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EarthScope News

A Message from the EarthScope National Office Director

These are busy and important times for EarthScope and its scientific and education and outreach communities. In this issue of inSights, we are highlighting the ongoing research in Cascadia.

Cascadia (along with Alaska-Aleutians) is the US major subduction plate boundary. It last failed in an M9 earthquake in 1700 A.D. and represents a significant ground shaking concern for the Pacific northwest and a trans-pacific tsunami hazard. Studying an active system that crosses the shoreline and understanding the tectonic framework of Cascadia requires an amphibious approach. The lead science article by Doug Toomey and the Cascadia Initiative Expedition Team (*at right, and back page*) reviews the great challenges and successes of the Cascadia initiative—a grand community experiment.

The main subduction zone is not the only study area utilizing continuous real time GPS (*see article by Tim Melbourne page two*); Cascadia's volcanoes are also targets (*see Mount St. Helens, page two*). Translating these observations to engage community educators in coastal Cascadia is the subject of the article by Beth Pratt-Situala and colleagues (*page three*). Finally, magnetotelluric data are sensitive to hydrous and magmatic fluids and are a valuable complement to characterizing and clarifying the underlying structures of of the region (*Adam Schultz provides an overview on page three*).

Finally, planning for the EarthScope National Meeting (June 15-17, 2015 in Stowe Vermont) is underway. Send us your good ideas and save the date for this biannual opportunity to celebrate the great science and education and outreach achievements of EarthScope.

Ramón Arrowsmith

Professor J Ramón Arrowsmith
EarthScope National Office Director

The Cascadia Initiative: A Sea Change in Seismology

The Cascadia Initiative Expedition Team (CIET)

Increasing public awareness that the Cascadia subduction zone is capable of generating signifigant earthquakes (M9 and greater) motivated the development of the Cascadia Initiative (CI). Located across the Pacific Northwest this ambitious onshore/offshore seismic and geodetic experiment utilizes an Amphibious Array to research topics ranging from megathrust earthquakes, to volcanic arc structure, to the formation, deformation, and hydration of the Juan De Fuca and Gorda plates.

Two novel aspects of the CI are changing both practices and capabilities within the ocean sciences community. First, the CI is a community-based experiment, meaning that the scientific community vets its objectives, experimental design and logistical implementation, and ensures all resulting data are publically available. Secondly, the CI is deploying a new generation of ocean bottom seismometers (OBSs) that are designed to withstand a direct hit by bottom trawling fishing vessels. The OBSs are equipped with sensors that are shielded from ocean bottom currents, opening up the shallow marine environment (<1000 m) for more routine geophysical investigations.

Addressing the diversity of the CI science objectives requires an ambitious, plate-scale seismic experiment, one that encompasses the onshore and offshore components of the Cascadia subduction zone as well as the underthrusting Juan de Fuca plate. The NSF supported a community workshop that convened in Portland, Oregon in October 2010. Two conclusions were made: the OBS should include a plate-scale deployment that replicates EarthScope's USArray (spacing at 70 km for a duration of 18 months), and secondly, also have a tigher array along the subduction zone, including several focused experiments at key sites. To achieve this coverage, the CI leverages seismic instrumentation from a number of international facilities, regional monitoring networks, and experiments proposed by Principal Investigators.

The benefits of a community experiment are several: The primary benefit is that the community can engage in experiments that would be unaffordable otherwise given the expense of working in the oceans. Large-scale experiments can only move forward by establishing community buy-in.

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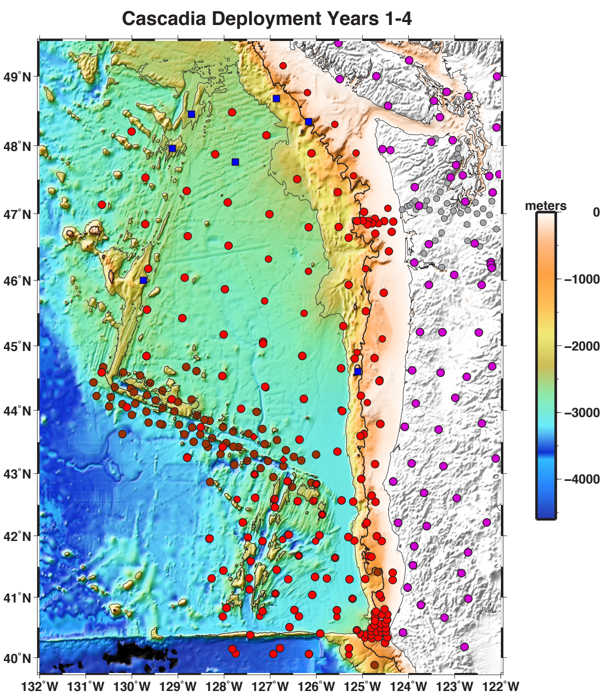
Above Right: Trawl resistant OBS deployment from the R/V Oceanus. These instruments are deployed in shallow water (<1000 m) and designed to withstand a direct hit by a bottom trawling fishing vessel. Photo: Lamont Doherty Earth Observatory.



