EarthScope

Exploring the structure and evolution of the North American Continent, and the physical properties that control earthquakes and volcanoes.

Kaye M. Shedlock
December 9, 2008

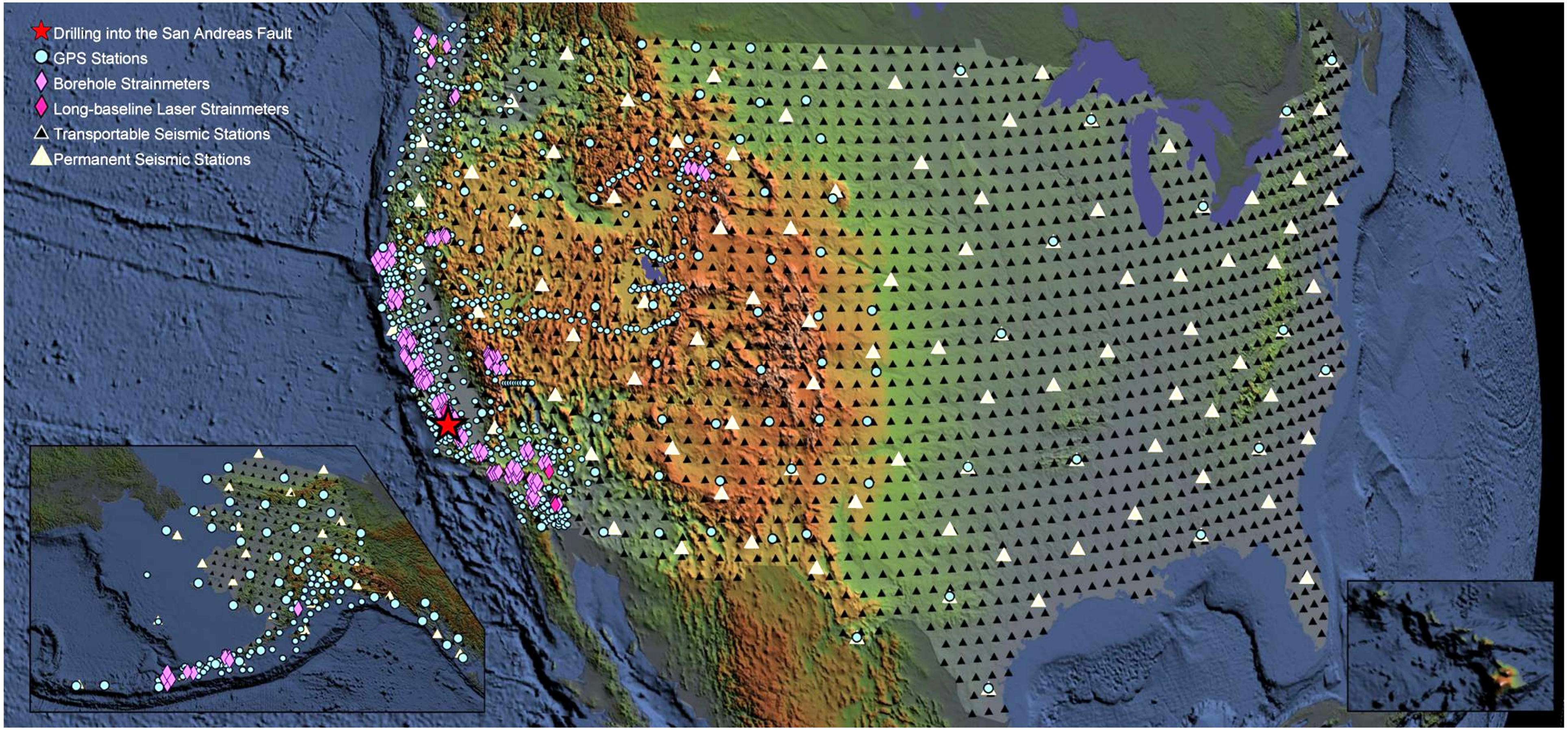
EarthScope

Integrated observational system of systems - $ 197.43 million

PBO is 1200 geodetic and 78 strain/seismic stations

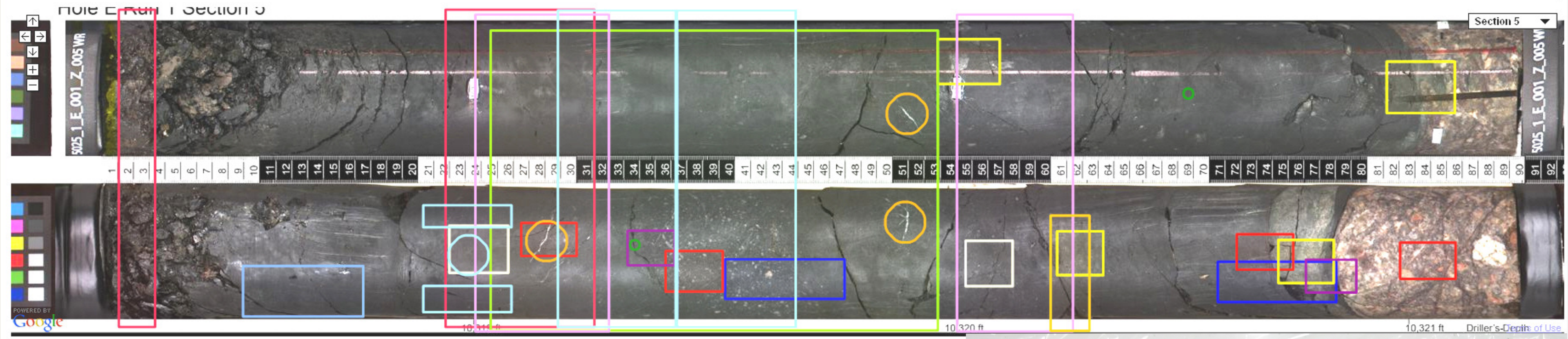
SAFOD is an instrumented 3.1 km borehole into the San Andreas Fault

USArray is 2605 seismic and 27 magnetotelluric stations

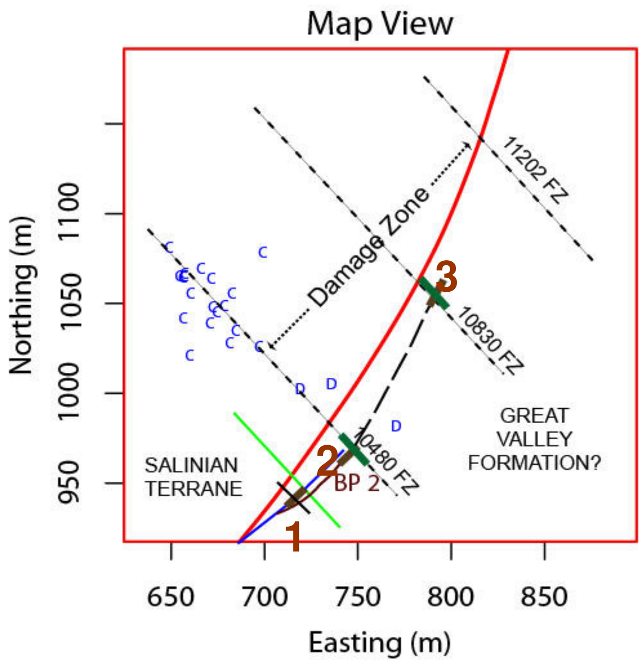


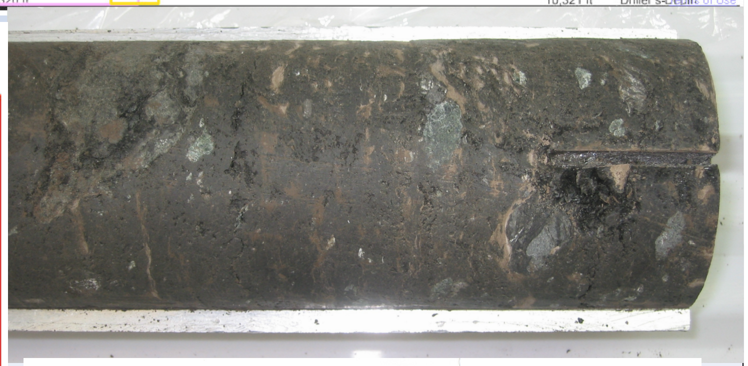
SAFOD Science Highlights

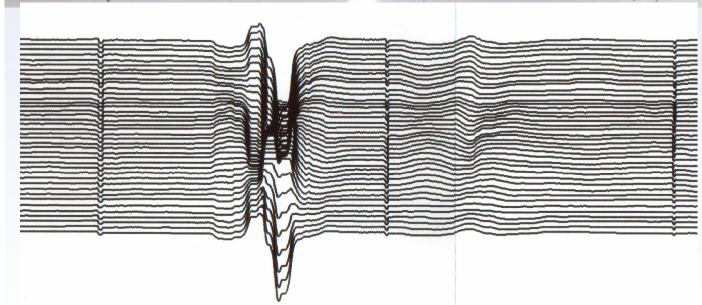
SAFOD Phase 3 Core [Hole E - Run 1 - Section 5]



