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Capturing the Acoustic Fingerprint of Stratospheric Ash Injection

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More than 100 separate incidents of interactions between aircraft and volcanic ash were documented between 1973 and 2003. Incidents on international flight paths over remote areas have resulted in engine failures and significant damage and expense to commercial airlines. To protect aircraft from volcanic ash, pilots need rapid and reliable notification of ash-generating events. A global infrasound array network, consisting of the International Monitoring System (IMS) and other national networks, has demonstrated a capability for remote detection of Vulcanian to Plinian eruptions that can inject ash into commercial aircraft cruise altitudes (approximately 12 kilometers) near the tropopause. The identification of recurring sound signatures associated with high-altitude ash injection implies that acoustic remote sensing can improve the reliability and reduce the latency of these notifications.

Eruptions release excess pressure within volcanoes, and infrasound sensors capture the inaudible atmospheric pressure waves induced by eruptions. Seismometers record ground vibrations and are most responsive to subsurface volcanic activity, though the relationship between seismicity and volcanic ash emissions is complex and not fully understood. Satellite remote sensing techniques are currently the primary means of identifying and tracking volcanic ash, in conjunction with volcano observatories and aircraft pilot reports. Cloud cover and sampling interval limitations can interrupt satellite remote sensing data, while acoustic sensors record eruptive activity even when the volcano is visually obscured by clouds. A combination of seismic, satellite, and infrasound coverage can decrease ambiguity between subterranean and surface activity and reduce uncertainty in the timing and intensity of eruptions.

Volcano monitoring is one of various natural hazards applications of the technology developed for the IMS infrasound array network [*Hedlin et al.*, 2002]. As the IMS infrasound network has expanded to 39 operational arrays, it has captured a growing collection of acoustic signals from volcanoes tens to thousands of kilometers away from monitoring stations [e.g., *Le Pichon et al.*, 2005]. As a result, the International Civil Aviation Organization (ICAO) expressed an interest in the potential of global and regional infrasound networks to provide eruption notifications to the aviation community through the existing international Volcanic Ash Advisory Center (VAAC) framework (http://www.ssd.noaa.gov/VAAC/vaac.html). Because data distribution and latency issues may complicate the release of IMS data for practical operational use, international groups in the United States, Canada, Ecuador, France, and Australia are collaborating in the design of prototype low-latency infrasound surveillance systems specifically tailored to the needs of the aviation community [*Garcés et al.*, 2007].

Robust, Low-Latency Acoustic Monitoring Over Regional Distances

One of the key monitoring goals is to distribute operationally useful notifications

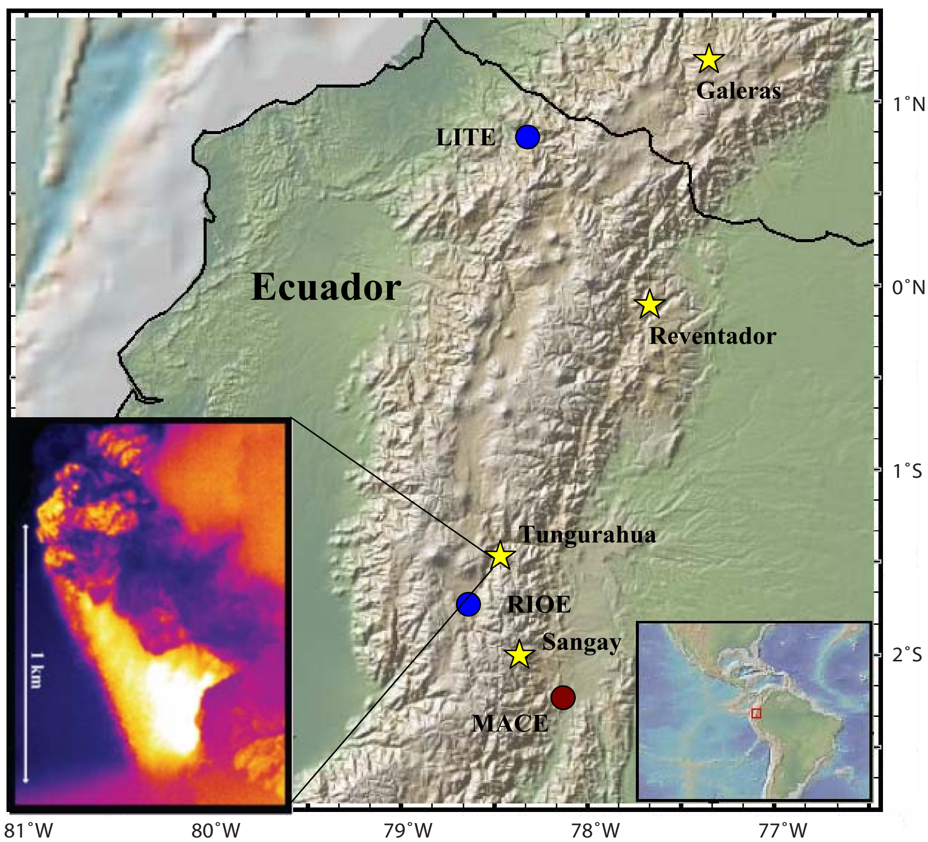

Fig. 1. Location of prototype seismoacoustic station deployments in Ecuador. The blue circles denote four-element infrasound arrays with colocated wind sensors and two components of a broadband seismometer. The red circle is a broadband seismometer. The yellow stars show the locations of recently active volcanoes. The inset to the left is an infrared image of Tungurahua volcano taken on 17 August 2006 at 0451:22 UT, showing the incandescent eruption column that injected volcanic ash into the stratosphere (image courtesy of the Instituto Geofísico, Escuela Politécnica Nacional).

