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IN THIS ISSUE:

Inequalities in the Networks of Virtual Water Flow

J. CARR, P. D'ODORICO, F. LAIO, L. RIDOLFI, AND D. SEEKELL

The globalization of water associated with the trade of food commodities [*Hoekstra and Chapagain,* 2008] has often been acclaimed as a means to save water, mitigate the effect of regional- and local-scale water scarcity, and meet the demand for food in overpopulated and water-poor countries [*Allan,* 1998]. However, there are negative implications for water use from globalization of trade. For instance, globalization disconnects populations from local sustainable freshwater use [*Allan,* 1998; *D'Odorico et al.,* 2010]. This distance between societies and the resources on which they rely is a major obstacle to the emergence of behaviors that foster ecosystem stewardship [*Chapin et al.,* 2009] through a responsible management of the environment. The globalization of water is also expected to reduce societal resilience to drought by decreasing the redundancy of freshwater resources, thereby limiting opportunities to meet human needs during periods of crisis [*D'Odorico et al.,* 2010]. Overall, globalization enhances inequalities in the way different societies may have access to freshwater resources [*Chapin et al.,* 2009]. In fact, only a few countries control most of the water that is virtually exchanged—through food trade—in the global market.

Because food production requires adequate soils, climate, and water (neglecting trade), there exists a tight relationship between population and the sustainable use of local resources. With human societies employing approximately 85% of their freshwater use for food production, population growth has led to an increase in freshwater utilization, thereby enhancing the potential for local water stress. However, when food production is inadequate to meet the demands of a population, importation of food commodities from other regions allows societies to reduce stresses associated with limited water resources.

This trade of agricultural and industrial products creates a mechanism by which societies virtually transfer freshwater resources [*Allan,* 1998]. The virtual water of a commodity is the water required to produce that commodity. As such, virtual water trade is often considered as a solution to limited water availability in many regions. Virtual water trade can prevent societal water stress, malnourishment, and water wars [*Allan,* 1998; *Barnaby,* 2009]. Virtual water trade also provides a means to ameliorate regional changes in food production due to the impacts of climate change. Thus, global food security depends, in part, on virtual water trade [*Hanjra and Qureshi,* 2010]. However, differential resource and trade accessibility among countries introduces the potential for large inequalities to arise. Because of its important role in determining global food security, recent studies have begun to examine the major drivers of virtual water trade and how the global redistribution of (virtual) water has changed in the past few decades [*Suweis et al.*, 2011; *Carr et al.*, 2012].

Trade Changes Over the Past Few Decades

The networks of virtual water trade for 1986–2008 have been reconstructed [*Carr et al.*, 2012] using detailed trade data on agricultural plant and animal commodities from the statistics division of the Food and Agriculture Organization of the United Nations combined with estimates of the water footprint of those products [*Mekonnen and Hoekstra*, 2011a, 2011b]. Analyses of these data have found that virtual water networks have changed substantially over the past few decades. The total number of trade connections has more than doubled, while the total trade in virtual water has increased from roughly 1×10^{12} to about 2.2×10^{12} cubic meters. This doubling in virtual water trade exceeds the rate of population growth, with an increase in virtual water trade of 200 cubic meters per person between 1986 and 2008. The increase has not been uniformly distributed across the network. Most trade partnerships have limited durations [*Carr et al.*, 2012]; only 3964 connections (about 25% of the links existing in 2008) were permanent throughout the study period. These links tend to organize the network in communities that exhibit numerous internal connections between community members and connect to other communities with only a few external connections [*D'Odorico et al.*, 2012].

What causes this repeated appearance and disappearance of virtual water trade partnerships? The majority of the connections and fluxes in the network seem to depend on a multitude of factors, including geopolitical and socioeconomical drivers, climate, fluctuations in crop yields, dietary changes, and conflicts. In some cases, factors controlling trade are readily identified, such as the lack of trade connection between Cuba and the United States. The increase in virtual water fluxes to the Russian federation in 1992 is attributed to post–Cold War subsidy reforms, associated decrease in livestock production (http://www.ers.usda.gov/publications/aer813/aer813c.pdf), and the corresponding increase in imports to the Russian federation. Similarly, the increase in soy trade between China and Brazil after 2000–2001 is explainable by changes (in 2000) in importation policies in China [*Dalin et al.,* 2012].

In other cases, however, drivers of trade are harder to discern, and the intermittent character of the virtual water network and its relatively low number of permanent links still needs to be elucidated. Moreover, it is unclear why the increase in total virtual water flow is not evenly distributed among all connections. Globally, most of the virtual water flux occurs through a small number of links (about 50% of the total flux is carried by 1.1% of the connections), and only a handful of countries control these fluxes. Approximately 40% of the net virtual water exports arise from Brazil, Argentina, and the United States—countries that in aggregate account for only 5.7% of the global population. Consequently, major changes in the network may be controlled by a relatively small number of trading partners [*Carr et al.,* 2012; *Konar et al.*, 2011].

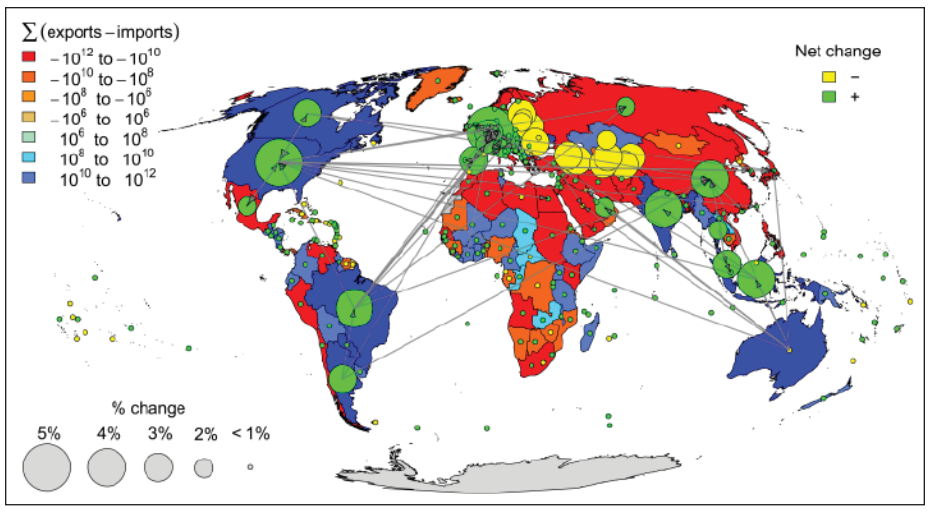

Fig. 1. A representation of the virtual water network showing only links associated with major virtual water flows (top 25%). For each country the net export-import balance is shown (background color, measured in cubic meters of water) along with changes in total strength in the 1986–2008 period (green and yellow disks).

A Few Countries Have a Large Impact

The total strength, i.e., the sum of imports and exports, of a node of the virtual water network can be used to examine the total impact each country has on the flow of virtual water in the network. Figure 1 shows (with circles) the change in strength for each of the trading countries between their first and the last reporting year. This change is shown superimposed on a map with the net export-import balance for each country for the year 2008 and the links that have carried the top 25% of all virtual water over the 23-year period. Of note is the paucity of countries that have a near-zero export-import virtual water balance: Most countries are either strong net importers or net exporters of virtual water. While most countries have increased their total strength over time, some of the major net exporters of virtual water, such as Australia, have maintained their total strength.

Of the countries that increased their total strength, Germany accounts for 6.7%, the Netherlands accounts for 6.5%, the United States accounts for 6.4%, and China accounts for 5.5% of the global increase. Altogether, these four countries account for a quarter of the global increase (3.15×10^{12} cubic meters) in the strength of virtual water trade through the study period. Ten countries account for about 51% and 25 countries account for 75% of this increase. Interestingly, these countries have access to large amounts of financial resources (Germany, United States, China), water (Brazil, Argentina, United States), and oil (United Arab Emirates, Iran), or they act as major trade hubs (Netherlands, United Arab Emirates). In contrast, the nodes undergoing a decrease in the strength of virtual water trade are dominated by former Soviet states and small island nations. Overall, the decrease found in Australia and Saudi Arabia, both large importers and exporters of products globally, is small (<1%). Africa remains only marginally affected by changes in virtual water trade.

Why Are There Inequalities in Virtual Water Trade?

This analysis reveals a select few countries dominating the changes in the network. The inequality in terms of access to resources appears to directly or indirectly drive the trade of virtual water. The relative distribution of freshwater resources and human populations opens important environmental and ethical questions. The existing inequality in the access to local water resources is mostly controlled by geography and climate conditions while access to virtual water resources depends more on gross domestic product [*Suweis et al.*, 2011].

Is this inequality unjust or only regrettable? While, by valuing environmental sustainability, many societies appear to have found an answer to a similar question in the time domain (i.e., it is unjust to deplete natural resources and reduce the availability of environmental goods and services for future generations), the assessment of what is just or unjust does not appear to be obvious in the space domain, when inequalities in per capita virtual water and resource availability exist among different countries and regions of the world. However, recent research may clarify some of the ethical implications of virtual water trade: Virtual water flows tend to be driven by gross domestic product and social development status rather than regional- and local-scale water scarcity and solidarity toward water-stressed populations [*Seekell et al.*, 2011; *Suweis et al.,* 2011]. As such, virtual water trade tends to further enhance inequality [*Seekell et al.*, 2011], and these socioeconomic drivers appear to prevail over the need to reduce inequalities associated with the global distribution of freshwater resources and people.

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NEWS

Drought Research and Monitoring Program Is Focus of Congressional Hearing

With more than 70% of the United States currently classified as being anywhere from abnormally dry to experiencing exceptional drought—according to the U.S. Drought Monitor, a consensus product of U.S. federal and academic scientists—witnesses at a 25 July U.S. House of Representatives committee hearing expressed concern about the impact of the drought and voiced strong support for reauthorizing the National Integrated Drought Information System (NIDIS).

