INCORPORATED RESEARCH INSTITUTIONS FOR SEISMOLOGY

2009

ANNUAL REPORT

TWENTY-FIVE YEARS OF IRIS

IRIS

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The Voting Members or the Board of Directors may elect not-for-profit organizations in the United States that are engaged in seismological research and development as U.S. Affiliates, not-for-profit institutions in the United States with a commitment to teaching in Earth science including seismology as Educational Affiliates, and institutions outside of the United States as Foreign Affiliates. Each Affiliate may send a nonvoting Representative to IRIS Member meetings.

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Statement From the Chair

Susan Beck · University of Arizona

During my second year chairing the IRIS Board of Directors, IRIS and the community have been busy pushing ahead to improve seismology activities and research. The core facilities – the Global Seismographic Network, PASSCAL, the Data Management System, and the E&O Program – are essential to seismology. In addition, IRIS is moving ahead on several fronts.

USArray is fully operational: the Permanent Array is returning data, the Transportable Array is rolling and inspiring new uses of large-scale arrays, magnetotelluric data are expanding rapidly, and the Flexible Array is in big demand. Undergraduate students continue to efficiently site TA stations. "Adoption" of TA stations is increasing the number of permanent broadband stations that operate efficiently and deliver outstanding real-time data. The EarthScope meeting in 2009 was particularly exciting with new discoveries that would have been impossible without USArray.

Seismologists have taken advantage of economic stimulus funding to improve the nation's seismology infrastructure – acquisition and deployment of the GSN's next-generation data loggers and additional instrumentation is off to an excellent start. Polar seismology has advanced rapidly, thanks partly to projects funded by NSF's Office of Polar Programs to develop more efficient instrumentation for Antarctica and to acquire instruments for International Polar Year experiments. The Board established the IRIS International Development Seismology Committee to help develop sustainable technical infrastructure and human capacity in low- and middle-income countries for geophysical research, education, hazard mitigation, and resource exploration.

Looking to the future, IRIS completed or contributed to reviews of the E&O Program, and its own management structure, each of which will move IRIS ahead in ways that best serve the community. With logistical help from IRIS, the seismology community and other geophysicists prepared "Seismological Grand Challenges in Understanding Earth's Dynamic Systems", which outlines the areas where scientific progress is most needed in the coming decade and will be invaluable as we plan ahead for IRIS.

I look forward to working with many of you in preparing the next 5-year proposal for a new Cooperative Agreement between IRIS and the NSF. As always, I welcome comments and ideas from the community as we move IRIS forward, and I thank all of the partners that work with IRIS, IRIS committee members, IRIS staff, and NSF program managers for another successful year at IRIS.

Susan Beck

Publications

Raymond Willemann · IRIS Consortium

The IRIS Consortium serves as a forum for exchanging ideas, setting community priorities, and fostering cooperation, in part through workshops and publications. At the IRIS Workshop and other meetings, the community assesses the state of the science, learns about programs, and gains access to training. Through student grant programs, early career scientists attend IRIS workshops at little or no cost, and are introduced to the programs and services of the Consortium. IRIS publications, which are widely distributed without charge, are organized around topical issues that highlight emerging opportunities for seismology. As a consortium, IRIS also represents the Geoscience community, providing information to Members of Congress, the Office of Science and Technology Policy, and several agencies of the government.

Meetings

Workshop on a Long-Range Science Plan for Seismology (LRSPS)

To help articulate the role of seismology in a broad range of basic research and identify the facilities needed to sustain progress in promising directions, NSF funded workshop on a Long Range Science Plan for Seismology. The IRIS Board of Directors asked Rick Aster, Don Forsyth and Barbara Romanowicz to convene the workshop and IRIS staff provided logistical support. Well over 100 participants at the workshop included senior staff from several divisions of NSF and other government agencies, representatives from industry, and researchers based at U.S. and foreign institutions from many fields of seismology and related disciplines. Plenary sessions with ample time for freewheeling discussion and numerous breakout sessions facilitated broad input.

Robert Detrick, NSF Division Director for Earth Sciences, speaks at the IRIS Annual Membership Meeting.

Attendees enjoy the camaraderie and lively discussion at the IRIS Annual Membership Meeting.

Annual Membership Meeting

Representatives from the IRIS Member Institutions, members of the seismological community, and a IRIS staff gathered at the Yank Sing Restaurant in San Francisco for the Annual IRIS Membership Meeting December 15, 2008. Susan Beck and David Simpson provided a brief overview of IRIS accomplishments during 2008, and the chairs of IRIS Standing Committees and other governing reviewed major activities through the year. Bob Detrick, Director of the NSF's Division of Earth Sciences shared his vision for seismology and Earth science research.

EarthScope National Meeting

The Third EarthScope National Meeting was held on May 13-15, 2009 in Boise, Idaho, and attracted several hundred participants. The meeting emphasized the new EarthScope Thematic Working Groups (TWGs), with objectives designed to review recent successes and outline research needs. Mini-workshops and field trips combined thematic subject matter with localized areas of scientific interested. IRIS provided logistical support and organized a mini-workshop on "Leveraging USArray: Opportunities for Onshore/Offshore experiments."

Publications

Seismological Grand Challenges in Understanding Earth's Dynamic System

Drawing on presentations and discussion at the LRSPS workshop, a comprehensive report was published just a few months later in January 2009. At the request of the IRIS Board of Directors, Thorne Lay led a writing team of Earth scientists that identified ten grand challenges where seismology holds great promise for achieving major breakthroughs and delivering societal benefits. The report has been widely used in NSF strategic planning and a policy maker summary has been welcomed at several government agencies and in the offices of Members of Congress.

E&O Publications

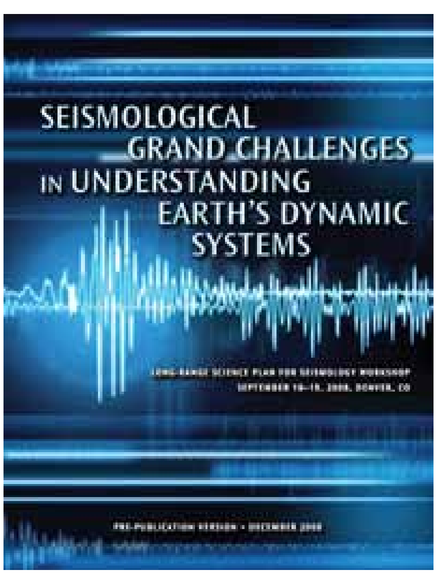
The IRIS E&O program is organizing a growing volume of material for the Active Earth Display, including a new module on Cascadia. E&O print publications include a collection of educational posters and one-page handouts in both Spanish and English on seismology and related topics for use in the classroom or public information forums.

onSite

In a collaborative effort, IRIS and UNAVCO continued publishing *onSite*, a quarterly newsletter for EarthScope station hosts and the general public that provides a brief update of the EarthScope facilities and features articles on how the station they are hosting contributes to expanding our knowledge of the North American continent.

Web Site

There were numerous new items on IRIS's redesigned web site, which is effectively the Consortium's updated online publication. An image gallery was also added to the web site, and has already grown to hundreds of images in dozens of albums and sub-albums.



The Seismological Grand Challenges report and the main pages of IRIS' new Image Gallery and Seismographs in Schools web sites.

GSN

Rhett Butler and Kent Anderson,
IRIS Consortium

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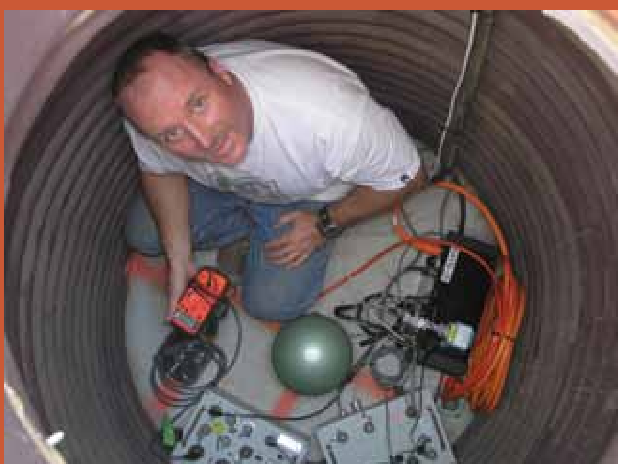


GSN-RAYN Ar Rayn, Saudi Arabia (vault). IDA field engineer works in small vault to upgrade acquisition system of the GSN station RAYN to the next generation

GSN-OTAV Otavalo, Ecuador (vsat). Adding a bit more baling wire to the vsat fence, station hosts (Fenny and Lore) work with the security guard to protect the antenna at the GSN station in Otavalo, Ecuador. This photo was taken during the recent upgrade of the station to the next generation system.

The Global Seismographic Network is a permanent network of state of the art seismological and geophysical sensors connected by available telecommunications to serve the scientific research and monitoring requirements of our national and international communities. All GSN data are freely and openly available to anyone via the Internet. Installed to provide broad, uniform global coverage of Earth, 153 GSN stations are now sited from the South Pole to Siberia and from the Amazon basin to islands in the Indian Ocean, in cooperation with over 100 host organizations and seismic networks in 69 countries worldwide. The GSN coordinates closely with other international networks through the International Federation of Digital Seismograph Networks (FDSN), of which the IRIS is a founding member. The GSN is primarily operated and maintained through the USGS Albuquerque Seismological Laboratory (ASL) and through the University of California at San Diego IRIS/IDA group. Twenty GSN-Affiliate stations and arrays contribute to the network, including the 9-station USGS Caribbean Network. In collaboration with the U.S. National Earthquake Information Center, the GSN and NEIC are principal global sources of data and information for earthquake locations, earthquake hazard mitigation, and earthquake emergency response. In collaboration with National Oceanic and Atmospheric Administration (NOAA) Tsunami Warning Centers, the GSN provides essential data for tsunami warning response globally. The GSN participates within the Global Earth Observing System of Systems (GEOSS). The GSN serves as a foremost resource for seismological research and for training and educating the next generation of earth scientists.

Three new seismic stations were installed in 2008-09 (see map), including Canary Islands and Baja California, Mexico by ASL, and United Arab Emirates by IRIS/IDA. The Canary Island site is collaborative with Spain's Instituto Geographico Nacional, which provided both STS-1s and telemetry. The Mexico site has a VSAT link to the US, and a telemetry link is being established for the U.A.E. site.

The transition from air-mailed data media and dial-up telephone access to continuous, real time telemetry of all GSN data is nearly complete. Globally, only 5 sites in the GSN now lack real-time telemetry circuits (~96% connectivity).

The GSN is working closely with the International Monitoring System (IMS) for the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO). With the addition of a communications link at a GSN site in Brazil this year, 31 GSN stations and 7 GSN Affiliates are now linked directly to the CTBTO International Data Centre (IDC), mostly via their global communication infrastructure (GCI). The shared GCI enables remote operations, maintenance, and quality control for the IMS, and provides for open, real-time data access from 17 GSN sites for the scientific community, and elsewhere serves as a redundant backup for GSN telecommunication

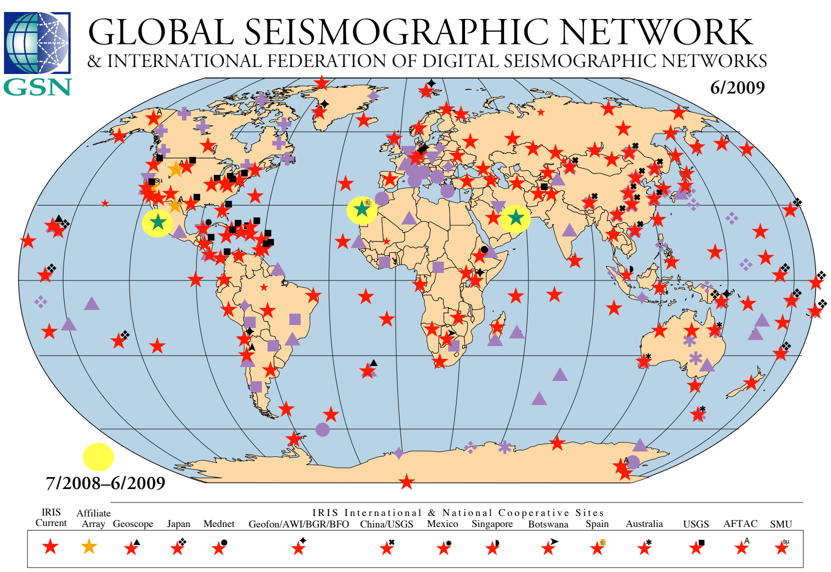
Recording at GSN station PAB-IU (San Pablo, Spain) of the Mw 7.9 earthquake that occurred in Eastern Sichuan, China on May 12, 2008. The station is located 83 degrees (9200 km) from the earthquake. The vertical-component seismogram has been bandpass filtered in the period range 125-250 s, revealing the minor-arc, major-arc, and higher-orbit Rayleigh waves.

