earthscope

inSights
the EarthScope newsletter

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## Inside this issue...



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## The Magnetotelluric (MT) Component of USArray

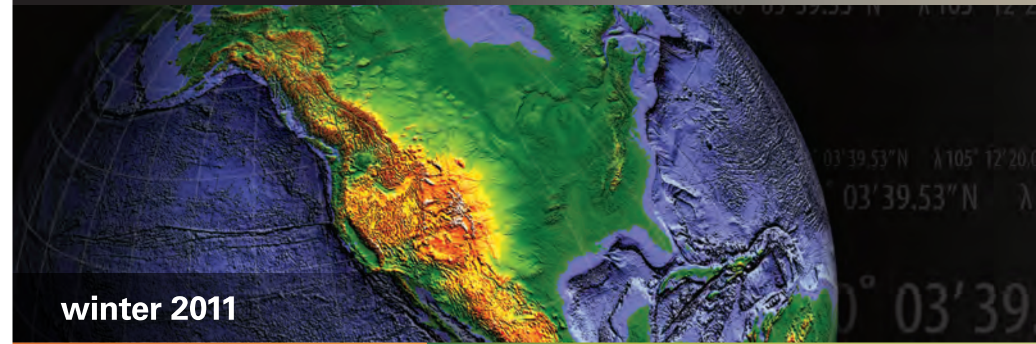
The MT component of USArray, operated and maintained by Oregon State University, acquires measurements of the natural electric and magnetic fields at sites in the contiguous US. The MT Transportable Array has occupied 271 sites during 2006-2010. In 2011, 54 sites will be added to complete the "Southern Exension" of the current Pacific Northwest MT footprint. The extension runs from the Oregon-California state line south to approximately Sacramento and from the Pacific Coast east to NW Colorado and SW Wyoming.

In contrast to previous years, the MT transportable component is moving toward year round permitting and, where possible, field operations, as opposed to spring-summer only campaigns. The regional footprint for 2012 and beyond will be in the area of the Mid-Continent Rift. Planning documents proposing a 1600-station MT array across the entire continental US have been prepared by the IRIS EM Advisory Group, endorsed by USAAC and the IRIS Board, and presented to NSF. Of the seven permanent MT Backbone stations most now have live data telemetry to Oregon State University. Three stations have already achieved the design goal of high quality MT responses to periods up to 100,000 seconds. Longer period means deeper penetration for MT data and we hope to be able to use MT Backbone data to constrain the electrical conductivity through the upper mantle and into the top of the mantle transition zone.

*By Adam Schultz and Tristan Peery, Oregon State University, Corvallis, OR.*


Map showing locations of MT Backbone stations (red) and MT Transportable Array sites (blue) as of December 2010.

Aaron Cooper (left) and Tristan Peery (right) testing the impedance of electric dipole receivers at station CAM04 in north-central California, September 2010. Drought conditions and fine powdery topsoil required us to devise new methods of coupling to obtain high-quality electric field measurements.



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## EarthScope News

Presentations, abstracts, selected posters and photos from the EarthScope Institute on the Spectrum of Fault Slip Behaviors are available at www.earthscope.org/institutes/spectrum_fault_slip_behaviors.

- The **2011 EarthScope National Meeting** will be held May 18-20 (Pre-meeting workshops on the 17th) at the AT&T Executive and Education Center at UT Austin. Details at www.earthscope.org/meetings/national_meeting_11.
- The **Seismological Society of America** will hold its annual meeting April 13-15 in Memphis, Tennessee commemorating the bicentennial of the New Madrid earthquakes.
- The **Great Southern California ShakeOut** of 2010 was the largest earthquake drill in US history. This year, drills will be conducted in Oregon and British Columbia on January 26 (date of the Cascadia subduction zone earthquake of 1700), in the central US on April 28, and in California, Nevada and Guam in October. Learn more at www.shakeout.org.
- The next EarthScope **workshop for interpretive professionals** in parks and museums will be held March 17-20 in Memphis, Tennessee and covers the central US. Details at www.earthscope.org/workshops/new_madrid.
- Please participate in an **inSights reader satisfaction survey** at tinyurl.com/inSightsSurvey. We want to know how we are doing and how we can improve.

