UNAVCO/GGAO monument study

Thomas Herring, MIT
tah@mit.edu

Overview

- Stability of GNSS monuments. Two aspects to be considered:
  - Physical stability: We will concentrate on local (<50 m) stability. Assess with L1+L2 solution
  - Electrical stability: Assess by comparing L1+L2 solution with ionospheric free (LC) solution. Site separation is small enough that LC=L1+L2 (±<0.1 mm)
- Specific sites:
  - UNAVCO GAGE monument tests:
    - P591,P811,P812 ; P565,P809,P810 ; (P804,P805,P806)
  - Goddard Geophysical and Astronomical Observatory (GGAO)

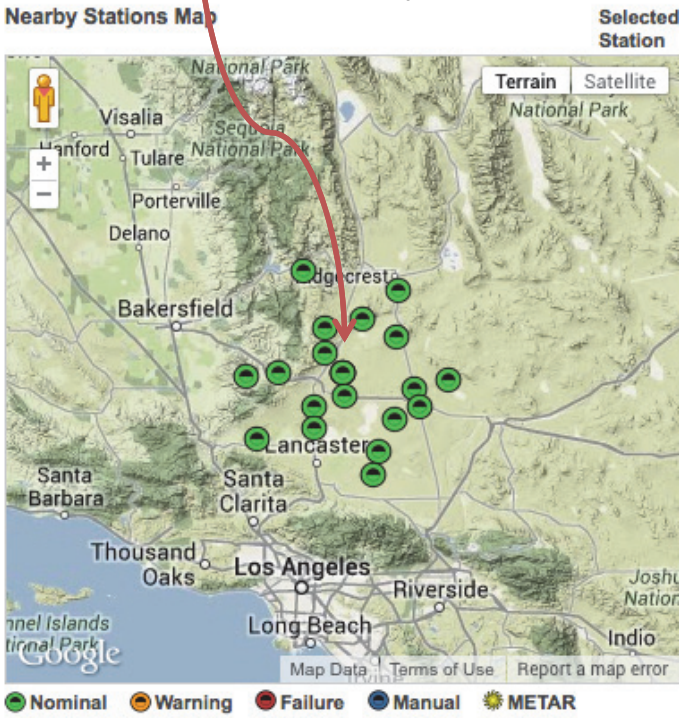
Analysis Methods

- The analyses here will concentrate on short-baseline processing. Site separations are less than 50 m.
- For these lengths compare L1+L2 phase solution with ionospheric free phase (LC):
  - For GPS: PC = 2.5 P1 – 1.5 P2 Range equation
  - LC = 2.5 L1 – 2.0 L2 Phase equation (result in L1 cycles, 190 mm wavelength)
- Noise amplification of ionosphere observable makes it useful for seeing electrical effects at site (multipath and other frequency dependent errors).
- LC is observable used standard processing.
- In these analyses, atmospheric delays are not estimated.

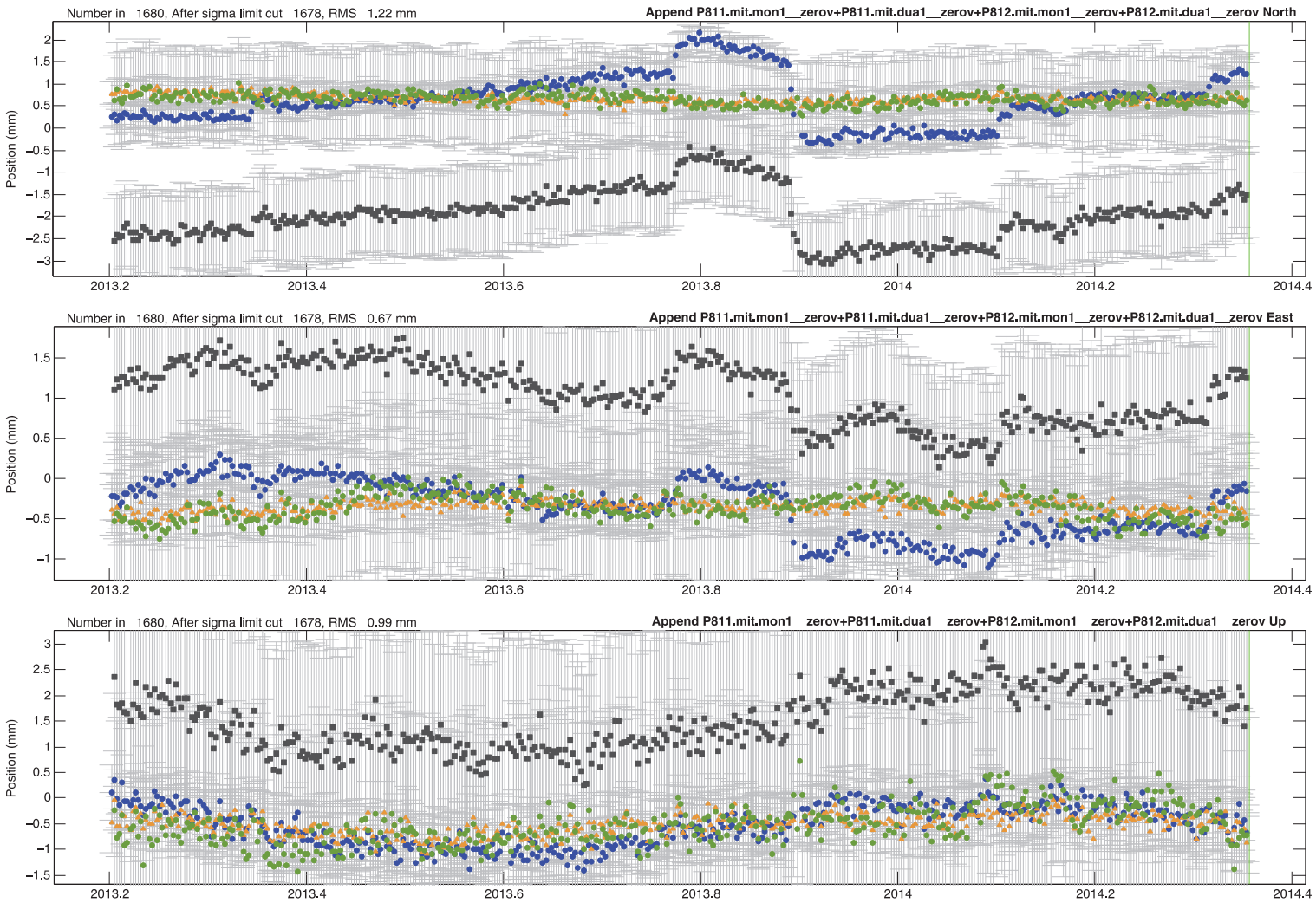
P591+P811+P812 GPS sites

- These sites are part of the UNAVCO GAGE/PBO monument stability test that has been running for about 1 year so.
- P591: Deep drilled braced monument; P811: Pillar design; P812 short drilled braced monument.

