



# Director's Report Dynamic Datums

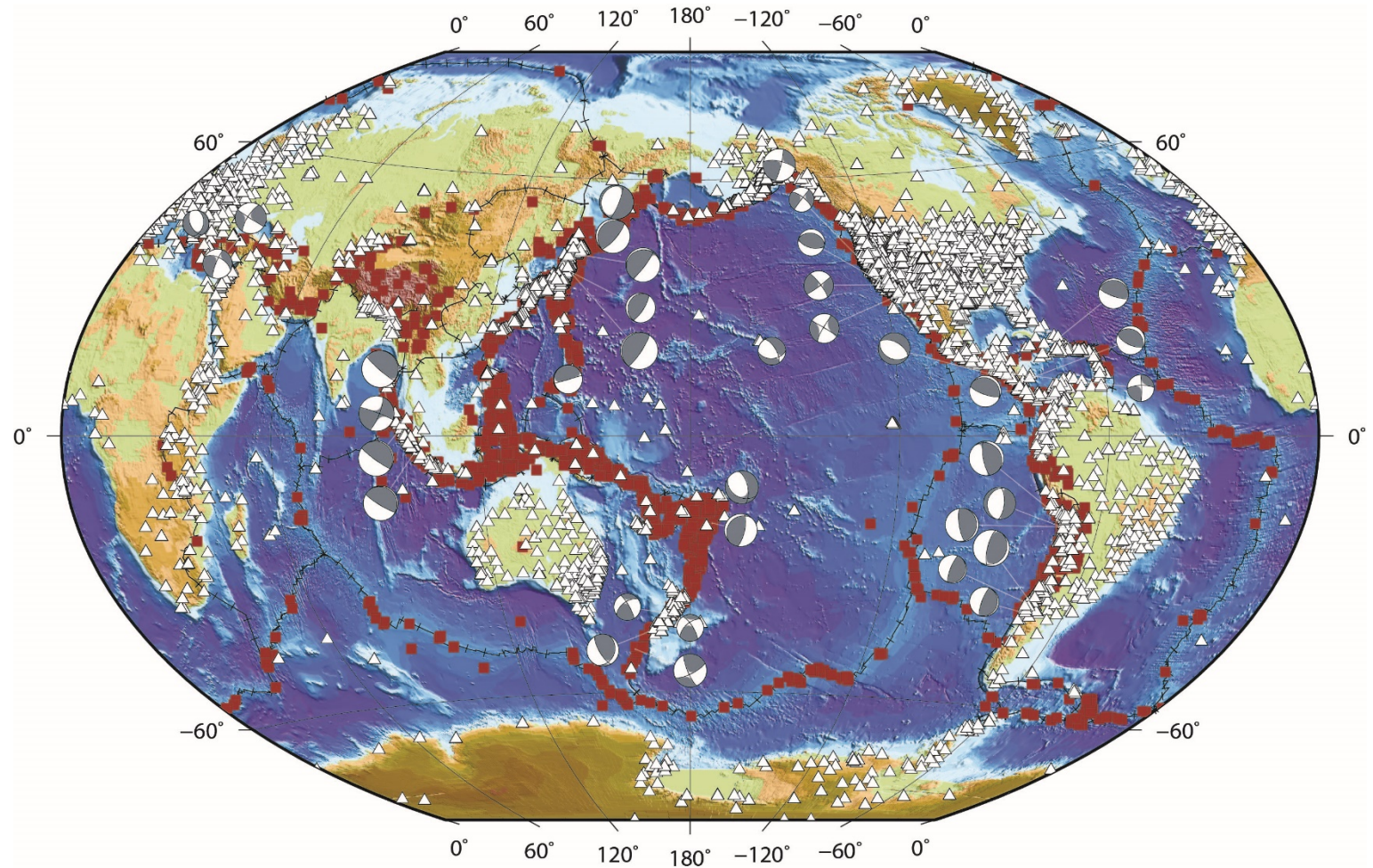


**Yehuda Bock**

**California Spatial Reference Center (CSRC)  
Scripps Orbit and Permanent Array Center (SOPAC)  
Institute of Geophysics and Planetary Physics  
Scripps Institution of Oceanography  
University of California San Diego**

**October 6, 2016  
Caltrans TransLab Sacramento**

## CGPS Data and Metadata



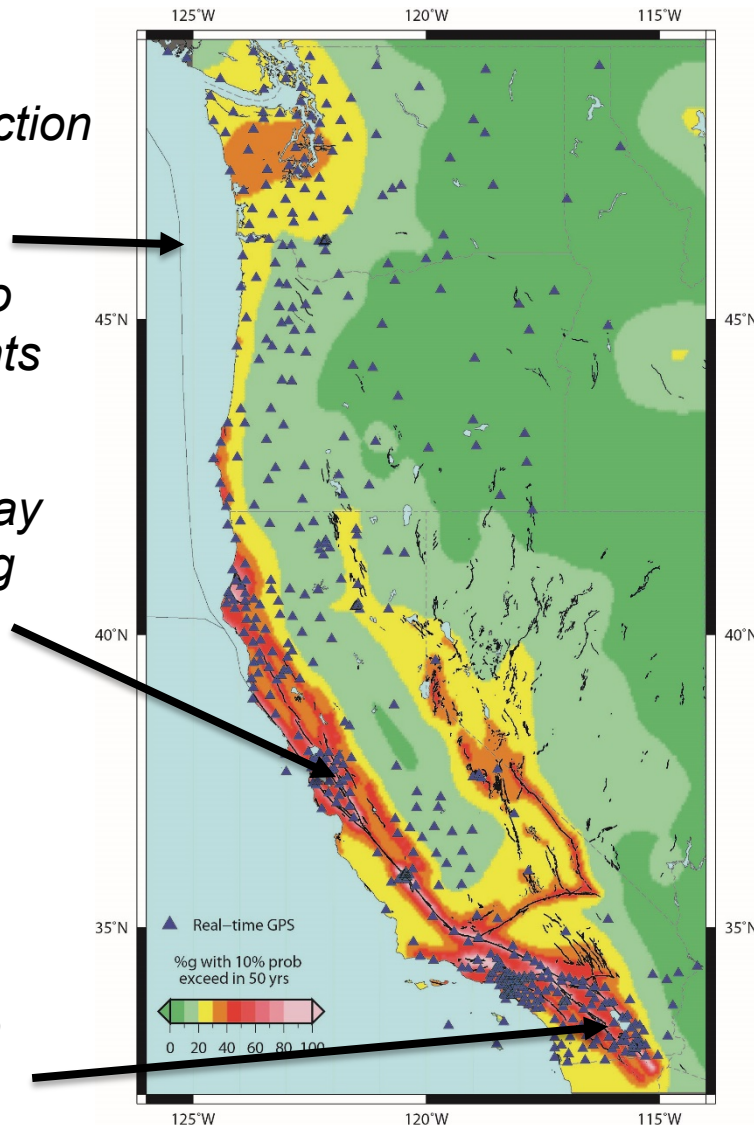
Stations archived by SOPAC and analyzed by SOPAC and JPL. Brown boxes denote historical earthquakes  $>$  magnitude 5. Beach balls denote type of earthquake for largest events since 1992.

# West Coast Earthquake Hazards

*Cascadia Subduction Zone – Mw 9.0 earthquake & tsunami similar to 2011 Japan events*

*San Francisco Bay Area – Increasing risk of large earthquake on Hayward fault*

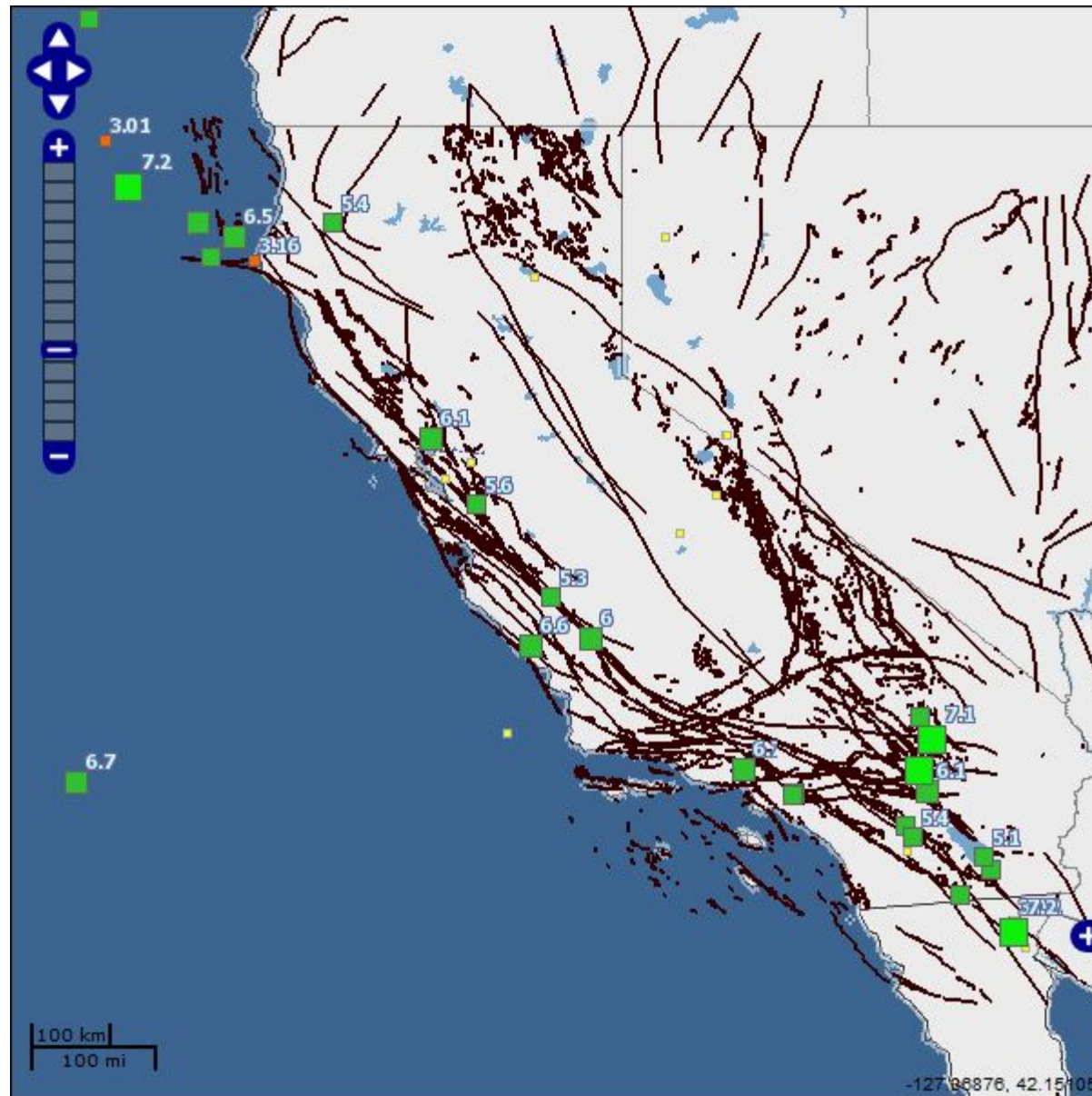
*Southern San Andreas fault – overdue for large earthquake*



