,000 people. Texas A&M University is an affirmative action/equal opportunity employer committed to excellence through the recruitment and retention of a diverse faculty and student body and compliance with the Americans with Disabilities Act. We encourage applications from minorities, women, veterans, and individuals with disabilities. Texas A&M University also has a policy of being responsive to the needs of dual-career partners.

To apply, please send a CV, statement of research and teaching interests, and names and contact information for at least three references to:

Prof. Kenneth P. Bowman

Chair, Faculty Search Committee Department of Atmospheric Sciences Texas A&M University

College Station, TX 77843-3.150 Email: k-bowman @tamu.edu The position will remain open until a suitable candidate is found. Initial review of applications will begin on December 1, 2015.

Endowed Chair (Associate/Full Professor) of Unconventional Energy

The Department of Earth, Atmospheric, and Planetary Sciences at Purdue University invite applications for the Steven and Karen Brand Chair in unconventional energy resources. Candidates with a core expertise in unconventional energy with a strong and consistent track record of applying this expertise to unconventional petroleum resources will be considered. Candidates with expertise including, but not limited to, unconventional exploration and production, tight reservoir characterization, geophysics and seismic data analysis, subsurface integration, hydraulic fracture mechanics, pore/ fluid interactions, water and environmental issues, and enhanced oil and gas recovery are encouraged to apply. Excellence in and/or commitment to multi-disciplinary research and teaching is a requirement. It is expected that the candidate hired would significantly enhance Purdue's visibility and impact in this key area; increase opportunities for industry collaboration and grant funding; and inspire and train the next generation of leaders in the field.

This is an open-rank search; senior or mid-career scientists with academic, national laboratory, and industry background are all encouraged to apply. Applicant must hold a doctorate in an appropriate field; salary and rank are commensurate with qualifications and experience. The Department of Earth, Atmospheric, and Planetary Sciences, and the College of Science at Purdue embrace diversity and seek candidates who will create a climate that attracts students of all races, nationalities, and genders. We strongly encourage women and under-represented minorities to apply.

The department, in collaboration with other departments, has expertise in solid earth geophysics and crustal seismology, fracture mechanics, fluid flow in porous media, hydrogeology, clay mineralogy and surface chemistry, and basin analysis. The department has a long tradition of training students for careers in the petroleum industry and is part of a new multidisciplinary initiative at Purdue University aimed at addressing the energy needs of the country and is affiliated with the newly established Enhanced Oil Recovery Laboratory located in Discovery Park. Faculty members have a long history of working closely with and providing leadership to various Purdue University Discovery Park Centers (www.purdue. edu/DP). The successful applicant will conduct research, will advise graduate students, will teach undergraduate and graduate level courses, and will perform service. The successful applicant will be expected to work across these existing areas of Purdue expertise and

build on them with a focus on unconventional resources. Applicants should have a vision for the design and execution of a cross-functional program that achieves the intended mission as described above.

Interested applicants should visit https://hiring.science.purdue.edu; submit a curriculum vitae, a research statement, a vision statement, a teaching statement, and complete contact information for at least 3 references. Review of applications will begin January 15, 2016, and continue until the position is filled. Questions related to this position should be sent to Drs. John Cushman or Ken Ridgway, Co-Chairs of the Search Committee (phone: 765-494-3258, email jcushman@purdue.edu or ridge@ purdue.edu. Applications will be accepted until the position is filled.

Purdue University is a dynamic, growing university and a great place to work. Our inclusive community of scholars, students and staff impart an uncommon sense of larger purpose and contribute creative ideas to further the university's mission of teaching, discovery and engagement.

Purdue University is an EOE/AA employer. Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. All qualified

applicants for employment will receive consideration without regard to race, religion, color, sex, national origin or ancestry, genetic information, marital status, parental status, sexual orientation, gender identity and expression, disability or status as a veteran.