P591 (Southern California)



Short baseline processing



Results are relative to P591 deep drilled braced monument

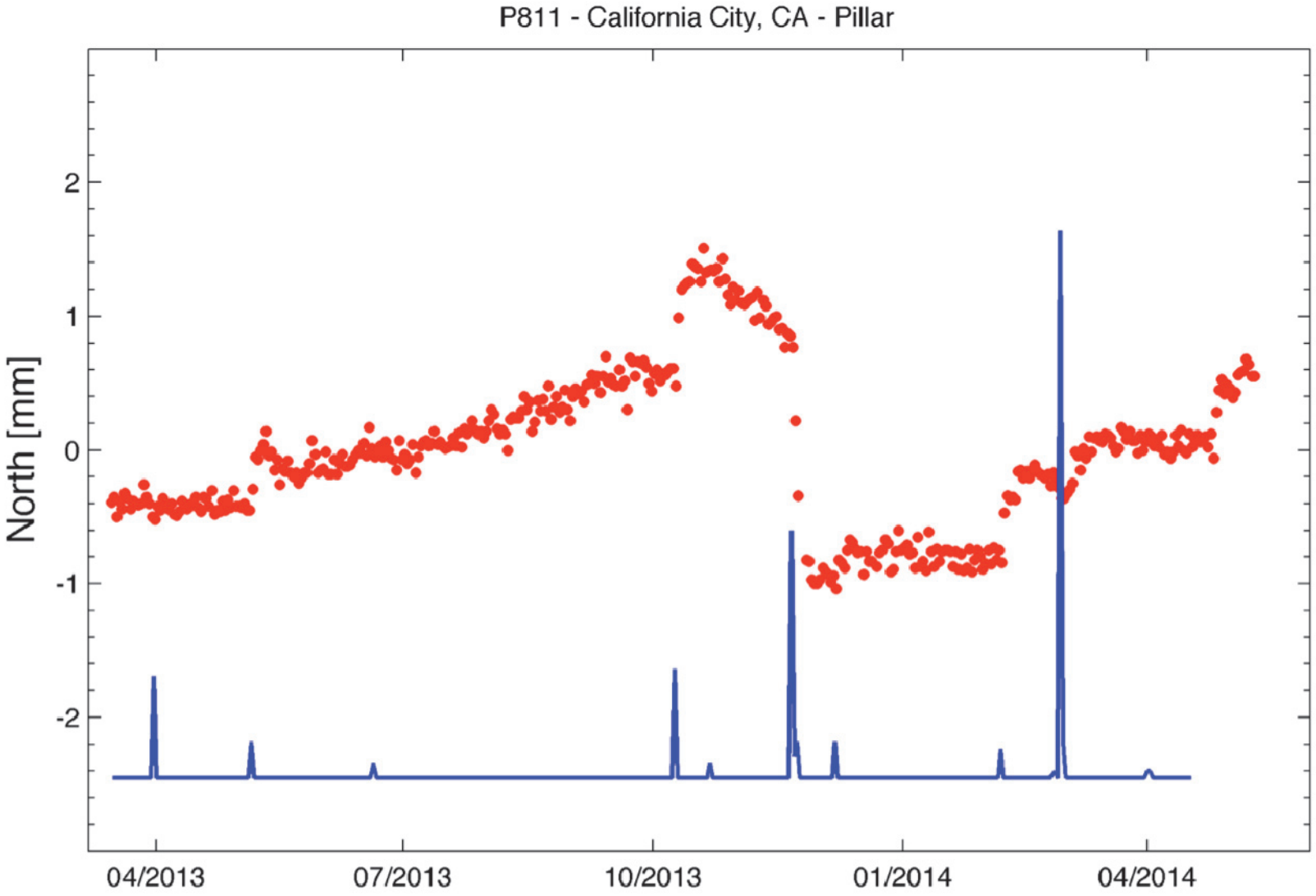
Colors:

Brown and Green are P812 short drilled braced, L1+L2 and LC

Blue and black are P811 pillar, L1+L2 and LC

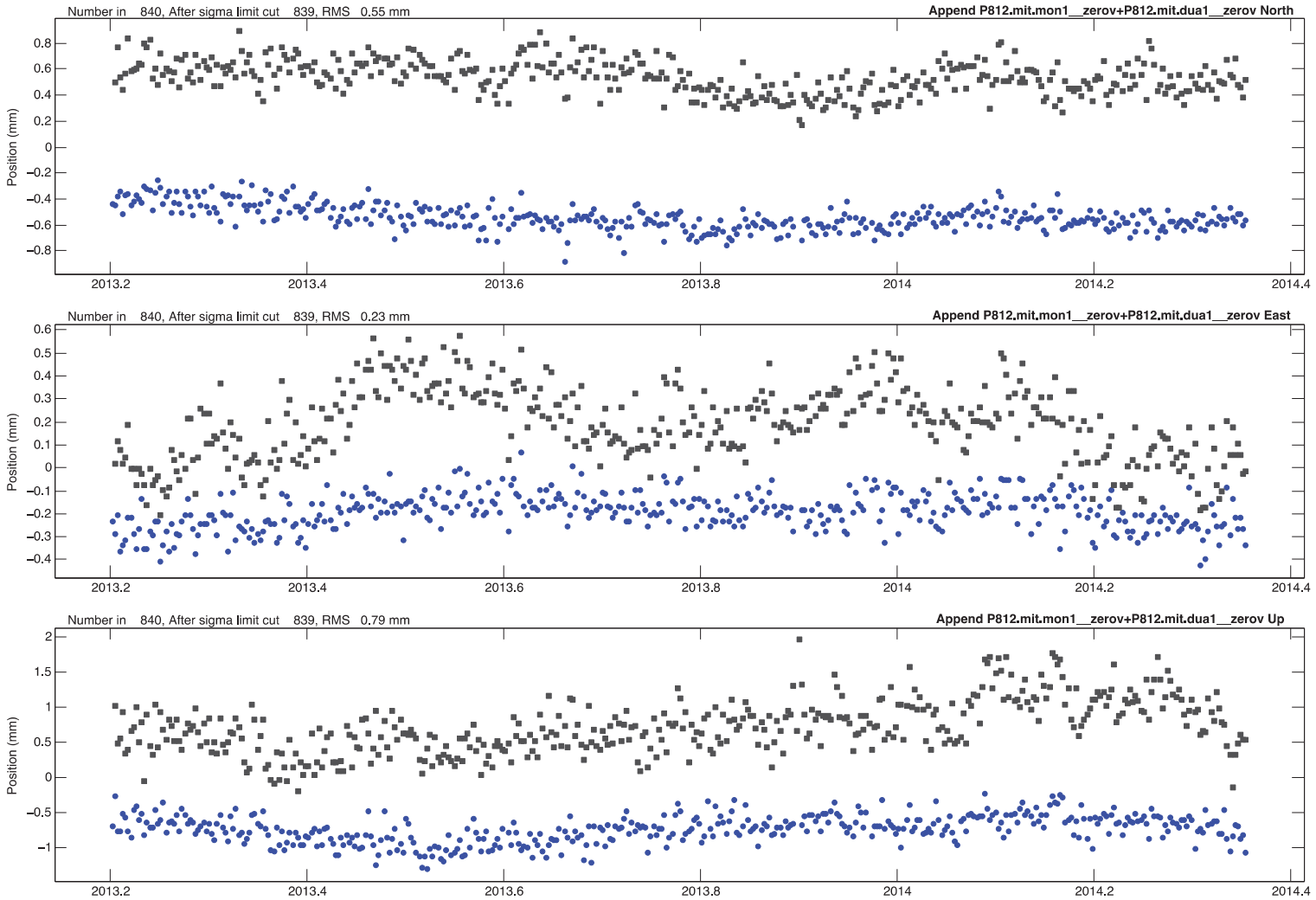
Pillar is unstable at 1 mm level; physical motion implied similar L1+L2 and LC changes. Offset between L1+L2 and LC suggest antenna element centering problem.

Individual sites: P811 Pillar



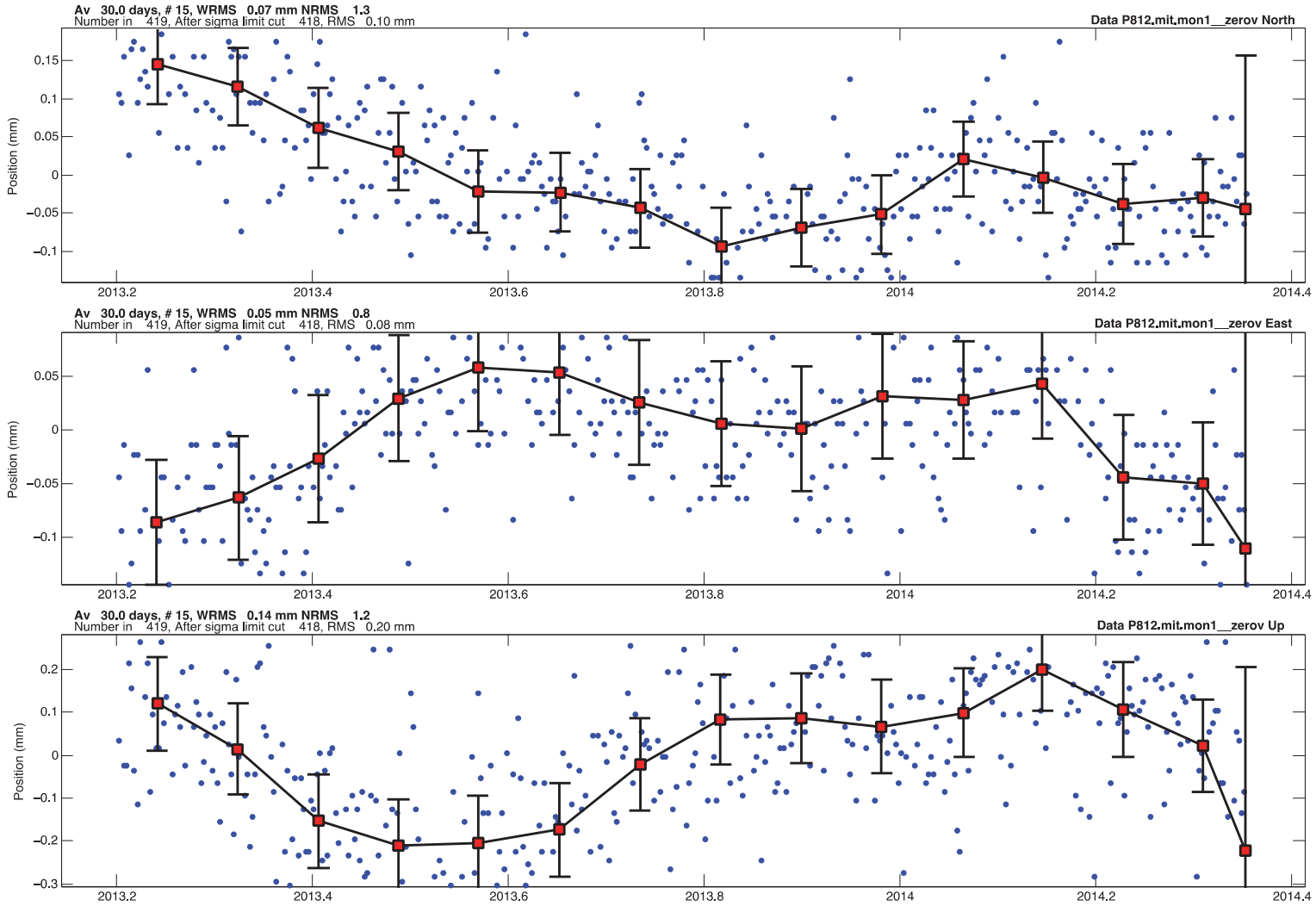
Blue line is rainfall suggesting that the pillar is reacting to soil moisture changes.

