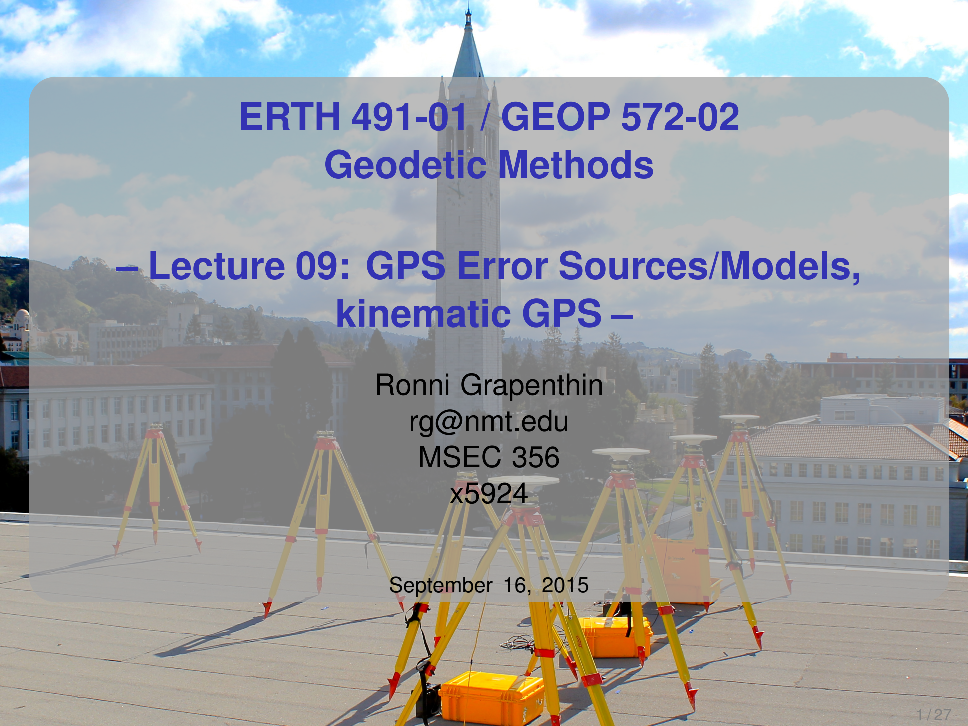

ERTH 491-01 / GEOP 572-02 Geodetic Methods

– Lecture 09: GPS Error Sources/Models, kinematic GPS –

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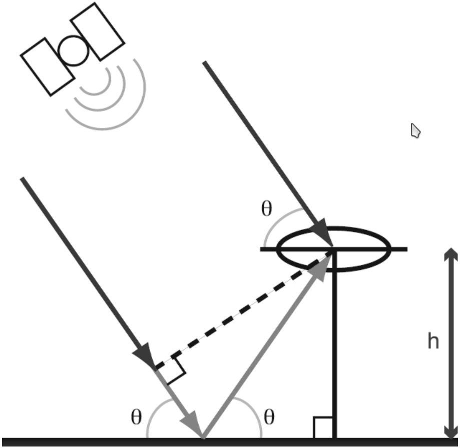
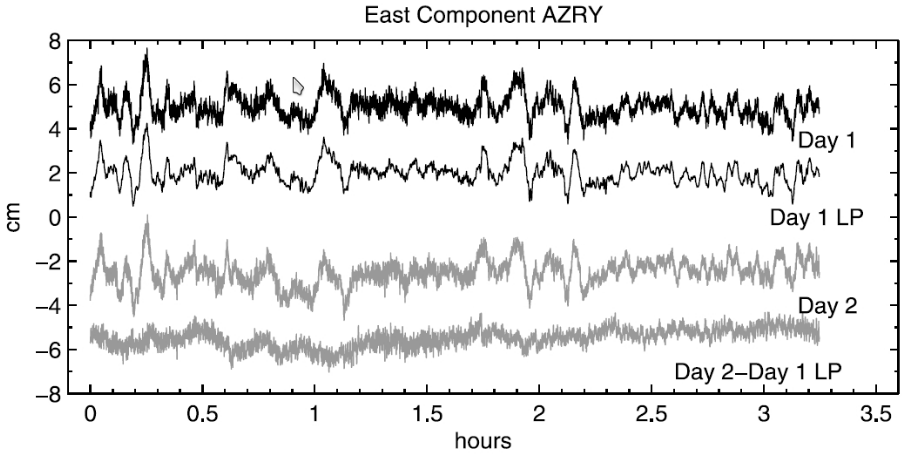
Multi-Path



