EOS

EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

VOLUME 92 NUMBER 17 26 APRIL 2011

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A New International Network for in Situ Soil Moisture Data

The International Soil Moisture Network (ISMN) is a new data-hosting center where globally available ground-based soil moisture measurements are collected, harmonized, and made available to users through a Web interface (http://www.ipf.tuwien.ac.at/insitu). As the first international initiative of its kind, the ISMN will play a crucial role in globally assessing the quality of soil moisture estimates from spaceborne microwave sensors and land surface models; in uncovering how the hydrological cycle integrates with land, the atmosphere, and the ocean; and in studying climate change. The ISMN is fully operational and currently hosts soil moisture data from more than 500 stations spanning 18 different networks. For scientific use, access to the data is free of charge.

Overcoming Obstacles Through ISMN

Soil moisture observations provide the link between terrestrial water, energy, and carbon cycles. Further, soil moisture determines how precipitation is partitioned into infiltration and runoff [*Dirmeyer et al.*, 2006]. Hence, it is fundamental in streamflow forecasting [*Koster et al.*, 2010] and in determining water and energy budgets. The importance of soil moisture in the global climate system has recently been underlined by the Global Climate Observing System (a joint undertaking of the World Meteorological Organization, the United Nations, and the International Council for Science), which in 2010 endorsed soil moisture as an "essential climate variable."

Although several local and regional meteorological and hydrological networks routinely measure soil moisture, globally the number of long-term ground-based monitoring networks is still small and largely restricted to midlatitude regions. Moreover, the lack of standard measurement techniques and protocols complicates the use of network data. As a result, there are many differences between measurement depths, units of soil moisture, sampling interval, and precision. Also, the fact that the various data sets are managed by a large number of organizations means that global studies incorporating ground-based soil moisture measurements are tedious to perform.

To overcome these issues, the Global Energy and Water Cycle Experiment (GEWEX) of the World Climate Research Programme (WCRP), with the continued support of the Group on Earth Observations (GEO) and Committee on Earth Observation Satellites (CEOS), envisioned and began developing an integrative platform for ground-based soil moisture measurements in 2006. The launch of the Soil Moisture and Ocean Salinity (SMOS) mission (http://www.esa.int/esaLP/LPsmos.html) in November 2009 by the European Space Agency (ESA) provided decisive impetus for this platform—in support of calibration and validation of SMOS products, an integrative system was needed to host quality-controlled and harmonized soil moisture measurements emerging from various ground validation campaigns and operational networks. Consequently, ESA provided the financial support for the development of this platform, which became ISMN.

The network itself is managed at the Vienna University of Technology. The first phase of ISMN has been completed—it involved designing and implementing the system and ingesting the first data sets. The second phase, which began in January 2011, entails the implementation of an improved quality control system, inclusion of additional networks, and the development of a plan that works toward full automation and near–real time ingestion of data sets. Subsequent phases will likely involve transferring the whole system to a fully operational organization.

Data Management

Input to ISMN is provided on a voluntary basis by locally and regionally operating networks—any network is encouraged to join. Currently, data from 18 historical and operational networks in North America, Europe, Asia, and Australia are hosted by ISMN (Figure 1), while several other networks have announced plans to participate in the near future. The Global Soil Moisture Data Bank [see *Robock et al.*, 2000], which until the launch of the ISMN was the only significant effort to centralize soil moisture measurements from various ground-based networks, has merged its data collection with the ISMN and has now closed.

Data streams in on various time scales: Some networks post data in near real time, while others share them only after they are published in a peer-reviewed journal. Incoming soil moisture measurements are checked for consistency and quality and converted into a common volumetric unit of measurement.

A graphical user interface allows the user to search, for example, by geographical extent or time period and visualize the selected data. After selection of specific records, the data sets are prepared for download according to prevailing standards for data and metadata, as established by WCRP/GEWEX.

Although initially set up to support the SMOS mission, other current and upcoming satellite soil moisture missions will be supported by the established network because more harmonized data will be available globally for calibration and validation. Already, several satellite product validation studies have benefited from the network [e.g., *Brocca*

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Multidisciplinary Collaborations in Mid-Ocean Ridge Research

The global mid-ocean ridge (MOR) is one of Earth's most fundamental geologic structures. Active volcanic, tectonic, hydrothermal, and biological processes occurring at the MOR affect nearly every attribute of the world's oceans and oceanic crust. For the past quarter century the overarching goal of the U.S. National Science Foundation (NSF)–funded multidisciplinary Ridge 2000 program (http://www.ridge2000.org/) and its predecessor, Ridge Interdisciplinary Global Experiments (RIDGE), here collectively called "R2K," has been to use observations, experiments, and models to answer fundamental questions about oceanic spreading center processes.

Since its inception, R2K has worked to develop a holistic understanding of MORs. There are multiple interrelated consequences of oceanic crust generation at MORs, including transfer of material and energy from the mantle to the crust and ocean; impacts on marine ecology; and temporal, spatial, and rate-dependent interactions between biological and geological processes. Consequently, a diverse yet tightly knit community of collaborating scientists, including geologists, chemists, geophysical modelers, microbiologists, and oceanographers, has developed under R2K programs. This research community has spanned multiple generations of investigative effort, requiring it to confront transformations in communications technology, tools for use and access of data, and attitudes about cooperative approaches to scientific discovery. The tools and approaches R2K has used to enhance cross-disciplinary understanding of complex problems are adaptable to other multidisciplinary research efforts.

A Systems Approach

A key strategy recently adopted by the R2K community is a systems approach to knowledge compilation and hypothesis formulation. The program established topically and geographically focused working groups to investigate various ridge processes and structural elements of ridge environments, thereby stimulating discussion and synthesis of results on program-relevant topics. Group topics include controls on hydrothermal biogeochemistry, vent chemistry and heat fluxes, melt extraction, magmatism and ridge morphology, system responses to tectonic/volcanic events, and cross-topic groups on emerging seafloor technologies and paradigms for expanding education and outreach (see http://ridge2000.marine-geo.org/ for a full list of working group titles). These topical, cross-disciplinary working groups focus research efforts by highlighting points of intersection between the data and models of different disciplines. This approach was adapted from other successful implementations of the working group paradigm (e.g., http://www.nceas.ucsb.edu/ and http://www.nescent.org/). In the R2K case, individuals self-selected to join groups. Topics were developed by the program leadership roughly 4 months before an NSF-funded community meeting in Portland, Oreg. (29–31 October 2010), attended by 140 participants. These groups, consisting of 10–20 members, collaborated before and during the meeting and will continue to work toward high-profile publications on topics (e.g., see Figure 1) and data sets within their focus areas.

Group activities are governed by operational and ethical protocols formulated by program leaders in accordance with collaboration and publication norms in the physical and biological sciences (http://ridge2000.marine-geo.org/community-meetings/october-2010/working-group-protocols). Members were drawn from multiple disciplines and seniority levels and are committed to communicating, learning from each other, and developing a shared vision for their objectives and published products. A benefit of such an approach is that additional collaborations are expected to be born of this process, and new ideas for the next decades of oceanic spreading center research will spring from the synthesis effort.

Embracing New Technologies

By embracing a combination of new electronic tools for remote communication and through new paradigms for compiling and understanding shared knowledge (e.g., wikis, databases, and social software, as in Figure 1), R2K researchers have been able to

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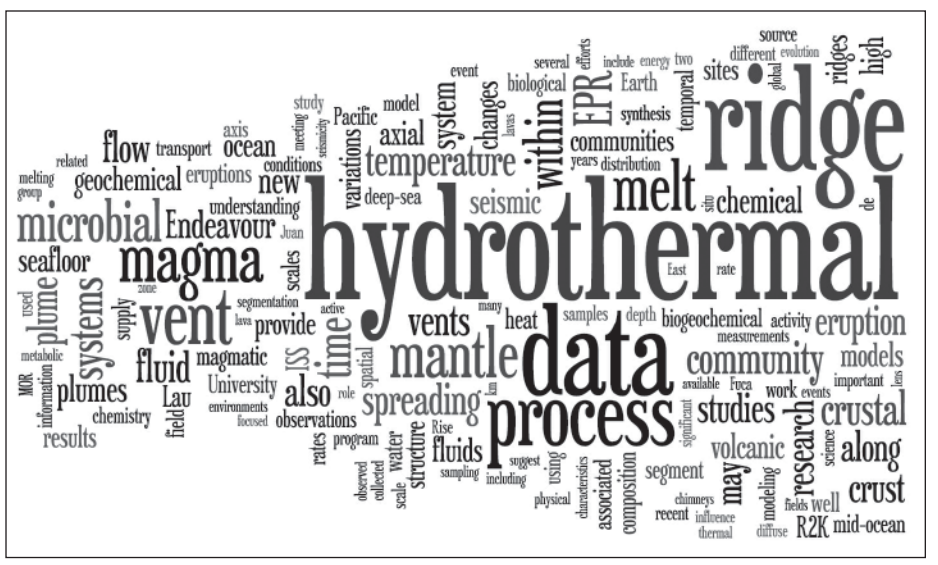

Fig. 1. Ridge 2000 research themes depicted in a word cloud of the text within white papers submitted to a recent community meeting show the most common (i.e., by word size) topics and concepts across the nearly 100 papers. Representations such as this (see http://www.wordle.net/) allow researchers using different methods, approaches, and disciplines to identify common ground and thus points of intersection within their work. These and other collaboration methods are being used to synthesize observations from a quarter century of mid-ocean ridge research.