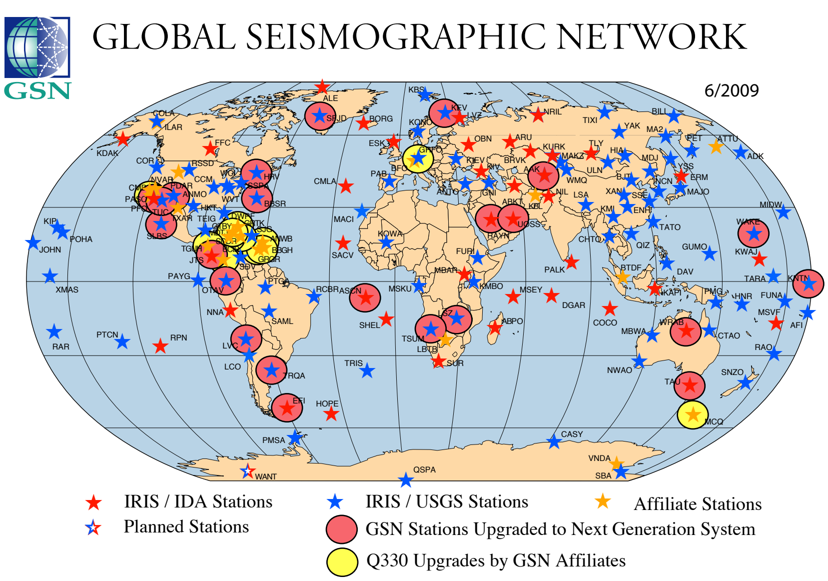
GSN-LVC Limon Verde, Chile NGS. Our Chilean host (Luis) taking notes and observing the operations of the next generation GSN system recently installed at Limon Verde, Chile.

infrastructure.

Within the US, Caribbean nations, and Mexico, the USGS Advanced National Seismic System provides VSAT infrastructure for 18 GSN stations and Affiliates. In the Pacific, close collaboration with the NOAA National Weather Service brings data from 10 GSN stations directly to the Oahu hub at the Pacific Tsunami Warning Center, which are then forwarded to the Internet.

The GSN has initiated its first major renewal of all of its data acquisition systems, beginning a multi-year program to upgrade and replace systems—many which are more than 15 years old—throughout the network to a new standard based upon the Quanterra Q330HR. Both UCSD IDA and USGS ASL have collaborated in the design and development of standard interface boxes for both sensor interfaces and power distribution subsystems. ASL and IDA have moved expeditiously to field 19 next-generation systems (NGS) globally during this past year (see map). These upgrades are complemented by Q330 installations by GSN Affiliates. In addition to NGS upgrades, the GSN has used the opportunity afforded by these visits to maintain critical infrastructure, repair sensors, install additional strong-ground motion sensors (5) and microbarographs (16), and embark on a systematic analysis of sensor calibration and azimuth. Supplementing yearly relative calibration procedures, network operators now measure with portable equipment the absolute calibration, orientation, and location of deployed GSN sensors.





Many GSN sites have evolved into geophysical observatories. A variety of geophysical instrumentation now uses GSN logistical and telemetry infrastructure, including GPS, gravimeters, magnetometers, microbarographs, and meteorological sensors. The 65 microbarographs installed globally at GSN sites are the largest open data source of its kind.

Both NSF and USGS received substantial additional funding in FY09 through the American Recovery and Reinvestment Act of 2009, which has led to substantial supplementary funding (over $9M) for the GSN. Through carefully coordinated efforts between USGS and IRIS/NSF a comprehensive, integrated plan has been developed encompassing both ASL and IDA components of the GSN. Funds for a broad renewal of GSN equipment are focused on: all NGS needed to complete the upgrade of the GSN; secondary broadband sensors for all GSN stations with only a primary sensor; replacements and spares for failed and obsolete sensors and electronics; portable sensor calibration and orientation systems; ancillary equipment and power systems. An accelerated deployment of NGS systems and sensors will be coordinated with routine operations and maintenance of the GSN. Through June 2011, it is anticipated that over 55% of the Core GSN will have been upgraded and enhanced.

Studying Earth's Ocean Wave Climate Using Microseisms

Richard C. Aster[1], Daniel E. McNamara[2], and Peter D. Bromirski[3]

1 Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico; 2 U.S. Geological Survey, Golden Colorado; 3 Scripps Institution of Oceanography, La Jolla, California

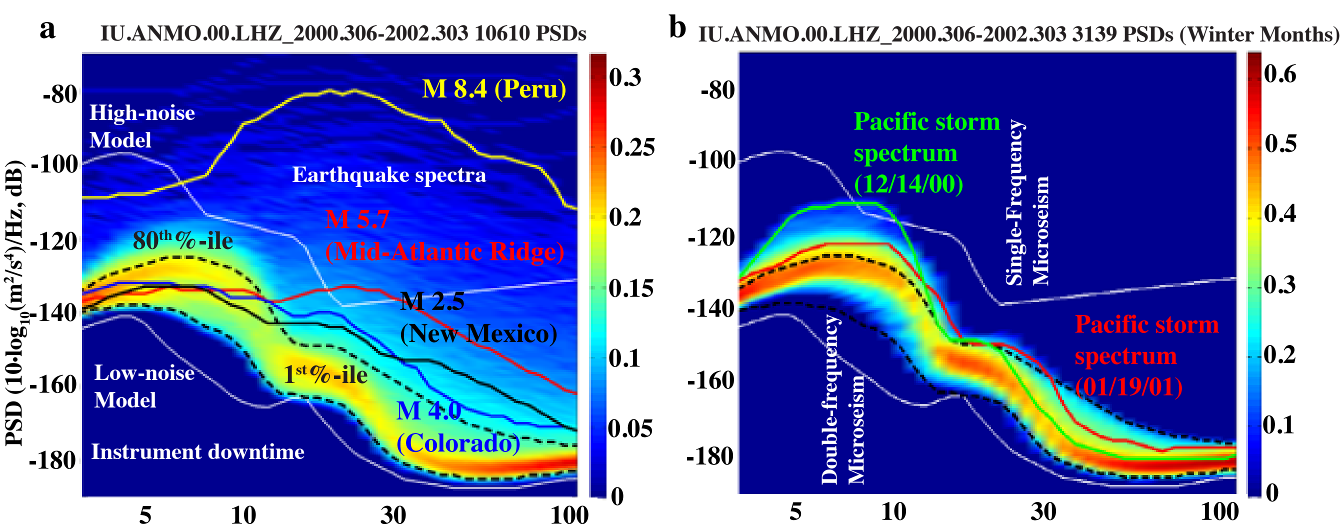
Everywhere that they are deployed, seismographs record incessant signals at periods between approximately 4 and 25 s that are commonly referred to as microseisms. Microseisms are dominated by Rayleigh waves that arise from gravity waves in the global ocean forced by surface winds. The period range of microseisms are dictated by the physics of gravity wave generation constrained by the speed and extent of Earth's surface winds (e.g. Bromiriski, 2009). Thus, seismic data hold a record of wave activity, weather, and climate extending back to the early 20th century. Continuous digital records from the Global Seismographic Network (GSN) and its precursor networks alone now extend back approximately 40 years.

The microseism spectrum is bimodal because two distinct physical mechanisms transfer ocean wave energy to seismic waves in the solid Earth (Figure 1). One spectral peak between approximately 12 - 30 s, commonly called primary, or single-frequency microseism (SFM), arises from the transfer of ocean gravity wave (swell) energy to seismic waves as ocean waves shoal and break in shallow waters. The highest amplitude and longest period swell is created by large and intense storms that generate strong sustained winds over a large area. Swell propagates dispersively across ocean basins, which results in an increasing delay of coastally arriving ocean swell with decreasing period. This period-dependent delay is readily measured in data recorded by seismic stations, ocean buoys, and seismographs deployed recently atop giant Antarctic icebergs (MacAyeal et al., 2009).

The second, predominant, microseism peak between approximately 4 and 10 s, the double-frequency microseism (DFM), results from the nonlinear interaction of interfering ocean wave components that produces a pressure pulse at double their frequency. This pressure pulse propagates nearly unattenuated to the sea floor where it generates seismic waves. The DFM is generated both near coasts, where coastal swell reflection can provide the requisite opposing wave components, and in the deep ocean.

The power spectral density (PSD) probability density function (PDF) method is a powerful tool for analyses of long continuous time series [McNamara and Buland, 2004] that we have found to be extremely useful for studying microseisms. The PSD PDF evaluates spectra in moving time windows, normalized to provide estimates of seismic power as a function of frequency. For a longer time period comprised of many such windows, the individual PSDs form an empirical PDF that characterizes seismic power and its variability as a function of frequency. The PSD PDF method facilitates the analysis of subtle time-spectral variations by providing statistical measures of power and frequency evolution, and also makes it easy to identify and remove "contaminants" such as earthquakes and instrumentation artifacts. For example, the median PSD PDF over time provides a striking record of Earth's storm frequency and intensity.

Microseism measurements are a useful proxy for characterizing ocean wave climate and global storm intensity, complementing other estimates of storm and wave intensity (such as ocean buoys or satellite measurements) because the mechanisms that generate them integrate ocean wave energy over appreciable geographic regions. Individual stations respond most strongly to wave activity at regional shorelines, and the sensitivity of specific stations to wave climate is controlled by factors such as storm tracks and coastal bathymetry. For stations located at temperate to polar latitudes, a very strong



(a) PSDs from four representative earthquakes at GSN station ANMO and PDF of PSDs for an epoch of unchanged instrumentation (November 2000 to November 2002). PSDs dominated by earthquake signals are readily recognized since they are above the PDF 80th percentile between 30 and 200 s. Possible station downtime periods are similarly recognized and excluded as PSDs that fall below the 1st percentile of the PDF. (b) PDF of ANMO PSDs for winter months (November-March) of the same epoch, but with earthquake transients removed (approximately 25% of the PSDs).

degree of inter-annual variability reflects the proportionately large influence of winter extratropical cyclonic storms that commonly affect the northern Pacific and Atlantic, as well as the southern ocean (Aster et al., 2008).

The long-running status of the GSN and predecessor stations, the global distribution of sensors, continuous recording, and substantial efforts expended in the calibration and standardization of seismic networks allows for quantitative assessment of wave climate variability. Projections from global climate models under anthropogenic greenhouse scenarios predict an increasing incidence of extreme storms. To assess the incidence of extreme storms using long-duration continuous seismic data, we are currently developing and implementing microseism index and trigger algorithms to identify statistically significant outlier events that correspond to especially notable wave events. Because the microseism methods discussed here can be self-normalized to instrument response epochs, the method is useful for microseism event intensity and occurrence analyses, even in the face of early instrumentation variability and data incompleteness. Digitization and analysis of paper and film records from the analog recording era may further facilitate extending these sorts of type of measurement as far back as the early 20th century.

Commonly viewed as a distraction and consequently commonly filtered from seismic signals for decades, the microseism signal is now seeing resurgent interest – for its use as the predominant source in ambient noise tomography as well as its ability to monitor the global wave climate. These recently emerging applications for investigating the atmosphere/ocean/solid Earth system provide a strong endorsement for the sustained operation of standardized networks such as the GSN. This and other unforeseen applications have been made possible by continuous recording, open data access, and deploying instruments with the greatest possible bandwidth, dynamic range, and geographic coverage.

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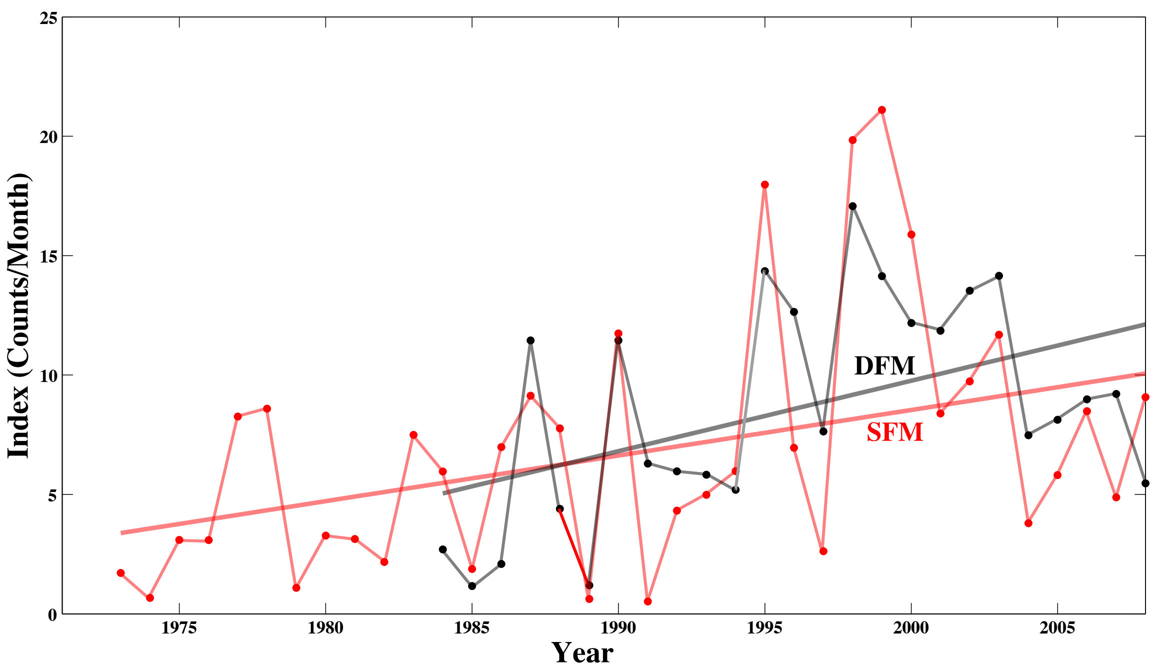
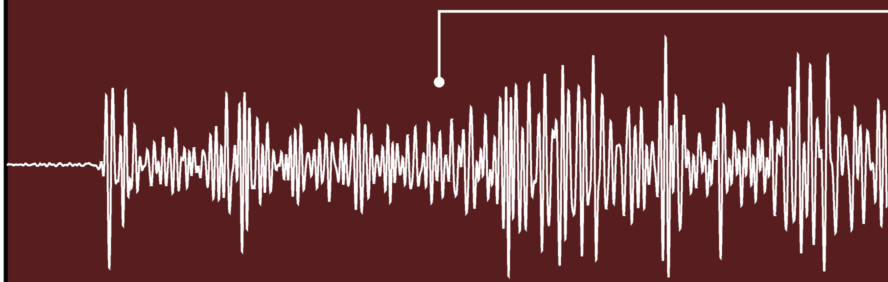


GSN station ANMO (including HG.ALQ,--.LHZ, SR.ANMO.--.LHZ, IU.ANMO.--.LHZ, and IU.ANMO.00.LHZ) microseism index count of 6-hour extremal PSD levels that exceed the 95th percentile of PSD PDF for both the SFM and DFM spectral bands during northern hemisphere winter months (November – March). Because this station has a North Pacific regional sensitivity, these positive slopes suggest generally increasing wave activity along west coast of North America during this period, and are consistent with ocean buoy observations that show upward trends in higher waves along the west coast of the US associated with increased storminess in the North Pacific. Large numbers of extremal microseisms in 1977-78, 1983, and 1997-99 correlate with strong El Nino Southern Oscillation episodes that abet the formation of strong North Pacific storms.

