

spring/summer 2015

EarthScope News

Future Seismic and Geodetic Facility Needs in the Geosciences

Future seismic and geodetic facility needs in the geosciences were discussed in a workshop May 4-6, 2015. The lively meeting included plenary presentations and breakouts on the general themes of Earth structure, rheology and geodynamics; Time-variant behavior of faults and magmatic systems; Evolving landscapes and global environmental change; and Links to industry and discovery-mode science from new technologies.

Discussions focused on foundational facilities (what is needed in the short term to support geoscience research and broader impacts) and frontier facilities (new capabilities, beyond those that might presently exist, which will be required to make rapid progress in addressing one or more science grand challenge questions).

White papers and some of the presentations are on the web site: http://www.iris.edu/hq/workshops/2015/05/future_seismic_and_geodetic_facility_needs_in_the_geosciences. A report summarizing the outcomes of the meeting is under development and will be available for community comment in Summer 2015 and presented to the National Science Foundation in early Fall 2015.

A Coast-to-Coast View of the Mantle Beneath the United States

Brandon Schmandt, University of New Mexico and Fan-Chi Lin, University of Utah

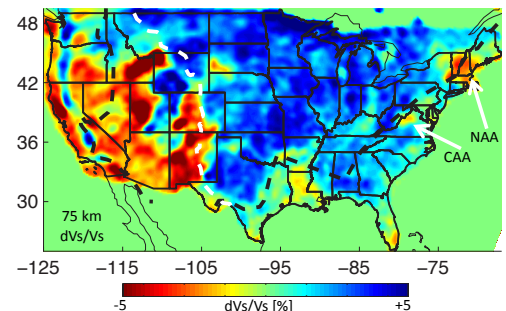
One of the major observational components of the EarthScope program is the Transportable Array (TA) network of broadband seismometers. The TA is composed of 400 seismometers that were first installed near the west coast of the U.S. in 2005-2007 and have progressively moved eastward until reaching the northeastern coast of the U.S. during Fall 2013. One of the initial goals of the TA was to enable coast-to-coast seismic imaging of the North America lithosphere and underlying mantle convection with resolution comparable to that within regional observatories. Many more analyses are yet to come, but new travel-time tomography images made with continuous data coverage from southern California to northeastern Maine provide a glimpse of the multi-scale structure of the mantle beneath North America.

The tomography images shown here use measurements of body waves and surface waves recorded by the TA and other networks in U.S. The body waves used result from distant earthquakes (>3000 km from the TA) and they propagate deep into the Earth before arriving at near vertical angles beneath the TA. The surface waves were extracted from correlations of ambient seismic noise recorded during the approximately two years that each TA station is deployed. Ocean waves are the primary source of the seismic surface wave energy present in ambient noise. By measuring the propagation of both wave types across the TA for a range of frequencies we infer and estimate the 3-D seismic velocity structure beneath North America. Volumes of unusually low velocity mantle dominantly result from warmer than average temperatures at a given depth, and volumes of unusually high velocity result from colder temperatures.

Multiple spatial scales and a long record of geologic time are reflected in the imaged seismic velocity variations. The elevated and tectonically active western U.S. is generally underlain by low-velocity upper mantle indicative of high temperatures and a thin portion of the tectonic plate. High temperatures are further indicated by the widespread presence of Quaternary (< 2 million years old) volcanic rocks in the western U.S. Isolated volumes of high velocity mantle beneath the western U.S. represent subducting slabs or locally thicker parts of the tectonic plate. The central U.S. is generally underlain by high velocity mantle indicative of lower temperatures and a thicker portion of the North America plate. This area has been mostly free of tectonic deformation and magmatic activity since the Precambrian (> 542 million years ago). Intermediate seismic velocities are found beneath the eastern margin of the U.S., which has not been an active plate boundary since the Atlantic Ocean began to open about 200 million years ago.

Prior to the arrival of the TA, seismic sampling of the passive margin of the eastern U.S. was sparse compared to the western U.S. and little was known about variations in upper mantle temperature. Interest in thermal convection beneath the passive margin is stimulated by geological evidence for magmatic events and evolving topography long after the area became a passive margin. Initial images of seismic structure beneath the passive margin detect two distinct upper mantle low velocity anomalies beneath the central and northern Appalachians, respectively. These relatively high temperature volumes probably reflect lasting thermal scars in the lithosphere from magmatic events that occurred approximately 45 – 125 million years ago.