- **Real-Time Earthquake Analysis for Disaster mItigation network (READI):** ~600 GPS stations, a NASA driven project
- Super set of GPS networks maintained by (sorted according to largest to smallest number of stations):
  - UNAVCO/PBO
  - CWU/PANGA
  - USGS/Pasadena-SCIGN & Menlo Park
  - UC Berkeley/BARD
  - Caltrans CVSRN/CCSRN
  - SIO/SCIGN



# Significant Earthquakes in California 1992-2016





# Significant Earthquakes in California (1992-2016)

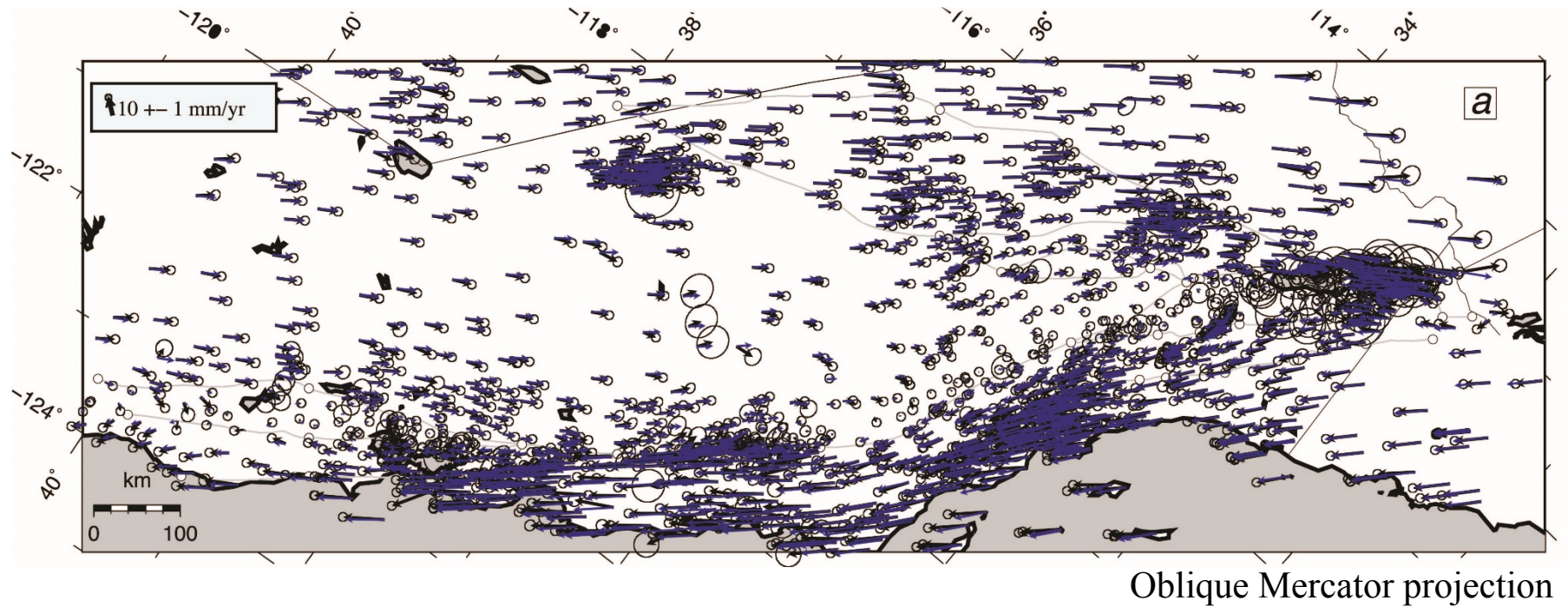
Date (UTC)	Time (UTC)	California Earthquake	Mw	Depth (km)	Epicenter (decimal degrees)		Stations Affected
4/23/1992	4:50:23	Joshua Tree	6.1		33.96N	116.32W	0
<b>6/28/1992</b>	11:57:34	<b>Landers , Southern California</b>	<b>7.3</b>	<b>1.1</b>	<b>34.217N</b>	<b>116.433W</b>	<b>5</b>
1/17/1994	12:30:55	Northridge	6.7		34.2131N	118.5369W	0
<b>10/16/1999</b>	9:46:44	<b>Hector Mine</b>	<b>7.1</b>	<b>0.1</b>	<b>34.6N</b>	<b>116.267W</b>	<b>142</b>
10/21/1999	1:57:38	Hector Mine aftershock	5.0		34.86N	116.39W	0
10/23/2002	11:27:18	Central Alaska (Denali)	6.7	10	63.62	148.04W	0
<b>12/22/2003</b>	<b>19:15:56</b>	<b>Cambria, San Simeon, Central California</b>	<b>6.5</b>	<b>7.6</b>	<b>35.706N</b>	<b>121.102W</b>	<b>23</b>
<b>9/28/2004</b>	<b>17:15:24</b>	<b>Parkfield, Central California</b>	<b>6.0</b>	<b>7.9</b>	<b>35.815N</b>	<b>120.374W</b>	<b>28</b>
6/12/2005	15:41:46	Anza, Southern California	5.2	14.1	33.533N	116.578W	0
<b>6/15/2005</b>	2:50:54	<b>Gorda Plate, CA</b>	<b>7.2</b>	<b>10</b>	<b>41.284N</b>	<b>125.983W</b>	<b>7</b>
6/16/2005	20:53:26	Yucaipa, Southern California	4.9	11.8	34.058N	117.011W	0
6/17/2005	6:21:41	Off the Coast Northern California	6.7	10	40.758N	126.595W	7
9/2/2005	1:27:19	Obsidian Buttes Swarm, Salton Trough	5.1		33.16N	115.637W	3
10/3/2006		Superstition Hill Seismic Swarm - silent slip	4.7	9.2			0
10/31/2007	3:04:55	Alum Rock, San Jose, California	5.6	9	37.432N	121.776W	1
4/30/2008	3:03:06	Northern California	5.4	28.5	40.837N	123.499W	
7/29/2008	18:42:15	Chino Hills, California	5.5	14.7	33.95N	117.76W	1
1/10/2010	0:27:39	Eureka , Offshore Northern California	6.5	29.3	40.652N	124.692W	11
2/4/2010		Offshore Northern California, Humboldt Coun	5.9		40.42N	124.92W	0
<b>4/4/2010</b>	<b>22:40:43</b>	<b>El Mayor-Cucapah, Northern Baja California</b>	<b>7.2</b>	<b>10</b>	<b>32.259N</b>	<b>115.287W</b>	<b>209</b>
6/15/2010	4:26:59	Aftershock, El Mayor-Cucapah	5.7		32.698N	115.924W	7
7/7/2010	23:53:33	Borrego Springs, Southern California	5.4		33.417N	116.483W	3
8/26/2012	19:31:22	Brawley Seismic Swarm, Imperial Valley	5.3, 5.4	9.2	33.019	115.546W	4
10/21/2012	6:55:09	Central California	5.3		36.31N	120.856W	4
3/10/2014	5:18:13	Northern California offshore Ferndale	6.8	7	40.821N	125.1277W	6
3/30/2014	4:09:42	La Habra, Northwest Orange County	5.1	7.5	33.92N	117.94W	1?
8/24/2014	10:20:44	South Napa	6.1	10.7	38.215N	122.318W	

## Dynamic Datums - I

Surveyors do not like changing reference frames and coordinates.

In California and other seismically active regions this is not possible. Therefore, CSRC publishes a new epoch date every few years (2007.00, 2009.00, 2011.00, ...)

## Velocity field for San Andreas fault system



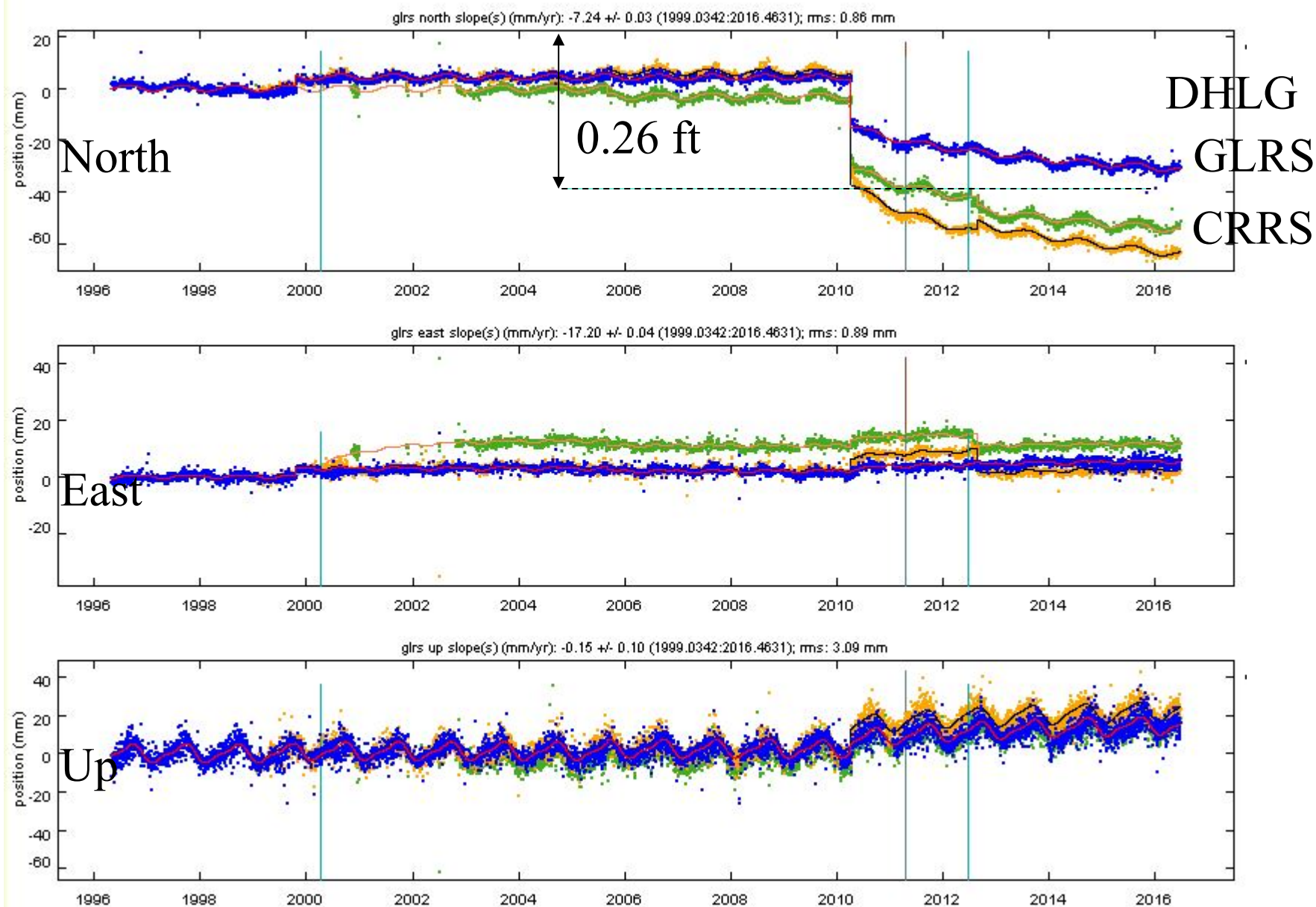
Velocities with respect to Pacific–North America  
pole of rotation reference frame with half of plate  
motion subtracted

