ERTH 455 / GEOP 555
Geodetic Methods

– Lecture 09: Kinematic GPS –

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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

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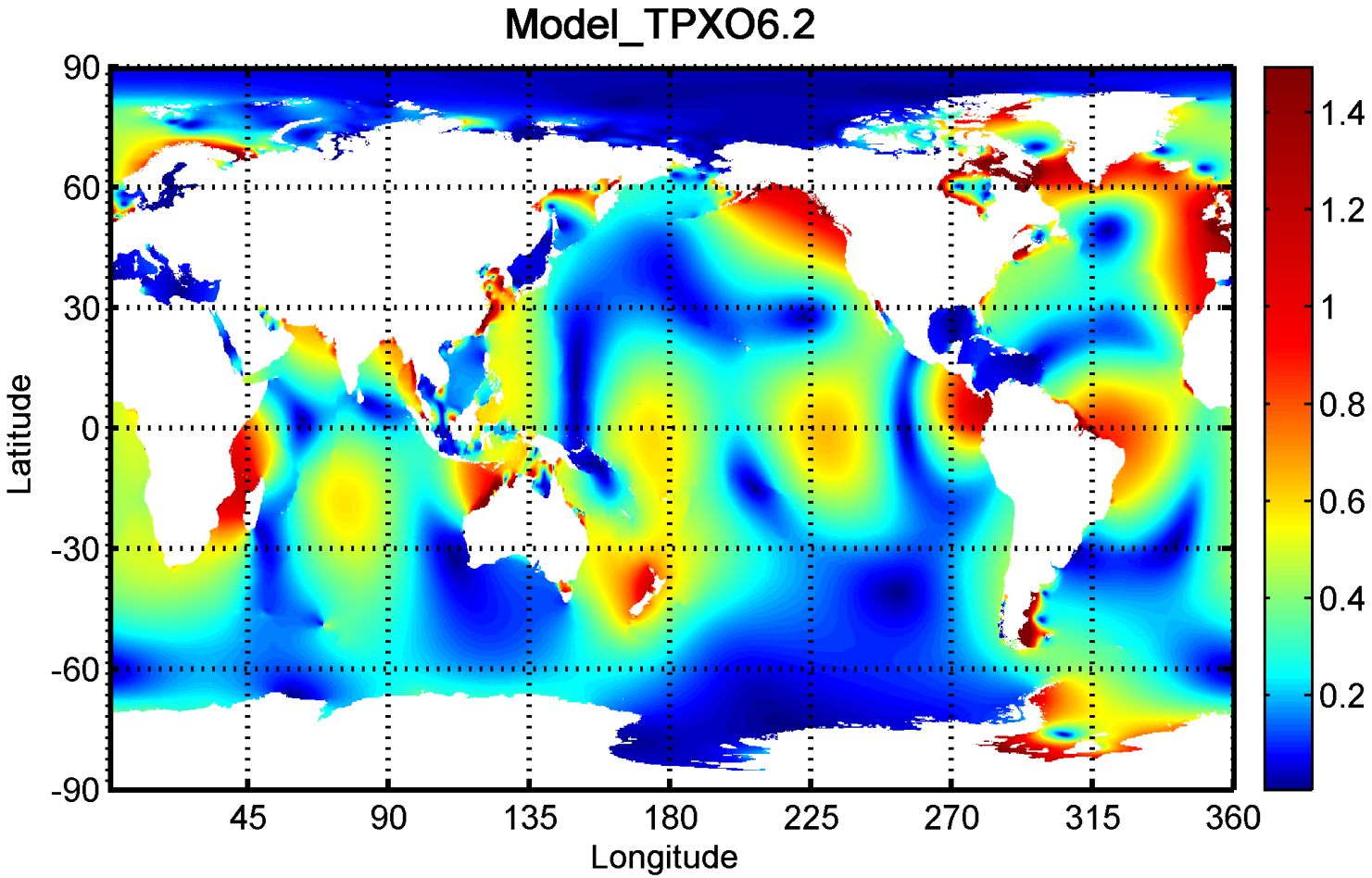
e.g., TPXO6:

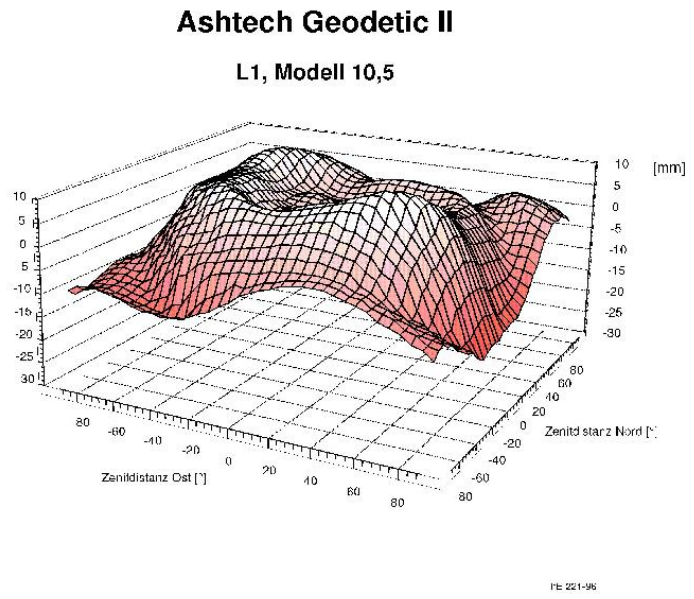
- eight primary constituents M2, S2, N2, K2, K1, O1, P1, Q1
- two long period Mf,Mm constituents
- three non-linear M4, MS4, MN4 harmonic constituents
- on 1/4 degree resolution full global grid (for versions 6.* and later).

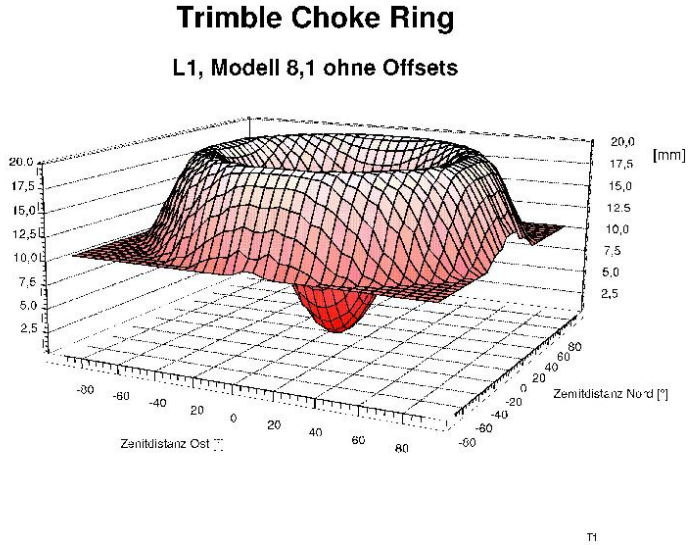
Ocean Tidal Loading



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

Antenna Phase Center Models





- 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 Processing

You're solving the same observation equations, but now for each epoch of data!

carrier phase (unit of cycles):

$$\phi = \frac{1}{\lambda} * (r + I + T) + f * (\delta t_u - \delta t^s) + N + MP + \epsilon_\phi$$