Post-Doc in atmosphere-land interactions at the University of California, Los Angeles

The UCLA Department of Geography seeks applicants for a Post-Doc position. A Ph.D. in atmospheric sciences, or a related discipline and experience in utilizing a GCM and/or a RCM are required. Background knowledge on land surface processes and climate-land interaction is desirable. The Post-Doc will conduct numerical experiments to understand land surface processes and their interactions with climate. This position is initially for one year but is renewable based on satisfactory performance. Please send an application with a statement of research interests, CV, and contact information for two references to Dr. Yongkang Xue (yxue@geog.ucla.edu). The UCLA is an equal opportunity action employer.

Postdoctoral Research Associate Position University of Washington, Seattle, WA

The Joint Institute for the Study of the Atmosphere and Ocean (JISAO) at the University of Washington is seek-

Graduate Student Opportunities in Earth, Ocean, and Atmospheric Sciences

Rutgers University's new Institute of Earth, Ocean, and Atmospheric Sciences (EOAS) offers an exciting, interdisciplinary environment for the integrated study of our planet's atmosphere, oceans, cryosphere, solid Earth and biosphere. EOAS's strong research programs include focuses on global climate change, ocean modeling and observations, paleoceanography and Earth history, planetary science, geobiology, marine ecology, molecular ecology, and environmental biophysics. EOAS welcomes applications for graduate study toward a Ph.D. degree in Atmospheric Science, Ecology and Evolution, Geography, Geological Sciences, and Oceanography. For more information and to apply, please visit our website at http://eoas.rutgers.edu.

Rutgers is an Equal Opportunity/ Affirmative Action Employer. ing Post-doctoral Research Associates with research interests in atmospheric science, oceanography, climate science, and fisheries science and management. JISAO encompasses a broad range of scientific interests including large-scale atmospheric-ocean interaction, ocean and atmospheric dynamics, biogeochemical cycles, ocean acidification, marine ecosystems, climate impacts on ocean and land ecosystems, high-latitude climate, paleoclimate studies, ocean and atmospheric model development and evaluation, and climate forcing and feedbacks, including both aerosol and clouds. JISAO operates jointly between the University of Washington and the NOAA research laboratories in Seattle, particularly the Pacific Marine Environmental Laboratory (PMEL).

We anticipate that two positions will be filled. Terms of appointment are for one (1) year, renewable for a second year, subject to approval and availability of funding. Positions are not project specific; a successful applicant is expected to define his/her research goals within the broad program areas of JISAO and are strongly encouraged to collaborate with University of Washington and NOAA PMEL scientists. Applicants who can demonstrate research relevance to both JISAO and PMEL programs are preferred. Successful applicants must hold a recent Ph.D. in order to assume a post-doctoral position.

Applicants are asked to submit electronically: (1) a curriculum vitae, (2) a publication list, (3) a brief research proposal (no more than 5 pages, double-spaced, excluding bibliography and figures) describing research to be pursued during a two-year tenure at the University of Washington, and (4) the names of four individuals who can provide a letter of reference. In addition, a letter of support from a mentor at the UW or PMEL is strongly encouraged. Research mentors may be IISAO research scientists, PMEL research scientists, and/or UW faculty members in relevant departments. (A list of possible mentors and their research interests can be found on the JISAO web page [http://jisao.washington.edu/ research/postdocs]. This list is not inclusive; mentors at PMEL or the UW not on this list may also be considered.)

Applications should be received prior to January 1, 2016. Applications received after that date are not likely to be considered. Applications should be sent to: Collen Marquist, Administrative Specialist, at marquist@uw.edu. Inquiries may be directed to Collen electronically by Fax at 206-685-3397; or by mail to the Director, Joint Institute for Study of Atmosphere and Ocean, Attn: Collen Marquist, Box 355672, University of Washington, Seattle, WA 98195.

University of Washington is an affirmative action and equal opportu-

Undergraduate Programme Director (Lecturer/ Senior Lecturer)

Young and research-intensive, Nanyang Technological University (NTU Singapore) is ranked 13th globally. It is also placed 1st amongst the world's best young universities.

