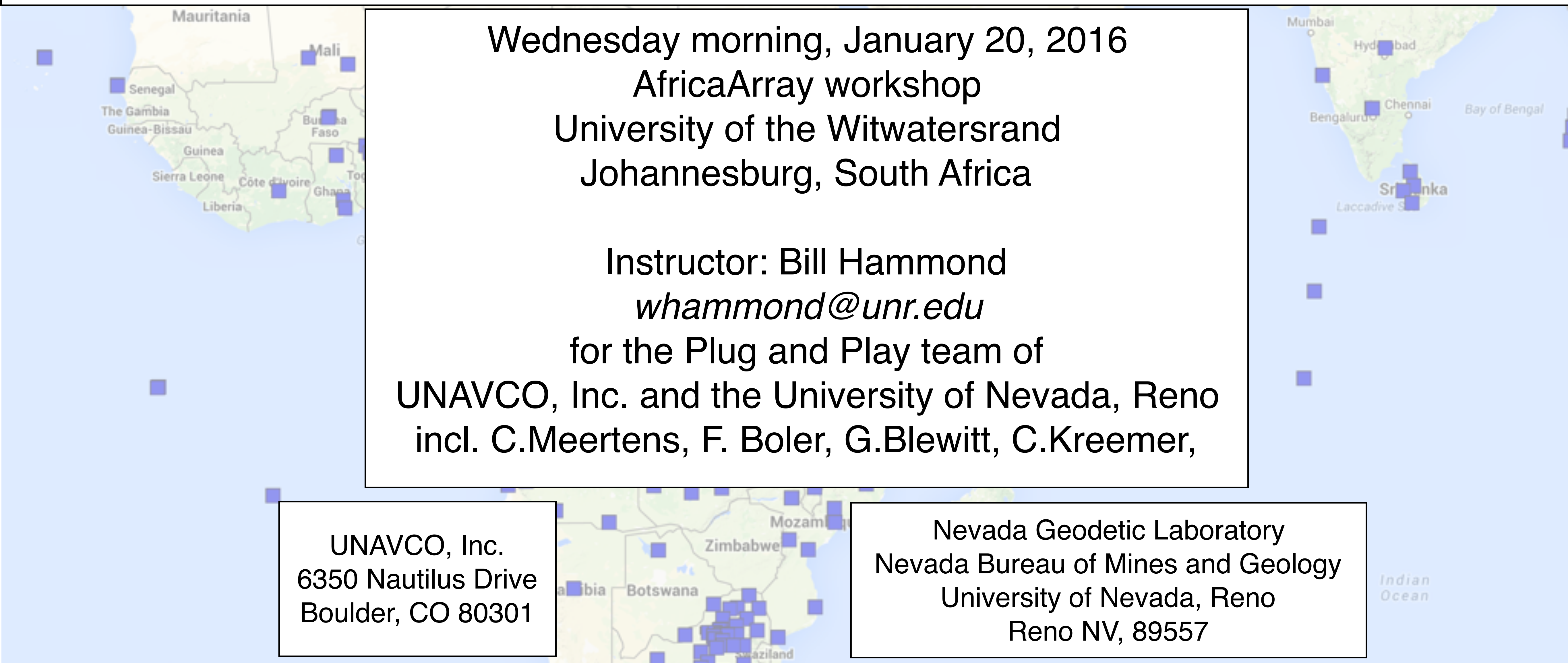
Short Course

Plug and Play GPS for Earth Scientists:

Providing Immediate Access to Low-Latency Geodetic Products for Rapid Modeling and Analysis of Natural Hazards



Wednesday morning, January 20, 2016
AfricaArray workshop
University of the Witwatersrand
Johannesburg, South Africa

Instructor: Bill Hammond
whammond@unr.edu
for the Plug and Play team of
UNAVCO, Inc. and the University of Nevada, Reno
incl. C.Meertens, F. Boler, G.Blewitt, C.Kreemer,

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Nevada Geodetic Laboratory
Nevada Bureau of Mines and Geology
University of Nevada, Reno
Reno NV, 89557

Plug and Play Portal and Short Course Materials

ftp://gneiss.nbmg.unr.edu/PlugNPlay/ShortCourseAfricaArrayJan2016

Includes:

- Short Course Agenda
- 1 Pager handout with description and link to signup form
- Short Course slides (.pdf of this presentation)

https://www.unavco.org/projects/other-projects/plug-and-play-gps/plug-and-play-gps.html

Plug and Play: Introduction of Scope and Philosophy

- **Why are we doing this?**
  - Provide FREE GPS data processing service that minimizes effort on part of network operators who contribute data
  - Reduces barriers to maximize scientific impact of GPS networks
  - Promotes of data sharing for science and society
  - Maximize discovery of data for scientific applications
- **Who is involved? The PnP Team players**:
  - UNAVCO, UNR
  - plus *beta testers* and *unfunded collaborators*, e.g. USGS, JPL, … i.e. you!
- **Who is funding the project?**
  - Collaborative NASA ACCESS program project UNAVCO and UNR
  - History of scientific, processing, and data products development at these institutions.

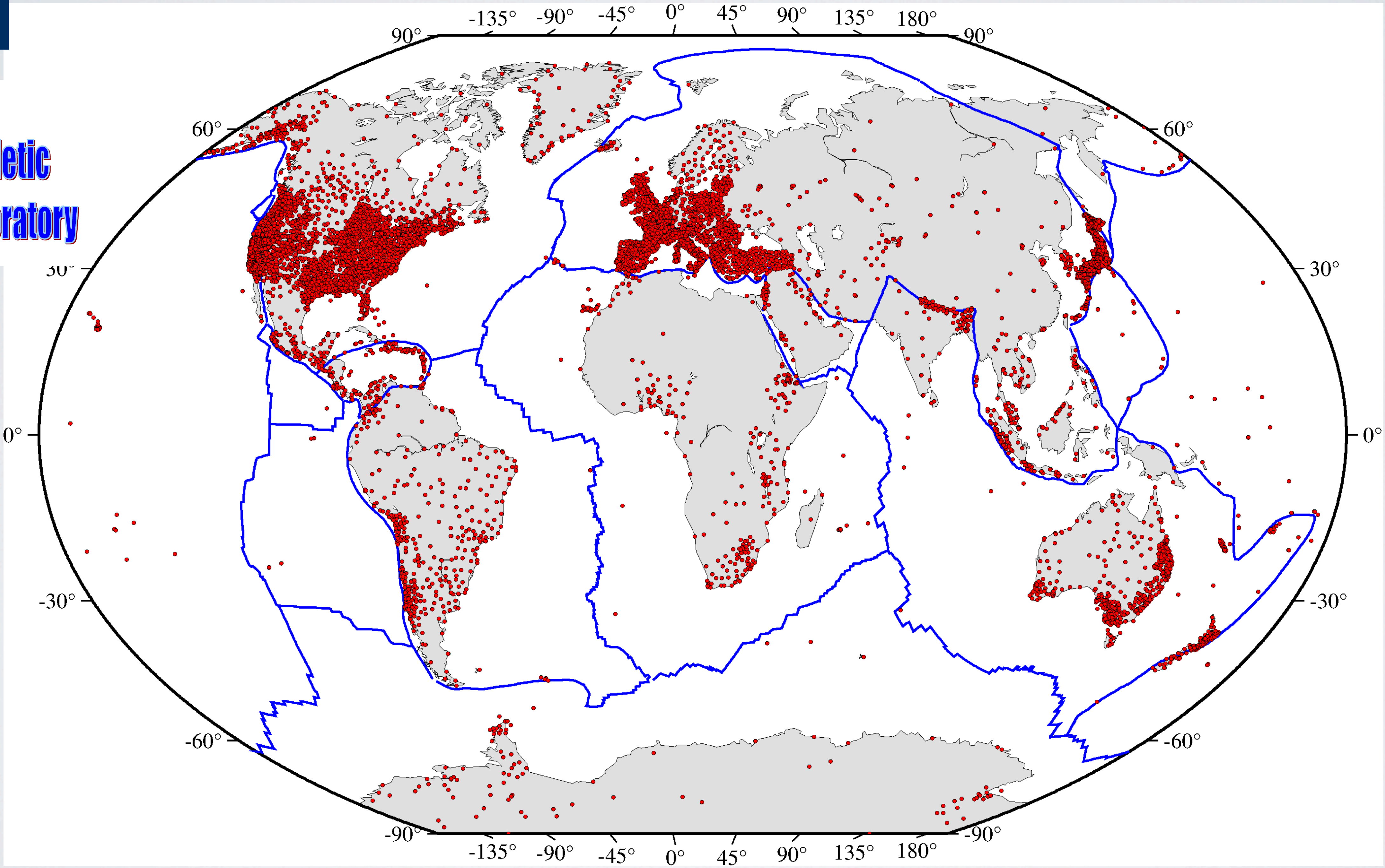
Plug and Play: Introduction of Scope and Philosophy

