

spring 2016

EarthScope News

Speaker Series

The EarthScope National Office is pleased to present the EarthScope Speaker Series for 2016–2017, supported by the National Science Foundation. Speakers were selected based on their outstanding research accomplishments involving EarthScope, as well as their ability to engage diverse audiences. Each speaker presents their own EarthScope-related science and introduces broader EarthScope objectives and accomplishments. Complete information about the EarthScope Speaker Series, including speaker biographies and an online application form, can be found on the website. School selections are made by the EarthScope National Office.

Apply before July 1st for a 2016–2017 EarthScope speaker.

<http://www.earthscope.org/resources/speaker-series/2016-2017-speaker-series>

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A Magnetic Meeting of Space and Earth

How EarthScope magnetotelluric data protects your power

by Josh Hartman

Magnetic storms, triggered by the interaction of the solar wind with Earth’s magnetosphere, not only produce our aurora light shows, but can also induce electric fields in our planet’s subsurface. Although usually small, magnetic storms can sometimes be large enough to create aurora as far south as Cuba or Honolulu. Such large storms can cripple a power grid by inducing unregulated electric currents into the power system.

Recently, two scientists from very different fields joined forces to begin tackling the problem of geomagnetically induced currents by mapping their distribution through Earth after simple magnetic storms. Paul Bedrosian, a solid-earth geophysicist, and Jeffery Love, a space-weather physicist, are using magnetotelluric (MT) data from the EarthScope USArray program to study how Earth’s variable conductivity structure impacts the electric fields generated during magnetic storms. In the process, they have highlighted the simplicities and

inaccuracies of the more commonly assumed layer-cake conductivity structure.

“Geomagnetic storms are infrequent,” Bedrosian says, “but an extreme storm is a high-risk event and a blackout on a regional scale would be quite deleterious. This research is trying to use information about the solid earth to effectively map out areas that are more or less vulnerable to such a magnetic storm.”

“We both understood that the electric power grid industry was interested in predicting these geoelectric fields and we both understood that the EarthScope magnetotelluric data recorded the relationship between magnetic activity and geoelectric activity,” Love says. “The hazard at Earth’s surface that is caused by space weather is utterly and absolutely dependent upon the nature of the solid earth beneath our feet,” he adds.



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Powerful magnetic storms produce aurora as far south as the tropics, and can also cripple a power grid. EarthScope magnetotelluric data is being used to calculate variations in Earth’s magnetic field. Photo ©Briansedgbeer, Dreamstime.com

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Call for Science Nuggets!

To PIs who received an EarthScope grant:

The EarthScope National Office is compiling information that highlights the scientific achievements of the EarthScope program. Science Nuggets are catchy, short, non-technical, and visually pleasing one-page (or less) highlights about a specific interesting, high-impact research result.

Speaker Series Participants

The 2016–2017 EarthScope speaker series includes (left to right): Amanda Thomas (University of Oregon), Steve Semken (Arizona State University), Diane Moore (Earthquake Science Center, U.S. Geological Survey), William Hammond (Nevada Bureau of Mines and Geology & Nevada Seismological Laboratory, University of Nevada Reno), and Maureen Long (Yale University).

Our goal is to keep track of the multiple achievements of this large NSF-funded program and share them across the scientific community and the public through our website, social media, and other outreach venues.

Please use this online form to provide us with:

- A catchy title
- The award number and years funded
- The name(s) and affiliation(s) of your collaborator(s)
- 250-word summary/explanation

- At least one high-quality visual (graph, image, figure). Format: jpg, pdf. Resolution: 300 dpi
- A caption for the figure
- A bibliography if applicable

The ESNO will format documents for consistency before sharing them online. You may provide us with more than one nugget per project.