- 40+m; ~ 1 ton
- Core/samples requests semi-annually
  - 28 Proposals
  - 98 Principal Investigators
  - 790 Requests



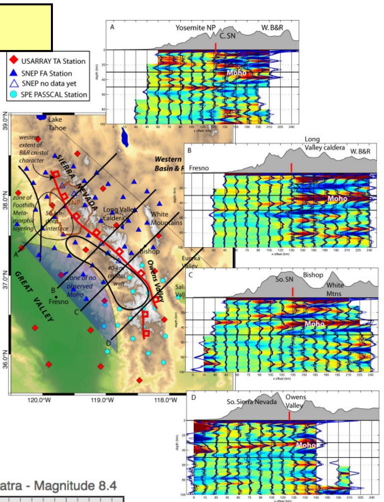




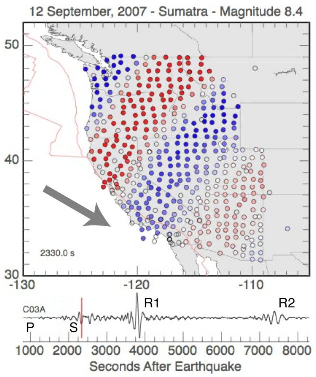
3300 Fault Zone

USArray Science Highlights

FA



SNEP Lithospheric Structure: Zandt, et al

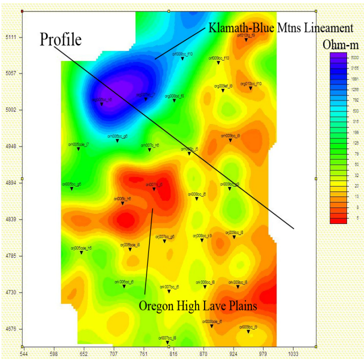


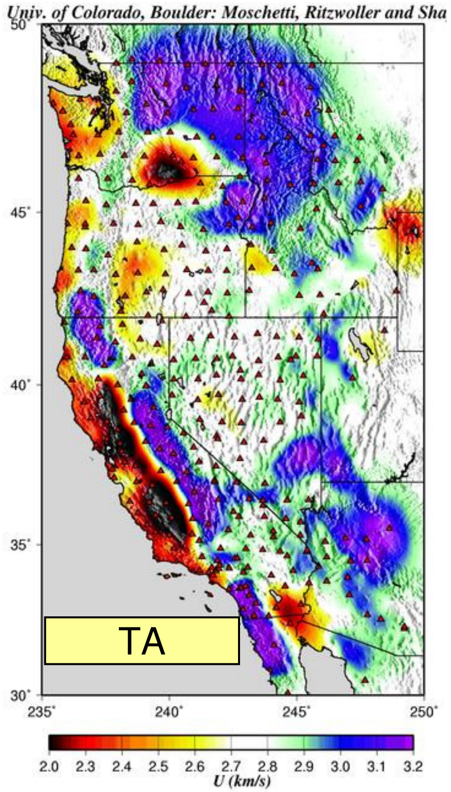
TA

Seismic wavefield: Ammon and Lay

Magnetotellurics

Resistivity - 2006 Oregon Transportable Experiment: Mickus, et al





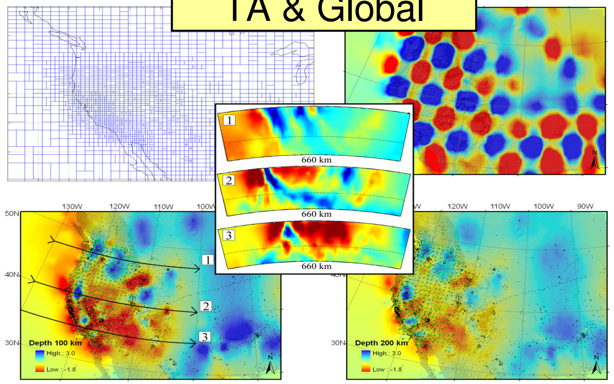
TA

Rayleigh wave group velocity @ 8 s: Moschetti, Ritzwoller, et al

USArray Seismic Data

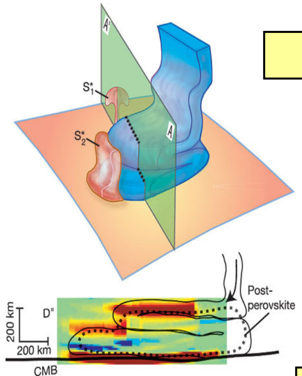
- Acquiring ~4.9 GB/day
- ~ 8.0 TB in archive
- Availability (uptime) Performance Metric = 85%
- Consistently > 90%

TA & Global



Body wave tomography: Burdick et al

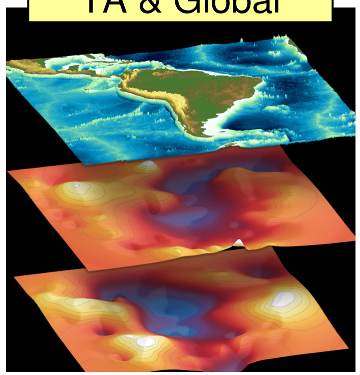
TA & Global



Folded Slab and Post-perovskite phase imaging:Hutko,at al

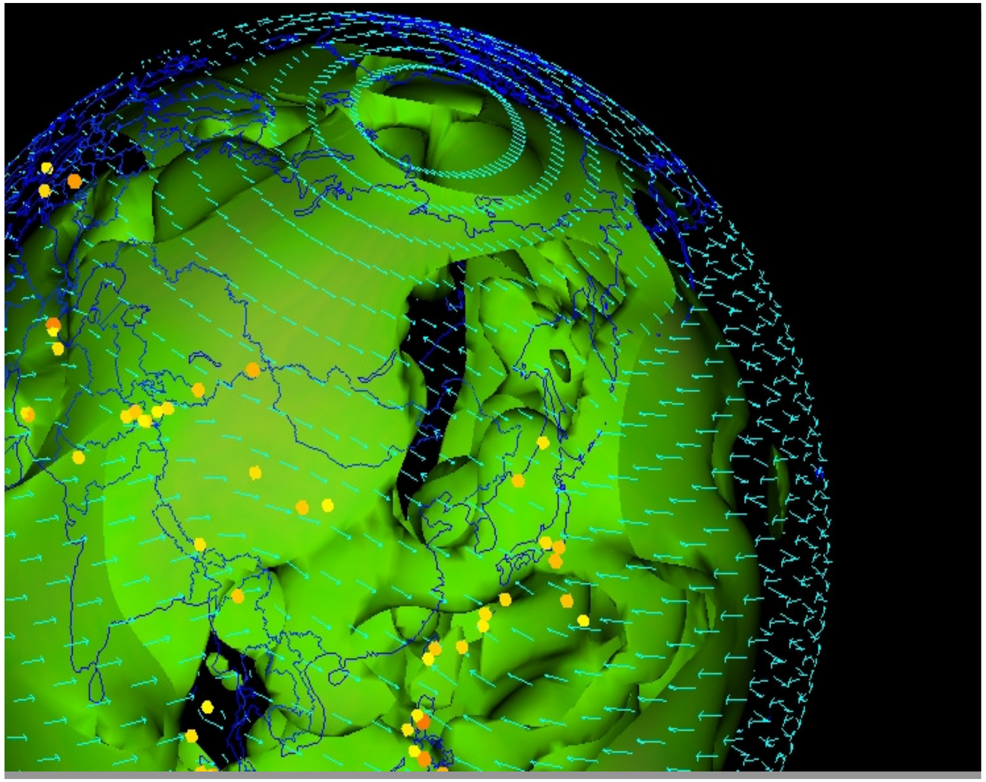
TA & Global

Topography of UM discontinuities: Schmerr and Garnero



PBO Science Questions

- What are the forces and processes driving deformation at plate boundaries and in plate interiors?
- What is the rheological structure of the lithosphere and where is its strength?
- What drives strain release on active faults (e.g. earthquake and/or aseismic slip events)?
- How is magma transported within the crust and to the surface?
- How can we reduce the hazards of earthquakes and volcanic eruptions?
- Is there long-term transient deformation within the plate boundary zone, and if so, what are the characteristic temporal scales and underlying causes?