Larson et al. (2007)

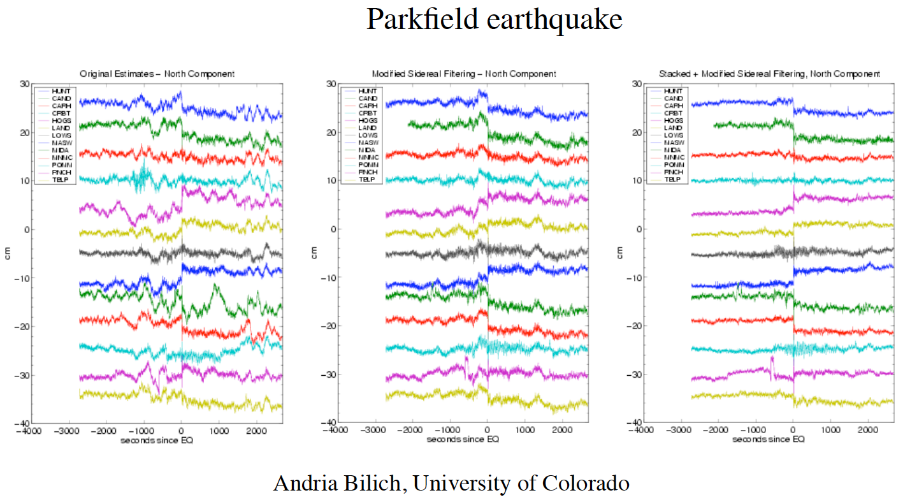
- best seen in subdaily solutions
- signal reaches antenna via direct and indirect paths
- reflected signal delayed, weaker
- mitigation: antenna design, receiver algorithms
- code and phase measurement are sum of received signals
- pseudorange: 1-5 m error
- phase: 1-5 cm error (no worse than 1/4 cycle)

Eliminating Multi-Path through Sidereal Filtering



Larson et al. (2007)

Eliminating Multi-Path through Sidereal Filtering



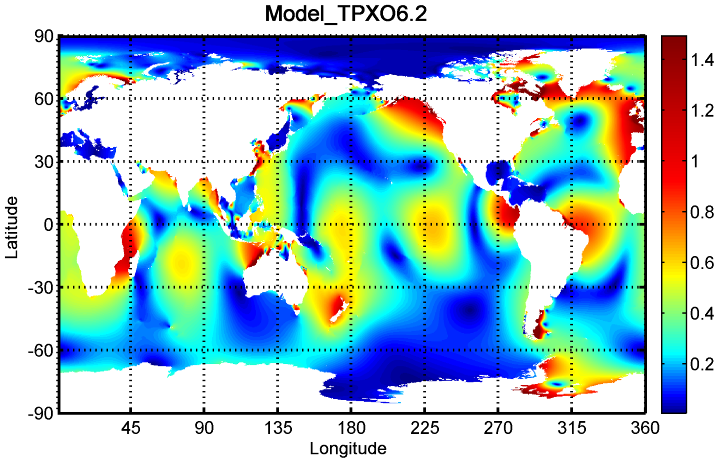
Ocean Tidal Loading

- solid earth responds to changing load due to ocean tides
- large near coast (with large tidal range, depends on coastline)
- need good tidal models for removal

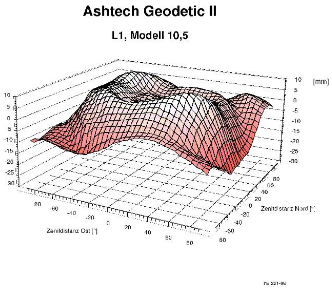
e.g., TPXO6:

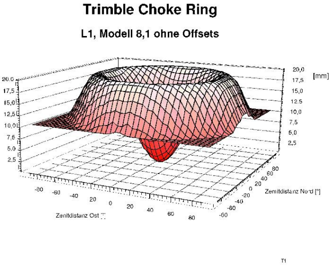
- eight primary constituents M2, S2, N2, K2, K1, O1, P1, Q1
- two long period Mf,Mm constituents
- three non-linear M4, MS4, MN4 harmonic constituents
- on 1/4 degree resolution full global grid (for versions 6.* and later).