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to VAACs within 5–20 minutes of an eruption that could threaten air traffic. In contrast to most ground-based volcano surveillance systems, infrasound arrays may be sited tens to hundreds of kilometers away from the devastation zones of erupting volcanoes, offering coverage over broad areas while improving personnel safety and operational continuity during eruptive episodes. On the basis of ongoing automatic data processing for stations at ranges of approximately 10, 40, and 250 kilometers, real-time processing can produce eruption notifications in 2.5, 4, and 17 minutes, respectively. Recent studies have shown that Vulcanian, sub-Plinian, and Plinian eruptions can be consistently detected by regional and distal stations in the global infrasound network (see http://www.isla.hawaii.edu/volcano/iwars06.php). For telesonic ranges, latency increases to about 1 hour per 1000 kilometers of distance of a station from a volcano.

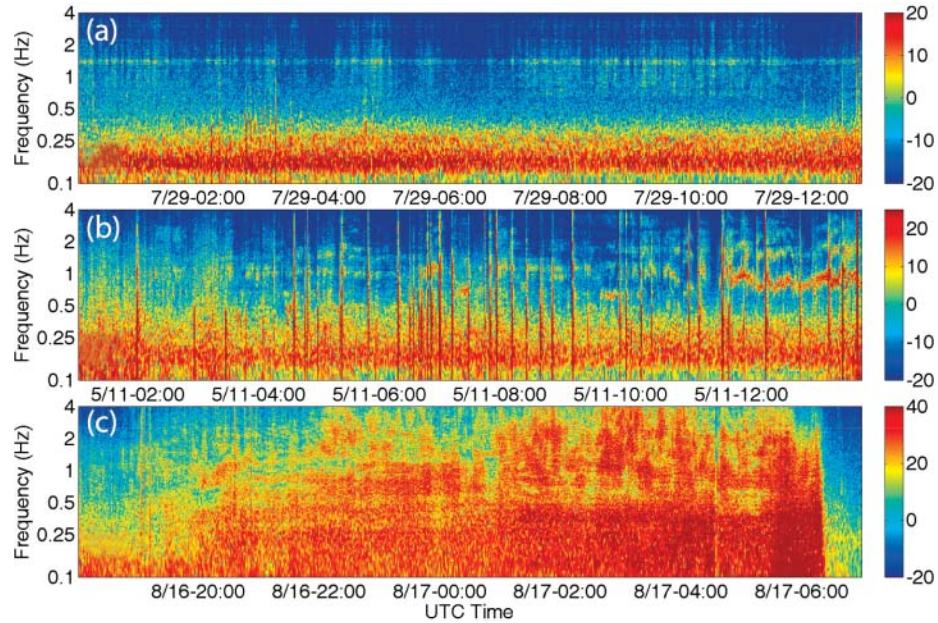

Fig. 2. Spectrograms for three different eruption styles seen at Tungurahua in 2006. The horizontal axis represents 13 hours of data, and the vertical scale shows frequency in a logarithmic scale from 0.1 to 4 hertz. The color denotes acoustic power in decibels referenced to 1 pascal squared per hertz. Ocean noise shows up in Figures 2a and 2b as a red band centered about 0.2 hertz; it is not of volcanic origin. Explosive events appear as intense vertical bands. Figure 2a shows the infrasonic levels for low activity, with continuous infrasonic tremor at 1.4 hertz. Figure 2b shows a moderate level of eruptive activity, corresponding to explosions and harmonic tremor during an ash-poor eruption. Figure 2c shows high activity levels, corresponding to the onset of a Vulcanian eruption after 1900 UT on 16 August 2006 and transitioning into Plinian after 0500 UT on 17 August 2006. Note the change in power levels in Figure 2c due to acoustic pressures an order of magnitude greater than low (Figure 2a) and moderate (Figure 2b) eruption levels.

Prototype System Design and Testing

Most acoustic studies have concentrated on Strombolian and mild Vulcanian eruptions [e.g., *Harris and Ripepe*, 2007] because of their relative abundance. However, a different approach would be used to target larger Vulcanian to Plinian ash-laden columns that may threaten aircraft. *Matoza et al.* [2007] describe prototype autonomous stations consisting of a four-element infrasound array with an aperture of about 100 meters, a broadband seismic sensor, and a wind sensor. A satellite dish sends real-time data from remote locations to collaborating parties. In October 2004, shortly after the onset of the latest activity of Mount St. Helens, two of these prototype stations were deployed approximately 13 and 250 kilometers away from the volcano. The remarkably aseismic eruption of 16 January 2005 and the explosive, steam-rich eruption of 8 March 2005 were captured in their entirety by the arrays [*Matoza et al.*, 2007], confirming the potential to monitor eruptive activity at regional distances.

