PBO:
A Multi-Use Geodetic Network

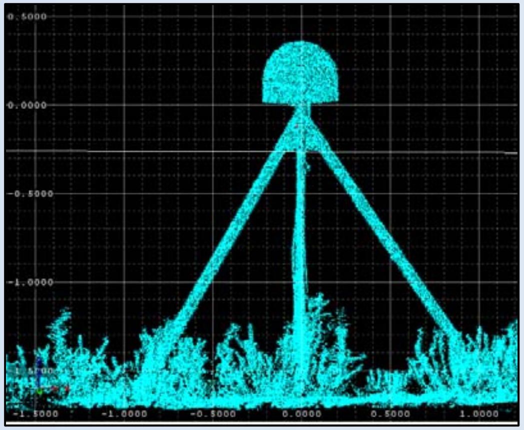
Chris Walls
Plate Boundary Observatory, UNAVCO

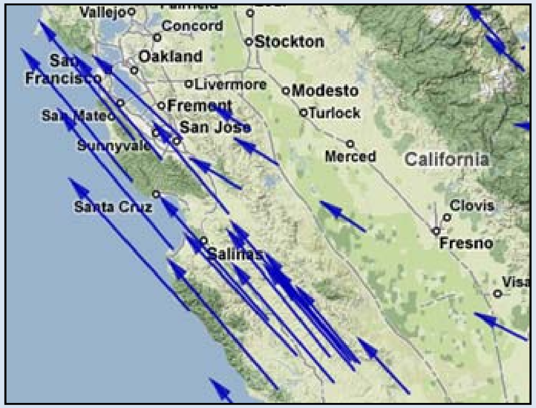
USSLS Regional Meeting
Sacramento, August 24, 2011

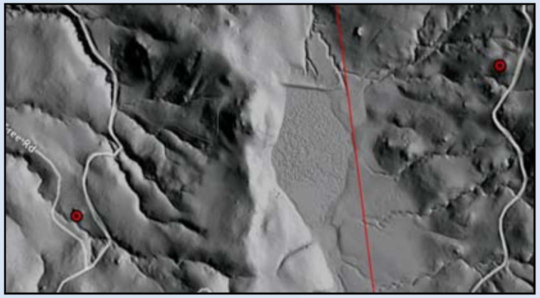
UNAVCO

Talk Summary

- UNAVCO/PBO
- Data Products
- What Impacts Data
- Uses of GPS Data







UNAVCO Consortium

UNAVCO, a non-profit membership-governed consortium, facilitates geoscience research and education using geodesy.

Currently there are 149 UNAVCO Members
(87 Full Members, 62 Associate Members)

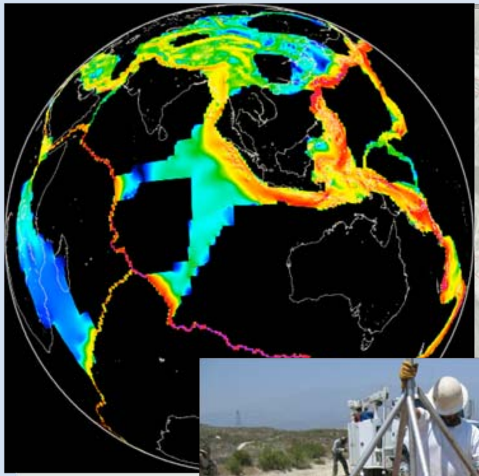
UNAVCO Services and Technologies

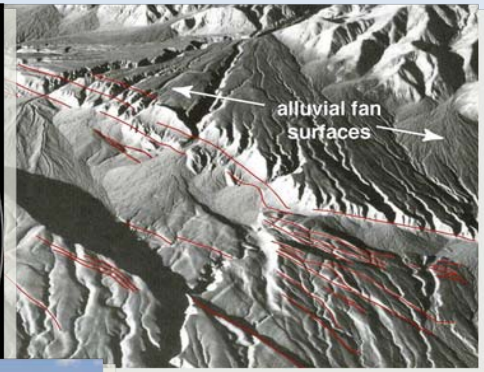
<u>UNAVCO Support</u>

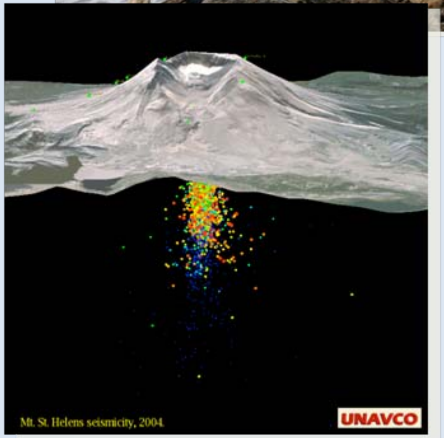
- Engineering Services
- Small and Large network Installation,
- O&M
- Development and Testing
- Equipment Pool
- Data Management and Archiving
- CyberInfrastructure
- Education and Outreach

<u>Technologies - A Growing Geodetic “Toolbox”</u>

- GNSS (GPS, GLONASS, Galileo)
  with ancillary meteorological instruments
- Borehole Strainmeters and Seismometers
- Accelerometers
- Borehole Tiltmeters
- Geodetic Imaging
- Terrestrial Laser Scanners
- Airborne Laser Swath Mapping project support
- InSAR Data Archives (WInSAR/EarthScope)







UNAVCO Instruments

GPS: 2000 Continuous , >2000 Campaign

75 Borehole Strainmeters and Seismometers

6 Laser Strainmeters

28 Shallow Borehole Tiltmeters

EarthScope & Partners

EarthScope is funded by the National Science Foundation and conducted in partnership with the US Geological Survey.

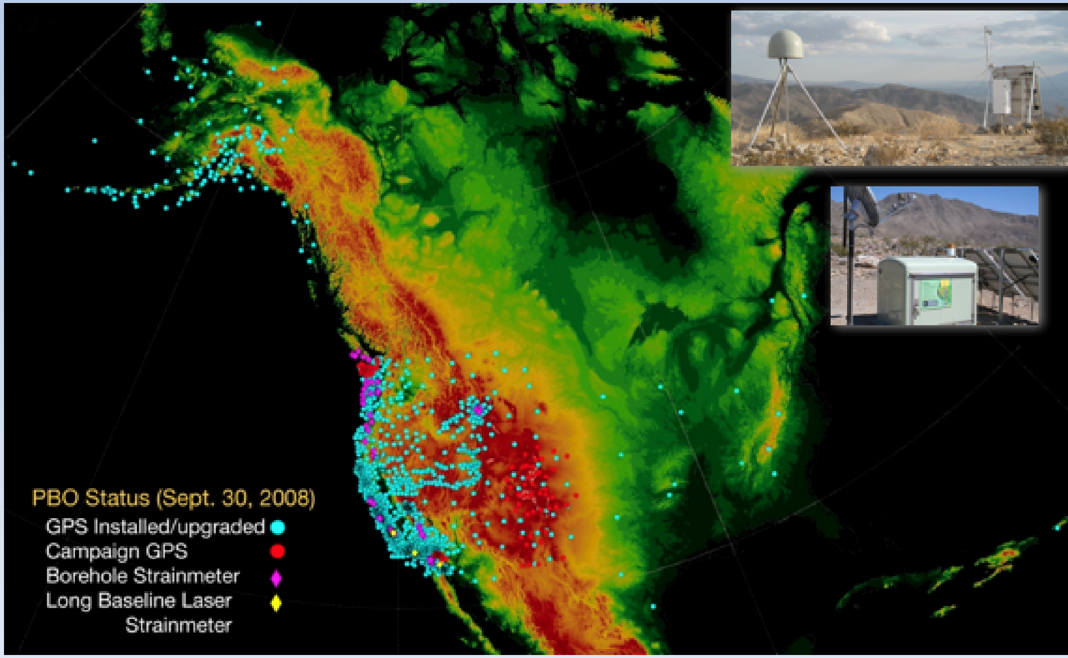
Three Observatories: Plate Boundary Observatory, US Array, SAFOD

The data collected by EarthScope's three observatories will **help us to understand processes that control earthquakes, volcanoes and the structure of the North American Continent.**

EarthScope is being constructed, operated, and maintained as a collaborative effort with UNAVCO, IRIS, and Stanford University, with contributions from NASA and several other national and international organizations.

Plate Boundary Observatory

2004 → 2011

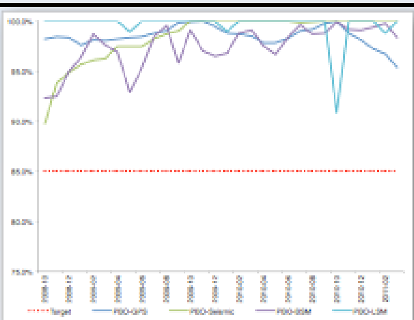


Instrumentation

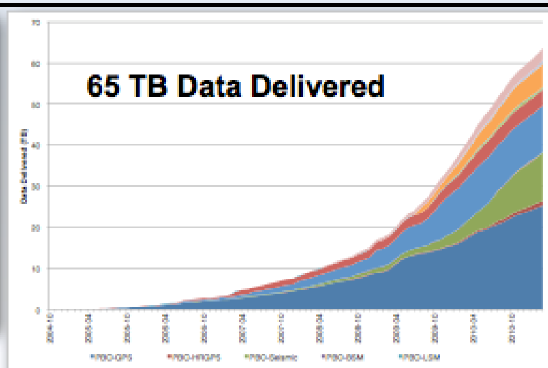
- 1100 continuous GPS Stations (~300 real-time stations)
- 100 MET sensors
- 74 borehole strainmeters
- 78 borehole seismometers
- 6 long baseline strainmeters
- 26 Tiltmeters
- 100 portable GPS receivers
- InSAR imagery covering the western US.
- LIDAR imagery covering active faults

Network Data Return

Network Data Delivery

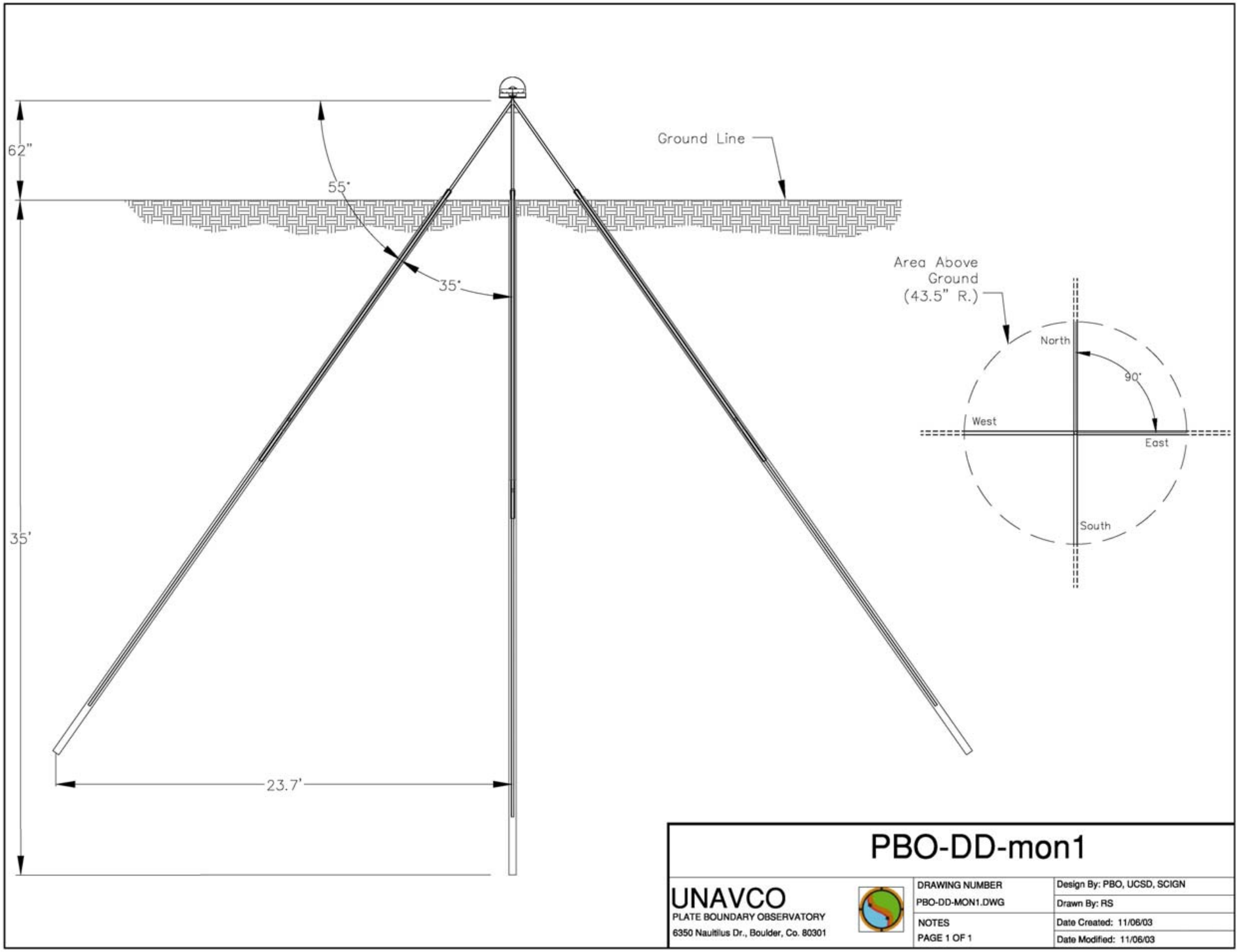


98% Data Return

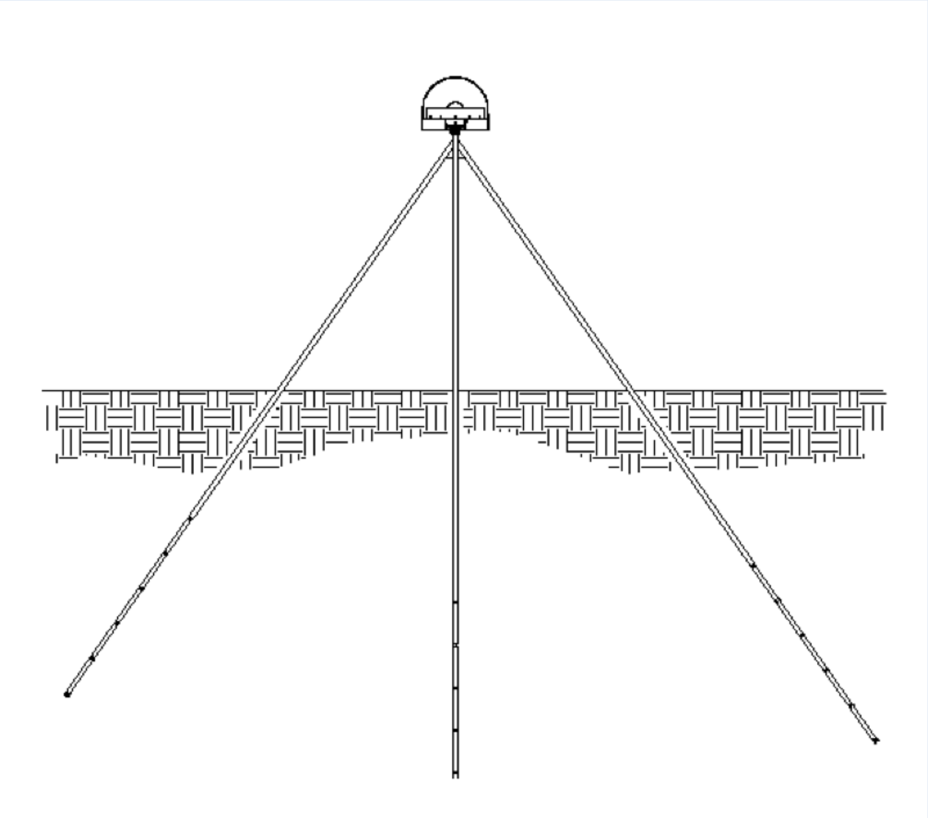


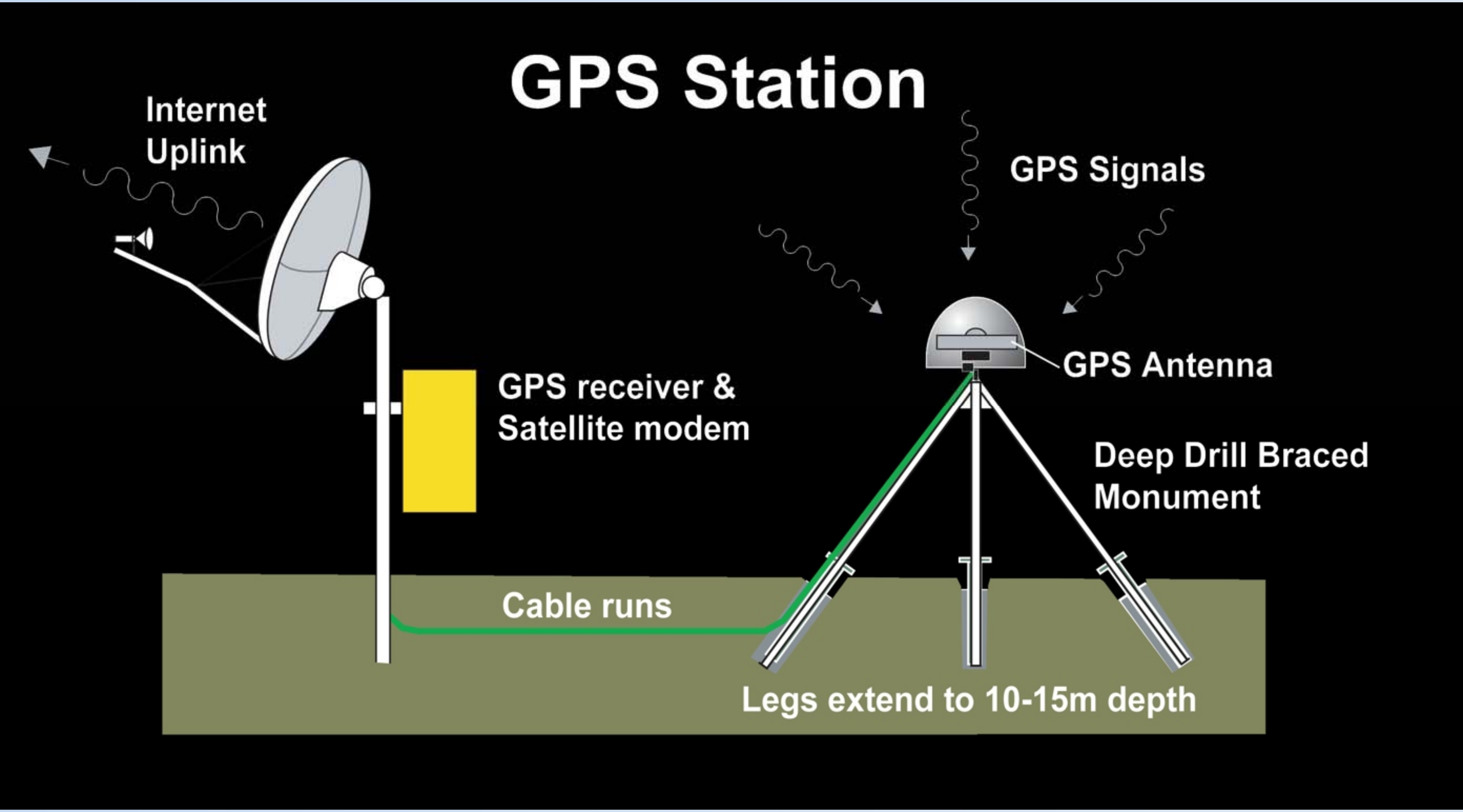
97% Network Uptime

Deep Drilled-Braced Monument



Short Drilled-Braced Monument




GPS Station
Internet Uplink
GPS Signals
GPS Antenna
GPS receiver & Satellite modem
Deep Drill Braced Monument
Cable runs
Legs extend to 10-15m depth