Eos, Transactions, American Geophysical Union (ISSN 0096-3941) is published weekly by the American Geophysical Union, 2000 Florida Ave., NW, Washington, DC 20009, USA. Periodical Class postage paid at Washington, D. C., and at additional mailing offices. POSTMASTER: Send address changes to Member Service Center, 2000 Florida Ave., NW, Washington, DC 20009, USA. *Member Service Center:* 8:00 A.M.–6:00 P.M. Eastern time; Tel: +1-202-462-6900; Fax: +1-202-328-0566; Tel. orders in U.S.: 1-800-966-2481; E-mail: service@agu.org. Information on institutional subscriptions is available from the Member Service Center. Use AGU's Geophysical Electronic Manuscript Submissions system to submit a manuscript: http://eos-submit.agu.org.

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Christine W. McEntee, Executive Director/CEO

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et al., 2010; *Liu et al.*, 2011; *Loew and Schlenz*, 2011]. However, the scope of the ISMN is to go beyond the role of a satellite validation resource and serve other communities such as hydrologists, meteorologists, climate modelers, and water managers. To help find comprehensive answers to fundamental science questions related to soil moisture and its role in the integrated water cycle, the ISMN stores soil moisture measurements not only of the surface layer but also of deeper layers, along with relevant auxiliary variables such as precipitation, temperature of air and soil, soil porosity, and soil texture.

Next Steps

The establishment of the ISMN marks a first important step toward the fully integrated soil moisture observing system envisaged by GEO. Nevertheless, it will be necessary to establish, expand, and improve current soil moisture observations by, for example, developing a coordinated plan for networks through standardizing measurement techniques, data formatting, and selecting sites to improve global spatial coverage; designing a "supersite" program with high-density measurements over a small spatial area; and enhancing consistency and standardization of measurements, data, and metadata. Existing networks should be encouraged to share their data with the community and continue their measurements to obtain long-term records.

The success of these efforts will depend upon long-term financial commitment. Fortunately, the positive contributions from international organizations such as WCRP/GEWEX, the support of space agencies, and voluntary contributions from numerous individual networks are widespread, raising confidence in the scientific community's willingness to realize an integrated soil moisture observing system.

For more information about the ISMN and to share or download data, visit http://www.ipf.tuwien.ac.at/insitu or contact Wouter Dorigo (ismn@ipf.tuwien.ac.at).

Fig. 1. Locations of stations currently in the International Soil Moisture Network (blue droplets). Map courtesy of Google Earth imagery © Google Inc., Europa Technologies, Geocentre Consulting, Instituto Nacional de Estadística y Geografía (INEGI), Map Link, Tele Atlas, WhereiS®, and Sensis Pty Ltd. Used with permission.

Acknowledgments

We greatly thank all networks that have shared their data with the ISMN. The ISMN is funded through ESA's European Space Research and Technology Centre (ESTEC) contracts 22954/09/NLCT and 4000102722/10/NL/FF/fk. Alan Robock is supported by NASA grant NNX09AJ99G.

References

Brocca, L., F. Melone, T. Moramarco, W. Wagner, and S. Hasenauer (2010), ASCAT Soil Wetness Index validation through in-situ and modeled soil moisture data in central Italy, *Remote Sens. Environ.*, *114*, 2745–2755, doi:10.1016/j.rse.2010.06.009.

Dirmeyer, P. A., X. Gao, M. Zhao, Z. Guo, T. Oki, and N. Hanasaki (2006), GSWP-2: Multimodel analysis and implications for our perception of the land surface, *Bull. Am. Meteorol. Soc.*, *87*, 1381–1397, doi:10.1175/BAMS-87-10-1381.

Koster, R. D., S. P. P. Mahanama, B. Livneh, D. P. Lettenmaier, and R. H. Reichle (2010), Skill in streamflow forecasts derived from large-scale estimates of soil moisture and snow, *Nat. Geosci.*, *3*, 613–616, doi:10.1038/ngeo944.

Liu, Y. Y., R. M. Parinussa, W. A. Dorigo, R. A. M. de Jeu, W. Wagner, A. I. J. M. van Dijk, M. F. McCabe, and J. P. Evans (2011), Developing an improved soil moisture dataset by blending passive and active microwave satellite-based retrievals, *Hydrol. Earth Syst. Sci.*, *15*, 425–436, doi:10.5194/hessd-7-6699-2010.

Loew, A., and F. Schlenz (2011), A dynamic approach for evaluating coarse scale satellite soil moisture products, *Hydrol. Earth Syst. Sci.*, *15*, 75–90, doi:10.5194/hess-15-75-2011.

Robock, A., K. Y. Vinnikov, G. Srinivasan, J. K. Entin, S. E. Hollinger, N. A. Speranskaya, S. Liu, and A. Namkhai (2000), The Global Soil Moisture Data Bank, *Bull. Am. Meteorol. Soc.*, *81*, 1281–1299, doi:10.1175/1520-0477(2000)081<1281:TGSMDB>2.3.CO;2.

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more fully identify the ways in which different types of data and causally linked observations inform overarching research questions. These new approaches and technologies have been used to explore relationships between theories, data sets, and models and to plan for the transfer of this knowledge to peer-reviewed literature and beyond. The approaches will continue to be used to deliver R2K knowledge to the broader scientific, educational, and lay communities over the next several years.

Access to the latest information is central to any effort to determine, model, and explain causal linkages in complex natural processes. Perhaps the most important tool the program has used to achieve its goals is the development of an easy-to-use online system for cross-disciplinary data archiving and discovery among R2K investigators before and after formal publication, as well as protocols for data sharing, attribution, and metadata documentation. The R2K data portal (http://www.marine-geo.org/portals/ridge2000/), administered by the Data Management Office of the Marine Geoscience Data System at Lamont-Doherty Earth Observatory, has made such sharing far more efficient for investigators and students, facilitating publication of field study results. This approach permits data sets to be readily available for comparative and follow-on studies. For example, access to submeter-scale digital elevation models of high-resolution bathymetry produced by various researchers has enabled other independent researchers to identify and target individual volcanic and hydrothermal features for site-specific investigations of ecology and community structure at each of the program's focused study sites. These studies include relationships to time series chemical data generated by in situ sensors, all of which enable new models of spatial and temporal biogeochemical variations in regional geological context. The future possibilities are nearly limitless because almost all environmental metadata and field data from R2K-funded cruises are available through this system.

In addition, groups of R2K researchers have heavily exploited an array of modern electronic remote communication and idea-sharing mechanisms (e.g., Web-based collaboration such as wikis, shared online documents, e-mail, social networking Web sites, and voice and video teleconferencing), which allow group-intensive multiperson tasks to be conducted without the need to be together in the same room. This tool kit helps to overcome both the limitations of each individual tool and the substantial range of capabilities and comfort levels that individual group members have with these often cutting-edge technologies. Nonpublic wikis have been particularly useful for easily compiling and refining group ideas and interpretations of data, because users can interact directly with the evolving content and groups can take collective ownership of the product.

Synthesizing Data

The final R2K program phase is focused on synthesis of existing data sets to achieve greater understanding of how oceanic spreading centers operate. This involves integrating different observations into conceptual, semiquantitative, and/or quantitative models to help understand the forcing functions of ridge phenomena and their responses to changing conditions and perturbations. This work has just begun, but already the synthesis of the large body of accumulated data and the integration of diverse observations, measurements, and ideas are leading to new models of volcanic, hydrothermal, and biological interactions at MORs. These models include quantitative knowledge about feedbacks and exchanges within submarine hydrothermal systems and the oceans at large, the role of volcanic and tectonic perturbations in controlling ecology in the deep ocean, and the forcing functions and time scales of processes that affect the architecture of the MOR crust and upper mantle.

These new ideas are stimulating research themes for the future and continuing to provide the impetus for ocean-observing systems and other significant advances in deep-seafloor technology, sensors, and the development of deep submergence vehicles to explore the abyss. Although the tools and strategies used by R2K are only a part of the process, they have empowered the research community to make the most of its rich legacy of data, ideas, and human resources.

Acknowledgments

Ridge 2000 research is supported by the Division of Ocean Sciences of NSF. The Ridge 2000 office at Woods Hole Oceanographic Institution is supported by NSF grant OCE-0838923. Past and present Ridge 2000 science coordinators Breea Govenar and Stace Beaulieu contributed significantly to the efforts described in this report.

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NEWS

Ocean Drilling Science Plan to Be Released Soon

The upcoming International Ocean Discovery Program, which is slated to operate from 2013 to 2023 and calls for an internationally funded program focused around four science themes, will pick up right where its predecessor, the Integrated Ocean Drilling Program, ends, explained Kiyoshi Suyehiro, president and chief executive officer of IODP, a convenient acronym that covers both programs. At a 5 April briefing at the 2011 European Geosciences Union General Assembly in Vienna, Austria, he outlined four general themes the new program will address.

IODP involves 24 nations and utilizes different ocean drilling platforms that complement each other in drilling in different environments in the oceans.

The new IODP science plan, which is expected to be released in May, will focus on climate and ocean change, biosphere frontiers, Earth connections, and Earth in motion. These four themes were identified by scientists "as important for basic research and also important for society," Suyehiro said, adding that the themes are interconnected. "We believe it is quite important that we try to understand the Earth as a system," he said.

The first theme—Climate and Ocean Change: Reading the Past, Informing the Future—will explore questions such as how Earth's climate system responds to elevated levels of atmospheric carbon dioxide; how resilient the climate system is to chemical perturbations, including acidification, to oceans; how ice sheets and sea level respond to a warming climate; and what controls regional patterns of precipitation. "We believe that IODP can contribute to climate change problems by providing accurate records of the past history to reduce the uncertainties in the prediction of our future," Suyehiro said.

The Biosphere Frontiers theme—subtitled "Deep Life" and Environmental Forcing of Evolution—will explore the composition, origin, and biogeochemical mechanics of deep subseafloor communities; the limits of life in the subseafloor realm; and the sensitivity of ecosystems and human societies to environmental change. "The existence of deep microorganisms beneath the deep seafloor not connected to photosynthesis is an exciting world of discovery," Suyehiro said. "In the next 10 years, we will try to answer questions such as, How do these microorganisms fit in the evolution of life?"

