Director's Report

Yehuda Bock

Jennifer Haase

Scripps Orbit and Permanent Array Center (SOPAC)

California Spatial Reference Center (CSRC)
Scripps Institution of Oceanography
University of California San Diego

CSRC Coordinating Council Spring Meeting
La Jolla, CA
May 16, 2013

SOPAC/CSRC Staff

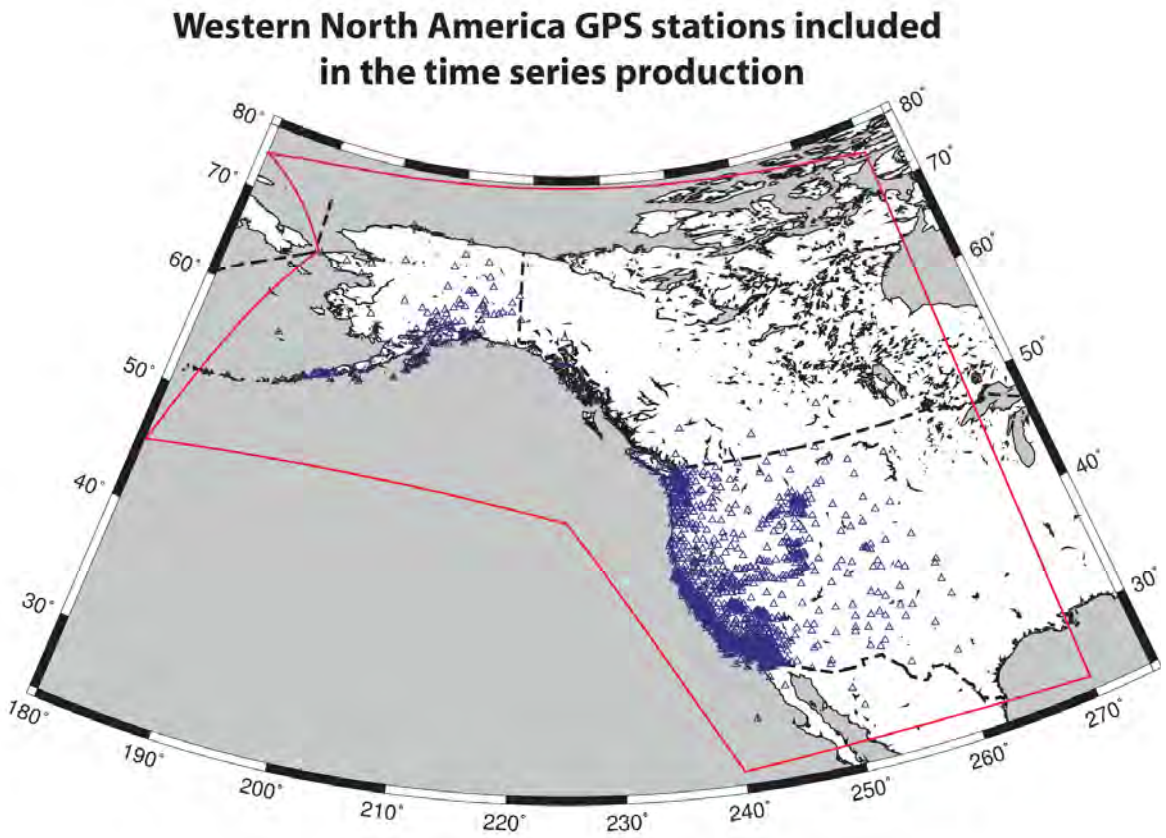
- Director: Yehuda Bock
- Researcher: Jennifer Haase
- Coordinator: Maria Turingan
- Analysis: Peng Fang
- Lead Programmer: Mindy Squibb
- System Administrator: Anne Sullivan
- SCIGN and CRTN Engineer: Glen Offield
- Graduate Student: Brendan Crowell, PhD, Diego Melgar
- Postdoctoral Researchers: Jianghui Geng & Yuval Reuveni
- PLS Consultant: John Canas

CSRC Executive Committee

- *Chairperson: Art Andrew*
- *Vice-Chairperson: Dan Gilleland*
- Secretary: Richard Maher
- Treasurer: Bill Hofferber
- Member: Armand Marios
- Member: Brian Wiseman
- *Member: Larry Gill*
- *Member: Dave Olander*
- *Member: Vacant*
- Past Chairperson: Dick Davis

CGPS Data & Metadata

- **RINEX files archived at SOPAC from over 2000 stations in Western NA including PBO, SCIGN, BARD, WCDA and PANGA stations & global stations**
- **Earliest CGPS data are from 1991 – two decades worth**
- **Use a common source of metadata to reduce systematic errors**
- **RINEX data processed independently at JPL (GIPSY software) and SOPAC (GAMIT software)**
- **Combination daily position time series is produced & updated weekly**



GPS/GNSS Positioning – Reference Frames

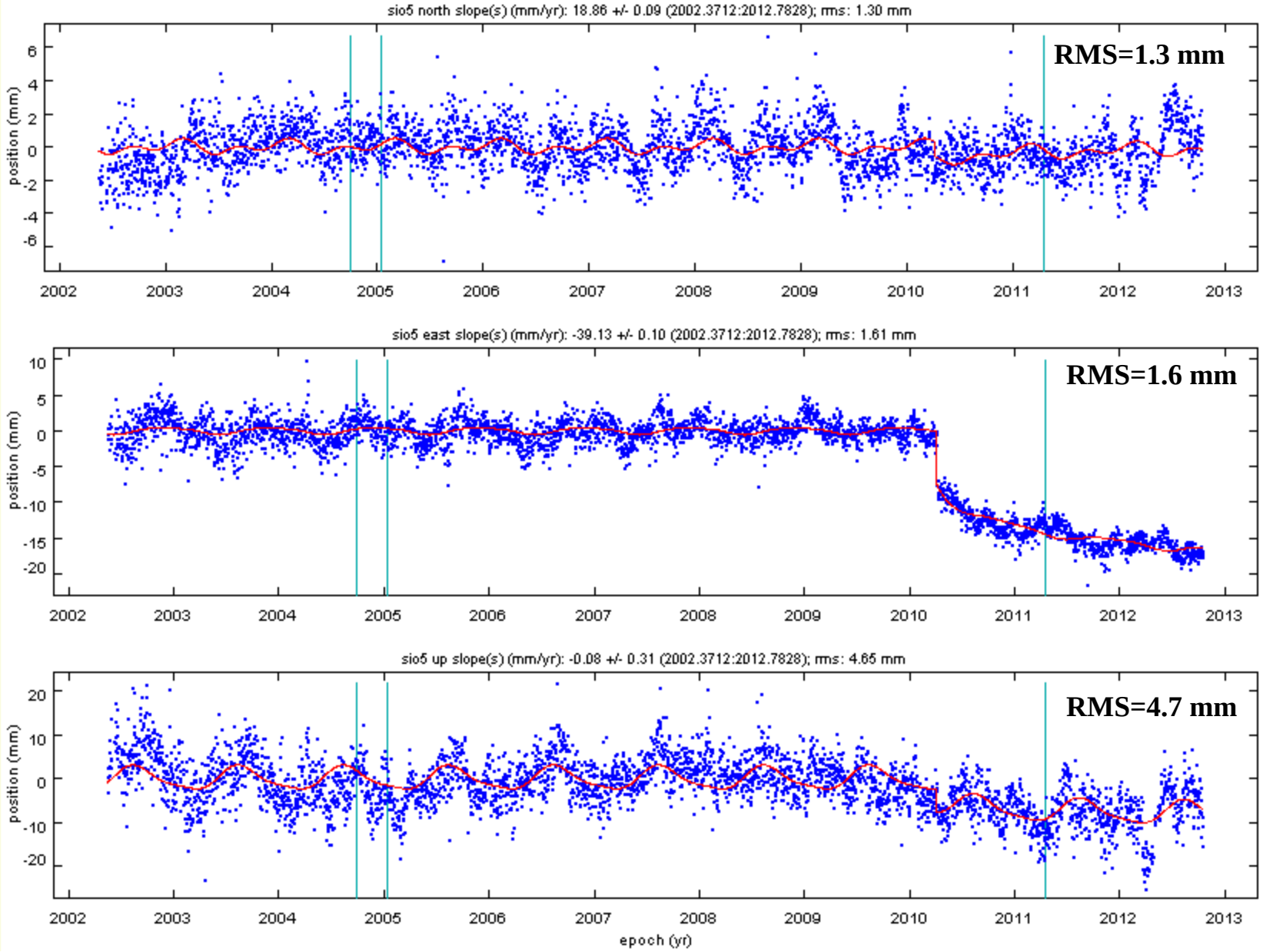
- The natural reference frame of GPS/GNSS is an Earth-Centered Earth-Fixed Reference Frame (ITRF)
- ITRF is defined by the positions and velocities of a global network of space geodetic tracking stations, to account for plate tectonic motions
- Precise GPS orbits (IGS) and broadcast ephemeris are with respect to ITRF (currently ITRF2008)

In California:

- We experience tectonic motion, earthquakes, subsidence, and volcanic activity so the reference network is deforming, while surveyors would like a static datum
- Multiple reference frames in use are tied to North America and the National Spatial Reference System (e.g., NAD83)
- Multiple epoch dates are in use
- Multiple positioning sources are available

CSRC/CRTN Can Help!

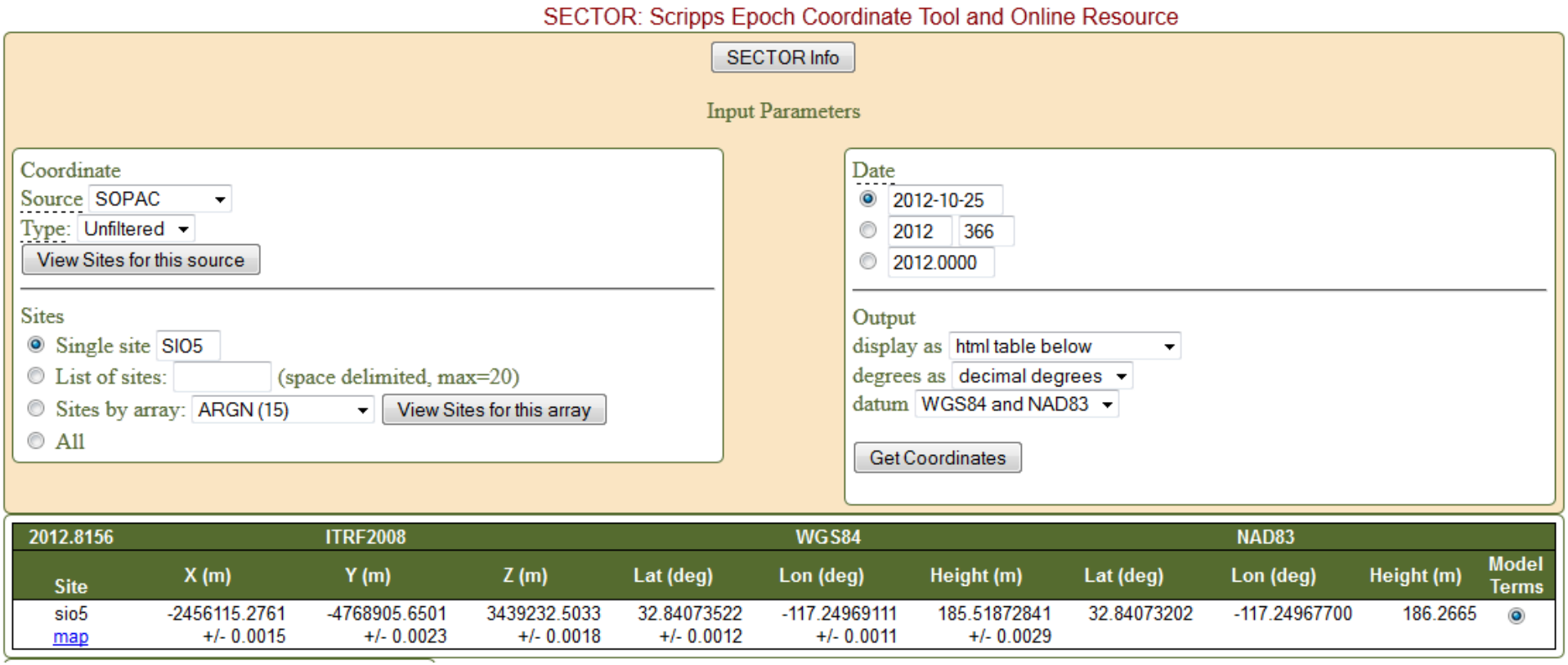
SIO5 Time Series (North, East, Up)



Significant Earthquakes in Western North America (1996-2013)

10/16/1999	**Hector Mine, Southern California**	**7.1**	**142**	**exp**	**OPRD: 6 km**	**LAND: 408 km**
2/29/2001	Nisqually Fault, Seattle	6.8	4	exp	RPT1: 30 km	HUSB: 340 km
11/3/2002	Denali, Alaska	7.9	12	exp	GNAA: 136 km	KEN1: 441 km
12/22/2003	**Cambria, San Simeon, Central California**	**6.5**	**23**	**log**	**P278: 4 km**	**ORES: 131 km**
6/28/2004	Queen Charlotte Fault	6.8	4	exp	AC64: 1023 km	AC63: 1139 km
9/28/2004	**Parkfield, Central California**	**6.0**	**28**	**log**	**P281: 4 km**	**CUHS: 115 km**
6/12/2005	Anza, Southern California	5.2	0		AZRY: 8 km	
6/15/2005	**Gorda Plate, CA**	**7.2**	**5**	**exp**	**CME1: 188 km**	**P170: 216 km**
6/16/2005	Yucaipa, Southern California	4.9	0		CRFP: 15 km	
9/2/2005	**Obsidian Buttes Swarm, Salton Trough**	**5.1**	**3**	**exp**	**GLRS: 5 km**	**DHLG: 31 km**
10/3/2006	Superstition Hill Seismic Swarm - silent slip	4.7	0		CRRS: 16 km	
10/31/2007	Alum Rock, San Jose, California	5.6	1	none	MHCB: 7 km	
7/29/2008	Chino Hills, California	5.5	1	none	TWMS: 4 km	
1/10/2010	Eureka Earthquake, Offshore Northern Califor	6.5	11	exp	P159: 45 km	P156: 95 km
2/4/2010	Offshore Northern California, Humboldt Coun	5.9	0		P159: 60 km	
4/4/2010	**El Mayor-Cucapah, Northern Baja California**	**7.2**	**208**	**exp**	**P500: 62 km**	**P567: 485 km**
6/15/2010	**Aftershock, El Mayor-Cucapah**	**5.7**	**7**	**exp**	**P481: 16 km**	**P496: 31 km**
7/7/2010	**Borrego Springs, Southern California**	**5.4**	**3**	**exp**	**P490: 13 km**	**P742, P484: 14 k**
8/26/2012	**Brawley Swarm, Imperial Valley**	**5.3, 5.4**	**2**	**none**	**P506: 8 km**	**P498, P499**

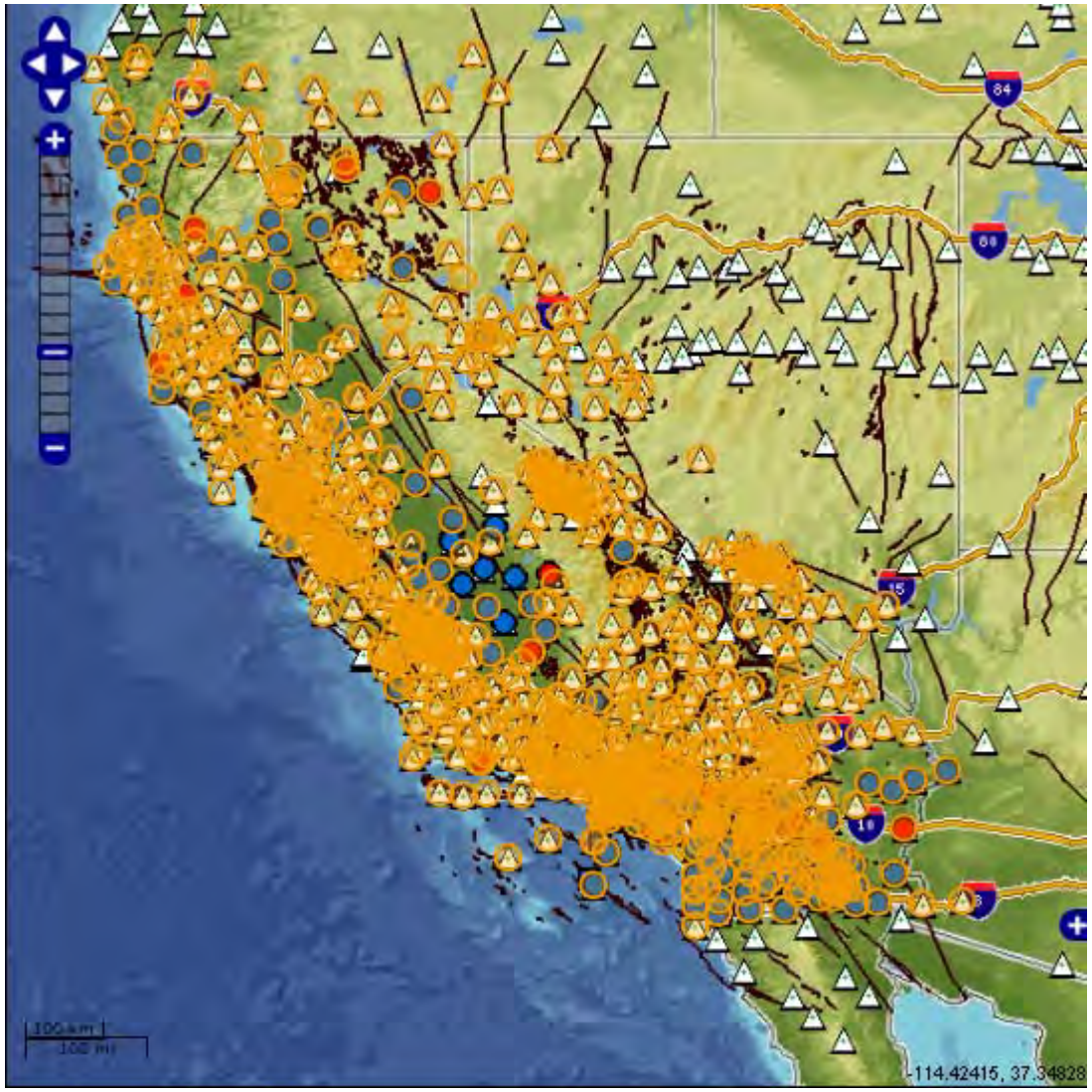
SECTOR Epoch-Date Coordinates
(New Version – October 2012)