Deadline: July 15th, 2016

<http://www.earthscope.org/information/funding/call-for-science-nuggets> ■



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A Magnetic Meeting of Space and Earth How EarthScope magnetotelluric data protects your power

To study induced electric fields, Bedrosian used a part of the publicly available magnetotelluric dataset collected by USArray, currently consisting of more than 700 stations covering nearly half of the contiguous U.S. at a spacing of ~70 km. “Taking a data set with a very academic purpose and coming up with results applicable to a totally different field is of great importance from a hazard perspective,” Bedrosian says. “It’s a bit of add-on science which we’ve managed to do with the excellent public data resource provided by EarthScope.”

Changes in the electric field are, to a first order, governed by changes in the electrical conductivity of Earth’s subsurface, which, in turn, is governed by variations in rock type. “The more conductive an area, the smaller are the electric fields,” explains Bedrosian.

Treating MT data as the filter through which a simplified magnetic storm can be passed, Bedrosian was able to calculate the magnitude and direction of the electric field. Bedrosian’s and Love’s findings are presented in a recently published paper in the journal *Geophysical Research Letters*. “This paper is a first step at improving our ability to map out electric field disturbances associated with electric storms,” Bedrosian says. “That information is needed to better assess and mitigate the risk to electric power utilities during magnetic storms.”

Currently, the U.S. Federal Energy Regulatory Commission mandates that electric power utilities assess vulnerabilities and create plans to reduce potential damage from geoelectric currents. These strategies are expensive and time-intensive because they cast a large net and don’t necessarily target the places that would be hit by a real event.

The team plans to examine data from more complex—in other words, more realistic—magnetic storms, as well as expanding their analysis to USArray data from the northwestern U.S. They hope to eventually have data for the entire country, and, adds Bedrosian, “Further into the future we’d like to have sort of a nowcast,” a system for fast data input to calculate the electric field in an area within a few hours of a magnetic storm. ■

Bedrosian, P. A., and Love, J. J. (2015). Mapping geoelectric fields during magnetic storms: synthetic analysis of empirical United States impedances. Geophysical Research Letters, 42. 10160- 10170. doi:10.1002/2015GL066636

Getting Hands On with EarthScope

"Wow, it's moving!" was called out frequently in the busy hall that housed the largest (and free!) national science festival. More than 365,000 people of all ages and backgrounds attended the three-day festival, geared at inspiring the modern STEM generation. The EarthScope–UNAVCO exhibit demonstrated how Earth's moving surface—through glacial isostasy, volcano inflation, or earthquakes—undetectable to the naked eye, is captured

by GPS monuments. In the booth next door, IRIS showcased how seismometers record seismic waves, from hand crank- or jump- triggered earthquakes. IRIS also provided an interactive earthquake browser, and printed out BirthQuake certificates to emphasize continuous earthquake monitoring. People of all ages were astounded by how frequent earthquakes are.

In Alaska, EarthScope takes advantage of team sports to reach students from rural communities. Ten days after a magnitude 7.1 earthquake struck near Anchorage, the Nicolaevsk Warriors, from a community just 60 miles east of the epicenter, visited ESNO headquarters at University of Alaska Fairbanks. They saw first-hand how stations near their school monitored the ground movements in the Kenai Peninsula during the earthquake, and how seismic waves spread out over hundreds of miles.

Regular earthquakes, volcanic eruptions, and Arctic responses to climate change make Alaska a rich environment to develop and communicate the EarthScope educational motto: Science in action! Through hands-on educational programs and events, as well as this newsletter, the website, and social media, the EarthScope National Office participates in science and outreach across the country. We welcome input on how we can improve on these efforts.

BirthQuake link: <http://www.earthscope.org/birthquake> ■



Nikolaevsk students learn about real-time earthquake data while visiting the Alaska Earthquake Center. Photo courtesy of EarthScope National Office.



