

Examples using track

M. A. Floyd T. A. Herring

Massachusetts Institute of Technology, Cambridge, MA, USA

GNSS Data Processing and Analysis with GAMIT/GLOBK and track

Virtual (online only) hosted by EarthScope

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http://geoweb.mit.edu/gg/courses/202407_EarthScope/

Material from R. W. King, T. A. Herring, M. A. Floyd (MIT) and S. C. McClusky (now at ANU)

Outline

- Kinematic examples
 1. GNSS seismology
- Kinematic/static example
 2. Rapid deformation
 3. Episodic and continuous deformation
- Static examples
 4. Short-static occupations
 5. Deciphering interference
- Remember the rule-of-thumb for proportional errors:

$$\epsilon_{BL} \sim \epsilon_{SV} \times BL/h_{SV}$$

Example 1: GNSS seismology

- April 4, 2010 El-Mayor Cucapah earthquake in Baja California
 - 5-Hz results
 - Look later at long baseline processing for these sites
- Track results are generated in two steps:
 - First solution uses zero process noise except during time of earthquake (long baseline solution)
 - Final results generated with fixed ambiguities from first solution read in (-a option)
 - Long baseline ambiguity resolution with stochastic site coordinates needs LC estimate which can be noisy due to stochasticity

Zoom around border

Sites near the epicenter.

Blue circle is 60 km radius

Displacements

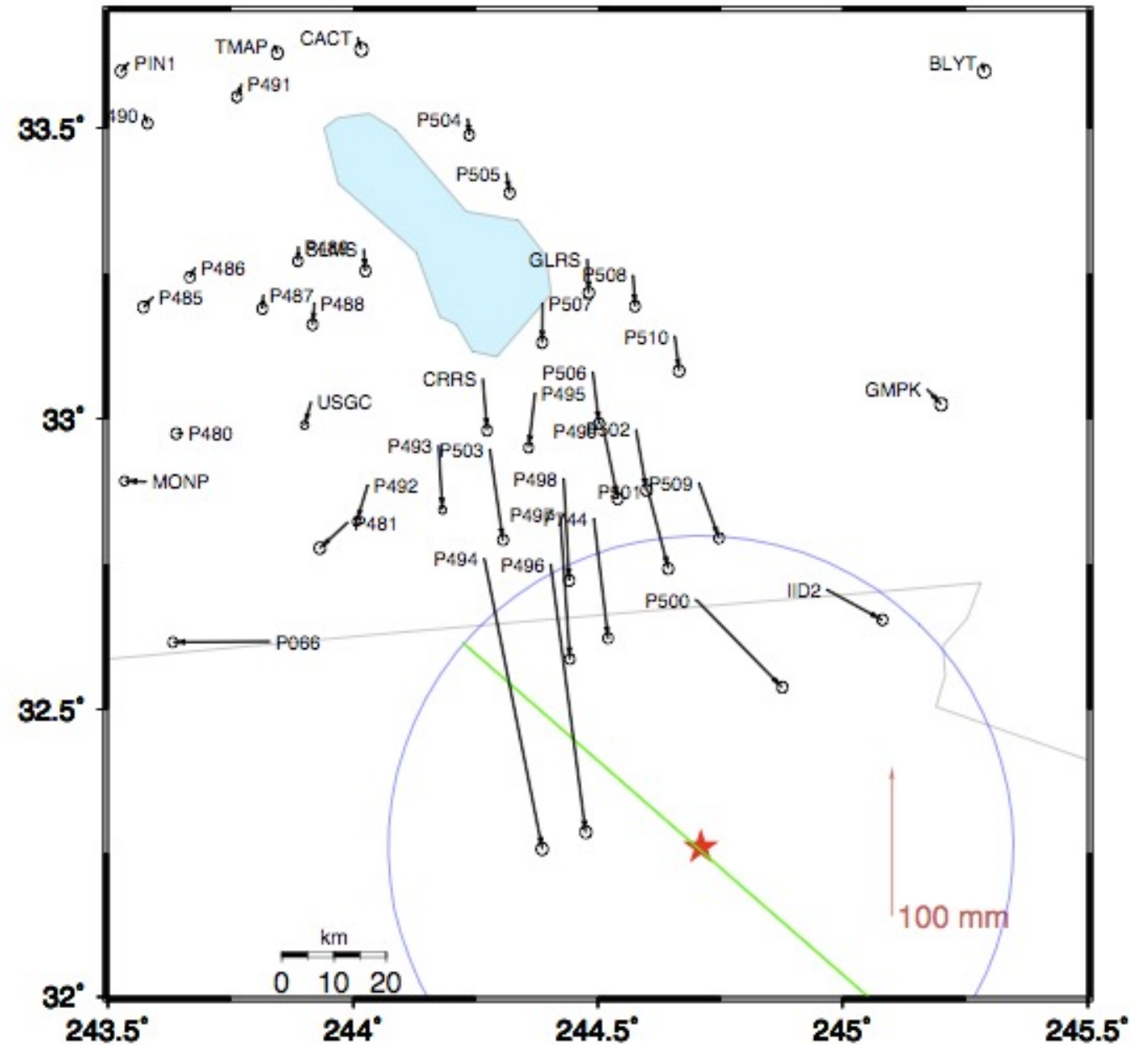
P494 200 mm

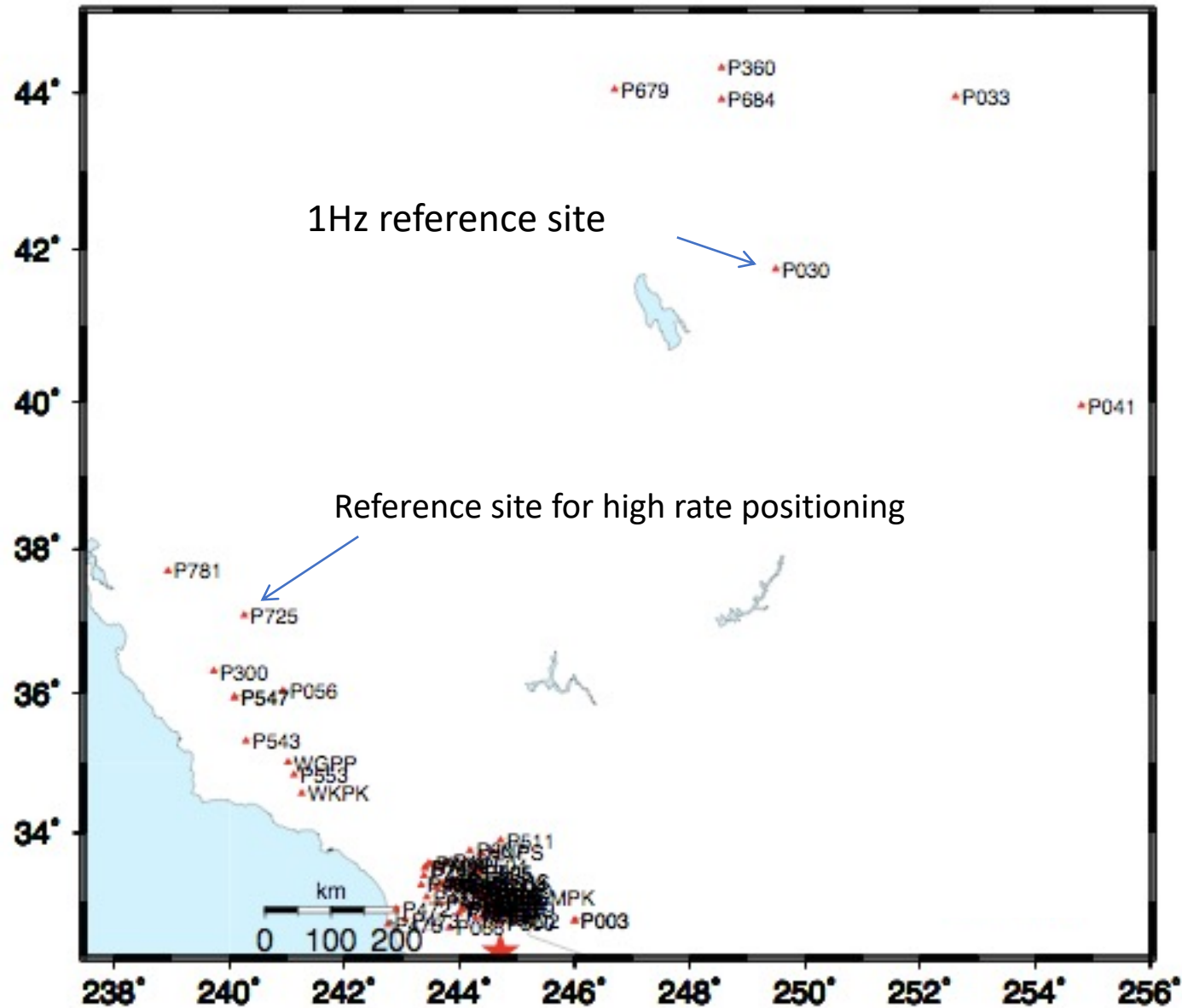
P496 182 mm

P497 97 mm

...