Individual Sites P812 short drilled braced



This monument is stable relative to P591 although still some motion at sub-millimeter level. RMS scatters are 0.10, 0.08 and 0.20 mm in NEU for the L1+L2 solution. Difference between L1+L2 and LC 1.1, 0.4 and 1.5 mm in NEU Error bars not shown for clarity. Height variation similar to P811

30-day averages of P812

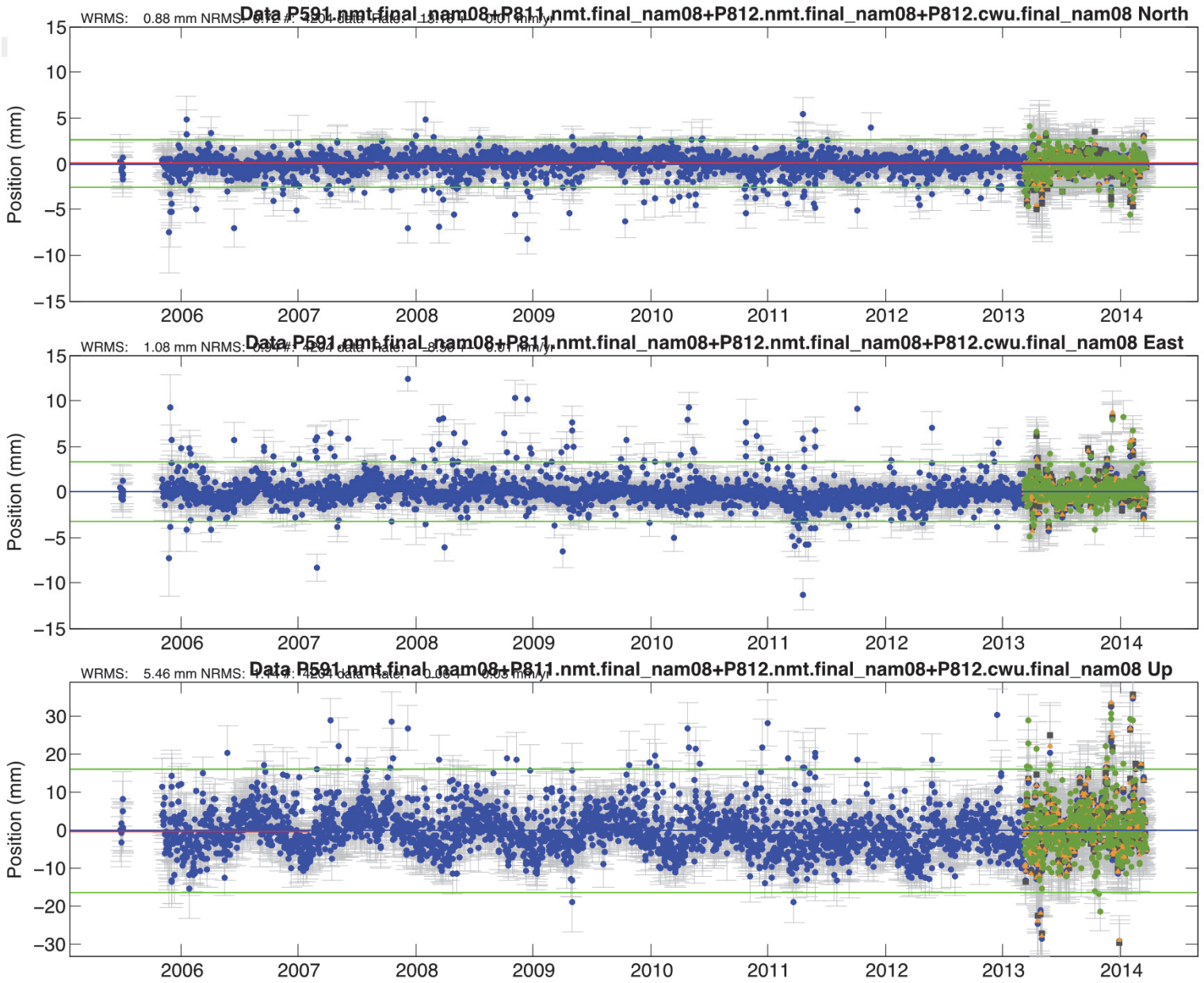


30-day averages show systematics at the 0.15 mm level in N and E; 0.2 mm in U RMS of 30-day averages: 0.07, 0.05 and 0.14 mm in NEU

If trend and annual removed RMS reduce to 0.02, 0.03 and 0.05 mm.

Long term view: Standard processing

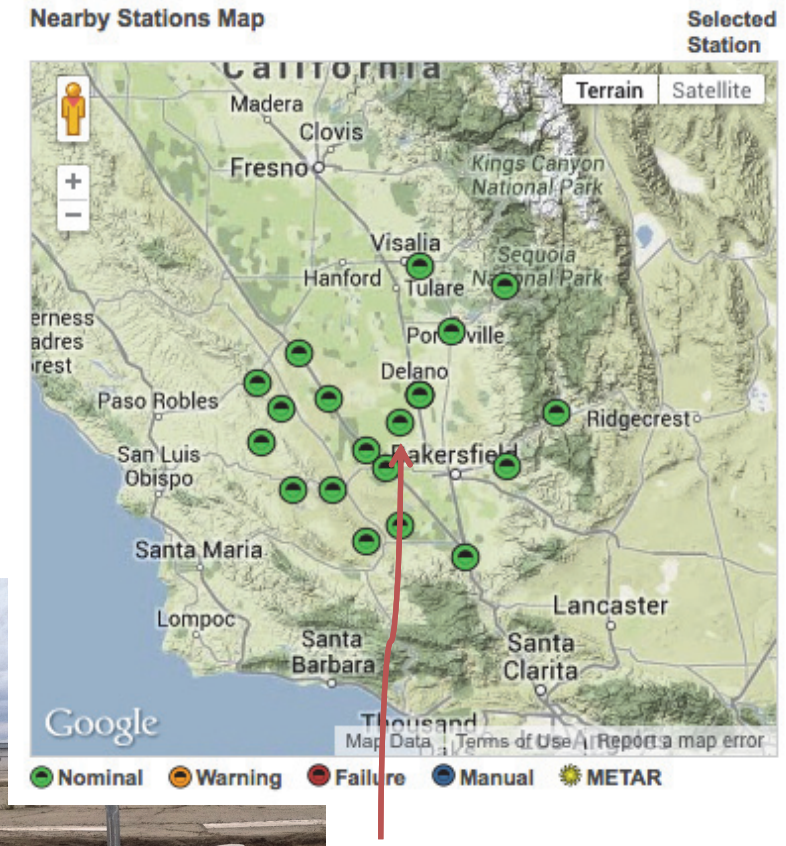
http://pbo.unavco.org/station/overview/P591