Tong et al., 2013



# Detrended Displacement Time Series (1996-2016)

## Coseismic & Postseismic Motions

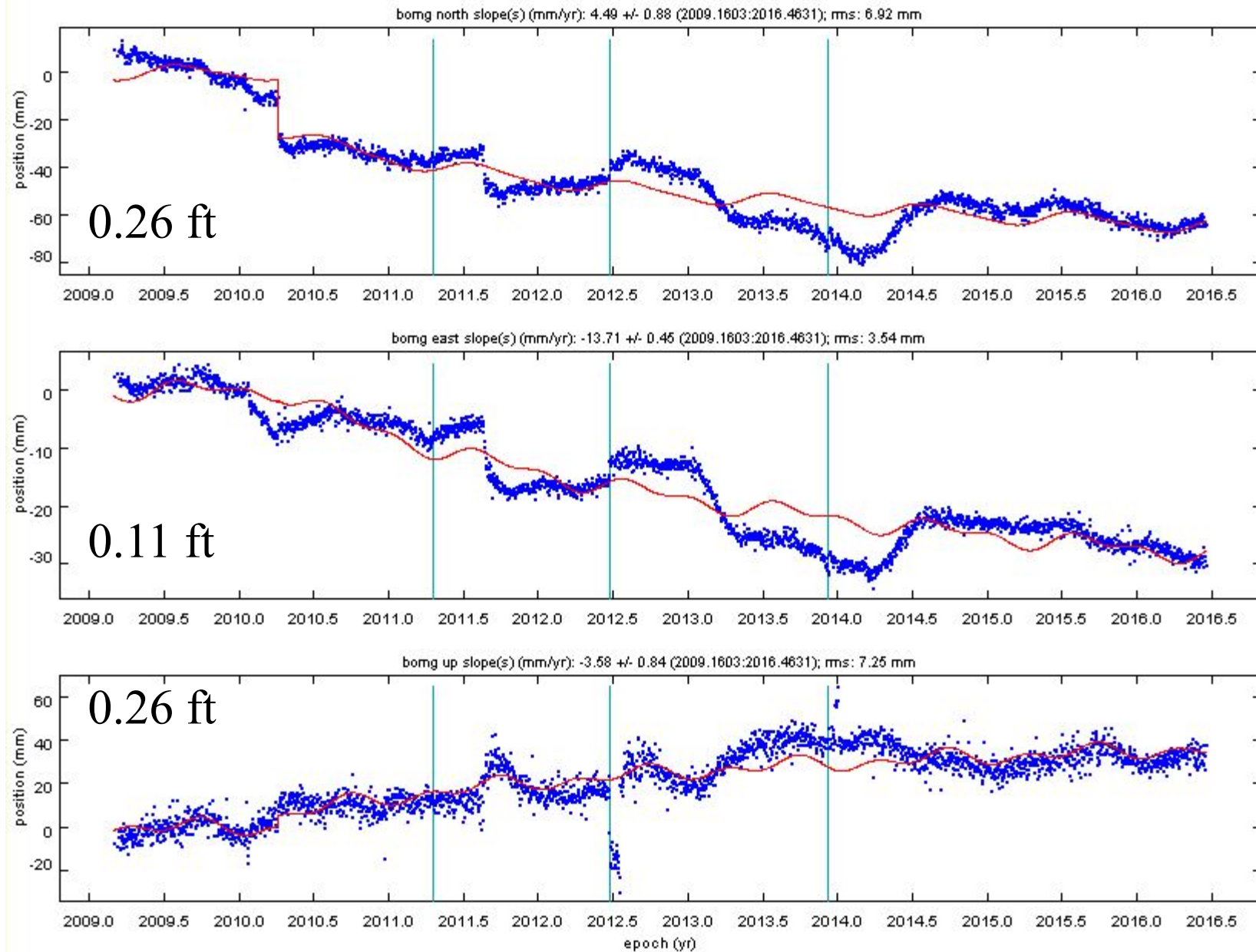


## Dynamic Datums - II

Reference frames need to be periodically updated to accommodate new types and number of observations and stations.

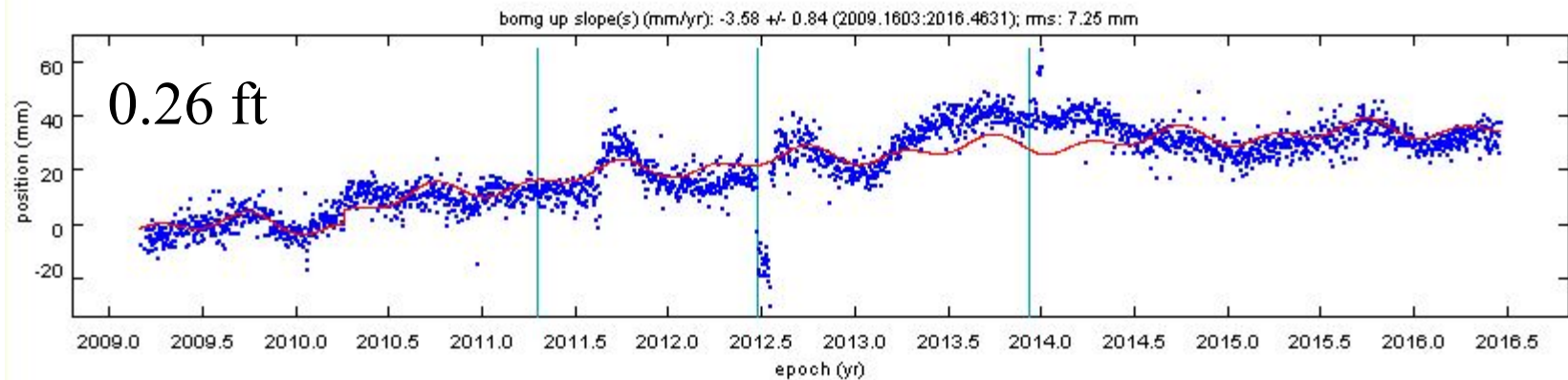
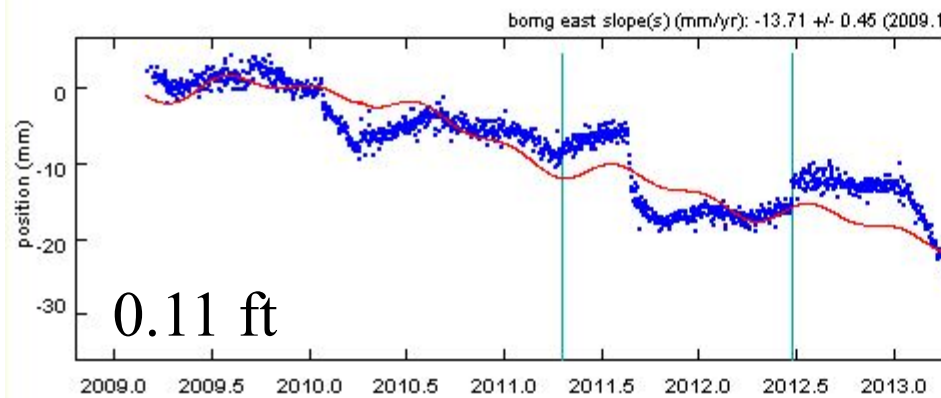
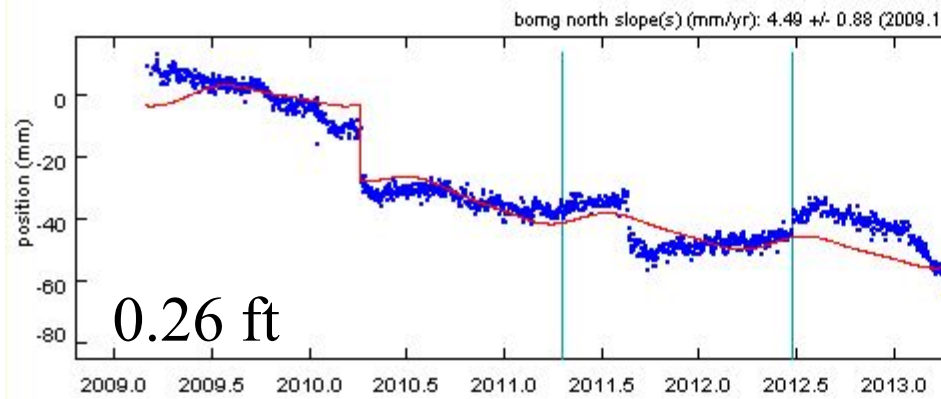
There are other phenomena other than tectonic motions that cause significant changes in coordinates (e.g., vertical land motion) requiring quality control to identify and possibly discard these stations.

