UNAVCO

USING GPS OBSERVATIONS TO UNDERSTAND THE EARTH: EXAMPLES FROM PBO, COCONET, AND TLALOCNET

Glen S. Mattioli, Ph.D.
Director of Geodetic Infrastructure and
PBO Director

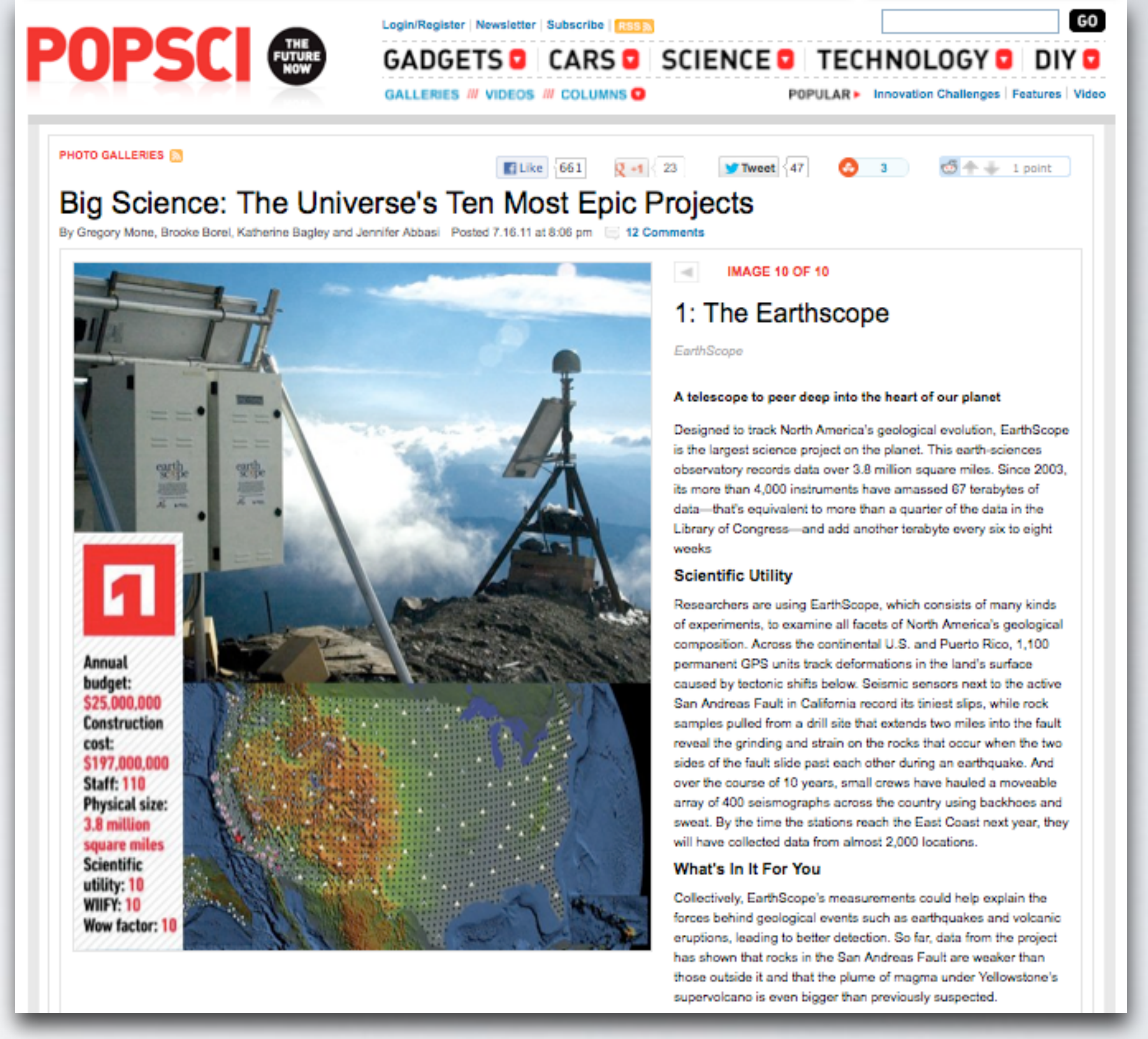
GSA Annual Meeting, October 19-22, 2014 - Vancouver, BC

TALK OUTLINE

- EarthScope overview: PBO infrastructure current status, data return, products
- Science highlights: Napa valley earthquake, ETS in Cascadia, transient slip along the SAF, and hydrogeodesy
- Vision for the future: PBO as a basis for a multi-hazard network of networks across the Americas (COCONet and TLALOCNet)
- Summary and challenges going forward...

EarthScope Background

- **Funded by NSF**
- **Project started in 2003 - continues through 2018**
- Three Components - Geodetic, Seismic, and Drilling
- Deploys thousands of seismic, GPS, and other geophysical instruments
- Purpose: To study the structure and evolution of the North American continent and the processes the cause earthquakes and volcanic eruptions.
- A collaboration between scientists, educators, policy makers, and the public to learn about and utilize exciting scientific discoveries as they are being made.
- **Total EarthScope Budget: ~$500M over the lifetime of the project**



POPSCI THE FUTURE NOW

Login/Register | Newsletter | Subscribe | RSS

GADGETS CARS SCIENCE TECHNOLOGY DIY

GALLERIES /// VIDEOS /// COLUMNS

POPULAR ▸ Innovation Challenges | Features | Video

PHOTO GALLERIES

Like 661 +1 23 Tweet 47 3 1 point

Big Science: The Universe's Ten Most Epic Projects

By Gregory Mone, Brooke Borel, Katherine Bagley and Jennifer Abbasi Posted 7.16.11 at 8:06 pm 12 Comments

IMAGE 10 OF 10

1: The Earthscope

EarthScope

A telescope to peer deep into the heart of our planet

Designed to track North America's geological evolution, EarthScope is the largest science project on the planet. This earth-sciences observatory records data over 3.8 million square miles. Since 2003, its more than 4,000 instruments have amassed 67 terabytes of data—that's equivalent to more than a quarter of the data in the Library of Congress—and add another terabyte every six to eight weeks

Scientific Utility

Researchers are using EarthScope, which consists of many kinds of experiments, to examine all facets of North America's geological composition. Across the continental U.S. and Puerto Rico, 1,100 permanent GPS units track deformations in the land's surface caused by tectonic shifts below. Seismic sensors next to the active San Andreas Fault in California record its tiniest slips, while rock samples pulled from a drill site that extends two miles into the fault reveal the grinding and strain on the rocks that occur when the two sides of the fault slide past each other during an earthquake. And over the course of 10 years, small crews have hauled a moveable array of 400 seismographs across the country using backhoes and sweat. By the time the stations reach the East Coast next year, they will have collected data from almost 2,000 locations.

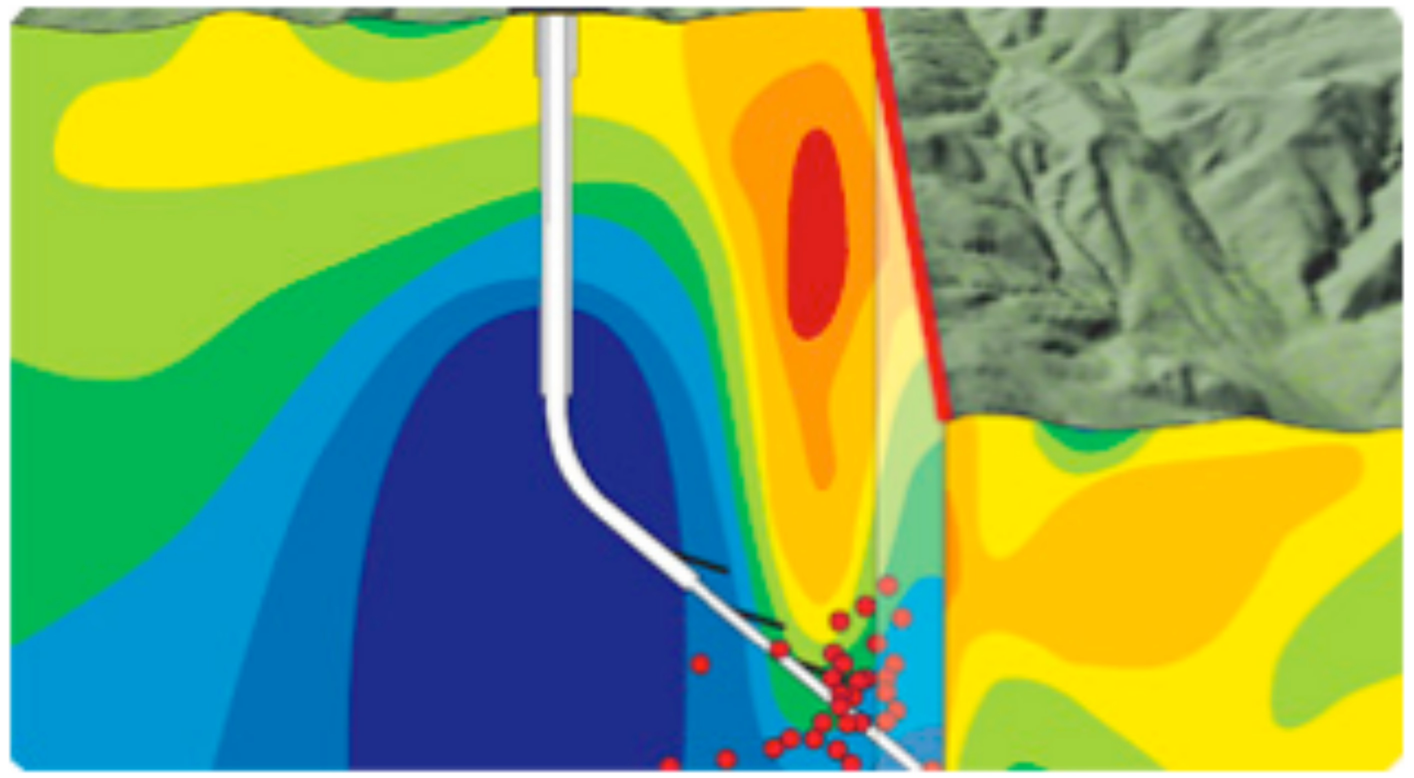
What's In It For You

Collectively, EarthScope's measurements could help explain the forces behind geological events such as earthquakes and volcanic eruptions, leading to better detection. So far, data from the project has shown that rocks in the San Andreas Fault are weaker than those outside it and that the plume of magma under Yellowstone's supervolcano is even bigger than previously suspected.

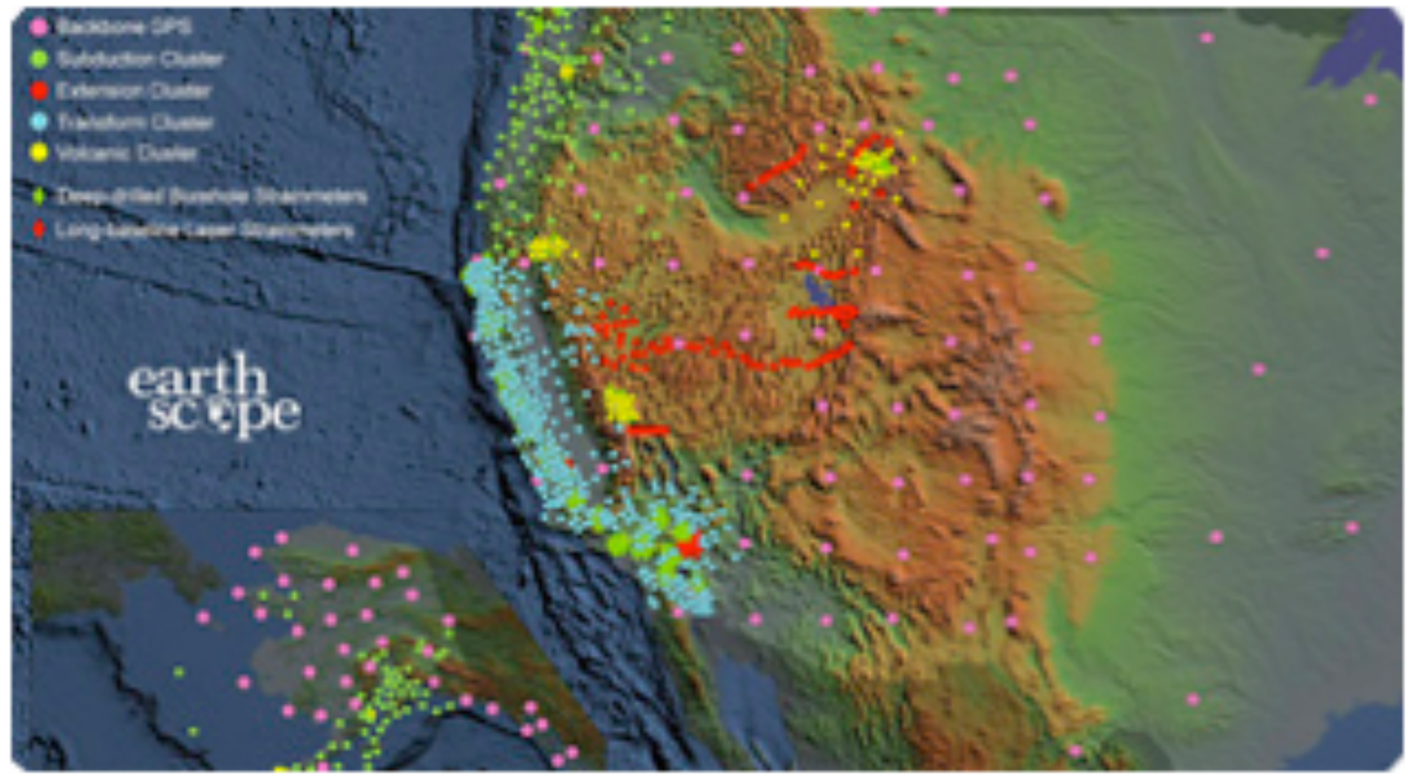
1

Annual budget: $25,000,000
Construction cost: $197,000,000
Staff: 110
Physical size: 3.8 million square miles
Scientific utility: 10
WIIFY: 10
Wow factor: 10

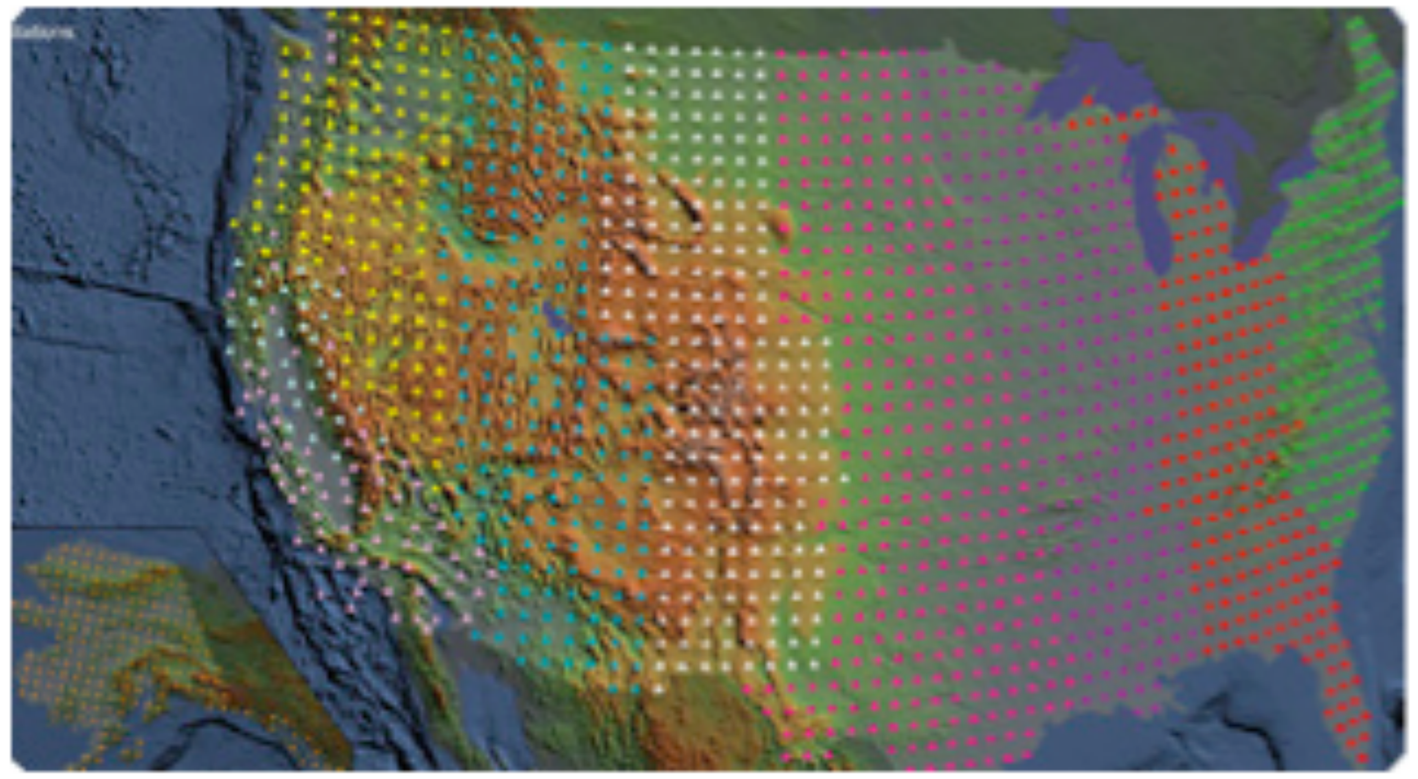
Drilling Component - SAFOD



Geodetic Component - PBO



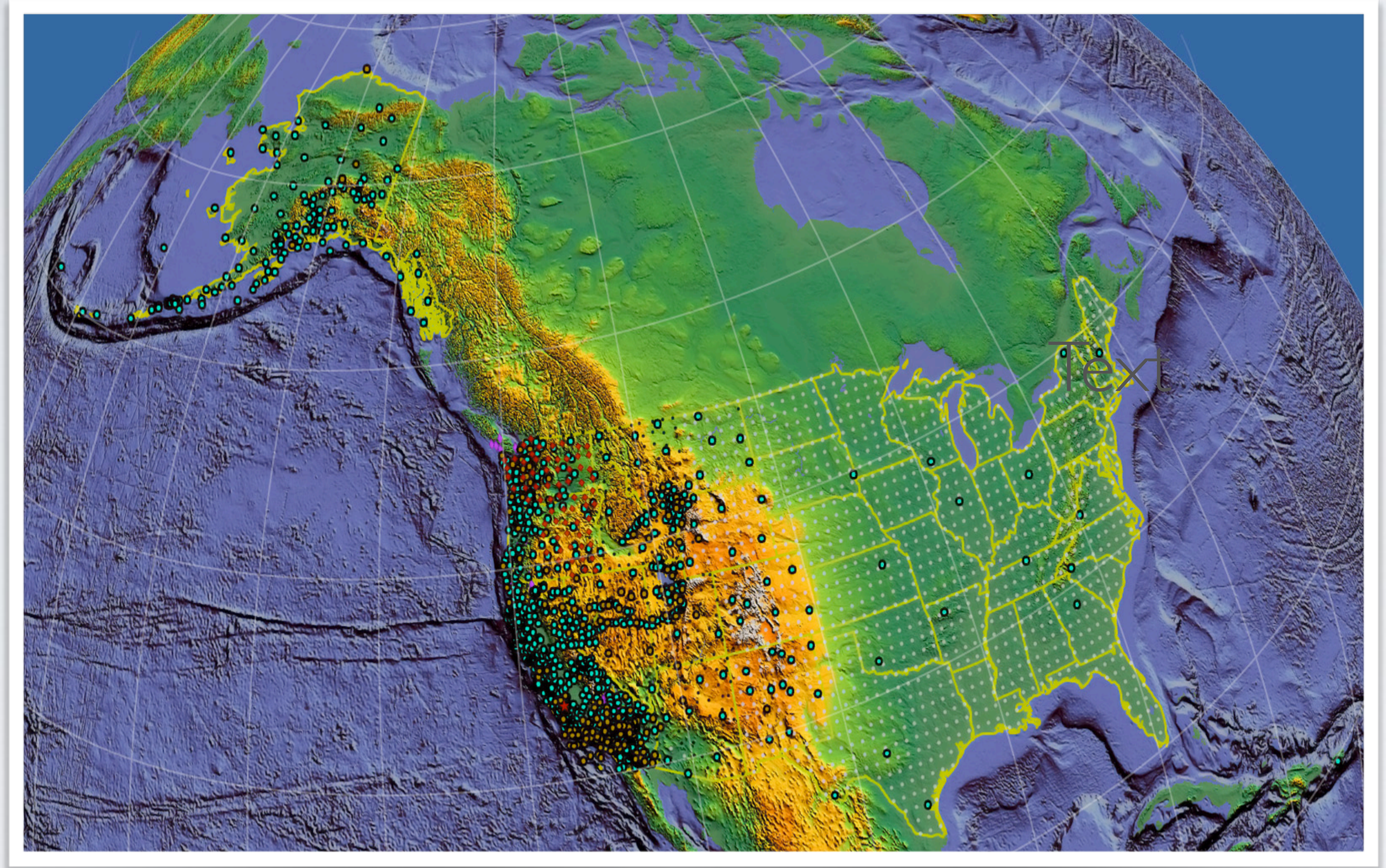
Seismic Component - USArray



UNAVCO

EARTHSCOPE: INTEGRATION OF GEODESY AND SEISMOLOGY

Designed as a 15 year experiment with sunset in 2018



PBO is the geodetic component of EarthScope (~$200M):
1100 cGPS, 78 BSM, 6 LSM, 26 tiltmeters

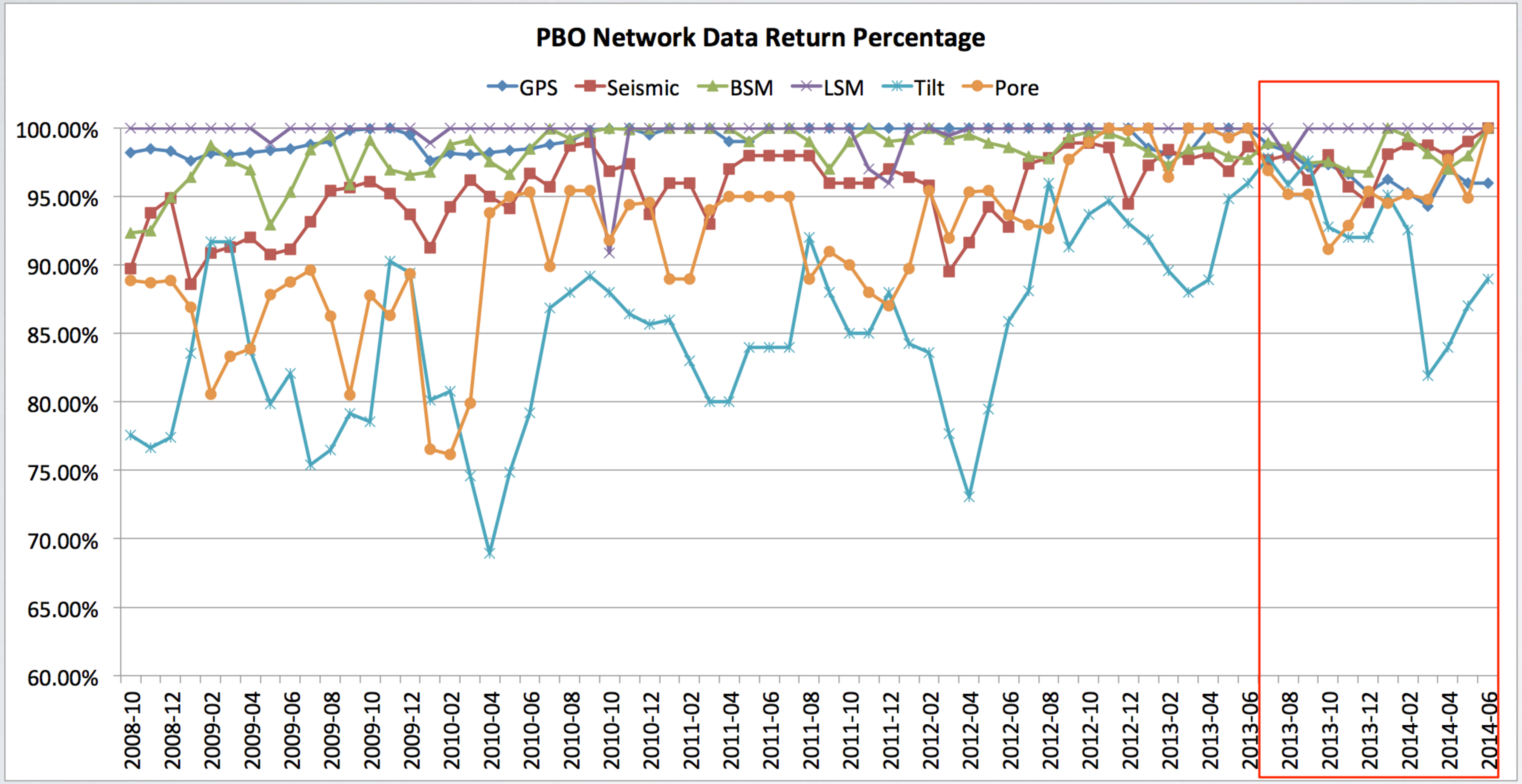
Technical advancements:

