summer 2016

inSights
the EarthScope newsletter

EarthScope News

EarthScope Synthesis Workshops

Apply to a workshop planned for 2016–2017, and/or think about hosting your own in the near future:

Applications to host the next round of synthesis workshops will be accepted starting in September 2016. The deadline is Monday, October 10, 2016. Complete applications include the following information: workshop title; primary contact name & email; potential additional co-organizers; anticipated key participants; proposed location; proposed time of year; motivation for the workshop; types of EarthScope data used; relationship of the topic to EarthScope science goals; anticipated progress toward synthesis to be made at the workshop; and additional text and figures that represent a commitment to work

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Creeping Calamity

Using the Plate Boundary Observatory to monitor landslide motion

by Gail McCormick

GPS Station AC55 in Alaska was moving more than expected. Some movement was normal due to tectonic plate movement and residual motion from previous earthquakes—other GPS stations in the area moved around 0 to 3 mm per year, after all. But AC55 moved over 5.5 cm per year.

"We saw that something was wrong and then realized—no, that's a landslide," says Dr. Guoquan Wang, Associate Professor of Geophysics, Geodesy, and Geosensing Systems Engineering at the University of Houston.

Landslides can damage infrastructure and prove fatal, leading to yearly losses of up to $4 billion and as many as 50 human lives in the United States alone. To better understand how and when these potentially destructive forces strike, researchers have utilized GPS technology to monitor landslides in real time. Wang and his team took advantage of AC55's placement on a landslide to fine tune a new technique that distinguishes landslide motion from other background movement in the area.

From 2006 to 2010, GPS Station AC55 was located on an elevated area near the bank of the Yentna River in southcentral Alaska. It was part of an immense network of GPS, seismic, and other geophysical instruments comprising the Plate Boundary Observatory (PBO). The PBO was constructed across the western United States and Alaska to help understand processes that occur at plate boundaries, but researchers continue to find new and unexpected ways to utilize the vast publicly accessible data collected from these stations.

"By using the existing infrastructure of the PBO network, we can easily and precisely monitor landslides on the west coast and Alaska," says Wang.

How does it work?

Researchers have used GPS technology to monitor landslides in the last decade, but Wang and his team have updated these methods to take advantage of the PBO infrastructure. Typically, at least one unit

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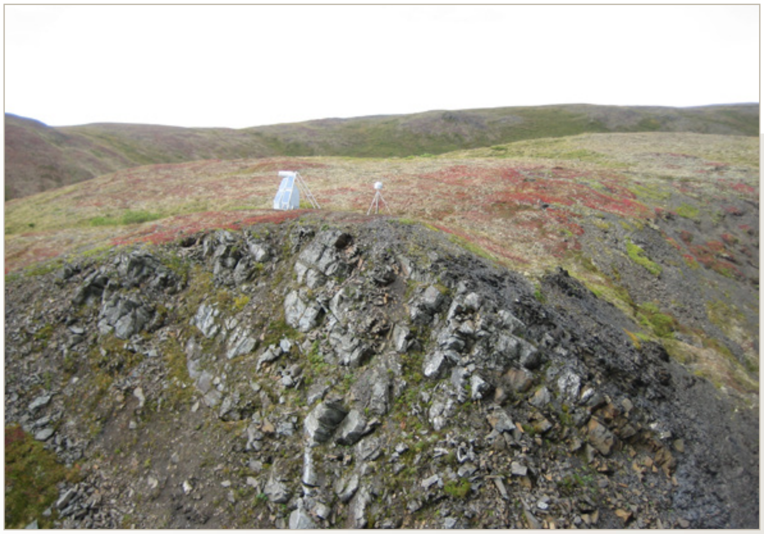

Plate Boundary Observatory GPS Station AC55 was mistakenly installed on a landslide site near the Yentna River in southcentral Alaska. Researchers took advantage of this to develop a new method that distinguishes landslide movement from background motion in the area. The method relies on the larger PBO network in the area as a reference. Photo by Chris Walls, UNAVCO

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Creeping Calamity
Using the Plate Boundary Observatory to monitor landslide motion

like AC55 is placed on and moves with the landslide, providing continuous position data in real time, regardless of the time of day or weather conditions. Another GPS station is installed just outside of the landslide boundaries and acts as a reference. The landslide movement is tracked relative to this reference station, so that researchers can determine how much the landslide moved and in what direction.

