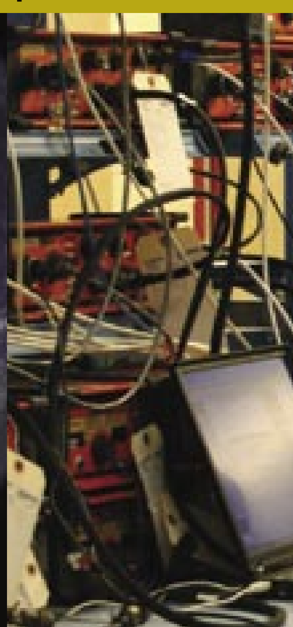
2005

2005 Annual Report


IRIS

2005 Annual Report

IRIS is a university research consortium dedicated to monitoring the Earth and exploring its interior through the collection and distribution of geophysical data. IRIS programs contribute to scholarly research, education, earthquake hazard mitigation, and the international verification regime for the Comprehensive Nuclear Test-Ban Treaty. IRIS operates through Cooperative Agreements with the National Science Foundation under the Division of Earth Science's Instrumentation and Facilities Program and the EarthScope Program. Funding is provided by the National Science Foundation, other federal agencies, universities, and private foundations. All IRIS programs are carried out in close coordination with the US Geological Survey and many international partners.

Statement from the Chair

The pre-AGU crunch is now in full bloom, but it is time to pause and look back over the past year, my first serving as Chair of the IRIS Board of Directors. I've had varying levels of involvement with IRIS since its inception, but nothing compares to the immersion that accompanies being Chair. From that unique vantage, I have gained an even deeper level of respect and admiration for the IRIS community, ranging from the staff to technicians to program managers and top administration, along with the many volunteer participants from the community. In helping to prepare the 5th IRIS 5-year proposal, I witnessed the sustained creativity and dedication of the full span of IRIS participants. We should all recognize the special nature of this collective enterprise which is admired by many scientific communities and has gained increasing national and international attention. IRIS' response to large earthquakes, contributions to nuclear testing treaty monitoring, advocating of open-data policies, and enabling of a breathtaking range of exciting science applications using its facilities have all been amply demonstrated this year. In undertaking the USArray project on behalf of EarthScope, IRIS has rapidly added equipment, facilities, personnel and capabilities, the research impact of which is only beginning to emerge. Exciting times lie ahead for seismology and geophysics!

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doubling trajectory envisioned when the EarthScope MRE was developed, and many big science programs in the country are competing for diminished resources.

Sustaining IRIS facilities is an expensive investment for NSF, which must be justified by the research contributions of the seismological community. There can be no sense of entitlement or unlimited ambition for IRIS programs; the competition for alternate uses of NSF funds is ongoing and increasing. Long-term operation of the USArray facility, as it sweeps across the country and then heads to Alaska is a very expensive undertaking as well, and will further pressure NSF resources for Earth Sciences.

So, i

straightforward, but will require the IRIS user-community to exercise a muscle that has never been developed to its fullest potential.

All of us can make far greater effort to acknowledge when and how IRIS facilities contribute to our scientific efforts. When you use IRI -

ment of doing so in public talks and publications. While most research articles provide some opportunity to do this in parallel with grant numbers, it is also valuable to reference articles such as those for GSN [Butler, R., et al. (2004), The Global Seismographic Network Surpasses Its Design Goal, Eos Trans. AGU, 85(23), 225.], or PASSCAL [Aster, R., B. Beaudoin, J. Hole, M. Fouch, J. Fowler, and D. James (2005), IRIS Seismology Program Marks 20 Years of Discovery, Eos Trans. AGU, 86(17), 171.]. By your conscientious ackno

this effort to sustain the facilities and data that are intended to serve you.

Thorne Lay

Chair, IRIS Board of Directors

The Year in Review

At the start of 2005, the attention of the world was focused to an unprecedented degree on earthquake-caused hazards. The tragedy of the great earthquake in Sumatra and the ensuing tsunami was still unfolding towards a death toll greater than any other natural disaster since the Tangshan earthquake of 1976. IRIS activities were driven by widespread recognition of the role of open data from the Global Seismographic Network in rapidly assessing the size of the earthquake and a responsibility to use an exceptional "teachable moment" to increase awareness of the political and individual steps that can mitigate earthquake disasters.

But Sumatra-related events were far from the only activities of IRIS during those busy months. A proposal for EarthScope O&M was completed, laying out detailed plans for long-term operation of USArray, PBO and SAFOD. The newly organized Board of Directors met for the first time and began tackling its corporate and science guidance responsibilities. On top of all this, the Board and the Planning Committee began preparing a proposal for a new 5-year cooperative agreement with NSF.

A PASSCAL strategic planning workshop in February was an opportunity to rethink the program's goals and the activities needed to reach them. The workshop endorsed evolution of PASSCAL from a lending library of seismic instruments to a set of services supporting all phases of geophysical experiments, and laid out a vision for services required to advance Earth science.

The E&O program took an important step forward with the first meeting of the E&O Affiliates, which defined itself as a community looking to establish collaborations with all IRIS members.

IRIS occupied the USArray Operating Facility, a new building constructed by New Mexico Tech that adjoins the PASSCAL Instrument Center, hired new staff, and ordered and took receipt of many instruments for the Flexible Array.

The monitoring role of the GSN gained further prominence with growth of GEOSS, a high-priority initiative seeking societal benefits from Earth observations. The GSN is a leader in dealing with the challenges inherent in building and operating a global network of "in-situ" observatories, which are now recognized as an essential complement to satellites.

Taking advantage of technological advances, the DMS transcended the "near-line" approach to mass storage that it has used since its inception. Storing continuous data on a disk-based system will facilitate a new generation of user services, while the tape-based system continues to serve as the primary storage for data from the most prolific sources and as an automated back up for all of the data.

The Standing Committees and the Annual Workshop were, in part, forums for deliberation on the IRIS proposal to NSF. "Cornerstone Facilities for Seismology and Earth Science" identifies Multidisciplinary Integration, Incorporating R&D in Core Operations, Partnering in the Poles and Oceans, and Leveraging Partnerships as themes for the next five years. With more than 200 synopses of projects that were facilitated by IRIS, the proposal received generally excellent evaluations from NSF reviewers and panels.

IRIS is pushing ahead with activities related to the proposal themes, including plans to develop robust instrumentation for Antarctica jointly with UNAVCO, increasing the number and role of International Affiliates, and improving the cross-program activities of IRIS, such as supporting AfricaArray through long-term loans of reconditioned instruments and provision of data management services. These advances are typical of IRIS's more than 20-year history, which shows that leading development in promising areas depends foremost on strong scientific direction and broad community participation in all of IRIS's affairs.

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The IRIS management structure is an interface between the scientific community, funding agencies, and the programs of IRIS. The structure is designed to focus scientific talent on common objectives, to encourage broad participation, and to efficiently manage IRIS programs.

Representatives from all of the member institutions meet annually to elect a Board of Directors, which governs IRIS. The Board of Directors appoints members to the Planning Committee, the Program Coordination Committee, the USArray Advisory Committee, and the 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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GSN

GLOBAL SEISMOGRAPHIC NETWORK

The Global Seismographic Network is a permanent network of state of the art seismological and geophysical sensors serving national and international requirements for research and monitoring through free and open data access. Installed to provide broad, uniform global coverage of Earth, 138 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 59 countries. The GSN coordinates with other networks through the international Federation of Digital Seismograph Networks, of which the IRIS is a founding member.

The GSN is operated and maintained through the USGS Albuquerque Seismological Laboratory (ASL) and through the University of California at San Diego IRIS/IDA group. Twelve GSN-Affiliate stations and arrays contribute to the network, and are operated and maintained independently of IRIS and USGS. 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 U.S. Tsunami Warning Centers and Japanese Meteorological Agency, the GSN provides essential data for tsunami warning response globally. The GSN is an official observing system within the Global Earth Observing System of Systems.

The M>9 Sumatra-Andaman Earthquake on December 26, 2004 was an extraordinary test of the system, which the GSN met well with full-fidelity data available in real-time from most of the network. In testimony to Congress in February 2005, Arden L. Bement, Jr., Director of the National Science Foundation gave prominent recognition to "the real-time Global Seismographic Network (GSN), the data from which forged the critical core of the early warning of the December 26, 2004, earthquake." The breadth, quality, and number of scientific papers arising from the GSN data set for this event and its aftershocks highlight the fundamental scientific merit of this fiducial network.

The GSN grew by one Affiliate Station in 2005 with the completion of MCQ on Macquarie Island between New Zealand and Antarctica. The seismometers were provided by the GSN and the data acquisition and telemetry systems were provided by Geoscience Australia, which will operate the station jointly with the GSN. One GSN station (SFJ) was relocated in Greenland, where the seismic equipment was moved to a new, quieter seismic vault 300m from its former location (now SFJD).

Eleven new telemetry circuits were established in 2005 and 90% of the GSN is now on-line via Internet and VSAT links, including all GSN stations in the United States.

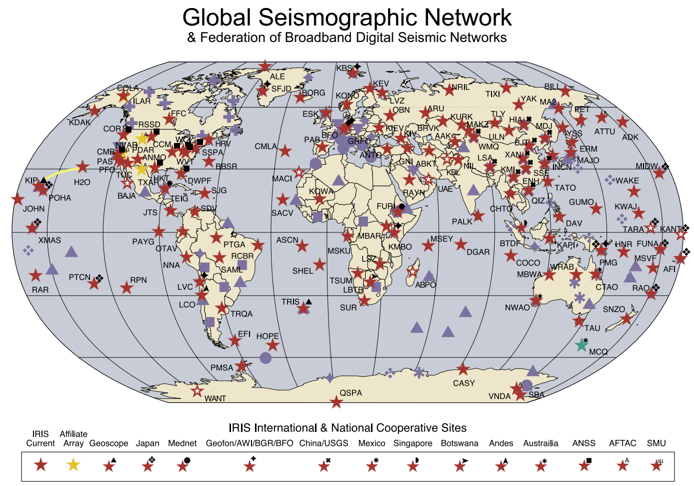
The IRIS/IDA group arranged for Internet connectivity to GSN stations on Ascension Island and the Azores, and established a VSAT system on South Georgia Island in the southernmost Atlantic Ocean and in the Seychelles in the Indian Ocean. Through collaboration with IRIS and station hosts, ASL established new Internet links to GSN sites in Finland, Ukraine, and Tuvalu in the west-central Pacific. Geoscience Australia provides the VSAT link for the new Macquarie Island site.