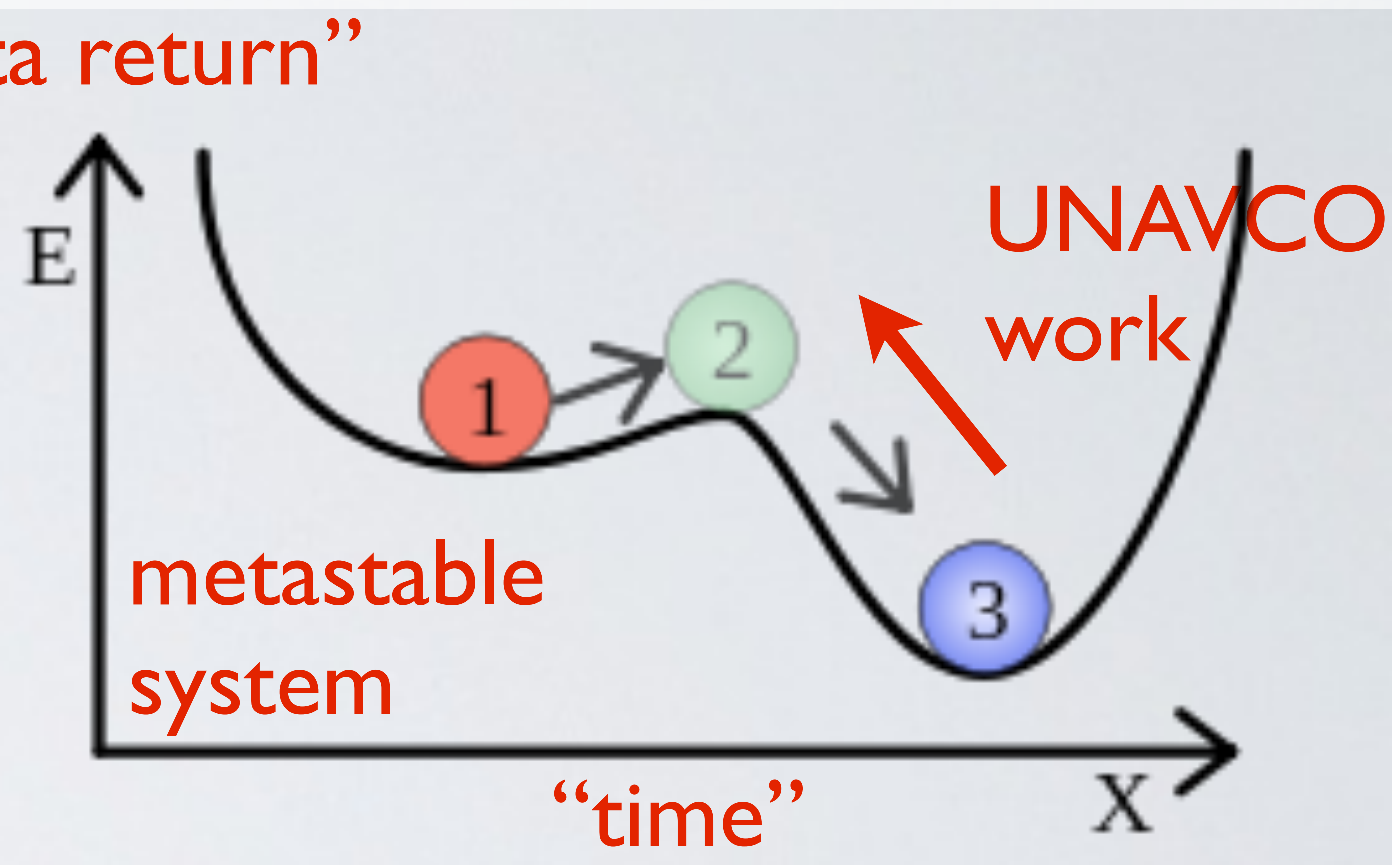
- *community data formats for real-time GPS*
- *collocation of accelerometers & high-rate GPS*
- *Cascadia & planned GAGE upgrades*
- *changes in the landscape with vendors*

Integrative science:

- *tomography & kinematics for geodynamics*
- *episodic tremor and slip*
- *GPS seismology*
- *early GPS centroid determination*
- **Total EarthScope Budget: ~$500M**

PBO SENSOR DATA RETURN



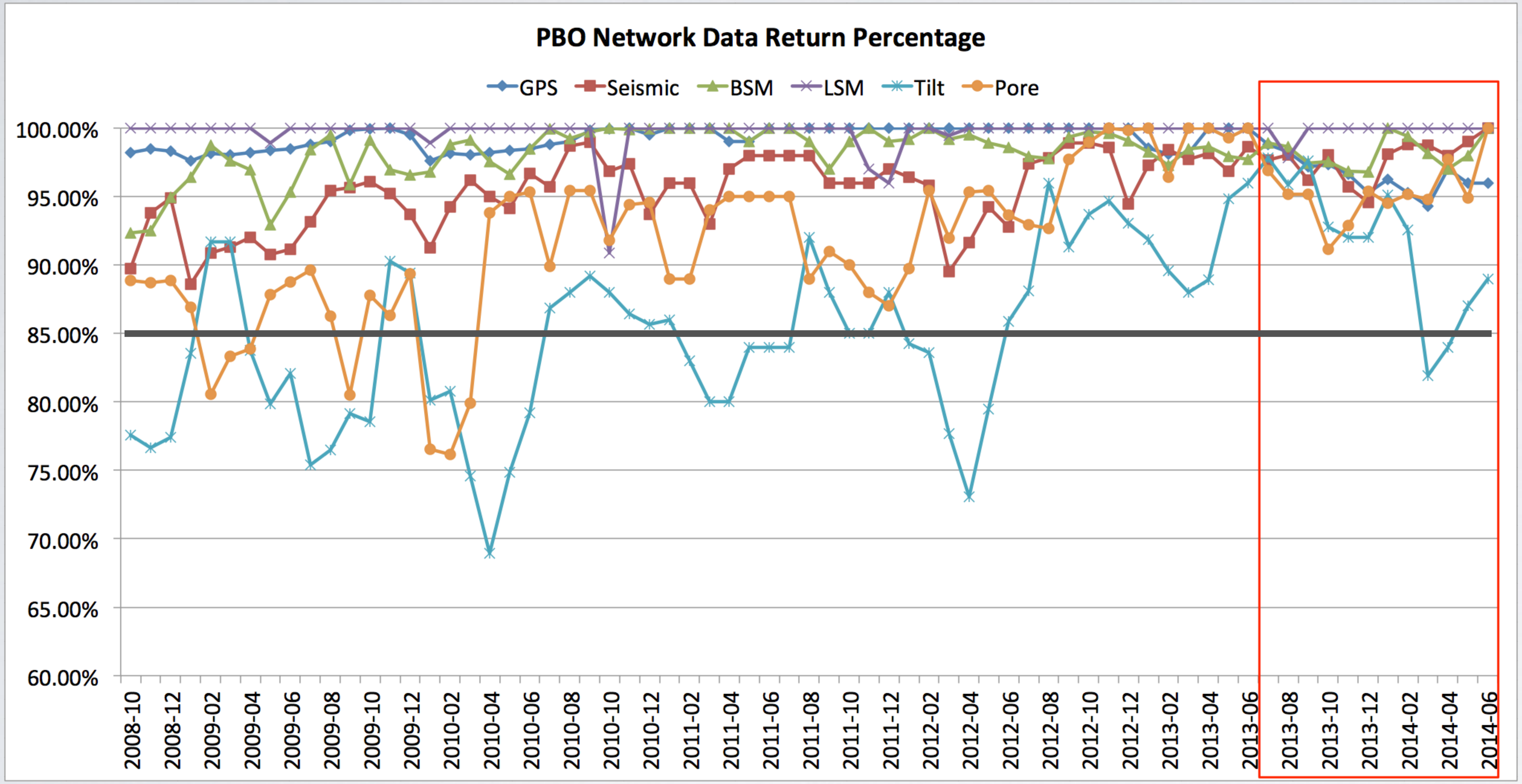


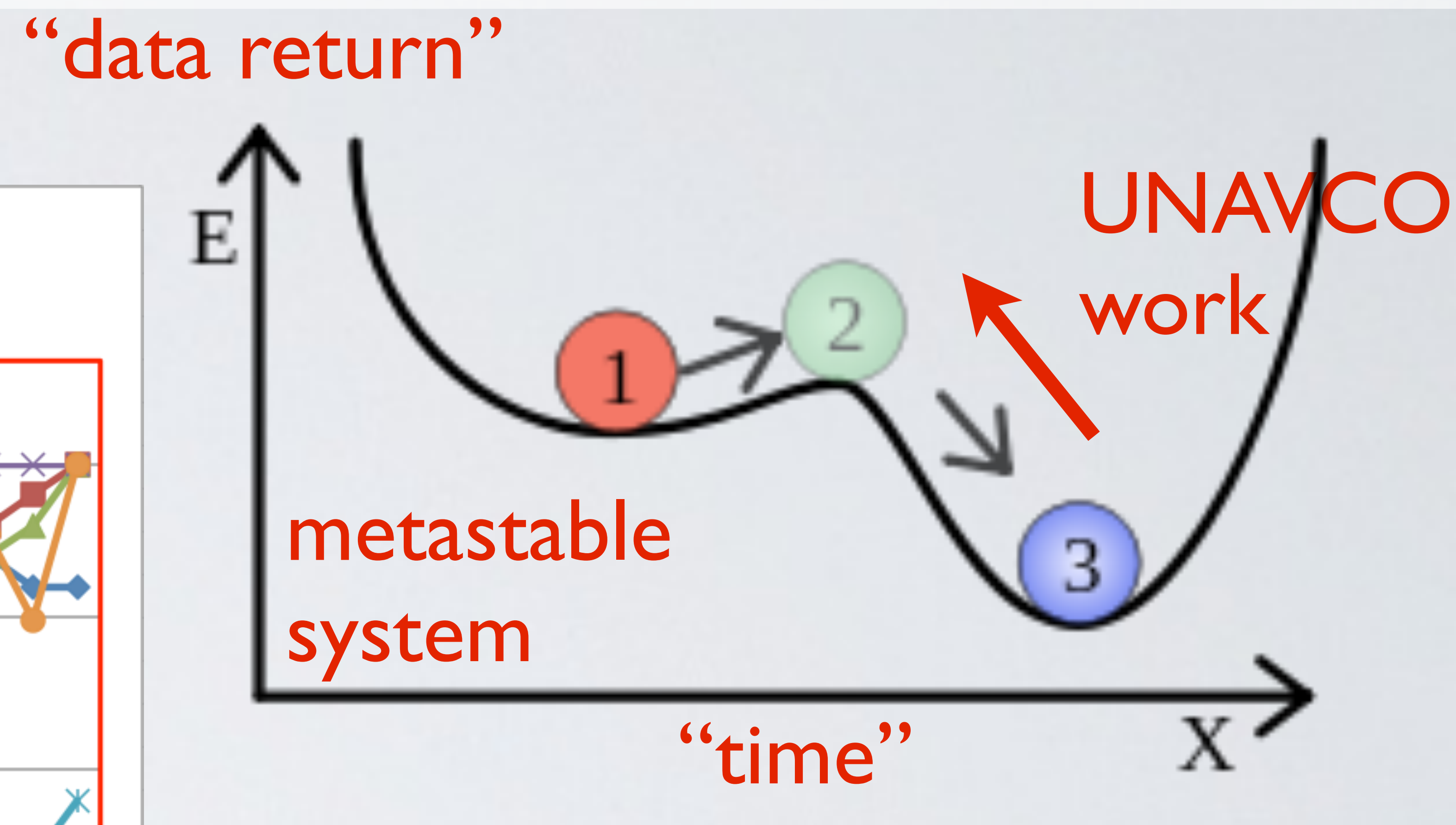
Cumulative data return for the PBO network since the beginning of the O&M period (FY2009) is:

- 99% for GPS/Met
- 96% for seismic
- 98% for BSM
- 100% for LSM
- 92% for pore pressure
- 86% for tilt.

Metrics complete through June 30, 2014 (YR6Q3- GAGE YR1Q3)

PBO SENSOR DATA RETURN



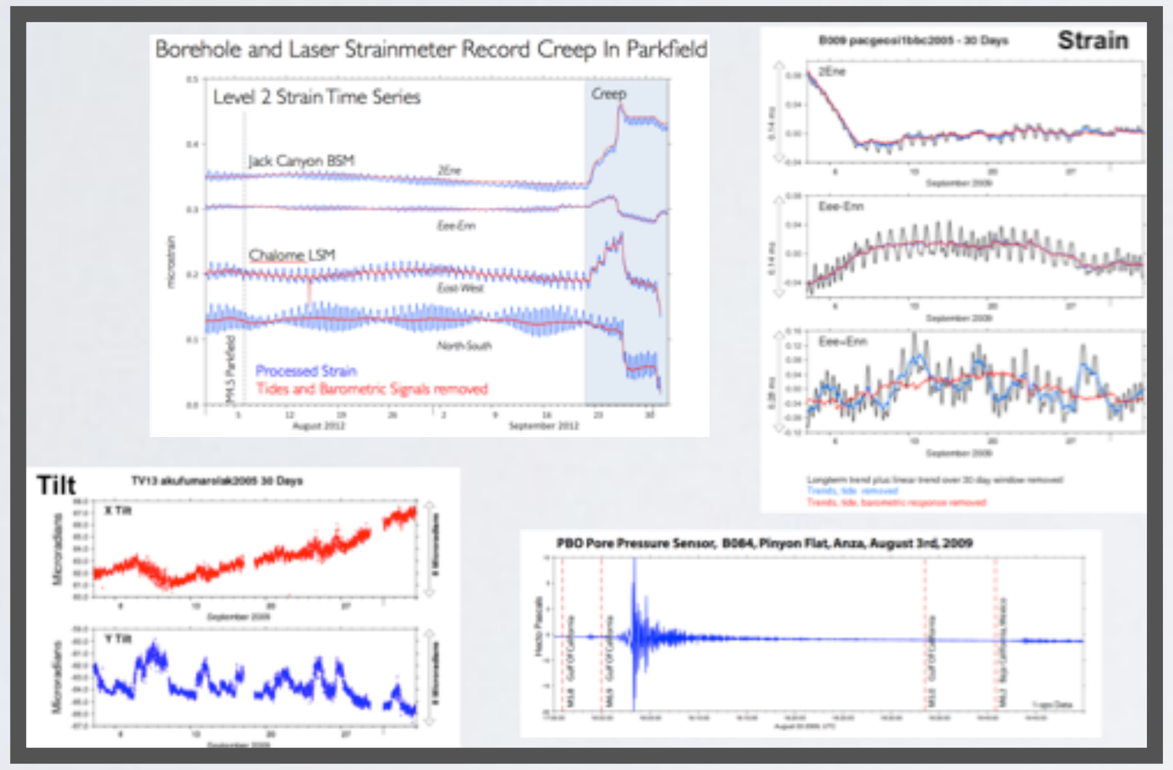


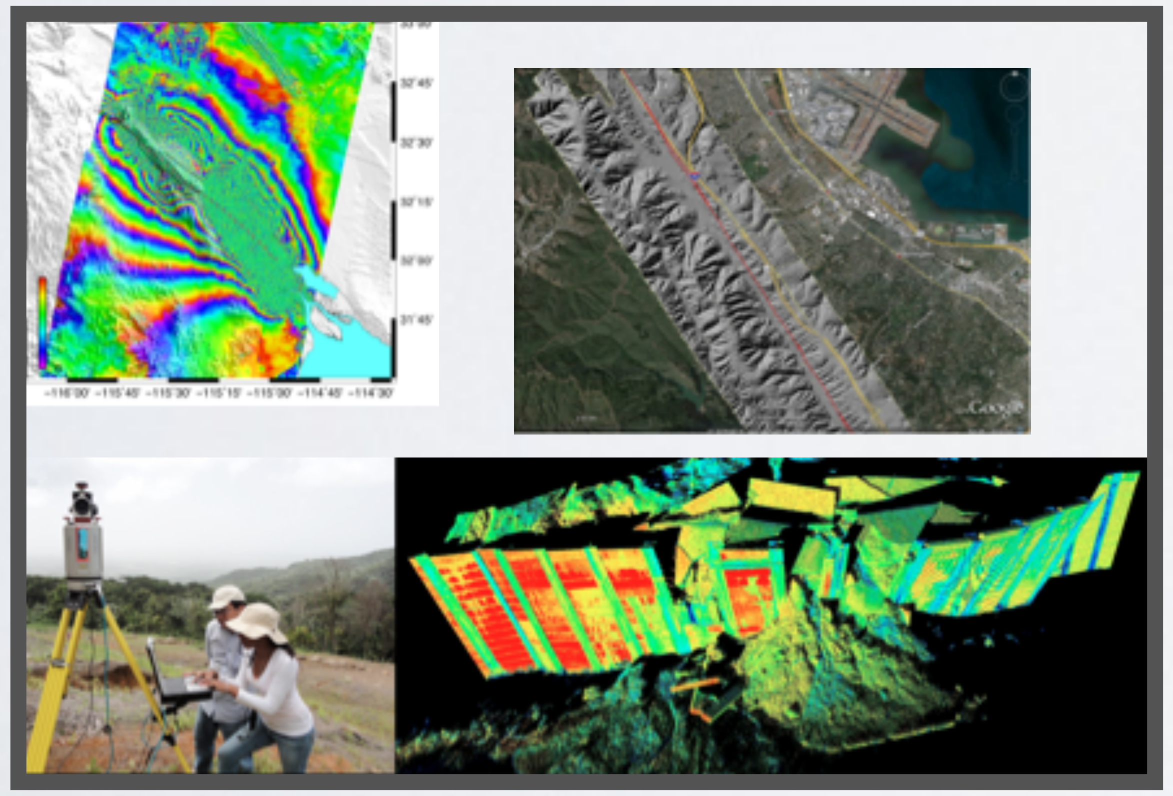
Cumulative data return for the PBO network since the beginning of the O&M period (FY2009) is:

- 99% for GPS/Met
- 96% for seismic
- 98% for BSM
- 100% for LSM
- 92% for pore pressure
- 86% for tilt.

Metrics complete through June 30, 2014 (YR6Q3- GAGE YR1Q3)

PBO Data Products





GPS data products from PBO, COCONet, other networks

- Level 1: RINEX
- Level 2: Station positions, time series, velocities (in various ref. frames)
- Level 3: Community contributed products such as H2O (K. Larson)

Borehole Geophysics data products (Levels 0,1,2)

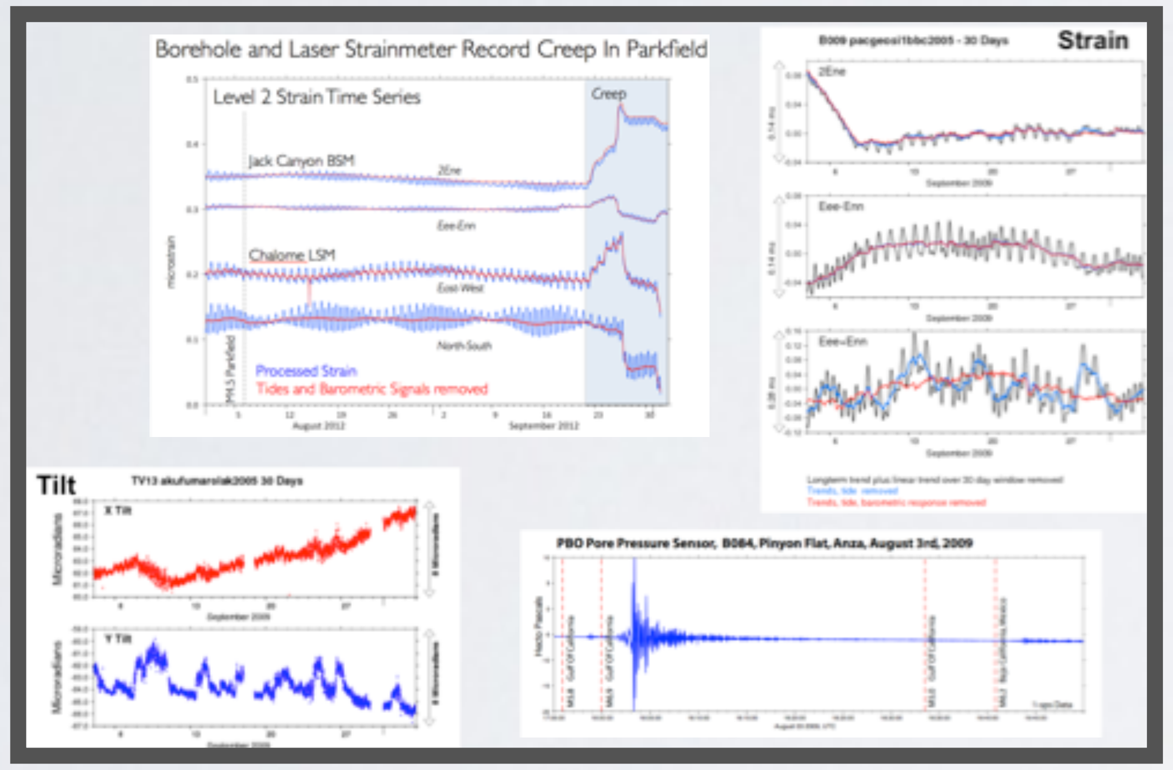
- Borehole Strainmeter (BSM)
- Laser Strainmeter (LSM)
- Tiltmeter (Tilt)
- Pore Pressure (Pore)
- Seismometer (Seismic)

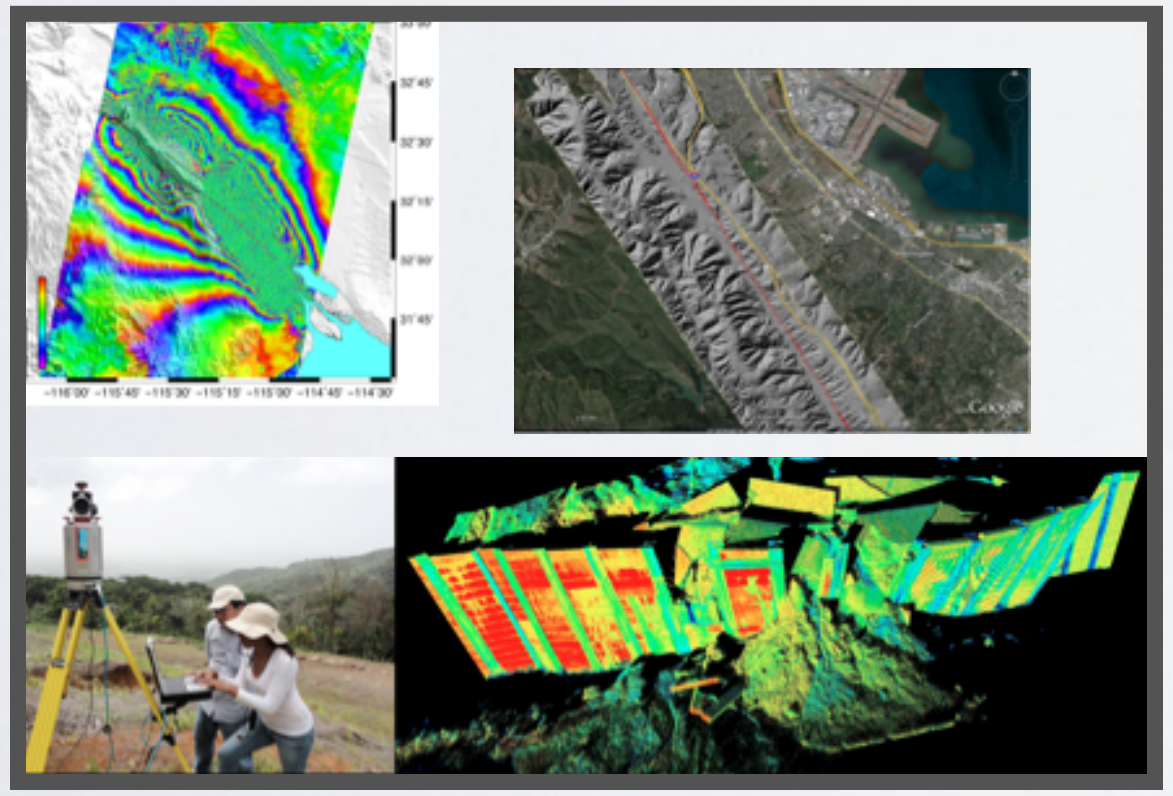
Geodetic Imaging data products

- Airborne LiDAR (ALS) from GeoEarthScope (Level 3)
- Terrestrial LiDAR (TLS) (Levels 0, 2)
- InSAR (Levels 0,1)