But placing a reference station can be challenging, Wang notes. "You may not know the boundary of your landslide," he says, which may lead to installing the reference station too far away to provide an adequate reference, or possibly installing it on the landslide itself.

To avoid these pitfalls, Wang and his team used as reference stations the permanent GPS monuments of the PBO. Using these stations in concert with AC55, they continuously monitored the landslide near the Yentna River in Alaska over four years.

What is "normal" movement?

Before Wang could determine how much the Yentna River landslide was moving, he first had to account for the "normal" movement in the area. In central Alaska, there is considerable tectonic activity. The Pacific Plate is subducting under the North American plate just south of Alaska, which triggers motion along a number of major faults, including the Denali fault, site of the 2002 magnitude 7.9 Denali quake. In addition to the motion of the plates themselves, residual seismic motion from major earthquakes such as the one in 2002, and even the magnitude 9.2 Great Alaska Earthquake of 1964, affects the landslide area, which is located about 300 km between the earthquake epicenters.

By using different combinations of PBO reference stations near the landslide area, Wang and his team established what they call a "local reference frame." This accounts for background tectonic movement, which caused reference stations in the area to move an average of 1.5 mm per year. Wang included this information in a series of complex models used to describe the landslide motion.

In addition to tectonic activity, seasonal changes in groundwater level, the amount of water or snow on the surface, and soil moisture can induce periodic ground motion that could be mistaken for landslide movement. A specific point at a reference station near the landslide could be displaced as much as 1.5 cm throughout the year, mostly due to inflation of the ground as it absorbs water from snow melt. Wang and his team included this periodic variation in their models.

Additionally, Wang and his team had to deal with snow and ice accumulation on the GPS antenna, which degrades or bounces the signal. This can cause a delay in receiving the data, making the GPS unit appear to be at an incorrect location at a certain time.

"We don't try to correct the data, we just find the problem," says Wang. They identified where data was degraded and removed it from their analysis.

"After you remove the tectonic and seasonal motion and the snow and ice errors," says Wang, "you are left with the pure landslide movement." At this point, Wang determined that the Yentna River landslide moved northeastward at about 5.5 cm per year, and also subsided at a rate of 2.6 cm per year.

Not all landslides are fast

"Landslide" is a catch-all word for Earth surface mass movements, but not all landslides involve sliding. Some, for example, involve rotation (rotational slides) or fracturing (lateral spreads). Due to its relatively slow rate of movement, the Yentna River landslide is considered a creeping landslide.

Creeping landslides are common in mountainous areas and can be just as costly as fast-moving landslides. Because they are always in motion, creeping masses can place continuous stress on human infrastructure, making roads inaccessible and damaging utility lines and other property. Short bursts of rapid movement can also occur at these sites. In some cases, communities are unknowingly built on creeping masses, like the Terra Navita neighborhood in Boise, Idaho, whose residents plan to sue developers for failing to consider the area's previous history with landslides.

Because the Yentna River landslide is in a rural area, Wang and his team were able to fine tune monitoring methods without the added complexity of buildings and roads. These methods could then be applied to creeping masses that pose a threat to communities.

GPS landslide monitoring is not limited to creeping landslides. "It works for slow movements," says Wang. "Absolutely it works for faster ones." If recording stations are installed where we expect fast movements to occur, for example on creeping masses or where landslides have occurred in the past, this method could also be used to monitor mountain slides and avalanches. Real-time GPS monitoring may also detect early signs of rapid movement, which could be integrated into a warning system.