Left: Locations of ocean bottom and onshore seismometers deployed during the Cascadia Initiative (CI). The amphibious array covers the entirety of the Juan de Fuca plate and the Cascadia Subduction Zone. Red circles indicate CI OBSs; brown circles indicate OBSs of PI-driven experiments complementing the CI design; blue squares are permanent seismometers attached to cabled observatories of Neptune Canada and the Ocean Observatories Initiative. Purple circles are onshore seismometers.

The Plate Boundary Observatory in Cascadia: Focus on Mount St. Helens

Donna Charleviox, UNAVCO

Thirty nine borehole strainmeters, eight tiltmeters, and 244 continuous GPS stations operate throughout the Pacific Northwest as part of the Plate Boundary Observatory (PBO). These instruments inform us about Cascadia by recording episodic tremor and slip events, monitoring volcanic deformation, and measuring the slow landward crunch of the coastline as strain builds toward the next major subduction earthquake. Two hundred thirty two of these GPS sites provide real-time data for use in a prototype earthquake early warning system and also for surveyors requiring real-time corrections to Global Navigation Satellite System (GNSS) observations. Maintenance of these sites can be challenging, especially on active volcanoes like Mount St. Helens where weather conditions are extreme, slopes are steep, and access to sites is limited to helicopter travel.

UNAVCO staff work with JL Aviation to maintain PBO sites on Mount St. Helens in September 2014. (Photo/Mike Gottlieb, UNAVCO)

Mount St. Helens was selected as one of PBO's magmatic systems targets. Sensor installations began in late 2004, just one month after the beginning of unrest that led to a multi-year eruption. Continuing data retrieval is challenged by harsh weather conditions, including up to 30 feet of snow on the upper reaches of the volcano. In September of 2014, a team comprised of UNAVCO staff and others performed annual network maintenance to repair and/or upgrade 11 GPS sites. Three of the sites were upgraded from eight-battery enclosures to 20-battery huts to assure data collection through the snowy winter. An additional six sites were brought back online after resolving problems including receiver, radio, and cable failures. UNAVCO and the USGS' Cascade Volcano Observatory (CVO) decided to decommission site P699, West Radial; the first site to be intentionally decommissioned in the PBO network. The site was plagued by ongoing damage from snow and ice. UNAVCO and CVO made the decision to decommission the site but to keep the GPS antenna on the mount for potential future GPS measurement campaigns.

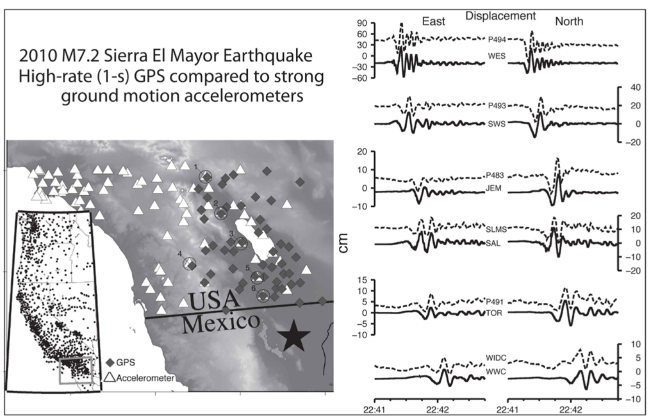
The Plate Boundary Observatory data have been critical to understanding the volcanic deformation of Mount St. Helens, the most active of the Cascade volcanoes. These data, along with data from the seven USGS GPS sites on the volcano, are available online through the UNAVCO data archive.

Real-time GPS in the Plate Boundary Observatory

Tim Melbourne, Central Washington University

Over the past century, seismic networks have provided the primary source of rapid earthquake characterization that inform first responders [e.g., Richter and Benioff, 1939]. As earthquakes grow large they exhibit fault rupture times exceeding several seconds in duration and fault ruptures of tens of kilometers, the complexity and extended coda of local body waveforms. When coupled with variable local network saturation these complications can make accurate magnitude estimation and scale of rupture difficult to ascertain without depending on teleseismic waveforms and their attendant travel-time delays of minutes. As a result, rapid and accurate magnitude estimation of the largest earthquakes based solely on conventional seismic measurements remains challenging.