- **What is the arrangement**?
  - Network operators contribute data to UNAVCO or UNR directly
  - UNR picks up data, processes with GIPSY and generates data products (e.g. time series results files, plots, maps, velocity fields, quality control products, etc.)
  - Data products are placed on open access data products services, e.g. web pages, GSAC services.
- **Open access**.
  - Reduces barriers to setting up or expanding networks.
- **This is a rollout**
  - Many of the individual 'services' have been available for some time in the form of research projects.
  - Much of this is in beta mode… feedback is welcome.
  - New products available

2015: Exponential explosion

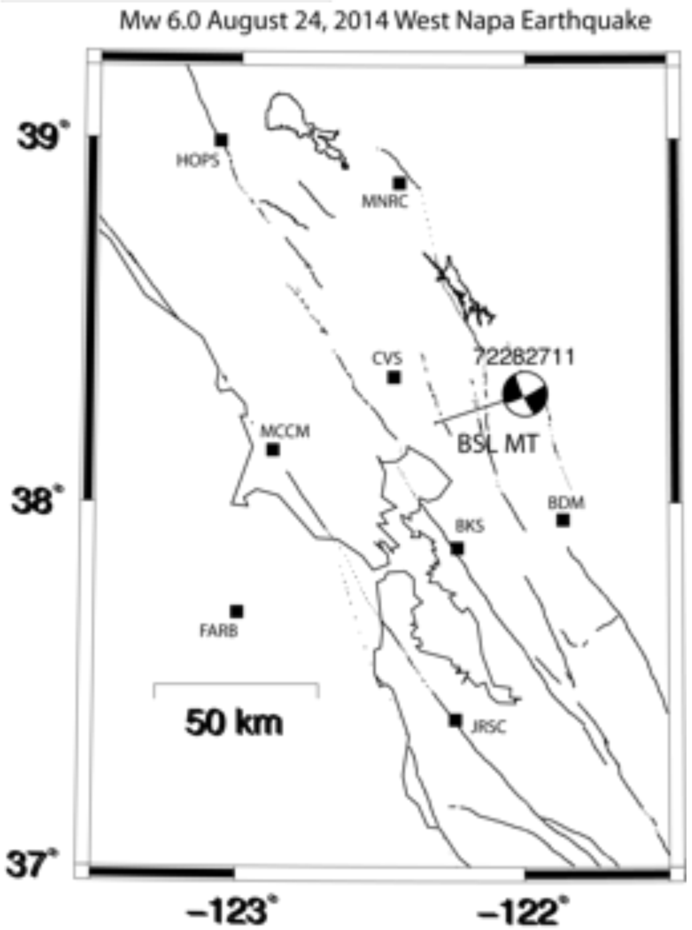
~~>13,700~~ stations processed by NGL http://geodesy.unr.edu

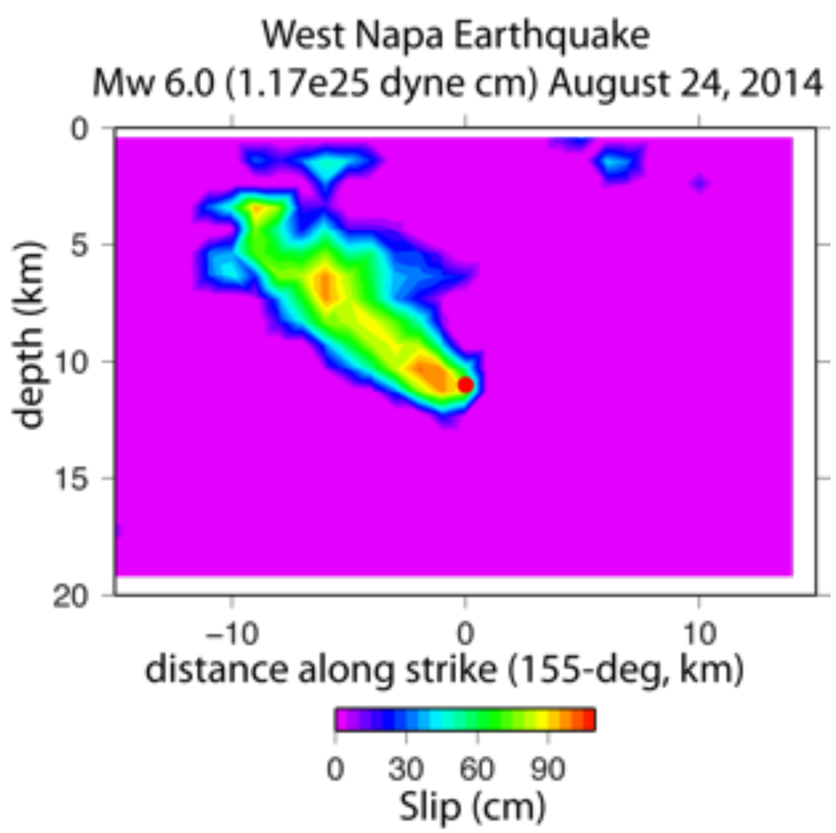
>14,400

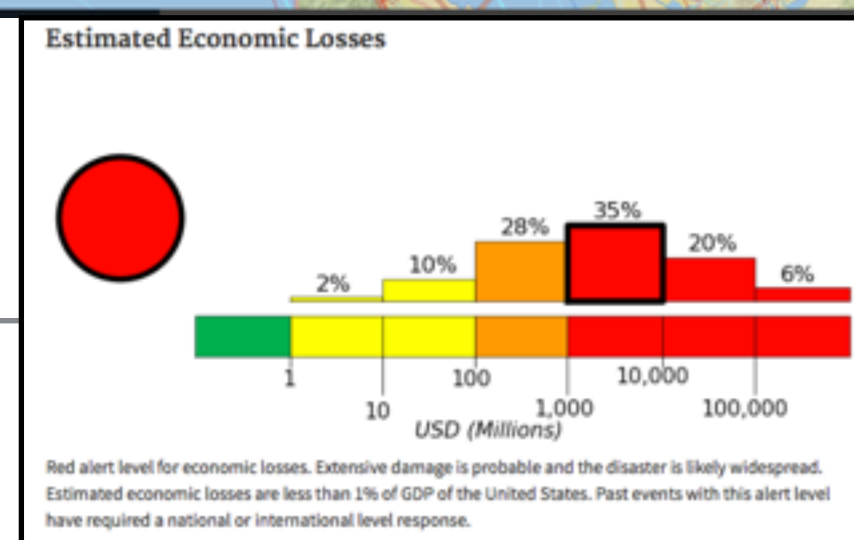


Case Study: The August 24, 2014 Napa M_W6.0 Earthquake

http://earthquake.usgs.gov/earthquakes/eventpage/nc72282711







Case Study: The August 24, 2014 Napa M_W6.0 Earthquake

Imagine this happens
And you want GPS solutions.