Ocean Tidal Loading



Map of M2 sea surface height amplitude (m) from TPXO6.2
`https://www.esr.org/polar_tide_models/Model_TPXO62.html`





- imaginary point in space that we measure distances to
- different for every type of antenna
- ideally point in space, but depends on azimuth and elevation of signal
- models assume azimuthal independence, fit elevation

http://www.geopp.de/gnpcv/

Kinematic GPS 1/

- Kinematic positioning evolved out of tracking moving platforms (planes etc.) since 1980s.
- Same principles apply to a station that moves because of Earth/Ice processes
- About cm-level positioning w/ fixed reference receiver within 10s of km.
- Can be better if change in position over time is focus: can get away without resolving ambiguities
- **kinematic GPS**: roughly falls into **post-processed sub-daily** positioning (30 s, 15 s, 1 s, 0.2 s . . .) and **real-time** positioning (currently routinely 1 Hz, limit)
- There's some confusion in the literature, most real-time papers are actually high-rate / post-processing

Kinematic GPS 2/

- **sub-daily post-processing** possible with absolute (PPP) or relative techniques.
  - need high-rate clock corrections for PPP processing
  - can be interpolated from standard products
- **real-time** processing currently mostly relative (baseline) techniques
  - Different agencies produce real-time clock corrections, latencies high (10s of seconds)
  - PPP-AR (ambiguity resolved) techniques, may require long time to resolve ambiguities
  - Trimble RTX streams corrections; some receivers provide PPP-AR position streams

Kinematic GPS 3/

- Issues with relative positioning
  - Need to choose reference frame carefully (should be stable)
  - Motion at base station maps into rover (e.g. earthquake surface wave, 2nd arrival)
  - Regional reference frame easily disturbed by regional event
  - May not capture network translation! (e.g. big earthquake)
  - Thorough book-keeping critical in modeling steps
- Real time issues:
  - data gaps / telemetry outages
  - latencies: how to keep network sync'ed, do you need to?
  - can't do same filtering for smoothing
  - not much time to iterate to fit parameters!

Kinematic GPS Processing

Traditional GPS:

- sample at 30 s or 15 s
- edit data
- decimate to 5 min
- estimate one position per day

High-rate GPS:

- sample at 1 Hz or higher
- edit data (post-process)
- no decimation
- estimate one position per epoch

The same analysis software can be used for both applications.

Kinematic GPS Applications

- Post-processing:
  - processes that happen on sub-daily time scales
  - ice motion, tidal studies, vehicle tracking
  - earthquake studies (kinematic slip models) – GPS seismology
  - atmosphere: loading, water vapor
  - ionosphere: TEC fluctuations
  - to some extent hazard monitoring
- Real-time:
  - Hazard monitoring: landslides, volcanoes, earthquakes, solar storms
  - Early warning: Earthquakes, Tsunamis (ionosphere detections)
  - Surveying
  - low orbit missions
  - FAA - WAAS (wide area augmentation system) real-time navigation
- Post-processing will always be more precise (see below)