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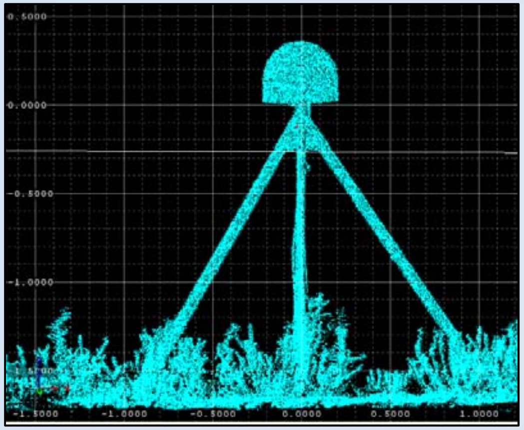
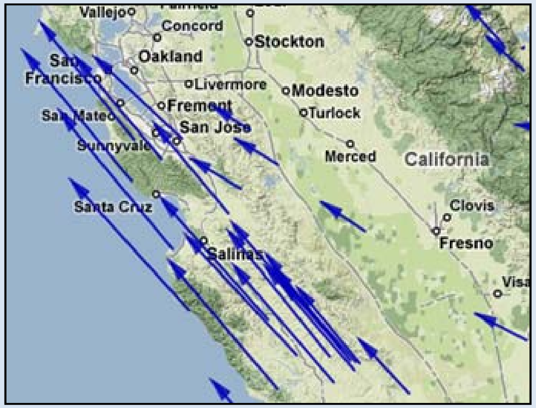
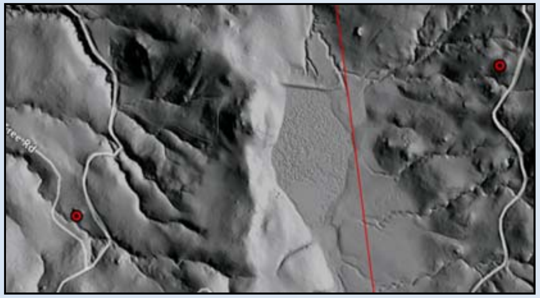
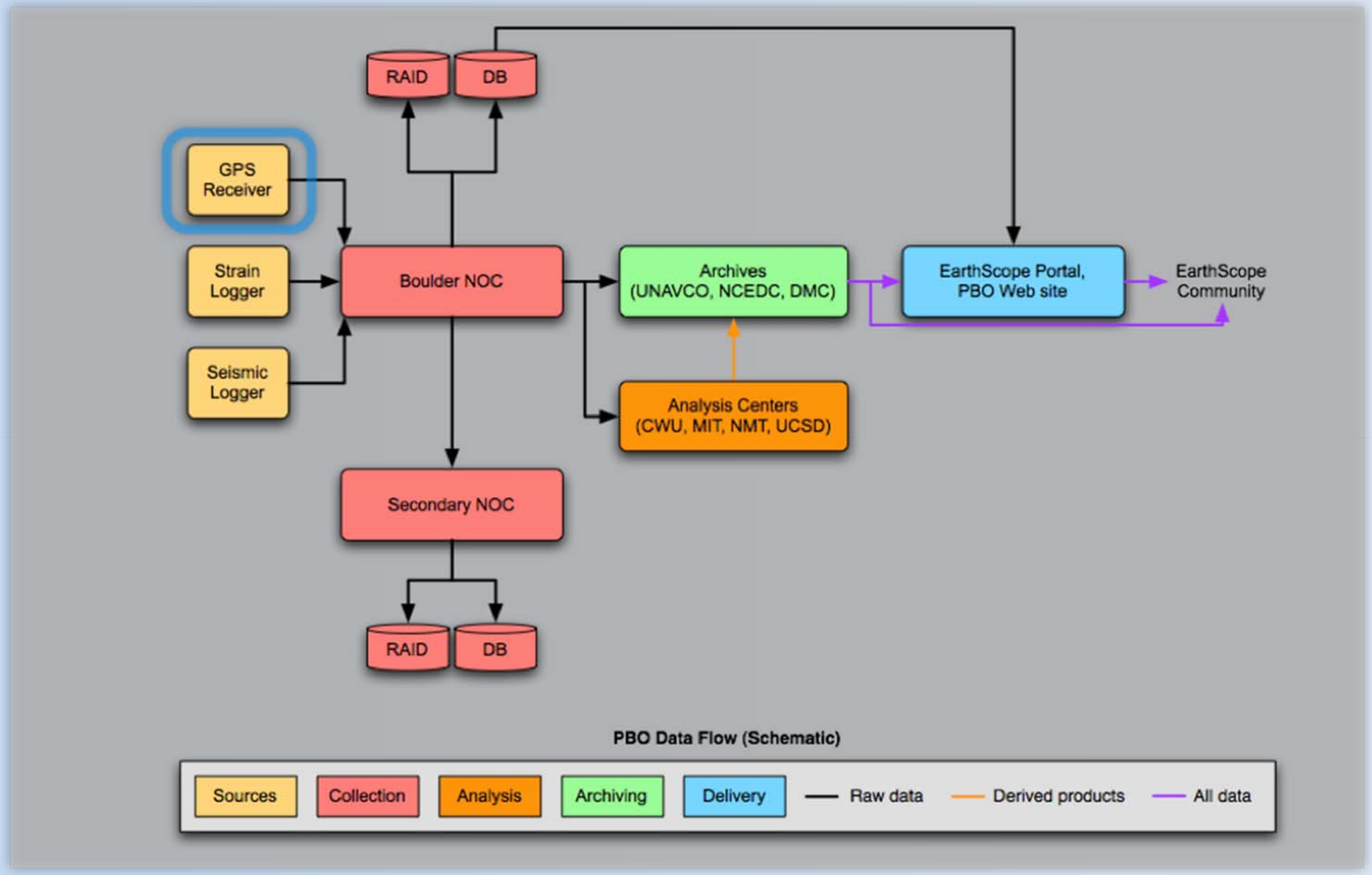


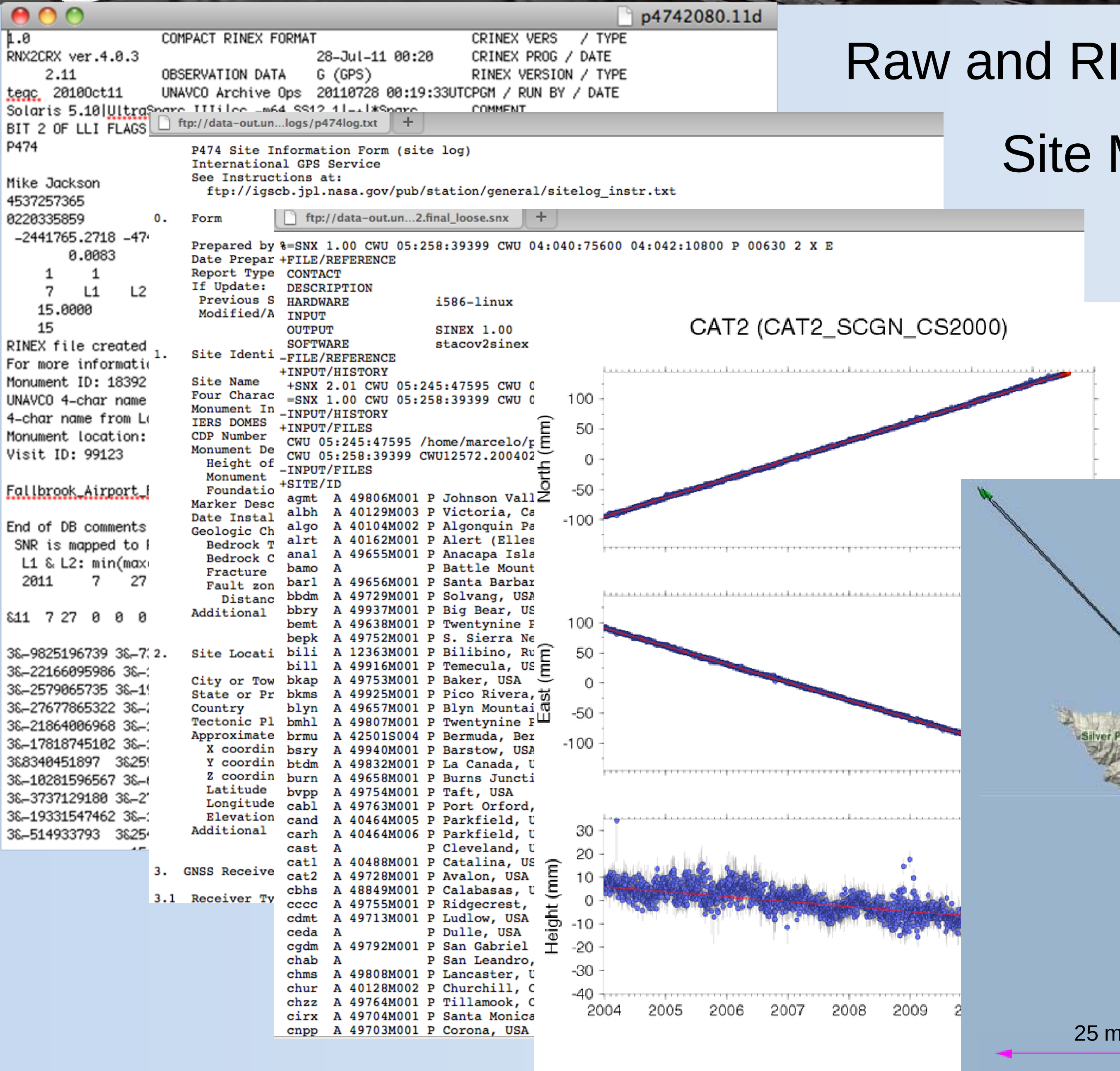




Archiving and Analysis Centers



GPS Data Products



Raw and RINEX Data

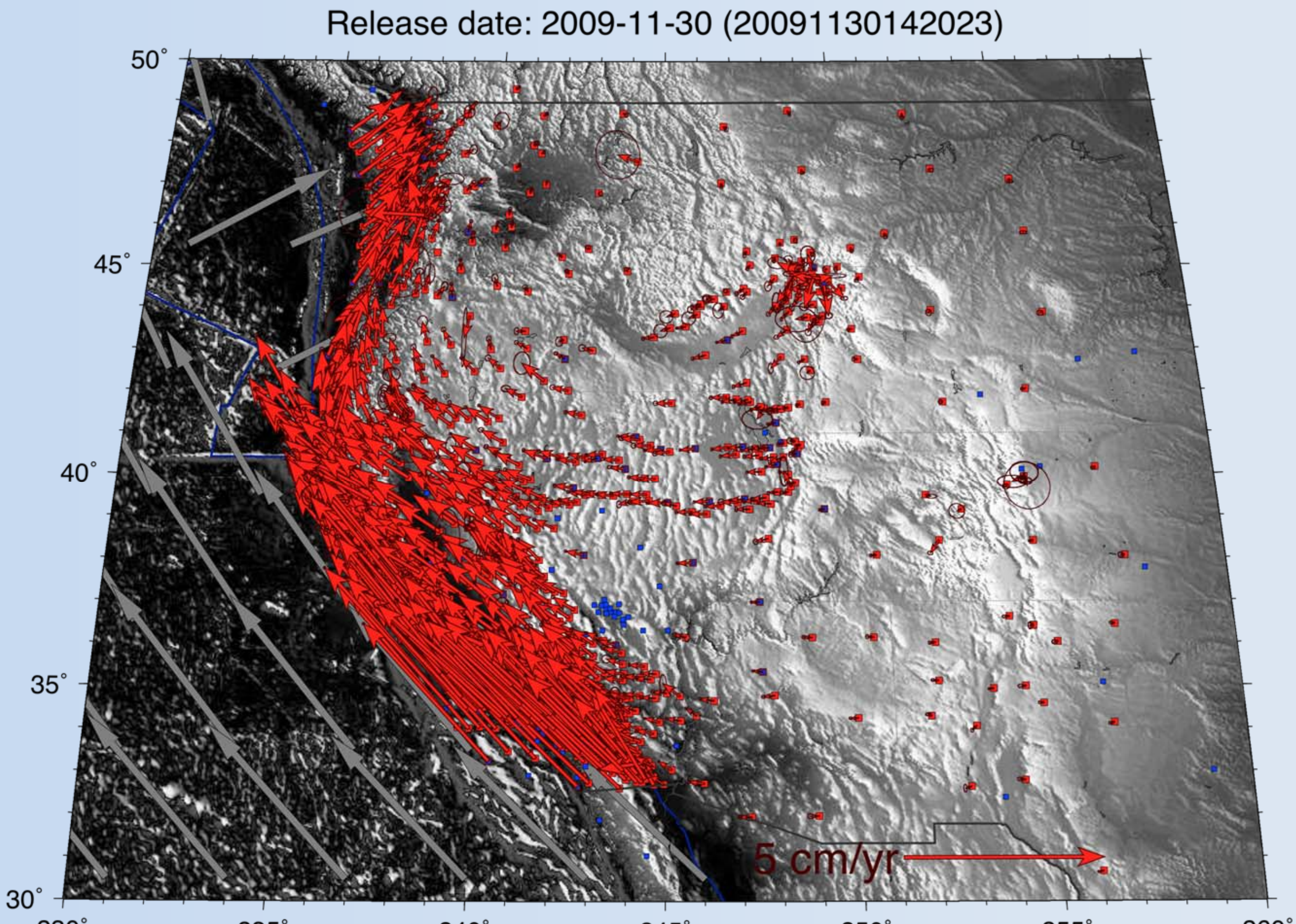
Site Metadata & Logs

SINEX

Time Series

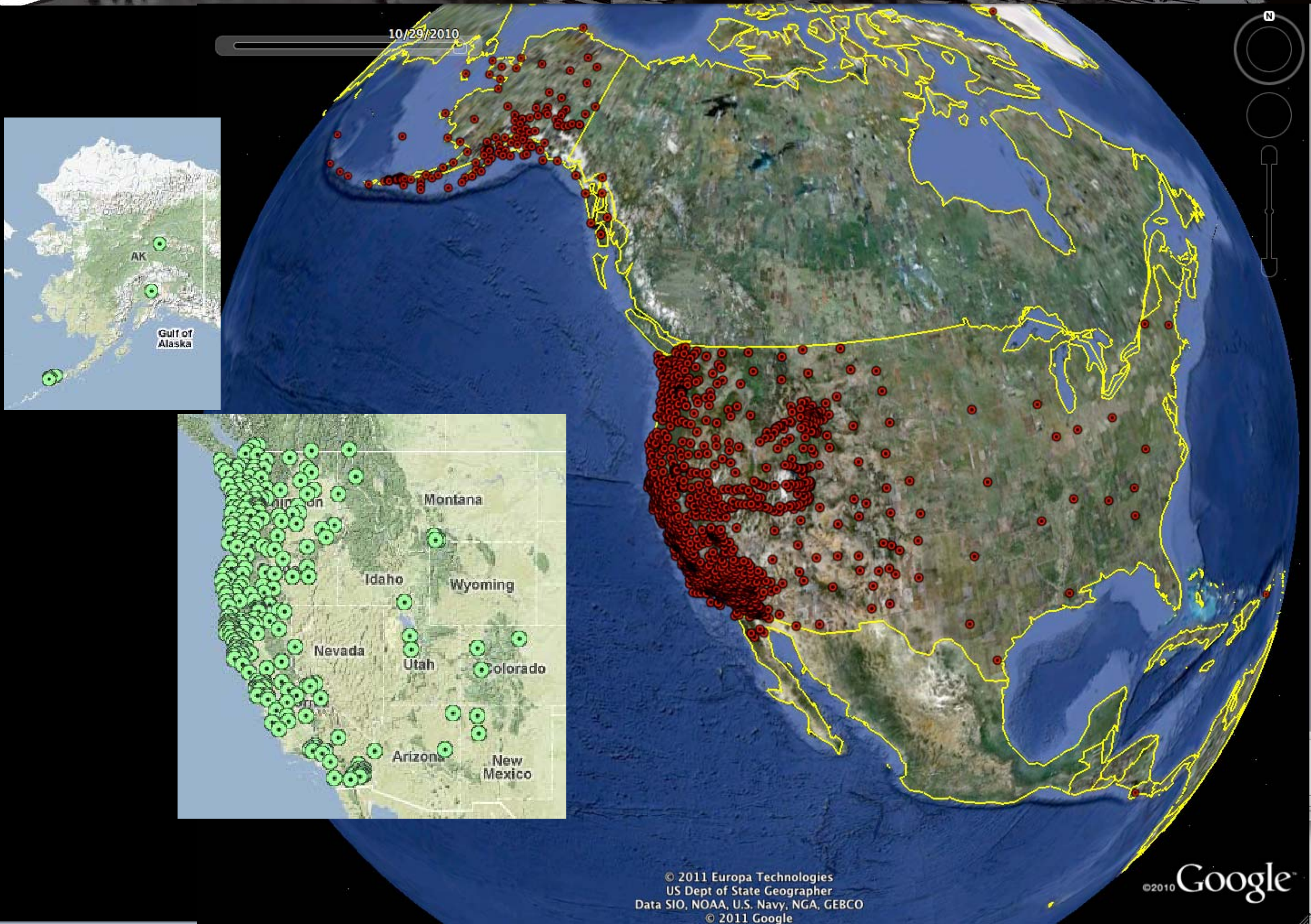
Velocities

PBO Level 2 GPS MIT Station Velocities



Thorsten Becker, 2010

PBO's 293-Station Realtime GPS Network



Timeline of PBO Realtime GPS Activities

2006		PBO Data Critical Design Review describes RTGPS plan for PBO
2007		SOW issued for UStream software development work by Stark Consulting
	UStream	UStream delivered to PBO (initial cost $39K development + hardware)
2008	UStream	
2009	UStream	RFP issued for realtime GPS network controller software
	UStream	Proposals from Trimble, Geodetics, and GPS Solutions received
	UStream	**Cascadia ARRA Proposal funded**
	UStream	Decision made to purchase Trimble VRS3Net software
	UStream	Trimble VRS3Net delivered to PBO
2010	UStream	First attempt to switch over to VRS3Net (failed)
	VRS3Net	Second attempt to switch over to VRS3Net system (successful)
2011	VRS3Net	Realtime VRS3Net GPS positioning roll out (beta)
	VRS3Net	293 PBO stations streaming in real time

UNAVCO

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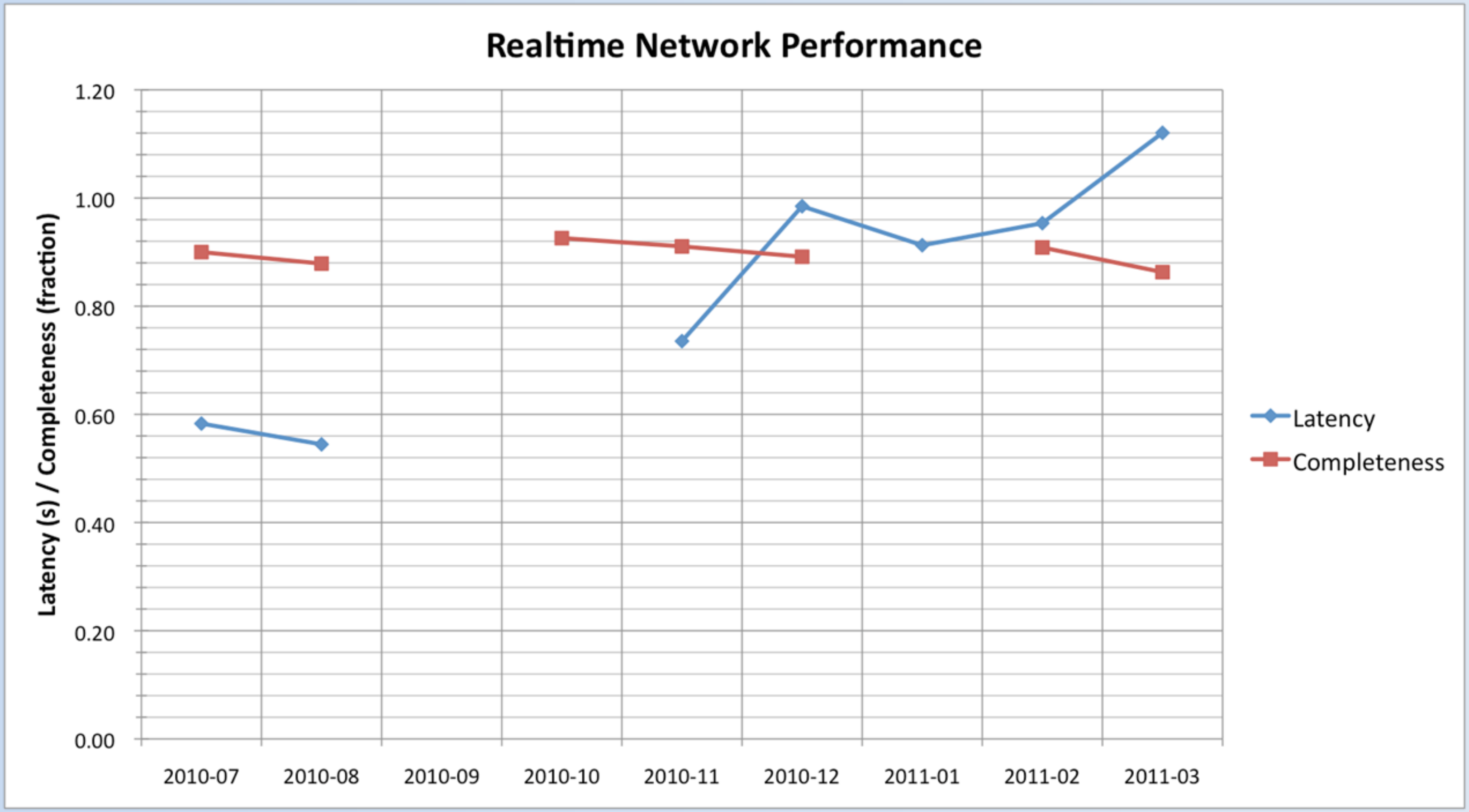
UStream data format and capacity problems

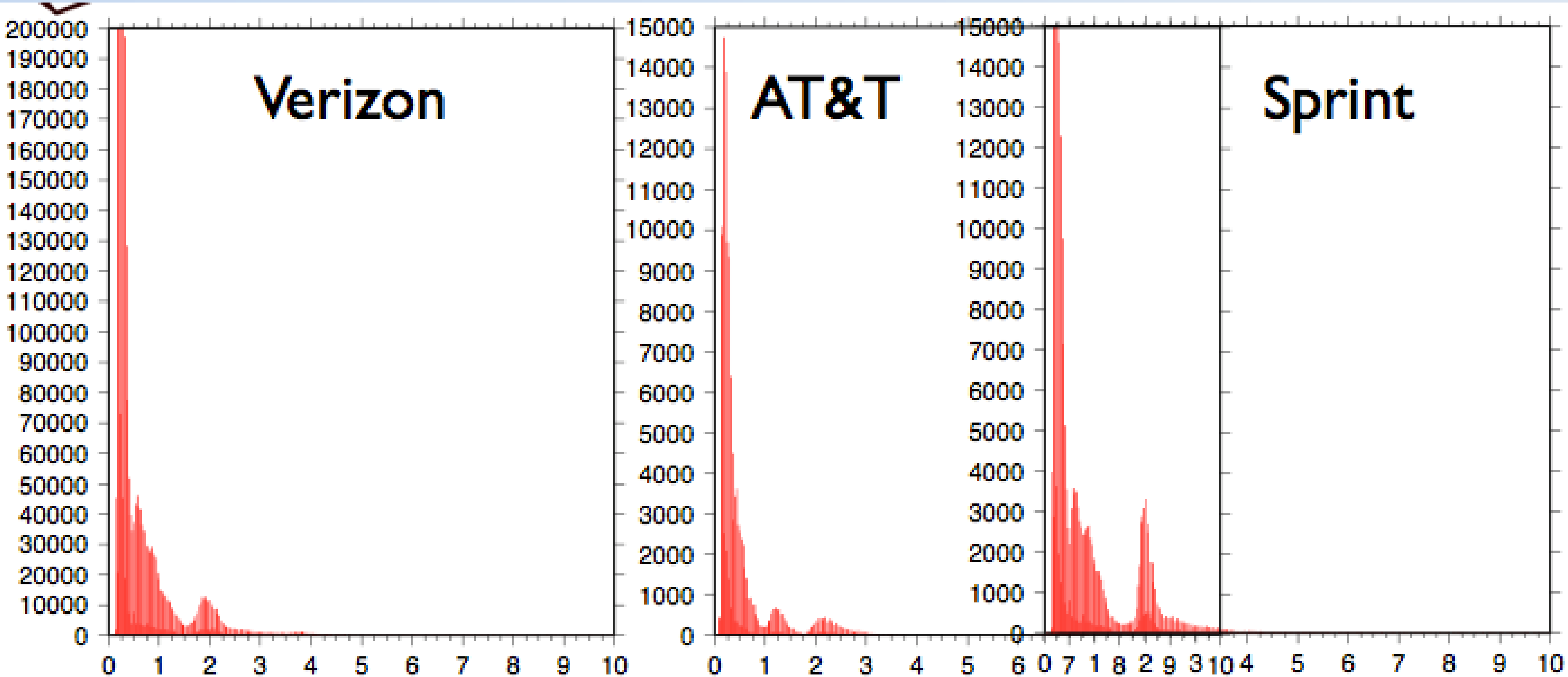
VRS3Net stability and capacity problems

Realtime GPS Network Performance



Completeness stable around 90%, latency increasing as we load the current 2-server system. Additional hardware is waiting to be racked.