The Asian School of the Environment (ASE) at NTU Singapore, seeks to hire an environmental earth system scientist as Undergraduate Programme Director. ASE, a new interdisciplinary school, consection of a science state of the science state of the science state of the science science state of the science science science state science scie Sustainability, and teaches large courses to support the minor and general education requirements for students from across the University.

The selected candidate will:

- Lead the Undergraduate Programme Committee in administration of all aspects of the undergraduate major and minor programmes
- Manage a diverse group of administrative, and undergraduate laboratory and field staff
 Develop and teach introductory and advanced courses including laboratory and/or discussion sessions for the undergraduate major and minor
- Maintain research in their field, focusing on projects that involve undergraduates in research (up to 15% of the appointment)
- The position will be appointed for a 1-3 year term, with the ability to renew. The Lecturer/Senior Lecturer is a member of the Asian School of the Environment reporting to the Chair of the School and the Associate Chair (Academic). He/she will work closely with a team including faculty and staff at the Asian School of the Environment and across the University

Qualifications:

- PhD in environmental science, ecology, earth science, environmental social science or a related field
- Strong organisational and project management skills Strong interest in and aptitude for teaching and mentoring at the undergraduate level
- Ability to work well with a team in a dynamic working environment
- · Effective oral and written communication skills in English In-depth knowledge of learning theory and supporting pedagogy
- · Experience in teaching and mentoring undergraduate
- To apply, please submit the following materials to: sccl_ase@ntu.edu.sg

• Teaching Statement • Curriculum vitae • Names of 2 references who are familiar with your work Review of applications will begin immediately and continue until the position is filled.

www.ntu.edu.sa

nity 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. To request disability accommodation in the application process, contact the Disability Services Office at 206.543.6450 / 206.543.6452 (tty) or dso@u .washington.edu

The Department of Meteorology and Climate Science at SJSU invites applications for a tenure-track faculty position at the Assistant Professor level, to begin August 22 2016.

We seek applicants with specialization in Western US weather as it relates to precipitation events, together with impacts of climate change. The successful candidate will teach classes in the areas of synoptic and mesoscale meteorology as they relate to precipitation in the western US, as well as classes in the broad area of impacts of climate change on western precipitation patterns. Teaching responsibilities may over time include General Education, majors (BS) and graduate (MS) courses. The successful candidate will also be expected to develop a research program involving both graduate and undergraduate students, and also participate in advising, committee, and departmental outreach activities.

Applicants must have a completed PhD in Atmospheric Science or a closely related field by the start of the appointment. Applications will only be accepted online via apply.interfolio. com/31100. For full consideration, send/upload: (i) a letter of application; (ii) CV; (iii) undergraduate and graduate transcripts (copies now, originals later); (iv) a statement of teaching interests/philosophy; (v) a statement of research plans; and (vi) three original letters of reference with contact information by January 19, 2016. This is IOID 23434.

Dr. Alison Bridger

- Chair, Department of Meteorology & Climate Science
 - San Jose State University
 - One Washington Square
 - San Jose CA 95192-0104
 - Tel: (408) 924-5200
 - Fax: (408) 924-5191
 - Email: Alison.Bridger@sjsu.edu

A complete announcement is located on our web page. SJSU is an Affirmative Action/Equal Opportunity employer and is committed to increasing the diversity of its faculty.

Geochemistry

Faculty positions at the Department of Geosciences, National Taiwan University

The Department of Geosciences at NTU is seeking active scientists to fill faculty positions starting from 1st August, 2016. The positions are open to all fields in geosciences, but those who have strong background in the fields of mineralogy and petrology, geo-resources, stratigraphy, sedimentology, structural geology and applied geology will receive more favored consideration. Applicants are requested to submit the following documents: CV, list of publications, three to five copies of refereed articles published within the last seven years (one of which shall be designated as representative paper and must be published after 1st August, 2011), plans for teaching and researching WORD or PDF files, and names of three potential referees. Application material should be sent to Professor Ya-Hsuan Liou, the Chairman of the Searching Committee, by post or emails at yhliou@ntu.edu.tw. Address: Department of Geosciences, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei 106, Taiwan.