The third theme, Earth Connections: Deep Processes and Their Impact on Earth's Surface Environment, will look into the composition, structure, and dynamics of the planet's upper mantle; the interconnections between mantle melting and plate spreading that control mid-ocean ridge architecture; the mechanisms, magnitude, and history of chemical exchanges between the oceanic crust and seawater; and how subduction zones initiate, cycle volatiles, and generate continental crust. "Deep drilling will open new doors in connecting the interior and the surface of Earth where we live," Suyehiro said. "Fifty years ago, there was a project called Moho, which attempted to drill into the mantle. We have yet to attain that target. With the new science plan, we are going to target this. We are now preparing ourselves to get into the mantle within the next decade."

Finally, the theme of Earth in Motion: Processes and Hazards on Human Time Scales explores mechanisms that control the occurrence of destructive earthquakes, landslides, and tsunamis; the properties and processes that govern the flow and storage of carbon in the subseafloor; and how fluids link subseafloor tectonic, thermal, and biogeochemical processes.

Noting that the fourth theme "is about human time scale changes," Suyehiro said that the 11 March Tohoku earthquake and tsunami "occurred as if to defy the most scientific understanding of how the Earth works." He said that many seismologists, including himself, did not previously think that a magnitude 9 earthquake could occur where it did.

In the Wake of the 11 March Tsunami

Suyehiro said that in the wake of the disaster in Japan, the Japanese science drilling community is in the process of talking to funding agencies about what direction should be taken. The D/V *Chikyu*, a deep-sea drilling vessel operated by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) and used for IODP drilling, "so far has been engaged in trying to understand the seismogenesis, not in the area where we saw the earthquake but in the southwestern part of Japan, which also will experience magnitude 8 class earthquakes in decades to come," he said. "We are quickly forming, as IODP, a science team to quickly plan for studying the area where the March 11 earthquake struck." Suyehiro added that he hoped this could result in some drilling within 1–2 years.

In an interview with *Eos*, Suyehiro elaborated that the drilling community is forming a group to write a proposal to drill through the tsunami-generating fault of 11 March, if it can be identified. "The actual rupture initiation point is too deep to get to. But in order to generate that size tsunami, I think it must have ruptured through the seafloor," Suyehiro said, noting that it would be important to identify the fault and try to penetrate it as deeply as possible.

"Scientific drilling through the seismogenic zone may tell us what actually made [the 11 March and other earthquakes] so big," he said. "That kind of information can only be obtained through getting what the frictional dynamics were during the earthquake, and it requires drilling."

Ocean drilling "is the only way to access the actual Earth material that is causing all of these processes," including earthquakes, he told *Eos*. "People do all sorts of studies in laboratories or on computers, but without the actual material that is composing this Earth, everything is assumption. The only way to verify what is real is by drilling."

Among IODP's drilling platforms, the R/V *JOIDES Resolution*, which is run by the U.S. Implementing Organization, can drill to about 2 kilometers beneath the seafloor. Mission-specific platforms contributed by the European Consortium for Ocean Research Drilling (ECORD) are useful for recovering samples from shallow or ice-covered waters.

At the 5 April briefing, Catherine Mevel, director of the ECORD Managing Agency, noted that the consortium plans to be involved in a number of scientific investigations, including drilling in the Arctic to better understand the tectonic evolution of the Arctic basin. She added that the Mediterranean also would be an important focus because it is the most tectonically active area in Europe, with a long history of devastating geohazards, and because "it records all the archives of environmental change, and these archives are really necessary to feed the climate models."

The D/V *Chikyu* IODP drilling platform sustained damage to one of its six thrusters due to the tsunami resulting from the 11 March earthquake. *Chikyu* had been in a port in northeastern Japan in preparation for an upcoming expedition. The ship, which can still be navigated under its own power, currently is in dry dock for repairs.

Suyehiro told *Eos* that he does not think the damage to the *Chikyu* is too serious because the ship can still move on its own power. "We'll know the situation within a month or so," he said. "My optimistic view is that it will be back in business within a few months' time." Damage to the *Chikyu* prompted the cancelation of IODP Expedition 337, which was to have explored a deep coal bed biosphere off the coast of the Shimokita peninsula on the Japanese island of Honshu.

For more information, see http://www.iodp.org/.

—Randy Showstack, Staff Writer

Concerns Over Modeling and Warning Capabilities in Wake of Tohoku Earthquake and Tsunami

Improved earthquake models, better tsunami modeling and warning capabilities, and a review of nuclear power plant safety are all greatly needed following the 11 March Tohoku earthquake and tsunami, according to scientists at the European Geosciences Union's (EGU) General Assembly, held 3–8 April in Vienna, Austria. EGU quickly organized a morning session of oral presentations and an afternoon panel discussion less than 1 month after the earthquake and the tsunami and the resulting crisis at Japan's Fukushima nuclear power plant, which has now been identified as having reached the same level of severity as the 1986 Chernobyl disaster.

Many of the scientists at the EGU sessions expressed concern about the inability to have anticipated the size of the earthquake and the resulting tsunami, which appears likely to have caused most of the fatalities and damage, including damage to the nuclear plant.

"We completely failed to estimate this occurring, the tragic earthquake and tsunami," Hiroshi Sato, professor at the Earthquake Research Institute (ERI), University of Tokyo, told *Eos* in an interview.

During the 8 April morning EGU session, Sato explained that prior to 11 March, many evaluations had indicated that the maximum magnitude of future earthquakes in the northern Honshu region of Japan would be around 8. "Nobody expected a magnitude 9 earthquake," he said.

Noting that the northern Honshu region, where the 11 March earthquake struck, forms a classic example of a trench/arc/back-arc system, Sato said that direct measurement of the megathrust activity is needed to better understand seismicity in the region. "To evaluate the risk of subduction megathrusts, we have to handle the

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records covering longer time periods." What is really needed is "to understand the whole process of strain buildup and release in [the] subduction zone."

Sato also noted that the region had experienced four or five large tsunamis over the past 3800 years and that the area submerged on 11 March is similar to the distribution of the tsunami resulting from the great Jogan earthquake in 869 C.E.

"The earthquake we suffered on March 11 was much, much bigger than what we expected and have experienced, and that was devastating not just for people but for scientists," added ERI professor Teruyuki Kato.

Kato said that although Japan already has a vast Global Positioning System (GPS) array and many other instruments, including tidal gauge records and ocean bottom pressure sensors, there is a need for more observations to monitor seismicity and tsunamis. "In the coming days," Kato said, "we should deploy a dense array offshore in the hypocentral region from the northern end of Japan to the southern end of the Japanese island, not just for Japan but for any subduction zones that could be eligible for supermegathrust earthquakes."

He also mentioned some key questions that need to be resolved, including why the northeastern Pacific coast subsided rather than uplifted. "We have to think about what kind of mechanism is working here," he said.

Emile Okal, professor in Northwestern University's Department of Earth and Planetary Sciences, Evanston, Ill., said the earthquake itself, with its classical subduction quality, was not surprising. However, he said several aspects were surprising, including its size, making the Tohoku quake the fourth-largest event ever recorded for which a documented, verified seismic moment is available.

Megaquakes that reach magnitude 9 "were generally unknown" in old subduction zones, Okal said, adding that megaquakes also were "generally unknown" in relatively poorly sedimented areas. "So several models, several paradigms of the expectability of these mega events, have to be abandoned now," he explained.

"We thought we were smarter than Mother Nature, and Mother Nature has taught us a lesson. It's a lesson in humility when you realize that, 'gee, I thought I understood something and I don't,'" Okal told *Eos*.

He added that there has to be a precautionary approach regarding megaquakes and that scientists should consider that all long subduction zones of more than 400 or 500 kilometers may produce very large earthquakes in the future. "There are a few places where we felt a little bit too secure, and we have to have renewed and new vigilance," Okal said, specifically noting Tonga and the Kermadec Islands, the Mariana Islands, Java and East Luzon, the Caribbean, and the Solomon Islands.

During the afternoon panel discussion at the EGU General Assembly, scientists also focused on the nuclear crisis affecting Japan that resulted from tsunami waves damaging the Fukushima power plant. "What is in order is a review of nuclear plants," many of which are located along shorelines, Okal said. He recommended that scientists investigate how other such nuclear plants might fare under similar conditions.

Andreas Stohl, senior scientist with the Norwegian Institute for Air Research, Kjeller, Norway, who has developed an atmospheric dispersion model useful for tracking various materials including radiation released at the Fukushima power plant as well as volcanic ash that drifted across Europe last year from Iceland's Eyjafjallajökull volcano, said the risk of nuclear power should not be judged by the accident at the Fukushima power plant, because the event could have been even worse. "We were extremely lucky that the wind was blowing in the right way," out to sea, he said. "Imagine the same situation in a nuclear power plant somewhere in central Europe where, regardless of which direction the wind would blow, it's just a question of which city you pollute most. The risks there will be much higher."

Stohl said that Europe may need an emergency response center to deal with these types of situations, and he also stressed the need for improved prediction models. "That concerns probably ocean models, but that also concerns especially atmospheric models because that is the immediate threat to people," Stohl said. "But there is little opportunity to test these models because, fortunately, these accidents are not happening too often."

—Randy Showstack, Staff Writer

FORUM

Making Sense of the Water Resources That Will Be Available for Future Use

Societally and environmentally important resources can be separated into five major categories: water, food, energy, human health, and ecosystem function. These resources, however, are intimately interlinked (Figure 1). Water, for example, is required for each of the other four resources. Estimating availability of water resources, as well as other resources, requires an assessment of the threats they face. As stated by *Pielke et al.* [2009],

> If communities are to become more resilient to the entire spectrum of possible environmental and social variability and change [*Vörösmarty et al.,* 2000], scientists must properly assess the vulnerabilities and risks associated with the choices made by modern society and anticipate the demands for resources several decades into the future.