Latency by Carrier



Though our network is dominated by Verizon modems, the latency behavior is similar for all 3 of the major carriers

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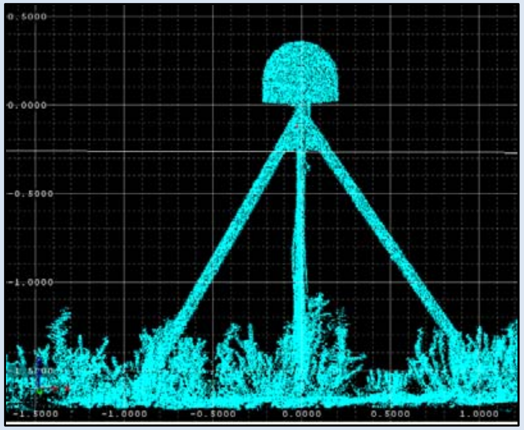
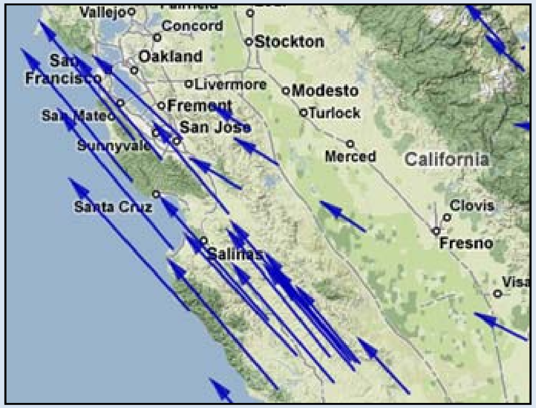
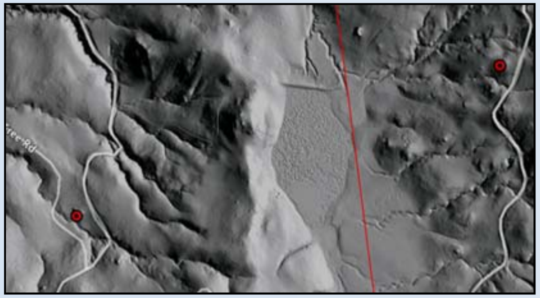
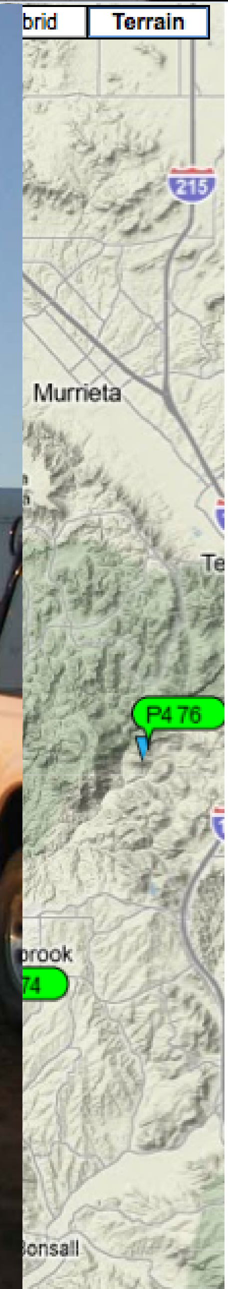