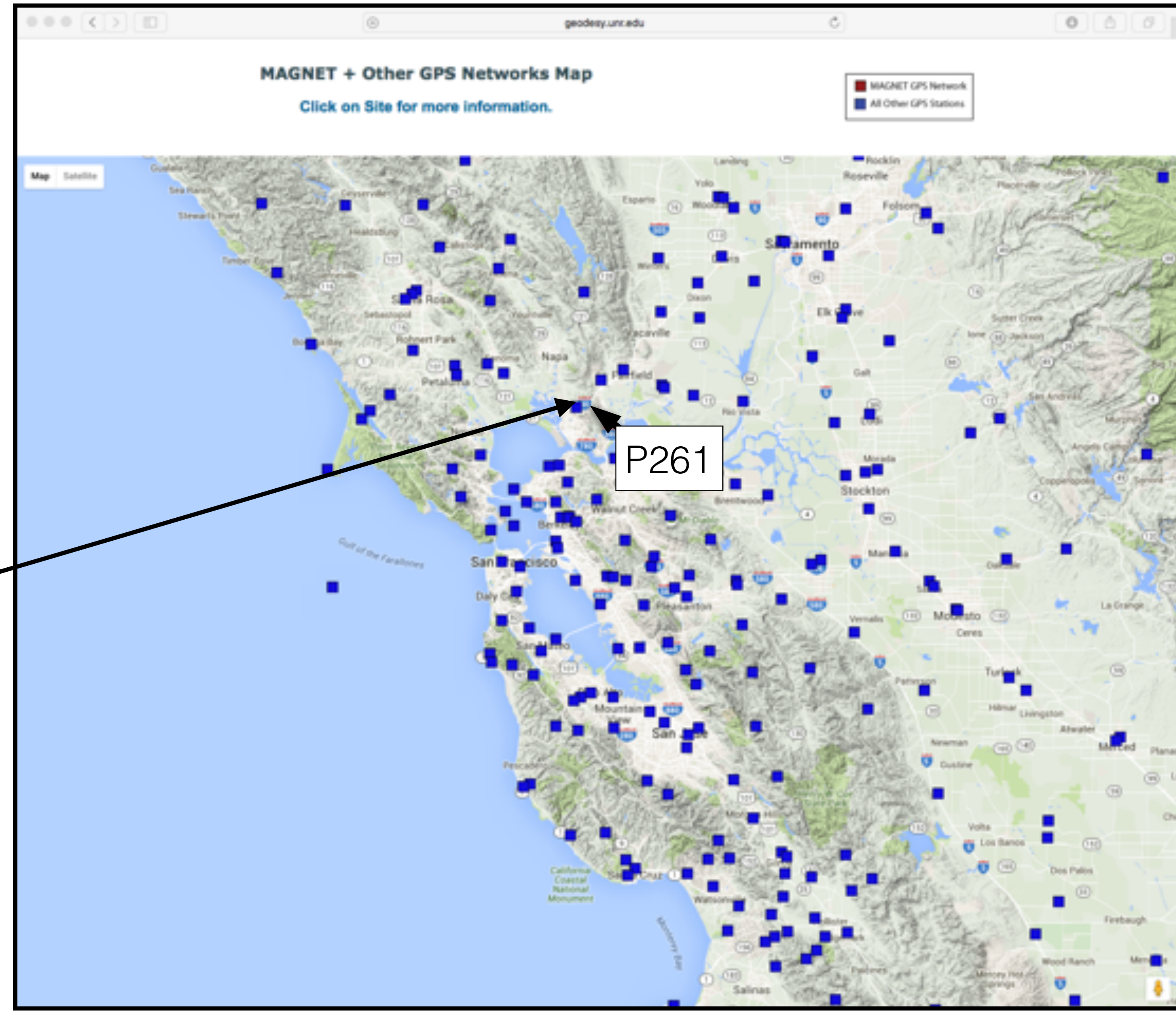
You go to http://geodesy.unr.edu/
You see there are many stations …

You might want an example time series. You might want to grab a couple plots.

Hover you mouse to get s click! me.

Or if you want everything and you are OK writing scripts you might try the:

- Data Holdings files…
- GSAC search tools…



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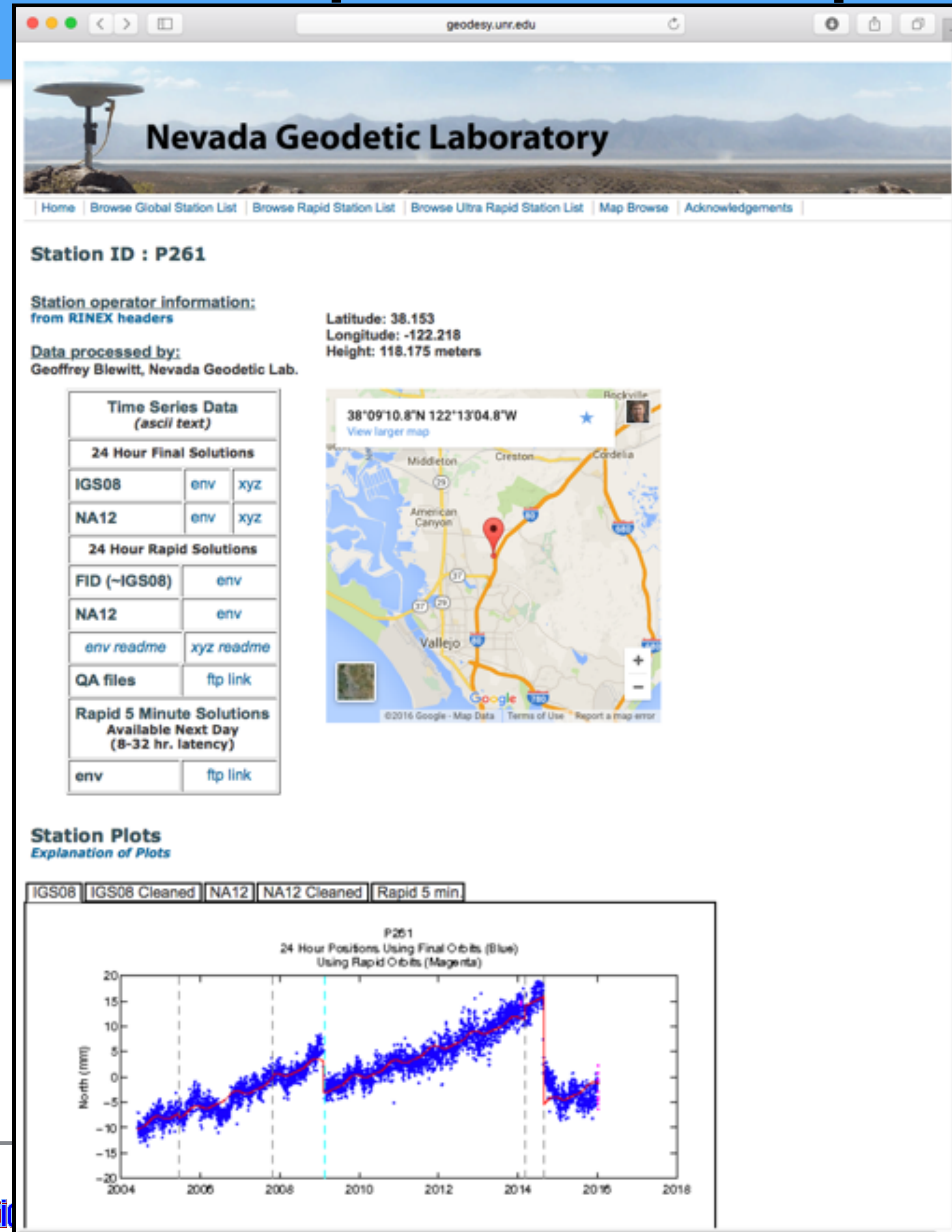

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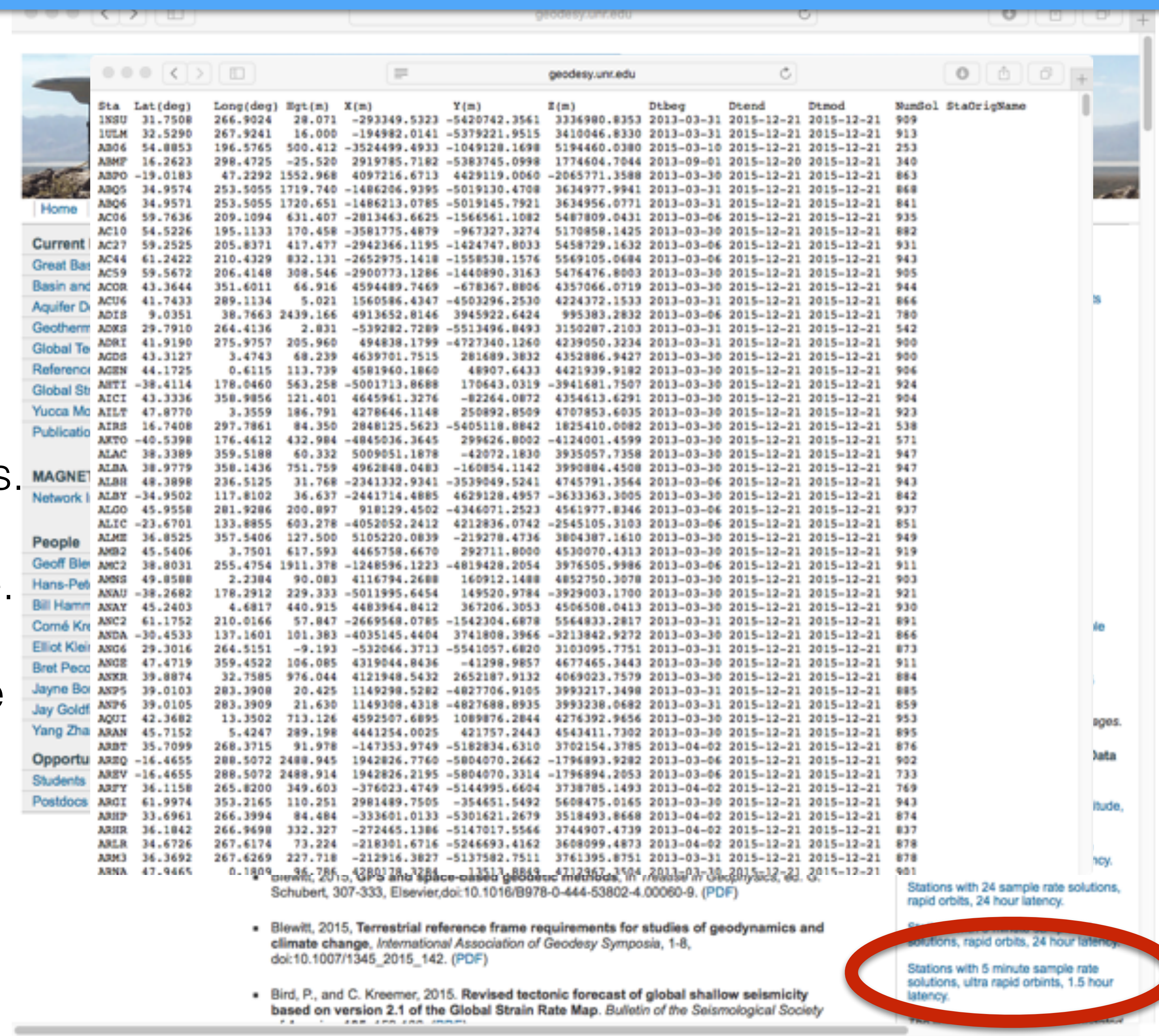

