Geodesy Advancing Geosciences and EarthScope (GAGE) GPS Result Characterization

Thomas Herring, Massachusetts Institute of Technology, Cambridge, MA
Timothy Melbourne, Central Washington University, Ellensburg, WA
Mark Murray, New Mexico Institute of Mining and Technology, Socorro, NM
Michael Floyd, Massachusetts Institute of Technology, Cambridge, MA
Walter Szeliga, Central Washington University, Ellensburg, WA
Robert King, Massachusetts Institute of Technology, Cambridge, MA
David Phillips, UNAVCO, Inc. Boulder, Boulder, CO
Christine Puskas, UNAVCO, Inc. Boulder, Boulder, CO
OVERVIEW

• GAGE Processing
  • Characterization of results
• Earthquakes and postseismic motions
• Slow slip events
  • Alaska
• Anthropogenic signals in data
• Anomalous motions
• Access to information and products

GAGE Processing

- Time tables of results:
  - Rapid solutions: latency 1 day
  - Final solutions (used IGS final orbits) 2-3 weeks
  - Supplemental runs at 12 and 24 weeks to add stations missed in finals
  - Reprocessing runs. Next will start soon for ITRF2014/IGS14
- Products: All available through UNAVCO http/ftp/php and web services (soon)
  - Time series: North America “Fixed” and IGS08
  - Secular velocity fields (released monthly based on time series analyses).
  - SINEX files: Full covariance files
  - Event files for earthquakes
  - Atmospheric delay estimates, phase RMS scatters and other quality metrics
Tools

This is one of the data visualization tools available through UNAVCO.

Other tools allow time series viewing and station and data information to be accessed.

Station homepage:
http://www.unavco.org/instrumentation/networks/status/pbo/overview/<site>
Characterization of non-secular variations

One method of characterizing non-secular motions: Horizontal position variations parameterized as a random walk.

Plot of log of value in mm$^2$/yr
Standard deviation over a decade:
- Dark blues: 0.3 mm
- Light greens: 3 mm
- Browns: 4.5 mm
- Pinks: 30 mm

Each site needs careful examination to assess nature of signal

Statistics computed with annual and in some cases post-seismic log terms estimated

From Herring et al., Reviews of Geophysics
Low Level of systematic noise

Red squares are 30-day averages. RMS <0.4 mm; daily RMS <0.7 mm
Even the lowest noise sites are not white noise.
High level of systematics

RMS scatters are now 2-4 mm. (Earthquake offset 2007 10 31 Mw 5.6, Event 12)
Between 1996 and now, we account for 38 Earthquakes
18 Fault plane solutions
10 with postseismic signals

Most earthquakes are given a 2-digit numerical code. In some cases letter codes are used for well known events.
Denali Postseismic

Mw 7.9 Date 2002 11 3
Data below starts over 2 years after the earthquake.
We estimate site would have been displaced
410 mm N, 140 mm E
Central America Postseismic

EVENT EQ21:
Mw 7.6
Location 10.1N 85.310W
Date 2012 9 5 UTC 14 42

Event file generated initially generated from rapid solutions 3-4 days after event.

Circle is estimated region where coseismic displacements up to 1 mm may occur.

Postseismic assessment happens months after event based on time series behavior and time constant determination.
Time series example

WRMS: 2.23 mm NRMS: 8.17 #: 2903 data Rate: 20.65 +- 0.19 mm/yr

WRMS: 2.25 mm NRMS: 6.33 #: 2903 data Rate: 19.71 +- 0.18 mm/yr

WRMS: 7.45 mm NRMS: 5.04 #: 2903 data Rate: -0.91 +- 0.51 mm/yr
Transient Events: Alaska

Site names: We will look at sites on the Kenai Peninsula
Secular Velocities: North America ”fixed”
Kenai Peninsula: De-trended and 30 day average
One event pattern: Deviation from secular trend

Rich pattern on transient signals in this region
Example of human induced changes in The Geysers, California, Geothermal injection.

Plate Boundary Observatory (PBO) continuous GPS site P203

North-westward motion relative to North America

Minor subsidence

In collaboration with Gareth Funning, UC Riverside
Plate Boundary Observatory (PBO) continuous GPS site P203

Start of EGS demo injection

Increased westward motion

\( v_e = 16.62 \pm 0.09 \text{ mm/yr} \)

\( v_n = -3.11 \pm 0.21 \text{ mm/yr} \)

Uplift
UNAVCO GDS Technical News: Google Plus

Find on UNAVCO page or Google search “UNAVCO GDS Technical News”
Ground water: Poroelastic P271

Nearby P268 shows little vertical motion but anti-correlated north-south motion.
Red line is temperature at Manly Hot Springs Airport. Plot below shows “square wave” structure possibly related to freeze-thaw cycles.

Transition seems to coincide with temperatures above and below freezing.
ANA1: Alfred Hitchcock's Birds

Late 2015: Thin mess over the site to stop bird’s landing on monument. Article and video on UNAVO GDS Technical news page.

Vertical line marks time of update

We can tell the preferred direction for sitting on the radome – New application for GPS. Bear aggression can also be studied in Alaska (See GDS notes)
Summary

• All of the GAGE processing results are available on-line and suggestions for updates are welcome.
• Access is through www.unavco.org under Instrumentation and Data tabs. FTP access is through ftp://data-out.unavco.org/pub/products/
• There are a wide variety of signals and noise in the GAGE analysis products with new insights being gained all the time.
• Methods have been fully discussed in Herring et al., Plate Boundary Observatory and Related Networks: GPS Data Analysis Methods and Geodetic Products, (2016) Rev. Geophys., 54, doi:10.1002/2016RG000529