Examples of `track` use

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

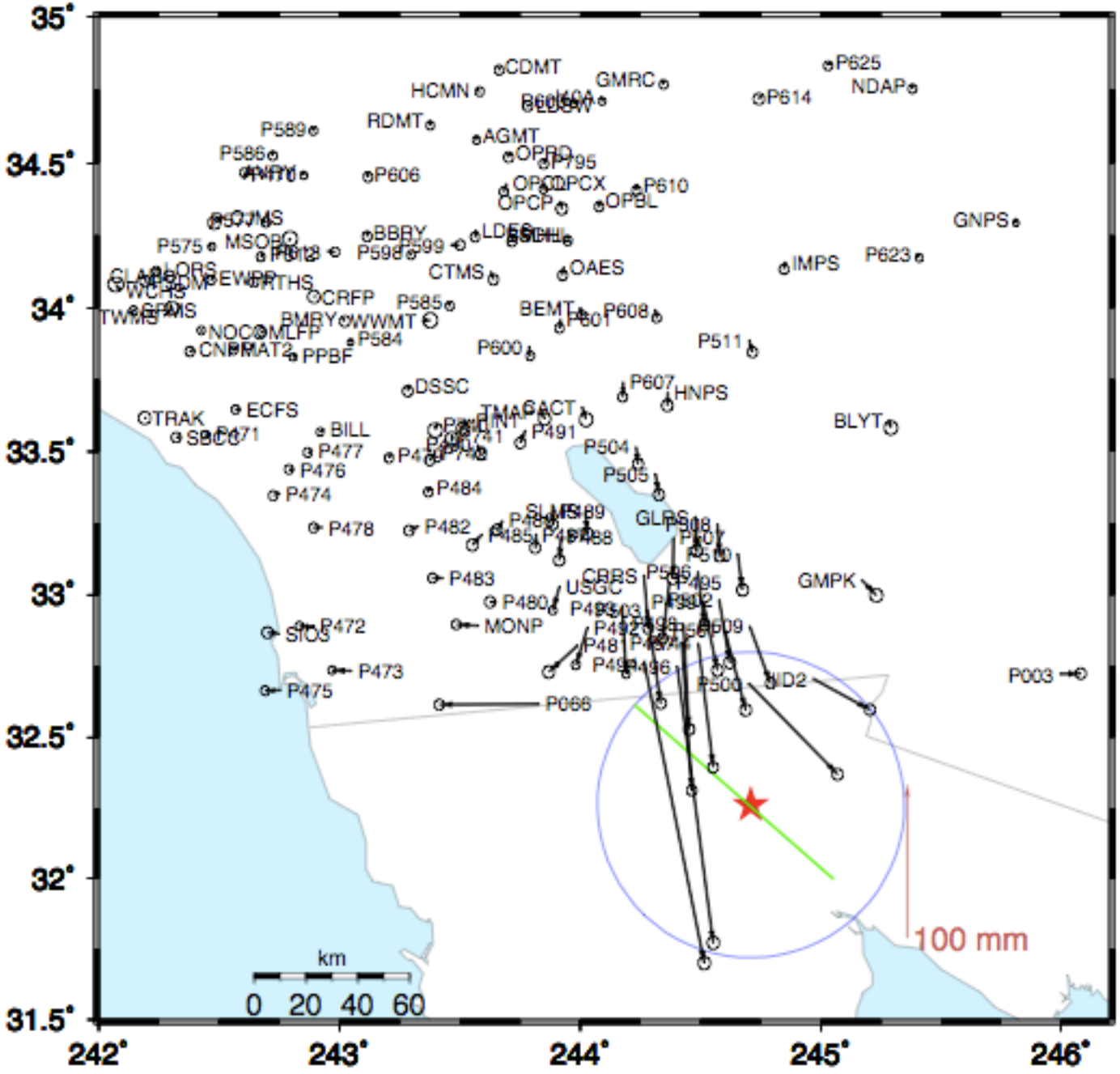
Outline

- Kinematic examples
  1. GPS seismology
  2. Roving GPS
  3. Rapid deformation
- Static examples
  4. Short-static occupations
  5. Deciphering interference
- Remember the rule-of-thumb for proportional errors:

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

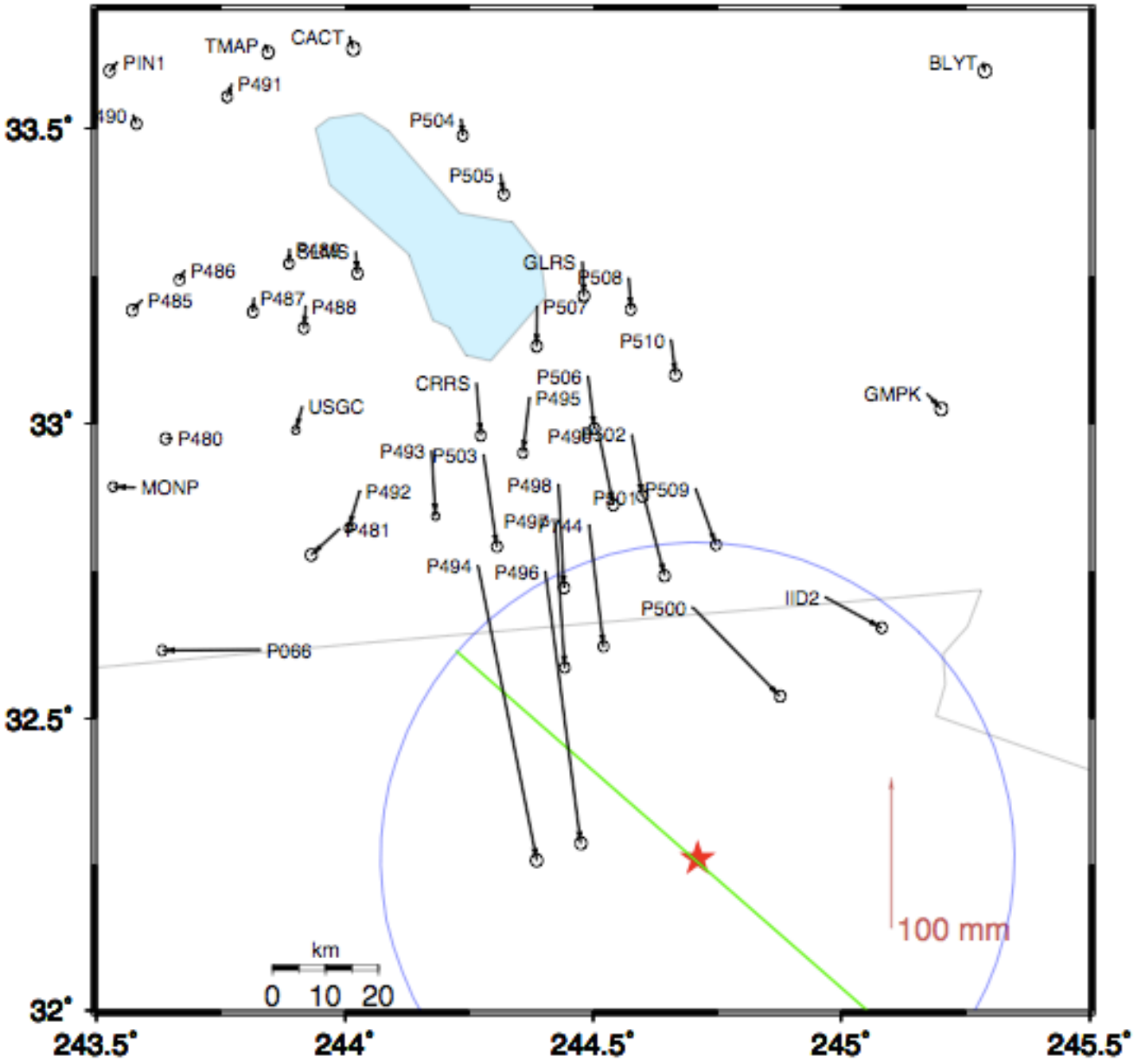
Example 1: GPS seismology

- Examine the short baseline MIT results: Look at this example in more detail later
- 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 noisy due to stochastics.