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	
map	+/- 0.0015	+/- 0.0023	+/- 0.0018	+/- 0.0012	+/- 0.0011	+/- 0.0029				

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

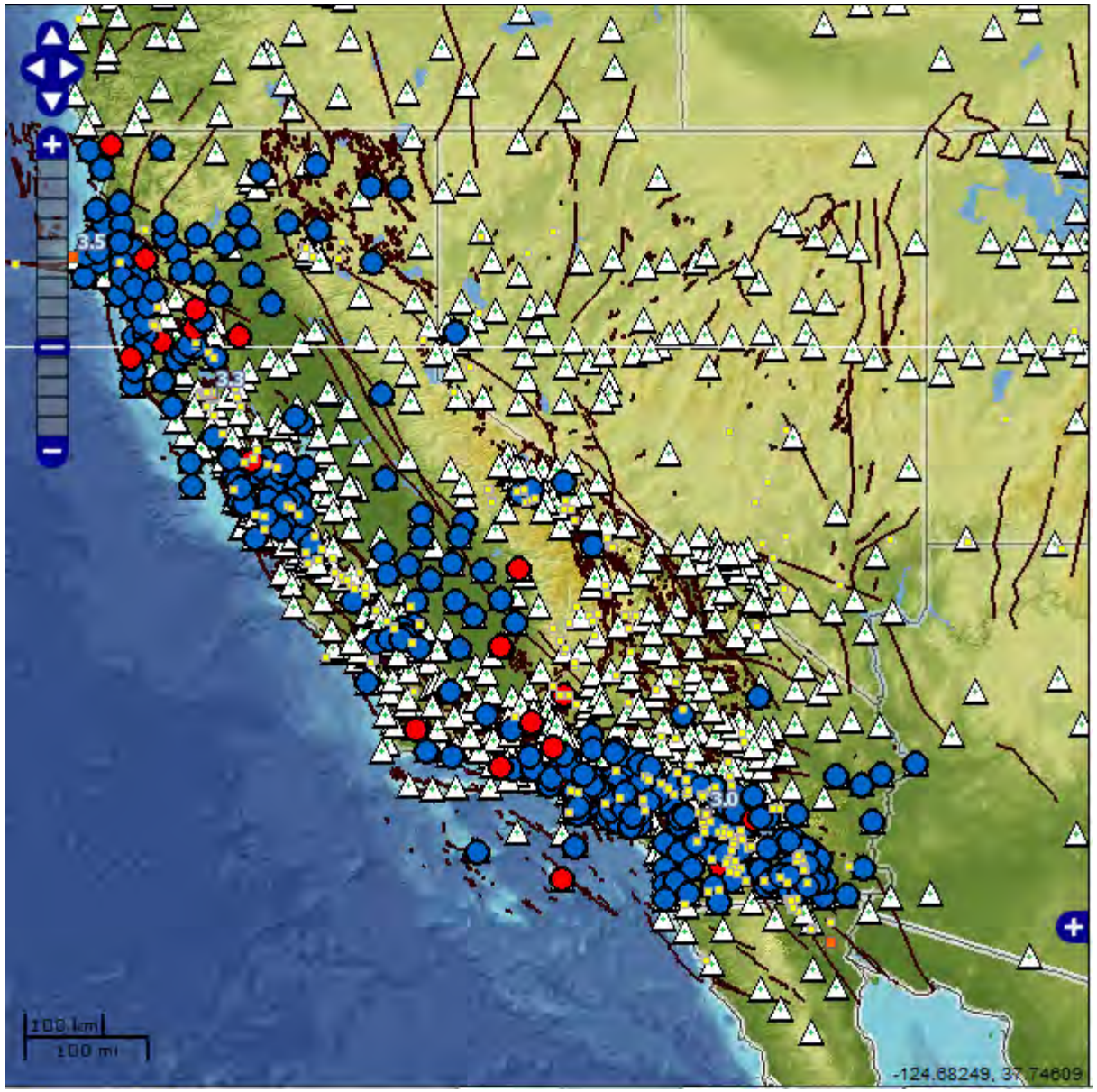
CSRS Coordinate Epoch (2011.00)



- **830 CGPS stations (766@epoch 2009.00; 551@epoch 2007.00) – includes observations until 2011.2918**
- **ITRF2005 coordinates & velocities (will update to ITRF2008 with planned reprocessing)**
- **NAD83(NSRS2007) coordinates & velocities**
- **Includes uncertainties to comply with California Public Resources Codes**
- **Will tie into NGS National Adjustment of 2011 (NA2011), NAD 83(2011) epoch 2010.00**

http://csrc.ucsd.edu/input/csrc/csrsEpoch2011.00.xls

California Real Time GPS Network (CRTN)

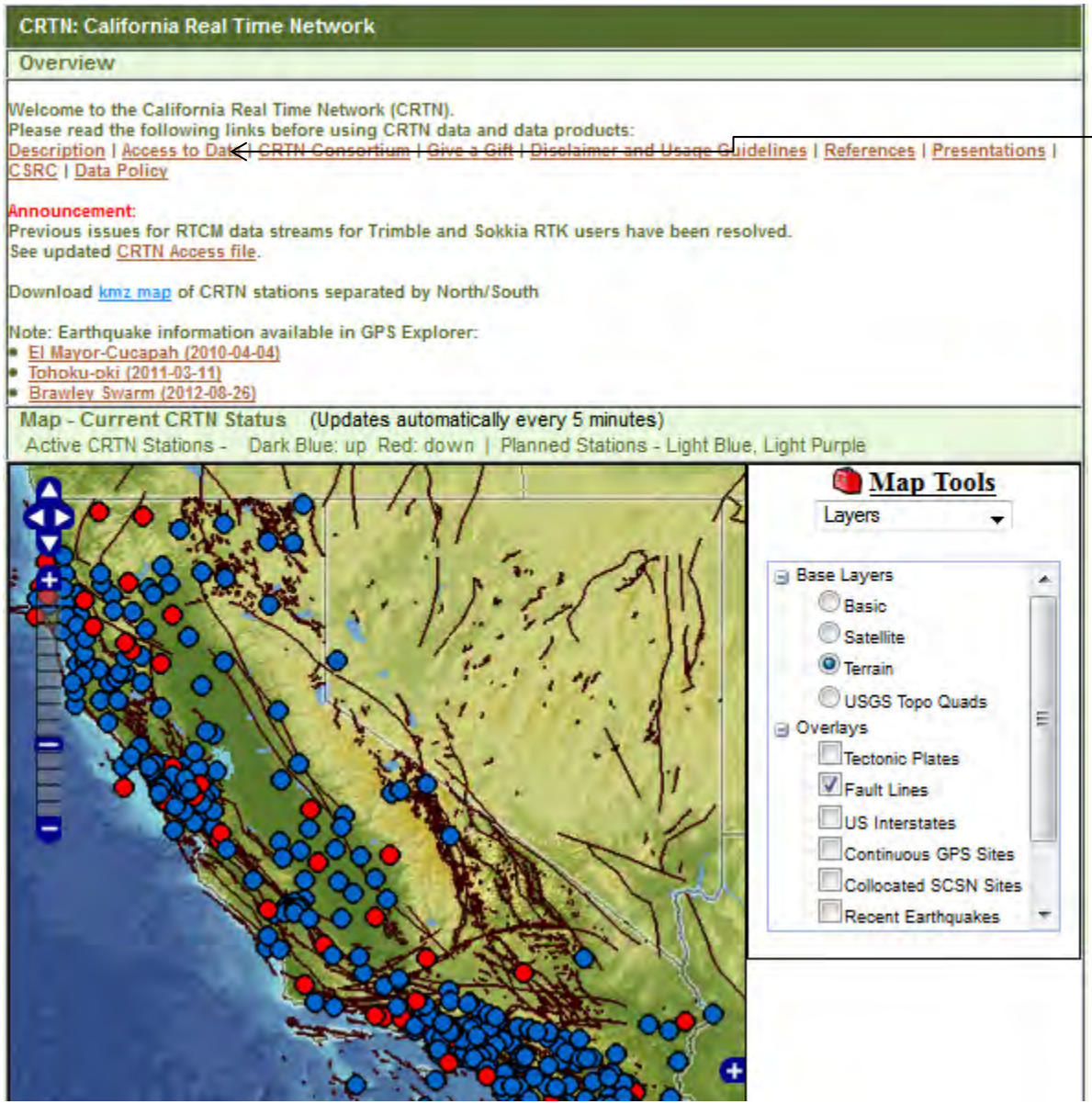


CRTN is a multipurpose statewide real-time network that utilizes the existing geophysical CGPS infrastructure in California. Started in 2003, 1 Hz RTCM 3.0 data are available from 339 stations from 2 CRTN servers (SC & NC) at SIO with a latency of ~0.4 s. Data are directly collected from SCIGN/PBO stations via UCSD's HPWREN, and from servers at UNAVCO/PBO, USGS Pasadena, UC Berkeley, Caltrans, Orange County, and Metropolitan Water District.

California Real Time GPS Network (CRTN)

- Multipurpose statewide real-time network that utilizes the existing geophysical CGPS infrastructure in California.
- Backbone for the geodetic control network that is outlined in the CSRC Master Plan.
- Accurate and reliable real-time positioning services that are consistent and in a common reference system – California Spatial Reference System (CSRS).
- Fulfills the requirements of the California Public Resources Codes 8856(c)(e), 8857(c), and 8858(b) for GPS-derived geodetic coordinates and orthometric heights.
- RTCM 3 data streams for single-base RTK positioning with respect to the CSRS reference epoch (2011.00).
- Multiple real-time data streams to Contributing and Consortium Members.

http://sopac.ucsd.edu/projects/realtime/CRTN/



NTRIP access and Epoch 2011.00 coordinates

http://csrc.ucsd.edu/

Forums

Published Coordinates

Real-Time Map

Various CSRN & CRTN Maps

Presentations

Forums

UBB.classic

SOPAC Geophysical Forums
login | register | search | faq | forum home

» Today's Active Topics «

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Registered Members: 1247
Welcome to our newest member: Bob MacKenzie

SOPAC Geophysical Forums Recent Visitors: 50
50 guest(s)

Forum Categories	Total Forums in Category
MEASURES/REASoN	7
SOPAC	7
GSAC	1
CSRC California Spatial Reference Center. Includes forums on CSRC website, height modernization projects, and PGM (Pocket GPS Manager).	16
CRTN The California Real Time Network provides real-time GPS connectivity in California. Enter the forum to view general notices or participate in discussions pertaining to CRTN.	3
SOMI Discussion, feature requests, bug reports and announcements for the SOPAC Online Mapping Interface (SOMI).	6
GPS Explorer Discussion, feature requests, bug reports and announcements for GPS Explorer.	7

CRTN

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	Forum	Topics	Posts	Last Post	Moderators
CRTN The California Real Time Network provides real-time GPS connectivity in California. Enter the forum to view general notices or participate in discussions pertaining to CRTN.					
	CRTN Community Notices CRTN notices of community-wide relevance. All messages posted here (by moderator) go to the **crtn-l@gpsmail.ucsd.edu** mailing list. Go to the CSRC to register.	86	90	CRTN CVSRN stations (ybock) 03-04-2013 07:24 AM	crtn-l administrator
	CRTN General Discussion CRTN-related topics, user-specified and updated. Topics may be posted here by any user.	26	71	Re: Single Data Stream or... (ybock) 04-10-2012 09:51 PM	ybock, Marti, mindy, Maria Turingan, Anne Sullivan
	RYO Format Discussion of the RYO format, streaming and conversion.	0	0		no one

Icon Legend	
New Posts Since Your Last Visit	No New Posts Since Your Last Visit

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CRTN Community Notices

		Topic	Topic Starter	Replies	Last Post
		CRTN CVSRN stations	ybock	0	**03-04-2013** 07:24 AM
		UNAVCO Network Upgrades and Outages	Maria Turingan	0	**02-11-2013** 04:00 PM
		All RTCM3 streams okay	ybock	0	**01-29-2013** 10:12 AM
		OCRTN & CVSRN updates	ybock	0	**12-10-2012** 10:21 AM
		New CRTN Stations	ybock	0	**11-20-2012** 09:17 PM
		Topcon RTCM3 and GLONASS Tracking	ybock	0	**08-13-2012** 09:42 AM
		GLONASS satellites available in San Diego	ybock	0	**07-31-2012** 11:17 AM
		SOPAC 20th Anniversary and Your Feedback	Maria Turingan	0	**07-06-2012** 12:30 PM
		RTCM streams for Trimble/Sokkia Users	ybock	0	**06-01-2012** 10:37 AM
		Transition to NTRIP	ybock	0	**03-13-2012** 03:41 PM
		Update from UNAVCO	Maria Turingan	0	**02-28-2012** 04:09 PM
		UNAVCO-PBO outage	Maria Turingan	0	**02-28-2012** 01:39 PM
		Extension to March 1	ybock	0	**02-12-2012** 11:10 AM
		Important: Access to CRTN Data after Feburary 17th	ybock	0	**01-26-2012** 10:30 AM
		Important CRTN changes	ybock	0	**01-17-2012** 10:48 AM
		CRTN NTRIP Servers and RTCM3.0	ybock	0	**01-05-2012** 12:19 AM

UBBFriend: Email this page to someone!

