Sentinel 3 USO observation with GNSS

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S3A Doris USO observation

Summary :

- S3A configuration
  USO observation using GNSS

- flight results

- observed on board USO characteristics
  evolution during a Doris pass

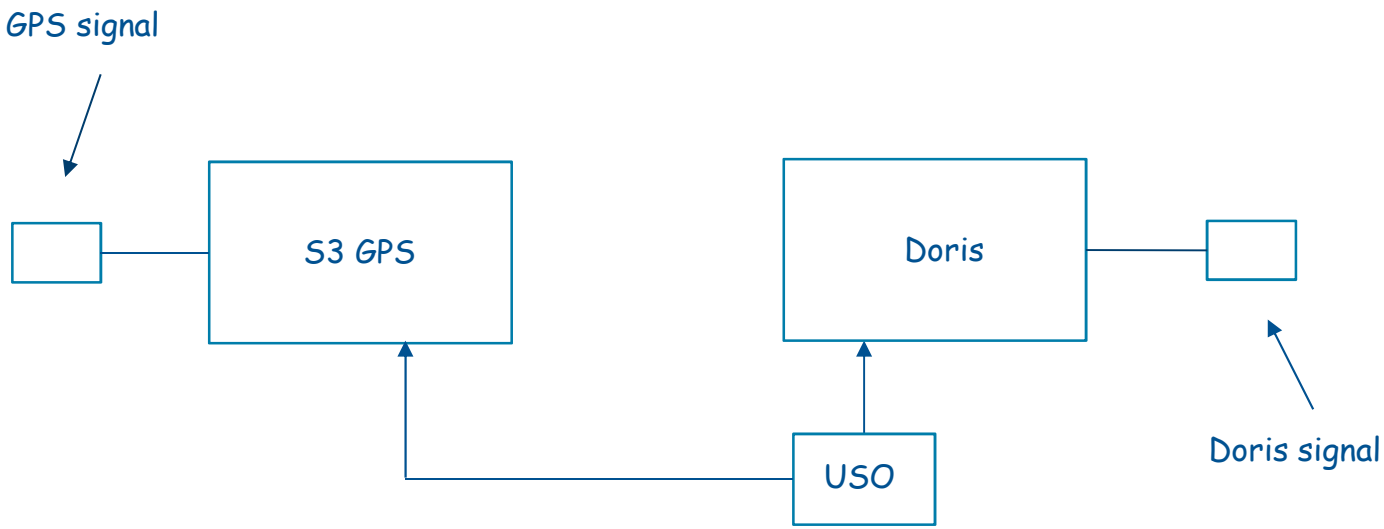
- SAA effect consequences on Doris performance
  residuals and station positioning

S3A satellite

USO monitoring for altimetry

Sentinel 3 : USO reference frequency must be characterized using the S3 GPS receiver

(usually Doris is used for this, cf Jason, Cryosat, Saral)