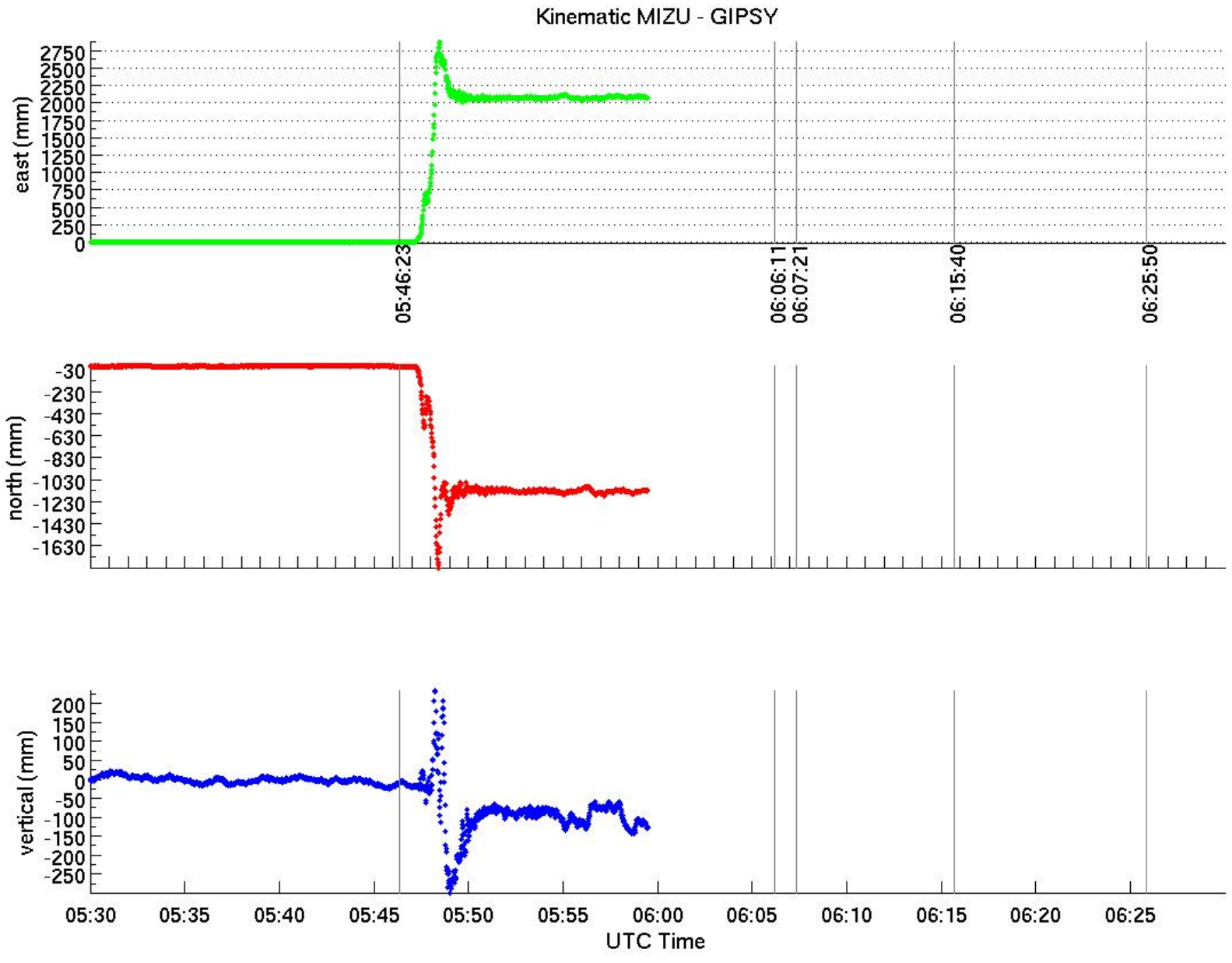
code measurement eqn (units of distance):