Garcés et al. [2007] describe the deployment of similar stations in Ecuador (Figure 1). Two infrasound arrays were sited to permit detection within 15 minutes of volcanic eruptions in Ecuador and southern Colombia, and as early as 5 minutes for volcanoes within 40 kilometers of an array. In a period of 2 years, these two arrays recorded eruption signals from Tungurahua, Sangay, Reventador, Galeras, and Nevado del Huila volcanoes. However, the acoustic activity accompanying the destructive July and August 2006 eruptions of Tungurahua volcano was exceptionally relevant. Satellite imagery confirmed that both of these eruptions injected ash above a height of 14 kilometers. These Vulcanian to Plinian eruptions produced powerful infrasonic signals that were recorded clearly by both arrays in Ecuador, by near-field networks [*Kumagai et al.*, 2007], and by at least one IMS array. The distinct acoustic signatures produced by high-altitude ash injection were used to train detection algorithms, which successfully triggered automatic eruption notifications to the VAACs during the 6 February 2008 Vulcanian eruption of Tungurahua.

Acoustic Fingerprint of Stratospheric Ash Injection

Array processing is the most effective method for identifying sounds originating from the known direction of a volcano. To minimize the effects of geometrical spreading and topography, the acoustic energy estimated from the array detections can be compared with that of a selected reference event. The energy ratio between the signal of interest and the reference event is used to define an intensity threshold that activates an eruption notification to the VAACs. This method may be used to automatically trigger on eruptive events and produce near-real-time notifications of large explosions and changes in tremor levels, as well as to compile daily volcano infrasound summaries that include events below the notification threshold.

At least three distinct types of eruption signatures were characterized at Tungurahua in 2006 (Figure 2) and used to define event trigger levels. Observations from the Instituto Geofísico (IG), Escuela Politécnica Nacional, in Ecuador, and ash height information from satellite data and pilot reports were used to classify the eruptions. The first and most common eruption style is low ash-producing background tremor with a dominant frequency of 1.4 hertz (Figure 2a). Ash injection to the atmosphere during this eruptive stage is associated with atmospheric stability and plume convection.

During mid-May 2006, a second type of eruptive regime was exhibited when volcanic activity increased and transitioned toward large explosions followed by harmonic tremor (Figure 2b). This type of eruptive regime was characterized as ash-poor and gas-rich by the IG and satellite observations, and it represents a moderate level of activity.

The third eruptive type corresponds to intense Vulcanian to Plinian eruptions and defines the acoustic fingerprint of stratospheric ash injection. On 14 July 2006 a large Vulcanian eruption produced dangerous pyroclastic flows, substantial ash clouds, and a drastic increase in tremor. During 16–17 August 2006, a larger Vulcanian to Plinian eruption (Figure 2c) was characterized by lethal pyroclastic flows, a larger stratospheric ash cloud, and powerful infrasonic tremor. As the eruption intensified to Plinian, acoustic energy shifted to much deeper frequencies, reaching a peak power level of approximately 10 megawatts between 0.06 and 0.1 hertz during its paroxysmic stage. The acoustic fingerprints of the two major July and August 2006 eruptions are easily identifiable in infrasonic records due to the vast amount of energy present over a broad band of frequencies. The seismic records of the two major eruptions appear to have a significantly different spectral signature, suggesting seismoacoustic decoupling. These two eruptions injected a substantial amount of ash into the atmosphere. We used these eruption signals to define a high level of activity, which would automatically trigger an eruption notification to the VAACs.

Using the principles described in this article, a prototype autonomous notification system was successfully triggered on 6 February 2008 during a climactic Vulcanian eruption sequence at Tungurahua that had been preceded by months of explosive activity. Because of the relative proximity of the RIOE infrasound array to Tungurahua (37 kilometers; Figure 1) and lessons learned from previous eruptions, the capacity to deliver notifications within 5 minutes of substantial changes in eruptive activity was demonstrated.

The Future: Test Operations

This article describes how acoustic remote sensing may complement seismic observations and satellite remote sensing to improve continuous monitoring of wide regions of potential eruption hazard. The acoustic sensing techniques described have been used as prototypes by the Acoustic Surveillance for Hazardous Eruptions (ASHE) project [*Garcés et al.,* 2007]. The ASHE prototypes presently produce automated notification products on a test basis to a participating ICAO-designated VAAC for comparison against, and possible integration with, its existing warning systems. These notifications are coupled with more detailed real-time data products (presently provided in designated Web pages), and they could be used by volcano observatories to disseminate updated information.

On the basis of acoustic records captured during the Vulcanian to Plinian eruptions of Tungurahua volcano, source parameters that may be estimated during large eruptions include (but may not be limited to) the height probability, start time, and duration of an ash cloud injection that could pose a hazard to international carriers at cruising altitudes. The possibility of inferring these source parameters even at greater distances was suggested by the recognizable acoustic fingerprints of the summer 2008 eruptions of Okmok and Kasatochi volcanoes in the remote Aleutian Arc of Alaska. These eruptions were recorded at distances of 1700–4500 kilometers by infrasound arrays in Fairbanks, Alaska, Washington state; Hawaii; Russia, and Japan.