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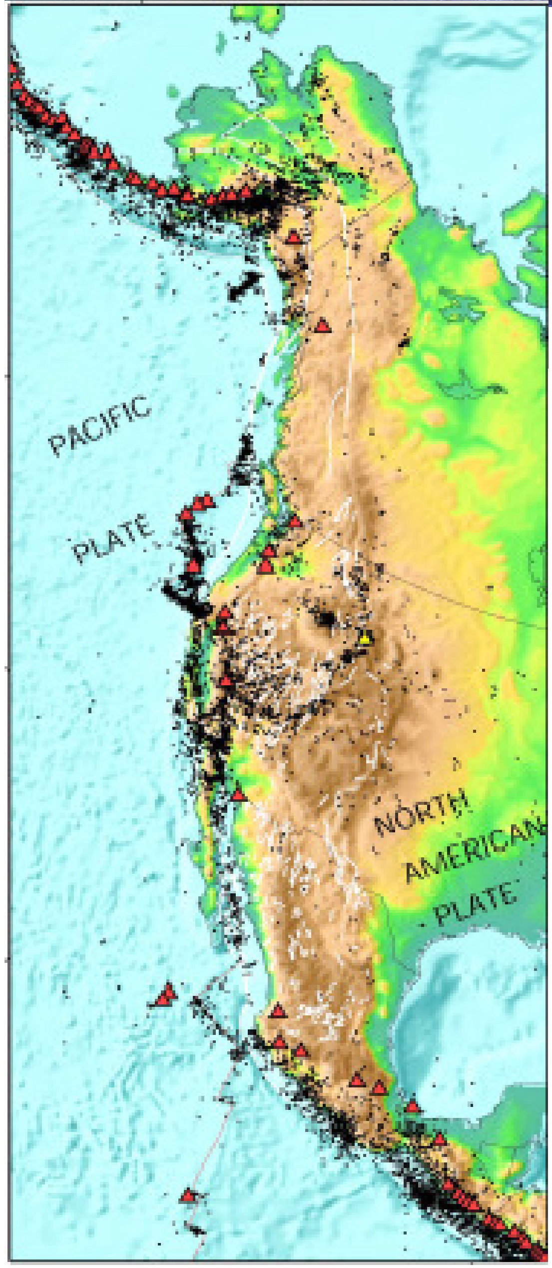
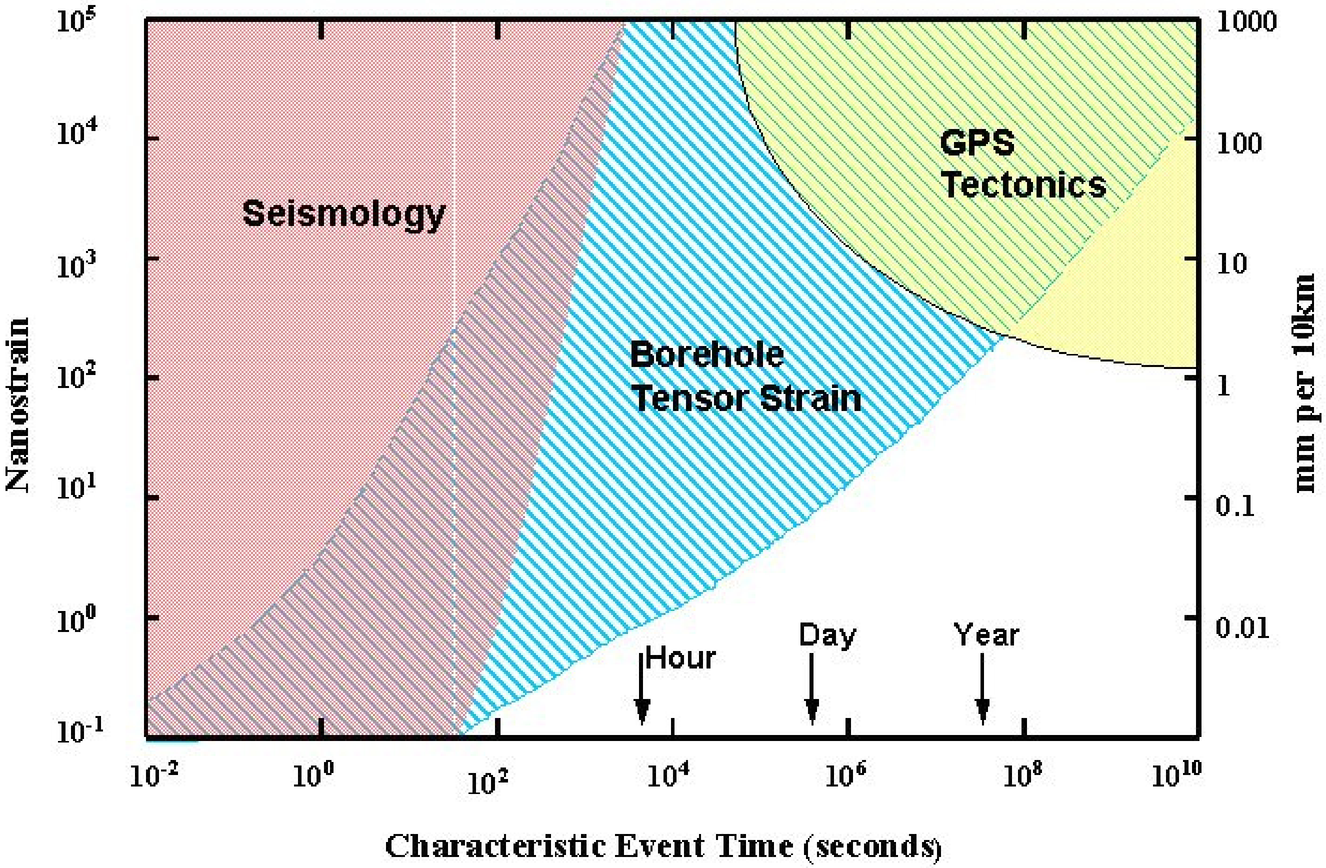
- How can we reduce the hazards of earthquakes and volcanic eruptions?

Why GPS and Strainmeters



- Instruments chosen for PBO Observatory cover broad frequency range
- Allow the study of the four-dimensional strain field