Republican and Democratic members of the House Science, Space, and Technology Committee also expressed their support for NIDIS, which is part of the National Oceanic and Atmospheric Administration's (NOAA) Climate Program Office and is currently authorized through 2012. However, members of Congress expressed differing perspectives about the potential relationship between climate change and extreme events such as drought.

NIDIS is authorized to provide an effective drought early warning system, coordinate and integrate federal research in support of an early warning system, and build on existing forecasting and assessment programs and partnerships. The currently proposed reauthorization language would largely support the continuation of NIDIS while also requiring the undersecretary of the U.S. Department of Commerce to provide Congress with a report analyzing NIDIS implementation among other measures.

Committee Chair Ralph Hall (R-Tex.) noted that droughts have been frequent and recurring events in the United States and that the current drought is negatively affecting important crops. "There are some, of course, who would attribute this year's drought to climate change," Hall said. "However, the Congressional Research Service tell[s] us that 'drought has afflicted portions of North America for thousands of years' and 'history suggests that severe and extended droughts are inevitable and part of natural climate cycles.' In any event, debating the causes of drought is not in front of us today," he said. "The real question is, What can be done to provide better and timelier information to help enable federal, state, and local governments and individual citizens to better deal with droughts' impacts and how to afford better forecasting and quicker reactions by government entities?"

In contrast, ranking committee member Eddie Bernice Johnson (D-Tex.) noted that "we cannot have a comprehensive approach to drought research and mitigation without exploring the potential linkages with a changing global climate. While I will be the first to urge caution [about] jumping to conclusions about the present-day impacts of a warming planet, I know that climatologists around the world are coming to a much better understanding of this complex relationship.

"We should leave the science to the scientists," she said. "To play politics and categorically deny the linkage between climate change and extreme weather is both irrational and irresponsible. Policy makers at every level have a duty to protect public welfare. And ignoring the realities of climate change simply leaves us less informed and ill prepared for catastrophic events such as droughts and floods."

Johnson added that she is "a bit baffled" by the bipartisan support for NIDIS and said that Republicans "have otherwise been relentless [during] this Congress in trying to undermine or outright kill every other climate-related product, service, or research program."

NIDIS program director Roger Pulwarty testified that NOAA supports several NIDIS initiatives, including providing grants to assess drought impacts on agriculture, ecosystems, and water resources; conducting research to improve predictions and links between climate forecasts and streamflow projections for particular basins; and maintaining the U.S. Drought Portal and the Regional Drought Early Warning Information Systems.

Pulwarty pointed to a number of ways that reauthorization could help NIDIS, including improving the understanding and predictability of droughts across many time scales and improving the collaboration among scientists and managers to increase awareness and effectiveness of observational networks, monitoring, and prediction.

In testimony before the committee, James Famiglietti, director of the Center for Hydrologic Modeling at the University of California, Irvine, called drought "an insidious and patient killer of food and fuel crops, of livestock, of other flora and fauna, and of humans." He said that current investments in drought forecasting, monitoring, and planning tools are far too small to help make progress toward mitigating drought impacts. Famiglietti said the $13.5 million authorization included in the draft reauthorization legislation would be sufficient if NIDIS were to play only a coordinating role in dealing with drought. However, he said that "a factor of 10 increase will be required" to make significant advances in more realistic hydrological simulation modeling, fill in fundamental knowledge gaps of Earth's water environment at the surface and shallow subsurface, and meet other critical needs. "Water is on a trajectory to rival energy in its importance, yet the investment in observations, models, and exploration of the subsurface pales in comparison," he noted.

Also supporting reauthorization was Patricia Langenfelder, president of the Maryland Farm Bureau. She said that NIDIS has become "an invaluable tool" within the agricultural community and that the data about rainfall, soil moisture, and other indicators "provide a comprehensive view of drought conditions as they develop, allowing those affected—including farmers and ranchers—to more adequately plan for and respond to a drought's impacts."

J. D. Strong, executive director of the Oklahoma Water Resources Board, testified that while long-term predictions of climate and its variability over decades would be great, "as a practical matter, what we are more interested in at this moment is can we get to a year forecast of drought that will be something we can take to the bank?"

He added that the nation's cyclical way of dealing with droughts needs to change. "Our society often falls into what we call the 'hydro-illogical cycle,'" Strong said. "That is, we ignore drought until the situation is dire, lament the impacts, justifiably call for help, and clamor for emergency funding. But invariably it rains, at which point we forget there was ever a problem and go back to business as usual. We must break this cycle."

—Randy Showstack, Staff Writer

G E O P H Y S I C I S T S

Cornelius Schiller (1961–2012)

Cornelius Schiller, an international leader in high-altitude water vapor measurements and quality assessment who took charge of several research campaigns and mentored many young scientists, passed away on 3 March 2012 in Neuss, Germany, after a battle with cancer. He was 50 years old.

Cornelius spent his childhood and most of his life in the Niederrhein region of Germany, close to Düsseldorf. He studied physics at the University of Bonn, and his developing interest in the physics and chemistry of the atmosphere led him to work with Dieter Ehhalt at the Forschungszentrum Jülich (Research Centre Jülich) in Germany. Cornelius' career started shortly after the discovery of the ozone hole, and he had the opportunity to participate in the first large-scale ozone measurement campaign in the Arctic, known as the Airborne Arctic Stratospheric Expedition, during January and February 1989; he contributed airborne observations of ozone-depleting chlorine and bromine substances.

Throughout most of his career, Cornelius's scientific interests focused on making and analyzing highly precise water vapor measurements in the upper troposphere and stratosphere (UT/S). In the mid 1990s, he established the water vapor group in the stratospheric research program at the Jülich research center. He led this group for the past 20 years.

Cornelius developed the Fast In situ Stratospheric Hygrometer (FISH), which has served as a reference for UT/S water measurements on balloons and aircraft worldwide for more than a decade now. A hygrometer (from the ancient Greek words *hygrós* (humid) and *métron* (measure)) is an instrument that determines the humidity of air. FISH uses the Lyman-α photofragment fluorescence technique to measure water vapor, and unlike standard operational hygrometers, it is accurate at the very low concentrations present in UT/S. With the development of FISH, Cornelius started a new era in measuring water vapor in the upper troposphere and lower stratosphere. Taking quality water vapor measurements under the conditions in this altitude region of the atmosphere is exceedingly difficult, but Cornelius and his Jülich colleagues succeeded in pushing the boundaries of science and technology by taking measurements with FISH on multiple platforms and at various latitudes from the deep tropics to the high Arctic. Thanks to Cornelius's sense that assessing the absolute accuracy of measurements at UT/S water is extremely important, FISH has been at the forefront of international efforts to study UT/S water vapor.

Cornelius served as lead author and coinitiator of Stratospheric Processes and Their Role in Climate assessments of stratospheric water vapor. He also played important roles in large-scale European and U.S. projects related to the stratosphere and its interaction with climate (e.g., Stratosphere Troposphere Experiment by Aircraft Measurements; the Third European Stratospheric Experiment on Ozone; the European Polar Stratospheric Cloud and Lee Wave Experiment; the Tropical Convection, Cirrus, and Nitrogen Oxides Experiment; Stratospheric-Climate Links with Emphasis on the Upper Troposphere and Lower Stratosphere (SCOUT-O3); African Monsoon Multidisciplinary Analyses-SCOUT-O3; and NASA's Mid-latitude Airborne Cirrus Properties Experiment (MACPEX)).

One of Cornelius's major achievements was his contribution in establishing the Russian-owned high-altitude research airplane Geophysica as part of the European research infrastructure. In 2005, within the SCOUT-O3 project, he managed the extraordinary task of facilitating Geophysica's flight to Australia; with landings in India, Indonesia, and Thailand and with diplomatic permissions to take measurements along the entire route. Because of his dedication to Geophysica, this unique research platform is expected to remain available to the European research community for the foreseeable future.

Up until his untimely death, Cornelius continued to work in his signature disciplined, well-organized manner. In spring 2011, while undergoing chemotherapy treatment, Cornelius participated in the MACPEX airborne field campaign in Houston, Tex., to investigate cirrus cloud properties and processes that affect radiation. He managed to do what not many non-U.S. scientists had done: flew "his" instrument, the FISH, on a NASA high-altitude WB-57 aircraft to contribute to the comparison of a number of U.S. hygrometers. While in cancer treatment, Cornelius also finished the thesis for his habilitation, the highest academic qualification a scholar can achieve at a German university, and played a central role in coordinating a new research proposal involving a Geophysica campaign.

Cornelius was not only an excellent, focused, and hard-working scientist but also a friendly, modest, and encouraging person of integrity who was highly respected among his peers. He was also an important mentor for the next generation of young scientists. The motivation for his work was always clear: He strived for scientific truth and obtaining a better understanding of Earth's atmosphere and climate. He was inspired by the need for environmental protection and the quest to safeguard the Earth for future generations.

He also had a delightful sense of humor and a strong loyalty to his home region, where he spent most of his life. He enjoyed attending the famous carnival in Düsseldorf, supported local traditions as a member of a

Cornelius Schiller

Schützenverein (marksmen club) in Neuss, and was an enthusiastic supporter of the Fortuna Düsseldorf football team. He was active in his church and served as the head of his local parish council. Above all, Cornelius was devoted to his family, including his wife, Barbara, and his children, Katharina, Andreas, and Christoph.

Cornelius left us behind all too early. He had many plans and was still actively working on his initiative for improved water vapor measurements. We will not forget him and will continue to work in his spirit on the questions that he raised about the processes controlling water vapor in UT/S and their impact on the Earth's climate.