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NEWS

Temporary Seismic Broadband Network Acquired Data on Hellenic Subduction Zone

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Data acquired from a network of seismic broadband stations that recently operated in the eastern Mediterranean region will be made available to the seismological community after the project concludes, in June 2011. The network, which consisted of both land and ocean bottom seismographs, functioned from October 2005 until its deinstallation in March 2007 as part of the Exploring the Geodynamics of Subducted Lithosphere Using an Amphibian Deployment of Seismographs (EGELADOS) project (Figure 1). The network, which covered the entire southern Aegean Sea from the Peloponnesus region in the west to western Turkey in the east, was designed to study seismicity as well as the distribution of the elastic and anelastic material properties in the Hellenic subduction zone to better understand its complex geotectonic setting and evolution.

The network encompassed 45 Güralp 60-second seismometers, four Streckeisen STS-2 seismometers, and seven 1-hertz Mark seismometers at land sites. The seismometers were supplemented by 22 ocean bottom seismographs equipped with Güralp 60-second seismometers and broadband hydrophones. In addition, the network was designed to incorporate the seven permanent broadband seismographs of the GeoForschungsNetz (GEOFON) network and one Mediterranean Very Broadband Seismographic Network (MedNet) station.

Selected data of regional seismological permanent networks operated by the National Observatory of Athens and the Kandilli Observatory in Istanbul, Turkey, have been integrated into the data set. The acquired data are archived at the GEOFON data center at GeoForschungsZentrum Potsdam. For more information, visit http://www.geophysik.ruhr-uni-bochum.de/research/egelados/index.html.

The principal investigators of the EGELADOS project are the authors as well as collaborators with a number of institutions, including Geophysical Laboratory, Aristotle University of Thessaloniki (Greece); Department of Geophysical Engineering, Istanbul Technical University (Turkey); Institute of Geodynamics, National Observatory of Athens (Greece); Institute of Geophysics, University of Hamburg (Germany); GeoForschungsZentrum Potsdam (Germany); and the Technical University of Crete (Greece). Funding for the project and the network is provided by the German Science Foundation (Deutsche Forschungsgemeinschaft).

The complete list of collaborators is available in the electronic supplement to this *Eos* issue (http://www.agu.org/eos_elec/).

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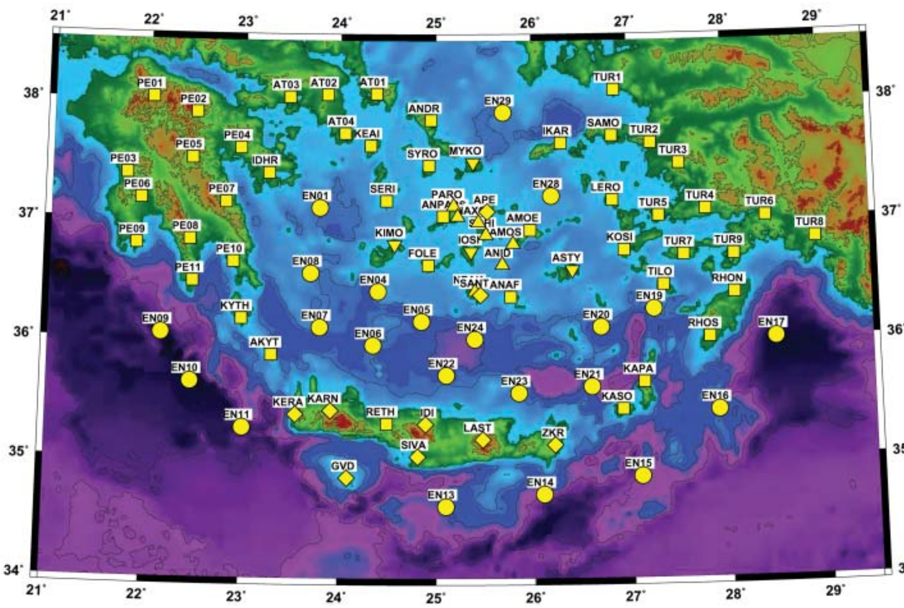

Fig. 1. Map of the locations of the seismographs of the Exploring the Geodynamics of Subducted Lithosphere Using an Amphibian Deployment of Seismographs (EGELADOS) network. Squares indicate broadband stations with Güralp 60-second seismometers; upright triangles indicate 1-hertz seismometers; inverted triangles indicate Streckeisen STS-2 seismometers; diamonds indicate GeoForschungsNetz (GEOFON) and Mediterranean Very Broadband Seismographic Network (MedNet) stations; and circles indicate ocean bottom seismographs.

In Brief

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Montgomery chosen as MacArthur Fellow David Montgomery, a professor in the Department of Earth and Space Sciences at the University of Washington, Seattle, was selected as a MacArthur Fellow, the John D. and Catherine T. MacArthur Foundation announced on 23 September. A geomorphologist, Montgomery was cited for "making fundamental contributions to our understanding of the geophysical forces that determine landscape evolution and of how our use of soils and rivers has shaped civilizations past and present."