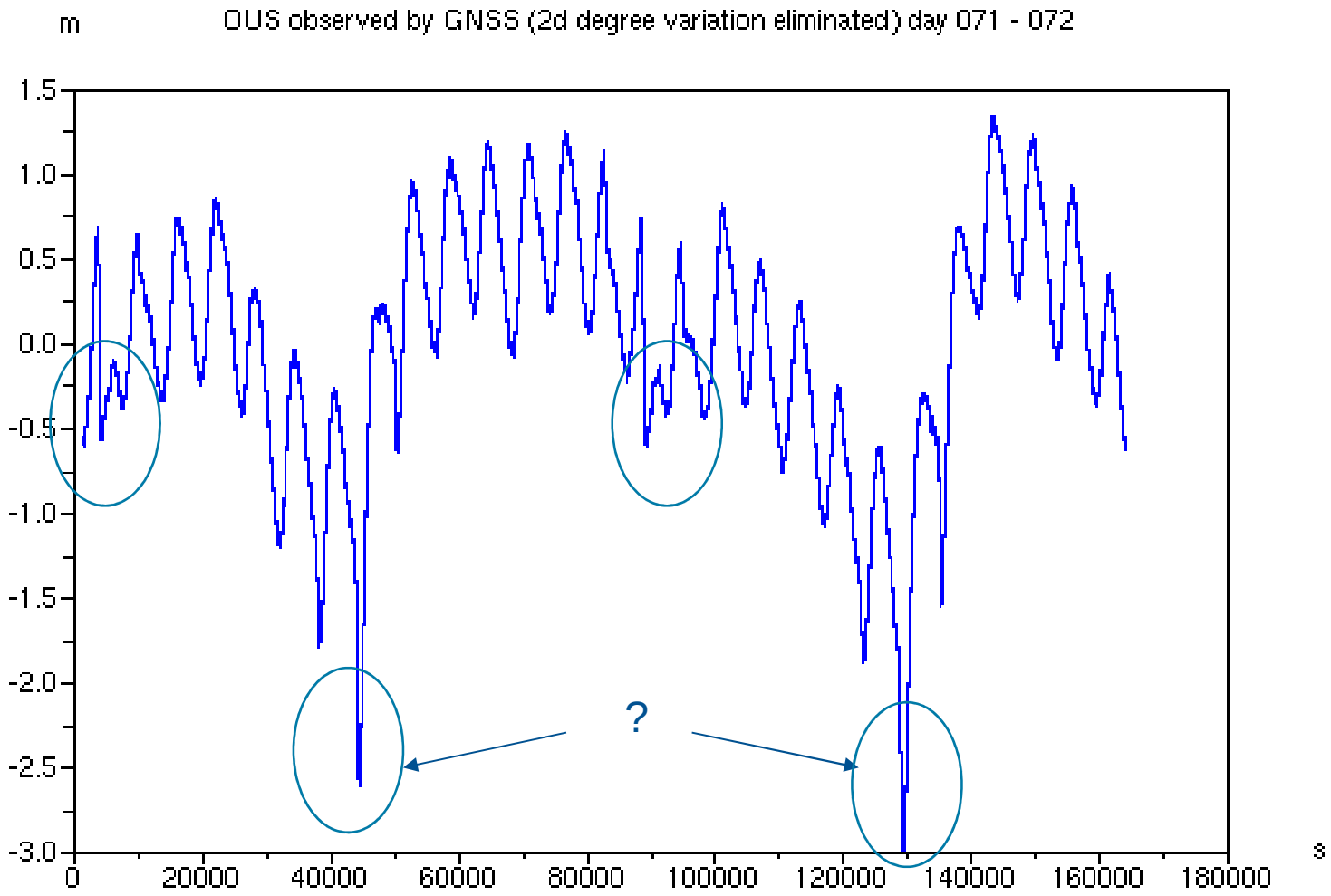


USO monitoring :

Doris : pseudo range measurements, synchronization, mean term frequency identification (degree 3 polynomial fitting on 2 days), delivery of mean observed frequency on each reference beacon pass.

GPS : continuous monitoring of pseudo range and phase, possible to have an estimation of the frequency over short intervals (sampling 1 s to 10 s)

Clock (2d degree polynomial removed) days 071 - 072



Relativistic effect not modelled --- > periodic orbital oscillations, constant amplitude
Some anomalies not due to relativity effects

Long term variations

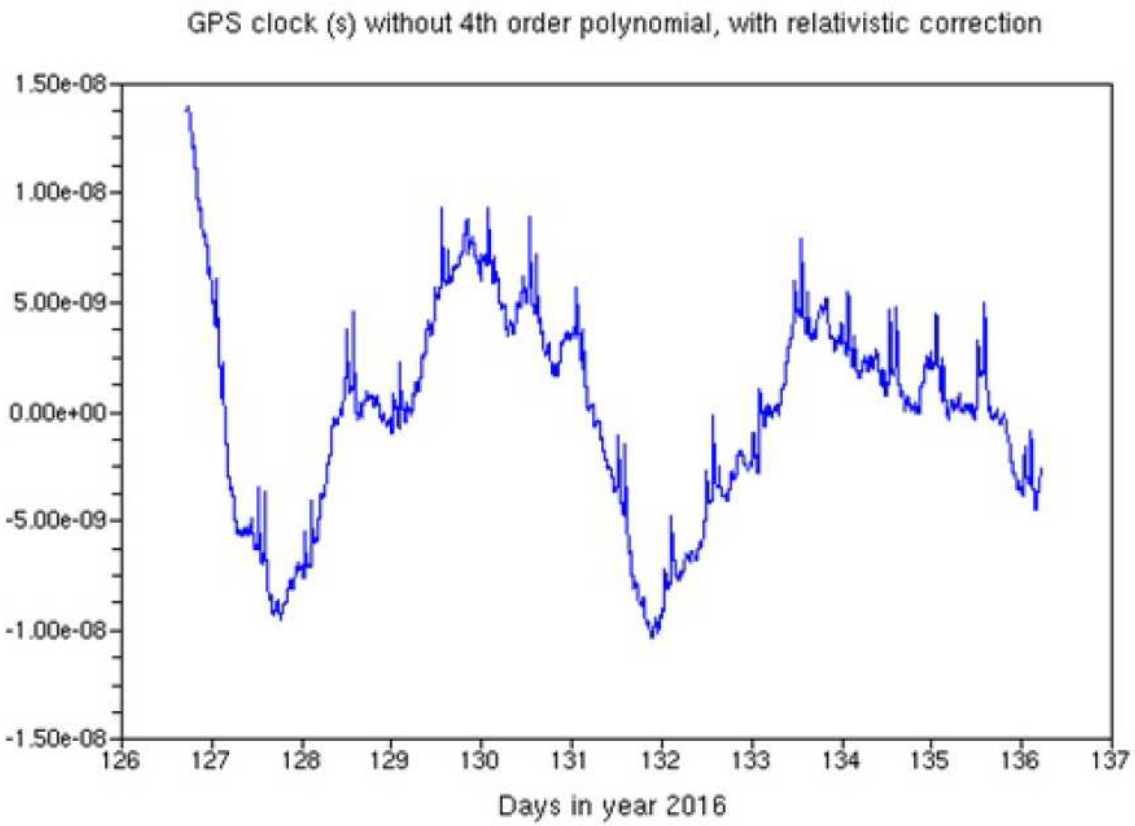


Figure 5. USO behaviour as seen by GPS measurement, i.e. GPS clock without a 4th order polynomial, and relativistic correction applied

Mid term frequency drift analysis

For the clock contribution, the Doris processing is equivalent to :

- remove the long term effect for the on board clock
  (here : second degree polynomial on one or two days)