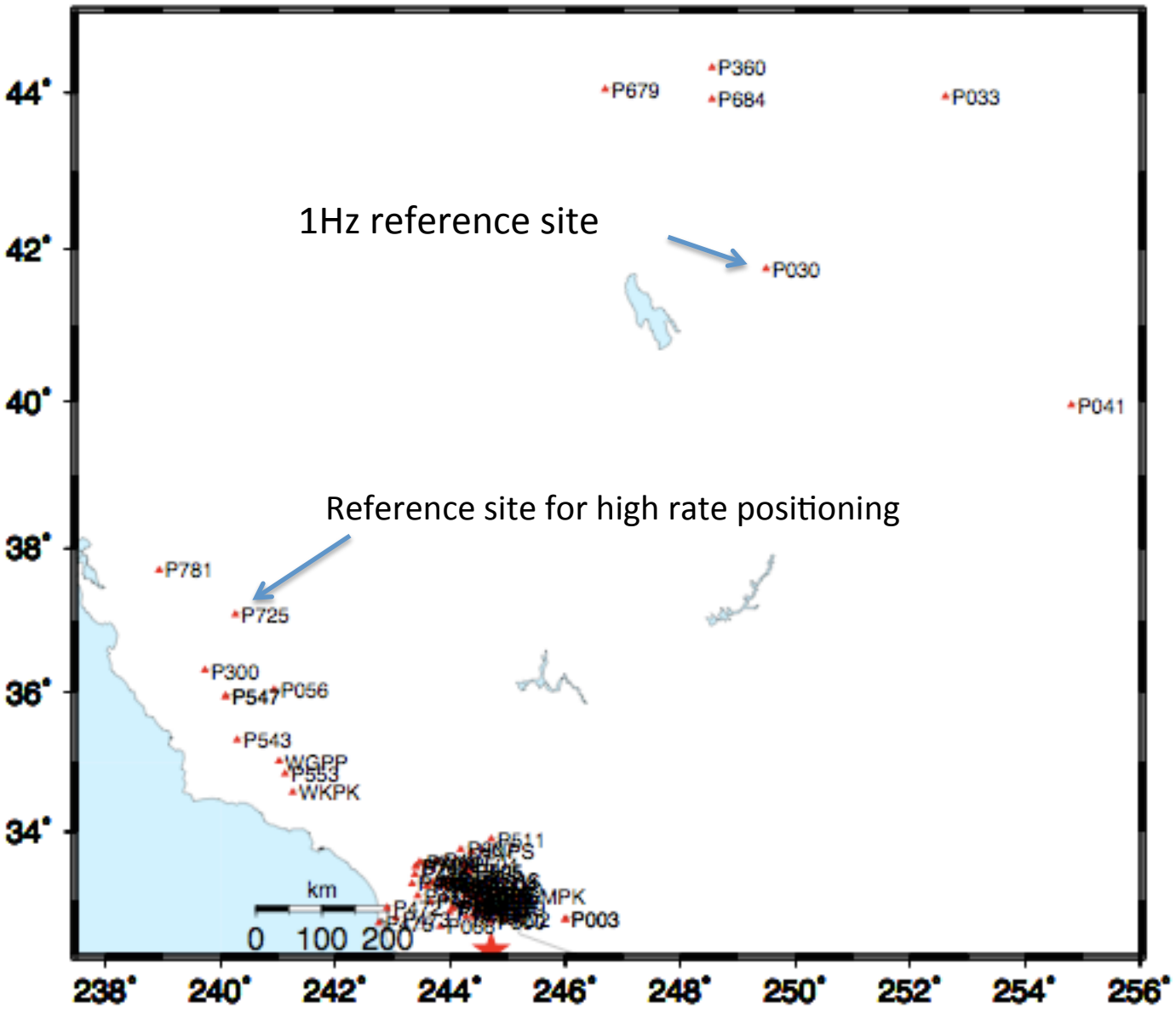
Coseismic offsets

- Offsets based on 2-days before and after earthquake.
- Two days used is reduce leakage of postseismic motions.
- Red Star is epicenter; blue circle is 60 km (15-20 seconds surface wave speed)



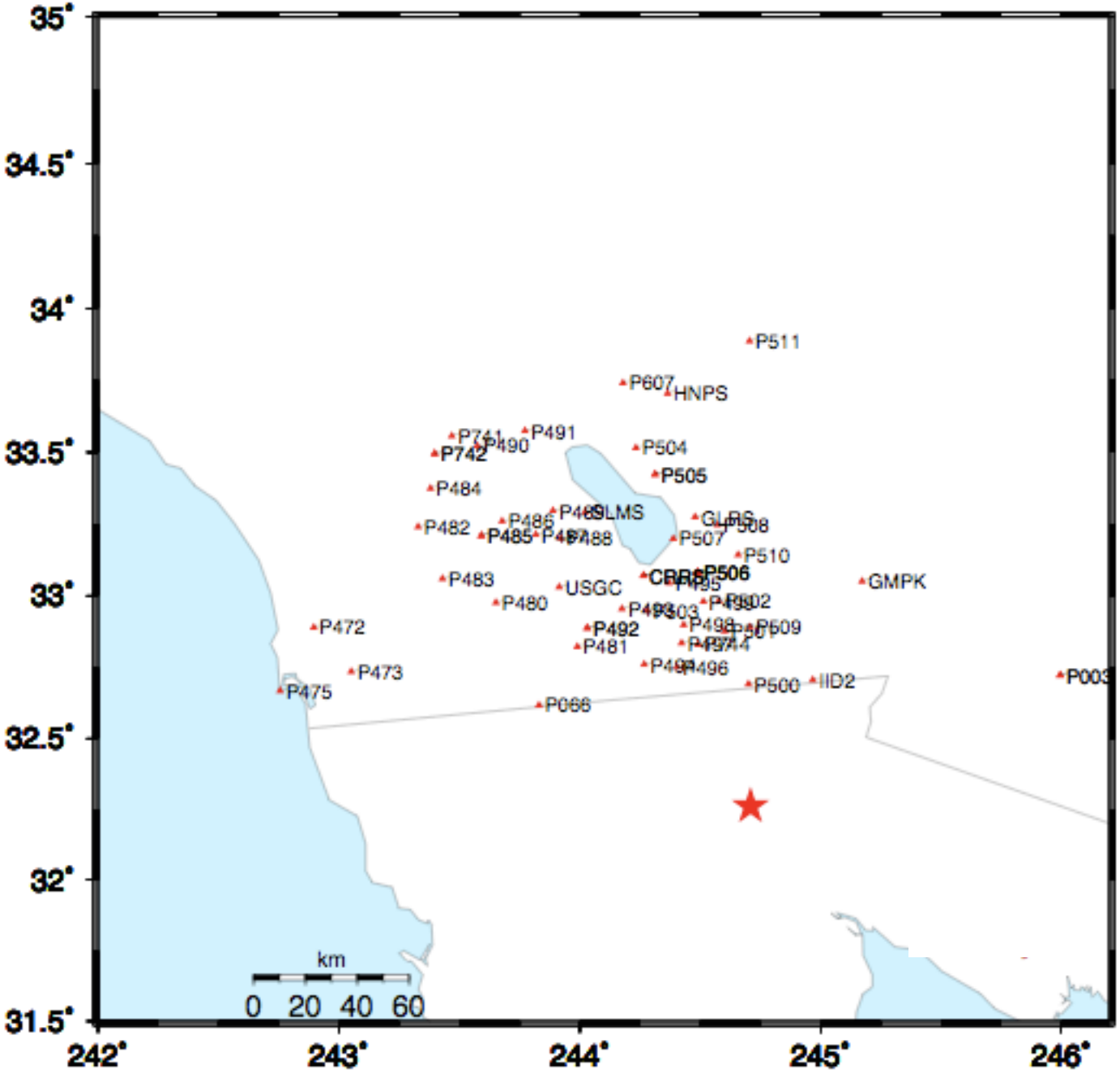
Zoom around border

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 GPS site download

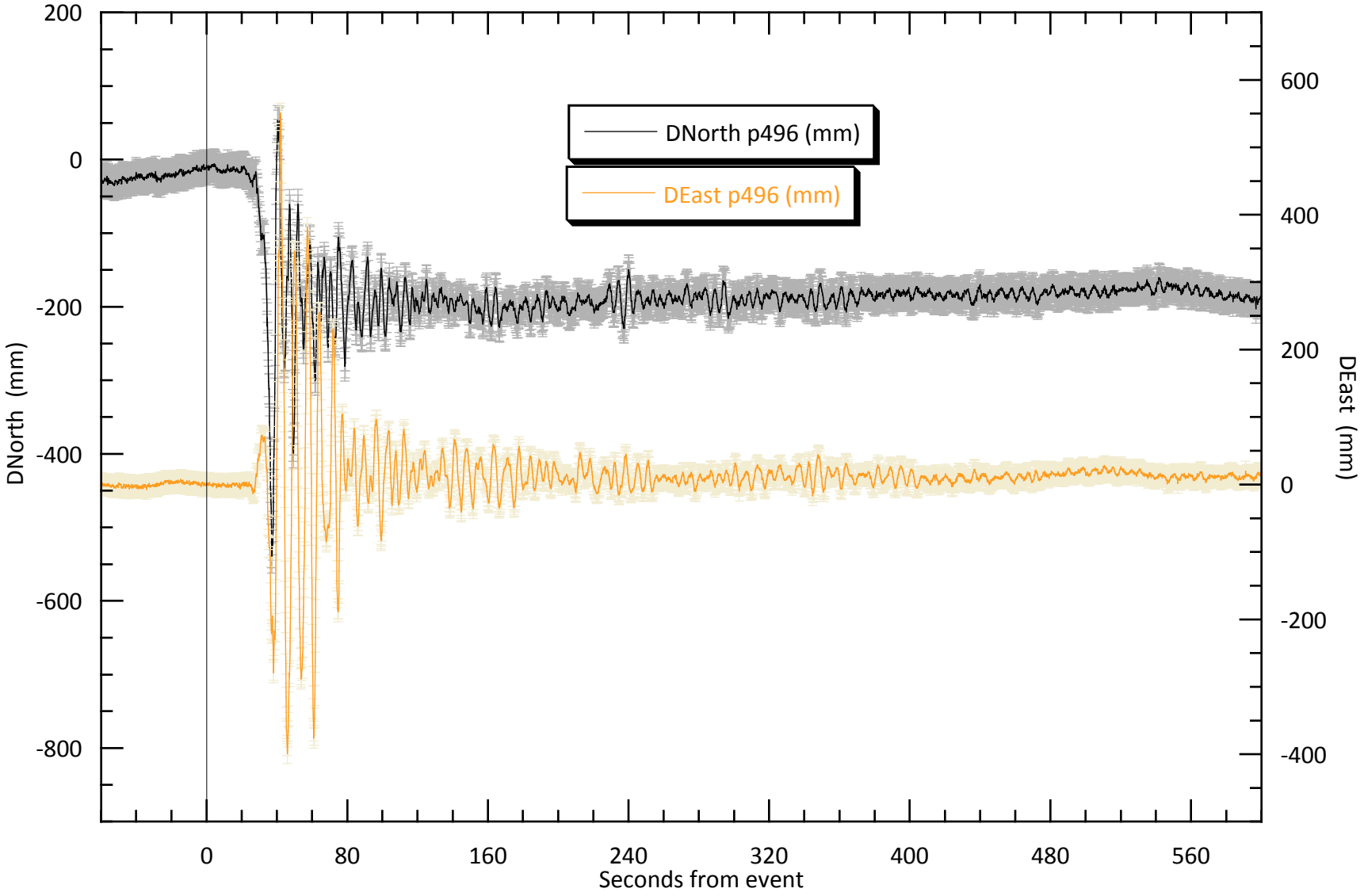
- High rate data from these sites downloaded after event.
- Most sites are 5-Hz; more distant sites are 1-Hz.