Two budding scientists discover how EarthScope instruments measure ground motion, in a hands-on display at the USA Science & Engineering Festival in Washington, D.C. in April. The setup demonstrates how different kinds of instruments measure volcano inflation and deflation. (Photo by Maité Agopian)



Triangulation Point, Oregon PBO Station P405 battles the elements at an energetic plate boundary

Located near the crest of the Oregon Coast Ranges, GPS station P405 sits on the edge of the Cascadia margin where the North American plate meets the subducting Juan de Fuca plate. P405 is subject to severe weather—its solar panels were destroyed twice by winds in excess of 120mph. Why fight the elements? This station is recording close to the maximum deformation caused by the converging plates, as well as the "silent earthquakes" produced by slow-slip events approximately every 14 months. It is part of the Cascadia real-time network, transmitting data continuously at one sample per second, which is crucial for many applications including local surveys and a prototype earthquake early warning system. In the event of a large Cascadia earthquake, it can keep data flowing via a recent backup satellite communications system upgrade. Learn more about P405 on UNAVCO's [P405 station page](#) or University of Colorado's educational [GPS Spotlight Website](#). ■

To Boldly Go... EarthScope Firsts in Alaska

by Dr. Adam Schultz, Oregon State University

While staying true to its intent as a telescope to peer into Earth's interior, EarthScope has also been looking up to the heavens. In 2015, SRI International and Oregon State University, with the assistance of Zonge International and Green Geophysics, deployed a Data-Fusion Imaging Observatory for Space and Solid Earth. This project sits in a region where it intersects with cratonic North America, and is positioned to answer fundamental questions about the structure and conditions within the broad Alaska continental margin. It also examines how electric currents in the ionosphere couple to the solid earth below.

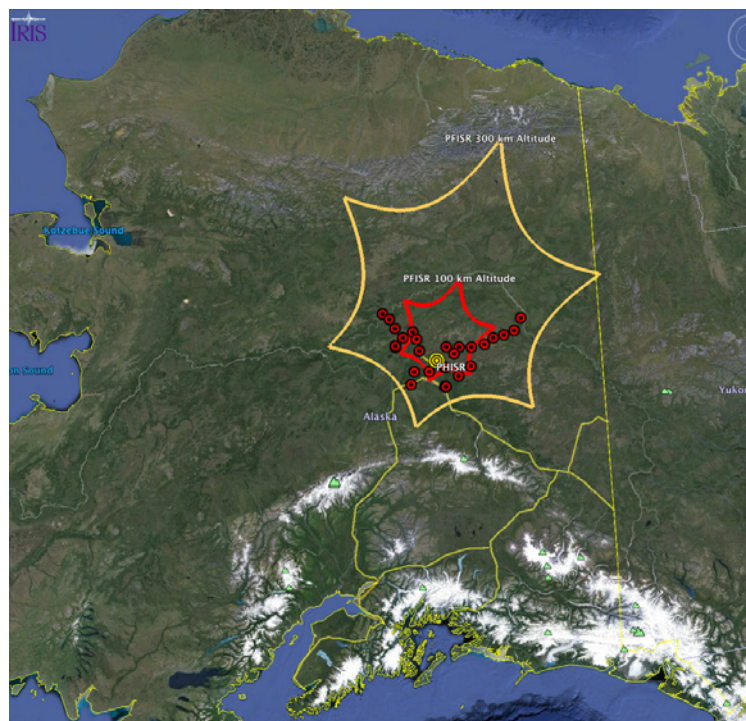
The solar wind, magnetosphere, ionosphere, and atmosphere are coupled to Earth's crust and mantle by electromagnetic induction, with geomagnetically induced currents arising from geomagnetic disturbances and penetrating deep into the planet. The currents are a major threat to communications and navigation systems, and can prematurely age the electric power grid and pipeline systems. This happens during extreme space weather events—Toronto's stock market came to a halt during the geomagnetic storm that triggered the 1989 Quebec Hydro blackout.

The intensity of geomagnetically induced currents in the power grid is highly dependent on the 3D electrical conductivity structure of the crust and mantle. However, research in the Atmospheric and Geospace Sciences and the Earth Sciences communities is decoupled across the air–earth boundary by a set of assumptions and simplifications that limit the interpretation of data and may mask unexpected effects.

