San Diego County Real Time Network

Background and Status

Yehuda Bock
Glen Offield, Hans-Werner Braun, Frank Vernon
UCSD/Scripps Institution of Oceanography
Ross Carlson, Phil Giurbino, Steve Martin, Norman Peet
San Diego County Department of Public Works
Chris Walls (UNAVCO/PBO), Bob Packard (CSRC)

Contributions: Atsushi Yamagiwa (GSI), Jeff Genrich (SIO)

Real Time GPS Networks Symposium
February 4, 2005 - Irvine, CA
First 20 Hz Real Time Station in SDCRTN

Ramona Airport
Components of a Real-Time Network

Geodetic-Grade GPS Receivers

Bluetooth → Serial

Internet

RTCM, CMR+

Comm.

Server

Base Stations

Los Angeles County

San Bernardino County

Orange County

Riverside County

San Diego County

Scale 1:500,000

Components:
- Geodetic-Grade GPS Receivers
- Base Stations
- Internet
- Camera
- Server

Communications:
- Bluetooth
- Serial
- RTCM, CMR+
Some Milestones in Development of Real Time Networks in Southern California

A Home Grown Solution
Natural Setting in Southern California

- Complex transform plate boundary with ~48 mm/yr deformation distributed over several hundred km, including several major faults.
- Seven large earthquakes in last 12 years
- Regions of land subsidence
Circa 1985: Begin GPS Campaign/Field Surveys

Established bond between geophysicists and surveyors

CSRC Master Plan - 2002
1990: Kennedy Ranch 1 Hz Survey

Performed 1 Hz GPS measurements in 1990 on a USGS (short-range) alignment array across the SAF south of Parkfield. Concluded that 1 Hz instantaneous GPS position solutions could be used to detect 2 mm of horizontal displacement ($1 \sigma$).

Genrich and Bock [1992].
1990-1995: Southern California PGGA Monumentation

County Participation
1991: Orbit Determination

CIGNET operated by NGS

Establishment of Scripps Orbit and Permanent Array Center (SOPAC)
Current Distribution of IGS Global Tracking Stations and ITRF 2000 Velocities
1994 Mw 6.7
Northridge Earthquake

1996-2001:
Southern California Integrated GPS Network
Provide the necessary geodetic services to ensure the availability of accurate, consistent, and timely spatial referencing data.

Monitor temporal changes in geodetic coordinates due to tectonic motion, earthquakes, volcanic deformation and land subsidence.

Establish the legal spatial reference system for California (the “CSRS”).

1999: Establishment of CSRC
Location of the October 16, 1999 Mw 7.1 Hector Mine earthquake (star) and fault rupture. Contours (in mm) and arrows show the magnitude and direction of modeled static (permanent) horizontal displacements. Diamonds show 25 SCIGN sites. Epicentral distances range from 53 to 205 km. Maximum displacements > 1 meter.
2000: Instantaneous Positioning

- Instantaneous cm-precision relative site positions over distances of 10’s of km with only a single epoch of data from 5 or more satellites, demonstrated with SCIGN data.
- Dual-frequency integer-cycle phase ambiguities are resolved independently at each epoch for a network of GPS receivers.
- Unaffected by cycle-slips and receiver losses of lock.
- Orders of magnitude less cpu intensive than batch processing methods, allowing for real-time positioning.
- Instantaneous positioning takes advantage of very high rate sampling provided by GPS receivers (1-20 Hz).
Analysis of low rate (30s) SCIGN data after the 1999 Hector Mine Earthquake in southern California using instantaneous positioning (Bock et al. 2000) detected seismic waves and long-period basin resonance effects (Nikolaidis et al., 2001).
2002: Orange County Real Time Network

Map of Orange County, California, showing points of interest such as "blsa" and "sacy".
GPS Seismology and the Denali EQ

The 2002 Mw=7.9 Denali fault earthquake in Alaska (3900 km distance) provided us the first opportunity to measure displacements caused by teleseismic waves with high rate (1 Hz) SCIGN/OCRTN data, and compare with displacements measured by seismometers.
Seismic Displacements

Blue:
Integrated seismic velocities

Red:
Instantaneous 1 Hz GPS positions
SCIGN Real-Time High-Rate Upgrades

Diamonds: Real-Time (<1 s) High-Rate (1 Hz) Stations

Squares: 3-24 hr downloads, 5-30 s sampling rate.
Instantaneous Positions: Mw 6.0 Parkfield EQ

September 28, 2004
Crustal Deformation Measurements

North Displacements (m)

-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07


9/28/2004 17:14
9/28/2004 17:15
9/28/2004 17:15
9/28/2004 17:15
9/28/2004 17:15
9/28/2004 17:16
9/28/2004 17:16
9/28/2004 17:16
9/28/2004 17:17

North Displacements (m)
2004: Plate Boundary Observatory
Figure 1. Distribution of new stations (red/blue circles) and existing station (black circles) as of 2003. New stations include Fuji-san (Mt. Fuji) and Minamitorishima.
Development of Real Time Networks: Southern California County Model
San Diego County Real Time Network

- Total of 22 stations
- 7 existing SCIGN stations (3 upgraded)
- 4 new sites built by County to SCIGN standards, 20 Hz receivers – Ramona Airport came on line yesterday
- 11 PBO stations (7 built)
- Seismic/GPS collocation at Monument Peak and Camp Elliot for PBO/USArray
- Using Sheriff’s Dept. and HPWREN communications backbone

Partners: San Diego Dept. of Public Works and Sheriff’s Dept., UCSD (ROADNet, HPWREN, SOPAC), PBO, SCIGN, CSRC
Communications Options