# EarthScope Participates in **Open Data Seismic Deployment** Following 2010 Chile Earthquake

The global seismology community established a new model of international cooperation in response to the great Chile earthquake of February 27, 2010. The adaptable framework is geared to produce a high-quality, open-access data set of seismic waveforms collected in the wake of great earthquakes. Collection of the unprecedented Maule International Seismic Dataset (MISD) was supported by an NSF RAPID award and used fortuitously available EarthScope Flex Array (FA) sensors. IRIS PASSCAL personnel and volunteers from the IRIS Community deployed and maintained 58 broadband seismic stations from April-September 2010. The FA sensors constituted the IRIS CHAMP (for Chile RAMP) network, the largest equipment contribution to the MISD. Three CHAMP stations transmitted continuous data to PASCAL in Socorro, NM – the first time data have been telemetered from a temporary deployment outside of North America.

When great earthquakes strike, will we be ready to exploit all they can potentially tell us about the processes occurring at the end of the seismic cycle? Although the great 2004 Sumatra earthquake caught Earth scientists largely unprepared, when the $M_w$ 8.8 February 27, 2010, Maule earthquake struck – thanks in large part to a quick decision to use available EarthScope equipment, and to a flurry of negotiations between national groups responding to the crisis – the global seismic community did everything possible to collect unique seismic and geodetic data as they accrued following the event. The Maule earthquake damaged central Chile to a degree commensurate with its magnitude, mitigated by careful preparation by Chilean civil defense authorities and scientists. Rapid repair and restoration of critical infrastructure allowed seismologists from Germany, France, the UK, and the US, working with seismologists in Chile, to coordinate sensor deployment, thus capturing aftershocks and other signals associated with this significant earthquake. In all, 91 broadband, 48 short period (1 Hz), and 25 accelerometer stations were installed. The CHAMP sites were deployed by the end of March and decommissioned in late-September 2010 to return equipment to a scheduled FA project. The six-month CHAMP dataset – all freely available from the IRIS Data Management Center (network code XY) – provides an unprecedented view of end-seismic cycle processes, including a detailed look at seismic tremor in the wake of a great earthquake.

*Open data: a new model for international collaboration in aftershock studies.* One of the most important policies implemented at the inception of EarthScope established the immediate open access to data recorded at the EarthScope facilities. Recognition that open access to all data collected following the Maule earthquake would ensure both its maximum and timely use spurred IRIS leadership to negotiate an open data access agreement with other international groups deploying instruments. Cooperation allows for the most efficient use of equipment, obviating redundant network designs. The MISD will therefore contain data from a relatively uniform network covering virtually the entire on-land rupture region, some 90,000 km², at a nominal station spacing of ~30 km (Figure 1).

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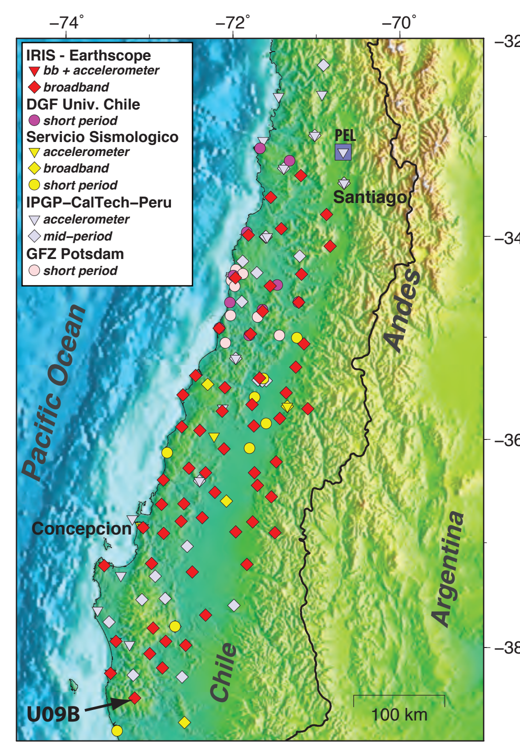
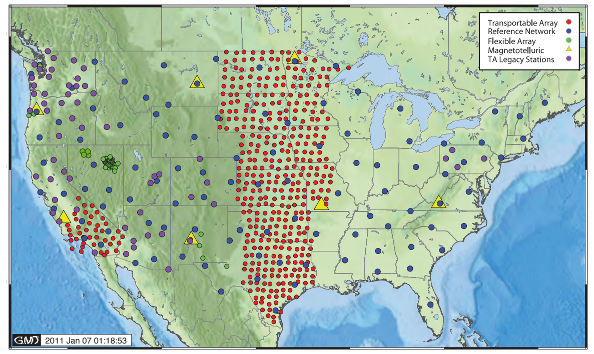



**Figure 1:** Location map of stations deployed to capture seismic signals following the Maule earthquake. Groups overseeing deployed stations contributing to the MISD are indicated in key, upper left. U09B mentioned in Figure 2 is labeled.