Author	Topic: CRTN CVSRN stations
ybock Member Member # 17 Member Rated: ★★★★★	posted 03-04-2013 07:24 AM CRTN transmits RTCM3.0 data streams obtained from the Caltrans' Central Valley Spatial Reference Network (CVSRN) server. We now stream data from all 22 stations (P056, P300, P302, P544, P566, RBRU, ALTH, CRCN, *DONO, RAPT, CHOW, DOND, DLNO, LEBC, LEMA, *MULN, TEHA, TAFT, TRLK, SHP5, *JLN5, SIMM). The stations with an asterisk are not currently available. We've also updated the transmitted Epoch 2011.00 NAD83 (NSRS2007) coordinates for those stations that were not part of the Epoch 2011.00 adjustment (except for JLN5 from which we have not yet obtained any data). As such they should be considered as provisional. See http://sopac.ucsd.edu/input/realtime/CRTN_Access.xls, which will be updated later today, for details. The changes are reflected in the CRTN Northern California NTRIP source table @ http://132.239.154.101:2103/. Thanks to Anthony Beliew who pointed out a problem with our RBRU coordinates and to Eric Adney and Bryan Banister at Caltrans for their assistance. Please notify us of any problems that you may experience. --Yehuda Posts: **215** | Registered: **Feb 2005** | IP: Logged

CRTN – Google Earth & Maps

Google Earth/
Google Maps

Featured links:

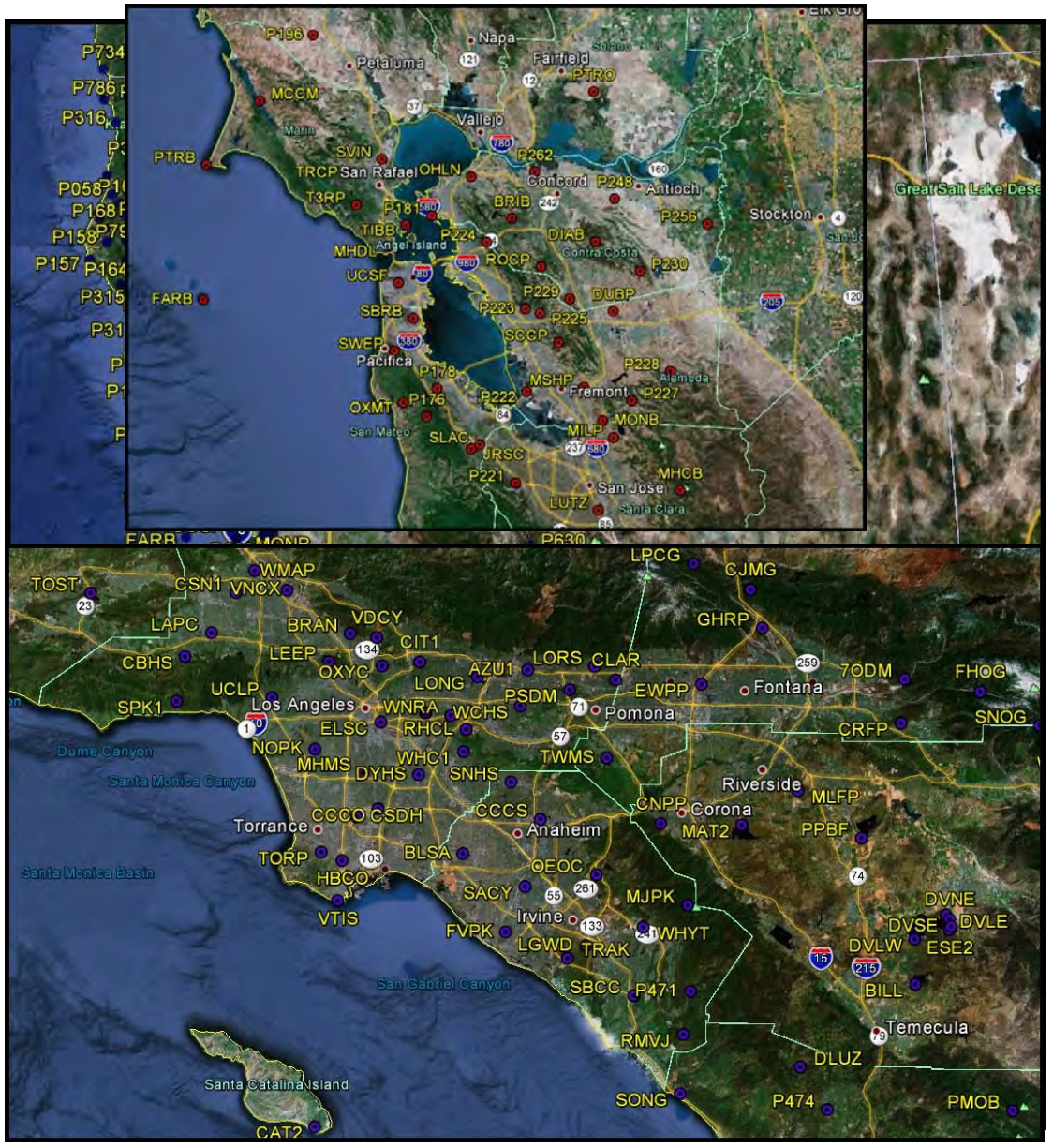
Current CRTN and CSRN Maps

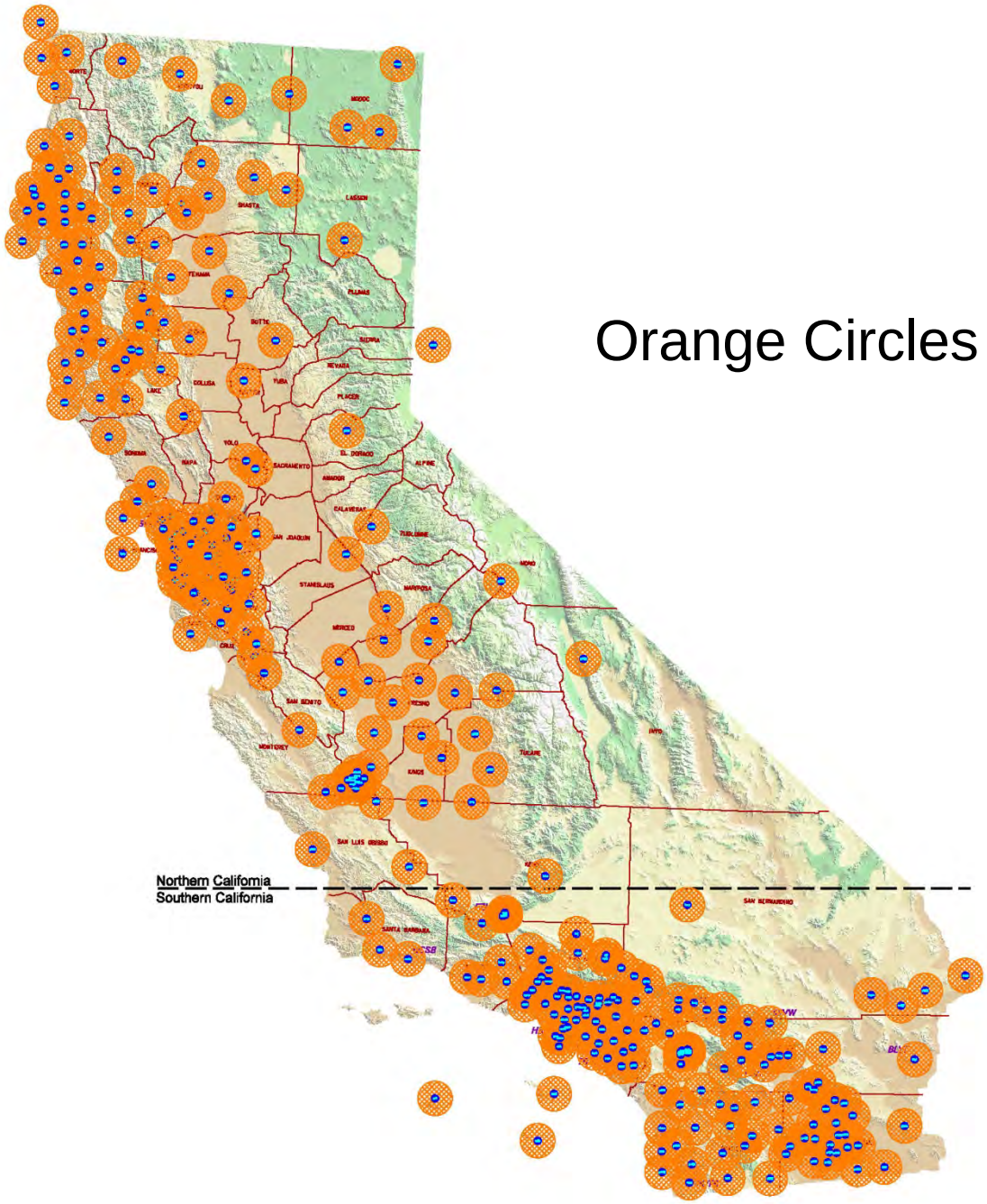
CRTN North/South Stations(kmz)
Google Earth Map showing all current active real-time CGPS stations available via NTRIP separated by North/South

CRTN All Stations(pdf)
Map showing all current active real-time CGPS stations available via NTRIP

CRTN Backbone(pdf)
Map showing proposed CRTN Backbone network as well as NGS CORS stations

CSRN 2011.00 Epoch
Map showing all CGPS stations included in the 2011.00 Epoch adjustment





CRTN – *2013*

All CRTN sites

Orange Circles = 16km (10 mile) Radius

339 stations (303 in 2012)

currently streaming

in real-time

176 – North

163 - South

Relevant CRTN Metadata

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:

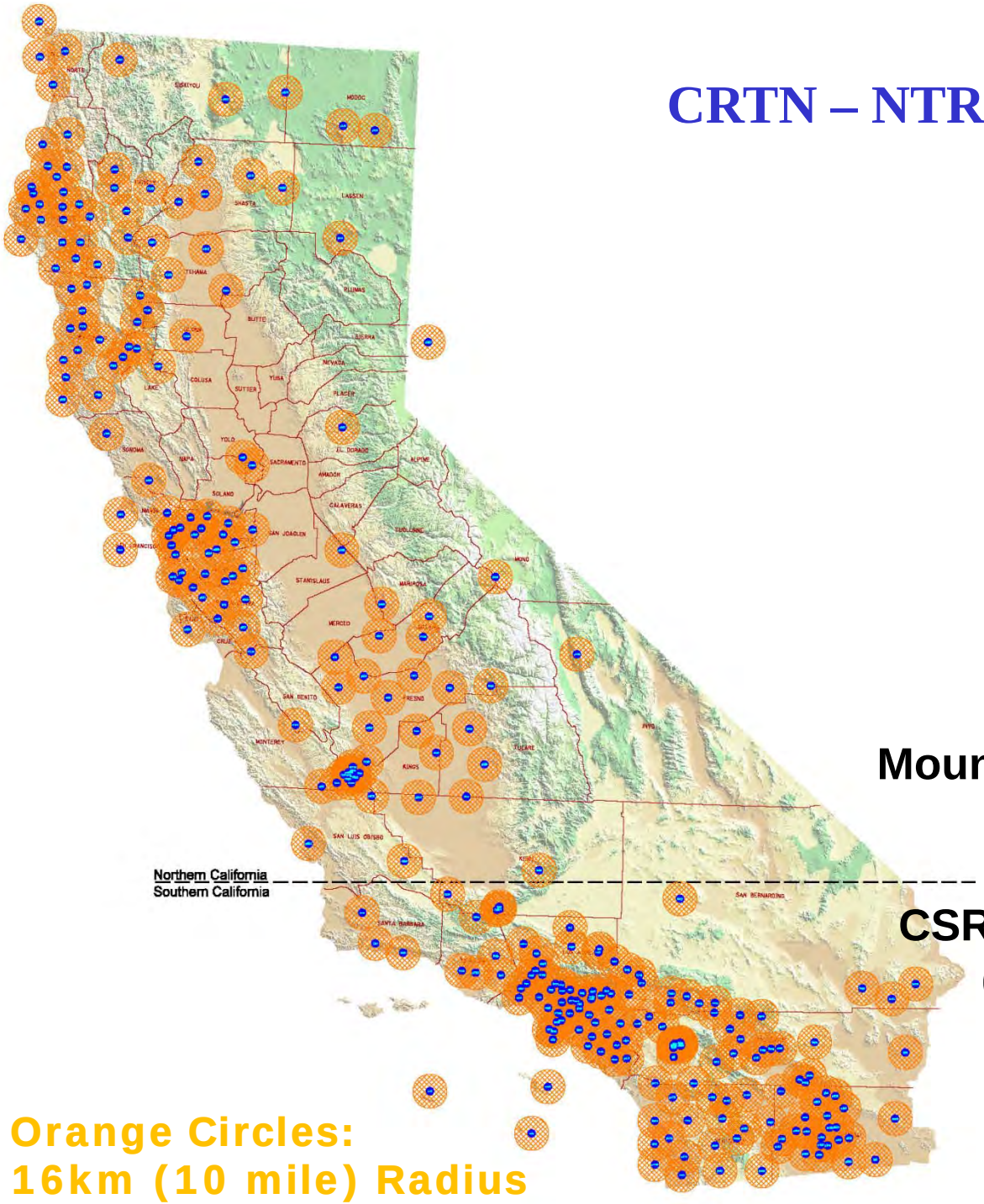
- Receiver serial number
- Antenna serial number

Transmitted in RTCM 3.0 message for real-time stations

CRTN – Real-time Data Access

- March 1, 2012 – real-time data available via NTRIP
- A user account is required and can be requested by emailing the CSRC director, Yehuda Bock (ybock@ucsd.edu)
- 200 NTRIP accounts for 176 individual companies and organizations

CRTN – NTRIP



Northern California
IP: 132.239.154.101
Port: 2103

Southern California
IP: 132.239.152.72
Port: 2103

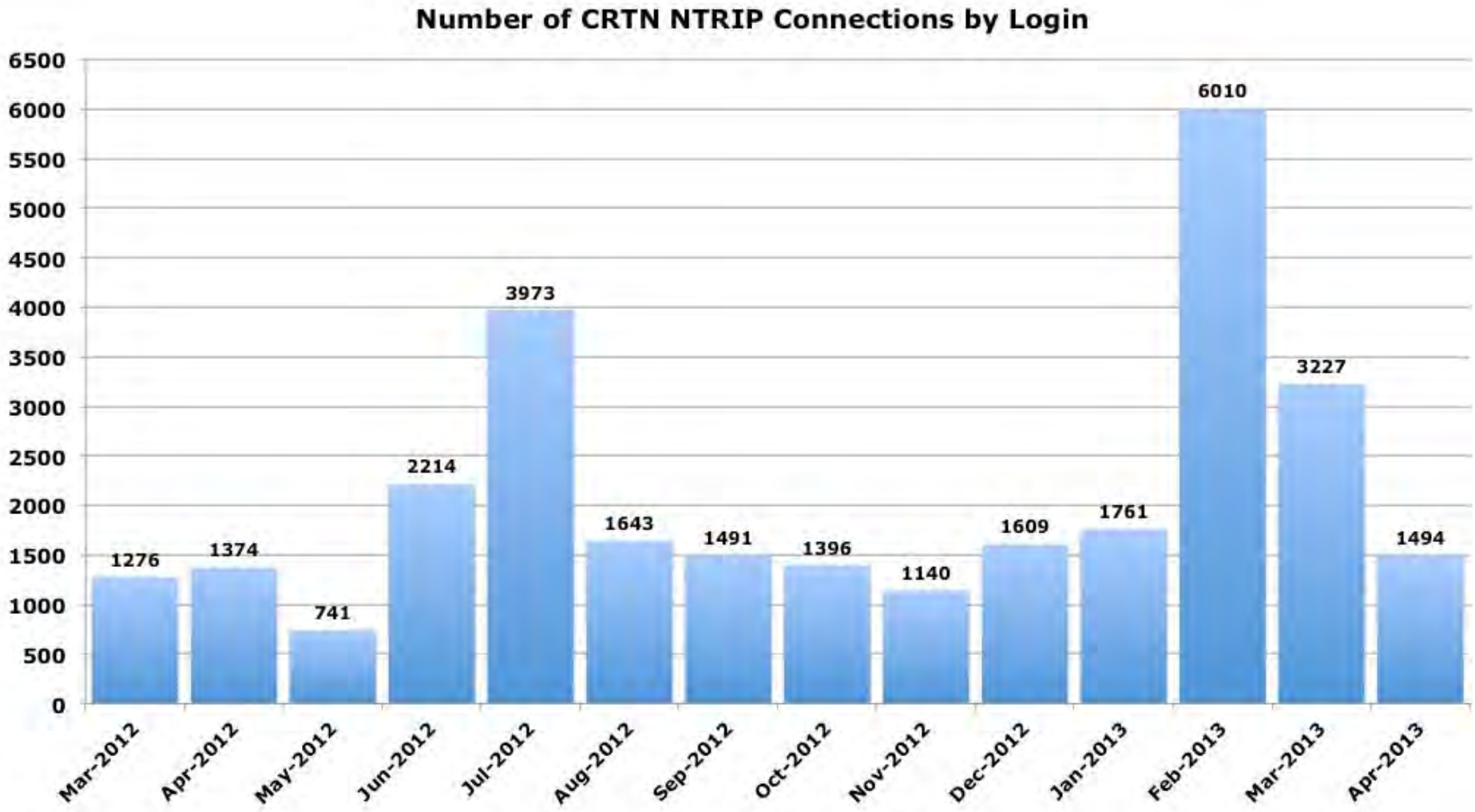
RTCM 3.0

Mountpoints: “SITE_ RTCM3”
SITE=4-character code

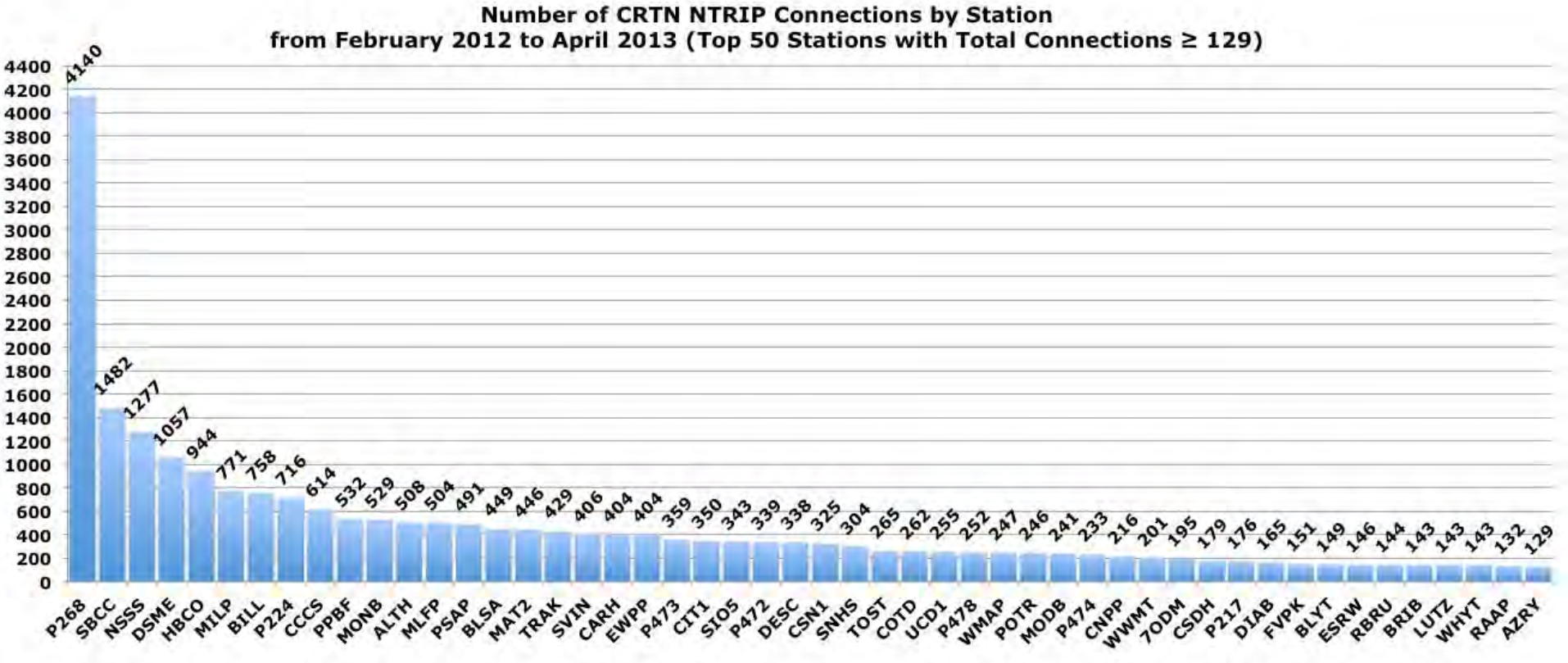
CSRC 2011.00 Epoch NAD83
(NSRS2007) Coordinates