With respect to water, the world we live in has finite water resources that are under stress from rising demand due to population growth, urbanization, and industrialization [*Gleick and Palaniappan,* 2010]. According to a United Nations report, the current rate of growth is expected to take world population to 9 billion by the end of this century. More than 80% of this population will be residing in urban areas [*United Nations Department of Economic and Social Affairs,* 2008]. A dramatic expansion in urban and industrialized areas of the world is likely. Thus, knowledge of water that can actually be harnessed for use is the key element in defining society's ability to achieve sustainable living in the 21st century.

Gaining an accurate understanding of how much water will be available for future use requires a multidimensional approach. The water that is usable can occur in various forms such as rainfall, surface water, rechargeable and fossil groundwater, snow, natural lakes, and artificial reservoirs, and through state and international treaties. There are multiple threats to these water resources through health epidemics and contamination, changes in precipitation extremes, population demand, industrial and agricultural consumption, contamination, national water policies, and climate. Lately, the consideration of such issues (or threats) has led to the coining of the term "nexus." A nexus can be regarded as a joint investigation addressing a few key issues, such as the "water-energy nexus," "water-health nexus," "water-weather nexus," or even the "water-weather-energy nexus." But is such a focus adequate, or should we attempt to integrate as many major threats as possible?

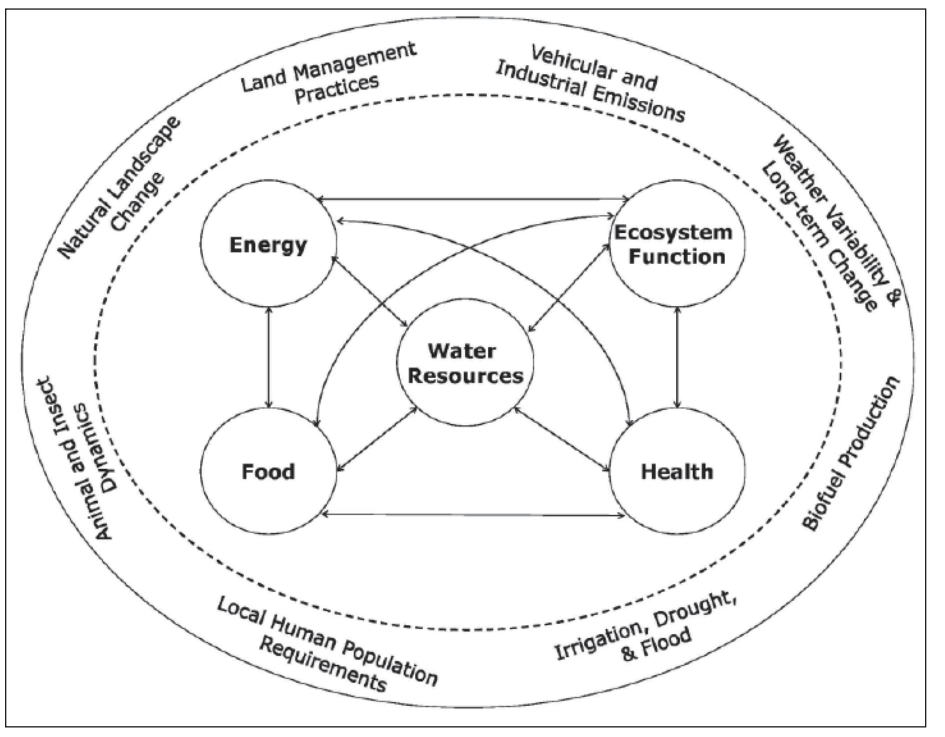

Fig. 1. The relationships among five key resources (water, food, energy, health, and ecosystem function). Outer ring shows a nonexhaustive list of stressors that affect availability or quality of the resources.

The resilience to known threats to water availability can be region specific and vary due to a multiplicity of factors. For example, annual flooding of about one fourth of the Ganges River delta is considered an integral part of livelihood and sustainability (by recharge of shallow aquifers and enrichment of soil with silt and nutrients [*Mirza,* 2003]). Yet similar levels of annual flooding in the Mississippi River delta would spell disaster possibly more catastrophic than 2005's Hurricane Katrina. Similarly, it takes about 100 liters of water to produce 1 kilowatt-hour of fossil fuel–based electricity [*Jones,* 2008]. But the dependence on energy is not the same everywhere. A 15-minute power outage has a far more drastic impact on water supply in New York City than on the island of Fiji. The factors affecting availability of water in most parts of the world are many, and more than a few key issues are involved. For example, the most pressing factors affecting water availability for the vast majority in Bangladesh are arsenic contamination of shallow aquifers, impoundment of transboundary rivers by upstream nations, treatment of water and wastewater effluents, arrival times of monsoons, agricultural demand, and public health epidemics such as cholera in coastal regions [*Ahmed and Karmakar,* 2006; *Akanda et al.,* 2009; *Hossain and Sivakumar,* 2008; *Nishat and Rahman,* 2010]. Almost all nations today have multiple threats to the availability of water resources, if not as many as Bangladesh [*Gleick,* 1998].

It is now important to gain a much broader view of what really affects today's water resources. To make sense of the water that we have at our disposal for future use, we need to ask ourselves the following questions:

- What are the key environmental and social variables that influence water resources?
- What is the sensitivity of these water resources to changes in each of these key variables?
- What actions (adaptation or mitigation) can be undertaken to minimize or eliminate the negative consequences of these changes (or to optimize a positive response)?

We now need a vulnerability assessment approach to evaluate the effect of environmental and societal threats to fresh water. This vulnerability concept requires the determination of the major threats to

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these resources, not only from climate but also from other social and environmental issues such as the ones described above. After these threats are identified for each resource, the relative risk from natural and human-caused climate variability and longer-term change should be compared with other risks so that the optimal mitigation or adaptation strategy can be adopted. The advantage of this vulnerability strategy, which should be location-specific, is that even if the forecast of water availability due to, say, climate or other threats were deemed to be unfounded years later, the optimal mitigation or adaptation strategy identified from multiple threats should have allowed for this margin of error during planning. In essence, such an approach guarantees a higher chance of success than would a one-dimensional strategy such as one based on projections only from global climate models that are reported in literature [*Schneider et al.,* 2007].

References

Ahmed, R., and S. Karmakar (2006), Arrival and withdrawal dates of the summer monsoon in Bangladesh, *Int. J. Climatol., 13*(7), 727–740, doi:10.1002/joc.3370130703.

Akanda, A. S., A. S. Jutla, and S. Islam (2009), Dual peak cholera transmission in Bengal Delta: A hydroclimatological explanation, *Geophys. Res. Lett., 36,* L19401, doi:10.1029/2009GL039312.

Gleick, P. H. (1998), Water in crisis: Paths to sustainable water use, *Ecol. Appl., 8,* 571–579, doi:10.1890/1051-0761(1998)008[0571:WICPTS]2.0.CO;2.

Gleick, P. H., and M. Palaniappan (2010), Peak water limits to freshwater withdrawal and use, *Proc. Natl. Acad. Sci. U. S. A., 107*(25), 11,155–11,162, doi:10.1073/pnas.1004812107.

Hossain, F., and B. Sivakumar (2006), Spatial pattern of arsenic contamination in shallow tubewells of Bangladesh: Regional geology and non-linear dynamics, *Stochastic Environ. Res. Risk Assess., 20*(1-2), 66–76, doi:10.1007/s00477-005-0012-7.

Jones, W. D. (2008), How much water does it take to make electricity?, *IEEE Spectrum,* April.

Mirza, M. M. Q. (2003), Three recent extreme floods in Bangladesh: A hydro-meteorological analysis, *Nat. Hazards, 28*(1), 35–64, doi:10.1023/A:1021169731325.

Nishat, B., and S. M. M. Rahman (2009), Water resources modeling of the Ganges-Brahmaputra-Meghna River basins using satellite remote sensing data, *J. Am. Water Resour. Assoc., 45*(6), 1313–1327 doi:10.1111/j.1752-1688.2009.00374.x.

Pielke, R., Sr., et al. (2009), Climate change: The need to consider human forcings besides greenhouse gases, *Eos Trans. AGU, 90*(45), 413, doi:10.1029/2009EO450008.

Schneider, S. H., et al. (2007), Assessing key vulnerabilities and the risk from climate change, in *Climate Change 2007: Impacts, Adaptation and Vulnerability—Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* edited by M. L. Parry et al., pp. 779–810, Cambridge Univ. Press, Cambridge, U. K.

United Nations Department of Economic and Social Affairs (2008), World population prospects: The 2008 revision, New York. (Available at http://esa.un.org/unpd/wpp2008/index.htm.)

Vörösmarty, C. J., P. Green, J. Salisbury, and R. B. Lammers (2000), Global water resources: Vulnerability from climate change and population growth, *Science, 289*(5477), 284–288, doi:10.1126/science.289.5477.284.

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MEETINGS

Planning the Next Generation of Arctic Ecosystem Experiments

Climate Change Experiments in High-Latitude Ecosystems; Fairbanks, Alaska, 13–14 October 2010

A 2-day climate change workshop was held at the International Arctic Research Center, University of Alaska Fairbanks. The workshop, sponsored by Biological and Environmental Research, Office of Science, U.S. Department of Energy (DOE), was attended by 45 subject matter experts from universities, DOE national laboratories, and other federal and nongovernmental organizations. The workshop sought to engage the Arctic science community in planning for a proposed Next-Generation Ecosystem Experiments (NGEE-Arctic) project in Alaska (http://ngee.ornl.gov/).