PASSCAL

Jim Fowler, Marcos Alvarez
IRIS Consortium



PASSCAL Standing Committee

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Matt Fouch	Arizona State University
Jesse Lawrence	Stanford University
Aibing Li	University of Houston
Doug MacAyeal	University of Chicago
Beatrice Magnani	University of Memphis
Tom Pratt	USGS, Seattle, WA
Arthur Rodgers	Lawrence Livermore Natl Lab
Lara Wagner	University of North Carolina, Chapel Hill

Students work in the High Lava Plains experiment instrument center near Burns, Oregon. They are preparing some of the 2612 Texan recorders deployed in this extensive one-week experiment. In the foreground is IRIS intern Helen Feng from UCLA (left) and University of Oklahoma graduate student Christine Worthington (right).

PASSCAL provides and supports a range of portable seismographic instrumentation and expertise to diverse scientific and educational communities. Scientific data collected with PASSCAL instruments are required to be archived at the IRIS Data Management Center. The access to professionally supported state-of-the-art equipment and archived, standardized data has revolutionized the way seismological research is conducted in the US. By integrating planning, logistical, instrumentation and engineering services and supporting the efforts with full-time professional staff, PASSCAL has enabled the seismology community to mount hundreds of large-scale experiments throughout the United States and around the globe at scales far exceeding the capabilities of individual research groups. Individual scientists and project teams can now focus on optimizing science productivity, rather than supporting basic technology and engineering. Small departments and institutions can now compete with large ones on a equal footing in instrumentation capabilities. Scientists working outside of traditional seismological subfields now have the ability to undertake new and multidisciplinary investigations. Standardized equipment and data formats greatly advanced long-term data archiving and data re-use for novel purposes.

PASSCAL has also influenced academic seismology in all parts of the world explored by US seismologists, and the program has on many occasions provided significant instrumentation to spur or augment international collaborations. Many of the standards and facilities pioneered by IRIS for instrumentation and data collection, archival and open exchange have been adopted by other groups in the United States and by seismological networks and organizations worldwide. This open-data culture has been embraced by other US data collection groups, and obligatory data archival requirements and standards have increasingly been stipulated by federal agencies.

PASSCAL facilitates portable array seismology worldwide with end-to-end experiment support services, state-of-the-art portable seismic instrumentation, and advanced field and database management tools. Over its history, PASSCAL has supported more than 600 deployments to image plate boundaries, cratons, orogenic systems, rifts, faults, and magmatic systems. Data from roughly 5000 PASSCAL stations are now in the Data Management Center.

This last year the program supported over 60 new experiments and roughly 35 ongoing experiments. Over 30 support trips were taken ranging in length from 2 weeks to 12 weeks to support these experiments. 800 broadband sensors were tested and 450 broadband stations prepared and tested for the PASSCAL core support and the Flexible Array. Three large Asian active source experiments were conducted during the last year. Portable broadband experiments continue to utilize more and more stations and there are currently three large broadband experiments in the US. The

Vertical component seismogram from High Lava Plains broadband array station OR080 (Fillmore Ranch, north of Rome, Oregon) of a shallow (10 km) Mw 6.7 event in New Hebrides on June 28, 2007. The station is located ~94 degrees (~10,400 km) from the earthquake. Waveform has been bandpass filtered between 8 and 30 seconds. Phases PcP, PP, and PPP are clearly evident in the first half of the record, while the second half of the record is dominated by higher frequency minor- and major-arc Rayleigh waves.

SEIDCAR installation team near Carizozo, NM 2008

NSF sponsored High Lava Plains (HLP) experiment has 100 broadband instruments deployed in the western US and the EarthScope funded Flexible Array Mendocino Experiment (FAME) has ~80 broadband stations in the Mendocino region of California. The EarthScope funded SEIDCAR experiment has 75 broadband stations operating in western Texas and eastern New Mexico.

The PASSCAL Instrument Center (PIC) staff helped archive 4 TB of data from PASSCAL supported experiments. The archiving process has been streamlined with full implementation of a new data delivery system. An integral part of the new system is a web interface that allows both PIC staff and eventually PI's to track the progress of the data archiving process. In addition to the data progress, the new system provides the staff with tools to access statistics and maintain a history of data archived.

PASSCAL Polar Program is supporting a growing community of high latitude researchers. This last Austral season, PASSCAL sent 6 staff in support of 8 International Polar Year (IPY) experiments in Antarctica. They developed 124 temporary seismic stations along with 20 new broadband stations, and serviced 48 existing stations. See http://www.passcal.nmt.edu/Polar/index.html. This spring the polar group will test 6 borehole 40TBs deployed near the terminus of the Yahtse Glacier in Alaska and work on the development of a new type of quick deploy and waterproof seismic system for use in wet glacial environments and volcanos.

The major purchasing phase of the Flexible Array under the 5 year Major Research Equipment (MRE) EarthScope award is now complete. The program finished on schedule and slightly under budget. To date, over 20 experiments comprised of over 350 seismic stations have been deployed. Eleven of these experiments were funded by programs other than EarthScope. With the direct assistance of the Array Operations Facility, approximately 3 Terabytes of Flexible Array data have been archived at the DMC since 2004. Currently there are over 90 Flexible Array stations transmitting data in real-time. The final numbers of stations which comprise the Flexible Array are 326 broadband stations, 120 short period stations and 1700 active source stations.

TA has entered a phase where the design and procedures are not changing greatly. However, PIC support has changed in that we are now supplying equipment for removal activities and supplementary equipment to installations. TA shipments remain at a steady 18 constructions and 18 installs per month.

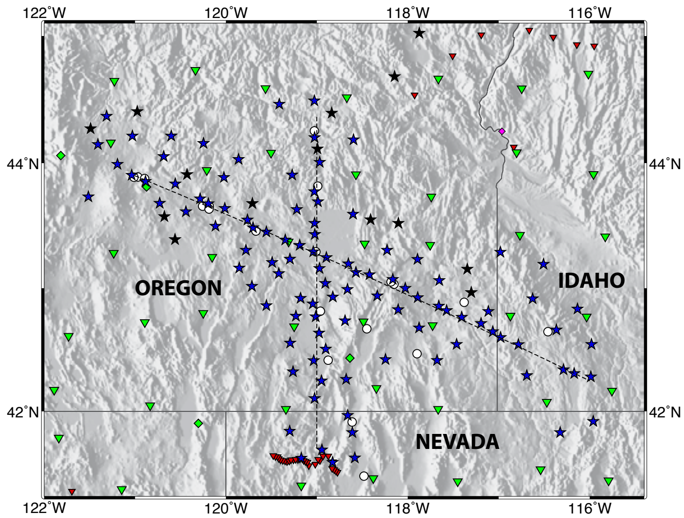
SEIDCAR station being installed in West Texas by volunteer teachers.

Multi-scale Seismic Imaging of the High Lava Plains: Field Trials and Triumphs

David E. James[1], Matthew J. Fouch[2], G. Randy Keller[3], Richard W. Carlson[1], and the High Lava Plains Seismic Group[4]

January 2006, in ground blanketed with snow, the first of the 104 broadband stations were installed in the Cascadian back arc of central and eastern Oregon at the launch the largest PI-driven portable seismic experiment ever undertaken. The multidisciplinary NSF-funded High Lava Plains (HLP) Project, of which complementary broadband and controlled source seismic experiments are a centerpiece, is designed to study one of the youngest and most accessible, yet least understood, examples worldwide of voluminous and regionally extensive intra-continental magmatism. By synthesizing multi-level seismic images with results from geology, geochemistry, geochronology and petrology, our aim is to better understand the relative roles of lithospheric structure, tectonics, flat-slab subduction, slab roll-back, slab migration, and plumes as instigators of aerially extensive magmatism that extends from the Cascades into stable North America.

Seismic observations for the HLP project come from three arrays of increasing station density: (1) the USArray Transportable Array (TA), a cornerstone of EarthScope, with spacing ~70 km, provides a broad regional “footprint” across the whole of the Pacific Northwest; (2) the higher density 118 station HLP array, embedded within the TA and spaced ~15-20 km, is deployed in two swath-like transects, one from the eastern Cascades southeast into the stable Proterozoic crust of southwestern Idaho and a second from the non-extensional region of accreted terranes in the Blue Mountains north of the High Lava Plains southward into the pre-Cenozoic basement of northern Nevada; and (3) the HLP controlled source experiment, with deployments along the main broadband transects, was performed to provide detailed crustal structure. The embedded nature of the seismic deployments means that the process of data analysis is stepwise – the HLP broadband results draw on the TA for regional control, and the controlled source results draw on the broadband data for local control.



HLP station map. Blue stars indicate currently operating stations; black stars represent decommissioned HLP stations. Transportable Array stations are shown as large green inverted triangles; other portable stations as small red inverted triangles. White circles show locations of one-ton borehole shots used for the HLP controlled source experiment, while dashed lines denote general orientation of active source transects.

The 118-station HLP broadband array was deployed in three phases, with typically 10-25 participants per deployment. The first phase, in winter and spring of 2006, involved installation of a skeleton network of 16 stations and provided important feedback for refining station design [see http://www.anisotropy.net/StationDesign/] before construction and installation of the full 104 broadband systems in spring and summer of 2007. Lessons learned included (1) the critical need for a comprehensive permitting plan, with awareness of state and federal restrictions on use of public lands; (2) the advantages of well designed “waterproof” stations; (3) realistic estimates of time and manpower needed for site construction

PhD student Maxwell Okure supervises the drilling. A portion of the data will be used for his PhD dissertation.

Catherine Cox uses the new "lunch box" interface that helped when Texans were deployed at a single station to obtain 3-Component recording. Catherine is using a portion of the active source data for her MS thesis.