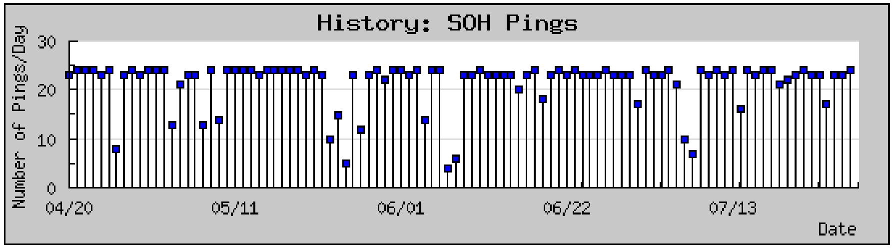


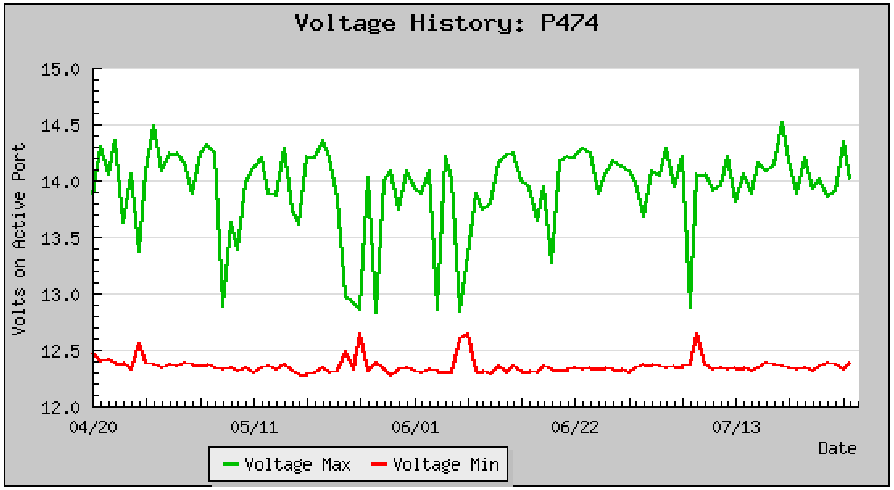


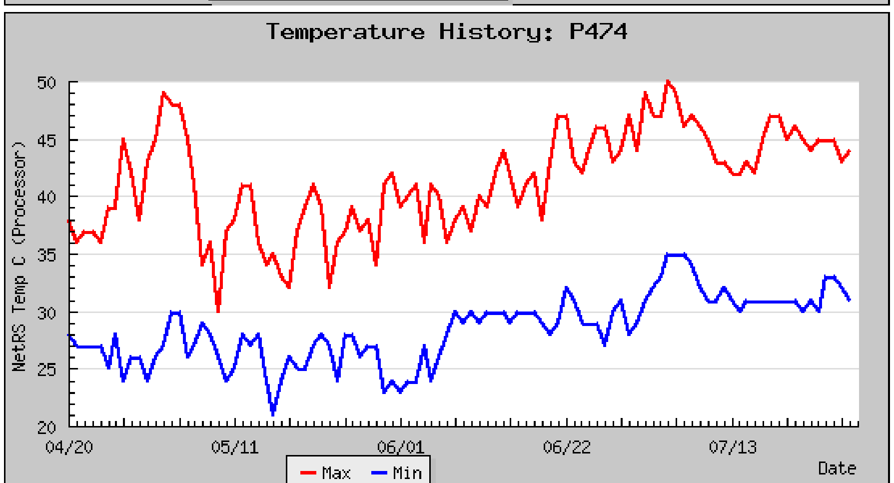
P474 – Example of Good Data Quality



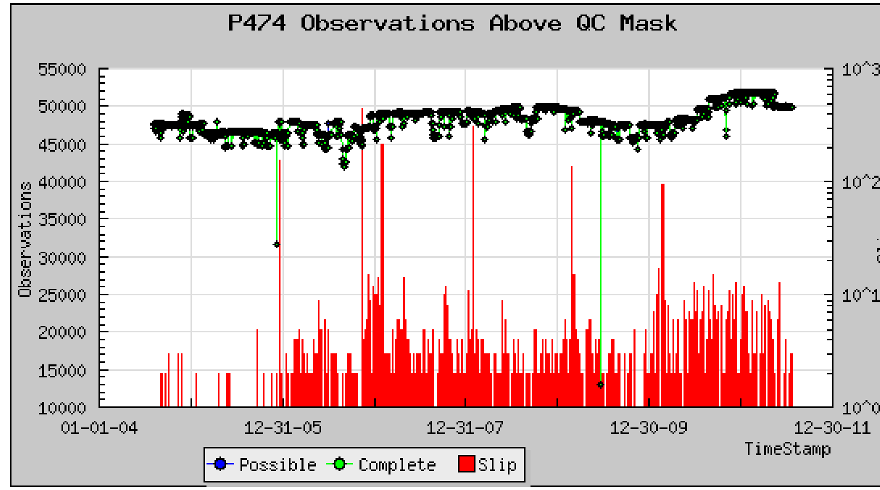
State of Health and QC Statistics

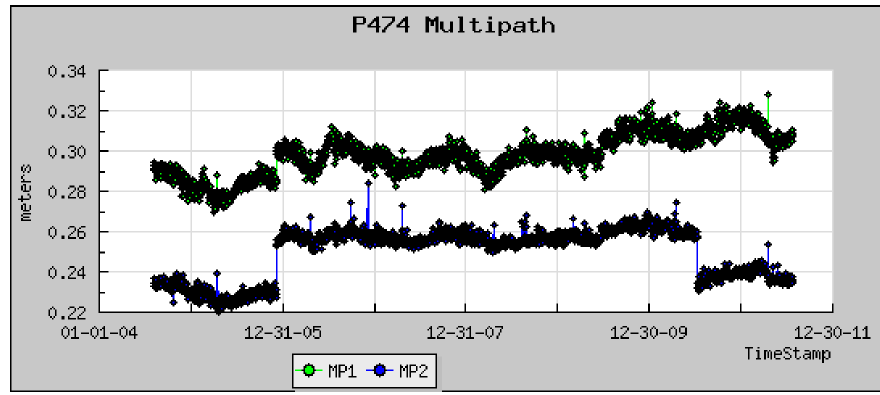


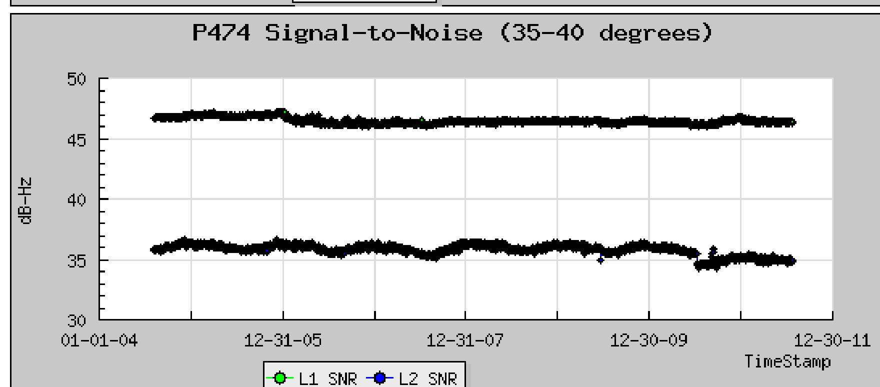




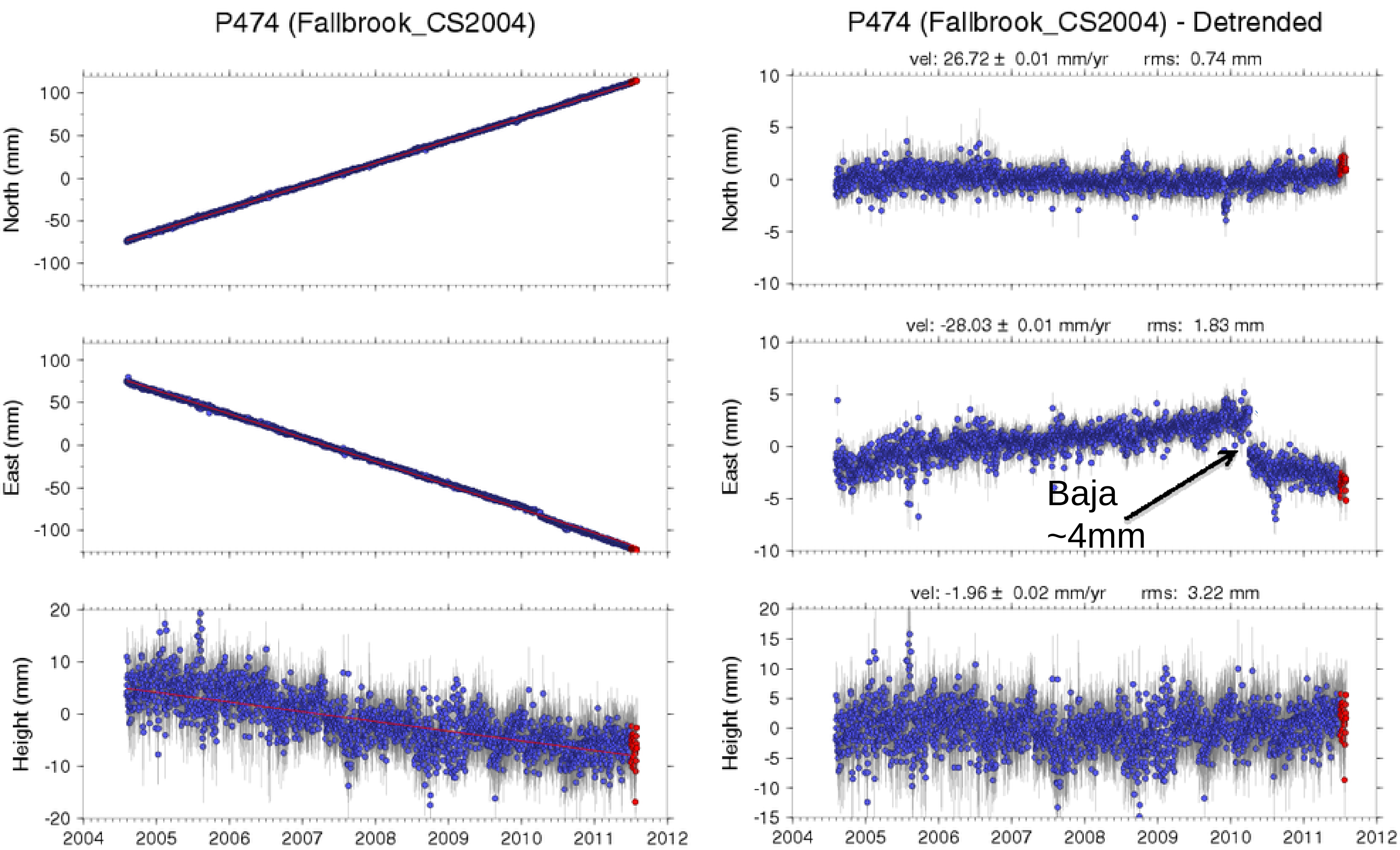
CARH 2010-03-11 to 2010-3-26



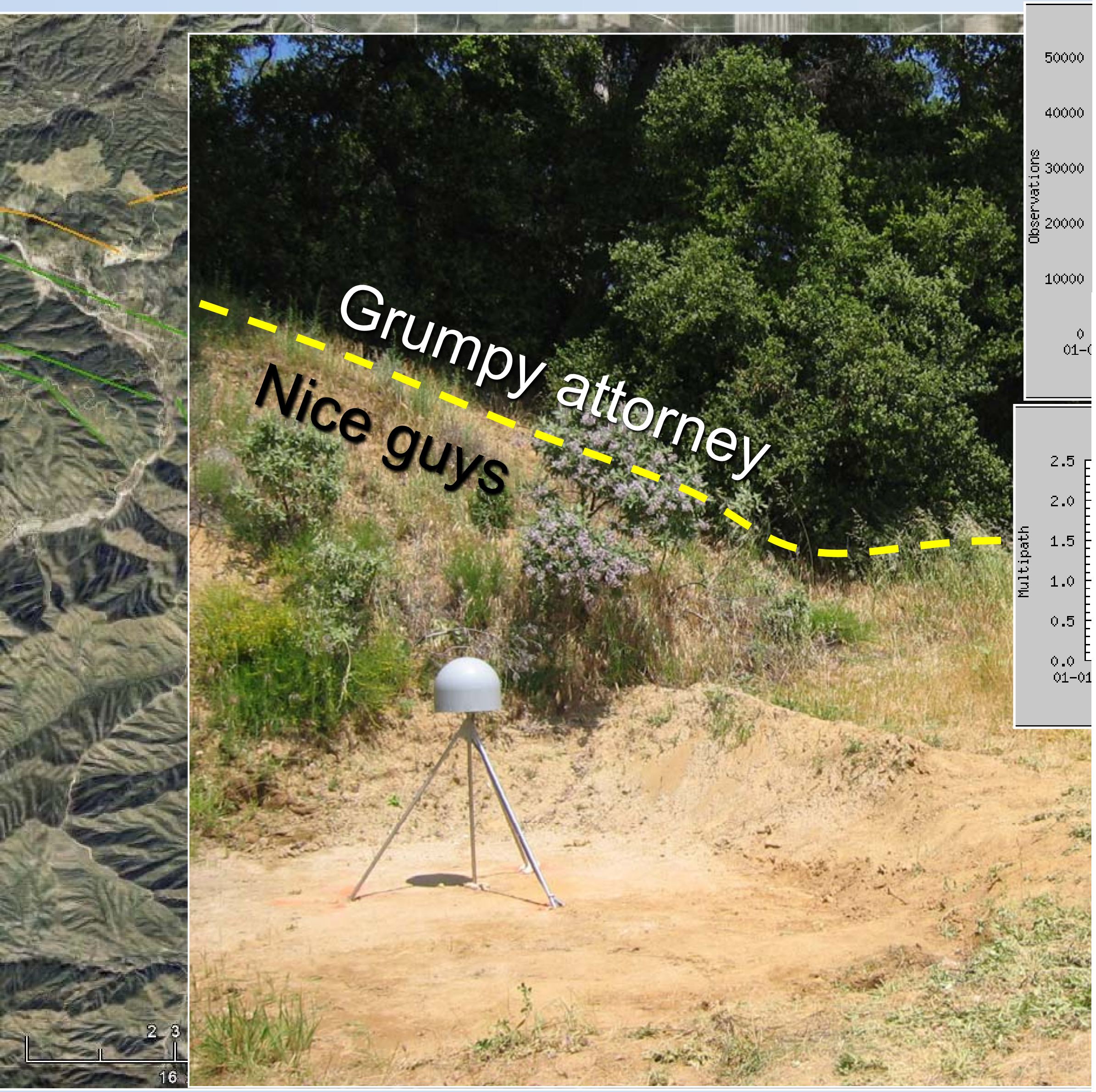


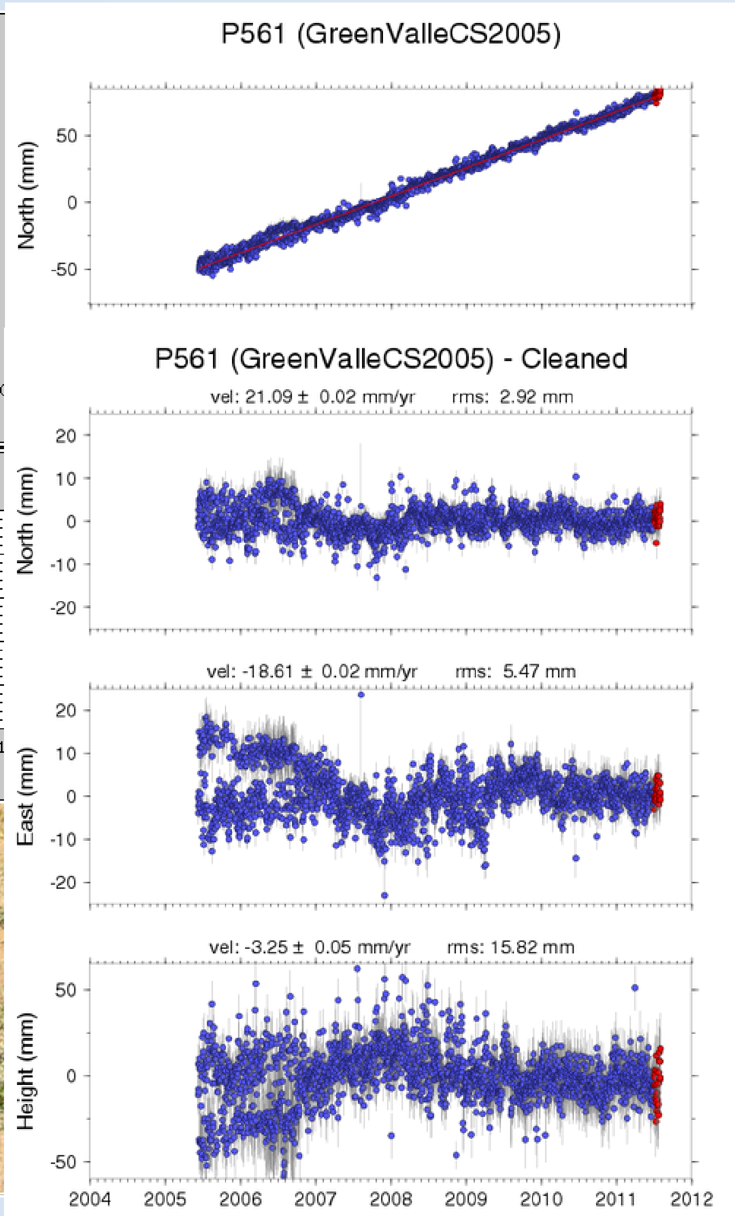


Timeseries

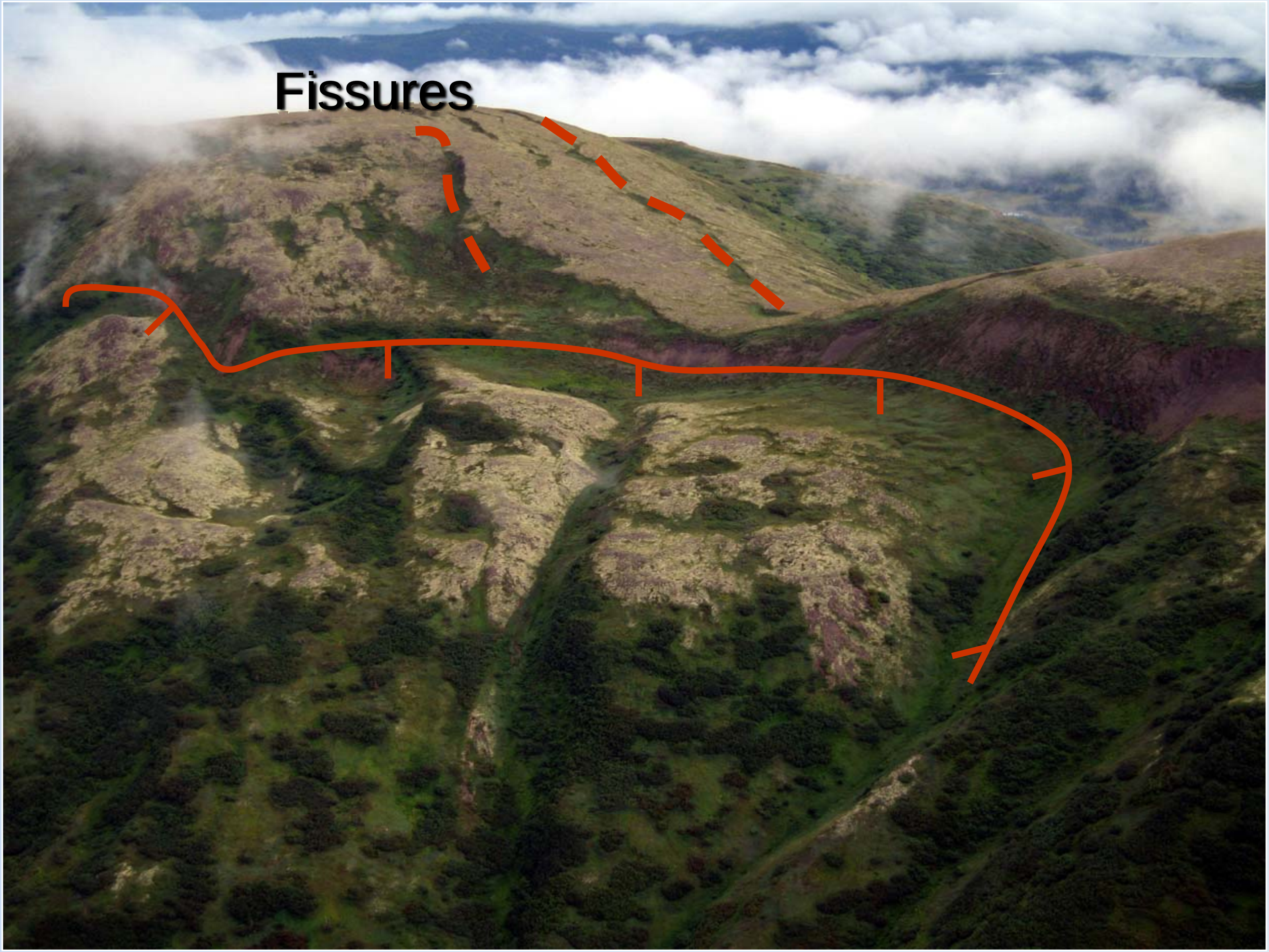

P474 (Fallbrook_CS2004)
P474 (Fallbrook_CS2004) - Detrended
vel: 26.72 ± 0.01 mm/yr rms: 0.74 mm
vel: -28.03 ± 0.01 mm/yr rms: 1.83 mm
vel: -1.96 ± 0.02 mm/yr rms: 3.22 mm
North (mm)
East (mm)
Height (mm)
Baja
~4mm
2004 2005 2006 2007 2008 2009 2010 2011 2012

Vegetation - P561

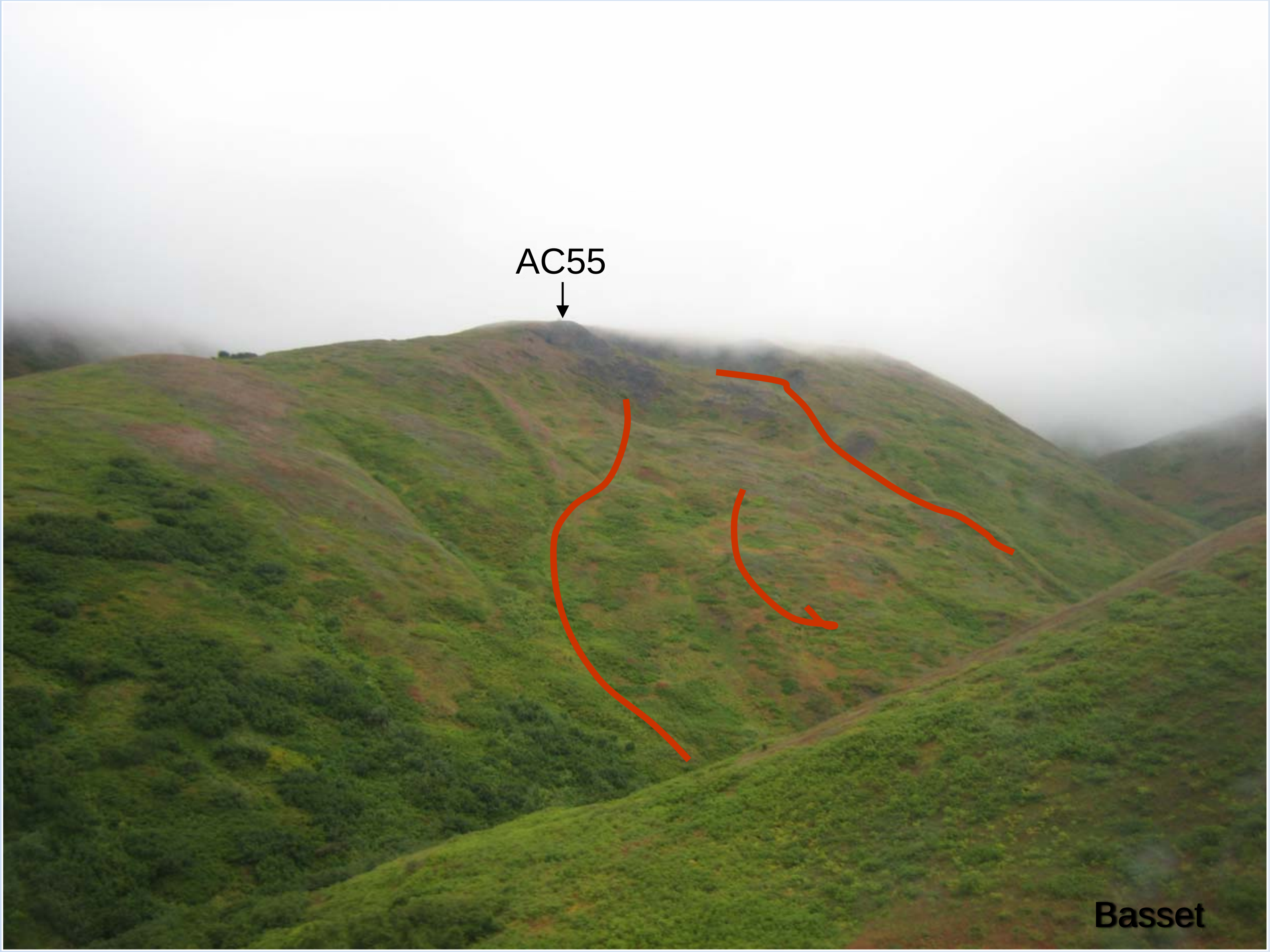




AB14 Dillingham Recon

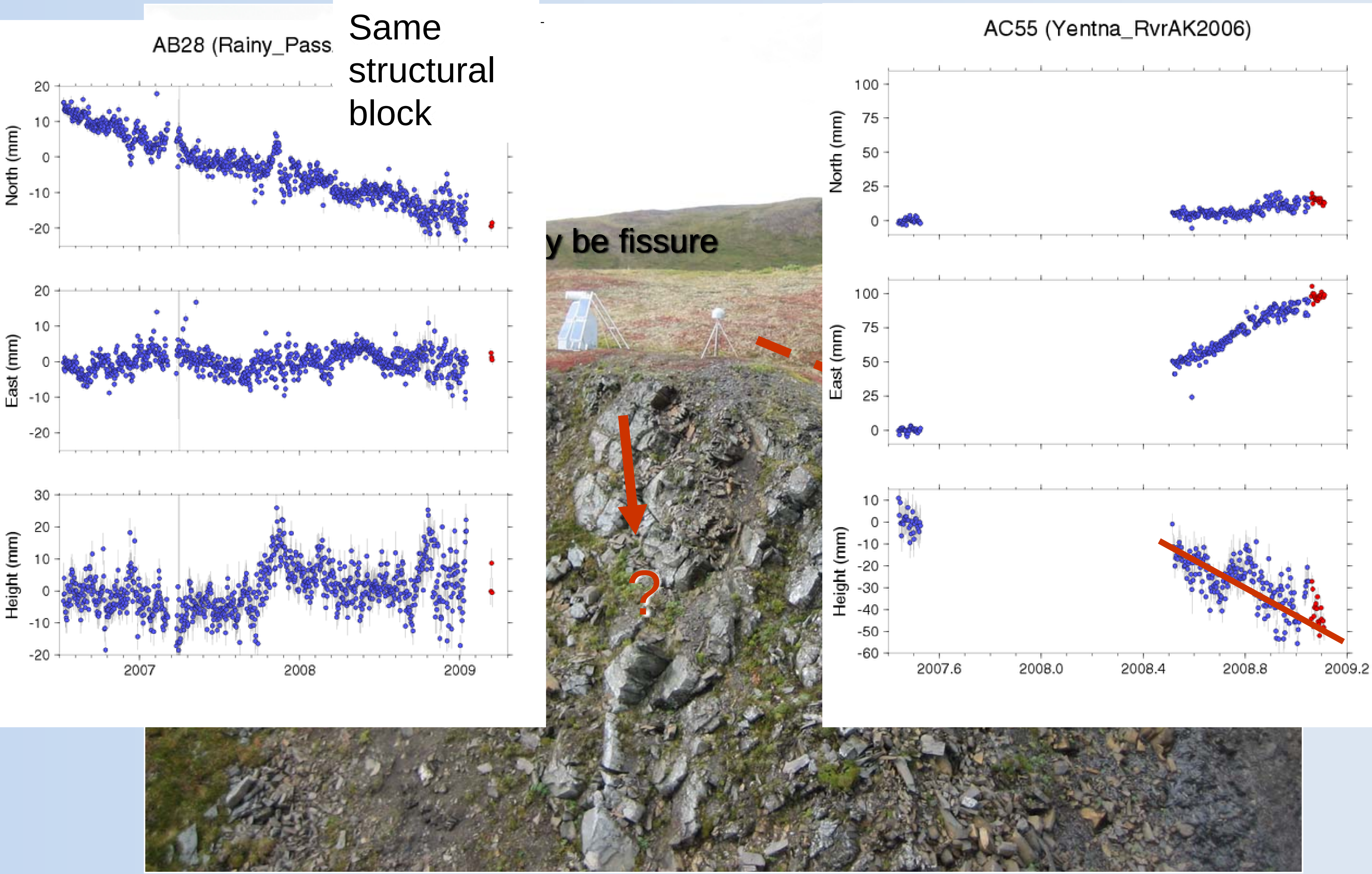


AC55 – top of slump

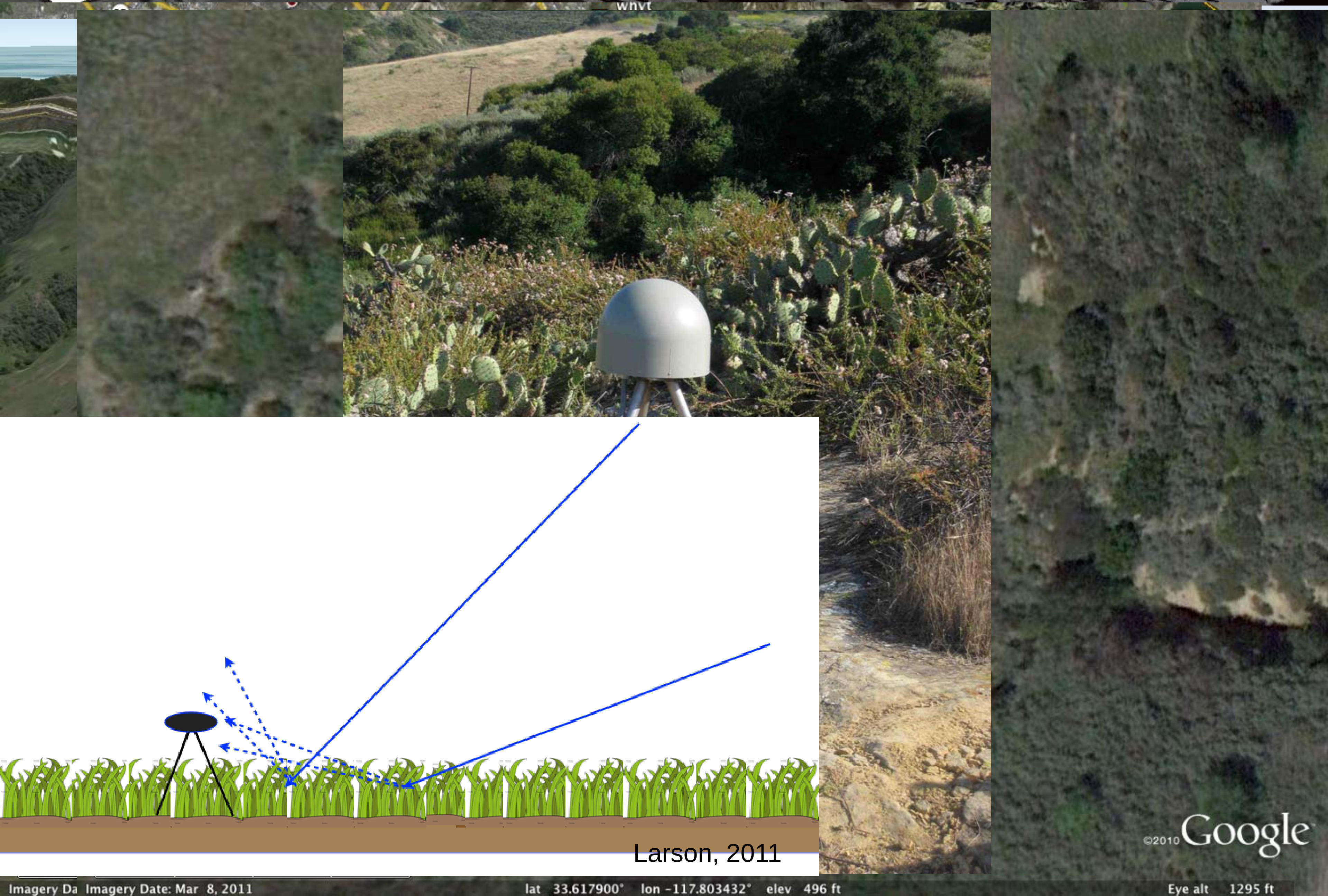


AC55

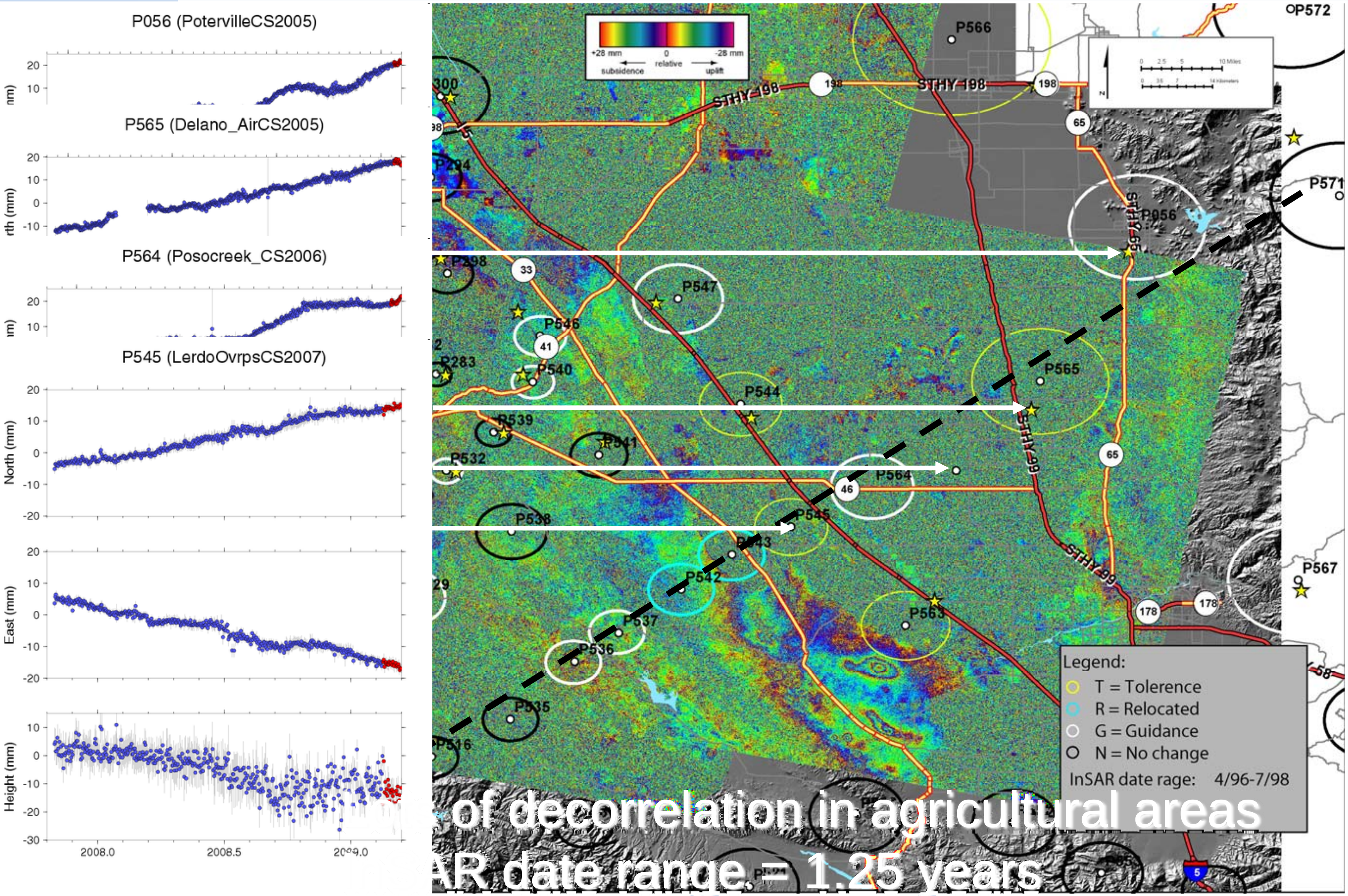
Same structural block



TRAK


Larson, 2011
©2010 Google
Imagery Da Imagery Date: Mar 8, 2011
lat 33.617900° lon -117.803432° elev 496 ft
Eye alt 1295 ft

Subsidence – S. San Joaquin Valley



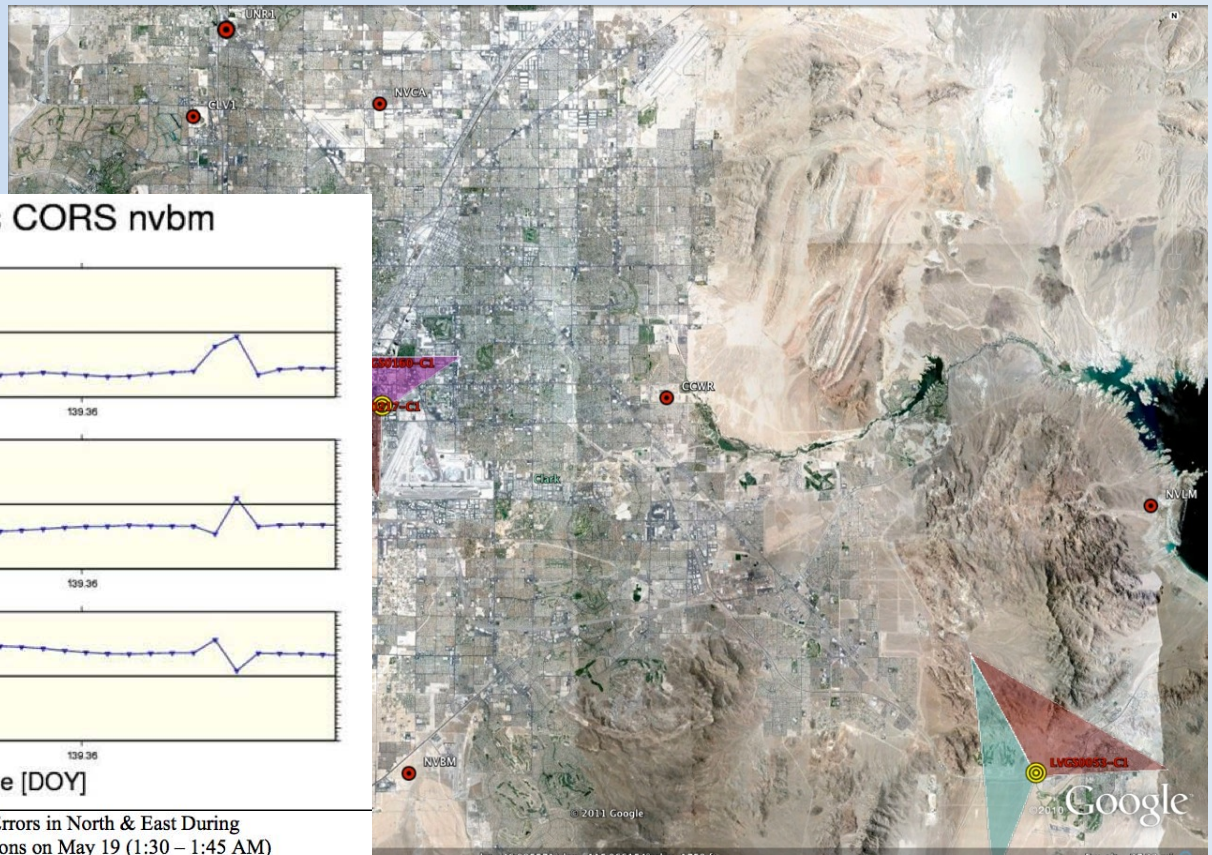
of decorrelation in agricultural areas

AR date range = 1.25 years

LightSquared?