$$\rho = r + I + T + c * (\delta t_u - \delta t^s) + MP + \epsilon_\rho$$

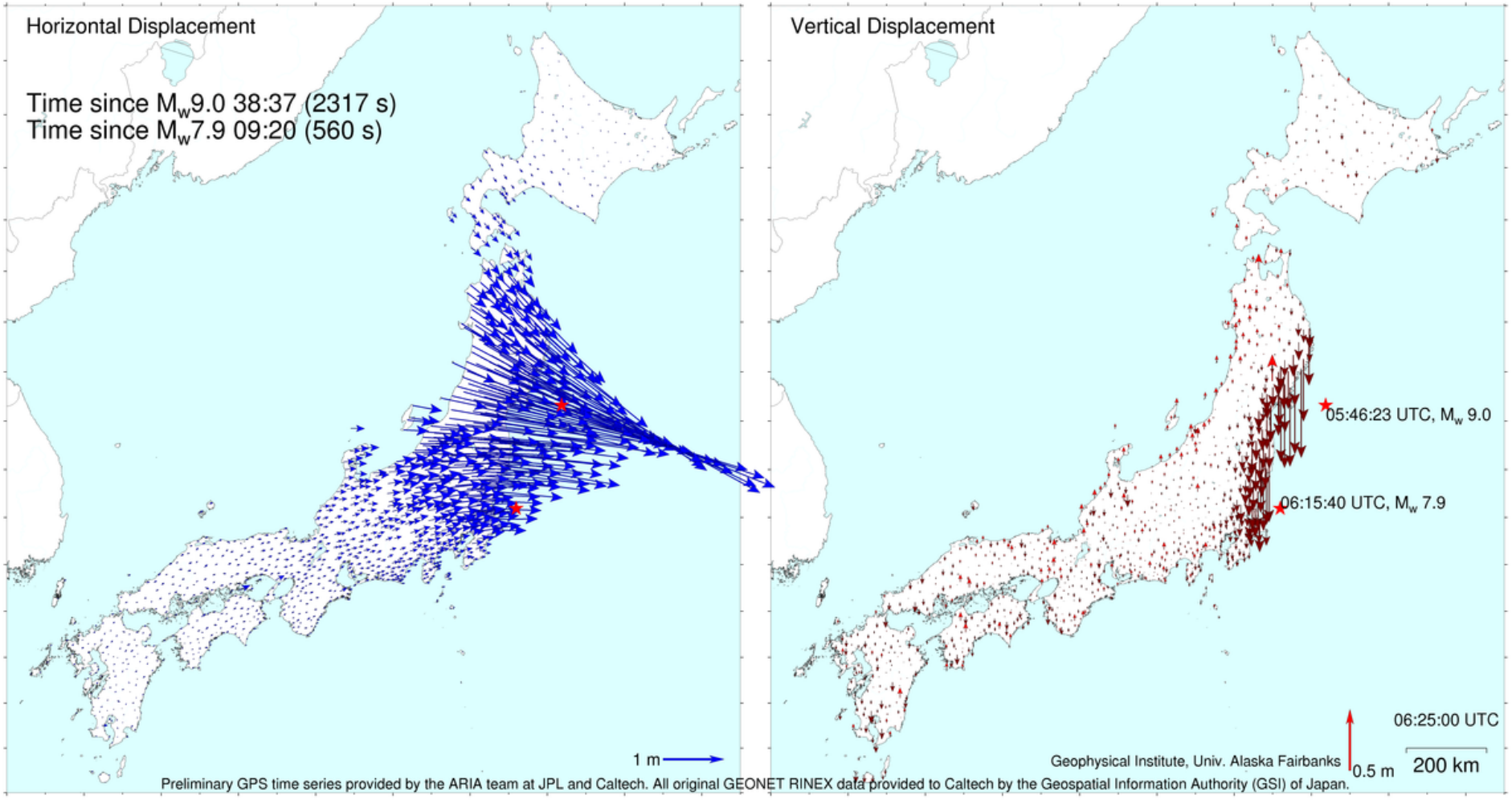
Kinematic GPS Applications

- 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: 2011 Tohoku Oki time series