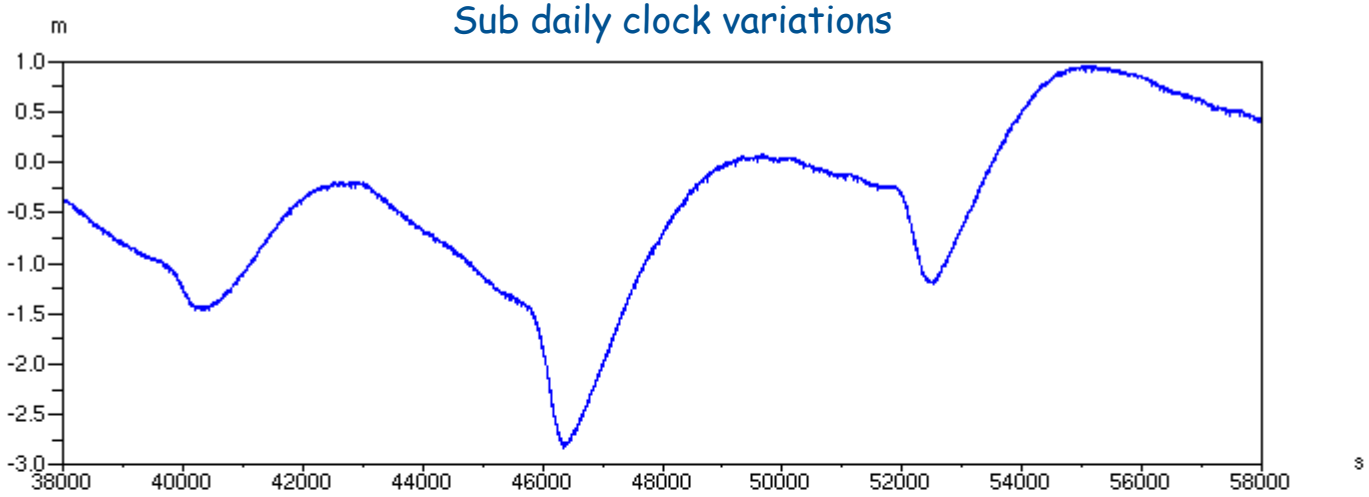
- adjust a linear variation for a pass (typically 600 s duration)
  equivalent to the classical beacon frequency bias adjustment

→ impact of the actual on board frequency errors (w.r.t. long term model)
  on the residuals

  station positioning

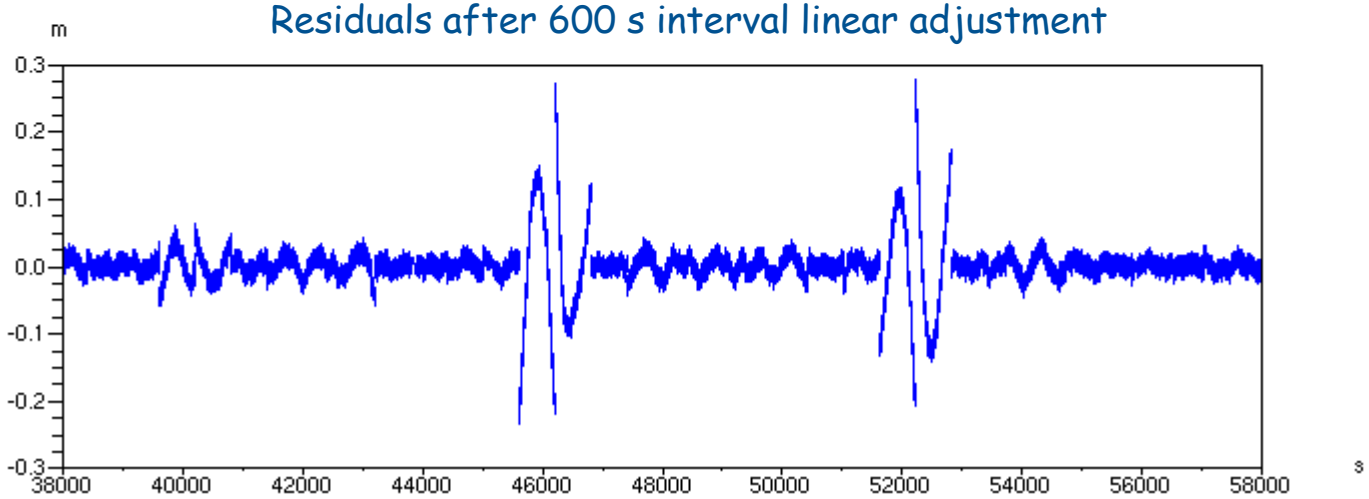
600 s interval linear adjustment

Sub daily clock variations



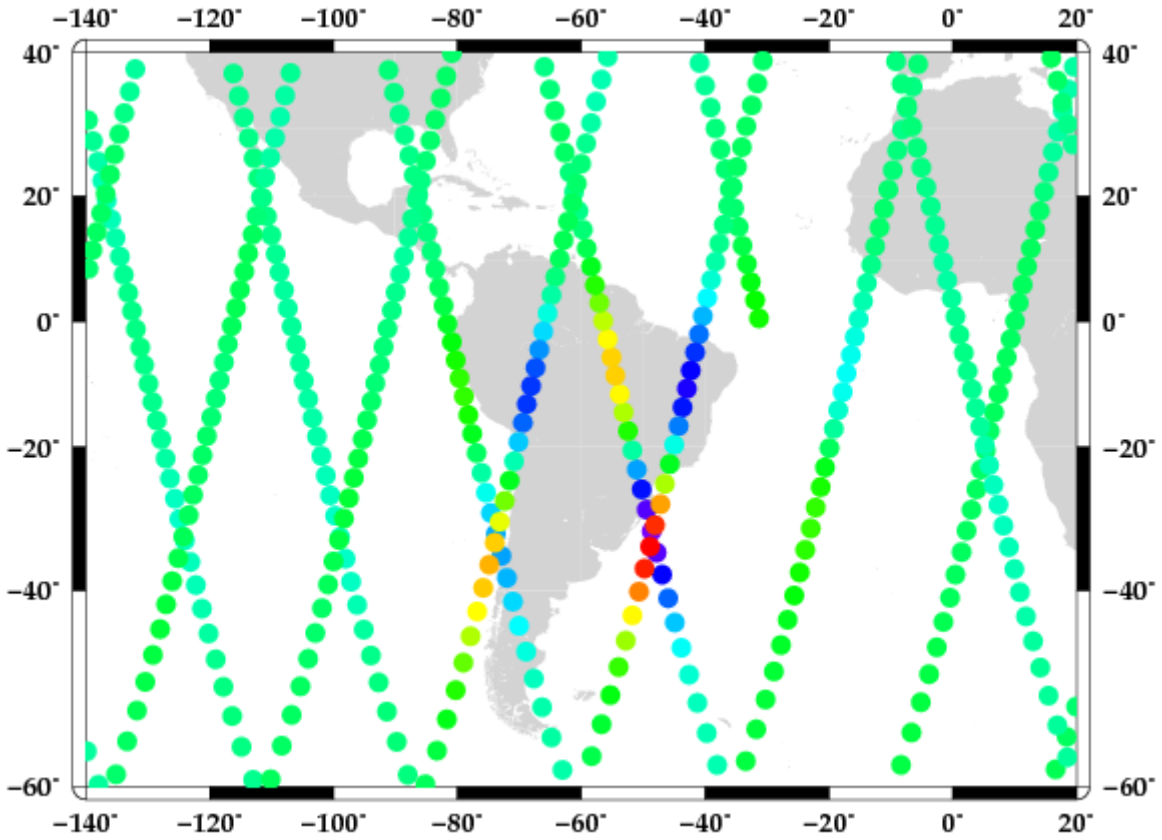
Residuals after 600 s interval linear adjustment