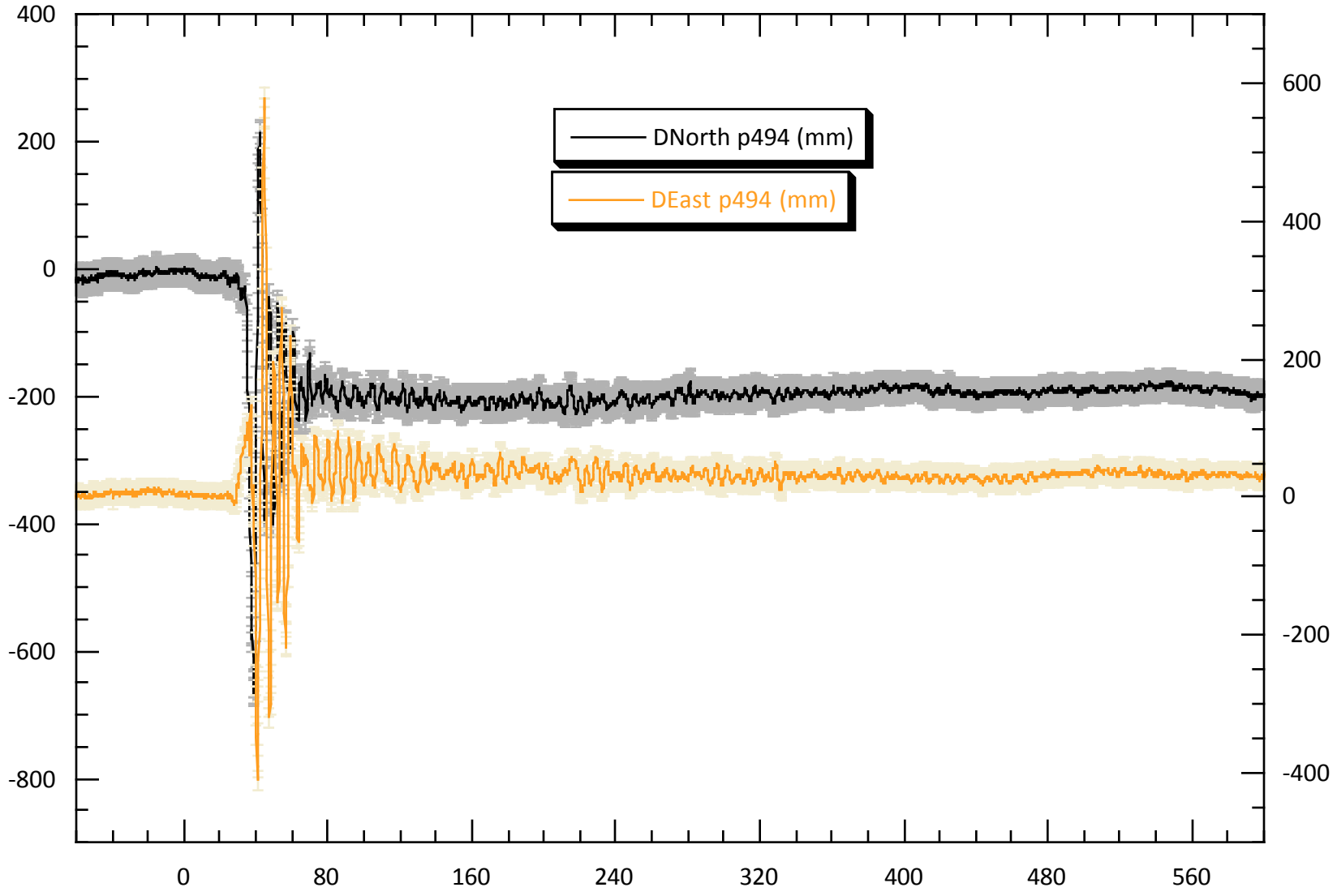
Sites in coseismic region

- Sites shown have 5-Hz data for 3-days before and after the earthquake
- Examine sequence of sites along US/Mexico border and North

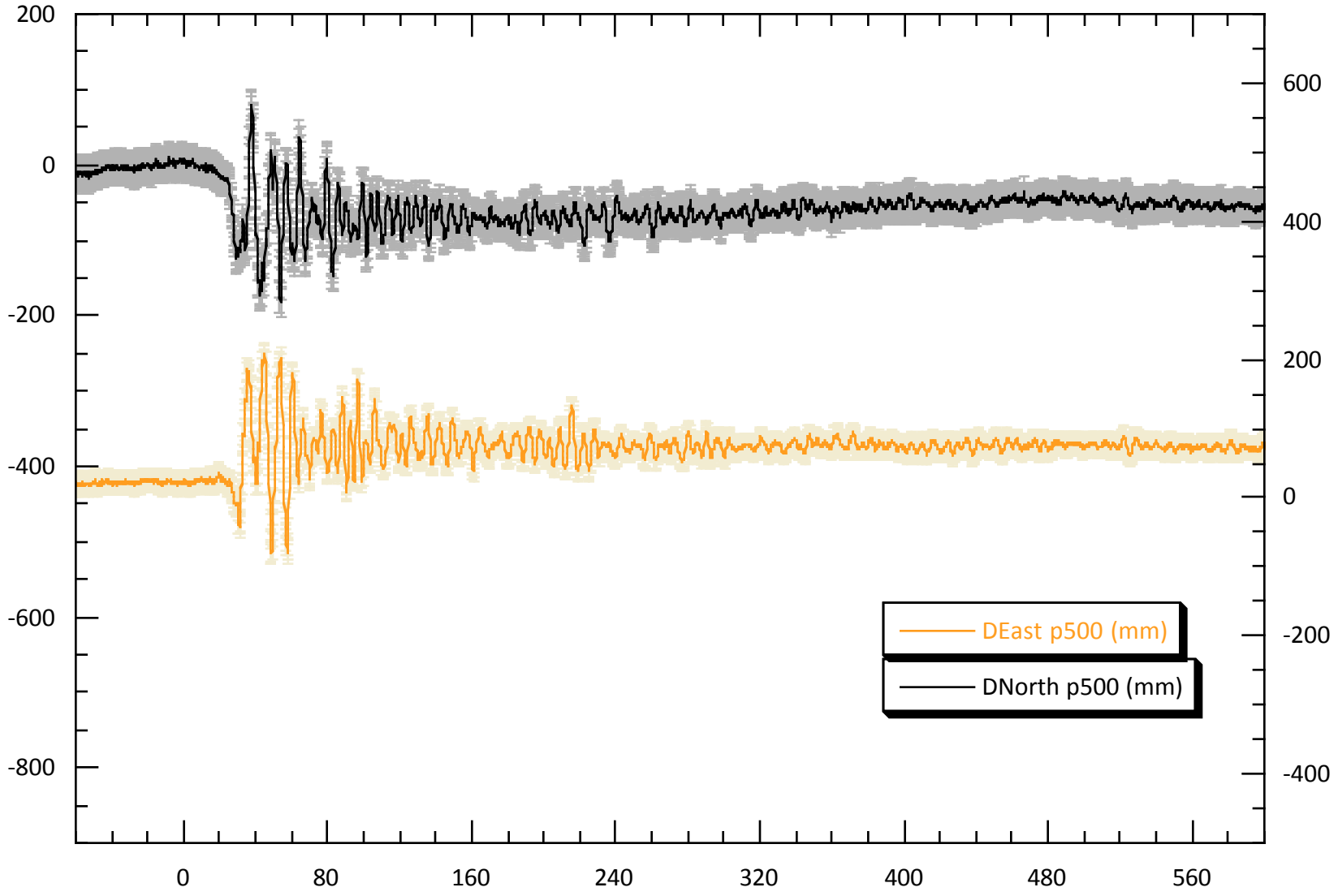
P496


DNorth p496 (mm)
DEast p496 (mm)
DNorth (mm)
DEast (mm)
Seconds from event
200
0
-200
-400
-600
-800
600
400
200
0
-200
-400
0
80
160
240
320
400
480
560