Deadline for application: 15th January, 2016. Web site: http://web.gl.ntu. edu.tw/

Tenure-Track Faculty - Geochemistry

The Department of Geosciences at The Pennsylvania State University invites applications for a tenure-track faculty position in Geochemistry. Although the primary target of this search is at the assistant professor level, the committee will also consider senior candidates with exceptional qualifications. We seek a colleague who creatively uses theoretical, observational, and/or experimental approaches to address fundamental problems related to the mineralogy and geochemistry of the Earth's surface. Successful applicants will be expected to contribute to a diverse research and teaching community in the Department of Geosciences through the development of a vigorous, internationally recognized and externally funded research program, and through teaching courses in their discipline at the undergraduate and graduate levels. The Department of Geosciences is part of the College of Earth and Mineral Sciences, and houses research programs spanning a broad spectrum of Earth Science disciplines (further information is available at: http://www.geosc. psu.edu). We especially encourage applicants whose research activities will prove synergistic with the Materials Research Institute and/or the Earth and Environmental Systems Institute at Penn State. Applicants must have a Ph.D. in geosciences or a related field at the time of appointment.

Applicants should submit a cover letter, a statement of professional interests (research and teaching), a curriculum vitae, and the names and addresses of three references. Appointment may begin as early as July 1, 2016. Review of applications will begin on January 4, 2016 and continue until the position is filled. For further information or questions, please contact Peter Heaney, Chair of the Search Committee at pjh14@psu.edu or Stacie

Hugney, Administrative Assistant at slg9@psu.edu.

Apply to job 60731 at http://apptrkr. com/710880

CAMPUS SECURITY CRIME STATIS-TICS: For more about safety at Penn State, and to review the Annual Security Report which contains information about crime statistics and other safety and security matters, please go to http://www.police.psu.edu/clery/, which will also provide you with detail on how to request a hard copy of the Annual Security Report.

Penn State is an equal opportunity, affirmative action employer, and is committed to providing employment opportunities to all qualified applicants without regard to race, color, religion, age, sex, sexual orientation, gender identity, national origin, disability or protected veteran status.

Hydrology

Research Scientist - Earth Sciences Remote Sensing

Agency: National Aeronautics and Space Administration

Field Center: George C. Marshall Space Flight Center - Huntsville Alabama, USA

Job Announcement: https://nasai. usajobs.gov/GetJob/ViewDetails/ 421637300

OPEN PERIOD: Tuesday, November 17, 2015 to Thursday, January 7, 2016

This is a research position directed toward discovering, disseminating, and applying new or expanded knowledge

in a professional discipline. Duties include: Perform research into land surface processes involving the analysis of data obtained from instruments onboard satellite and airborne platforms, models, and from ground-based instrumentation Develop and apply techniques for using data from remote sensing assets for research and applications in agriculture, water resources, and hydrology. Serve as Principal Investigator or Project Scientist to develop innovative analysis methods, models, and end-user driven applications to support scientific research and decision making. Coordinate and oversee the development of new and innovative uses of NASA data, products, and applications to benefit national or regional governmental institutions. Provide advice and guidance in the area of earth sciences analysis and applications product development. Utilizes remotely sensed data for assessment of water resource availability, land use, and changes to land cover. Pursue funding opportunities for research that aligns with the Earth Science Offices major initiatives.

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?

iobid=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 with focus on the dynamics of sediment transport.