—KAREN ROSENLOF, Earth System Research Laboratory, National Oceanic and Atmospheric Administration, Boulder, Colo.; and ROLF MÜLLER, Forschungszentrum Jülich, Institute of Energy and Climate Research, Jülich, Germany; E-mail: ro.mueller@fz-juelich.de

FORUM

Is Pretenure Interdisciplinary Research a Career Risk?

Despite initiatives to promote interdisciplinary research, early-career academics continue to perceive professional risks to working at the interface between traditional disciplines. Unexpectedly, the inherent practical challenges of interdisciplinary scholarship, such as new methodologies and lexicons, are not the chief source of the perceived risk. The perception of risk is pervasive across disciplines, and it persists despite efforts to support career development for individuals with common interests [*Mitchell and Weiler*, 2011]. Suggestions that interdisciplinary work can go unrewarded in academia [*Clark et al.*, 2011] foster a concern that targeting interdisciplinary questions, such as those presented by climate change, will pose problems for acquiring and succeeding in a tenure-track position. If self-preservation limits the questions posed by early-career academics, a perceived career risk is as damaging as a real one to new transdisciplinary initiatives. Thus, institutions should address the source of this perception whether real or specious.

The challenges and benefits of early-career interdisciplinarity emerged at the recent Dissertations Initiative for the Advancement of Climate Change Research (DISCCRS, http://disccrs.org) Symposium. Despite new ideas for collaborative work, numerous discussions fixated on perceived hurdles. Here we maintain that early-career interdisciplinary researchers can boost personal success, and we also discuss how funding and incentive structures could be amended.

Personal Success

Early-career incentives can create pressure to establish a disciplinary academic identity and postpone interdisciplinary projects. New entrants may see a competitive job market where specialization is rewarded, and those already in tenure-track positions may question whether working across departments could leave them homeless. However, another way to establish identity is to create and pursue common research threads, for example, a regional focus or pioneering analytical approach. Well-framed research statements are critical to creating a recognizable specialty even in an interdisciplinary context. Moreover, effectively advocating for a particular interdisciplinary research pathway may prove a mark of excellent work. Bolstered by strong communication, innovative approaches are more likely to be recognized as such.

Mentorship forms a vital part of academic success, particularly for early-career scholars seeking to establish their identity. Yet graduate students are more likely than faculty to have participated in an interdisciplinary venture [*Rhoten and Parker*, 2004], so there are fewer advanced researchers to serve as role models. Interdisciplinary scholars may benefit from multiple mentors in different disciplines because involvement with several research groups can familiarize scholars with "the culture, language, technology, and literature of two scientific disciplines" [*Sung et al.*, 2003]. Early-career researchers should also consider nontraditional mentors and networking at problem-focused symposia [*Mitchell and Weiler*, 2011; *Weiler*, 2007].

Interdisciplinary collaboration can be daunting because of conflicting disciplinary norms, but there are ways to establish effective teams. Groups can dedicate time at project inception to develop methodologies, scope, authorship expectations, and a common language. Those interested in fostering collaboration while developing their own specialty can generate knowledge that is clearly transferable to other disciplines. This will involve framing information without jargon, a valuable skill in any research track [*Dilling and Lemos*, 2011].

Structural Issues

Funding remains a significant perceived barrier to interdisciplinary research, as most grants and fellowships are earmarked for specific disciplines. Broader methodologies can make interdisciplinary proposals more difficult to evaluate, and multiple investigators give the work a higher price. The discipline-grounded peer review process is also often cited as an obstacle to interdisciplinary work [*Newell et al.*, 2005], promoting the idea that eventual publications could prove problematic.

Should these issues still dissuade early-career investigators, or are these problems on track to be resolved? Two new U.S. National Science Foundation (NSF) initiatives, for example, focus on interdisciplinary projects: Science, Engineering and Education for Sustainability [*Kileen et al.*, 2012] and Creative Research Awards for Transformative Interdisciplinary Ventures. Proposals to these programs will be explicitly evaluated on the basis of interdisciplinary approaches to global questions, helping to alleviate competition with disciplinary projects. Nevertheless, there is a sense that these initiatives are designed to support large projects and early-career investigators will not be competitive. Early-career investigators also have to trust these new programs to continue to support their established research paths. Parallel programs that support smaller interdisciplinary collaborations among early-career scholars would be timely. Proposals could be evaluated on potential for integration and teaching, in addition to discovery [*Boyer*, 1990]. Funding graduate students and postdoctoral researchers poses a further challenge when their work falls between departments. Many graduate fellowships that support interdisciplinary research require outside partnerships, which promotes networking but adds another requirement. Accordingly, extra constraints should be avoided when designing new funding opportunities.

Funding issues aside, institutional policies present another perceived challenge to interdisciplinary research [*Paytan and Zoback*, 2007]. Most institutions appear to remain structured around long-standing disciplinary divisions [*Fox et al.*, 2006]. Departments and programs

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usually have established expectations for success, including publications in particular venues. However, interdisciplinary success may be defined in different ways [*Pohl*, 2011]. It can be appropriate for scholars to follow different timelines, publish in different journals, or generate different products, such as policy reports or decision support tools. The lack of precedent for evaluating nontraditional accomplishments can leave early-career scholars doubting whether interdisciplinary research is the best path to academic success [*Schmidt and Moyer*, 2008].

A growing number of university research institutes have begun integrating sciences and humanities in areas such as climate change. As with other new disciplines, their arrival on campus often required an infusion of external money. If successful, these types of institutes could provide new research models. Meanwhile, departments that have historically used disciplinary journal publications or single-authored monographs for tenure review should recognize an apparent risk associated with interdisciplinary work. The potential for tenure committees to undervalue shared students and large multiauthored projects may be enough to discourage early-career faculty from following their curiosity. Given these concerns, department chairs could pay particular attention when selecting letter writers and comparing tenure candidates. Establishing guidelines in this process in collaboration with new faculty ought to be prioritized.

Early-career scholars and seasoned practitioners alike perceive barriers to interdisciplinary research (S. Pfirman and M. Begg, Perspective: Troubled by interdisciplinarity?, 2012, http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2012_04_06/caredit.a1200040). To overcome them, institutions can design more comprehensive metrics for evaluation and combat any perceptions that interdisciplinary work is only a sideline to a traditional academic career. Given the exciting questions posed by interdisciplinary researchers, these efforts would be worthwhile.

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MEETING

Bridging the Gap Between Modelers and Experimentalists

Second International Enzymes in the Environment Research Coordination Network Workshop: Incorporating Enzymes and Microbial Physiology Into Biogeochemical Models; Colorado State University, Fort Collins, Colorado, 15–18 May 2012

Recent studies have provided new insights into the factors controlling the production and activities of extracellular enzymes, the proximate agents of organic matter decomposition. Enzymes and other aspects of microbial physiology have been incorporated into simple models but have not yet been explicitly incorporated into biogeochemical models capable of predicting fluxes of carbon and nutrients. One reason for this is that empirical data collected at one or few locations and time points do not meet the needs of modelers attempting to integrate across spatial and temporal scales. Furthermore, there is a disconnect between the types of data measured in observational and experimental studies and the data needed to parameterize biogeochemical models. For example, the most common approach is to measure maximum potential enzyme activities in laboratory assays, whereas models require measurements of enzyme kinetics when substrate is limiting.

Biogeochemists often conclude that because they have shown that a parameter they measured is strongly correlated to a biogeochemical pool and/or flux, it should therefore be incorporated into biogeochemical models. On the other hand, modelers strive to explain rates and fluxes with the simplest possible models because adding complexity to models incurs tradeoffs, including increased computational effort and the requirement of additional data parameterization.

In an attempt to bridge the gap between modelers and experimentalists, the meeting Incorporating Enzymes and Microbial Physiology Into Biogeochemical Models was organized as an activity of the U.S. National Science Foundation–funded Enzymes in the Environment Research Coordination Network. The meeting included 37 international participants who work in terrestrial, aquatic, and marine ecosystems. The program consisted of talks from both modelers and experimentalists and breakout working group discussions. Discussion groups were facilitated using the "World Café" format to harvest the collective experience and expertise of participants on specific issues including priming, effects of exogenous nitrogen, scaling, trade-offs, and defining data needs. The following insights emerged from the workshop:

The incorporation of enzymes into models requires information on enzyme production and turnover, enzyme kinetics, diffusion and convection, and interactions with soil and sediment matrices. Model development should occur in tandem with experimental design and data acquisition.

Enzymes and microbial physiology could be integrated into global-scale models through a hierarchical approach. In this approach, the output of finer-scale models is used to parameterize larger-scale models that contain fewer parameters and interactions.

Enzyme-explicit models may be able to predict processes and fluxes that are beyond the scope of current biogeochemical models. For example, the chemistry of dissolved organic matter could be predicted by models that include specific enzymes acting on specific substrates. Detailed information on the products of microbial decomposition could improve scientists' ability to predict long-term carbon sequestration in soils and sediments.

The workshop agenda and more details can be found at http://enzymes.nrel.colostate.edu. A special issue is planned for the journal *Biogeochemistry* to disseminate emergent perspectives, empirical results, and modeling efforts that were presented at the workshop, with the aim of demonstrating the benefits of collaborations between experimental scientists and modelers working in this field.

—Matthew Wallenstein, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins; E-mail: matthew.wallenstein@colostate.edu; Mary Stromberger, Department of Soil and Crop Sciences, Colorado State University, Fort Collins; and Colin Bell, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins

GEOPHYSICAL YEAR MEETINGS CALENDAR

This column announces upcoming meetings and symposia of interest to Earth and space scientists. To submit an announcement for the Geophysical Year Meetings Calendar, go to http://www.agu.org/cgi-bin/geosoc/cal-submit?cal=gycal. There is no fee for these brief listings.