## Example of Non-Tectonic Motions (Station BOMG near Salton Sea)





# Non-Tectonic Motions

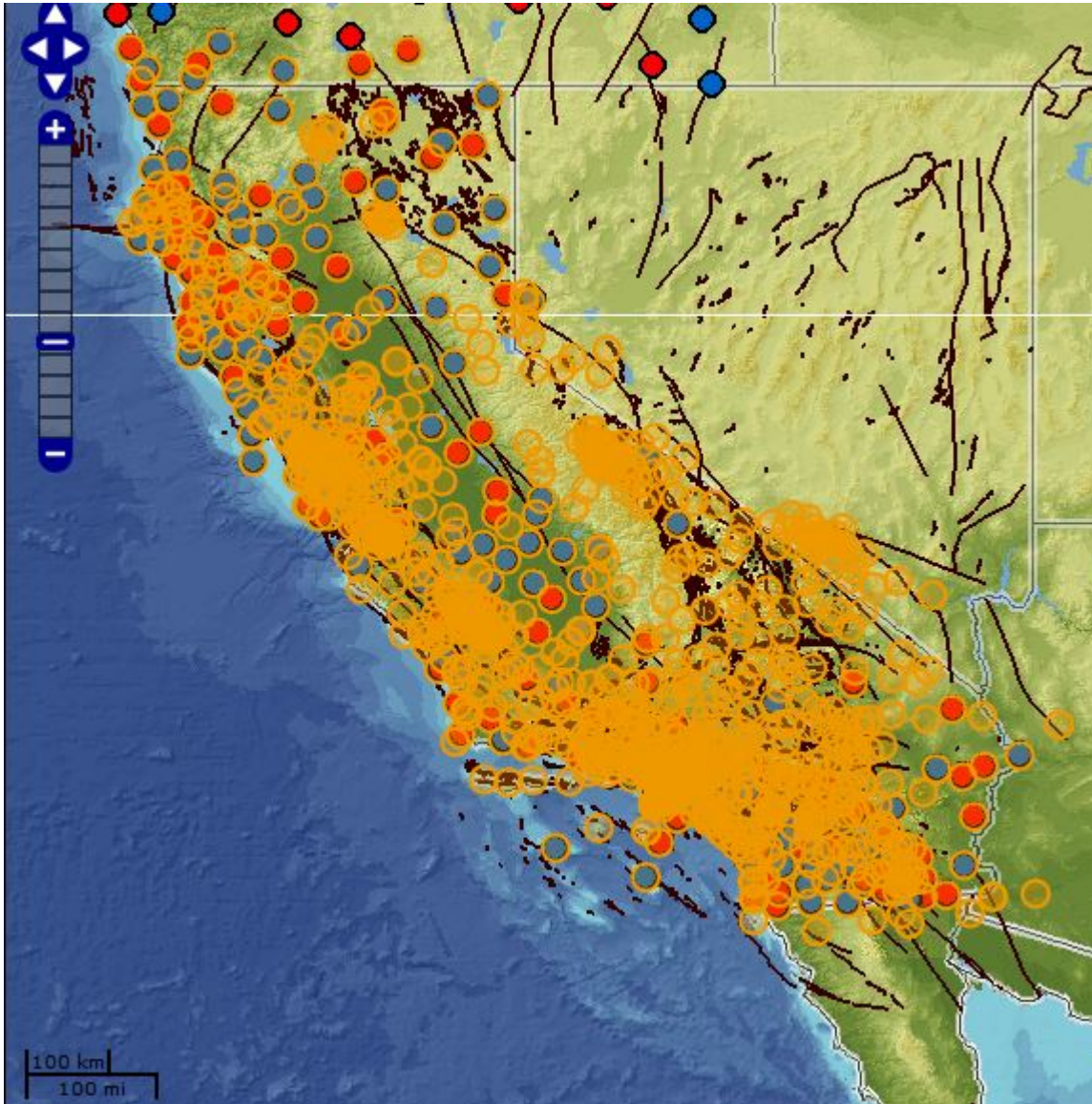


## Dynamic Datums - III

Creating a new epoch date for coordinates with an increase in number of stations modifies the reference system, realized through the epoch-date coordinates of the permanent GNSS stations. So does the change from, say, ITRF2008 to ITRF2014

You can think of the reference frame as a triangulated network in 2-D (or a polyhedron in 3-D) whose shape and size changes in time. The epoch-date coordinates are a snapshot at a particular epoch of time.

## New CSRS Coordinate Epoch



**2007.00 – 511 stations**

**2009.00 – 766**

**2011.00 – 830**

**2017.00 – ~950**

**CRTN - ~400 stations**

**ITRF2008 to ITRF2014**

**Connect CSRS to NSRS:**

NAD83 (NSRS2007)

NSRS (2022)



## Caltrans Task Order: New Epoch Date for California

- **Work authorized by Mark Turner on March 16, 2016**
- **Updated metadata for Caltrans real-time stations in SOPAC database (CVSRN, CCSRN), Bryan Banister and Eric Adney**
- **Included remaining CVSRN and CCSRN data into CRTN (collect RINEX data from all Caltrans stations and store in SOPAC archive) – Added full set to “Master List” for processing**
- **Backfilled missing RINEX data from CVSRN**
- Add new California stations in California (USGS, PBO, other) into the Master List for reprocessing
- Double check metadata and completeness of data for all stations on Master list
- Assign preliminary quality codes to stations
- Convert to ITRF2014 with IGS analysis centers
- Start reprocessing of entire data set and continue forward with regular SOPAC processing, in new ITRF2014 reference frame

## Dynamic Datums - IV

The reference frame is defined by the positions of the permanent GNSS at a particular epoch of time (now CSRC Epoch 2011.00), and you can update CSRS station coordinates to any other epoch through, for example, SOPAC's SECTOR application.

However, estimating the true-of-date coordinates of a survey station with respect to the reference frame requires an additional step.

There are at least two approaches: interpolation or crustal deformation model

# SECTOR Utility

## Epoch-Date Coordinates

SECTOR: Scripps Epoch Coordinate Tool and Online Resource

### Input Parameters

**Coordinate**

Source:

Type:

**Date**

☒ 2012-10-25

☐ 2012

☐ 2012.0000

**Sites**

☒ Single site:

☐ List of sites:  (space delimited, max=20)

☐ Sites by array:

☐ All

**Output**

display as:

degrees as:

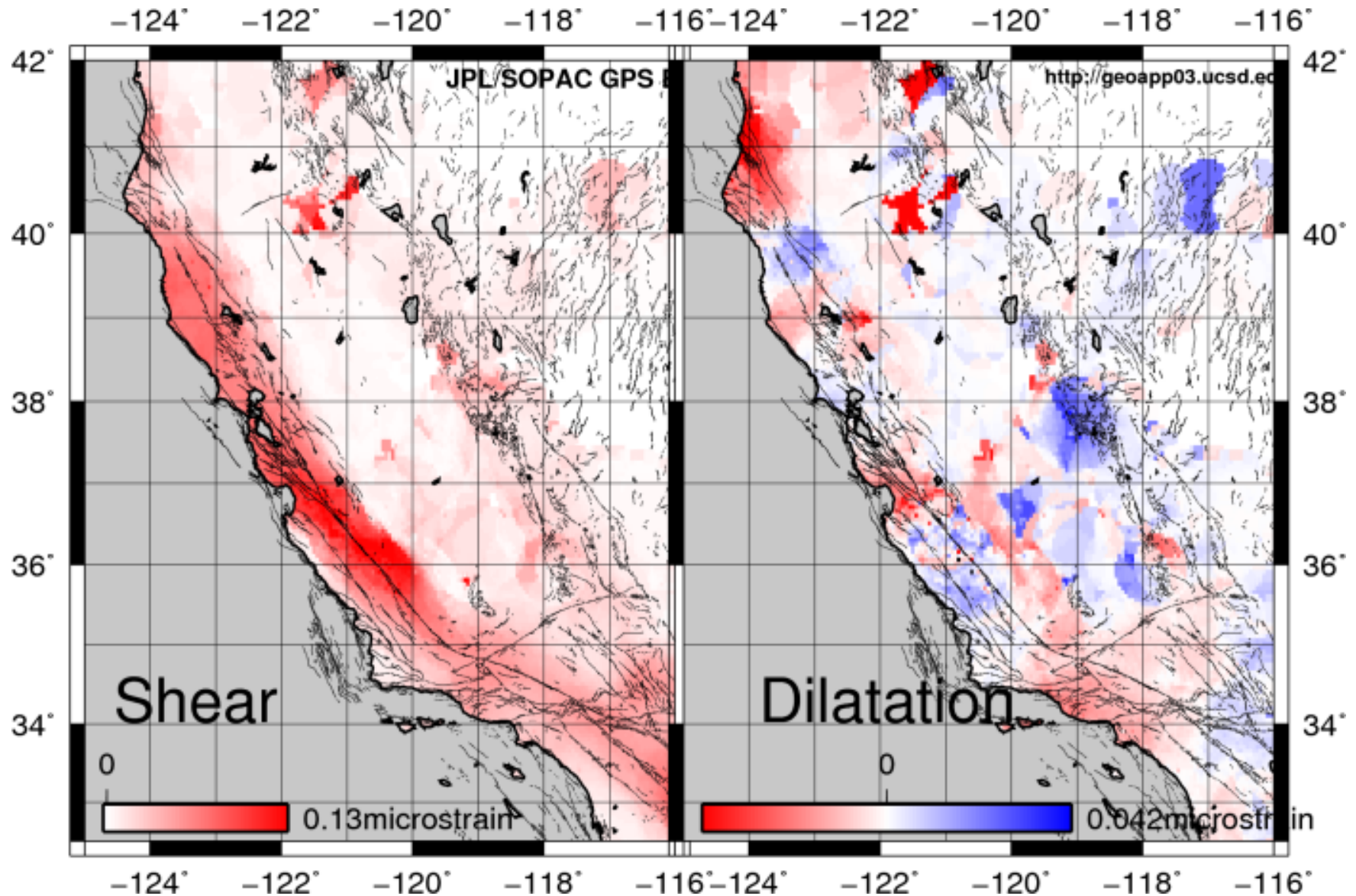
datum:

2012.8156		ITRF2008			WGS84			NAD83			
Site	X (m)	Y (m)	Z (m)	Lat (deg)	Lon (deg)	Height (m)	Lat (deg)	Lon (deg)	Height (m)	Model Terms	
sio5	-2456115.2761	-4768905.6501	3439232.5033	32.84073522	-117.24969111	185.51872841	32.84073202	-117.24967700	186.2665	<input checked="" type="radio"/>	
<a href="#">map</a>	+/- 0.0015	+/- 0.0023	+/- 0.0018	+/- 0.0012	+/- 0.0011	+/- 0.0029					

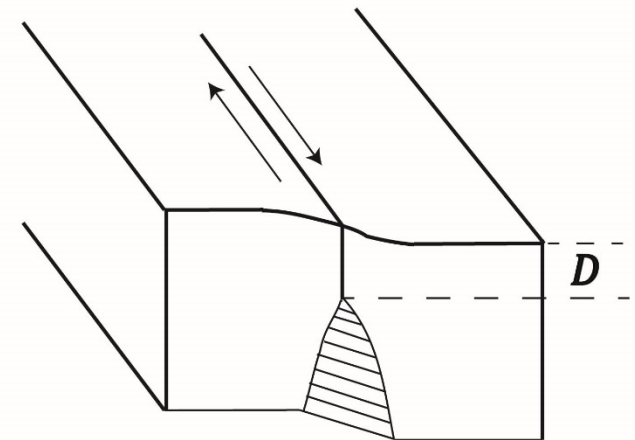
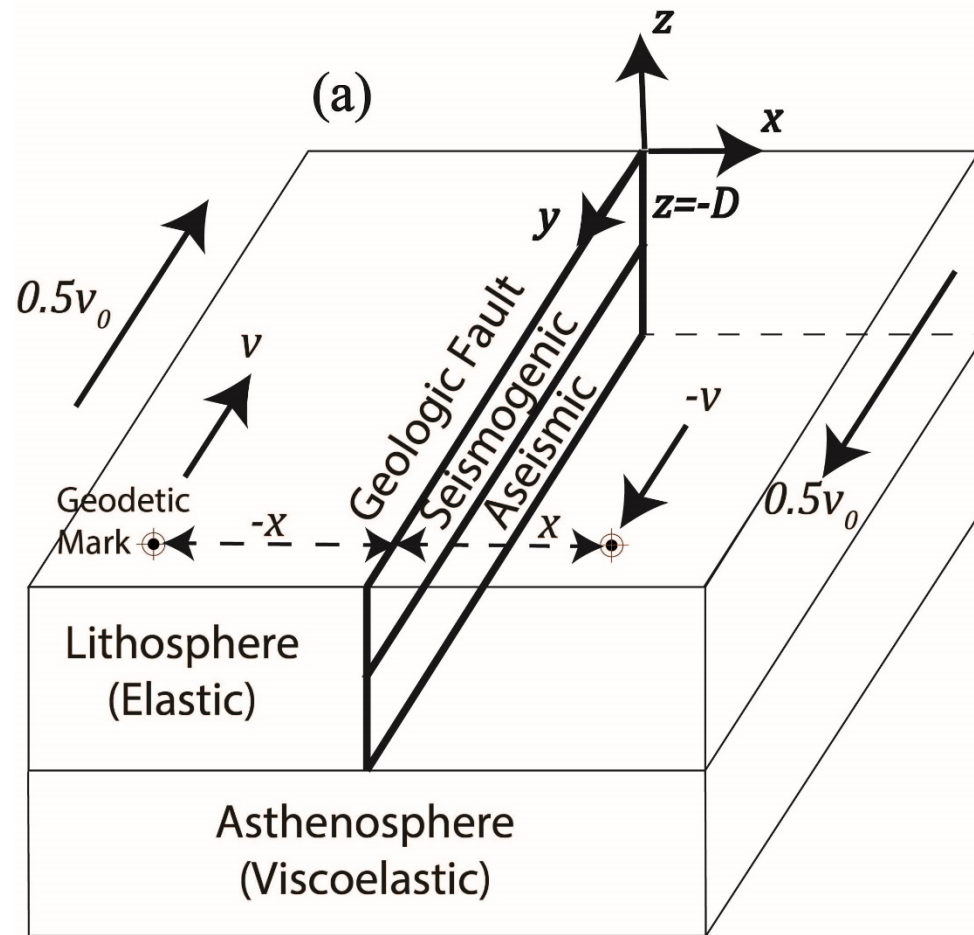
<http://sopac.ucsd.edu/processing/coordinates/>