Applications: 2011 Tohoku Oki time series



1 second per frame

Grapenthin, 2012

video doesn't work? try: `https://www.youtube.com/watch?v=rMhhyb6Yy94`

Application: Turn into Dynamic Slip Model

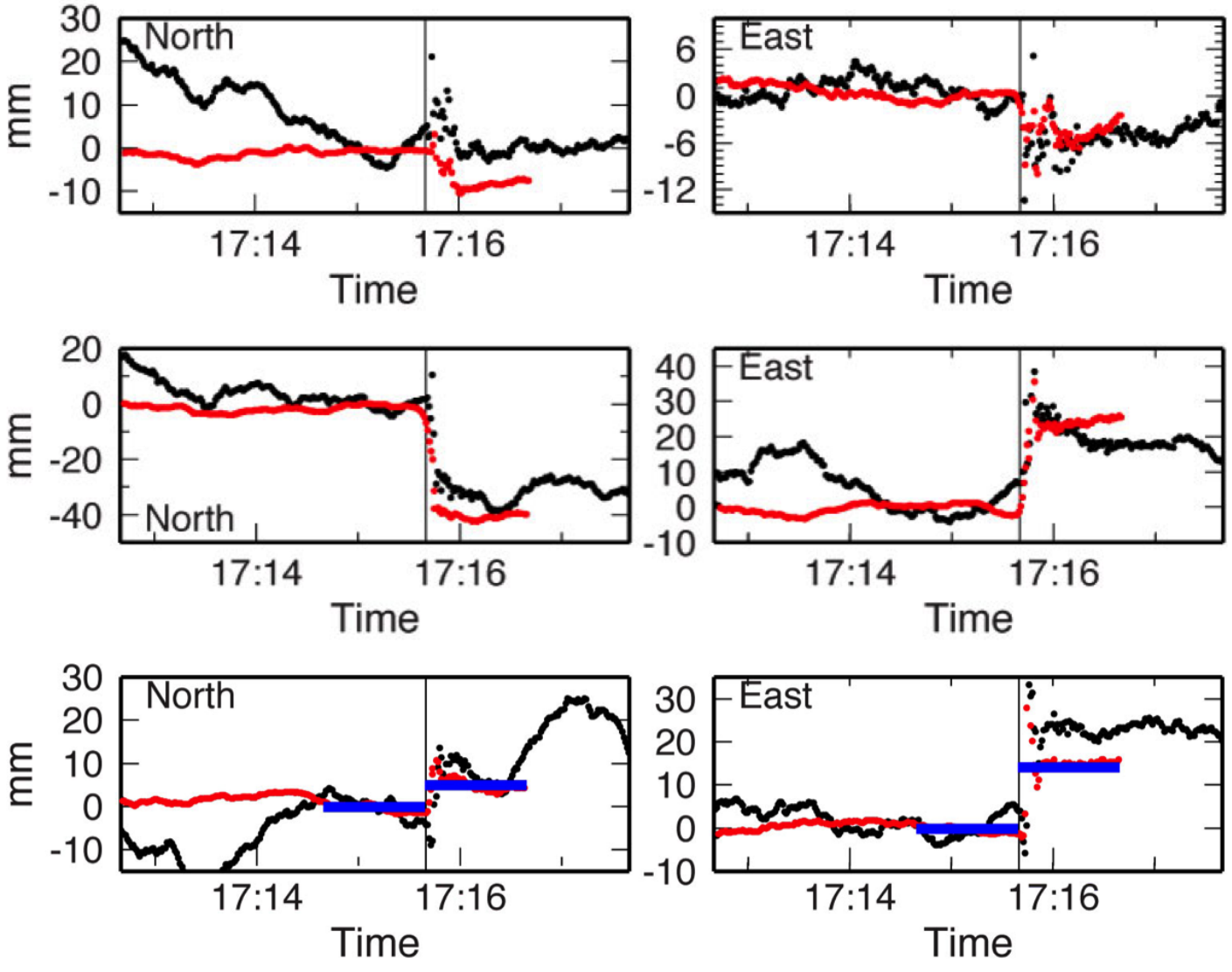
Yue and Lay 2011, GRL

Application: Dynamic Slip Model, M_w7.8 Gorkha 2015