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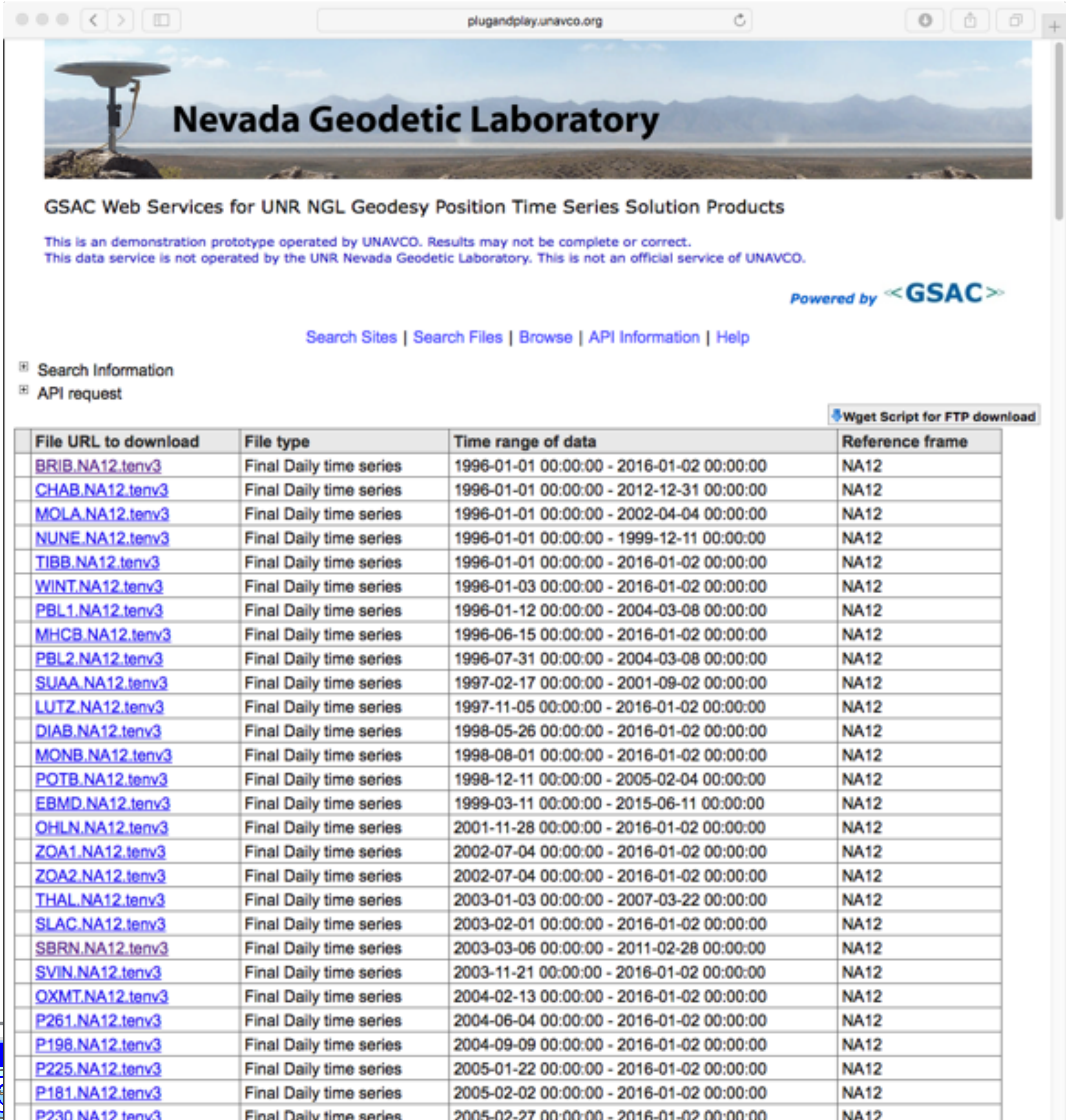

plugandplay.unavco.org

Nevada Geodetic Laboratory

GSAC Web Services for UNR NGL Geodesy Position Time Series Solution Products

This is an demonstration prototype operated by UNAVCO. Results may not be complete or correct.
This data service is not operated by the UNR Nevada Geodetic Laboratory. This is not an official service of UNAVCO.