The College of Earth, Ocean, and Atmospheric Sciences at Oregon State University located in Corvallis, Oregon invites applications full-time, 12 month tenure-track position. We seek a colleague to develop and maintain a vigorous, externally funded research program in sediment transport. This position is expected to combine field observations, theory, and modeling to study the dynamics near the sediment-water interface. We seek a scholar with experience in any environment along the source-to-sink continuum. Sediment dynamics near the land-sea interface, environments affected by surface gravity waves, are of particular interest. The successful applicant will participate in teaching undergraduate and graduate curriculum and advise/mentor students, and postdocs. Requires: Ph.D. in geology, geomorphology, oceanography, coastal engineering or other related physical discipline by the start of employment; scholarly potential demonstrated by a

record of peer-reviewed publications and a clearly defined research agenda; potential for establishing a funded research program; potential for teaching excellence, student success, mentoring students/postdocs; English proficiency; and a commitment to diversity. For CEOAS information see: http://ceoas.oregonstate.edu To apply go to: http://oregonstate.edu/jobs posting #0016541. For full consideration apply by 01/12/2016. Closing date: 02/01/2016.

Climate and Coastal Hazards Science Faculty Position

The Department of Marine Sciences at The University of North Carolina Chapel Hill (http://marine.unc.edu) invites applications for a tenure track faculty position for an individual working at the interface between climate science and coastal hazards / risk assessment. We anticipate filling the position at the Associate to Full Professor level, but will consider outstanding candidates at the Assistant Professor level. The successful candidate will be expected to maintain a vigorous, extramurally-funded research program; teach courses and mentor student research at the undergraduate and graduate levels; and provide outreach and engagement within and outside of the University. The University of North Carolina at Chapel Hill is an equal opportunity employer that welcomes all to apply, including protected veterans and individuals with disabilities. Additional information on

PLACE YOUR AD HERE

Contact advertising@agu.org for information

this position is available at http:// marine.unc.edu

To apply for the position, please follow this link: http://unc.peopleadmin. com/postings/84101. Applicants must submit a cover letter with the names of at least 4 references, a Curriculum Vitae and research and teaching statements; the position will remain open until filled with application review beginning December 1, 2015. The University of North Carolina at Chapel Hill is an Equal Opportunity Employer.

Solid Earth Geophysics

ASSISTANT PROFESSOR Structural Geology (tenure track)

The Nevada Bureau of Mines and Geology (NBMG) at the University of Nevada, Reno (UNR) seeks applicants with expertise in field-oriented structural geology. NBMG is a public service unit of UNR and serves as both the state geologic survey of Nevada and as a research department in the UNR College of Science. Faculty at NBMG have tenure-track academic appointments, with both research and teaching obligations.

Position Responsibilities: Primary responsibilities of this position include development of productive externally funded, research programs in the field of structural geology. Research will focus on structural geology as it relates to the tectonic evolution of Nevada, utilizing innovative approaches to detailed geologic mapping, structural analysis of faults and folds, and geochronology. The successful candidate will also be expected to contribute to understanding natural resources and geologic hazards in the context of structural settings and deformational events. Duties will include supervising graduate students and teaching courses in the candidate's area of expertise within the Department of Geological Sciences and Engineering (DGSE).

Qualifications: Applicants must have a doctorate in geology or a related geoscience field by the time of hire and a demonstrated record of research on topics related to Structural Geology, as indicated by dissertation research, industry experience, and/or peer-reviewed publications. The successful candidate must also have experience in field-oriented research and a desire to conduct such research on future projects. Expertise in geologic mapping, fault kinematics, rock mechanics, and/ or geochronology will be valued. Excellent communication skills, as demonstrated in written application materials; commitment to public service;

potential for, or established record of publications; and ability to attract funding are essential. We encourage candidates to explain achievable plans for funded research on Nevada-focused topics in Structural Geology in their letters of interest.

Salary and Date of Appointment: The position will be a tenure-track fac-

Facilitate intergovernmental cooperation in ocean sciences

Head, Ocean Science Section Intergovernmental Oceanographic Commission of UNESCO

UNESCO is known as the "intellectual" agency of the United Nations. It is a key player in the global effort to build sustainable future for our planet. The Intergovernmental Oceanographic Commission (IOC) of UNESCO is the only specialized body in the UN system for ocean science, observations, services, and related capacity development.