Orange Circles:
16km (10 mile) Radius

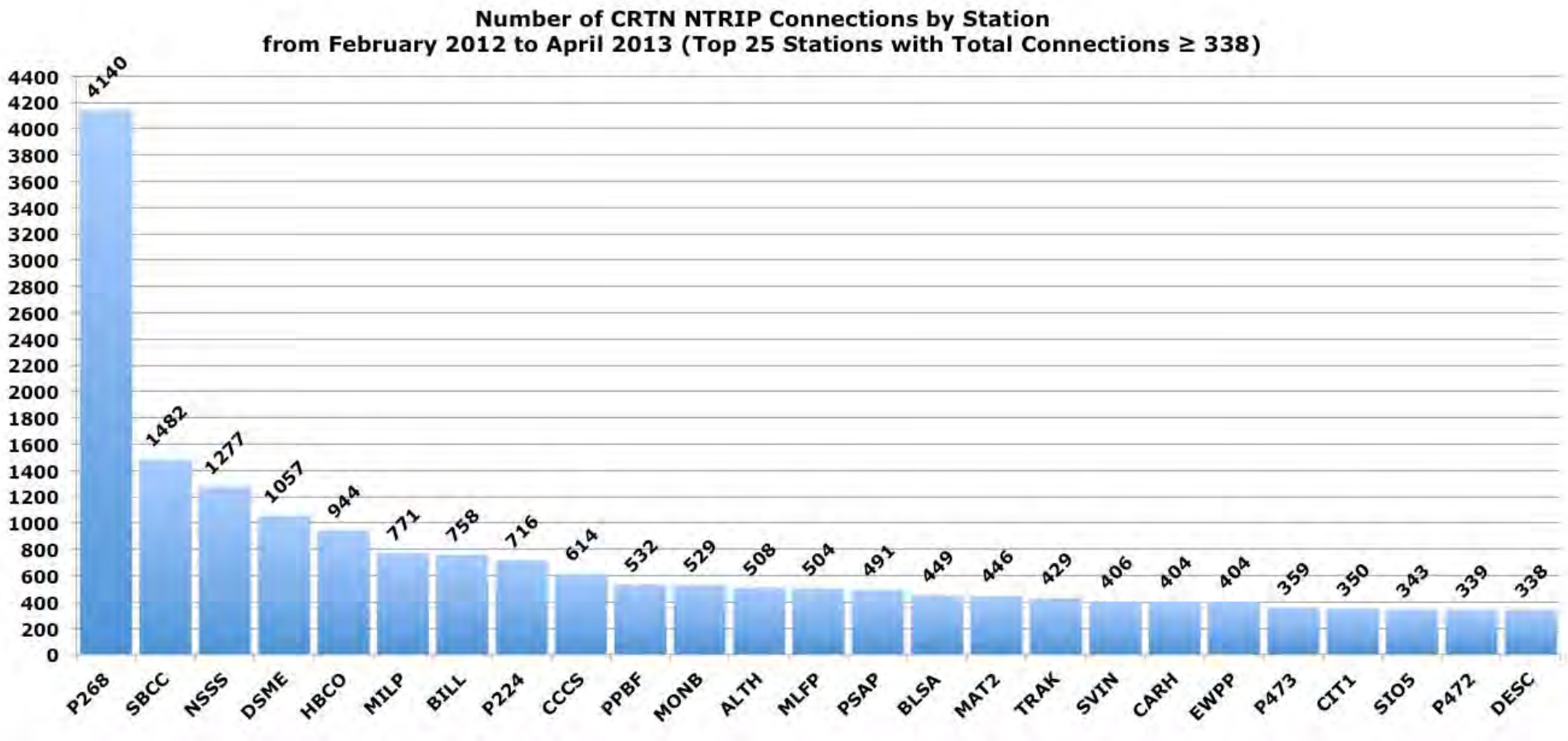
CRTN Metrics



CRTN Metrics



CRTN Metrics



CRTN – Single Base User

- March 1, 2012 – real-time data availability transitioned to NTRIP protocol
- An NTRIP account (username & password) is required, and requested by emailing the CSRC director (ybock@ucsd.edu)
- After CLSA workshops, 125 companies/agencies registered (up 25%) – 8 multi-account (CRTN Consortium) users
- CRTN Web Page: http://sopac.ucsd.edu/projects/realtime/CRTN/
- CRTN Access File:

http://sopac.ucsd.edu/input/realtime/CRTN_Access.xls

Precise Point Positioning Service for real-time clients developed by SOPAC

Predicted orbits from IGS

ITRF positions & metadata (SOPAC)

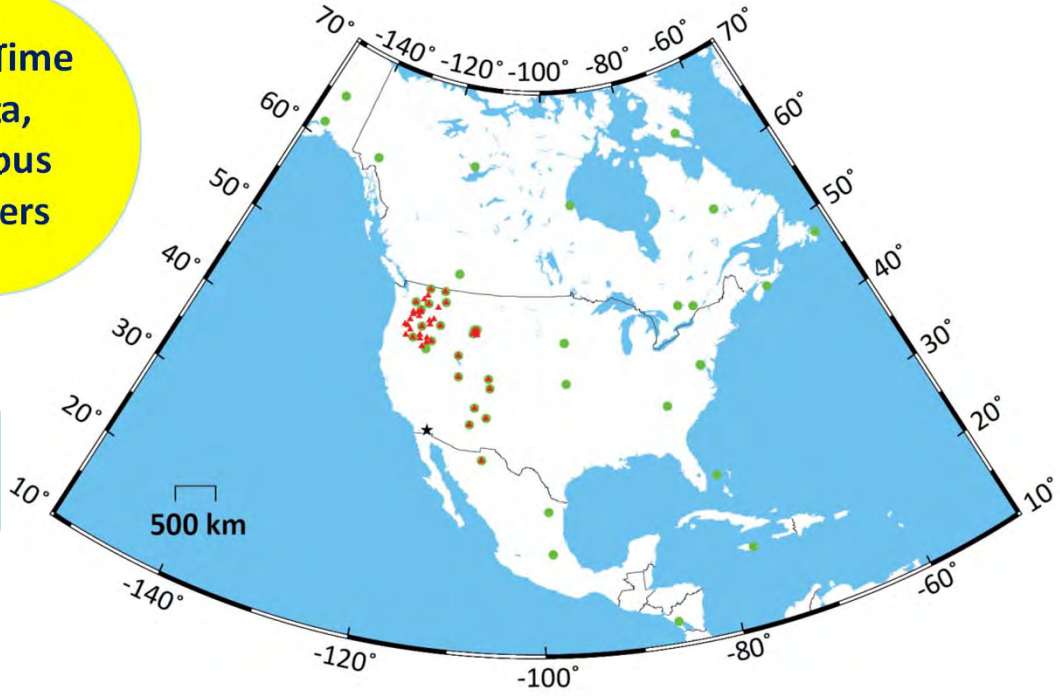
Real-Time Data, Various Servers

Generate Satellite Clocks

Generate Fractional-Cycle Biases

CRTN Server

Operational



Generate California-Based Troposphere and Ionosphere Model

RTCM 3

PPP client

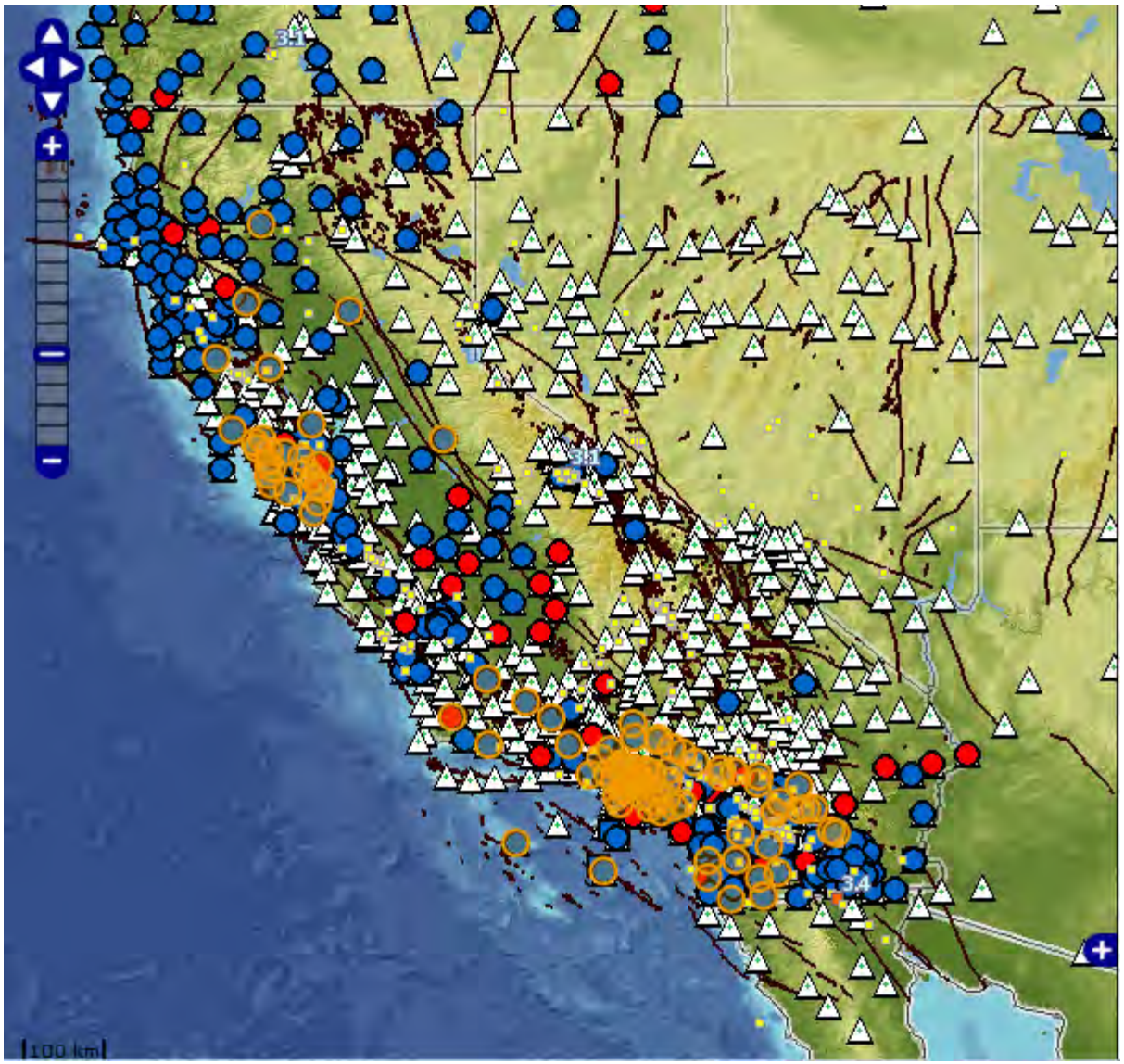
RTK User

Structural Monitoring

Other Users

75 stations used as reference stations which are located >200 km away from western US coast

Topcon GNSS Receivers



- **Topcon NET-G3A GNSS capable receivers at 96 CRTN stations**
- **Only 23 of these stream GLONASS data – all in southern California by CRTN Consortium members**
- **Hoping to extend capability to USGS and BARD Topcon receivers, in southern California, the greater SF Bay Area and northern California**

CRTN – Membership Options

- ***CRTN Consortium Membership Tiers:***

  - **Contributing Members:** donate $1,000 annually, which provides access to a ***second*** NTRIP account for real-time access to RTCM 3.0 data (all users have free access to a single account). Additional access increases by $1,000 per account. Please note that contributing members do not participate in oversight/management of the network.

  - **CRTN Consortium Members**: contribute $15,000 annually, which provides access to any 20 real-time CGPS sites 24/7. This membership has voting privileges on the CRTN Consortium, which oversees the development and management of the network.

  - **Statewide CRTN Consortium Members:** contributes $150,000 annually to fund CRTN and has access to all real-time CGPS sites 24/7. This membership has voting privileges but is limited to three voting members, and also includes being part of the team that will oversee the development and management of the network.

CRTN – Members

Current Consortium Members:

1. Scripps Institution of Oceanography, University of California San Diego, Yehuda Bock
2. City of Los Angeles, Tony Pratt
3. Riverside County Flood Control and Water Conservation District, Bill Hofferber with Jim McNeill and Gary Poor
4. Orange County, Art Andrew
5. San Diego County, Terry Connors
6. Riverside County Transportation Department, Ken Teich with Ed Hunt and Tim Rayburn
7. Santa Clara Valley Water District, Thomas Dougherty
8. City of Long Beach, Gas and Oil, Kimberley Holtz

Contributing Members:

1. East Bay Municipal Water District, Steve Martin
2. Rail Surveyors and Engineers Incorporated, Cody Festa
3. East Bay Regional Parks, Duncan Marshall

CRTN – Gifts

★ required

Your Gift Information

The California Real Time Network (CRTN) is a multipurpose statewide real-time network that utilizes the existing geophysical GPS infrastructure in California and provides the backbone for the geodetic control network that is outlined in the California Spatial Reference Center (CSRC) Master Plan. It provides accurate and reliable real-time positioning services that are consistent and on a common reference system, the California Spatial Reference System (CSRS), which fulfills the requirements of the California Public Resources Codes 8856(c)(e), 8857(c), and 8858(b) for GPS-derived geodetic coordinates and orthometric heights. CRTN offers multiple real-time data streams to CRTN Consortium Members as well as free open access to RTCM data streams for single-base RTK positioning with respect to the CSRS.

Your donation will be used towards operating and maintaining CRTN and our data services. You will receive a charitable donation receipt for your files. If you would like to become a CRTN Consortium Member or need additional information, please call or email Maria Turingan at (858) 822-2156 or mariaturingan@ucsd.edu.

When you submit personal information to us, we use a secure server and a secure server software (SSL) that encrypts all information you input. We keep information about you secure and confidential. However, if you would prefer to send your donation by mail, please write a check to "The Regents of the University of California," email Maria so we can be on the look out for it, and address it as follows: Attention: Maria Turingan; Dept. IGPP, SIO, UCSD; 9500 Gilman Drive #0225, La Jolla, CA 92093.

Thank you for your donation!