Powered by <GSAC>

Search Sites | Search Files | Browse | API Information | Help

Search Information
API request

Wget Script for FTP download

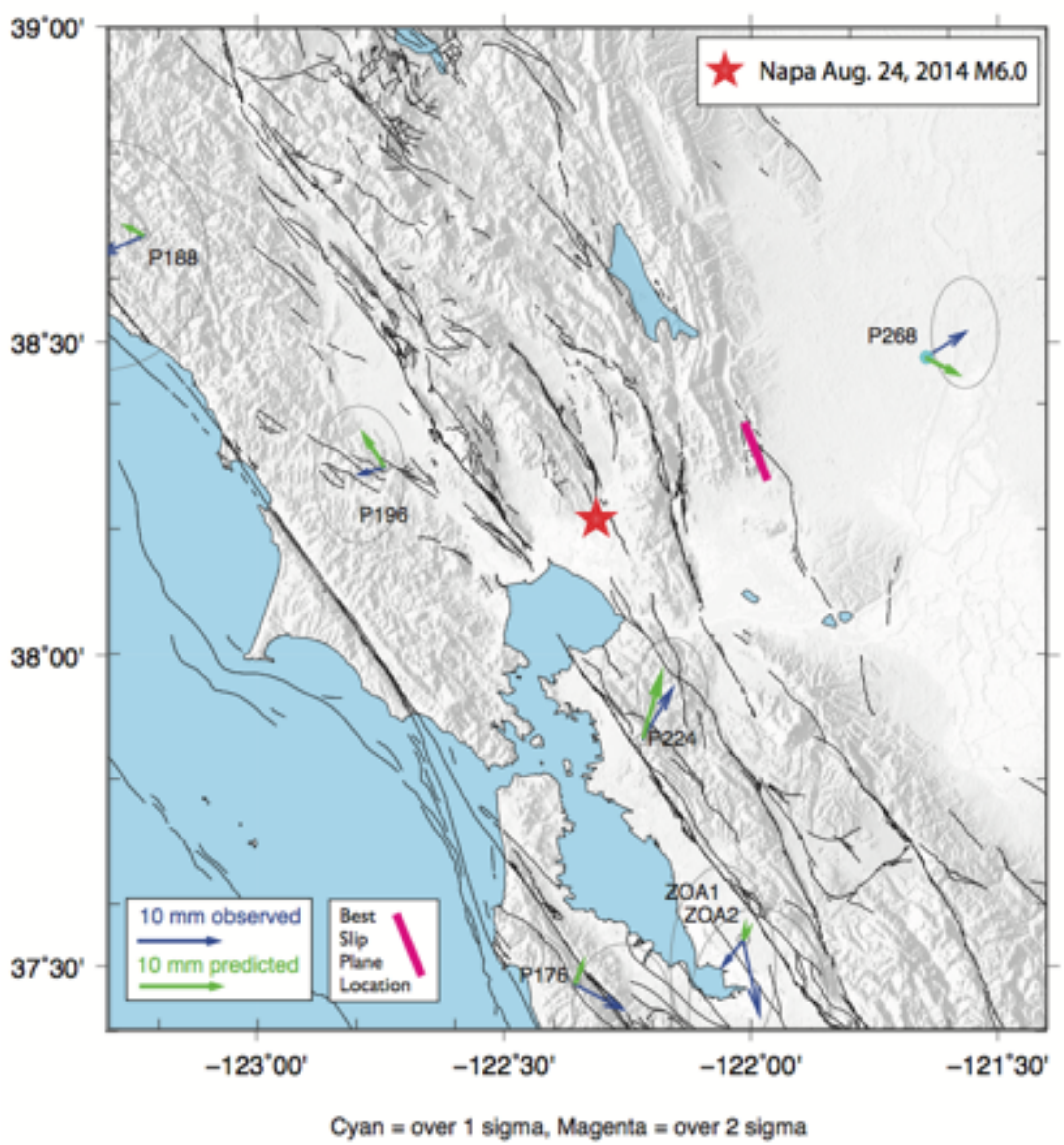
File URL to download	File type	Time range of data	Reference frame
BRIB.NA12.tenv3	Final Daily time series	1996-01-01 00:00:00 - 2016-01-02 00:00:00	NA12
CHAB.NA12.tenv3	Final Daily time series	1996-01-01 00:00:00 - 2012-12-31 00:00:00	NA12
MOLA.NA12.tenv3	Final Daily time series	1996-01-01 00:00:00 - 2002-04-04 00:00:00	NA12
NUNE.NA12.tenv3	Final Daily time series	1996-01-01 00:00:00 - 1999-12-11 00:00:00	NA12
TIBB.NA12.tenv3	Final Daily time series	1996-01-01 00:00:00 - 2016-01-02 00:00:00	NA12
WINT.NA12.tenv3	Final Daily time series	1996-01-03 00:00:00 - 2016-01-02 00:00:00	NA12
PBL1.NA12.tenv3	Final Daily time series	1996-01-12 00:00:00 - 2004-03-08 00:00:00	NA12
MHCB.NA12.tenv3	Final Daily time series	1996-06-15 00:00:00 - 2016-01-02 00:00:00	NA12
PBL2.NA12.tenv3	Final Daily time series	1996-07-31 00:00:00 - 2004-03-08 00:00:00	NA12
SUAA.NA12.tenv3	Final Daily time series	1997-02-17 00:00:00 - 2001-09-02 00:00:00	NA12
LUTZ.NA12.tenv3	Final Daily time series	1997-11-05 00:00:00 - 2016-01-02 00:00:00	NA12
DIAB.NA12.tenv3	Final Daily time series	1998-05-26 00:00:00 - 2016-01-02 00:00:00	NA12
MONB.NA12.tenv3	Final Daily time series	1998-08-01 00:00:00 - 2016-01-02 00:00:00	NA12
POTB.NA12.tenv3	Final Daily time series	1998-12-11 00:00:00 - 2005-02-04 00:00:00	NA12
EBMD.NA12.tenv3	Final Daily time series	1999-03-11 00:00:00 - 2015-06-11 00:00:00	NA12
OHLN.NA12.tenv3	Final Daily time series	2001-11-28 00:00:00 - 2016-01-02 00:00:00	NA12
ZOA1.NA12.tenv3	Final Daily time series	2002-07-04 00:00:00 - 2016-01-02 00:00:00	NA12
ZOA2.NA12.tenv3	Final Daily time series	2002-07-04 00:00:00 - 2016-01-02 00:00:00	NA12
THAL.NA12.tenv3	Final Daily time series	2003-01-03 00:00:00 - 2007-03-22 00:00:00	NA12
SLAC.NA12.tenv3	Final Daily time series	2003-02-01 00:00:00 - 2016-01-02 00:00:00	NA12
SBRN.NA12.tenv3	Final Daily time series	2003-03-06 00:00:00 - 2011-02-28 00:00:00	NA12
SVIN.NA12.tenv3	Final Daily time series	2003-11-21 00:00:00 - 2016-01-02 00:00:00	NA12
OXMT.NA12.tenv3	Final Daily time series	2004-02-13 00:00:00 - 2016-01-02 00:00:00	NA12
P261.NA12.tenv3	Final Daily time series	2004-06-04 00:00:00 - 2016-01-02 00:00:00	NA12
P198.NA12.tenv3	Final Daily time series	2004-09-09 00:00:00 - 2016-01-02 00:00:00	NA12
P225.NA12.tenv3	Final Daily time series	2005-01-22 00:00:00 - 2016-01-02 00:00:00	NA12
P181.NA12.tenv3	Final Daily time series	2005-02-02 00:00:00 - 2016-01-02 00:00:00	NA12
P230.NA12.tenv3	Final Daily time series	2005-02-27 00:00:00 - 2016-01-02 00:00:00	NA12

Case Study: The August 24, 2014 Napa M_W6.0 Earthquake

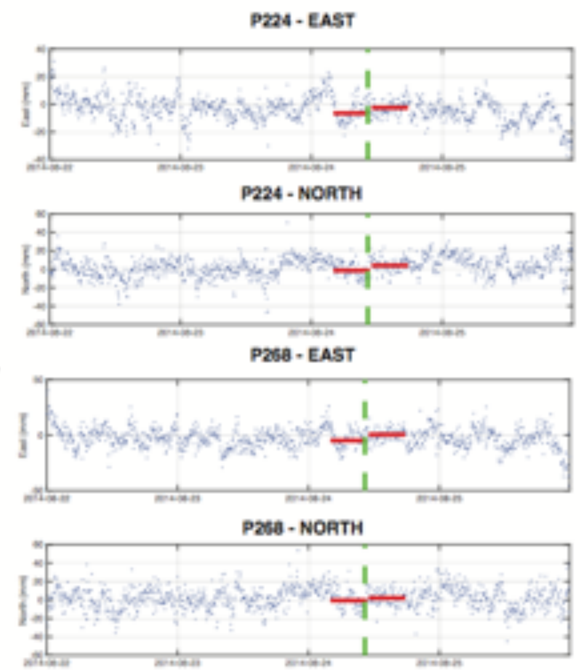
Two Hours After Event: Ultrarapid Orbits

- Not “real time” i.e. 1 Hz with 1 s latency
- From Hourly RINEX
- Not all stations providing hourly
- Working on that
- Offsets detected
- But uncertainties are large
- Inferred source poorly constrained

Earthquake Displacements from 5 Minute Sample Rate Time Series



Cyan = over 1 sigma, Magenta = over 2 sigma



Left) GPS offsets from 5 minute sample rate time series estimated from ultra-rapid orbits roughly two hours after the earthquake. Station distribution reflects data that were actually available at the time of this analysis.

Data were available from relatively few stations, though offsets from station P196, P224 appear to move roughly in the direction substatiated by later data.

We used the offset data to solve for latitude, longitude, length, dip, down-dip width, and two slip components on a single rectangular patch. The solution was obtained using simulated annealing (Kirkpatrick et al., 1983) with starting parameters based on the reported seismic solution (USGS, 2014)

The solution for the slip patch location (magenta line segment) based on these data is misplaced with respect to the epicenter by almost 20 km. Constraint on the fault slip paramters was poor because of poor data availability, though did provide some information about the limit of earth-quake magnitude.