P491 9 mm

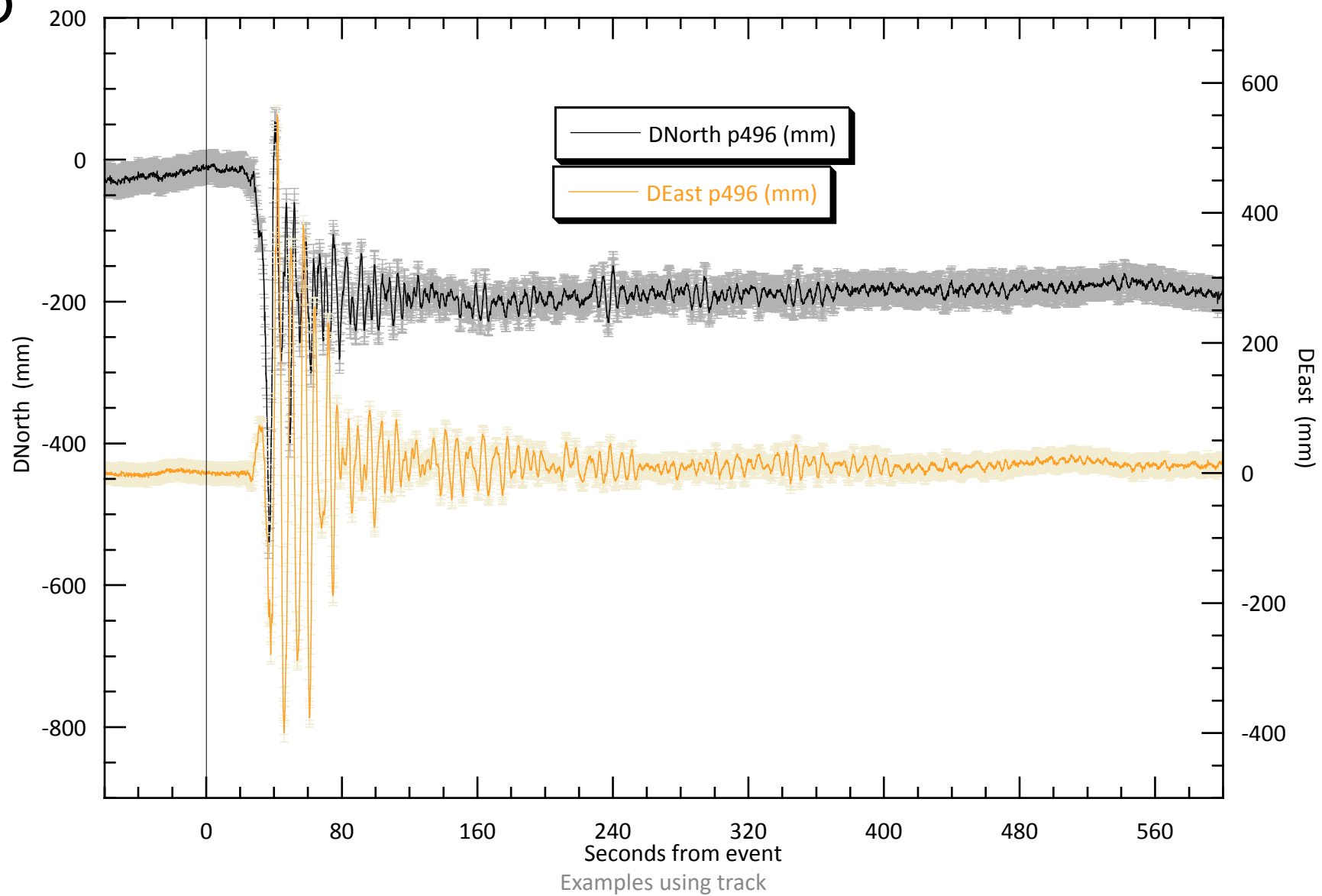




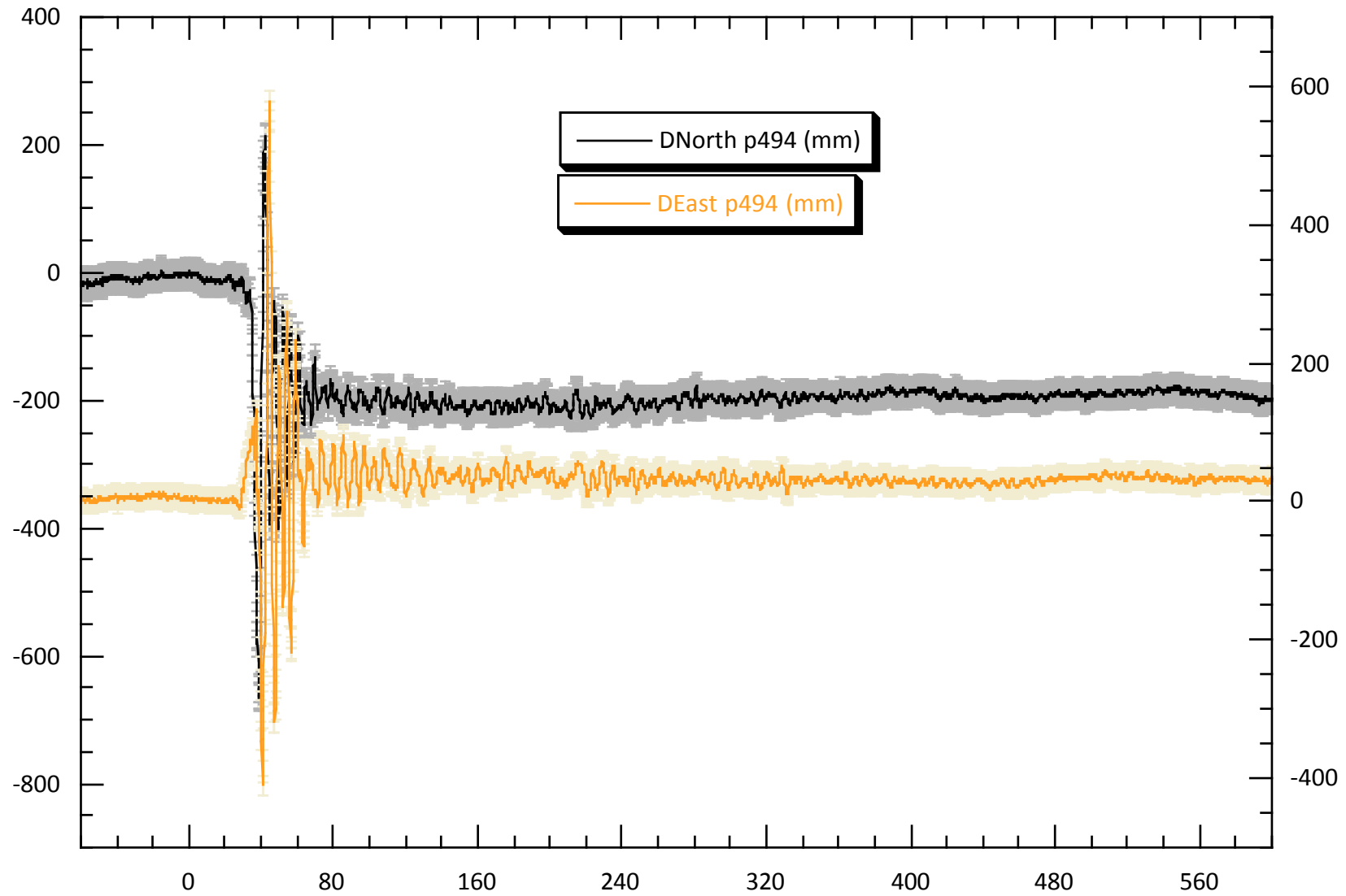
High-rate GNSS site download

- High rate data from these sites downloaded after event.
- Most sites are 5-Hz; more distant sites are 1-Hz.