30 cm



Important parabolic signatures are remaining (~ 30 cm on one pass)

Geographic position of the anomalies



Estimation of the residuals curvature (600 s duration)
normalized in [-1,1] ⟶ very clear SAA effect on the USO

USO correction in Doris processing

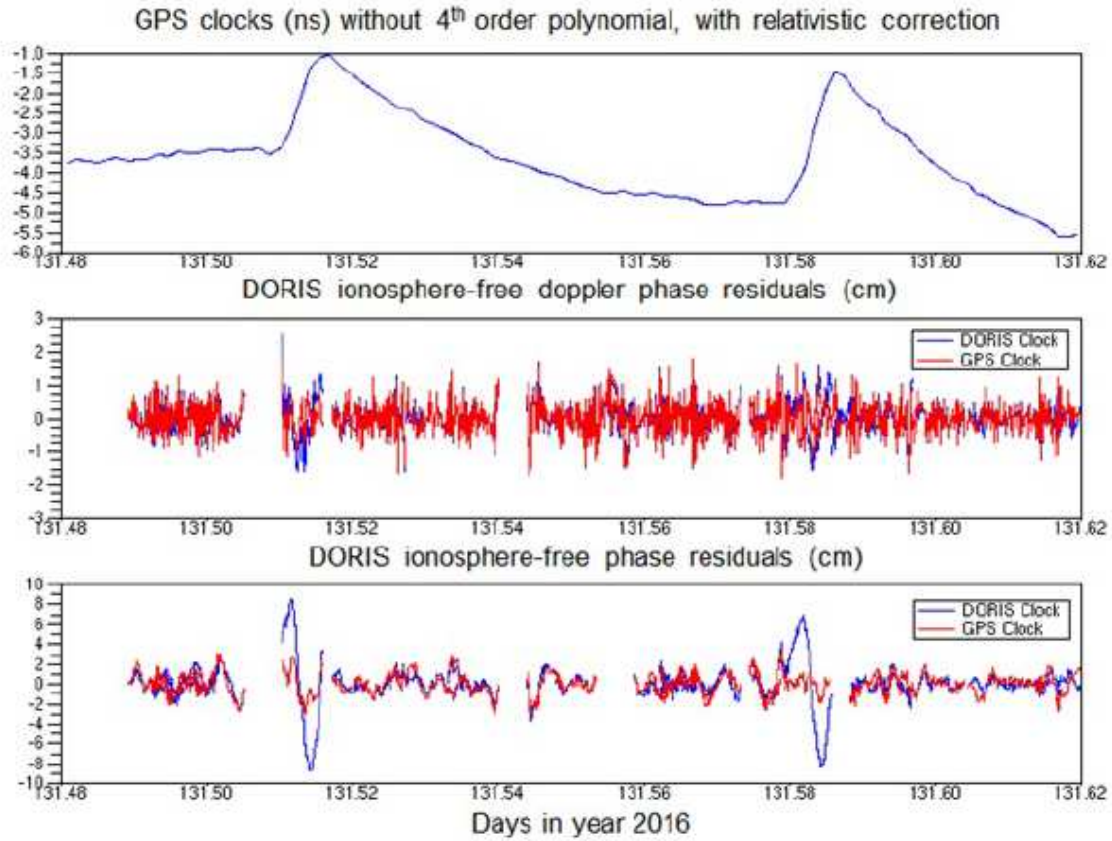


Figure 12. DORIS measurements residuals, from two different processings : with GPS clock and with DORIS clock