Other data products

PBO Data Products



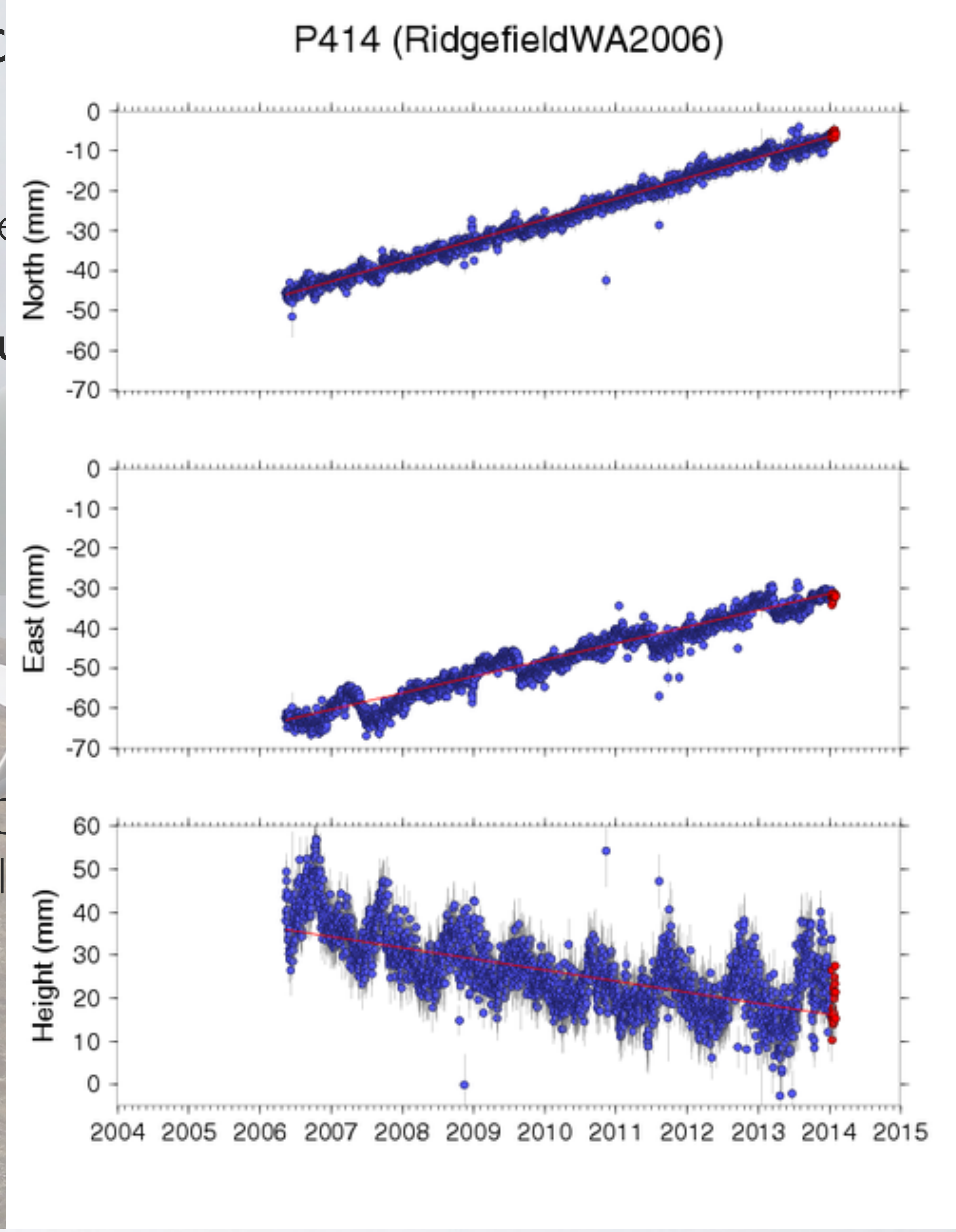


GPS data products from PBO, C
- Level 1: RINEX
- Level 2: Station positions, time
- Level 3: Community contribute

Borehole Geophysics data produ
- Borehole Strainmeter (BSM)
- Laser Strainmeter (LSM)
- Tiltmeter (Tilt)
- Pore Pressure (Pore)
- Seismometer (Seismic)

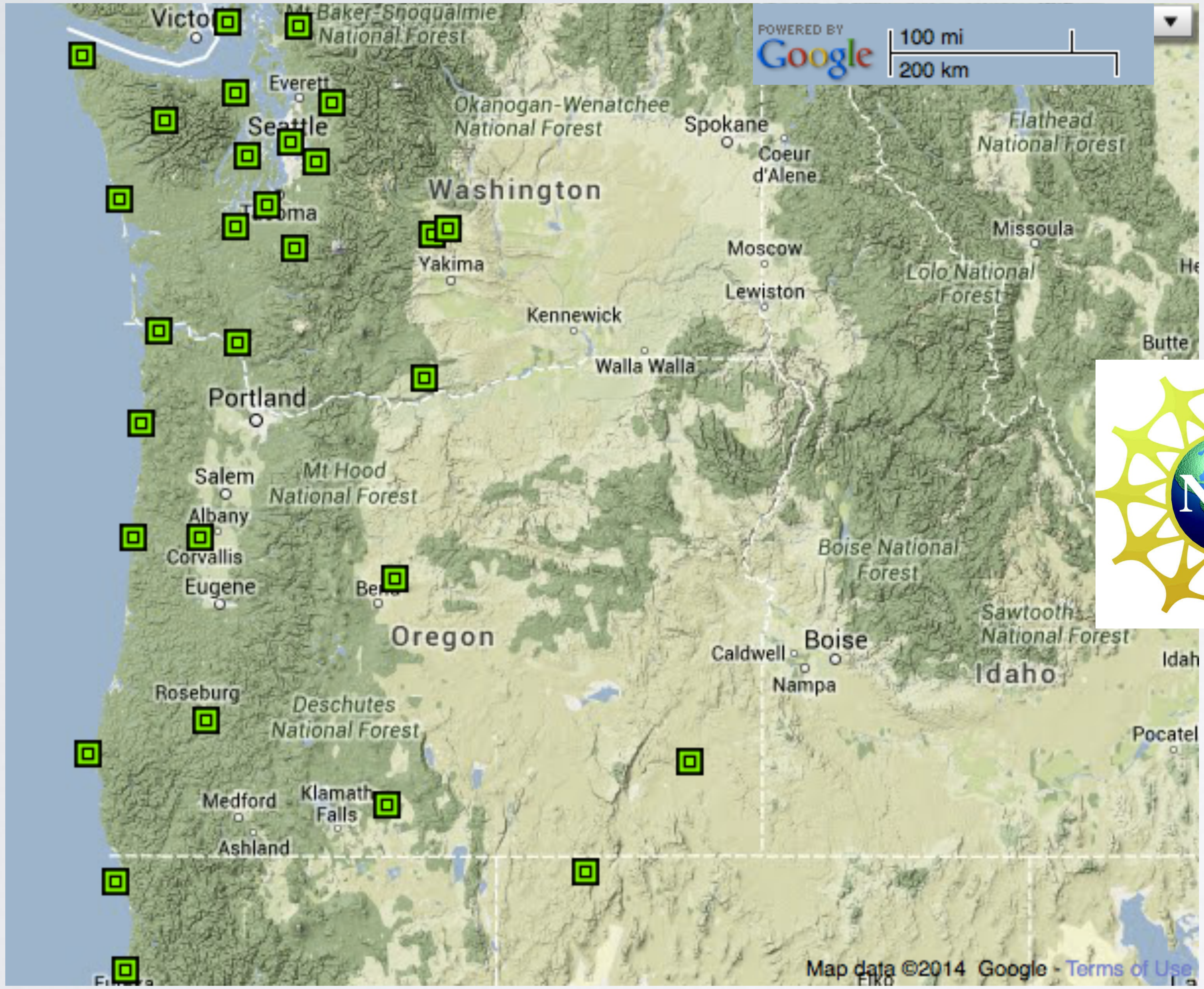
Geodetic Imaging data products
- Airborne LiDAR (ALS) from C
- Terrestrial LiDAR (TLS) (Level
- InSAR (Levels 0,1)

Other data products

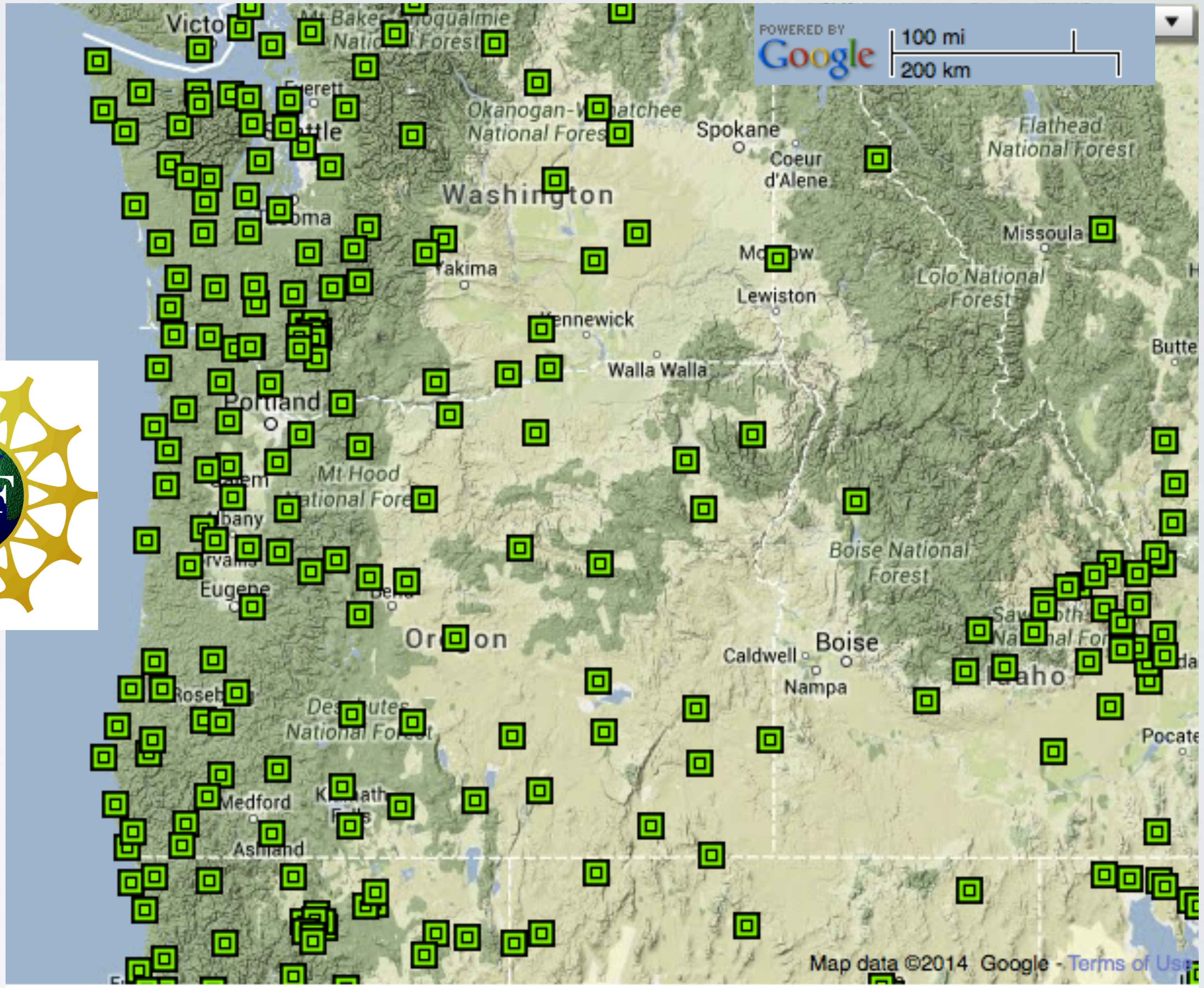


CASCADIA PBO ASSETS: INITIAL AND SUPPLEMENTAL INVESTMENTS

cGPS stations operated, processed, and maintained by UNAVCO



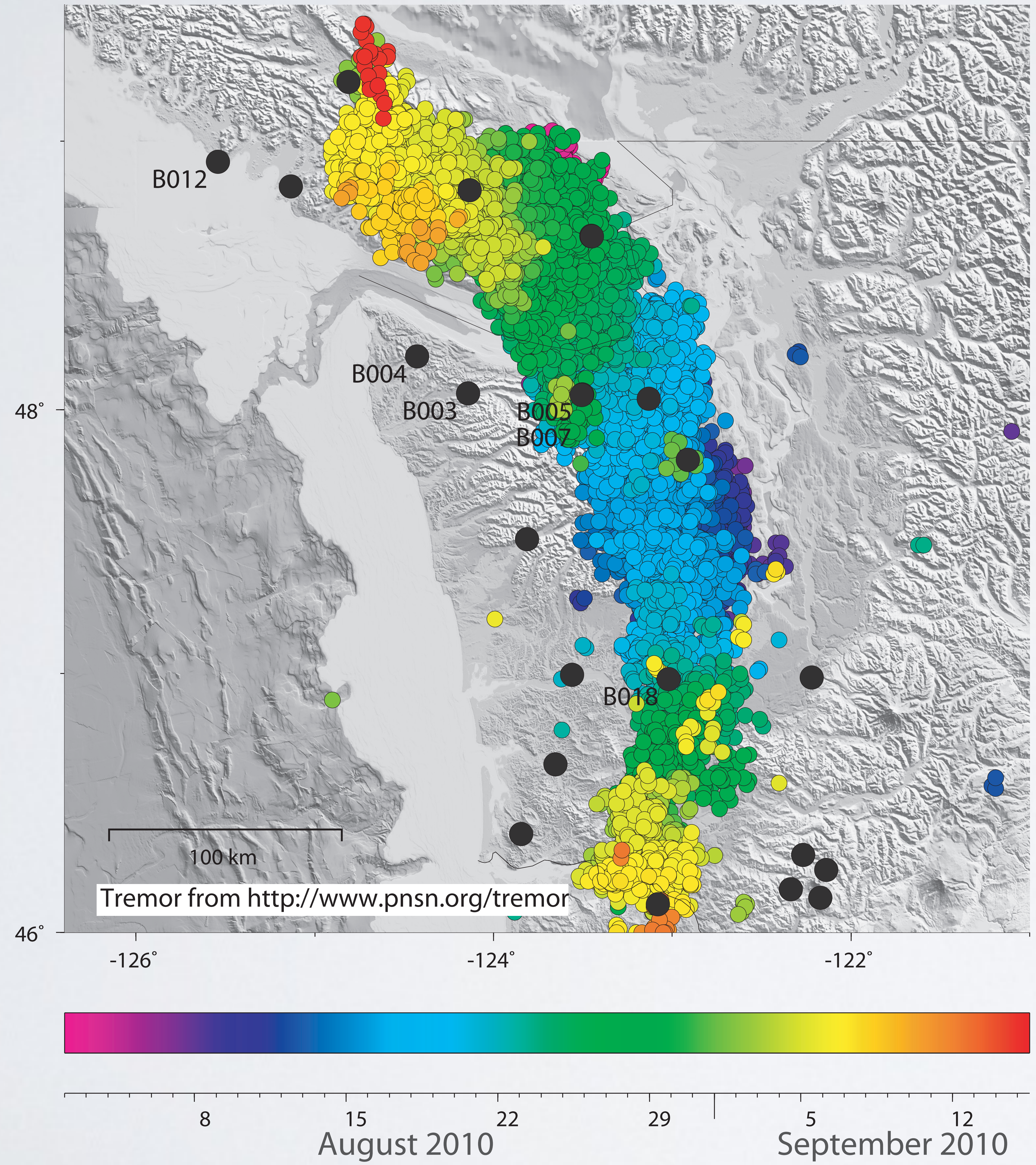
Original 29 PANGA cGPS stations



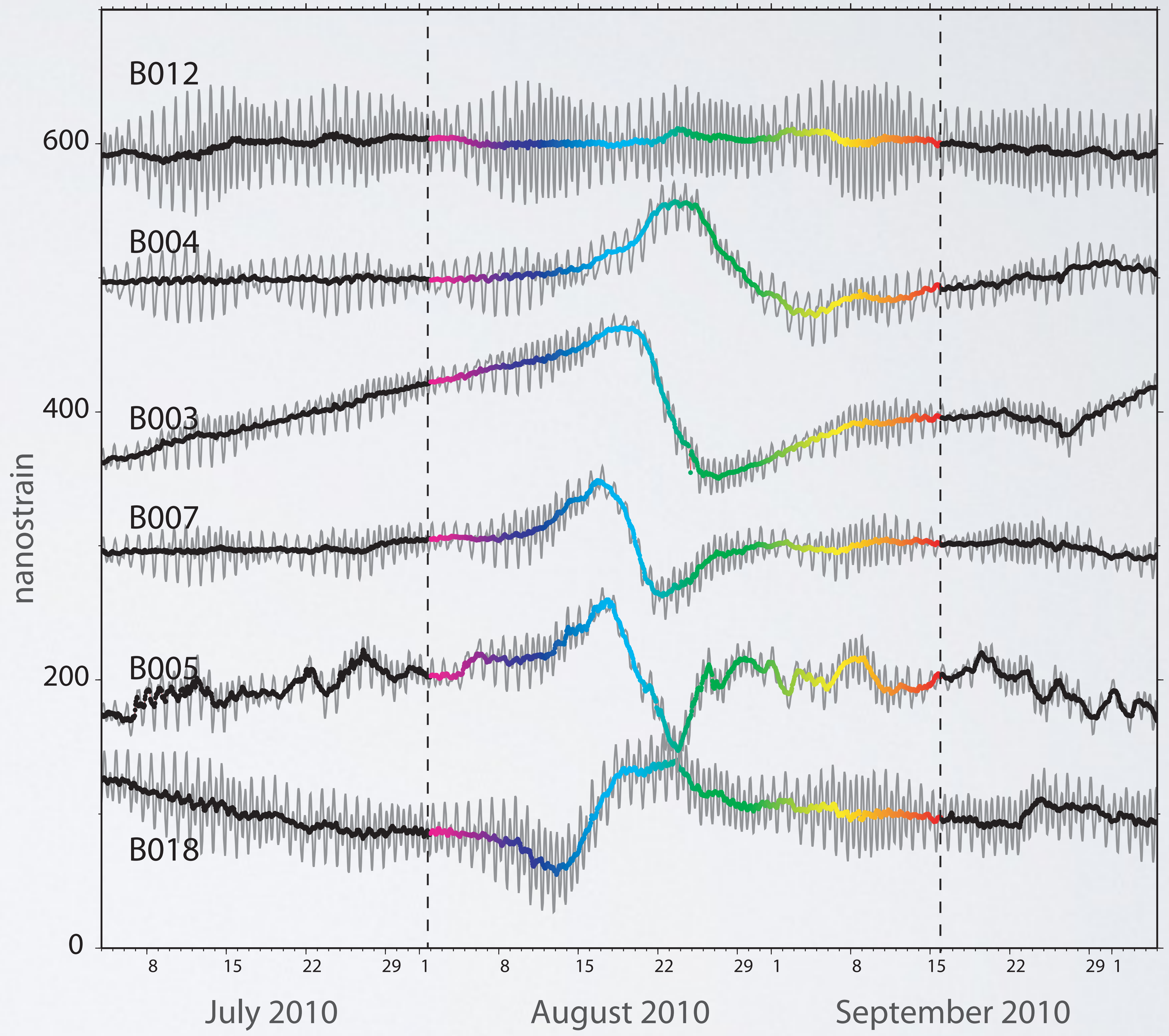
Current 234 PBO cGPS stations

CASCADIA: EPISODIC TREMOR AND SLIP EVENTS

Cascadia Episodic Tremor and Slip, 2010



2010 Cascadia ETS, 2Ene Strain

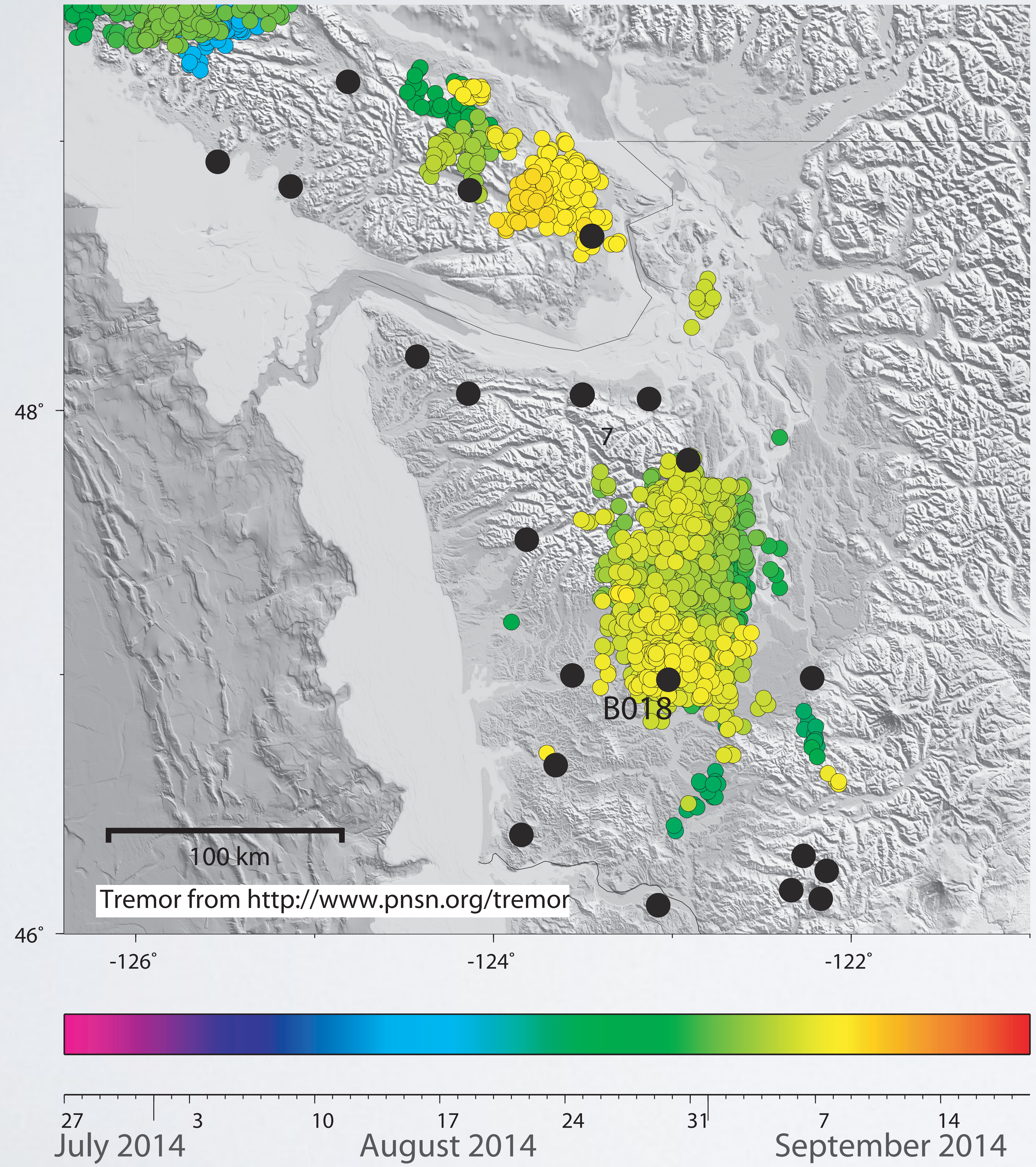


From Hodgkinson et al., 2014 (GSA)

