

earth scope

onSite

newsletter

From the National Science Foundation

EarthScope is ushering in a new era in the Earth sciences by providing the first integrated, real-time measurements of deformation at micro to macro spatial scales and instantaneous to millennial temporal scales. EarthScope is providing data necessary to understand continental structure and evolution, regional and continental tectonics, the structure and dynamics of Earth's interior, earthquakes and seismic hazards, and magmatic systems and volcanic hazards. EarthScope scientists are at the forefront of discovery and the development of imaging, visualization, and educational tools. Current research methods are becoming automated procedures, paving the way for new and as yet unknown research directions.

Construction of the EarthScope facility, "the most ambitious earth science project ever attempted,"¹ is now complete and outstanding scientific results are already appearing. Friction and other physical properties measurements and research are underway on core samples from the actively deforming San Andreas Fault system. Collection of extraordinary amounts of high quality seismic and geodetic data is driving methodological improvements and development of integrated analyses to resolve the interior structure and deformation of the Earth, from crust to core, in unprecedented detail. Seismic and geodetic instrumentation have already recorded eruptive volcanic sequences on two types of volcanoes and captured slow earthquakes in Cascadia and California. Continuous interseismic data, long discarded as noise, are used for high-resolution structural images of the crust and lithosphere.

It has been a remarkable five years of concurrent facilities construction and research growth. The next decade promises to be very exciting and we are proud to be supporting the Earth science community as you lead the EarthScope effort.



Kaye Shedlock

Kaye M. Shedlock
NSF EarthScope Program Director

¹San Jose Mercury News, 8/13/08

featured science:

Looking up with USArray

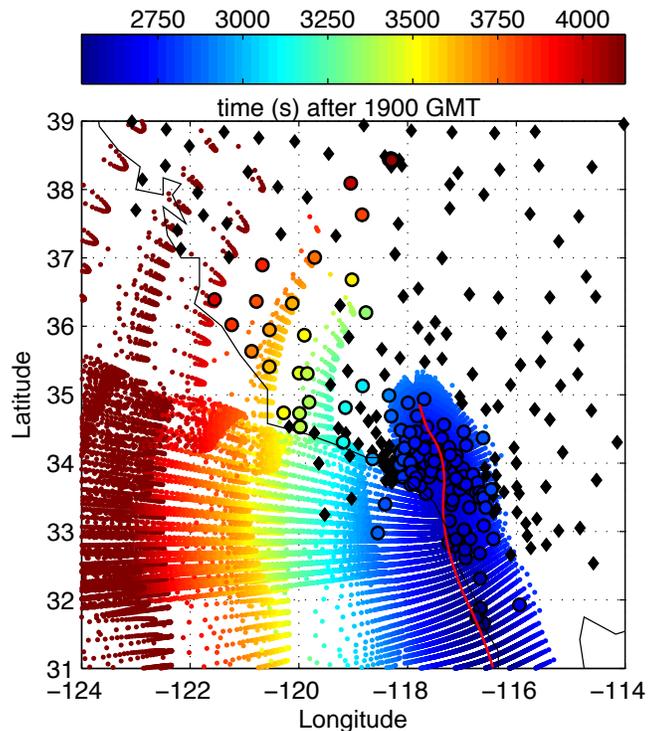
It has been said that "Serendipity is putting a quarter in the gumball machine and having three pieces come rattling out instead of one—all red." The beauty of science is that it occasionally serves up extra red gumballs. Although USArray was designed to probe Earth's internal structure, it can also be useful for studies of atmospheric structure, dynamics, and sound-producing phenomena. Infrasound is subaudible sound that can travel thousands of kilometers through the Earth's atmosphere with relatively little attenuation at speeds of ~250-350 m/s. The atmospheric velocity structure is relatively complicated and varies with direction, as it depends mainly on time-varying temperature and wind. The global suite of infrasound stations is sparse, complicating infrasound research. Far-reaching infrasound propagates near-horizontally along the Earth's surface and creates a seismic displacement that travels at near-acoustic velocities. As a result, the relatively dense USArray combined with stations in other seismic networks can be used to probe the skies in unprecedented detail. To demonstrate this potential, we briefly discuss two recent atmospheric events studied with seismic data: a space shuttle re-entry and a bolide explosion.