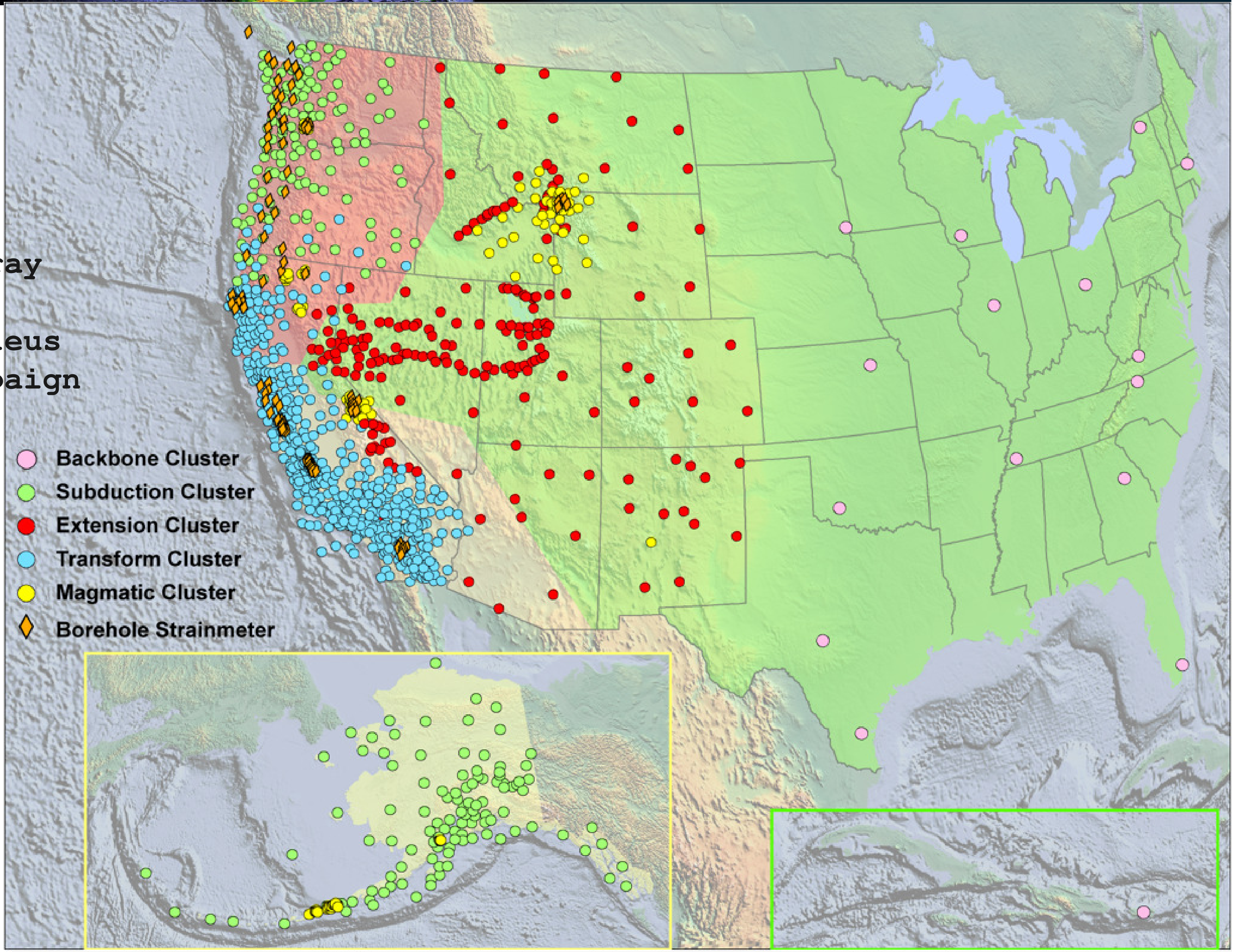
PBO Instrumentation

GPS:
- 1100 permanent
- 880 PBO
- 11 USArray joint
- 209 Nucleus
- 100 campaign

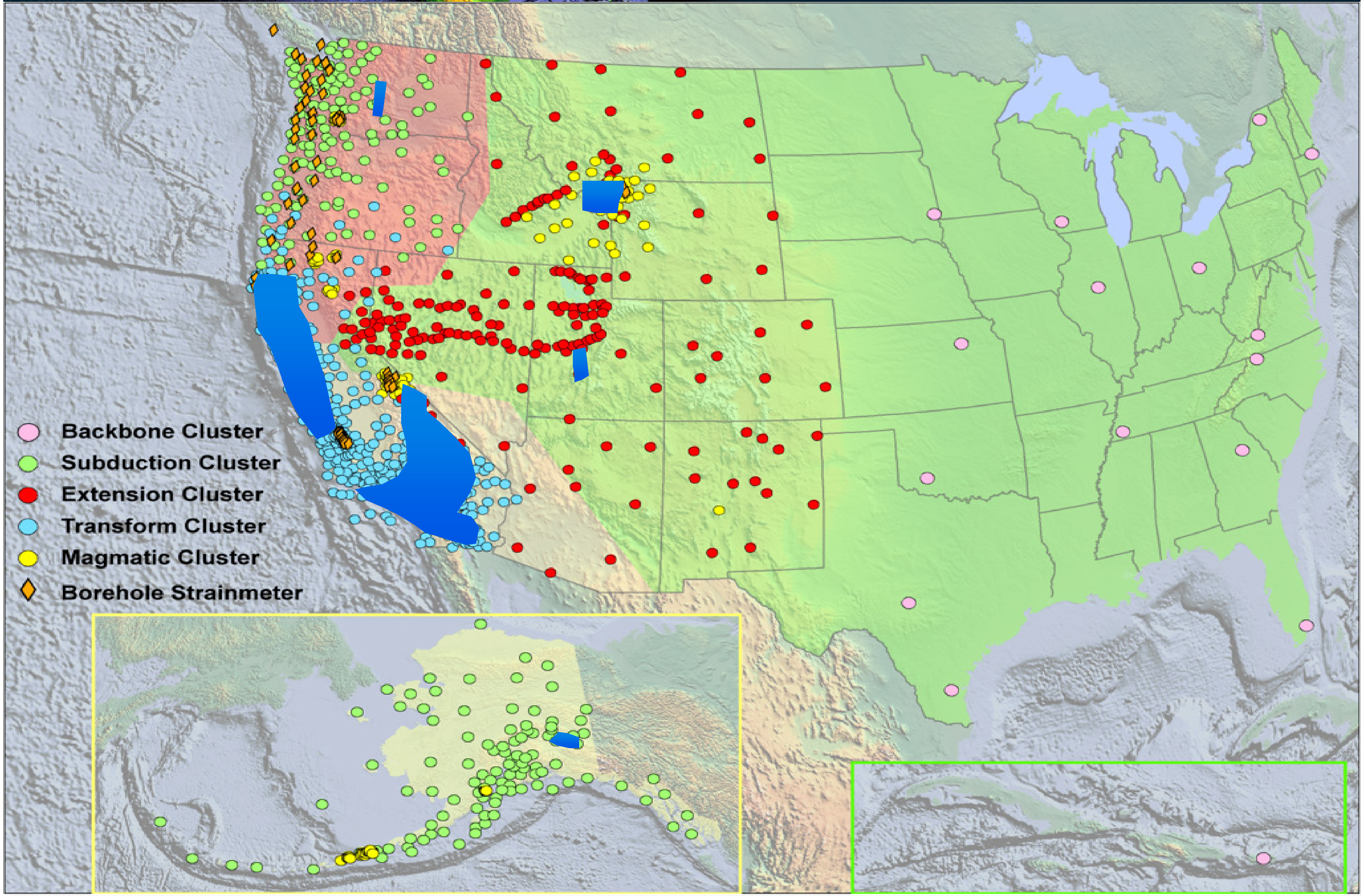
Strain:
- 73

Seismic:
- 78

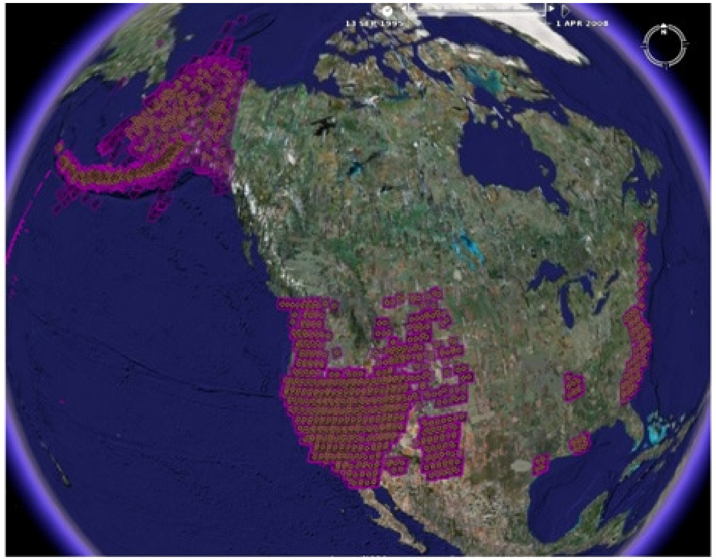
Tilt:
- 26



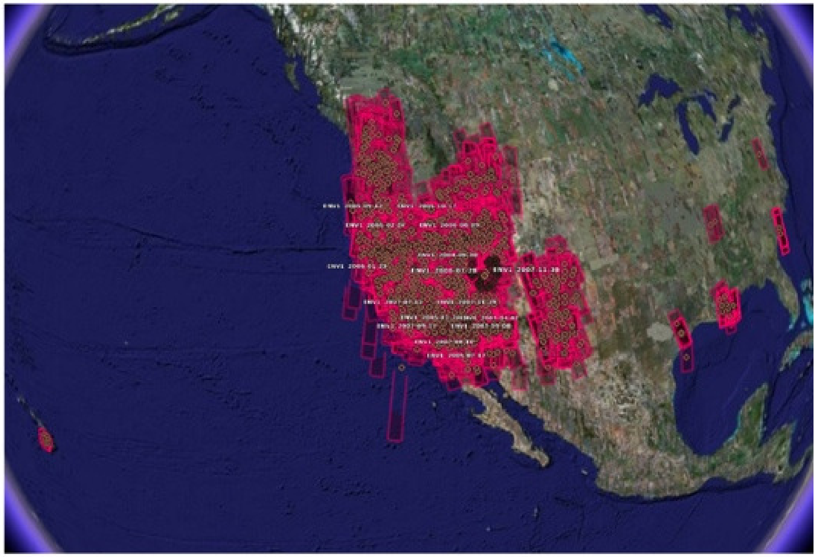
Airborne LiDAR



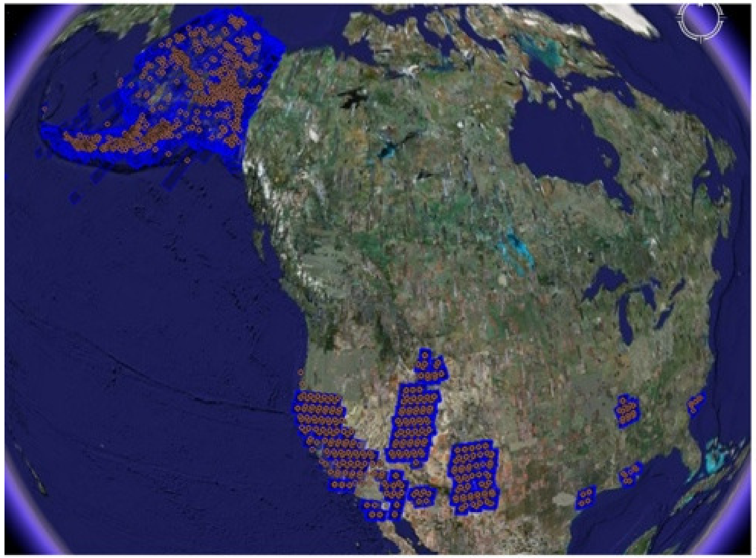
InSAR Imagery