■ 27–31 August 2012 **GEOCEAN: Geodynamic Processes and Biochemical Interactions at Seafloor Spreading Ridges**, Brest, France. Sponsors: Laboratory of Excellence Mer; University of Brest; Centre National de la Recherche Scientifique; Ifremer; Région Bretagne; Conseil Général Finistére; Brest Métropole Océane. (Royer Jean-Yves, Institute for Marine Studies at the University of Brest, rue Dumont d'Urville, Plouzane F-29280, France; Tel.: +33 298 49 87 67; E-mail: geocean@sciencesconf.org; Web site: http://geocean.sciencesconf.org)

■ 3–7 September 2012 **Ninth International Symposium on Tropospheric Profiling**, L'Aquila, Italy. Sponsors: Center of Excellence for the Forecast of Severe Events; University of L'Aquila. (Nico Cimini; E-mail: istp9@aquila.infn.it; Web site: http://cetemps.aquila.infn.it/istp/)

■ 9–14 September 2012 **11th International NCCR Climate Summer School**, Ticino, Switzerland. Sponsors: Swiss National Science Foundation; University of Bern; ETH Zurich; others. (Lorenz Martin, National Centres of Competence in Research (NCCR) Climate Management Centre, University of Bern, Bern, Switzerland; E-mail: nccr-climate@oeschger.unibe.ch; Web site: http://www.nccr-climate.unibe.ch/summer_school/2012/)

■ 18–19 September 2012 **Models of Spectral Irradiance Variability: Origins in the Solar Atmosphere and Impacts on Earth's Atmosphere**, Annapolis, Maryland, USA. Sponsor: Solar Radiation and Climate Experiment. (Vanessa George; E-mail: vanessa.george@lasp.colorado.edu; Web site: http://lasp.colorado.edu/sorce/news/2012ScienceMeeting/)

■ 19–21 September 2012 **KSEG International Symposium on Geophysics for Discovery and Exploration**, Jeju, South Korea. Sponsor: Korean Society of Earth and Exploration Geophysicists (KSEG). (Mutaek Lim, 124 Gwahang-no, Yuseong-gu, Daejeon 151-747, South Korea; Tel.: +82-42-868-3157; Fax: +82-42-868-3418; E-mail: limmt@kigam.re.kr; Web site: http://2012symp.seg.or.kr)

■ 20–23 September 2012 **First Annual World Congress of Ocean-2012**, Dalian, China. Sponsors: China State Administration of Foreign Experts Affairs; Chinese Ship-Owner Association; China Fisheries Association; China Association of the National Shipbuilding; Chinese Fishing Association; China Council for the Promotion of International Trade Dalian Sub-Council; others. (Gloria Su, Organizing Commission of WCO-2012, East Area, F11, Building 1, Dalian Ascendas IT Park, 1 Hui Xian Yuan, Dalian Hi-tech Industrial Zone, Dalian 116025, China; Tel: 0086-411-84799609-804; Email: gloria@bitcongress.com; Web site: http://www.bitconferences.com/WCO2012/default.asp)

■ 17–19 October 2012 **Particles in Europe Conference**, Barcelona, Spain. Sponsors: Sequoia Scientific, Inc.; Institut de Ciencies del Mar; EMS Sistemas de Monitorizacion Medio Ambiental, S.L. (Ole Mikkelsen, 2700 Richards Rd., Bellevue, WA 98005, USA; Tel.: +1-425-641-0944; Fax: +1-425-643-0595; E-mail: ole.mikkelsen@sequoiasci.com; Web site: http://www.sequoiasci.com/research/pie2012.cmsx) Abstract deadline is 7 September 2012.

■ 28–30 October 2012 **84th Annual Meeting of the Eastern Section of the Seismological Society of America**, Blacksburg, Virginia, USA. Sponsor: Eastern Section Seismological Society of America. (Katie Kadas, 400 Evelyn Ave., Ste. 201, Albany, CA 94706, USA; Tel.: +1-510-559-1783; E-mail: katie@seismosoc.org; Web site: http://www.geol.vt.edu/outreach/vtso/esssa2012/)

■ 12–16 November 2012 **AGU Chapman Conference on Longitude and Hemispheric Dependence of Space Weathe**r, Addis Ababa, Ethiopia. Sponsor: AGU. (AGU Meetings Department, 2000 Florida Ave. NW, Washington, DC 20009, USA; Tel.: +1-202-462-6900; Fax: +1-202-328-0566; E-mail: chapman-spaceweather@agu.org; Web site: http://www.agu.org/meetings/chapman/2012/fcall/index.php)

■ 19–23 November 2012 **Cities on Volcanoes 7**, Colima, Mexico. Sponsors: Universidad de Colima; International Association of Volcanology and Chemistry of the Earth's Interior; Universidad Nacional Autónoma de Mexico. (Nick Varley, Colima, Mexico; Tel.: +52-312-3161134; E-mail: cov7@citiesonvolcanoes7.com; Web site: http://www.citiesonvolcanoes7.com) Abstract deadline is 28 August 2012.

AGU BOOKSHELF

Abrupt Climate Change: Mechanisms, Patterns, and Impacts

In the span of only a few decades, the global temperature can soar by more than a dozen degrees Celsius, a feat that 20 years ago was considered improbable, if not impossible. But recent research in the nascent field of rapid climate change has upended the dominant views of decades past. Focusing primarily on events during and after the most recent glaciation, from 80,000 years ago, the AGU monograph Abrupt Climate Change: Mechanisms, Patterns, and Impacts, edited by Harunur Rashid, Leonid Polyak, and Ellen Mosley-Thompson, explores the transient climate transitions that were only recently uncovered in climate proxies around the world. In this interview, Eos talks to Harunur Rashid about piecing together ancient climes, the effect of abrupt change on historical civilizations, and why younger researchers may be more worried about modern warming than their teachers.

Eos: *The concept of abrupt climate change did not really exist prior to the early 1990s. What was the dominant view before this time, and what made researchers change their minds?*

Rashid: The defining moment for abrupt climate change research came in 1993 when Willi Dansgaard and his colleagues published oxygen isotope records for Greenland ice core samples that showed the air temperature swinging back and forth, meaning warming and cooling, over periods as short as a thousand years. Those temperature swings are now famously known as Dansgaard-Oeschger (D-O) oscillations, and though they were first discovered in Greenland ice cores, they were later observed in North Atlantic marine sediment samples. In subsequent studies, these abrupt climate events were found any place on Earth that was studied sufficiently, including Antarctica, the Pacific Ocean, the Atlantic Ocean, the Indian Ocean, and even on land if you look at the climate record as captured in cave mineral deposits.

Prior to this, the main argument in paleoclimate or paleoceanographic research was that the climate is governed by Milankovitch forcings—cycles related to the position and angular orientations of the Sun and the Earth—that cause the climate to change in 100,000-year, 41,000-year, and 21,000-year cycles. These cycles are driven by the eccentricity or procession of Earth's orbit, and the planet's obliquity, or axial tilt. At that time, these were considered abrupt climate change, but we now know that is not accurate. Before the advent of the Greenland ice core isotope record the idea of abrupt climate change, meaning a shift from warm to cold in a couple of decades, did not exist. Even though some modelers may have thought so, there was no data documenting it.

Eos: *What is the primary mechanism of abrupt climate change?*

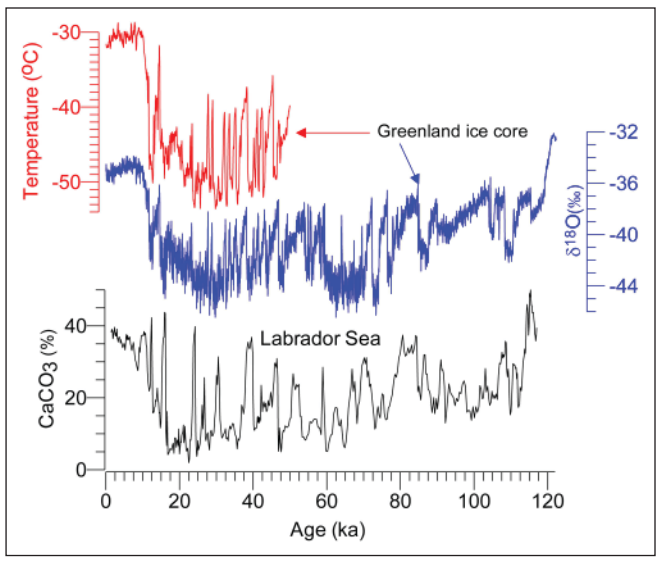
Rashid: If you polled climatologists, probably 99% of them would agree that the interaction between freshwater in the North Atlantic and the Atlantic Meridional Overturning Circulation (AMOC) is the biggest driver of abrupt climate change. So the idea is that, in the past, there was a big ice sheet sitting on North America that would shed icebergs. These icebergs would float along the surface of the North Atlantic where they would eventually melt, forming a freshwater cap on the ocean's surface. As a result, the formation of North Atlantic deep water would slow down, and the AMOC would weaken. This weakening reduces the amount of heat and moisture exchange into the atmosphere, and as a result, the entire North Atlantic would start to cool. That cooling at first propagated to northwestern Europe, then all the way to Eurasia, and would be associated with an increase in sea ice. In the Southern Hemisphere, however, there would be a reverse effect. Because the AMOC is no longer transporting as much heat into the Northern Hemisphere, it would accumulate in the south. The temperature would go up, and the extent of sea ice around Antarctica would decrease. Alongside these thermal changes, there would be an effect on the hydrological cycle in the tropics. From paleogeochemical proxies, we can prove that the AMOC was significantly weakened during Heinrich Event 1—a period of sudden global climate change that persisted for less than 1000 years—but this is something we cannot clearly demonstrate for D-O events.