## USArray Status

The Transportable Array (TA) continues to roll eastward across the US. Thus far, over 1000 sites have been commissioned in 21 states. Nearly 600 of these sites were removed after two years of service; however, some stations have continued to operate with new owners. The TA legacy is growing as over 40 stations and more than 25 vaults have been "adopted" in the western US. In addition, four "advance adoption" stations in Pennsylvania were deployed several years before their planned installation.




Data quality and reliability of TA stations remain high as sites are installed in different geologic regions; data availability consistently exceeds 95%. Recent station design enhancements include a package of environmental monitoring sensors and a vault interface enclosure to provide power regulation, protection for electronics and uniform cable connectors. Beginning in 2011, new installations will include infrasound sensors.

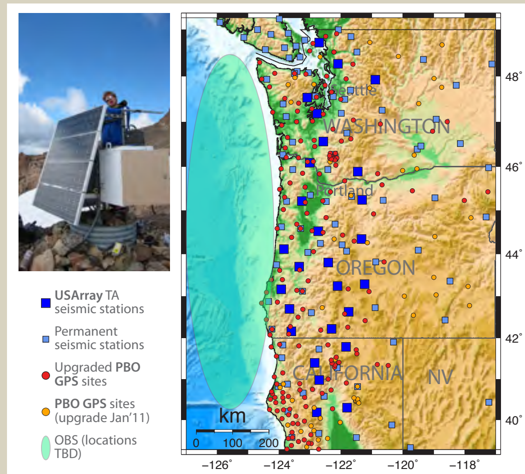
The Flexible Array (FA) instrument pool continues to be fully utilized. The new FA "quick deploy" enclosures for shipping and deployment contain an entire short period (L22 or CMG40T) seismometer. With the enclosures, a single Bighorn team (www.bighorns.org) could install up to 14 stations per day for a 6 month deployment. The teams finished installation of 170 instruments a week ahead of schedule.

The TA Student Siting Program continues to engage students in EarthScope. Last summer, students identified sites to be installed on the eastern side of the Mississippi River. Other outreach activities and products include content development for the Active Earth Display together with the EarthScope National Office and UNAVCO, creation of wave visualization movies, and the onSite publication for landowners. ■

## Cascadia Initiative

The National Science Foundation received funding through the 2009 American Recovery and Reinvestment Act for facility-related investments to support multi-disciplinary EarthScope and GeoPRISMS (www.geoprisms.org) science objectives. During its first phase, 2010-2015, the focus is on onshore/offshore studies of the Cascadia margin to better understand the nature of recently discovered, regularly occurring "Episodic Tremor and Slip" (ETS) events and how ETS is related to "normal" destructive subduction zone earthquakes. The amphibious Cascadia Initiative is one of only two NSF projects that has been selected as one of "100 Recovery Act Projects That Are Changing America." Visit the UNAVCO science highlight for additional information.

Installation of 27 new USArray TA seismic stations has been completed and over 75% of the 232 PBO GPS sites targeted for near real-time data transmission at 1 Hz sampling rate have been upgraded. Currently, 60 new Ocean Bottom Seismographs (OBS) are being built and tested for a first deployment in 2011. The workshop report from the Cascadia Initiative Workshop in October 2010 outlines the OBS deployment plan. ■




## PBO Status

A major Plate Boundary Observatory (PBO) activity in 2010 included its involvement in the UNAVCO response to the April 4th El Mayor-Cucapah earthquake in northern Baja California, Mexico (Star in Figure 1). The M=7.2 earthquake, which struck 40 miles south of the Mexico-US border, was the largest recorded earthquake in the area. PBO's immediate response was to download high rate (1 and 5 Hz) GPS data to provide unclipped displacement time-series at close epicenter distances. High rate GPS were also used to support airborne Lidar and photography missions imaging the rupture zone. PBO's standard 15-second GPS data helped to establish overall coseismic displacements. Additionally, four EarthScope campaign GPS receivers provided geodetic control for terrestrial laser scanner measurements. A science highlight describes the UNAVCO/PBO response and has further links and results.