Leading the Ocean Science Section of the IOC Secretariat requires top-level expertise in ocean sciences and a strong ability to identify requirements and opportunities for fruitful international cooperation in oceanography. You will be driven by priorities of IOC Member States, and your main task will be to shape the IOC response to ocean science challenges. In a team of highly dedicated professionals, you will facilitate formulation of the IOC scientific priorities, agendas, policies, bi-annual work programme, and budget. Your high-profile work will comprise scientific advice to ocean policy in all areas of IOC expertise including climate change and variability, ocean health and disaster risk reduction.

Holder of at least a Master Degree in Oceanography or Earth Sciences, you will exploit to the maximum your extensive experience in managing international research, gained in the capacity of e.g. the director of a major oceanographic programme, institute, centre, or agency.

We look for a specialist in oceanography, marine biogeochemistry, ecosystems dynamics or climate change. You should bring with you strong analytical, organisational and partnership-building skills, proven leadership ability and an excellent command of English and French. High academic distinctions, a record of specialist publications would be an advantage, as would be your knowledge of other official UNESCO languages (Spanish, Russian, Chinese and Arabic).

To view the full vacancy announcement and learn how to apply, please visit: http://en.unesco.org/careers/

ulty appointment at the assistant professor level with an academic-year base salary that is competitive with other research universities. Starting date will be July 1, 2016 or shortly thereafter, depending on availability of the successful candidate.

To apply, please visit: https://www. unrsearch.com/postings/19454. Please submit a letter expressing your interest in the position and research plans; names, e-mail addresses, postal addresses, and telephone numbers of at least three references; a complete curriculum vitae; and electronic copies of up to three of your publications to http://jobs.unr.edu/. Application deadline is February 1, 2016. For further information about NBMG, please consult our website (http://www.nbmg. unr.edu).

EEO/AA. Women, under-represented groups, individuals with disabilities, and veterans are encouraged to apply.

Colorado School of Mines Department of Geophysics Assistant/Associate Professor - Computational Seismology

Colorado School of Mines invites applications for a regular academic faculty position in Geophysics, which is anticipated to be filled at the rank of Assistant or Associate Professor.

The successful candidate will conduct a vigorous research program that includes (a) building strong collabora-

Faculty positions available at the Institute of Oceanography, National Taiwan University

The Institute of Oceanography, National Taiwan University (IONTU), invites applications for one to three faculty position(s), at the level of assistant professor or higher, starting on August 1, 2016 Applicants should hold a doctoral degree in research fields related to marine sciences, including physical oceanography, chemical oceanography, marine geology, marine biology or biological oceanography. Applicants should send (1) curriculum vitae (including publication list), (2) PDF reprints of up to three publications (published after June, 2012), (3) a proposal for future research and teaching preferences, via e-mail before December 31, 2015 to: Prof. Sen Jan

Chair, Faculty Search Committee Institute of Oceanography, National Taiwan University (senjan@ntu.edu.tw ; please also Cc to chienchung@ntu.edu.tw)

Tel: +886-2-3366-1373 Fax: +886-2-2362-6802 Please visit http://www.oc.ntu.edu.tw for general information of IONTU. Please also arrange for three recommendation letters to be sent directly to the Chair of the Faculty Search Committee. Upon receipt of the application, an acknowledgement email will be sent to the applicant within a week. Applicants who do not receive the acknowledgement email please contact the Chair of the Faculty Search Committee via fax or telephone for confirmation. tive relationships with industry, academic, research, and/or government institutions; (b) generating research funding; (c) supervising graduate students; and (d) maintaining a strong record of scholarly publishing. The successful candidate will teach at both the undergraduate and graduate levels, and participate actively in the international geophysics community.

Candidates must possess a doctoral degree in geophysics or a related field. Candidates must also possess superb interpersonal and communication skills and a collaborative style of research and teaching, and must have experience in collaboration with industry.

For the complete job announcement, full statement of qualifications and directions on how to apply, visit: http://inside.mines.edu/HR-Academic-Faculty

Mines is an EEO/AA employer.