Eos: *If the Atlantic Meridional Overturning Circulation were to weaken or collapse because of modern climate change, as some scientists have predicted, what would be the result?*

Rashid: I think it is important to keep in mind that the geographic configuration was very different during the immediate past glacial-interglacial cycle than it is now. If we think about the Younger Dryas or Heinrich events, the amount of freshwater available to perturb the AMOC was much larger than it is now. However, we still have a huge ice sheet on Greenland. And, if we continue to increase the atmospheric carbon dioxide concentration, then more Arctic sea ice will melt. Add to this the freshwater runoff from the repeatedly freezing and thawing northern continents, such as Siberia or northern Canada, and there will be the potential to add enough freshwater to the North Atlantic to perturb the AMOC. So, the question is, how different will the AMOC weakening be for the future climate as compared to past climates? Based on modeling work we do anticipate that if we add freshwater to the North Atlantic there will be cooling in the Northern Hemisphere. If the AMOC somehow weakens, even by as little as 20% or 30%, there will be a significant amount of cooling downwind, meaning England, Iceland, Norway, and the rest of western Europe. But the impact is not going to be restricted to these places. It will also affect the large populations in China and India, by reducing or modifying the monsoon, and it will also affect the United States' eastern seaboard.

Eos: *What is your area of research? How do you go about piecing together a coherent picture of an ancient climate?*

Rashid: My expertise is in paleoceanography, and in my research I use isotope geochemistry and interpret the concentrations of minor and trace elements. At present, most of my work is in biogenic carbonates, studying the chemistry of organisms that lived at the surface or grew at the bottom of the ocean. By measuring isotope ratios and the concentrations of minor and trace elements trapped in the calcite shells of ancient single-celled organisms, I can reconstruct past temperatures, past ocean circulations, and past hydrological cycles.



Combining the observed variations of a few important climate proxies representing the past 120,000 years, and the induced shifts in temperature for the more recent time interval, demonstrates the scale, and potentially swift rate, of climate variability. Greenland air temperature fluctuations (red), the ratio of oxygen isotopes (Oxygen-18/Oxygen-16 = $\delta^{18}O$) in Greenland ice cores (blue), and the percentage of bulk sediment carbonate ($CaCO_3$) measured from the seafloor sediments of the Labrador Sea (black). Courtesy of Harunur Rashid.

As an example, in the book I have a chapter related to the Younger Dryas, a period of sudden cooling that started roughly 12,900 years ago and interrupted the gradual warming of deglaciation. During this time there was freshwater sitting on North America in two proglacial lakes: Lake Agassiz and Lake Ojibway. This freshwater somehow got into the North Atlantic, leading to a 1200-year-long or 1300-year-long cooling period in the Northern Hemisphere. The Younger Dryas, however, is a "Big Foot" story. Big Foot, the quintessential American fairy tale, is blurry. That's the problem. The Younger Dryas is one of the most highly contested issues in the past 50 years of climate change research. There are people who have made their reputations working on the Younger Dryas. Yet, no one has been able to find the signature of this freshwater flux in the North Atlantic. No one. If you look at the Greenland ice core record, or the Asian monsoon record, or the cave deposit record, you can clearly see the Younger Dryas. But in the North Atlantic, where everyone says that meltwater came and weakened the AMOC, no one has been able to find any sign of that freshwater. So, in the book, I took a stab at this issue; I provided an alternative explanation as to why you should not be expecting a meltwater or freshwater signature in the North Atlantic.

Briefly, my idea is that during the Younger Dryas, freshwater admixed with fine-grained sediments were discharged underneath the Laurentide ice sheet through the Hudson Strait ice stream, like a river with fine-grained sediments. Since this freshwater runoff could not float freely on the top of the ocean due to its higher density, these waters would sink close to the bottom of the ocean. Over time, the suspended sediment would slowly rain down, and the meltwater would rise back toward the surface. But, by the time this meltwater made its way back up to the surface it would have lost its original isotopic signature. This is why you do not see, and should not expect to see, a meltwater signature associated with the Younger Dryas in the North Atlantic. This is what we documented in our sediment cores from in and around the

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What's on the Web?

Read the latest offerings from the AGU Blogosphere:

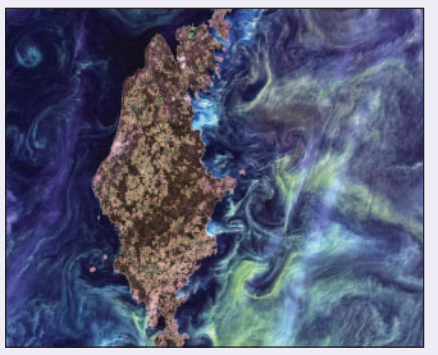
Dan's Wild Wild Science Journal: "Greenland melt was predicted in advance by paper awaiting publication" (http://bit.ly/PMC1jp)

Georneys: "Monday geology picture(s): A lava road closure on Hawai'i" (http://bit.ly/LYRvjN)

The Landslide Blog: "A landslide is rapidly destroying a World Heritage site in India" (http://bit.ly/NQQtF6)

The Martian Chronicles: "Blogging MSL" (http://bit.ly/T0W1yG)

The Plainspoken Scientist: "AGU video: Impartial observers in space: Four decades of Landsat images both delight and inform" (http://bit.ly/OD483J)



USGS/NASA

This Landsat image shows phytoplankton swirling in the waters around Gotland island in the Baltic Sea. The Plainspoken Scientist reports on Landsat's fortieth anniversary.

AGU Bookshelf

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Hudson Strait region, a 1-meter thick Younger Dryas sediment unit with a negligible freshwater isotopic signature.

Eos: *The book discusses in some detail the effects of abrupt climate change on long gone civilizations. How do some scientists think an early society living along the tributaries of the Indus River in India met its end?*

Rashid: In the monograph, B. S. Paliwal discussed the fate of the Vedic civilizations that flourished along the banks of the Sarasvati and Drishadvati rivers more than 12,800 years ago. He discussed how tectonic activity at the time could have negatively affected the strength of the rivers, which led to the formation of saline lakes. As a result, this disorganized drainage system ushered in the appearance of lakes, reversed the rivers' courses, and blocked water flow. It is now accepted that the Indian summer monsoon, commonly known as the southwest monsoon, was strong and wet during the early Holocene (11,000–6000 years ago) and that may have resulted in frequent flooding. As Paliwal suggests, this flooding might have caused the end of the Vedic civilization, though we have very little evidence to verify or confirm this hypothesis at present.

Eos: *How has the relatively recent boom in the understanding of abrupt climate change affected scientists' perceptions of the risks and consequences of modern anthropogenic climate change?*

Rashid: I think it has significantly changed the way that a majority of climate scientists think. If you look at my mentors, who are in their 60s or 70s, and you look at the papers they have written in their early years, they tend to focus on solar insolation, astronomical theory, and Milankovich cycles. So, compared to them, we are basically a completely different crop of scientists; my professors were worried about centuries, we are worried about decades. The understanding of the potential for abrupt climate change has led to two different urgencies and two different sets of worries, which I think comes across in the book. Unfortunately, some of these adverse changes might be seen in our lifetimes. That is probably one of the things that really got us up on our feet and working as feverishly as possible to convince the wider society about the importance of climate change.

Eos: *What is the future of abrupt climate change research?*

Rashid: At present, we are really only able to prove that the AMOC weakened or slowed down for two events: the Younger Dryas and Heinrich Event 1, which took place from 11,700 to 12,900 and 15,000 to 16,400 years ago, respectively. But there are other climate transitions for which we need a better understanding, such as Glacial Termination II, which took place 141,000 years ago. In other cases, such as 60,000 or 125,000 years ago, we have no clue what the climate looked like during those times. So, we've just scratched the surface.

This really is the cutting-edge research in climate science. Abrupt climate change research is the brand new science in the Earth sciences, and I see the field getting stronger and attracting many bright students. I think the field will be going strong for at least the next 20 years.

Geophysical Monograph Series, Volume 193, 2011, 242 pp., ISBN 978-0-87590-484-9, AGU Code GM1934849. List Price $120.00, AGU Member Price $85.

—COLIN SCHULTZ, Writer

CLASSIFIED

POSITIONS AVAILABLE

Atmospheric Sciences

Postdoctoral Position in Atmospheric Chemistry/University of British Columbia.

A postdoctoral research position is available in Professor Allan Bertram's research group at the University of British Columbia to study either ice nucleation properties of atmospheric aerosols or hygroscopic properties of atmospheric aerosols. Both projects will include laboratory and field measurements and instrumentation development. Details about the position can be found at http://www.chem.ubc.ca/about/positions-available. Information about the Bertram research group and the Chemistry Department at the University of British Columbia can be found at www.chem.ubc.ca. Applicants should have a CV and two letters of reference sent to Allan Bertram (Bertram@chem.ubc.ca), University of British Columbia, Department of Chemistry, 2036 Main Mall, Vancouver, British Columbia, Canada, V6T 1Z1.

The Princeton Environmental Institute and the Carbon Mitigation Initiative, Princeton University, along with the NOAA Geophysical Fluid Dynamics Laboratory (GFDL) seek postdoctoral researchers to pursue projects aimed to improve understanding of historical and future climate variability and implications of changes in climate variability for hydrological and carbon cycling in different regions of the World. Candidates must have a Ph.D. in a relevant discipline; candidates with strong computational and statistical skills with previous experience in use/analysis of climate models, earth system modeling, decadal prediction, or detection & attribution of climate change are especially encouraged to apply. These appointments are for one year, with the possibility for renewal pending satisfactory performance. Interested applicants should submit a current CV and a cover letter describing specific areas of expertise and interest to jobs@princeton.edu, position requisition number 1200443. Princeton University is an equal opportunity employer and complies with applicable EEO and affirmative action regulations.