1 Carnegie Institution of Washington, Department of Terrestrial Magnetism, Washington, D.C.; 2 Arizona State University, School of Earth and Space Exploration, Tempe, AZ; 3 University of Oklahoma, School of Geology and Geophysics, Norman, OK; 4 http://www.dtm.ciw.edu/research/HLP

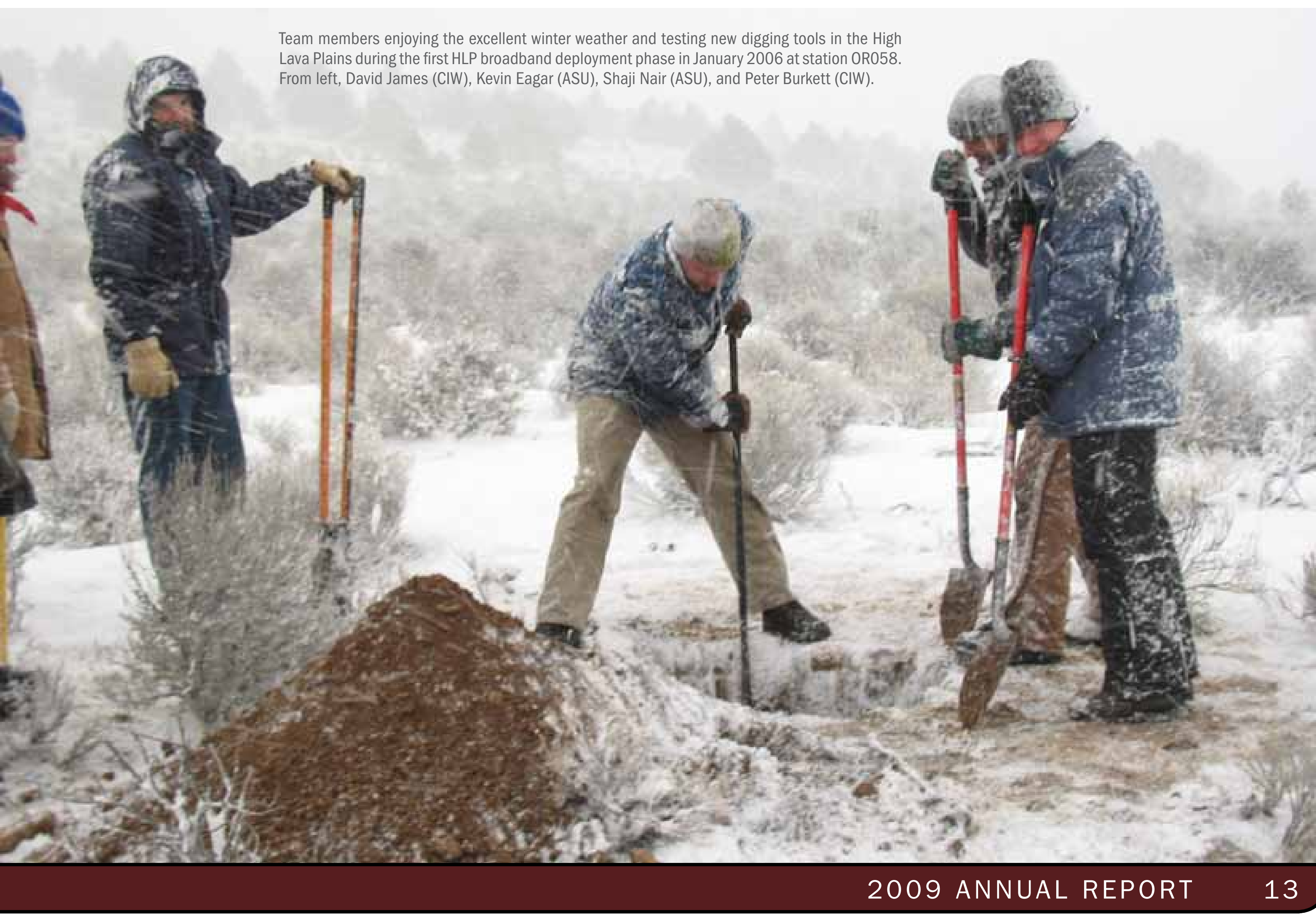
and installation when deploying very large numbers of instruments; and (4) assignment of a single person responsible for data downloads, database management, and delivery to the IRIS DMC of several terabytes of data.

In sharp contrast to the multi-year broadband experiment, the active source experiment was completed in less than a week following years of detailed planning. An army of 67 people participated in the deployment of more than 2700+ seismometers across the High Lava Plains in September of 2008. Sixteen two to three person teams drove across the HLP for two days burying seismometers every 800 meters along lines that spanned from Bend, OR, to southwestern Idaho, and from John Day, OR, into northern Nevada. The seismometers remained in place for two days while 15 borehole explosions were detonated across the area. All shots went as planned and virtually all seismometers performed flawlessly, providing data for detailed reconstruction of HLP crustal structure.

For more information visit http://www.dtm.ciw.edu/research/HLP.

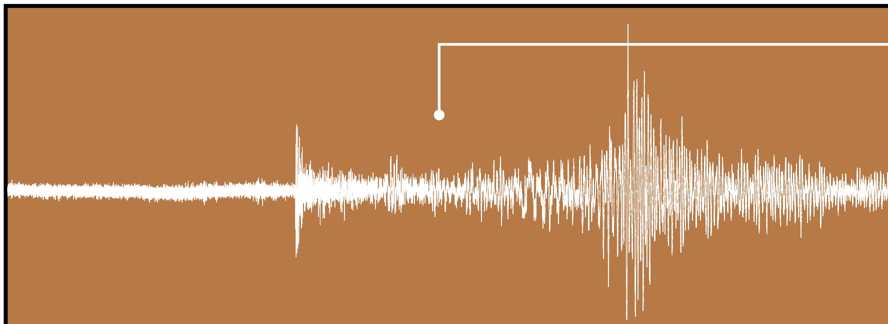
CIW Postdoctoral Fellow Maureen Long (currently on faculty at Yale University) and Burns (OR) High School student Krissandra Wright (background) completing the final installation documentation for HLP broadband station OR101.

Team members enjoying the excellent winter weather and testing new digging tools in the High Lava Plains during the first HLP broadband deployment phase in January 2006 at station OR058. From left, David James (CIW), Kevin Eagar (ASU), Shaji Nair (ASU), and Peter Burkett (CIW).



DMS

Tim Ahern · IRIS DMS Program Manager



Data Management System (DMS) Standing Committee

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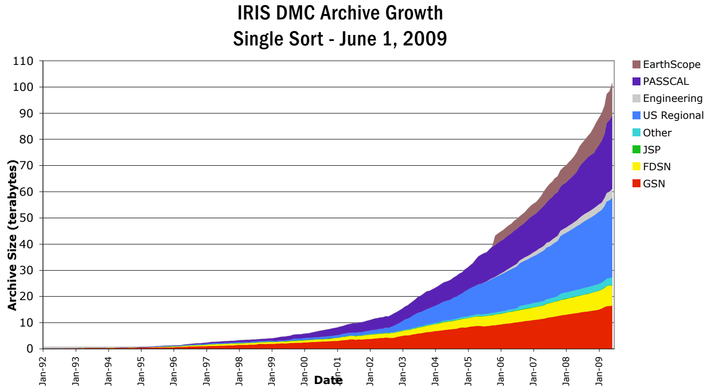
Meredith Nettles	Lamont Doherty Obsv.Columbia
Mike Ritzwoller	University of Colorado, Boulder
Catherine Snelson	New Mexico Tech
Doug Toomey	University of Oregon
Bill Walter	Lawrence Livermore Natl Labs

The Data Management System, with its focus at the Data Management Center in Seattle, Washington, offers a wide and growing variety of resources that seismologists and other Earth scientists rely on in their daily routines worldwide. Users from more than 200 countries accessed the IRIS web site during the past year and researchers outside the U.S. request roughly 20% of the data distributed from the DMC.

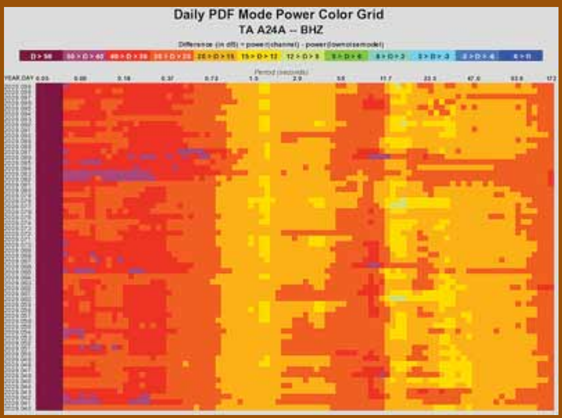
The total volume of data at DMC reached the milestone of 100 terabytes during this past year. This represents one of the largest scientific archives of data in the world for globally distributed

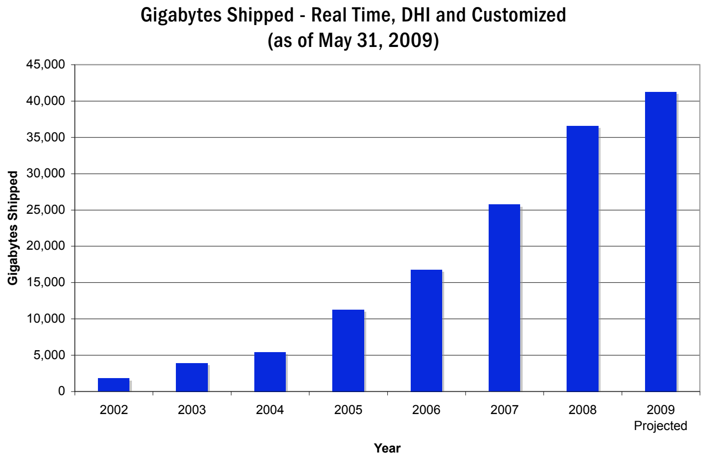
Servers and storage. The two servers on the bottom are Sun X4600 AMD Opteron based servers. One provides quality control and product development for USArray, while the other provides quality analysis of real time data. Above those is the M4000 Oracle Database server, and above the M4000 are two storage shelves, adding local storage to the M4000 for use by Oracle. Between the storage shelves are two Sun T5240 SPARC based servers. One T5240 collects USArray data while the second collects GSN real time data and other non-USArray data.



The IRIS DMC Archive. The IRIS DMC reached a milestone this year as the total amount of data in the archive exceeded 100 terabytes. Contributions to the archive include (from the bottom to the top) GSN-16.5Tb, FDSN-7.8 Tb, JSP-0.1 Tb, Other-2.9Tb, Regional Nets 30.4 Tb, Engineering 3.4 Tb, PASSCAL- 28.0Tb, and EarthScope- 12.5 Tb. The total archive size at the beginning of June 2009 was 101.6 Tb.

Automated measurements of Power Spectral Density at the DMC are used to create quality-control products such as the Mode Timeline and Color Grid, which visualizes changes in background noise and instrument performance over time.





Terabytes of Data Shipped. This figure shows that the DMC projects that it will ship more than 40 terabytes of data to the research community during calendar year 2009. 56.6% of requests are serviced from requests directed to the archive using tools such as BREQ_FAST, NetDC, or autoDRM, 34.3% of the data volume is serviced in real-time using SEEDLink, and 9.1% of the requests are serviced using the Data Handling Interface (DHI).

Recording of station CD2 from the Chinese National Network for an earthquake that occurred in Italy on April 6, 2009. It was a magnitude 6.8 event at 01:31:38.0 located at 42.450 N and 12.890 E.

The M4000 Oracle Database server is fully loaded with 128GB of RAM and 4 quad core SPARC processors, yielding a total of 16 cores (or processors). Designed by Fujitsu and manufactured by Sun Microsystems, the M4000 provides IRIS with plenty of database processing power.

observational data, and it's growing at a rate of 25 terabytes per year. Data from more than 100 networks operated by U.S. agencies and our partners in more than 60 countries contribute to this very valuable resource.

As remarkable as the data volume entering the DMC is, the volume distributed by the DMC to the research and monitoring communities worldwide is even larger. We project that more than 43 terabytes of data will be sent to researchers around the globe from the DMC during calendar year 2009.

Continued Expansion of Data Sources

While archiving and managing data from the GSN and PASSCAL is our core mission, collecting data from other seismological networks remains important. During the past year,

- We first received International Federation of Digital Seismographic Networks datasets from Norway, Denmark, Austria, Brazil, Dominican Republic, Great Britain, and China.
- We began receiving data from three permanent networks in the United States: the UCSB Geotechnical Network, the Eastern Tennessee Network, and the Hanford Washington Network.
- We received data from 24 PASSCAL experiments, 1 SEIS-UK experiment, 5 SEISMOBFR experiments, 2 OBSIP experiments, and several new data sets from the EarthScope project.

Methods of Accessing Archived and Real Time Data

Data requests directed to the DMC's 100-terabyte archive – such as BreqFast, NetDC, and JWEED – account for nearly 75% of the data by volume that leave the DMC. We project that more than 350,000 requests to the archive will be made this year. The DMC operations group reengineered the processing systems, which used to process a single request at a time. Leveraging the newer Opteron-based servers at the DMC, the new architecture supports roughly 100 concurrent requests.

The DMC has improved jWeed and VASE, two fundamentally new request mechanisms that are gaining in popularity. We are also making significant progress toward the development of web service based servers that will allow access to event catalogs, metadata, and waveform servers using SOAP- and REST-based web services.

While the DMS does not serve as a mission critical facility, the vast majority of the data we manage are available with only minor delays (tens of seconds). All real time feeds from the DMC now use the SeedLink method developed by the GEOFON group at GFZ in Potsdam, Germany. SeedLink real time feeds now represent 21% of the data leaving the DMC.

Workflows

A workflow is a system to connect a variety of web services so that, for example, data can be transformed to meet a user's specific requirements. We anticipate offering web services and workflows to apply gain corrections, down sample data, rotate components, and display seismogram graphically.

The DMC software team is developing the internal infrastructure to support workflows, working with the Microsoft Research group that is developing the Trident Scientific Workflow system. Several months remain to complete the internal infrastructure, but we expect to connect to the Trident system in the near future.

Unique visits to the IRIS Web. This figure shows the global impact of IRIS' presence. For the period July 1, 2008 through June 30, 2009 there were 631,607 unique visits to key IRIS web pages. These came from almost every country in the world with the exception of a few countries in equatorial Africa. The top ten visitors to the web site come from 1. United States, 2. China, 3. Italy, 4. Canada, 5. France, 6. United Kingdom, 7. Japan, 8. Germany, 9 Australia, and 10. South Korea.

New Seismic Event Data from CENC

Huang Zhibin, Liu Ruifeng, Yang Hui, and Zhao Xu, China Earthquake Networks Center

The China Earthquake Networks Center (CENC) is an important facility for Chinese seismology and serves as a center of technology for China earthquake disaster mitigation. Since it was established, CENC has been a major center participating in international data exchange with IRIS, USGS, and ISC.