Freddy Blume (UNAVCO) served as a technical advisor to the "High Precision, Timing, and Networks Sub-Team" of the FCC Technical Working Group

- “LightSquared's proposed MSS transmissions would affect most, if not all, high-precision GPS/GNSS receivers such as those in use by UNAVCO and its community.”



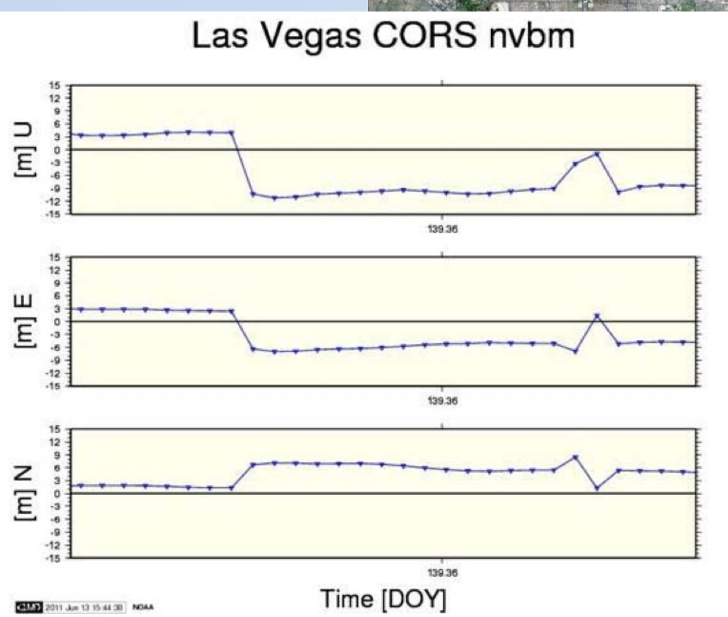


Fig. 5 Step (±6 m.) Errors in North & East During LightSquared Transmissions on May 19 (1:30 – 1:45 AM)

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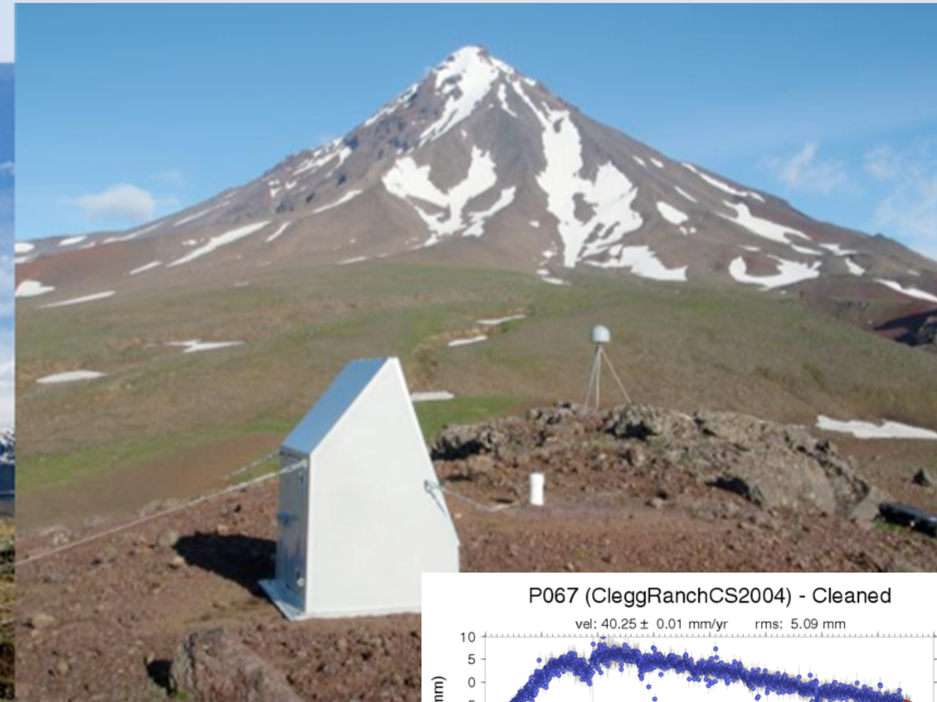

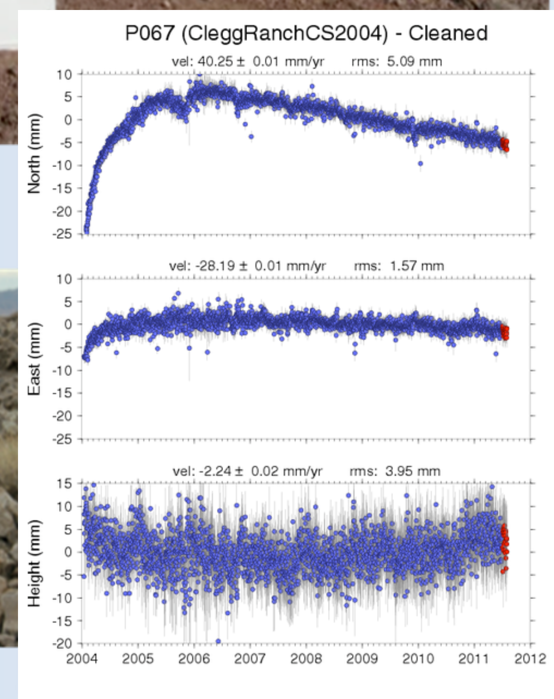
P067 (CleggRanchCS2004) - Cleaned
vel: 40.25 ± 0.01 mm/yr rms: 5.09 mm
North (mm)
vel: -28.19 ± 0.01 mm/yr rms: 1.57 mm
East (mm)
vel: -2.24 ± 0.02 mm/yr rms: 3.95 mm
Height (mm)
2004 2005 2006 2007 2008 2009 2010 2011 2012

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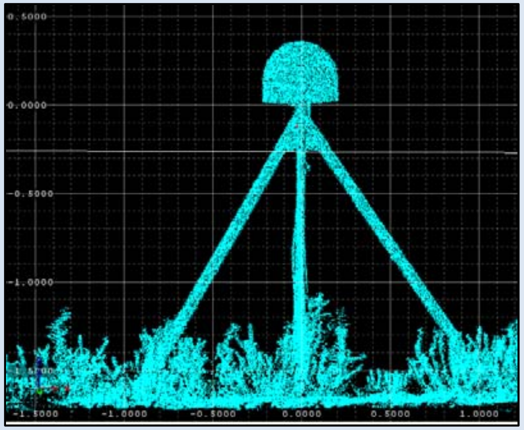
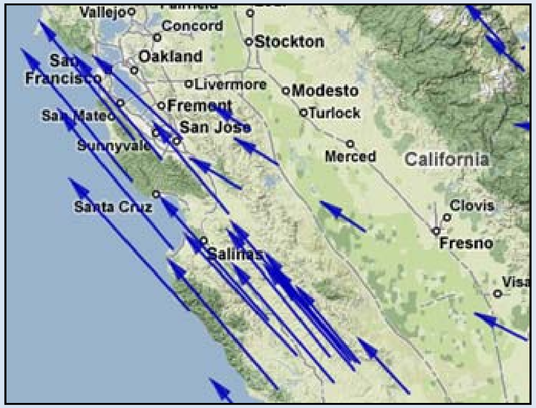
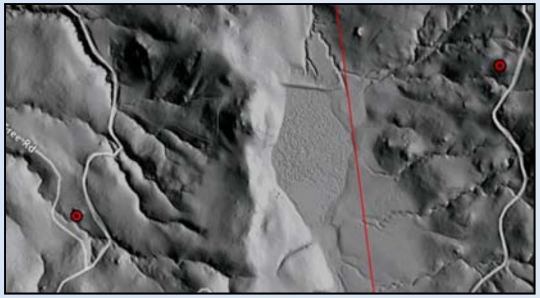
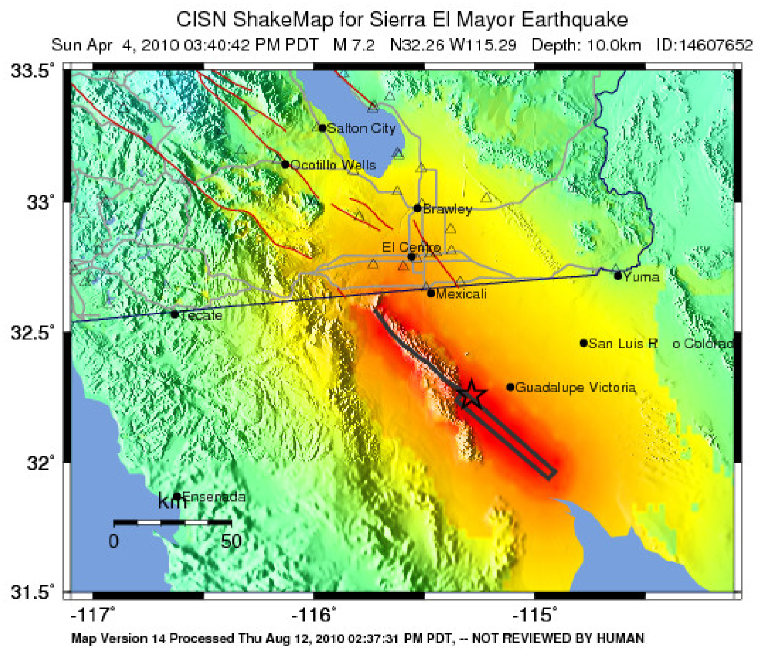


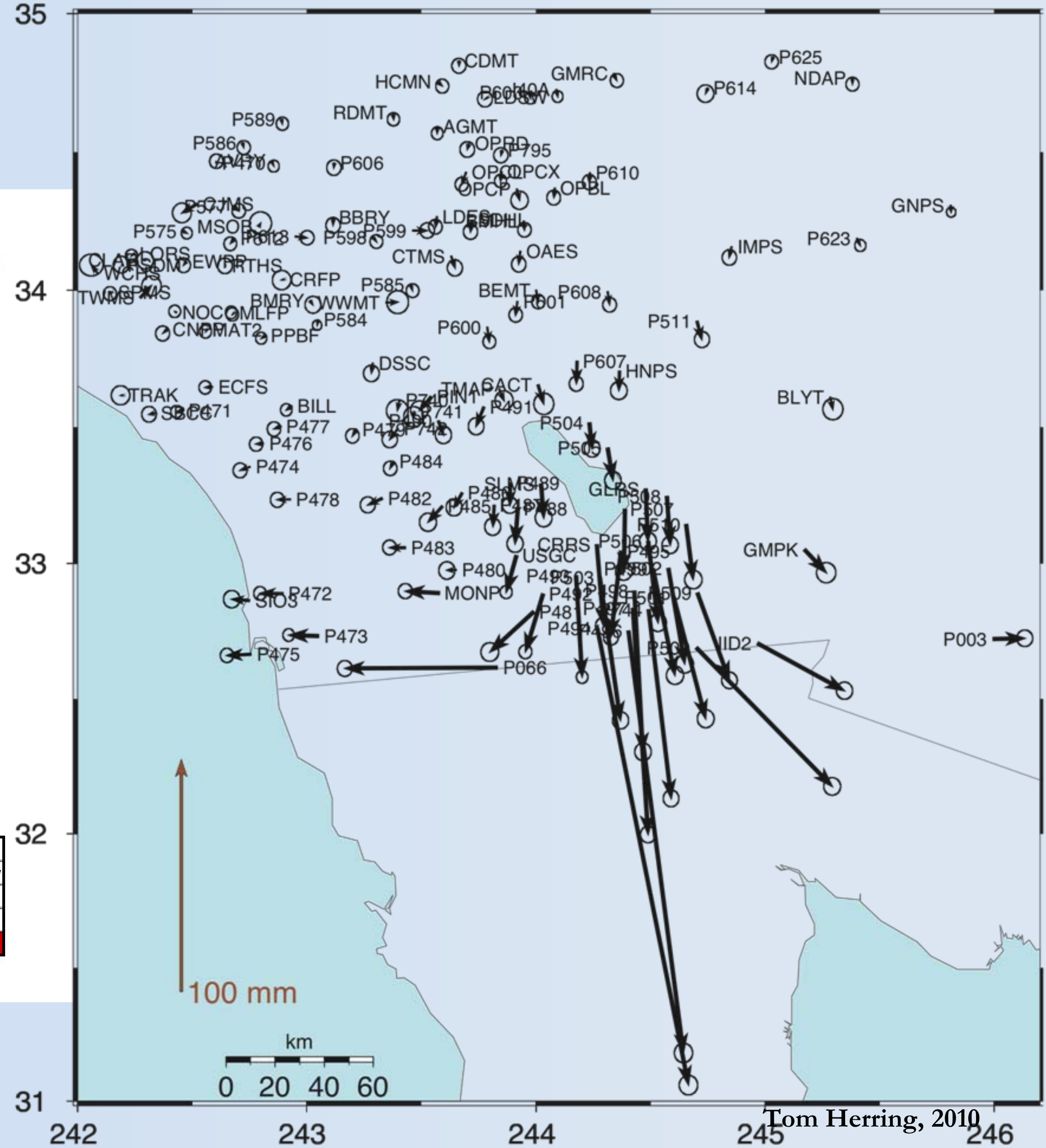




Earthquake applications of PBO GPS data

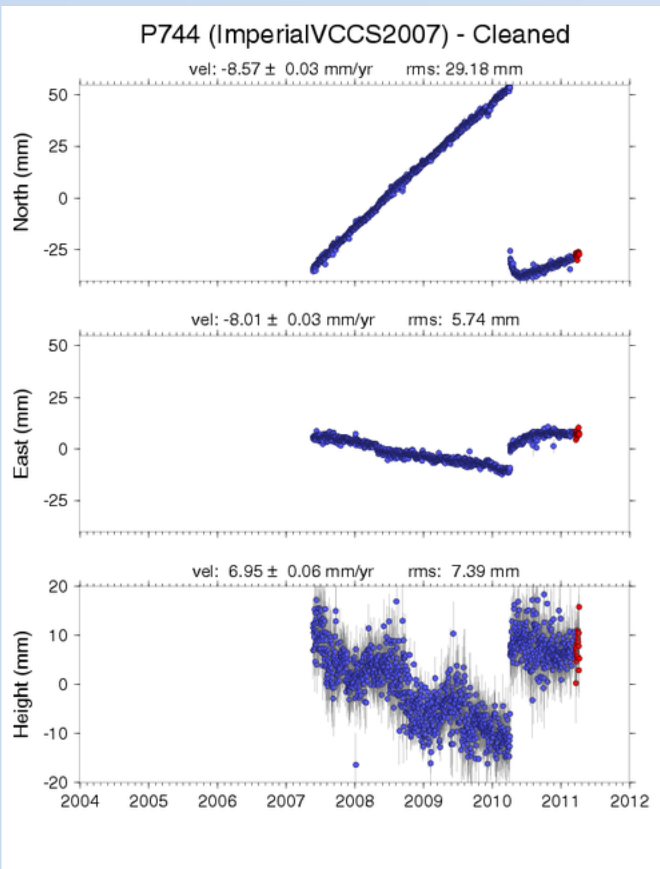


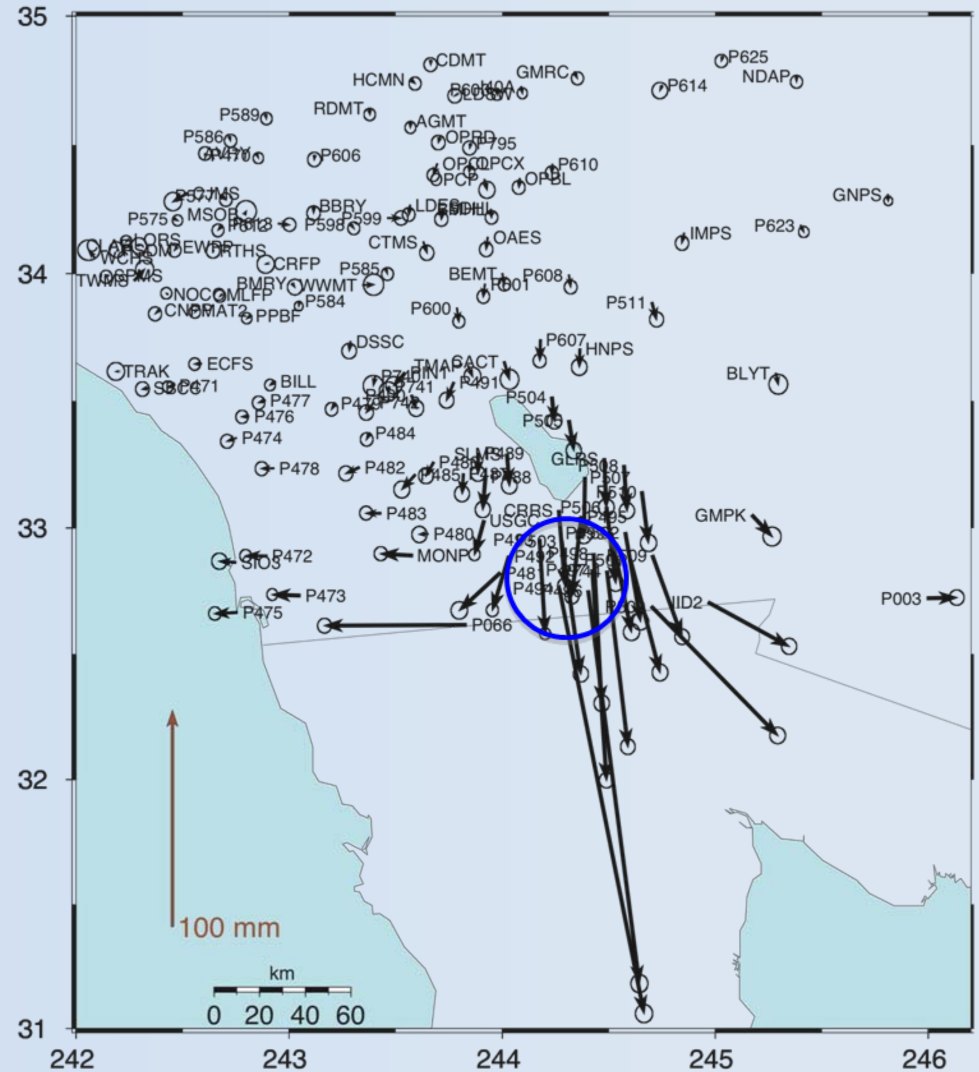
PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+



Tom Herring, 2010

Earthquake applications of PBO GPS data





Tom Herring, 2010

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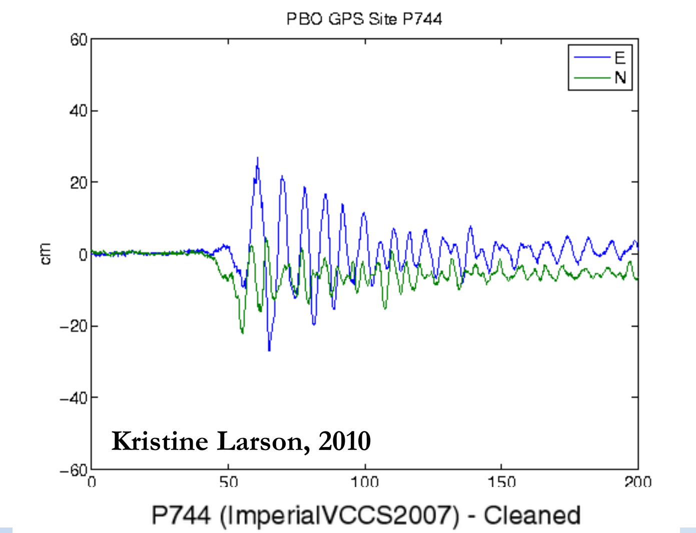