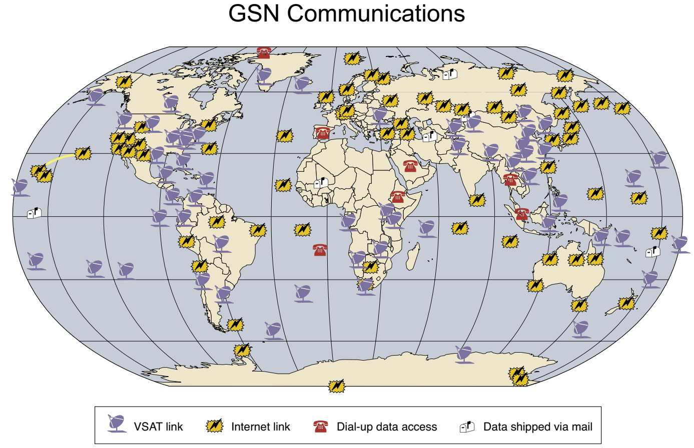
The GSN is working closely with the International Monitoring System (IMS) for the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) to share data from more than 50 designated GSN sites. Twenty-three GSN sites are now linked directly to the CTBTO International Data Centre, mostly via their Global Communication Infrastructure. This satellite infrastructure is shared with the GSN, enabling remote operations, maintenance, and quality control for the IMS, and providing real-time GSN data access for the scientific community. Three new shared VSAT links have been established this year, opening real-time access to GSN sites in Greenland and the Philippines, and providing for enhanced access to Indonesia. Though not associated with CTBTO, the GSN site in the Seychelles cooperatively uses their telemetry.

The GSN continues coordinating with the National Weather Service, which funds the satellite space segment costs to bring GSN data to the Oahu hub at the Pacific Tsunami Warning Center from Johnston Island (currently down due to power failure), Midway, Wake, Easter, and Pitcairn Islands in the Pacific. The Oahu hub is also being cooperatively used by UNAVCO/NASA for GPS telecommunication from Easter Island, and by the Pitcairn Islanders for their Internet access.

Many GSN sites have evolved into geophysical observatories. An extended suite of geophysical instrumentation can make use of GSN logistical and telemetry infrastructure, including GPS, gravimeters, magnetometers, microbarographs, and meteorological sensors. The 41 microbarographs installed globally at GSN sites are the largest open data source of its kind. The GSN continues its close cooperation with the GPS community with co-located instrumentation at 43 sites, and shared telemetry infrastructure in Africa and Siberia.

The nineteen GSN stations in the United States are part of the USGS Advanced National Seismic System (ANSS) Backbone. Under joint ANSS and GSN funding in 2005, site preparation was completed for a new Backbone station in Nacagdoches, Texas. GSN funds have contributed to nine ANSS stations in Montana (2), Oregon, California, Texas (3), Colorado, Pennsylvania, and Tennessee with another three stations in progress in California, Mississippi, and Utah. In addition, with funding from the EarthScope USArray program, the team at ASL completed 23 of the 39 planned seismic installations, and installed GPS shallow braced monuments with receivers at 5 of the 16 sites where they are planned.





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Rhett Butler	GSN Program Manager

The IRIS/IDA "Front Line" in the Indian Ocean

Jon Berger and Pete Davis (University of California, San Diego)

The recent disastrous earthquakes and tsunami remind us only too well of the human side to seismology. While we work with national government organizations, universities, and commercial entities to host our stations, the front lines of the GSN are the station operators and our host organization personnel who keep the network operating. Here we describe three of our Indian Ocean "front-line" stations and the people who run them.

COCO – Cocos-Keeling Islands, Australia

This station is located in Cocos-Keeling Islands, belonging to Australia. The islands consist of two flat, low-lying coral atolls lying some 1700 miles northwest of Perth. Volcanic in origin, the two coral atolls were formed on top of a seamount that was raised from the ocean floor as the Indo-Australian plate slid across a subsurface plume or "hot spot". Cocos-Keeling is one of two seamounts in the submarine range of mountains known as the Meinesz Seamounts that have risen above the surface of the ocean. The second and older of the two is Christmas Island which lies 560 miles north-east of Cocos Atoll.

Discovered in 1609 but not inhabited until the 19th century, the islands became part of the British Empire in 1857. [As a footnote in history, the islands became the site one of the first naval battles of World War I. On November 9, 1914, the telegraph station on the Cocos was attacked by the German light cruiser SMS Emden, fresh from her sinking of 18 merchantmen and the Russian light cruiser Zhemchug. Several hours after the attack, she was engaged by the Australian cruiser, HMAS Sydney which dispatched the Emden in short order.

The wellhead at the airport on Cocos-Keeling Islands.

Cocos is a U - shaped series of islets surrounding a shallow lagoon that is about six miles across at its widest. Only two of the islets, Home and West, are populated, with less than 2000 people total. West Island is the largest of the islets, shaped like a fish hook and measures six miles long, by half mile wide at its narrowest and a mile wide toward the north end of the island. Where Home Island can be described as residential, West Island is the business district containing Administrative offices, general store, the West Island Lodge, post office, various other government facilities, and, most importantly, the Airport. Across the runway is the Meteorological Station, the home of the IRIS/IDA station COCO. Not far away is a surface vault and 70m borehole.

Hosts are the Geosciences Australia and, on the island, the Bureau of Meteorology. The current Officer-in-Charge is Ray Stockton and our station operator is Jonn Dudely.

Diego Garcia, an island of the Chagos Archipelago in the Indian Ocean.

DGAR – Diego Garcia, British Indian Ocean Territory

DGAR is the newest IRIS/IDA station in operation. Diego Garcia is the largest and most southerly island in the Chagos Archipelago, which is comprised of 55 islands, covering some 54,400 sq km of ocean but with a land area of only 60 sq km. Diego Garcia is heavily vegetated with a maximum height of 7 m and an average elevation of just over 3 m above sea level. The shoreline is about 72 km long and the island encloses a lagoon 12 km by 24 km. Unpopulated for most of its history, today Diego Garcia is a British Indian Ocean Territory populated by some 700 US military personnel and 1,500 civilian contractors - a British territory that's been colonized by Americans. Rather than a sleepy tropical backwater, DG is more of a stationary aircraft carrier – the exclusive realm of the military. It can only be reached by military aircraft and nothing comes or goes without appropriate military orders (in-triplicate).

Hosts for the IRIS/IDA station are the USAF 18th Space Surveillance Squadron. The DGAR site is located on the grounds of the USAF GEODSS installation, slightly over 18 miles from the main Diego Garcia living area as measured along the island's principal highway. Northrup Grumman currently operates GEODSS for the Air Force, and it is with NG that IRIS/IDA has an operational support agreement. Bruce Bookout is currently the NG site man-

Grand Opening of the IRIS/IDA stations DGAR, May 2004.

ager at GEODSS, and we also received much help from Keith Giles, the maintenance manager. William Atkinson is our current station operator.

MSEY – Mahe, Republic of the Seychelles.

Some 1800 km to the west of Diego Garcia lies the beautiful island of Mahe and its satellite islands rising above the large submarine plateau of the granitic Mascarene Platform. The rock formations of the island are unique. Nowhere else can one find such an abundance of granite islands thousands of kilometers from the surrounding continents.

The seismographic station in the Seychelles has a long history. Originally it was one of the Project IDA ultra long-period gravimeter stations established in 1980 at

Granite boulders along a Mahe beach.

the USAF Tracking Station. Because of excessive seismic noise at that location, it was later moved to St. Louis Hill and operated by personnel of Cable &Wireless. In late1992 a new site was chosen for a IRIS/IDA borehole installation but drilling at that site failed to penetrate deeper than 30m. After a local noise survey, the site was moved back to the USAF tracking station and a successful drilling operation was completed in 1995. Shortly thereafter, the USAF ceased operation on Mahe and the site was taken over by the Seychelles Government.

Today, the Seychelles National Oil Company is our host organization. Eddy Belle is the company's Deputy Chief Operating Officer and Patrick Joseph and Patrick Samson are station operators. As has been the practice as the GSN expanded, the station hosts other geophysical instrumentation as well. Oivind Ruud of UNAVCO and David Stowers of JPL make use of the GSN site for GPS data collection purposes.

PALK – Palakelle, Sri Lanka

The original contact for the seismographic station in Sri Lanka came through Dr. N.P. Wijayananda, Director of the Geological Survey and Mines Bureau (GSMB) who was a graduate student of Tony Berger (brother of Project IDA PI, Jonathan Berger) who taught at the University of Peradeniya in the late 60's. The University is located in the

Todd Johnson and Phil Porter set up the joint seismic/GPS station at the USAF Tracking Station on Mahe.

Central Province of Sri Lanka, close to the historic Temple of Holy Tooth Relic in Kandy. During an initial visit to the area Jonathan noticed lots of good large granitic outcrops near the local GSMB office. As he scouted around he came upon a prison camp. With his GSMB hosts, he went to see the Commandante who was quite hospitable and showed the group around the 16 acre, minimum-security facility. They have power & phone service and, obviously, security. Most of the area is cultivated as the prisoners

Entrance to the Pallekele Prison Camp, the home of the IRIS/IDA station PALK.

PASSCAL

PROGRAM FOR THE ARRAY SEISMIC STUDIES OF THE CONTINENTAL LITHOSPHERE

The PASSCAL program supports 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. This year the program supported 28 broadband and 11 short period passive experiments as well as 25 controlled source experiments, 13 of which employed "Texan" single-channel recorders while 12 used multichannel recording systems. Over its history PASSCAL has supported more than 500 deployments to image plate boundaries, cratons, orogenic systems, rifts, faults, and magmatic systems. The instruments have also been essential in a variety of environmental research projects, including volcanic system imaging, fault-zone studies, basin-related seismic hazard, and hydrologic studies.

In response to a significant increase in the usage recently, PASSCAL took delivery this year of 150 new Texans, bringing the total pool to 950 units. The new Texans have four times as much memory, 256 Mbytes, which allows higher sample rates, longer recording times, and more shots per deployment. Yet they can be redeployed more quickly than the old Texans thanks to an even greater increase in data upload speed. The new units are designed with a user interface similar to the original units, which facilitates using both units in the same experiment. Even though many long-offset experiments now take advantage of European instruments pools, the PASSCAL Texans were in the field almost continually this year and there was time to service only half of the older units.

While the number of broadband experiments has remained relatively constant, the total number of instruments requested continues to grow as investigators increase the density and aperture of their arrays to image features with higher resolution at greater depth. To help address this growth in demand and to refresh the aging instrument pool, Congress appropriated $9,500,000 for PASSCAL over the past three years. Provided through the Department of Energy, the funding allowed acquisition of 400 new data recorders – allowing us to "retire" all of the originals – and development of a new generation telemetered array of 25 broadband stations. The telemetry equipment was initially deployed as part of a short period array in Parkfield, CA. The new data loggers have proven more reliable than the older units, in addition to being lighter, consuming less power, having better timing and providing IP connectivity. IP connectivity is expected to be extremely useful for state of health monitoring, remote re-configuration, and real-time data transmission as satellites, cell phones and other communications systems adopt the IP protocol and become more widespread.