The northward re-entry of the shuttle Atlantis (STS-117) occurred along the southern California coast, decelerating to Mach 1 near Edwards AFB in June 2007. Over a million people, three infrasound stations and over a hundred seismic stations detected the sonic boom. A GPS receiver onboard the shuttle that recorded positional information and the concurrent presence of USArray yielded a rare opportunity to evaluate regional-scale atmospheric velocity models. Travel times to seismic stations were predicted using 3-D ray tracing through an atmospheric model derived from meteorological data (provided by Doug Drob, Naval Research Laboratory). Comparison of predicted and observed travel times show agreement over much of the study area (Figure 1). Stations beneath the shuttle recorded the down-going sound carpet. More distant stations to the northwest recorded signals channeled within a stratospheric wave-guide due to the westward summer-time stratospheric jet. Some unpredicted recordings to the north hint at inaccuracies in our wind model, perhaps due to small-scale horizontal wind perturbations associated with the Sierra Nevada mountain range.

On February 19, 2008, a large bolide exploded above northeastern Oregon (Figure 2). The event was seen by thousands of people and was recorded by four infrasound arrays and over a hundred seismic stations. More stations to the west than to the east detected

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Figure 1. Map of stations operating during Atlantis re-entry to Edwards AFB on June 22, 2007. Stations recording signal are large circles color-coded by the signal arrival time. Solid diamonds are stations where no signal was detected. Small dots indicate where rays from the shuttle are expected to return to the ground and are color-coded according to predicted arrival time. Only stratospheric and tropospheric arrivals were considered. The red line is the shuttle's trajectory.



featured science:

Measuring Movement in the Rocky Mountains and Rio Grande Rift with GPS

The Rio Grande Rift crosses New Mexico from south to north before slicing through the Rocky Mountains of Colorado. Geophysicists from the University of Colorado at Boulder, the University of New Mexico, and Utah State University are using Global Positioning System (GPS) data to measure how fast the rift is extending and whether it continues into northern Colorado and southern Wyoming. Spreading rates for the rift previously determined from geology and trilateration range from 0.3-1 mm/yr. The expected <1 mm/yr signals require stable monuments, long observing periods, and

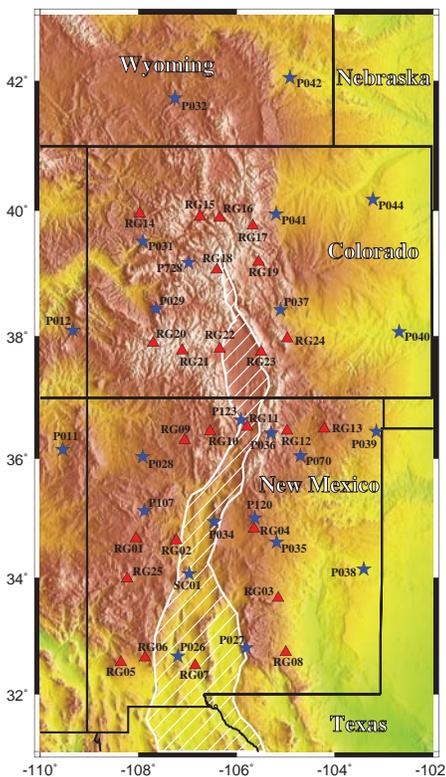


Figure 1. Topographic map of Colorado, New Mexico, and vicinity with Rio Grande Rift (white hatch), Rio Grande Rift GPS monuments (red triangles) and PBO GPS monuments (blue stars).



Figure 2. GPS monument RG23 in Great Sand Dunes National Park, Colorado.

careful processing. Continuous GPS recording helps determine whether deformation is steady or episodic. Extensional focal mechanisms suggest the Southern Rocky Mountains are being stretched, but low upper-mantle seismic wave speeds suggest buoyant uplift. Although GPS measurement of vertical velocity is challenging, a secondary goal is to determine whether the Rockies are rising or subsiding. The team has installed 25 GPS monuments throughout New Mexico and Colorado (Figures 1 and 2) to complement existing sites and densify coverage of EarthScope's Plate Boundary Observatory (PBO) there.