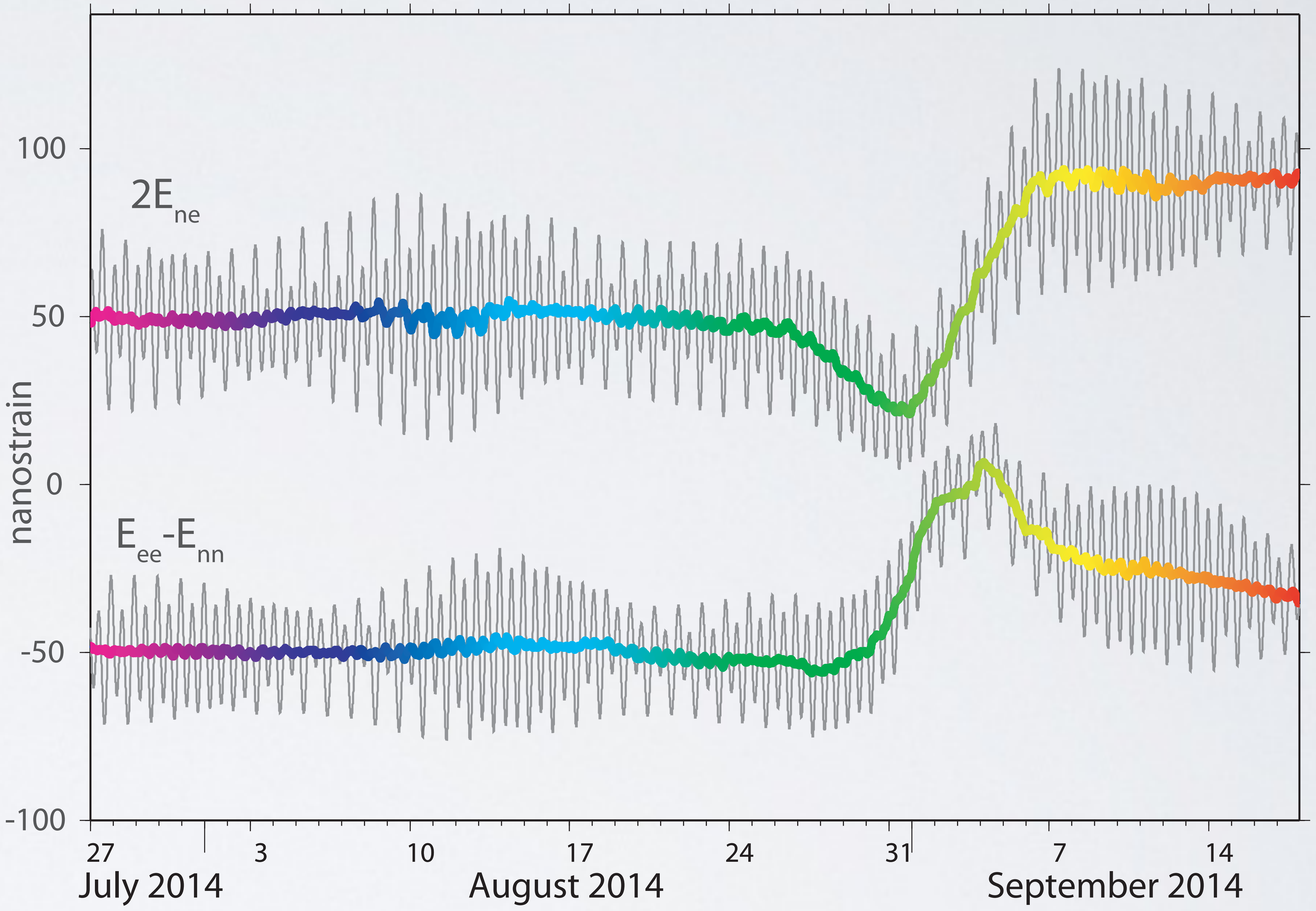
UNAVCO

CASCADIA: EPISODIC TREMOR AND SLIP EVENTS

Tremor Event September 2014

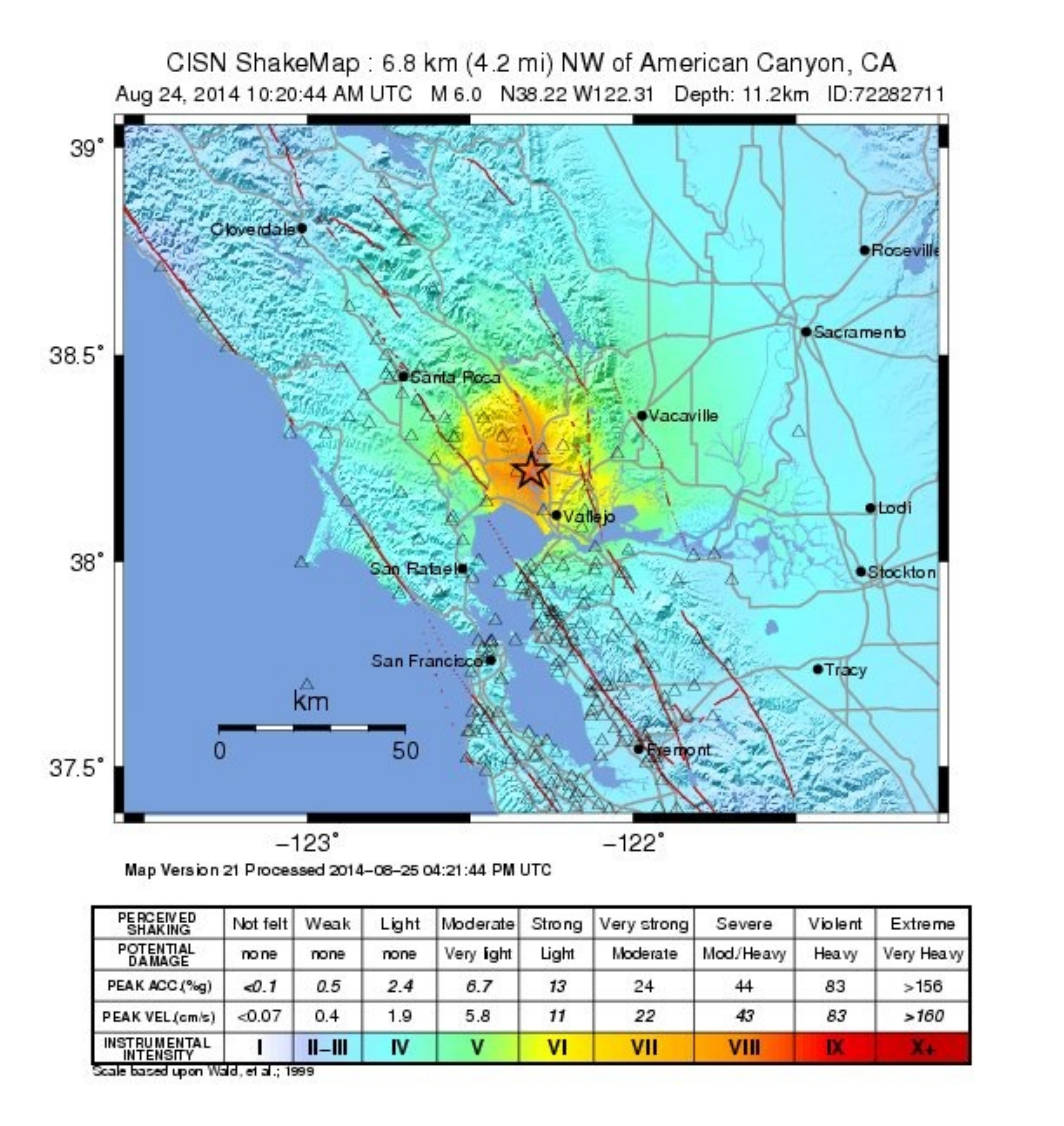


Shear Strains Recorded by B018, Washington

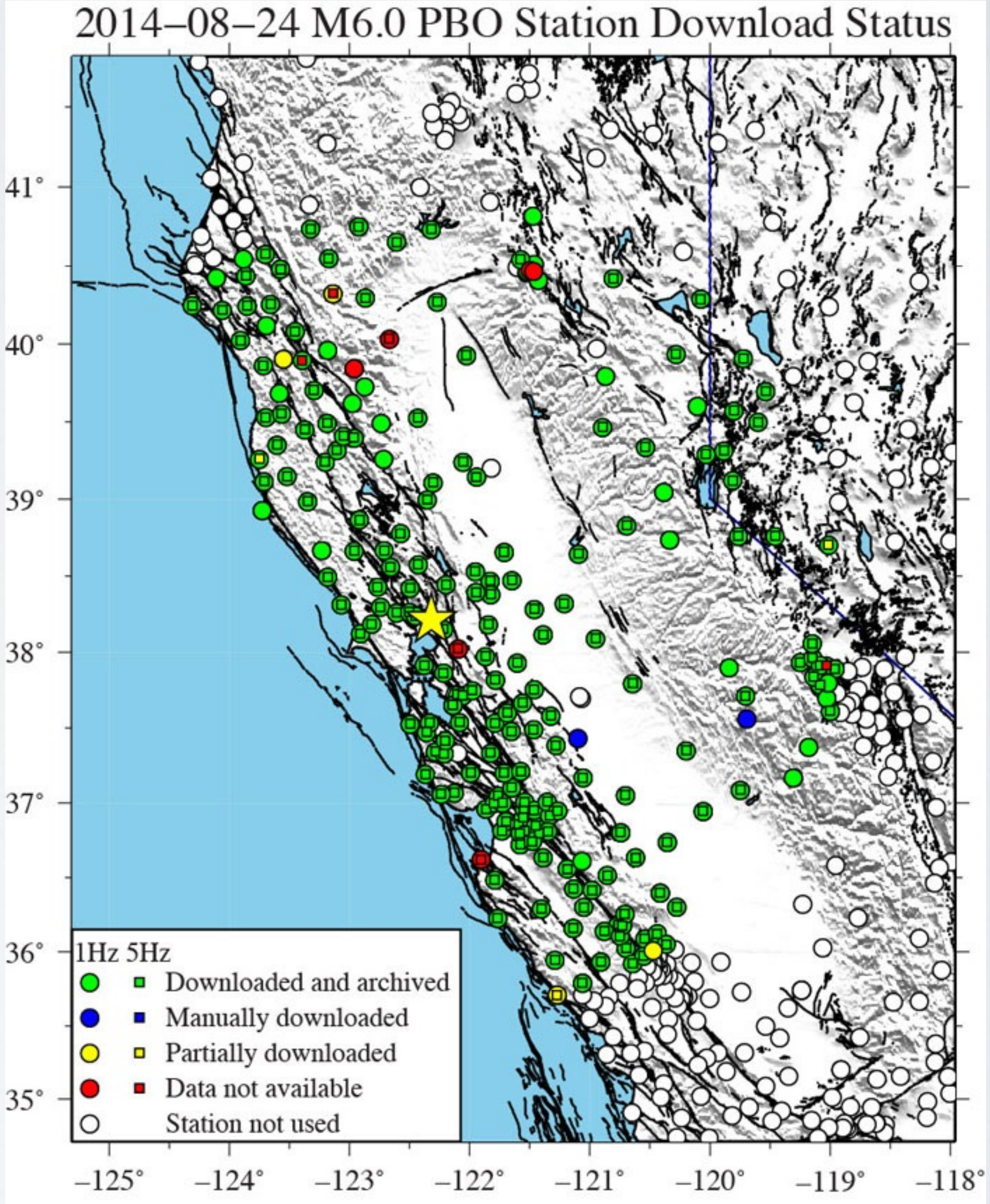


From Hodgkinson et al., 2014 (GSA)

PBO ASSETS IN ACTION: SOUTH NAPA M6 - 24 AUG 14

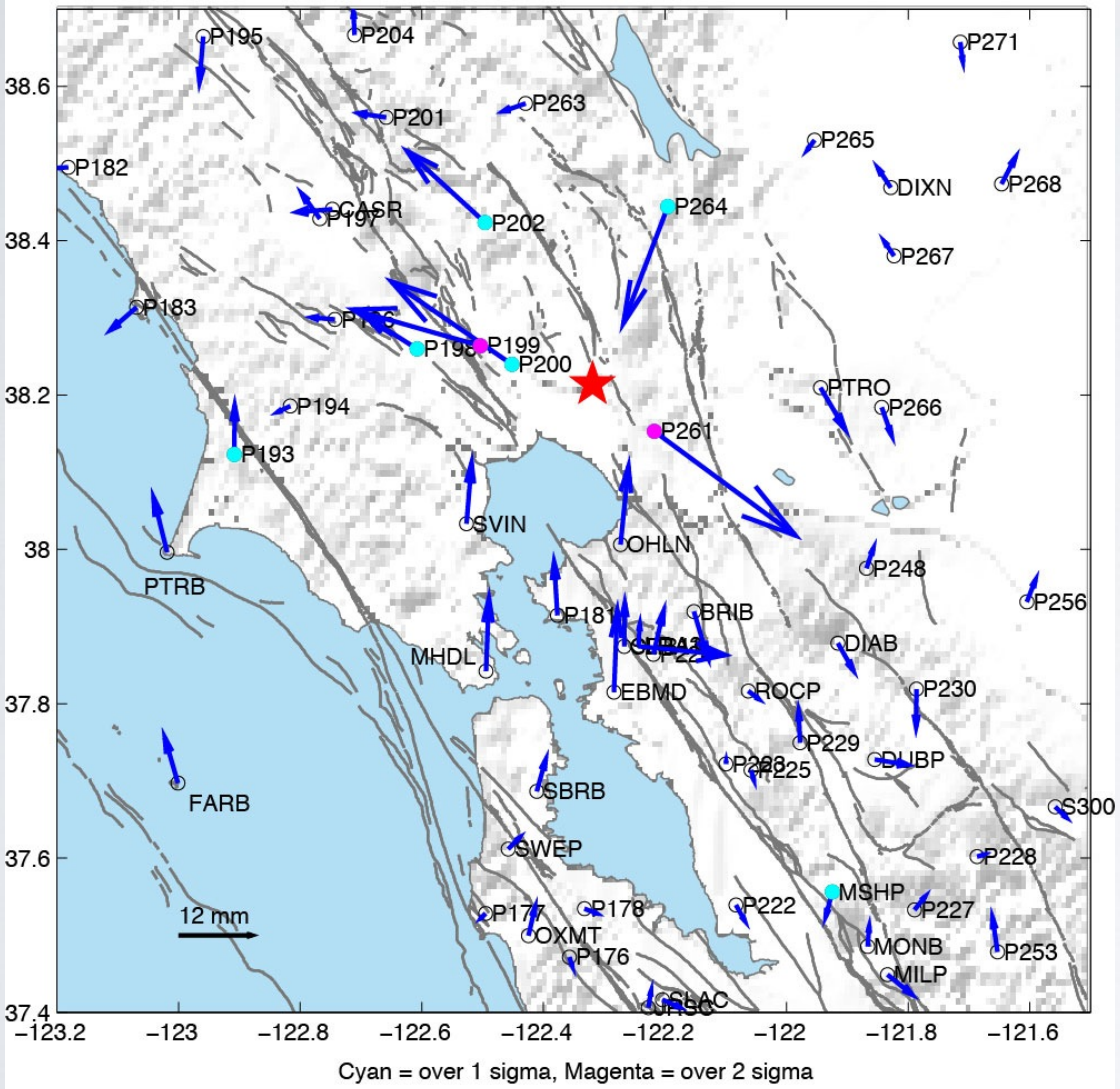


PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.1	0.5	2.4	6.7	13	24	44	83	>156
PEAK VEL.(cm/s)	<0.07	0.4	1.9	5.8	11	22	43	83	>160
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+



PBO ASSETS IN ACTION: SOUTH NAPA M6 - 24 AUG 14

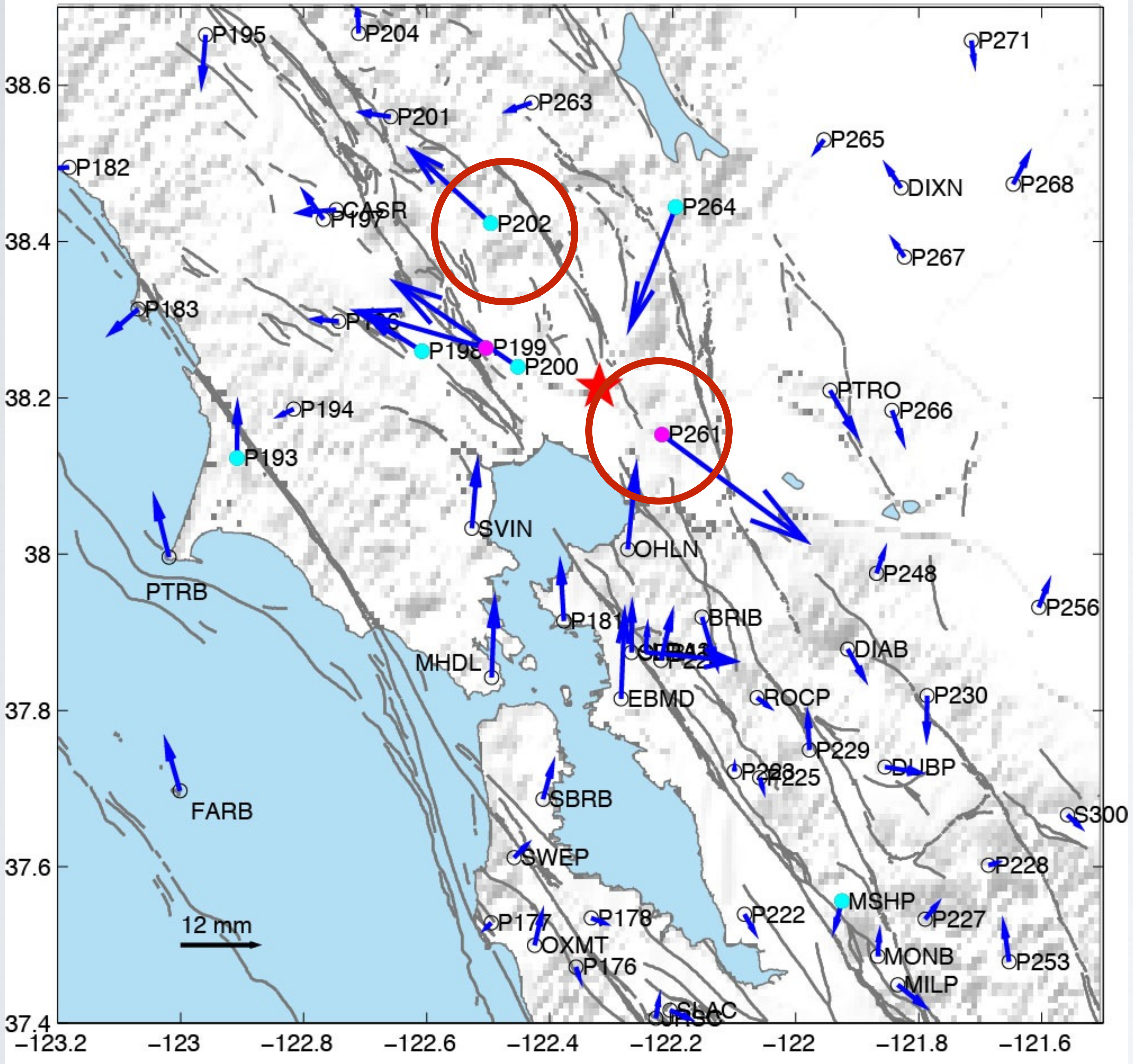
PBO ASSETS IN ACTION: SOUTH NAPA M6 - 24 AUG 14