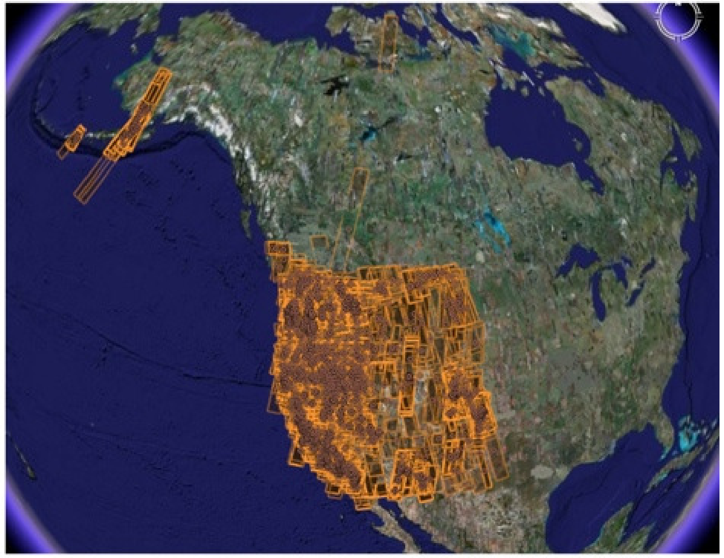
ERS-2



ENVISAT



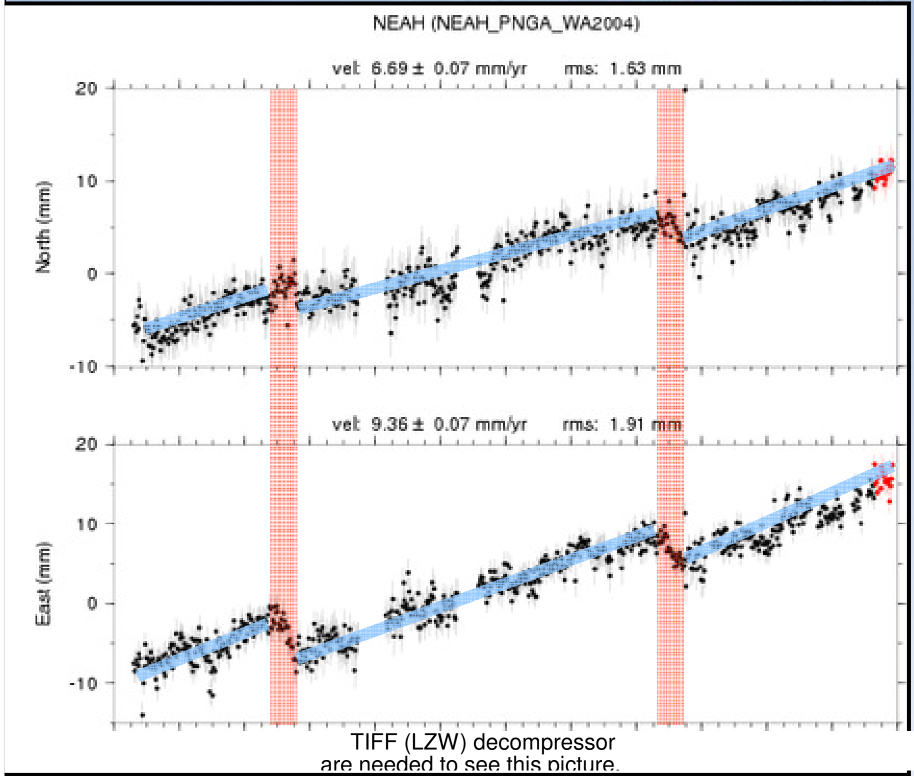
ERS-1

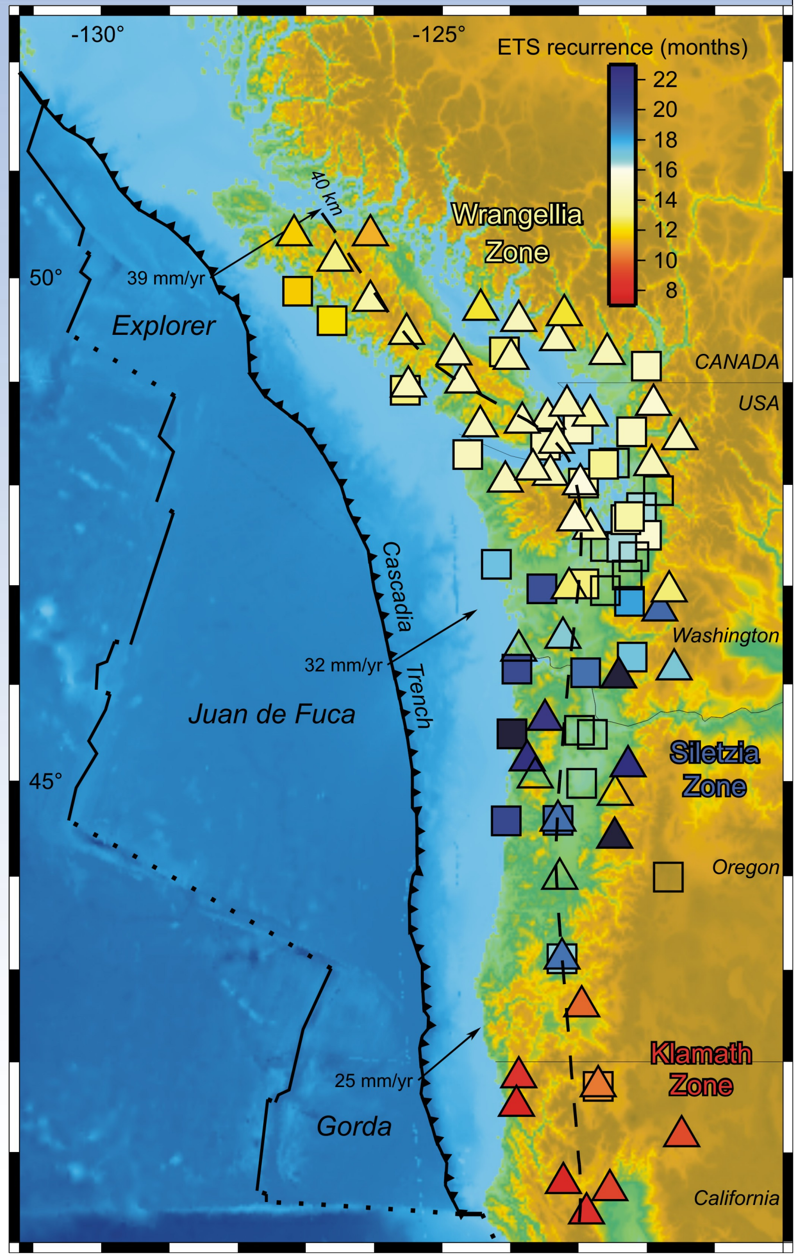


RADARSAT-1

PBO Science Highlights

ETS

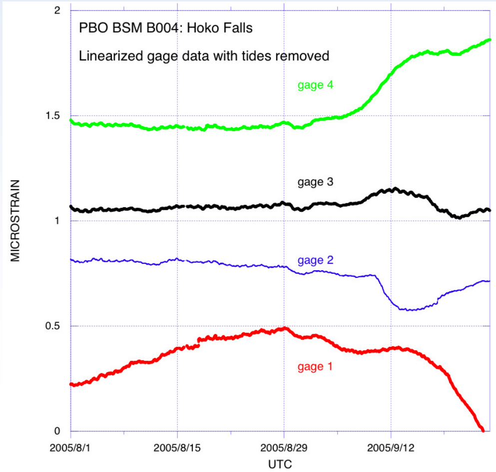




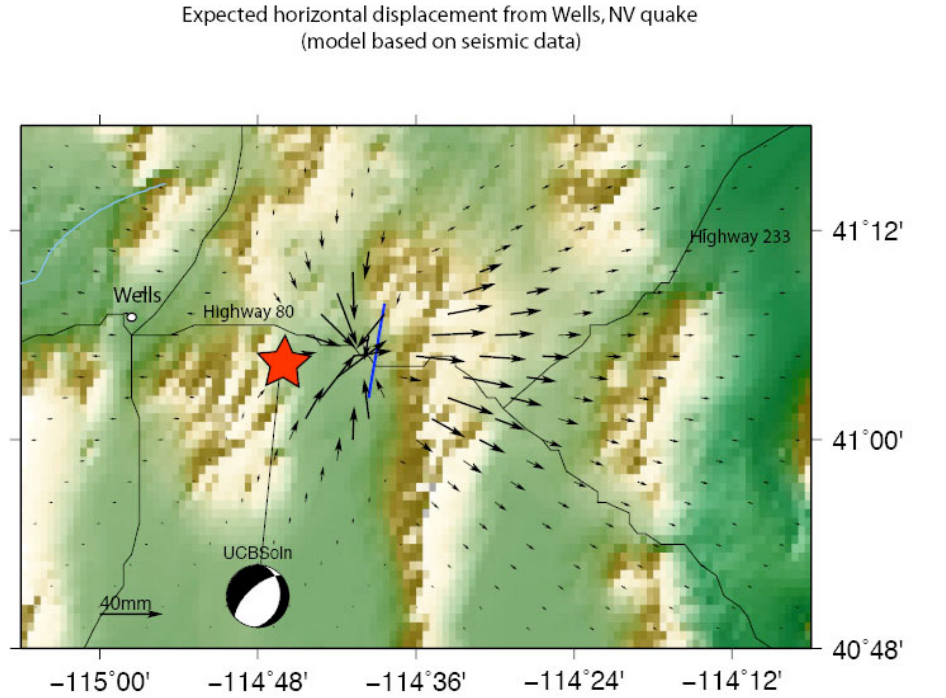
NEAH

B004

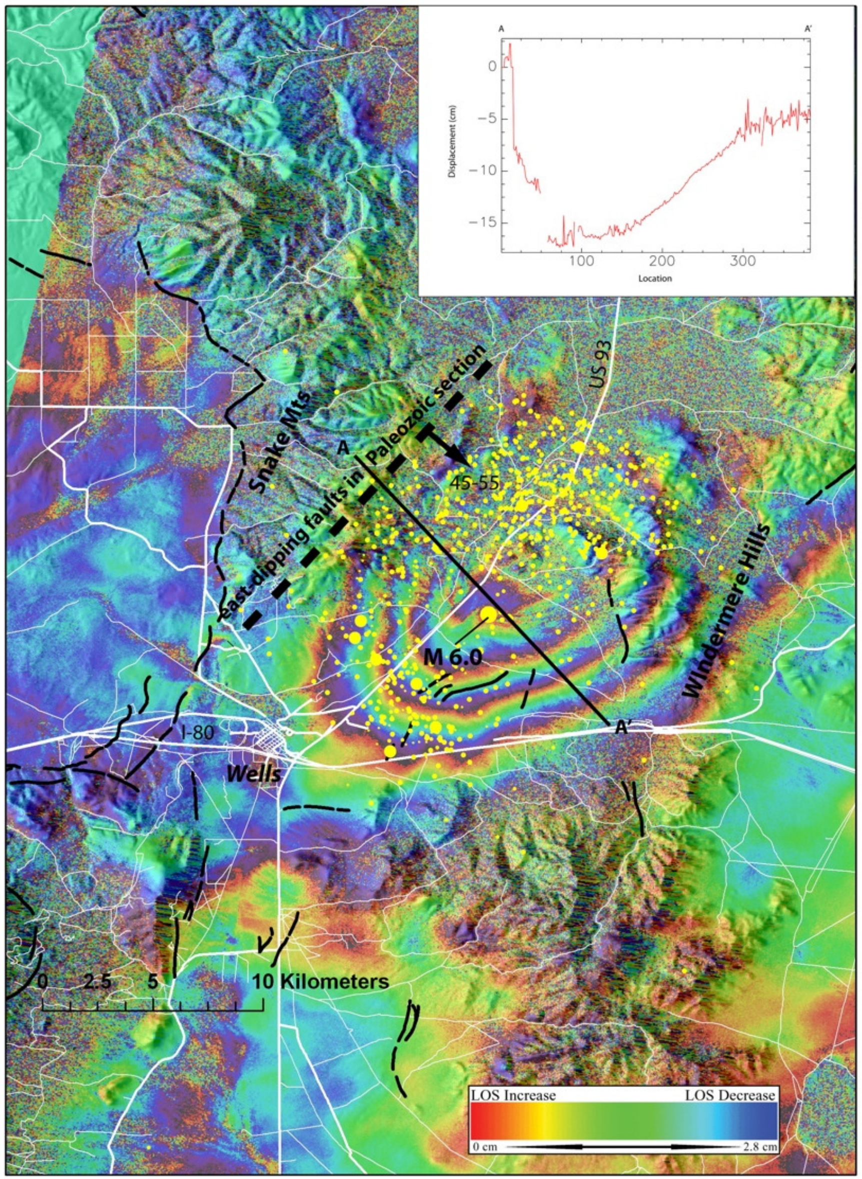
QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.