Impact on station positioning

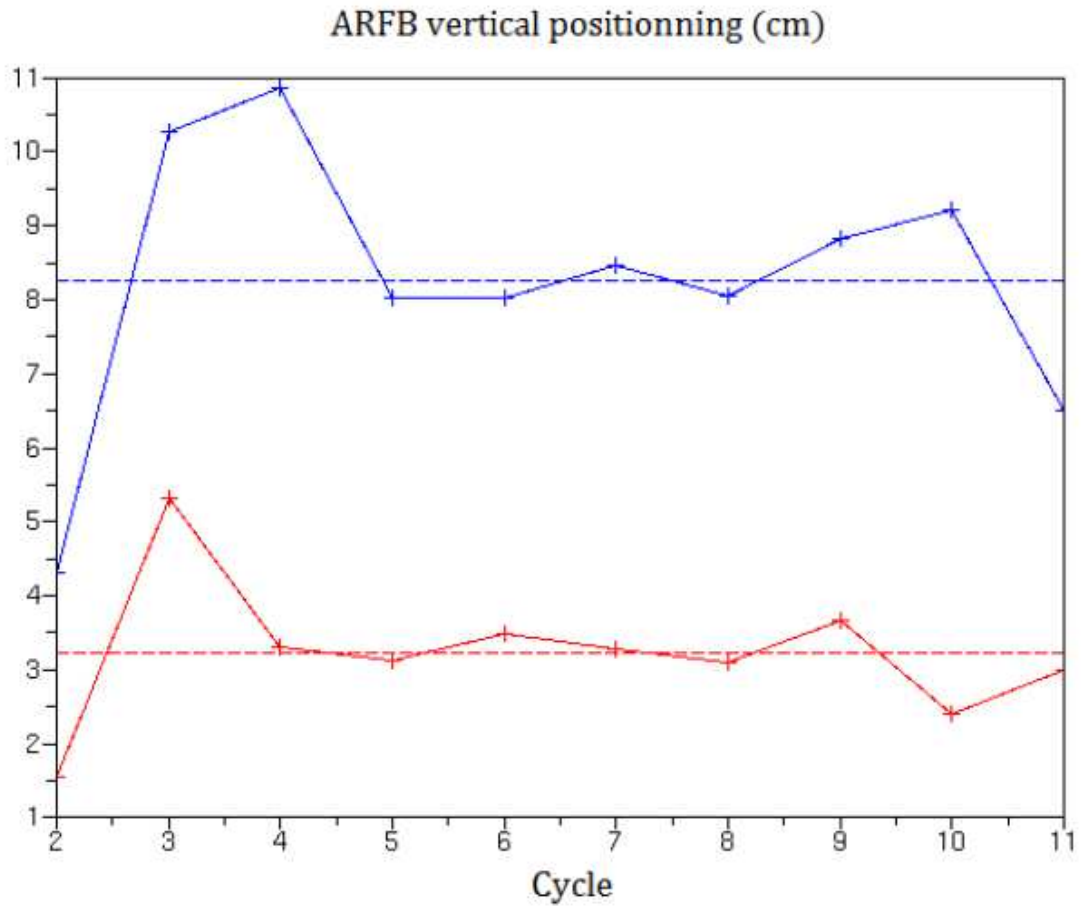


Figure 15. Vertical positionning on station ARFB, with GPS clock (red) and DORIS polynomial clock (blue)

Conclusion

The observation of the Doris USO with the GNSS is very promising for future improvements of the system

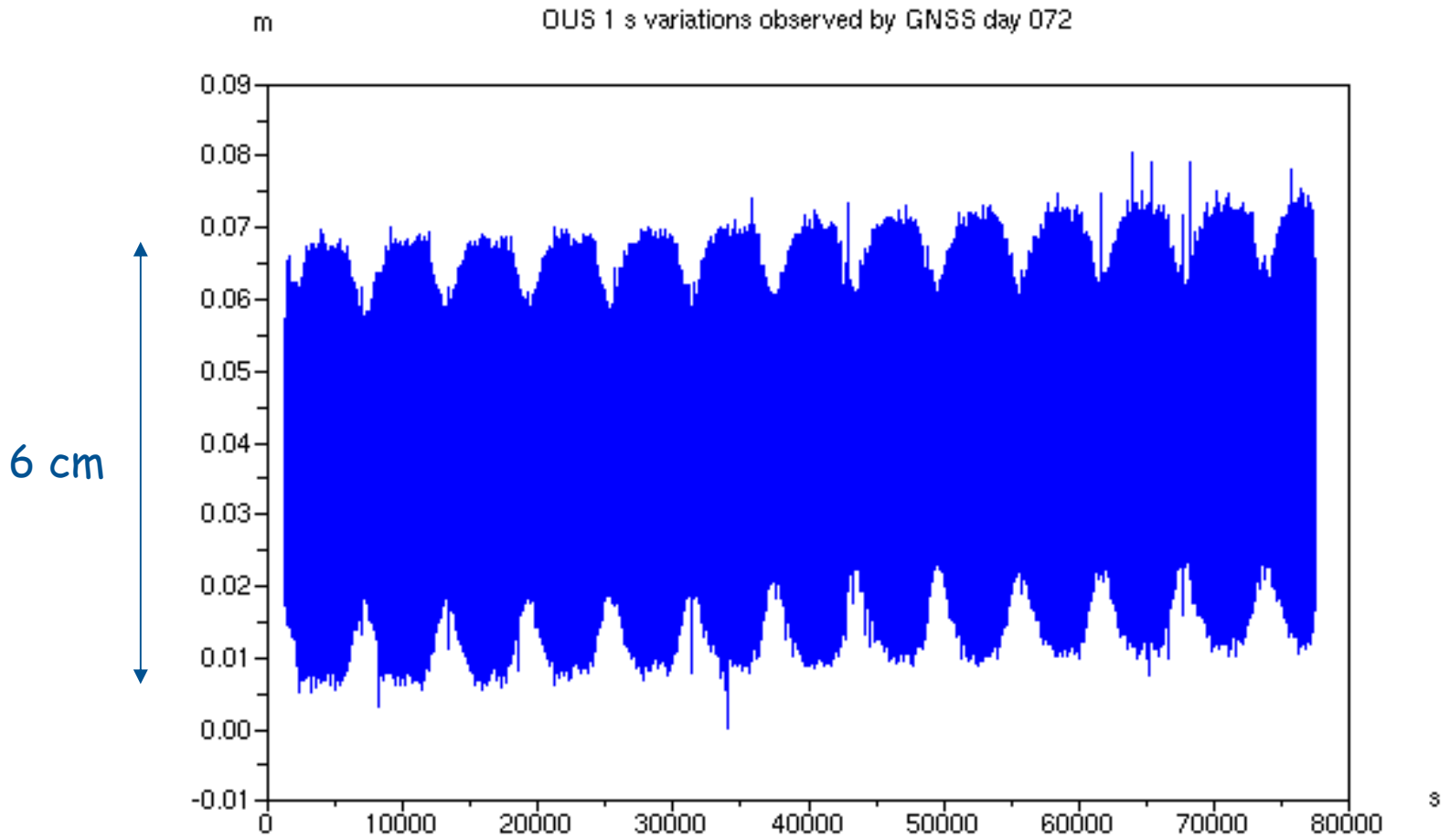
The USO shows clearly frequency variations related to the South Atlantic Anomaly, and these variations could induce more than 10 cm vertical errors on a single pass.