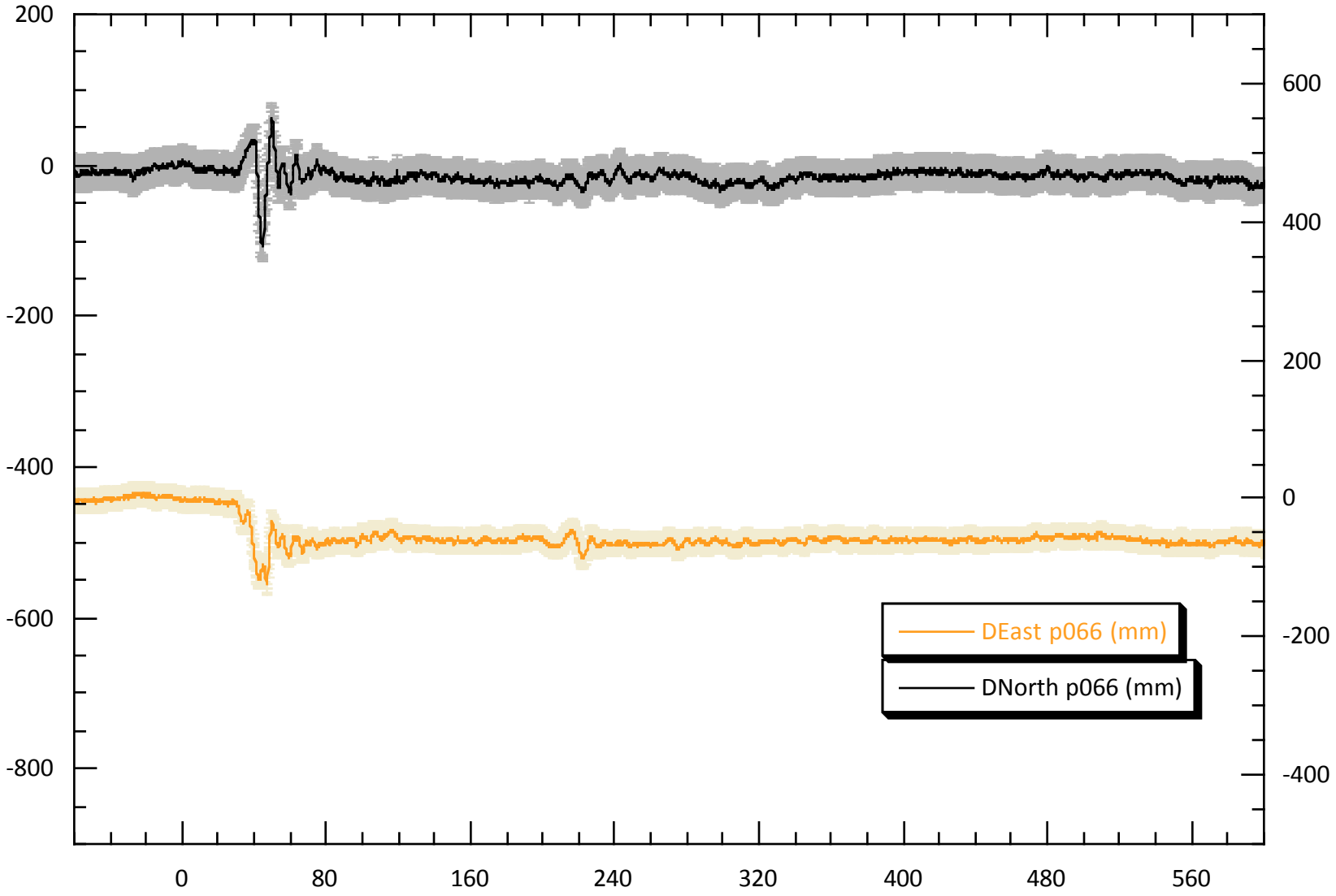
P494


DNorth p494 (mm)
DEast p494 (mm)
400
200
0
-200
-400
-600
-800
600
400
200
0
-200
-400
0
80
160
240
320
400
480
560

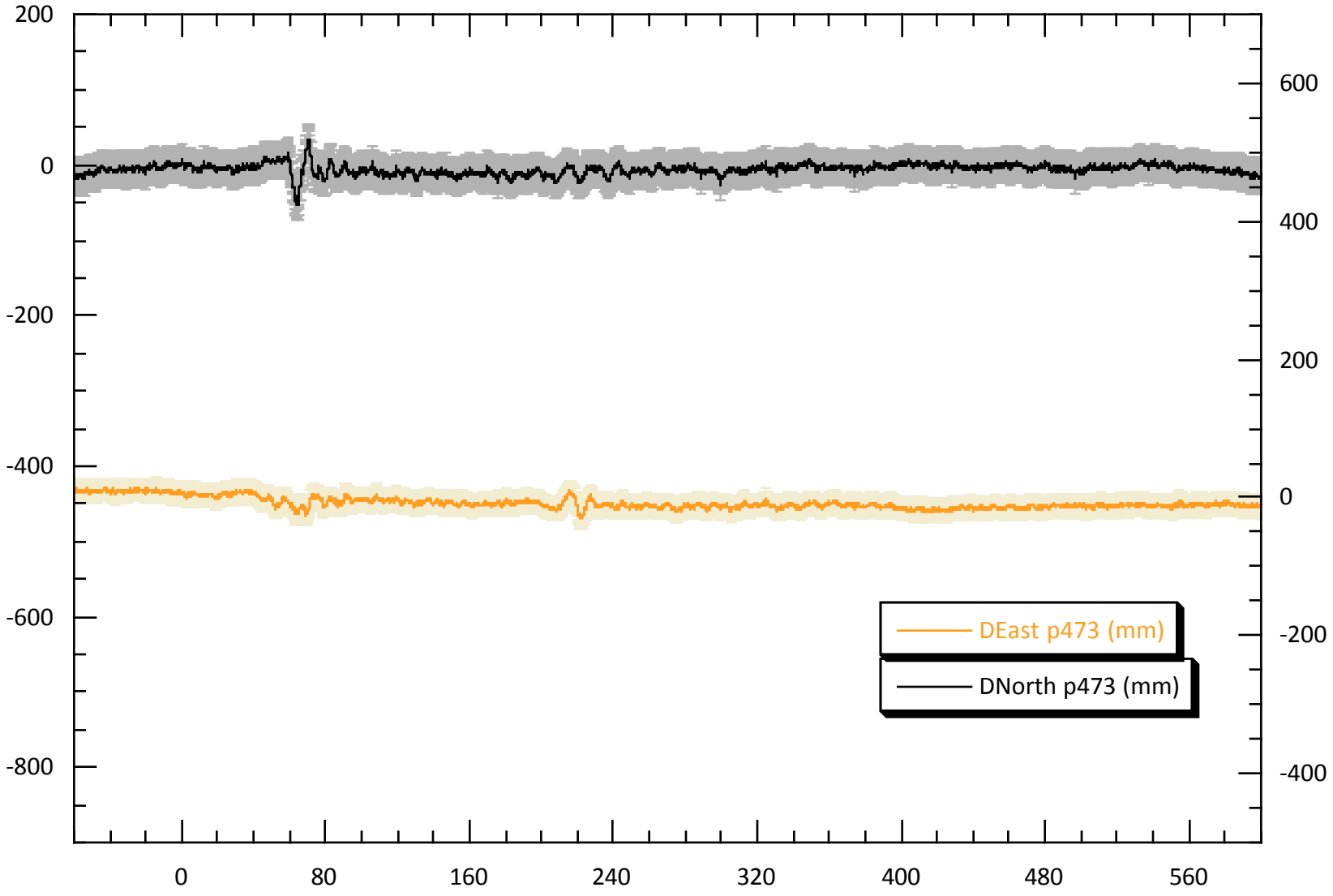
P500


200
0
-200
-400
-600
-800
600
400
200
0
-200
-400
0
80
160
240
320
400
480
560
DEast p500 (mm)
DNorth p500 (mm)