Near Fairbanks, Alaska, under the auroral oval, is a particular kind of multibeam radar—the Poker Flat Incoherent Scatter Radar, or PFISR—with a multispectral all-sky imager and an imaging Fabry Perot interferometer. By combining these facilities with the pool of magnetotelluric (MT) instruments operated by the National Geoelectromagnetic Facility at Oregon State University, a synchronous array of 25 MT systems was installed and operated in late 2015, under the Poker Flat instrument's field of view. The datasets are being fused to produce time-evolving 3D images of auroral arcs, including the current systems that connect them to the magnetosphere through field-aligned currents and that are the signal source for MT imaging of Earth's interior. The first view of the electrical conductivity structure of the Alaskan interior's lithosphere and upper mantle is being produced, along with a transect of the Alaska margin, through the Cordillera, and into cratonic North America.

This regional imaging observatory covers a range of scales for 2D and 3D ground-conductivity imaging under the Poker Flat instrument's field of view, with two nearly linear arrays—one extending 200 km to the northeast, and a second orthogonal to the first, to sample across several terrane boundaries within the broad Alaskan interior continental margin.

The 25 long-period MT instruments were spaced roughly 20 km apart and operated synchronously with PFISR. The survey design was developed to



Site map of the magnetotelluric (MT) array installed in the Alaska interior in 2015. The Poker Flat Incoherent Scatter Radar (PFISR) facility at Poker Flat, AK, just north of Fairbanks, is located at the intersection of the two MT profiles. The red- and mustard- colored star shapes represent the footprint of the PFISR radar at 100 km and 300 km altitude, showing the area of ionospheric electric fields imaged by this system.

simplify logistics—all of the stations are located near the few maintained roads in interior Alaska.

One of the MT profiles encompasses two spurs of the Tintina fault zone, an active plate-boundary zone between the Yukon–Tanana Terrane to the south and cratonic North America to the east. The other crosses several poorly delineated southwest-northeast-trending fault systems, potentially including the Susulatna and Kaltag faults and several terrane transitions. The full profile footprints provide a sufficient aperture to generate full mid-crustal to upper-mantle electrical conductivity sections to depths of ~300 km in this transitional region, which is currently completely absent.

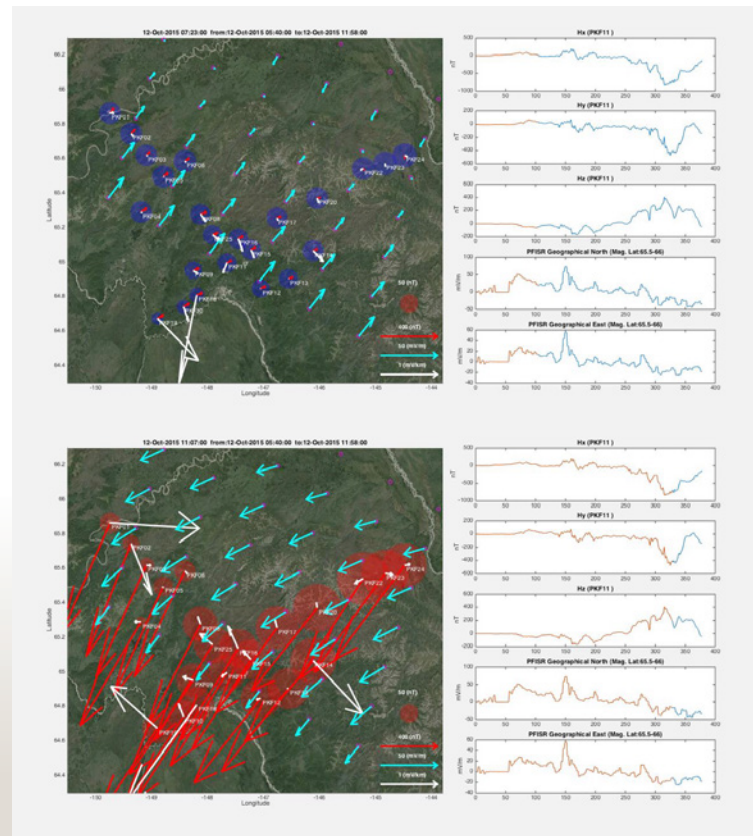
Preliminary results (see accompanying images) illustrate the relationship between the magnetic and electric fields measured at Earth's surface at the MT stations, and the electric field projected to the base of the ionosphere due to the 3D ionospheric Hall currents as inferred from PFISR measurements. The strongly non-uniform response of the electric fields at ground level, relative to the more uniform ionospheric inducing fields, is particularly notable. For an Earth with uniform or 1D conductivity structure, the electric fields at ground level would be orthogonal to the magnetic fields, and ground-level and ionospheric electric fields would be aligned. Clearly this is not the case, which is particularly evident during the more disturbed interval show, and indicates underlying 3D Earth structure. Furthermore, the assumption that is typically made for MT analyses, that the inducing field is plane-wave in form, also does not hold in this region.