The SAA effect is clearly observed in the Doris phase residuals

The stations in the perturbed area may have important vertical offsets in the single satellite positioning solution (ARFB example)

Backup

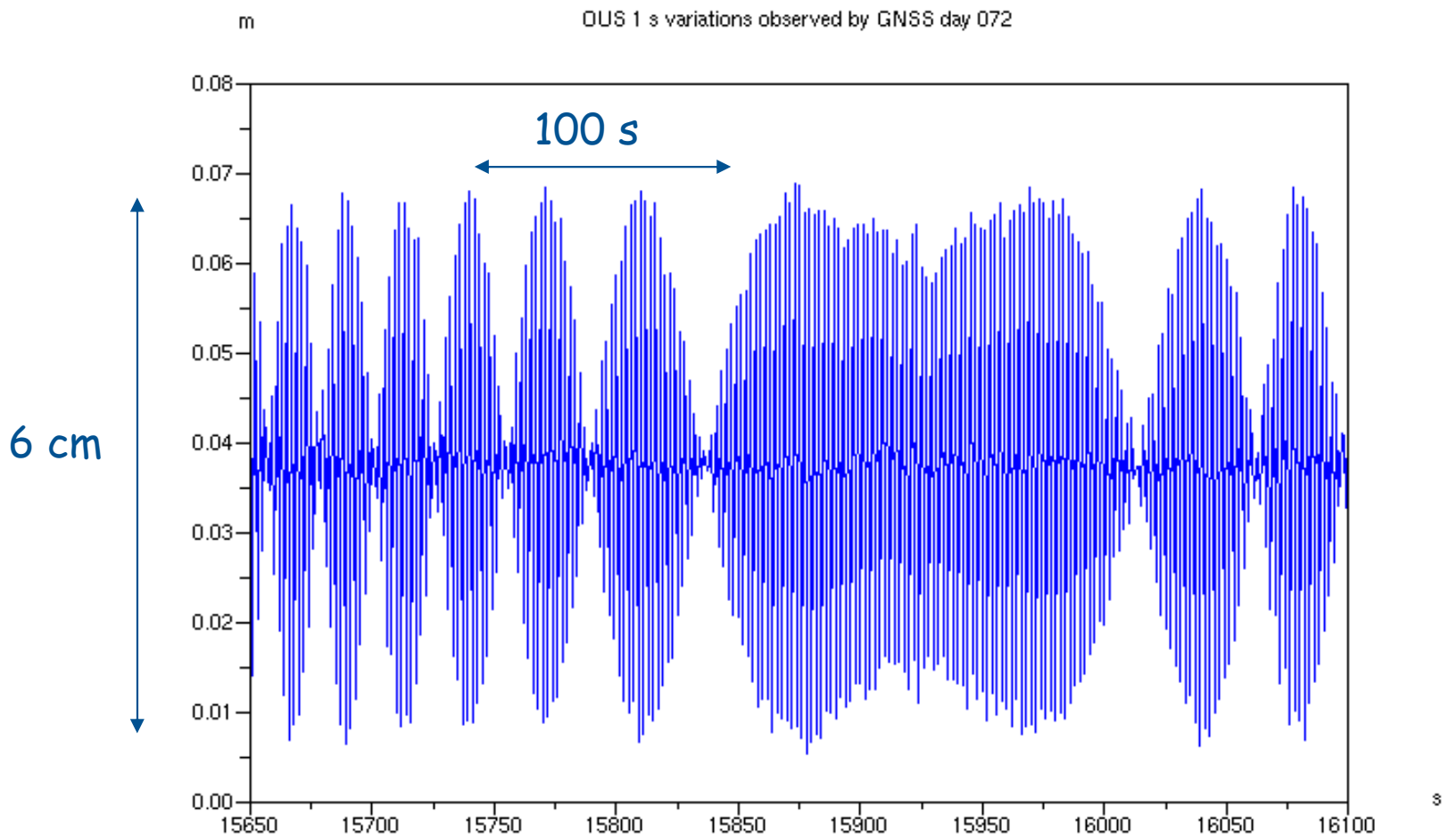
Clock 1 s variations, day 071



Anomaly : the 1 s oscillations are too important (6 cm peak to peak)