Montgomery, an AGU Fellow, is author of *King of Fish: The Thousand-Year Run of Salmon* (2003) and *Dirt: The Erosion of Civilizations* (2007). He is the nineteenth AGU member to be selected as a MacArthur Fellow since 1982. Each fellow receives $500,000 in "no strings attached" support over the next 5 years.

Marine debris plan A new U.S. federal interagency report on preventing and reducing marine debris focuses on responses to debris already in the environment, prevention of debris, research and development, and coordination among agencies. The report, released on 22 September, was prepared by 11 federal agencies and is intended to guide the strategies of federal agencies and the Interagency Marine Debris Coordinating Committee. The report is available at http://ocean.ceq.gov/about/docs/SIMOR_IMDCC_Report.pdf.

—Randy Showstack, Staff Writer

GEOPHYSICISTS

Karen L. Von Damm (1955–2008)

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Karen L. Von Damm, a professor and world-renowned researcher in marine geochemistry at the University of New Hampshire, passed away at her home in Durham on 15 August 2008, after having been diagnosed with liver cancer in April 2008. She was 53 years old.

Karen received her B.S. degree in geology and geophysics in 1977 from Yale University, where she completed a senior thesis in geochemistry under the mentorship of Karl Turekian. Karen's graduate studies were at the Massachusetts Institute of Technology (MIT) and Woods Hole Oceanographic Institution (WHOI) Joint Program in Oceanography, under the supervision of John Edmond. She received her Ph.D. in oceanography from MIT/WHOI in 1983. Her Ph.D. dissertation described the fluid chemistry of the first deep-sea high-temperature "black smoker" hydrothermal vents to be sampled on the mid-ocean ridge (on the East Pacific Rise at latitude 21ºN, and in Guaymas Basin, Gulf of California).

She subsequently spent 2 years as a National Research Council postdoctoral associate in the laboratory of James L. Bischoff at the U.S. Geological Survey in Menlo Park, Calif. There, she conducted experiments to determine the solubility of quartz in seawater at elevated temperatures and pressures. These experimental results permit accurate quartz geobarometry calculations of the depths of water-rock interaction in submarine hydrothermal systems. Karen then spent 4 years as a staff geochemist and environmental scientist at the Oak Ridge National Laboratory, in Knoxville, Tenn. She concurrently was a research associate professor at the University of Tennessee at Knoxville, where she continued her research on mid-ocean ridge hydrothermal systems.

Since 1992, Karen was on the faculty at the University of New Hampshire (UNH), in Durham, as a professor of geochemistry in the Department of Earth Sciences and as a researcher at the Institute for the Study of Earth, Oceans and Space. She also served briefly as an assistant director of UNH's Complex Systems Research Center.

Karen's seagoing and laboratory research forms the cornerstone of our understanding of seafloor hydrothermal systems. Her work was crucial to the spectacular advances made in this field since the discovery of scalding "black smoker" hot springs on the mid-ocean ridge in 1979. The exploration of hydrothermal vents along the mid-ocean ridge was one of the most important developments in marine science during the last quarter of the twentieth century, because this research changed preexisting paradigms for the chemical budget of the oceans, the accretion of oceanic crust along the mid-ocean ridge, the biology of the deep sea, and the origin of life on earth. Much of what was learned depended directly or indirectly on accurate measurements of the temperatures and compositions of vent fluids, which were made by Karen and her students and coworkers on samples collected in three oceans (the Pacific, Atlantic, and Indian) during hundreds of submersible dives to the deep ocean floor. Karen's careful analyses and innovative data interpretation were groundbreaking contributions that illuminated links between the chemical, physical, geological, and biological processes controlling marine hydrothermal fluid properties and chemical fluxes.

Karen L. Von Damm

Since 1991, Karen had been engaged in exciting studies of how the fluid chemistry at hydrothermal vents changes with time before, during, and after mid-ocean ridge volcanic eruptions. She and her colleagues monitored the East Pacific Rise (EPR) at latitude 9º–10ºN, which is the only location on the mid-ocean ridge where two successive volcanic eruptions have been observed (in 1991–1992 and 2005–2006), and is one of only three "Integrated Study Sites" being studied under the auspices of the U.S. National Science Foundation's Ridge 2000 program.

There, she demonstrated the dramatic initial impact of subseafloor phase separation on hydrothermal vent fluid compositions; the rapid deepening of water-rock reactions as the dike feeding the 1991–1992 eruption was chilled downward by hydrothermal circulation; the change from condensed vapor phase vent fluid compositions to conjugate brine phase compositions as fluid circulation deepened following the 1991–1992 eruption; and the shift back to vapor phase vent fluid compositions as fluid circulation shoaled prior to the 2005–2006 eruption. On the basis of this shift back to vapor phase compositions, Karen correctly predicted that the 2005–2006 eruption was imminent. She also used vent fluid compositions to distinguish a seismically detected cracking event from magmatic intrusion events on the EPR; to constrain vent fluid properties near the critical point; to constrain subseafloor water-rock reactions; to investigate the origin of diffuse hydrothermal fluids; and to link temporal changes in fluid compositions to observed changes in microbial and macrofauna communities at EPR hydrothermal vents.