The goal of this activity is to provide data, theory, and models to improve representations of high-latitude terrestrial processes in Earth system models. In particular, there is a need to better understand the processes by which warming may drive increased plant productivity and atmospheric carbon uptake and storage in biomass and soils, as well as those processes that may drive an increase in the release of methane (CH_4) and carbon dioxide (CO_2) through microbial decomposition of soil carbon stored in thawing permafrost. This understanding is required to quantify the important feedback mechanisms that define the role of terrestrial processes in regional and global climate.

Speakers and participants worked through a series of thematic questions that included the following: What are the greatest uncertainties and sensitivities in current generation Arctic ecosystem models and Earth system models? What are observations and experiments telling scientists about changes in rates and magnitudes of processes and responses, the relative importance of terrestrial processes, and the role of heterogeneity across scales in space and time? What are the strengths and limitations of current observations and experiments, and how can those limitations be overcome?

Participants recommended experiments and observations to elucidate mechanisms underlying greenhouse gas fluxes from warming permafrost, changing hydrology, shifting distribution of vegetation, and large-scale geomorphic dynamics. Research to address the vulnerability of Arctic ecosystems to global change should be designed to characterize chemical, physical, and biological processes in sufficient detail so that current representations in coupled land-atmosphere models can be improved and new mechanisms can be identified and quantified for future inclusion in regional and global climate models. Discussions highlighted the considerable degree of system complexity likely to be encountered in high-latitude ecosystems and the need to describe interactions and feedbacks among permafrost, snow, soil water, vegetation, microbial communities, and atmospheric processes.

Participants also emphasized that new experiments and observations must be designed to account for landscape dynamics, because disturbances like fire, subsidence, and thermokarst can be expected to exert a dominant control on biogeochemical, hydrologic, and ecosystem processes and thus shape how these events are ultimately represented in Earth system models. A science and implementation plan is being developed by a multidisciplinary team of scientists from across DOE national laboratories and strategic university partners. The plan will describe how integration of surface and subsurface science (e.g., genomics to geophysics) can help quantify the response of physical, ecological, and biogeochemical processes to atmospheric and climatic change.

—STAN D. WULLSCHLEGER, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.; E-mail: wullschlegsd@ornl.gov; LARRY D. HINZMAN, International Arctic Research Center, University of Alaska Fairbanks; and CATHY J. WILSON, Earth and Environmental Sciences Division, Los Alamos National Laboratory, Los Alamos, N. M.

Applying Spaceborne Gravity Measurements to Ocean Studies

"Gravity From Space" for Oceans, Land Ice, and Sea Level Rise; Hamburg, Germany, 29–30 September 2010

Twenty-five scientists met at the University of Hamburg's KlimaCampus to discuss current analyses and future applications of spaceborne gravity measurements to studies of ocean circulation, cryospheric science, and sea level rise. The Challenging Minisatellite Payload (CHAMP), Gravity Recovery and Climate Experiment (GRACE), and Gravity Field and Steady-State Ocean Circulation Explorer (GOCE) satellites, complemented with radar and laser altimeters, provide the necessary data.

Spaceborne gravity measurements provide two important quantities for ocean circulation studies: (1) the time-averaged geoid, which when subtracted from a time mean sea surface from radar altimetry yields the absolute surface dynamic topography and absolute surface geostrophic currents, and (2) time changes in ocean bottom pressure and total ocean mass. For sea level rise, the difference between the globally averaged trend from altimetry and that from GRACE is used to infer the top-to-bottom steric component (the component of sea level rise resulting from expansion of seawater due to temperature and salt), which is observable with data from the Argo system, a network of drifting probes that measure temperature up to 2000 meters in depth, and from expendable bathythermographs (XBT), temperature sensors deployed by ships.

Mean dynamic topographies have been created from the combination of geodetic and in situ oceanographic data; workshop participants expect these topographies to improve significantly at short wavelengths with the addition of GOCE data.

GRACE observes ice mass loss from Greenland, Antarctica, and glaciers in Alaska and Patagonia; much of this water enters the oceans. Trend retrievals depend critically on either using a model of glacial isostatic adjustment or estimating it together with the current mass loss; another complication noted by participants is the coarse "footprint" of GRACE, which mixes signals from neighboring areas.

In addition, participants pointed out that ocean bottom pressure signals (of the order of 10 millibars at high latitudes and 10 times smaller at low latitudes) are close to the noise level of GRACE and require special processing and filtering. Signals several hundred kilometers in extent match those obtained from in situ bottom pressure recorders in energetic regions and have been used to study the Antarctic Circumpolar Current, the Arctic, and interbasin mass exchanges. The data are now assimilated into numerical ocean models, although current models lack some of the physics measured by GRACE (loading and self attraction, mass conservation); the global ocean mean mass constrains the total freshwater flux in these ocean models.

In summary, time-averaged and time-varying satellite gravity data were demonstrated to be instrumental for physical oceanographic and sea level rise studies. The discussions centered on future processing, future applications of GRACE-like data, and future missions. Future missions include an expected GRACE continuity mission, which was strongly endorsed by the attendees, has been approved by NASA, and is under study in Germany for launch in 2016. The GRACE continuity mission is expected to close the gap between GRACE and missions under discussion for launch in the 2020s. From the improved processing and the future missions, scientists expect more accurate retrievals over smaller regions. Furthermore, ocean bottom pressure signals are small and require accurate removal of land signals, whether continental hydrology, strong earthquakes, or glacial isostatic adjustment. Participants believe that the addition of bottom pressure recorders at the Tropical Ocean–Global Atmosphere (TOGA) Tropical Atmosphere-Ocean (TAO) project locations (http://www.pmel.noaa.gov/tao/) would yield the overall ocean mass variability because the region is dynamically quiet. It is now timely to extend GRACE studies beyond the barotropic response of the ocean to wind.

The online supplement to this *Eos* issue (http://www.agu.org/eos_elec) contains a slightly expanded version of this report, including names of attendees, expertise, and references.

—VICTOR ZLOTNICKI, Jet Propulsion Laboratory, California Institute of Technology, Pasadena; E-mail: victor.zlotnicki@jpl.nasa.gov; and DETLEF STAMMER, KlimaCampus, University of Hamburg, Hamburg, Germany

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POSITIONS AVAILABLE

Atmospheric Sciences

Post-Doctoral Fellow 2. The Institute for Multidimensional Air Quality Studies at the University of Houston is seeking a post-doctoral fellow to analyze ambient atmospheric trace gas data collected in the greater Houston area. In particular, we are interested in a scientist with experience in conducting regional simulations of air quality using the WRF/SMOKE/CMAQ modeling platforms. Houston has a diverse and unique emission inventory that requires careful attention to obtain realistic model simulations. It is highly desirable that the successful candidate have experience in applying emission inventories and in quantifying uncertainties related to it. We are especially interested in quantifying the impact of industrial emissions on regional air quality. Chemical species of interest include Hg, O_3, CO, NMHCs, and halogens. The position has a duration of two years. Applications should include a full CV and the names of three references. Submit application through www.uh.edu/hr under job posting #066154. Send materials electronically to Professor Robert Talbot at rtalbot@uh.edu, Department of Earth & Atmospheric Sciences, University of Houston, Houston, TX. The University of Houston is an Equal Opportunity/Affirmative Action employer. Minorities, women, veterans, and disabled persons are encouraged to apply.

Research Associate. The Earth System Science Interdisciplinary Center (ESSIC) of the University of Maryland seeks a Post-doctoral or Early Career Scientist to conduct research using EOS-era satellite measurements to reduce uncertainty of radiative forcing due to tropospheric aerosols. The duty site will be at the NASA/Goddard Space Flight Center in Greenbelt, MD. For a more detailed job description, visit: http://essic.umd.edu/ebo/jobs.php.

Biogeosciences

Postdoctoral Position in Biogeochemistry. Seeking a post-doctoral scientist to work on applications of stable isotope analyses to proteomics. A Ph.D. in molecular biology, chemistry, geochemistry, or a related field is required. The individual should have prior experience in proteomics and/or molecular biological methods. Additional knowledge of stable isotope chemistry, oceanography, and ecology is desirable. Familiarity with environmental and/or complex prokaryotic systems is essential. The project entails extensive instrumental and analytical methods development, requiring high-level organizational and technical skills. The duration of the position will be 18 months with renewal contingent on subsequent funding. Submit a letter of application and CV by May 15, 2011 to: Professor Ann Pearson (pearson@eps.harvard.edu). Harvard University is an AA/EEO employer. Applications from women and minorities are encouraged.

Geochemistry

Post Doc in Radiogenic Isotopes. The Radiogenic Isotope and Geochronology Laboratory at Washington State University is accepting applications for a post-doctoral position in radiogenic isotope geochemistry. The position is open to applicants wishing to pursue any project that can be accomplished in our laboratory, but preference will be given to those interested in areas of either Lu-Hf and Sm-Nd geochronology applied to accessory minerals or integrated zircon U-Pb geochronology and Hf isotope geochemistry.

Applications should include a statement of research interests and contact information for 3 professional references. Applications will be reviewed as they are received and will be accepted until the position is filled. Please direct inquiries and applications to Jeff Vervoort (vervoort@wsu.edu), SEES, WSU, Pullman, WA. 99164. EEO/AA Employer.

Hydrology

Open Post Doctoral Position. A post doctoral associate is sought to work on a CO_2 modeling project funded by the U.S. National Science Foundation. The position is available June 1, 2011. An annual stipend of $42,000 is offered plus full employee benefits. The appointment will be for 2 years with potential extension to a 3rd year. Interested applicant should e-mail a CV with name and contact information of 3 referees to Dr. Ye Zhang (yzhang9@uwyo.edu). For more information about the research project, please visit: http://faculty.gg.uwyo.edu/yzhang/files/PostDocAd_2011.pdf.