Green vectors are the predicted displacements from the best model that was derived later (not in real time) from the GPS offsets. Uncertainties (1-sigma shown) are estimated from the scatter of the time series before and after the event.

from Hammond et al., 2014 Fall AGU poster

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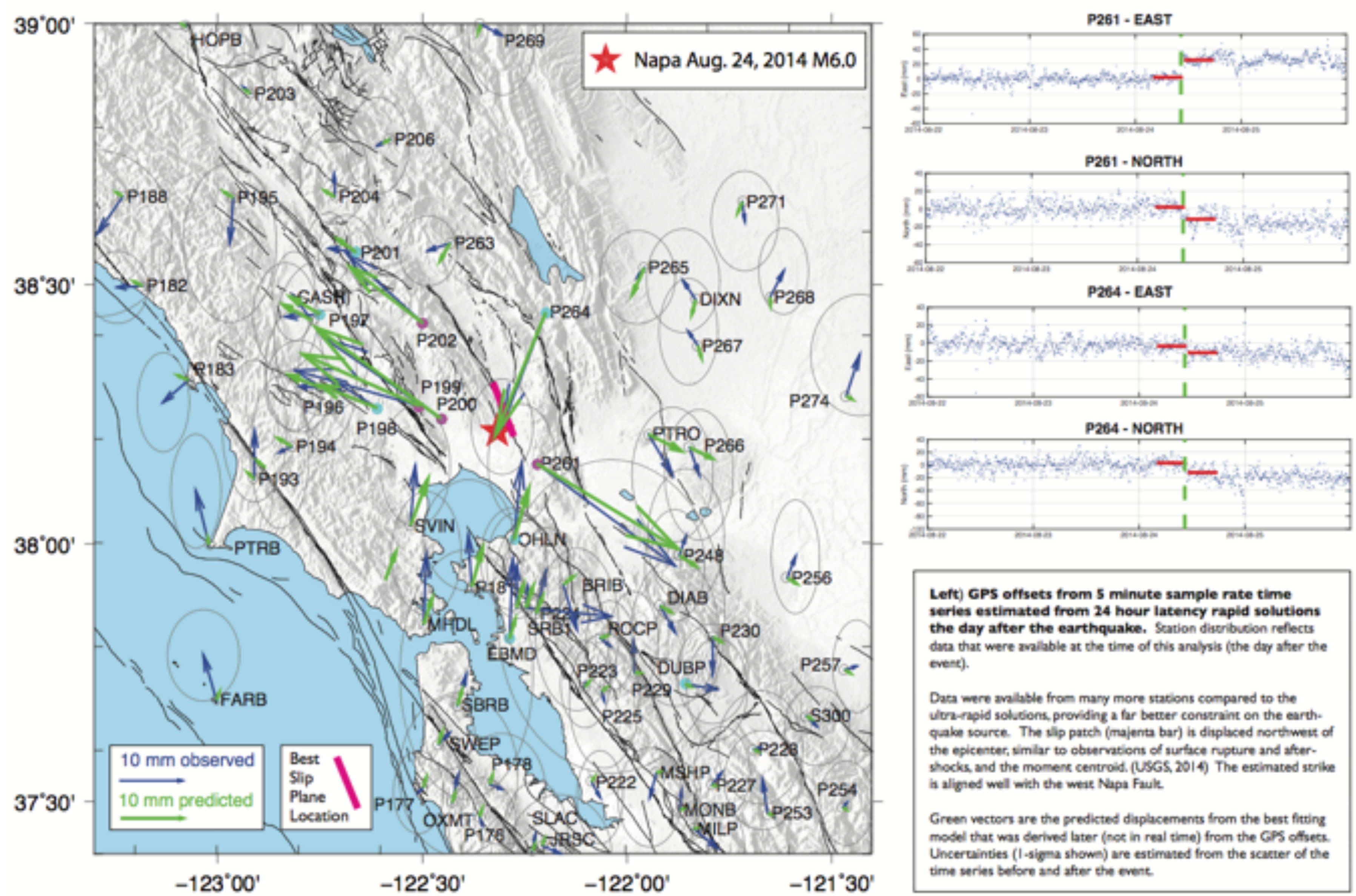
Case Study: The August 24, 2014 Napa M_W6.0 Earthquake

Next Day After Event: Rapid Orbits

- Many more stations contributing
- Time series better behaved
- Offsets show clear strike-slip character
- Significant offsets as far as e.g. south Bay Area
- Source location, style, slip better constrained
- Extent of significant displacement from earthquake more clear

Earthquake Displacements from 5 Minute Sample Rate Time Series



Left) GPS offsets from 5 minute sample rate time series estimated from 24 hour latency rapid solutions the day after the earthquake. Station distribution reflects data that were available at the time of this analysis (the day after the event).

Data were available from many more stations compared to the ultra-rapid solutions, providing a far better constraint on the earthquake source. The slip patch (majenta bar) is displaced northwest of the epicenter, similar to observations of surface rupture and aftershocks, and the moment centroid. (USGS, 2014) The estimated strike is aligned well with the west Napa Fault.

Green vectors are the predicted displacements from the best fitting model that was derived later (not in real time) from the GPS offsets. Uncertainties (1-sigma shown) are estimated from the scatter of the time series before and after the event.

Cyan = over 1 sigma, Magenta = over 2 sigma

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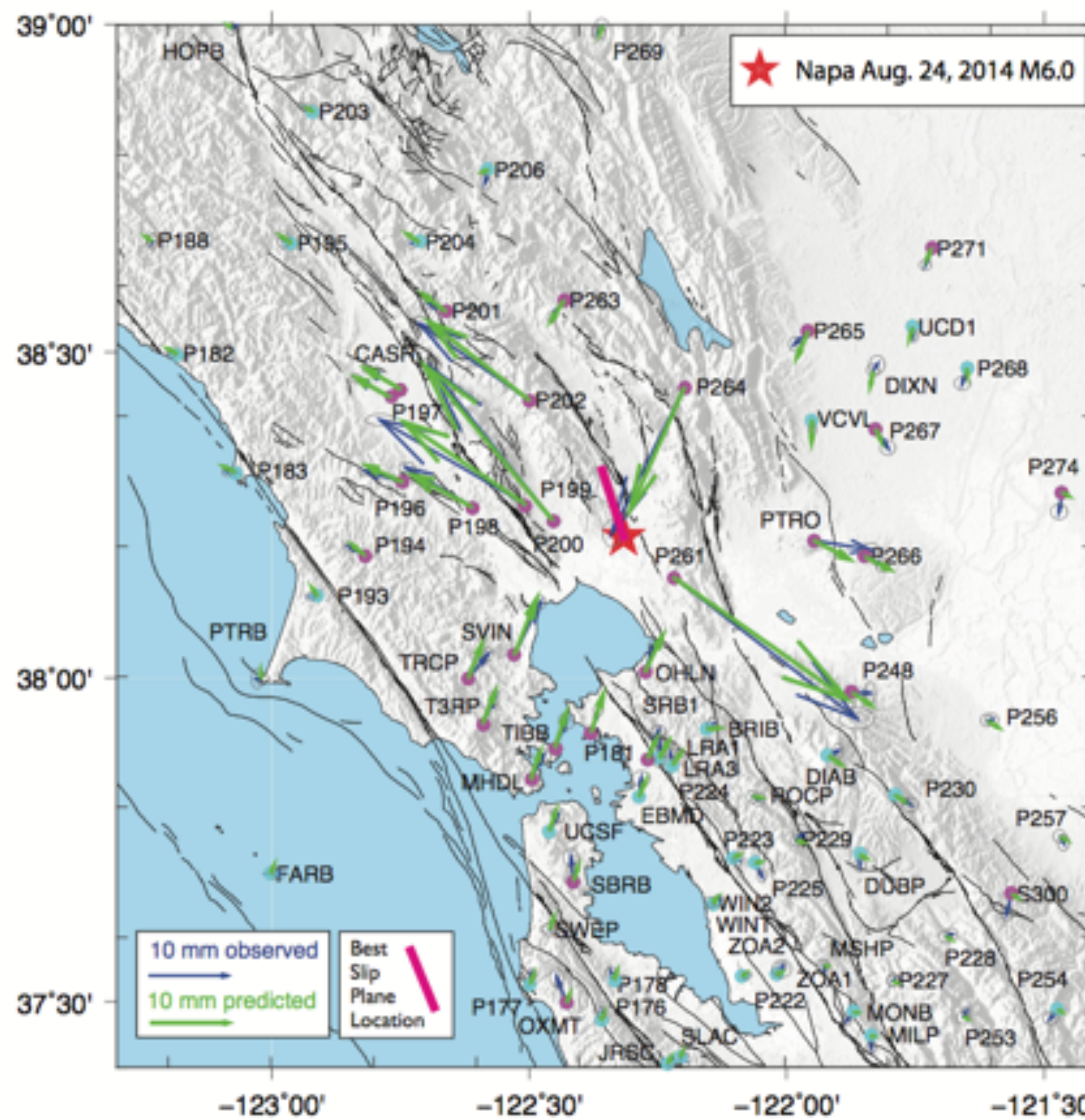
Case Study: The August 24, 2014 Napa M_W6.0 Earthquake

