IRIS

ANNUALreport

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BOARD of directors

The Board of Directors, selected by the Voting Members of IRIS in annual elections, is vested with full power in the management of IRIS' affairs. The Board 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 Public Outreach (EPO) programs. 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.

from the BOARD CHAIR

The time period July 2010 to July 2011 has been an incredibly active one for our discipline as well as for the Consortium and facility. The Consortium now consists of 114 US universities and research institutions and has a robust number of educational and foreign affiliates. As the new Board Chair, I have been impressed by the number of community members that take part in our governance structure and provide direct scientific leadership and feedback to our excellent facilities. This leadership is central to IRIS and assures that we remain nimble, responsive, innovative and cost-effective. Thank you to the nearly 80 individuals who are engaged in our governance structure. In addition, we owe a big thank you to the IRIS professional staff who understand the special relationship with the seismological community and, as a result, run facilities that continuously serve our needs.

The last twelve months have seen a number of changes in these facilities, which both enhance our operations and provide new resources for the community. The summer of 2010 saw the establishment of Instrumentation Services in order to coordinate the activities of Global Seismographic Network, PASSCAL, USArray and Polar Services. This new structure offers an opportunity for leveraging activities and prepares us for a new five-year proposal to the National Science Foundation, which will combine activities related to our core programs and USArray. This year has also seen advancements in the area of Data Services that now give us new tools for accessing data as well as data products that can impact both our research and educational activities. The Tohoku earthquake reminded us of the impact of earthquakes on people and societies, as well as the international nature of our science. Education and Public Outreach helps us spread this message while International Development Seismology continues on a path reaching out to other parts of the globe.

The coming year offers a number of new opportunities. In particular, we will be developing our vision for the next five years of IRIS and beyond. This proposal, with the inclusion of the USArray, provides the Consortium with the opportunity to strengthen our interactions with UNAVCO. I encourage all of you to help us articulate the type of facility we will need to push our science forward over the coming years. Finally, the IRIS Workshop is 13-15 June 2012 where we will explore as a community future opportunities in seismology and geophysics.

BRIAN STUMP

from the PRESIDENT

The staff at IRIS and at our partner institutions are very proud of the quality and breadth of the facilities we provide to support seismological research and Earth science education. We derive great satisfaction from watching exciting science emerge from the use of these resources in the US and throughout the world. We are constantly energized by engagement with the community – on our advisory committees and working groups, in the field and responding to data requests. We are pleased to see the growth of seismology in the faces of new graduate students and research scientists – some of whom were first introduced to seismology as IRIS summer interns.

This year sees the end of one Cooperative Agreement with the National Science Foundation, the start of a new one, and the initial development of a proposal that will merge the management of our traditional core programs and USArray starting in 2013. While significant effort and energy from the community and staff goes into the development of these multi-year proposals, they provide a stimulating and fertile opportunity to review and plan how our facilities should grow and evolve. Throughout our 25-year history, this continuous community engagement, coupled with stable and generous support from the National Science Foundation, have been essential ingredients in keeping your Consortium responsive and healthy.

This Annual Report provides an overview of the exciting activities carried out by IRIS over the past year and gives a brief glimpse into some of the scientific and educational advances based on IRIS data and facilities. As the core programs continue to serve your current research needs, we are working to improve data quality and explore new instrumentation, services and data products. The Transportable Array continues its amazing march across the continent, producing data of exceptional quality that are being applied to an increasing variety of new research projects. Our newest venture, International Development Seismology, continues to explore ways to open doors to new opportunities for research and hazard mitigation in developing countries.

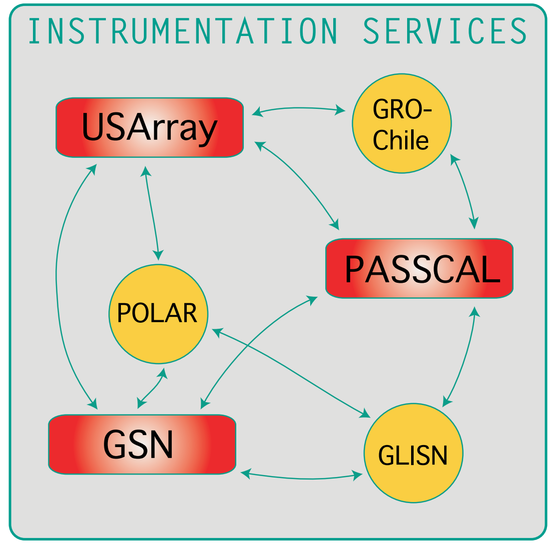
To those who serve in IRIS governance, and to our dedicated and talented staff – my sincere thanks. To all of you who make use of the resources that IRIS provides – please engage! IRIS is your Consortium and only with your constant guidance, encouragement and stimulation can we continue to sustain the highest quality services and products to serve your research and educational needs now and in the future.

DAVID SIMPSON

INSTRUMENTATION SERVICES

IS management

Robert WOODWARD IRIS



The current activities which comprise Instrumentation Services.

Summary

ABOUT INSTRUMENTATION SERVICES

In response to the expanding capabilities of IRIS, the Instrumentation Services (IS) directorate was created in FY2011 to coordinate the facility's instrument-related activities including the core facilities of the Global Seismographic Network (GSN), Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL), and USArray, as well as sub-programs including Polar activities, Greenland Ice Sheet Monitoring Network (GLISN), and the Global Reporting Geophysical Observatories within the Chilean National Seismic Network (GRO-Chile). IS leverages technical synergy across these programs, administers budgets, and improves interfaces with other IRIS programs, including Data Services and Education and Public Outreach. A key effort under Instrumentation Services is coordinating the portfolio of engineering activities executed by the PASSCAL Instrument Center (PIC), USArray, and GSN technical teams.

PROJECT ENGINEERING

The implementation of standard systems engineering tools, such as project initiation forms and project charters, enables joint review and discussion of engineering tasks. An online database of current and future engineering projects makes information readily accessible. Projects may be jointly managed between programs, and general knowledge sharing across groups expedites the engineering goals of the core programs and improves the allocation of resources at the PIC, the Transportable Array's Array Network Facility, the Albuquerque Seismological Laboratory, and the University of San Diego-International Deployment of Accelerometers Project. Development of new sensors, communication systems, and power systems occurs under this directorate. Improved strategies for sensor emplacement, integrated training for field crews, and efficient shipment of materials are all potential long-term outcomes from IS collaborations.

PROGRAM ACTIVITIES

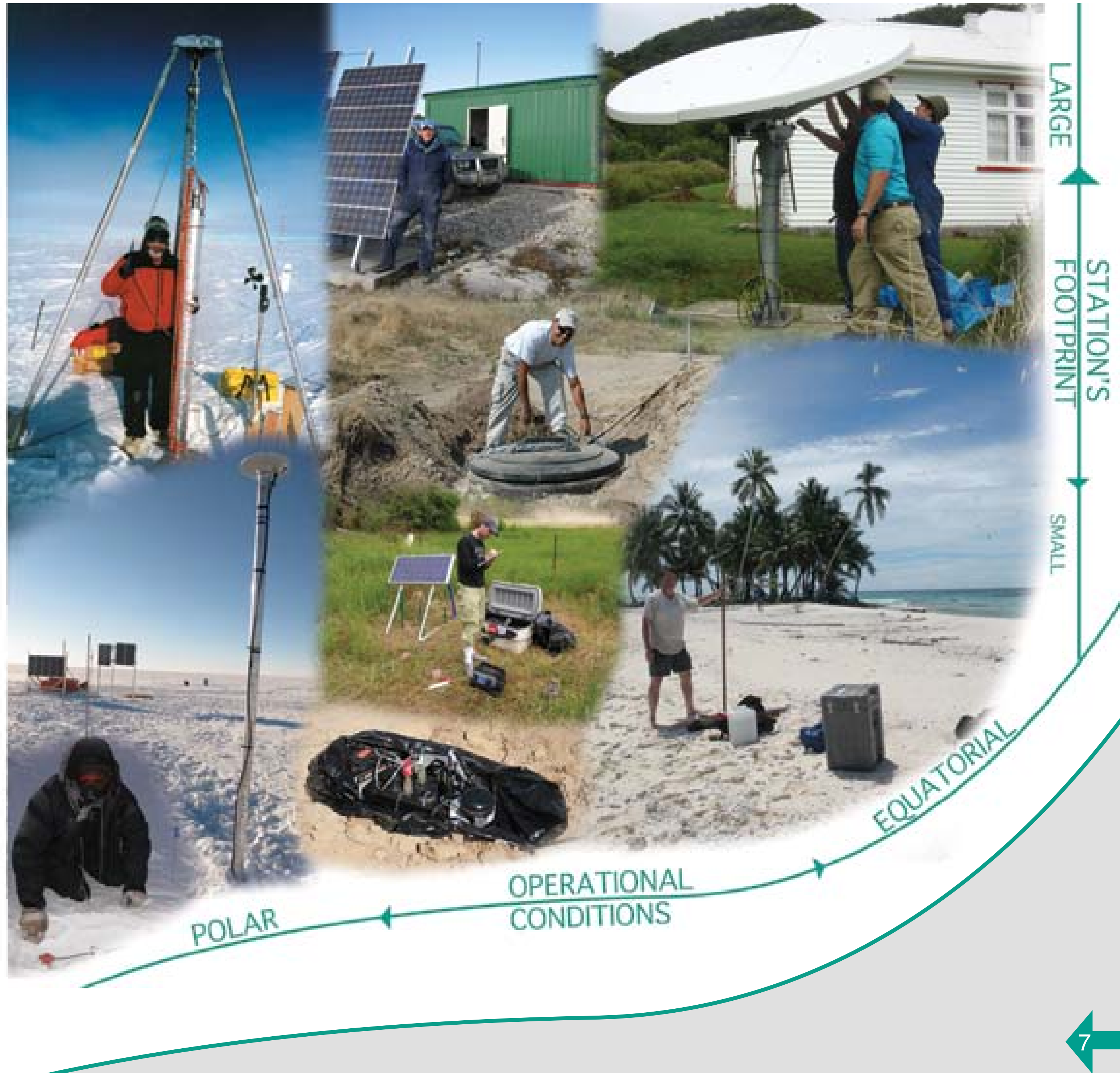
Program activities already underway have substantial cross-program impacts. Through the GSN, ongoing efforts include improving operational logistics, performing site upgrades, and relocating entire stations.