Biogeosciences

Tenure Track Faculty Position in Marine Microbial Ecology Old Dominion University.

The Department of Ocean, Earth and Atmospheric Sciences (OEAS) at Old Dominion University seeks to fill a tenure-track faculty position at the level of Assistant or Associate Professor in marine microbial ecology. We seek candidates with strong potential for outstanding accomplishments in research and teaching and excellent communications skills. Demonstrated skills in the use of developing technologies, next generation sequencing, genomics and proteomics, and biochemical or molecular-biology approaches are particularly desirable. In addition to excellence in scholarly research, the successful applicant will be expected to contribute to the department's overall curriculum through formal courses at the undergraduate and graduate levels and to supervise Ph.D. and M.S. graduate students. Many opportunities exist for disciplinary and interdisciplinary interactions with more than 25 other faculty in OEAS, its Centers for Coastal Physical Oceanography and Quantitative Fisheries Ecology and other departments within the university, particularly in areas of marine productivity, food web dynamics, and biogeochemical cycling. Information about the department and its facilities can be found at: http://sci.odu.edu/oceanography/. Research funding by OEAS faculty totaled over $6.2 M in FY11. An endowment of approximately $16 million provides additional support for programs within the Department.

Minimum requirements for appointment include a Ph.D. degree in oceanography or a related science with postdoctoral experience preferred. Appointment to the level of Associate Professor will be considered for applicants possessing an exceptional track record of scholarly independence, extramural funding, and appropriate productivity. Review of applications will begin September 1st, 2012 and continue until the position is filled. The appointment will be available as soon as July 25, 2013. Applications, including a cover letter, CV, teaching (1 page) and research statements (1 page), and contact information for three references must be submitted electronically to: oeassearch@odu.edu

Old Dominion University is an equal opportunity, affirmative action institution and requires compliance with the Immigration Reform and Control Act of 1986.

Hydrology

Three Postdoctoral Research Positions in Environmental Hydrology and Geophysics University of Wyoming.

The newly established Wyoming Center for Environmental Hydrology and Geophysics (WyCEHG) at the University of Wyoming seeks to fill three (3) postdoctoral research positions. This cluster hire will target individuals who work at the interface between the land-surface and groundwater systems and add complementary skills in one or more targeted areas: integrated modeling; near-surface geophysics; watershed to landscape scale scale hydrological observation and analysis; paleohydrology; remote sensing; and the application of geochemical and isotopic tracers. We especially are interested in candidates who will develop approaches for scaling observations from point to basin levels and provide new insights into hydrological changes associated with landscape disturbance and (paleo) climate change. Successful candidates will become part of a large, interdisciplinary research initiative and have access to state-of-the-art instrumentation within the newly established Facility for Imaging the Near- and Sub-surface Environment (FINSE) and Surface and Subsurface Hydrology Lab (SSHL).

Minimum qualifications include 1) an earned PhD at the time of hire in hydrology, geophysics, geomorphology, geochemistry, ecology, or a closely related area; and 2) evidence of research productivity in the form of peer-reviewed journal publications. Preferred qualifications include 1) the capacity to work productively in collaborative and interdisciplinary teams; 2) the willingness and ability to communicate research findings to stake holders; and 3) novel and complementary skill sets targeted for the new Center.

Applicants are encouraged to visit the WyCEHG website (http://www.uwyo.edu/epscor/wycehg/index.html) to learn more about the Center and identify potential collaborators. To apply, send a CV, statement of research interests, and contact information of three references to Rick Matlock (rixdogs@uwyo.edu). Review of applications will begin on August 15, 2012, but applications will be accepted until all positions are filled.

The University of Wyoming is committed to diversity and endorses principles of affirmative action. We acknowledge that diversity enriches and sustains our scholarship and promotes equal access to our educational mission. We seek and welcome applications from individuals of all backgrounds, experiences, and perspectives.

Solid Earth Geophysics

Chevron Industrial Research Chair in Petroleum Reservoir Characterization.

The Department of Earth Sciences at Memorial University seeks candidates for a Chair in Petroleum Reservoir Characterization. The selected candidate will contribute, through geological and/or geophysical studies, to the use of petrophysical, seismic and geological/geochemical data to characterize reservoir properties, potential and change during production. The offshore oil and gas fields of Newfoundland and Labrador provide one of the natural laboratories for these studies and provide an opportunity to develop innovative science.

The position is open to be filled at the rank of Assistant, Associate or Full Professor. The position will continue as a tenured or tenure-track appointment when the industrial funding expires. Applicants must possess a Ph.D. and should preferably have post-doctoral experience.

The Chair is funded by Chevron Canada Limited for a period of five years, with matching funds contributed by the Research & Development Corporation of Newfoundland and Labrador. Oil and gas companies operating in offshore Newfoundland and Labrador have a significant research and development spending obligation per regulatory requirements. The successful candidate will play a key role in helping Chevron Canada satisfy this obligation. There may be opportunities to collaborate with the holder of the Chevron Chair in Petroleum Engineering.

The successful candidate shall also seek additional funding through the Natural Sciences and Engineering Research Council of Canada Industrial Research Chair program . This position could be filled at the Associate or Senior Industrial Research Chair level, depending on the experience and background of the selected candidate. A clear outline of the expectations for candidates applying to this program are given at the NSERC/CRSNG website (http://www.nserc-crsng.gc.ca/Professors-Professeurs/CFS-PCP/IRC-PCI_eng.asp)

The successful candidate is expected to maintain a vigorous research program, sustain a strong record of peer-reviewed publication and external funding, advise and mentor undergraduate and graduate students, contribute energetically to the building of a basins group in the department, and support its teaching mission, including delivery of courses in petroleum geology.

Memorial University is the largest university in Atlantic Canada. As the province's only university, Memorial plays an integral role in the educational and cultural life of Newfoundland and Labrador. Offering diverse undergraduate and graduate programs to almost 18,000 students, Memorial provides

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a distinctive and stimulating environment for learning in St. John's (http://www.stjohns.ca/index.jsp), a very safe, friendly city with great historic charm, a vibrant cultural life, and easy access to a wide range of outdoor activities. For further information about Memorial, please view the website at www.mun.ca.

Applicants should send a curriculum vita, the names of three referees and a one-page statement of teaching and research interests. Copies of three relevant technical publications may also be included. Informal enquiries and formal applications should be addressed to:

Dr. John Hanchar, Head of Department
Department of Earth Sciences
Memorial University of Newfoundland
St. John's, Newfoundland, Canada, A1B 3X5
Tel. (709-864-4850
Fax. (709) 864-4851
E-Mail: jhanchar@mun.ca
REFERENCE: VPA-EASC-2011-001

The deadline for applications is 1 October 2012. The successful candidate would be expected to start in the new role early in 2013. This position is subject to budgetary approval.

Memorial University of Newfoundland is committed to employment equity and encourages applications from qualified women and men, visible minorities, aboriginal people and persons with disabilities. All qualified applicants are encouraged to apply; however Canadians and permanent residents will be given priority. Partners of candidates for positions are invited to include their resume for possible matching with other job opportunities and candidates eligible for NSERC University Faculty Awards are encouraged to apply.

Geophysics Post-doctoral Research Associates.

The Geophysical Monitoring and Characterization Team at Los Alamos National Laboratory seeks post-doc candidates to join a diverse team of scientists addressing local- and regional-scale seismological problems.

Candidates should have a strong core background in (one or more): seismology/geophysics, infrasonics/acoustics, physics of earthquake and explosive sources, and geophysical data analysis. Ph.D. completed in the last 5 years (or soon to be completed) required. Good oral/written communication skills demonstrated by publications/presentations essential. Creative, independent research abilities required. Must have experience with programming and scripting languages (e.g. C, Fortran, Java and Python, SQL, Perl, Cshell, MATLAB). Field instrumentation and data collection experience a plus.

For further information please contact Ken Rehfeldt, krehfeld@lanl.gov or Lee Steck, lsteck@lanl.gov. Apply to job# IRC8689 at http://bit.ly/lanlpostdocgeophysics

Equal Opportunity Employer

The Department of Geology and Geophysics at the University of Wyoming invites applications for a Postdoctoral Research Associate in geophysics, to begin as early as September 2012. The successful candidate will participate in analysis of either near-surface geophysical data for Critical Zone studies, and/or marine seismic reflection and refraction data, with special emphasis on seismic oceanography.

We seek candidates with knowledge of, and research experience in, processing, modeling, and interpretation of any of the following data types: multichannel seismic reflection, seismic refraction, electrical resistivity, electromagnetic, and ground-penetrating radar. An earned Ph.D. in geophysics or a closely related field is required at the time of appointment. Applicants should possess a demonstrated record of publication in the peer-reviewed literature, a willingness to participate in field programs, both at sea and on land, and familiarity with advanced imaging techniques. The successful candidate will join a vibrant research group possessing up-to-date computational and data analysis facilities.

The term of the position is two years, with potential reappointment for a third year. Applications, including a curriculum vitae, list of publications, statement of research interests, and names, addresses, phone numbers, and e-mail addresses of three references, should be sent to Dr. W. Steven Holbrook, by email at steveh@uwyo.edu. The position number on the University of Wyoming website is #4022. Review of applications will begin on August 1, 2012, and continue until the position is filled. The University of Wyoming is committed to diversity and endorses principles of affirmative action. We acknowledge that diversity enriches and sustains our scholarship and promotes equal access to our educational mission. We seek and welcome applications from individuals of all backgrounds, experiences, and perspectives.

Interdisciplinary/Other

Assistant Staff Scientist - OSIRIS-REx Image Processing Scientist.

