Director’s Report

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

CSRC Coordinating Council Fall Meeting
La Jolla, CA
October 24, 2013
SOPAC/CSRC Group

- 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 Students: Diego Melgar, Dara Goldberg, Jessie Saunders
- Postdoctoral Researchers: Jianghui Geng & Yuval Reuveni
- Consultant: John Canas, PLS
CSRC Executive Committee

- **Chairperson**: Rich Maher
- **Vice-Chairperson**: Scott Martin
- **Secretary**: Thomas Dougherty
- **Treasurer**: Bill Hofferber
- **Member**: Armand Marios
- **Member**: Brian Wiseman
- **Member**: Greg Helmer
- **Member**: Dave Olander
- **Past Chairperson**: Art Andrew
CGPS Data & Metadata

- RINEX files archived at SOPAC from over **2500** stations in Western NA, including PBO, SCIGN, BARD, WCDA and PANGA stations, other plate boundaries & globally

- Earliest CGPS data are from 1991

- Use a common source of metadata to reduce systematic errors – challenge to keep current

- RINEX data processed independently at JPL (GIPSY software) and SOPAC (GAMIT software)

- Combination daily position time series is produced & updated weekly
MAT2 Time Series (North, East, Up)

**MAT2 North Slope (mm/yr)**
- RMS: 0.6 mm

**MAT2 East Slope (mm/yr)**
- RMS: 0.8 mm

**MAT2 Up Slope (mm/yr)**
- RMS: 2.6 mm
## Significant Earthquakes in Western North America (1996-2013)

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Magnitude</th>
<th>Depth (km)</th>
<th>Type</th>
<th>Distance (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/16/1999</td>
<td>Hector Mine, Southern California</td>
<td>7.1</td>
<td>142</td>
<td>exp</td>
<td>OPRD: 6 km, LAND: 408 km</td>
</tr>
<tr>
<td>2/29/2001</td>
<td>Nisqually Fault, Seattle</td>
<td>6.8</td>
<td>4</td>
<td>exp</td>
<td>RPT1: 30 km, HUSB: 340 km</td>
</tr>
<tr>
<td>11/3/2002</td>
<td>Denali, Alaska</td>
<td>7.9</td>
<td>12</td>
<td>exp</td>
<td>GNAA: 136 km, KEN1: 441 km</td>
</tr>
<tr>
<td>12/22/2003</td>
<td>Cambria, San Simeon, Central California</td>
<td>6.5</td>
<td>23</td>
<td>log</td>
<td>P278: 4 km, ORES: 131 km</td>
</tr>
<tr>
<td>6/28/2004</td>
<td>Queen Charlotte Fault</td>
<td>6.8</td>
<td>4</td>
<td>exp</td>
<td>AC64: 1023 km, AC63: 1139 km</td>
</tr>
<tr>
<td>9/28/2004</td>
<td>Parkfield, Central California</td>
<td>6.0</td>
<td>28</td>
<td>log</td>
<td>P281: 4 km, CUHS: 115 km</td>
</tr>
<tr>
<td>6/12/2005</td>
<td>Anza, Southern California</td>
<td>5.2</td>
<td>0</td>
<td></td>
<td>AZRY: 8 km</td>
</tr>
<tr>
<td>6/15/2005</td>
<td>Gorda Plate, CA</td>
<td>7.2</td>
<td>5</td>
<td>exp</td>
<td>CME1: 188 km, P170: 216 km</td>
</tr>
<tr>
<td>6/16/2005</td>
<td>Yucaipa, Southern California</td>
<td>4.9</td>
<td>0</td>
<td>exp</td>
<td>CRFP: 15 km</td>
</tr>
<tr>
<td>9/2/2005</td>
<td>Obsidian Buttes Swarm, Salton Trough</td>
<td>5.1</td>
<td>3</td>
<td>exp</td>
<td>GLRS: 5 km, DHLG: 31 km</td>
</tr>
<tr>
<td>10/3/2006</td>
<td>Superstition Hill Seismic Swarm - silent slip</td>
<td>4.7</td>
<td>0</td>
<td></td>
<td>CRRS: 16 km</td>
</tr>
<tr>
<td>10/31/2007</td>
<td>Alum Rock, San Jose, California</td>
<td>5.6</td>
<td>1</td>
<td>none</td>
<td>MHCB: 7 km</td>
</tr>
<tr>
<td>7/29/2008</td>
<td>Chino Hills, California</td>
<td>5.5</td>
<td>1</td>
<td>none</td>
<td>TWMS: 4 km</td>
</tr>
<tr>
<td>1/10/2010</td>
<td>Eureka Earthquake, Offshore Northern Califor</td>
<td>6.5</td>
<td>11</td>
<td>exp</td>
<td>P159: 45 km, P156: 95 km</td>
</tr>
<tr>
<td>2/4/2010</td>
<td>Offshore Northern California, Humboldt Coun</td>
<td>5.9</td>
<td>0</td>
<td></td>
<td>P159: 60 km</td>
</tr>
<tr>
<td>4/4/2010</td>
<td>El Mayor-Cucapah, Northern Baja California</td>
<td>7.2</td>
<td>208</td>
<td>exp</td>
<td>P500: 62 km, P567: 485 km</td>
</tr>
<tr>
<td>6/15/2010</td>
<td>Aftershock, El Mayor-Cucapah</td>
<td>5.7</td>
<td>7</td>
<td>exp</td>
<td>P481: 16 km, P496: 31 km</td>
</tr>
<tr>
<td>7/7/2010</td>
<td>Borrego Springs, Southern California</td>
<td>5.4</td>
<td>3</td>
<td>exp</td>
<td>P490: 13 km, P742, P484: 14 km</td>
</tr>
<tr>
<td>8/26/2012</td>
<td>Brawley Swarm, Imperial Valley</td>
<td>5.3, 5.4</td>
<td>2</td>
<td>none</td>
<td>P506: 8 km, P498, P499</td>
</tr>
</tbody>
</table>
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.
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
CSRS Coordinate Epoch (2011.00)