1 Full GPS Day Later: Rapid orbits

- Time series greatly improved, reduced scatter from 24 hour sample rate solutions
- Offsets better constrained
- Dramatically smaller uncertainties
- Inferred source right on top of seismic epicenter

Earthquake Displacements from 24 Hour Sample Rate Time Series



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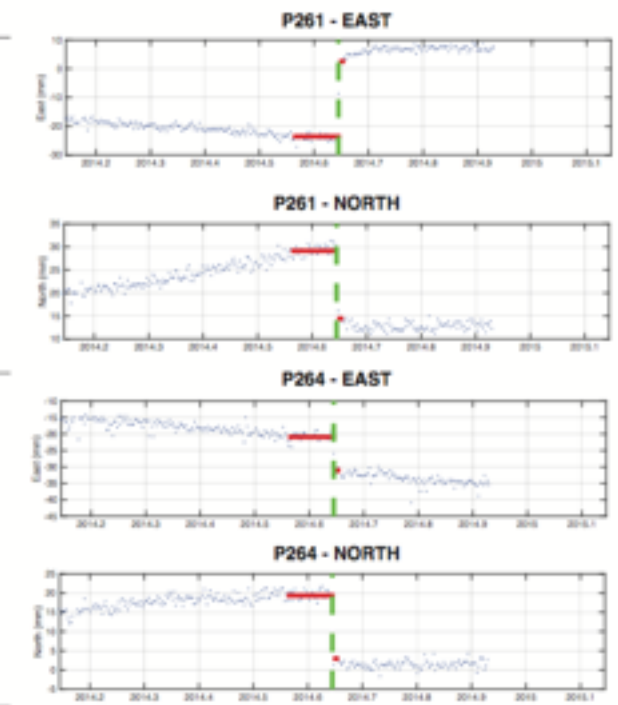


Left) GPS offsets from 24 hour sample rate time series estimated from rapid orbits. These results were available after one full GPS day transpired after the earthquake. The offset is the difference betwen position during the first full day after the event and the mean of 30 days prior to the event. Station distribution reflects data that were actually available at the time of this analysis.

Compared to the 5 minute sample rate time series, a greater number of GPS stations have provided data and the uncertainties in the displacements are far smaller.

The maximum displacements (29 mm) were at station P261. Marin County moved between 4 and 10 mm northeast.

The model slip patch is located in a similar location compared to the rapid 5 minute solutions, ~5 km northwest of the epicenter. This slip patch is in a simlar location to the seismogeodetic solution of Melgar et al., 2014 (see their poster in this session).

Green vectors are the predicted displacements from the best fitting model that was derived later (not in real time) from the GPS offsets. Uncertainties (1-sigma shown) are estimated from the scatter of the time series before and after the event.

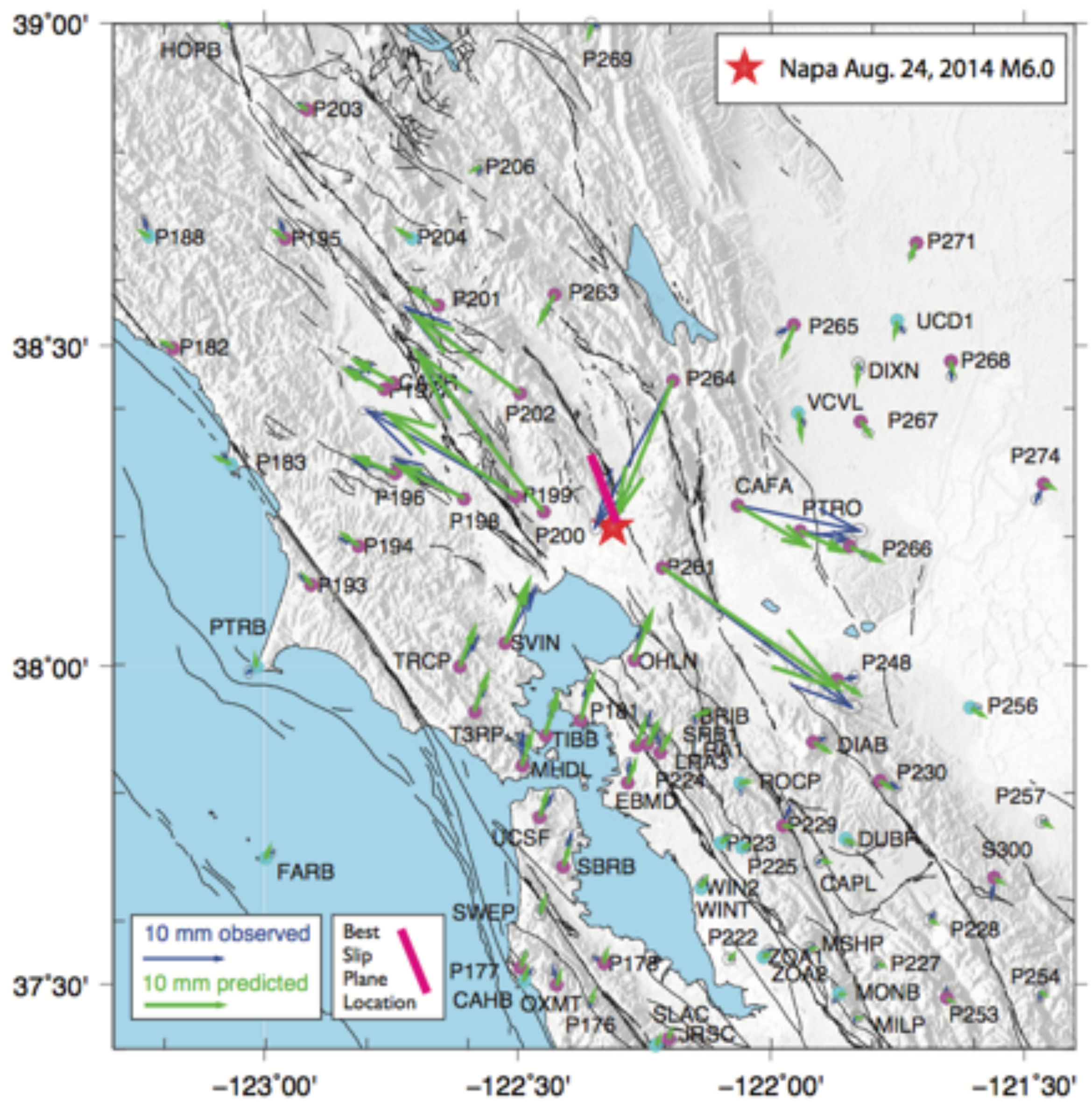
from Hammond et al., 2014 Fall AGU poster

Case Study: The August 24, 2014 Napa M_W6.0 Earthquake

10 Days After Event: Final Orbits

- Moderate improvement over rapids
- Shows stability in solution of source
- Similarity to seismic slip inversions
- Used to benchmark real-time source inversion studies, e.g. Melgar et al., 2015 JGR plus other groups used our rapid-offsets

Earthquake Displacements from 24 Hour Sample Rate Time Series



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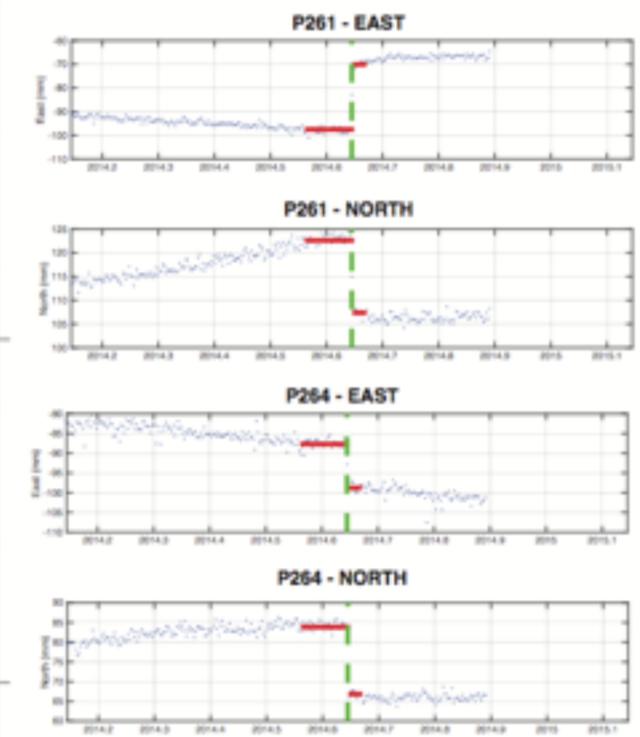

Left) GPS offsets from 24 hour sample rate time series estimated from solutions based on final orbit products, available roughly 10 days after the event. The offset is the difference between the mean station position 7 days after the event and 30 days before the event. Station distribution reflects data that were available at the time of the analysis, which is roughly the best possible coverage available from our system.