Results for standard UNAVCO GAGE project processing. These are available on web.
Linear trend removed. RMS scatters 0.9, 1.1 and 5.5 mm in NEU

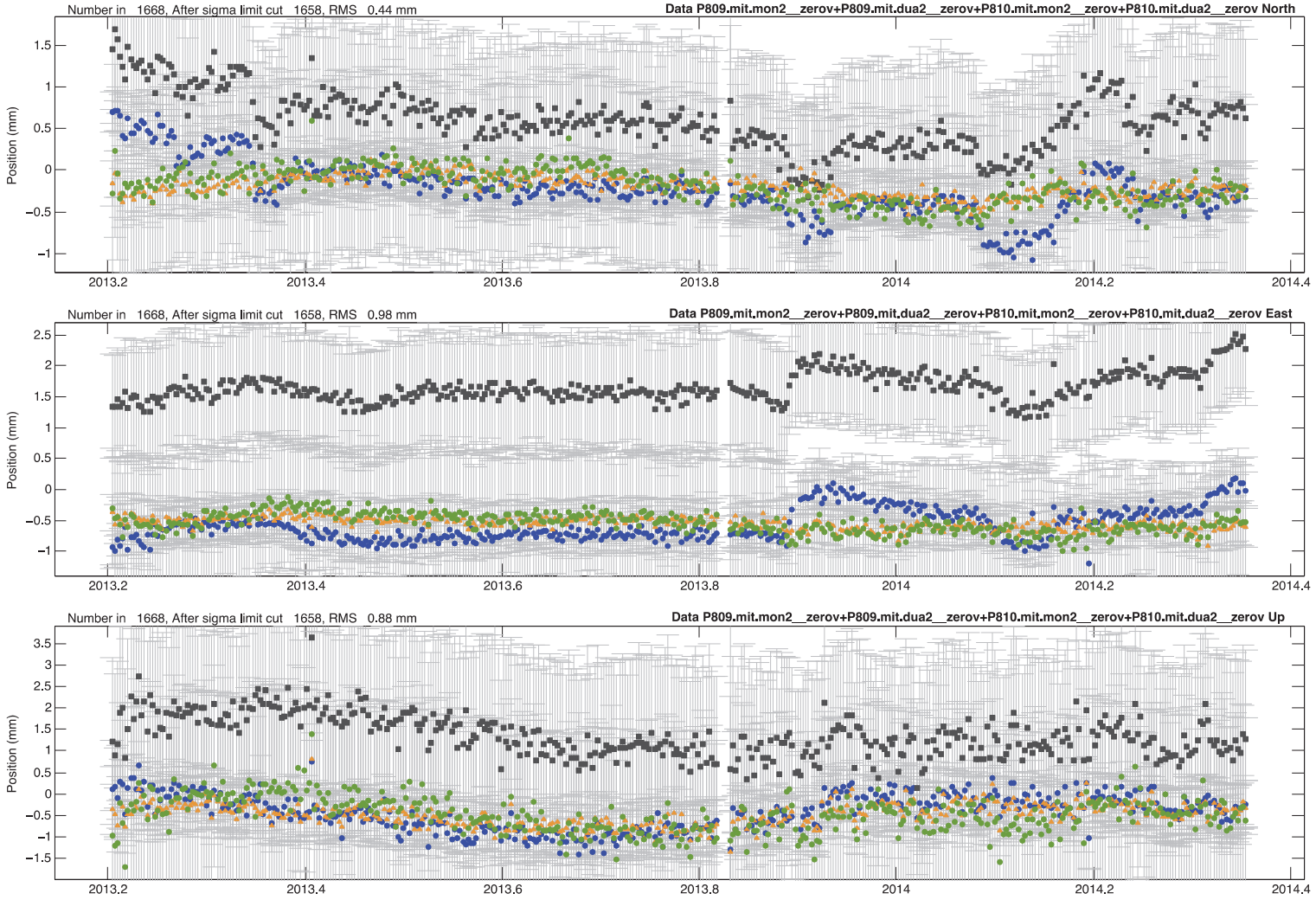
P565+P809+P810 GPS sites

- P565: Deep drilled braced monument; P809: Pillar design; P810 short drilled braced monument.



P565 (Central California)

Short baseline results: P565+P809+P810



Again the blue/black pillar monument is less stable relative to deep drilled braced monument than short drilled braced.