Sustained geodynamic activity along passive margins is not predicted (or precluded) by plate tectonic theory, rather it is largely a consequence of mantle convection beneath a plate's interior. This makes it difficult to understand the long-term geological evolution of the eastern U.S. without constraints on thermal structure and flow in the mantle. EarthScope seismic data are already advancing our understanding of the western U.S. where plate margin processes are the primary drivers and are now beginning to advance understanding of the passive margin in the eastern U.S. where the major driving forces are less evident at the surface.



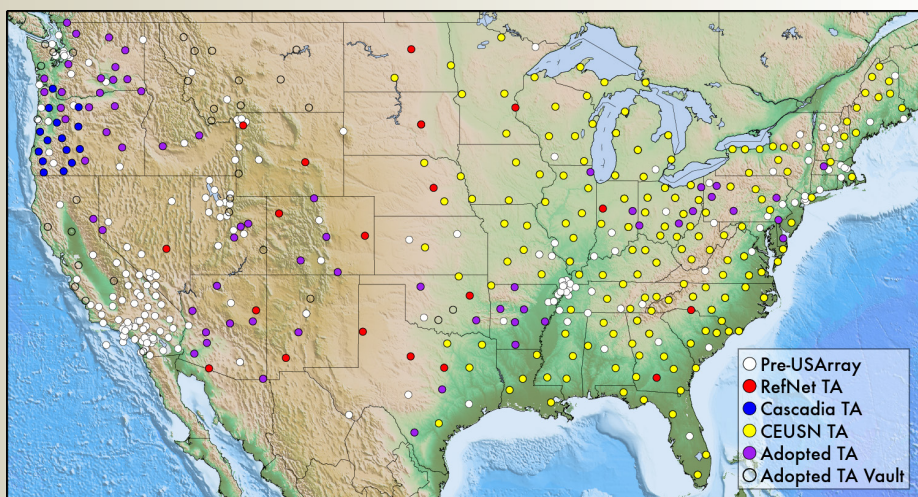
Tomography map of the shallow upper mantle. The colors show S-velocity deviations from the average at a depth of 75 km. Black dashed lines indicate Precambrian margins of the continent, white dashed line denotes the Rocky Mountain front. The locations of the central Appalachian anomaly (CAA) and northern Appalachian anomaly (NAA) are labeled.

The Legacy of the USArray Transportable Array Andy Frassetto, IRIS

In the fall of 2003, before EarthScope began, approximately 200 modern broadband seismic stations operated across the contiguous United States, primarily for earthquake monitoring. In 2015, nearly 1700 sites have been temporarily occupied by USArray Transportable Array stations. As the USArray TA concludes its operations in the Lower-48 and transitions to locations in Alaska and adjacent northwestern Canada, it leaves behind a substantial legacy.

About 260 former TA stations have been adopted or are continuing to operate in various capacities. The USArray Reference Network continues to operate 20 TA stations as part of a permanent backbone of stations. In addition, regional seismic networks, universities, and state geological surveys have or plan to adopt 81 TA stations, with some still being operated by IRIS as part of its Education and Research Network or "EARN" program. Finally the Federal government, through the National Science Foundation, supports the operation of 159 TA stations under the Central and Eastern United States Network initiative through at least 2017. The CEUSN stations have been reconfigured to record at 100 samples per second and 34 of them now been equipped with strong motion accelerometers, making this network an excellent platform to better understand seismic hazards, including those from induced seismicity, as well as to continue to explore the scientific questions posed by EarthScope. Altogether, these high-quality, real-time, long-term deployed broadband seismic stations have fundamentally improved the ability to monitor earthquakes and conduct seismology research in North America.

During its first decade, the Transportable Array recorded thousands of local, regional, and teleseismic earthquakes. These data, which are open and freely available for download to anyone around with the world, have already contributed to expanding our understanding of our planet and inspiring the next generation of earth scientists. Similar opportunities will undoubtedly follow as the Transportable Array deploys new stations and upgrades existing permanent stations across Alaska and adjacent portions of Canada from 2014-2018.



Right: Location of broadband seismic stations operating in the continental US before EarthScope (white circles). The Transportable Array leaves behind 260 new "legacy" stations (all non-white circles).

Hot New Science

In each inSights we feature a few recent publications of EarthScope results. Please submit your latest publications to earthscope@asu.edu

Entwistle, E., Curtis, A., Galetti, E., & Baptie, B. (2015). Constructing new seismograms from old earthquakes : Retrospective seismology at multiple length scales. *Journal of Geophysical Research*, 1–68.