- 830 CGPS stations (766@epoch 2009.00; 551@epoch 2007.00) – includes observations until 2011.2918

- Provisional coordinates estimated for new CRTN stations (SF Bay Area, Central Valley)

- ITRF2005 coordinates & velocities (update to ITRF2008 with planned reprocessing)

- NAD83(NSRS2007) coordinates & velocities

- Includes uncertainties to comply with California Public Resources Codes

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

- Forums
- Published Coordinates
- Real-Time Map
- Various CRTN Maps
- Presentations
SECTOR Epoch-Date Coordinates
(New Version – October 2012)

SECTOR: Scripps Epoch Coordinate Tool and Online Resource

<table>
<thead>
<tr>
<th>Coordinate</th>
<th>Date</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source: SOPAC</td>
<td>2012-10-25</td>
<td>display as html table below</td>
</tr>
<tr>
<td>Type: Unfiltered</td>
<td></td>
<td>degrees as decimal degrees</td>
</tr>
<tr>
<td>Sites:</td>
<td></td>
<td>datum WGS84 and NAD83</td>
</tr>
<tr>
<td>Single site: SIO5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>List of sites:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sites by array: ARGN (15)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Sites

<table>
<thead>
<tr>
<th>Site</th>
<th>X (m)</th>
<th>Y (m)</th>
<th>Z (m)</th>
<th>Lat (deg)</th>
<th>Lon (deg)</th>
<th>Height (m)</th>
<th>Lat (deg)</th>
<th>Lon (deg)</th>
<th>Height (m)</th>
<th>Model Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>sio5</td>
<td>-2456115.2761</td>
<td>-4768905.6501</td>
<td>3439233.5033</td>
<td>32.84073522</td>
<td>-117.24969111</td>
<td>185.51872841</td>
<td>32.84073202</td>
<td>-117.24957700</td>
<td>186.2666</td>
<td></td>
</tr>
<tr>
<td>map</td>
<td>+/- 0.0015</td>
<td>+/- 0.0023</td>
<td>+/- 0.0018</td>
<td>+/- 0.0012</td>
<td>+/- 0.0011</td>
<td>+/- 0.0029</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

http://sopac.ucsd.edu/processing/coordinates/
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: 163 stations; NC: 176 stations) at SIO with a latency of ~0.4 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.
CRTN – NTRIP

Northern California
IP: 132.239.154.101
Port: 2103
(176 stations)

Southern California
IP: 132.239.152.72
Port: 2103
(163 stations)