Karen was highly committed to teaching thousands of UNH undergraduate students in oceanography and geochemistry courses, and to careful training of her graduate students and postdoctoral associates. She also was dedicated to sharing her science with K-12 teachers and students. In these capacities, she was a powerful role model, particularly for young female scientists. In addition to the many research articles Karen published in scientific journals, expeditions in which she participated have been featured in venues for the general public, including educational broadcasts on public television, IMAX films, Internet Web sites, and an ocean science encyclopedia. At the national level, she served as chair of the Ridge Steering Committee from 1995 to 1998. More recently she served on the U.S. National Science Foundation's Geoscience Advisory Board and as chair of a committee to design a 21st-century research submersible for the U.S. science community. She is held in highest esteem by her students and by her colleagues at UNH and around the world.

In 2002, Karen was elected an AGU Fellow for her "unparalleled contributions to exploring and understanding the chemistry of submarine hydrothermal systems, and for her leadership and service to the mid-ocean ridge scientific community." In 2008, she also was elected Fellow of both the European Association of Geochemistry and the Geochemical Society.

Karen conducted her extensive teaching and research despite lifelong health problems. She was brilliant and dauntless, and had great intellectual and personal integrity. Karen will be missed by the many people whose lives and work were influenced by her and by her contributions to science. She is survived by her mother, Louise, who supported and nurtured Karen through her career and illness.

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LETTERS

Comment on "Unraveling the Causes of Radiation Belt Enhancements"

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The excellent article by M. W. Liemohn and A. A. Chan on the radiation belts (see *Eos, 88*(42), 16 October 2007) is misleading in its implication that the disturbance storm-time (*Dst*) index is an indicator of a magnetospheric ring current. That index is formed from an average of magnetic data from three or four low-latitude stations that have been fallaciously "adjusted" to a magnetic equatorial location under the 1960's assumption [*Sugiura*, 1964] that the fields arrive from the growth and decay of a giant ring of current in the magnetosphere. In truth, the index has a negative lognormal form [*Campbell*, 1996; *Yago and Kamide*, 2003] as a result of its composition from numerous negative ionospheric and magnetospheric disturbance field sources, each having normal field amplitude distributions [*Campbell*, 2004]. Some partial ring currents [*Lui et al.*, 1987] and their associated field-aligned currents, as well as major ionospheric currents flowing from the auroral zone to equatorial latitudes, are the main contributors to the *Dst* index. No full magnetospheric ring of currents is involved, despite its false name ("Equatorial *Dst* Ring Current Index") given by the index suppliers, the Geomagnetism Laboratory at Kyoto University, Japan.

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Reply to Comment on "Unraveling the Causes of Radiation Belt Enhancements"

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Numerous current systems contribute to the magnetic perturbations used to calculate the *Dst* index. Ionospheric and field-aligned current effects are minimized, although not always well [e.g., *Friedrich et al.*, 1999], by averaging measurements from a worldwide chain of low-latitude stations. The index is imperfect, but it has been shown that Biot-Savart magnetic perturbations from magnetospheric currents derived from in situ particle observations can account for most of the *Dst* variation [*Greenspan and Hamilton*, 2000; *Turner et al.*, 2001; *Jorgenson et al.*, 2004].

Lognormal distributions occur when many independent perturbations are initiated together but with each having a different growth and decay timescale. *Liemohn and Kozyra* [2003] showed that this scenario describes the ring current. The storm-time ring current (at first partial, eventually symmetric) can be thought of as a collection of many small currents created by the trajectories of the individual streams of particles swarming through the inner magnetosphere. These particles take different times to convect through the region and have different collisional decay lifetimes, depending on particle species, pitch angle, energy, and injection location. Therefore, although the *Dst* index is known to be flawed, we maintain that there is a significant link between *Dst* and the ring current.

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MEETINGS

First Coastal Altimetry Workshop

Cooperative Institute for Oceanographic Satellite Studies/National Oceanic and Atmospheric Administration Coastal Altimeter Workshop; 5–7 February 2008, Silver Spring, Maryland

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Satellite radar altimeter measurements of sea surface height (SSH), significant wave height, and wind speed have many potential applications in coastal zones, despite the common perception that altimetry does not "work" near the coast. The altimeter's primary measurement, the radar travel time from the spacecraft to the sea surface, is reliable seaward of 10 kilometers from the coast, and sometimes closer. The Ocean Surface Topography Mission altimeter on Jason 2, launched on 20 June 2008, has a new tracking mode that may recover more data in the coastal zone, and the launch of CryoSat 2 next year will demonstrate the coastal capabilities of a delay-Doppler altimeter. Turning radar travel time into accurate SSH requires ancillary water vapor radiometer measurements that may become unreliable within 50 kilometers of the coast. Interpretation of SSH data in the coastal zone is complicated where tides and other SSH corrections may change abruptly over shallow coastal shelves or near land.

A workshop on coastal altimetry was convened to explore the challenges and opportunities of altimetry in the coastal zone. Fifty-five participants, primarily from U.S. and European institutions, attended. The workshop was sponsored by the U.S. National Oceanic and Atmospheric Administration (NOAA), NASA, and the Cooperative Institute for Oceanographic Satellite Studies at Oregon State University.