Jones, C. H., Mahan, K. H., Butcher, L. a., Levandowski, W. B., & Farmer, G. L. (2015). Continental uplift through crustal hydration. *Geology*, 43(4), 355–358. doi:10.1130/G36509.1

Parker, E. H., Hawman, R. B., Fischer, K. M., & Wagner, L. S. (2015). Constraining lithologic variability along the Alleghanian detachment in the southern Appalachians using passive-source seismology. *Geology*, 43(5), 1–4. doi:10.1130/G36517.1

Pilger, C., Ceranna, L., Ross, J. O., Pichon, A. Le, Mialle, P., & Garcés, M. A. (2015). CTBT infrasound network performance to detect the 2013 Russian fireball event. *Geophysical Research Letters*, 1–9. doi:10.1002/2015GL063482.

Spinler, J. C., Bennett, R. A., Walls, C., Lawrence, S., & García, J. J. G. (2015). Assessing long-term postseismic deformation following the M7.2 April 4, 2010, El Mayor-Cucapah earthquake with implications for lithospheric rheology in the Salton Trough. *Journal of Geophysical Research - Solid Earth*, 120. doi:10.1002/2014JB011613

EarthScope National Meeting June 14-17, 2015 Stowe, VT

The sixth biennial EarthScope National Meeting was hosted in beautiful Stowe Vermont. Speakers and participants came from across North America to learn about recent EarthScope accomplishments and cutting edge research. The conference kicked off with a field trip examining the geology of Vermont that provides a record of the tectonic evolution of the eastern margin of North America.

Presenters offered a wide variety of talks spanning a vast array of EarthScope research in the following Plenary Sessions:

Dynamics and Evolution of the North American Continent: Crust, Lithosphere, and Deep Mantle

From groundwater to the Ionosphere

Active Tectonics and Modern Earth Processes of North America

Advances in Understanding and Forecasting Hazards

EarthScope Innovations and Looking into the Future

Special Session - Outcomes from the Future Seismic and Geodetic Facility Needs Workshop
(see front page sidebar for more information)



For the full agenda, go to http://www.iris.edu/hq/workshops/2015/06/earthscope_national_meeting_2015

Low-Cost Additions to the Plate Boundary Observatory for Earthquake Early Warning

One of the major benefits of the Plate Boundary Observatory (PBO) is its contribution to prototype Earthquake Early Warning systems (EEW). While systems to date have focused on seismic data, PBO affords the seismically active Western US the opportunity to incorporate GPS data into the mix. The two data sets are highly complementary. Seismometers measure acceleration and yield quick detection and location of earthquakes. GPS measures displacement, and yields rupture extent and magnitude. These latter quantities are especially important for large earthquakes, where the projected extent and strength of shaking may be underestimated by seismometers alone.

The first step in making PBO GPS stations valuable for EEW was to equip more than 400 stations throughout the Pacific Northwest and California with real-time streaming capabilities. Over the last 18 months, UNAVCO and partners furthered the effort by upgrading 22 sites in California with low-cost seismometers to provide both of these valuable data streams at each station. Each site is equipped with a small accelerometer clamped onto the GPS monument and a custom geodetic module that synchronizes the seismic data with the GPS data. The system was developed at Scripps Institution at the University of California San Diego, and the data are streamed in real time to the UNAVCO data archive in Boulder, Colorado where they are publicly available.

In Southern California, 12 PBO-GPS stations along the San Andreas and San Jacinto faults have these accelerometers, modules and upgrades. In Northern California, 10 PBO-GPS upgrades focus on the Hayward, Rodgers Creek, Concord, Greenville, and San Andreas faults. The next region to see these upgrades will be coastal Cascadia.

For more details, including an animation on how GPS and seismometers are used in concert to improve earthquake early warning systems, please visit www.unavco.org/highlights/2015/accelerometers.html.



Right: The accelerometer installed at P248, clamped to the vertical leg of the GPS monument. (Photo Doerte Mann, UNAVCO)

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 <http://insights.asu.edu>



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inSights is a quarterly publication showcasing exciting scientific findings, developments, and news relevant to the EarthScope program. Contact earthscope@asu.edu to be added or deleted from the hardcopy mailing list; electronic copies are available at www.earthscope.org. Editor: Devon Baumbach ASU/EarthScope National Office.

2015 - 2016 Speaker Series

The EarthScope National Office officially announces the EarthScope Speaker Series for 2015-2016, supported by the National Science Foundation. The five exemplary speakers for this series include (below, left to right): Adrian Borsa (Scripps Institute of Oceanography, UC San Diego), Reed Burgette (New Mexico State University), Melodie French (University of Maryland), Heather DeShon (Southern Methodist University), and Fan-Chi Lin (University of Utah).

Academic institutions are invited to apply for a Speaker visit for the 2015-2016 academic year. Complete information about the EarthScope Speaker Series, including speaker biographies and an online applications form, can be found on the EarthScope website at www.earthscope.org/speakers.