In addition to supplying instrumentation, PASSCAL provides services to support each phase of an experiment. Before the deployment, PASSCAL provides pre-proposal consultation and advice on experiment design, as well as training in use of the instrument hardware and software for data recording, QC and archiving. PASSCAL usually makes arrangements for shipping instruments both to the field area and back to the instrument center. The instruments and field computers are configured with a variety of custom software to support efficient operations, and Instrument Center personnel provide assistance by telephone and e-mail. Post-deployment services include software for data format conversion, data verification, and initial processing for both active and passive experiments.

Programs have been written recently to archive the data from new instruments, and we plan to develop software to improve efficiency and experiment support. Experiment support will be enhanced through software for an in-the-field "quick-look" and for troubleshooting. Newly developed software for testing and verifying the operation of instruments at the PASSCAL Instrument Center will help the staff to work more efficiently, cut the time that instruments are idle between experiments, and reduce the chance that an instrument will be deployed with an undetected problem.

EarthScope/USArray

This year saw completion of the Array Operations Facility, a major extension of the New Mexico Tech building that houses PASSCAL Instrument Center. Working in the expanded facility, a significantly larger New Mexico Tech staff will support both the Flexible Array and the Transportable Array components of EarthScope as well as PASSCAL experiments.

Initial support for the Transportable Array involves purchase, check-out, final assembly and shipping of sensors, dataloggers and telemetry gear for 400 broadband stations, which will be deployed over three years on a 1000 km wide grid adjacent to the west coast of the US stretching from Mexico to Canada. In the future, support will include refurbishing and re-testing systems as the array is moved across the US over approximately 12 years. Transportable Array systems are modified from PASSCAL broadband systems, and include the advanced capabilities of the DOE-funded data loggers.

The Flexible Array is planned to be a pool of 200 broadband, 200 short-period, and 2000 high-frequency instruments that can be deployed to image key targets at higher density than the other components of USArray, with both natural and active sources. This year the Flexible Array received 40 new broadband and 40 short period stations bringing the total to 80 for each type. Prototypes of the new "Texan" were delivered in January and the first production units were received in April and a total of 700 units were delivered by the end of the year.

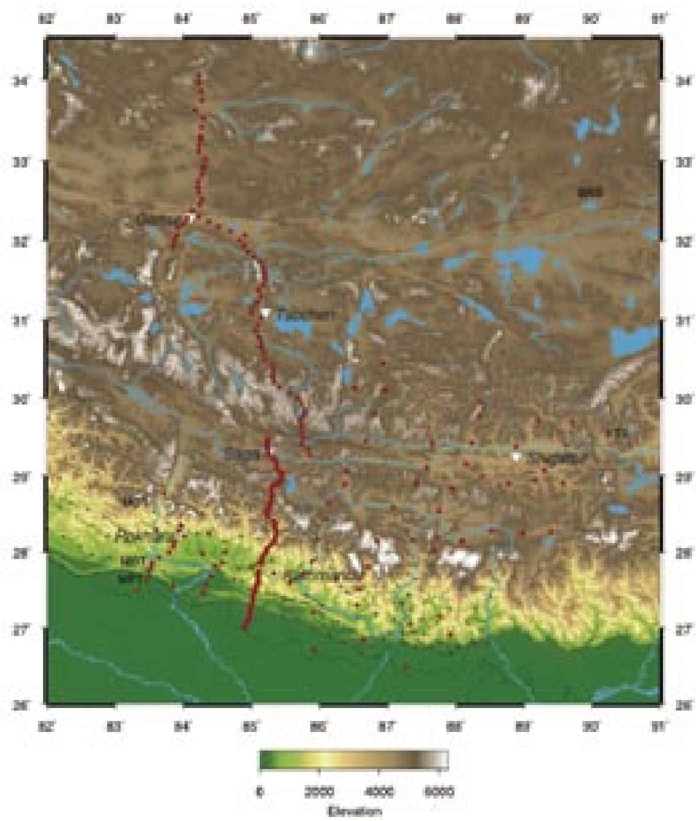
Three Flexible Array Experiments are currently supported. "PASO TRES" consists of 12 short-period passive sensors in a real-time telemetered network deployed around SAFOD to precisely locate target events near the drill hole and better define the region of penetration for SAFOD. The Sierra Nevada EarthScope Project consists of 45 broadband stations deployed in the Sierra Nevada Mountains in California to densify the Transportable Array in this area for a better picture of Earth structure. The Cascadia Tremor experiment is an array of 5 broadband and 6 short period stations deployed to record slow earthquakes in the Cascadia region.

HiCLIMB: A High-Resolution Seismic Profile Across the Himalayas and Southern Tibet

John Nabelek (Oregon State University), Wang-Ping Chen (University of Illinois), M. R. Pandey (Department of Mines and Geology, Kathmandu), Jiang Mei (Institute of Geology, Chinese Academy of Geological Sciences), John Chen (Peking University), Huang Bor-Shouh (Institute of Earth Sciences, Academia Sinica), and the Project HiCLIMB Team

Background

Project HiCLIMB, the study of the Himalayan-Tibetan Continental Lithosphere during Mountain Building, is a broadband seismic experiment whose goal is to produce a high-resolution continuous profile across the Himalaya and southern Tibet. The centerpiece of the project is a closely spaced, linear broadband array extending from the Ganga lowland, across the Himalayas, and onto the central Tibetan plateau, passing several key structural units. A complementary array of sparsely spaced stations flanks the linear array. The HiCLIMB seismic array comprises 75 broadband seismic stations from the PASSCAL program, supplemented in southern Tibet by 37 stations from the collaborating institutions from China and Taiwan. The recording started in September 2002 and was completed in September 2005. Through the experiment the instruments were moved several times, in total occupying 270 sites and making HiCLIMB the largest experiment of this sort thus far. The principal institutions involved in field operations were the Oregon State University and University of Illinois (USA), the Department of Mines and Geology (Nepal), the Chinese Academy of Geological Sciences and Peking University (China) and the Institute of Earth Sciences (Taiwan). The major funding for this project was provided by the National Science Foundation, Continental Dynamics Program.



Distribution of stations (red dots) deployed during the project HiCLIMB in Nepal and Tibet. In total, 270 broadband sites have been occupied.

Outline of the Field Deployments

The first phase of HiCLIMB, entirely in Nepal, was from September 2002 to April 2003 as a Maoist insurgency rose to its climax and compounded challenging field conditions. It took two full months to deploy 45 stations in a linear array at 3 km intervals and 30 stations on the flanks throughout eastern and central Nepal. The stations in eastern Nepal were deployed in the collaboration with the Himalayan Nepal Tibet Experiment (HIMNT) project. The main array extended from the Nepal-India border near Birganj, following the roads to Hetauda, Daman, Trisuli Bazaar, Dhunche, and Syaburbesi. Porters packed in five stations north of Syaburbesi up to the Nepal-China border at Rasuwagadhi.

For the second phase, the lateral array was dismantled and its 30 stations were redeployed in southern Tibet during May 2003 under challenging conditions provided by the high elevation, cold temperatures and high winds. Despite the SARS epidemic, road closures and restrictions in access along the proposed route, we again accomplished a 100% deployment, extending the HiCLIMB linear array by 120 km into the southern Tibet. With a station spacing of 4 km along this segment, the array passes the towns of Kyrong and Zongga and ends on the southern bank of the Yarlung River (Yarlung Tsagpo) near the town of Saga.

All stations from Nepal and southern Tibet were moved it to their final sites in central Tibet for the third phase, from June 2004 to August 2005. The new segment of the 75-station linear array with a nominal spacing of 8 km extended 500 km from the town of Saga, south of the Yarlung Tsangpo suture (YTS). It ended in a remote region at 34°N latitude, 200 km north of the Banggong-Nujiang suture, limited by difficulty navigating vehicles in muddy conditions. During this phase we also deployed 37 widely dispersed lateral stations targeting the region of unusual deep-crustal/upper-mantle seismicity. Unintentionally overlapping with the HIMNT project as the result of a permitting process set in motion several years in advance, our stations enlarged and densified the coverage of the their study region.

Field Notes

The recording conditions in Nepal were considerably noisier than in Tibet and the large topographic relief in Nepal causes unusually high amount scattering in ob-

Ouch! An STS-2 seismometer fully packed with sand by diligent termites.

served wavefields. The recording sites in Nepal suffered some damage due to high humidity, rodents chewing the electrical cables and termites infesting a sensor, but having a team permanently stationed in Nepal and conducting regularly scheduled service runs, considerably cut down on data collection disruptions. In Tibet the recording conditions were much more stable and the sites hardly deteriorated during the deployments. Working at high altitude, however, has its share of technical problems associated with it. For example, at least a half of recording disks would not operate at elevations above 5000 m. In Tibet, the main cause of instrumentation problems was vibration sustained during the transportation over large distances on extremely poor "roads", in spite of careful precautions.

First Cut on Data Analysis

The HiCLIMB team is now analyzing the vast (1.5 TB) and rich dataset acquired by the project. The first receiver function analysis, reported at AGU's Fall 2005 Meeting, shows clear images of the Moho and the upper-mantle discontinuities. The Moho, which in southern Nepal is at 45 km depth (relative to sea level), dips at a gentle angle under the Himalaya. Crossing the Himalaya, Moho depth rapidly increases, reaching 70 km near the Yarlung River. We have succeeded in imagining the Main Himalayan Trust (MHT) as it descends northward at a shallow depth from its surface expression, the Main Frontal Thrust in southern Nepal. In Nepal along the profile west of Kathmandu, MHT is expressed by a pronounced seismic low velocity zone, which we believe indicates a presence of trapped aqueous fluids in the fault zone, thus lowering the strength of the megathrust. The low velocity associated with the MHT disappears for a short distance north but reappears again as the MHT increases its dip under southern Tibet. We believe the characteristics of the low velocity associated with the MHT in southern Tibet indicate a presence of partial melt due to an increase in depth and frictional heating. A low-velocity wedge above the MHT suggests an accumulation of the melt. The Tibetan data reveal that the Indian crust tucks under the "Asian" crust, sliding under it all the way to the Banggong-Nujiang suture (BNS) where its lower portion peels off and subducts steeply under the Qiangtang terrene. Under the Lhasa terrene, where we observe fully doubled-up Indian and Asian crust, the relative motion appears to be taken up along a midcrustal low-viscosity/low-velocity zone. The lower crust is high velocity, dense and strong, thus enabling its subduction north of the BNS. The strength of the lower crust seems to be inherited from the lower Indian crust, which is high velocity already under Nepal (probably of diabase composition) and is undergoing further densification by eclogitation as it slides to greater depths under Tibet. North of the BNS the high-velocity lower crust is absent. The lower crust north of the BNS may be formed by a northward transfer of unsubducted viscous quartz-rich midcrustal material from the Lhasa terrene.

Nima, Tibetan driver, at a station at a lake south of Lugu, the northern segment of the HiCLIMB arary.