The geologic expression of the Rio Grande Rift includes volcanism, faulting, and sedimentary basin formation that began roughly 35 million years ago. Volcanic features in the rift (including the Valles Caldera near Los Alamos, New Mexico) are considered dormant, not extinct, and there is geodetic evidence of ongoing inflation of the Socorro magma body and other intrusions in the region. On the Sangre de Cristo Fault in south-central Colorado, trenching of fault scarps suggests normal-faulting earthquakes of magnitude ≥ 7.0 in the past 5000 to 15,000 years. Results from recent seismic experiments show thin crust and low seismic wave speeds in the upper mantle beneath the Southern Rocky Mountains and Rio Grande Rift, with low wave speeds continuing north of the rift.

The Rio Grande Rift GPS monuments were installed in 2006-2007 and will remain in place until 2010-2011 (Figures 1 and 2). Data are recorded every 30 seconds and downloaded manually during semi-annual station visits. Station time series from the first two years of the experiment show excellent monument stability with standard deviations in position of 1 mm for horizontal components and 5 mm for the vertical. Baseline length between stations has been measured using the GAMIT/GLOBK software (Figure 3). The ~1 mm amplitude annual signal is as expected from snow/water loading. The increased variance during the summer months may reflect the effects of high-energy convective cells in the atmosphere (thunderstorms). It is too early to attach much significance to baseline velocities (for example, P039-RG09 and P040-RG22 have opposite sign). Parameterization as velocity plus annual terms tends to be unsettled

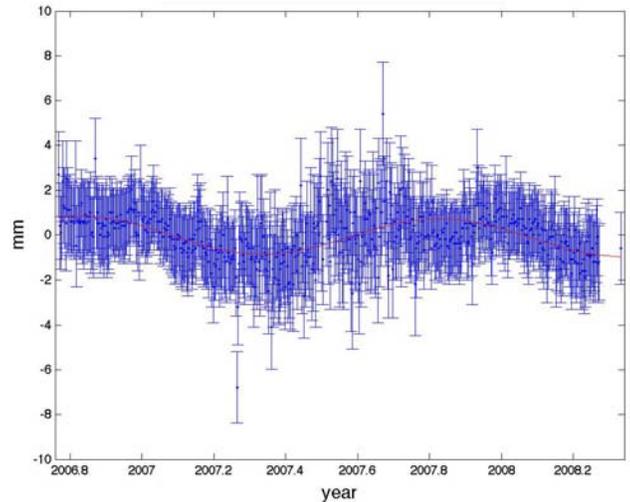


Figure 3. Daily solutions for baseline distance between stations RG09 and RG13 for September 2006- March 2008.

during the first two or three years of measurement and there are inter-annual variations in precipitation that can significantly influence the velocity estimates. However, it appears that the total opening rate of the Rio Grande Rift is on the low end of rates postulated previously (i.e. ≤ 0.5 mm/year).

Further data processing will include modeling the elastic load response using independent data for surface hydrologic and snow mass, and additional atmospheric modeling. The GPS data are being processed using three different software packages (GAMIT/GLOBK, Gipsy, and Bernese) to vet the reference frame and model parameterizations in each and to assess modifications of standard analysis practices. In addition, campaign measurements of 26 High Accuracy Reference Network (HARN, <http://www.ngs.noaa.gov/faq.shtml>) sites in Colorado were made in summer 2008, and will be differenced from measurements of the same sites made in 2001. Further information on the project can be found at http://ciei.colorado.edu/~arlowry/Rio_Grande_Rift.htm and http://www.earthscope.org/es_doc/en0/materials/riogrande.pdf.

The Rio Grande Rift GPS project is supported by the NSF EarthScope program with technical support from UNAVCO. We are grateful to the MIT GAMIT/GLOBK team for software support, to field volunteers, and to property owners who host GPS monuments. ■

By Anne Sheehan, Henry Berglund, and Steve Nerem, University of Colorado; Mousumi Roy, University of New Mexico; and Tony Lowry, Utah State University.