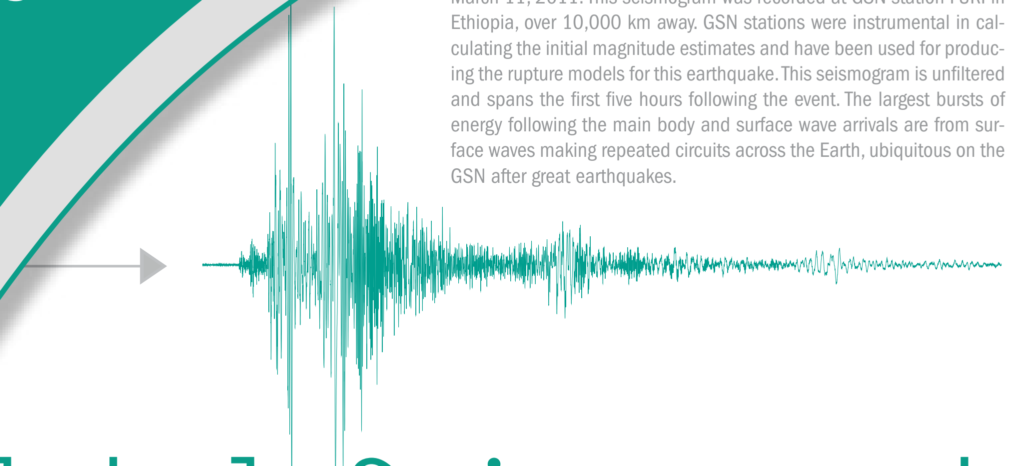
PASSCAL is focusing on testing new sources and systems for near-surface investigations. Both programs are working towards developing a new generation of sensors and systems for high-quality seismographic installations. Educational programs can make ample use of improved near-surface geophysical instruments in teaching settings.

DATA COLLABORATION

Collaborations between Instrumentation Services and other IRIS directorates are underway. Increasing the data management efficiency and capability within PASSCAL and USArray's Flexible Array can be achieved by using tools from IRIS Data Services and from the Transportable Array's Array Network Facility and the GSN Data Collection Centers. A major effort for IS in the coming months will be the development of new quality control software which requires coordination across all elements of Instrumentation Services as well as Data Services. This software will be applied to evaluate real-time data from the GSN and archived waveforms from PASSCAL and USArray experiments. Furthermore, interaction between Polar, GLISN, GSN, and PASSCAL with USArray will greatly benefit the anticipated deployment of the Transportable Array to Alaska.

The Instrumentation Services directorate will facilitate the management of large, cross-cutting instrumentation projects; assist in the creation of new data products; and support capacity building internationally. The presence of IS prepares IRIS to implement the integrated facility structure that NSF has requested beginning in 2013, identifying common needs and initiatives and building a better framework for continued high-level science.





An east-west channel recording of the M9.0 Tohoku earthquake on March 11, 2011. This seismogram was recorded at GSN station FURI in Ethiopia, over 10,000 km away. GSN stations were instrumental in calculating the initial magnitude estimates and have been used for producing the rupture models for this earthquake. This seismogram is unfiltered and spans the first five hours following the event. The largest bursts of energy following the main body and surface wave arrivals are from surface waves making repeated circuits across the Earth, ubiquitous on the GSN after great earthquakes.

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Michael HEDLIN	University of California, San Diego
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Meredith NETTLES	Lamont-Doherty Earth Obs of Columbia University
Gerardo SUAREZ	Instituto de Geofisica, UNAM
Michael THORNE	University of Utah

GSN management

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Peter DAVIS	UCSD IDA

Global Seismographic Network

OVERVIEW

The Global Seismographic Network (GSN) is a permanent network of state-of-the-art seismological and geophysical sensors connected by telecommunications to serve the scientific research and monitoring requirements of our national and international communities. Installed to provide broad, uniform global coverage of the Earth, all data from GSN stations are freely and openly available to anyone via the IRIS Data Management Center. In cooperation with over 100 host organizations and seismic networks in 70 countries worldwide, 153 GSN stations are now sited on all seven continents and near both poles. The GSN coordinates closely with other international networks through the International Federation of Digital Seismograph Networks (FDSN). The GSN is primarily operated and maintained through the US Geological Survey's (USGS) Albuquerque Seismological Laboratory (ASL) and through an IRIS subaward to the University of California, San Diego (UCSD) International Deployment of Accelerometers (IDA) group.

Twenty GSN Affiliate stations and arrays contribute to the network, including the nine-station USGS Caribbean Network. The GSN is the primary source of data used by the US Geological Survey's National Earthquake Information Center (NEIC) to monitor global earthquake activity and provide information on earthquake locations, earthquake hazard assessment, and earthquake emergency response. The GSN also provides essential data to the National Oceanic and Atmospheric Administration (NOAA) Tsunami Warning Centers for tsunami warning response globally. The GSN participates within the Global Earth Observing System of Systems (GEOSS). The GSN also works closely with the International Monitoring System (IMS) for the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO). Thirty-one GSN stations and seven GSN Affiliates are now linked directly to the CTBTO International Data Centre (IDC), mostly via their global communication infrastructure (GCI).

GSN DATA QUALITY INITIATIVE

During 2011, IRIS, in collaboration with the USGS/GSN, the GSN Standing Committee and the GSN network operators at ASL and UCSD, began implementing a new data quality assurance system that defines new policies, procedures, metrics and reporting schemes for describing GSN data quality to both the operations community and the data user community. Implementation of this effort is initially between the GSN operations centers and their respective Data Collection Centers (DCCs). As a part of the overall Data Management System, the DCCs will coordinate and implement GSN data quality requirements in conjunction with the IRIS Data Management Center. A new framework for implementing quality metrics within IRIS is underway and will be extensible to all IRIS data holdings. This effort was undertaken to assure that the quality of data from the GSN is as high as possible and that the quality status of each station is openly represented to the data user community.