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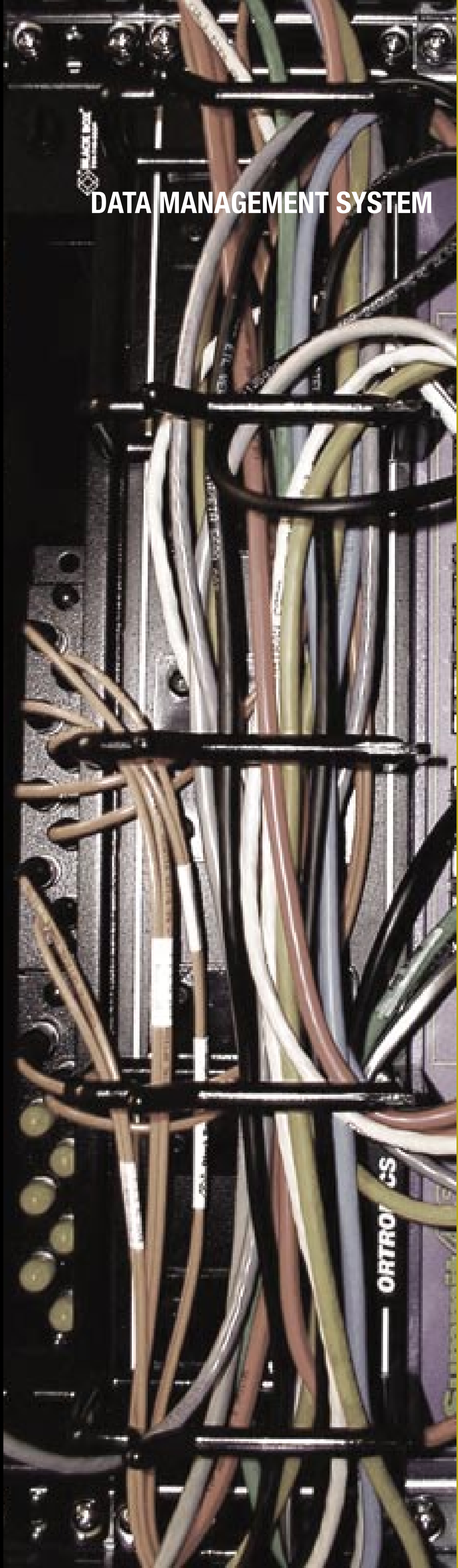


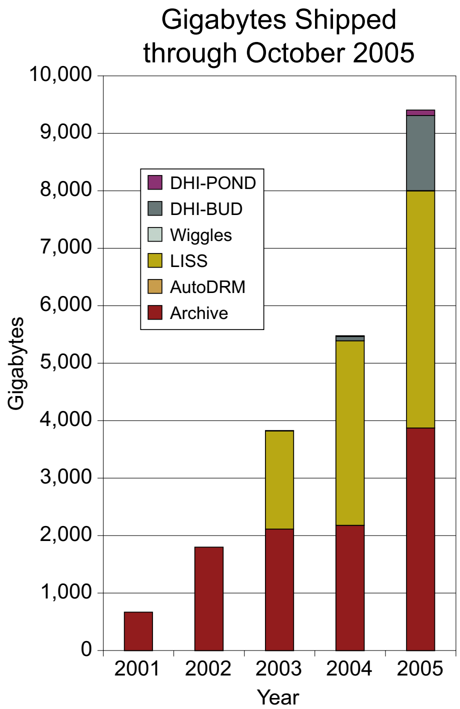
DATA MANAGEMENT SYSTEM

The IRIS Data Management System continues to be the data system of choice for most researchers in the seismological research community. Not only does it hold the largest inventory of seismological data in the world, nearly 80 terabytes and growing by 17 to 20 terabytes per year, it has a mature quality control system that assures researchers access to data of the highest reliability and fidelity.

Most data from the Global Seismographic Network are telemetered in real time to the IDA Data Collection Center at the University of California, San Diego or to the USGS operated Data Collection Center at the Albuquerque Seismological Laboratory for initial quality control. Data from PASSCAL deployments receive quality assurance by the P.I.s as well as the PASSCAL Instrument Center at New Mexico Tech. Researchers at Harvard University and the University of Washington are also supported by the DMS to add to the data quality effort that data at the DMC receives. Reviews by quality analysts are now supplemented by automated data quality evaluation at the Data Management Center, situated near the University of Washington.

Data from IRIS's GSN and PASSCAL programs are DMS's primary responsibility, and together contributed well over half of the new data archived at the DMC this year. IRIS partners with other organizations in the US and around the world to provide access to additional data sources, including the USGS's Advanced National Seismic System Backbone Network and USGS-supported regional monitoring networks. Data were contributed this year by more than 30 members organizations of the International Federation of Digital Seismographic Networks, by the SEIS-UK Portable Instrumentation Program and by the NSF-funded Ocean Bottom Seismometer Instrument Pool. Looking to help "bridge" the gap between seismologists and engineers, the DMS now collects real-time data that are primarily of engineering interest from the Factor Building on the University of California, Los Angeles campus and the Cape Girardeau Bridge in Missouri.

The DMC acquired a 50-terabyte Network Attached Storage RAID system from Isilon Systems and moved the primary copy of all Tier-1 seismic data to the Isilon, replacing the "near-line" tape-based approach to mass storage that the DMC has



used since its inception. The Powderhorn tape system continues to store backup copies of the Tier-1 data as well as storing Tier-2 data sets, which are voluminous and infrequently accessed. With all Tier-1 data available from the on-line RAID systems, data access is simplified and request-servicing time reduced. The disk-based mass storage system will support new capabilities that IRIS hopes to add during the next few years.

IRIS has led development of distributed data center access techniques, allow users to access data from multiple data centers seamlessly. The original email based system, NetDC, is now installed at the DMC, NCEDC at the University of California, Berkeley, SCEDC at the California Institute of Technology, ORFEUS in the Netherlands, MEDNET in Rome, the Geological Survey of Canada in Ottawa, and GEOSCOPE in Paris. Taking the next step, IRIS developed the "Data Handling Interface" based on industry standards. Led by the University of South Carolina, this effort has developed a stable and powerful method for users to interact directly with databases. This client-server system standardizes the interfaces to data centers globally, so a client can easily access data from multiple centers, directly exploiting the full power of Internet connectivity. DHI is now installed at the DMC, NCEDC, SCEDC, ORFEUS, the University of Memphis, and soon at the International Seismological Centre in the United Kingdom.

Rising from less than 50,000 in 2003 to nearly 100,000 in 2004, this year saw an increase to nearly 200,000 individual requests serviced at the DMC. The DMC has also seen substantial increases in the amount of data shipped, much of this growth coming from real time data distribution. While data were still shipped predominantly from the Live Internet Seismic Server (LISS) (3.7 terabytes) and directly from the archive (3.5 terabytes), the DMC provided more data using the new DHI systems (1.1 terabytes) than it shipped in total just four years ago. Automated DHI and LISS systems are largely responsible for our ability to sustain this pace, and the DMC now sends seismograms to researchers at a rate of 17.3 seismograms per second, 24 hours per day, 7 days per week.

EarthScope/USArray

The DMC receives data from the three major components of EarthScope (USArray, PBO, and SAFOD) and this year saw a marked increase in EarthScope-related capabilities. PBO contributed data from GPS receivers, borehole strain meters and laser strain meters, as well as preliminary data from borehole seismic sensors. SAFOD forwarded voluminous seismic data from the Paulsson Geophysical survey in their borehole, and discussions began to determine the DMC's involvement in managing seismic data from the down-hole seismic sensors. The DMC is the primary center managing data from the USArray component of EarthScope. Data from the USArray backbone, Transportable and Flexible Arrays are all available from the DMC using all of its data request mechanisms.

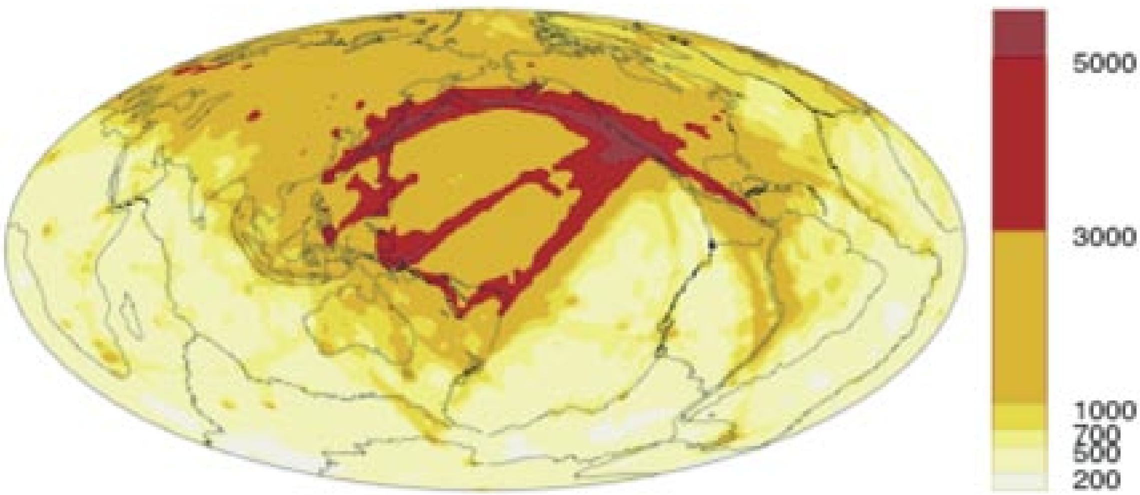
Since USArray relies upon seismic stations that are part of existing networks to make up both the Backbone and Transportable array, the concept of "virtual networks" was implemented to facilitate access to USArray data. Virtual networks allow scientists wishing to access data from USArray to simply designate a virtual network in the data request tools and the DMC translates the virtual request into the actual seismic networks and stations.

While the traditional time series data being collected as part of USArray are essential, the Earth science community is also in the process of defining products that result from processing the primary observational data. As part of EarthScope/USArray, IRIS is developing a product management system that can capture EarthScope products, archive them in a distributed manner, extract searchable metadata from the products and allow the broader community to find and recover products with desired attributes.