Projects at SOPAC/CSRC

- Developing prototype early warning system along the West coast
- Re-analyzing of all CGPS data since 1992 in ITRF2008
- Planning to publish new CSRS epoch-date coordinates tied to NGS National Adjustment of 2011 (NA2011), NAD 83(2011) epoch 2010.00 – can be provided for multiple reference epochs
- Planning to implement statewide “network solution” for CRTN users, based on precise point positioning (PPP) architecture developed at SOPAC and troposphere and ionosphere models, accessible through NTRIP servers and existing field equipment
- Planning to modernize websites (CSRC, SOPAC, CRTN)

Relevant Websites

Scripps Orbit and Permanent Array Center (SOPAC):
http://sopac.ucsd.edu

California Spatial Reference Center (CSRC):
http://csrc.ucsd.edu

GPS Explorer (create free user account):
http://geoapp.ucsd.edu

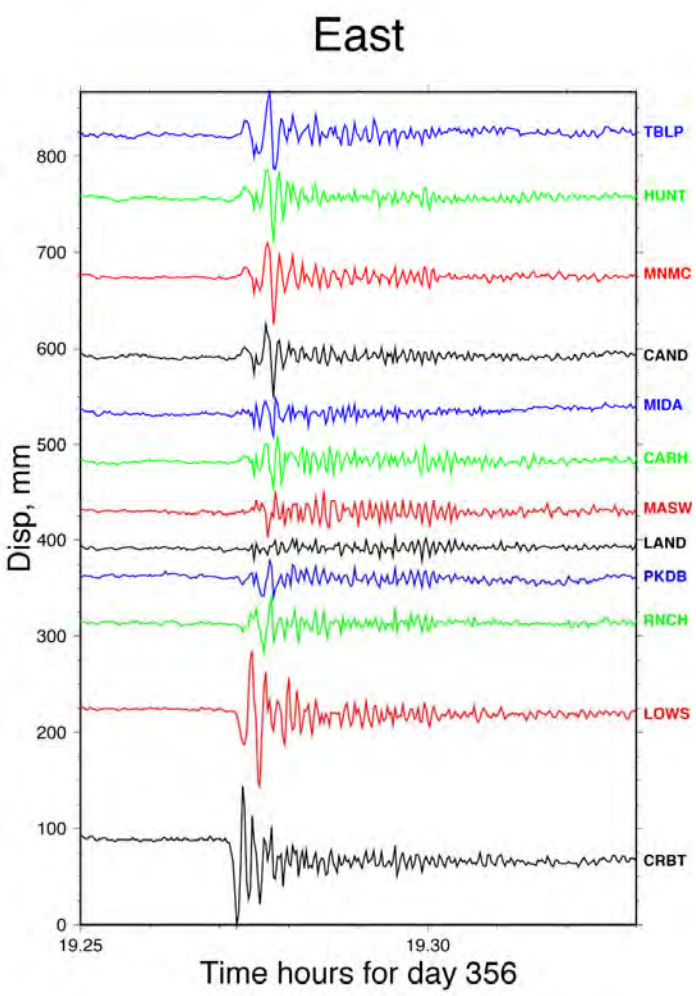
California Real Time Network (CRTN):
http://sopac.ucsd.edu/projects/realtime/CRTN

Real-time Earthquake Analysis for Disaster Mitigation Network (READI):
http://sopac.ucsd.edu/projects/realtime/READI

CRTN as a Test Bed for Early Warning Systems for Natural Hazards

- **GPS seismology**
- **Tsunami warning**
- **Severe storm and flooding forecasts**
- **Structural monitoring**
- **Volcano monitoring**

LA freeway after 1994 Northridge earthquake



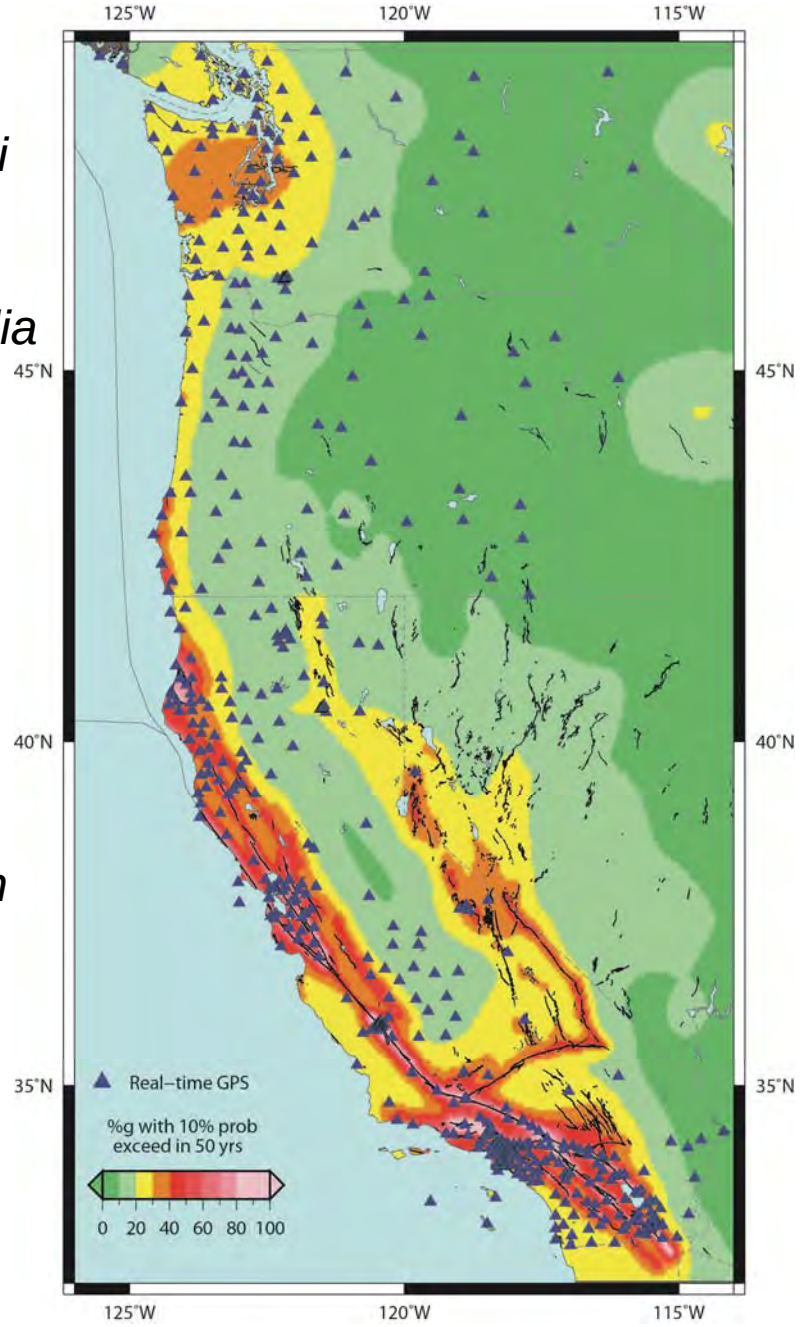
Displacement waveforms, 2004 Parkfield event

Earthquake Hazards for the West Coast

Earthquake/tsunami of the magnitude of Tohoku-oki is possible on Cascadia Subduction Zone

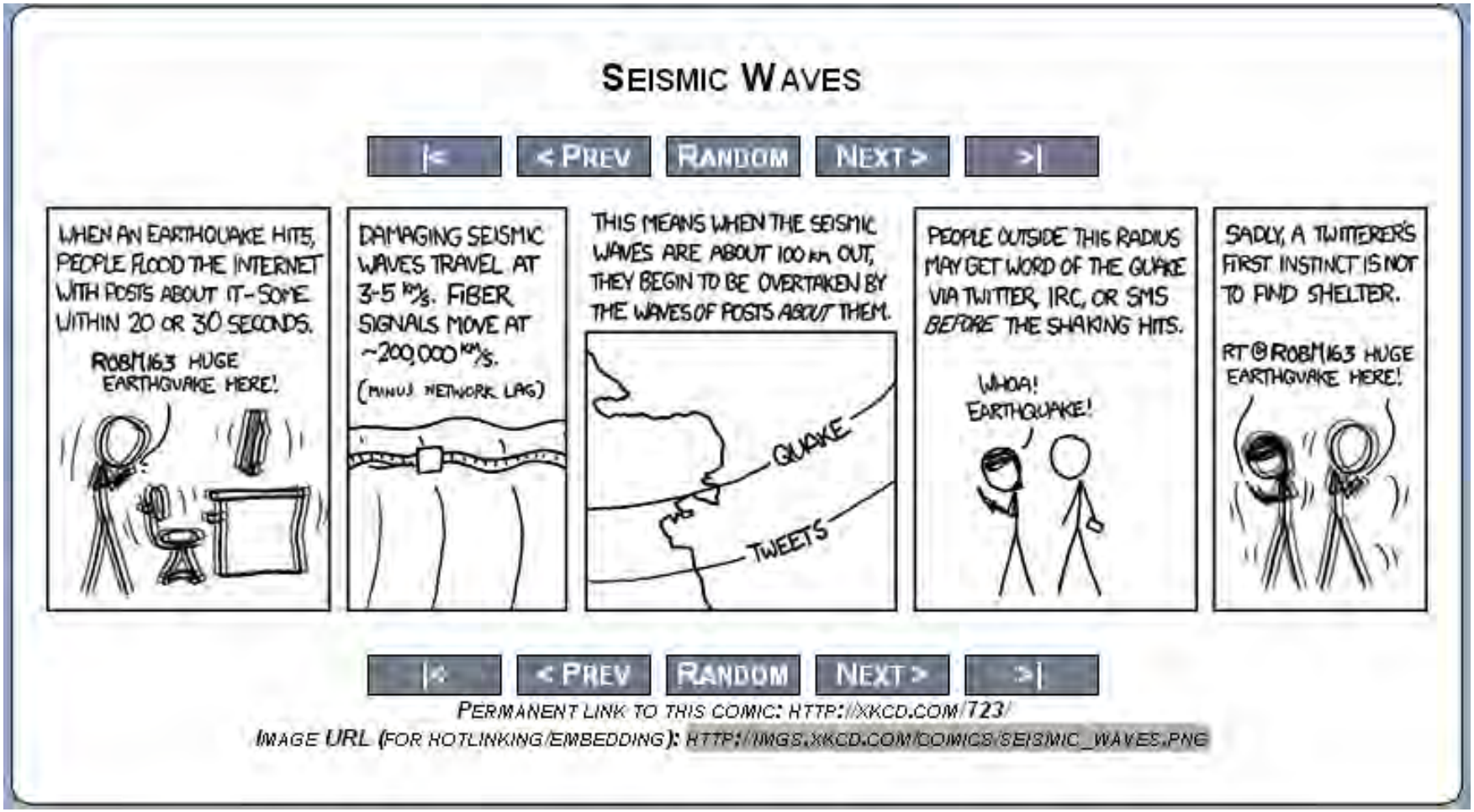
Increasing risk of large earthquake on the Hayward fault

Overdue large earthquake on the southern San Andreas fault



500+ stations of the real-time continuous GPS stations comprising the READI network (including CRTN). The network stations are overlain on a USGS seismic hazard map showing areas forecast to have a 10-percent probability of exceeding a certain level of ground shaking within the next 50 years. Areas in shades of red have the strongest shaking, while areas in green shades have the weakest shaking.

Popular Description of Earthquake Early Warning



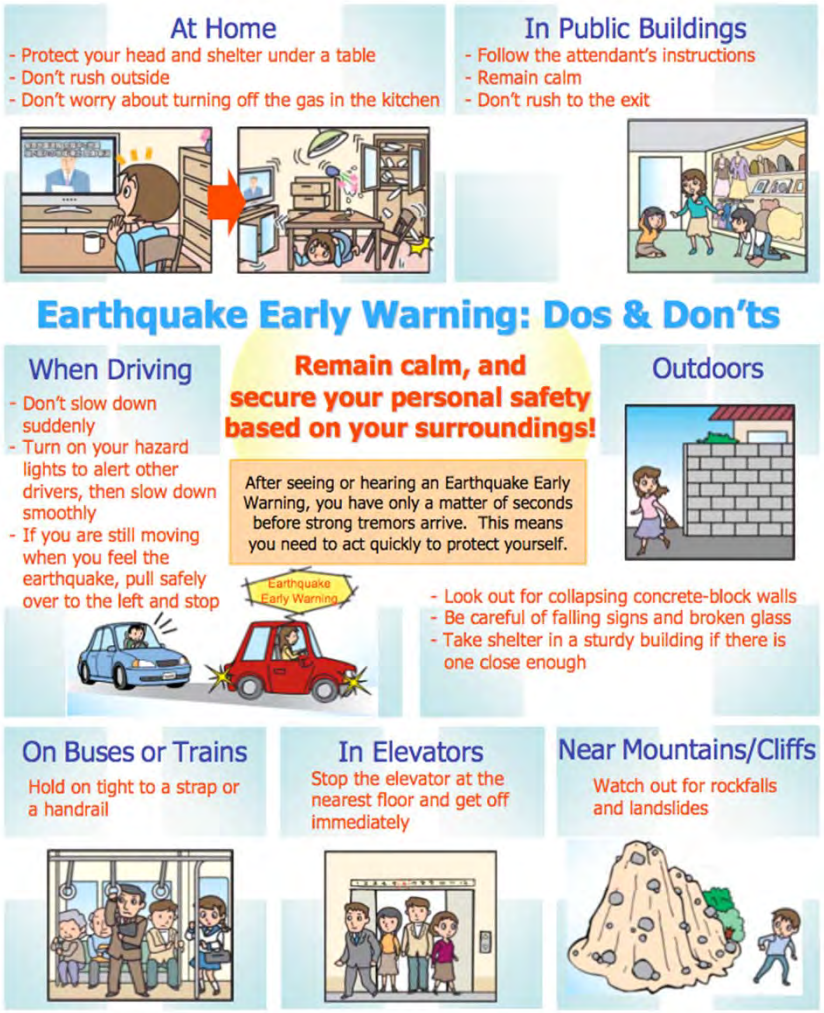
Radio waves are faster than seismic waves

P (primary) wave carries information - compressional

S (secondary) wave carries energy – shearing, shaking

(Hiroo Kanamori)

Uses of Earthquake Early Warning



Public service guidelines for earthquake early warning in Japan

Some targets of early warning:

- emergency service providers
- transportation (public & private)
- power plants – **nuclear**
- gas supplies
- factories
- schools
- hospitals
- shopping malls
- police
- structures (dams, bridges)
- public (see graphic to the left)

Of course, this requires interfacing properly with first responders and development of automatic procedures and rapid response guidelines.

The New York Times

Europe

WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SI

AFRICA | AMERICAS | ASIA PACIFIC | EUROPE | MIDDLE EAST

Italy Orders Jail Terms for 7 Who Didn't Warn of Deadly Earthquake

Alessandro Bianchi/Reuters

L'Aquila on April 6, 2009, when a quake struck, killing 309 people.

By ELISABETTA POVOLEDO and HENRY FOUNTAIN
Published: October 22, 2012

Perils of Earthquake Forecasting & Earthquake Early Warning

New Observations

GPS/GNSS

+

MEMS Accelerometer Module

=

Very-high-rate (1-100 Hz) broadband <u>displacements</u> with 1-2 s latency and mm accuracy in three dimensions

+

MEMS Met Sensors (pressure, temperature)