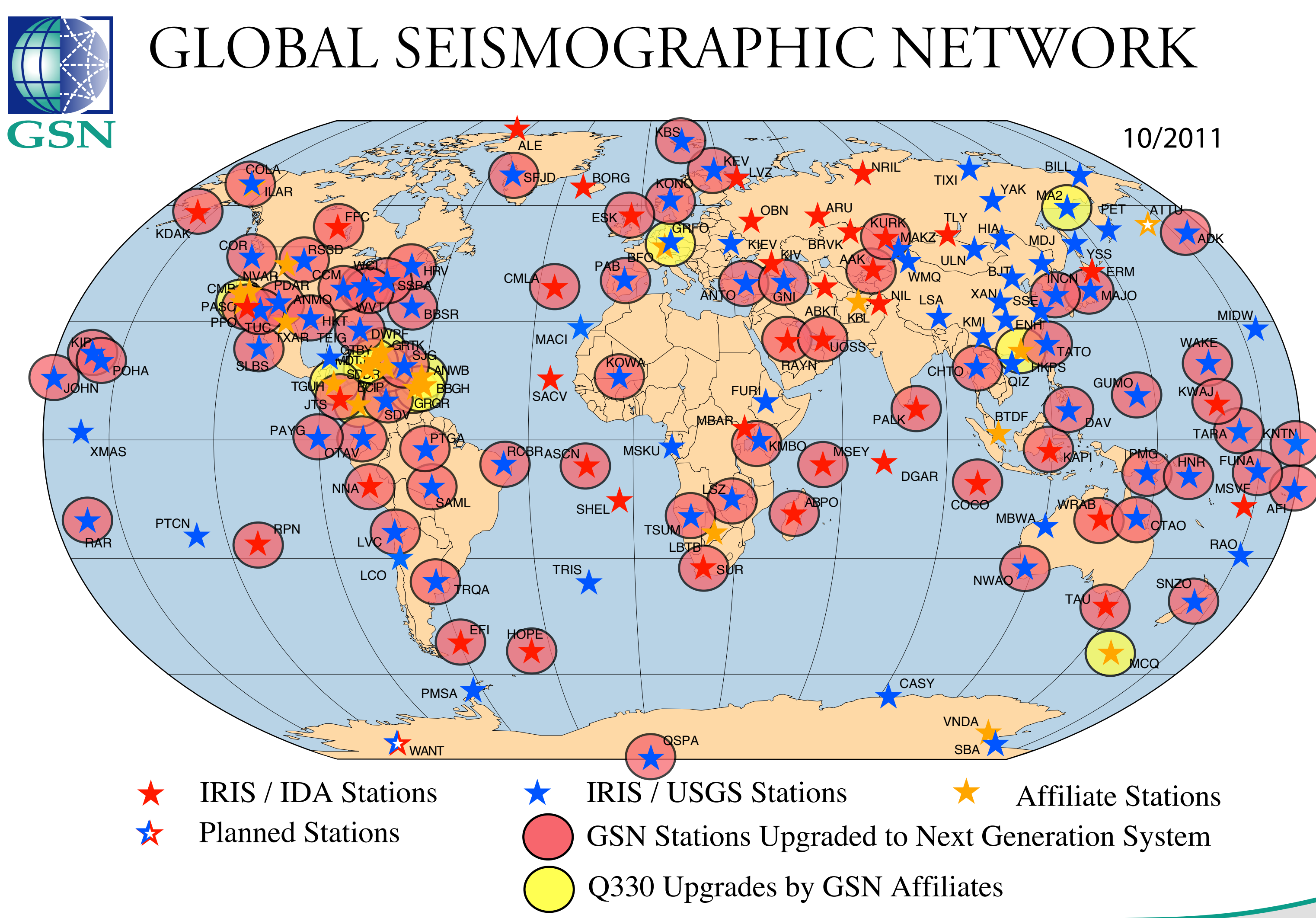
DATA QUALITY

Information and updates on the GSN Quality Initiative can be found at:
http://www.iris.edu/hq/programs/gsn/quality

NEXT GENERATION UPGRADES

The GSN is continuing its major overhaul and upgrade of stations and field equipment. The network upgrade is now over 60% completed (see map) and most of the network is expected to have next generation equipment by the end of 2013. The systems installed across the network are based on the Quanterra Q330HR (high resolution) acquisition system and marks a new era in the GSN with standardized data collection systems between the network operators of the GSN. 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. These upgrades are complemented by Q330 installations by GSN Affiliates.

In conjunction with the next generation system upgrades, the GSN has used the opportunity afforded by these visits to maintain critical infrastructure, repair sensors, install or repair secondary broadband and strong-ground motion sensors and microbarographs, and embark on a systematic analysis of sensor calibration and azimuth. As a supplement to yearly relative calibration procedures, network operators now measure *in situ* calibrations with portable equipment, verifying sensor and system responses, orientation, and location of deployed GSN sensors.



IDA engineer David Chavez adjusts an STS1 seismometer at station JTS (Las Juntas, Costa Rica). The station's pier was rebuilt and a recording building replaced during a major renovation this year.

Back-Projection Results for the Mw 9.0 March 11, 2011 Tohoku, Japan Earthquake

Eric Kiser
Miaki Ishii
Harvard University

The Transportable Array (TA) component of USArray, consisting of 400+ seismic stations within the US, has become an important tool for studying the source processes of earthquakes from around the world, including regions with no local seismic networks (Figure 1a). We use data from the TA and the back-projection technique to image the spatial and temporal distribution of energy release for the Mw 9.0 March 11, 2011, Tohoku, Japan earthquake. This earthquake was the fourth largest event ever recorded and produced a massive tsunami that devastated northeastern coastal areas of Honshu, Japan. Our method time-reverses seismic waves recorded at seismic stations in North America (Figure 1a) back to the source region to determine their origin time and location. From this distribution of energy, characteristics of the earthquake, such as the rupture duration, direction, and speed, can be estimated.

The Tohoku event lasted about 220 seconds (more than 3.5 minutes), with the highest energy release occurring about 95 seconds after initiation of the earthquake (Figure 1b). During this time, the rupture shows a large degree of complexity, with at least five different rupture directions. These rupture directions show that a counterclockwise propagation characterizes this event (Figure 1c), with highly variable rupture speed ranging from 0.8 to 3.0 km/s. These results are obtained using data filtered to a very narrow frequency range (0.8-2Hz). However, seismic waves with a broad range of frequencies are recorded and can be used in the back-projection analysis. Back projection of the North American data filtered to four different frequency ranges reveals that the spectrum of slip energy is distributed geographically. Lower frequency energy originates from regions very close to the Japan trench, while higher frequency energy is concentrated farther to the west, near the coast of Honshu (Figure 1c). The general shapes of the ruptures are very similar suggesting that, while high- and low-frequency sources are not collocated, they do affect each other's rupture characteristics (Figure 1c).

The observation of frequency-dependent rupture characteristics is important for evaluating the hazards associated with large earthquakes.

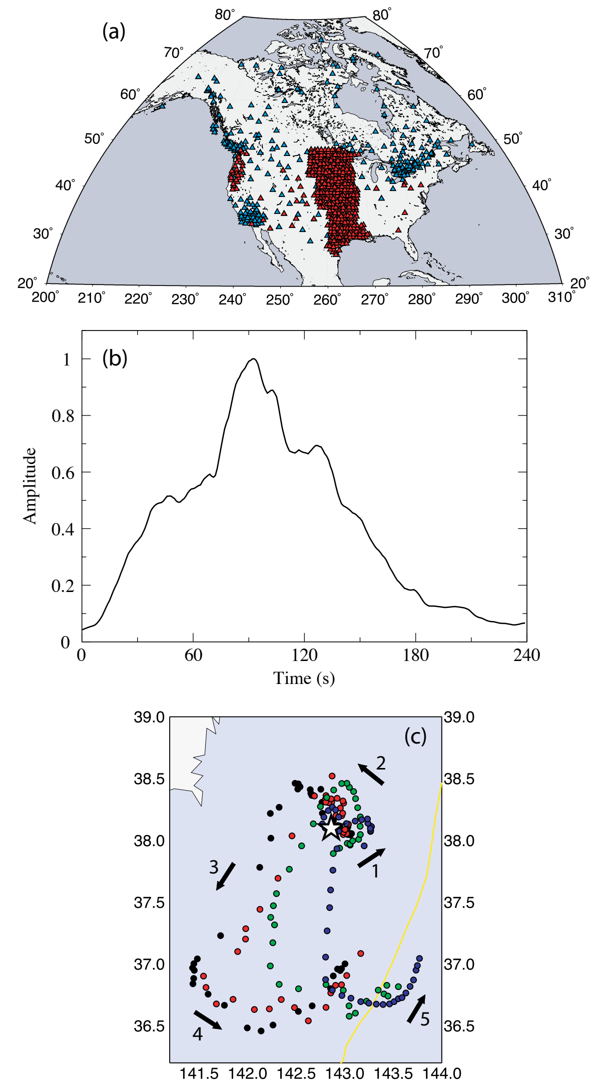


FIGURE 1: (a) Data are used from stations (triangles) across North America, including the Transportable Array (red) and various other networks (blue). (b) Relative amplitude of the back-projection results with respect to the hypocentral time using bandpass-filtered data between 0.8 and 2 Hz. (c) Locations of energy release at different times (5 second intervals) during the mainshock using bandpass-filtered data between 0.8-2Hz (black dots), 0.25-0.5Hz (red dots), 0.1-0.2Hz (green dots), and 0.05-0.1Hz (blue dots). The white star is the epicenter, and the yellow line is the Japan Trench. The black arrows show general propagation directions of the rupture from the initial up-dip propagation (1) to the final episode of energy release near the trench (5).