EarthScope News

- Mark your calendars for the **2009 EarthScope National Meeting** in Boise, Idaho, May 12-15. There will be pre- and post-meeting workshops and field trips. For deadlines and agenda, visit www.earthscope.org/meetings/national_meeting_09.
- The next ESN0-sponsored **workshop for interpretive professionals** in parks and museums will be at the San Bernardino County Museum (California), April 19-22, 2009, and will focus on the San Andreas Fault (www.earthscope.org/eno/parks).
- Processed **Magnetotelluric (MT) transfer functions** (impedances) are now available at ftp://www.iris.washington.edu/pub/MT_ED1 for all long period temporary MT sites occupied through the summer of 2008.
- **GeoEarthScope airborne LiDAR** (Light Detection and Ranging) data are now easily viewable in Google Earth. KML hill shade files currently available at www.opentopography.org include coverage of active faults in California (including the San Andreas and San Jacinto faults). Imagery from Yellowstone, the Grand Tetons, Alaska and other regions will be available soon. LiDAR is a remote sensing technique that images ground surfaces — even through vegetation — producing stunning 3-D topographic maps (www.earthscope.org/es_doc/onsite/onsite_fall07.pdf).
- New **SAFOD core sample** request date expected this spring. Watch www.earthscope.org for an announcement.
- “**Imaging and Discovery from USArray and EarthScope**” is the title of one of the special sessions during the 2009 Annual Meeting of the Seismological Society of America, April 8-10, in Monterey, California. For more information, visit <http://www.seismosoc.org/meetings/2009/index.php>.
- Interested in **adopting a Transportable Array station**? Information is available at <http://www.iris.edu/USArray/researchers/adopt.html>.
- Attend **Interpretive Methods for Scientists: Communicating EarthScope to the Public** and other workshops on May 12 prior to the EarthScope National Meeting (www.earthscope.org/meetings/national_meeting_09/pre_meeting_workshops).

featured science: Looking up with USArray

(continued from front)

the event. Although the explosion was large enough to be located with the distant infrasound arrays (using another model provided by Doug Drob), the seismic data provided a much more accurate source location. The seismic disturbances are a result of the down-going sound carpet out to a range of ~250 to 300 km. Stratospherically ducted energy arrives later and first appears ~200 km from the event (Figure 2). A lack of stratospheric arrivals detected to the east may indicate that stratospheric wind influenced regional propagation, although this is still being investigated.

The time is ripe for atmospheric infrasound research to progress in leaps and bounds as USArray marches across the U.S. Each region should provide its own panoply of interesting atmospheric sources, velocity structures, and atmospheric dynamics – e.g., tornadoes in the Midwest and hurricanes in the South. Because conversion efficiency from acoustic to seismic depends on many factors that are usually unknown *a priori*, the true amplitude and character of the associated acoustic signals will be unknown. Collocation of USArray seismometers with inexpensive, single-channel infrasound sensors could yield an even more extraordinary return on our investment. More on infrasound research can be found at <http://www.inframatics.org>. ■

By Michael A.H. Hedlin, Catherine D. de Groot-Hedlin and Kris T. Walker, Laboratory for Atmospheric Acoustics, Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, University of California, San Diego.

Glossary

Infrasound: Sound waves below the lower hearing limit of 20 Hz.

Bolide: A fireball associated with a large meteor passing through the atmosphere.

Troposphere: The lowest layer of the atmosphere. The layer cools from bottom to top and is inherently unstable; hence the prefix “tropo.”

Stratosphere: The stratified layer just above the troposphere that warms from bottom to top.

Stratospheric jet: High winds in the stratosphere that reverse twice per year. In the northern hemisphere in the winter, they are directed from west to east.

