READI Activities at SOPAC

Yehuda Bock Peng Fang, Jianghui Geng, Dara Goldberg, Jennifer Haase, Diego Melgar, Glen Offfield, Jessie Saunders, Melinda Squibb, Anne Sullivan, Yuval Reuveni
Scripps Orbit and Permanent Array Center
Institute of Geophysics and Planetary Physics
Scripps Institution of Oceanography
University California San Diego

Collaborators:
Robert Clayton (Caltech), Seth Gutman (NOAA), Mark Jackson (NOAA), Sharon Kedar (JPL), Jayme Laber (NOAA), Angelyn Moore (JPL), Susan Owen (JPL), Ivory Small (NOAA), Frank Webb (JPL), Ellen Yu (Caltech)

READI WG Meeting
San Francisco
December 11, 2013
Western U.S. – Utilizing 550-station real-time GPS network spanning areas of high seismic and tsunami risk

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

NASA-funded Real-Time Earthquake Analysis for Disaster mitigation network (READI): ~550 GPS stations maintained by UNAVCO, USGS (Pasadena and Menlo Park), UC Berkeley, SIO, SoCal MWD, Caltrans

17 stations (green circles) upgraded with our sensors in summer, 2013

http://sopac.ucsd.edu/projects/realtime/READI/
Seismodeodetic Upgrades

Upgraded GPS station RAAP

Geodetic Module in equipment box

MEMS accelerometer deployed on GPS monument

Other sensors can be accommodated
Providing warnings of natural hazards through integration of GPS with small, inexpensive seismic and meteorological sensors deployed over networks of field stations and/or large engineered structures.

Continuous measure of seismic motions

Continuous atmospheric water vapor maps

GPS (on building) + Accelerometer =

GPS (in field) + Meteorological Sensors (pressure, temperature) =
Project Components and Data Flow

Sensor Web

Displacements
Velocities
PWV
Alerts

GAM client
ACE upload
SGM in house

SGM: seismogeodesy/meteorology analysis and output

MEMS Sensors

Serial

Serial

Serial
Seismogeodetic Monitoring System

- SOPAC get_acc client
- SOPAC RTD positioning
- Network Adjustment
- Kalman Filter
- Seismogeodetic combination: x(t), v(t), a(t)
- SOPAC get_met client or other sensor data
- GPS positions
- Real-time Wavepool
- SCEC DC wave pool and archive
- AIST2STP to user
- QC, variance statistics
- detection
- Other analysis centers i.e. CWU GPS Cockpit
- Other analysis centers
- fastCMT moment tensor line source
- rapid finite fault inversion: fault slip model
- fault inversion with offshore data: fault slip model
- tsunami model
- Other EQ event trigger
- Pd scaling traveltime + 5s EQ magnitude
- PGD scaling max moment release time EQ magnitude
- EQ magnitude
- Other analysis centers
- Common Alert Protocol
- Other EQ event trigger
Monitoring System

December 9-10 test run with shake table measurements
Recent Advances in Seismogeodetic Analysis

1) A real time GPS service that produces satellite clocks and fractional cycle biases available for positioning individual sites. This means cpu requirements increase linearly with the number of sites in PPP mode, increasing the feasibility of analyzing data from large dense networks in real time;

2) The tightly-coupled Kalman filter combination of GPS observations with local accelerometer data. This provides ambiguity resolution comparable in quality to a network solution and real-time precision of < 15mm horizontal standard deviation;

3) Finite CMT and fault slip models (Tokachi-oki, El Mayor-Cucapah, Tohoku-oki)
Recent Advances in Seismogeodetic Analysis

3) Real time integration of accelerometer data to velocity and displacement without baseline corrections, providing the fundamental input for rapid finite fault source inversion;


4) Tsunami Modeling (Tohoku-oki)


5) Simultaneous solution for ground motion tilt to mitigate errors in accelerometer recordings;


6) P-wave detection and low frequency estimates of P-wave arrival displacement to support single station earthquake early warning.

After a large earthquake buildings can be damage-tagged based on their permanent tilt and displacements.

A 1° degree tilt would be enough to red-tag a building.
Model of 2011 Tsunami in Honshu: Movies

Use GPS data available in 157 seconds after earthquake origin time

Use GPS and near-shore ocean buoys available after 20 minutes
Total precipitable water from satellite (not available over land)

Loop Starts December 18, 2010
Loop Ends December 22, 2010

Moisture Source

Heavy rain in southern Calif.
Accurate forecasts and warnings of flash flooding events depends in large part on timely and accurate information of the moisture available for intense thunderstorms.

Strong thunderstorm with flash flooding near Ludlow, Calif. (Photo Credit: Will Wilkens)
GPS system first used in July, 2013 by NOAA National Weather Service in San Diego and Oxnard, Calif. to forecast a summer monsoon and issue accurate flash flood warnings.

Flooding across Highway 78, San Diego County, Calif., 2013 (Credit: NOAA)
Real-time GPS precipitable water estimates were trending higher over eastern portions of the forecast area... a flash flood watch will be needed for Saturday.

In order to see the character of the precipitable water values between Yuma and San Diego in the absence of a morning Yuma sounding, the GPS meteorology data was utilized.

Highway 78 flooded in two locations at Yacqui Pass with 30 vehicles trapped between the two flooded locations. Many large rocks in the roadway.

Battalion Chief flagged down by the public to report debris moving across the roadway on Sunrise Highway.
Surface-based Water Vapor Data Sites

★ = Weather balloon sites (max of 2x per day)
● = GPS Integrated Precipitable Water sites (continuous)