Interdisciplinary/Other

Assistant Professor in Geodesy and Remote Sensing (Tenure-track) University of Colorado Boulder https://www.jobsatcu.com/

postings/111214

The Cooperative Institute for Research in Environmental Sciences (CIRES, www.cires.colorado.edu), an interdisciplinary research institute within the University of Colorado Boulder, invites applications for a tenure-track faculty member at the Assistant Professor level specializing in the areas of geodesy and remote sensing of Earth. The position is rostered in CIRES, with tenure and teaching responsibilities in a relevant academic department including, but not limited to, Geological Sciences, Aerospace Engineering Sciences, Physics, or Geography.

We are seeking a multidisciplinary Earth scientist who uses advanced geodetic and remote sensing techniques to study surface and subsurface processes of the Earth. It is anticipated that the successful candidate will have research interests in one or more areas related to earth-surface change detection of environmental processes. Techniques might include terrestrial, airborne, or satellite LiDAR, radar altimetry, GPS, optically sensed image coregistration, InSAR, or other methods. Candidates whose expertise complements that of existing CIRES faculty and researchers in cryospheric processes, natural hazards, tectonics, geomorphology, or geohydrology are particularly encouraged. Potential synergies in CIRES, on campus, and from the larger Boulder community include the Earth Science and Observation Center (ESOC, cires. colorado.edu/esoc), the National Snow and Ice Data Center (NSIDC; nsidc.org), Western Water Assessment (wwa. colorado.edu), UNAVCO, and NOAA. The successful candidate will be expected to maintain an active, externally funded research program, supervise graduate students, and teach at both undergraduate and graduate levels.

Applicants must apply online at https://www.jobsatcu.com/

postings/111214

Review of applications will begin December 1, 2015, and will continue until a successful applicant is selected.

Effective December 5, 2015 applicants will need to apply at a new site, www.cu.edu/careers. Please use the keyword search for position number 660551 or F03052.

Inquiries may be sent to Search Committee Chair Prof. Anne Sheehan at Anne.Sheehan@colorado.edu

The University of Colorado is an equal opportunity and affirmative action employer committed to assembling a diverse, broadly trained faculty and staff. In compliance with applicable laws and in furtherance of its commitment to fostering an environment that welcomes and embraces diversity, the University of Colorado does not discriminate on the basis of race, color, creed, religion, national origin, sex (including pregnancy), disability, age, veteran status, sexual orientation, gender identity or expression, genetic information, political affiliation or political philosophy in its programs or activities, including employment, admissions, and educational programs. Inquiries may be directed to the Boulder Campus Title IX Coordinator by calling 303-492-2127.

Assistant Professor, Sedimentary Geology/Paleoclimate

The Department of Geology at Occidental College invites applications for an Assistant Professor in sedimentary geology with a research focus in paleoclimate, paleoenvironmental change, and/or fluvial – coastal processes. Occidental is a nationally ranked liberal arts college recognized for its diverse student body and outstanding undergraduate research program. We seek a colleague who values undergraduate teaching and can sustain an active research program involving undergraduates. In addition to courses related to specialty, the successful candidate will contribute to teaching introductory geology, support the Environmental Science concentration, engage undergraduates in research, and mentor students through completion of senior theses.

Applications should include a statement of teaching and research interests in the context of a liberal arts college. Candidates should specifically address their ability to 1) teach in a socioeconomically, ethnically and culturally diverse environment, and 2) engage students in an ongoing research program. Submit statement, curriculum vitae, 1-3 significant publications, and contact information for three referees to Dr. Margi Rusmore, Search Committee Chair, at geosearch1@oxy.edu. Members of underrepresented groups are especially encouraged to apply. Review of applications will begin October 15, 2015, and will continue until the search closes on December 22, 2015, Search committee members will meet interested candidates at the GSA and AGU meetings; email the committee to make arrangements.