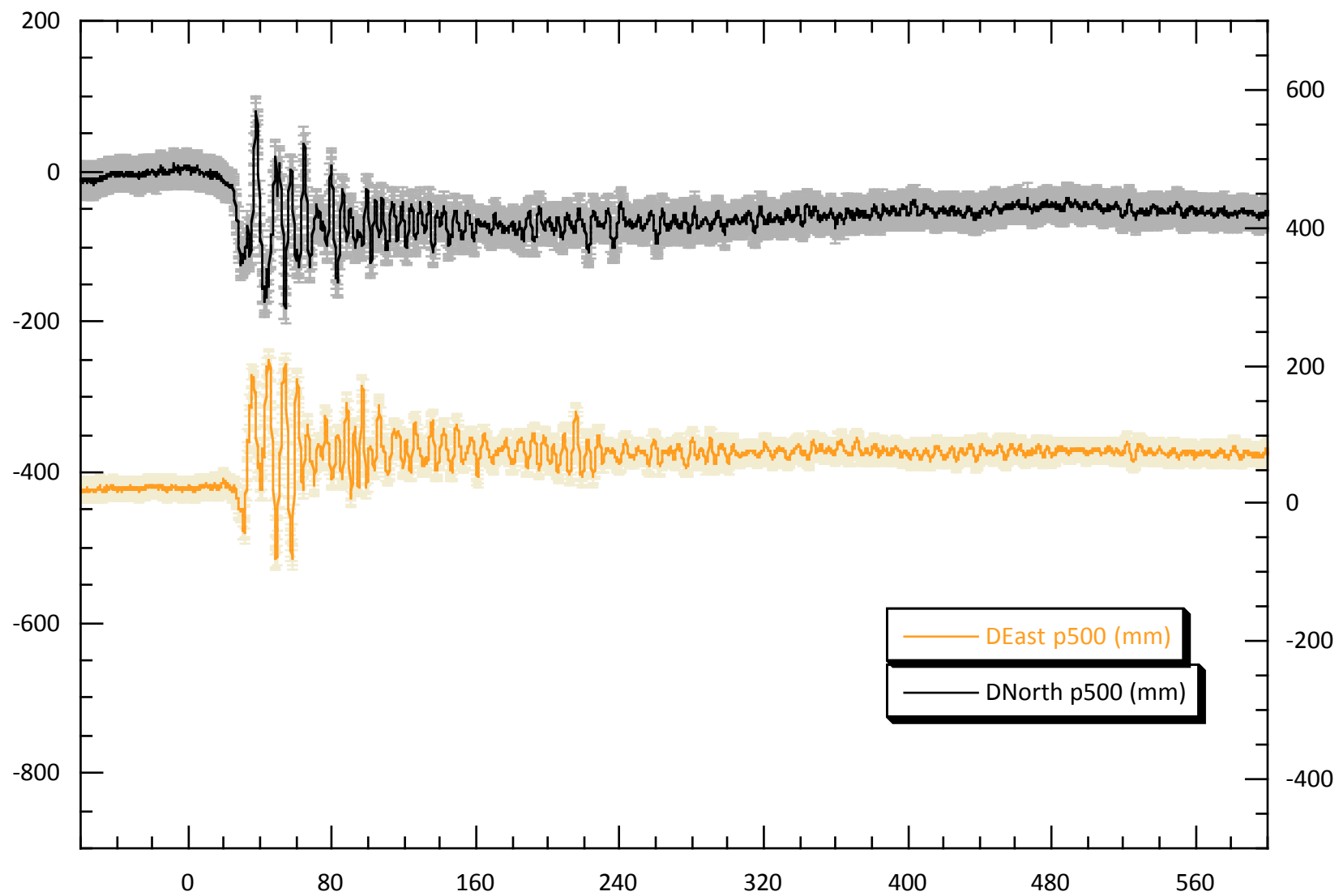
P496



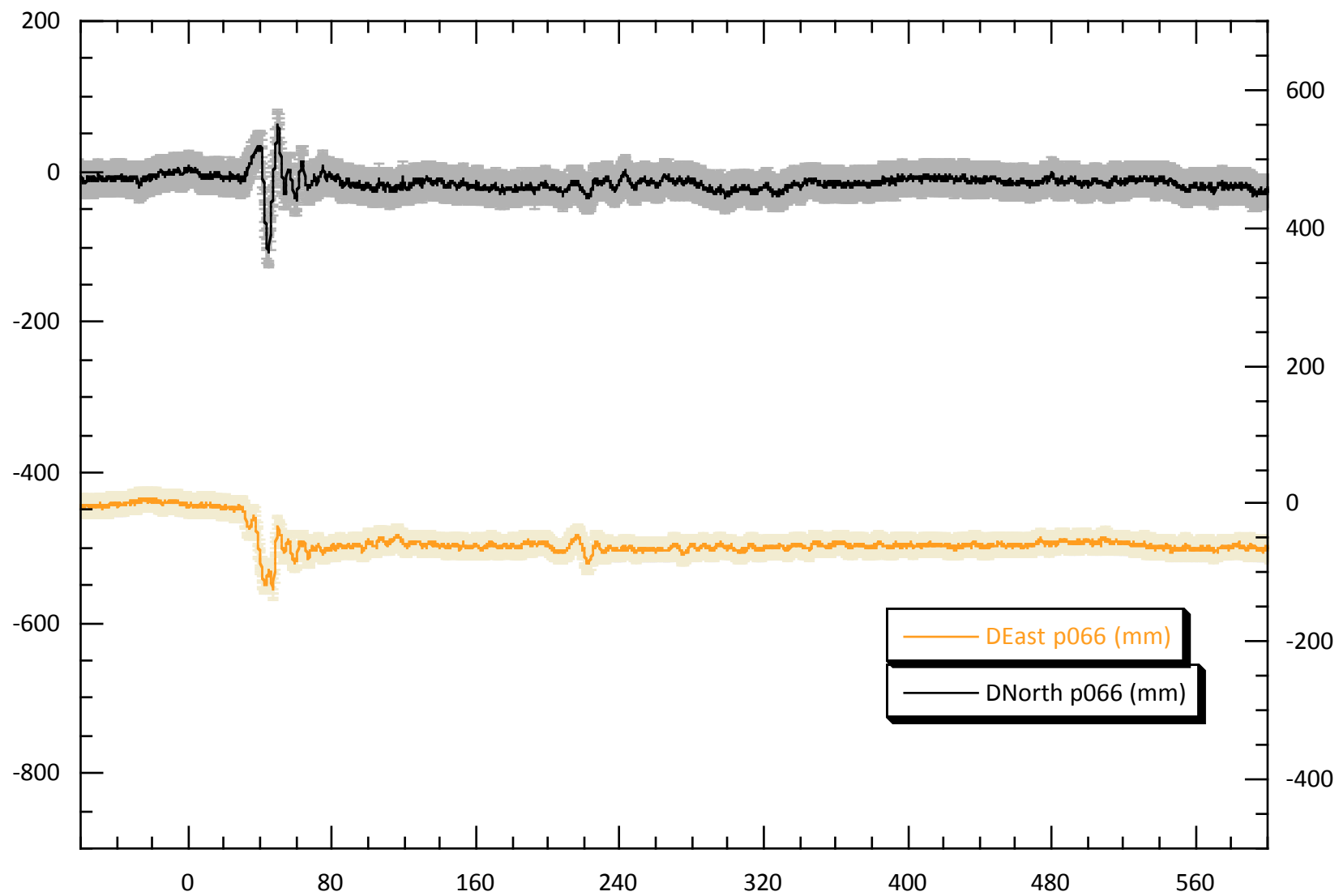
P494



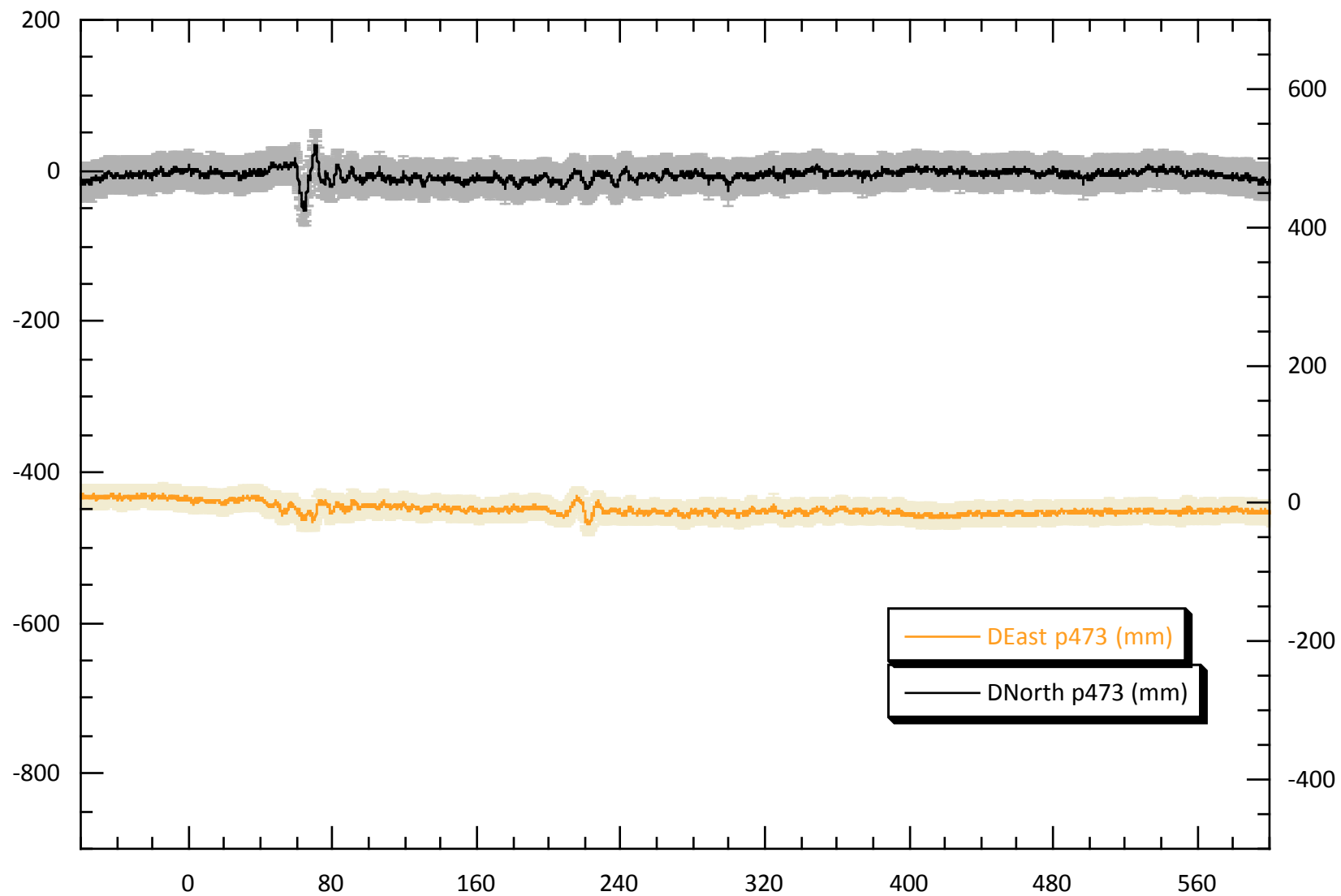
P500



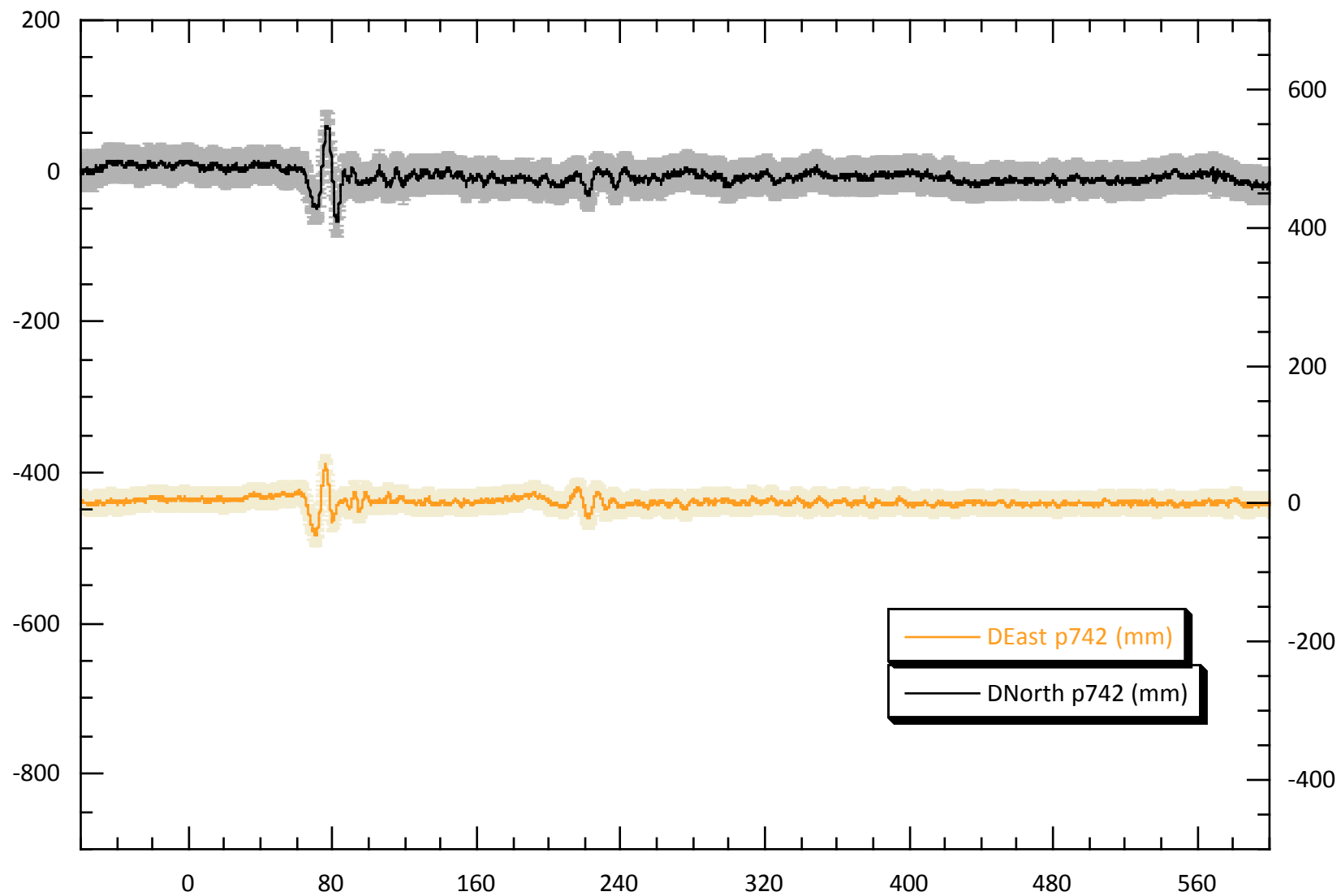
P066



P473

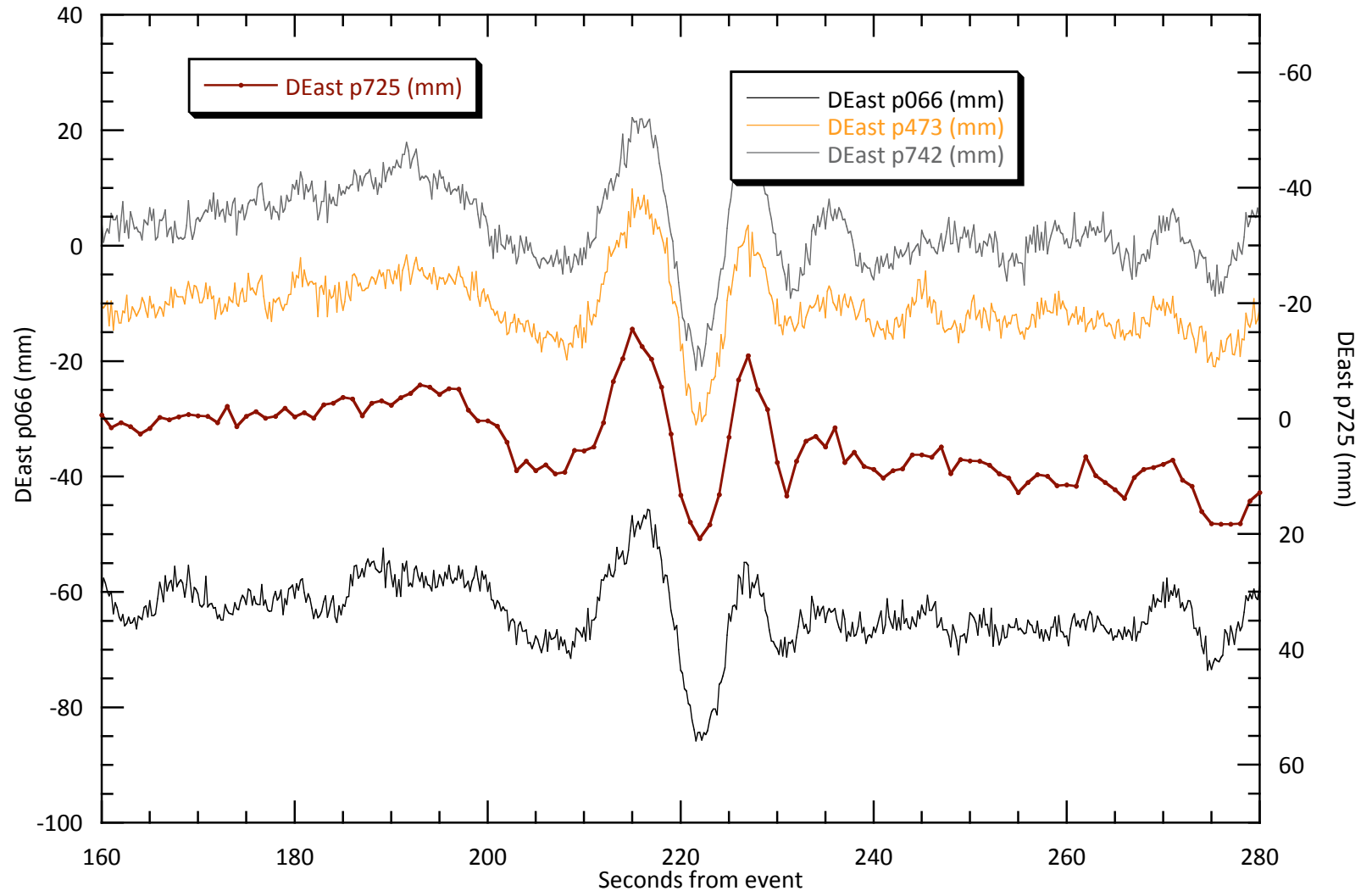


P742



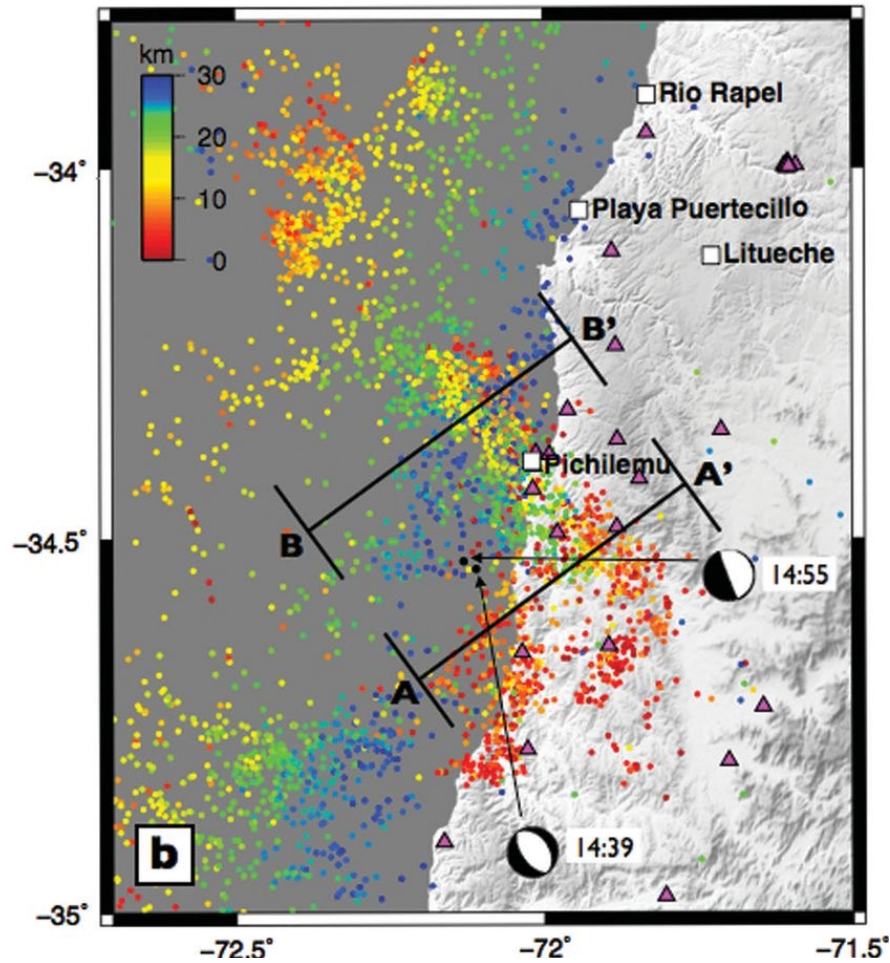
Surface wave arrival at P725

- P725 is ~600 km from epicenter. This signal common to sites is the arrival at the “reference site”



Example 2: Rapid deformation

(from Ryder et al., 2012)

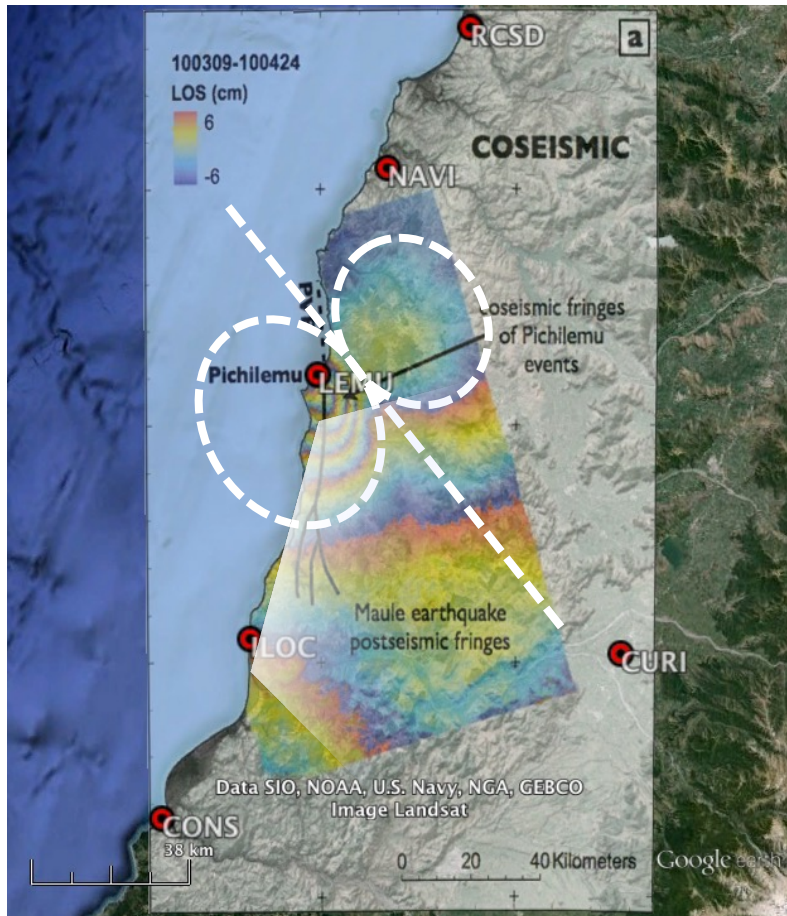


Ryder et al. (2012), Figure 1

- Two earthquakes within 15 minutes of one another
- InSAR shows cumulative deformation with no way to separate events
- Epoch-by-epoch (rather than batch) GNSS processing may help...