Postdoctoral Research Associate. The USDA, Agricultural Research Service (ARS), Animal and Natural Resources Institute's Hydrology and Remote Sensing Laboratory, in Beltsville, Maryland, is seeking a Postdoctoral Research Associate, Research Physical Scientist, for a two year appointment.

A Ph.D. in physical science, hydrology, atmospheric sciences, geography or some related field is required. Salary is commensurate with experience and can range between $62,467 to $81,204 per annum, plus benefits.

The incumbent will develop and apply remote sensing and data assimilation techniques to enhance the calculation of water balance storage and flux terms within a hydrologic model. Recently-developed techniques will be applied that assess the added utility of assimilating remote sensing data into a land surface model relative to a baseline case of no constraint using remote sensing. Previous experience with land surface or hydrologic modeling is strongly preferred and familiarity with thermal remote sensing, microwave remote sensing or land data assimilation techniques is desirable.

To apply refer to announcement #RA-11-0058-L at: http://www.afm.ars.usda.gov/divisions/hrd/hrdhomepage/vacancy/pd962.html to obtain the full text announcement, complete application instructions, and further information on Postdoctoral Research Associate positions. Send application information, a statement of research interests and the names of two references to Dr. Wade Crow, USDA/ARS/ANRI/HRSL Bldg. 007, Room 104, Beltsville, MD 20705 or e-mail (wade.crow@ars.usda.gov) by May 13, 2011. USDA/ARS is an equal opportunity provider and employer.

Senior Software Engineer/Architect. The Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) seeks a senior software engineer/architect to lead the development of data services for the academic water science research community. The Senior Software Engineer/Architect will develop a strategy to transition a standards-based services-oriented architecture for publication and discovery of water data from a research project to an operational service. The research project, CUAHSI Hydrologic Information System (HIS) consists of a central metadata catalog (HydroCatalog), a data publication server stack (HydroServer) and a data access, visualization, and analysis client (HydroDesktop). HIS has been developed in a Microsoft.NET environment and utilizes various commercial packages, including Microsoft SQL Server and ESRI's ArcGIS Server software. The ideal candidate will have both a background in water science research (in the fields of Earth science, engineering, or ecology) and a strong informatics background with understanding of Open Geospatial Consortium (OGC) web service and data encoding standards, web services, and relational databases.

To be considered for this position, candidates must possess a combination of degrees that provide expertise in hydroinformatics with the highest degree being either a Ph.D., multiple Master's Degrees or a Master's Degree with at least 3 years of experience. The degrees may be in computer science, hydrologic science or engineering, or a combination of fields.

Please submit your resume-including names, addresses, and contact information for 3 to 5 references-and cover letter to busmgr@cuahsi.org. Interviews will begin in May 2011 and continue until a suitable candidate has been found. We have a target hiring date of July 1, 2011. An expanded version of this listing is available at http://www.cuahsi.org/docs/CUAHSI-SE-PD.pdf. CUAHSI is an equal opportunity/affirmative action employer.

Ocean Sciences

Post-doctoral Position in Ocean Modeling. Applications are invited for a post-doctoral scholar in the Department of Ocean Sciences at U. C. Santa Cruz to help develop and maintain a 30 year analysis of the California Current using the ROMS 4D-Var data assimilation systems. Position available initially for 1 year with a possible extension contingent on funding and performance. A Ph.D. in Physical Oceanography or related field is required. Experience in ocean modeling, 4D-Var or data assimilation is desirable. Applications due by 18 May 2011. Send a brief letter of research interests, curriculum vitae, and names of three references with contact information to Prof. Andrew Moore, Dept. of Ocean Sciences, University of California, 1156 High Street, Santa Cruz, CA. 95064, USA, (ammoore@ucsc.edu). UCSC is an AA/EEO employer. Please visit: www.ucsc.edu/about/employment.asp for more information.

Solid Earth Geophysics

Assistant or Associate Professor in Tectonophysics. The Department of Geology and Geophysics at the University of Utah seeks applicants for a tenure track position at the Assistant or Associate Professor level in Tectonophysics. Scientists from all subdisciplines of tectonophysics are welcome to apply, but preference will be given to candidates with research interests that complement existing geophysical strengths in the department. These include seismic imaging of Earth's deep interior, earthquake seismology, and hazard assessment as carried out by the University of Utah Seismograph Stations, active source seismology, electromagnetic studies of Earth's interior, and tectonics.

The successful candidate must be committed to excellence in geophysics teaching at both the undergraduate and graduate levels, and should have either the proven ability or potential to attract external funds and to build an internationally recognized research program involving students and post-docs. Applicants must hold a Ph.D. in geophysics, or a closely related discipline.

Applicants should e-mail an application package describing research, teaching, and career interests, a curriculum vitae, and the names and contact information for three referees, all in a single PDF document to: tectonophysics-search@lists.utah.edu. Review of applicants will begin August 15, 2011, and continue until the position is filled.

The University of Utah is fully committed to affirmative action and to its policies of nondiscrimination and equal opportunity in all programs, activities, and employment. Employment decisions are made without regard to race, color, national origin, sex, age, status as a person with a disability,

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DIRECTOR
SIR ALISTER HARDY FOUNDATION FOR OCEAN SCIENCE (SAHFOS)
Plymouth, Devon, UK

SAHFOS is a UK registered charity and the Council of the Foundation invites applications for the appointment of a full time Director. SAHFOS is currently funded by the UK Government (Defra and NERC) and a consortium of international agencies. A joint position with a University might be considered with a view to building collaborative links. Candidates might also propose secondment from their present organisation.

To be successful you will have: extensive expertise in marine ecological or global environmental research, including publications in high-impact journals; experience of directing and running a small/medium sized research operation and knowledge of relevant government policy issues; experience of, or the clear potential for spearheading funding initiatives and enthusiasm for science and for people.

The salary will reflect the role and calibre of the appointed candidate.

A full job specification is available at http://www.sahfos.ac.uk/about-us/vacancies.aspx.

Interviews will be held in Plymouth, Devon on 7 June 2011. To apply please send electronically a covering letter, your CV and names and contact details of three referees **by 6 May 2011** to: Marion Smith, SAHFOS, The Laboratory, Citadel Hill, Plymouth, PL1 2PB Tel: 01752 633271. E-mail: masm@sahfos.ac.uk

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religion, sexual orientation, gender identity or expression, and status as a protected veteran. The University seeks to provide equal access for people with disabilities. Reasonable prior notice is needed to arrange accommodations. Evidence of practices not consistent with these policies should be reported to: Director, Office of Equal Opportunity and Affirmative Action, (801) 581-8365 (V/TDD).

The University of Utah values candidates who have experience working in settings with students from diverse backgrounds, and possess a commitment to improving access to higher education for historically under-represented students.

Two Senior Researcher (Oberassistant) Positions in Solid Earth or Planetary Dynamics at ETH Zurich. The GFD group in the Institute of Geophysics, ETH Zurich, Switzerland (led by Professors Paul Tackley and Taras Gerya, see http://www.gfd.ethz.ch) seeks two senior researchers to join our vigorous research program in the geodynamics of the solid Earth and planets. Applicants' field of expertise may be anything in the group's range of interests, which covers crust and lithosphere dynamics, mantle dynamics, solid planetary dynamics, two-phase flow, planetary formation and core-mantle differentiation, etc. Strong numerical modeling skills including the ability to develop codes are an advantage. The working language of the group is English.

The successful candidates are expected to perform research independently as well as in collaboration with other group members, and to teach. This includes raising funding and supervising Ph.D. students, teaching M.Sc. and B.Sc. courses (in English) and supervising M.Sc. and B.Sc. projects. A starting date in late 2011 to early 2012 is negotiable and the contract is for 2 years renewable up to a total of 6 years. An attractive salary will be in accordance with the regulations of ETH Zurich.

To apply, please e-mail a CV, publication list, statement of research interests, and the names and contact information of at least two references to Prof. Paul Tackley (ptackley@ethz.ch), by 20 May.

The ETH Zurich is committed to an equal opportunities policy in the recruitment and selection of staff.

Interdisciplinary/Other

Physical Or Environmental Chemist, Haverford College. One year position beginning September 2011 to teach introductory chemistry, a course for non-scientists and advanced seminars in the area of the candidate's expertise, and preferably also mentor undergraduate students in research. Ph.D. required. The applicant should submit a c.v., an outline of research ideas, undergraduate and graduate transcripts, and arrange to have three letters of recommendation forwarded to Terry Newirth, Chair, Department of Chemistry, Haverford College, Haverford, PA 19041. We will consider applications from March 18 until the position is filled. Haverford College is an Equal Opportunity/Affirmative Action employer, committed to excellence through diversity, and strongly encourages applications and nominations of persons of color, women, and members of other under-represented groups.

Planetary Remote Compositional Analysis. The Department of Geological Sciences at Brown University (http://www.geo.brown.edu/) invites applications for a tenure-track faculty appointment in Planetary Remote Compositional Analysis. The emphasis of this position is on the application of experimental and quantitative analytical approaches to the characterization, analysis and understanding of remotely sensed spectroscopic data to address critical problems in planetary sciences. Such problems might include the composition of materials comprising planetary bodies, the physical and chemical weathering of surfaces, and the nature of planetary processes. Analysis of field data and spacecraft data in addressing such problems is also strongly encouraged. Available facilities for such research include the Reflectance Experiment Laboratory, a facility permitting high-quality emission and reflectance spectroscopic measurements from 0.3-50 microns.

Candidates should complement our current planetary science strengths in planetary evolution, volcanism, impact cratering, climate history, and remote sensing, as well as departmental focus areas of Earth system history, solid Earth dynamics, and Earth and planetary materials and processes.