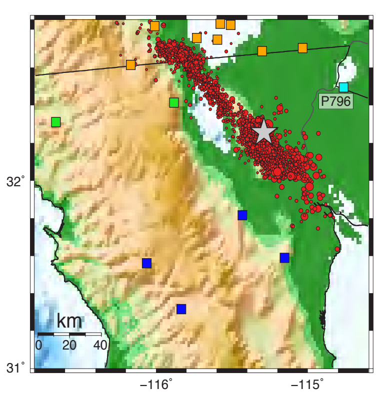



**Figure 1:** Location of new permanent GPS sites near San Luis, AZ (P796) and in Baja California (blue, green (permit pending)) extending the existing southern California PBO network (orange). Red dots are aftershock locations.

GPS station P796 was constructed near the border in San Luis, AZ, to capture post-seismic signals. In addition, an NSF Rapid Response Research (RAPID) project is deploying six new permanent GPS stations in Baja California. Sites will be installed and maintained by UNAVCO/PBO in coordination with CICESE, an UNAVCO Associate Member in Mexico. Four stations have already been installed. Another RAPID project will co-locate accelerometers at seven existing PBO sites along the San Jacinto fault. Fieldwork for stations P486 and P485 started in October 2010.

PBO engineers Shawn Lawrence and Chris Walls identified a slow slip signal at site P613 (Figure 2), possibly triggered by the earthquake. P613 is about 220 km north of the rupture and 10 km from the San Andreas Fault. Anomalous south- and west-directed slip of up to 1 cm amplitude occurred over a few months after the event. Although the transient may be due to unidentified site-specific causes, the signal is consistent with a combination of shallow dipping thrust and strike-slip motion. PBO alerted the EarthScope community about the signal and investigates its origins. ■

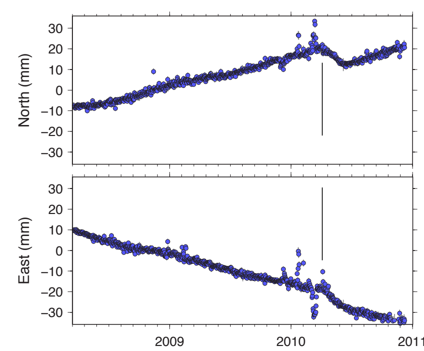



**Figure 2:** The GPS time series for site P613 shows slow transient motion starting at the time of the El Mayor-Cucapah earthquake (solid vertical lines).



*continued from front*

## Open Data Seismic Deployment Following 2010 Chile Earthquake

Uniform coverage of the Maule rupture region allows us to address some interesting questions. Episodic tremor, slow slip events, and low frequency earthquakes (LFEs) have been observed at the down-dip edge of megathrust rupture zones in Japan, Cascadia, Costa Rica, Mexico and southern Chile, revealing a strong correlation between tremor and slow, aseismic back-slip of the forearc region that relieves stress on the deeper portions of the interplate interface. Improvements in tremor locations have shown that tremors occur on or very near the interplate interface in both Japan and Cascadia, and are part of a continuum of shear slip processes occurring at high pore-fluid pressures that include aseismic slip, slip producing tremor, LFEs and seismic slip. However the relationship between episodic tremor and megathust earthquakes is not understood. Is tremor excited by megathrust ruptures, or is it suppressed or forced to migrate elsewhere in the system? Does tremor occur only along the boundaries of the Maule slipped region, as has been suggested for other subduction zones? If nonvolcanic tremor in the Maule rupture zone region conforms to type, we expect to detail regions of slower slip that produce LFEs and tremor along the interplate interface. Identification of such regions may have implications for slip acceleration during rupture near the down-dip seismogenic limit.

Initial analysis of MISD data provides observations of LFEs (Figure 2), and indications of non-volcanic tremor activity (Figure 3) in central Chile (~33-38°S). These are the first observations ever of tremor in the wake of a mega-thrust earthquake. A major challenge to detect tremor in the Maule rupture zone is the extreme frequency of high-amplitude "normal" aftershocks (Figure 3), which make identification of distinct tremor wave packets difficult. A preliminary search for