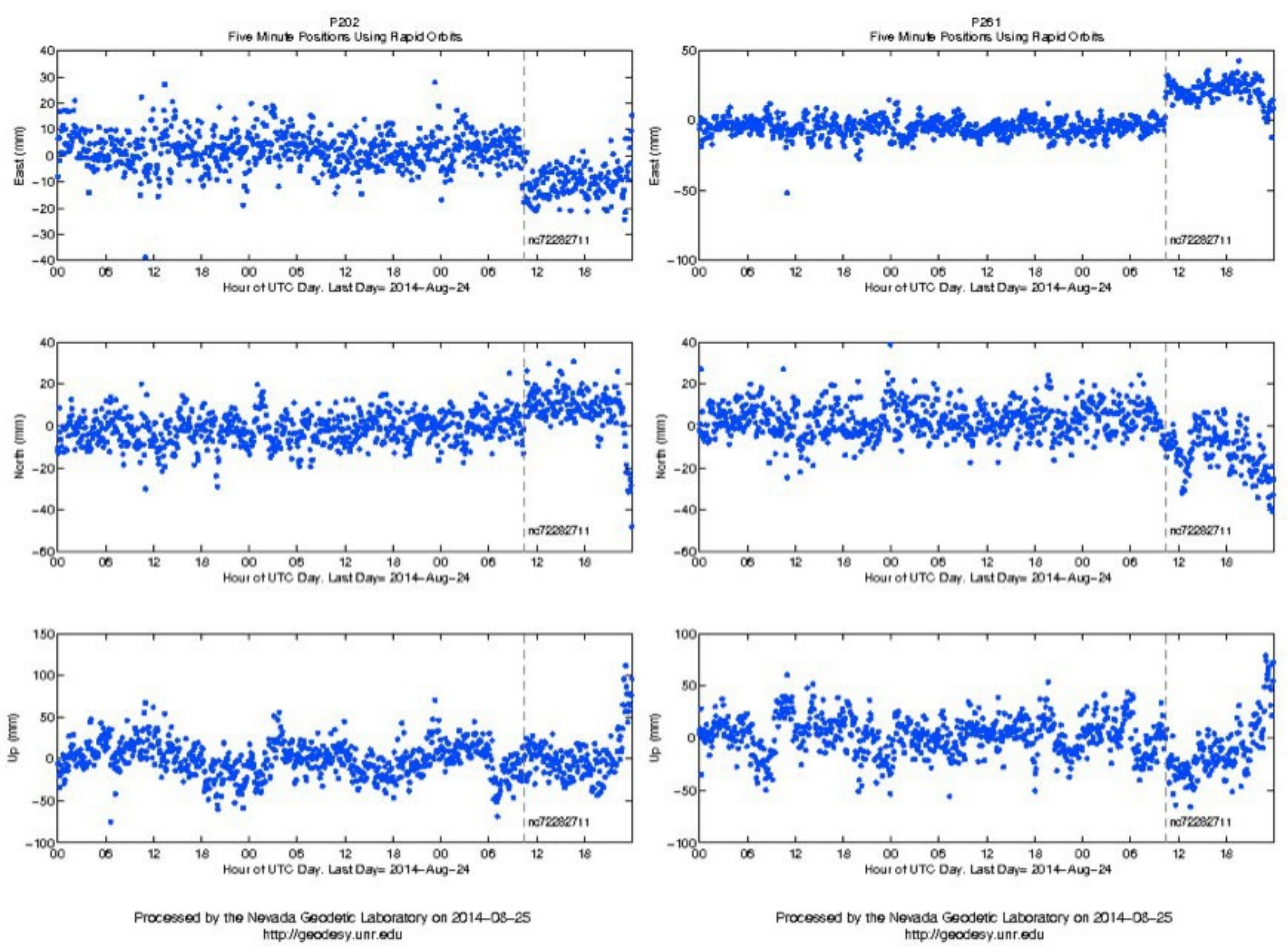
Coseismic cGPS - UNR

PBO ASSETS IN ACTION: SOUTH NAPA M6 - 24 AUG 14

Coseismic cGPS - UNR 5 m solutions

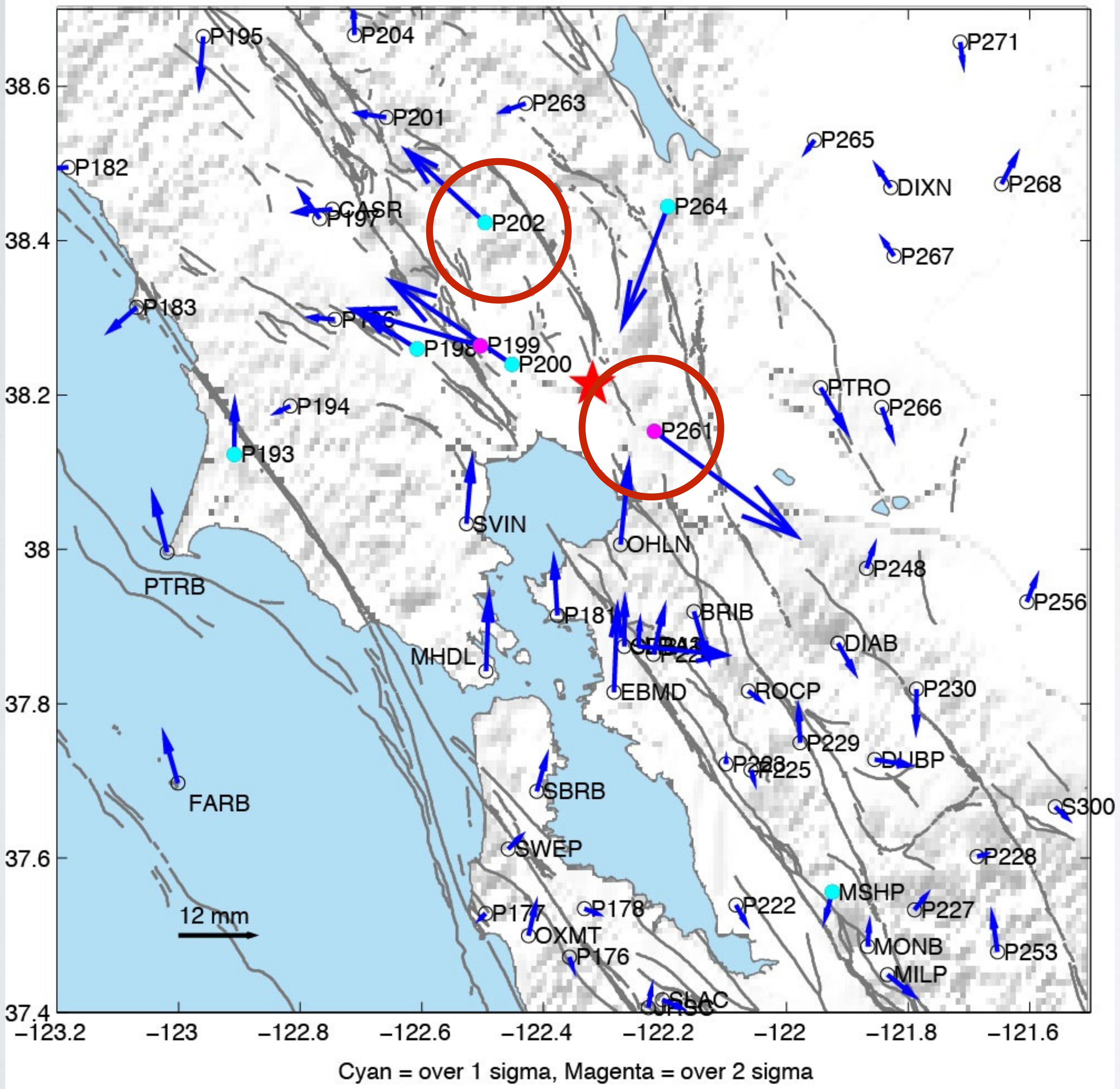


Cyan = over 1 sigma, Magenta = over 2 sigma



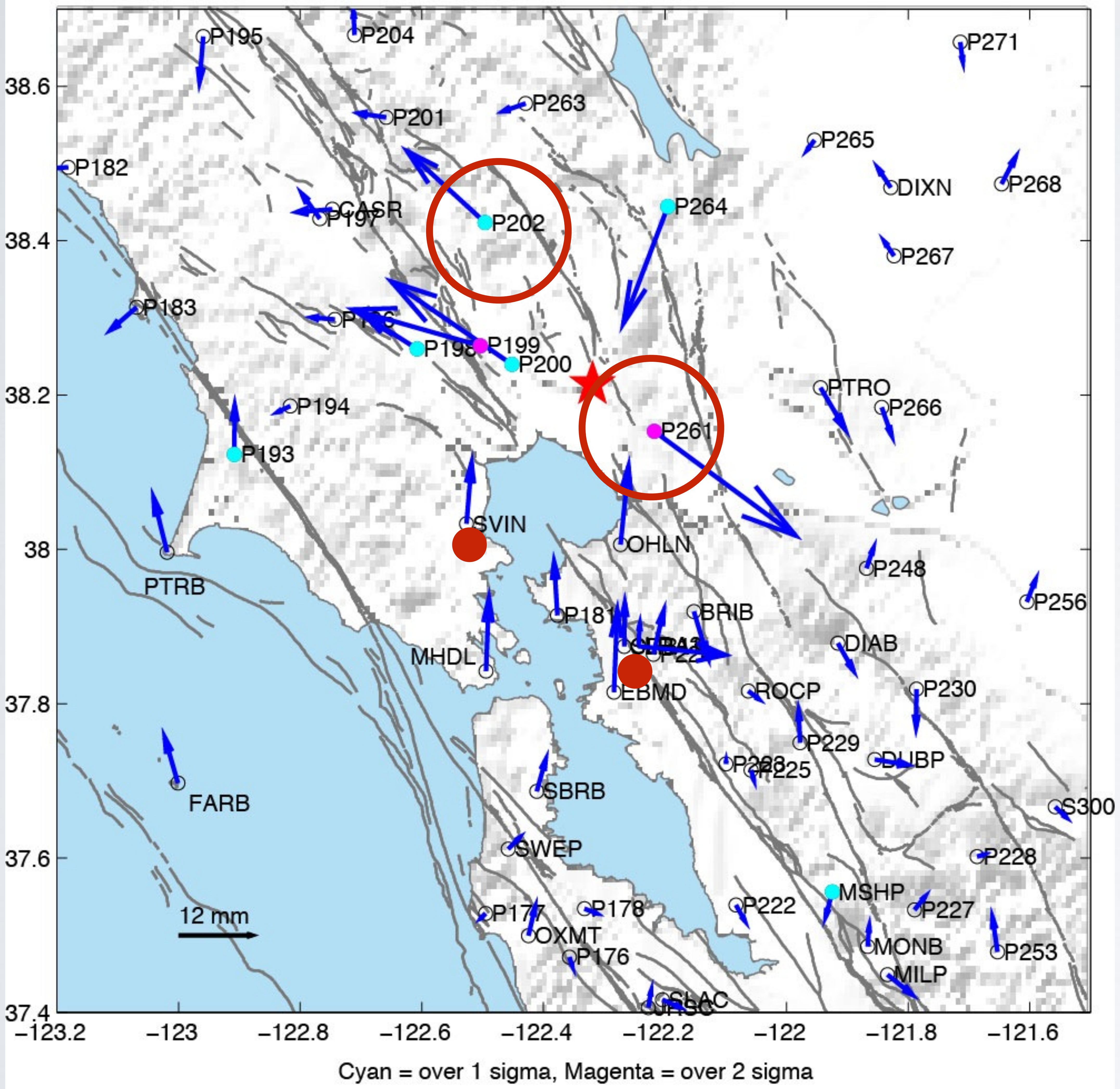
Coseismic cGPS - UNR

PBO ASSETS IN ACTION: SOUTH NAPA M6 - 24 AUG 14

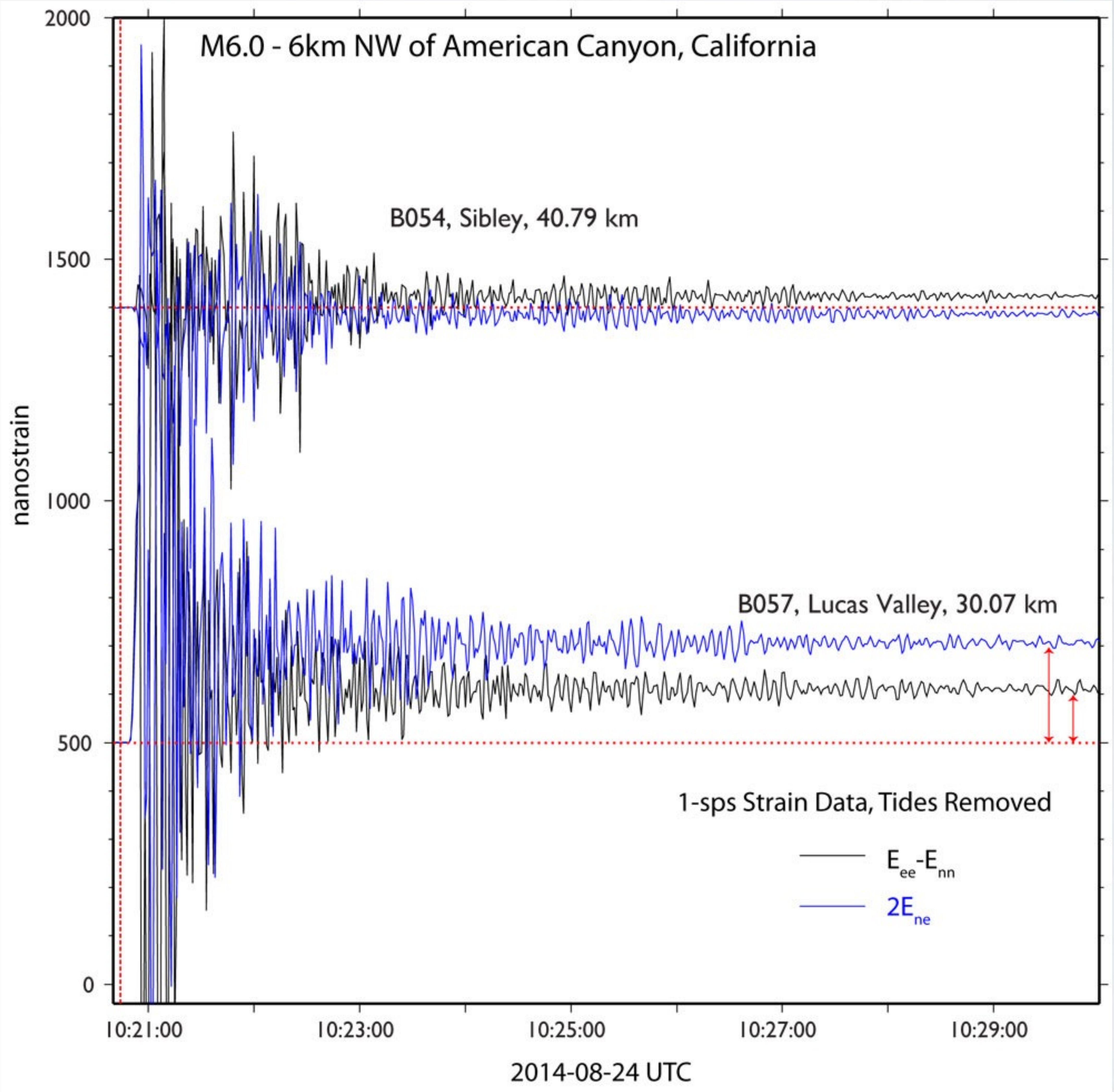


Coseismic cGPS - UNR

PBO ASSETS IN ACTION: SOUTH NAPA M6 - 24 AUG 14

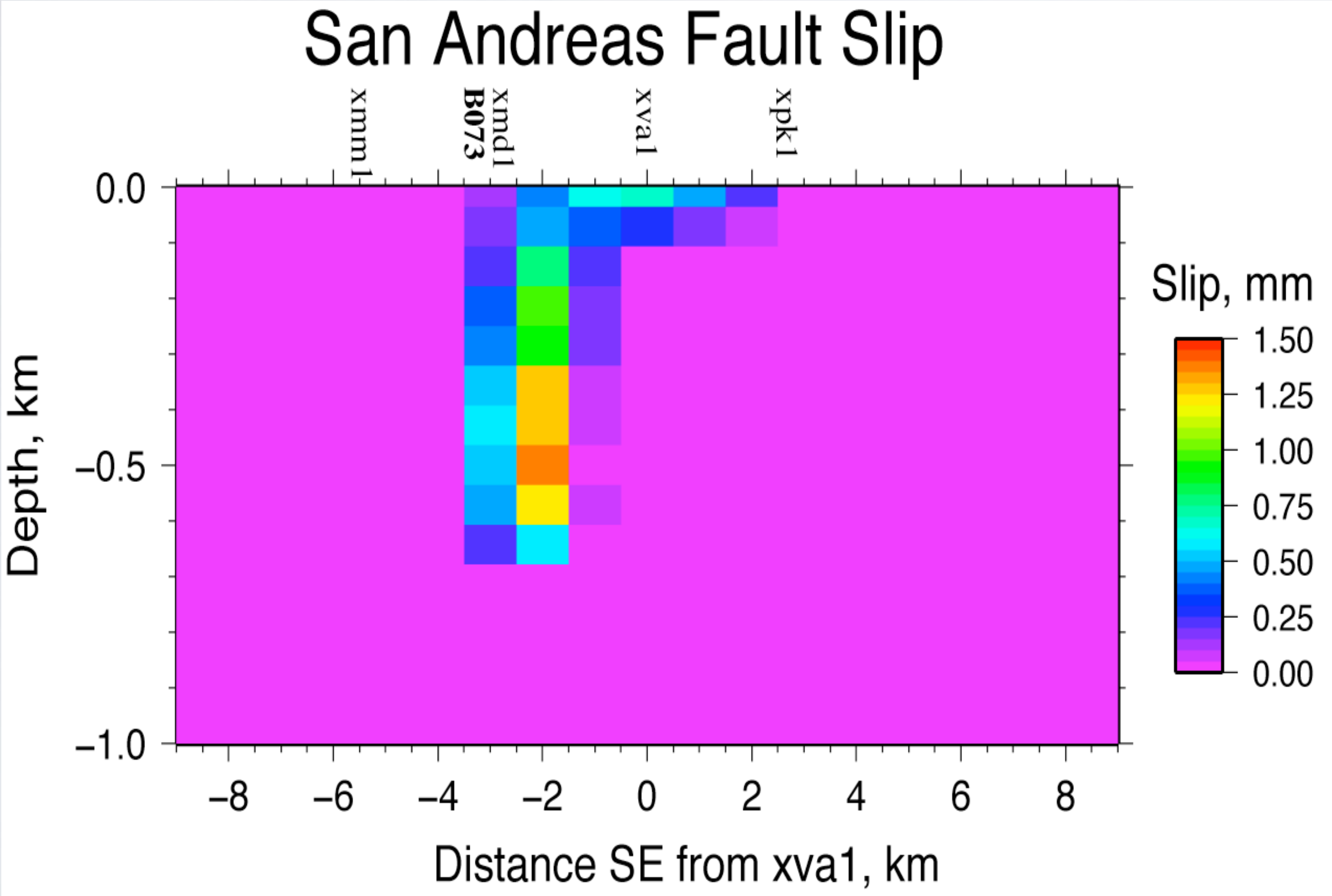


Coseismic cGPS - UNR



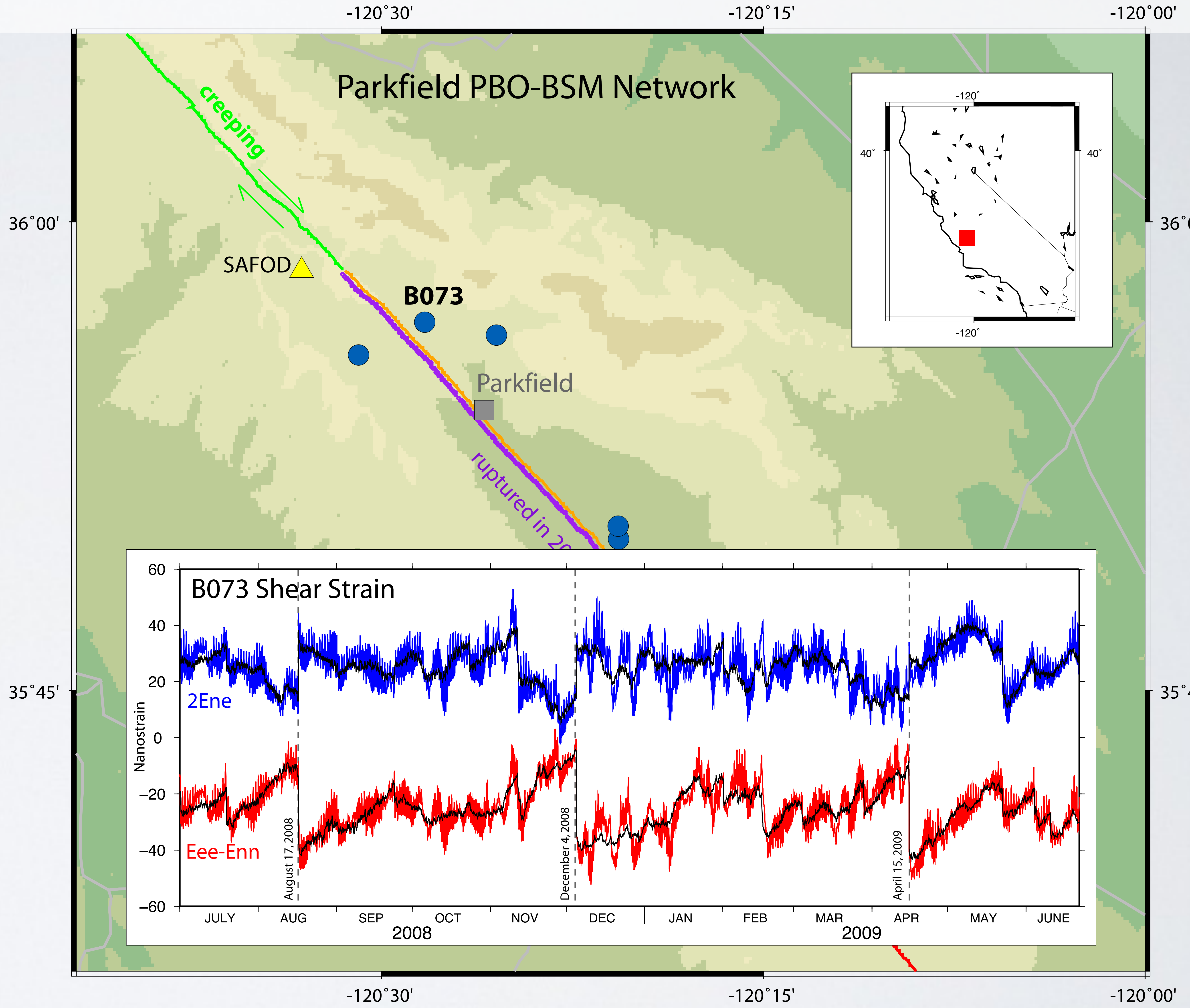
Coseismic BSM

OBSERVATION OF SMALL TRANSIENT CREEP EVENTS ON SAF



A cross-section of the fault centered on the creepmeter at xva1 and looking at the fault from the SouthWest. The location of USGS creepmeters xmm1, xmd1, xva1 and xpk1 and PBO strainmeter B073 are shown for reference.

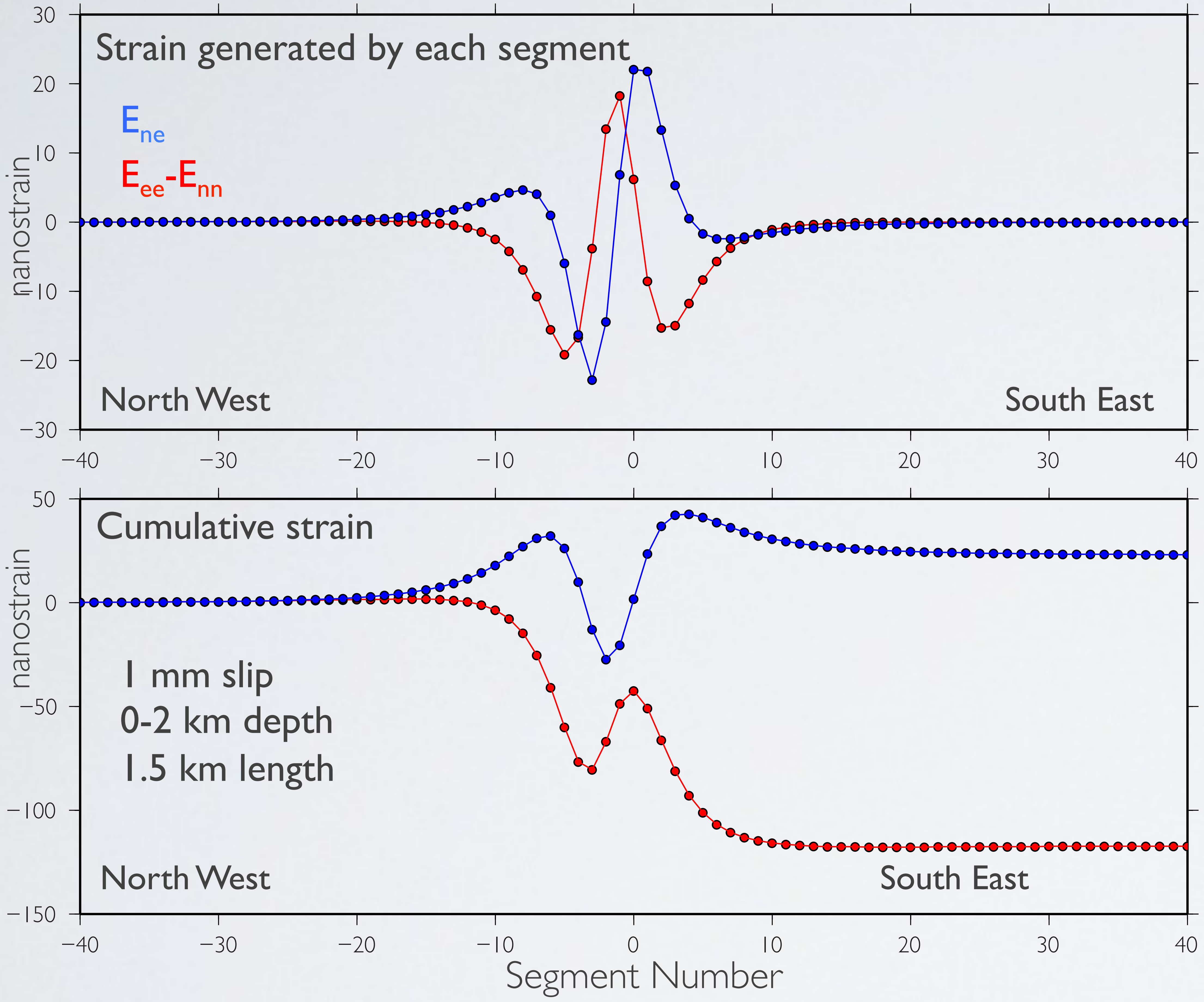
Inversion from John Langbein, 2009, Personal Communications



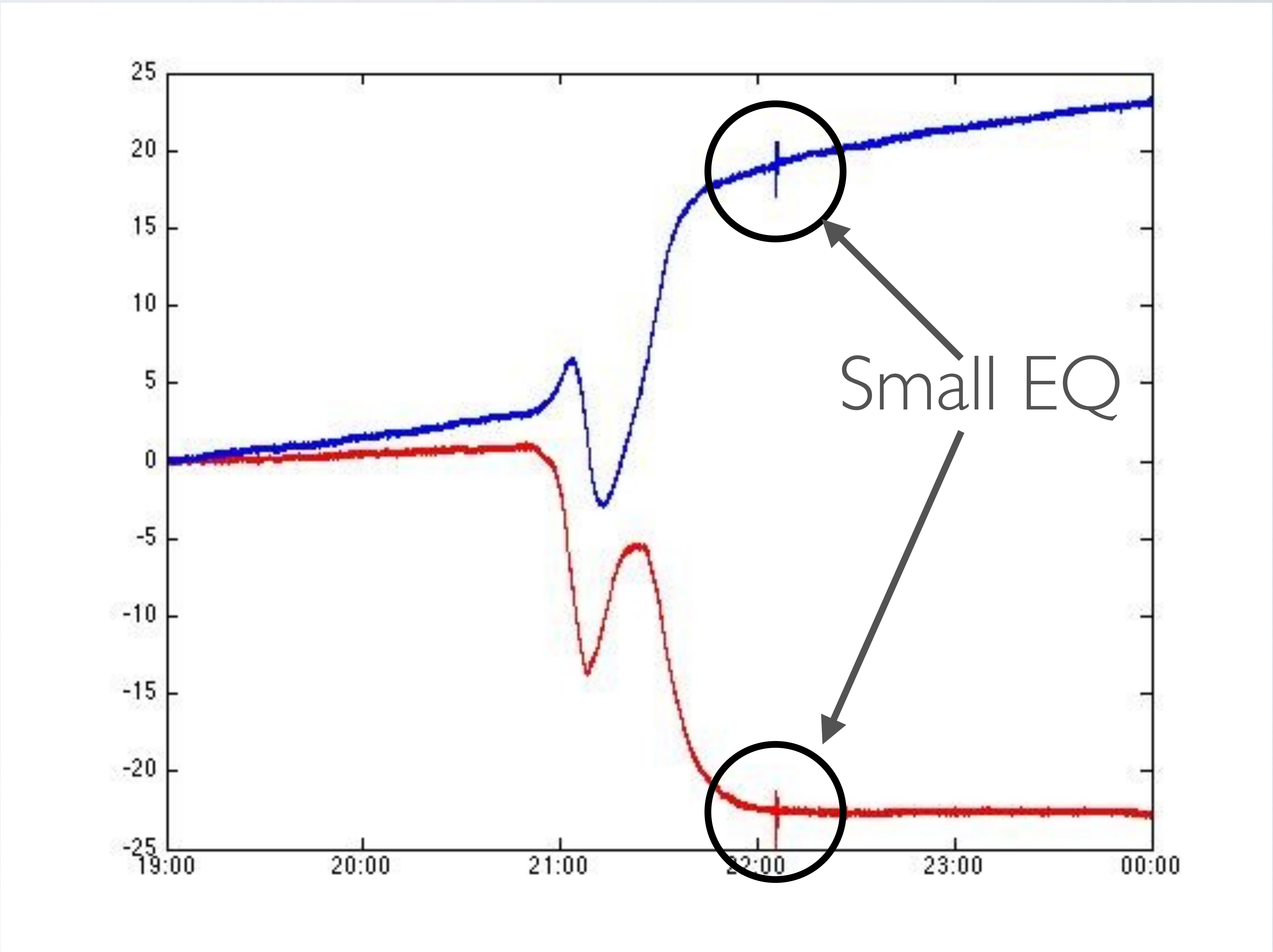
From D. Mencin (pers. comm., 2014)