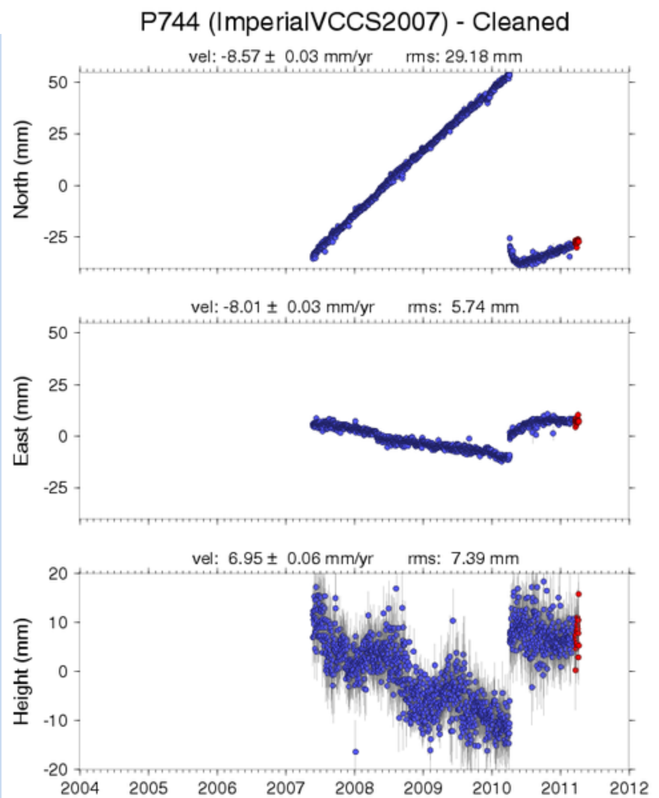

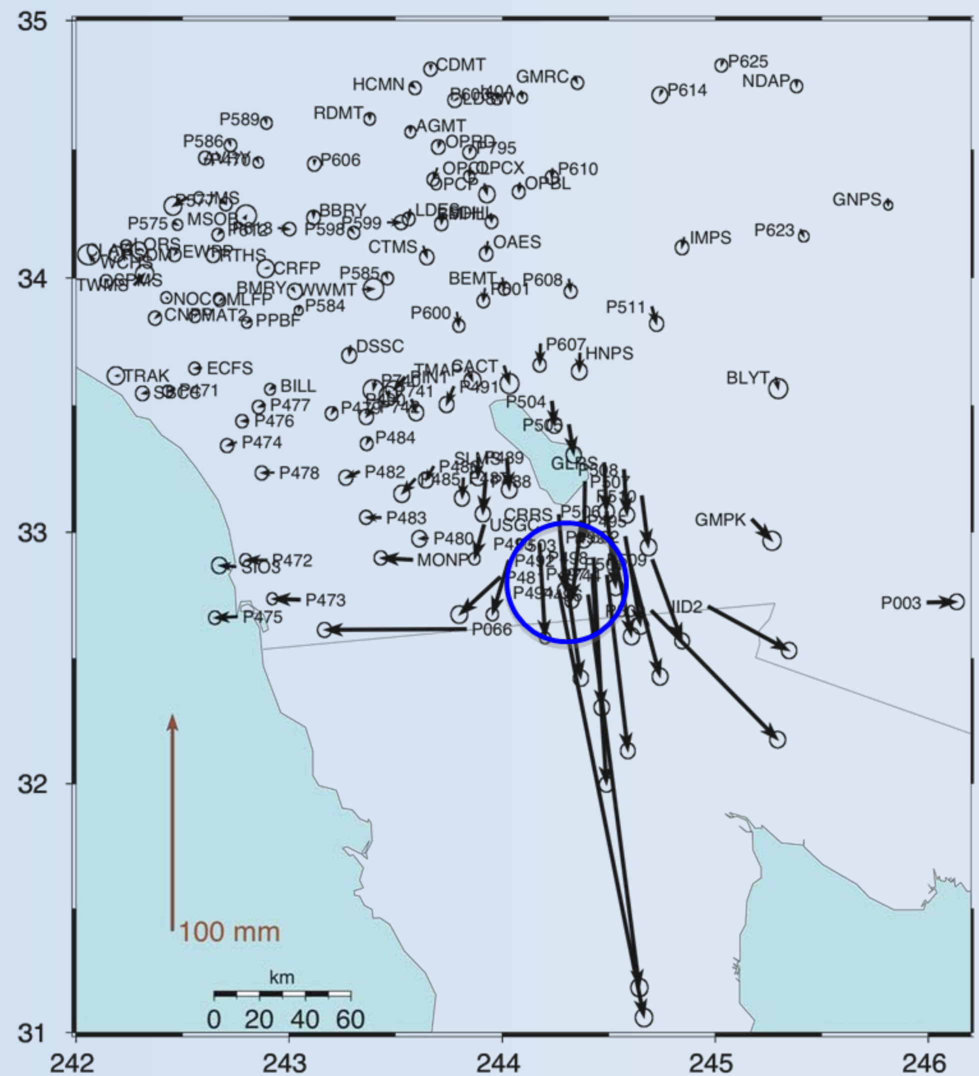

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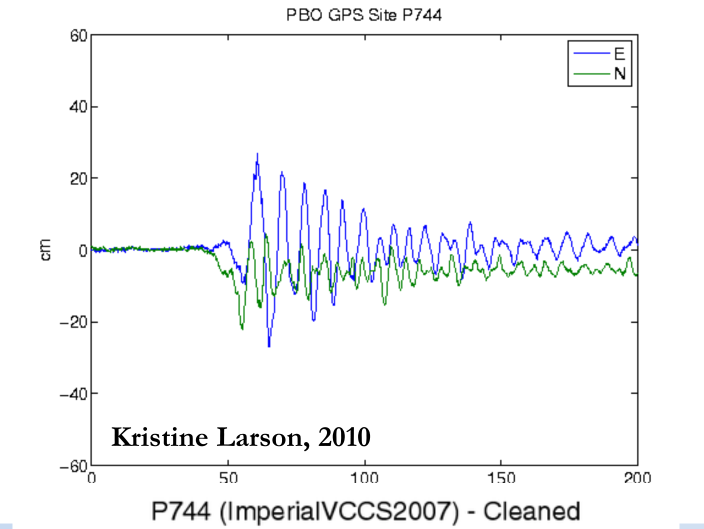
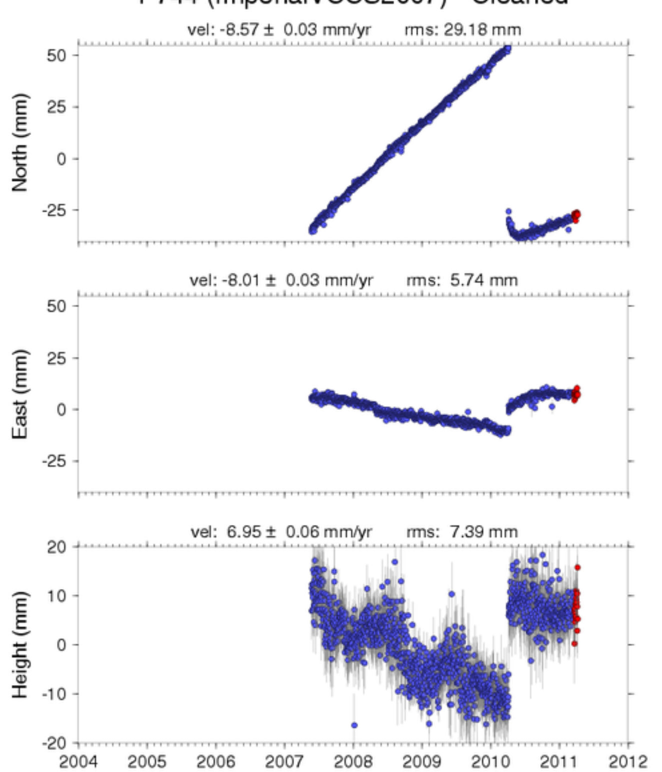
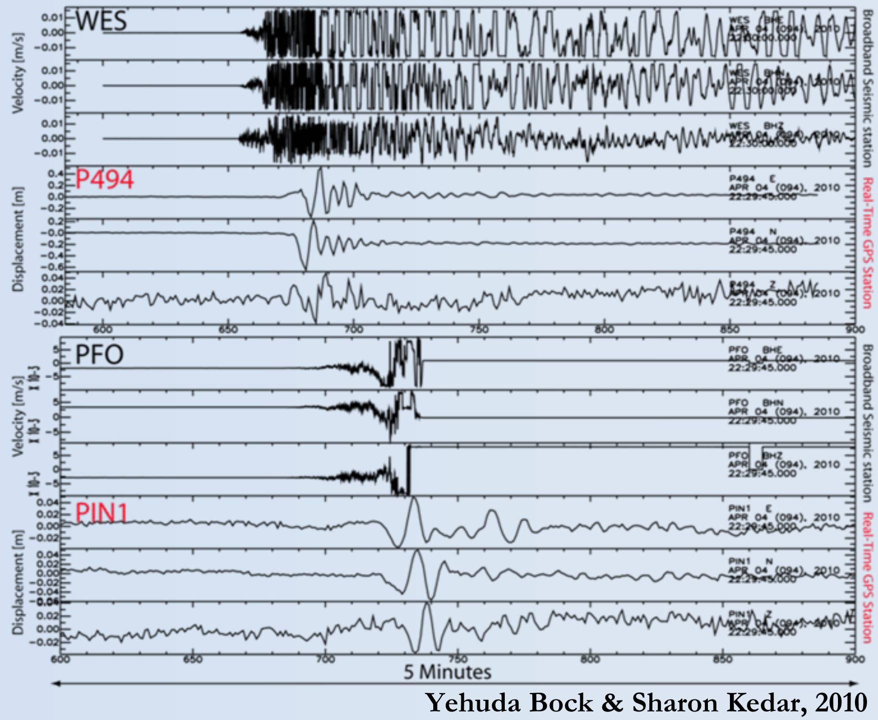
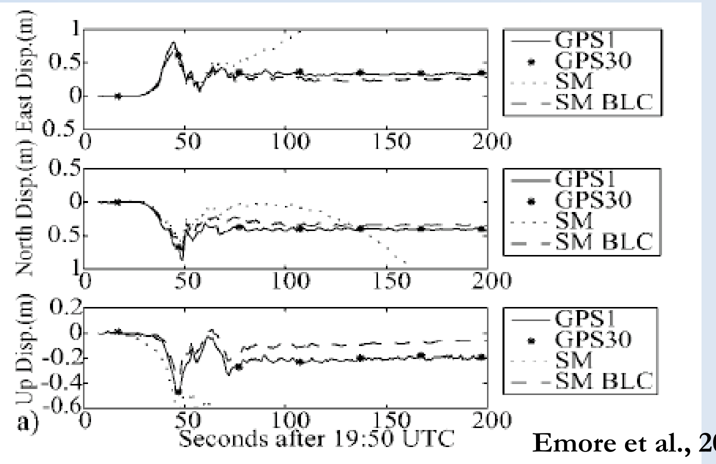


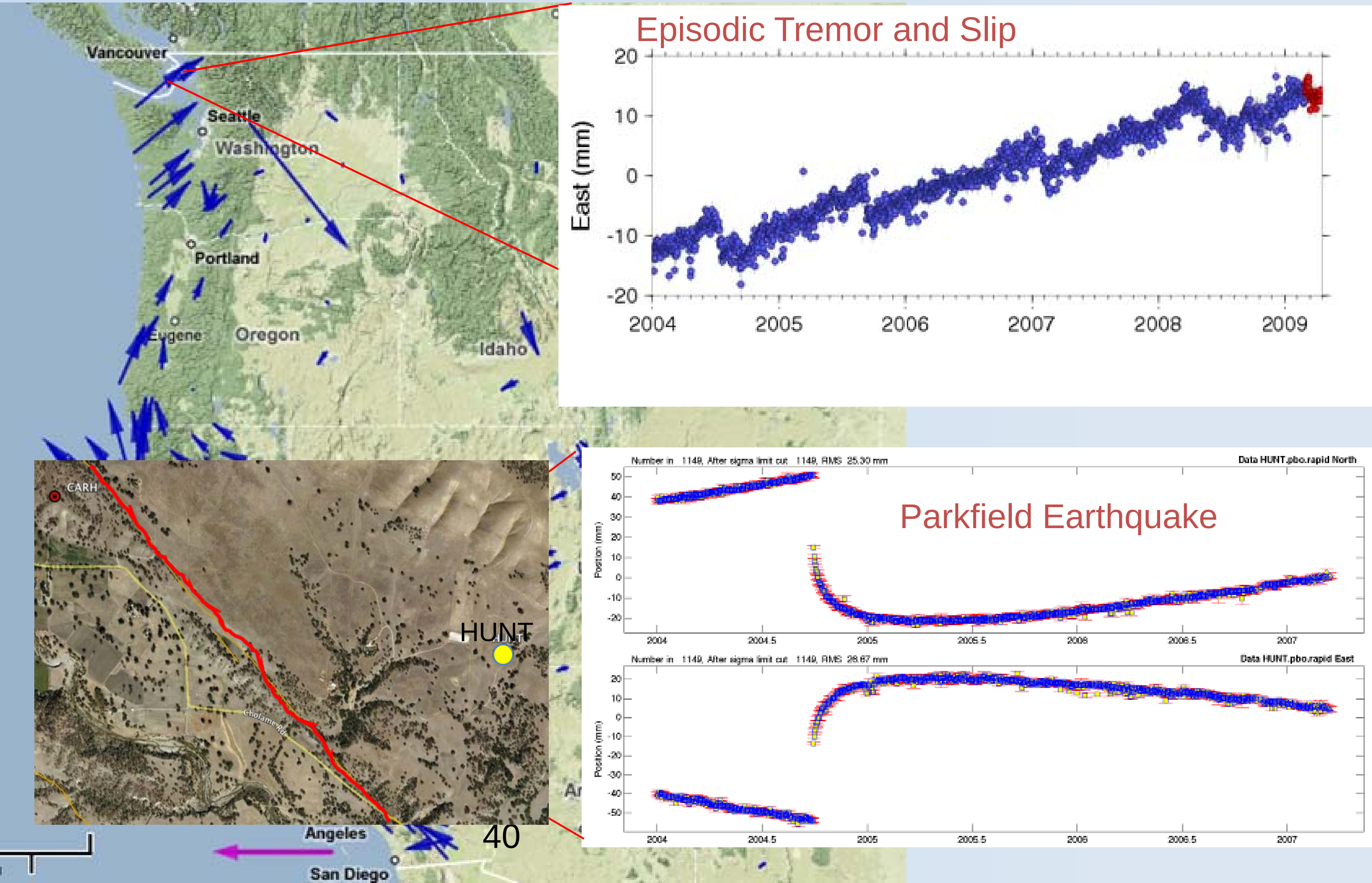




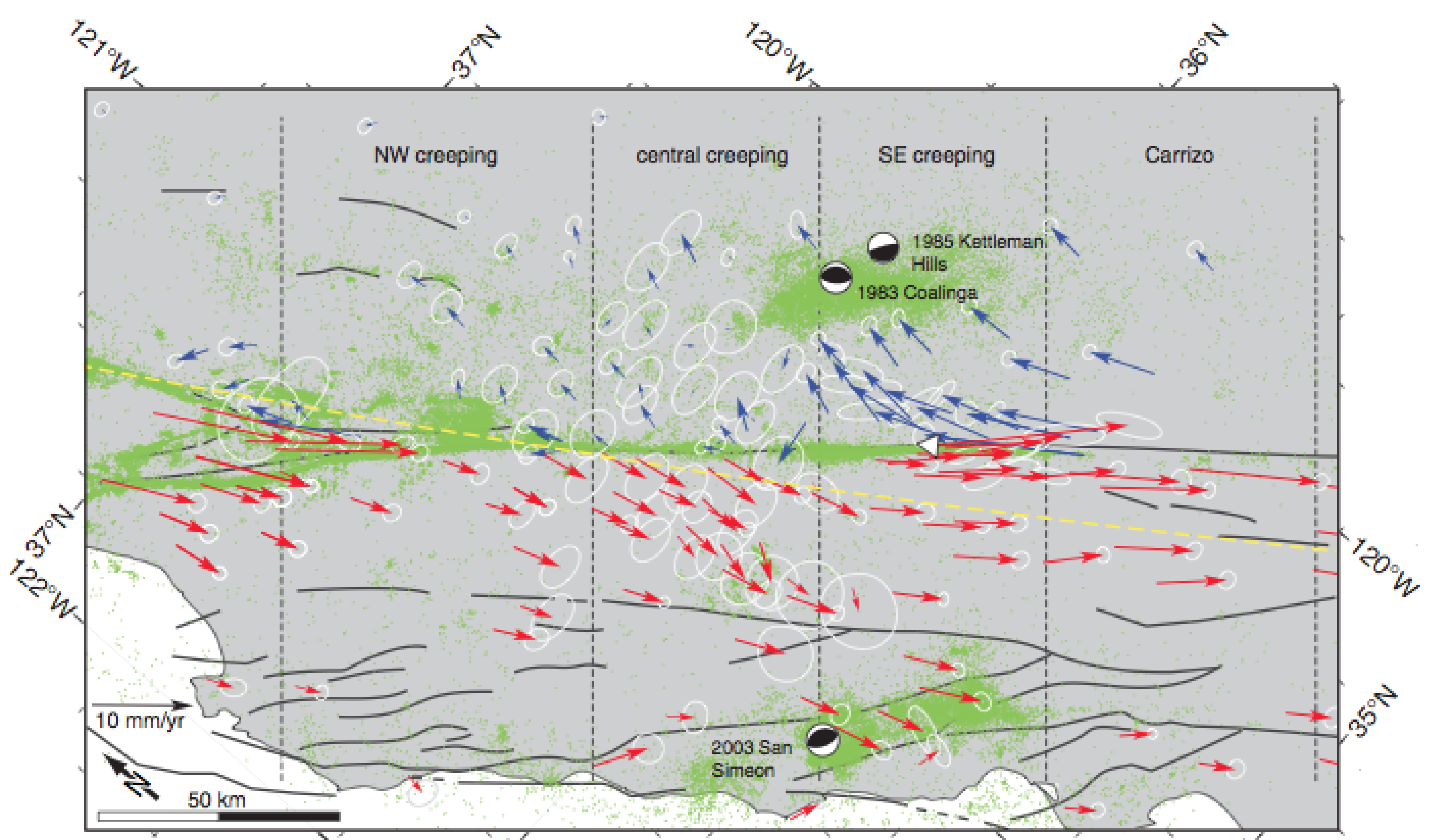


Emore et al., 2007

Transient motion associated with faults



Off Fault Deformation

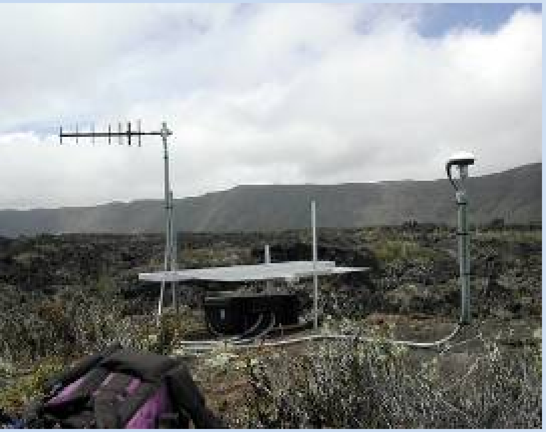


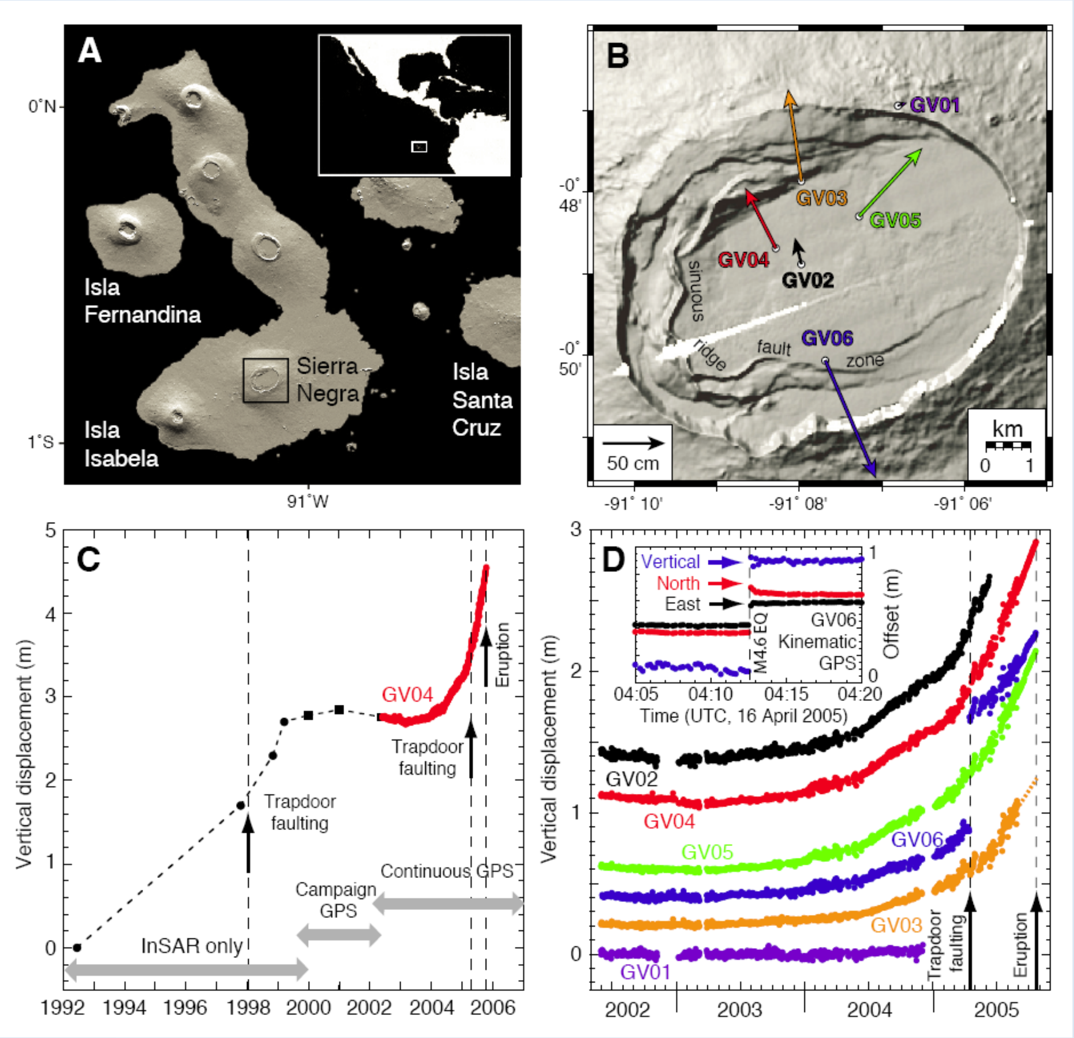
Geologic versus geodetic deformation adjacent to the San Andreas fault, central California: Sarah J. Titus1,†, Mark Dyson1, Charles DeMets2, Basil Tikoff2, Frederique Rolandone3, and Roland Bürgmann, Bulletin, June 2011.