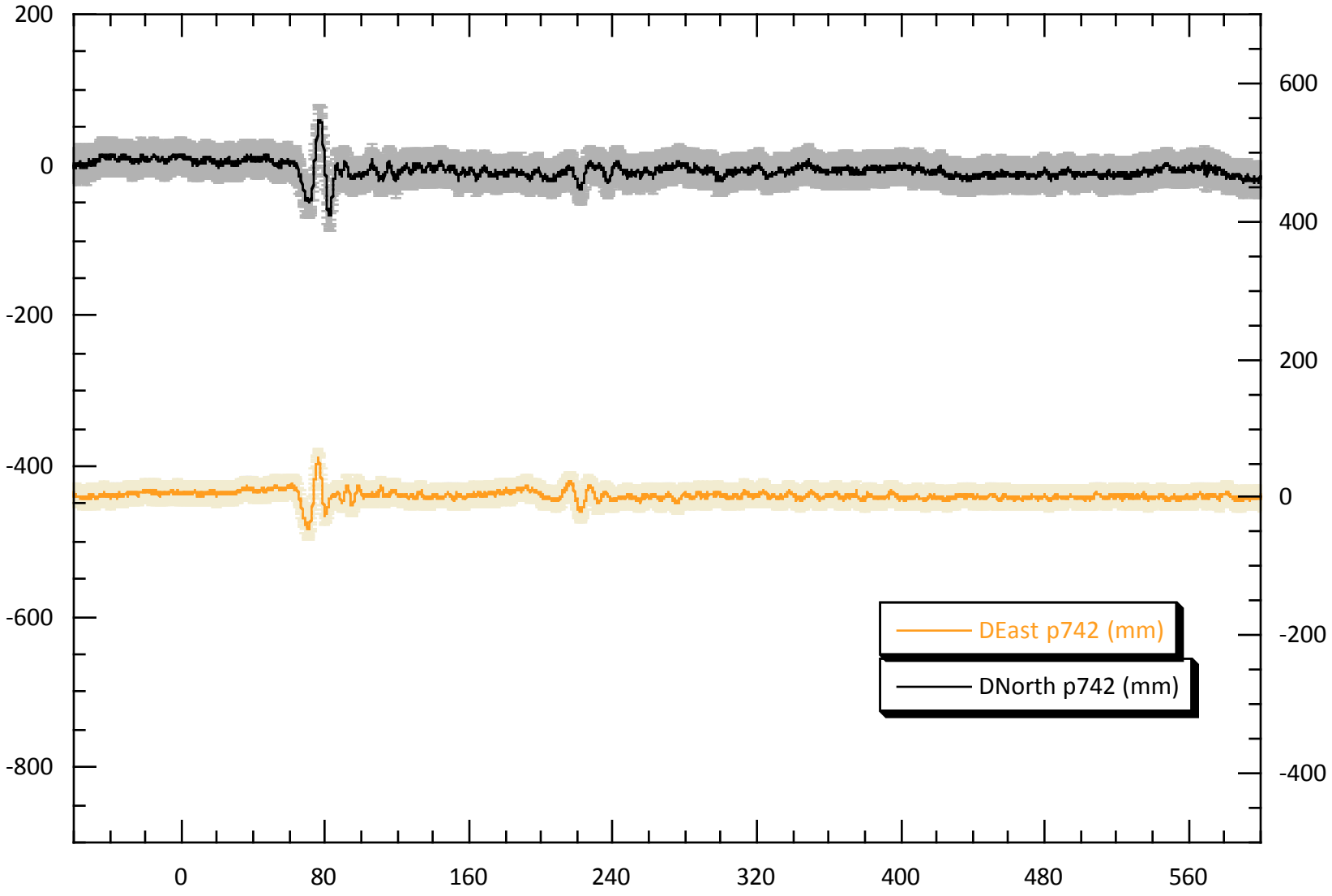
P066


200
0
-200
-400
-600
-800
600
400
200
0
-200
-400
0
80
160
240
320
400
480
560
DEast p066 (mm)
DNorth p066 (mm)

P473

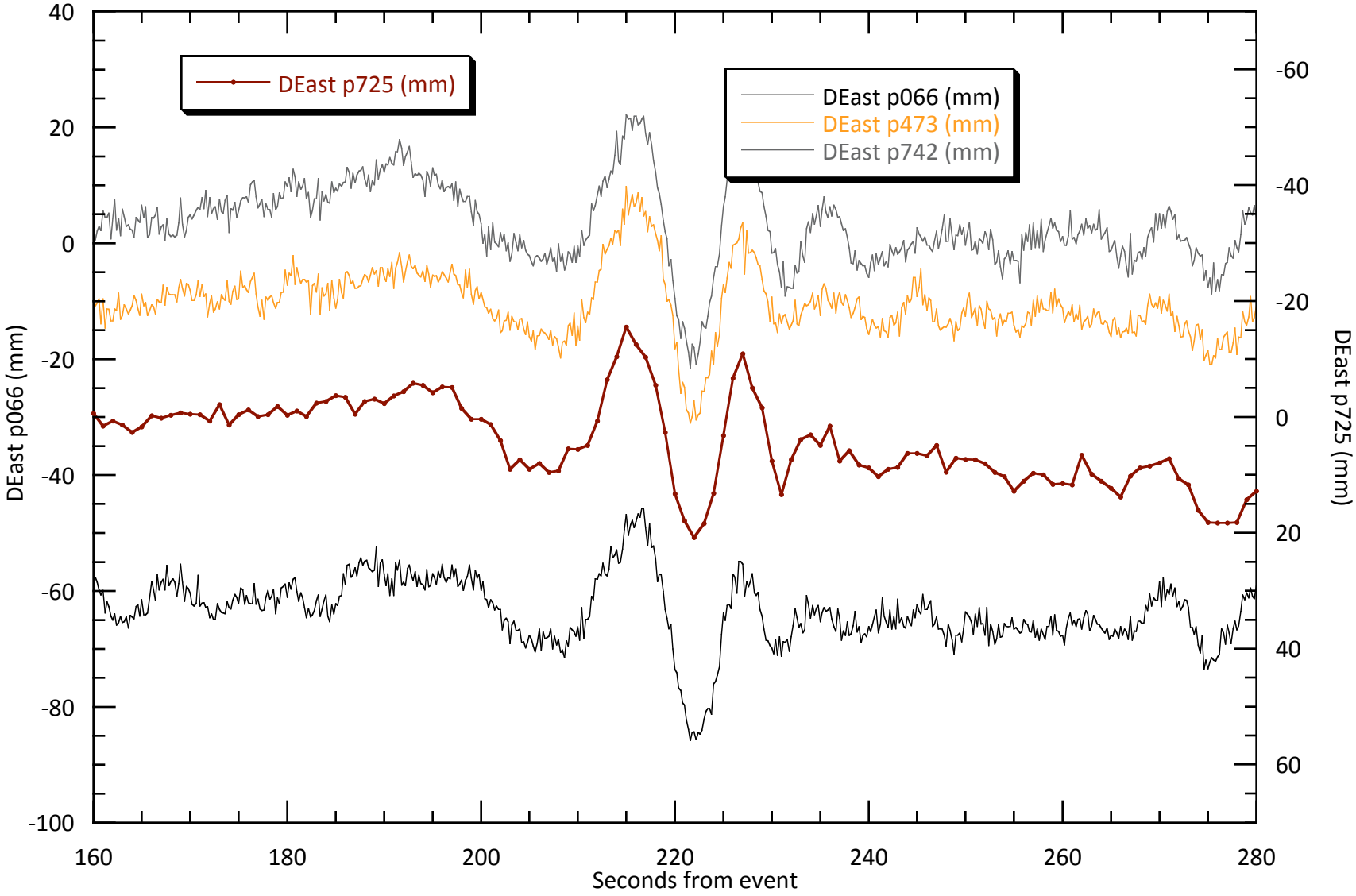

200
0
-200
-400
-600
-800
600
400
200
0
-200
-400
0
80
160
240
320
400
480
560
DEast p473 (mm)
DNorth p473 (mm)

P742


200
0
-200
-400
-600
-800
600
400
200
0
-200
-400
0
80
160
240
320
400
480
560
DEast p742 (mm)
DNorth p742 (mm)