RTCM 3.0

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

CSRC 2011.00 Epoch NAD83
(NSRS2007) Coordinates

Orange Circles:
16km (10 mile) Radius
CRTN – Google Earth & Maps

Google Earth/Google Maps

Featured links:

- **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
NTRIP access and Epoch 2011.00 NAD83(NSRS2007) coordinates
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
- No progress in extending capability to USGS and BARD Topcon receivers, in southern California, the greater SF Bay Area and northern California
# CRTN Community Notices

## Topic Table

<table>
<thead>
<tr>
<th>Topic</th>
<th>Topic Starter</th>
<th>Replies</th>
<th>Last Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRTN CVSRN-stations</td>
<td>ybook</td>
<td>0</td>
<td>02-04-2013 07:24 AM</td>
</tr>
<tr>
<td>UNAVCO Network Upgrades and Outages</td>
<td>Maria Turingan</td>
<td>0</td>
<td>02-11-2013 04:00 PM</td>
</tr>
<tr>
<td>All RTCM streams play</td>
<td>ybook</td>
<td>0</td>
<td>01-29-2013 10:12 AM</td>
</tr>
<tr>
<td>CRTN &amp; CVSRN updates</td>
<td>ybook</td>
<td>0</td>
<td>12-10-2012 10:21 AM</td>
</tr>
<tr>
<td>New CRTN Stations</td>
<td>ybook</td>
<td>0</td>
<td>11-20-2012 00:17 PM</td>
</tr>
<tr>
<td>Topcon RTCM3 and GLONASS Tracking</td>
<td>ybook</td>
<td>0</td>
<td>08-13-2012 00:40 AM</td>
</tr>
<tr>
<td>GLONASS satellites available in San Diego</td>
<td>ybook</td>
<td>0</td>
<td>07-31-2012 11:17 AM</td>
</tr>
<tr>
<td>SOPAC 30th Anniversary and Your Feedback</td>
<td>Maria Turingan</td>
<td>0</td>
<td>07-06-2012 12:36 PM</td>
</tr>
<tr>
<td>RTCM streams for Trimble/ Sokkia Users</td>
<td>ybook</td>
<td>0</td>
<td>06-01-2012 10:37 AM</td>
</tr>
<tr>
<td>Transition to NTRIP</td>
<td>ybook</td>
<td>0</td>
<td>03-13-2012 00:41 PM</td>
</tr>
<tr>
<td>Update from UNAVCO</td>
<td>Maria Turingan</td>
<td>0</td>
<td>02-28-2012 04:00 PM</td>
</tr>
<tr>
<td>UNAVCO-PRD outage</td>
<td>Maria Turingan</td>
<td>0</td>
<td>02-28-2012 01:39 PM</td>
</tr>
<tr>
<td>Extension to March 1</td>
<td>ybook</td>
<td>0</td>
<td>02-12-2012 11:16 AM</td>
</tr>
<tr>
<td>Important: Access to CRTPN Data after February 17th</td>
<td>ybook</td>
<td>0</td>
<td>01-26-2012 10:36 AM</td>
</tr>
<tr>
<td>Important CRTN changes</td>
<td>ybook</td>
<td>0</td>
<td>01-17-2012 10:48 AM</td>
</tr>
<tr>
<td>CRTN NTRIP Servers and RTCM3.0</td>
<td>ybook</td>
<td>0</td>
<td>01-03-2012 12:19 AM</td>
</tr>
</tbody>
</table>

---

**Author:** ybook  
**Member # 17**

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, *DCON*, RAPT, CHOW, DOCN, DLNO, LEBE, LEMA, *MLIN*, TEHA, TAFT, TRLK, SHPS, *XJNS*, SIMM). The stations with an asterisk are not currently available. We’ve also updated the transmitted Epoch 2011.00 NAD83 (HRSB2007) coordinates for those stations that were not part of the Epoch 2011.00 adjustment (except for JNS from which we have not yet obtained any data). As such they should be considered as provisional. See [http://sopac.ucsd.edu/inst/realtime/CRTN_Access.xls](http://sopac.ucsd.edu/inst/realtime/CRTN_Access.xls), which will be updated later today, for details. The changes are reflected in the CRTN Northern California NTRIP source table at [http://132.275.154.103:21032](http://132.275.154.103:21032). Thanks to Anthony Bellwe who pointed out a problem with our RBRU coordinates and to Eric Knodle 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