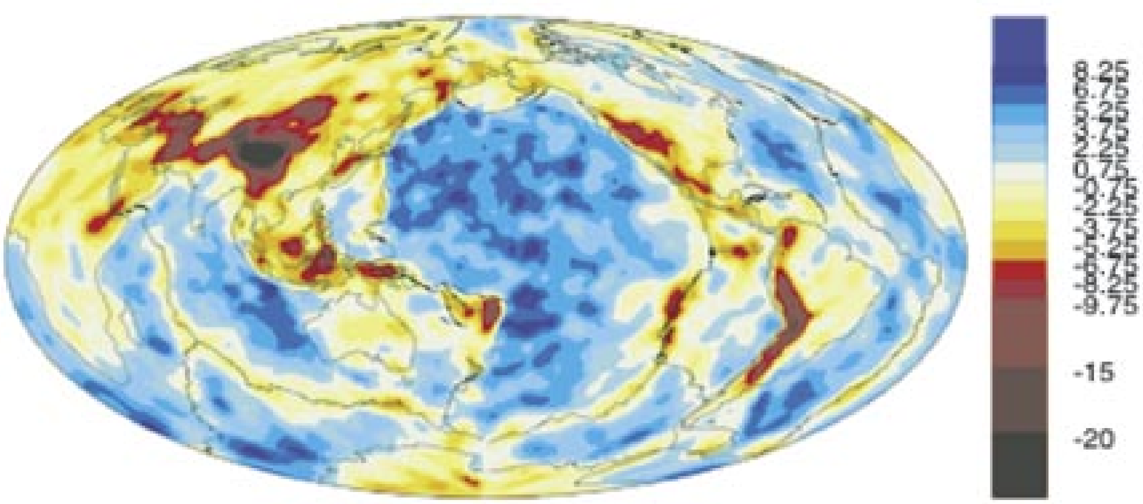
Consistent Interface to Data from Multiple Experiments Facilitates Joint Inversions

Guy Masters (University of California, San Diego)

In global tomography, we are interested in resolving Earth structure as best as we can everywhere. Many PASSCAL experiments have been performed in remote locations and provide important coverage that complements the coverage from the global networks. A consequence of this is that the database of seismograms for doing global seismic tomography is expanding at a rapid rate and it is becoming increasingly difficult to keep up with the data flow using traditional intensive interactive techniques either for surface or body waves. As a result, we have developed techniques that allow the rapid estimation of relative travel times of a variety of phases from large datasets. These techniques are based on waveform (or waveform envelope) cross-correlation with the application of cluster analysis to identify clusters of similar waveforms. Taking advantage of the DMC's consistent access protocol and format for data from numerous experiments, we have nearly automated the procedure, manually intervening only to control the quality of our measurements. Here we describe an application to the measurement of the relative group arrival times of surface wave packets. We illustrate the technique by applying it to 50 second Rayleigh waves recorded on the various global seismic networks and PASSCAL deployments through the end of 2004. The analysis resulted in a dataset of over 250,000 relative group arrival times.



Hit count map for an inversion employing equal area blocks of dimension 2 degrees at the equator. All blocks are hit by at least 100 rays while some blocks in the western US are hit by over 10,000 rays.



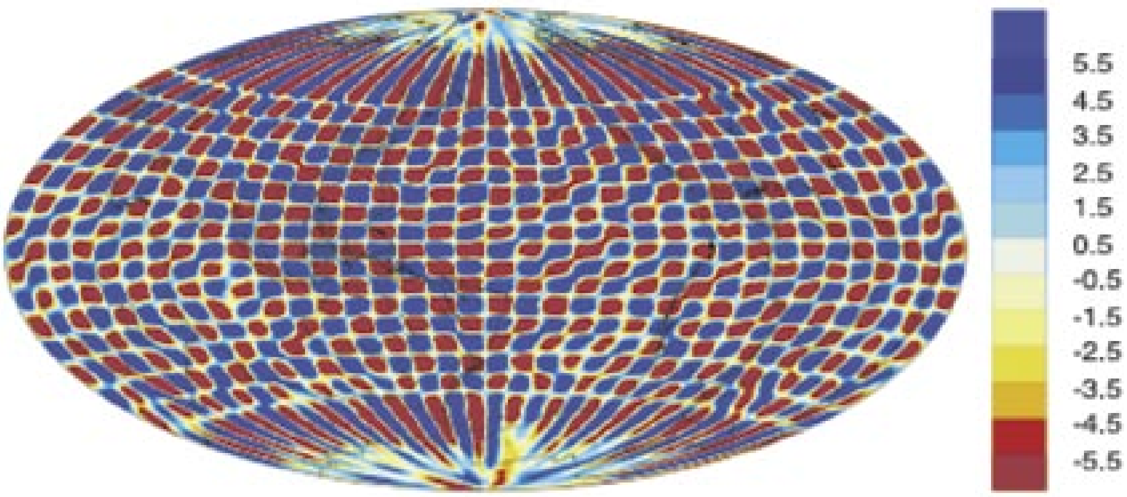
Group velocity perturbation maps for 50 sec Rayleigh waves (in percent). Note the extreme negative perturbations under Tibet and South America associated with continental crustal thickness variations. There are also many interesting signals in the oceans where the crust is relatively uniform.

To evaluate the internal consistency of our relative group arrival time measurements, we have performed a simple inversion based on ray theory assuming great circle propagation. We discretize the Earth's surface into equal area cells of dimension 1 or 2 degrees at the equator (the 2 degree cells are sufficient to capture most of the signal in the data). Sampling of the Earth is quite non-uniform though most cells have more than 500 hits and all cells have more than 100 hits. Some cells in the western US have over 10,000 hits suggesting that more sophisticated inversions could use a finer parameterization in this region.

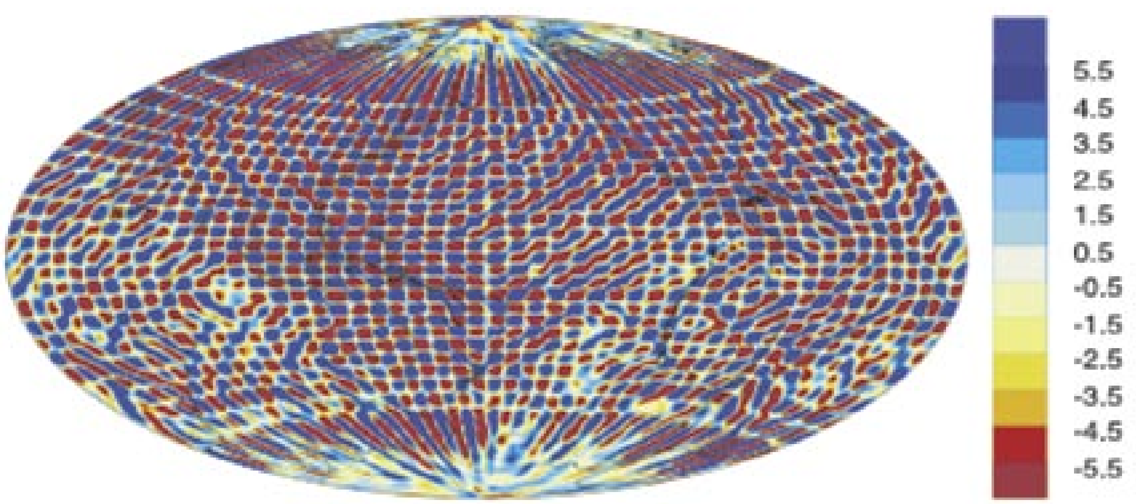
The data are inverted using a conjugate gradient technique with a light smoothing constraint on the first lateral derivative of structure. Convergence is fast, reflecting the well-conditioned nature of the inversion. The resulting model achieves a variance reduction of nearly 90%.

Clearly, the biggest signal in continental regions is due to variations in crustal thickness. Most extreme group velocity variations occur under Tibet (30%) and under the Andes. This is not surprising since the sensitivity of 50 second Rayleigh waves peaks at 70-100 km so we are actually seeing a crust-mantle signal. Other continental signals seem to be associated with hot spots, such as East Africa. The signal in oceanic regions is also interesting; there are extremely slow regions associated with back-arc basins (e.g. the Lau basin) and some hot spots (e.g. Galapagos), but the Iceland and Hawaii hotspots notably lack a significant anomaly. Some parts of the East Pacific Rise are clearly very slow and there is a perceptible slow anomaly associated with the Australian-Antarctic discordance.

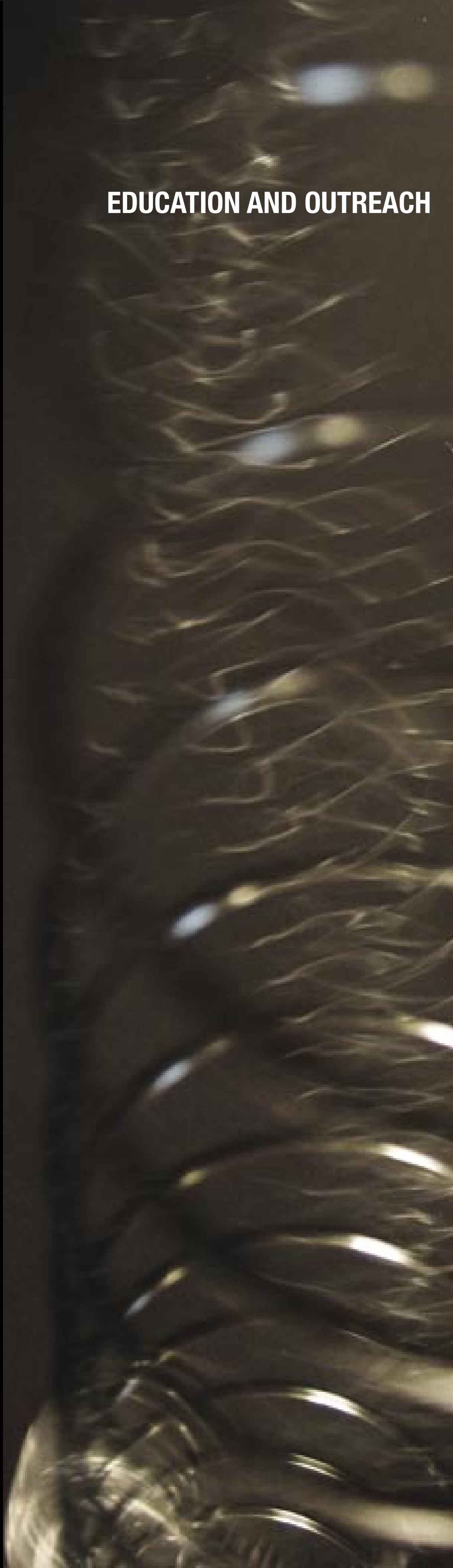
Our knowledge of crustal structure in many parts of the world is currently very limited, particularly in South America, Africa, Antarctica, and Indonesia. A checkerboard test shows the ability of the data to globally resolve structure of various wavelengths. Features of 1000km scale length and greater are resolved everywhere but we also get good resolution for most of Indonesia and South America. We anticipate that the final inversions of our datasets will result in vastly improved models of crustal thickness in these regions.



Checkerboard tests to show recovery of structure of 1000 km scale length (top) and 500km scale length (bottom)



E&O



EDUCATION AND OUTREACH

The Education and Outreach (E&O) program is committed to using seismology and the unique resources of the IRIS Consortium to make significant and lasting contributions to science education, science literacy and the general public's understanding of the Earth. The E&O program has continued its development and dissemination of a well-rounded suite of educational activities designed to impact a spectrum of learners, ranging from 5th grade students to adults. These learning experiences transpire in a variety of educational 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.