Envisat Results from Wells Earthquake



Hammond and Kreemer



Envisat Track 127 Frame 2781 Descending Orbits 28738-31744
8/29/2007 - 3/26/2008

Yellowstone Deformation

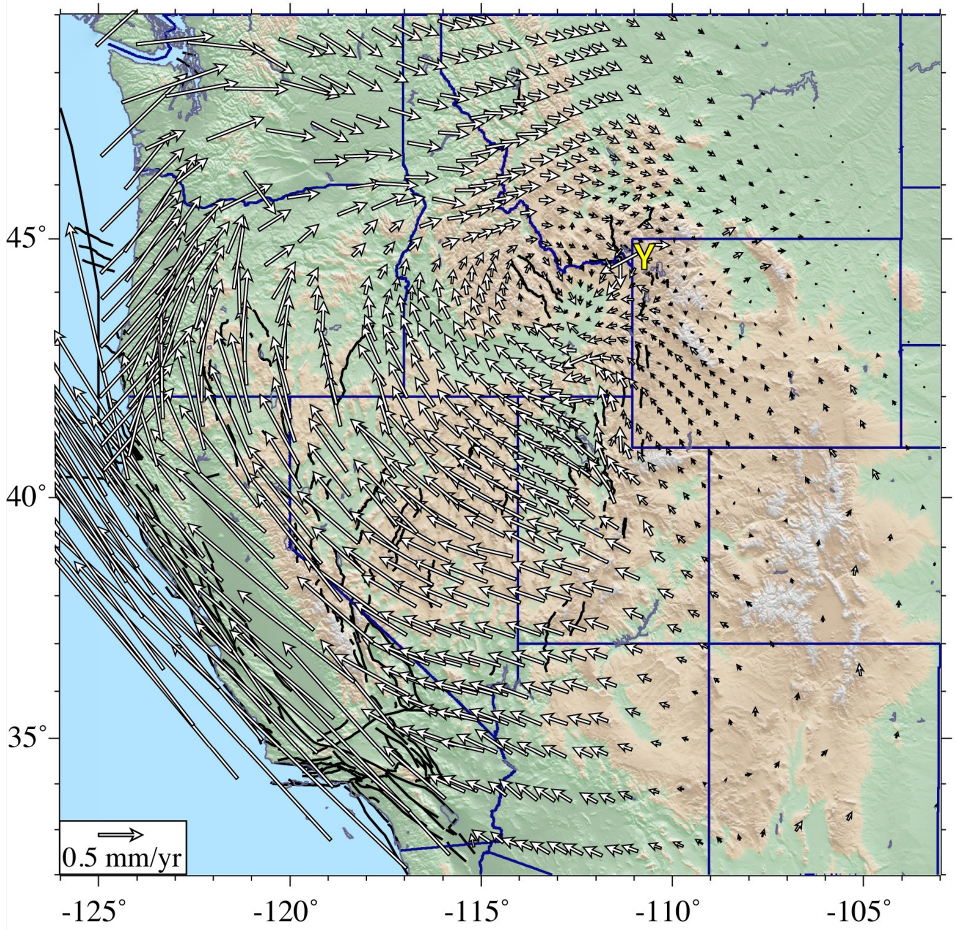
QuickTime™ and a
decompressor
are needed to see this picture.

Smith, et al., in press

Rapid uplift of the Yellowstone caldera revealed by GPS and InSAR data (2004-2007).

