GPS Lessons Learned

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Global geodesy has improved dramatically over the past decade starting with the GPS for IERS and Geodynamics demonstration campaign in 1991 (GIG 91). At that time it took over a week of CPU time to process a network solution based on 21 global receivers and orbit overlaps were in the 40 cm range. Today it is possible to process a network solution based on 80 global receivers in less than one day of CPU time and orbit overlaps are in the 4 cm range. Special methods are under development for efficient processing of increasingly large regional networks which may contain hundreds or thousands of GPS receivers. Along the way there have been many lessons learned about GPS satellites, receivers, monuments, antennas, radomes, analysis, reference frames, error sources, and interpretation. A wide range of scientific disciplines have been impacted including studies of plate motion, post-glacial rebound, seasonal loading, deformation in plate boundary zones, coseismic displacements due to major earthquakes, postseismic relaxation, and interseismic strain accumulation related to assessment of seismic hazards. Lessons learned will be presented in the context of new dense networks such as the Plate Boundary Observatory (PBO).
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Satellites

Current
II/IIA - 20, Rockwell, 2 Cs + 2Rb, 7.3 yr
IIR - 8, Lockheed, 3 Rb, 7.8 yr

Future
Galileo - 30 satellites with new signals
GPS III - add C2, M1, M2, L5

Lessons
Non-gravitational satellite forces are a limiting error source
Atmospheric delay is a limiting error source
Anti-Spoofing (AS) limits LC range quality to about 50 cm
M code may allow removal of AS
Satellite antenna pattern not well understood
New satellites, new signals, more power will all help
Receivers

Current
Reduced code tracking provides dual-frequency range and phase data
Encrypted Y-code is a slowly modulated version of known P-code
Ashtech and AOA receivers are most common in the global network

Future
New satellites and signals from Galileo and GPS III
New networks such as the Plate Boundary Observatory (PBO)

Lessons
Buy receivers at last minute to get newest features for lowest price
Budget for receiver upgrades related to Galileo and GPS III
Monuments/Antennas/Radomes

Current
Range of monument designs - stability versus expense
Dorne-Margolin choke ring antenna - multipath reduction
Radome - protection from water and snow

Lessons
Get permits for monumentation as early as possible
Continue to use a range of monument designs
Minimize equipment changes
Elevation mask affected by changing plants and structures
Receiver antenna pattern not well understood
Analysis Strategies/Reference Frame

Undifferenced
LC Range and Phase
GPS Orbits and Clocks
Point positions+Ambiguity Resolution+Regional Filter

Double difference
LC Phase Double Difference
GPS Orbits
Network baselines+Ambiguity Resolution+Regional Filter

Reference Frame
ITRF2000, One Plate Fixed

Lessons
Support 2-3 analysis centers to benefit from competition and diversity
Use of a standard frame simplifies comparisons and combinations
Regional Deformation

Right Lateral Shear: San Andreas Fault, San Jacinto Fault
Compression: Ventura Basin, Los Angeles Basin

Helflin et al., 2003.8
Linear Motion

Filtered time series for CAT1.

Co- and Post-Seismic

Filtered time series for LDES.
Non-linear Volcanic Deformation

Filtered time series for CASA.

- Latitude (cm)
- Longitude (cm)
- Height (cm)

Seasonal Aquifer

Filtered time series for FVPK.

- Latitude (cm)
- Longitude (cm)
- Height (cm)
Tree Growth/Trimming

Filtered time series for HOLP.

Latitude (cm)

Rate 9.34 ± 0.02 mm/yr

Longitude (cm)

Rate -35.95 ± 0.02 mm/yr

Height (cm)

Rate 3.94 ± 0.10 mm/yr

Repeatability

3.1 mm

2.1 mm

8.4 mm
Construction

Filtered time series for MHMS.

Latitude (cm)

Rate 13.57 ± 0.04 mm/yr  Time (years)  Repeatability 3.1 mm

Longitude (cm)

Rate -37.24 ± 0.05 mm/yr  Time (years)  Repeatability 4.4 mm

Height (cm)

Rate -0.49 ± 0.19 mm/yr  Time (years)  Repeatability 13.6 mm
Summary

Get permits for monumentation as early as possible
Continue to use a range of monument designs
Avoid trees, buildings, and other elevation masking objects

Buy receivers at last minute to get new features and best price
Budget for receiver upgrades related to Galileo and GPS III
Minimize equipment changes

Support 2-3 analysis centers to benefit from competition and diversity
Use a standard reference frame for basic products
Provide time series to handle linear and non-linear signals