---

[http://sopac.ucsd.edu/ubbcgi/ultimatebb.cgi?category=6](http://sopac.ucsd.edu/ubbcgi/ultimatebb.cgi?category=6)
Forums

If we don’t know something is wrong we can’t fix it!
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 Metrics

Number of CRTN NTRIP Connections by Login

Mar-2012: 1276
Apr-2012: 1374
May-2012: 741
Jun-2012: 2214
Jul-2012: 3973
Aug-2012: 1643
Sep-2012: 1491
Oct-2012: 1396
Nov-2012: 1140
Dec-2012: 1609
Jan-2013: 1761
Feb-2013: 6010
Mar-2013: 3227
Apr-2013: 4066
May-2013: 2831
Jun-2013: 2732
Jul-2013: 3458
Aug-2013: 4261
Sep-2013: 5471
CRTN – Single Base User

- An NTRIP account (username & password) is required, and requested by emailing the CSRC director (ybock@ucsd.edu)
- To date 219 companies/agencies registered (up from 125 in May) – 12 multi-account (CRTN Consortium & Contributors) users
- Highest usage in September, 2013
  - Vessel tracking, dredge pos., hydrographic surveys company: 993 (SF Bay Area)
  - Department of public works (southern California): 365 (4 accounts)
  - Surveying engineering company (southern California): 323
  - Digital mapping company: 252 (central California)
  - Wired and wireless communications company (SF Bay Area): 202
  - Hydrographic engineering and surveying company (Los Angeles): 197
CRTN Metrics

Cumulative Number of CRTN NTRIP Connections by Station from February 2012 to September 2013 (Top 50 Stations with Total Connections ≥ 232)
Current Consortium Members:
1. City of Los Angeles, Department of Public Works, Bureau of Engineering, Tony Pratt
2. Riverside County Flood Control and Water Conservation District, Bill Hofferber, Jim McNeill, Gary Poor
3. Orange County Public Works, Art Andrew
4. San Diego County, Department of Public Works, Terry Connors
5. Riverside County Transportation Department, Ken Teich, Ed Hunt, Tim Rayburn
6. Santa Clara Valley Water District, Thomas Dougherty
7. City of Long Beach, Gas and Oil, Kimberley Holtz
8. California Spatial Reference Center
9. Scripps Institution of Oceanography, University of California San Diego, Yehuda Bock

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
SOPAC Research Highlights

• GPS/seismic integration (seismogeodesy) for earthquake early warning
• Estimation of coseismic tilts
• Successful monsoon and flooding forecasts
• Troposphere and ionosphere maps (basis for statewide “network solution”)

Continuous mm-level precipitable water
(integrated water vapor in troposphere)

GPS Integration

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

GPS/GNSS

+ MEMS Accelerometer Module

= MEMS Met Sensors (pressure, temperature)
GPS Integration

Green dots are stations upgraded with Geodetic Modules and MEMS Accelerometer packages.
Example of Seismogeodetic Upgrade

Upgraded GPS station RAAP

MEMS accelerometer deployed on GPS monument

Geodetic Module in equipment box
Estimation of Coseismic Tilts

Geng et al., GRL, 2013
Successful Monsoon and Flooding Forecasts

• Successful monsoon and flooding forecasts for event that occurred in the period July 20-22, 2013.

• Use GPS network to track extreme weather events in collaboration with NOAA and U.S. Weather Service Offices in San Diego (Encinitas) and Los Angeles (Oxnard) – four-year project funded by NASA.

• GPS network allows us to measure amount of atmospheric water vapor, the main indicator of extreme weather.

• The Weather Service uses balloon launches every 12 hours from Yuma and San Diego to determine profile of atmospheric water vapor. One of the balloons did not provide data for one Monsoon event, so they used GPS data.

Monsoon Movie
Precise Point Positioning Service for real-time clients implemented by SOPAC

- Predicted orbits from IGS
- ITRF positions & metadata (SOPAC)
- Real-Time Data, Various Servers

- Generate Satellite Clocks
- Generate Fractional-Cycle Biases
- CRTN Server
- Generate California-based Troposphere and Ionosphere Model

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

PPP client, RTK User, Network Service, Other Users

Operational
Ionosphere and Troposphere Maps
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
Questions?