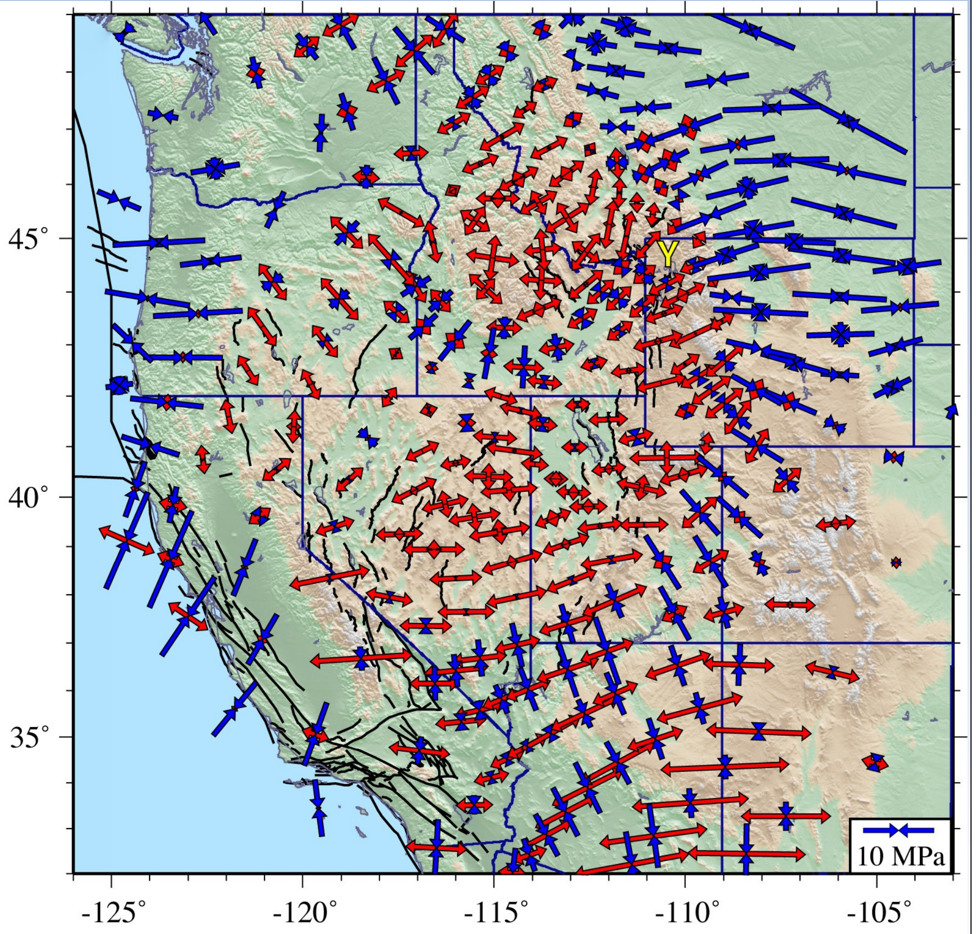
Chang, et al., 2007

Western US Deformation



Velocity field (kinematic)

GPS, Fault slip



Stress field (dynamic)

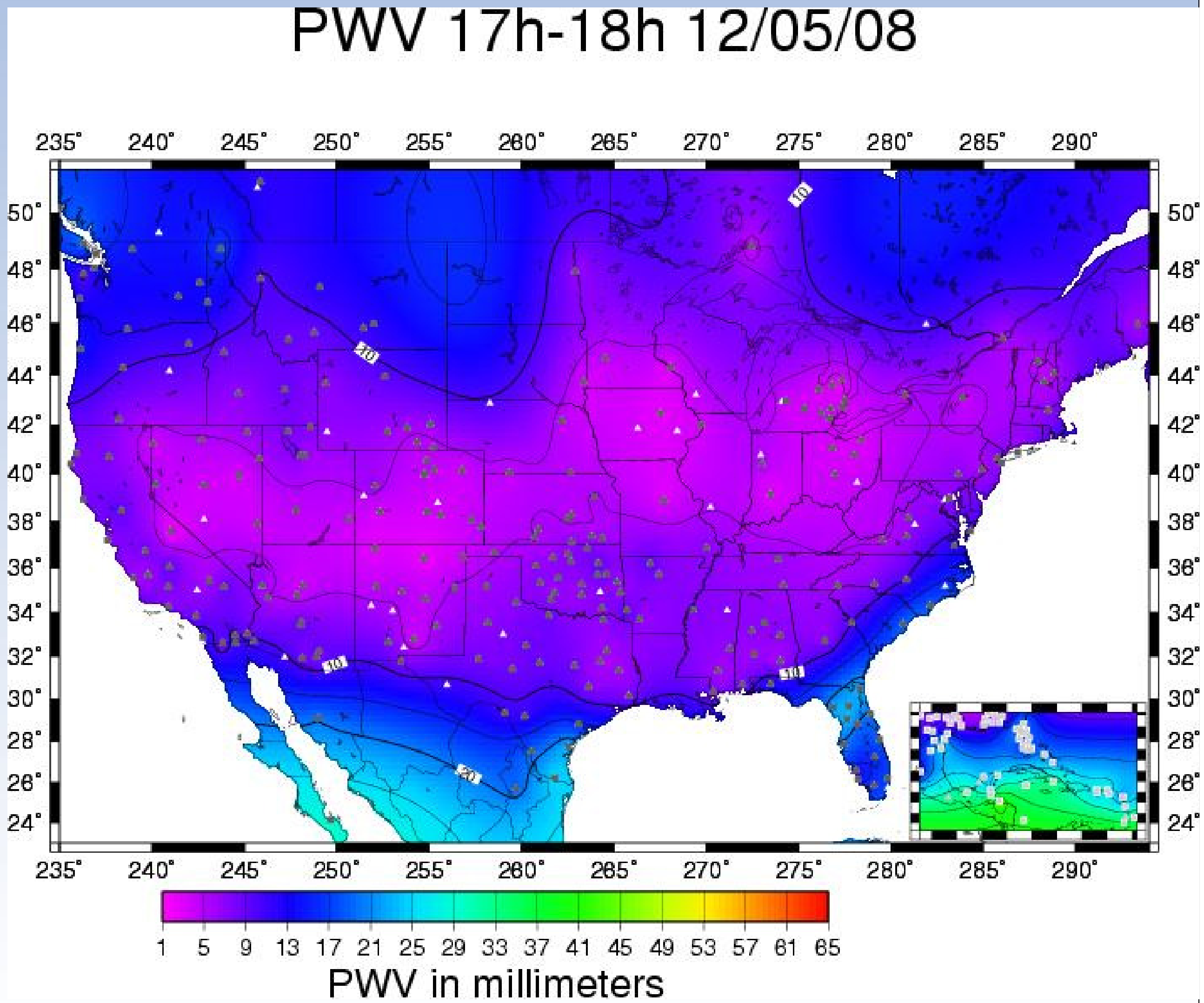
Lithospheric density

Kinematic constraints

Smith, et al., in press

PW Estimates from PBO Network

The COSMIC program is now routinely including approximately 80 stations from the Plate Boundary Observatory (PBO) in our near real-time analysis of GPS data within the continental United States.



Current Precipitable Water Vapor - US

www.cosmic.ucar.edu, www.suominet.ucar.edu

Plume Tracking

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PAGES 277–284

Volcanic Plume Above Mount St. Helens Detected With GPS

PAGES 277, 281

Eruptions can produce not only flows of incandescent material along the slopes of a volcano but also ash plumes in the troposphere [*Sparks et al.*, 1997] that can threaten aircraft flying in the vicinity [*Fisher et al.*, 1997]. To protect aircraft, passengers, and crews, the International Civil Aviation Organization and the World Meteorological Organization created eight Volcanic Ash Advisory Centers (VAAC, http://www.ssd.noaa.gov/VAAC/vaac.html) around the globe with the goal of tracking volcanic plumes and releasing eruption alerts to airports, pilots, and companies. Currently, the VAAC monitoring system is based mostly on the monitoring systems of any local volcano observatories and on real-time monitoring of data acquired by meteorological satellites.

In the case of the 18 August 2000 eruption of the Miyakejima volcano in Japan, *Houlié et al.* [2005] showed that the Global Positioning System (GPS) might be used as an additional tool for monitoring volcanic plumes. The present article indicates that the 9 March 2005 eruption of Mount St. Helens, Washington, also produced detectable anomalies in GPS data.

Since September 2004, the Cascades Volcano Observatory of the U.S. Geological Survey (CVO/USGS, http://vulcan.wr.usgs.gov/) has registered a period of activity at Mount St. Helens (46.2N, 122.2W), with two phreatic eruptions on 16 January and 9 March of 2005 (Figure 1) [*Major et al.*, 2005]. The CVO research team has monitored several parameters (including deformations, gas samplings, and seismicity) in order to understand the volcanic process and alert the local population of a possible risk [*Dzurisin et al.*, 2005]. Pilots of commercial aircraft reported that on 9 March 2005, an atmospheric plume propagated upward and reached an elevation of about 13 km above sea level (a.s.l.) [*Major et al.*, 2005]. The VAAC Office of Vancouver (Washington) tracked the volcanic plume over the United States in the hours that followed.