Some differences at pillar between L1+L2 and LC

RMS scatters

P809: 0.35, 0.22 0.46 mm

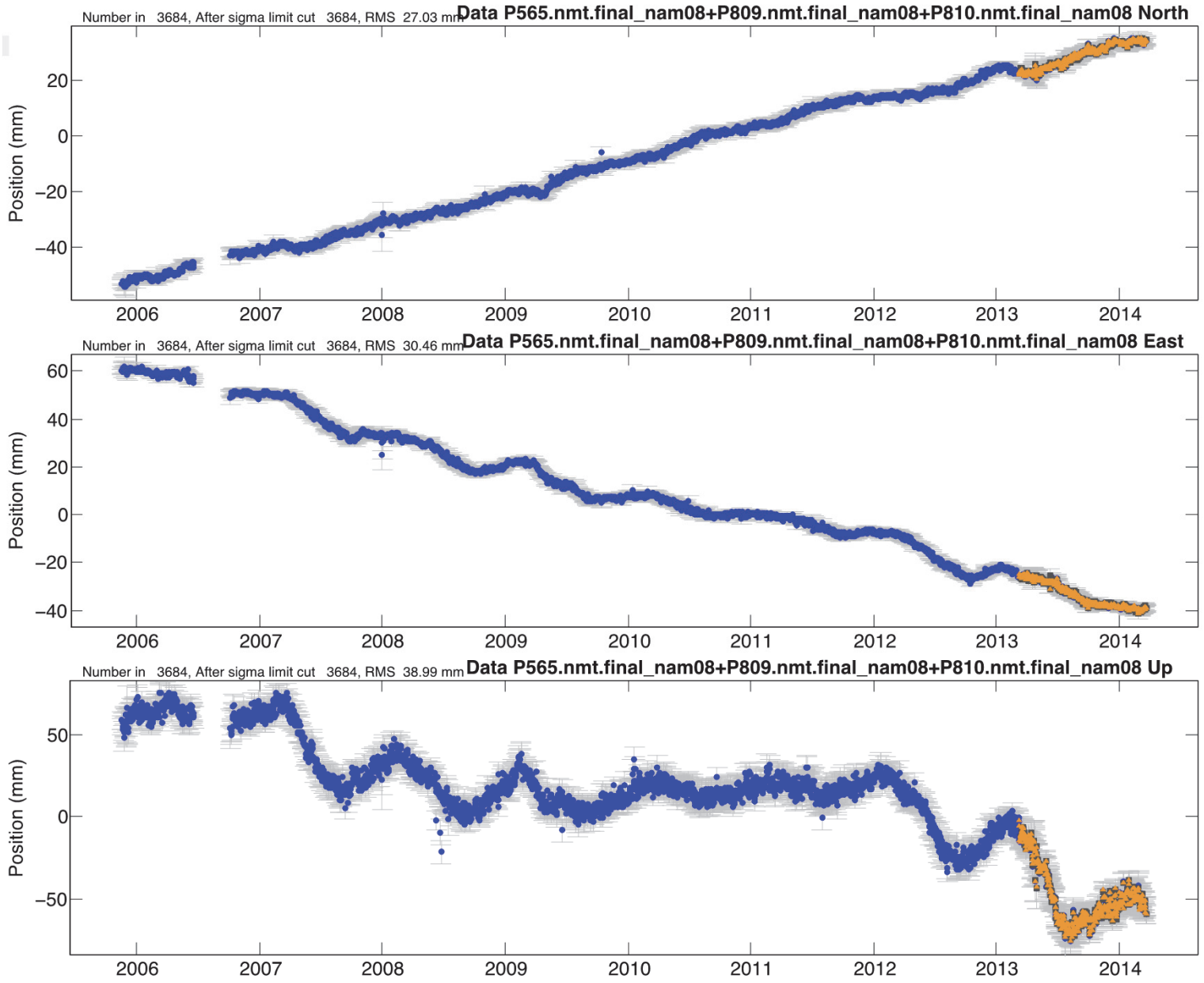
P810: 0.18, 0.13, 0.36 mm

NEU

Offset between L1+L2 and LC

Long term P565

http://pbo.unavco.org/station/overview/P565

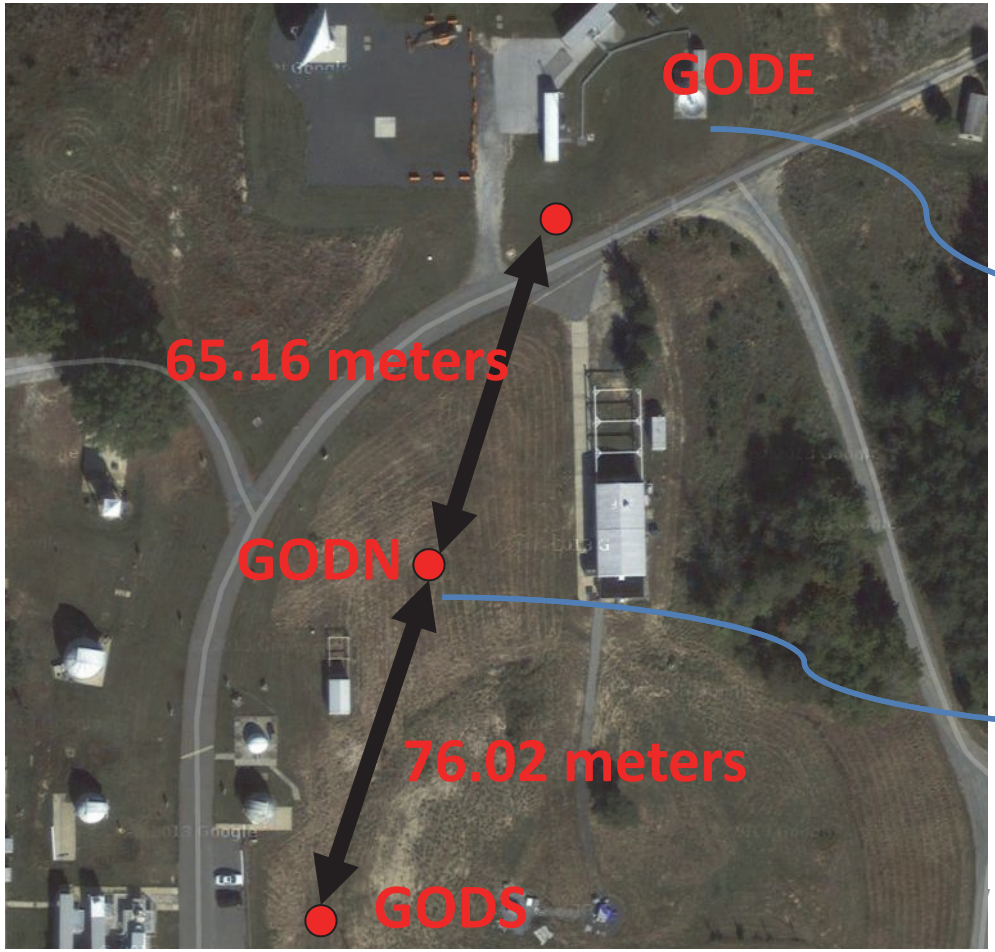


Sites are in the Central Valley of California and there are large non-secular motions due to ground water changes (most likely).