The efforts of the IRIS E&O program during the past year have been focused on the refinement and enhancement of ongoing core activities, and the expansion of their impact. The museum program highlights these efforts, with 15 million people potentially interacting annually with the IRIS/USGS museum displays, many of them at the American Museum of Natural History and the Smithsonian Institution National Museum of Natural History. An evaluation of these two displays showed that the displays are very popular in both museums, with audiences particularly interested in the presentation of near real-time seismic data. Our new smaller, more flexible version of the museum display has been tested in a small museum, a science center and a visitor center. Served via a web browser, the display is customizable for each museum and touch screens provide an interactive experience.

Another program aimed at general audiences is the IRIS/SSA Distinguished Lecture Series. This was the third year of the series, and our two speakers presented a total of 16 lectures at major museums and universities throughout the country to audiences of up to 400 people.

The E&O Program continues to refine its highly effective, one-day professional development experience designed to support the background and curricular needs of formal educators. Leveraging the expertise of Consortium members, IRIS delivers content such as: plate tectonics, propagation of seismic waves, seismographs, earthquake locations, and Earth's interior structure. A focused workshop was also offered this year to teachers who use AS1 seismographs in their classroom that they received through the IRIS seismographs in schools program. There are now more than 100 such seismographs in use by schools around the US.

The first in a series of professional development sessions for high school teachers in Yuma, AZ was conducted over three days this year. The effort, designed in collaboration with the Yuma Union High School District is part of

a systemic reform endeavor, which supports the district's need to prepare its Earth Science teachers to adequately address the newly adopted Arizona state science standards, as well as developing a scope and sequence of resources to support all of the district's Earth Science teachers.

At the core of the IRIS professional development model is the philosophy that improvements in the level of teacher use of material can be achieved by increasing teacher comfort in the classroom. Specifically, we provide professional development which:

- Increases an educator's knowledge of scientific content,
- Provides educators with a variety of high-quality, scientifically accurate activities to deliver content to students,
- Provides educators with inquiry-based learning experiences,
- Provides direct contact with research and E&O professionals from IRIS and Consortium institutions.

The short and long-term assessment of the workshops continues to provide IRIS with critical data to document the impact the program has on educators. Using this information as a guide, IRIS will continue to monitor and alter its curricular resources and implementation style in an effort to maximize this impact.

The Sumatra earthquake resulted in a new level of public interest and awareness of earthquakes. To address this interest we published a new poster highlighting the GSN recording of the Sumatra earthquake (in English and Spanish). In a related effort, the E&O Program partnered with the National Earth Science Teachers Association (NESTA) to produce an issue of their journal The Earth Scientist focused on seismology and the Sumatra earthquake. The journal has a regular distribution of 1100 members and IRIS will widely distribute the issue to help publicize the Society and to provide seismology content and classroom activities to a wide audience.

The Educational Affiliate membership category and the Undergraduate Internship program have increased IRIS' impact among their respective audiences of undergraduate faculty and students. The objective of Educational Affiliate membership is to cultivate a base of non-research colleges and universities committed to excellence in undergraduate geoscience education through the co-development of E&O activities designed to address their needs. A workshop for Educational Affiliate members held this year further clarified these needs. The first such activity to be developed was a sabbatical experience designed to provide faculty of an Educational Affiliate institution a chance to interact with seismologists at an IRIS institution (see next article). Nine undergraduates spent the past summer engaged in research at an IRIS institution. Through their participation in the program, these students gain experience in and exposure to Earth science as a potential career path.

The E&O web pages remain a primary means of dissemination of information and resources. The Seismic Monitor is the most popular IRIS Web page and we continue to add new material. Ongoing collaboration with University of South Carolina and the Digital Library for Earth System Education (DLESE) has led to the release of the Rapid Earthquake Viewer (REV). REV is a simple, real-time Web interface for viewing and exploring the seismic data that are available via the IRIS Data Management Center. A special set of Web pages was created this year for the IRIS community to quickly share scientific results relating to the Sumatra earthquake and tsunami.

Additional audiences are reached via collaboration with other regional and national geoscience programs. For example, 16,000 copies of the "History of Seismology" poster were provided this year for AGI's Earth Science Week packets. We also leverage our resources by providing materials for workshops organized by other organizations. EarthScope related activities are and will continue to be an important focus and we are working closely with both EarthScope and UNAVCO E&O programs to maximize our impact.

Standing Committee

Richard Aster (Chair)	New Mexico Tech
Kathy Ellins	University of Texas, Austin
Susan Eriksson	UNAVCO
Alan Kafka	Boston College
Steven Semken	Arizona State University
Catherine Snelson	University of Nevada, Las Vegas
Seth Stein	Northwestern University
Lisa Wald	US Geological Survey, Golden
Aaron Velasco	University of Texas, El Paso
John Taber	E&O Program Manager

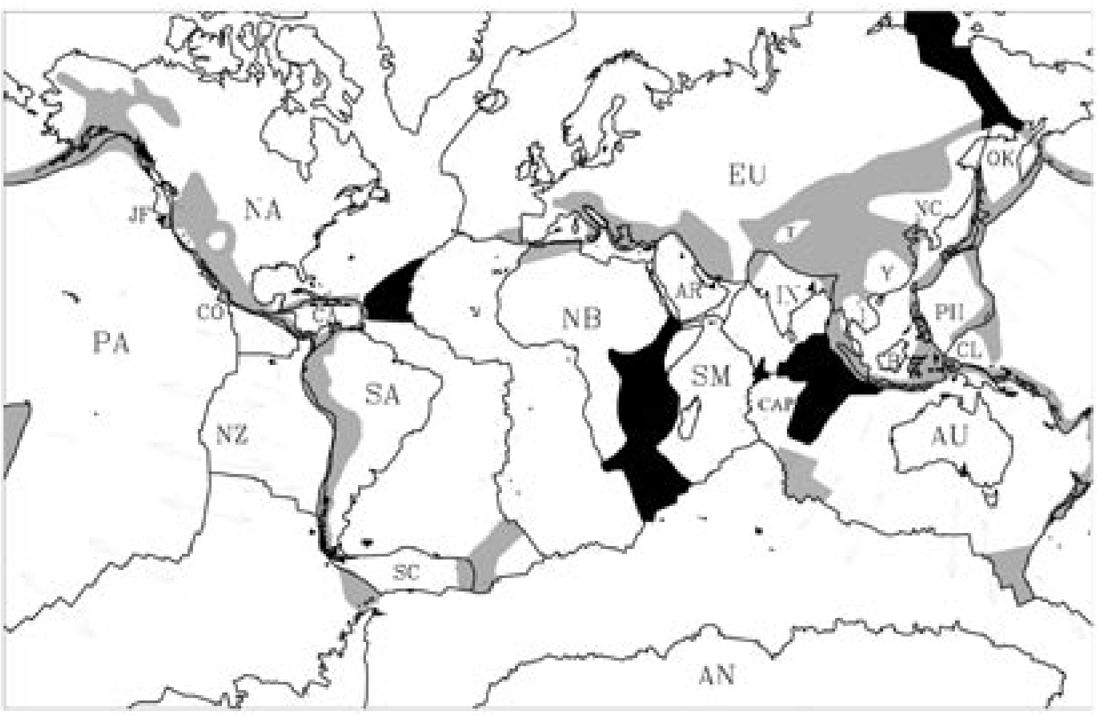
Tectonics of Oceanic Plate Boundaries

Cliff Frohlich (University of Texas at Austin) and Laura Reiser Wetzel (Eckerd College)

The IRIS Sabbaticals in Seismology (SIS) is a new initiative designed to serve the needs of faculty and students at IRIS Educational Affiliate (EA) institutions, typically colleges that do not have graduate programs in seismology but with a strong focus on undergraduate teaching. The SIS program provides support to individual faculty at Affiliate institutions so that they can collaborate with scientists at other IRIS member institutions. To facilitate different research interests and family obligations, the SIS program is flexible concerning how the interaction is organized. However, generally the sabbatical will involve one or more extended visits to a host institution, and the collaboration will focus either on a field program, a specific research project, or on activities that involve upper-level undergraduate participants. The ultimate goal of the SIS program is to promote high-quality geophysics instruction and research opportunities for undergraduates.

One of us, Laura Wetzel, is an associate professor of Marine Science at Eckerd College in St. Petersburg, FL, and became the first SIS recipient in January 2005. Eckerd College, with about 1600 students, is a small private liberal arts college whose campus lies along the coast of the Gulf of Mexico. For my sabbatical I visited the Institute for Geophysics (UTIG) at the University of Texas at Austin, one of the world's largest public universities with about 48,000 students. My sabbatical consisted of four separate extended meetings in Austin, separated by about six-week intervals. This allowed me to get research-related software running productively at Eckerd between visits, and, since I am the mother of a three-year-old child, minimized the family disruption.

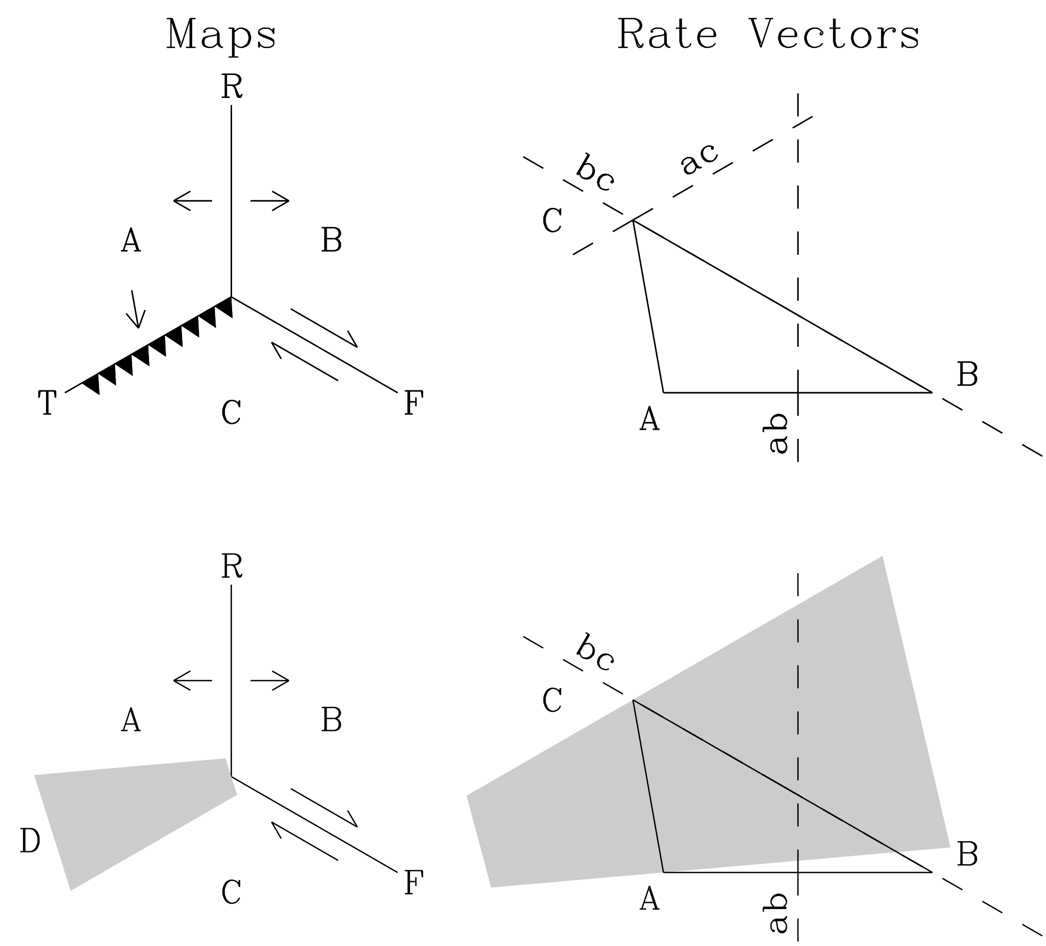
At UTIG, we collaborated on several projects evaluating properties of earthquakes along plate boundaries and near triple junctions. We chose to focus on research projects analyzing data in widely available earthquake catalogs. With catalog analysis, it is possible to frame questions that undergraduates with little or no formal background in seismology can tackle. While researching these questions the students develop general data-handling and data-analysis skills that are useful in a wide variety of disciplines.