The Department of Geosciences at North Dakota State University

Invites applicants for a tenure-track Assistant Professor position in Quaternary geology, in order to strengthen the department's research reputation and education profile in surficial processes and geology of Polar regions. The successful candidate will demonstrate potential for continued professional development and scholarship at a Carnegie Very High Research Activity institution. Review will begin January 8, 2016 and continue until the position is filled. NDSU hosts a NSF ADVANCE grant, which supports professional advancement of women faculty through mentoring programs, research support, and leadership training opportunities. North Dakota State University is an Affirmative Action/Equal Opportunity Employer, Committed to Diversity in Hiring. For application details see jobs.ndsu.edu/postings/7032.

Student Opportunities

EarthCube's Visiting Scientist Program

Offers up to \$2000 each to support five graduate students and early career scientists for travel and related expenses incurred while incorporating EarthCube technologies and capabilities in their own research agendas.

For more information or to apply for funding, please go to:

http://earthcube.org/info/ visiting-scholar-program

PhD Fellowships in Hydrologic Sciences available at the University of Nevada, Reno and Desert Research Institute

The Graduate Program of Hydrologic Sciences at the University of Nevada, Reno and the Desert Research Institute seeks PhD candidates in hydrology and hydrogeology to fill graduate teaching and research assistant positions beginning in Fall 2016. Three year research fellowships are available for a wide range of topics, including effects of halophytic plants on soil quality; climate patterns and tree rings; groundwater residence times and aquatic ecology of springs; snow ecohydrology; and Nevada water resources. Details are available at http://www.hydro.unr.edu/research/ research_funding.aspx.

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 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.

Be inventive.

Looking for a postdoctoral or sabbatical research opportunity? The CIRES Visiting Fellows Program attracts scientists from around the world. Many postdoctoral Fellows have gone on to careers at CIRES, NOAA, and other prestigious academic, government, and private institutions. We select Visiting Fellows who work on a wide range of environmental science topics, and we place great value on interdisciplinary research. Candidates are strongly encouraged to contact CIRES in advance of the January 11, 2016 deadline.

More: http://cires.colorado.edu/visiting-fellows

Lindsay Chipman Postdoctoral Visiting Fellow, 2012-2013 Center for Limnology, Cooperative Institute for Research in Environmental Sciences

Postcards from the Field

Dear AGU,

Hello from the Juneau Icefield Research Program (JIRP)! JIRPers have been hard at work over the summer digging snow pits all over the Juneau Icefield, measuring the winter accumulation and calculating the mass balance of the Taku Glacier, the largest outlet glacier of the Icefield. Here a hardy group digs a pit just beneath the dramatic Emperor Peak and the imposing Taku Towers.

Wish you were here,

Allen Pope, postdoc at the National Snow and Ice Data Center, University of Chicago Boulder, and the Polar Science Center, University of Washington) Twitter: @PopePolar.

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

2015 AMERICAN GEOPHYSICAL UNION HONORS TRIBUTE

Recognizing the exceptional scientific contributions and achievements of eighty-five individuals

Prize Recipients • Union Awardees • Fellows • Medalists

Ceremony

Wednesday, 16 December, 6:00 PM Moscone North, Hall E Moscone Convention Center

Open to the Public

Banquet

Wednesday, 16 December, 8:30 PM Yerba Buena Ballroom, San Francisco Marriott Marquis

Ticketed Event • Dinner and Dancing • Business Attire Cash bar in the Honors Banquet Lounge

Apply for Amazon Web Services Research Grants Online During the AGU Fall Meeting

Visit AWS at Booth #516

Amazon Web Services and AGU are excited to announce a special Live Granting of Amazon Web Services research grants at the 2015 Fall Meeting.

Applications will be accepted and evaluated 20 October–31 December 2015 with the opportunity for live applications and granting at the AWS booth (#516) during the Fall Meeting. Grants will be awarded during and following the Fall Meeting.

Visit **FallMeeting.agu.org/2015/AWSLiveGranting** for more information and to apply.