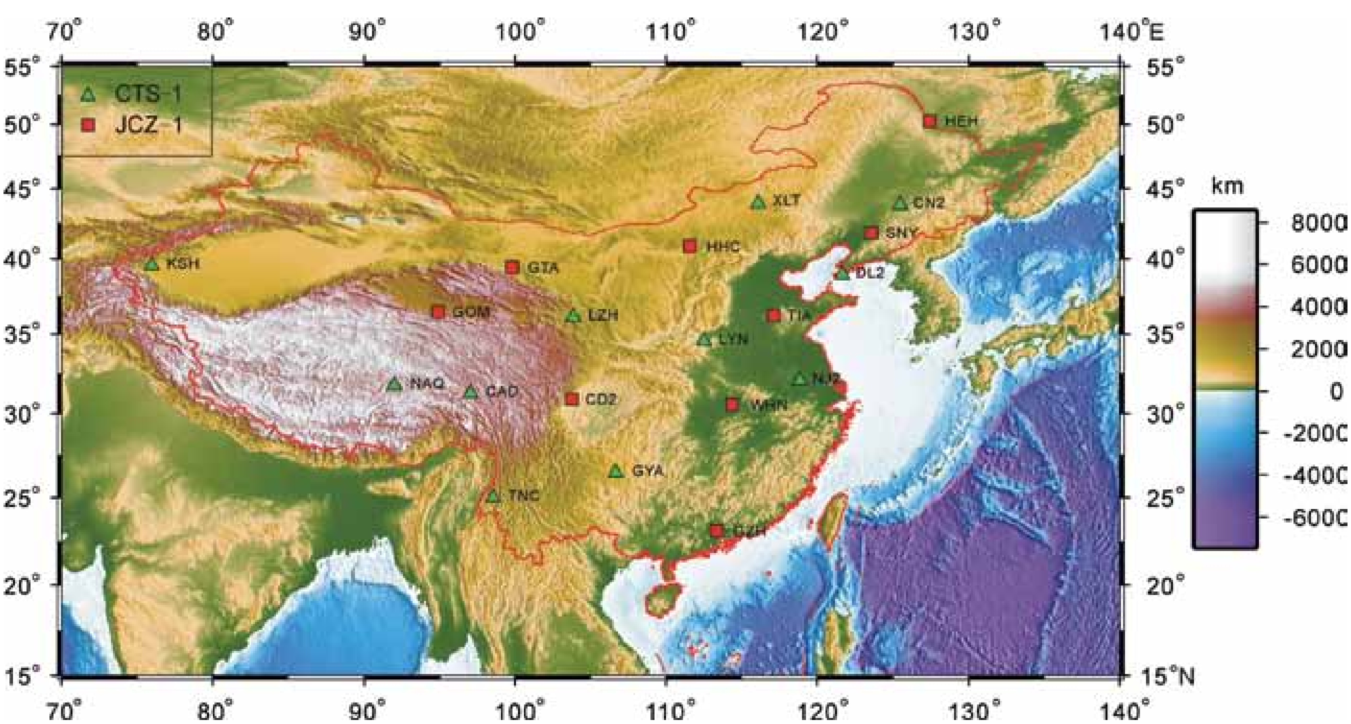
After two years of work, CENC has made further progress in the cooperation with IRIS in seismic data exchange. According to the joint agreements at the Annual China-United States meeting in Beijing 2007, CENC has begun to provide extra event waveforms from 20 seismic stations from the National Network of China since May 2009. Event data from 20 stations are transmitted monthly to the IRIS DMC as part of a data exchange effort between China and the United States. Selected earthquakes are those above M5.0 in China and above M5.5 for events outside of China.

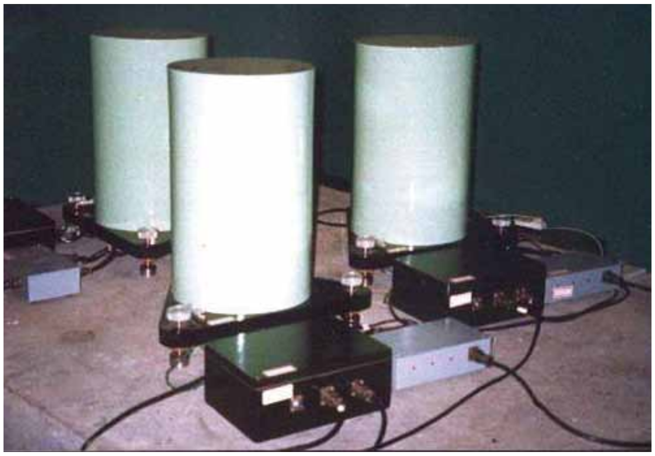
To provide broad and uniform coverage of China, these 20 stations are distributed from the north of Hei'hongjiang province to the south of Guang'dong province, and from the east of Jiang'su province to the west of Xin'jiang province. With funding from China Digital Earthquake Observatory Networks Project finished in April 2008, the acquisition equipment for these stations has been upgraded to digital electronics. Each of the 20 stations is equipped with a JCZ-1/CTS-1 seismometer, and an EDAS-24IP acquisition system. The seismic data of 20 stations are to be transmitted in real-time to CENC through the Intranet.

CENC has taken a series of measures for improving the administration, grading, classification standards and quality controlling of these stations and CENC has established a persistent, stable, and dependable operation of the seismic data service. The seismic data accumulated over a long period of time in China have been standardized by integration and transformation. For instance, standardization of the seismic waveform data and phase data collected since 2001 has been accomplished. A database system has been established, with on-line data exceeding 1 terabyte.

In the future, CENC will further cooperate with IRIS and other organizations for seismic data exchange, and we will try our best to provide more seismic data services online for worldwide scientists. One step in this direction is the operation of the WILBER II system in China where CENC and IRIS cooperated to bring event windowed data to the international community. WILBER II from China can be accessed at http://www.csndmc.ac.cn/wdc4seis@bj/earthquakes/csn_wilber.jsp.

The distribution of 20 exchange stations

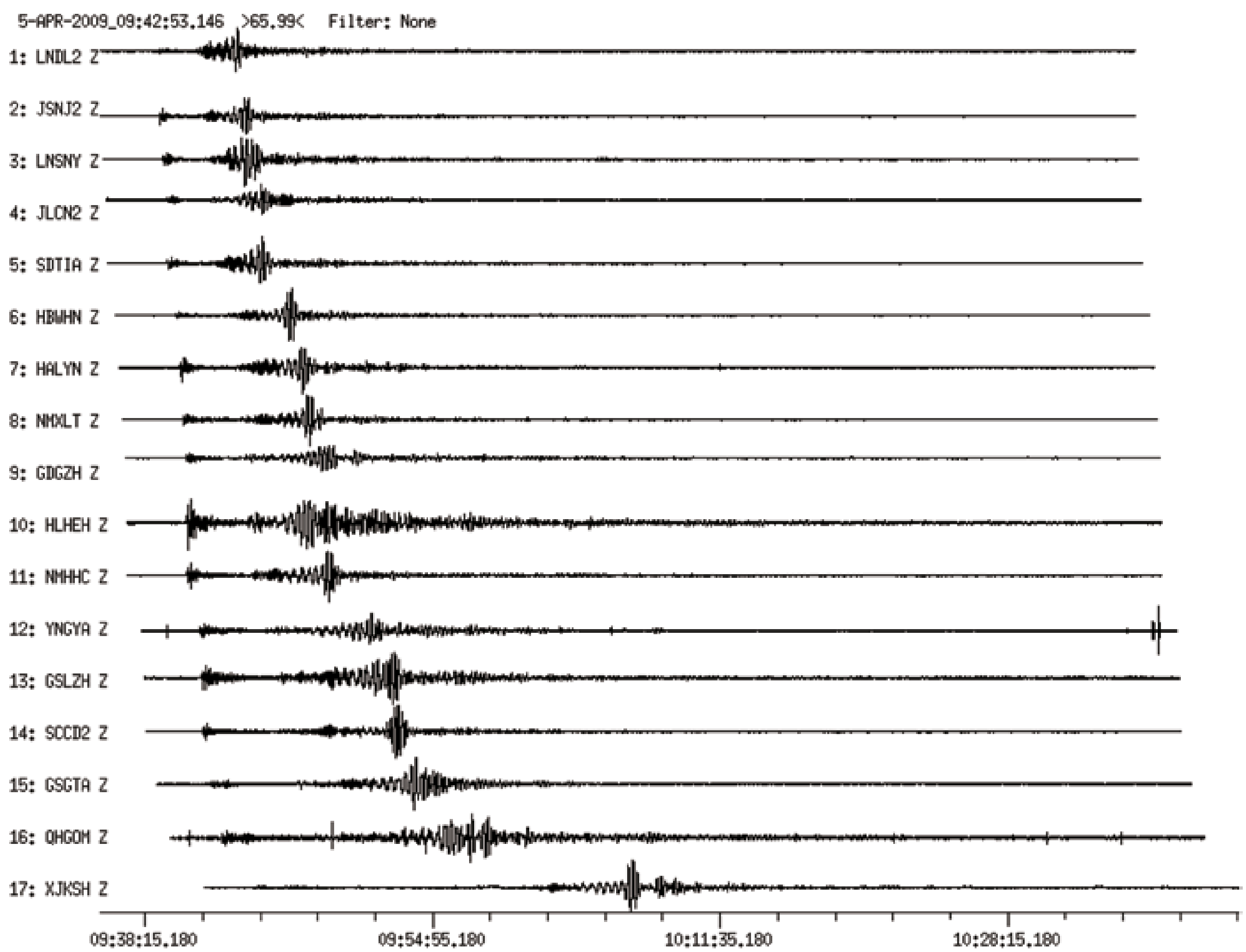




JCZ-1 seismograph (Frequency range from 0.0028~50HZ)

CTS-1 seismograph (Frequency range from 0.0083~50 HZ)

Seismogram of the 20 stations for the earthquake that occurred in Japan (latitude 32.007 N and longitude 131.417 E) on April 5, 2009



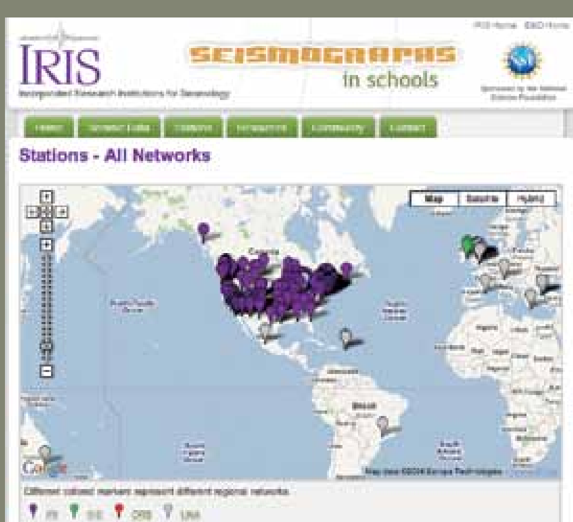
E&O

John Taber and Michael Hubenthal
IRIS Consortium

Education and Outreach (E&O)

Michael Wysession (Chair)	Washington University, St Louis
Bob Butler	University of Portland
Ines Cifuentes	AGU
John Hole	Virginia Tech
Glenn Kroeger	Trinity University
Gary Pavlis	Indiana University
Wayne Pennington	Michigan Technological University
Laura Serpa	University of Texas, El Paso
Christa von Hillebrandt	University of Puerto Rico

Above: New Cascadia Active Earth Display
Below: Station map for the new Seismographs in Schools web pages



A fund in memory of John Lahr was established this year at the request of the Lahr family (www.iris.edu/hq/sis/tribute). The fund will be used to provide educational seismographs and training for teachers.

The Education and Outreach (E&O) program is committed to advancing awareness and understanding of seismology and earth science while inspiring careers in geophysics. The E&O program develops and disseminates a suite of educational activities designed to impact 5th grade students to adults in a variety of settings, ranging from self-exploration in front of one's own computer, to the excitement of an interactive museum exhibit, a major public lecture, or in-depth exploration of the Earth's interior in a formal classroom.

In the past year, the efforts of the IRIS E&O program have focused on the enhancement of ongoing core activities and the expansion of their impact, as well as a careful look at the outcomes of the first 10 years of the program. The E&O program review included an external evaluation and a panel review, both of which were very positive about the value and impact of the program while also providing suggestions for the enhancement of program elements.

Our summer internship program has expanded this year from 10 to 14 students through a new Research Experiences for Undergraduates grant from NSF and through positions funded by USArray and the UNAVCO RESESS program. IRIS is a partner in the RESESS program that is designed to provide multi-year research experiences for students from underrepresented groups with some students joining the IRIS student cohort in their final year. IRIS interns begin the summer with a one-week orientation hosted by New Mexico Tech where the students are introduced to key aspects of modern seismology, as well as to computer tools and seismic equipment that they may use during their internship. Classroom labs and lectures are led by scientists from within the IRIS community, who generously donate their time to participate. The undergraduates then spent the rest of the summer engaged in research at thirteen different IRIS institutions, where they kept in

AS-1 educational seismograph record of the M 4.6 Seattle earthquake on January 30, 2009 recorded at station ACWA in Vancouver, Washington. While the earthquake caused very little damage, it was recorded in classrooms across the area. It engaged students as a powerful reminder of the seismic hazard risk in the Pacific Northwest.