Volcanic Deformation

Volcanic Signals

Sierra Negra, Galapagos



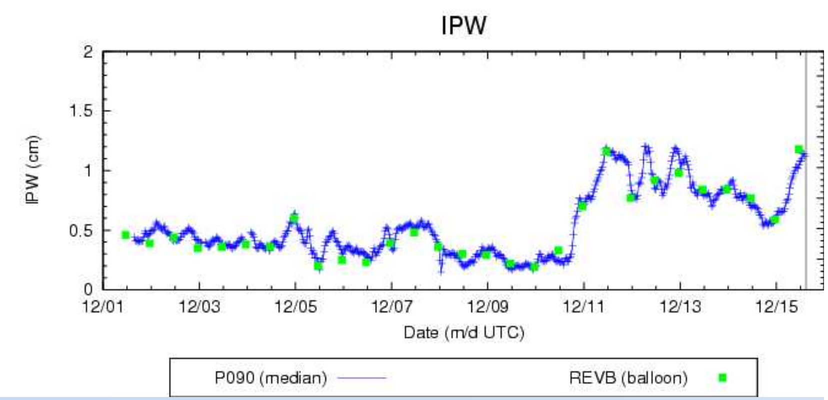


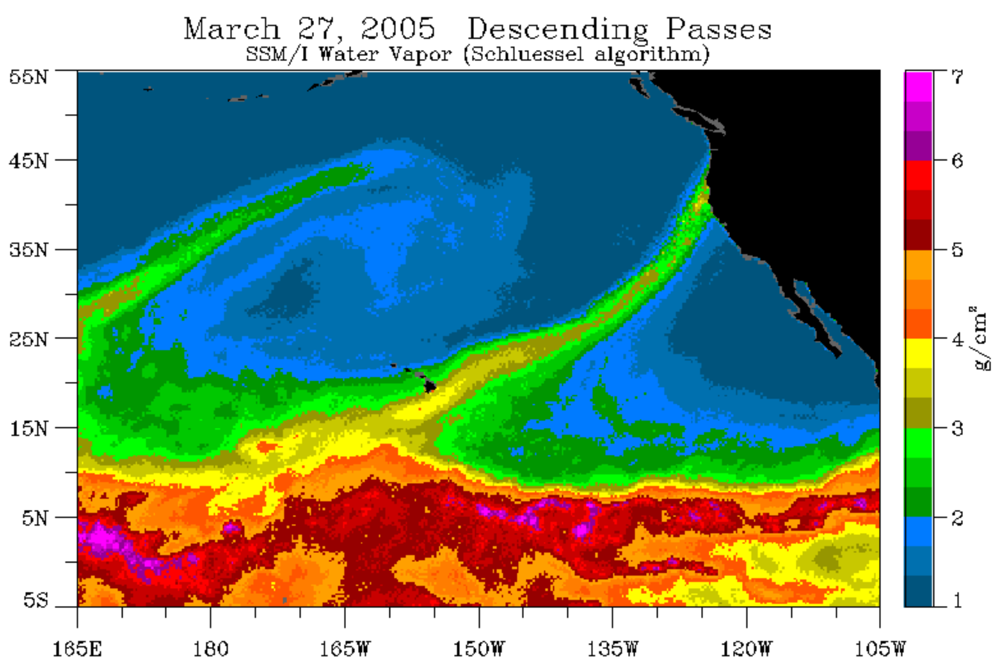
Dennis Geist, U. Idaho

Influence/Measurements of the Atmosphere

Atmospheric Measurements

- Precipitable Water Vapor (PWV) derived from GPS signal delays
- Assimilation of PW into weather models improves forecasting for storm intensity

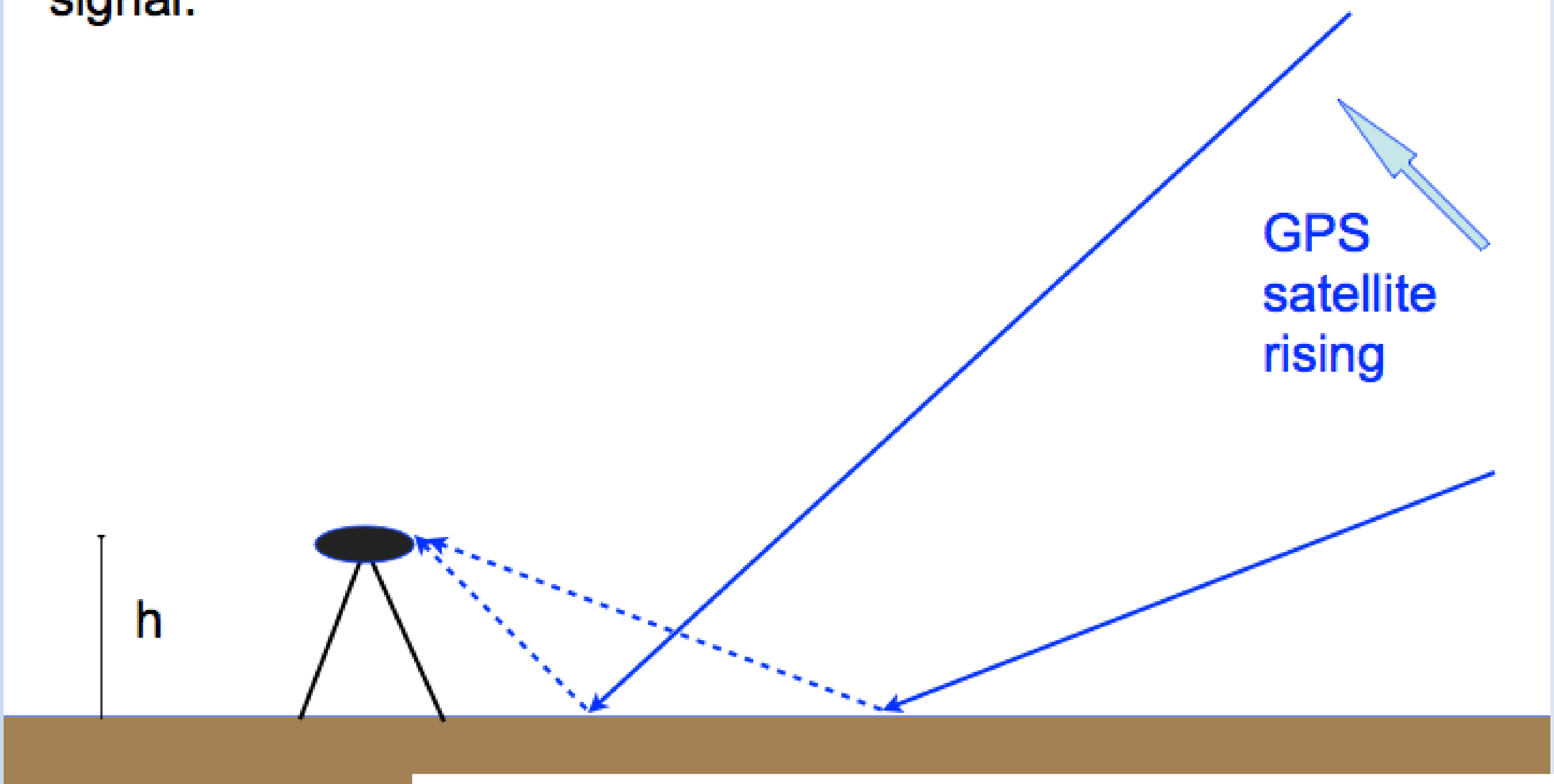




White, 2010

Measuring Snow Depth?

GPS signal to noise ratio - SNR - data are directly related to the interference of the direct and reflected signal.



observed SNR fre
depends on heigh
the reflector

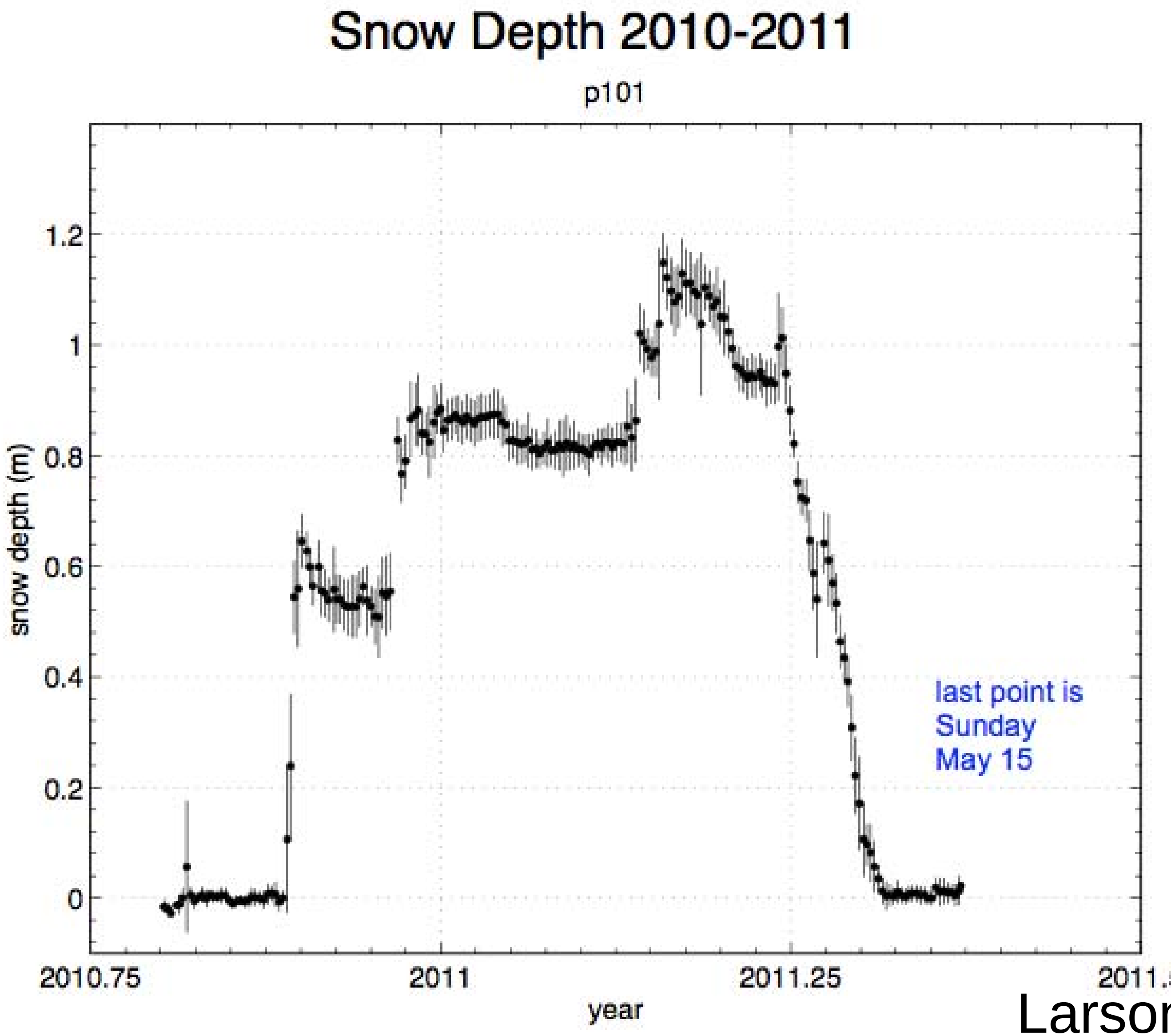
Can we measure snow depth with GPS receivers?

Kristine M. Larson,[1] Ethan D. Gutmann,[2] Valery U. Zavorotny,[3] John J. Braun,[4] Mark W. Williams,[5] and Felipe G. Nievinski[1]

GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L17502, doi:10.1029/2009GL039430