Example 2: Rapid deformation

(from Ryder et al., 2012)



Ryder et al. (2012), Figure 3a
overlaid in Google Earth

- Selecting fixed site:
- CURI is
 - Further from the main subduction earthquake
 - Outside the deformation zone of the major aftershocks
 - Along the nodal (zero deformation) plane of the major aftershocks

Example 2: Preliminary run

Constrained first runs for ambiguities

- Key track commands:

```

site_stats
iloc 10 10 10 0 0 0
lemu 10 10 10 0 0 0
navi 10 10 10 0 0 0

timedep_procs
iloc 1 1 1 2010 03 11 14 40 29 2010 03 11 14 40 30
lemu 1 1 1 2010 03 11 14 40 29 2010 03 11 14 40 30
navi 1 1 1 2010 03 11 14 40 29 2010 03 11 14 40 30
iloc 1 1 1 2010 03 11 14 55 59 2010 03 11 14 56 00
lemu 1 1 1 2010 03 11 14 55 59 2010 03 11 14 56 00
navi 1 1 1 2010 03 11 14 55 59 2010 03 11 14 56 00
    
```

Second run (updated apr):

```

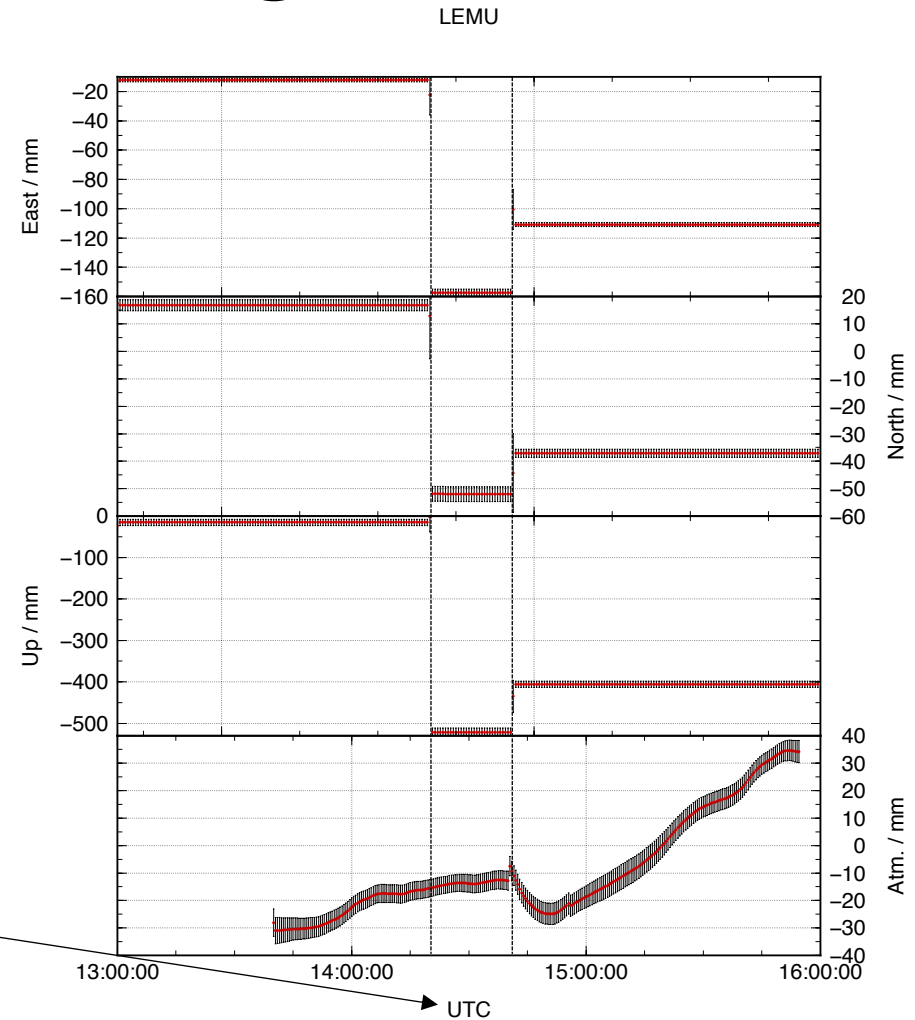
site_stats
iloc 0.02 0.02 0.02 0 0 0
lemu 0.02 0.02 0.02 0 0 0
navi 0.02 0.02 0.02 0 0 0

timedep_procs
iloc 1 1 1 2010 03 11 14 40 29 2010 03 11 14 40 30
lemu 1 1 1 2010 03 11 14 40 29 2010 03 11 14 40 30
navi 1 1 1 2010 03 11 14 40 29 2010 03 11 14 40 30
iloc 1 1 1 2010 03 11 14 55 59 2010 03 11 14 56 00
lemu 1 1 1 2010 03 11 14 55 59 2010 03 11 14 56 00
navi 1 1 1 2010 03 11 14 55 59 2010 03 11 14 56 00
    
```

site_pos

...

N.B. Remember GNSS is in GPS time, not UTC
(need to add leap seconds; axis label is incorrect)



Example 2: Final run

Let the data freely define the noise

Read ambiguities from preliminary, constrained run, e.g

```
grep 'FINAL' <sum-file> > track.amb
```

- Key track commands:

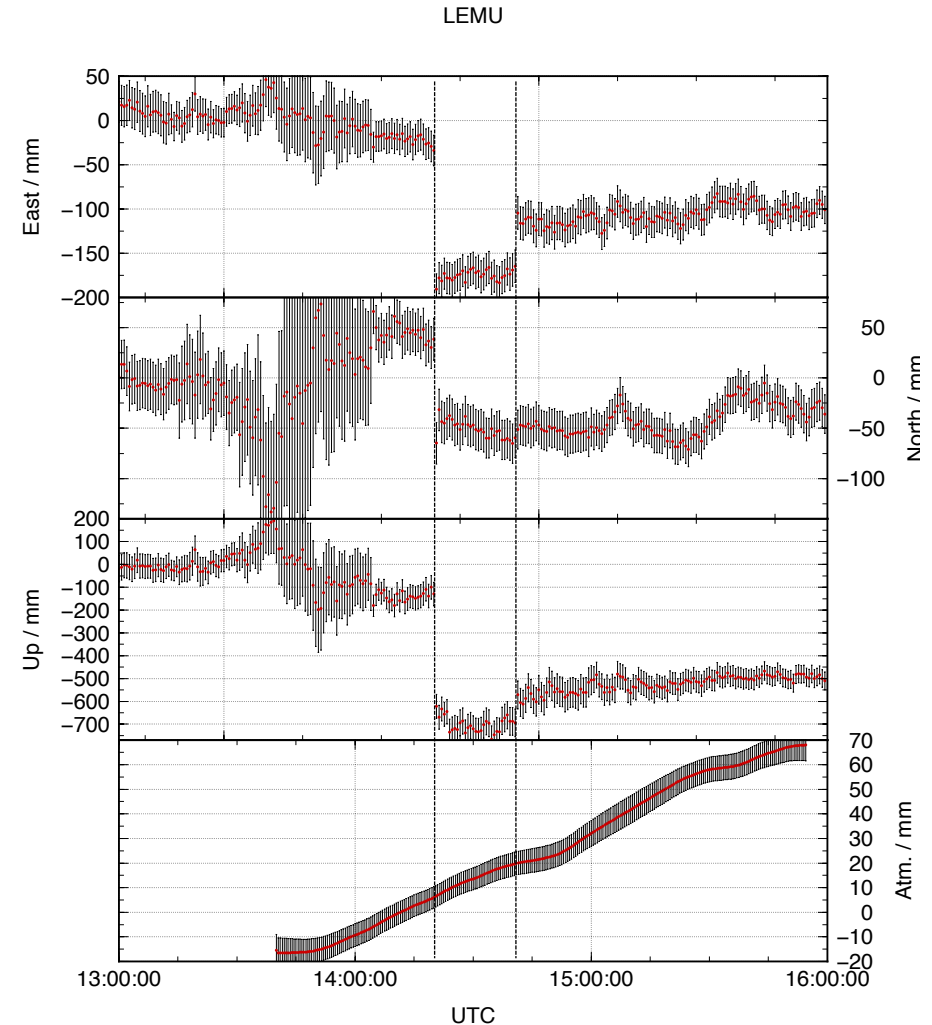
```
site_stats
```

```
iloc 10 10 10 1 1 1  
lemu 10 10 10 1 1 1  
navi 10 10 10 1 1 1
```

```
timedep_procs
```

```
iloc 1 1 1 2010 03 11 14 39 52 2010 03 11 14 40 00  
lemu 1 1 1 2010 03 11 14 39 52 2010 03 11 14 40 00  
navi 1 1 1 2010 03 11 14 39 52 2010 03 11 14 40 00  
iloc 1 1 1 2010 03 11 14 55 35 2010 03 11 14 56 00  
lemu 1 1 1 2010 03 11 14 55 35 2010 03 11 14 56 00  
navi 1 1 1 2010 03 11 14 55 35 2010 03 11 14 56 00
```

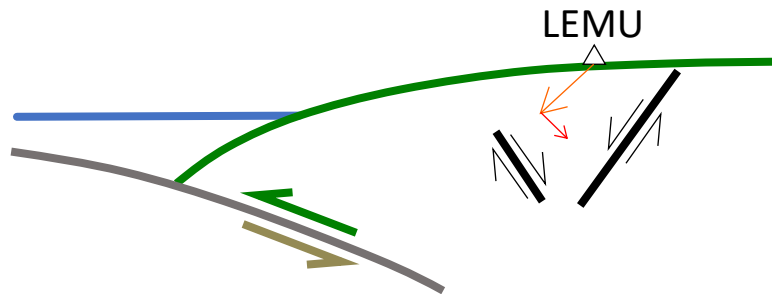
```
ambin_file track.amb
```



Example 2: track alters perspective

Initial hypothesis

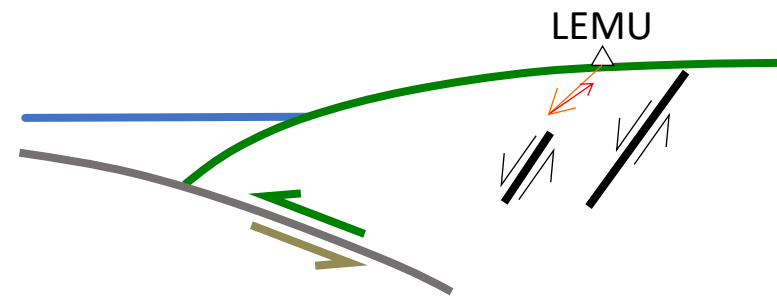
- Earthquakes took place on antithetic normal faults in the upper plate of subduction interface



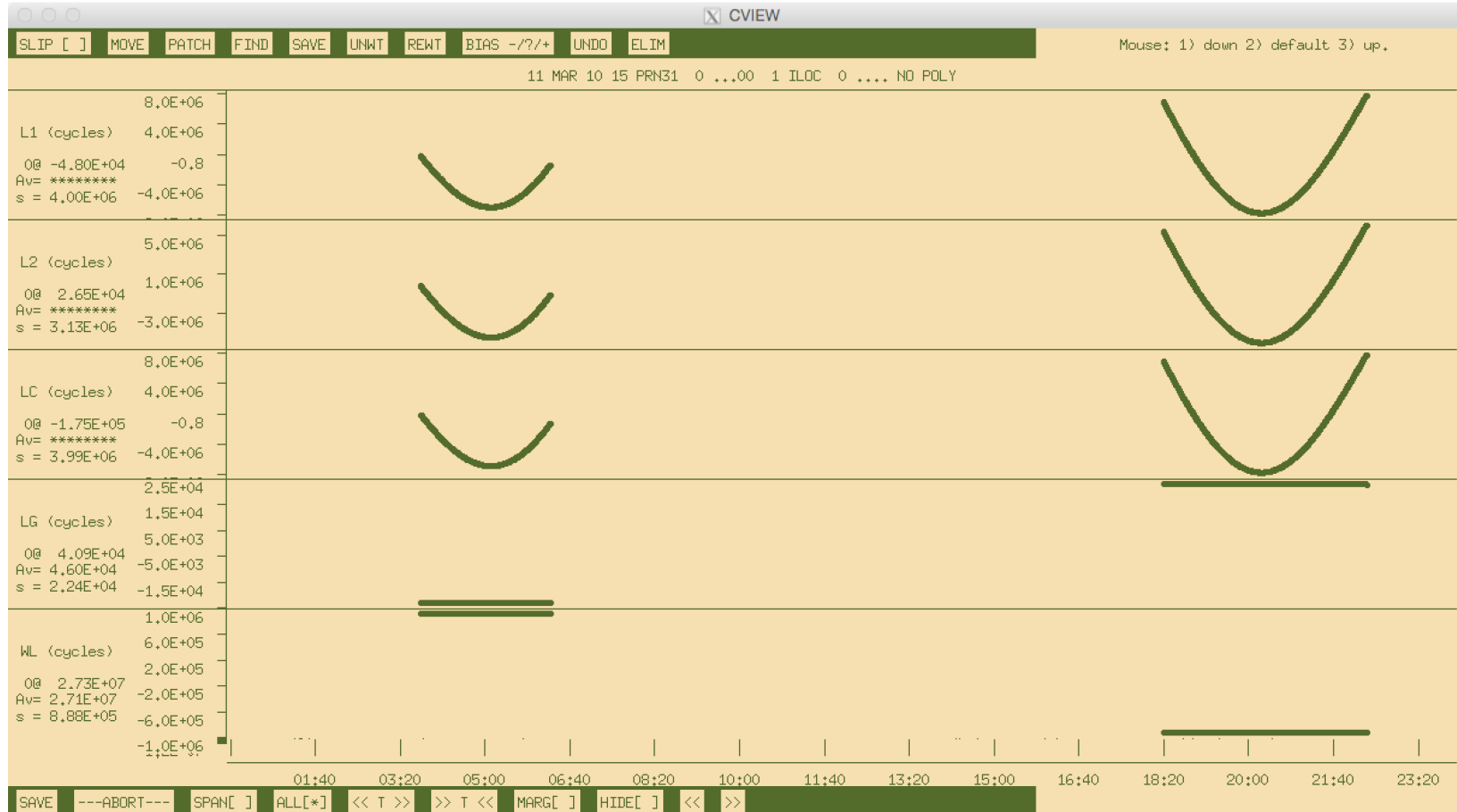
- But cGNSS site LEMU experiences opposite vertical motion due to first and second earthquakes