Diffuse plate boundaries addressed in this study (black) and diffuse deformation associated with other plate boundaries (gray). (Modified from Gordon, 1998.)

In one project, we collaborated with Eckerd undergraduate Alexis Clark to evaluate how moment release varied along plate boundaries in different tectonic environments, and how moment release depends locally on the length of plate boundary segments along oceanic ridge-transforms. Clark joined us during on one of our extended meetings in Texas, and we all coauthored a poster on this research at the Fall 2005 AGU in San Francisco.

In a second project, we focused on how the presence of diffuse plate boundaries affect triple junction stability. A diffuse plate boundary is a broad zone of deformation between two rigid plates that move independently. Along such boundaries seismic activity is typically low and distributed over a zone hundreds to thousands of kilometers wide. Examples of diffuse boundaries include the boundaries between the North American and South American plates, the Nubian and Somalian plates, the Indian and Australian plates, and the Eurasian and North American plates. In each of these cases, the velocities across the boundary are slow (less than 4 cm/yr) because the pole of rotation for the plate



Schematic plate boundary maps and rate vector diagrams for a regular and diffuse triple junction. (Top) The regular Transform-Ridge-Trench (FRT) triple junction is unstable because the three dashed lines representing the strikes of the plate boundaries do not meet at a single point on the rate vector diagram. (Bottom) The diffuse triple junction is stable because the gray region representing the diffuse plate boundary ac encompasses the intersection of lines ab and bc.

pair is located within or near the diffuse plate boundary. This geometry causes extension on one side and compression on the other side of the pole, producing both normal-faulting and thrusting earthquake mechanisms.

One can determine the stability of diffuse triple junctions by modifying the velocity vector diagram method of McKenzie and Morgan (Nature, 1969). In this method, one draws a vector diagram representing the relative velocity of each pair of plates, and constructs a stability line representing all possible vector motions that remain along the plate boundary. For a diffuse plate boundary, the edge of the plate is not clearly defined by a spreading center, trench, or transform; rather, the ongoing deformation is distributed over a broad zone. As a result, a considerable range of vectors will represent motions that remain in this zone. On a velocity vector diagram the stability line becomes a broad zone rather than a single line. At triple junctions with one diffuse boundary, this 'stability zone' typically encompasses the stability lines of the remaining two plate boundaries where they intersect. This indicates that triple junctions with one diffuse boundary are stable for a wide range of plate boundary orientations, and may explain why diffuse-boundary triple junctions are as common as they are.

The three of us are all very positive about our experience in the SIS program, and we expect to submit two journal articles describing our research. Wetzel notes that, "The IRIS Sabbaticals in Seismology program gave me the first opportunity since graduate school to immerse myself in a research environment, and allowed me to develop some new tools." Frohlich states, "My collaboration with Laura provoked me to think about shallow earthquakes along oceanic ridge-transform boundaries, a new area for me. Laura's marine background is stronger than mine and we had many productive discussions about what's happening along oceanic plate boundaries. I'm also hoping that, because of the SIS visits, more Eckerd students like Alexis Clark will consider coming to Texas for graduate school." At this time Clark won't say what her plans are, stating only that "Austin is cool."

EARTHSCOPE

TRANSPORTABLE ARRAY

The Transportable Array is a dense array of broadband seismographs that is being installed across the continental United States and Alaska as part of the USArray component of the NSF-funded EarthScope project. With a station spacing of ~70 km, the array will provide unprecedented coverage for producing 3-D images of the Earth interior and new insights into the earthquake process. The array will consist of 400 transportable broadband seismic stations that will advance across the country in a roll-along fashion. The stations will have an average residence time of about 24 months to cover 2000 locations over a period of 10-12 years.

Installation of the 127th Transportable Array station was completed this year, including all of the California stations, many of which are part of existing permanent networks. Installations in Oregon and Washington are building across the Cascades and then eastward and southward into Nevada. More than 220 stations will be installed by the end of 2006 and the first complete footprint of the 400-station array will be installed by September 2007. Daily updates on the status of the Transportable Array and other EarthScope facilities are provided on the EarthScope home page (www.EarthScope.org) and plots of data from both local and distant earthquakes show the quality and quantity of data already available for each event.

The installation process has been perfected over the past year to allow the field crews to move efficiently from site to site and to install approximately 10 new stations per month. A construction crew digs the holes, pours the concrete and installs the tank for the seismometer and electronics during one day. A separate crew arrives on a second day after the cement has set and installs the seismometer, electronics, and communication equipment. Data are telemetered in a variety of ways, including cell phone modem, broadband Internet, and satellite link. The remote sites are all solar powered, though satellite links use mains power where available.

Support Facilities

While roving field teams do reconnaissance, construction and installation, their success and the distribution of the data to users depends on the support of staff at a several fixed facilities including the Transportable Array Coordinating Office, Array Operations Facility, Array Network Facility and the IRIS Data Management Center.

The New Mexico Institute of Mining and Technology houses the Array Operations Facility (AOF) and the Transportable Array Coordinating Office (TACO) in the newly expanded PASSCAL Instrument Center building in Socorro. The AOF supports both the Transportable Array and Flexible Array, fulfilling a role similar to that of the PASSCAL Instrument Center, which consists primarily of testing new equipment then packing and shipping it to the field. The AOF has also helped in field operations for a few of the first five stations, but the field operations for the Transportable Array are largely run through contracted services. The TACO at the Instrument Center began operation near the end of 2005, and will provide much needed support for permitting, and schedule and materials coordination between the AOF and field crews. The AOF employs 3 FTEs (full-time equivalent staff) for the Transportable Array, 4 FTEs work in the TACO, and 9 FTEs are engaged in field operations.

Signals are flowing smoothly from the field installations to the Array Network Facility at the University of California, San Diego. There, 4 FTEs check the data for quality and store them using applications to display the real-time data and perform online analysis of station and instrument status, environmental monitoring, and state of health. Then the data are forwarded to the IRIS Data Management Center in Seattle, which does further quality control, including routine checking of power spectral density plots to examine noise characteristics of each site. The data are then archived and made available to all users.

Cooperative Siting

A key element in the success of the Transportable Array has been the involvement of regional networks and IRIS members in station siting and permitting, tailored to suit the partners in each region. In states with regional networks, the network operators conduct much of the siting. A prime example is California, where the University of California, Berkley, the California Institute of Technology, and the University of California, San Diego participated both in siting new locations and upgrading and making existing stations available to the Transportable Array. The University of Washington is currently involved in Washington State siting and the University of Nevada, Reno has completed much of the siting in Nevada.

Graduate students from Oregon State University helped find sites for 48 Transportable Array stations throughout the state using their knowledge of geoscience. A multi-day training workshop was held for the students at the beginning of the summer where the students learned to identify sites that meet the requirements of the Transportable Array using a Geographic Information System and their own field investigations. Eight students then worked in pairs, each covering a quarter of the state, to identify potential sites and make initial contact with landowners. Once the students identified the sites they turned the information over to a professional permitter who completed the siting process. Some of the students continued with the project after the Oregon siting was completed and helped find sites in southern Washington.

A workshop at Arizona State University trained graduate students to help site stations in Arizona and provided a forum for consulting with Native American communities, including the Navajo, Hopi, Hualapai, and Gila River nations. With demonstrations of EarthScope stations, the workshop initiated EarthScope education and outreach partnerships with Native American schools and communities and facilitated permitting and access to Native lands for USArray. Similar, future initiatives plan to engage the University of Idaho, Boise State University, and the University of Utah.

Transportable Array Working Group

Gary Pavlis (Chair)	Indiana University
John Collins	Woods Hole Oceanographic Institution
Matt Fouch	Arizona State University
Hersch Gilbert	University of Arizona
Egill Hauksson	California Institute of Technology
Michael Ritzwoller	University of Colorado
Suzanne van der Lee	Northwestern University
Timothy Ahern (obs)	DMS observer
Marcos Alvarez (obs)	PASSCAL observer
Bruce Beaudoin (obs)	Array Operating Facility - observer
James Fowler (obs)	PASSCAL observer
Shane Ingate (obs)	USArray MT
Alan Levander (obs)	PASSCAL SC Chair
David Simpson (obs)	USArray PI
John Taber (obs)	E&O observer
Gregory van der Vink (obs)	EarthScope
Frank Vernon (obs)	Array Network Facility - observer
Robert Woolley (obs)	USArray Project Director

In addition to program oversight and administration, the Consortium also serves the role of an on-going forum for exchanging ideas, setting community priorities, and fostering cooperation. Our publications, which are widely distributed without charge, are organized around education materials and topical issues that highlight emerging opportunities for seismology. The annual workshop is used to assess the state of the science, introduce programs, and provide training. Through a student grant program, young scientists attend the workshop at little or no cost. As a Consortium, IRIS also serves as a representative for the Geoscience community. IRIS staff and Committee members serve on federal agency panels, and testify before Congress. Such broad interactions raise the profile of Geosciences and provide a direct societal return from the federal investment in IRIS.

Joint IRIS-UNAVCO Workshop June 9-11 2005

The 17th Annual IRIS Workshop, held at Skamania Lodge in the dramatic Columbia River Gorge, vividly demonstrated the power of multidisciplinary science. Held jointly with UNAVCO for the second time in just three years, the Workshop attracted more than 300 participants.

From the nearly equatorial great earthquake in Sumatra to Antarctica, and from volcano dynamics to Earth structure imaging, the complementary nature of seismic and geodetic techniques was unmistakable in each of the four plenary sessions. Talks of broad interest were complemented by in-depth presentations and extended discussion of in a closely related special interest group meeting following each of the plenary sessions. More than a dozen additional special interest group meetings and over 100 poster presentations enhanced the breadth of the workshop.