The frequency of seismic energy radiated at different locations can be associated with the type of slip during an earthquake. For example, a rupture with slow slip is expected to radiate lower frequency energy compared to one with faster slip. Such slow slip ruptures are observed near the trench and can act as tsunami sources. Therefore, observing low-frequency energy near the trench could, and in the case of the 2011 Tohoku earthquake did, indicate strong tsunami potential for the event. Implementing a multi-frequency back-projection analysis in real time could provide important information regarding the hazards associated with large earthquakes.

The magnitude of the 2011 Tohoku earthquake was surprising because past seismicity in this region suggested maximum magnitudes of 7.5-8.0. Based upon the rupture distribution, one explanation for the large magnitude comes from the fact that the 2011 event caused failure on multiple fault patches that had broken individually in the past (Figure 2a). Slip on multiple faults during a single earthquake results in a large total fault area, giving rise to the large magnitude. To provide insight into the potential magnitude due to combined failure of all fault patches related to the Tohoku event, we perform a continuous back-projection analysis of the initial seismic sequence. We observe that nearly 91,000 km^2 of the plate interface ruptures during the March 9 foreshocks, the mainshock, and the first 4.5 hours of aftershocks (Figure 2b). This area is much larger than the mainshock area (64,000 km^2; Figure 2b). If the individual fault patches that slipped during the foreshocks, mainshock, and initial aftershocks could fail together in the future to produce a single earthquake, the estimated magnitude of this event would be 9.2.

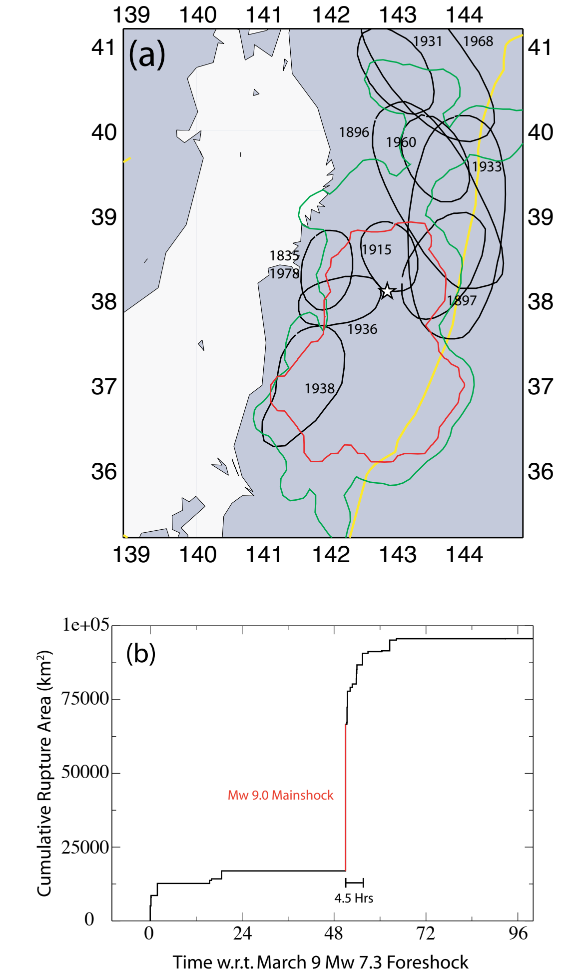
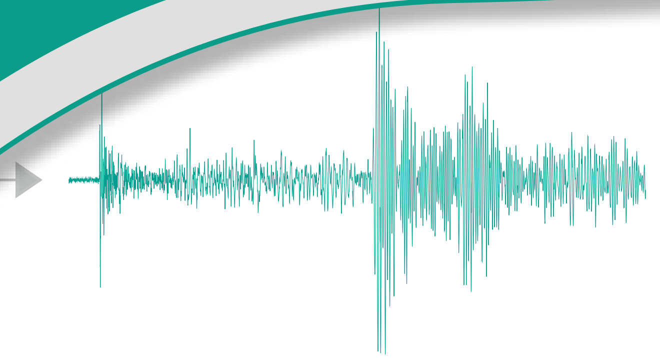


FIGURE 2: (a) The rupture distribution of the mainshock (red contour) obtained by combining back-projection results from the four frequency ranges (0.05-0.1Hz, 0.1-0.2Hz, 0.25-0.5Hz, 0.8-2Hz) and cumulative rupture distribution for Mw≥6 events between March 9, 2011, and April 7, 2011 (green contours). The white star is the epicenter of the mainshock and the yellow line is the trench location. The black ovals are approximate rupture areas from tsunamigenic earthquakes for the past 200 years. (b) The cumulative rupture area as a function of time for Mw≥6.0 earthquakes for the first 100 hours following the Mw 7.3 March 9 foreshock. The red line is the contribution from the Mw 9.0 mainshock.

INSTRUMENTATION SERVICES



A vertical channel seismogram from a M7.1 aftershock to the Tohoku earthquake occurring on April 7, 2011. This earthquake was recorded by a broadband seismometer deployed in Bolivia as part of the CAUGHT experiment. This recording demonstrates the excellent teleseismic data typically obtained by PASSCAL deployments abroad. Two years after the last instrument loaned from PASSCAL is demobilized, these data become publically available and may be incorporated into global seismic studies. The seismogram above is unfiltered and spans 1 hour and 45 minutes.

PASSCAL STANDING committee

Richard ALLEN (Chair)	University of California, Berkeley
Cynthia EBINGER	University of Rochester
Katie KERANEN	University of Oklahoma
Jesse LAWRENCE	Stanford University
Lee LIBERTY	Boise State University
Doug MACAYEAL	University of Chicago
Beatrice MAGNANI	University of Memphis
Seth MORAN	USGS, Cascades Volcano Observatory
Meghan S. MILLER	University of Southern California

PASSCAL management

James GRIDLEY	IRIS
Bruce BEAUDOIN	PIC, New Mexico Tech

PASSCAL

OVERVIEW

PASSCAL develops and maintains a range of portable seismographic instrumentation and expertise for diverse scientific and educational communities. The access to professionally supported state-of-the-art equipment has revolutionized the culture of seismological research in the US. Through integrated planning, logistical, instrumentation and engineering services delivered by a full-time professional staff, PASSCAL has enabled the seismological community to mount hundreds of experiments throughout the world at scales exceeding the capabilities of a single research group. Individual scientists and project teams are free to focus on optimizing science productivity, rather than supporting basic technology and engineering. Enhanced instrumentation capabilities allow small institutions to compete equally with large ones. Scientists working outside of traditional seismological subfields are offered the ability to undertake innovative and multidisciplinary investigations. Scientific data collected with PASSCAL instruments must be archived in standardized SEED format at the IRIS Data Management Center and become available to the general community after two years. Uniform equipment and data formats greatly improve long-term archiving of data and encourage the re-use of data for novel purposes.

STANDARDS AND EXPERIENCE

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

Mike Fort (PASSCAL) services a CDPAPUA seismic station in New Guinea.

PASSCAL facilitates portable array seismology worldwide with comprehensive 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, orogens, rifts, faults, and magmatic systems. Data from more than 5000 PASSCAL stations are now in the Data Management Center.

RECENT DEPLOYMENTS

Over the past year, the PASSCAL Instrument Center (PIC) at New Mexico Institute of Mining and Technology, Socorro, New Mexico, has supported some of the largest experiments to date, including EarthScope-funded efforts, while at the same time facilitating more diverse scientific exploration. For example, PASSCAL provided over 2000 sensors and support for the Salton Seismic Imaging Project (SSIP). The PIC facilitated SSIP with systems from the core PASSCAL and Flexible Array equipment pools, as well as manpower and expertise through its technical staff. Similarly, the Wellington Transect II experiment deployed a substantial number of systems to New Zealand, utilizing the PASSCAL and Flexible Array equipment pools and PIC staff support, with significant international impact. PASSCAL continues to spearhead the Rapid Array Mobilization Program (RAMP), deploying instruments to New Zealand in the wake of the recent earthquakes near Christchurch.