The data used in this study were acquired at seven permanent GPS stations deployed in the vicinity of the Mount St. Helens lava dome by the U.S. National Science Foundation's EarthScope Plate Boundary Observatory (PBO, http://www.earthscope.org/) since the volcano's September 2004 reawakening after 15 years of rest. Figure 2 shows the locations of the seven stations (P690, P693, P695, P696, P697, P698, P699). The data were processed daily using GAMIT (GPS Analysis MIT) software [*King and Bock*, 1999], assuming the troposphere is fully modeled by a standard meteorological model with a troposphere parameter estimated every four hours.

The hypothesis, successfully validated in the case of the 18 August 2000 Miyakejima eruption, is that the single- or double-difference phase residuals were containing a clear signature of the presence of the plume, and that this signature was relatively easy to extract and model and interpret quantitatively. (The single-difference phase is the difference of phase emitted by one satellite and received at two different sites; the double-difference phase is the difference of the phases emitted by two satellites and received by two receivers.)

Figure 3 shows the six residuals of the LC frequency (LC is a linear combination of the two carriers emitted by the GPS satellites L1 and L2; LC = 2.545 L1 + 1.545 L2) computed using each satellite seen by each receiver with respect to the satellite PRN22 and the site P690.

The amplitude of the typically observed noise is about 0.15 cycles on LC frequency (or 7 cm of anomalous pseudorange; the pseudorange is the distance between the satellite and the GPS receivers), and the anomalies observed during the eruption are about twice this value (0.3 cycles). The error on the location of a given site perturbed by a plume is about 14 cm (Figure 2). The event is visible for 20 min on the GPS residuals of satellites PRN18 and PRN22. However, the residuals presented here are less than for the Miyakejima eruption in 2000, and this made them less obvious to locate in the data.

Anomalous signals were observed only for satellites PRN18 and PRN22. These two satellites were located between the azimuth N0 and N90 during the eruption with elevation angles equal to 27° for PRN18 at 1.35 (UT) and 59° for PRN22 at the same time. The spatial location of the plume anomaly retrieved by GPS is compatible with the lateral drift of the volcanic plume pushed to the east by the wind, as reported by direct observations from ground and air during the event (see Figure 1 and *Major et al.* [2005]).

Fig. 1. Photo of the 9 March 2005 Mount St. Helens eruption. The plume reached 11.2 km above sea level. Image credit: U.S. Geological Survey.

By N. Houlié, P. Briole, A. Nercessian, and M. Murakami

Retrieval of clear anomaly in GPS phase delay modeling residuals (5 - 10 cm of equivalent pseudorange delay)

Anomalies compatible with eastward lateral drift (confirmed via ground and air reports)

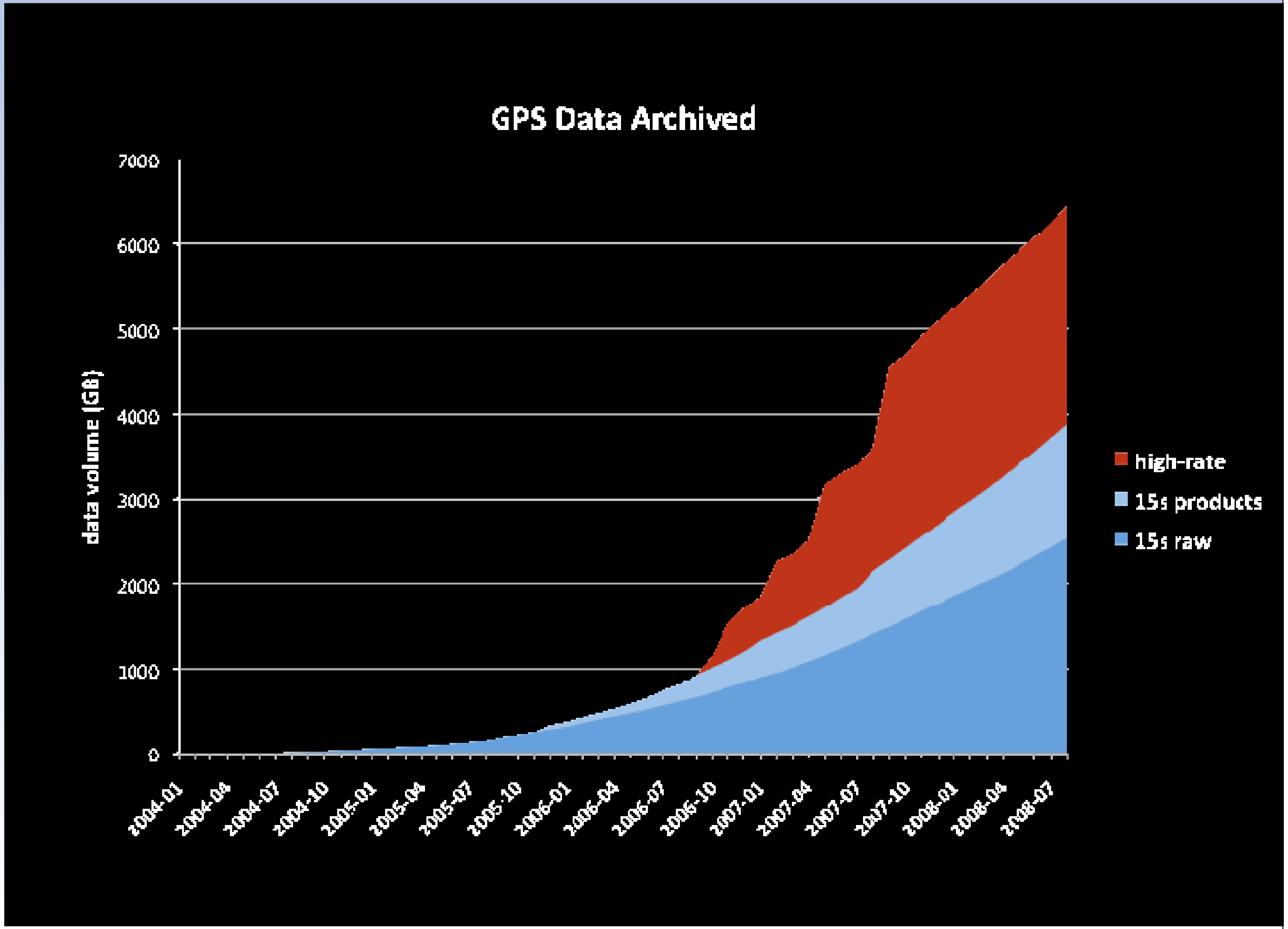
GPS data can be used to detect and quantify volcano plumes.

High-Rate GPS

Almost evenly split between academia, government and private sector.

Support GPS positioning of airborne/mobile instrument platforms (for lidar, photo-grammetry, bathymetry, etc.).

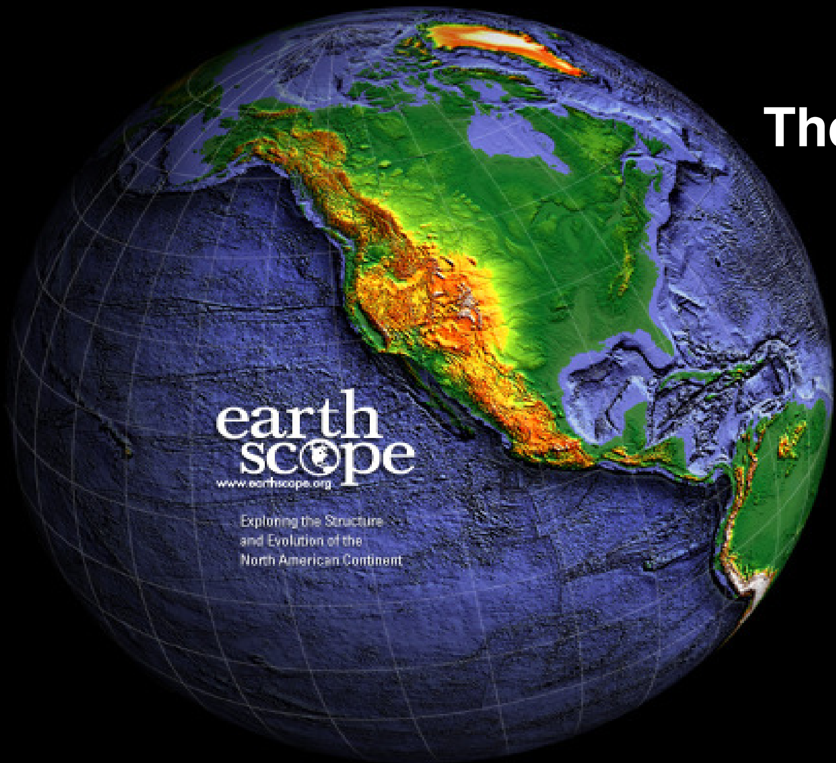
Research for hazard early



Archived volume of user-requested high rate da
equals that of standard 15-second data (2.6 T

The End

of the construction



The continued growth of unprecedented

Science….