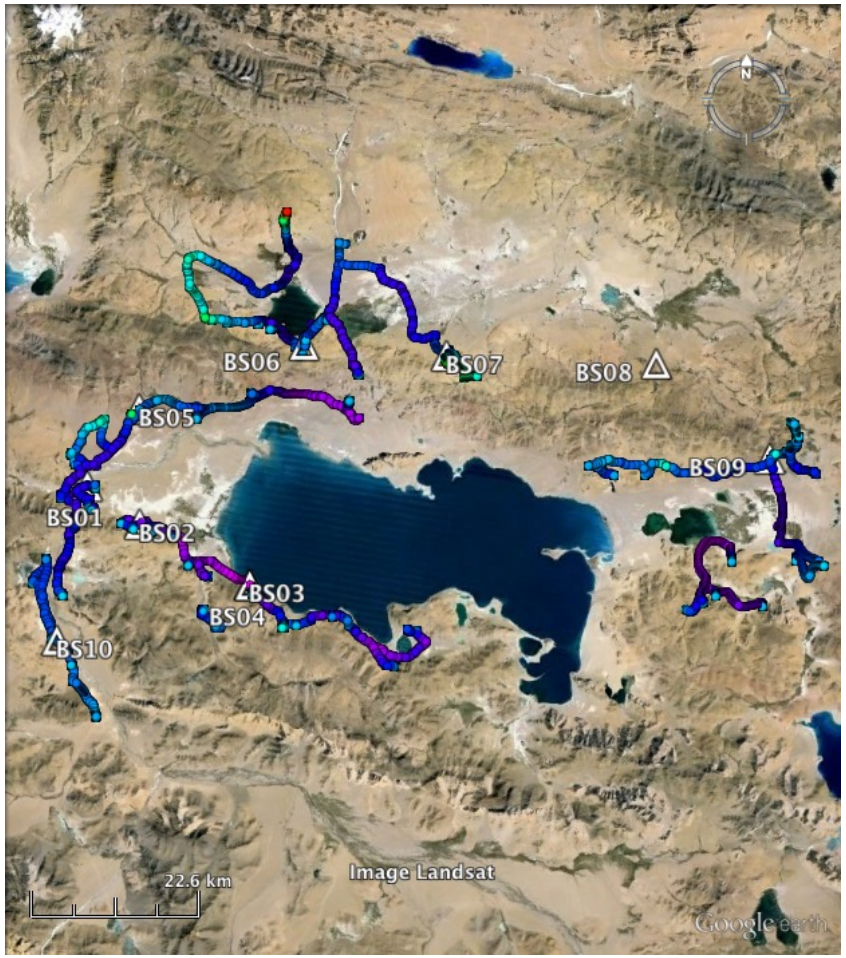
Surface wave arrival at P725

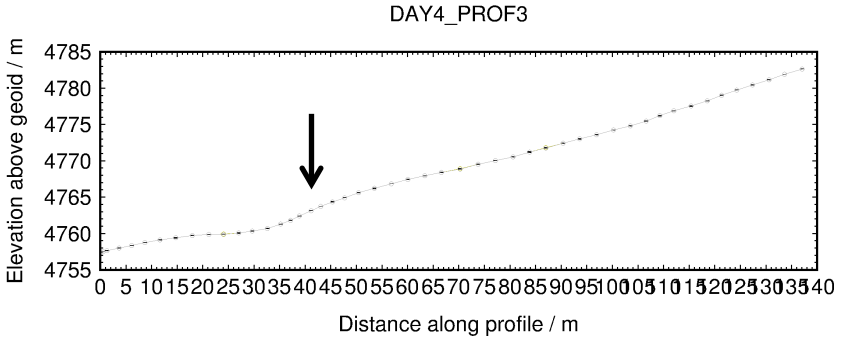
- P725 is ~600 km from epicenter. This signal common to sites is the arrival at the "reference site"

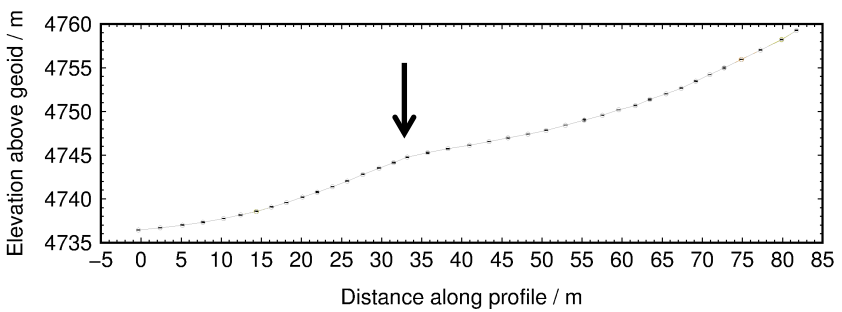


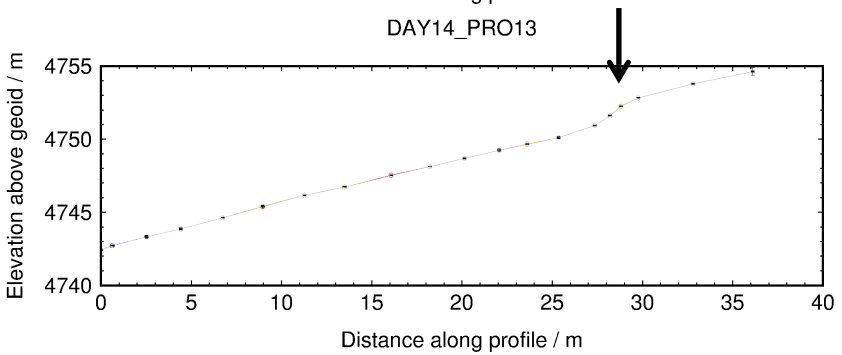
Example 2: Roving GPS

(from England et al., 2013)



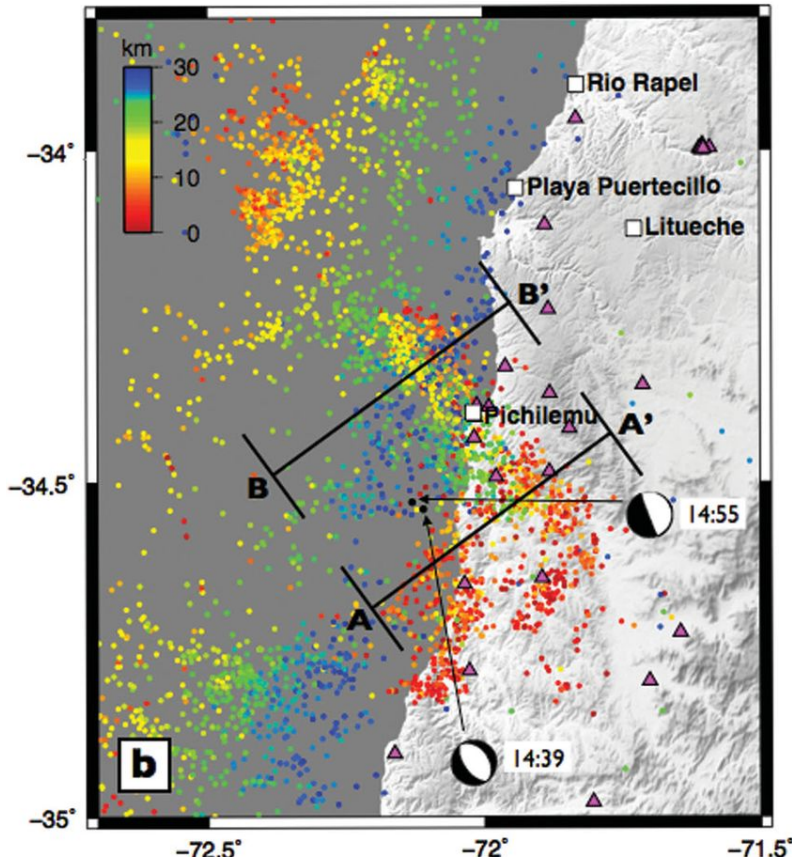






Disclaimer: This example was *not* processed using TRACK because the kinematic equipment was single-frequency, i.e. L1-only, and TRACK requires dual-frequency data

Example 3: 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 but no way to separate events
- Epoch-by-epoch (rather than batch) GPS processing may help...

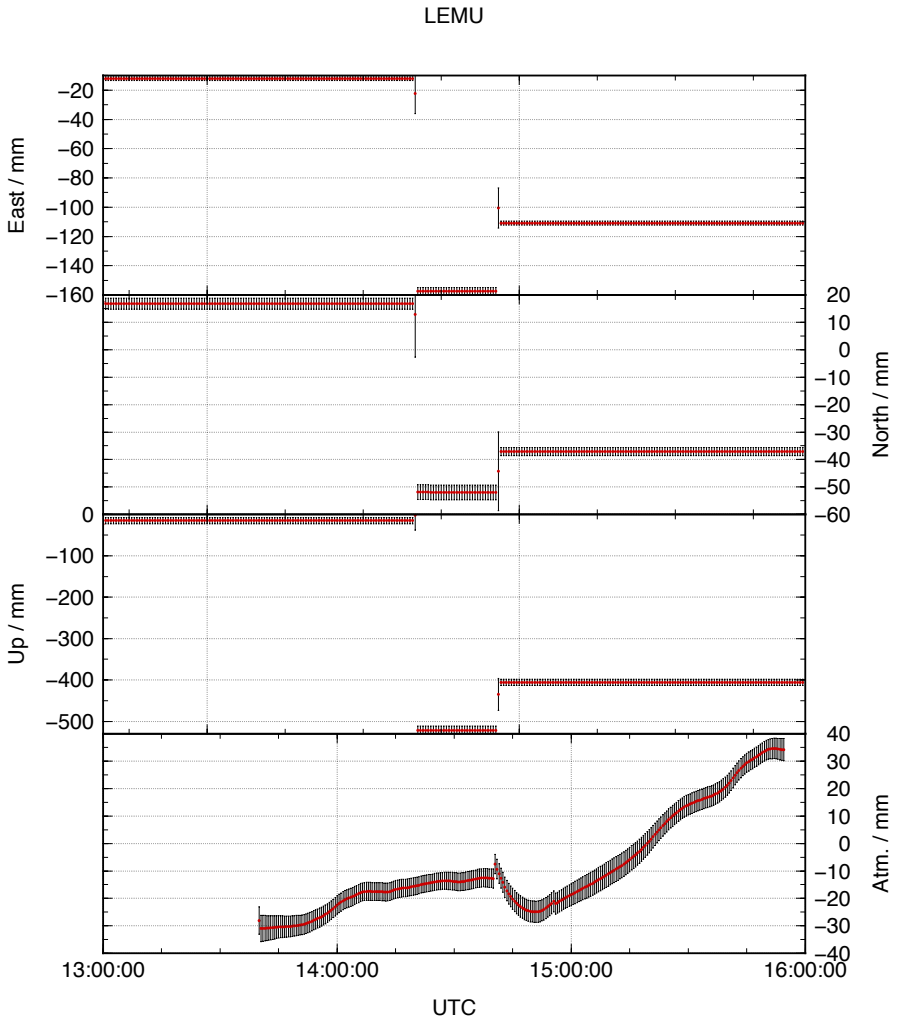
Example 3: First run

Key TRACK commands:

```
site_stats
 iloc 0.5 0.5 0.5 0 0 0
 lemu 0.5 0.5 0.5 0 0 0
 navi 0.5 0.5 0.5 0 0 0
timedep_procns
 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
```

Second run (updated apr):