The PIC continues to assist and enable traditional broadband deployments such as SNAG in the Sierra Negra Volcano region of the Galapagos Archipelago, PICASSO across southern Iberia and North Africa, STEEP in the St. Elias Mountains of southern Alaska and northwestern Canada, and Africa Array.

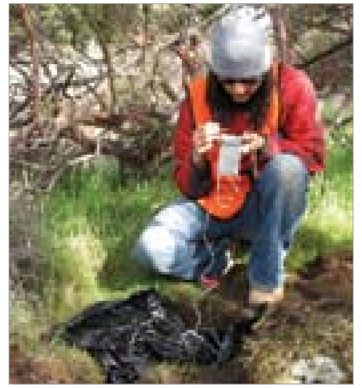
George Zandt and Susan Beck (University of Arizona), students, and local participants following a CAUGHT seismic station installation in Bolivia.

COLLABORATIVE ACTIVITIES

The staff at PIC works closely with investigators to meet the individual challenges of each research study and maximize gains. In the past year, the PIC has supported numerous investigations with more exotic uses or locations for its instrumentation. In Fairmont, Montana, a passive seismic array in conjunction with electrical resistivity and temperature measurements is being used to evaluate geothermal resources. In South America, linear and traditional seismic arrays and infrasound sensors are deployed across the Villarrica Volcano to study activity related to observations from traditional gas emission monitoring.

Support for Polar Science continues to be an important and growing aspect of the PASSCAL mission, as investigators reach into the remote locations and extreme climates of the Arctic and Antarctic. Polar sciences is a particular challenge within the PASSCAL program in that systems require a specialized level of support, which is further complicated by the logistics required for working in these regions. This past year, PASSCAL sent multiple staff in support of Polar research and supported 20 experiments.

Meghan Miller (University of Southern California) at the southernmost PICASSO seismic station PM35 located in Merzouga, Morocco.



A volunteer checks the settings on a Texan seismograph.

Dozens of Texan instruments are readied for deployment.

The Salton Seismic Imaging Project: Rift Processes and Earthquake Hazards

John Hole
Virginia Tech
Joann Stock
Caltech
Gary Fuis
US Geological Survey
Neal Driscoll
Scripps Institution of Oceanography
Graham Kent
University of Nevada, Reno
Simon Klemperer
Stanford University
Antonio Gonzalez-Fernande
CICESE
Octavio Lazaro-Mancilla
Universidad Autonoma de Baja California

The San Andreas Fault ends in southern California, and strike-slip plate motion is transferred to the Imperial Fault. This step-over is the northernmost element of the Gulf of California extensional province and created the Salton Trough, a basin extending from Palm Springs to the Gulf of California. Previous studies suggest that North American lithosphere has rifted completely apart in the central Salton Trough. However, instead of the onset of seafloor spreading as has occurred in the southern Gulf of California, rifting has been strongly affected by rapid sedimentation from the Colorado River. The 20-25 km thick crust in the central Salton Trough is composed entirely of new crust added by magmatism from below and sedimentation from above. Between the major transform faults, active rifting is manifested by faults observed in modern sediment, abundant seismicity, minor volcanism, very high heat flow, and corresponding geothermal energy production. The mechanisms of rifting here are insufficiently understood.

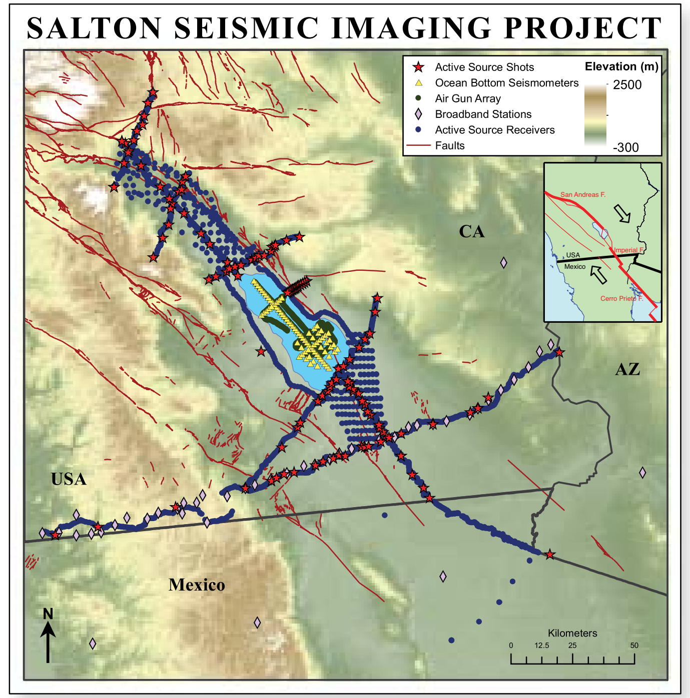
Based on the paleoseismic record, the southern San Andreas Fault is considered overdue for an earthquake of magnitude >7.5. Several other faults in the Salton Trough have had historic earthquakes with magnitudes >7. Earthquake hazard models and strong ground motion simulations require knowledge of the dip of the faults and the geometry and wavespeed of the adjacent sedimentary basins, but these parameters are currently poorly constrained.

To address these fundamental questions, the Salton Seismic Imaging Project (SSIP) acquired seismic data along and across the Salton Trough in March 2011. The seismic datasets include seven lines of onshore refraction and low-fold reflection data, airguns and OBS data in the Salton Sea, onshore-offshore data, and a line of broadband stations. The controlled-source data were acquired over three weeks. A total of 33,329 kg of explosives were detonated in 126 explosive shots in plugged boreholes along 7 lines. In addition, a 3.4-liter GI airgun was fired 2330 times along a series of lines in the Salton Sea. The surveys were coordinated so that seismographs recorded both sources. Onshore, seismographs were obtained from both the EarthScope FlexArray and PASSCAL instrument pools, with field support from PASSCAL personnel. 2595 "Texan" seismographs with single-component 4.5-Hz geophones were used in 4739 deployments at 3958 unique sites. In addition, 186 RT-130 recorders were deployed at 277 sites with 3-component 4.5-Hz geophones. Land seismographs were deployed at 100-500 m spacing along several lines, and in grids in the valleys. Offshore seismographs were obtained from the Ocean Bottom Seismograph Instrument Pool (OBSIP). Forty-eight 3-component OBS's were deployed at 78 sites in the Salton Sea along two densely sampled lines and a grid in the southern sea.

Student Kathy Davenport deploys a Texan seismograph on a wind farm near Palm Springs.

About 120 people participated in the data acquisition, about half of whom were students from 31 different colleges and universities. Since data acquisition was during the academic year, many students rotated on 1-week shifts. Over three-quarters of the field crew were volunteers, with travel expenses paid by the project. This crew was so efficient that we returned one more instrument to PASSCAL than their inventory said they sent us!

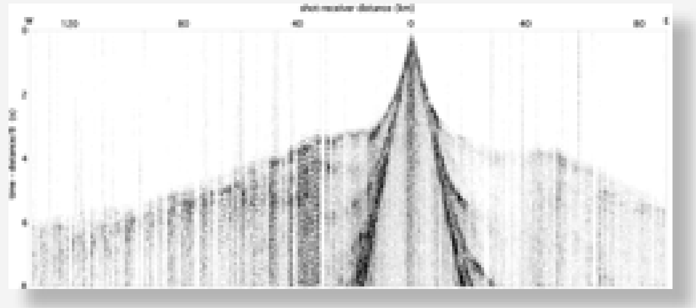
To complement the controlled-source studies and extend the imaging to greater depth, broadband seismometers were deployed at 5-km spacing across the Salton Trough. The instruments, obtained from PASSCAL, were installed in January 2011 for a planned 18-month deployment. The line is coincident with a crustal-scale refraction-reflection line and recorded the controlled sources. Sixteen people from 5 universities participated in the deployment.



SSIP project map. Red lines are faults; symbols (see index) are seismic sources or seismographs. Inset map shows simplified plate boundary faults.