Final conclusion

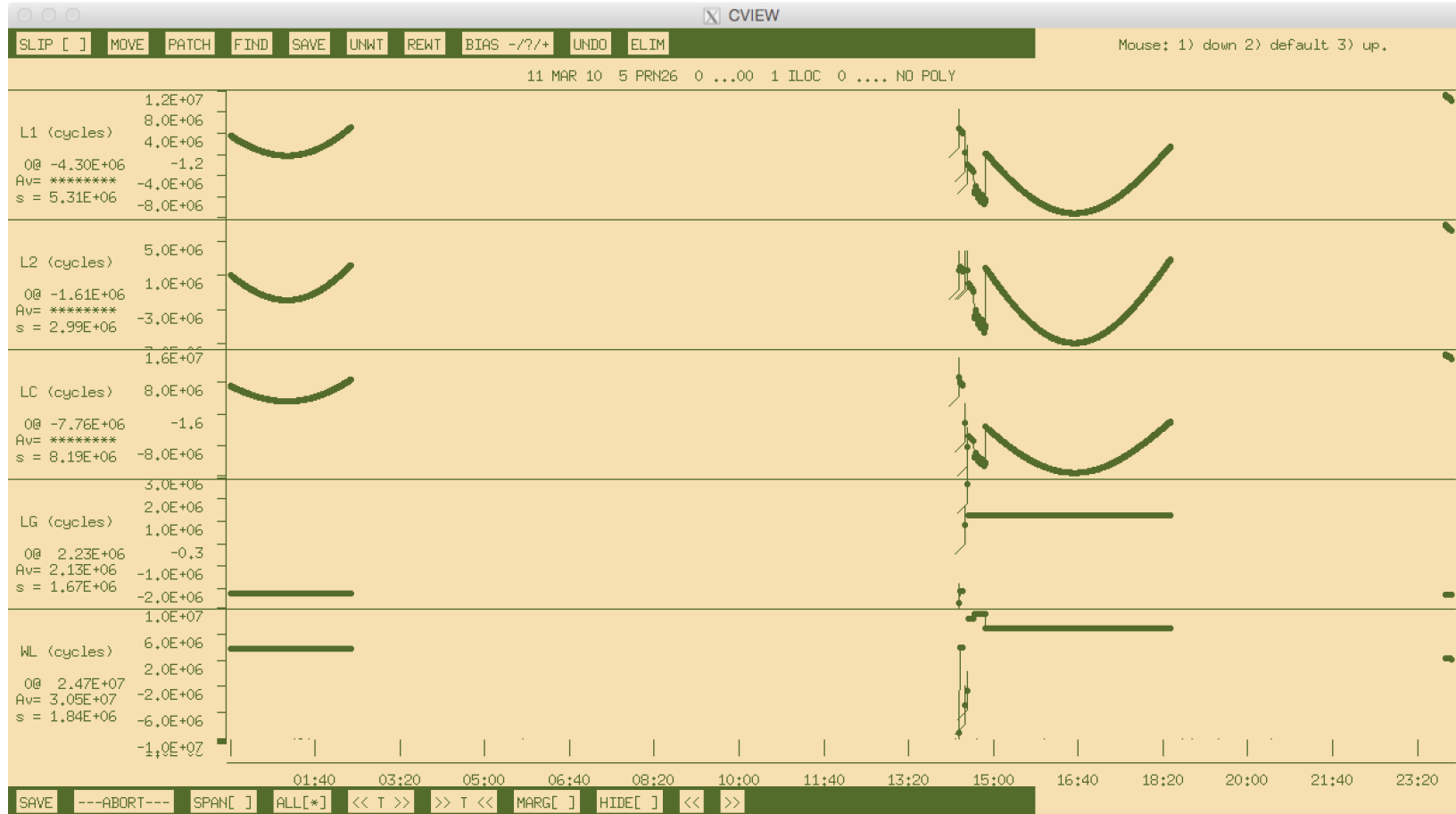
- LEMU is on the hanging wall of first earthquake and footwall of second
- Therefore faults must be synthetic normal faults



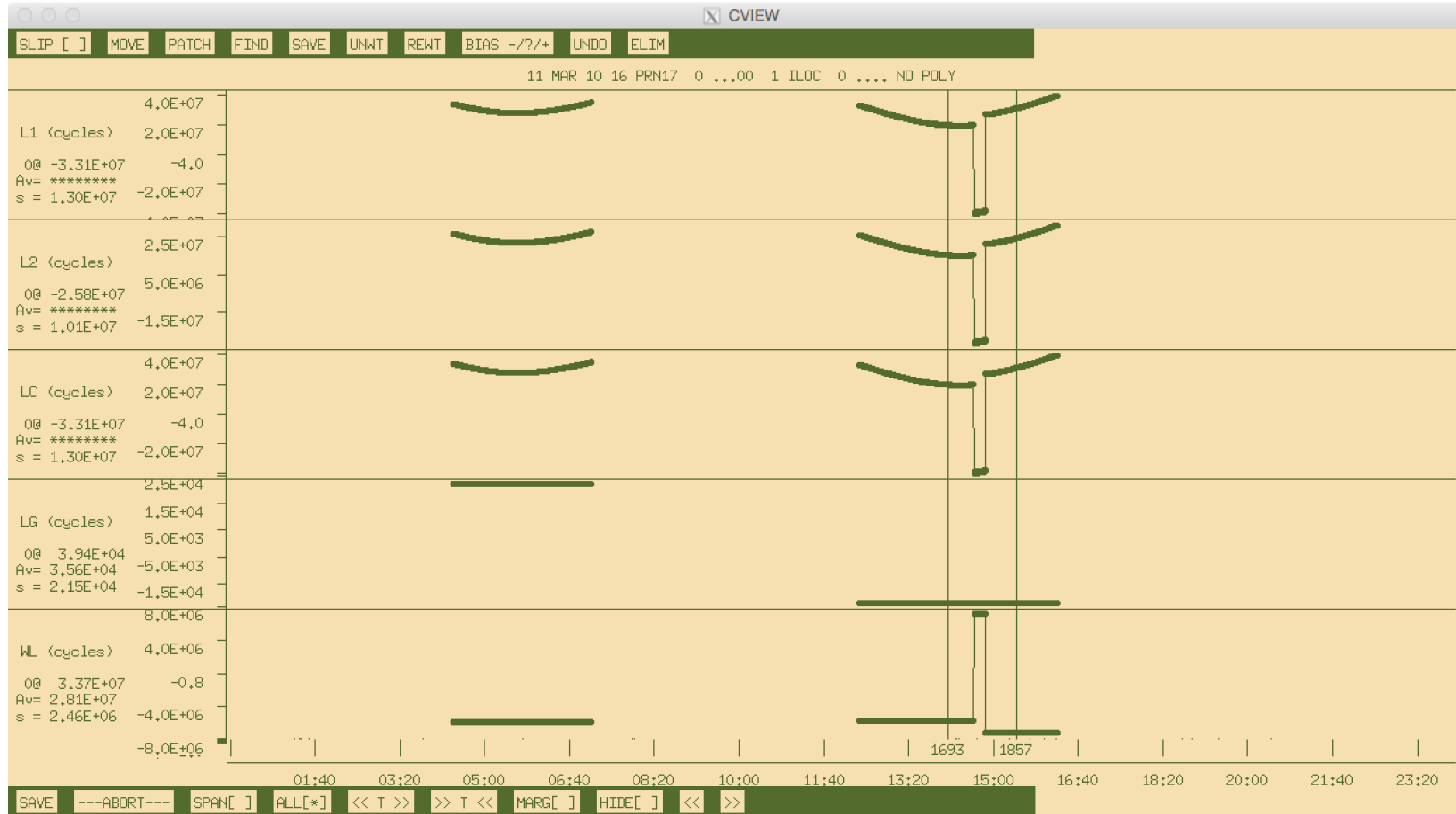
A good satellite in cview



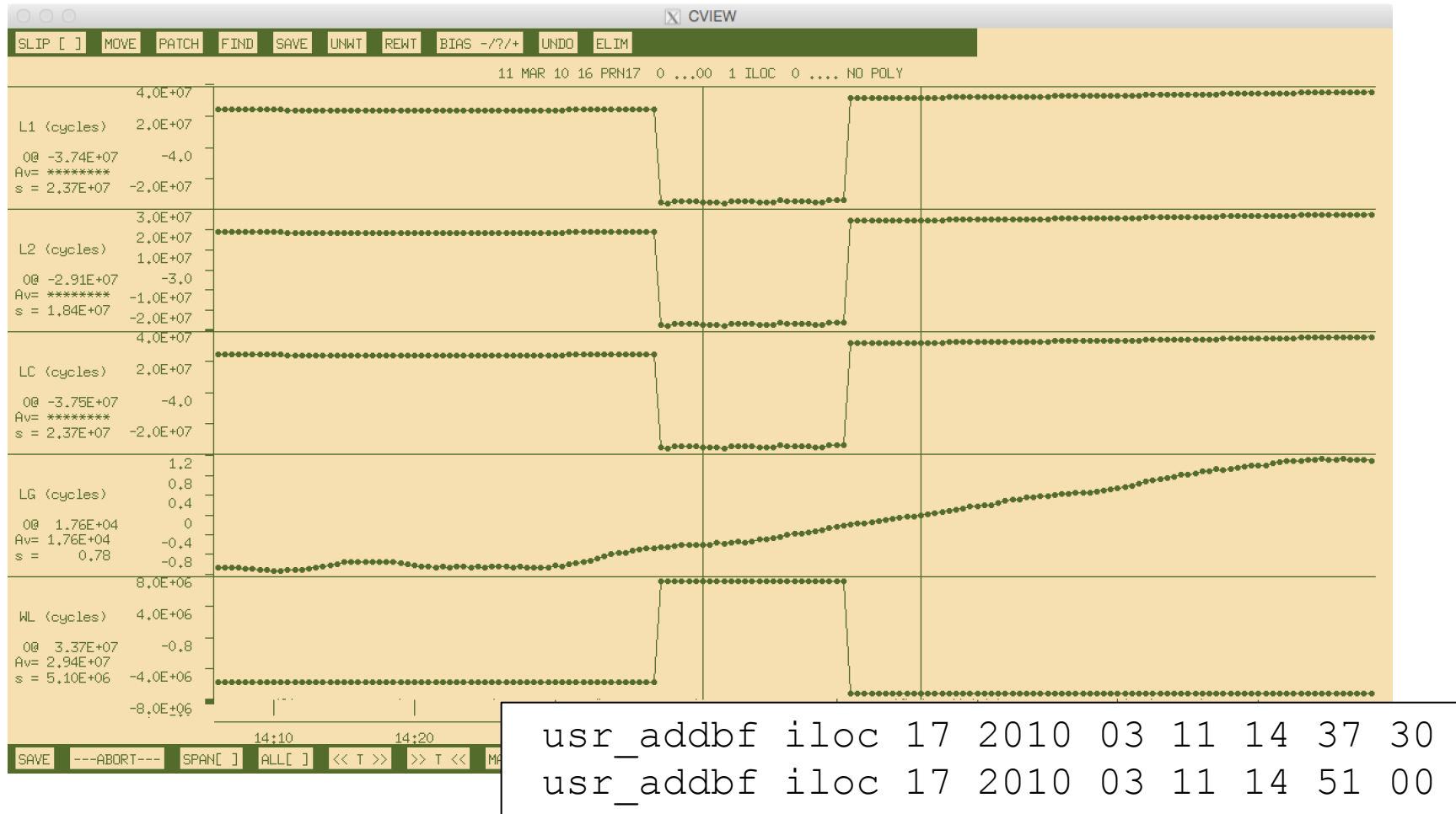
A satellite with some problems cview



A problematic satellite in cview



A problematic satellite in cview



Example 3:

Episodic and continuous deformation

GAMIT/GLOBK processing

- Process network of available data at nearby sites
- Find candidate stable fixed site(s)
- Ensure accurate coordinate coordinates for fixed site(s)

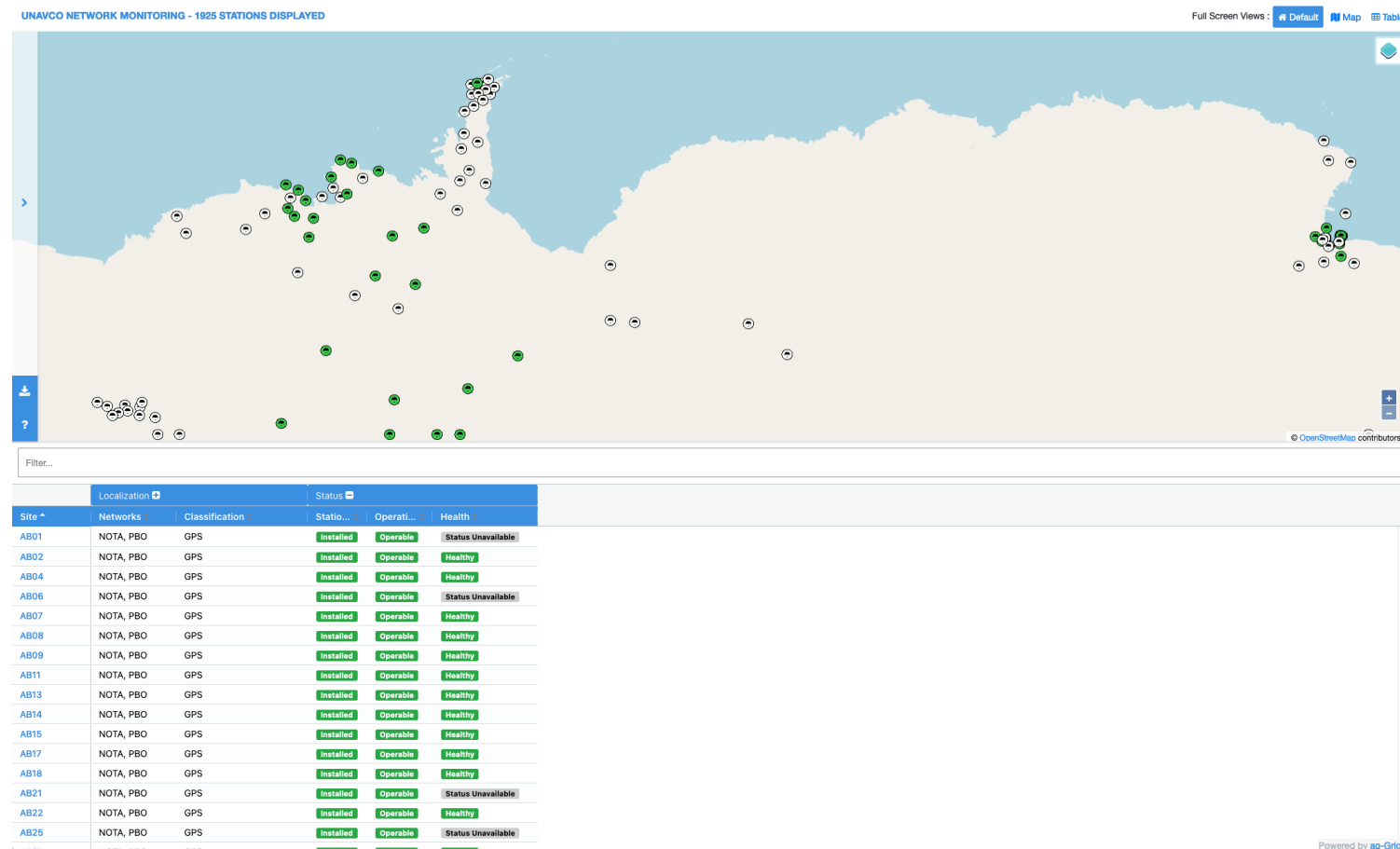
track processing

- Use network of nearby, bedrock sites as base sites for kinematic processing of ice-flow
- One fixed site natural but multiple constrained sites may provide redundancy
- Ambiguities must still be resolved correctly

Building the static network

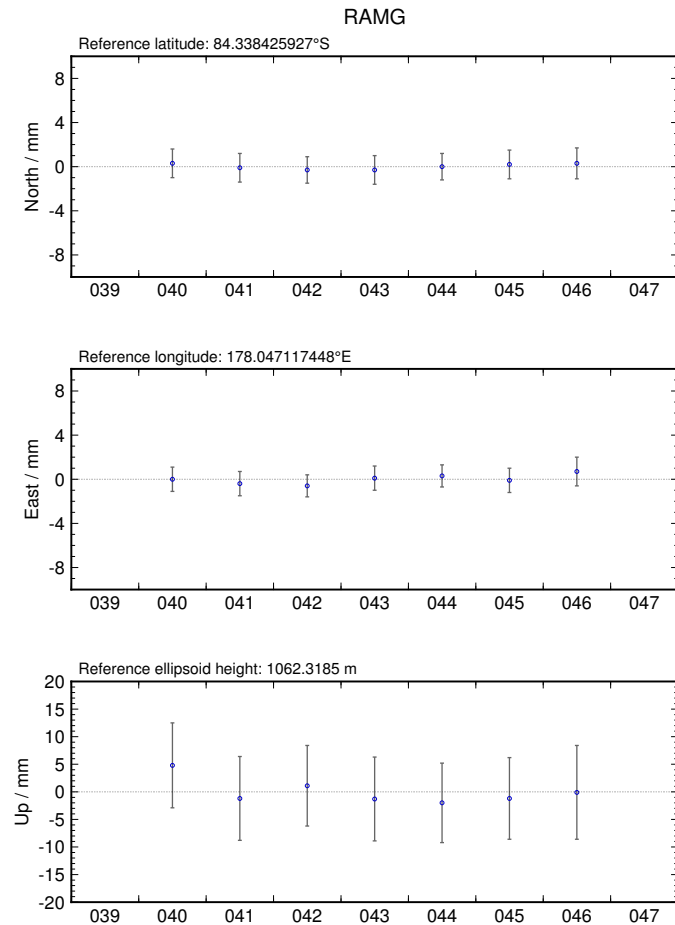
<https://www.unavco.org/instrumentation/networks/status/all>

<https://observablehq.com/@earthscope/gnss-data-access?collection=@earthscope/nsf-gage-facility-data-access>

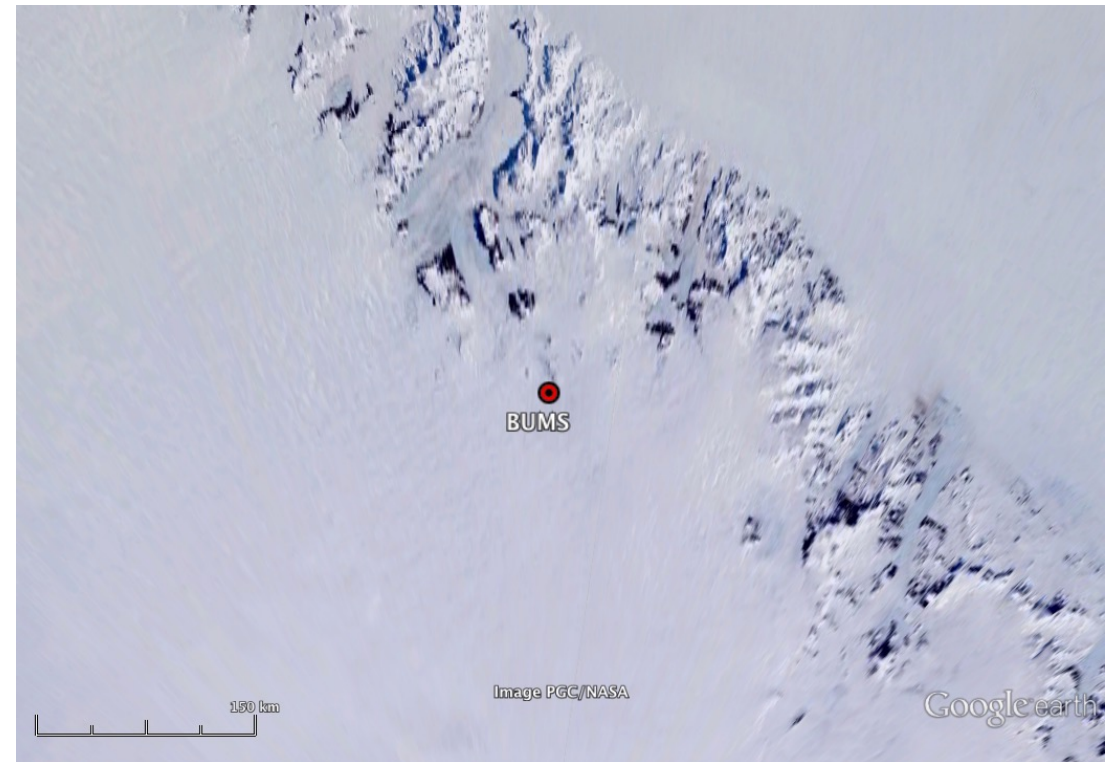
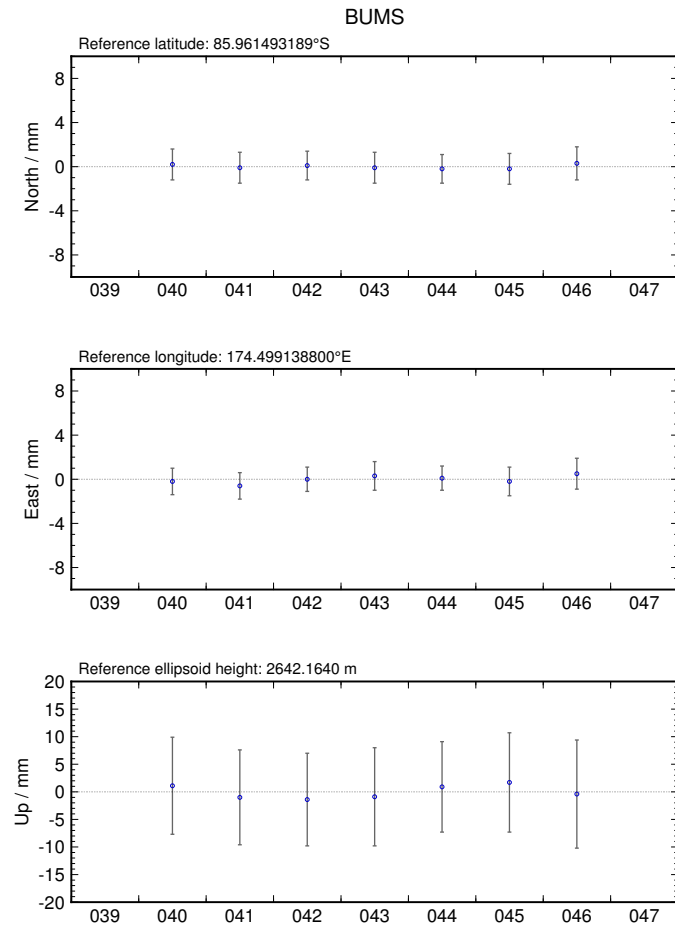


Ice flow or bedrock?