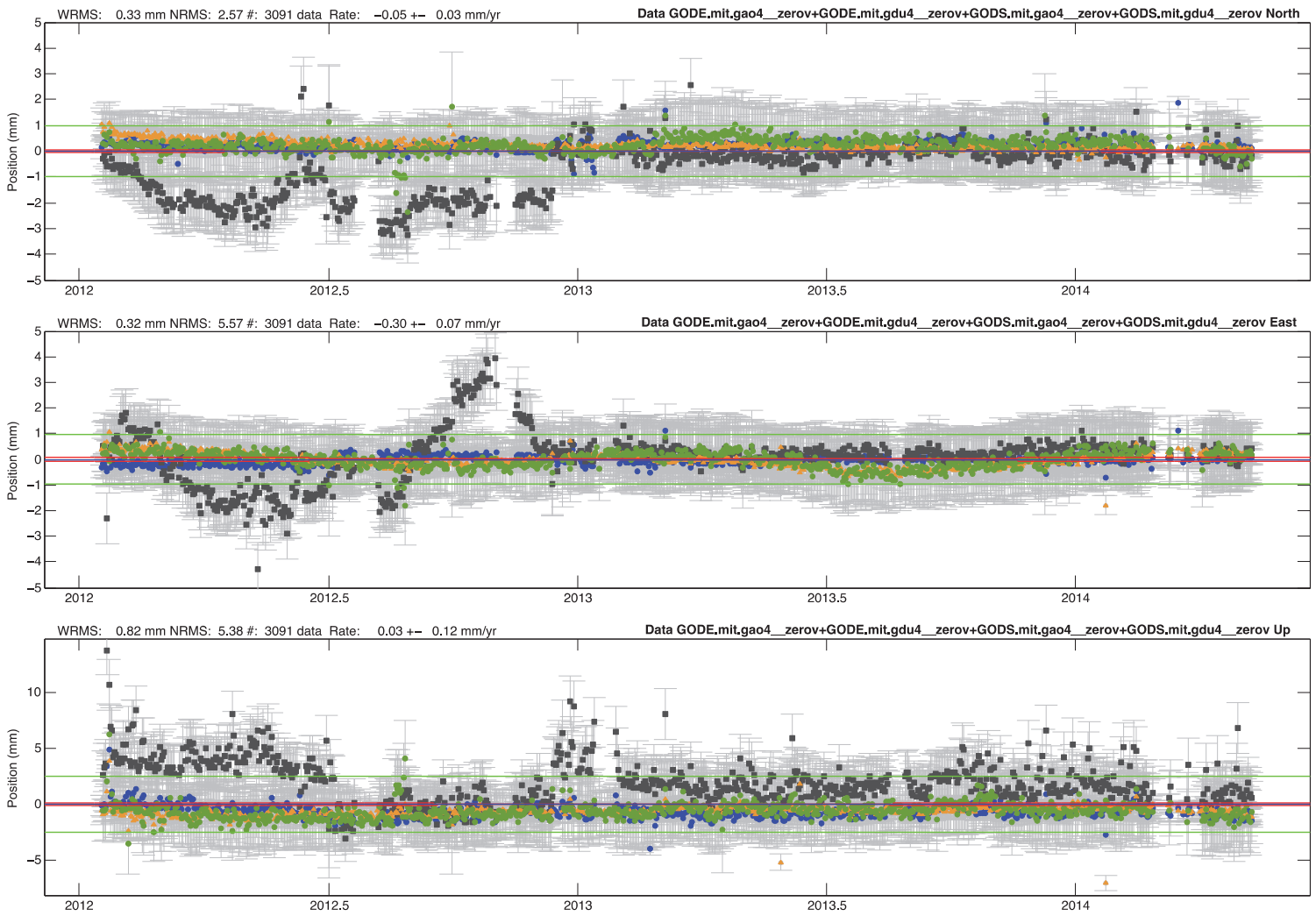
All monuments types see this motion.

Goddard Geophysical and Astronomical Observatory

- GGOS core site with VLBI, SLR and GNSS
- Multiple GNSS sites at facility: The original GODE/GODZ site and two drilled braced monuments GODN and GODS (north/south)