The Annual Workshop also provided an opportunity for groups with overlapping interests to hold complementary workshops. This year there were Web Services, Educational Affiliates, Infrasound and Computing Infrastructure for Geodynamics (CIG) workshops on the days immediately before and after the main event.

Workshop Reports Published during 2005

"Prospects for Low-Frequency Seismometry", edited by Shane Ingate and Jon Berger, summarizes the outcome from the IRIS Broadband Seismometer Workshop, held in March 2004. The report provides an overview of the important challenges faced by the global seismology community with the end of production of the Streckeisen STS-1 and suggests the steps that could be taken to meet those challenges.

The report from the Workshop on Data Products for Education and Research from the USArray, held in October 2004, was edited Anne Trehu, who also chaired the organizing committee. The report summarizes the suggestions of the workshop participants on how to obtain the full benefit from USArray data by developing a standard set of products that could be prepared and centrally managed for each phase of the Transportable Array deployment and many Flexible Array experiments.

Meetings and Publications Subcommittee

Greg Beroza (Chair)	Stanford University, IRIS Board
Richard Aster	New Mexico Tech, E&O
David James	Carnegie Institution of Washington, PASSCAL
Guust Nolet	Princeton University, DMS
Jeffrey Park	Yale University, GSN
Raymond Willemann	IRIS Director of Planning

Financial Overview

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 US Geological Survey. 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, University of Hawaii, Albuquerque Seismological Laboratory, Synapse Science Center, Moscow, Woods Hole Oceanographic Institution, Montana Tech, University of Texas at Austin, and Texas Tech University.

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, the University of California, San Diego, 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. Subawards include the University of Washington, Harvard University, the University of California, San Diego, Columbia University, Synapse Science Center, Moscow, University of South Carolina, and 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 hard-copy, 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.

Indirect Expenses

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

Other Activities

Other activities include IRIS workshops, publications and special projects such as KNET.

IRIS Budgets

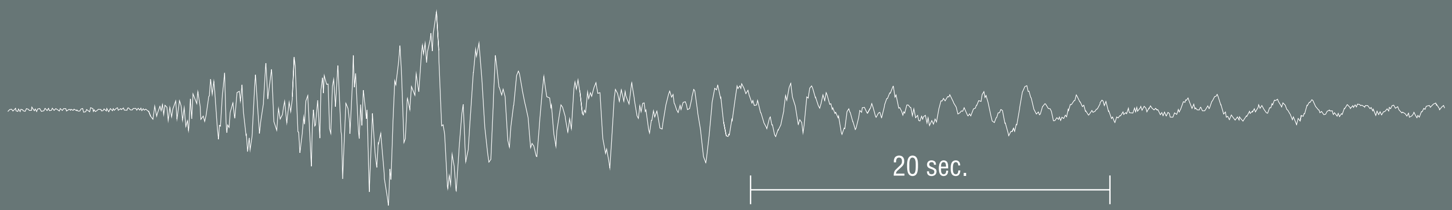
Core program budgets* (July 1, 2004 – June 30, 2005)	*FY2005*	Earthscope awards** (Oct. 1, 2004 – Sept. 30, 2005)	
GSN	3,444,761	Permanent Backbone	2,077,021
PASSCAL	3,506,617	Transportable/Flexible Arrays	11,240,363
DMS	3,400,514	Data Management	751,622
E&O	650,164	Siting Outreach	64,600
Other	523,942	Other	55,202
		Earthscope Office	1,451,656
Indirect Costs	1,299,529	Indirect Costs	1,419,084
Total	***12,825,527***	***Total***	***17,059,548****

* 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 Ocean Sciences, DOE, CTBTO, SCEC, JPL, etc.

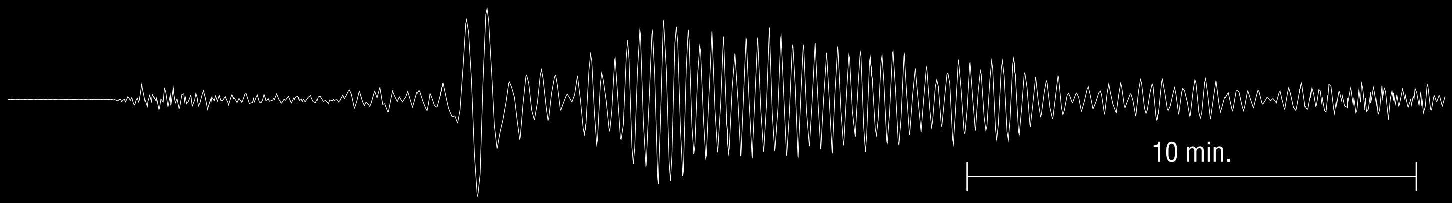
** Includes budgets for USArray MREFC & O&M, and the Earthscope Office Cooperative Agreements.

The consolidated financial statements of IRIS and IRIS Ocean Cable, Incorporated, and the Auditor's Report are available from the IRIS business office upon request.

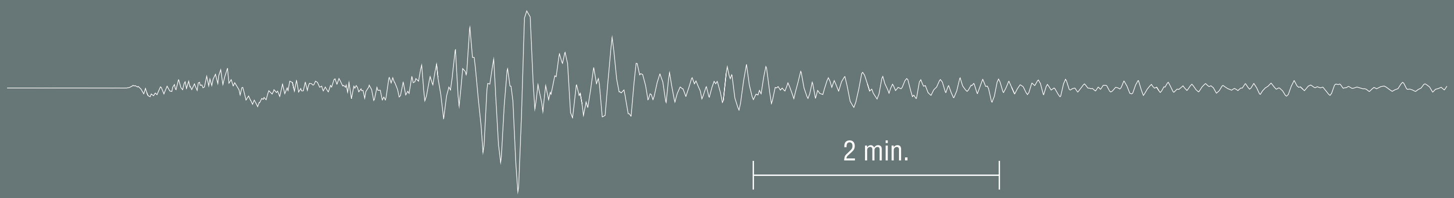
Budget and Finance Subcommittee	
Susan Beck (Chair)	University of Arizona
Arthur Lerner-Lam	Columbia University
Brian Stump	Southern Methodist University
Candy Shin	Director of Finance & Administration



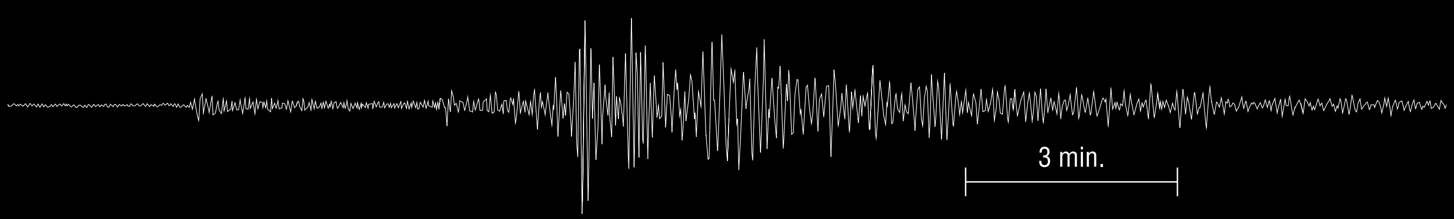
Recording from the PASSCAL experiment "Yellowstone RAMP" of an M4.4 earthquake 30 miles from "Old Faithful" geyser on August 21, 2003. The experiment was deployed in the Norris Geyser Basin to record seismic energy related to increased ground surface temperature and changes in geyser and hot spring activity in the Norris Spring geyser basin.



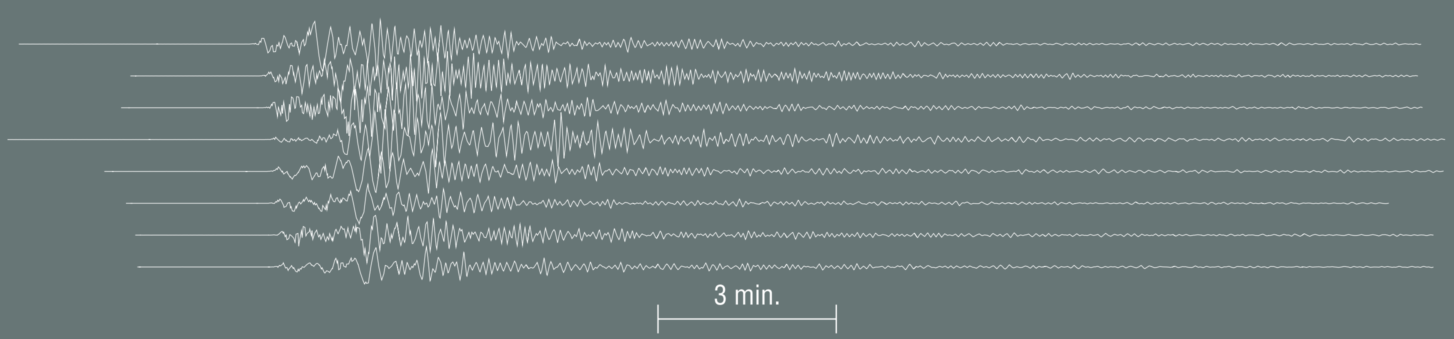
Vertical broadband recording of the MW8.6 earthquake near the Sumatran island of Nias. The seismogram was recorded at Diego Garcia, 26° from the epicenter. The second largest earthquake since 1964, the rupture zone of this aftershock extended along the Australia-Sunda interplate thrust zone southeast from the MW9.3 earthquake of December 2005. No hazardous tsunami resulted in this case, partly because slip was concentrated at greater depth, but more than 1000 people died and hundreds of buildings were destroyed.



Recording from Shymkent, contributed to the DMC by the Kazakhstan Academy of Sciences, of the of the October 8, 2005 MW7.6 earthquake in Muzaffarabad in northern Pakistan, which killed more than 86,000 people, injured tens of thousands, left several million homeless, and cutoff access to much of the region as the result of landslides and rockfalls that damaged or destroyed mountain roads. Earthquakes in the region on numerous active thrust faults result from collision between the Indian subcontinent and Eurasia.



Recording from Crawfordsville High School, Indiana of the July 26 MW5.6 earthquake near Dillon in western Montana, the largest earthquake within the conterminous 48 states during 2005. The earthquake, which had a normal faulting mechanism, caused strong shaking in Dillon and was felt as far away as Seattle. At a distance of 20° from the earthquake, the record from this educational seismic station clearly shows the P and S body phases, high frequency crustal waves, and a dispersed Rayleigh wavetrain.



Selected Transportable Array recordings between 1° and 4° from the June 15, 2005 MW7.2 earthquake off the coast of northern California, which resulted from left-lateral slip on a northeast striking fault within the Gorda plate. Light shaking was felt widely along the coastline in northern California and southern Oregon. Strike-slip earthquakes, which are typical in this area, cause little vertical surface displacement and so rarely produce large tsunamis; tide gauges recorded a wave height of just 3 centimeters in this case.

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