The successful candidate will maintain an active, externally-funded research program and enjoy a commitment to teaching at both undergraduate and graduate levels. Appointment is expected at the Assistant Professor level, although exceptional circumstances could warrant appointment as Associate Professor.

A Ph.D. degree is required, and postdoctoral experience is considered important. Applicants should forward a curriculum vita, descriptions of research and teaching interests, and three letters of reference to: James W. Head, Chair, Search Committee, Department of Geological Sciences, Box 1846, Brown University, Providence, RI 02912-1846 at planetarysearch@brown.edu. Inquiries and other communications may be directed to the same addresses. Applications received by June 15th, 2011 will receive full consideration, but the search will remain open until the position is closed or filled.

The start date for this position is July 1st, 2012, pending final administrative and budgetary approval. Brown University is an equal opportunity/affirmative action employer.

Post-Doctoral Fellow-Global Freshwater Initiative. Stanford University's Dept. of Environmental Earth System Science and Woods Institute for the Environment seek applications for a post-doctoral fellow in quantitative water resources analysis in support of the Global Freshwater Initiative (GFI). A major goal of the GFI is to develop integrated hydrologic-economic models used for comparative policy evaluation primarily among developing nations. An initiative of the Woods Institute, the GFI is highly interdisciplinary, linking quantitative analysis of hydrologic systems, economics, and institutions. For additional information on the GFI, please see http://woods.stanford.edu/ideas/global-freshwater-initiative.html.

Effort of the post-doctoral fellow will be split among site-specific studies, developing proposals, and supporting collaborations. Applicants must have a demonstrated ability to generate new research questions, collect data from multiple sources, run hydrologic models, conduct economic analysis, and evaluate water allocation strategies.

Stanford University is an equal opportunity employer and is committed to increasing the diversity of its staff. It welcomes nominations of and applications from women and minority groups, as well as others who would bring additional dimensions to the university's research, teaching, and clinical missions.

Interested applicants should e-mail a CV, transcripts, one relevant publication, a one-page statement describing past research and future goals, and the names and addresses of three references to Steven Gorelick (gorelick@stanford.edu) by June 1, 2011.

Post-doctoral Researcher-Global CO_2 Emissions Research. A post-doctoral position focused on the construction of a global, high resolution greenhouse gas emissions data product is available in the School of Life Sciences at Arizona State Univ. Part of a cutting-edge effort aimed at high resolution quantification and understanding of fossil fuel greenhouse gas emissions from the global to the individual building level. The successful candidate will contribute to the development of a high resolution fossil fuel CO_2 emissions data product at the global scale availing of bottom up datasets, remote sensing data products, and model algorithms. This effort will combine a wide array of knowledge and skills including energy consumption statistics & modeling, remote sensing, geospatial statistics, & data assimilation techniques. Given the multi-disciplinary nature of the research, a highly self-directed, creative, and self-motivated individual is sought. The appointment will be made for the period of 6/1/10 through 5/31/12 with possibility of extension for additional years. Start date is flexible.

Candidates must have received a Ph.D. in the geosciences or a field related to position (e.g. Ecology, Remote Sensing, Civil engineering) from an accredited college or university.

Necessary skills: geospatial statistics, remote sensing applications (Nightlights, LandSat), programming abilities (e.g. Java, C++, Fortran). Desired skills: data assimilation experience, GIS software and analysis, carbon cycle science, carbon/energy accounting. The applicant will be expected to publish peer-reviewed literature and effectively communicate with a wide range of scientists, planners, and policy makers.

Applicants should send a cover letter describing their experience and interests, a CV, and have three reference letters sent to (e-mail or surface mail): Prof. Kevin Gurney, School of Life Science, Arizona State University, P.O. Box 874501, Tempe, AZ, 85287-4501. krgurney@email.asu.edu (e-mail preferred).

A background check is required for employment. Arizona State University is an equal opportunity/affirmative action employer committed to excellence through diversity. Women and minorities are encouraged to apply.

Research Associate Postdoctoral. The College of Oceanic and Atmospheric Sciences at Oregon State University, Corvallis Oregon, invites applications for two Institutional Postdoctoral Research Associate positions in the general area of Earth System Sciences. Awards are competitive, with a major emphasis on potential for independent, creative research. These are 12-month, fixed-term positions at full-time (1.0 FTE) for year one. Funding in year two will be at 0.75, and year three at 0.50 FTE. FTE in years 2 and 3 can be increased to 1.0 with external funding. Postdoc will be paired with faculty mentors for training in the development and submission of fundable research proposals, research collaboration, and publication of results. COAS Institutional postdocs will be encouraged to seek external funding, and may serve as Principal Investigator or co-Principal Investigator on grant proposals. Requires completed Ph.D. degree in general area of Earth System Sciences or related field prior to appointment.

We encourage applicants to contact COAS faculty members with research interests fitting the proposed work. Position announcement: http://www.coas.oregonstate.edu/. To apply http://oregonstate.edu/jobs, posting 0007139. For questions contact Dr. Eric Skyllingstad: skylling@coas.oregonstate.edu, 541-737-5697. Information may also be found at http://www.coas.oregonstate.edu/index.cfm?content.display&pageID=763. For full consideration apply by June 1, 2011. OSU is an AA/EOE.

Tenure Track Positions: Planetary Sciences. China University of Geosciences (Wuhan), a key national university with leading geoscience programs in China, invites applications for several positions at the levels of full professor, associate professor, or assistant professor in the broad field of planetary sciences. Emphasis will be placed on but not limited to: planetary geology, remote sensing, cosmo-geochemistry, astrobiology and exploration instrumentation. Hiring levels and compensations will be commensurate with qualifications which include a Ph.D. in planetary science or a related field, a record of publications in refereed journals, and proposal development experiences. Each successful candidate is expected to develop

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a vigorous and externally funded program that involves graduate research. We will also sponsor the qualified applicants to apply for the various state and province supported start-up projects such as the "Thousand-Talents Project" and "Chutian Scholar Project". Interested individuals should send a resume, statements of research and teaching interests, and representative reprints and name and contact information of at least three potential references. Send applications to: Dr. Hao Zhang, Research Center for Space Science and Technology, China University of Geosciences, 388 Lumo Road, Hongshan District, Wuhan, Hubei Province, 430074, China. E-mail: zhanghao@cug.edu.cn.

Three Post-doctoral Research Scientists. N.C. State University, Raleigh, N.C. is accepting applications for 3 Post-Doc. positions. Atmospheric Chemistry/Aerosol Modeler in 3-D air quality modeling with a focus on aerosol chemistry & dynamics. Earth System Modeler in Earth system modeling with foci on aerosol-cloud-precipitation interactions & coupling of component models. Regional Hydrology & Forest Ecosystem Modeler in hydrology & forest ecosystem modeling with foci on integrating climate, air quality, hydrology, water quality, & forest ecosystems. To apply visit: http://jobs.ncsu.edu Position #: 102075, 102076, & 102074. Contact: Dr. Y. Zhang (yzhang9@ncsu.edu) for details.

UNESCO International Geoscience Programme Secretary and Global Earth Observation Section Chief. Assume the overall responsibility to develop and implement UNESCO's international geology, geophysics and Earth observation programmes. For the full vacancy posting, go to: https://recrutweb.unesco.org/pdf/SC330.PDF.

Visiting Assistant Professor. The Department of Geological Sciences at Indiana University seeks applicants for a Visiting Assistant Professor position in the field of sedimentary geology to begin on August 1, 2011. Candidates must have a Ph.D., prior teaching experience, and an ongoing program of research that complements or enhances current strengths of the Department. The appointee will be expected to teach graduate courses in one or more of the following areas: depositional systems, basin analysis, and petroleum geology. Teaching duties may also include sedimentology/stratigraphy at the undergraduate level, and a section of an established introductory course for non-science majors. Instructional responsibilities will not exceed two courses per semester. Salary and funds in support of research activities will be based on academic record. An additional stipend for summer teaching and an extension of the position for a second year are also possible. Our Department anticipates permission to search for an endowed tenure-track position in sedimentary geology in the near future.

Review of applications will start May 31, 2011, and continue until the position is filled. Applicants should submit a curriculum vitae, plus concise teaching and research statements (less than two pages), and contact information for at least three referees. Applications should be submitted electronically via e-mail to geochair@indiana.edu citing VAP Application as the subject line.

You may submit paper applications to: Dr. Simon Brassell, Geological Sciences, Indiana University, 1001 E. 10th Street, Bloomington, IN 47405.

Indiana University is an Affirmative Action/Equal Opportunity Institution M/F/D. The university promotes cultural diversity with regard to gender, race, ethnicity, nationality, sexual orientation, and religion.

Visiting Professor-Bowdoin College. The Bowdoin College Department of Earth and Oceanographic Science invites applications for a one-year (with possible extension), full-time, visiting assistant professor position. Ph.D. required. Three-course load (includes environmental geology and hydrology, geomorphology, and one other).

Please visit: https://careers.bowdoin.edu to apply.

Bowdoin College is committed to equality through Affirmative Action, and is an equal opportunity employer. For a full text description of the above position and for further information about the college, please visit our website at: www.bowdoin.edu.

STUDENT OPPORTUNITIES

Ph.D./M.Sc. Graduate Research Assistanceship (2 Ph.D. Positions, 3 M.Sc.). Research assistantships are available in the area of Environmental Geochemistry. Seeking motivated students interested in multidisciplinary research investigating metal contaminants behaviour (novel isotope tracers and applied geomicrobiology) associated with novel natural & anthropogenic disturbed ecosystems and wetlands. Projects are laboratory-based and/or contain field components and involve access to state-of-the-art analytical instrumentation. Synchrotron-based X-ray techniques, electron microscopy for the characterization of samples and metal speciation. Please Contact: Dr. Christopher G. Weisener, weisener@uwindsor.ca; University of Windsor, Spring/Fall 2011.