GODE/GODS relative to GODN

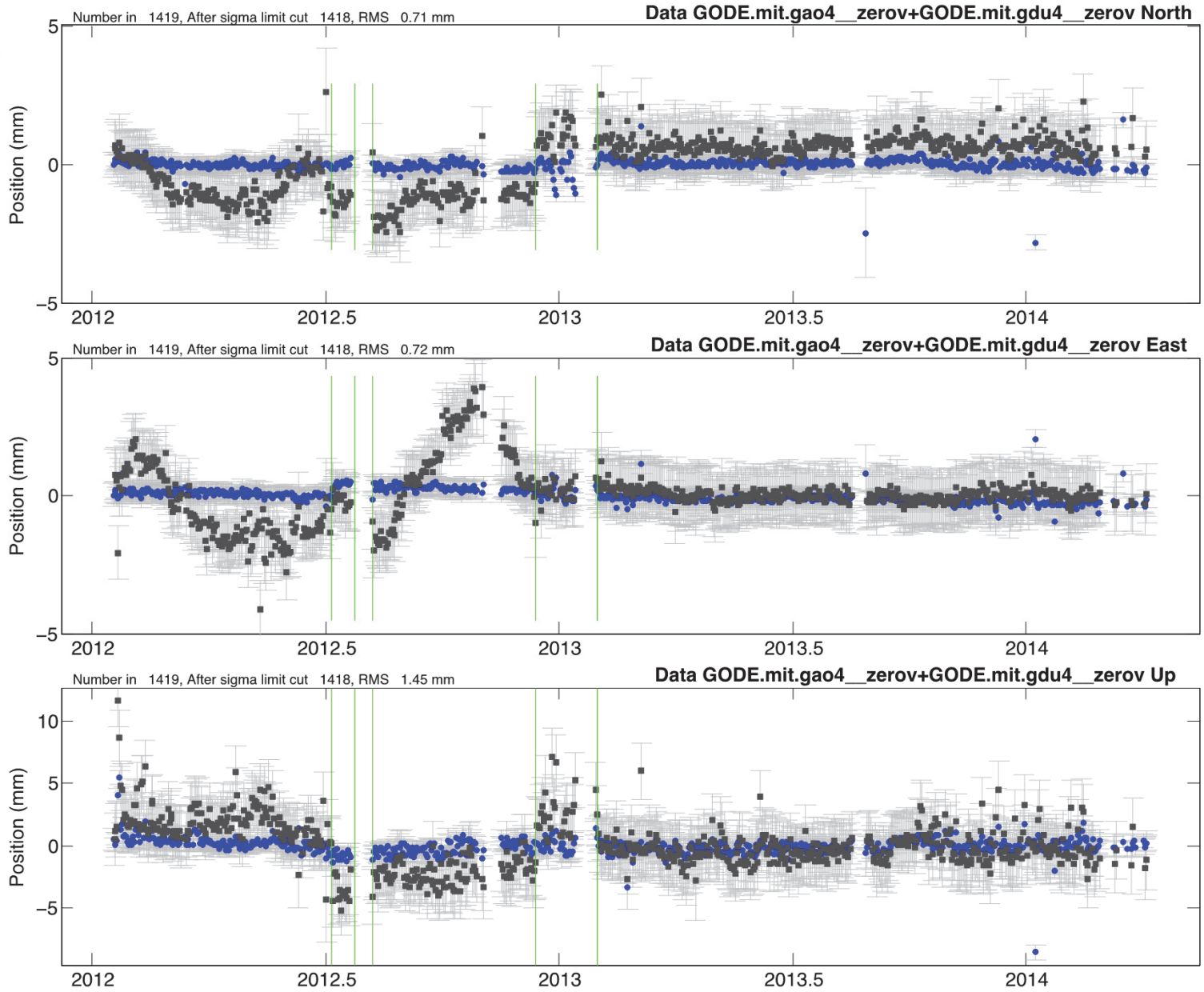


Blue and black are L1+L2 and LC solution for GODE.

We see large differences between the two solutions suggesting electrical phase center errors.

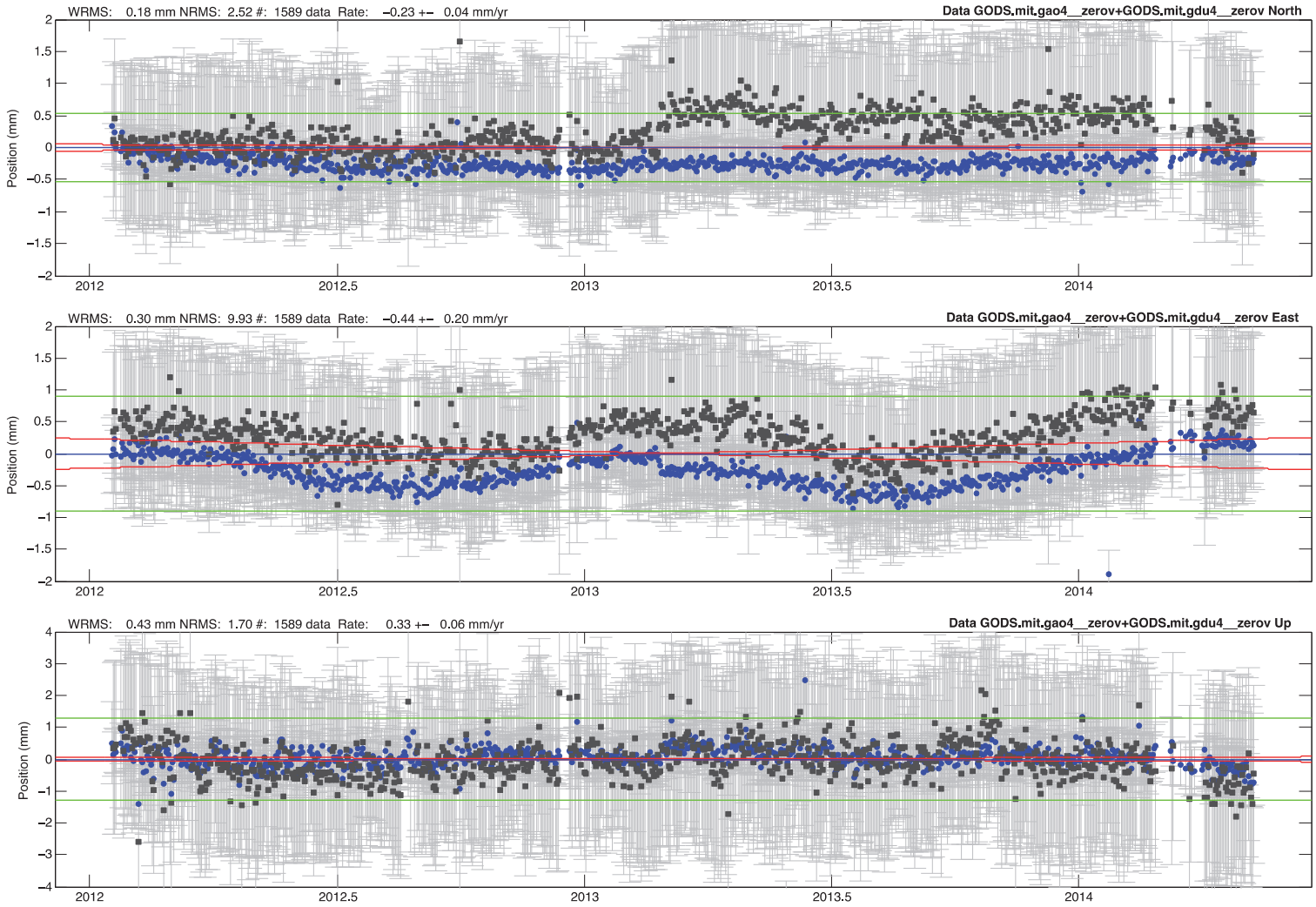
Green lines are antenna and dome changes.

GODE L1+L2 and LC solutions



The L1+L2 solution shows small variations but as the antenna and radome are changed we see effects in LC solution.
We are still checking that correct antenna types were used (different logs have different information).

GODS L1+L2 and LC solution



Relative positions between two drilled braced monuments at GGAO.

In this case we see both electrical and presumably physical motions of sites.

RMS scatters are still 0.2, 0.4, and 0.5 mm but still systematic

Mean difference 0.5 NE, -0.08 U

Conclusions

- Monument stability studies show that there can be “motions” over short distances and in trying to achieve mm level positioning these motions need to be considered.
- We looked at
  - Electrical “phase center” stability (enhanced with ionospheric delay free solution) and
  - Physical stability with L1+L2 solution.
- Some monument types show millimeter level motions (pillars mostly but not always) and some good monuments (drilled braced in the cases shown) have stability at the 10s of micron level.