UNAVCO

PRELIMINARY MODEL FOR TRANSIENT CREEP EVENTS ON SAF



Model data based on Okada (1992) data is normalized in length



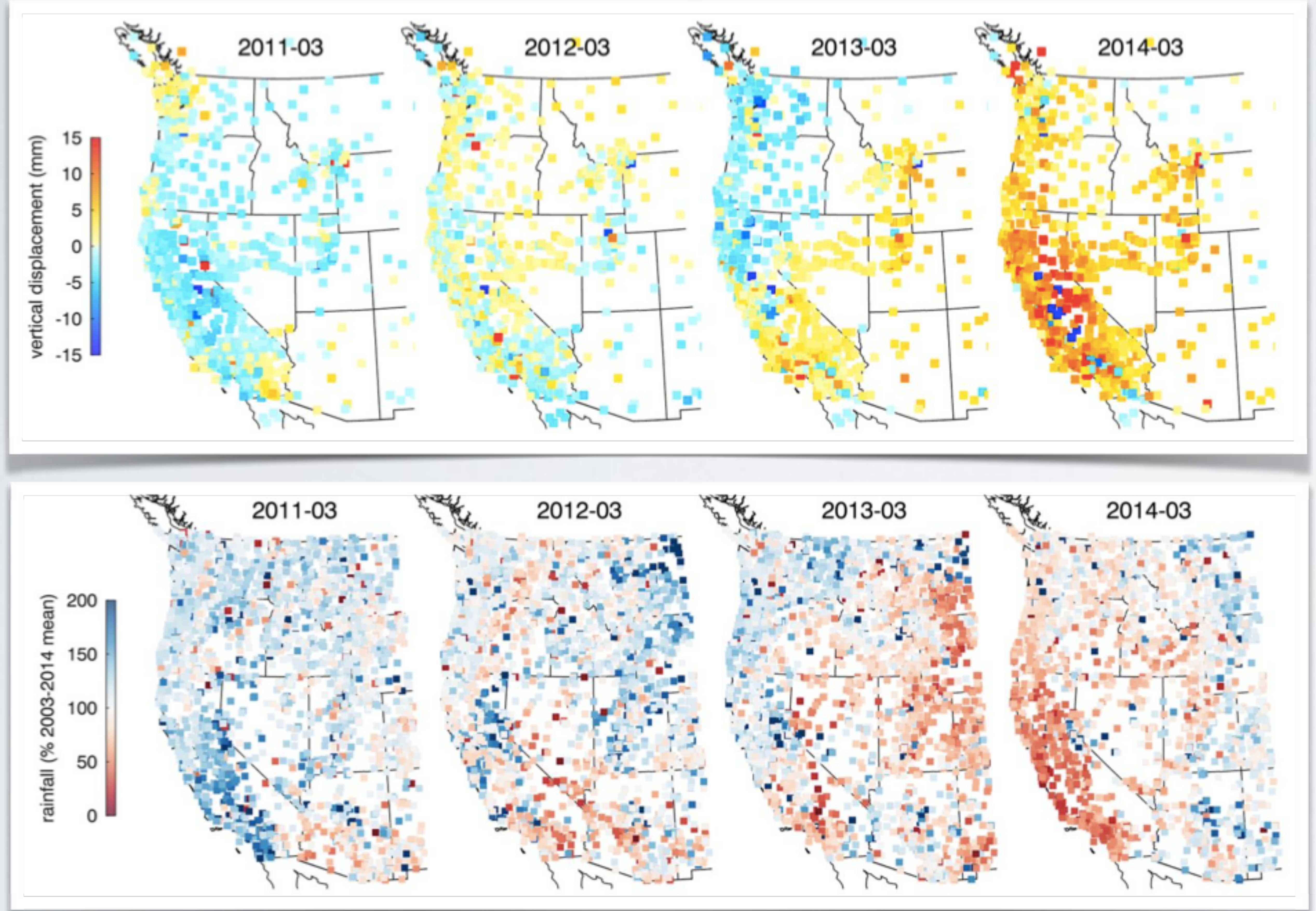
Observational Data

From D. Mencin (pers. comm., 2014)

UNAVCO

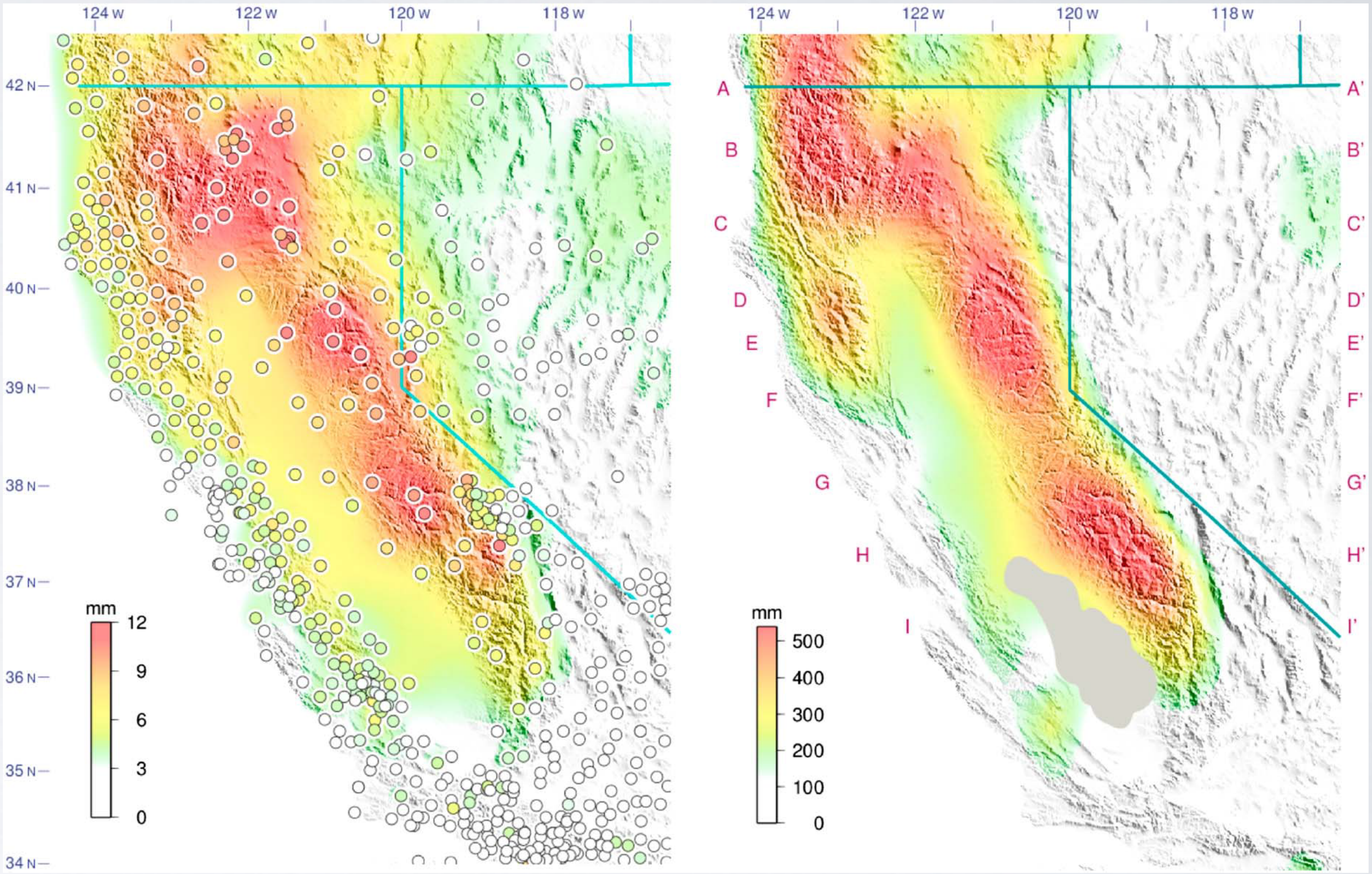
ONGOING DROUGHT-INDUCED UPLIFT IN THE WESTERN US

Borsa et al., Science, 2014

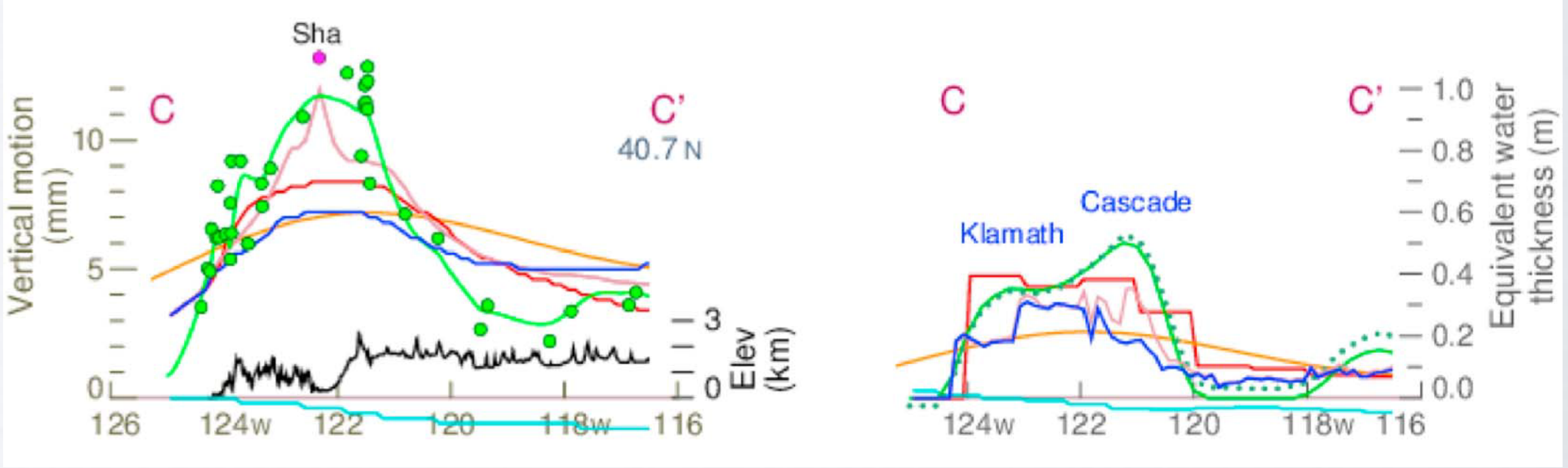


- GPS vertical 2011 - 2014
- vertical inter-annual variable
- detrended & seasonal load (SLT) removed
- widespread uplift reflects water loss
- March 2014: 240 GT water deficit
- =10 cm water over entire W. USA

Argus et al., GRL, 2014



GPS
GRACE
NLDAS
GLDAS



MULTI-HAZARDS OBSERVATORIES: COCONET

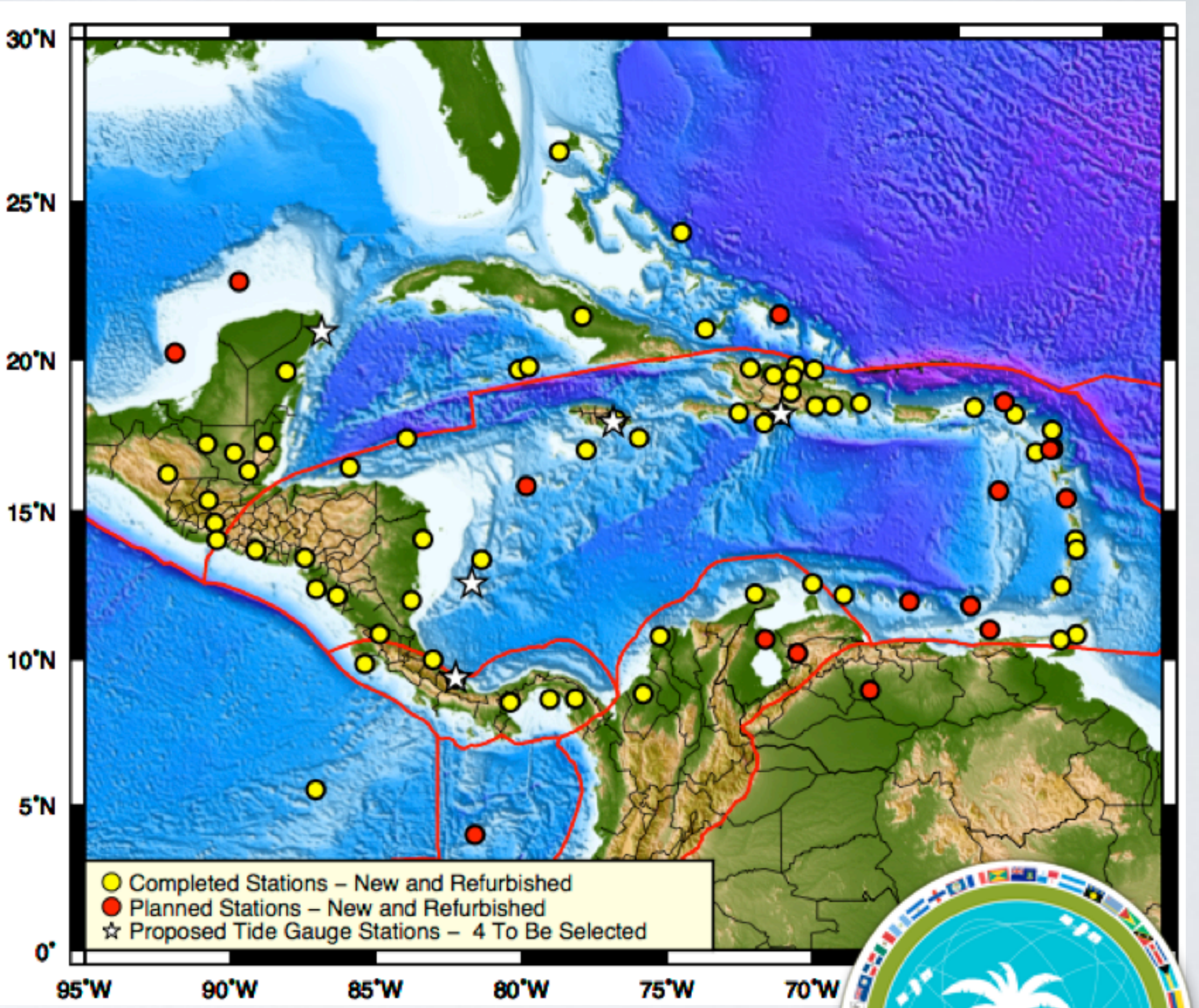
100+ cGPS and meteorology stations in the circum-Caribbean:

>70 existing international stations to be included in data products

>60 new or upgraded stations to provide a regional kinematic framework **(yellow dots)**

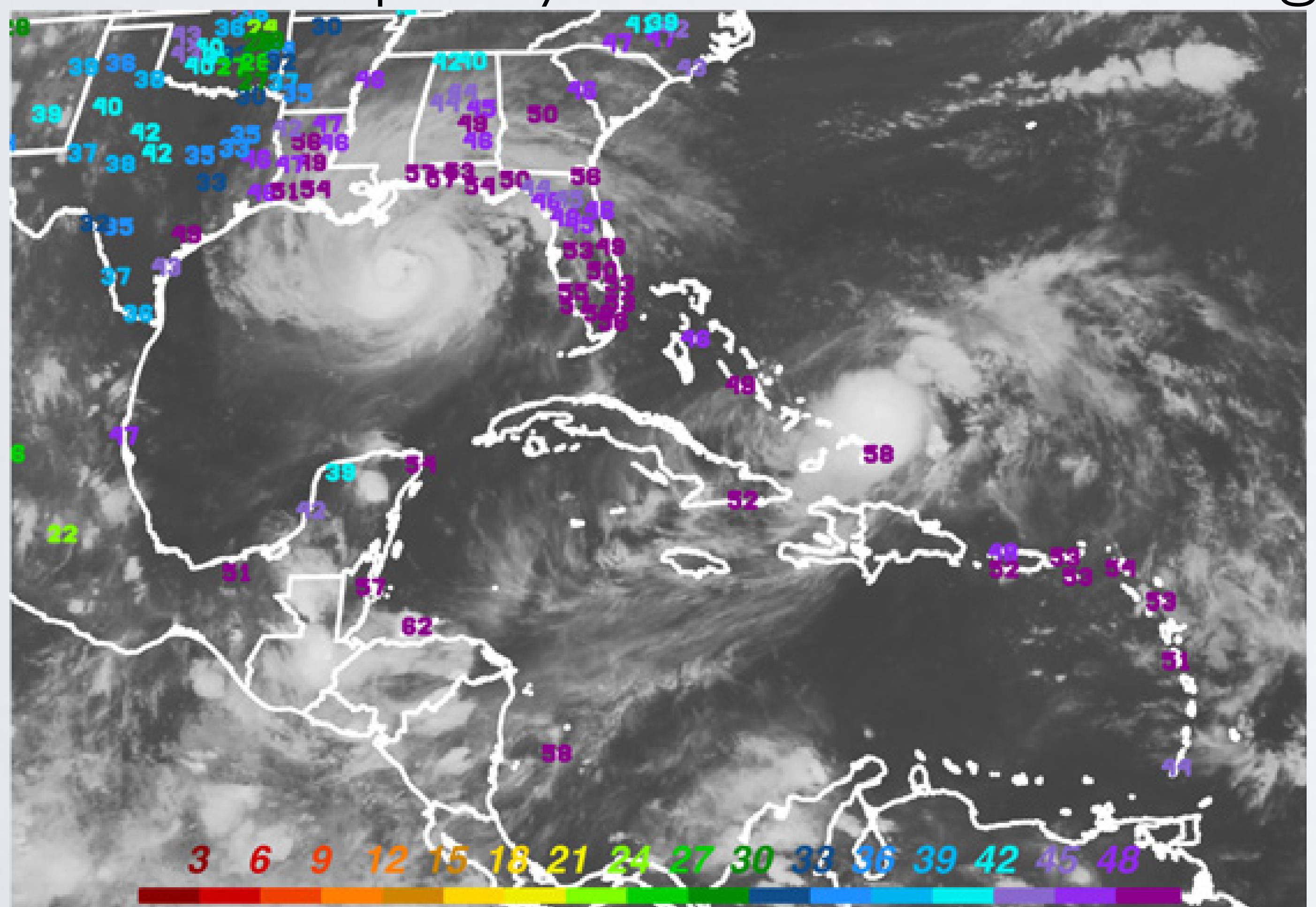
~16 stations remain to be refurbished and upgraded **(red dots)**

Co-located tide gages at 2 supersites and 2 upgraded sites



Science and impact goals:

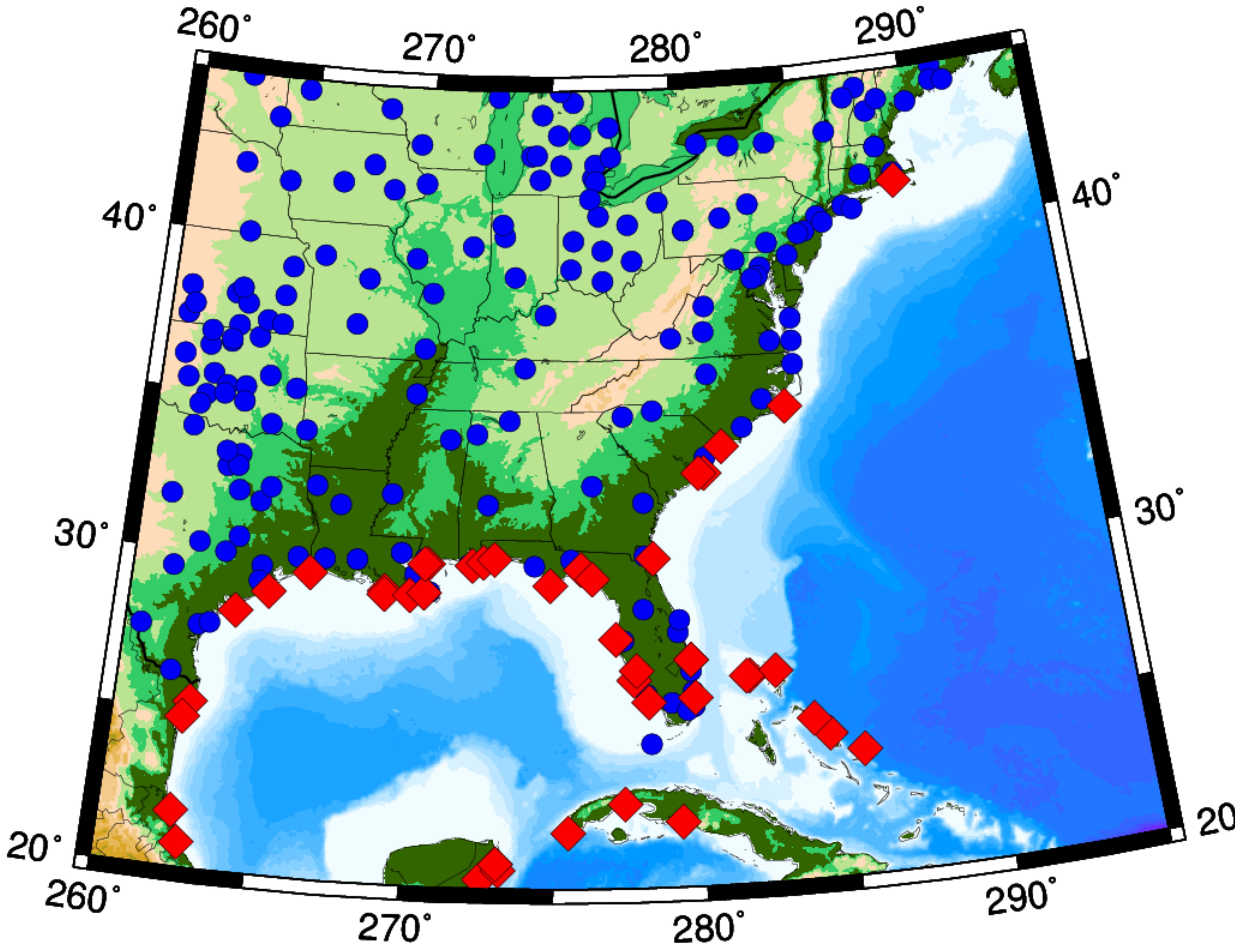
- Caribbean plate motions
- Earthquake and tsunami hazards
- Hurricane intensity and track forecasting
- Regional framework for studies of specific faults and volcanoes
- Shared capacity for disseminated regional archives

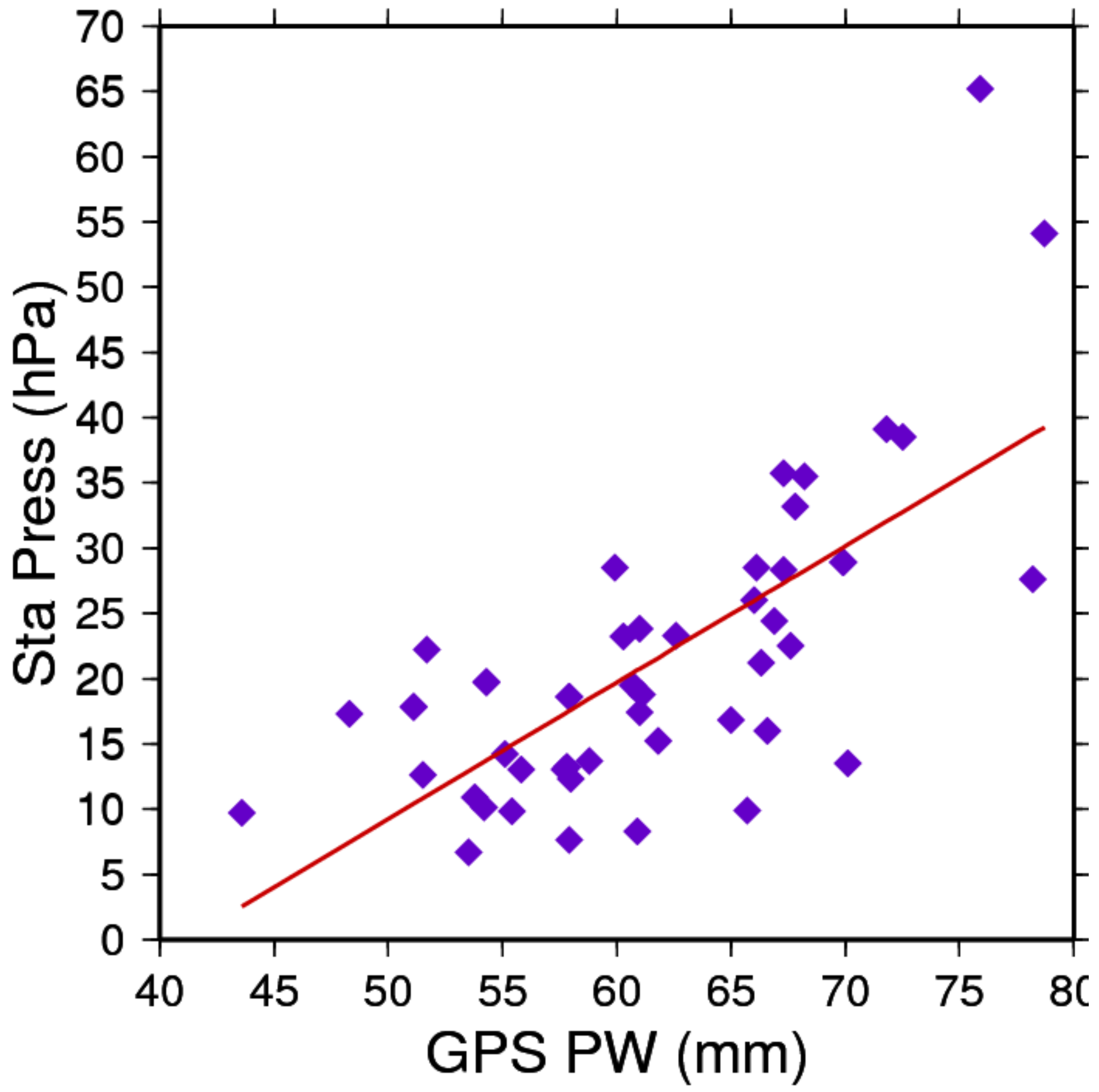


UNAVCO · UNIVERSITY OF HOUSTON · UCAR UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH · NSF · COCONet CONTINUOUSLY OPERATING CARIBBEAN GPS OBSERVATIONAL NETWORK

COCONET: ATMOSPHERIC PROCESSES

What is the impact of continuous estimates of PW on hurricane intensity forecasts?