## Interpolation – Model Independent

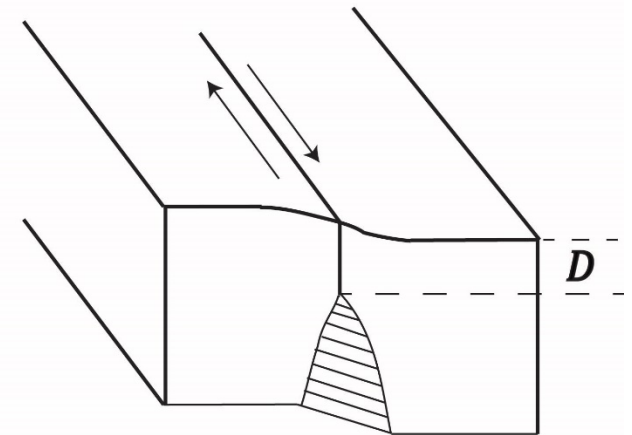
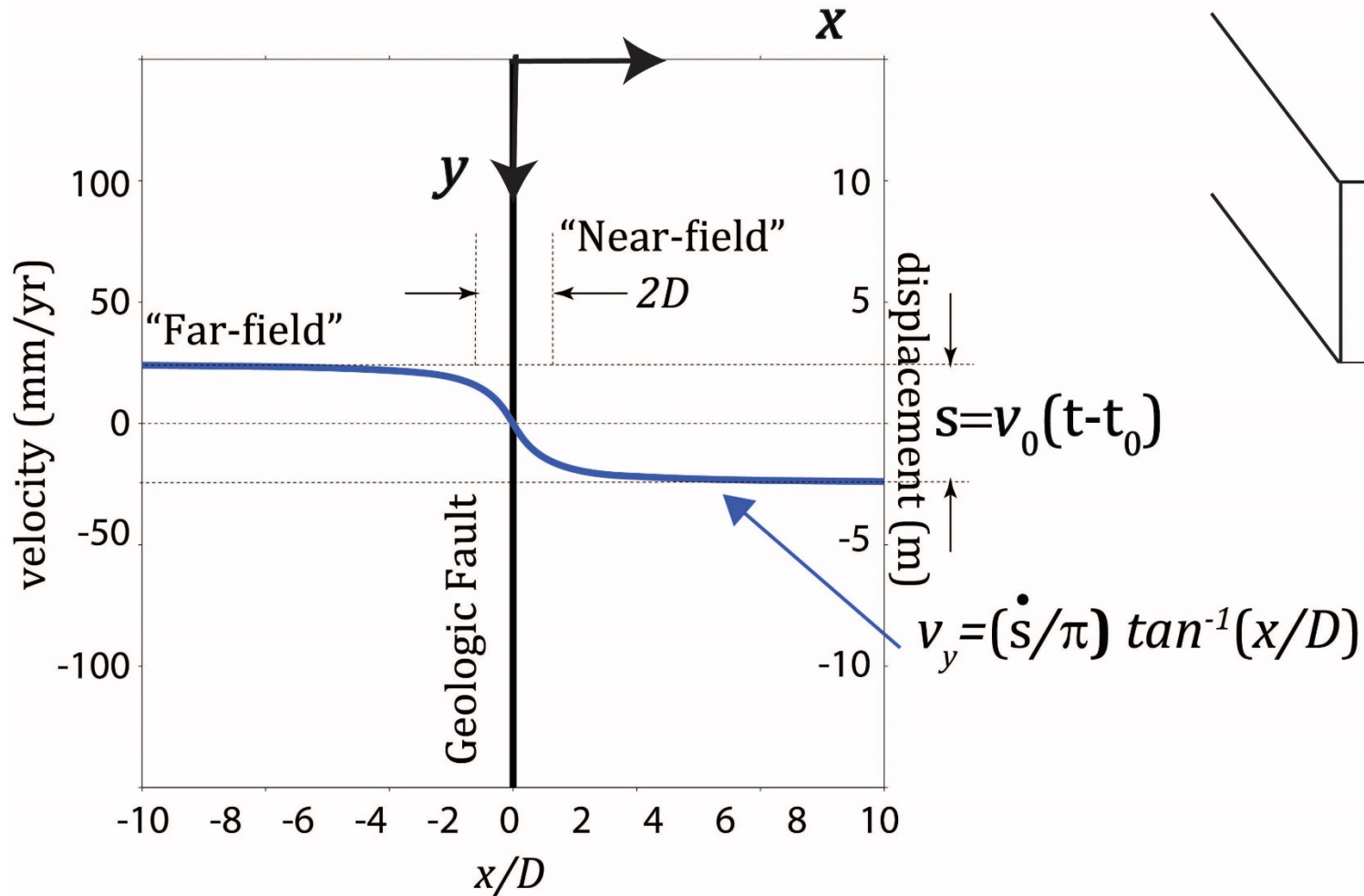


# Crustal Deformation Model Such as HTDP



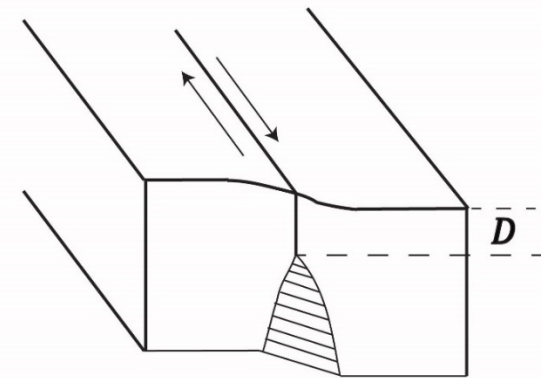
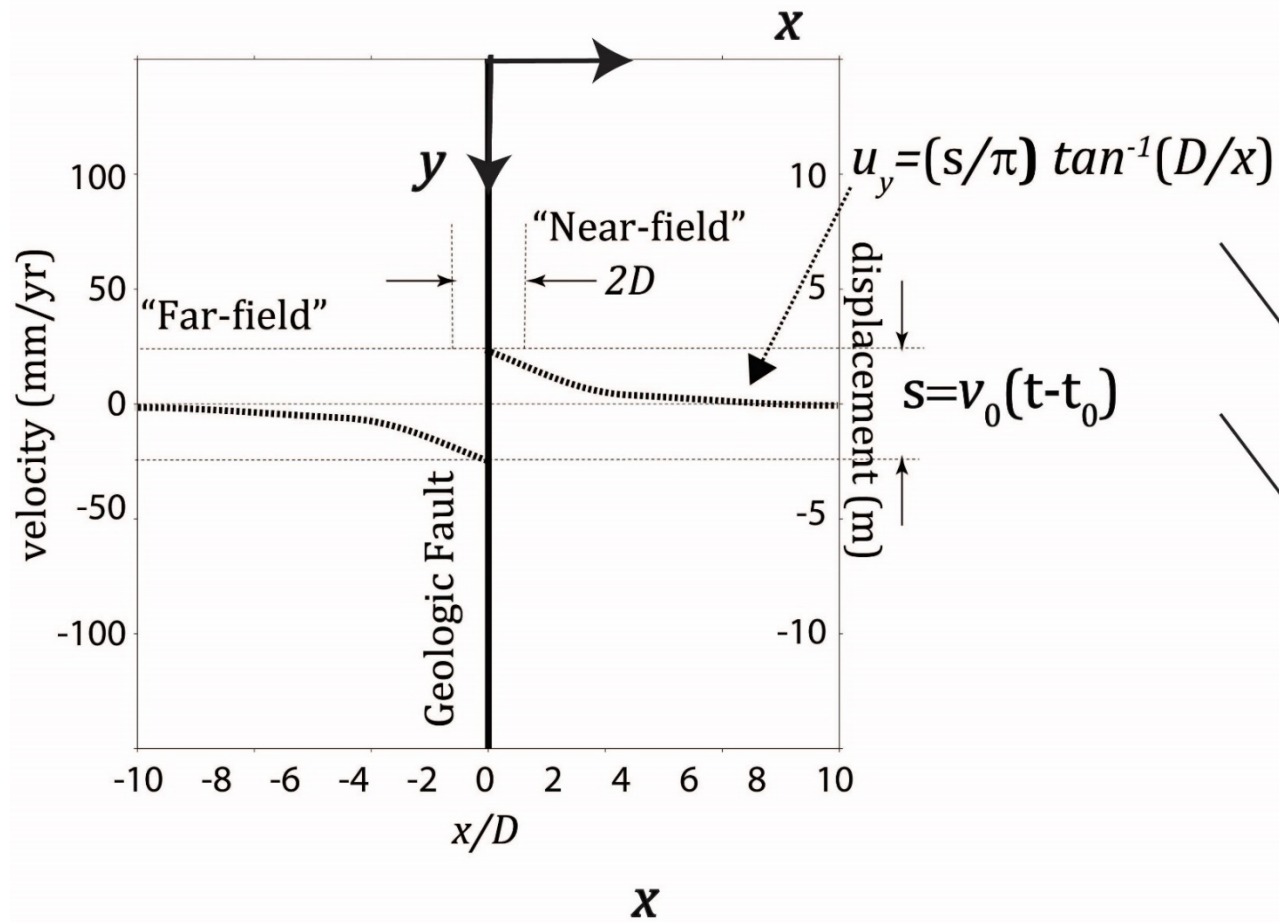
**HTDP - Horizontal Time-Dependent Positioning**