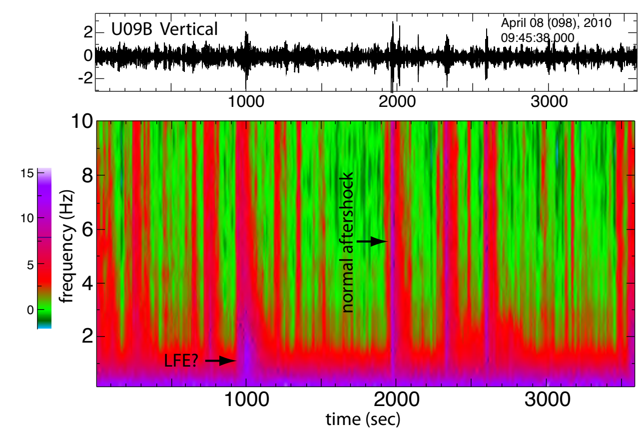



**Figure 2:** Spectrogram of an apparent low frequency earthquake (LFE) at station U09B (see Figure 1). Vertical red streaks are high-amplitudes of normal Maule earthquake aftershocks, some of which are visible on the seismogram above the spectrogram. Note the longer-duration low frequency power of the LFE. The LFE was recorded on all three components.

tremor in the frequency domain shows significant power in the characteristic 2-10 Hz tremor frequency band. Signals are stronger on the horizontal components consistent with propagation of tremor as shear waves, as observed elsewhere. Tremor signals occur at nearly all the CHAMP stations (Figure 3) and have persisted during the entire recording period. Although we have not yet located these tremors and are therefore unable to say whether they occured on the fault that slipped during the Maule earthquake, their existence indicates that tremor is not suppressed following great earthquakes. This is unexpected since seismic slip during the earthquake certainly relieves built-up interplate stress, which, in classic elastic-rebound models, must accumulate again before episodic slow slip and tremor again begin to operate. Given this observation, a more likely scenario is that tremor is currently generated during the slow, long-duration aseismic slip on the rupture interface that has been observed to follow other great earthquakes.

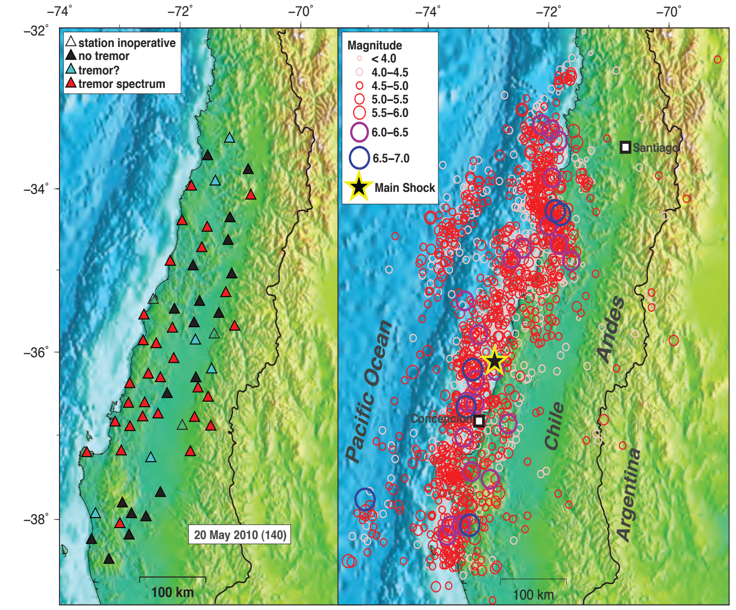



**Figure 3: Left:** Tremor occurrence as observed in power spectra on May 20, 2010, a day chosen at random. Note tremor is not confined to coastal stations sited above the region of active aftershock generation, but also is recorded at stations at or near the Andean front. Similar analyses for other days show tremor signals occur at nearly all CHAMP stations. **Right:** Aftershocks of the Maule earthquake (star) located by the US National Earthquake Information Center, February 27 – October 1, 2010. Preliminary analysis of MISD data by groups at Liverpool University and GFZ Potsdam, Germany, has resulted in more than 30,000 located aftershocks.

Ongoing and future studies of the MISD will certainly take us further towards resolving the presence of tremor and other issues concerning end-seismic cycle processes. Thanks to EarthScope, IRIS and PASSCAL, and to our international collaborators, the global seismological community will have the opportunity to attack these problems with an unprecedented data set in hand. ■

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See online version for expanded article with references.

The IRIS website www.iris.edu/hq/chile describes the community instrument deployment in Chile, including a list of all field team members, provides information on data access and includes a blog "News From the Field".