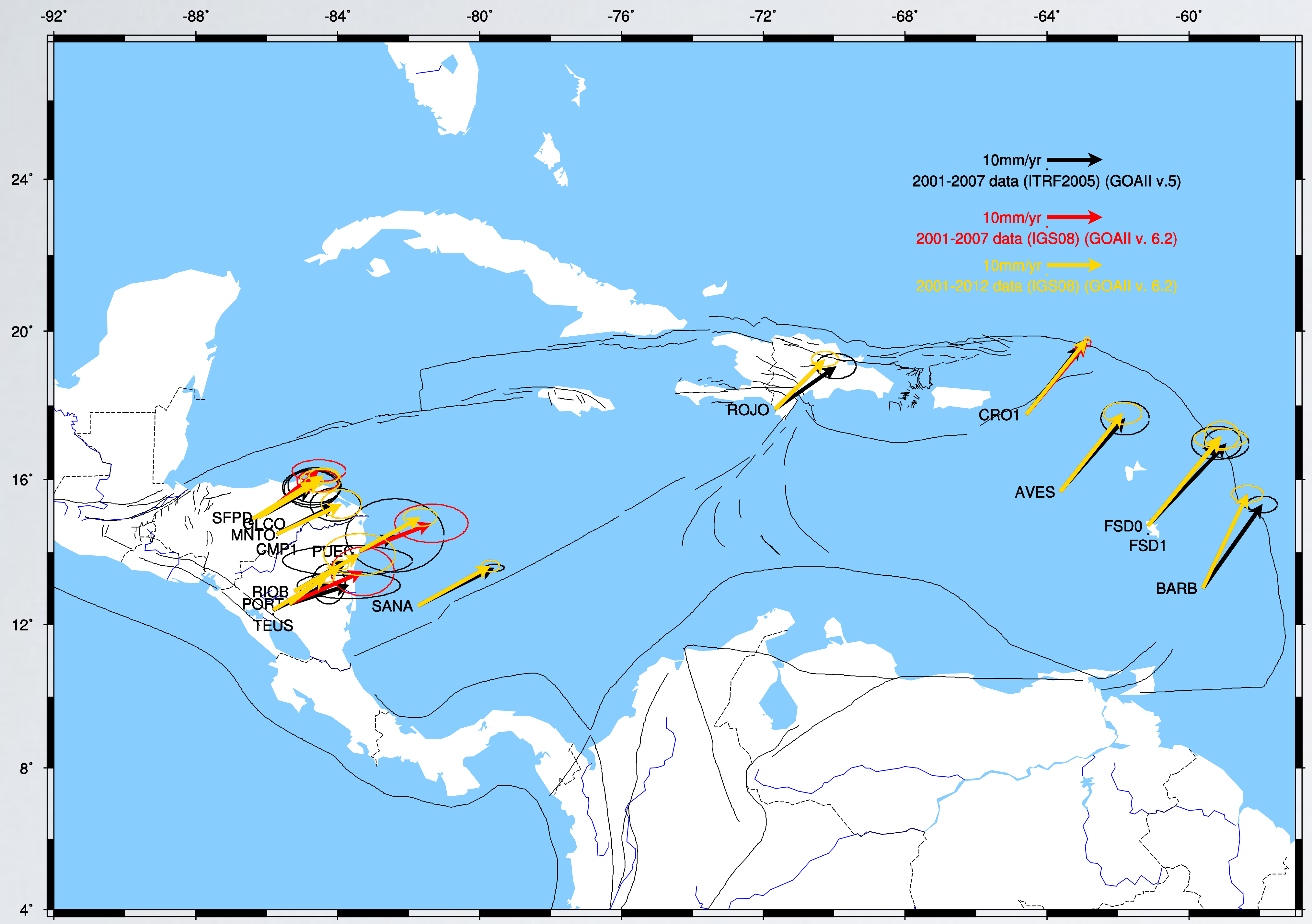


Figures from J. Braun, UCAR

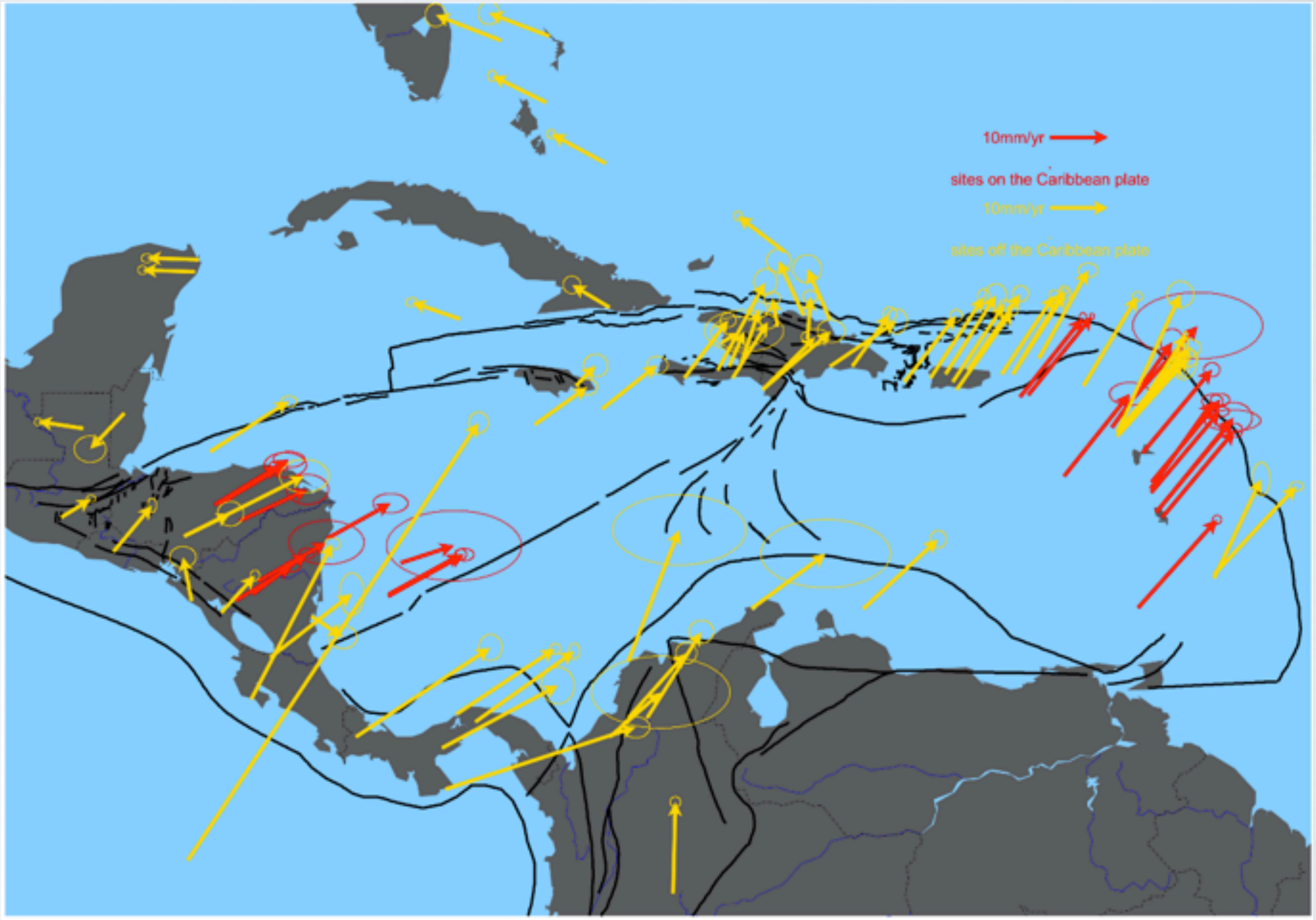
The map shows GPS stations (in blue) and locations of hurricane landfall (in red). The scatterplot shows the correlation between GPS-derived PW and drop in surface pressure (1013 - Surf_Press) for stations within 200 km of hurricane landfall.

The correlation between PW and surface pressure is -0.71. This high correlation suggests that GPS PW can be used to improve intensity forecasts in numerical weather models.

CARIBBEAN KINEMATICS FROM EGPS AND COCONET



From Miller (2013, PhD, UTA) updated velocities of Demets et al., 2007 in IGS08

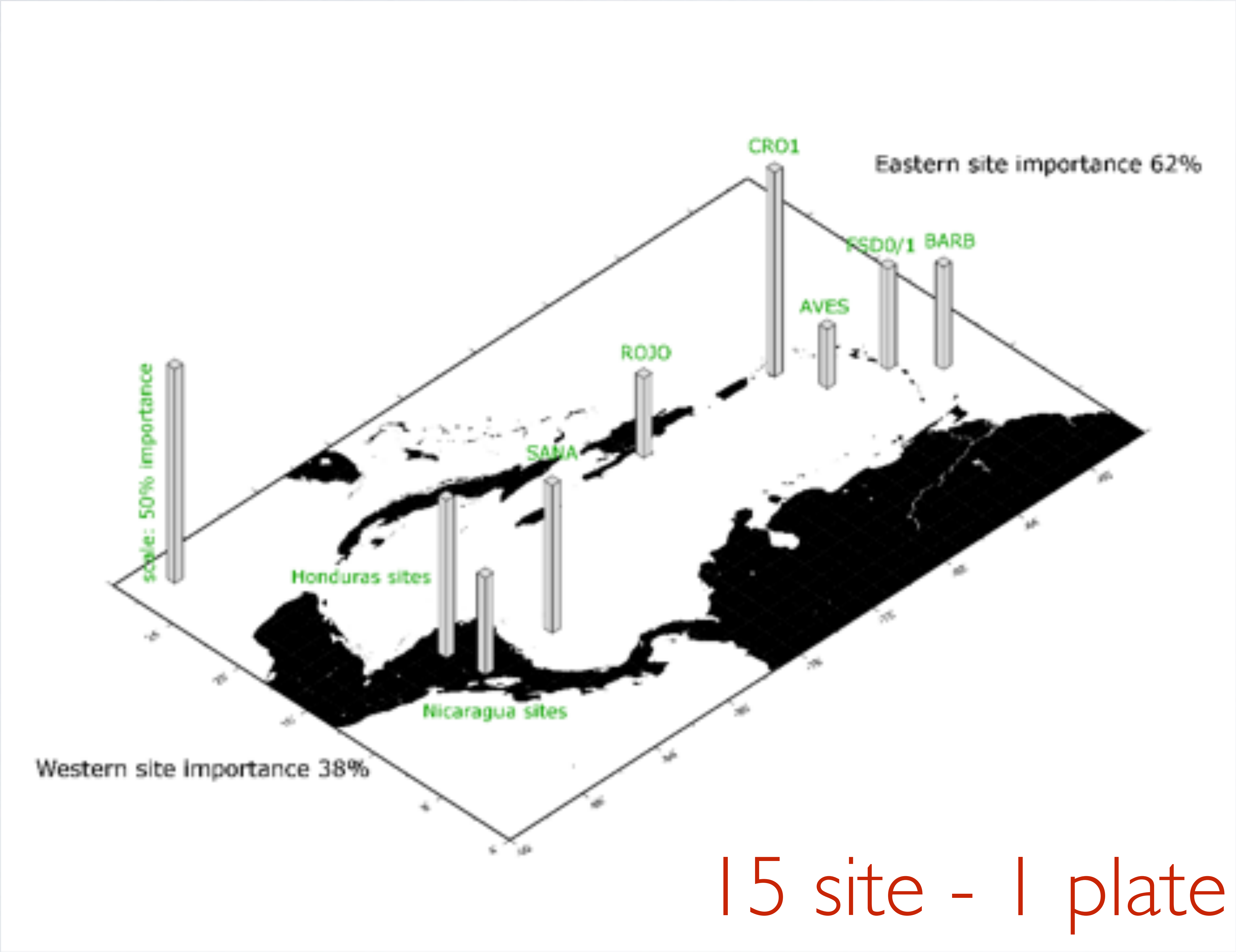


From Miller (2013, PhD, UTA)

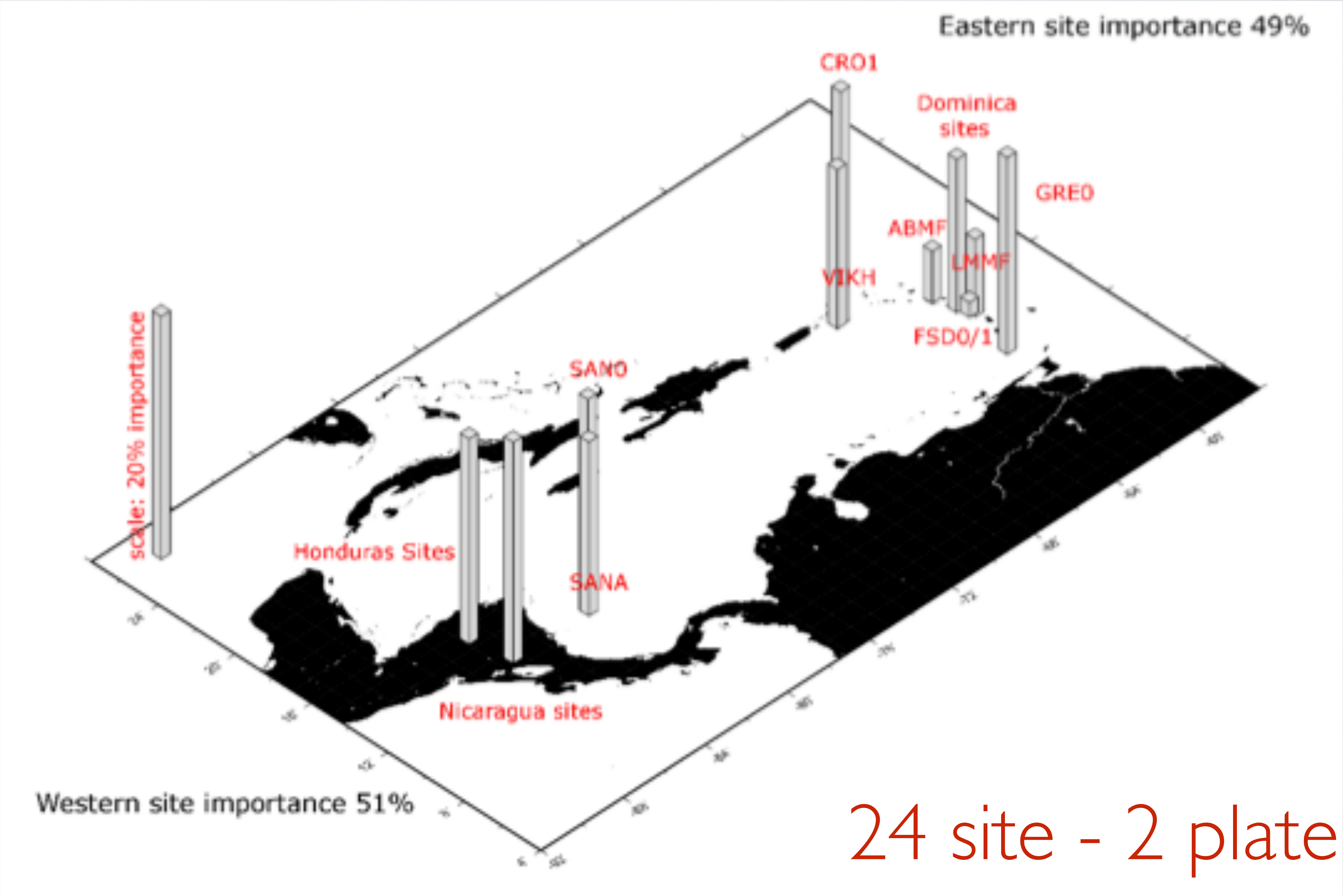
UNIVERSITY OF TEXAS ARLINGTON

CARIBBEAN KINEMATICS FROM EGPS AND COCONET

Demets et al., 2007 updated to IGS08

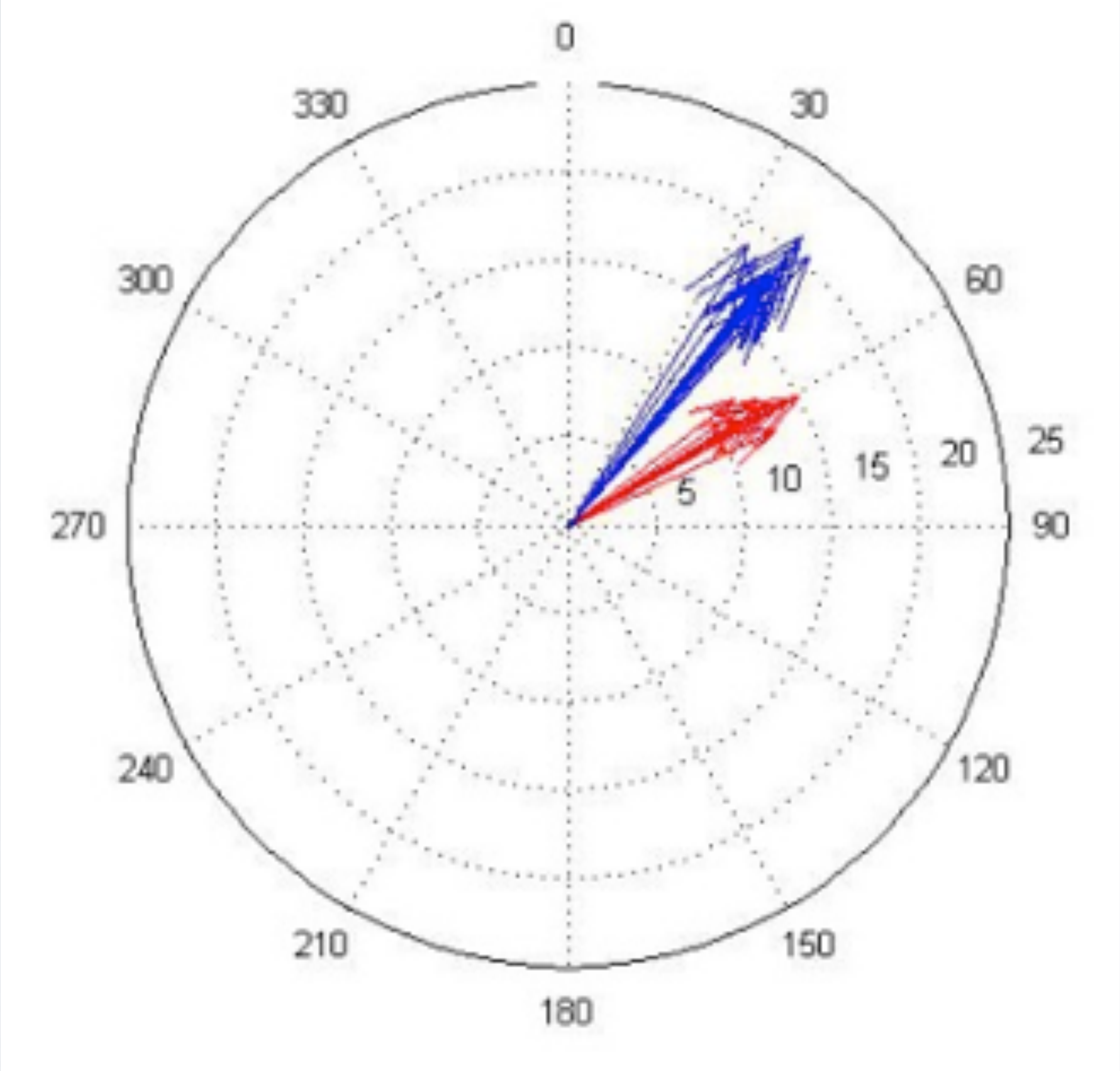


Updated single CAR plate with COCONet data

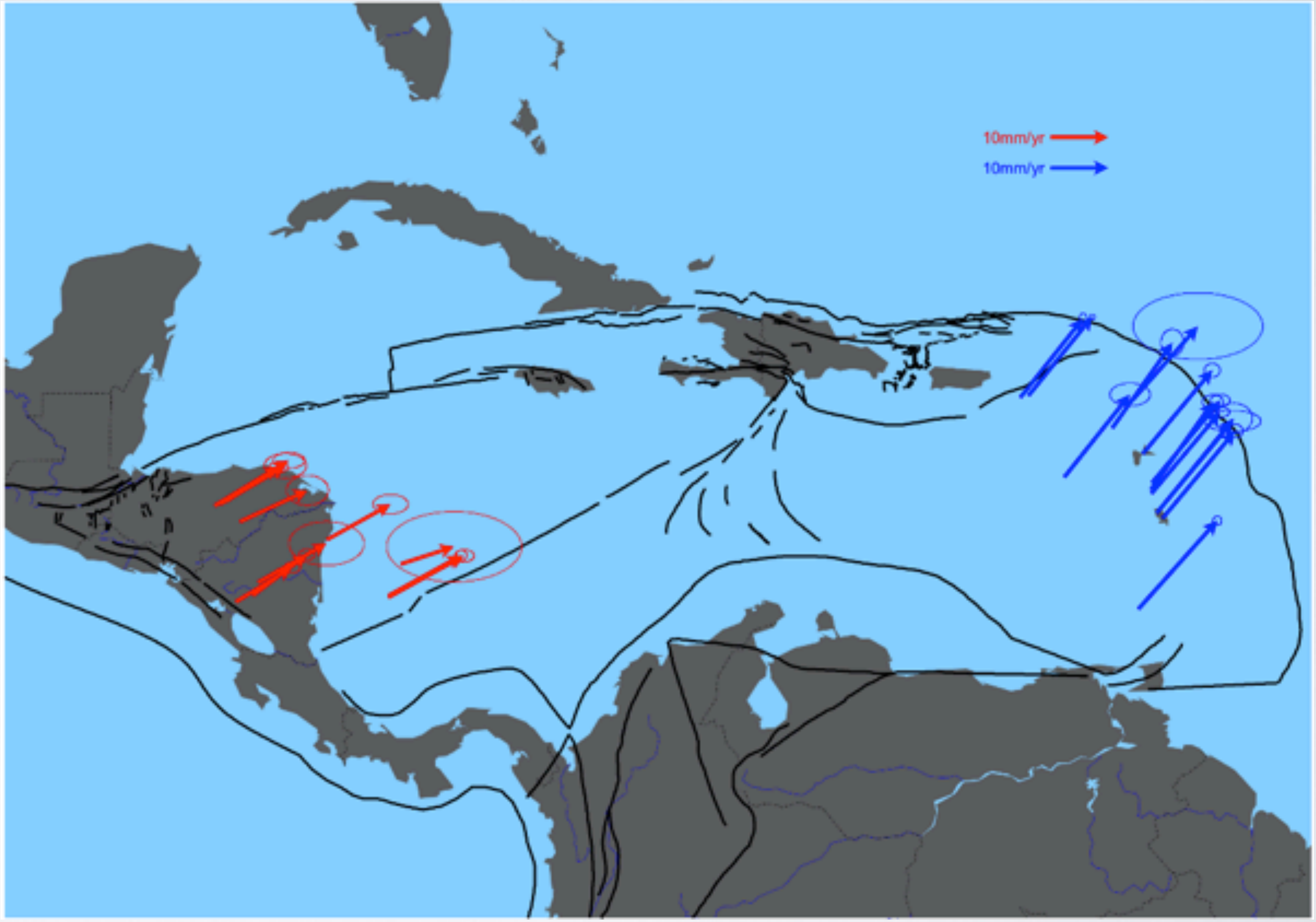


From Miller (2013, PhD, UTA)