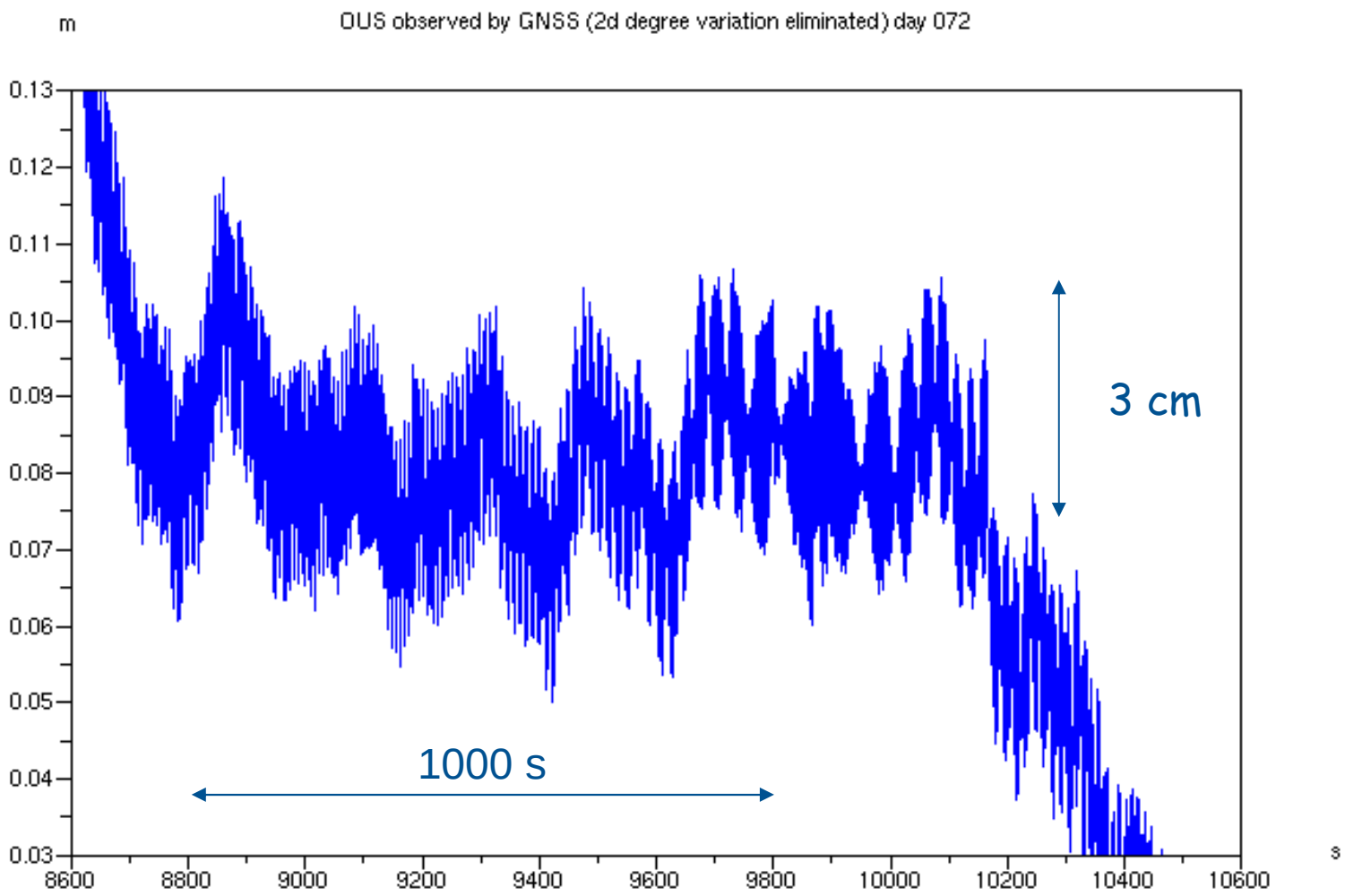
- a millimeter value is expected
- the Doris residuals are correct (such amplitudes are not observed in the 10 s Doris measurements)
- stable and systematic effects (orbital period amplitude variations)

Clock 1 s variations, day 071, zoom



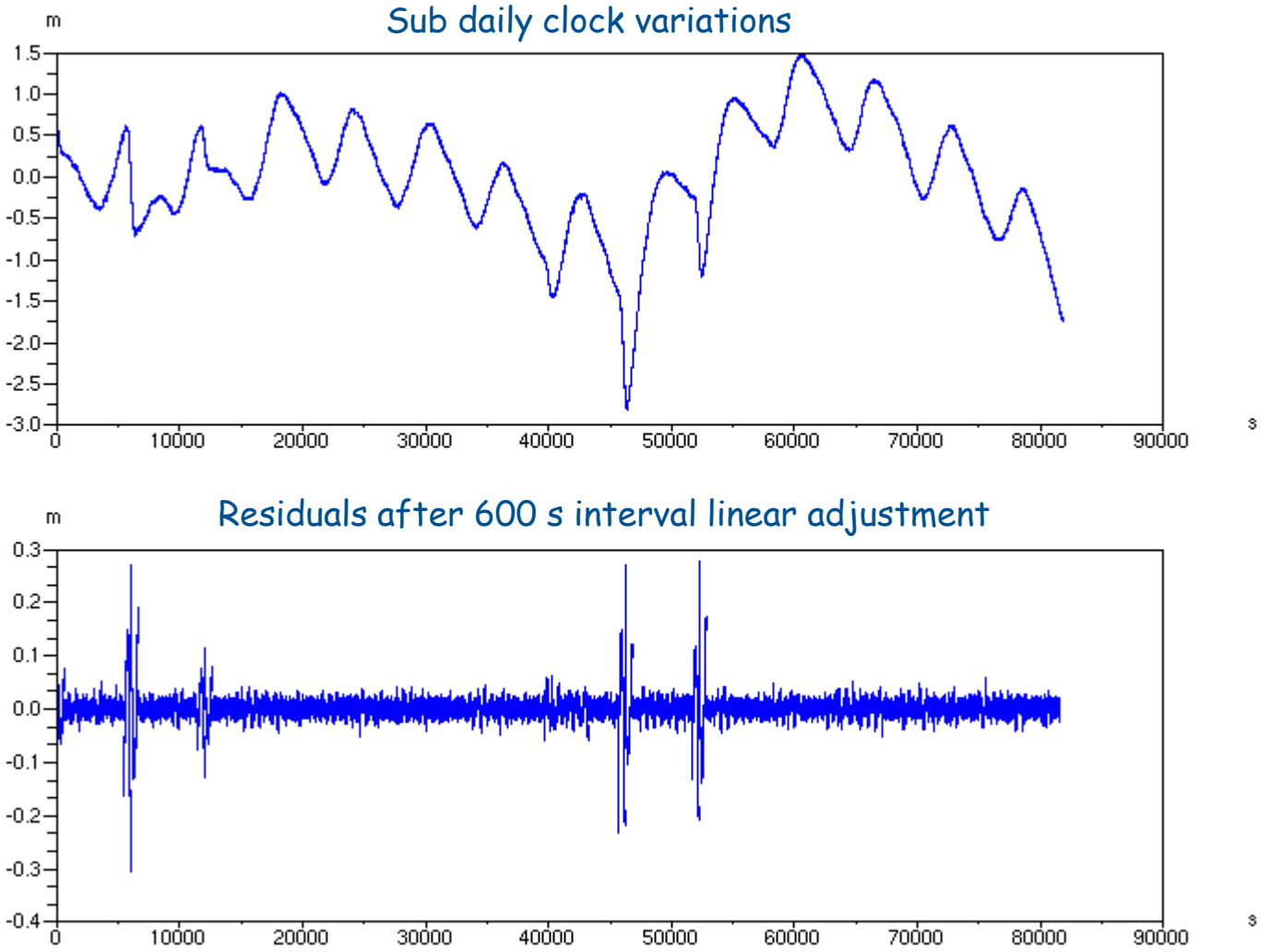
Beating between two close 1 Hz frequencies
or aliasing of higher frequencies