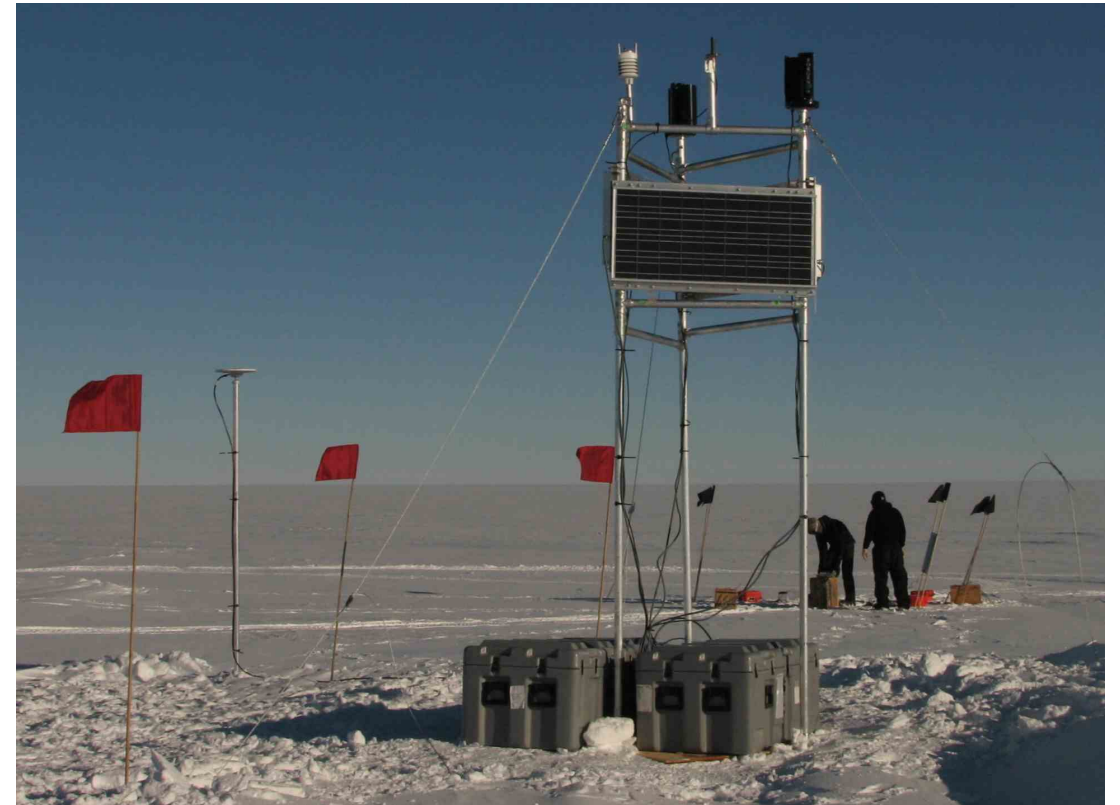
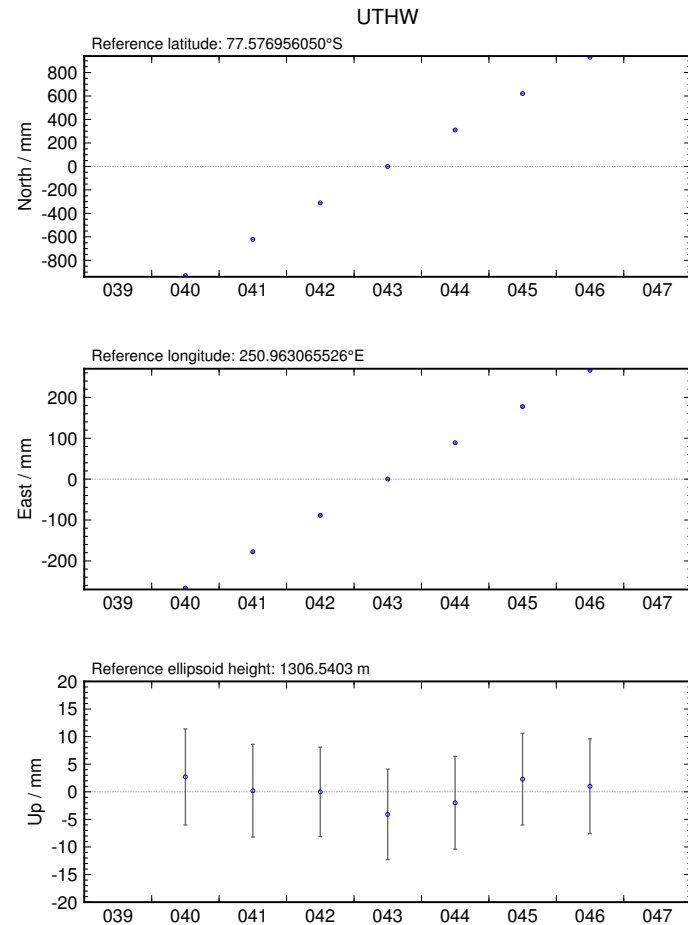
Ice flow or bedrock?



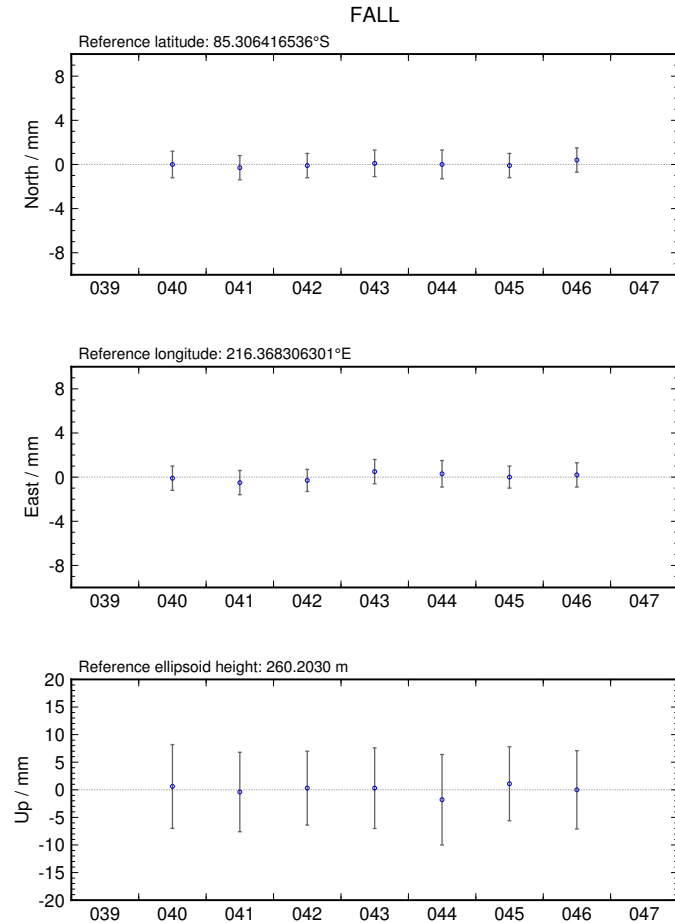
Ice flow or bedrock?



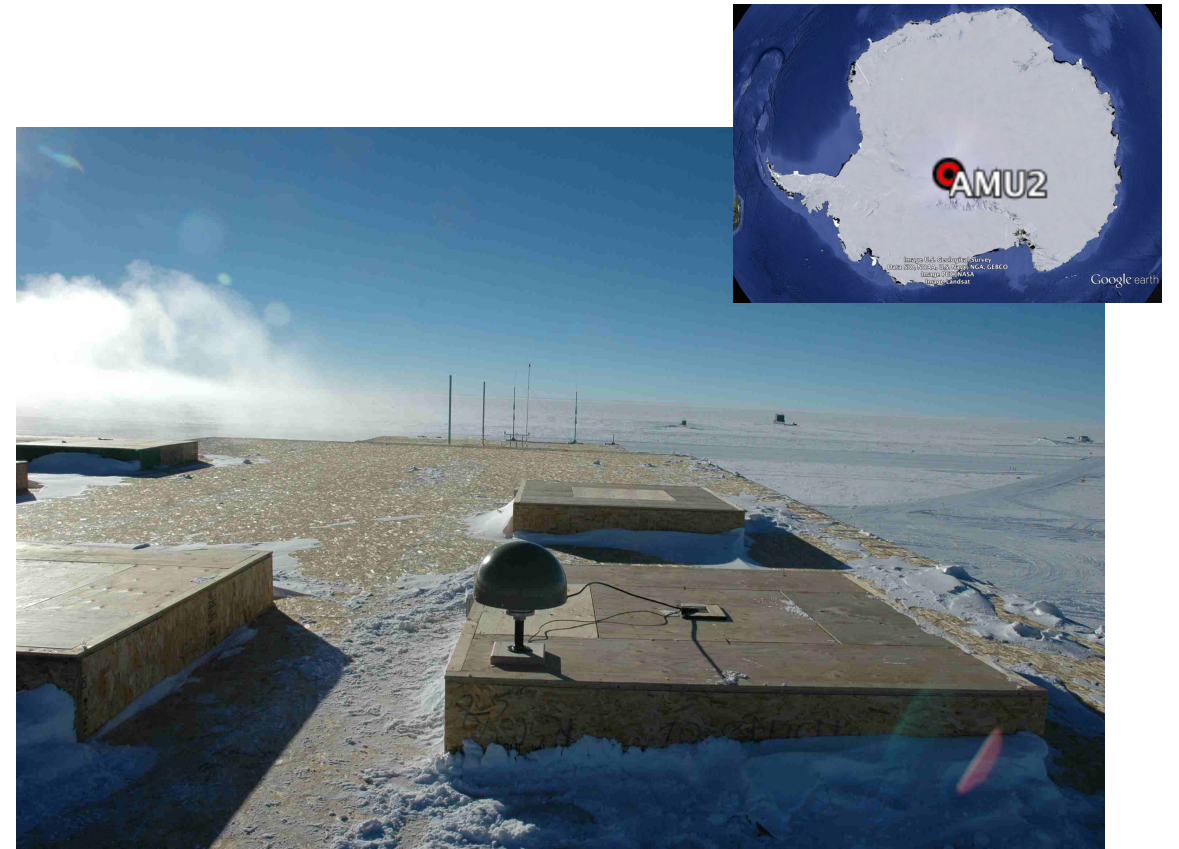
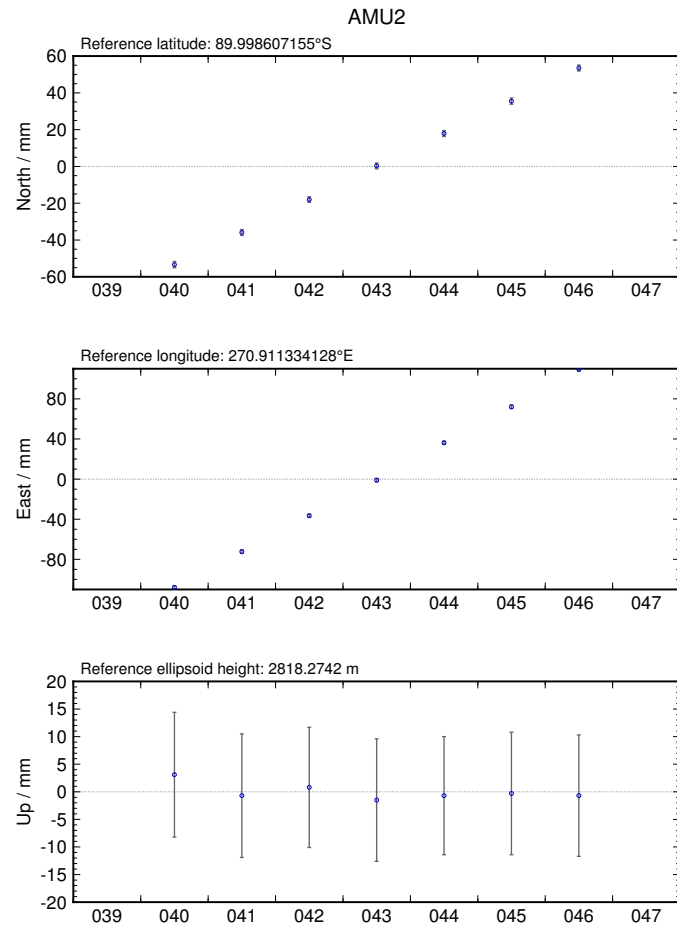
Ice flow or bedrock?



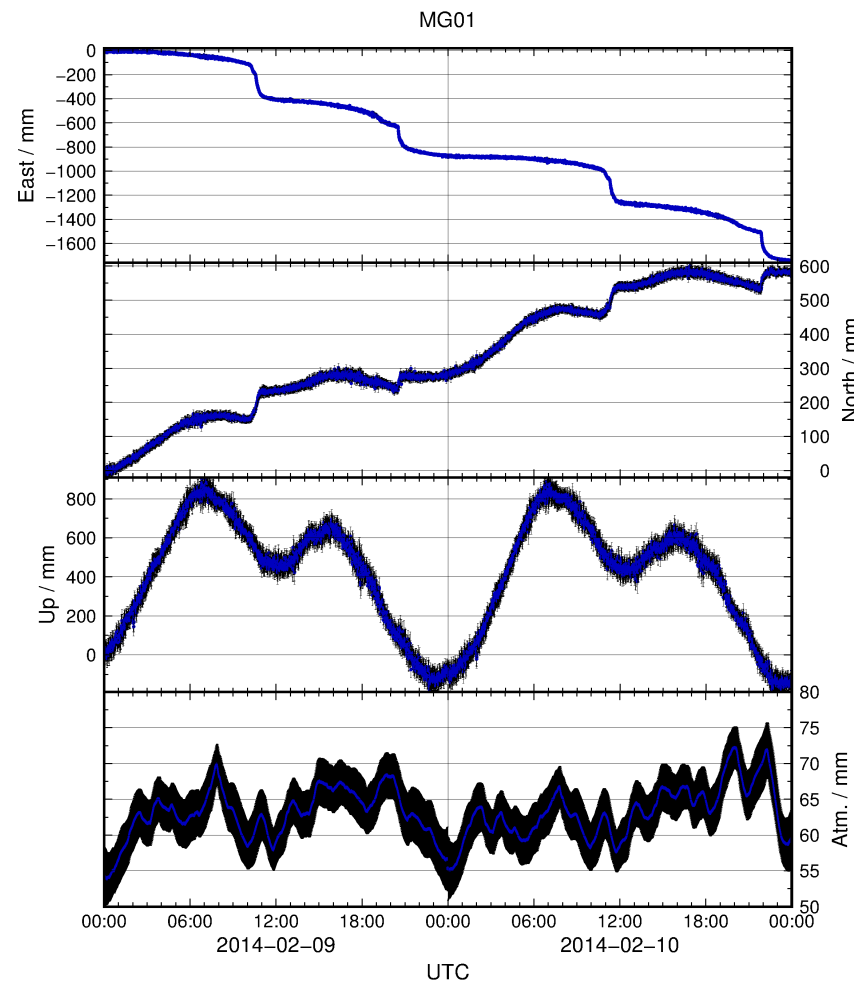
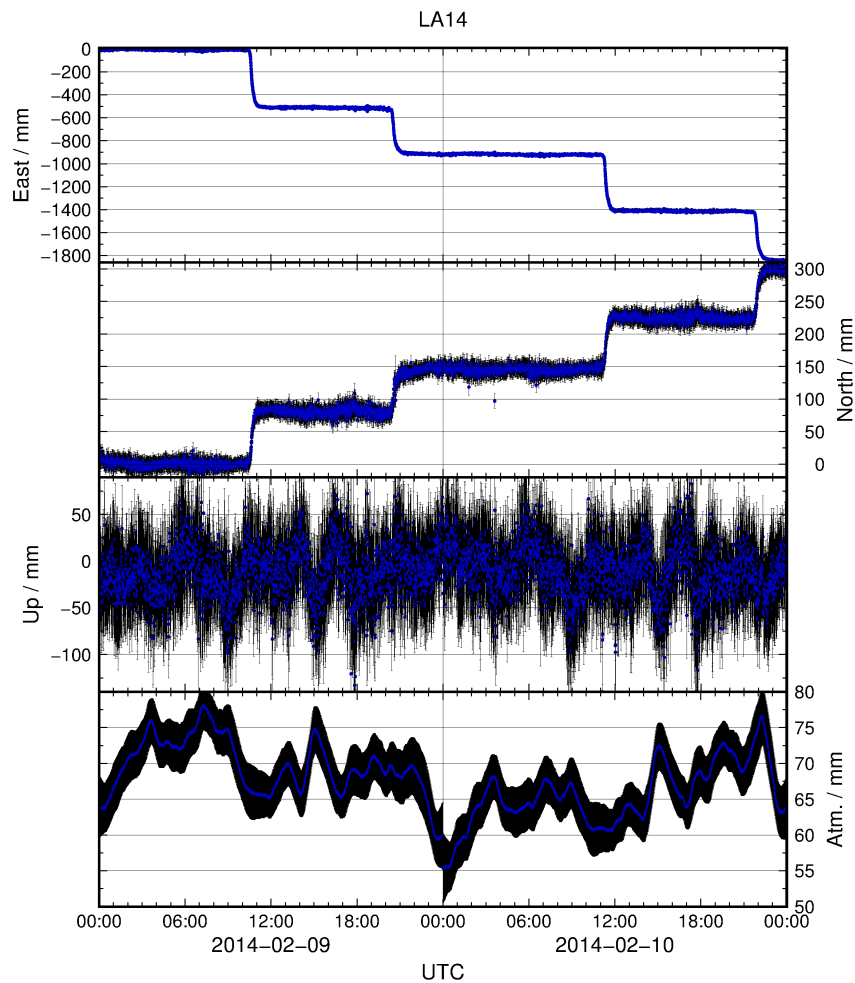
Ice flow or bedrock?