Wang's method of using existing GPS stations to account for background motion could easily be applied to areas with existing long-term networks of recording stations, including much of the United States (PBO, CORS) and Japan (GEONET). In these areas, researchers may be able to identify creeping sites and to assess the potential for landslides to become hazardous.

GPS Station AC55 has since been removed, but others like it will continue to monitor Earth movement as a part of the PBO. Its unanticipated movement at the landslide site draws attention to one of the many ways researchers can make the most of this publicly available infrastructure. ■

Wang and colleagues published their new method in the July 2015 issue of Natural Hazards.

IRIS 2016 Workshop highlights emerging fields and technologies in seismology

by Perle Dorr, Danielle Sumy and Justin Sweet, IRIS

Over the last 30 years, advances in instrumentation and analytical techniques have facilitated new developments in seismology, including applications in non-traditional areas and the integration of seismology with related disciplines in Solid Earth sciences. The 2016 IRIS Workshop, in Vancouver, Washington, hosted more than 230 participants who engaged in presentations, posters, and discussions on these cutting-edge topics.

The *Science Planning Committee, with assistance from members of the seismology community, developed a program consisting of seven plenary sessions, two associated poster sessions, and ten special interest group meetings.

In the Induced Earthquakes session, Paul Segall (Stanford University) discussed the relationship between earthquakes and fluids, describing poroelastic effects, laboratory experiments, and how the space-time evolution of seismicity depends on fault friction and hydraulic properties. Beatrice Magnani (Southern Methodist University) provided insight into the relationship between fluid migration at depth and micro-seismicity along pre-existing fault structures in the Fort Worth basin of Texas. The session concluded with Susan Hough (USGS-Pasadena) presenting evidence that suggests induced or triggered earthquakes may have occurred in the early 20 th century in the Los Angeles basin.

Another session focused on the multidisciplinary nature of subduction zones. Kelin Wang (Pacific Geoscience Center, Geological Survey of Canada) outlined six areas where recent insight and technological advances provide new opportunities for discovery, including coseismic slip of the shallowest, near-trench part of the megathrust; the relation of slow slip events with earthquakes; and continued postseismic monitoring to yield information on mantle rheology, fault friction and stress transfer. In her presentation, Heidi Houston (University of Washington) spoke about the evolution of the relationship between tremor and tidal sensitivity over the slow-slip seismic cycle, and its effects on plate interface healing and tectonic stress reload. Lastly, Bernd Schurr (GFZ-Potsdam, Germany) presented an analysis of the stressing and breaking of a single strong asperity during the Mw8.2 earthquake in northern Chile.

In a session on seismology for non-traditional targets, Emily Brodsky (University of California, Santa Cruz) reviewed the types of transient forces on Earth's surface that can produce observable seismic waves, such as rivers and landslides. Jeffrey Johnson (Boise State University) then described the use of seismic, infrasound, and video observations at two active volcanoes to look at surface activity, such as explosions, vigorous degassing, pyroclastic flows and lahar activity. Timothy Bartholomaus (University of Idaho) outlined seismic techniques he uses to study calving, sliding, and water discharge in glaciers, and Steven Holbrook (University of Wyoming) described the use of active-source reflection seismology to study the thermohaline fine structure in the oceans and near-surface seismic refraction tomography to image the structure of mountain watersheds.

Other plenary sessions highlighted the legacy of the Transportable Array; integration of seismic data across multiple scales to enhance imaging and source characterization; deployment of thousands of small, portable sensors that record continuously for high-resolution subsurface imaging; and science with low-cost sensors and disparate instrumentation, such as smart phones.

Pre-workshop activities included a *field trip to Mount St. Helens, a workshop on active-source seismology, and a half-day data services short course. During the workshop dinner, Steve Malone (University of Washington) spoke about how the 1980 eruption of Mount St. Helens catalyzed the development of improved seismic networks. ■

*IRIS thanks the Science Planning Committee (Miaki Ishii, Harvard University; Michael West, University of Alaska Fairbanks; Lindsay Lowe Worthington, University of New Mexico), the field trip leaders (Seth Moran–Cascades Volcano Observatory; and Steve Malone–University of Washington), and the National Science Foundation for their support of this biennial workshop.