Galetzka et al., Science, 2015

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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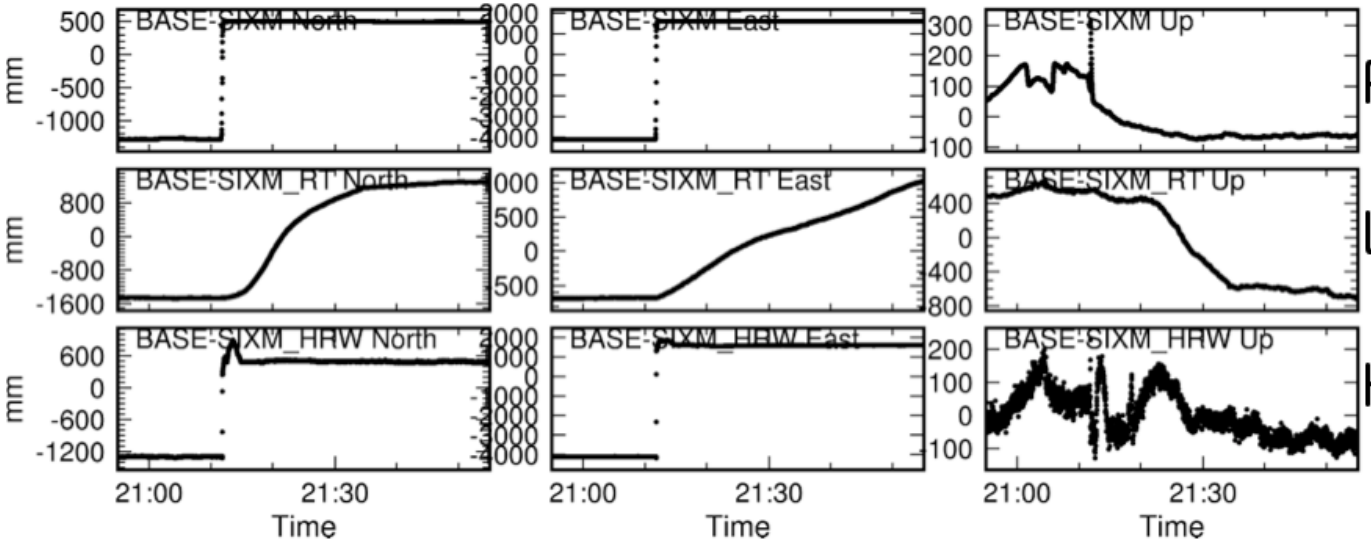
Roof Test Insight: Don't Optimize for Noise

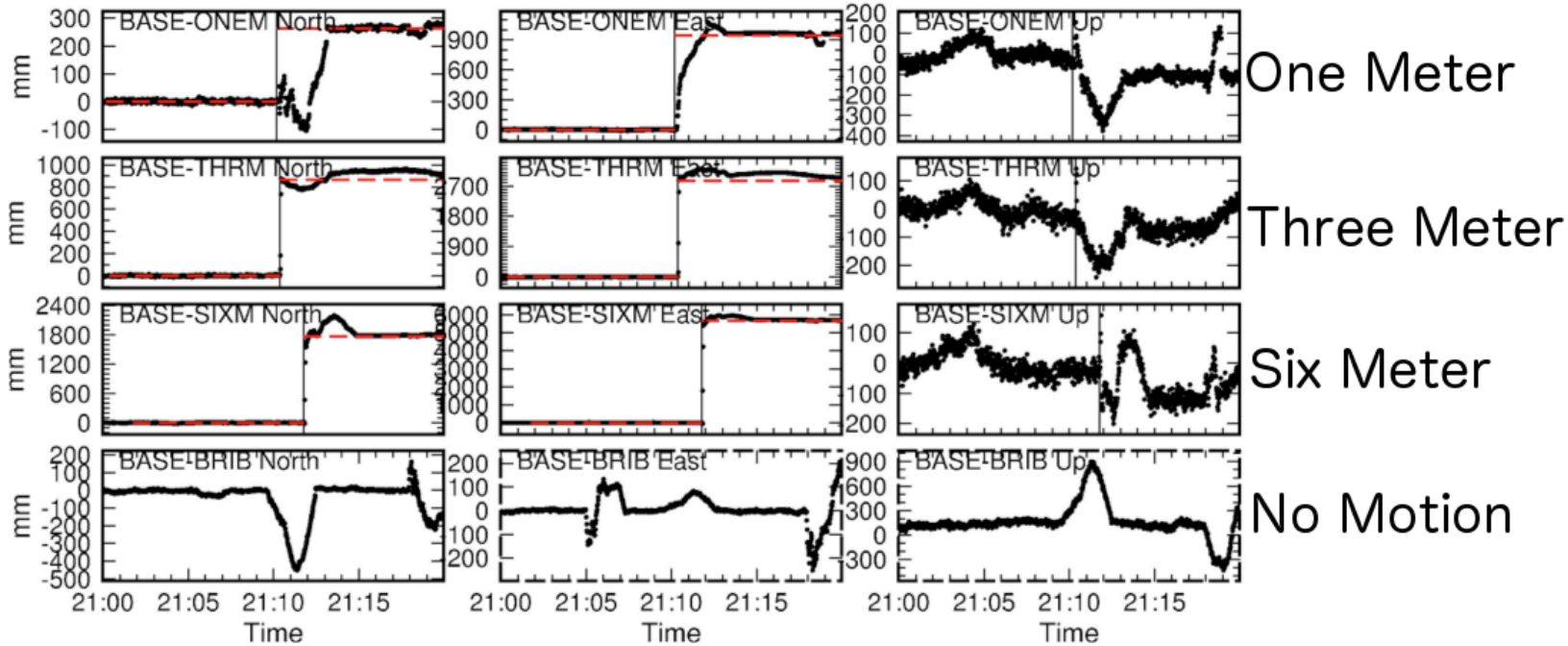
Six Meter Offset:



courtesy: *Ingrid Johanson*

Roof Test Insight: Don't Optimize for Noise

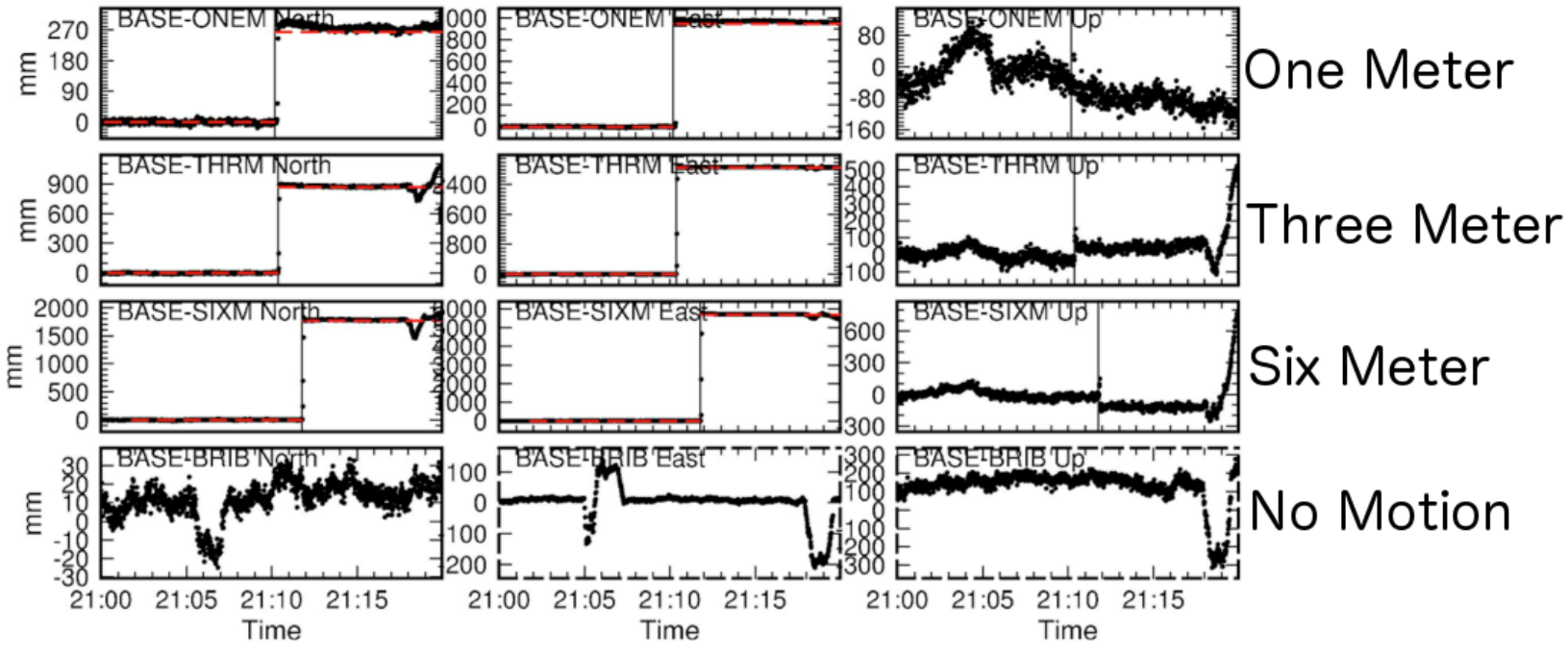
Bay Area "optimized" parameters:



courtesy: *Ingrid Johanson*

Roof Test Insight: Don't Optimize for Noise

Supressing Cycle Slips at 10× default:



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