Experts in altimeter and ancillary data retrieval, high-resolution regional-scale modelers, and users of data and model outputs were assigned to work together in thematic teams and were charged with developing a consensus presentation on their theme in advance of the workshop. These theme presentations, available at http://cioss.coas.oregonstate.edu/CIOSS/altimeter_workshop.html, were then used to begin the discussion of each topic. Topics covered included tracking/retracking (improving the radar travel time measurement), wet troposphere (correcting radar travel time for delay by atmospheric water), tides, inverted barometer (the ocean's response to atmospheric forcing), sea state bias (error in SSH due to the instrument's response to wind and waves), wave height, data sets and management, and modeling and applications. There were no breakout groups or parallel sessions so that everyone participated in discussion of each theme.

The Centre National d'Études Spatiales (CNES) and the European Space Agency (ESA) have funded coastal altimetry programs; experts from the CNES Pistach and ESA Alticore and Coastalt programs presented their preliminary findings and future plans. Also represented was the ESA Samosa project, which is using the waveform simulator for the CryoSat 2 altimeter to study altimeter-coastline interactions in conventional and delay-Doppler modes. Funding-agency program managers offered their perspectives.

The workshop's findings, recommendations, and initial steps toward an error budget can be found in the electronic supplement to this *Eos* issue (http://www.agu.org/eos_elec/). A second coastal altimeter workshop will be held in Pisa, Italy, 6–7 November 2008 (see http://www.coastalt.eu/pisaworkshop08).

The information reported here does not constitute a statement of policy, decision, or position on behalf of NOAA or the U.S. government.

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Cultural Uses and Impacts of Fire: Past, Present, and Future

Analysis, Integration and Modeling of the Earth System (AIMES) Fourth Young Scholar's Network (YSN) Workshop; Boulder, Colorado, 14–18 July 2008

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Fire is a global phenomenon transcending social, economic, and political boundaries. Effective decision making regarding fire policies requires integrating knowledge of human, ecological, and climatic components of fire research over a range of spatial and temporal scales.

The Analysis, Integration and Modeling of the Earth System (AIMES) fourth Young Scholar's Network workshop brought together early-career researchers representing anthropology, archaeology, atmospheric science, climate modeling, ecology, fire management, geography, paleoclimate, political science, and remote sensing. Goals of the workshop were to explore the drivers, impacts, and feedbacks of human use of fires and to contextualize the management of fires.

The participants identified three important issues during the workshop. The first involves human use and the perception of fire. Although humans have used fire for millennia, public opinion about fire depends on geographic location and social, economic, and political factors. In many places, fire remains an essential landscape management tool, but it can also be associated with negative consequences such as deforestation, air pollution, and loss of livelihood. Meeting attendees agreed that because fire is both a natural process and a process readily altered by human management, public information campaigns must present a more nuanced message regarding this fundamental ecological process.

A second issue brought up at the meeting centered around the consequences of fire. The interplay of changing land use patterns, climate change, and invasive plant species contributes to significant uncertainties for fire management and the assessment of fire emissions. This lack of knowledge, combined with a poorly defined history of fire use and emissions, confounds accurate climate simulations. Participants suggested that cross-disciplinary research, blending local- to regional-scale information with paleofire and current fire data, offers the best method to understand fires in the Earth system.

A third point of discussion contemplated the future significance of fire for society. Fire management requires the integration of knowledge regarding historical anthropogenic fire use, the physical mechanisms controlling fire, and the ecological feedbacks of fire with vegetation and climate change. While management practices that alter the timing and intensity of fires can be effective, globally limiting fire is likely to be unsuccessful and an inappropriate method of reducing total anthropogenic emissions because it does not consider potential ecosystem feedbacks or the economic and cultural significance of fire in many parts of the world. Because fire emissions are a major component of the Earth system, meeting participants recommend that fires be fully incorporated into global climate models but that fire management goals and policy be composed on a regional level.

The Young Scholar's Network is an activity of the AIMES project of the International Geosphere-Biosphere Programme (IGBP). The workshop was supported by the National Science Foundation, the National Center for Atmospheric Research Advanced Studies Program, IGBP Past Global Changes (PAGES), and the Natural Environment Research Council. For more information, please visit http://www.aimes.ucar.edu/ysn.shtml.

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BOOK REVIEW

Science for Agriculture and Rural Development in Low-Income Countries

R. P. Roetter, H. van Keulen, M. Kuiper, J. Verhagen, and H. H. van Laar, Editors
Springer; 2007; 222 pp.; ISBN 978-1-4020-6616-0; $169.

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During recent months, another sign of the global fragility to sustain the increasing human demand for resources has appeared with merciless cruelty. Increasing food prices, paradoxically driven to a large extent by the rapid economic growth of vast regions of the emerging world, are affecting hundreds of millions of the poorest people in Africa, Asia, and Latin America. As described in *Science for Agriculture and Rural Development in Low-Income Countries*, most of the poorest people in these low-income countries live in rural areas and are engaged in agriculture or related activities. Because many people in these areas are engaged in subsistence agriculture, they do not share in the added income derived from higher market prices for food.

In this context, in many cases, higher prices increase social vulnerability to climate or other hazards that affect agriculture. Enhancing efficiency in the agriculture sector through enhancing rural development will improve food security, especially as the cost of imported food increases. Understanding the variety and complexity of circumstances that could frame rural development in low-income countries is part of the long-term solution to the food security issue, and this is one of the more relevant contributions of this book.