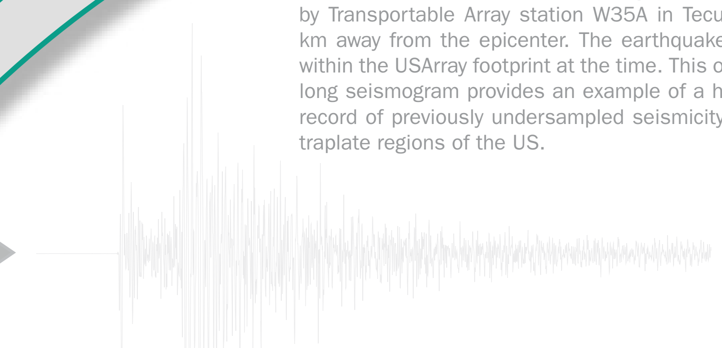
SSIP will ultimately constrain the initiation and evolution of nearly complete continental rifting, emplacement of magmatism, effects of sedimentation upon extension and magmatism, and partitioning of strain during continental breakup. To improve earthquake hazard models, SSIP will image the geometry of the San Andreas, Imperial and other faults; structure of sedimentary basins in the Salton Trough; and three-dimensional seismic wavespeed of the crust and uppermost mantle. Funding for SSIP was from four programs at NSF (MARGINS, EarthScope, Marine Geology and Geophysics, and Geophysics) and the USGS.

Student volunteers Melissa Bernadino, Gabrielle Zamora, and Erin Carrick hike across a naval bombing range. Each is carrying a backpack with eight Texan seismographs and deployment equipment. This hike required training to avoid unexploded ordnance.



Shot gather for 1142 Texans deployed as a transect from the suburbs of San Diego and Tijuana to the Colorado River. Shot originated from along the Imperial Fault.

INSTRUMENTATION SERVICES



A vertical channel recording of the M4.4 earthquake occurring approximately 35 km from Oklahoma City on October 13, 2010. This seismogram was recorded by Transportable Array station W35A in Tecumseh, 41 km away from the epicenter. The earthquake occurred within the USArray footprint at the time. This one-minute long seismogram provides an example of a high-quality record of previously undersampled seismicity within intraplate regions of the US.

USARRAY ADVISORY committee

Matthew Fouch (Chair)	Arizona State University
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Roger HANSEN	University of Alaska, Fairbanks
Karl KARLSTROM	University of New Mexico
Charles LANGSTON	University of Memphis
Maureen LONG	Yale University
Guy MASTERS	University of California, San Diego
David SNYDER	Geological Survey of Canada
Donna SHILLINGTON	Lamont-Doherty Earth Obs of Columbia University
Chester WEISS	Virginia Polytechnic Institute

USARRAY management

Robert BUSBY	IRIS
Katrin HAFNER	IRIS
Robert WOODWARD	IRIS

USArray

OVERVIEW

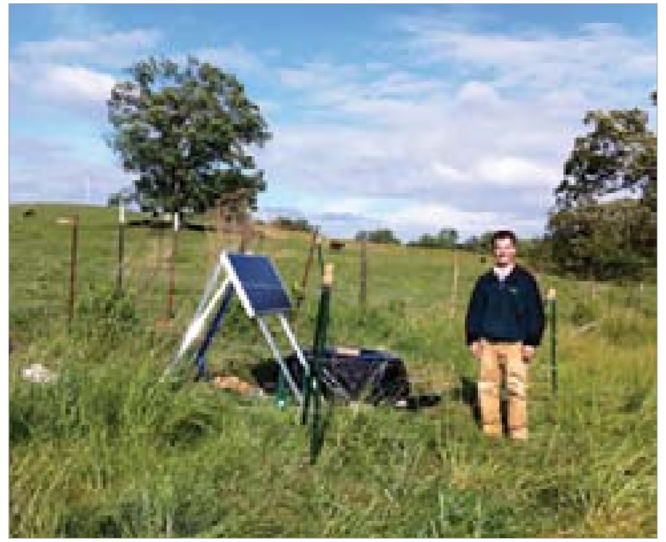
The USArray component of EarthScope (http://www.earthscope.org), continued to make major strides in FY2011. In mid-March, the first Transportable Array (TA) station in the regular footprint became operational east of the Mississippi River. At the end of June 2011, 1174 TA stations had been commissioned and the main deployment operated from North Dakota to Texas and east to Alabama. The legacy of the TA expanded to nearly 50 transfers through the NSF-approved "Adopt A Station" program with the advance adoption of four stations by the state of Pennsylvania. Field crews continued to work at full capacity, removing, relocating, and installing around 18 stations each month. The final 14 stations were redeployed in the Pacific Northwest as part of the NSF-funded Cascadia Initiative, combining 27 land-based stations with a broad program of marine geophysics.

TRANSPORTABLE ARRAY

In February 2011, the Transportable Array began installing an atmospheric acoustic sensor package that includes a high-performance barometer and an infrasound microphone. These units immediately provided a unique meteorological dataset for the severe spring weather throughout the Midwest and Southeast. The TA continues to adapt as operational needs change. A rotomolded vault was designed and manufactured and is now being used in new stations. Drilled vault emplacements were tested in Alaskan permafrost for future operations. Despite a particularly wet spring in the Midwest, station reliability and data quality remained high. The construction of the TA and the collection and distribution of its data depend on many 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.

STUDENT SITING PROGRAM

The Transportable Array Student Siting Program continues to successfully engage students in EarthScope. This summer, student teams identified about 200 sites for future stations across southernmost Canada, the Midwest, and the Southeast. Since 2005, approximately 118 students from more than 44 universities have identified about 1170 TA sites



E. Horry Parker Jr. (University of Georgia) at a SESAME seismic station in northern Georgia.

in 30 states (and one Canadian province). USArray also conducted its annual data processing short course for 23 advanced graduate students. Hosted by Northwestern University, the week-long course delved into the intricacies and state-of-the-art practices for seismic data processing and examined the handling of large volumes of data from USArray stations.

SITING OUTREACH ACTIVITIES

The Siting Outreach component facilitates siting of TA stations and works with state and local organizations to raise awareness of EarthScope and USArray. In the summer and fall of 2010, University-issued press releases generated several dozen stories in local and regional newspapers and on local television. In late summer 2010, the National Geographic Channel filmed the installation of a TA station near Parkston, South Dakota. Aired in May 2011, the first segment of the show, "X-Ray Earth," prominently featured EarthScope and seismic tomography. Other outreach activities and products include the development of regional content for the Active Earth Monitor in partnership with EarthScope and UNAVCO; presence at numerous workshops, conferences, and meetings; the creation of wave visualization movies; and a biannual newsletter for landowners hosting TA stations.

FLEXIBLE ARRAY

The Flexible Array (FA) pool of portable instruments (consisting of 347 broadband, 141 short period, and 1700 "Texan" active source instruments) continued to be heavily utilized by principal investigators to conduct high-resolution studies that address EarthScope's scientific goals. In February 2011, the FA furnished its entire supply of Texan seismometers and a considerable number of additional instruments for the Salton Seismic Imaging Project. This experiment, one of EarthScope's largest, was executed with help from Array Operations Facility staff and numerous student volunteers (see article on page 18). Some of the Texan instruments subsequently traveled to Wellington, New Zealand, to assist with a controlled-source experiment above the subduction zone. At the end of June, there were approximately 330 FA broadband stations in the field actively recording data for eight experiments across the US.

MAGNETOTELLURIC OBSERVATORY

The USArray magnetotelluric (MT) observatory measures the natural electric and magnetic fields at the Earth's surface that are caused by electromagnetic waves radiated from the sun and distant electrical storms. These data can be anazlyzed to constrain the electrical conductivity of the upper mantle and provide an excellent complement to the seismic tomography being produced from the TA. During the 2010-2011 field season, more than 100 temporary sites were occupied on a 70-km by 70-km grid for two to three weeks across Northern California, Nevada Utah, Colorado, and Wyoming. Seven stations comprising the permanent magnetotelluric (MT) observatory continue to send telemetered raw data in near real time to the MT facility at Oregon State University.

Demand for USArray data by scientists from the US and throughout the world continues to grow. 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. Over 36 terabytes of EarthScope data have been archived to date, and about 10.6 terabytes of USArray-related data have been shipped in the past year.

Amanda Klaus (University of Washington) services a station in the Big Skidder Array section of the Arrays of Arrays experiment.

Sarah Hedgecock-Hanson (University of North Carolina), Pnina Miller (PASSCAL), Julia MacDougall (Brown University) and Ved Lekic (University of Maryland) perform a huddle test for SESAME.

