12.540 Principles of the Global Positioning System
Lecture 24
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http://geoweb.mit.edu/~tah/12.540
OVERVIEW

• Examination of results from Earthscope
• Reference frame definition: SNARF
• High-rate GPS results
• Episodic Tremor and Slip (ETS) events
• Two types of water events.
• Tools
ACs (NMT and CWU) are routinely generating PBO GPS data products

- Rapid Sinex files: 24 hour latency
- Final Sinex files: 6-13 day latency, weekly run started after IGS final products become available
- Supplemental Sinex files: 12-week latency, weekly run. Includes missed sites and a 3-4 tie sites from final runs to link network. Tests show performance similar to finals. Bias fixing not quite so good due typically to wider site spacing.
- Supplemental runs also add sites to original final submission (until re-processing generates new set of final runs).
- SINEX and RMS files ftp’d to MIT
- Recently campaign processing (Bob Smith) added to processing first as an additional run similar to the supplemental runs and once caught up, included in the supplementals.
- Added USGS processing of SCIGN sites (SCEC funding). Results appear in combined product.
PBO Combination Analysis

• ACC:
  – Rotates, translates, and scales each AC to PBO SNARF reference frame; check and correct meta data (when possible)
  – Combine AC results and transforms combined product to PBO SNARF (Stable North America Reference Frame)
  – Outlier checks and report generated that is emailed to
  – SINEX and time-series files sent to UNAVCO via LDM
  – The PBO realization of SNARF is updated about once-per-year: Requires re-submission of all frame defined sinex files and time series files. Latest version 20070919173418. At 6-month intervals updates are made for new stations. (Reference frame sites are not updated in these incremental updates and thus the time series and SINEX do not need release.)
254 sites used to estimate daily rotation, translation and scale onto the North America Frame. Outlier detection during estimation.
RMS daily scatter: PBO Sites

Daily RMS Scatters for 2004-2007.9 Combined solution for PBO Sites

Median North  1.1 mm  
Median East  1.4 mm  
Median Height  3.9 mm

Mean (mm) : 1.5  
Sigma (mm) : 1.5  
50% < 1.1 (mm)  
70% < 1.4 (mm)  
95% < 3.3 (mm)  

Mean (mm) : 1.7  
Sigma (mm) : 1.6  
50% < 1.4 (mm)  
70% < 1.7 (mm)  
95% < 3.3 (mm)  

Mean (mm) : 4.5  
Sigma (mm) : 2.3  
50% < 3.9 (mm)  
70% < 4.6 (mm)  
95% < 8.1 (mm)
Daily RMS Scatters for 2004-2007.9 Combined solution for Nucleus Sites

Median North  1.2 mm  
Median East    1.4 mm  
Median Height  4.2 mm

Nucleus are pre-existing GPS sites that will be merged into PBO at the end of construction (10/2008).
RMS scatters for Nucleus sites (purple) and PBO sites (yellow), RMS scatter > 3 mm (black, 1mm). Red circle shows 1 mm RMS scatter.
Alaskan Sites

RMS scatter of these sites is higher than CONUS; regional frame stabilization yields only small improvement.
The RG sites are mostly only processed by CWU and the results are very noisy.

Only one the RG sites is meant to be processed by CWU.
SCIGN site analysis:

These results have implications for how well external or campaign processing can incorporated into PBO.

Current analysis looks very good.
RMS Scatter of merged SGIGN sites

Quality is very similar to other PBO sites.
Arrival of surface waves from San Simeon Earthquake (1-Hz)

GPS stations around Parkfield operate at 1-Hz sampling rates, which allows us to study surface wave arrivals from nearby and large magnitude earthquakes.
Time zoom of arrivals

In addition to the surface waves, the static co-seismic offset can also be seen here.

Real time high rate GPS data useful for surveying and engineering communities.
Episodic Tremor and Slip (ETS) events in Casadia (Pacific North West)

- Examine overlay of strainmeter results and GPS coordinates
- Strainmeters measure small displacements in bore-hole (10-cm diameter) to measure strain (dl/l). GPS measures the integrated effects of all strains between site and stable North America.
  - Strain meter data downloaded from: [http://pboweb.unavco.org/?pageid=89](http://pboweb.unavco.org/?pageid=89) level 2 processed data (ASCII form)
  - Files give gauge data calibrated to strain units with corrections offsets, trends and tides.
  - Four gauge readings converted to 3 components of strain in east, north and EN directions (Eee-Enn, Eee+Enn, 2Een) through gauge orientations and least-squares (could test rms here).
  - Eee-Enn strain compared GPS East coordinates after removing polynomial from strain.
  - Data available in a number of formats including SEED
Borehole strainmeter GPS comparison

Transient appears shorter in strain record? However is this expected from spatially transient strain event: Position will see continued integration.
Comparison in Northern Casadia/Vancouver Island
Motions in California

Red vectors relative to North America; Blue vectors relative to Pacific

Motion across the plate boundary is ~50 mm/yr.

In 100-years this is 5 meters of motion which is released in large earthquakes

Look at motion here
Site BBDM (using GoogleEarth)

Courtesy of MDA EarthSat. Used with permission.
Water level in DAM versus site east coordinate

![Graph showing water level in DAM versus site east coordinate. The x-axis represents the year from 2000 to 2006, and the y-axis represents volume in acre-feet (1e6). The graph includes two lines: one for volume and another for east rate removed (mm).]
Closer Look (water change is rapid)
Another Water effect

2005-Anomaly Baldwin Park Areas

Velocity Legend
Red: 2003-2005;
Blue 2005-2005.5;
Black 2005.5-2007

Examine 3 sites
Baldwin Hills Velocity anomaly

95% confidence ellipses

Grey scaled version of 2005 rate

Rapid response thought to be due to water; reason for long term change not clear
Summary of Water Effects

• While onset on motion in 2005 in Baldwin region coincides with heavy rains; the motions in this region continue well after the end of rains.

• BBDM: Dam site shows rapid response to water changes in the dam and so effect in basin seem to be of a different nature.
Cautions: Bad antenna artifact (several sites of this nature)
Repeating slow earthquakes in Pacific North West

Example of repeating “slow” earthquakes (no rapid rupture)

These events give insights into material properties and nature of time dependence of deformation

GPS Measured propagating seismic waves

Data from 2002 Denali earthquake

05/14/12
Tools

• Most modern GPS analyses now contain hundreds of GPS sites
• For the remainder of the lecture we examine results with the GAMIT/GLOBK matlab tools available at: http://www-gpsg.mit.edu/~tah/GGMatlab
• Current programs are velview and tsview.
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