Enter EarthScope's Cascadia Initiative and the brave, new world of real-time GPS. Because near-field (static) deformation grows linearly with respect to earthquake moment, as opposed to the moment rate that controls far-field, teleseismic amplitudes, Global Navigation Satellite System (GNSS) position measurements computed in real-time can, provided sufficient instrument density, be highly complementary to traditional seismometers in characterizing large earthquake sources rapidly. The EarthScope Plate Boundary Observatory now contains over 300 continuously-telemetered GPS receivers, (*see article above*) most of which were upgraded to this capacity largely due to supplemental funding from NSF. These new instruments are proving to be incredibly useful for rapid earthquake characterization, tsunami excitation, and volcanic unrest. In conjunction with other real-time networks, currently over 600 GPS receivers blanket the San Andreas and Cascadia fault systems that define the North American plate boundary and can provide on-the-fly characterization of transient ground displacements highly complementary to traditional seismic strong-motion monitoring. A myriad of different University and federal agencies are currently developing new algorithms to better employ the existing and incipient real-time streams for a wide variety of applications that depend on accurate, rapid earthquake characterization, including Earthquake Early Warning, tsunami excitation and volcanic inflation.



EarthScope Science and Disaster Preparedness

Engaging Educators Through Professional Development Workshops in Coastal Cascadia

Beth Pratt-Sitaula (CWU/UNAVCO), Robert Butler (UP), Nancee Hunter and Robert Lillie (OSU), Bonnie Magura and Roger Groom (Portland Public Schools), Bob de Groot (SCEC), Jenda Johnson (Volcano Video Productions), Chris Hedeen (Oregon City SD), Shelley Olds and Donna Charlevoix (UNAVCO), and Michael Coe (Cedar Lake Research Group)

Tens of thousands of coastal Cascadia residents live within severe earthquake-shaking and tsunami-inundation zones, and millions of tourists visit state and federal parks in these same areas each year. Public understanding of hazards and emergency procedures is required to achieve disaster resilience. The Cascadia EarthScope, Earthquake, and Tsunami Education Program (CEETEP, http://ceetep.oregonstate.edu/) is conducting professional development workshops for K-12 teachers, park and museum interpreters, and emergency management educators in Cascadia coastal communities to better enable them to address earthquake and tsunami science and preparedness with their learners. CEETEP workshops feature EarthScope science, earthquake/tsunami geology, and preparedness actions. Since 2013, CEETEP workshops have been held in Newport and Astoria, Oregon and Aberdeen and Forks, Washington, and have included representatives from the Makah, Quinault, and Shoalwater Bay Native American tribes. In 2015, the final two workshops will be held in Coos Bay, Oregon, and Arcata, California.

CEETEP builds on the success of the EarthScope Earth Science Interpretive Workshop Series for parks interpreters (http://www.earthscope.org/events/workshops) and the EarthScope-funded Teachers on the Leading Edge (https://wordpress.up.edu/totle/) program for K-12 Earth science teachers. However, in an innovative step, CEETEP brings these teachers and interpreters together with emergency management educators to form community-based action teams with all three types of educators. While retaining many earthquake science and preparedness activities from earlier educational programs, new wave-tank modeling, vertical evacuation, and emergency planning learning activities related to tsunamis have been developed. EarthScope seismology is featured in visualizations of seismic waves traversing USArray from distant earthquakes to illustrate differences in velocity and ground motions of P, S, & surface waves. EarthScope's Plate Boundary Observatory data are analyzed to show the accumulation of elastic energy within the Cascadia continental margin that will be released in the next great megathrust earthquake. In collaboration with UNAVCO, CEETEP developed animations on: What GPS Can Tell Us About Earthquakes in the Pacific Northwest and Japan and GPS and Earthquake Early Warning (www.youtube.com/user/unavcovideos, "animations"). In collaboration with the Southern California Earthquake Center (www.scec.org), 32 Quake Catcher Network seismometers have been installed at schools, parks, and museums where CEETEP participants educate coastal residents and visitors. Many CEETEP participants have initiated ShakeOut drills in Cascadia coastal communities.

CEETEP workshop participants experiment with a hands on tsunami model (left), and extracting tsunami sand cores in the field (right).