See if you can find yourself! IRIS 2016 workshop participants gathered in Vancouver, WA, for a week of scientific presentations, discussions, field trips, and workshops. Photo by Perle Dorr.

Augustine Island, Alaska
PBO station AV03 takes a blow

by Beth Bartel

What's wrong with this picture? Well, PBO GPS station AV03 was built to last. Its stainless steel legs were drilled into bedrock and its robust power system was designed to last through the harsh winter. Unfortunately, not even stainless steel and weatherproof seals could protect the antenna from a volcanic eruption. AV03 recorded inflation of the Augustine Volcano in southwest Alaska until it was taken out by a pyroclastic flow in January 2006. The damaged antenna, partially melted and filled with volcanic ash, now lives in the UNAVCO lobby. AV03 was replaced by station AV18 in September 2006, which continues its work as part of a six-station team monitoring the volcano.

Learn more about AV03 on UNAVCO's AV03 station page or University of Colorado's educational GPS Spotlight Website.

2016 AGeS Awardees (EarthScope Awards for Geochronology Student Research)

The EarthScope AGeS (Awards for Geochronology Student Research) program is a multi-year educational initiative aimed at enhancing interdisciplinary, innovative, and high-impact science by promoting training, education, and interaction between graduate students, scientists, and geochronology labs at different institutions. The program offers support of up to $10,000 for graduate students to collect and interpret geochronology data that contribute to EarthScope science targets through visits and hands-on data acquisition in participating geochronology labs. We congratulate the 2015 winners listed below, and look forward to seeing their results.

Alyssa Abbey,
University of Michigan
Arkansas River development and late Cenozoic exhumation in the southern Rocky Mountains, Colorado.
Method: Detrital U-Th-Pb

James Chapman,
University of Arizona
Zircon $\delta^{18}O$ Trends in Cordilleran Magmatism in the Western U.S. and the Relationship to Mantle Lithosphere Geodynamics
Method: zircon U-Pb geochronology and zircon $\delta^{18}O$ isotope geochemistry

Jeremy Cordova,
Western Washington University
Pressure-temperature-time evolution of the Easton terrane, North Cascades, Washington State: the record of subduction initiation.
Method: $^{40}Ar/^{39}Ar$

Luke Fairchild,
University of California, Berkeley
Constraining rapid paleogeographic change in the Mesoproterozoic as recorded by the North American Midcontinent Rift
Method: U-series

Emilie Gentry,
Colorado School of Mines
In situ U-(Th-)Pb LA-ICP-MS analysis of monazite in high-strain zones to test the extent and origin of the Norumbega fault system in the New England Appalachians, a San Andreas-type fault system.
Method: U-(Th-)Pb LA-ICP-MS

Benjamin Klein,
Massachusetts Institute of Technology
A detrital zircon study of metasediments in lower arc crust in the Southern Sierra Nevada, California.
Method: Detrital U-Th-Pb

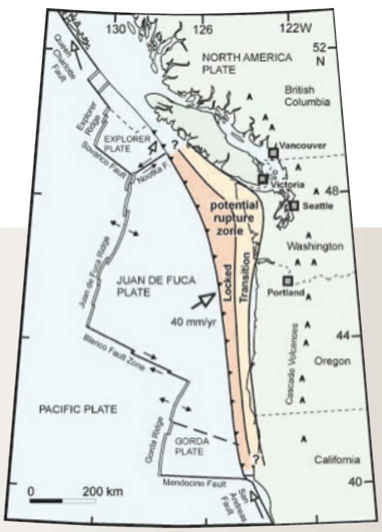
James Mauch,
Utah State University
Quantifying active salt deformation in Spanish Valley, UT, utilizing a chronostratigraphy of offset stream terraces
Method: cosmogenic radionuclide (CRN) ^{10}Be-^{26}Al isochron burial dating