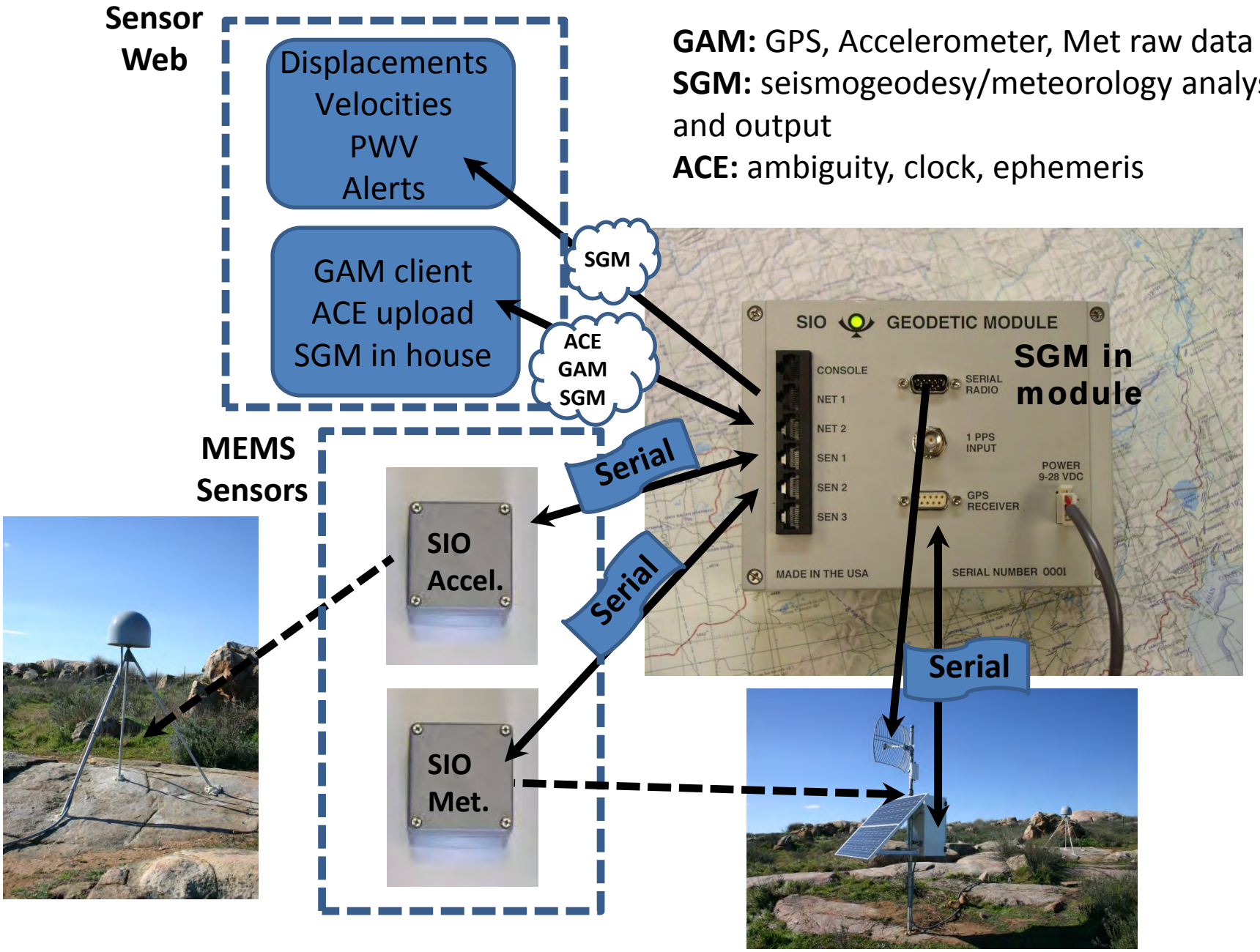
=

Continuous mm-level <u>precipitable water</u>

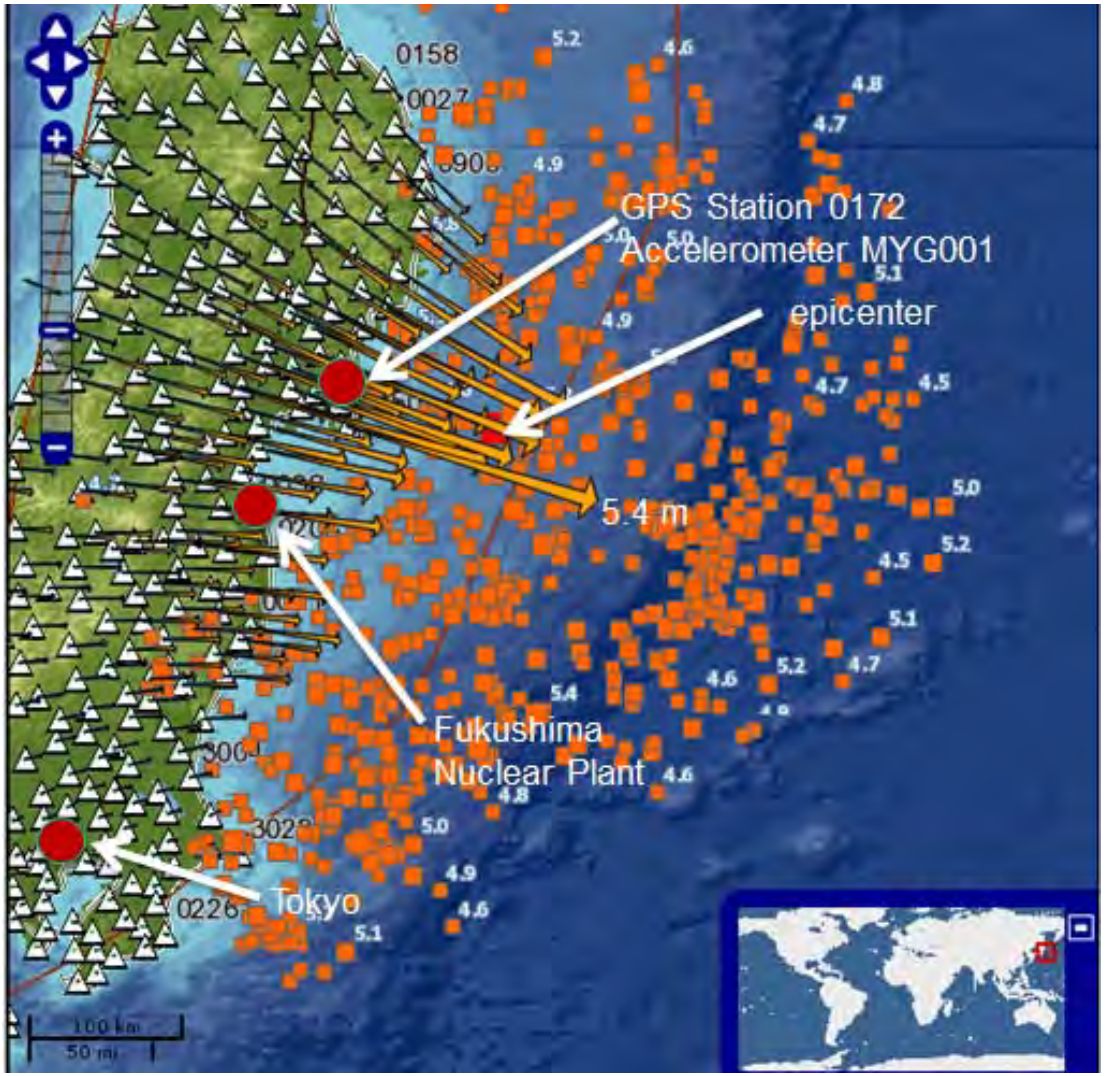
(integrated water vapor in troposphere)

Upgrades to CRTN Stations

GAM: GPS, Accelerometer, Met raw data
SGM: seismogeodesy/meteorology analysis and output
ACE: ambiguity, clock, ephemeris



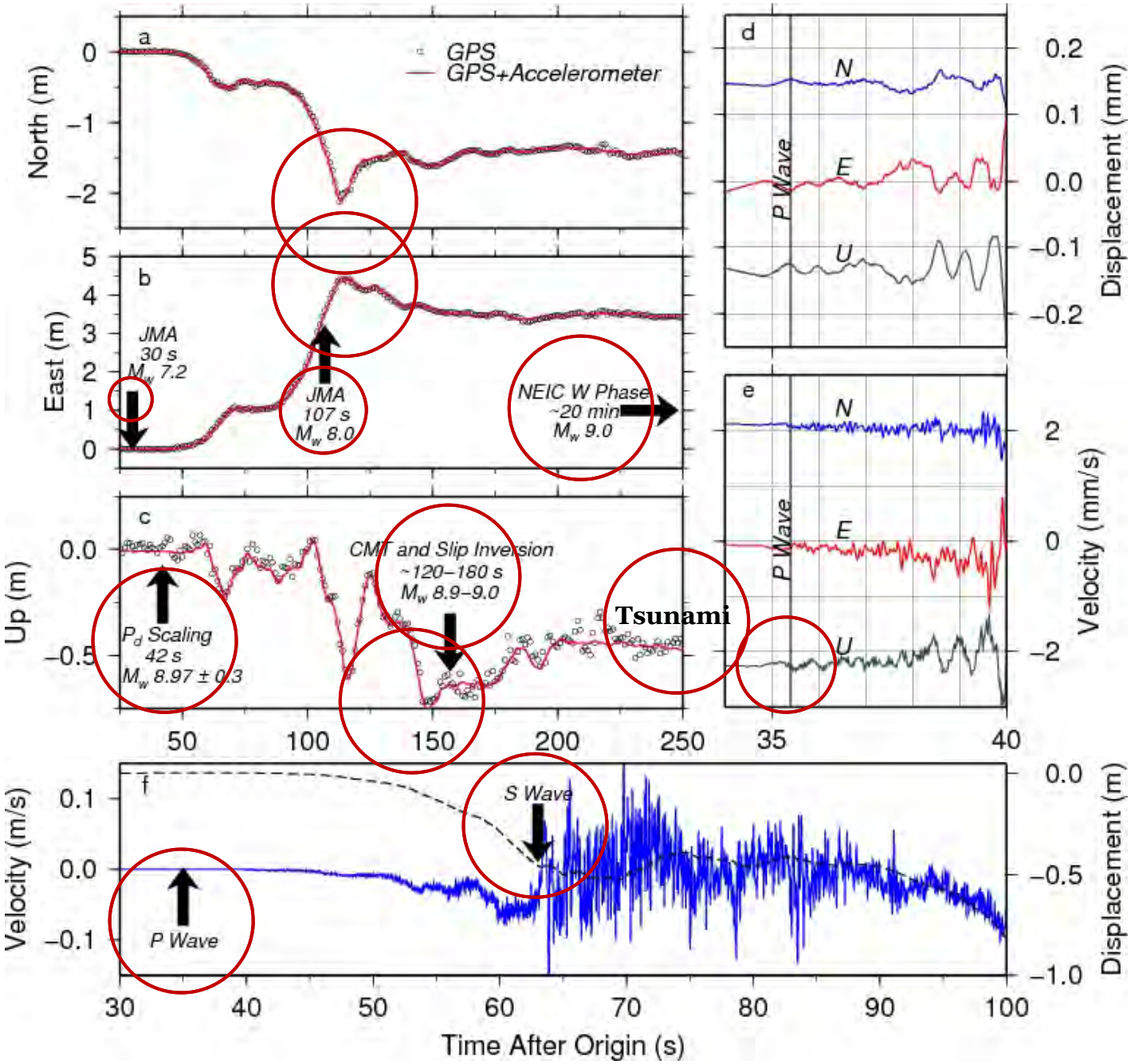
Fusion of GPS and Seismic Data: Motivation



Coseismic displacements for 2011 Mw 9.0 Tohoku-oki earthquake computed from Japan's 1200+ station CGPS Network (GEONET) by ARIA group at Caltech/JPL (Susan Owen, PI). Maximum surface displacement on land was 5.24 meters at station 0550 on coast about 100 km from epicenter

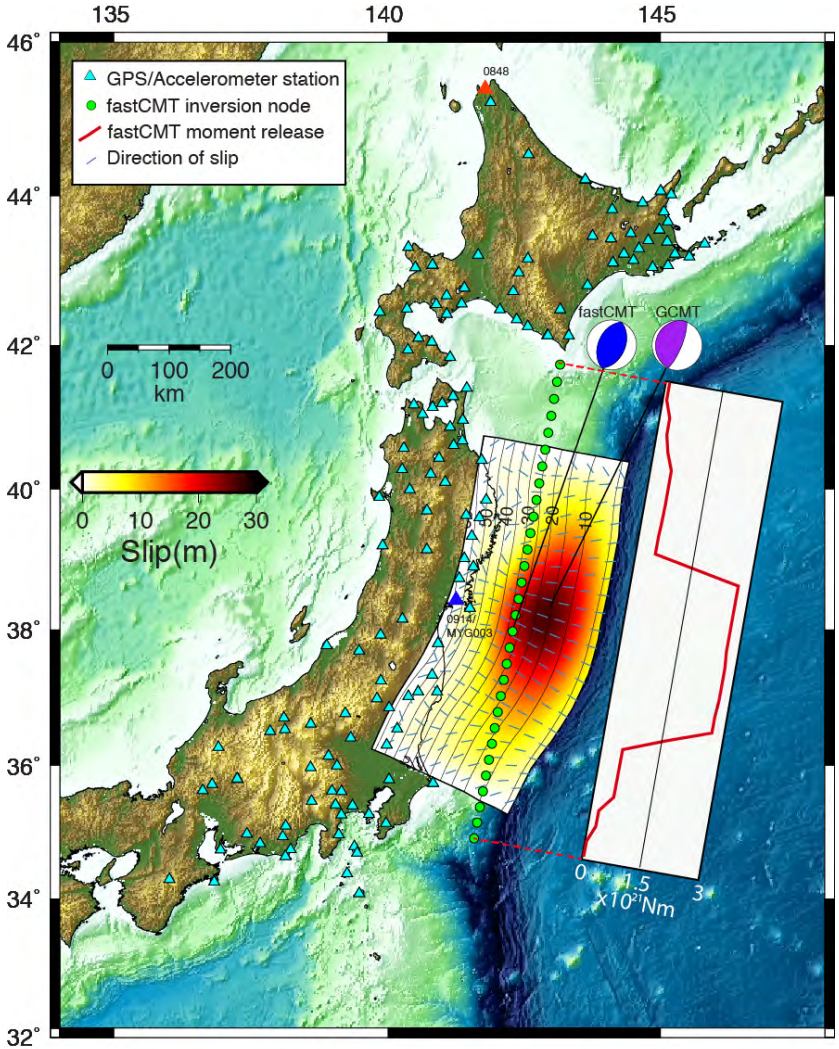
Identified 142 "collocated" NIED stations with triggered 100 Hz KiK-net and K-Net accelerometer data (e.g., 0914/*MYG003*) and estimated 100 Hz displacements and velocities using a Kalman filter

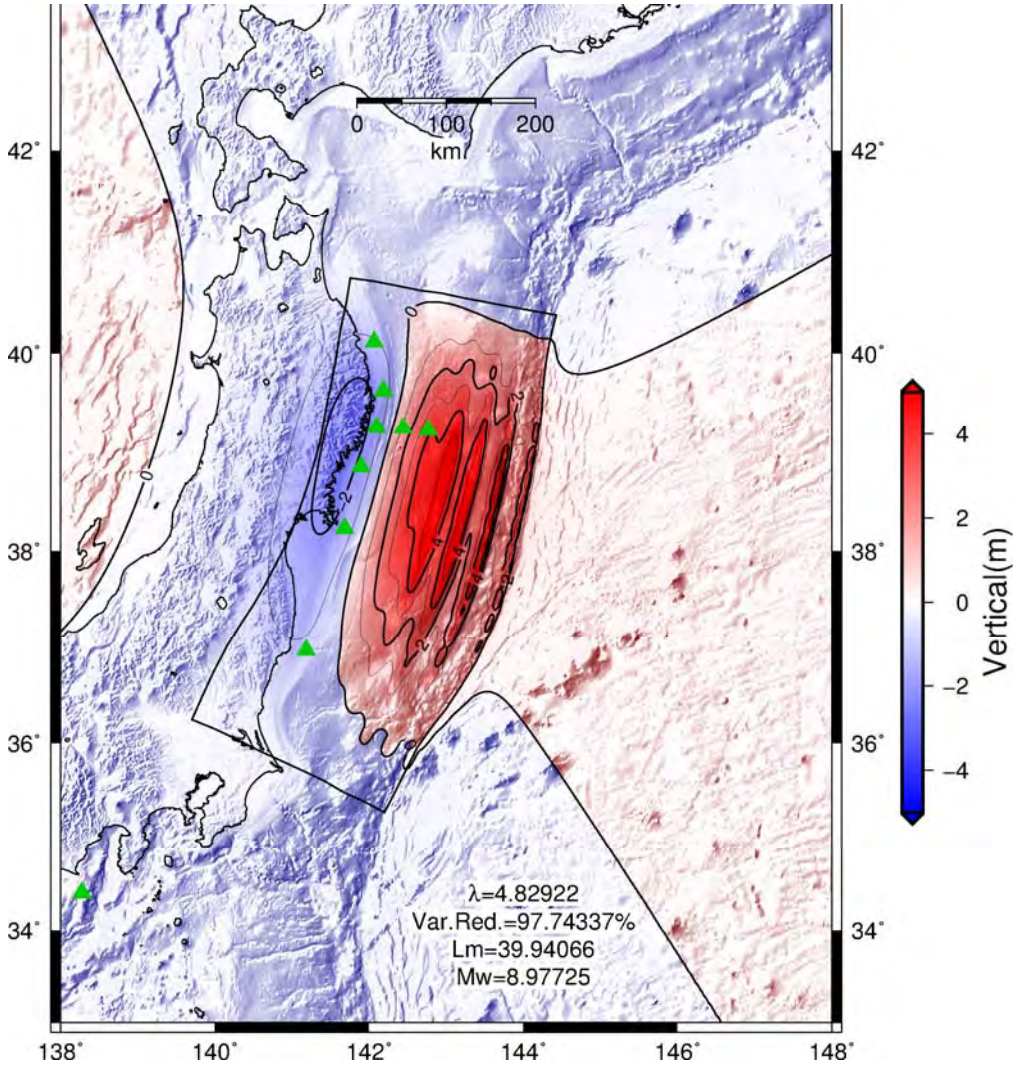
Fusion of GPS & Seismic Data: 2011 Mw 9.0 Tohoku-oki event