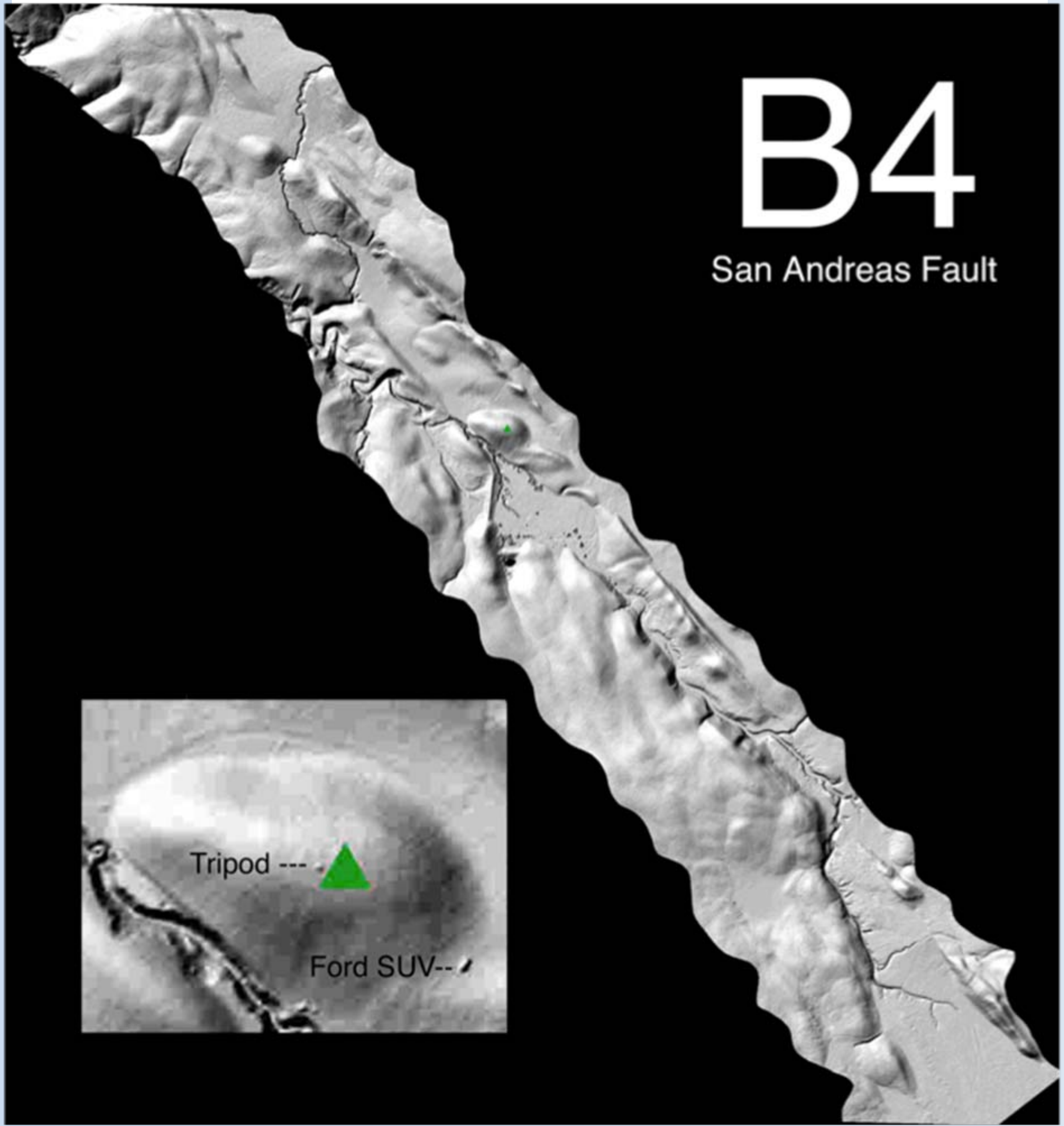
Snow Depth

Snow Depth



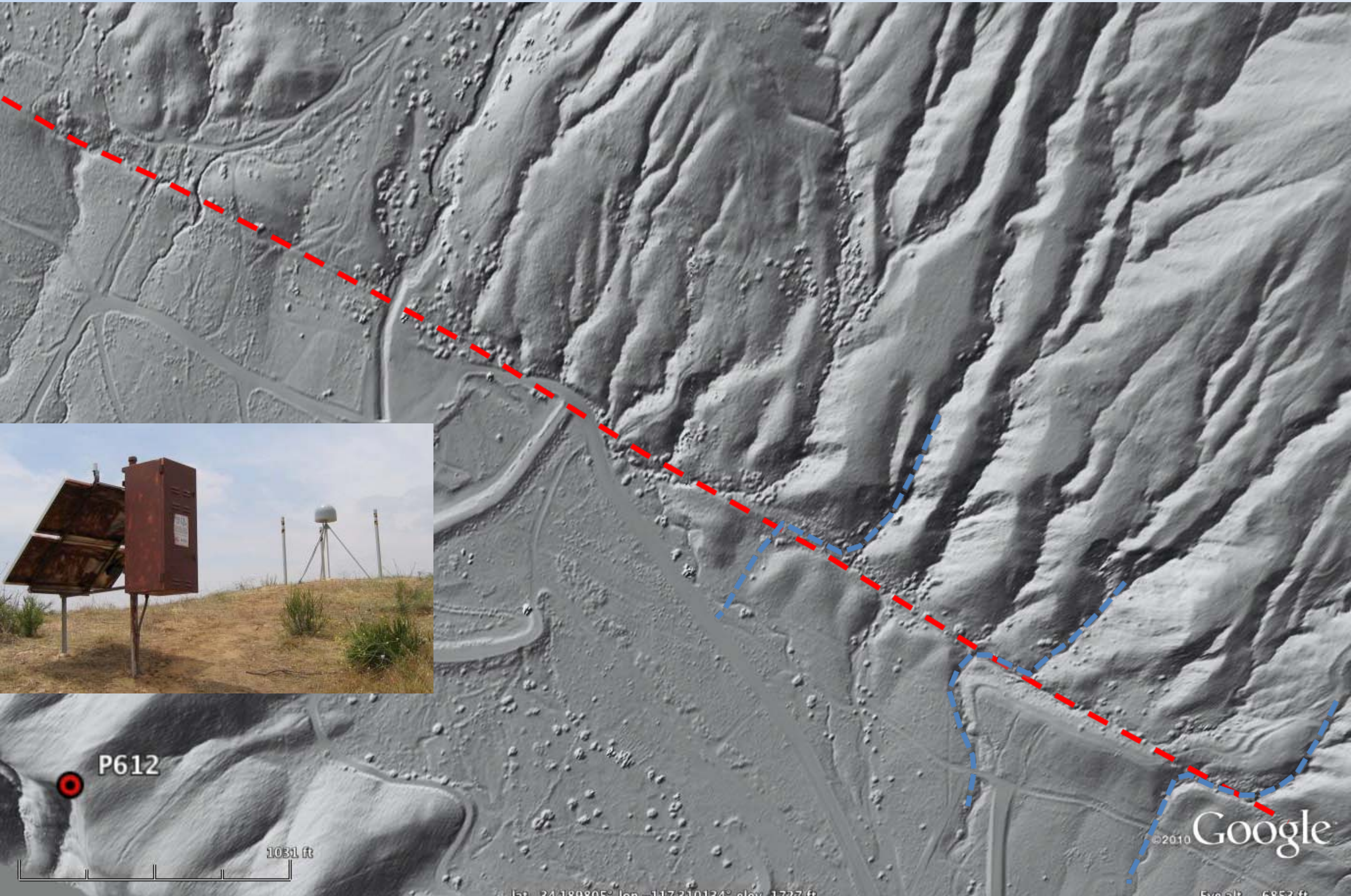
Larson, 2011

Airborne Lidar

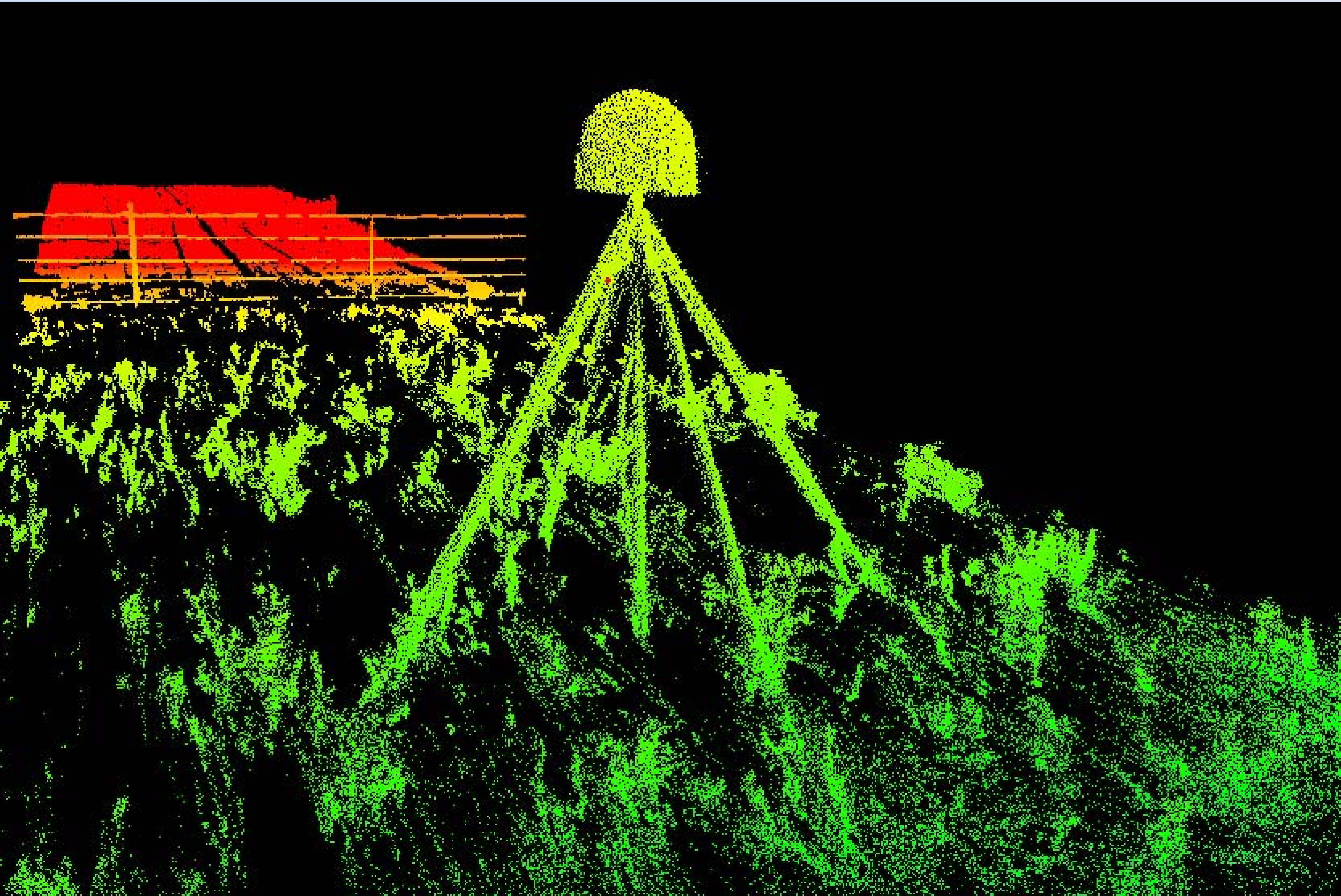


K. Hudnut

P612 Base Station B4 Lidar



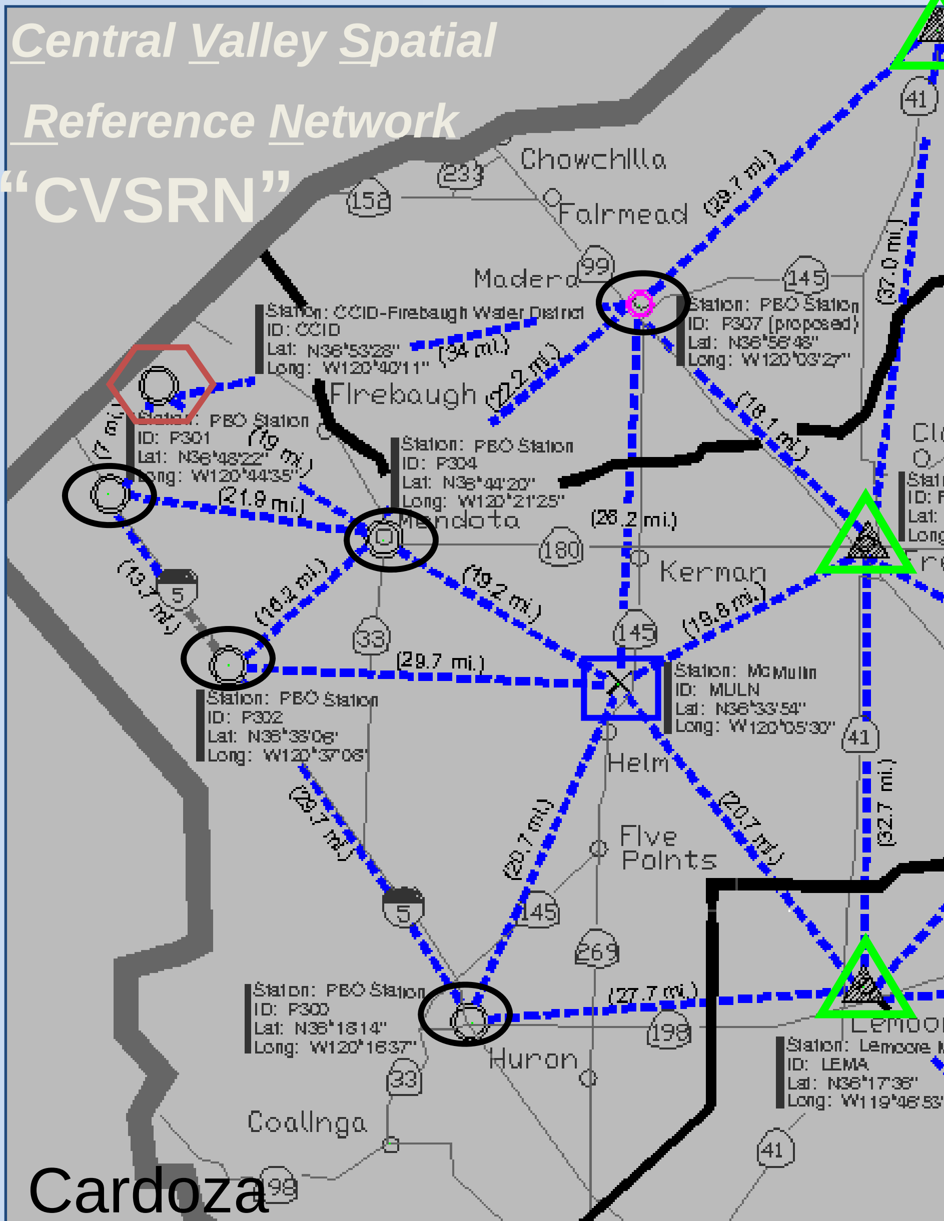
Tripod Lidar Scanner - TLS



Central Valley Spatial Reference Network

Central Valley Spatial Reference Network

"CVSRN"



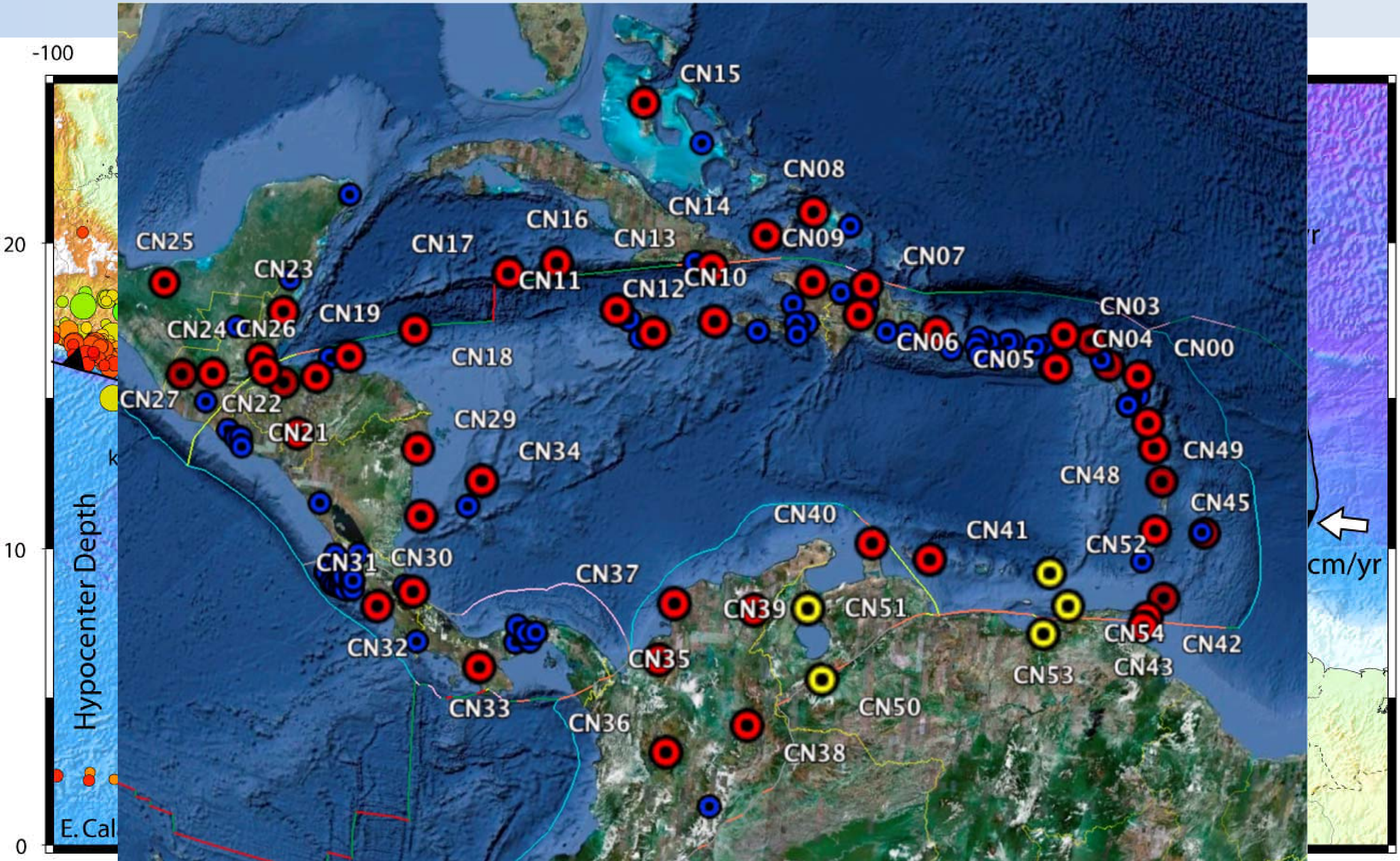
Cardoza

Banister: P056, P300, P302, P304, P566

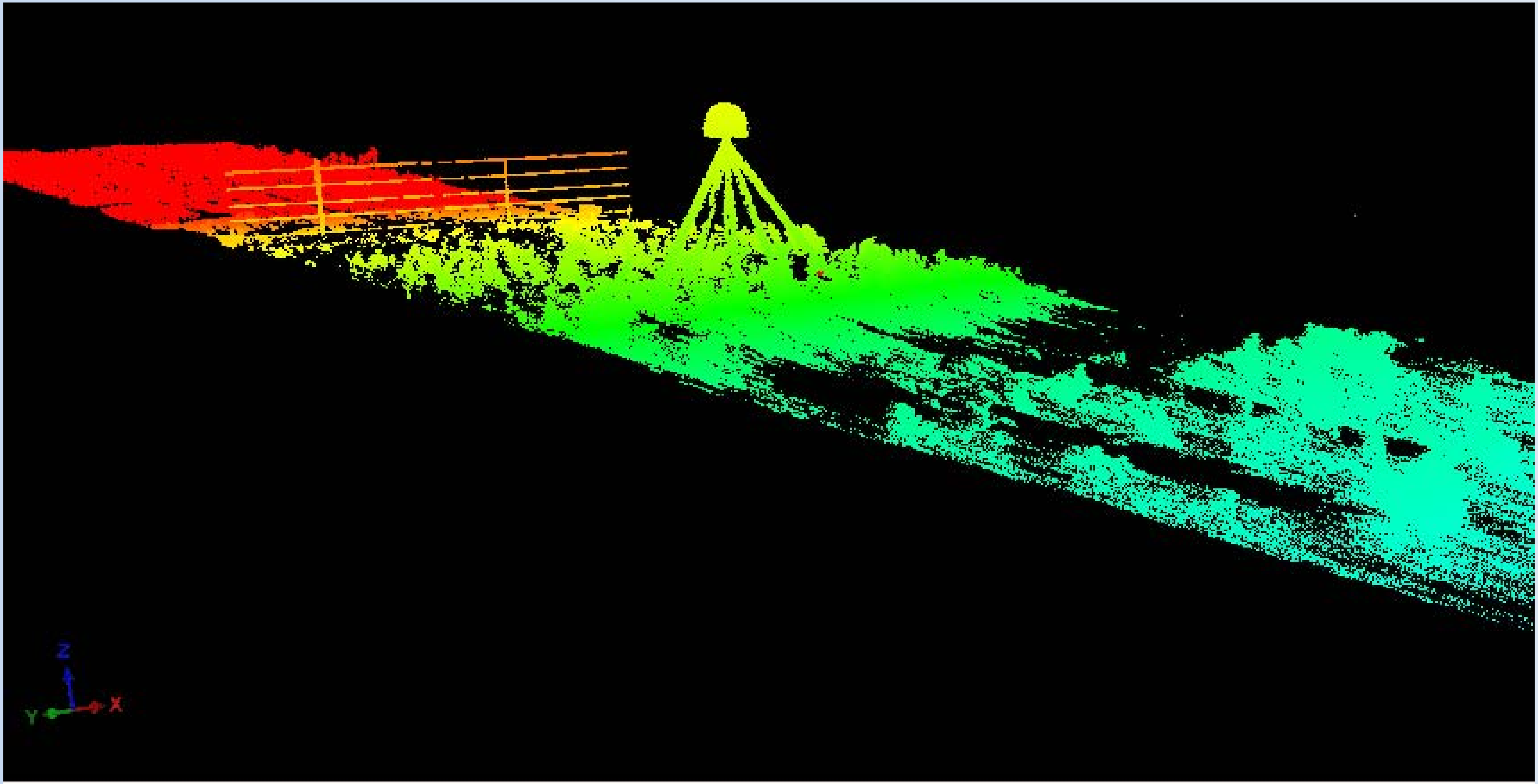
Baja Earthquake Response

UNAVCO

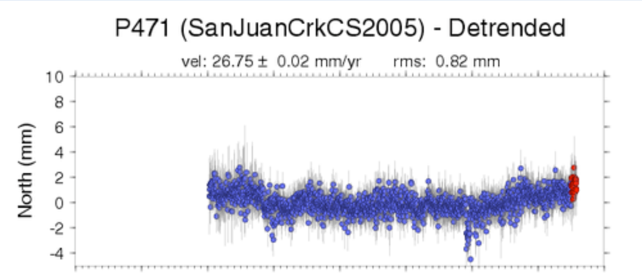
COCOnet



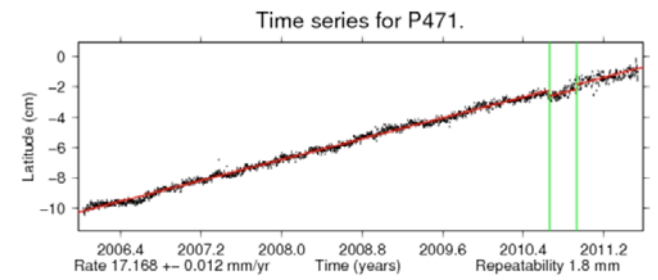
Questions?



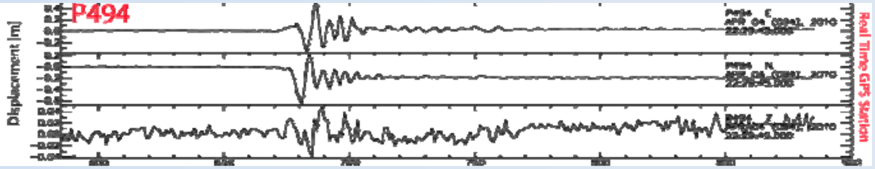
Data Portals



http://geon.unavco.org/unavco/UNAVCODataViewer.php



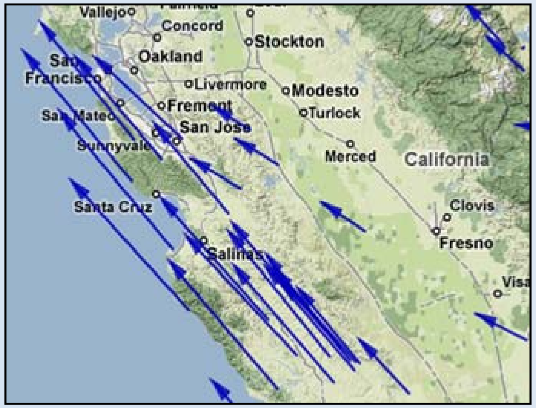
http://sideshow.jpl.nasa.gov/mbh/series.html



http://sopac.ucsd.edu/maps/index.html

Talk Summary

- UNAVCO
- Basics of GPS
- Data Products
- Uses of GPS Data
- What Impacts Data
- **GPS Near SONGS**



Real-Time P475 Point Loma

Serves:
SD County
SD City
Caltrans
CRTN
(<0.2s/100%)

Other Issues

1. Use of realtime latency and completeness data to troubleshoot the realtime network.

- Historical completeness/latency data will be stored in the PBO Operational Database (POD). Software development team is finishing up this step.
- Email notifications of problem stations (e.g. completeness < 85%, latency > 2.0 s over 24 hours) will go to all field personnel.
- PBO webpages will have region-sortable color-coded realtime SOH displays covering the previous 7 days.

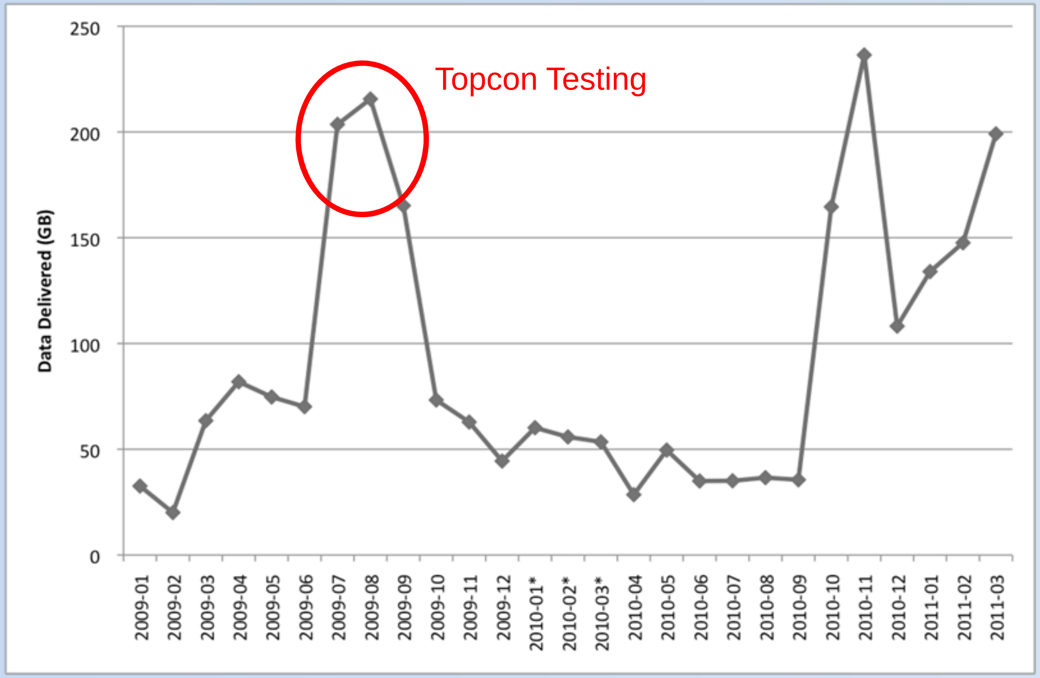
2. Expected performance of the network and data distribution system in the event of a large earthquake within the PBO footprint (particularly in Cascadia).

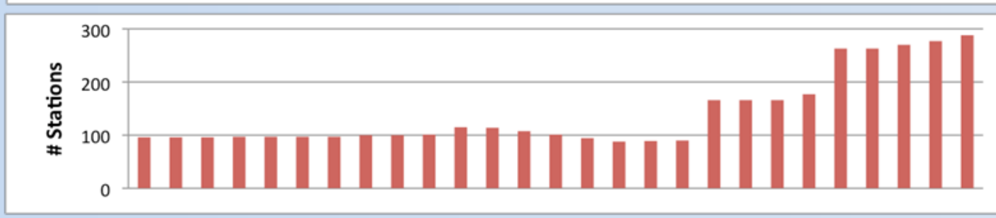
- Because of the real time nature of this dataflow, users who aren't on the system at the time of an earthquake will miss it entirely and will not load the system immediately afterwards. Outgoing bandwidth is not currently a bottleneck.
- Dataflow robustness after heavy shaking is not known. Expect better performance than cellular voice traffic, but if we are skipping epochs systemwide, realtime positioning will be unstable for many of the current algorithms.

3. UNAVCO's realtime GPS and high-rate GPS strategies are linked. We can use them together to achieve more than either alone.

Realtime GPS Statistics

Data Usage



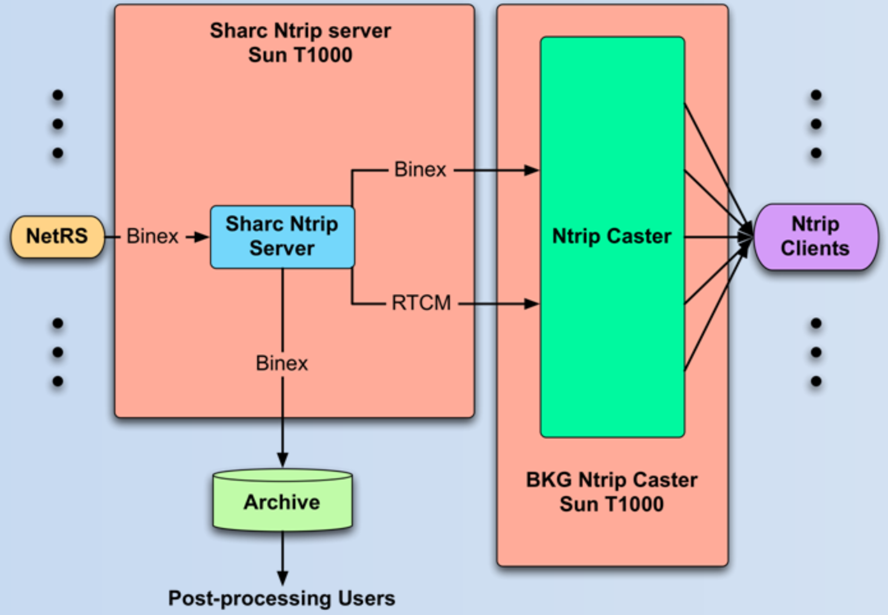


Since switch to VRS3Net system in 7/2010, there have been 40 unique users of PBO's realtime GPS streams and 35% of streaming data delivery has been in BINEX.

User	% Total
Earthquake Warnings INC	22.1%
Scripps Institution of Oceanography	14.3%
GPS Solutions Inc	12.9%
Topcon	12.1%
Central Washington University	9.4%
NOAA OAR ESRL	7.7%
USGS Cascades Volcano Observatory	7.2%
Oregon Department of Transportation	2.8%
GMV	2.5%
AZGPS	2.5%
Natural Resources Canada	1.1%
Utah State DTS	1.0%
Washington State Reference Network	0.8%
JPL	0.7%
USGS Menlo Park	0.7%
Other	2.3%

Realtime GPS Dataflow

Original Schematic for UStream-based Realtime GPS Dataflow



Realtime GPS Dataflow

Original Schematic for UStream-based Realtime GPS Dataflow