The SIEDCAR team.

The SIEDCAR team gathers for an installation.

Seismic Investigation of Edge-Driven Convection Associated with the Rio Grande Rift

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Baylor University
Stephen P. Grand
University of Texas at Austin
Carrie V. Rockett
Baylor University
Yu Xia
University of Texas at Austin

The Rio Grande Rift marks the easternmost extent of deformation in western North America due to the subduction and foundering of the Farallon plate during the late Cenozoic. However, there is only a tenuous linkage between the second phase of regional uplift, extension, and magmatism in the rift and the passage of the Farallon Plate. Previous seismic analyses from the 1999-2001 PASSCAL-supported Colorado Plateau/Rio Grande Rift Seismic Transect Experiment (LA RISTRA Experiment) discerned a fast seismic anomaly near the eastern edge of the rift. These results, while limited in the their coverage to two dimensions, suggested that upper mantle convection driven by the edge of the North American craton may continue to influence extension and magmatism within the rift, without requiring a purely tectonic cause.

In general, understanding the interaction between the tectonically active and inactive zones of continents is an important topic in North America and one that can be addressed under the framework of USArray.

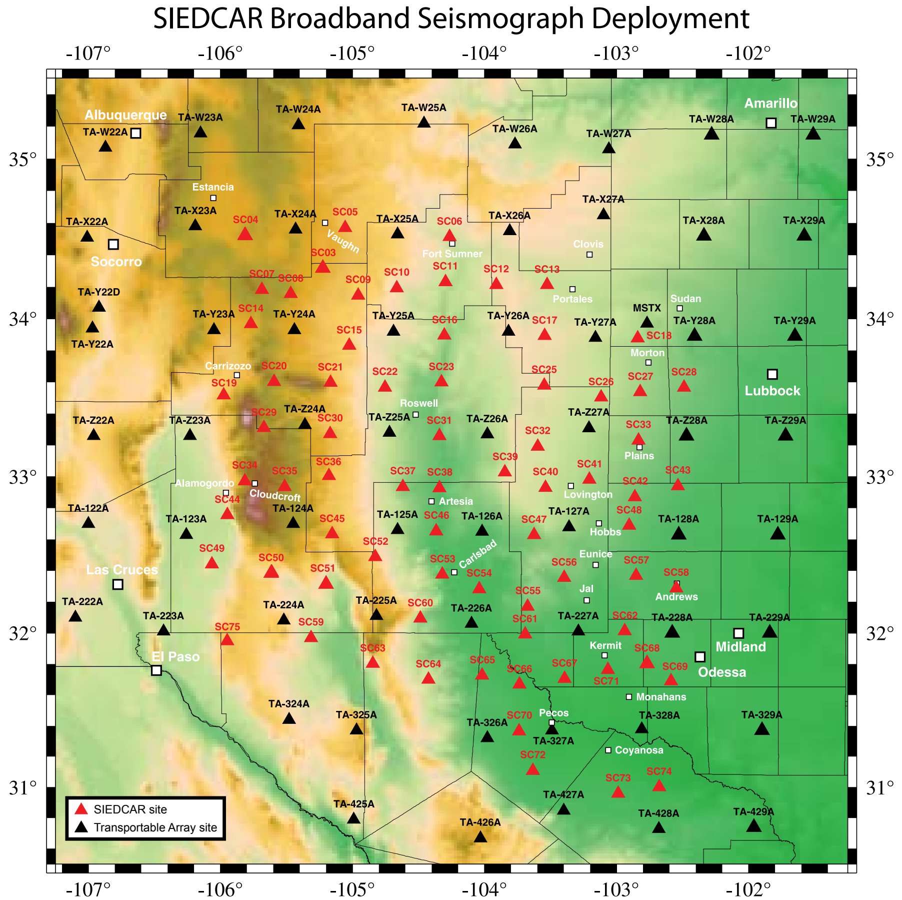
To confirm the existence of this unusual feature, characterize its extent and seismic properties, and better understand its cause, the EarthScope-funded experiment Seismic Investigation of Edge-Driven Convection Associated with the Rio Grande Rift (SIEDCAR) installed 71 broadband seismometers during 2008-2011 to densify the Transportable Array footprint as it passed through southern New Mexico and western Texas. SIEDCAR is an example of how the USArray program can be exploited to investigate previous compelling observations with a comprehensive array experiment. SIEDCAR is also unique in its use of EarthScope's Flexible Array to uniformly enhance the existing array spacing by effectively reducing the grid from 70 km to approximately 35 km.

In addition to the scientific focus, SIEDCAR served as a major educational outreach initiative. Siting, permitting, and installation of the array were conducted by a group of high school teachers and undergraduates along with graduate students, post-docs, and Principal Investigators, and with assistance from staff at the Array Operations Facility. Teachers and students were trained in site selection and preparation prior to the start of the experiment. SIEDCAR stations spanned a variety of environments, from the forested highlands bordering the southern Rio Grande Rift to the arid plains of eastern New Mexico and West Texas. All the sites were on private land.

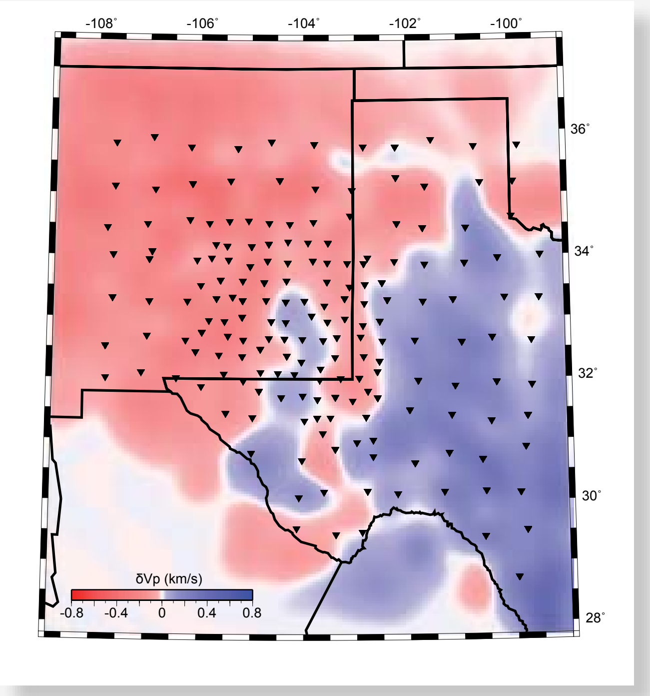
Data from SIEDCAR and neighboring stations have already been used for several different seismic studies and contributed to a Master's thesis and a PhD thesis. Here we focus on the tomographic investigation of the upper mantle beneath the region. In total, 206 stations from the Flexible and Transportable Arrays and other stations from existing networks were used to perform P- and S-wave travel-time tomography. The dataset encompassed teleseismic earthquakes with magnitude >5.0 occurring at distances of 30-90° from the stations. Nearly 20,500 relative arrivals for P-waves and about 9,700 relative arrivals for S-waves were picked across the array and then inverted from the AK135 reference Earth model using FMTOMO, a widely-used tomography code.

The three-dimensional P and S tomographic models developed from SIEDCAR show a broad zone of slow material beneath the Rio Grande Rift. These models show that the previously observed fast anomaly to the east of the rift extends slightly further to the north and much further south, into Mexico. This anomaly also deepens from south to north. Comparing these new results to existing geodynamic models shows that the zone of fast material does not appear to be edge-driven convection related to the North American craton. Instead, the size, magnitude, and proximity of the anomaly to the Great Plains craton suggests that continental lithosphere is being removed or eroded from the western edge of relatively undeformed continental North America.

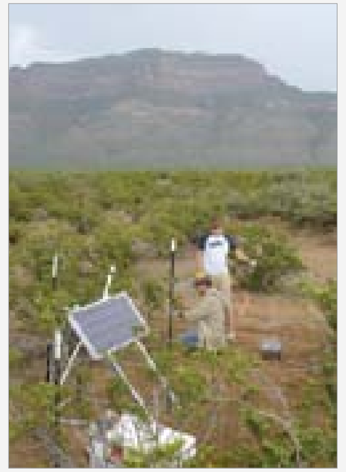
Interpreting this anomaly as a dynamic process within the upper mantle is compatible with the variations in magma chemistry, uplift, and extension throughout the region, and may also explain along-strike variations in the surface expression of the Rio Grande Rift. Further integration of this tomography with other seismic products from SIEDCAR will provide an opportunity to better understand the interaction between the tectonically active and the cratonic sections of the North American continent and the relationship to the evolution of the Rio Grande Rift.