Another important concern that underlies this well-structured book is the importance of the specific application of scientific knowledge. Despite the universal value of science, the regional and local circumstances of low-income regions call for the development of specific knowledge, both social and physical, to overcome barriers to development.

This was the task of the 8 years of research on rural development and sustainable agriculture that involved scientists with the Wageningen University and Research Centre in the Netherlands (including the editors of this book) and more than 35 collaborative North-South projects. The research began in 1998 with support from the Dutch Ministry of Agriculture, Nature and Food Quality through the ministry-funded International Cooperation Research Program. The book, which addresses the main lessons that resulted from that extensive research, is of interest to scientists, and also to planners and policy makers involved with rural development and sustainable agriculture in the least developed regions.

Science for Agriculture and Rural Development in Low-Income Countries begins with a review of the historical development of agriculture, the current urgent problem of food security, and the global driving forces affecting agriculture in a rapidly changing world. It then places agriculture in the context of rural livelihood, considering the improvements in both farm and nonfarm activities as necessary in alleviating poverty. The book also considers environmental goods and services related to agriculture, conservation, and the role of science.

The two last chapters focus on the description and conclusions of the research itself, including lessons learned. The chapters emphasize that agricultural development requires a multidisciplinary and multiscale approach, that rural development is not simply agricultural development, that there is a need to consider the farm household within the context of national policies and applied technologies, and that active involvement of stakeholders groups is essential for successful outcomes.

The book includes a description of 12 specific projects dealing with different topics of rural development in Africa and Asia. The projects cover a variety of subjects, including deforestation, erosion, soil and water management, and land use change. In many cases, the projects involved the development of methods, management strategies, or policy options. The projects are presented more as final project reports than as a part of the book. Except in some cases, this type of presentation made for some choppy writing that was not well focused on each project's key findings.

In a world in need of sustainable development strategies, especially for low-income countries, this book is a valuable contribution that is of particular interest to those concerned with food security and global environmental and economic change. Because the book's price may be steep for many scientists and practitioners in developing countries, it would be helpful if the publisher would consider making electronic copies of some key chapters available online.

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MEETING ANNOUNCEMENTS

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■ 10–13 November 2008 **Quaternary Climate: From Pole to Pole (EPICA 2008)**, Venice, Italy. Sponsors: European Project for Ice Coring in Antarctica (EPICA); British Antarctic Survey; Swiss National Science Foundation; others. (C. Barbante, Department of Environmental Sciences, University of Venice, Institute for the Dynamics of Environmental Processes, CNR-IDPA, Venice 30123, Italy; E-mail: epica2008@unive.it; Web site: http://www.epica2008.eu/)

Topics include the climate of the past million years, forcings and feedbacks, past interglacials, thermohaline circulation, methods for paleoclimate reconstruction, ice instabilities and sea level, and the causes of glacial/interglacial climate change.

■ 2–4 December 2008 **EPA Symposium on Groundwater-Borne Infectious Disease, Etiologic Agents and Indicators**, Washington, D. C., USA. Sponsor: Carnegie Institution of Washington. (P. Berger, Office of Ground Water and Drinking Water, U.S. Environmental Protection Agency, Washington, DC 20460, USA; Tel.: +1-202-564-5255; E-mail: Berger.philip@epa.gov; Web site: http://es.epa.gov/ncer/events/calendar/2008/dec02/agenda.html

The symposium's topics include groundwater epidemiology, infectious disease transmission and occurrence models, and pathogen occurrence and transport.

■ 12–16 January 2009 **International Conference of Science and Information Technologies for Sustainable Management of Aquatic Ecosystems**, Concepción, Chile. Sponsors: International Association for Hydraulic Engineering and Research; International Water Association; International Association for Hydrological Sciences; others. (Conference Secretariat, HIC 2009, c/o Integrated Meetings Specialist, Blk 998, Toa Payoh North 07-18/19, Singapore 318993; Tel.: +65-6356-4727; Fax: +65-6356-7471; E-mail: hic2009@inmeet.com.sg; Web site: http://www.heic2009.org/)

At this joint meeting of the Seventh International Symposium on Ecohydraulics and the 8th International Conference on Hydroinformatics, topics include sensor technology; cyberinfrastructure and regional or global communications; and recent advances in hydroinformatics, ecohydraulics, and ecohydrology.

■ 30 August to 5 September 2009 **Natural Dynamos**, Stará Lesná, Slovakia. Sponsors: Academy of Sciences of the Czech Republic (AVCR); Slovak Academy of Sciences; Comenius University Department of Astronomy, Physics of the Earth and Meteorology. (J. Simkanin, Institute of Geophysics of AVCR, Bocni II/1401, Prague 14131, Czech Republic; Tel.: +420-267-103-342; Fax: +420-267-103-332; E-mail: tatry2009@ig.cas.cz; Web site: http://rebel.ig.cas.cz/Tatry2009/index.html)

Conference topics include hydromagnetic dynamos, magnetoconvection and various hydromagnetic processes, and laboratory hydromagnetic and dynamo experiments. Abstract deadline is 31 May 2009.