Ice flow or bedrock?



Kinematic results using FALL, RAMG and BUMS as fixed sites*



* FALL is the declared fixed site ("F" flag under "obs_file" option); RAMG and BUMS are technically kinematic sites ("K" flag) but are constrained by zero process noise.

Experiment-specific constraints

Justification

- We wish to apply our own temporal constraints (we have moving sites), so let's be clear on units
- Atmosphere is more stable in Antarctica (cold, high pressure)
 - Evident in daily GAMIT processing "o"-files
- Previous studies show maximum displacement rates of 0.5 m over 30 mins (but loosen temporal constraints for final solution with "ambin_file")

Key track commands

```
time_unit second
```

```
atm_stats
```

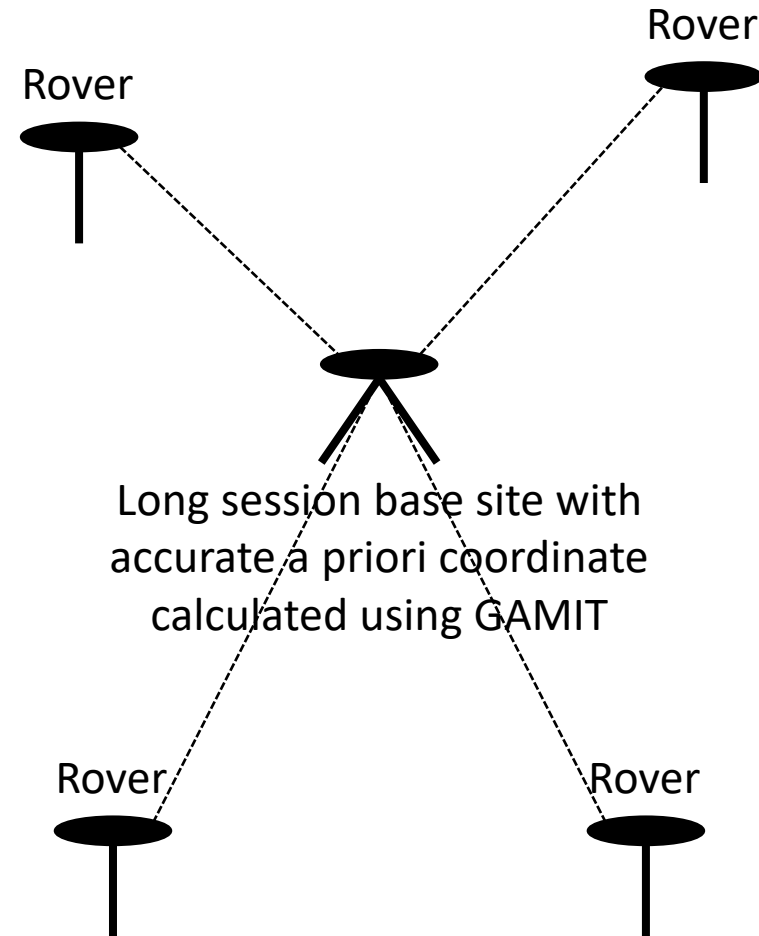
```
FALL 0.1 0.0001 0  
RAMG 0.1 0.0001 0  
: : : :
```

```
site_stats
```

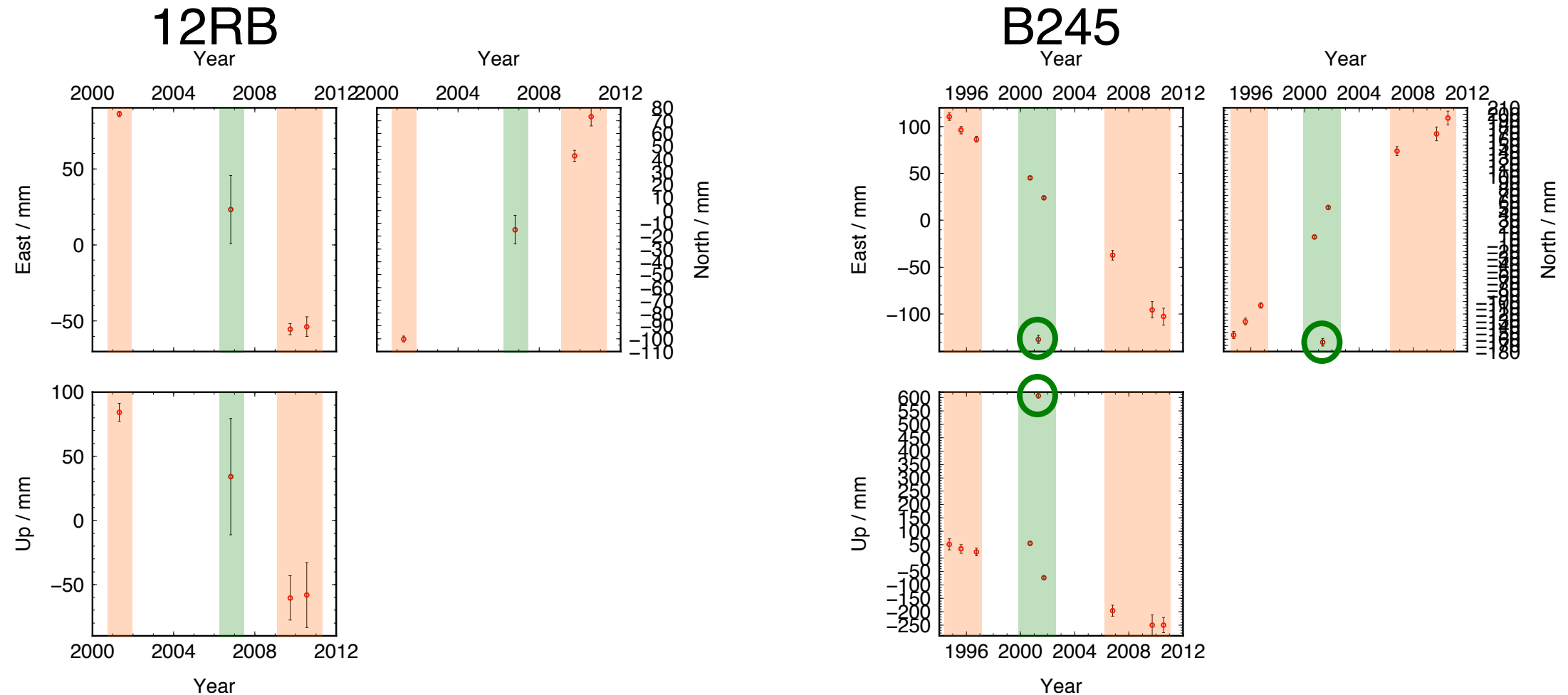
```
FALL 10 10 10 0 0 0  
RAMG 10 10 10 0 0 0  
: : : : : :  
LA14 10 10 10 0.1 0.1 0.1  
MG01 10 10 10 0.1 0.1 0.1
```

Example 4: Short-static occupations

- Short spans of data (e.g. 30 minutes) may be processed with GAMIT
- Risk of all data being removed during cleaning (`autcln`) if not high quality
- `track` may be used in “short-static” approach with fixed, continuously recording and well positioned base site



Example 4: Short-static occupations





Sometimes, this happens...

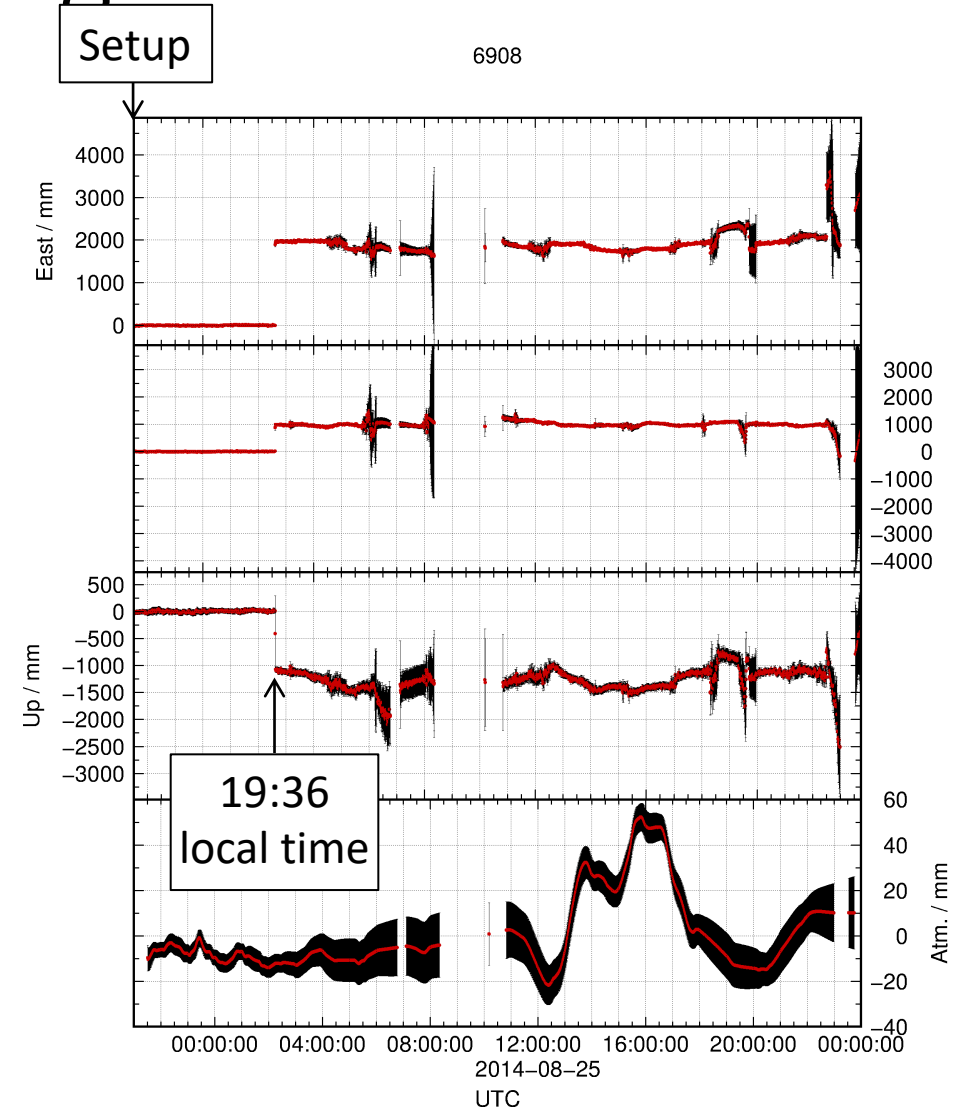


1.2810 m

Photographs courtesy of Gareth Funning (University of California, Riverside)

Example 5(a): Deciphering interference

- First, run `track` with loose constraints to identify probable epoch of disturbance
- Update a priori position and re-run `track` for solution
- Re-run `teqc` with “-e” option to truncate RINEX file at epoch of disturbance so as not to propagate bad data



Example 5(b): A complex example