OSIRIS-REx is an asteroid sample return mission scheduled for launch in September, 2016. The University of Arizona team leading this historic mission seeks a full-time assistant staff/image processing scientist who will help define and create the image processing requirements and algorithms needed to achieve the mission's goals. The selected candidate will use their knowledge of image processing algorithms and tools to manage routine pipeline processing of returned images, and the creation of ad hoc imaging products. They will also support the creation of higher-level image data products to support the selection of a sampling site.

The University of Arizona is an EEO/AA employer - M/W/D/V

Duties, qualifications, and application are available at http://www.hr.arizona.edu/jobs

Job Number: 50477

Environmental Sciences Department Chair.

A Chairperson for the Environmental Sciences Department at Brookhaven National Laboratory is sought. The department has internationally competitive programs in climate, environmental science and technology with a staff of 58 and a yearly operating budget of $18M. The successful candidate will be expected to maintain their own active research program in one or more of the following areas: terrestrial ecosystem science, aerosol and cloud properties and their effects on climate, and/or climate model development particularly related to improving atmospheric and/or carbon cycle processes that are relevant to US Department of Energy missions in energy and environment. Additionally, they are expected to provide intellectual and managerial leadership for the department staff, develop a scientific vision for the department appropriate for a leading national laboratory, and build strategic partnerships that enhance the department R&D efforts. The potential for a joint appointment with Stony Brook University can be explored for interested candidates. A full description of the department, the position and its requirements, and how to apply are given at http://www.bnl.gov/envsci/chair.php. Interested candidates are encouraged to apply prior to 10 September 2012. Brookhaven National Laboratory is an equal opportunity employer committed to building and maintaining a diverse workforce.

Faculty Positions in Aqueous/Low-Temperature Geochemistry, Geochronology, and Global Climate Change.

The Department of Earth and Environmental Sciences at the University of Michigan is searching for tenure-track faculty candidates for a university-year appointment in the areas of Aqueous/Low-Temperature Geochemistry, Geochronology, and Global Climate Change, starting September 2013. Appointments at the assistant professor level are preferred, but exceptional candidates at higher levels will be considered. We encourage applications from candidates with records of research and teaching in any one of these areas:

Aqueous/Low-Temperature Geochemistry: We seek applicants who investigate the diverse geochemical processes that occur in environments at or near Earth's surface. Potential areas of interest include, but are not limited to, (bio)geochemical and nutrient cycles, water-rock interactions, "critical zone" processes, organic geochemistry, and the environmental chemistry of metals and nanoparticles. Candidates that utilize experimental, analytical, observational, and modeling approaches at any time scales (from early Earth to present) or environment (marine and terrestrial) are encouraged to apply. Candidates would ideally complement existing departmental strengths in paleoclimate, biogeochemistry, mineralogy and isotope geochemistry.

Geochronology: We seek applicants with expertise in the application and development of geochronologic methods. Potential areas of interest include, but are not limited to, application of geochronologic techniques to the growth, stabilization or thermal evolution of the lithosphere, time scales of magmatic and volcanic processes, calibration of the geologic time scale, early Earth and solar system history and evolution, Quaternary geology, landscape evolution, surface processes, paleoclimate and planetary evolution. Applicants with demonstrated achievement in geochronologic technique development are particularly encouraged to apply. Candidates would ideally complement existing departmental strengths in isotope geochemistry, petrology, mineralogy, paleontology, tectonics, and/or geomorphology.

Global Climate Change: We seek applicants who explore various elements of the water cycle and their linkages to climate change. Candidates for this position should investigate global change in one or more components of the Earth's climate system, including but not limited to the cryosphere, atmosphere, ocean, and biosphere. Candidates whose research touches upon issues of great societal interest such as sea level rise, water sustainability, land surface-atmosphere interactions, and the changing polar carbon cycle are especially encouraged to apply. Applicants may use field, monitoring, and/or experimental studies, geochemical or geophysical techniques including remote sensing, and/or modeling. Candidates would join a multidisciplinary group of recently hired faculty in global climate change.

Successful candidates are expected to establish an independent research program and contribute to both undergraduate and graduate teaching in a large public university. Candidates whose research and teaching complement and enhance the existing programs in the Department of Earth and Environmental Sciences will receive special consideration. Applicants must have a PhD and should submit a CV, statement of current and future research plans, statement of teaching philosophy and experience, and contact information for at least four persons who can provide letters of recommendation.

Further information about the Department can be found at: http://www.lsa.umich.edu/earth.

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

The application deadline is September 24, 2012 for full consideration, but applications will continue to be reviewed until the position is filled. Women and minorities are encouraged to apply. The University is supportive of the needs of dual career couples. The University of Michigan is an equal opportunity/affirmative action employer.

Professorship and two lectureships. As part of a continuing investment programme, the Department of Earth and Environmental Sciences invites applications for three staff members who will teach and establish world-leading research groups. These include a Professorship and a Lectureship in Environmental Earth Sciences, as well as a third Lectureship linked to the University's 600th Anniversary initiative for the Centre for Earth, Life and Oceans. Exceptional candidates could be considered for appointment at a higher position. Candidates will have an outstanding record of innovative internationally recognised research, publications and funding success. Although no restriction is placed on the specific area of expertise, we seek to build on and enhance research expertise in biogeochemistry and Earth Surface Processes for the Chair and Lectureship in Environmental Earth Sciences. The third position is targeted at the broad field of Geobiology.

Further details are given on http://earthsci.st-andrews.ac.uk/

Informal enquiries are encouraged and should be directed to Professor Peter Cawood (tel: +44 (0)1334 463911, email pac20@st-andrews.ac.uk).

Please quote ref: ME1114, MR1195 and ME1196
Closing date: 31 August 2012

Applications should be submitted online at www.vacancies.st-andrews.ac.uk/welcome.aspx,

however if you are unable to do this, please call +44 (0)1334 462571 for an application pack.

The University is committed to equality of opportunity.

The University of St Andrews is a charity registered in Scotland (No SC013532).

The Engineering School of Sustainable Infrastructure and Environment (ESSIE) at the University of Florida invites applications for a tenure-track faculty position at the Assistant or Associate Professor Level in its Geotechnical Engineering Program for January 2013.

The school is actively recruiting, recently hiring three new assistant professors and anticipate filling an additional four to six faculty positions in various areas in the next two years.

ESSIE is the nexus where civil, environmental, and coastal and oceanographic faculty come together to solve unique problems of sustainability. We have strong teaching and research programs and are committed to establishing a world-class Geotechnical Engineering program. The School is home to the Departments of Civil and Coastal Engineering and Environmental Engineering Sciences. In addition, it encompasses seven research centers and institutes: the Center for Environmental Policy, Center for Multimodal Solutions for Congestion Mitigation, the Howard T. Odum Center for Wetlands, Center for Infrastructure Protection and Physical Security, Transportation Research Center, Water Resources Research Center, and the Bridge Software Institute.

ESSIE is investing to ensure the success of new faculty. By August 2013, we expect approximately 20% of our faculty to be assistant Professors. ESSIE is designed to foster collaboration between its faculty and those across campus. New hires will join a dynamic, cross-disciplinary group of researchers, and will have ample opportunities for collaborations, both within their research field and with interdisciplinary teams. Instilling excellence in teaching, research, leadership, innovation, and entrepreneurship are ESSIE's highest priorities. A growing number of our undergraduate and graduate students are participating in a College-wide initiative to foster concomitant training in entrepreneurship,

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Max-Planck-Institut für Meteorologie

MAX-PLANCK-GESELLSCHAFT

The **Max Planck Institute for Meteorology (MPI-M)** conducts fundamental research focusing on climate related problems. The institute closely cooperates with the University of Hamburg, the German Climate Computing Centre (DKRZ) and the Institute of Coastal Research of the Helmholtz Zentrum Geesthacht (HZG) within the Cluster of Excellence **"Integrated Climate System Analysis and Prediction" (CliSAP)**.

Within the MPI-M department **"The Ocean in the Earth System"** we are looking for a

Scientist / Postdoc (m/f) - SAS2012-09

The project aims at a better understanding of the role of small-scale and short-term fluctuations on large-scale circulations and on the response behaviors of large-scale circulations to changes in external forcing factors, and from that a better assessment of the predictability limit due to inherent fluctuations. The study will be based on high-resolution simulations performed with the uncoupled atmosphere/ocean GCM, and the coupled AO-GCM, which are components of the MPI Earth System Model. Two multi-decadal uncoupled simulations, one atmosphere-only simulation with ECHAM6 at T255 horizontal resolution and one ocean-only simulation with MPIOM at one tenth degree resolution, have been completed within the German consortium project STORM. A coupled simulation is underway. Statistical mechanics approaches, additional scaling analyses, and if required further high-resolution numerical experiments, will be used to quantify the effects of fluctuations.

An individual with a PhD in meteorology, oceanography, and physics is sought. Excellent programming skills, and an ability to communicate effectively in spoken and written English is desired. For more information please contact *jin-song.von.storch@zmaw.de*

The position is offered for the duration of 5 years, **starting in November 2012** or soon thereafter. Payment will be in accordance with German public service positions (TVoeD E13/14), including extensive social security plans. The conditions of employment, including upgrades and duration, follow the rules of the Max Planck Society for the Advancement of Sciences and those of the German civil service.

The Max Planck Institute for Meteorology seeks to increase the number of female scientist and encourages them to apply. Handicapped persons with comparable qualifications receive preferential status.