Alexander Morelan,
University of California, Davis
Alluvial Fan Morphology Along Faulted Range Fronts as a Recorder of Slip Rate
Method: ^{10}Be CRN

Matthew Morris,
University of Oregon
Thermochronometric constraints on the age of Hells Canyon, testing lithospheric foundering in NE Oregon.
Method: (U-Th)/He

Education Corner

Over the years, an array of tools, modules, and activities applying EarthScope scientific data have been developed for a wide variety of users. K–12 and university educators, or informal programs like museums, can benefit from these freely available resources. inSights will feature two examples in each issue. Find more links to resources online: http://www.earthscope.org/resources

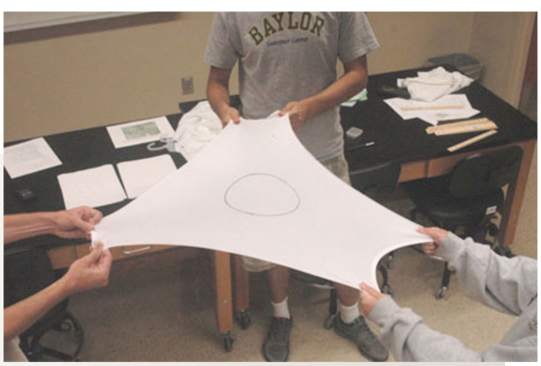


Investigating Episodic Tremor and Slip (ETS) along the California coast. Photo ©IRIS

Investigating Episodic Tremor and Slip:
Mysterious motions along the California coast

This one-hour activity, designed for high-school and early undergraduate students, teaches about Episodic Tremor and Slip (ETS) and how it differs from the traditional earthquake cycle. In small groups, students consider local tectonic boundaries, investigate earthquake history using the IRIS Earthquake Browser, and analyze GPS displacement and seismic data from the Cape Mendocino, CA region. ■

VIEW ONLINE



Undergraduates use stretchy material to model crustal strain. Photo ©UNAVCO

Infinitesimal strain analysis using GPS data:
Module for structural geology or geophysics

Through analysis of GPS displacement velocity data from the Plate Boundary Observatory (PBO), undergraduate structural geology students investigate ongoing (infinitesimal) strain. Optional short lab exercises introduce the idea of strain and how to find location and velocity data for PBO GPS stations. Students consider GPS data from three stations arrayed in a triangle, assess how the ellipse inscribed within this triangle deforms, and relate the deformation to regional geology, tectonics, and ongoing hazards.

This module was designed for structural geology but could be applied to geophysics, tectonics, or physics courses. Elements from the module can be used as a single lab activity or extended over several weeks. ■

VIEW ONLINE

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on the topic (size should not exceed 5 MB). Information available on our website.

Apply to participate in our Fall and Spring workshops:

1) Mendocino Triple Junction Observatory October 20–22, 2016. Application deadline: August 19th, 2016. Apply here.

2) Developing a New Model for the 4-D Evolution of North America November 18–20, 2016. Application deadline: September 16th, 2016. Apply here.

3) Structural and Tectonic Evolution of the Southern Margin of North America February 6–8, 2017. Application deadline: December 2, 2016. Apply here.

4) Evolution of the Southern Appalachian Lithosphere March 28-30, 2017. Application deadline: January 27th 2017. Apply here.

Visualization Competitions

Visualization has always been an important part of EarthScope Outreach. If you have been dreaming about your EarthScope results in a creative form, consider submitting to these opportunities:

AGU offers two challenges: the Vizzies, and a new data visualization and storytelling competition.

EarthScope National Office, in collaboration with UNAVCO and IRIS, will launch an EarthScope Science & Visual Art competition the Fall. Stay tuned for more info!

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Production Manager/Editor
Elisabeth Nadin
UAF Dept. of Geosciences
ESNO associate director for education and outreach,
enadin@alaska.edu

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