CARIBBEAN KINEMATICS FROM EGPS AND COCONET



Clearly different motion for western and eastern CAR…



From Miller (2013, PhD, UTA)

UNAVCO

MULTI-HAZARDS OBSERVATORIES: TLALOCNET

Plan for 120 new cGPS and meteorology stations in the Mexico:

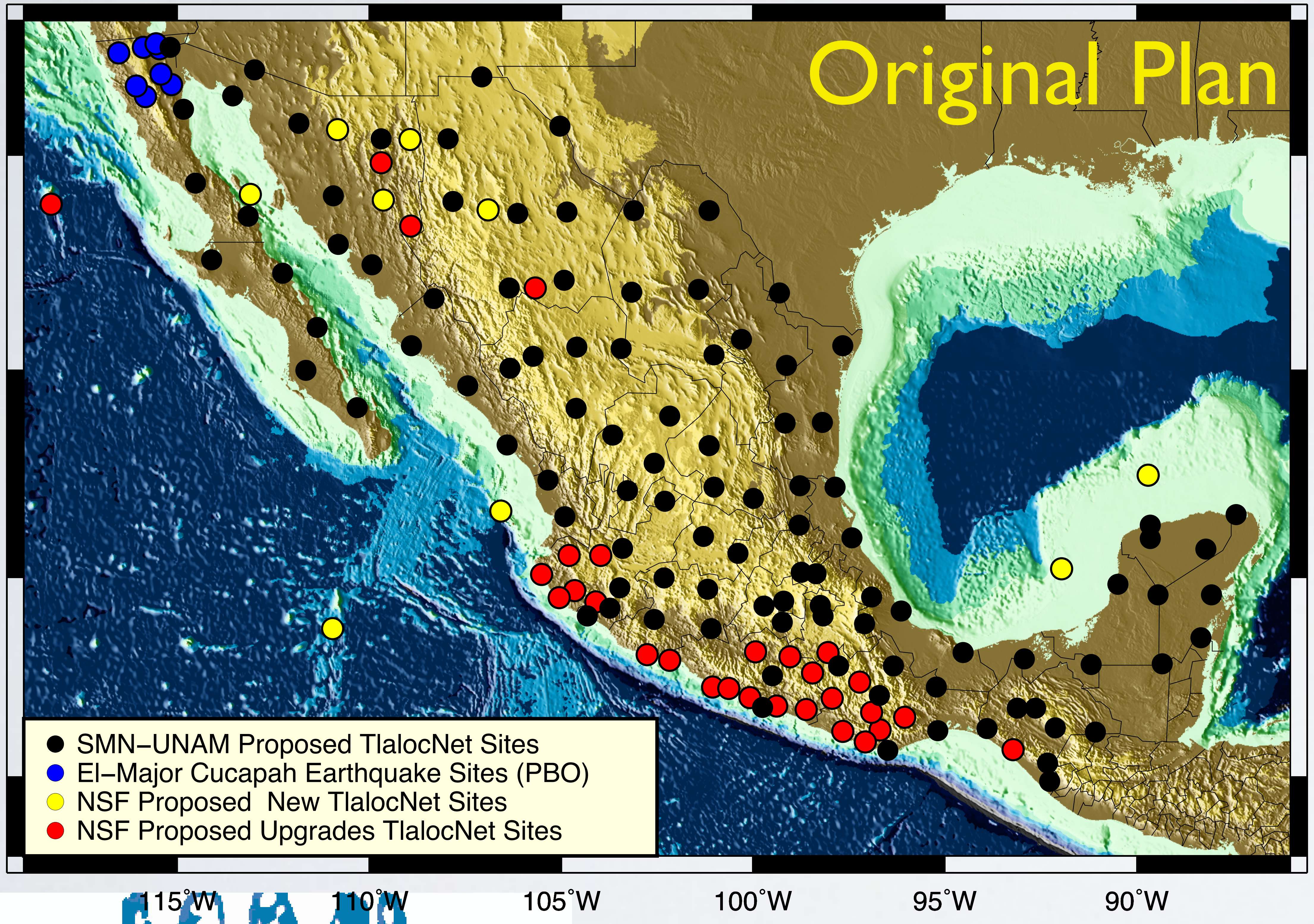
100 cGPS stations to be collocated with SMN weather observatories
existing stations refurbished and upgraded for telecommunications
possible select new cGPS stations for science enhancements

Science and impact goals:

- North America Monsoon studies
- Weather and climate
- Regional framework for studies of specific faults and volcanoes
- Earthquake cycle deformation including episodic tremor and slip (ETS)
- Earthquake hazards - subduction zone

TLALOC net

MULTI-HAZARDS OBSERVATORIES:TLALOCNET



Plan for120 new cGPS and meteorology stations in the Mexico:

100 cGPS stations to be collocated with SMN weather observatories

existing stations refurbished and upgraded for telecommunications

possible select new cGPS stations for science enhancements

Science and impact goals:

- North America Monsoon studies
- Weather and climate
- Regional framework for studies of specific faults and volcanoes
- Earthquake cycle deformation including episodic tremor and slip (ETS)
- Earthquake hazards - subduction zone

TLALOC net

UNAVCO

MULTI-HAZARDS OBSERVATORIES: TLALOCNET

Plan for 120 new cGPS and meteorology stations in the Mexico:

100 cGPS stations to be collocated with SMN weather observatories

existing stations refurbished and upgraded for telecommunications

possible select new cGPS stations for science enhancements

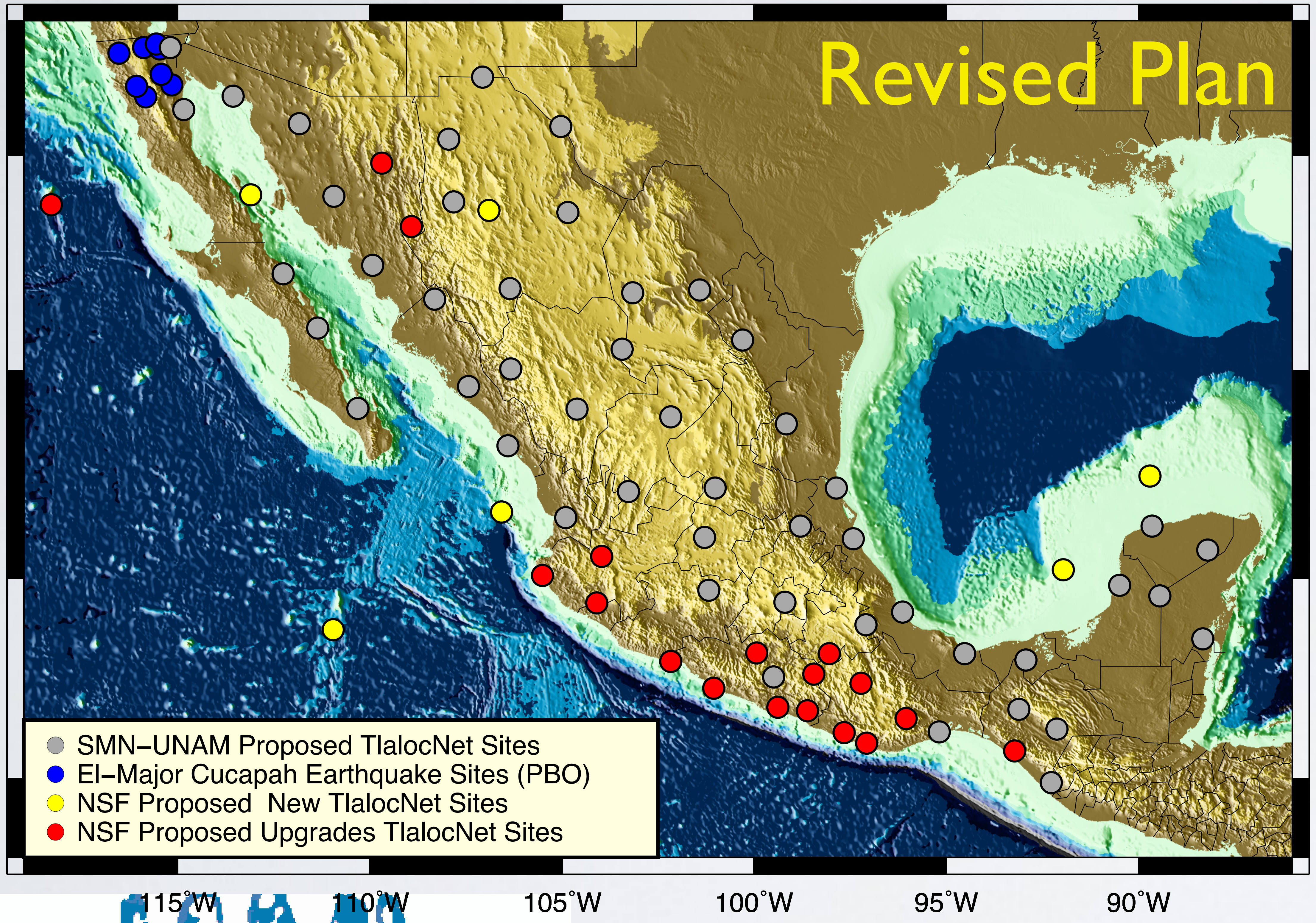
Science and impact goals:

- North America Monsoon studies
- Weather and climate
- Regional framework for studies of specific faults and volcanoes
- Earthquake cycle deformation including episodic tremor and slip (ETS)
- Earthquake hazards - subduction zone

TLALOC net

UNAVCO

MULTI-HAZARDS OBSERVATORIES: TLALOCNET



Plan for 120 new cGPS and meteorology stations in the Mexico:

100 cGPS stations to be collocated with SMN weather observatories

existing stations refurbished and upgraded for telecommunications

possible select new cGPS stations for science enhancements

Science and impact goals:

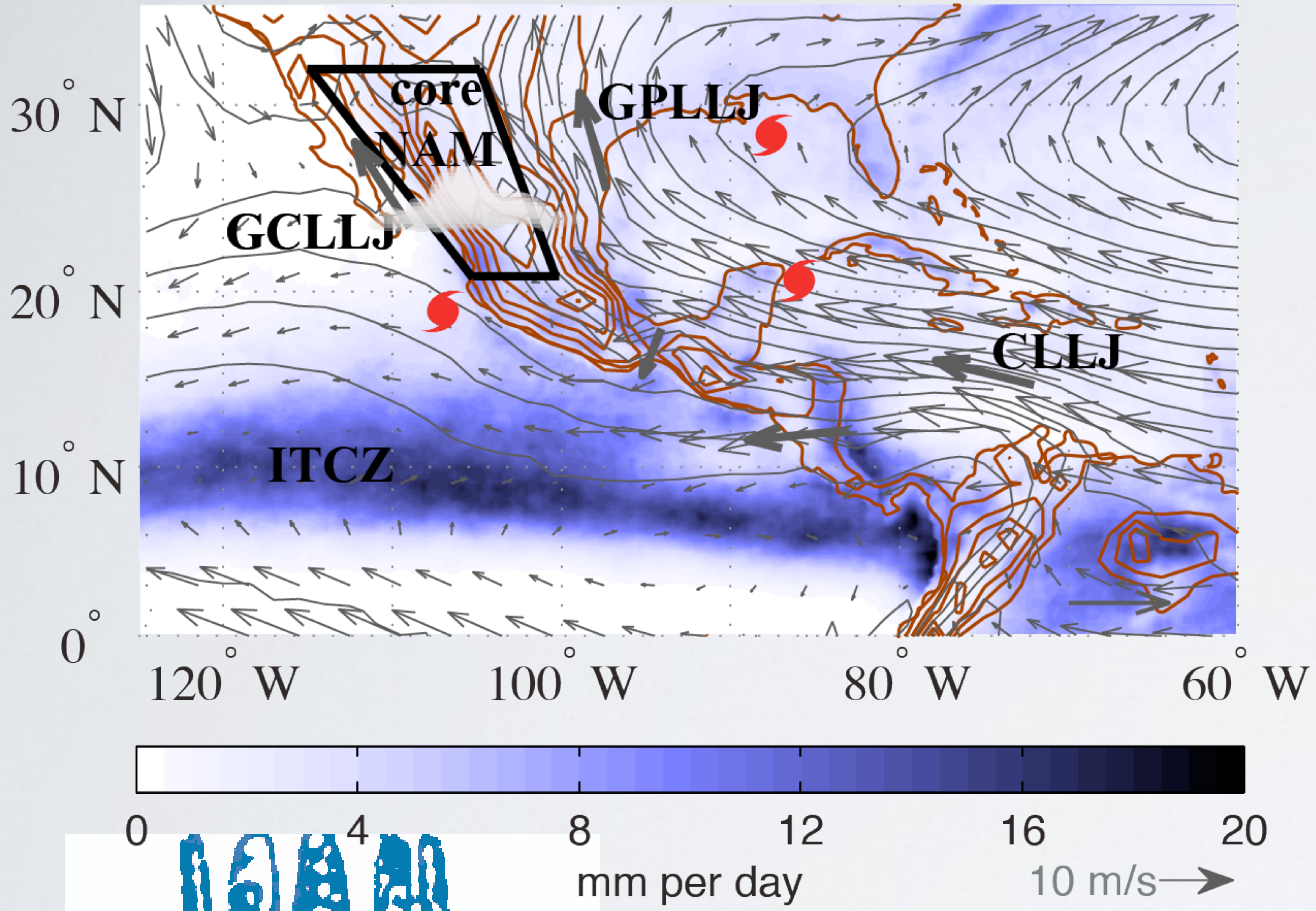
- North America Monsoon studies
- Weather and climate
- Regional framework for studies of specific faults and volcanoes
- Earthquake cycle deformation including episodic tremor and slip (ETS)
- Earthquake hazards - subduction zone

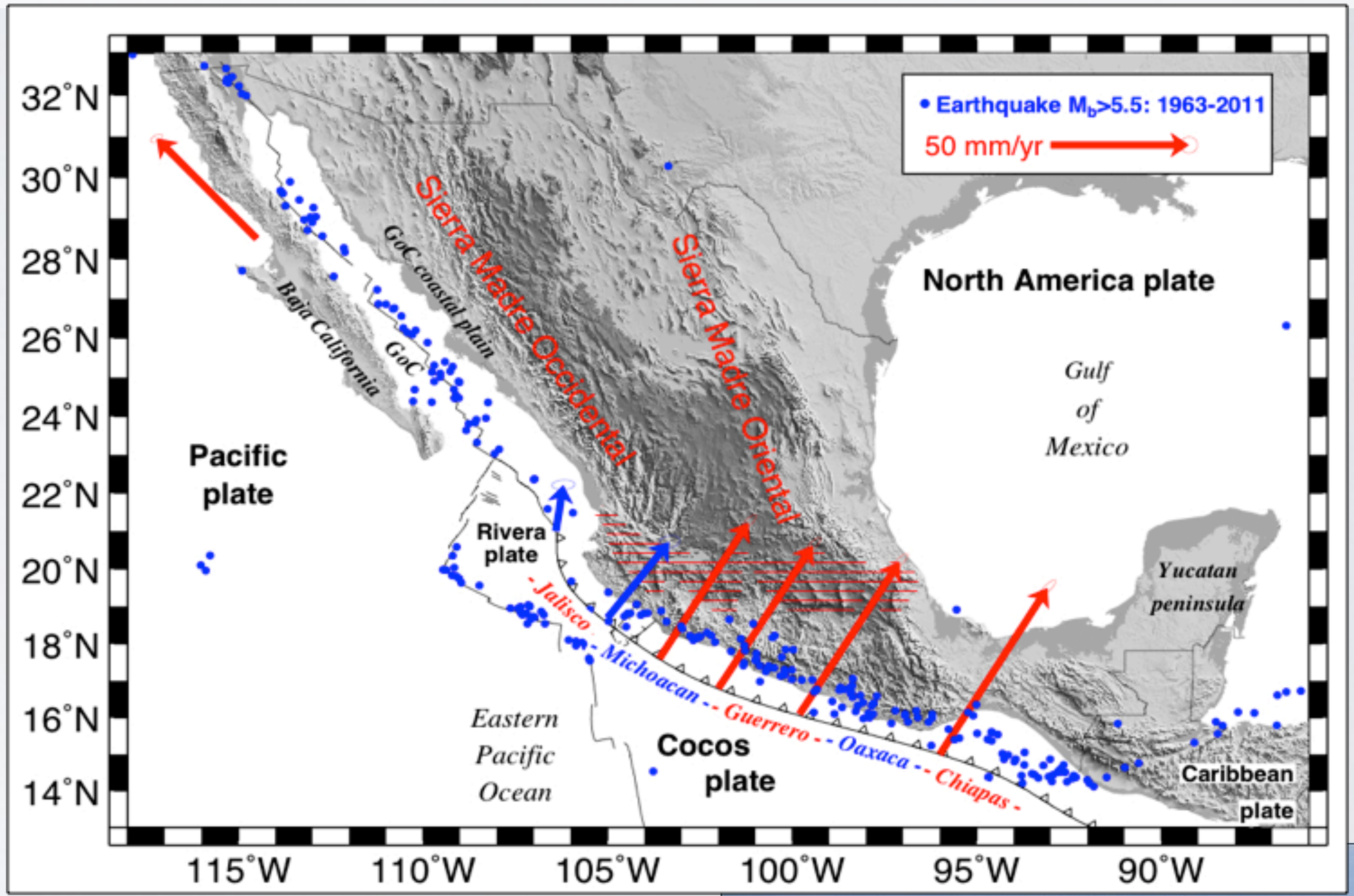
TLALOC net

UNAVCO

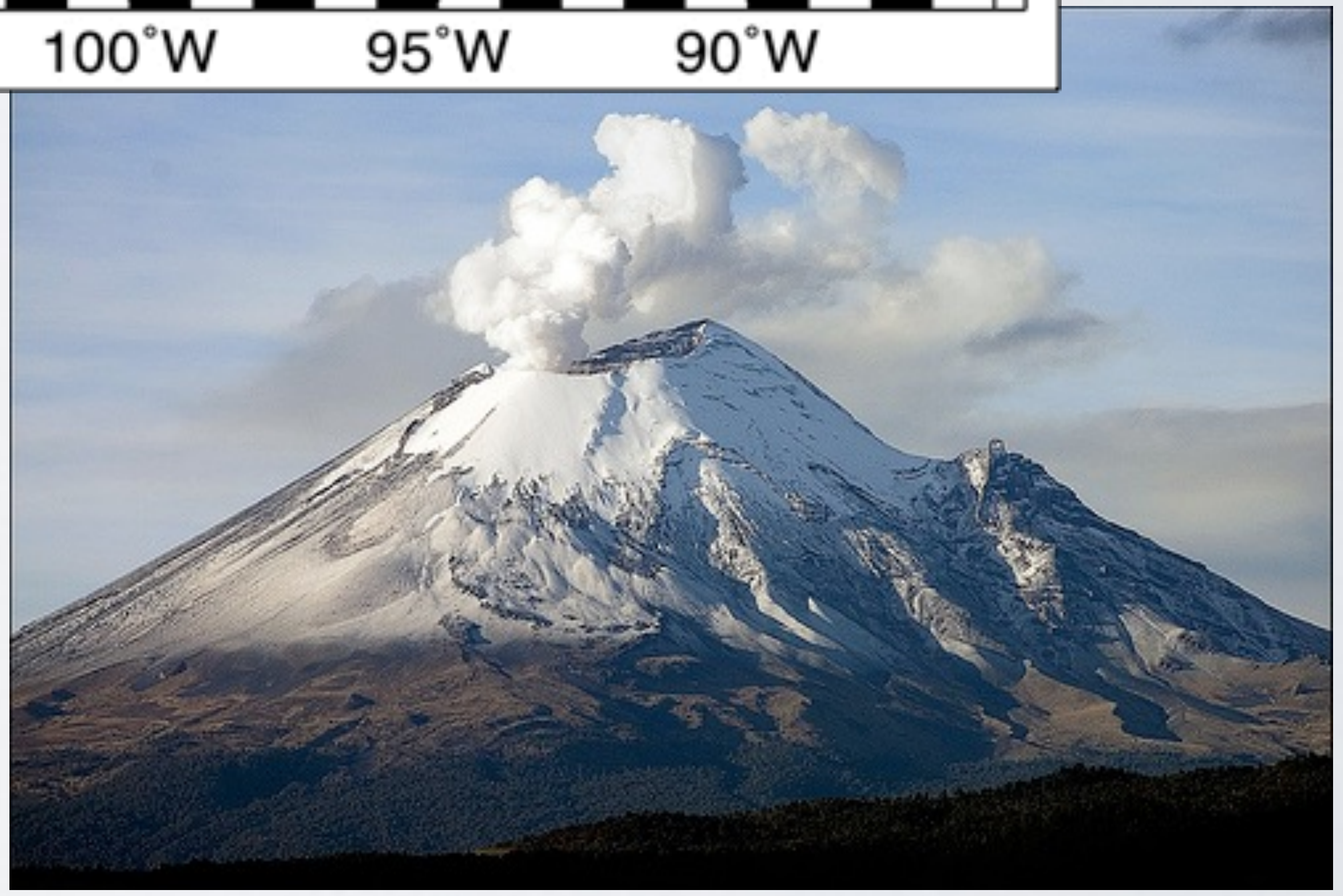
MULTI-HAZARDS OBSERVATORIES: TLALOCNET

JULY





TLALOC net



From C. DeMets (pers. comm., 2013)

PBO AND RELATED NETWORKS - CRITICAL RESOURCES: SUMMARY OF IMPORTANT CONCERNS

Aging PBO infrastructure - planned replacement in GAGE, not possible under current budget scenarios. **Reduced O&M for PBO means possible loss of data and likely will decrease up-time in long-run.**

Need for **high-rate and real-time data streams** and archived products to position UNAVCO for future (NSF and non-NSF) funding and relevance. **PBO is now viewed as a "utility" by many critical stakeholders.** Cost to renew and upgrade just PBO-AK stations to real-time would be considerable ($2.1M one-time funds and $1.0M/yr ongoing costs using current technologies).

- Geodetic Infrastructure is **vital** to multiple communities and agencies - how will it be sustained?
- NSF (and NASA/USGS to a lesser degree) has made the **initial investment** - but the need for **sustaining partners** remains paramount…

Impact of loss (descoping NSF project) or degradation of PBO assets (physical and human) on stakeholders are charged with *Safety of Life* warnings, *Initial Crisis Response*, and development and maintenance of state-wide *Spatial Reference Network* systems needs evaluation and mitigation.

GEODESY LANDSCAPE:
LOOKING FORWARD ACROSS THE AMERICAS

UNAVCO

Interdisciplinary leverage for multi-hazards observatories
Collaborative multi-national efforts
Growing the commitment to truly open data access
Commitment to geodetic quality monumentation
International federations linking networks across borders
Disseminated archives for shared capacity
Driving development of new technology
for sea-floor geodesy