Source:
Melgar et al.,
GRL, 2013

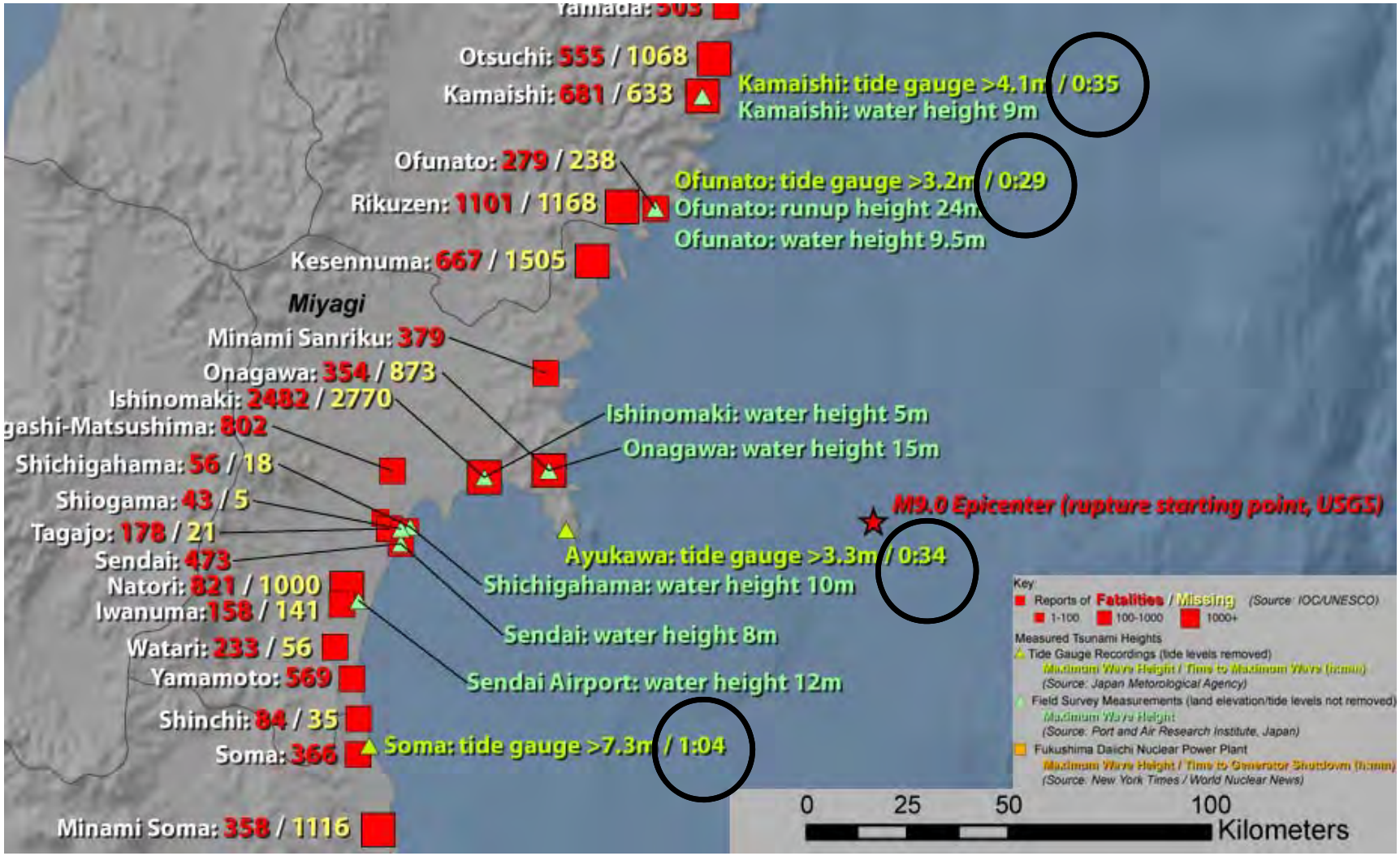
Finite source analysis in simulated real-time mode
2011 Tohoku-oki Mw 9.0 earthquake





Melgar et al., in prep

Tsunami travel times: 2011 Mw 9.0 Tohoku-oki earthquake



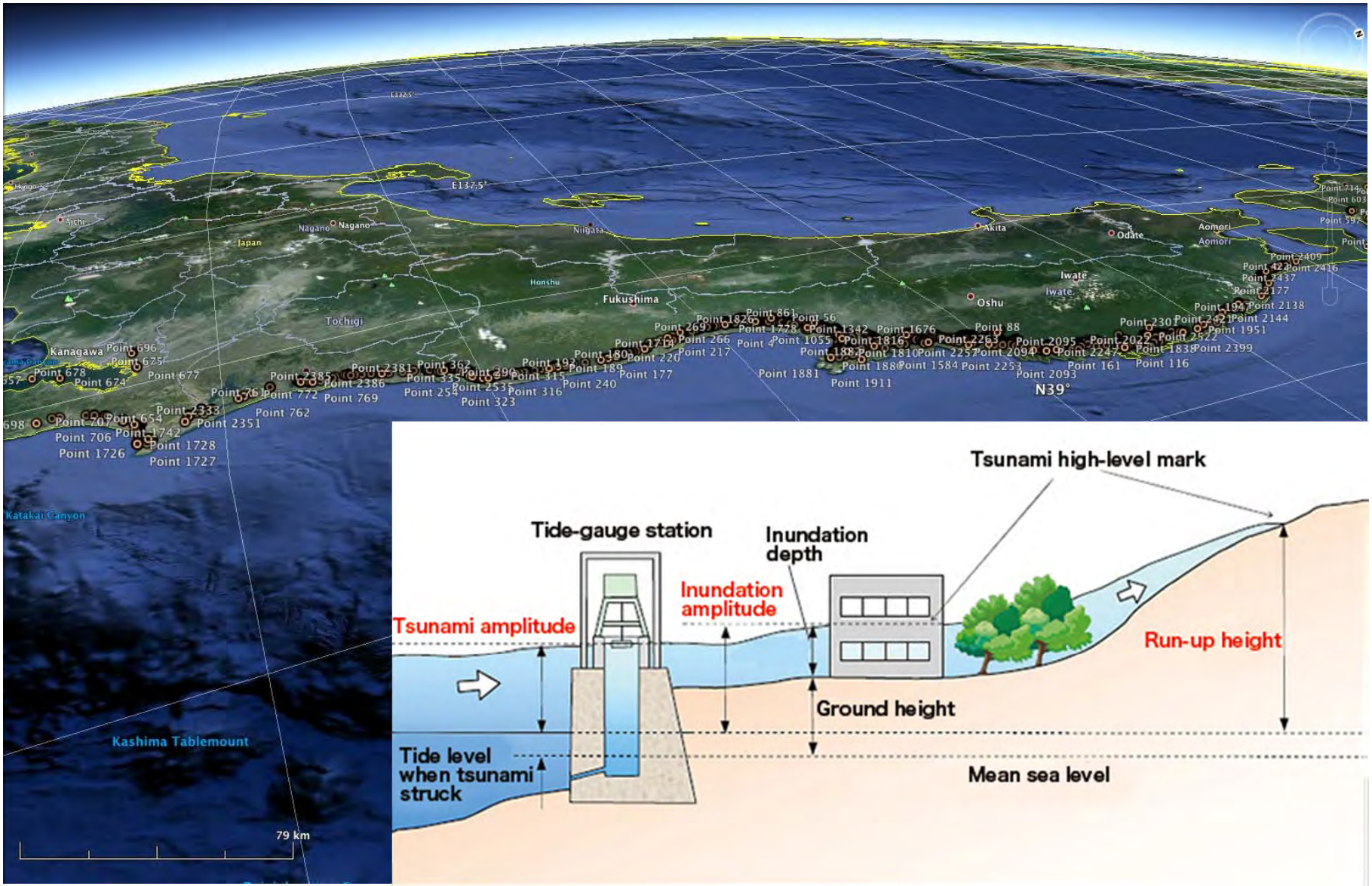
Rapid high-order modeling of large subduction zone earthquakes is critical for accurate tsunami warnings

Tsunami Warning System

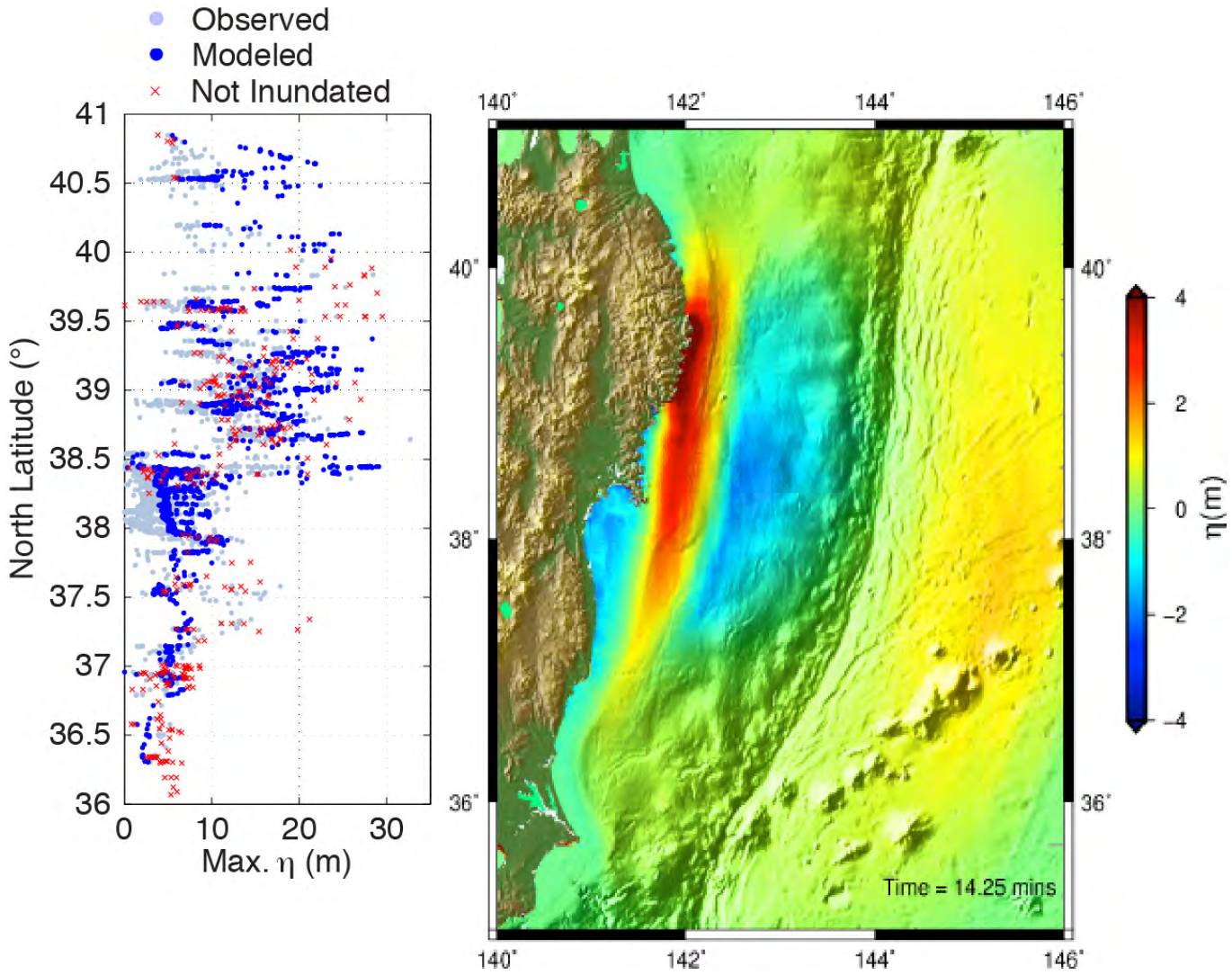
Model of 2011 Tsunami in Honshu: Movie

Click on photo to start tsunami model movie

Validating tsunami model

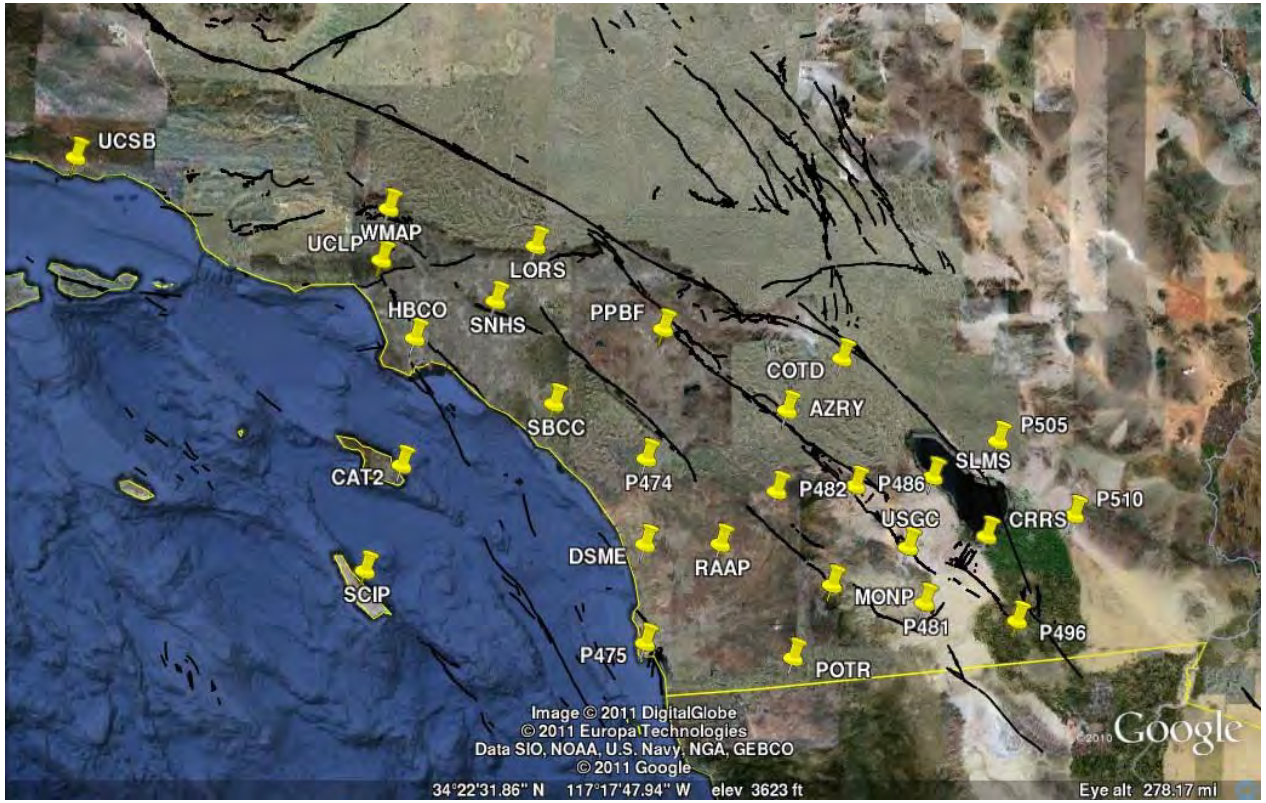


Comparison with post-event survey: 2011 Mw 9.0 Tohoku-oki Earthquake



Compared to 2000+ quality A and B inundation measurements collected in post-event survey by Mori et al. (2012)

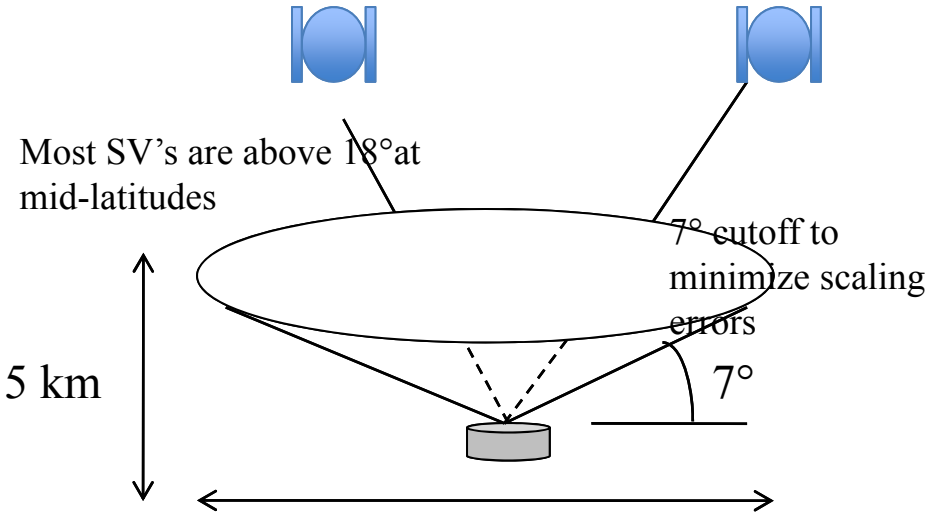
GPS Meteorology Network



Adding Geodetic Modules and MEMS meteorological packages to existing GPS stations

Monitoring network in collaboration with NOAA and U.S. Weather Service Offices in San Diego and Los Angeles (Oxnard), funded by NASA (4-year project)

GPS Meteorology - Theory



Estimating Precipitable Water from ground GPS networks

$$\Delta t_{total} = \Delta t_{geom} + \Delta t_{iono} + \Delta t_{trop} + \ldots$$

In solving for this — we estimate this

$$PW = \kappa \times ZWD$$

$$1/\kappa = 10^{-6} \times \rho R_v[(k_3/T_m) + k_2'] \approx 6.5$$

Mean atmospheric temperature

Zenith hydrostatic delay = f(surface pressure)

Zenith wet delay

$$TD(\theta) = ZHD \bullet mh(\theta) + ZWD \bullet mw(\theta)$$

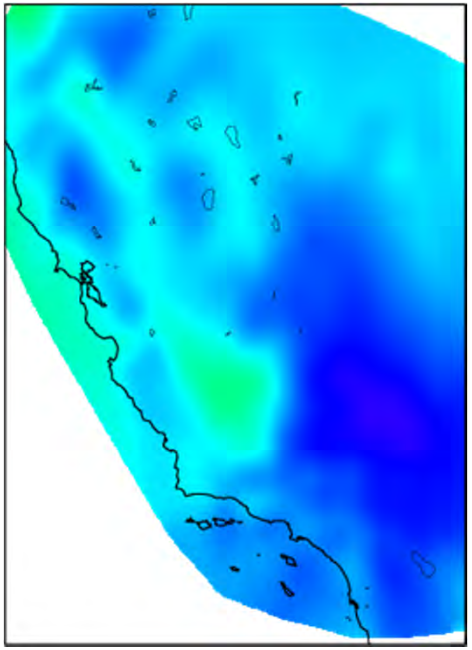
Total trop delay

Mapping functions

➔With surface pressure and a surface temperature, we derive PWV from zenith troposphere delay