- Point-to-point (900 MHz) radios: DVL, OCRTN
- Ethernet-based 2.4 GHz radios: Parkfield
- Ethernet-based 2.4 GHz radios + Microwave
- Public Internet (OGHS)
- Cell Modems (BLSA - OCRTN, PBO Model)
Typical SCIGN/PBO Station
900 MHz Point-to-Point-Transmitting
900 MHz Point-to-Point-Receiving
Radios and Terminal Server
Ethernet-Based 2.4 GHz Radio System

Carr Hill Master Site
(omni-directional receiving antenna at very top of mast)

Table Mtn Station

Mine Mtn Station + Repeater

Scripps Telemetry Buffer – 20 min. short term buffer, 10 days long-term buffer (@1 Hz)
Five PBO sites constructed in San Diego County will be upgraded to high-rate real-time streaming capability in the next few months.
Advantages of Very High Rate (10-20 Hz) Measurements
Ultra-High-Rate (10-20 Hz) Tests
Very High Rate Data Noise Characteristics

- Ultra-high frequency response is flat ("white noise" above 0.05-0.5 Hz (<2-20 s) for 10-20 Hz instantaneous positions.
- Precision of 10-20 Hz data is similar to 1 Hz data for short- and medium-scale baselines, therefore well suited for dynamic positioning.
- Can benefit from "square-root-of n" averaging to improve precision of, for example, 1 Hz samples.
# Short-Term Precision

<table>
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<tr>
<th>Baseline length</th>
<th>Time interval</th>
<th>Data Type</th>
<th>East [mm]</th>
<th>North [mm]</th>
<th>Vertical [mm]</th>
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<tr>
<td>50 m</td>
<td>24h</td>
<td>decimated</td>
<td>1.3</td>
<td>1.7</td>
<td>4.2</td>
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<tr>
<td>50 m</td>
<td>24 h</td>
<td>averaged</td>
<td>1.1</td>
<td>1.4</td>
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<tr>
<td>50 m</td>
<td>1 s</td>
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<td>0.6</td>
<td>0.8</td>
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<tr>
<td>50 m</td>
<td>1 s</td>
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<td>0.2</td>
<td>0.2</td>
<td>0.5</td>
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<tr>
<td>39 km</td>
<td>24 h</td>
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<td>8.1</td>
<td>9.9</td>
<td>51.8</td>
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<tr>
<td>39 km</td>
<td>24 h</td>
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<td>9.3</td>
<td>48.2</td>
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<tr>
<td>39 km</td>
<td>2 s</td>
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<tr>
<td>39 km</td>
<td>2 s</td>
<td>averaged</td>
<td>0.7</td>
<td>0.8</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Standard deviations of (factor 10)-decimated and (10-point)-averaged instantaneous baseline components for 2 baselines sampled with Leica GPS1200 receivers at 10 Hz (39 km) and 20 Hz (50 m).
Improvements in Accuracy

- Ultra-Rapid Orbits (available today)
- Troposphere models
- Ionosphere Models
Reference Frame Issues
The natural reference frame of GPS/GNSS is an Earth-Centered Earth-Fixed Reference Frame (ITRF).

Precise GPS orbits (IGS) and broadcast ephemerides are with respect to ITRF (currently ITRF2000).

ITRF is defined by the positions and velocities of a global network of space geodetic tracking stations, to account for plate tectonic motions.

California experiences tectonic motion, earthquakes, and subsidence.

The reference network is deforming, while surveyors would like a static datum.
13-Year Daily Coordinate Time Series at PIN1 & PIN2
**SECTOR Coordinates Utility**

**SECTOR: Scripps Epoch Coordinate Tool and Online Resource**

**Results:** Coordinates for reference epoch 2004.117 (2004.3197)
Use the links for site information, maps, time series and model parameters

Time series problems? Try: Non-applet plots, or download the Sun Java plug-in (and restart your browser)

<table>
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<tr>
<th>Site</th>
<th>X (m)</th>
<th>Y (m)</th>
<th>Z (m)</th>
<th>Latitude (deg.)</th>
<th>Longitude (deg.)</th>
<th>Height (m)</th>
<th>Time Series</th>
<th>Model terms</th>
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</tr>
</tbody>
</table>

**Get Epoch-Specific Coordinates:**

[option: reload site list below using only sites in array: ] ALL  Reload Site List  array maps

Select site code: NONE  Enter space-separated sites: pin1 pin2  [choose one site option]

Select year: 2004  Enter day-of-year: 177  Select filter type: filtered

[note: filtered coordinates are available for western North America sites only] Get Coordinates

**Site coordinates resources:**

- Get coordinates for all sites at any epoch, via e-mail
- Coordinates from the most recent SOPAC weekly globk run
- ITRF2000 IGS core site coordinates
- Help with this utility
- SCOUT - process your own RINEX data
- Site coordinate time series

**: coseismic offset
ps decay: postseismic decay
Semi-Dynamic Datum

- Define an epoch for ITRF coordinates of base stations (e.g., 2004.0).
- Determine base station coordinates and velocities at the survey epoch using SCIGN combined time series and SOPAC’s SECTOR utility, for example.
- Survey new stations with respect to “true of date” coordinates of base stations.
- Apply crustal motion model to bring surveyed station coordinates to reference epoch.
New Zealand Velocity Model

NEW ZEALAND VELOCITY MODEL
from 1992-2003 GPS data
Version 2.2 - Nov 2003

Australian Plate

Pacific Plate

Height above sea level (m)

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