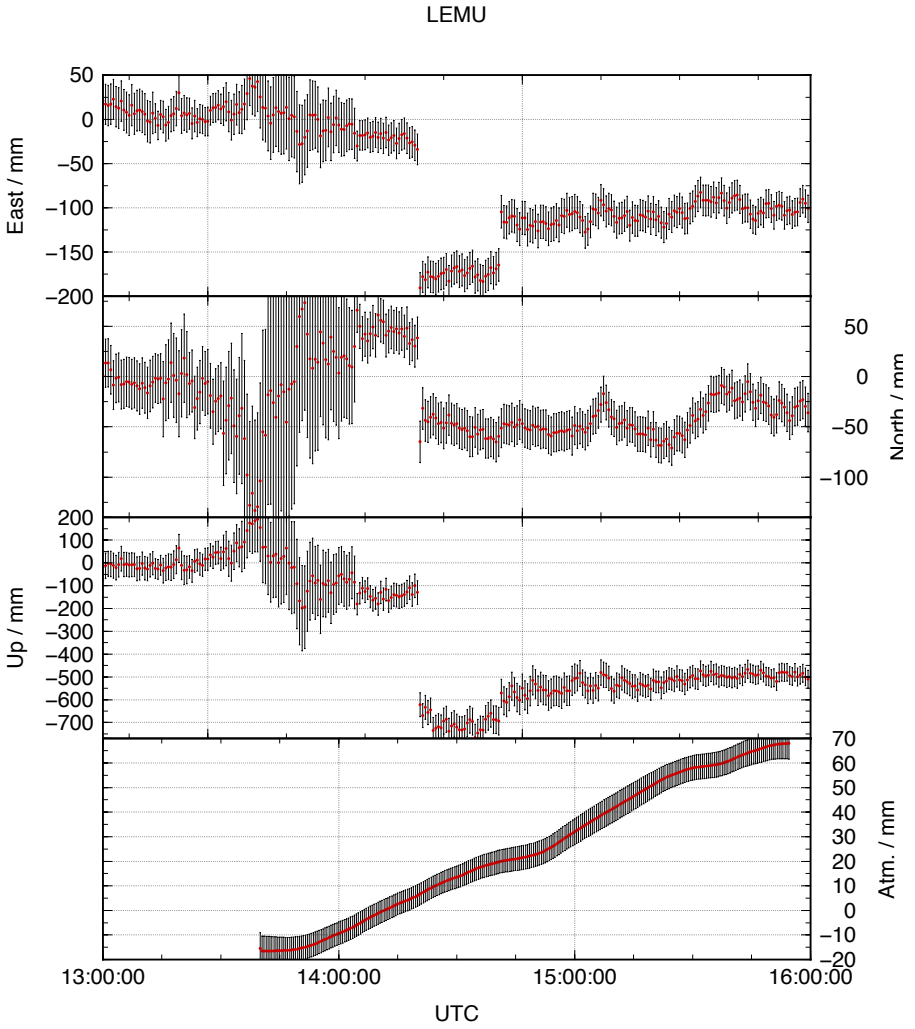
```
site_stats
 iloc 0.02 0.02 0.02 0 0 0
 lemu 0.02 0.02 0.02 0 0 0
 navi 0.02 0.02 0.02 0 0 0
timedep_procns
 iloc 1 1 1 2010 03 11 14 39 52 2010 03 11 14 40 00
 lemu 1 1 1 2010 03 11 14 39 52 2010 03 11 14 40 00
 navi 1 1 1 2010 03 11 14 39 52 2010 03 11 14 40 00
 iloc 1 1 1 2010 03 11 14 55 35 2010 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
site_pos ...
```



Example 3: Final run

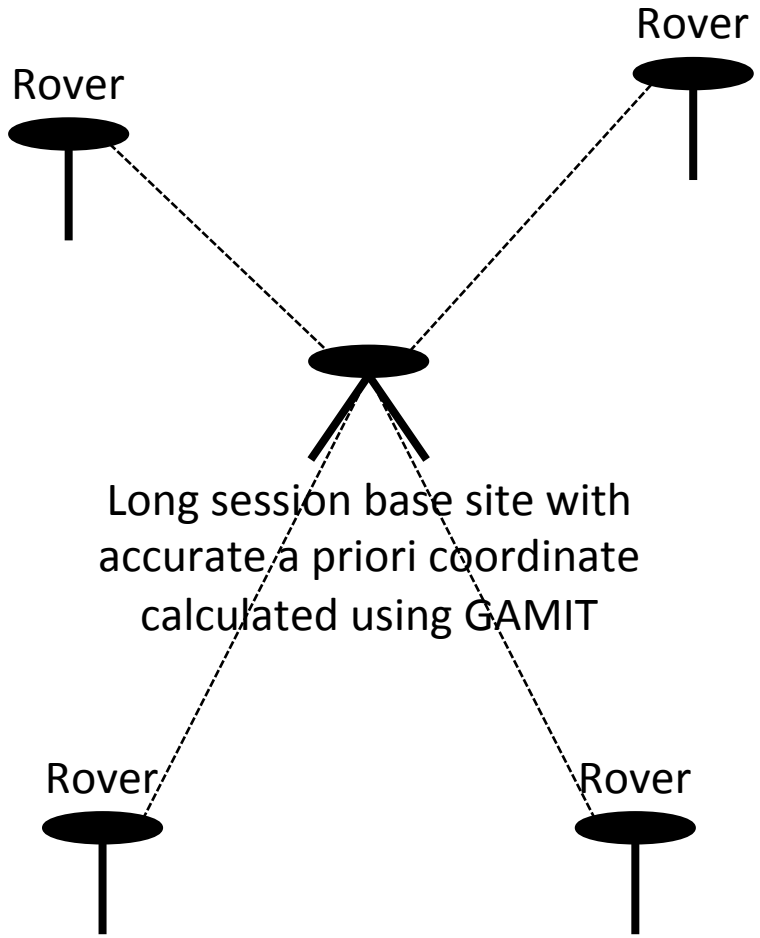
Key TRACK commands:

```
 site_stats
  iloc 0.02 0.02 0.02 1 1 1
  lemu 0.02 0.02 0.02 1 1 1
  navi 0.02 0.02 0.02 1 1 1
#timedep_procns
# 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
```