# Crustal Deformation Model Interseismic Motion



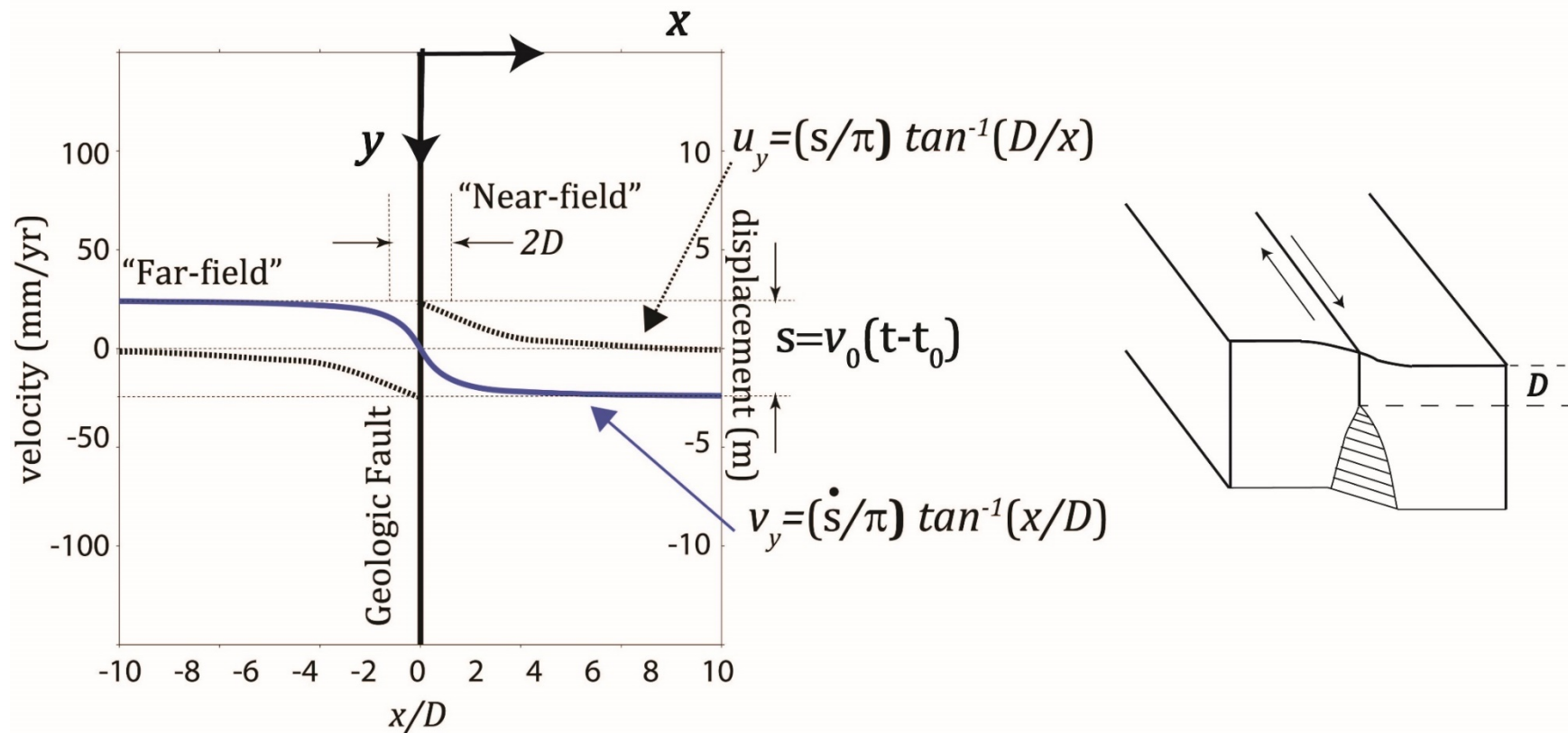
# Crustal Deformation Model

## Coseismic Motion



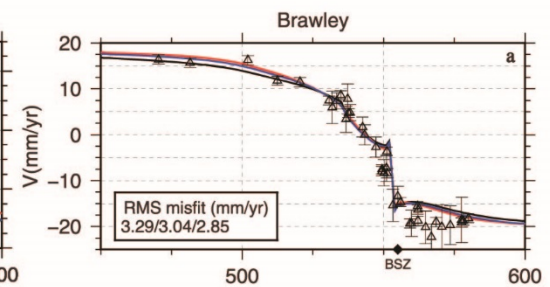
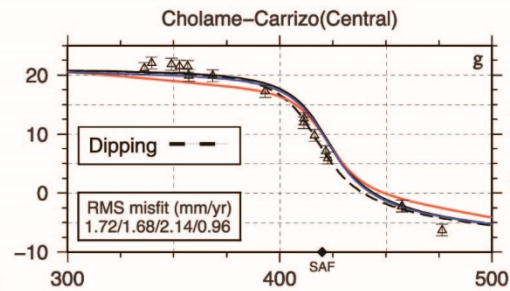
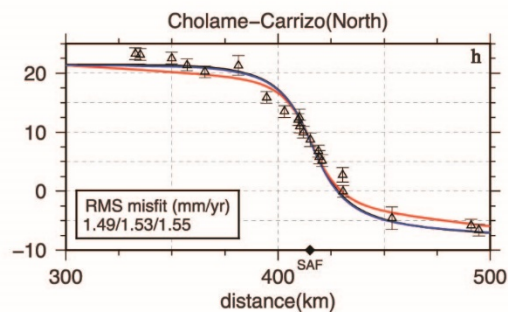
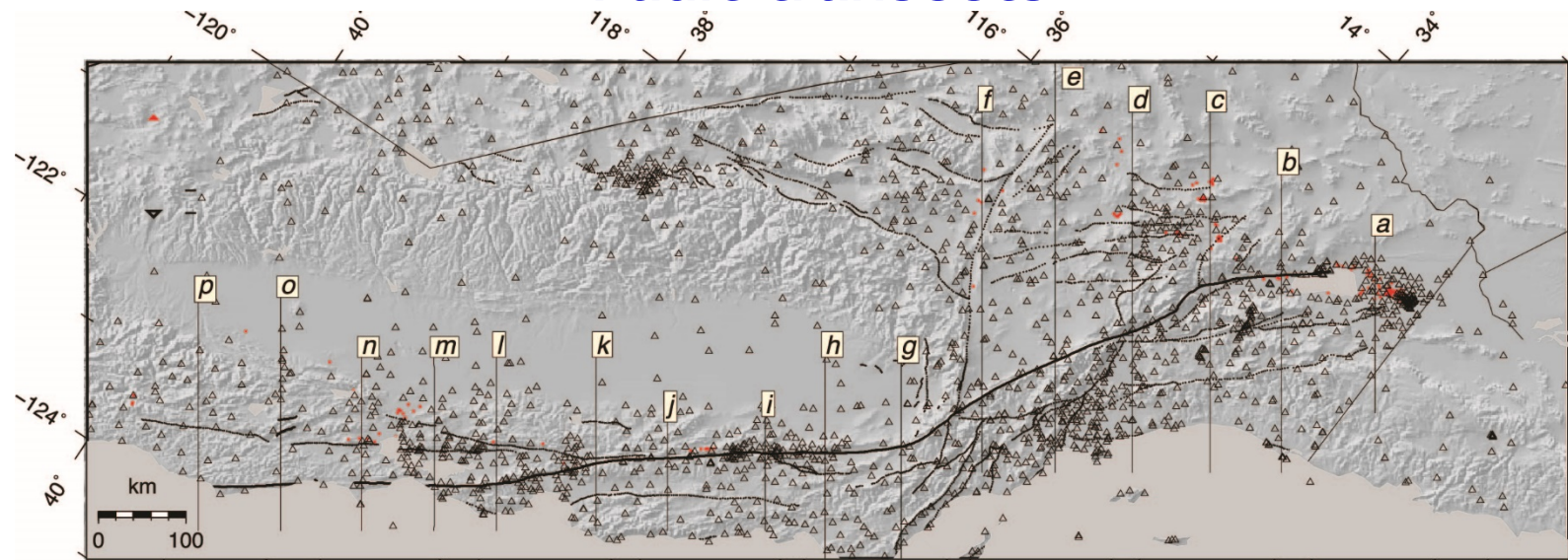