Please submit **before September 14, 2012** a letter of interest, curriculum vitae, and the names, addresses, and telephone numbers of two references to *jobs@vw.mpimet.mpg.de* (1 pdf-attachment with max. 5 MB only), or by post to:

Max Planck Institute for Meteorology
Administration (SAS2012-09)
Bundesstraße 53
20146 Hamburg
Germany

Isotope geochemistry/ microanalysis

Naturhistoriska riksmuseet

The Swedish Museum of Natural History (NRM), invites applications for a senior research position in isotope geochemistry with a speciality in microanalysis by laser ablation ICPMS. The successful candidate will also manage the Vega Centre, a newly established national research infrastructure at NRM.

More information: www.nrm.se/vacancies

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innovation, and leadership skills in engineering. We have five NSF CAREER awardees, and almost 50% of our faculty members are past recipients of College, University, or National awards recognizing excellence in teaching and mentoring.

State-of-the-art laboratory and facilities for teaching and research include 89,000 square feet of existing laboratory space, $4 M of new laboratories under construction, 3-D X-ray Tomographic Unit, Category 5 Hurricane Wind Simulator, Signal Control Lab, Vehicle Based Traffic Data Acquisition System, Full-scale Geoengineering Soil Test Chambers, 2.5m Centrifuge, TARP Certified Stormwater Unit Operations and Process (UOP) Testing Facility, UF Atmospheric Photochemical Outdoor Reactor, and access to the high-performance computing center, as well as Major Analytical Instrumentation Center. These facilities and others are available to support faculty engaged in interdisciplinary sustainability research and to promote active collaborations with faculty campus wide.

The School offers ABET-accredited bachelor's degrees in both civil engineering and environmental engineering. Master's and doctoral degrees are available in Civil Engineering, Environmental Engineering Sciences, and Coastal and Oceanographic Engineering. ESSIE has 43 faculty, 753 undergraduate, 337 masters and 161 doctoral students. The School has approximately $40 million in research funding. These funds support 78% of the doctoral students, while fellowships sponsor another 12%, and the remaining 10% are supported through teaching stipends. ESSIE's total annual expenditures exceed $27.3 million, with $19.5 million in research expenditures generated from external contracts and grants.

The College of Engineering has over 270 Faculty, over 2,600 Graduate Students and over 5,000 Undergraduates. It is one of the most comprehensive Engineering Colleges in the country and ranked 15th among public Colleges of Engineering in the US News and World Report. In addition, Gainesville is a vibrant community and has been rated as one of the best places in America to live.

Applicants must possess a PhD in a related field that compliments ESSIE's strategic goals. The appointment is expected to be at the assistant or associate professor level. The successful individual will join the Department of Civil and Coastal Engineering, a unit of ESSIE. The new faculty member will be expected to actively pursue sponsored research in the broad area of geomechanics with interest in any, but not limited to analytical geophysics, numerical modeling, stochastic/ risk assessment, soil chemistry, etc. The anticipated teaching assignment will be both undergraduate and graduate level courses.

Special Notes to applicants: To be considered interested candidates must apply through the University of Florida by visiting https://jobs.ufl.edu/ , but may submit a complete curriculum vitae referencing requisition number 0900451, a statement of teaching and research plans with the focus on how those plans will support departmental, School and global initiatives in sustainability, up to three representative journal articles, and the names, addresses, phone numbers, and e-mail addresses of five references to Professor Mike McVay, Search Committee Chair, electronically geojobsearch@ce.ufl.edu . Questions may be referred to Dr. McVay at Mcm@ce.ufl.edu . Review of applications will begin November 1, 2012 and will continue until the position is filled. For more information about ESSIE and the department, visit http://www.essie.ufl.edu.

SERVICES, SUPPLIES, COURSES, & ANNOUNCEMENTS

United States Polar Rock Repository. Rock samples are available as no-cost loans for research, teaching & museum use.
http://bprc.osu.edu/emuwebusprr.

RESEARCH SPOTLIGHT

Highlighting exciting new research from AGU journals

New model to estimate water in the Earth's mantle

The Earth's mantle could be holding as much water as the ocean and atmosphere combined—but in the form of defects in dry minerals, such as olivine, that make up a large fraction of the mantle. Water in mantle minerals weakens chemical bonds, affecting physical and chemical properties of the mantle, particularly viscosity and electrical conductivity.

Scientists continue to debate not just the amount of water but also its distribution in the mantle. Seismic velocity profiles, typically used to map the water content of the mantle, are, in fact, not sensitive to the amount of water. An increase of 1% by weight of water in mantle minerals, i.e., from "dry" to "very wet" conditions, reduces seismic velocities by at most 1%, which is often below the detection limit. On the other hand, an increase in water content by only 0.01%, from "dry" to "damp" conditions increases electrical conductivity in mantle minerals by an order of magnitude or more, making electrical conductivity a more sensitive tool to estimate the water content of mantle minerals.

Laboratory-derived models used to estimate electrical conductivity through the mantle not only fail to replicate geophysical and petrological observations but also have large disparities between models used by different laboratories. As a result, although electrical conductivity models are sensitive, many in the scientific community are skeptical of them.

Jones et al. calibrated laboratory-derived models of electrical conductivity of mantle minerals with well-constrained petrological observations of water content from two sites on the cratonic lithosphere in South Africa. However, unlike for previous models, these authors use a statistical approach, called Monte Carlo, to fit model parameters to field observations. Their findings show that two factors that critically affect estimates of water in minerals were not well defined in the previous models: one is the presence of excess charges (protons) that diffuse through the network of water molecules by a process called proton hopping, and the second is the amount by which water in mantle minerals reduces its total energy or enthalpy.

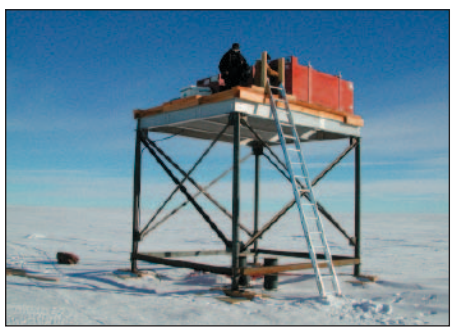
At present, the lack of petrological observations of the amount of water in mantle minerals at most sites in the world makes it difficult to constrain the above two factors. On the basis of their study, the authors propose more petrological studies and calibration of laboratory models with other geophysical and petrological field observations that may prove invaluable in understanding the behavior of the mantle. (*Geochemistry Geophysics Geosystems*, doi:10.1029/2012GC004055, 2012) —AB

Atmospheric turbulence not simply two-dimensional or three-dimensional

A complete mathematical description of turbulence is one of the most sought-after prizes in physics, and although the research of *Pinel et al.* does not provide a full account, it does aim to pin down the answer to one subset of that effort: Are two-dimensional (2-D) or 3-D the main options for atmospheric turbulence? In the earliest statistical descriptions, scientists assumed that turbulence was direction independent (isotropic) but in two separate regimes: at large scales being horizontally isotropic, while at small scales being isotropic in 3-D space. In this view, only large-scale turbulence behaves differently in the vertical and horizontal directions, that is, with horizontally stratified vortices.

For atmospheric physics, many researchers maintained this isotropic 2-D (large-scale) and isotropic 3-D (small-scale) picture, a claim refuted by the present research. Working with atmospheric pressure, wind speed and direction, temperature, and other data collected during 14,500 flights of commercial aircraft equipped with GPS equipment, the authors found that the observations supporting the proposed 3-D isotropy to 2-D isotropy transition were affected by a methodological flaw. The previous work, which also relied on aircraft-supplied observations, lacked the GPS observations of the present study.

Calculating the properties of atmospheric turbulence requires that observations be taken at consistent altitudes. Commercial airplanes, however, tend to fly along a path of consistent pressure—a path that has a gentle slope. As such, previous research had at times inadvertently measured vertical turbulent dynamics while trying to capture horizontal turbulence, giving the impression that the two had become equivalent. Drawing on their updated atmospheric observations, supplemented by GPS position measurements, the authors isolated the effect of the gradual divergence between altitude and pressure levels, using it to show that atmospheric turbulence is anisotropic over wide ranges of scale. (*Geophysical Research Letters*, doi:10.1029/2012GL051689, 2012) —CS



Paul Evenson

A neutron detector housed outside the Amundsen-Scott station at the geographic south pole could assist in the development of a solar radiation hazard prediction system

Prediction system to protect astronauts from solar storms

With the impending solar maximum expected to bring heightened rates of flares and coronal mass ejections (CMEs), putting at risk an ever-increasing human presence in space, *Oh et al.* designed and assessed a prediction system to keep astronauts safe from these solar storms. During a solar flare or CME, particles from the Sun can be accelerated to very high energies—in some cases traveling near the speed of light. Protons with energies surpassing 100 megaelectron volts (MeV) essentially sandblast everything in their path. Though people on Earth are protected by the planet's magnetic field and thick atmosphere, astronauts in spacecraft beyond low-Earth orbit or people at high altitudes near the poles can be exposed to this increased radiation, which can cause radiation sickness, with symptoms such as fever and vomiting.

The authors' prediction system uses two different types of neutron detectors installed at the geographic south pole to measure the intensity of the much faster gigaelectron volt neutrons also produced during a solar storm when protons interact with the atmosphere. By combining the observations of the two detectors—one located outside the Amundsen-Scott South Pole Station, the other housed inside the station—the authors calculated the energy spectrum of the arriving protons. They then extrapolated this spectrum to estimate the peak intensity and event-averaged flux (fluence) of the later-arriving MeV protons. The authors compared their predictions for 12 solar events against observations made by geosynchronous satellites, finding a good agreement for intensity and fluence predictions for protons with energies higher than 40 and 80 MeV, respectively.

The system provides a warning time of up to 166 minutes depending on the protons' energy, giving polar airplanes or astronauts ample time to reduce their altitude or seek out an armored area in their spacecraft. (*Space Weather,* doi:10.1029/2012SW000795, 2012) —CS

—Atreyee Bhattacharya and Colin Schultz, Writers