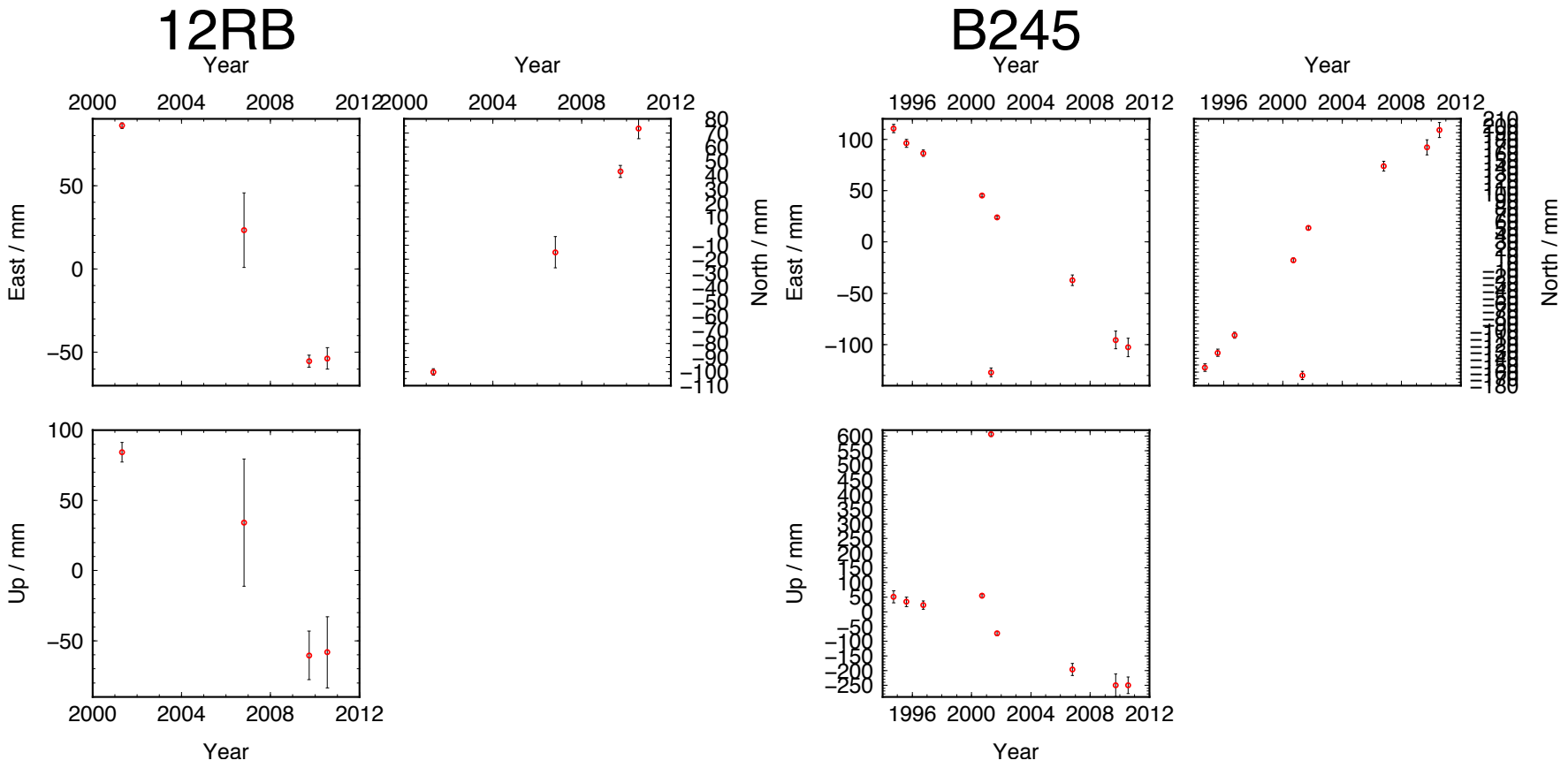


Example 4: Short-static occupations

- 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

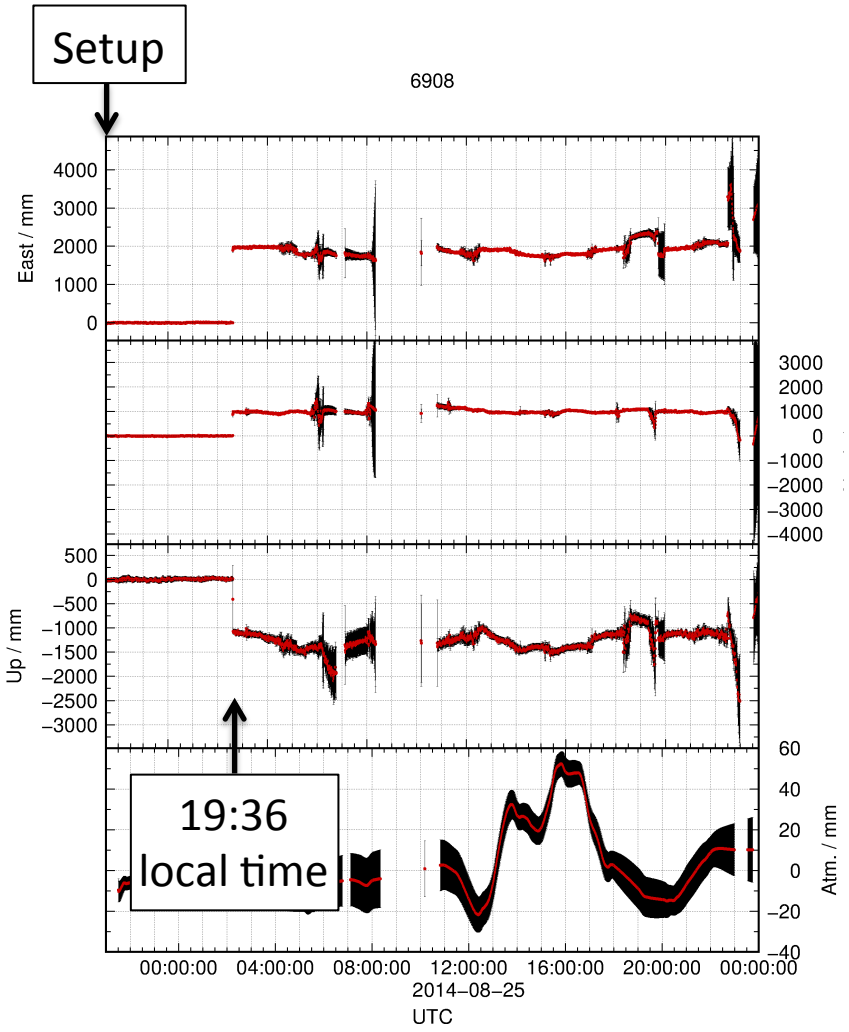


Sometimes, this happens…

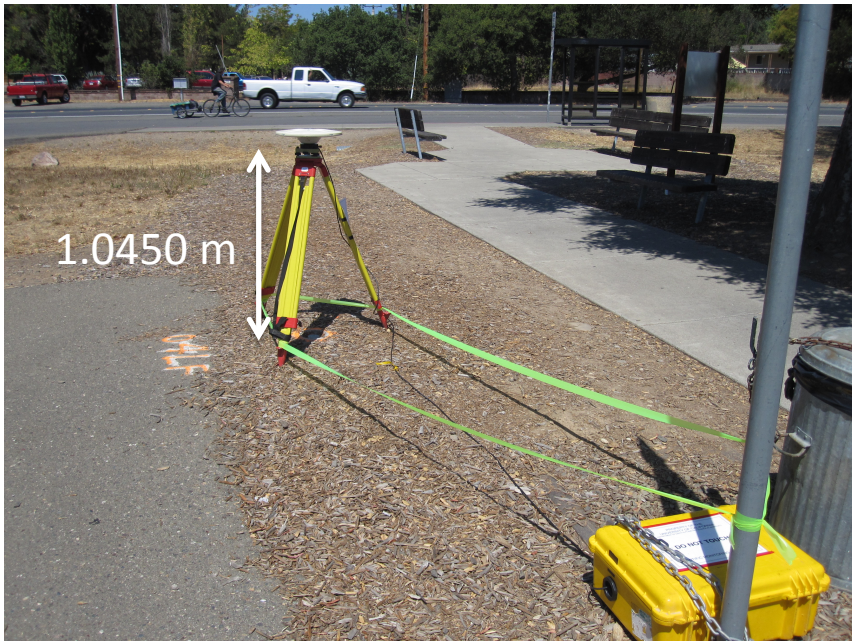
Photographs courtesy of Gareth Funning (University of California, Riverside)

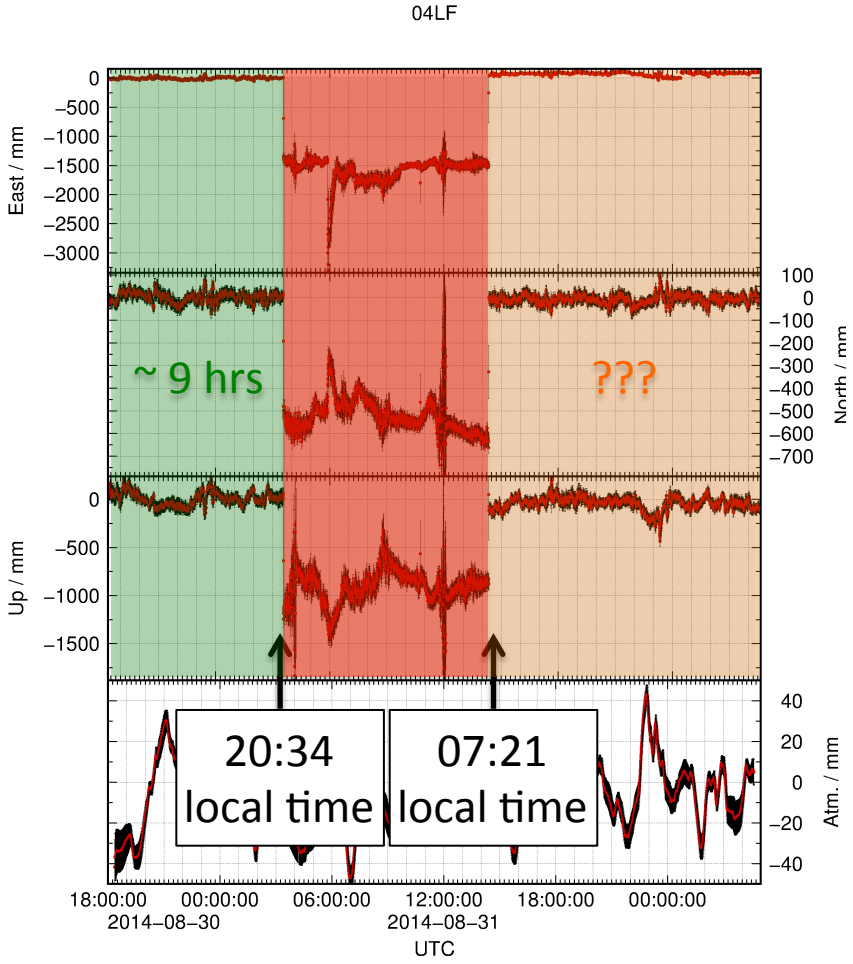
Example 5: Deciphering interference

- First TRACK run with
- Re-run teqc with “-e” option to truncate RINEX file at epoch of disturbance so as not to propagate bad data



Example 5: A complex example





sh_plot_track

- Reads track “NEU”, “DHU” or “XYZ” output file
- May add plot to view evolution of atmospheric delay

sh_kml

- Script for converting several formats of result into KML format for viewing in Google Earth
  - glist (may also be used with time slider)
  - ".org"-file / ".vel"-file
  - track "GEOD"-format output file

References

- England, P. C., R. T. Walker, B. Fu and M. A. Floyd (2013), A bound on the viscosity of the Tibetan crust from the horizontality of palaeolake shorelines, *Earth Planet. Sci. Lett.*, *375*, 44–56, doi:10.1016/j.epsl.2013.05.001
- Ryder, I., A. Rietbrock, K. Kelson, R. Bürgmann, M. Floyd, A. Socquet, C. Vigny and D. Carrizo (2012), Large extensional aftershocks in the continental forearc triggered by the 2010 Maule earthquake, Chile, *Geophys. J. Int.*, *188*, 879–890, doi:10.1111/j.1365-246X.2011.05321.x

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