# Crustal Deformation Model Earthquake Cycle



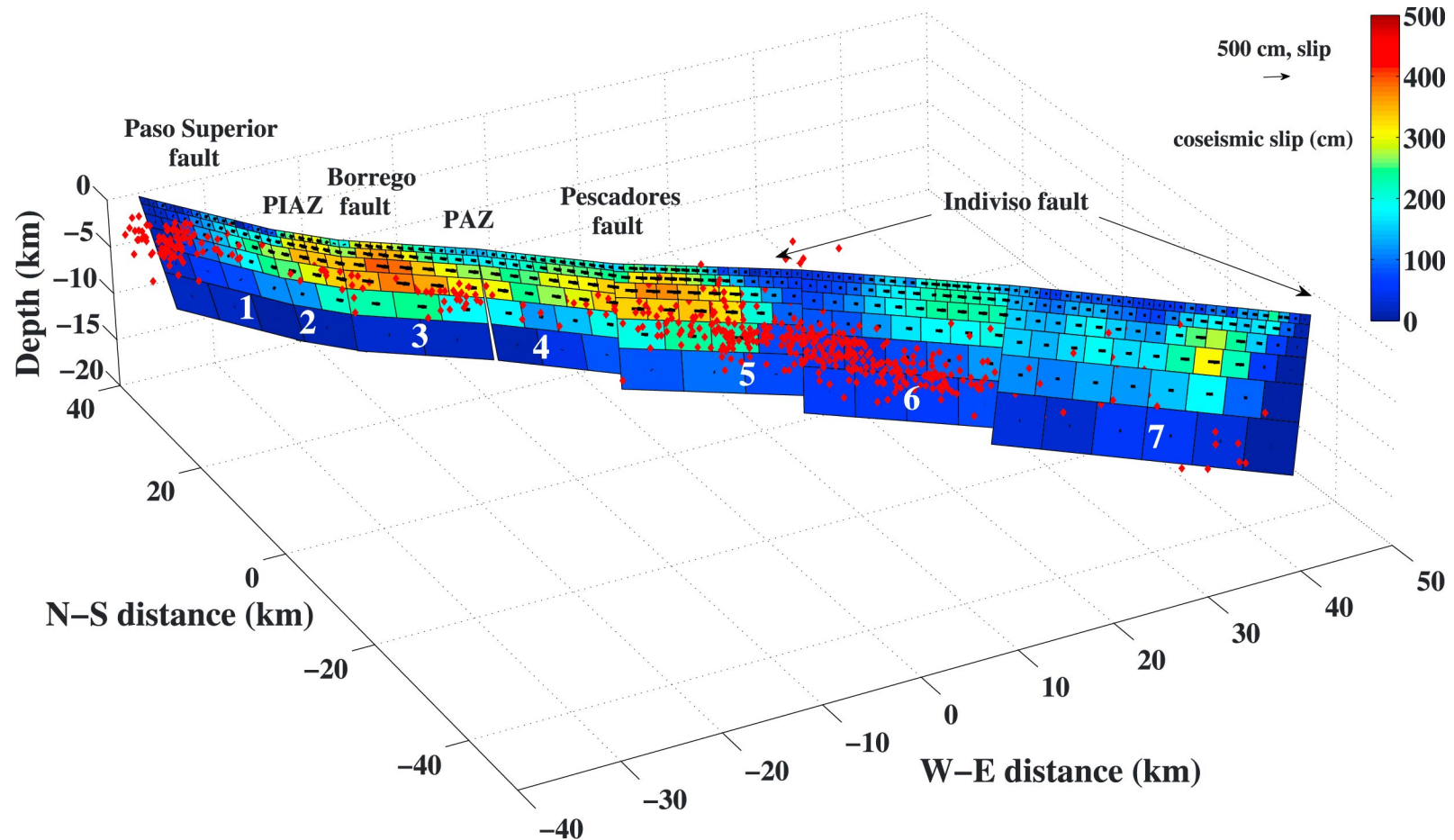
# Crustal Deformation Model

## Fault transects



# Crustal Deformation Model

## Coseismic Motion: 2010 Mw7.2 El Mayor-Cucapah



Gonzalez et al., 2014

## Dynamic Datums - V

- A GNSS survey (say RTK) is conducted at some date and positioned wrt the CSRS (say, in real time using CRTN). The surveyor receives the metadata for the reference station(s) and true-of-date ITRF coordinates as part of the RTCM3 message, consistent with the IGS frame and orbits, and estimates coordinates of surveyed marks with his/her usual field device. The true-of-date coordinates of the CRTN stations are derived using a SECTOR-type app.
- The surveyor can refer back to an earlier epoch date using an up-to-date HTDP-type model, which is consistent with the CSRS, since the model was derived from the CSRN coordinate time series.
- Whether at the survey date or an earlier date, the ITRF positions can then be converted to geodetic coordinates (say with respect to the NSRS) and then to map coordinates, if required.
- Is implementation and acceptance of a dynamic datum made any easier now that maps are digital, or after paper maps have been digitized?



## Relevant CRTN Metadata - Today

### **Essential:**

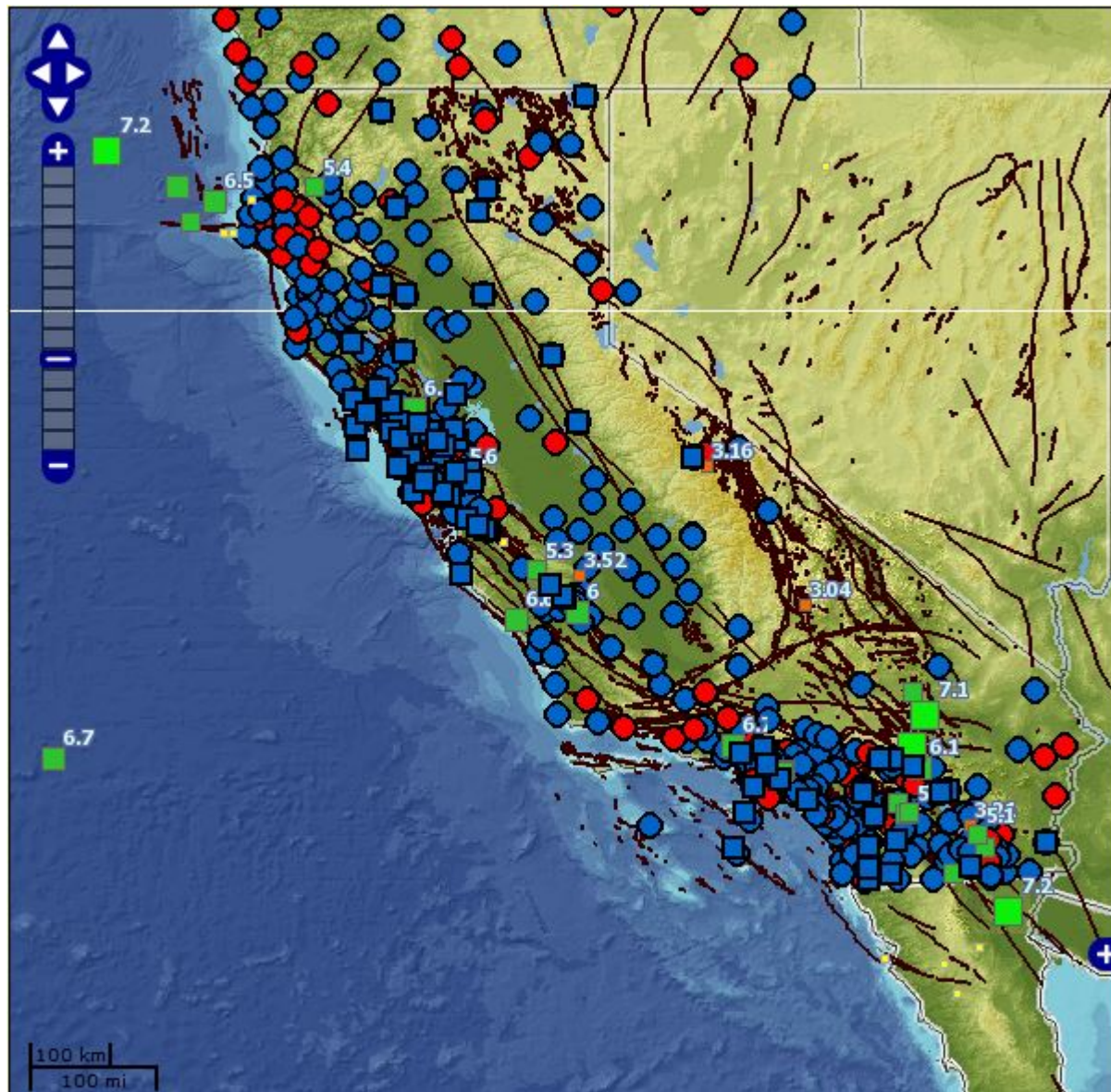
- Coordinates of CGPS stations – CSRS Epoch 2011.00 NAD83 (NSRS2007)
- Type/manufacturer of antenna
- Type/manufacturer of receiver
- Antenna reference point (ARP)
- Antenna offsets from reference point (height, mainly)

### **Optional:**

- Receiver serial number
- Antenna serial number

**Transmitted in RTCM 3.0/3.1 message for all stations**

# CRTN Station Status @ 10/5/2016 22:15 PDT



CRTN is a multipurpose statewide real-time network that utilizes the existing geophysical GNSS infrastructure in California. Started in 2003, 1 Hz RTCM 3.0 data are available from 384 stations from 2 CRTN servers (SC: 171 stations; NC: 213 stations) at SIO with a latency of  $\sim 0.4$ -1.0 s. Data directly collected from SCIGN/PBO stations via UCSD's HPWREN, and from servers at UNAVCO/PBO, USGS Pasadena, UC Berkeley, Caltrans, Orange County, and Metropolitan Water District.

NAD83(NSRS2007) 2011.0 coordinates transmitted, with station metadata in RTCM 3.0 format



## CRTN – NTRIP

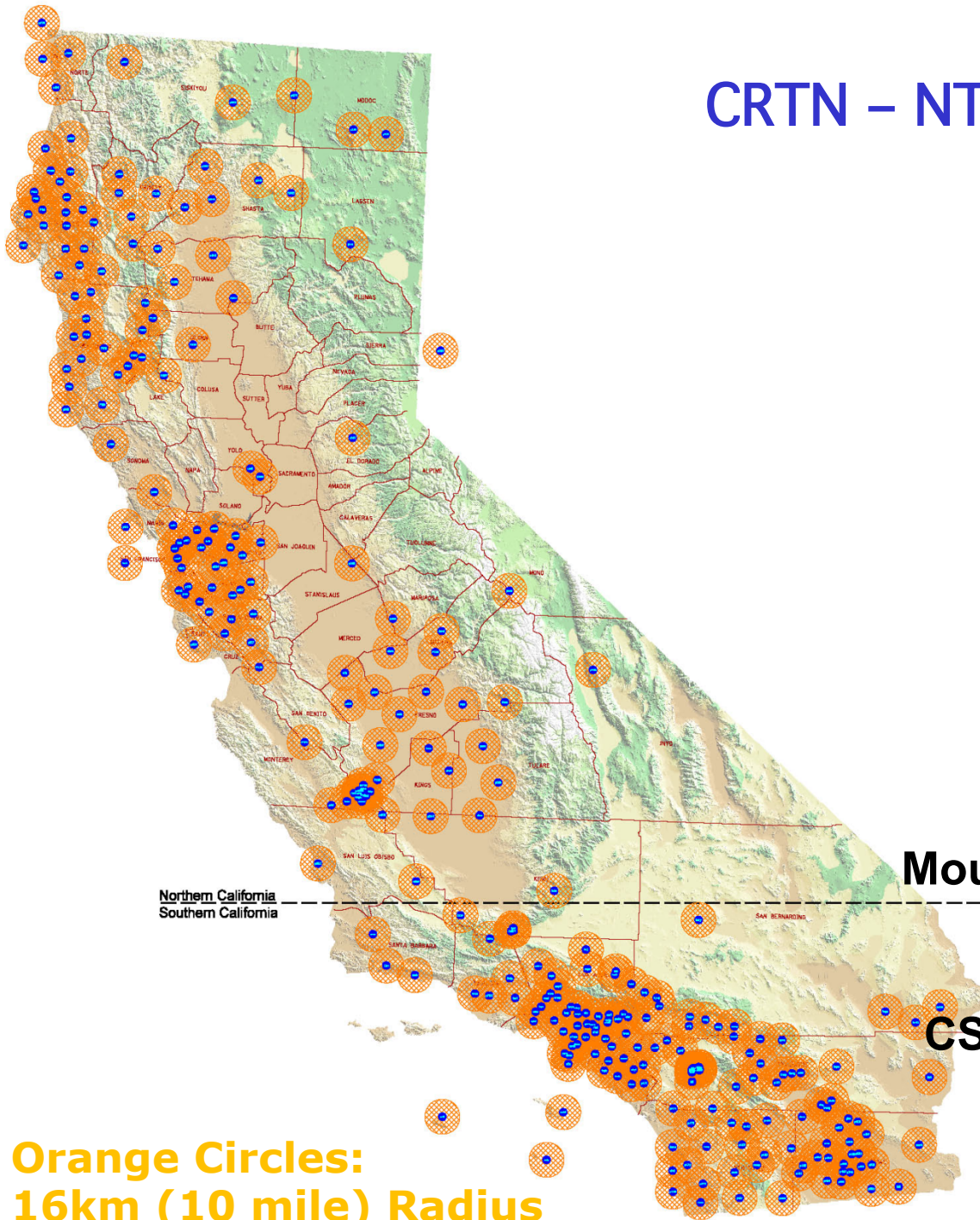
**Northern California**  
**IP: 132.239.154.101**  
**Port: 2103**  
**(213 stations)**