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To Boldly Go... EarthScope Firsts in Alaska

Much is left to learn from this remarkable data set. In order to fully tackle the complexities and richness of both ionospheric and solid-Earth content in these signals, a new method of MT data analysis is under development to handle the complicated nature of the ionospheric source fields. The MT waveforms and the ionospheric field data set are jointly inverted in the time domain for 3D Earth conductivity structure and for ionospheric current distributions. While computationally demanding, we are learning that this problem is tractable using GPU accelerated parallel computing methods. We look forward to reporting later this year on new insights into the structure of the Alaskan lithosphere, asthenosphere, and ionosphere from application of these new methods to this unique EarthScope/Aeronomy and Magnetospheric Physics data set. ■

Field vectors measured at Earth's surface, and those inferred in the ionosphere, for a geomagnetically quiet interval (top), and a geomagnetically disturbed interval (bottom). Colored vectors indicate the ionospheric electric field (cyan), the horizontal electric (white) and magnetic (red) field measured by the MT systems, and the vertical magnetic field downward (red) or upward (blue) circles whose radius is proportional to the intensity of the vertical component.



New Uses for the Plate Boundary Observatory Presented at the 2016 UNAVCO Science Workshop

by Beth Bartel and Linda Rowan, UNAVCO

The UNAVCO Science Workshop featured innovative, significant advances in research and broader impacts utilizing the dense network of more than 1200 instruments in the EarthScope Plate Boundary Observatory (PBO). Over 190 participants gathered to discuss the latest advancements in geodetic sciences in Broomfield, Colorado from March 29–31, 2016. PBO was prominently featured in talks, posters, and discussions.

Lucy Flesch, of Purdue University, combined GPS motions from PBO in Alaska with seismic and geologic data from many sources to show that mantle convection drives extension and mountain building in northern and central Alaska and northwestern Canada, and is the likely driver of Bering plate motion.

Adrian Borsa, of Scripps Oceanographic Institute, demonstrated that PBO can be uniquely utilized as a hydrological monitor to measure water loads for research on the water cycle and for water resource management. Data from PBO has led the way to considering water loads captured in other geodetic networks around the world. Kristine Larson, of the University of Colorado, showed that reflections of the satellite signal off of a surface and into a GPS antenna can measure snow depth, soil moisture, tides and sea level, vegetation, glacier height and likely other parameters. These data expand the use of PBO beyond its solid-earth science intentions into snow and soil science, ecology, oceanography, glaciology, and other fields