Students and faculty during the 2009 summer internship orientation.

touch with each other via Internet blogs and discussion boards. Of the 84 students who have participated in the program since 1998, over 85% of those who have completed their undergraduate degree have gone on to graduate school in the geosciences, often at school where they did their internship.

The E&O web pages remain a primary means of dissemination of information and resources and we continue to add new material, with a focus in the past year on animations and short instructional videos. IRIS E&O has continued to work with software developer Dan Griscom to expand the educational capabilities of SeisMac, a free application that turns Mac laptops into a 3-component seismograph. SeisMac can be used to help students get a better physical understanding of seismology concepts via IRIS-developed classroom activities.

Millions of people have interacted with IRIS/USGS museum displays, many of them at the American Museum of Natural History in New York and the Smithsonian Institution National Museum of Natural History in Washington, D.C. However, a growing number of people explore seismological concepts through our newest display, the Active Earth Display (AED). The AED is a new smaller, more flexible version of the museum display, and is now in use at universities and visitor centers throughout the US. Served via a web browser, the display is customizable and the software is available to anyone who applies via the IRIS E&O web pages. Touch screens provide an interactive experience and new content continues to be developed, including a new set of pages focusing on the Cascadia region. Another program aimed at general audiences is the IRIS/SSA Distinguished Lecture Series (see accompanying article).

The E&O Program continues to refine its professional development experiences designed to support the needs of formal educators. Leveraging the expertise of Consortium members, IRIS delivers seismology-related content in a range of workshop formats. For example, an annual 2.5 day workshop held in collaboration with Penn State and North Carolina A&T as part of the AfricaArray project has now been expanded to reach twice as many teachers. In addition, a series of short workshops are held each year as part of the National Science Teachers Association annual meeting. Similarly, a 2.5 day operators workshop was offered again this year to teachers who use AS1 seismographs in their classroom. To date, more than 160 such seismographs have been distributed by IRIS E&O to schools around the US, and over 175 users of educational seismographs from 38 states and 6 countries have registered their station in the IRIS Seismographs in Schools database.

To keep pace with the growth of the Seismographs in Schools program and to provide better service to the community, a new Seismographs in Schools web site was rolled out this year. This site has a number of new or enhanced functions to help teachers make use of seismic data and communicate with other educational seismology users. Users can view near-real-time displays of other participating schools, upload and download data, and use the “find a teacher” tool to contact nearby schools that also may be operating seismographs. In order to promote and maintain program participation and communication, the site features a discussion forum to encourage and support the growing global community of educational seismograph users.

Additional audiences are reached via collaboration with other regional and national geoscience programs. For example, an earthquake location activity was featured in the Earth Science Week calendar that was distributed to 16,000 teachers as part of AGI’s Earth Science Week packet. EarthScope related activities are and will continue to be an important focus and we work closely with the EarthScope National Office and the UNAVCO E&O program to maximize our impact. For example, we have jointly led teacher workshops to promote use of EarthScope data at a variety of venues and we are jointly developing EarthScope related content for the Active Earth Display.

IRIS E&O had a key role in the development of the Earth Science Literacy Principles that provides a summary of the major ideas in earth science for policy makers, educators, students and the general public. The document was developed by scientists from across the earth sciences and complements the efforts of ocean, climate and atmospheric scientists, educators and others to define the ideas and concepts essential for a geoscience-literate public.

Teachers explore the physics of earthquakes.

Engaging the Public: The IRIS/SSA Distinguished Lecture Series

Aaron A. Velasco, University of Texas at El Paso, El Paso, TX and Michael Wysession, Washington University, St. Louis, MO

As part of a broad plan to help improve the geoscience literacy of the general public, the IRIS Education & Outreach (E&O) program, in collaboration with the Seismological Society of America (SSA), coordinate an annual Distinguished Lecture Series. This series brings the excitement and relevance of earthquake- and seismology-related research directly to the public in many different venues, often as part of a local, well-established lecture series. The IRIS/SSA lecture series helps fill a strong demand at informal learning institutions like science museums to provide local communities with direct contact with distinguished scientists. It also highlights the importance and relevance of the geosciences, which can help to recruit new students into geoscience professions.

With the report "Rising above the Gathering Storm", the National Science Board has documented a "troubling decline" in the number of U.S. citizens who are training to become scientists and engineers at a time when the number of jobs requiring science and engineering skills is growing (NSB, 2004a). The decline is accompanied by an aging of the science and engineering workforce and a rapid shift towards a national population that is increasingly made up of minority group members who are currently less likely to study geoscience (Hobbs and Stoops, 2002; Czujko and Henley, 2003). Thus, a focus on creating and sustaining excitement for the geosciences among aspiring students and the general public must remain a high priority for all geoscientists, educational institutions, government science agencies, and the private sector.

To help address these goals, two prominent seismologists a year are chosen from a pool of applicants to serve as Distinguished Lecturers. Selections are based on the scientists' ability to convey both the excitement and the complexities of seismology to a general audience in a form that is engaging and enlightening. The Lecturers are instructed to give a talk that can reach a lay audience, yet articulate leading edge science that can impact their daily lives. The lectures are nominally 40-60 minutes in duration, but can run longer including the time for questions. The audience response at these presentations is enthusiastic and appreciative, with many requests for more information. For example, following one presentation at the New Mexico Museum of Natural History and Science, the question and answer period ran for much longer than an hour, and ended only when the building had to close up for the night.

The IRIS/SSA Distinguished Lecture Series began in 2003, and over the past seven years fifteen leading geoscientists have given talks on a range of seismology-related topics in a large number of public venues including museums, science centers, conferences, and universities/colleges throughout the U.S. Nearly 100 lectures have been given through September 2009, to a total of nearly 10,000 people. This includes a number of presentations that were leveraged on the main lectures organized for the speakers. The impact of the Lectureship program is also increased by having many venues arrange additional events in conjunction with the lectures, such as webcasts, radio interviews, teacher workshops, and even IMAX

Distinguished Lecturers and Titles

2009

Richard Aster:
Taking Earth's Pulse and Temperature Using Seismology: Roaring Oceans and Singing Icebergs

Aaron Velasco:
Can a Large Earthquake in Another Country Cause One in Your Backyard?

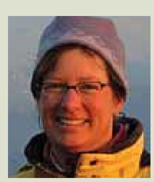
2008

Clifford Frolich:
Deep Earthquakes and the Secret of Seismology

Uri ten Brink:
Peace and Science in the Middle East

2007

Brian Atwater:
The Orphan Tsunami of 1700 – A Trans-Pacific Detective Story



Anne Sheehan:
Seeing Beneath Mt. Everest: Probing a Breeding Ground of Destructive Earthquakes

films. The advertising and local organization for the lectures are the responsibility of the venue, and IRIS provides posters, 1-pagers, and other materials to give to audiences as part of the presentation. In addition, speakers frequently give a separate technical talk on their research at nearby university geoscience departments while they are in town. Surveys have shown the positive reaction that audiences and hosts have to the lectures, and given the large number of people reached for a relatively small cost, this program is having a valuable impact on seismology outreach.

One of the challenges of being a scientist is reaching broad audiences, not just for advocating your own science, but to also for exciting the general public and the next generation of scientists as to the nature of discovery. It is a personal pleasure when you can inspire a lay audience, drawing upon your own experiences, to share your sense of wonder and love for the process of scientific discovery. For those of us who have participated in the program, being a Lecturer has assisted us with our own science by improving our ability to articulate our research to all audiences, whether they are of the general public or our field-specific colleagues. Thus, the program has positively touched the lives of not only the audiences, but also the scientists giving the lectures.

Of course, this kind of outreach is not limited to just a few individuals with an IRIS/SSA Lectureship. Many of us in our community regularly reach out to the public with presentations of our science, whether it is something formal like a museum presentation or informal like visits to our children's classrooms. With the growing awareness of the concerns brought to light by studies such as the "Gathering Storm" report, it is important for all of us to increase our outreach efforts. It is not enough for us to just do research. We have to work hard to make sure that the public understands, appreciates, and values this research if our science is to remain healthy. Towards these ends, the IRIS E&O Program has increasing amounts of materials available on-line to help carry out public outreach efforts (http://www.iris.edu/hq/programs/education_and_outreach). We also urge those seismologists who might be interested in being considered for the IRIS/SSA Distinguished Lectureship to contact Patrick McQuillan (mcquillan@iris.edu).

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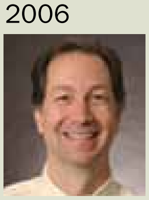
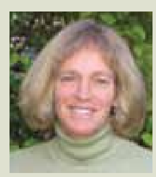
2006



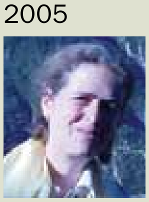
Ed Garnero:
Vibrations From the Deep: Deciphering the Birth and Death of the Earth's Surface

Seth Stein:
Giant Earthquakes: Why, Where, When and What We Can Do



Mary Lou Zoback:
The 1906 Earthquake – Lessons Learned, Lessons Forgotten, and Future Directions

2005

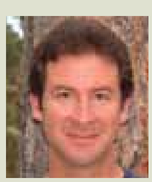


Susan Hough:
The Very Long Reach of Very Large Earthquakes

Michael Wysession:
Earthquakes, Tsunamis, and a Modern Journey to the Center of the Earth

2004

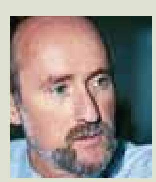
David James:
Revealing the Mysteries of the Earth's Deep Interior: Plates, Plumes, and the Birth of Modern Seismology



David Wald:
Rapid Earthquake Information: Citizen Science and New Tools for Emergency Response

2003

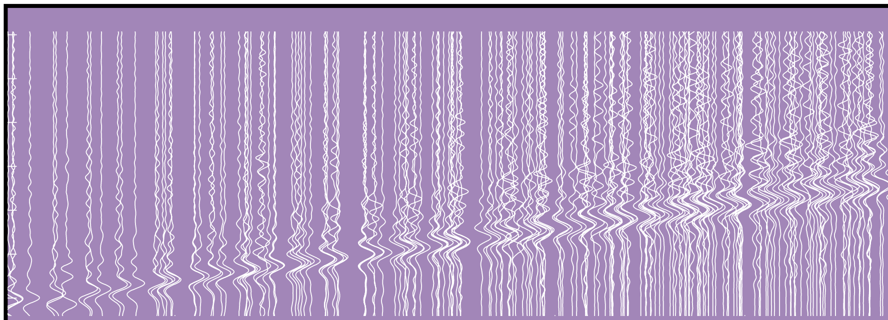
Roger Bilham:
Death and Construction: Earthquakes on an Urban Planet



Walter Mooney:
The Discovery of the Earth: The Quest to Understand the Interior of our Planet

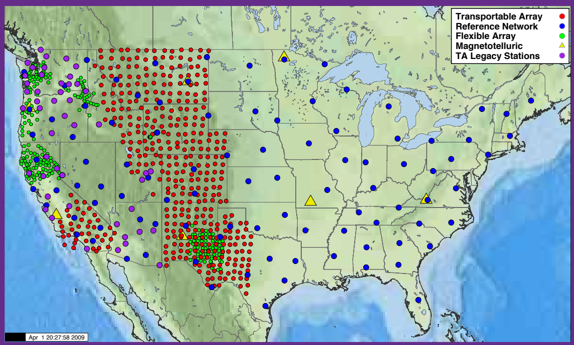
USArray

Bob Woodward, Perle Dorr
IRIS Consortium



USArray Advisory Committee

Matt Fouch (Chair)	Arizona State University
Larry Brown	Cornell University
Charles Langston	The University of Memphis
Maureen Long	Yale University
Guy Masters	University of California, San Diego
David Snyder	Geological Survey of Canada
Joann Stock	Caltech
Rob van der Hilst	Massachusetts Institute of Technology
J. Douglas Walker	University of Kansas



A snapshot in time showing the locations of USArray stations as of April 2009. Maps showing current station locations can be found at www.iris.edu/usarray.

A field engineer inspects the solar panel that provides power to a Transportable Array station.

USArray, the seismic and magnetotelluric component of EarthScope (www.earthscope.org), continued to make significant progress throughout the past year. The initial five-year construction phase, built with funding from the National Science Foundation's Major Research Equipment and Facilities Construction account, was successfully completed on September 30, 2008, and the facilities transitioned to an Operations & Maintenance status. The high quality USArray data have been in demand by scientists throughout the US and the world.

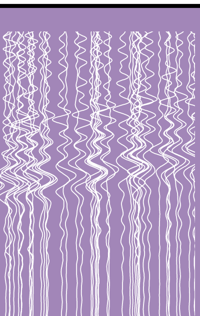
At the end of June 2009, nearly 800 Transportable Array stations have been commissioned. The 400 station array is advancing eastward across the US, having already moved well across the Great Plains. Over 300 stations have already been removed from the western states and redeployed along the leading (eastern) edge of the array. The construction, installation, and removal crews continue to work at full operational levels of approximately 18 installations and 18 removals each month.

The construction of the Transportable Array and the collection and distribution of data from the network depends on a wide range of dedicated personnel, from IRIS as well as from Honeywell Technology Solutions, Inc., Coastal Technologies, the Transportable Array Coordinating Office (at New Mexico Tech), the Array Operations Facility (at New Mexico Tech), the Array Network Facility (at the University of California, San Diego) and the IRIS Data Management Center.