Data were available from a similar number of stations compared to the rapid solutions (above), though uncertainties are a little smaller owing to the addtionally averaging of data after the event.

The slip patch location (majenta bar) has barely changed given the new data.

Green vectors are the predicted displacements from the best fitting model that was derived later (not in real time) from the GPS offsets. Uncertainties (1-sigma shown) are estimated from the scatter of the time series before and after the event.

from Hammond et al., 2014 Fall AGU poster

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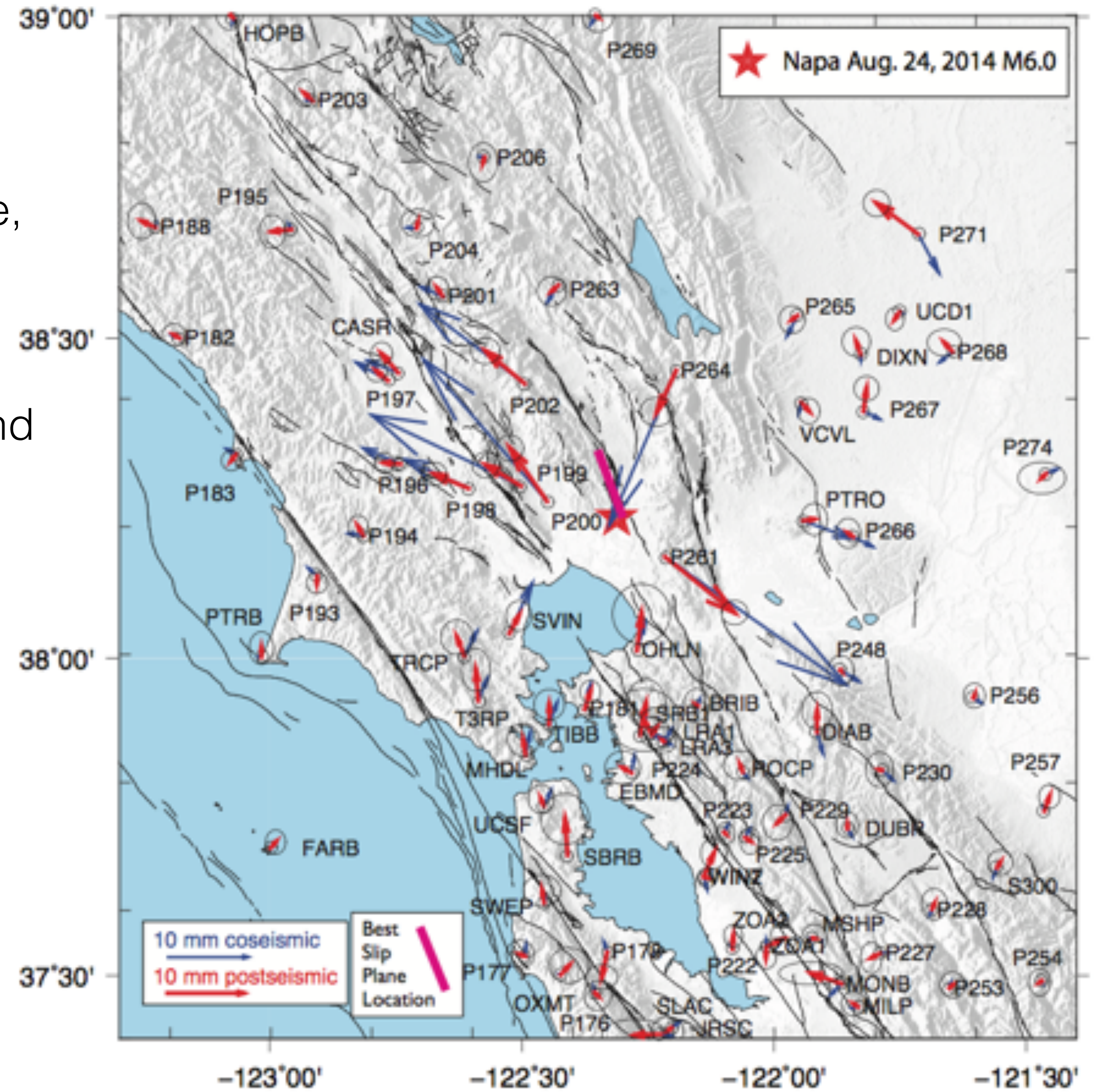
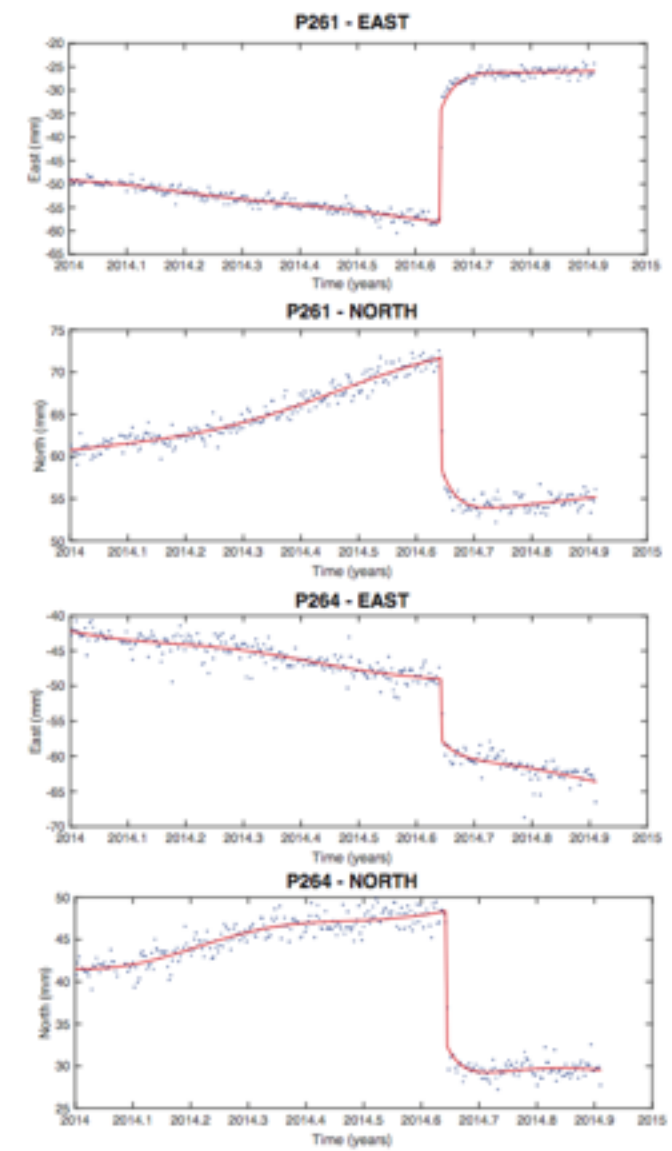
Case Study: The August 24, 2014 Napa M_W6.0 Earthquake

Months After Event: Final Orbits

- Time series modeled with slope, intercept, annual+semiannual terms, step, exponential decay after event
- Clear postseismic afterslip found
- Seen in GPS data and in situ surface observations
- Lasted weeks
- Coseismic M_W=6.07 versus postseismic M_W=5.75
- Clear implications for seismic hazard studies

Postseismic Displacements from 24 Hour Sample Rate Time Series





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Products Coming Soon

- **More reference frames** for existing products: e.g. tectonic plate based frames for Africa/Arabia, South America, Eurasia, Pacific, Australia/Oceana, Antarctica
- Median spatial filtered velocities
- Uplift Maps based on GPS imaging (flat maps and .kml)
- Better time series plotting tools
- Strain rate maps
- Earthquake offset pages, delivered with lowest possible latencies

Plug and Play: Future Plug n Play Events

- May 2014, NASA Awards Project
- 2015 presentation of service and available data products at workshops, conferences e.g. EarthScope, Fall AGU in San Francisco.
- AfricaArray, January 18-20, 2016
    - Rollout
    - New data products
    - First short course
- UNAVCO Science workshop, Boulder, CO March 28-31
    - Plug and Play highlighted in science sessions
- Less-Short course in Boulder, May 27, 2016
    - **Full day** workshop at UNAVCO facility
    - More extensive explanation of available tools, data resources
    - More information available soon at http://unavco.org