**Southern California**  
**IP: 132.239.152.72**  
**Port: 2103**  
**(171 stations)**

**RTCM 3.0**

**Mountpoints: “SITE\_RTCM3”**  
**SITE=4-character code**

**CSRC 2011.00 Epoch NAD83**  
**(NSRS2007) Coordinates**  
***CVSRN/CCSRN in***  
***Caltrans 2014.5 Epoch***



## CRTN Consortium Members

1. City of Los Angeles, Department of Public Works, Bureau of Engineering, Cesar Bregaudit, John Tosto, Robert Nielsen
2. Riverside County Flood Control and Water Conservation District, Jim McNeil
3. Orange County Public Works, Art Andrew
4. San Diego County, Department of Public Works, Ray Mathe
5. Riverside County Transportation Department, Rick Lantis, Ed Hunt, Tim Rayburn
6. Santa Clara Valley Water District, Kris Puthoff
7. City of Long Beach, Gas and Oil, Kimberley Holtz
8. California Land Surveyors Association, Michael McGee
9. California Spatial Reference Center, Rich Maher
10. Scripps Institution of Oceanography, UCSD, Yehuda Bock
11. California Department of Transportation, Scott Martin, Mark Turner
12. Swift Navigation, Rob Hranc



## CRTN Contributing Members

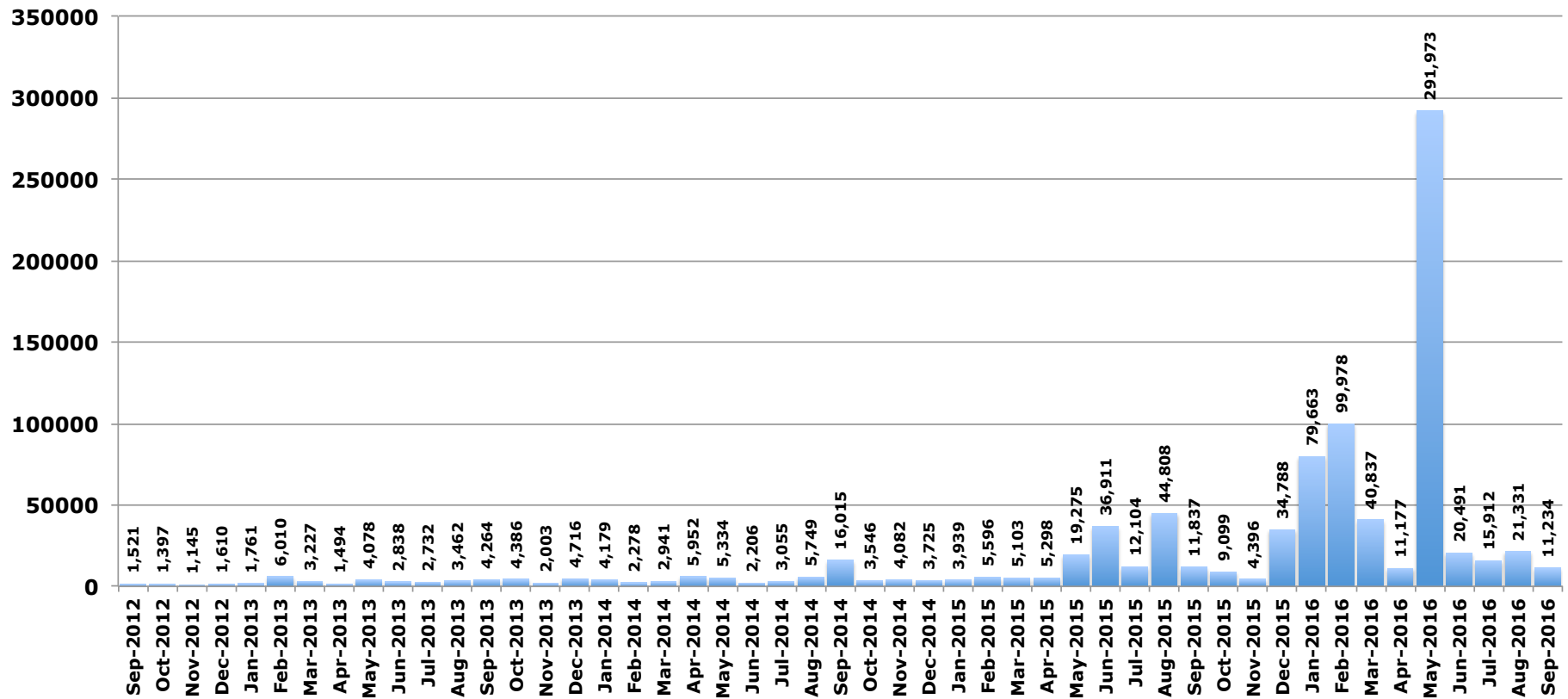
1. Adkan Engineers, Tom Chrisman
2. Bock and Clark Corporation, Eric Berben
3. Burkett and Wong Engineers, Casey Lynch
4. Coast Surveying, Inc., Ken Kasbohm, Gwen del Castillo
5. East Bay Municipal Water District, Steve Martin
6. East Bay Regional Parks, Duncan Marshall
7. Honda Research Institute USA, Inc., Paul Cummings
8. Japan Aerospace Exploration Agency, Satoshi Kogure, Mike Ramirez
9. Terra-Mark Surveying, Robert Shellman
10. LocusView Solutions, Eric Gakstatter
11. PSOMAS, Jeremy Evans
12. Quantum Spatial, Kenny Roberts
13. Rail Surveyors and Engineers Incorporated, Cody Festa
14. RBF Consulting, Company of Michael Baker Corporation
15. RSE Inc., Cody Festa
16. Salsbury Engineering, Inc., Jon Gauthier
17. San Francisco Water Department, Edward Peterson
18. SubCarrier Systems Corp., David Kelley
19. Cardno, Inc., Sean Fitzpatrick

## CRTN – Single Base Users

- An NTRIP account (username & password) is required, requested by on-line registration: ([https://www.surveymonkey.com/s/CRTN\\_Registration](https://www.surveymonkey.com/s/CRTN_Registration))
- 699 companies/agencies registered (up from 574 at 2015 Spring Meeting) > 20 multi-account users
- Recent accounts
  - 614. Welty Engineering, Inc. (Stanislaus, well monitoring)
  - 616. Pacific Survey Supply (Shasta, train surveyors)
  - 623. Sandoval & Associates (Monterey, GIS)
  - 628. Thomas Gast & Assoc. Environmental Consultants (Humboldt)
  - 650. Monterey Peninsula Water Management District
  - 653. Jacob Elliott (Alameda, automotive industry)
  - 660. Leigh Klatsky (Tulare County, RTK/GIS)
  - 662. InspecTools, Inc. (Santa Cruz, inspection, utilities)
  - 663. Phil Hanes (graduate student, Sonoma, archeology)
  - 667. Marin County (engineering, surveying, infrastructure)

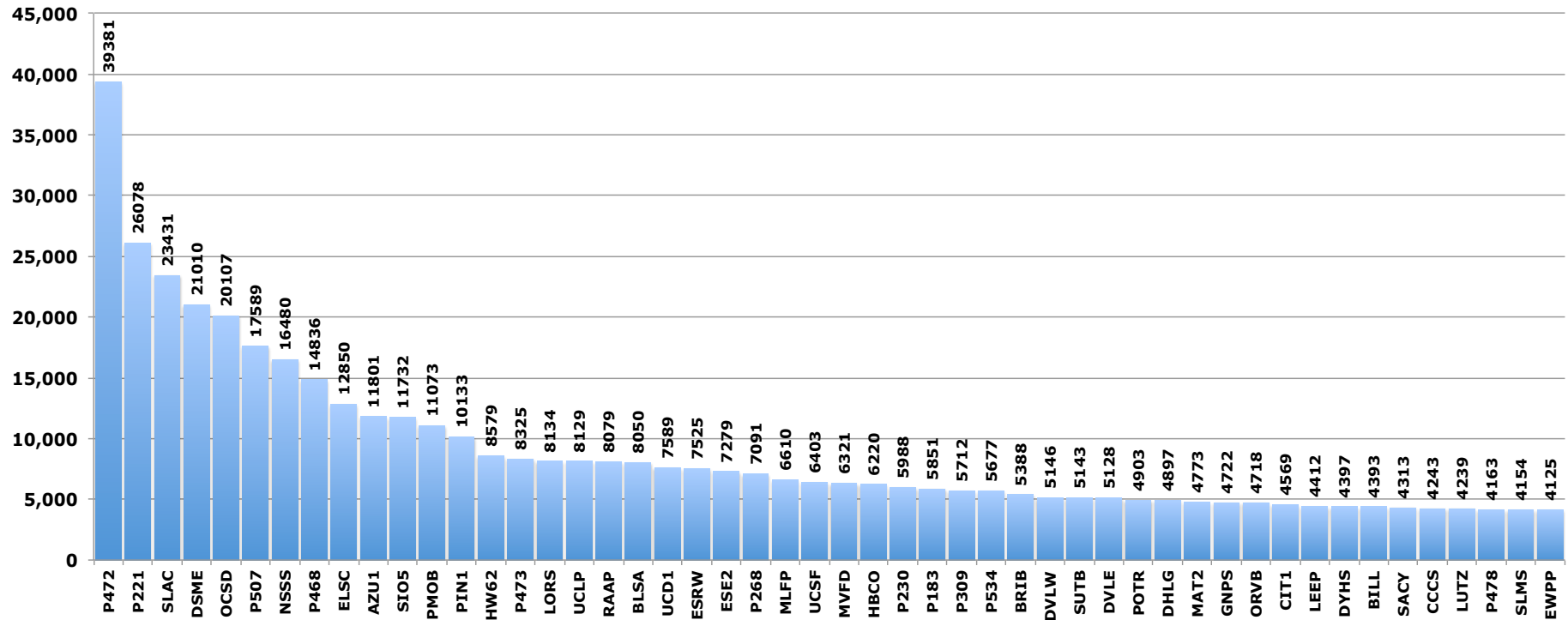
# Connections to CRTN through September 2016

**Number of CRTN NTRIP Connections by Login from 2012 through 2016  
(NTRIP Accounts Issued = 85 as of September 2012 and 537 as of September 2016)**



# Connections to CRTN Stations through September 2016

**Cumulative Number of CRTN NTRIP Connections by Station  
from February 2012 through September 2016 (Top 50 Stations with Total Connections ≥ 4125)**







## CSRC Executive Committee



- *Chairperson:* Richard C. Maher
- *Vice-Chairperson:* Scott P. Martin
- *Secretary:* Thomas Dougherty
- *Treasurer:* Jim McNeil
- *Member:* Bryan Banister
- *Member:* **Kimberley Holtz**
- *Member:* Greg Helmer
- *Member:* **Ken Joyce**
- Non-elected:
- *Past Chairperson:* Art Andrew
- *UCSD representative:* John Orcutt
- *Director of IGPP:* Steve Constable
- *NGS Adviser:* Dana Caccamise
- *CSRC Director,* Yehuda Bock

## SOPAC/CSRC Group

- Director: Yehuda Bock
- Researcher: Jennifer Haase
- Coordinator: Maria Turingan
- Analysis: Peng Fang
- Programmers: Mindy Squibb, Allen Nance, TBD
- System Administrator and Archivist: Anne Sullivan
- CRTN Engineer: TBD
- Graduate Students: Dara Goldberg
- *Consultant*: John Canas, PLS