MT FlexArrays in Cascadia

Adam Schultz, Oregon State University

As the snows of winter 2014 melted in western Oregon and southwest Washington, the most ambitious amphibious magnetoelluric (MT) experiment ever undertaken came to a successful conclusion. A consortium of Oregon State University, UC San Diego/SIO, University of Oregon and the USGS, under NSF EarthScope and Marine Geology & Geophysics Program support, completed the second and final stage of installing, operating and decommissioning a large array of land-based MT stations, and also successfully installed and retrieved a similarly large array of seafloor MT stations.

The MOCHA ("Magnetotelluric Observations of Cascadia using a Huge Array") array, comprising more than 150 land and marine MT stations, acquired long-period MT measurements across the Cascadia continental margin, providing a high-quality data set that spans the western edge of the Cascadia volcanic arc, through the forearc and out to the continental shelf, slope and Cascadia Basin beyond. The data obtained from this effort provides an unprecedented opportunity to study the details of convergent margin segmentation, and to examine the impact on processes such as Episodic Tremor and Slip of fluids in the mantle wedge and overriding crust derived from slab dehydration.

MT data are particularly sensitive to hydrous and magmatic fluids, thus the MOCHA data set will also prove highly complementary to a second EarthScope co-supported MT array, the iMUSH ("imaging Magma Under Mount St. Helens") array, which is currently installing 150 wideband MT stations in the southern Washington volcanic arc. iMUSH, which is a collaborative multi-institutional effort combining active and passive seismics with MT, is designed to image the magmatic roots beneath Mount St. Helens and the surrounding area, including Mount Rainier and Mount Adams.

Both projects illustrate the power of embedding successively higher-resolution regional and local MT arrays inside the footprint of the 70-km spacing EarthScope MT Transportable array. Each of these data sets complements the others, providing the ability to obtain 3D images of crust and mantle structure and processes at unprecedented resolution.

MOCHA MT station MJO11, Yamhill County, Oregon. MOCHA field crew member completing configuration of NIMS Long-Period MT data acquisition system.

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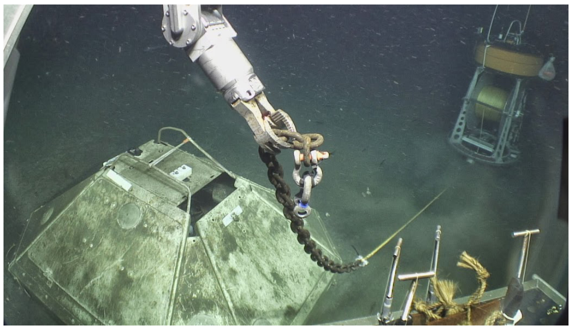
This includes defining the science objectives, the instrumental capabilities, the availability of data and metadata, and an overall plan for an integrated analysis and synthesis of results. Second, a policy of open-data access increases both the breadth of inquiry and types of methodologies applied to the resulting data, thereby increasing the data's value. To date, over 500 unique users at over 300 unique institutions in 25 different countries have downloaded over 20 terabytes of CI OBS data from the IRIS Data Management Center (DMC). The high number of users downloading CI OBS data ensures the broadest utilization of the data, enhances scientific returns, and generates high yields compared to program investment. Lastly, the CI is having a profound influence on the community that uses ocean-bottom seismometer data, particularly early career scientists. The Cascadia Initiative Expedition Team's Apply-to-Sail program has taken over 100 early career scientists to sea, including undergraduates, graduate students, and post-docs.

The sea-going component of the CI is in its final year of a four-year deployment/recovery cycle. Data from the first three years of the CI are openly available at the IRIS DMC. Currently, scientists from a wide range of disciplines — including solid earth geophysics, physical oceanography, ocean engineering, and marine biology — are analyzing CI data. These studies are providing new insights into seismicity of the Cascadia subduction zone, mantle flow and anomalous structures both onshore and offshore of Cascadia, the causes of microseismic noise, improvements in the design of ocean bottom seismometers, and the migratory habits of baleen whales.



Ocean Bottom Seismometer (OBS) being recovered using a remotely operated vehicle. Photo: Lamont Doherty Earth Observatory.

The new technology comprising the Amphibious Array Facility combined with the ambitious scale of the Cascadia Initiative constitutes a sea change in studies of subduction zones and continental margins in general. The success and enthusiasm for collaborative efforts between the terrestrial and marine seismology communities bodes well for future interdisciplinary experiments. To learn more please visit http://cascadia.uoregon.edu.