The Student Siting Program is now an integral part of the Transportable Array life-cycle process. This spring in Minneapolis, a workshop was held to train 16 graduate and undergraduate students and their faculty advisors how to perform site reconnaissance to identify sites for future stations in Minnesota, Iowa, Missouri, Arkansas and Louisiana. Since the pilot program was introduced in Oregon in 2005, nearly 850 Transportable Array sites in 19 states have been identified by approximately 90 students from more than 25 universities. This highly successful program provides an opportunity for students to participate in EarthScope — actively engaging the next generation of Earth scientists.

The Transportable Array is also having a dramatic impact on the number of permanent seismic stations in the US. Since 2007, when the National Science Foundation approved the "Adopt A Station" program, more than 30 Transportable Array stations have been adopted by universities, government agencies, and regional networks (organizations can adopt stations for the cost of the equipment). The data recorded by these adopted stations are contributed to the IRIS Data Management Center, thus expanding the archive of seismic data that are freely available to scientists and the public for research and education.

The permanent seismic stations of the Reference Network provide a fixed "reference frame" through which the Transportable Array rolls.



Record section from a subset of Transportable Array stations for the M7.3 earthquake that struck offshore of Honduras on May 28, 2009 at roughly 2:00 AM local time. The earthquake caused 7 fatalities. The TA network spans the distance of 18 to 32 degrees from the earthquake, with the record section providing a close up of the surface waves propagating across the array. The data are filtered between 50 and 250 s and the individual seismograms have been normalized for clarity.

Station hosts are interested in EarthScope and often visit with crew members during the construction and installation of Transportable Array stations.

Most of these ~100 permanent seismic stations are operated and maintained by the US Geological Survey; however, to enhance the uniformity of the network's coverage, the Transportable Array installed the last 20 Reference Network stations during the past year. These stations, primarily located in the central and eastern US, were constructed in the same manner as typical Transportable Array stations, but they will remain in place until 2014 rather than being removed after 24 months.

The Flexible Array's pool of 326 broadband, 120 short period, and 1700 active source instruments are being used by principal investigators to conduct high-resolution studies that address EarthScope's scientific goals. Over the last five years, the National Science Foundation has supported twelve major FA experiments focused on the western US. Collectively, these experiments have occupied thousands of individual station sites. In addition, the LaBarge experiment in Wyoming was partially supported by an oil and gas company. USArray's Array Operations Facility at New Mexico Tech supports all phases of these Flexible Array experiments including pre-deployment training, shipping, data processing, and delivery of data to the IRIS Data Management Center.

Seven stations spanning the continental US and comprising the permanent magnetotelluric (MT) observatory were completed in September 2008. MT stations measure the natural electric and magnetic fields at the Earth's surface that are caused by electromagnetic waves radiated from the sun and from distant electrical storms. These observations constrain the electrical conductivity of the Earth's lithosphere and asthenosphere and provide an excellent complement to the seismic tomography of the structure beneath North America. This summer, field crews are placing the 20 campaign MT instruments in more than 50 locations across Montana and Wyoming. Sites are chosen on a 70-km by 70-km grid and each site is occupied for two to three weeks before the station is moved to the next site. More than 170 temporary sites in the Pacific Northwest have been occupied during the previous three summers.

All USArray data, as well as PBO and SAFOD seismic data, are archived at the IRIS Data Management Center and are freely available to scientists and the public via the internet. Nearly eighteen terabytes of EarthScope data have been archived to date, and over two terabytes of data have been shipped in the past year.

The Siting Outreach component of USArray facilitates siting of USArray stations and works with numerous state and local organizations to raise awareness of EarthScope and USArray. For instance, several universities participating in the Student Siting Program have issued news releases about their role in EarthScope. In some cases, this has generated interest by the local television station as well as by the local press. Arizona State University conducted several television interviews last year when eight Transportable Array stations were adopted. USArray collaborates with the EarthScope National Office and PBO in publishing *onSite*, a quarterly newsletter that focuses primarily on EarthScope science, and supports regional groups, such as the Central Plains EarthScope Partnership, in promoting USArray.

A major outreach effort this spring was the EarthScope Symposium and Reception on April 29, 2009, in Washington, DC. To recognize the National Science Foundation and other federal and state agencies whose participation made the successful construction of the EarthScope facilities possible, IRIS, UNAVCO and other Earth science organizations sponsored a symposium and reception. The symposium, highlighting the latest research findings enabled by the EarthScope facilities, was attended by more than 50 scientists and the media from across the Washington, DC, region. More than 200 people from various federal and state agencies and a broad spectrum of Earth science organizations attended the EarthScope reception and heard the keynote presentation delivered by Dr. Tim Killeen, the NSF Assistant Director for the Geosciences.

Field engineers prepare to install the electronics for a Transportable Array station.

Scientists align a magnetometer in the vault of a permanent Magnetotelluric station.

The deployment team gets ready to construct a vault for a Flexible Array station.

New Insights into Episodic Tremor and Slip

Mike Brudzinski, Miami University; Richard Allen, University of California, Berkeley

Tectonic plate boundaries can generate large devastating earthquakes when there is a sudden release of elastic strain energy stored on the locked, seismogenic zone of the plate interface. Recent geodetic observations reveal that plate boundary faults can also release accumulated strain through slow slip – a process that releases energy so gradually that only the most sensitive instruments, located in the immediate vicinity of the subduction zone, can detect it. In many cases, the slow slip events have been shown to correlate with seismically recorded non-volcanic tremor, forming so-called episodic tremor and slip (ETS). The EarthScope facility provides a unique opportunity to examine the spatial and temporal patterns of this newly discovered behavior due to its broad geographic scale and multi-disciplinary observations. Interestingly, ETS was not an original target of EarthScope as the phenomenon had not yet been discovered when the project was initiated. Nevertheless, the flexible approach of EarthScope has allowed researchers to design experiments that target the origin of this new behavior and its potential relationships to hazardous earthquakes.

ETS is detected by measuring slow slip episodes with global positioning system observations and correlating these with non-volcanic tremor signals on seismograms. The EarthScope Flexarray Along Cascadia Experiment for Segmentation (FACES) has been designed specifically to target ETS observations in order to study how ETS characteristics are segmented along the length of the Cascadia subduction zone. Furthermore, the experiment is examining the potential links between episodic tremor and slip and the three-dimensional structure of the overriding plate, including differences in the geologic terrains and features associated with seismogenic behavior. In addition to FACES, several other EarthScope Flexible Array experiments are helping to examine the Cascadia subduction zone and ETS, including the Cascadia Arrays for EarthScope (CAFÉ), Central Oregon Locked Zone Array (COLZA), Mendocino, and Array of Arrays.

FACES deployed 23 broadband seismic instruments in an area that extends from northern California, through Oregon, to the northern border of Washington and from the Pacific coast to the eastern side of the volcanic arc. The locations of the stations in the FACES deployment were within the grid occupied at that time by EarthScope's Transportable Array and complemented by other Flexible Array experiments and permanent networks to provide a uniformly dense network with

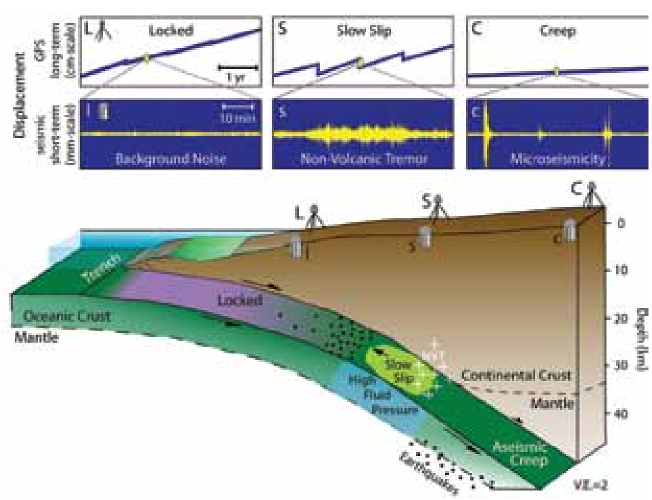
A typical Flexible Array station deployment. The seismometer is buried in the foreground, the electronics and battery are enclosed in the partially buried box, and the solar panel is to the right.

a typical station spacing of approximately 50 km. This seismic station coverage, combined with enhanced Global Positioning System (GPS) instrumentation from the EarthScope Plate Boundary Observatory, is being used to investigate spatial and temporal patterns of non-volcanic tremor and slow slip episodes and their relationship to velocity structure of the subducting and overriding lithosphere throughout the entire Cascadia subduction zone.

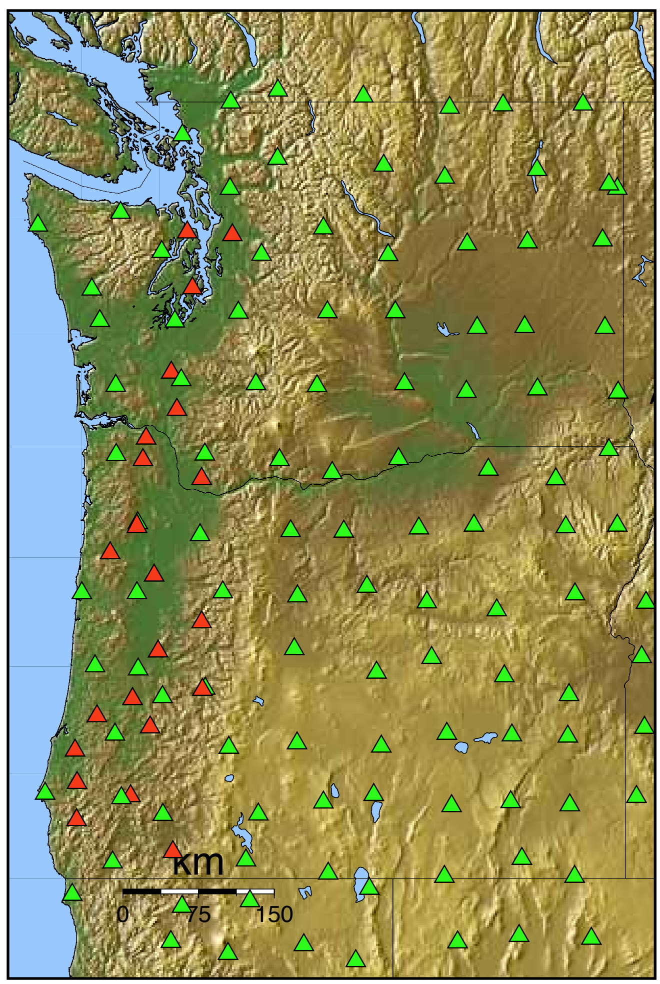
The data collected as part of FACES have helped to confirm that correlated ground vibrations and strain observations are found all along the subduction zone, demonstrating that ETS is an inherent part of the subduction process. Three broad (300–500 km), coherent zones with different recurrence intervals have been identified, where the recurrence interval duration is inversely proportional to upper plate topography and the spatial extent correlates with geologic terranes. These zones are further divided into segments of ETS that occur at times typically offset from each other. Modulation of tremor signals by tides and passing surface waves imply that very low effective stress is a necessary condition for ETS, supported by constraints from frictional modeling and the presence of ultra-low seismic velocities and high Vp/Vs ratios that indicate high pore-fluid pressures. In fact, global comparisons reveal that ETS is not tied to particular pressure-temperature conditions, but that slow slip occurs within the geodetically defined transition zone, while tremor may be further restricted to cases where neighboring high conductivity is consistent with fluids released from the source zone. This process could help explain why earthquakes appear to be spatially anti-correlated with tremor, particularly in the overlying crust, as the abundance of fluids promotes the occurrence of tremors instead of earthquakes.

The overall picture of ETS that is emerging from these studies is that the relationship between tremor and slip, over both time and space, is complex and may be linked to, or modulated by, a variety of geologic structures and processes. Based in large part on the exciting science of ETS, the National Science Foundation has launched the Cascadia Initiative – an adjunct to EarthScope that will combine offshore seismic observations with both seismic and high-rate GPS observations onshore to provide significant and exciting new data to bear on ETS studies. The first onshore seismic stations will be deployed by EarthScope's Transportable Array in the fall of 2009 and will help to ensure continuous recording of these new phenomenon after FACES and several other Flexible Array experiments are complete.

Illustration of slip along the plate boundary fault of a subduction zone characterized by sinking of an oceanic plate underneath a continental one. At relatively shallow depths, the plate interface is locked, producing long-term motion towards the upper plate interior recorded on GPS instruments (L). This strain accumulation can be released occasionally in the form of great earthquakes. Further down the interface, slow slip produces short-term motion that may be related to the reduction of effective stress due to high pore fluid pressure and can be associated with non-volcanic tremor (S). At even greater depths, the two plates creep past each other, but earthquakes within the plates can still be recorded (C).



Locations of FACES stations in Cascadia. The stations were deployed starting in September 2007 and are scheduled for removal in the fall of 2009.