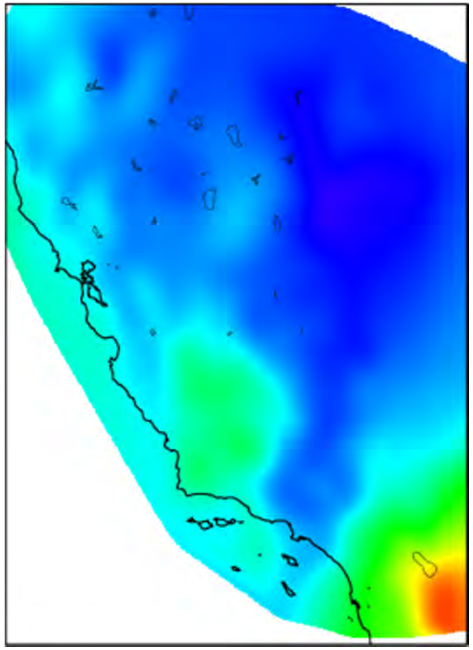
Fusion of GPS and meteorological data: Motivation – North America Monsoon

Pre-monsoon



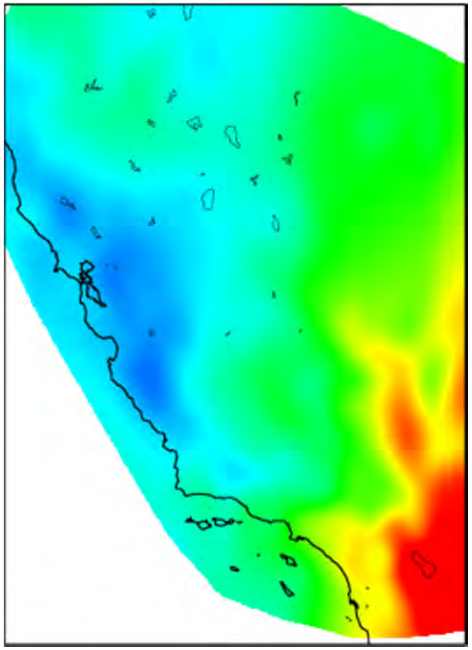
July 13, 2007 06:00 UTC

Monsoon onset



July 14, 2007 00:00 UTC

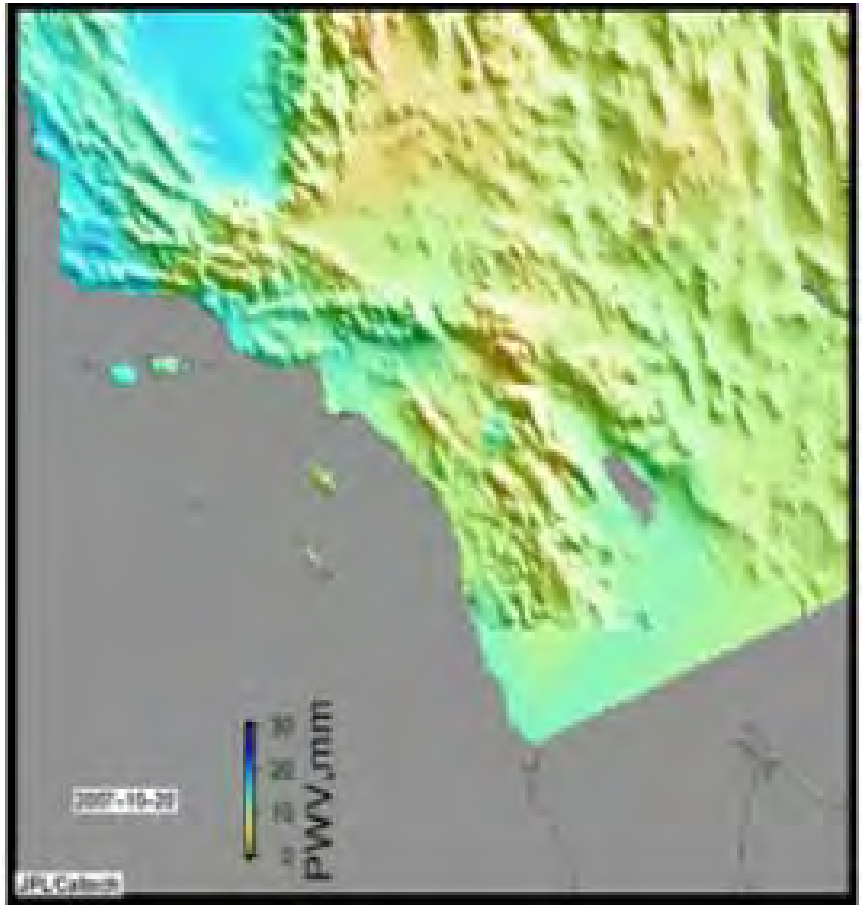
Peak monsoon



August 1, 2007 21:00 UTC

GPS-determined precipitable water vapor (PWV) has been shown to detect potentially dangerous weather conditions. Example: thunderstorm activity during the North American Monsoon.
Slide credit: Jim Means/UCSD

Fusion of GPS and meteorological data: Motivation – Santa Ana conditions (movie)



Click on graphic to start movie

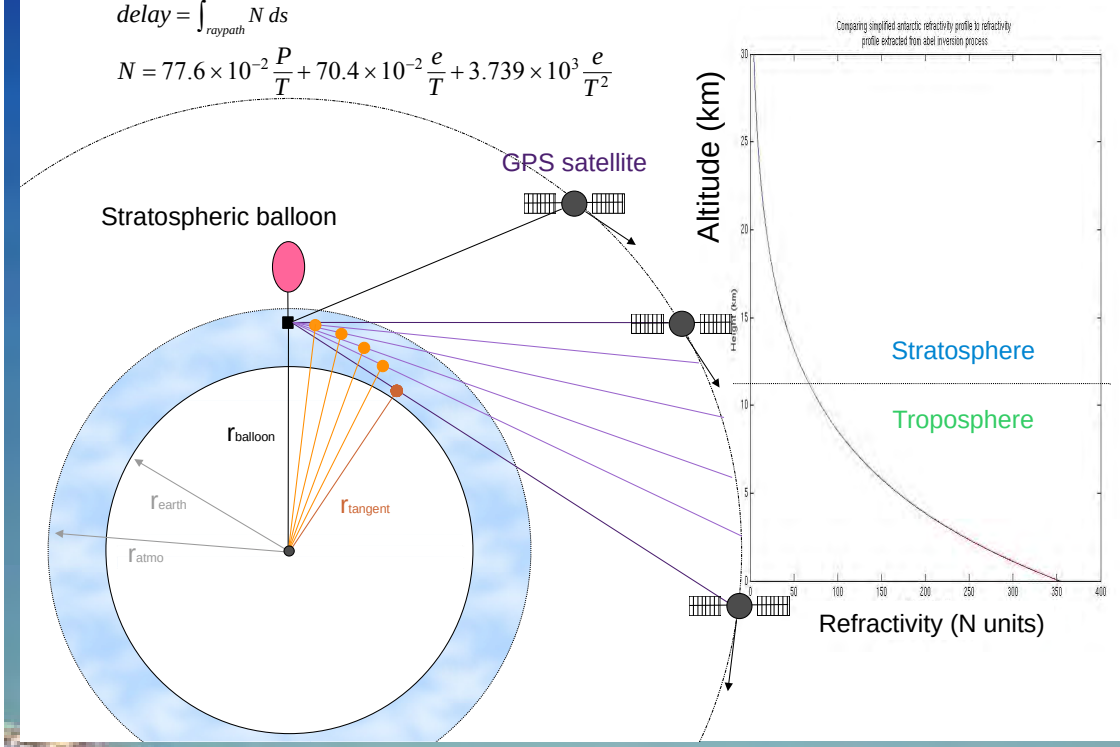
GPS-determined precipitable water vapor (PWV) has been shown to detect potentially dangerous weather conditions. Example: PWV during Oct 2007 Santa Ana, which contributed to wildfires burning more than 400,000 acres, computed by postprocessing southern California GPS data.
Slide credit: Angelyn Moore (JPL)

Studying Antarctic Climate with GPS Radio Occultat

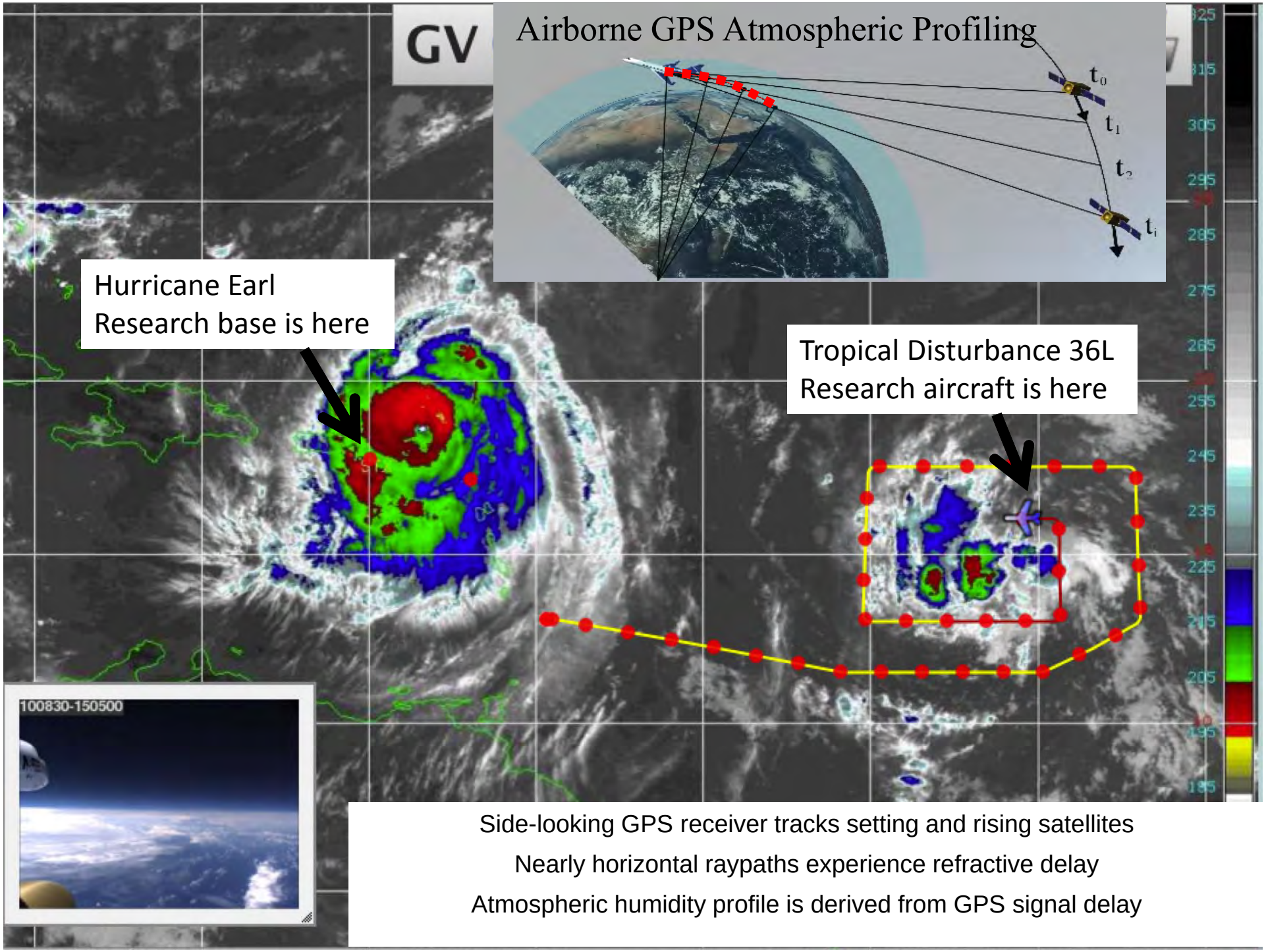
As a GPS satellite sets the amount of water vapor, *e*, present in the atmosphere is found from delays in the received signal

$$delay = \int_{raypath} N\, ds$$

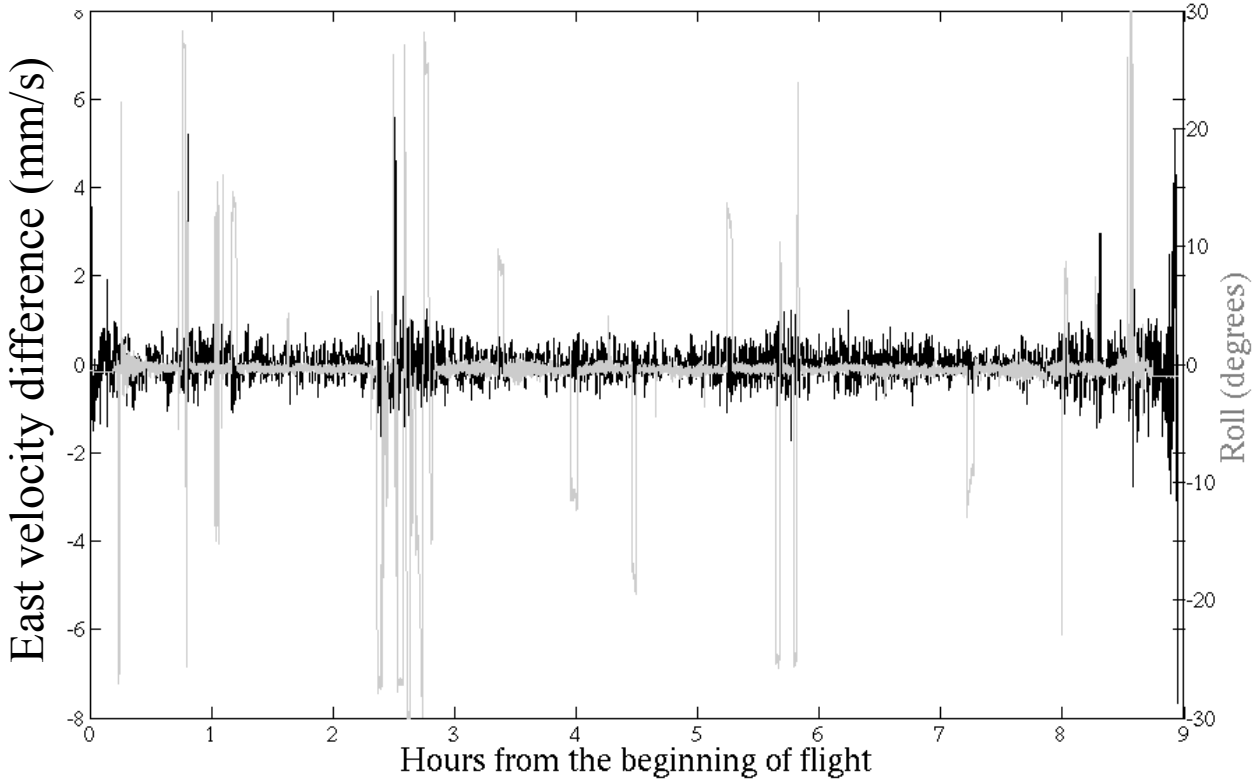
$$N = 77.6 \times 10^{-2} \frac{P}{T} + 70.4 \times 10^{-2} \frac{e}{T} + 3.739 \times 10^{3} \frac{e}{T^2}$$



In collaboration with CNES –French Space Agen


GV
Airborne GPS Atmospheric Profiling
t_0
t_1
t_2
t_i
Hurricane Earl
Research base is here
Tropical Disturbance 36L
Research aircraft is here
100830-150500
Side-looking GPS receiver tracks setting and rising satellites
Nearly horizontal raypaths experience refractive delay
Atmospheric humidity profile is derived from GPS signal delay

Aircraft Navigation Precision



New research pushes the limits of new technology
Continually improving accuracy of GPS solutions
Keeps SOPAC at the leading edge of geodetic research

Structural Monitoring

Measurements of shaking and displacement provide:

- Immediate assessment of post-earthquake structural condition
- Significant reduction of false alarms and improved detection of real events
- Long-term assessment of structural conditions

Shaketable test of M7.9 Denali EQ ground motions

Bridge and Dam Monitoring

Vincent Thomas Bridge, Long Beach, CA – in progress for Caltrans (2013)

Diamond Valley Lake, Metropolitan Water District, Hemet CA (since 2001)

- 3 – 25 sensors installed on structure
- Data relayed in real time by radio or optical cable
- Processing center runs control and monitoring software products
- Sensitive to wind modes, traffic loads, diurnal changes at sub-centimeter level

Photos: Scripps Oceanography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Questions?