Application: Dynamic Slip Model

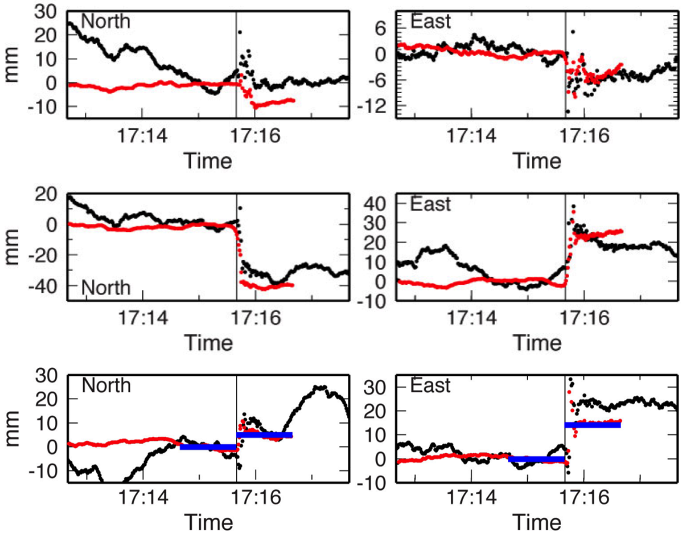
Yue and Lay 2011, GRL

Application: Dynamic Slip Model

Yue and Lay 2011, GRL

Real–Time (black) vs. Post–Processing (red)

2004, M6.0 Parkfield EQ:



Johanson and Dreger, AGU, 2012

Another Error Source: Your Parameter Choices!

GPS Processing Evaluation: Roof Test

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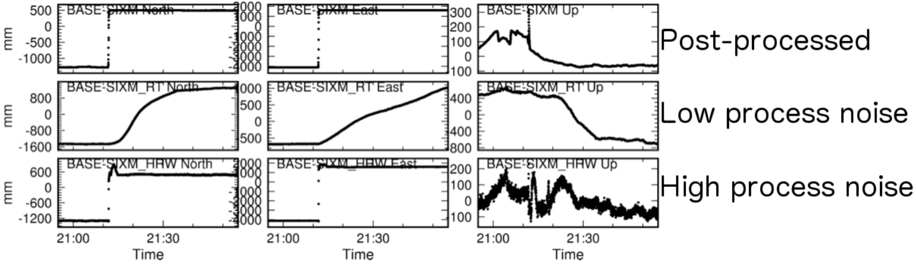
Roof Test Insight: Don’t Optimize for Noise

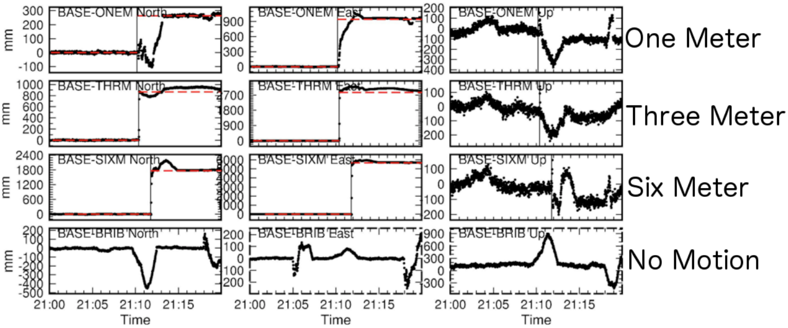
Six Meter Offset:



courtesy: *Ingrid Johanson*

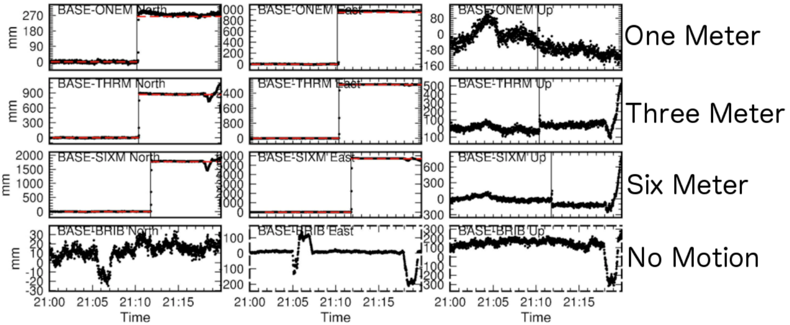
Roof Test Insight: Don’t Optimize for Noise

Bay Area “optimized” parameters:



courtesy: *Ingrid Johanson*

Supressing Cycle Slips at 10× default:



courtesy: *Ingrid Johanson*