Polar Operations

Kent Anderson · IRIS Consortium
Tim Parker · New Mexico Tech

IRIS and UNAVCO Polar Networks Science Committee

Doug Wiens (Chair)	Washington University
Sridhar Anandakrishnan	Pennsylvania State University
Rick Aster	New Mexico Tech
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Recording geophysical data at remote sites in the highest, driest, coldest continent on Earth has always presented a major challenge to not only the logistics capabilities of the United States Antarctic Program, but also to the instrumentation packages of the individual researchers wishing to collect these data. With six months of darkness at the higher latitudes and temperatures that hit -80C at times, standard instrumentation packages just won't work. To better serve the seismological community interested in working in these extreme environments, the IRIS Consortium has continued to expand its support capabilities in the world's cold regions through the Polar Support group at the PASSCAL Instrument Center (www.passcal.nmt.edu/Polar). IRIS has long recognized the extra efforts and specialized equipment required to successfully conduct temporary and permanent seismic experiments in Antarctica and the northern polar-regions. Through the recent awards of two NSF MRIs (MRI-1 - Development of a Power and Communications System for Remote Autonomous Polar Observations (collaborative with UNAVCO), and MRI-2 - Acquisition of Cold Hardened Seismic Equipment), PASSCAL has developed and established a pool of specialized seismic equipment specifically designed to operate in the extreme cold environments. With support from the National Science Foundation's Office of Polar Programs, PASSCAL has created a dedicated staff of two FTEs to support this equipment and the PI's requiring data from the cold.

MRI-1 is nearing completion with the only remaining experiment being a two-year, autonomous design that is currently running strong at the South Pole. This station was designed to run for ~27 months unattended to prove the concept that remote stations need not be visited annually, thus minimizing the logistics required by the NSF. Final design information from the MRI-grant is posted on the "Polar" webpage. Data from all the test systems are available in real time at the IRIS DMC (network code XD).

The equipment pool established with MRI-2 is made up of 40 cold-hardened broadband stations (as designed in MRI-1) specifically to support high latitude IRIS PASSCAL experiments. In addition to these cold-hardened broadband stations, the PASSCAL Polar equipment pool currently includes a 60-channel seismic snow streamer and a cold chamber for testing equipment at in situ temperatures. The broadband stations have been deployed for over 22 months in Antarctica (AGAP and Polenet experiments) and have returns >85% of their data, a vast improvement over past Antarctic experiments.

IRIS PASSCAL continues to support experiments (broadband, short period and controlled source) in Antarctica (AGAP, POLENET, MEVO, CRESIS and LARRISA), Alaska (Bering Glacier, Yakutak, Yahtse Glacier), and Greenland (CRESIS and RUMJAK). The emphasis on supporting climate research has created a new need for seismic instrumentation that can work in wet environments.

Seismic Installation at Miller Range, 2008 (Photo by Brian Bonnett, PASSCAL Polar Support Group)

Body waves and surfaces waves from the deadly MW 7.9 Wenchuan, China, earthquake of 2008 May 12 recorded at GAMSEIS-01 at a distance of 115° are among the data used to improve models of the crustal and lithospheric under the Gamburtsev Mountains, Antarctica.

Polenet Seismic installation in Antarctica. Part rock, part snow, all cold and windy. (Photo by Brian Bonnett, PASSCAL Instrument Center Polar Support group)

In addition to PI driven PASSCAL experiments, IRIS has submitted and has been awarded an international collaborative proposal to establish the Greenland Ice Sheet Monitoring Network (GLISN). The purpose of this award is to build a seismic network to monitor the seismic activity generated by the large glacier systems on Greenland and catalog glacier based activities. Over the next three years, the network will utilize and upgrade several stations on Greenland and in the vicinity as well as establish several new observatory-class seismic stations on the ice cap and around the margins of Greenland. This program involves the collaboration with seven international partners including organizations from Denmark, Switzerland, Germany, Italy, Norway, Canada, and Japan. This program establishes a new direction for IRIS incorporating permanent observatories with open, real-time data (ala GSN) in a more autonomous, higher station density network (similar to large PASSCAL experiments). Management for this program comes from GSN staff, engineering from the PASSCAL Polar Support group, and fieldwork will be accomplished with GSN and PASSCAL personnel as well as personnel from our international collaborators. Complementing the routine cataloging of glacier earthquakes by the Waveform Quality Center at Lamont, all GLISN data will be openly available through the DMS (virtual network _GLISN) to facilitate new international research in the relationship of seismology and global climate change in Greenland.

In response to the increase Polar activities at the IRIS PASSCAL Instrument Center, New Mexico Tech president Daniel H. López authorized the expansion of the on-campus building that houses the facility. The 1300 square foot addition, scheduled for completion in Fall 2009, will primarily provide laboratory and office space for PASSCAL's recently expanded Polar Program activities supported primarily by the National Science Foundation's Office of Polar Programs.

Gamburtsev Mountains experiment (AGAP) base camp. Tim Parker (PASSCAL Polar Support Group) and Masaki Kanao (National Institute of Polar Research, Japan) shown in this International Polar Year collaboration. (Photo by Guy Tytgat, PASSCAL Polar Support Group)

Financial Overview

Candy Shin · IRIS Consortium

The Incorporated Research Institutions for Seismology (the IRIS Consortium) is a 501(c)(3) non-profit consortium of research institutions founded in 1984 to develop scientific facilities, distribute data, and promote research. IRIS is incorporated in the State of Delaware.

GSN

The Global Seismographic Network is operated in partnership with the USGS. Funding from NSF for the GSN supports the installation and upgrade of new stations, and the operation and maintenance of stations of the IDA Network at University of California, San Diego and other stations not funded directly within the budget of the USGS. Operation and maintenance of USGS/GSN stations is funded directly through the USGS budget. Subawards include the University of California, San Diego, the University of California, Berkeley, the California Institute of Technology, Columbia University, and the USGS (Albuquerque Seismological Laboratory).

PASSCAL

Funding for PASSCAL is used to purchase new instruments, support the Instrument Center at the New Mexico Institute of Mining and Technology, train scientists to use the instruments, and provide technical support for instruments in the field. Subawards include the New Mexico Institute of Mining and Technology (New Mexico Tech), and University of Texas at El Paso.

DMS

Funding for the Data Management System supports data collection, data archiving, data distribution, communication links, software development, data evaluation, and Web interface systems. Major subawards include the University of Washington, the University of California, San Diego, Columbia University, and the Institute for Geophysical Research, Kazakstan.

Education and Outreach

Funding for the Education and Outreach Program is used to support teacher and faculty workshops, undergraduate internships, the production of hardcopy, video and Web-based educational materials, a distinguished lecturer series, educational seismographs, and the development of museum displays. Subawards are issued to IRIS institutions for software and classroom material development, summer internship support and support of educational seismology networks.

Budget and Finance Subcommittee

Ken Creager (Chair)	University of Washington
Don Forsyth	Brown University
Steve Grand	University of Texas at Austin
Ray Willemann	IRIS
Candy Shin	IRIS

Program Coordinating Committee (CoCOM)

Jim Gaherty (Chair)	Columbia University
Richard Allen	University of California, Berkeley
Keith Koper	Saint Louis University
Xiaodong Song	University of Illinois, Urbana Champaign
Michael Wysession	Washington University, St Louis
Ken Creager	University of Washington
Robert Busby	IRIS
Rhett Butler	IRIS
James Fowler	IRIS
Candy Shin	IRIS
David Simpson	IRIS
John Taber	IRIS
Robert Woolley	IRIS
Bob Woodward	IRIS
Timothy Ahern	IRIS

EarthScope

EarthScope awards include funding for USArray and EarthScope E&O activities. Subawards include the University of California, San Diego, New Mexico Tech, Oregon State University, UNAVCO, and other siting and partnership subawards. Contracts for USArray TA station construction and installation are to Honeywell and Coastal Technical Services.

Indirect Expenses

Costs include corporate administration and business staff salaries; audit, human resources and legal services; general headquarters and Seattle office expenses; insurance; and corporate travel costs.

Other Activities

Other activities include IRIS workshops, publications and special projects such as the Kyrghyz Seismic Network.

A complete copy of IRIS' financial statements and auditor's reports are available from the IRIS business office by contacting admin@iris.edu.

2008

IRIS Budgets

Core program budgets*
(July 1, 2007-June 30, 2008)
FY2008

GSN	3,445,254
PASSCAL	3,351,851
DMS	2,978,656
E&O	627,671
Community Activities	258,045
Indirect Costs	1,088,523
Total	**11,750,000**

EarthScope Awards

(Oct. 1, 2007 - Sept. 30, 2008)

USArray (MRE Year 5)	8,652,028
USArray (O&M Year 5)	7,315,448
EarthScope E&O	419,418
Total	**16,386,894**

*Budgets are for core IRIS programs from the NSF Earth Sciences Division Instrumentation & Facilities Program, and does not include additional funding from other sources, such as NSF Polar Programs, DOE, CTBTO, SCEC, JPL, etc.

2009

IRIS Budgets

Core program budgets*
(July 1, 2008-June 30, 2009)
FY2009

GSN	3,368,306
PASSCAL	3,284,656
DMS	2,864,243
E&O	761,645
Community Activities	239,895
Indirect Costs	1,427,102
Total	**11,945,847**

EarthScope Awards

(Oct. 1, 2008 - Sept. 30, 2009)

2009 EarthScope National Meeting	135,000
USArray (O&M Year 6)	13,570,000
Total	**13,705,000**

*Budgets are for core IRIS programs from the NSF Earth Sciences Division Instrumentation & Facilities Program, and does not include additional funding from other sources, such as NSF Polar Programs, DOE, CTBTO, SCEC, JPL, etc.

STAFF

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Matt Toigo	Web Developer
Russ Welti	Software Engineer - Education and Outreach
Ray Willemann	Director of Planning
Robert Woodward	USArray Director
Rob Woolley	Director of Program Support and Special Projects

Kent Anderson	GSN Operations Manager
Rhett Butler	GSN Program Manager

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Anthony Gonzales	USArray Lead Construction Engineer
Katrin Hafner	Transportable Array Chief of Operations
Howard Peavey	Station Specialist
Graylan Vincent	Transportable Array Reconnaissance Specialist

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Un Joe	Data Control Technician
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Linus Kamb	USArray Software Engineer
Tim Knight	Information Services Coordinator/Webmaster
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Anh Ngo	Operations Programmer
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Sandy Stromme	Software Engineer
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Marcos Alvarez	Deputy Program Manager
James Fowler	Program Manager

IRIS partners operating major facilities with separately employed staffs include Project IDA (http://ida.ucsd.edu), New Mexico Tech (http://www.passcal.nmt.edu), the USGS Albuquerque Seismological Laboratory (http://earthquake.usgs.gov/regional/asl), and the US Array Network Facility (http://anf.ucsd.edu).

The IRIS mission, actively supported by each Member and Affiliate Institution, is to:

- Facilitate and conduct geophysical investigation of seismic sources and Earth properties using seismic and other geophysical methods.
- Promote exchange of geophysical data and knowledge, both through use of standards for network operations, data formats and exchange protocols, and through pursuing policies of free and unrestricted data access.
- Foster cooperation among IRIS Members, Affiliates, and other organizations in order to advance geophysical research and convey benefits from geophysical progress to all of humanity.

Planning Committee

Brian Stump (Chair)	Southern Methodist University
Susan Beck	University of Arizona
Randy Keller	Oklahoma University
Thorne Lay	University of California, Santa Cruz
Kate Miller	University of Texas, El Paso
Andrew Nyblade	Pennsylvania State University
John Vidale	University of Washington
David Simpson	IRIS
Ray Willemann	IRIS

International Development Seismology Committee

Anne Melzer (Chair)	Lehigh University
Noel Barstow	PASSCAL Instrument Center
Susan Beck (Board Liaison)	Univ. of Arizona
Karen Fischer	Brown University
Art Lerner-Lam	Columbia Univeversity
Andy Nyblade	Penn. State University
Eric Sandvol	University of Missouri
Ray Willemann	IRIS Headquarters

Board of Directors

Susan Beck (Chair)	University of Arizona
Jim Gaherty (Vice Chair)	Columbia University
Kenneth Creager	University of Washington
Don Forsyth	Brown University
Ed Garnero	Arizona State University
Steven Roecker	Rensselaer Polytechnic Institute
Steve Grand	University of Texas, Austin
David Okaya	University of Southern California
Suzan van der Lee	Northwestern University

The Board of Directors, selected by the Voting Members of IRIS in annual elections, is vested with full power in the management of IRIS's affairs. The Board appoints members to the Planning Committee, the Program Coordination Committee, the USArray Advisory Committee, and four Standing Committees that provide oversight of the Global Seismographic network (GSN), the Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL), the Data Management System (DMS), and the Education and Outreach Program (E&O). For special tasks, the Board of Directors or President may convene special advisory committees and working groups, which currently include the Instrumentation Committee and working groups for the Transportable Array and the Magnetotellurics components of USArray. IRIS committees and working groups develop recommendations for consideration by the Board of Directors.

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ADDRESS SERVICE REQUESTED

Founded in 1984 with support from the National Science Foundation, IRIS is a consortium of over 100 US universities dedicated to the operation of science facilities for the acquisition, management, and distribution of seismological data. IRIS programs contribute to scholarly research, education, earthquake hazard mitigation, and the verification of a Comprehensive Test Ban Treaty.

IRIS is a 501 (c) (3) nonprofit organization incorporated in the state of Delaware with its primary headquarters office located in Washington, DC.

IRIS

Incorporated Research Institutions for Seismology