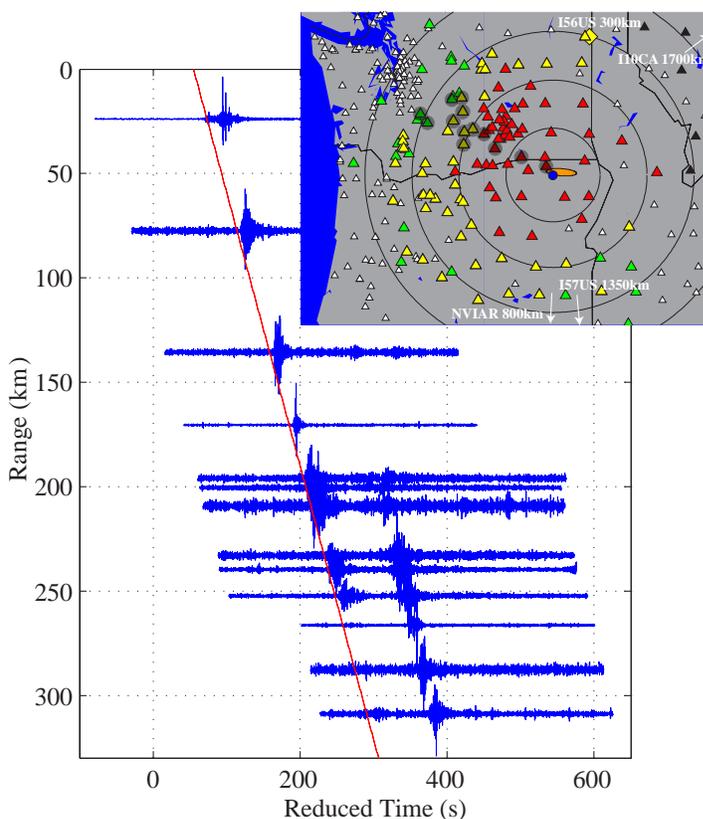


Figure 2. The terminal burst of the Oregon bolide was recorded by four infrasound arrays (I10CA, I56US and I57US in the International Monitoring System, plus NVIAR) and over 100 seismic stations in the USArray and regional networks. In the embedded map, stations not recording a signal are shown in white. Red symbols are stations recording just the down-going signal; green are just the upgoing stratospherically channeled signal; and yellow are both signals. Black stations recorded a signal which we believe is associated with this event but for which the propagation path is as yet unclear. Concentric circles around the seismic location (shown in blue) indicate 100 km distance increments. The infrasound location from arrival times and azimuths is shown in orange. Recordings from the shaded stations west of the bolide are shown in the record section. The traces show the gradual loss of tropospheric signal at distances beyond 200 km and the emergence of a later, stratospherically ducted signal near 200 km. The vertical component records have been bandpassed from 0.8 to 3.0 Hz and time has been reduced at 450 m/s. The red line indicates expected arrival times from the bolide at a propagation speed of 325 m/s.

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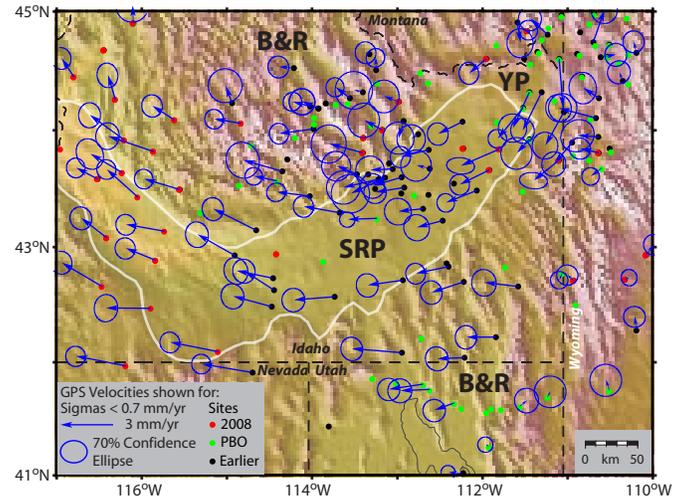
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New GPS Data Reveal Stiff, Rotating Snake River Plain

The Snake River Plain (SRP) stands out physiographically as an elongated, low-lying feature in the midst of the mountainous and actively extending Basin and Range (B&R) province. Its role in accommodating deformation and its relationship to the Yellowstone (YP) volcanic complex to the east have long been debated. To assess deformation in the SRP and environs, we occupied 73 survey-mode GPS sites from May-July 2008, with funding from EarthScope and support from the Idaho National Laboratory. The velocities derived from these and earlier occupations show the SRP is caught in a regional-scale clockwise rotation. The internal deformation is an order of magnitude lower than in the adjacent B&R, explaining the SRP's low seismicity. The differential strain rates require some relative shear along the northern and southern SRP boundaries though the nature of that deformation is still unclear (see Payne et al. 2008, *Geology* v. 36, p. 647-650). These types of fine-scale geologic problems highlight the effectiveness of survey-mode GPS to increase spatial density of PBO in active regions. ■

By Robert King, Massachusetts Institute of Technology; Suzette Payne, Idaho National Laboratory; and Robert McCaffrey, Rensselaer Polytechnic Institute.



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