Ph.D. Positions in Volcanic Geology and Hazards at the University of Auckland. The School of Environment at the University of Auckland, New Zealand, invites applications for two Ph.D. positions: 1. Volcanic Geology and 2. Volcanic hazard analysis of Harrat Al-Madinah, a Quaternary basaltic volcanic field in western Saudi Arabia. These Ph.D. projects form key components of a research collaboration with the King Abdulaziz University in Saudi Arabia. To apply, please e-mail your CV and the names of three referees to Jan Lindsay (j.lindsay@auckland.ac.nz).

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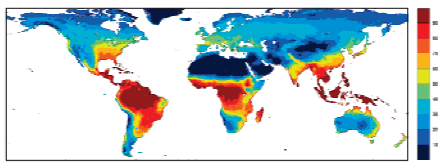
United States Polar Rock Repository. Rock samples are available as no-cost loans for research, teaching & museum use, http://bprc.osu.edu/emuwebusprr.

RESEARCH SPOTLIGHT

Highlighting exciting new research from AGU journals

Comparing different land surface heat flux estimates

Land surface heat fluxes are an important component of Earth's energy and water cycle, and quantifying these fluxes can help scientists better understand climate change. These heat fluxes are affected by factors such as cloud cover, precipitation, surface radiation, air temperature, and humidity. Different methods are used to estimate monthly mean land surface heat flux.



As part of an intercomparison study of different land surface heat flux products, researchers created this map showing the all-product annual average land surface latent flux (in watts per square meter) for 1994.

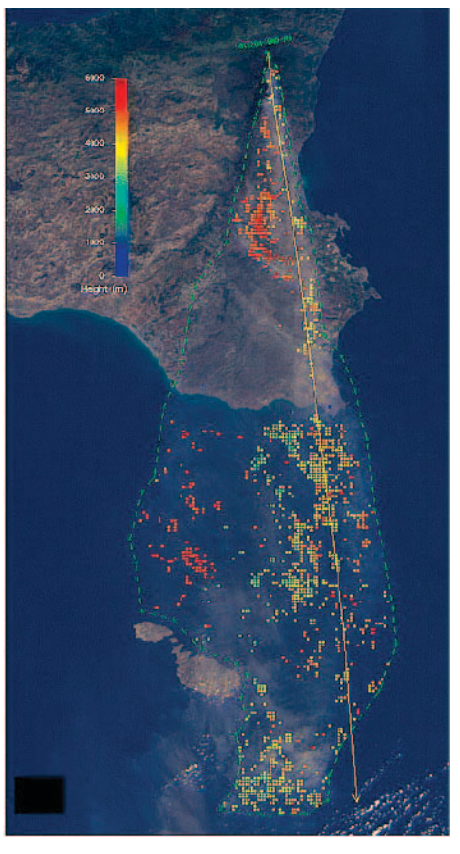
To determine how well these different methods agree with one other, *Jiménez et al.* present a detailed global intercomparison of 12 such products for the period 1993–1995. Some of these products are based on combining global satellite-based data and physical formulations, while others come from atmospheric reanalysis and land surface models. The authors found that although there were some differences among the products, the products all captured the seasonality of the heat fluxes as well as the expected spatial distributions related to major climatic regimes and geographical features. Furthermore, the products correlate well with each other in general, in part due to large seasonable variability and the fact that some of the products use the same forcing data. (*Journal of Geophysical Research-Atmospheres,* doi:10.1029/2010JD014545, 2011) —ET

Three-dimensional ash cloud observations could help aviation

In the spring of 2010 the Icelandic volcano Eyjafjallajökull erupted, sending a towering column of ash floating above the North Atlantic Ocean. The ash cloud shut down air traffic over much of Europe, significantly affecting the European economy. Although Eyjafjallajökull was one of the more recent, prominent displays of the effects of volcanic ash, similar disturbances are felt in the shadows of active volcanoes the world over.

To ensure the safety of both planes and passengers, regulators rely on ash cloud dispersal models to forecast areas that might be affected by an active volcano. The models use measurements of meteorological conditions and ground-or satellite-based observations of ash plumes to forecast the expected path and size of the cloud. Unfortunately, the two-dimensional plume observations used as inputs typically lack information that could significantly improve the forecast, such as details of the volcanic cloud's vertical extent.

In an attempt to improve forecasting accuracy, *Scollo et al.* used observations from the Multiangle Imaging Spectroradiometer (MISR) to produce three-dimensional reconstructions of ash cloud geometry. MISR, which flies aboard NASA's polar-orbiting Terra satellite, takes images across multiple angles and wavelengths using a suite of nine cameras and can be used to derive plume height, erupted mass, and the size distribution of fine particles—among the most sensitive inputs for ash dispersal modeling. The researchers found good agreement between observations made by MISR and model simulations produced using independent two-dimensional field data of two past eruptions of Mount Etna, a volcano in Italy. These results lend credence to the idea of using MISR for improving the reliability of particle dispersion forecasts and helping to mitigate the threat of volcanic eruptions to aviation. (*Journal of Geophysical Research-Atmospheres,* doi:10.1029/2009JD013162, 2010) —CS



Multiangle Imaging Spectroradiometer view of the Mount Etna volcano plume on 27 October 2002. The image shows wind-corrected heights (color coded), the digitized plume outline (green line), and the average wind direction (yellow line).

Low solar irradiance may not be the primary driver for the Little Ice Age

Total solar irradiance (TSI), essentially a measure of the amount of light the Sun puts out, varies with the 11-year sunspot cycle and influences Earth's climate, especially when TSI is notably higher or lower than its average values. It had been thought that TSI was especially low during a period known as the Little Ice Age, which began in the late seventeenth century and coincided with a period of unusually low sunspot activity known as the Maunder Minimum. However, *Schrijver et al.* now suggest that TSI during that period may not have been as low as previously thought. They analyzed direct measurements of solar magnetic activity during the recent 2008–2009 period of low sunspot activity, which they argue was similar to the activity level during the Maunder Minimum.

They found that even when there were no sunspots, the Sun had a baseline level of magnetic activity. This baseline had not been taken into account in previous estimates of TSI during the Maunder Minimum, which were based solely on sunspot numbers. Therefore, the authors suggest that earlier estimates of the TSI during the Maunder Minimum were too low. The researchers argue that the Maunder Minimum probably had levels of magnetic activity and TSI similar to 2008–2009 values, and therefore factors other than low solar irradiance resulting from low sunspot activity must have contributed to the Little Ice Age. (*Geophysical Research Letters*, doi:10.1029/2011GL046658, 2011) —ET

The traveling rings of the North Brazil Current

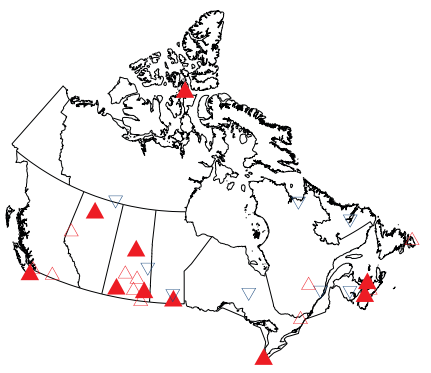
The North Brazil Current (NBC) moves northward along the northeastern coast of Brazil. Drawing from the South Equatorial Current and the outflow of freshwater from the Amazon River, the NBC carries warm, nutrient-rich water north of the equator. Up near the coast of French Guiana, part of the NBC makes a hard right, flowing east along the equator. Once in a while the turn is especially sharp and the current loops around, pinching off an independently traveling parcel of ocean water. This portion of current travels northwest with a clockwise rotation, moving through the ocean like a Frisbee™ travels through air.

These current rings have been known to exist for decades, but knowledge of their basic properties such as size, speed, depth, and rotation velocity is limited. Drawing on current profiles from both shipboard and stationary instruments, *Castelão and Johns* describe the basic properties of 10 rings sampled between 1998 and 2000. The authors find that the rings are best described as solid, clockwise-rotating parcels of water enclosed within a band of lower-speed water that tends to shield them from the surrounding environment.

For many of the rings the sea surface height increases parabolically toward the center, reaching to 38 centimeters above the surrounding ocean. The inner core can be more than 300 kilometers across, and the outer edge of the core can have a maximum speed of more than 1 meter per second. Overall, the NBC rings seem to be bigger, faster, and taller than previous observations suggested. (*Journal of Geophysical Research-Oceans,* doi:10.1029/2010JC006575, 2011) —CS

Soil temperature trends in Canada

Global warming increasingly is becoming a concern for society. Most reported warming trends are based on measured increases in air temperatures. However, trends in soil temperatures, also an important indicator of climate change, are less often reported. *Qian et al.* analyzed soil temperature data from 30 climate stations across Canada covering the period from 1958 to 2008; the data cover soil temperatures at several depths up to 150 centimeters. They also analyzed air temperature, precipitation, and snow cover depth at the same locations.



Trends of monthly mean soil temperature across Canada in May at a depth of 100 centimeters for the period 1958–2008. Red and blue triangles show positive and negative trends, respectively. Solid triangles indicate trends significant at the 5% level.

During that time period, rising soil temperatures were generally associated with rising air temperatures, and snow cover depth generally decreased, although there were variations between the sites. The researchers found that at about two thirds of the stations, soil temperatures at depths below 5 centimeters showed a warming trend over the 50-year record. Many sites showed a significant positive trend in average spring and summer soil temperatures but not in winter soil temperatures. Because snow insulates the ground, keeping soil warm, the trend of declining snow depth explains why winter soil temperatures did not show a warming trend. The median warming rate in spring for soil at all depths was about 0.3°C per decade. (*Journal of Geophysical Research-Atmospheres,* doi:10.1029/2010JD015012, 2011) —ET

—Colin Schultz and Ernie Tretkoff, Staff Writers