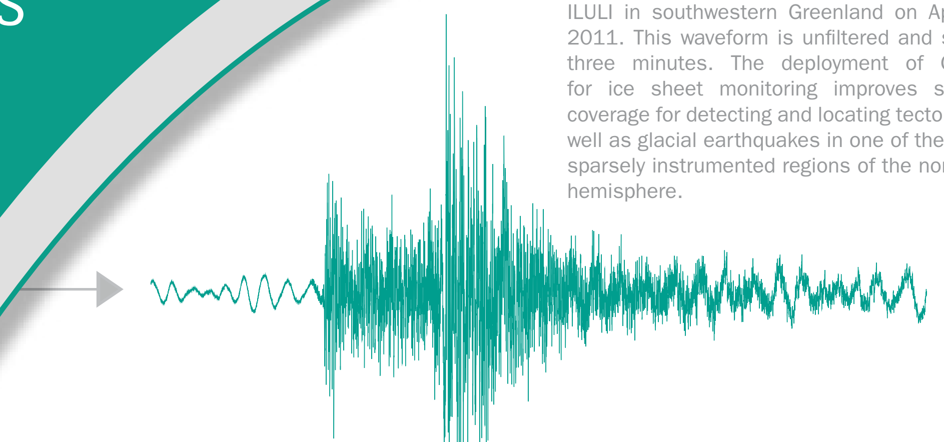
SIEDCAR array (red triangles) and adjacent Transportable Array stations (black triangles) superimposed on topography.



Horizontal section through the three-dimensional compressional velocity model at 225 km depth. The fast seismic anomaly is seen continuously accross southern New Mexico, West Texas, and nothernmost Mexico.



Joseph Dowdy (rear) and Derry Webb (front, PASSCAL) secure SC44.



A vertical channel seismogram from a M4.3 local earthquake recorded at GLISN station ILULI in southwestern Greenland on April 5, 2011. This waveform is unfiltered and spans three minutes. The deployment of GLISN for ice sheet monitoring improves station coverage for detecting and locating tectonic as well as glacial earthquakes in one of the more sparsely instrumented regions of the northern hemisphere.

POLAR NETWORKS SCIENCE committee

Carol RAYMOND (Chair)	Jet Propulsion Laboratory
Andy NYBLADE (Vice-Chair)	Pennsylvania State University
Mark FAHNESTOCK	University of New Hampshire
Erik IVINS	Jet Propulsion Laboratory
Douglas MACAYEAL	University of Chicago
Meredith NETTLES	Lamont-Doherty Earth Obs of Columbia Univ
Mike RITZWOLLER	University of Colorado
Leigh STEARNS	University of Kansas

POLAR management

Kent ANDERSON	IRIS
James GRIDLEY	IRIS
Bruce BEAUDOIN	PIC, New Mexico Tech

Polar Operations

OVERVIEW

IRIS has more than 20 years of experience in the engineering and deployment of specialized equipment required to field temporary and permanent seismic experiments successfully in the Arctic and Antarctic. Under the Instrumentation Services (IS) Directorate, polar activities are integrated within the Global Seismographic Network (GSN), Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL) and, looking toward the future, USArray's Transportable Array in Alaska, and continues to develop and expand its capabilities in the world's coldest regions. The interchange among the various IS branches has resulted in a vast improvement in the capabilities of the IRIS polar facilities, allowing the seismological community to record high-fidelity, robust data sets in these extreme environments. Management of IRIS polar activities consists of a pan-IRIS management team with the IRIS Polar Coordinator responsible for managing various program activities with the National Science Foundation's Office of Polar Programs (OPP). Supplemental funding from OPP allows advanced engineering and design work by the Polar Support Services (PSS) team at the PASSCAL Instrument Center (http://www.passcal.nmt.edu/content/ polar). This specialized staff and equipment helps ensure that investigator-driven experiments are successful in polar regions. The capabilities that IRIS has developed in polar operations provide the ability to study, with high resolution, seismological and glaciological phenomena associated with delicate polar regions. This allows further understanding of climate-related seismological phenomena at both poles, as well as improving constraints on shallow and deep structure in these sparsely instrumented areas of the Earth.

POLAR OPERATIONS

The PSS supported 23 investigator-led PASSCAL experiments in the polar regions during 2011. In Antarctica, these included the support of ten experiments requiring the deployment of over 100 broadband sensors and about 400 high frequency sensors as part of active source studies (utilizing the PASSCAL 40-kg weight drop source). Five PASSCAL personnel are currently deployed in austral summer operations. In addition, the PASSCAL group supported 13 experiments in the Arctic region, including the deployment of 27 broadband sensors, 45 short period sensors and a 360-channel active source experiment.

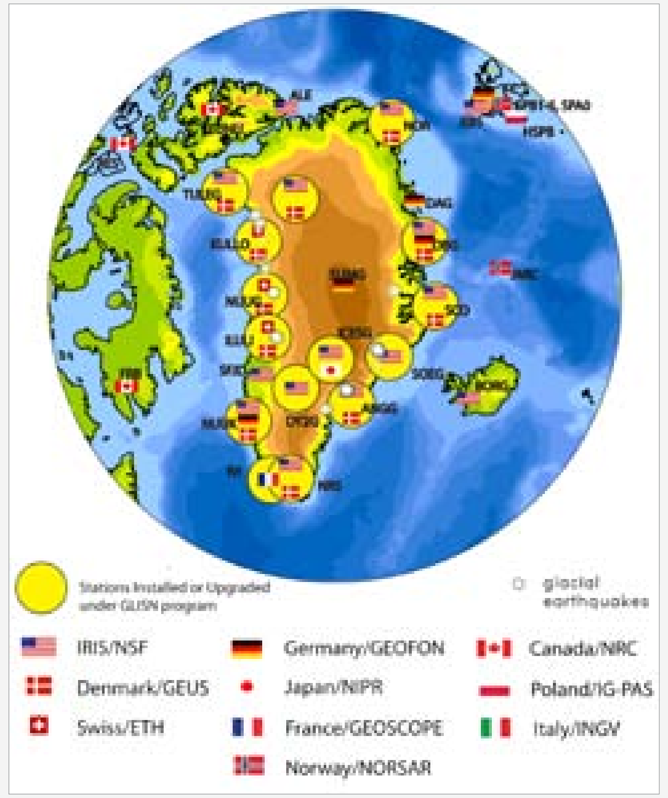
GLISN station DY2G and encampment in the midnight sun.

The PSS continued to develop and refine engineering designs of polar-rated equipment to push the extremes of environments where PASSCAL equipment can be deployed while improving the performance and data return from all polar experiments. Engineering work included battery and power system design; low-power, high-latitude real-time communications; and system designs for cold-wet environments to support experiments near glacier termini.

In addition to supporting temporary field programs conducted by principal investigators, IRIS is involved in permanent station operations at the poles. There are 12 GSN stations in high-latitude regions (five in Antarctica and seven in the Arctic) as well as the Greenland Ice Sheet Monitoring Network (GLISN), all of which benefit from the IRIS-wide interaction on enhanced polar station designs. At the request of the seismological community, IRIS established and is operating GLISN (http://www.iris.edu/ hq/programs/glisn), with the joint goals of monitoring glaciogenic and tectonic seismicity and improving knowledge of seismic structure beneath the ice sheet. With contributions from ten international partners (see map), there are now 31 stations on and around Greenland contributing data to the IRIS Data Management Center (DMC) under the _GLISN virtual network. Data from 26 of these stations are delivered in real time to the IRIS DMC. The remaining stations will soon include a real-time Iridium telecommunications system designed under the PASSCAL and GLISN programs.

COMMITTEE COORDINATION

We continue to coordinate and take guidance from the seismological community on their scientific requirements for these new capabilities through two advisory committees: 1) the Polar Network Science Committee (reporting to both the IRIS and UNAVCO Boards of Directors) and 2) the GLISN Science Advisory Committee. IRIS Polar Services also interacts with the GSN and PASSCAL Standing Committees and provides status reports to the IRIS Board of Directors.



Map of the GLISN network with national flags representing the contributions from the various partners to the project.

Bob Greschke (PASSCAL), Yoko Tono (JAMSTEC), Norlandair Pilots, Genchi Toyokuni (NIPR), and Masaki Kanao (NIPR) at ICESG.