of research. In particular, the data complement and extend the spatial and temporal coverage of observations from non-geodetic instruments and from satellite remote sensing. More on this work can be found on the comprehensive [PBO H2O project website](#). Another new result presented by Kyle Anderson, of the U.S. Geological Survey, used geodetic data together with other observations to measure the supply rate and volatile content of magma feeding volcanic eruptions. Better knowledge of water content will help resolve volcanic processes and potentially help track threatening volcanic ash plumes. Finally, reaching to the upper limits of Earth's atmosphere, Attila Komjathy, of NASA's Jet Propulsion Laboratory, demonstrated how geodetic data tracks disturbances in the total electron content in the ionosphere from tsunamis, volcanic eruptions and even a 65-ton TNT explosion created for the James Bond thriller, Spectre. This means there are now at least two different ways to provide tsunami early warning with geodetic data—the first by direct measurements of surface displacements resulting in water displacements, and the second by tracking the movement of the tsunami wave across the ocean via the corresponding ionospheric wave. These are just some of the highlights of the science and societal benefits of EarthScope's PBO and the rest of UNAVCO's pole-to-pole services and infrastructure that were discussed at the workshop. UNAVCO thanks NSF for supporting the workshop. See the [workshop website](#) for more information and details. ■

First Synthesis Workshops Announced

EarthScope is pleased to announce the following four synthesis topics that were approved by the national office and the steering committee. To apply to participate in a workshop, please visit the following link: <http://www.earthscope.org/science/about-synthesis-workshops>. Stay tuned for future synthesis calls!

Southern Exposure: Developing a Better Understanding of the Structural and Tectonic Evolution of the Southern Margin of North America

Convenors: Jay Pulliam, Harold Gurrola, Randy Keller, Kevin Mickus

Dates: October 2016

Location: Baylor University, Waco, TX

Objectives: This workshop will provide a forum to review available data, synthesize existing work, identify needs for new data acquisition, and foster new collaborations to address how events separated in geologic time and space influence the development, stabilization, and reactivation (or erosion) of continental lithosphere. Specific focus will be on the nature of accreted terranes, the transition from continental to oceanic crust, and the geometry of rifting vs. transform accretion and continental breakup.

Mendocino Triple Junction Observatory—Connecting Cascadia to the San Andreas

Convenors: Kevin P. Furlong, Mark A. Hemphill-Haley

Dates: mid–late October, 2016

Location: Arcata, CA

Objectives: This workshop will bring together active scientists with a focus on understanding the unique setting of the Mendocino Triple Junction and associated deformational and seismic processes along the San Andreas and Cascadia plate boundaries. It will inventory existing data collected under the EarthScope program, explore implications of those data and models, and delineate potential future experiments and projects that could build on this foundation. The workshop will include a field excursion to key sites in the MTJ region. This workshop will also exploit the MTJ and environs to provide modern, well-constrained educational materials.

Developing a New Community Model for the 4D Evolution of the North America Continent

Convenors: Steven Whitmeyer, John Hole, Terry Pavlis, Laura Webb, Mike Williams, Lara Wagner

Dates: Late Oct.–early Nov., 2016 (alternative: May 2017 after ES National Meeting)

Location: James Madison University, Harrisburg, VA (OR: Anchorage, AK after the 2017 National Meeting)

Objectives: This 3-day workshop will synthesize EarthScope results relevant to the tectonic evolution of North America, with a key objective to set the stage for a much larger collaboration to develop a community model for the 4D lithospheric evolution of North America. The principal goals are to 1) Synthesize EarthScope results from the primarily 3D geophysical experiments that captured a snapshot of present-day North America, especially those that have relevance to the temporal evolution of the continent; 2) Integrate EarthScope results with existing continent-scale geologic and tectonic knowledge; and 3) Produce a summary document that highlights EarthScope research that has advanced our knowledge of the 4D tectonic evolution of North America.

Evolution of the Southern Appalachian Lithosphere

Convenors: Karen Fischer, Donna Shillington, Lara Wagner

Dates: March 28–30, 2017

Location: Brown University, Providence, RI

Objectives: The goal of this workshop is to better understand lithospheric evolution in the southern Appalachians and adjacent passive margin through synthesis of geophysical and geological observations and modeling. We will focus on Phanerozoic processes spanning orogeny, rifting, and post-rifting evolution with an emphasis on how each stage of lithospheric evolution created structures and conditions that affected processes in the next. ■

inSights
the EarthScope newsletter

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