Clock, mid term evolutions (~1000s)

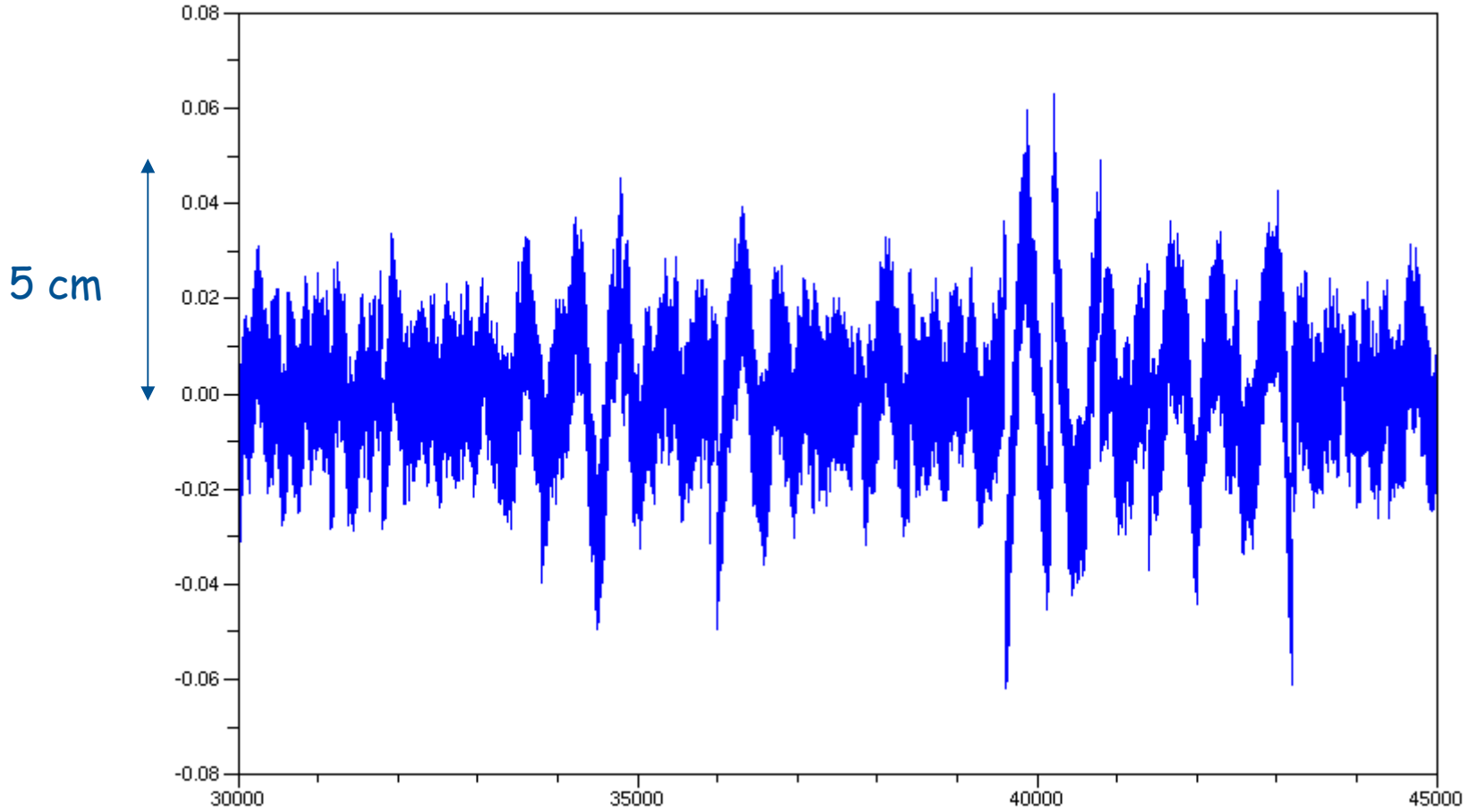


Mid term variations : ~2-3 cm for a Doris pass duration : effect of the Doris USO

600 s interval linear adjustment

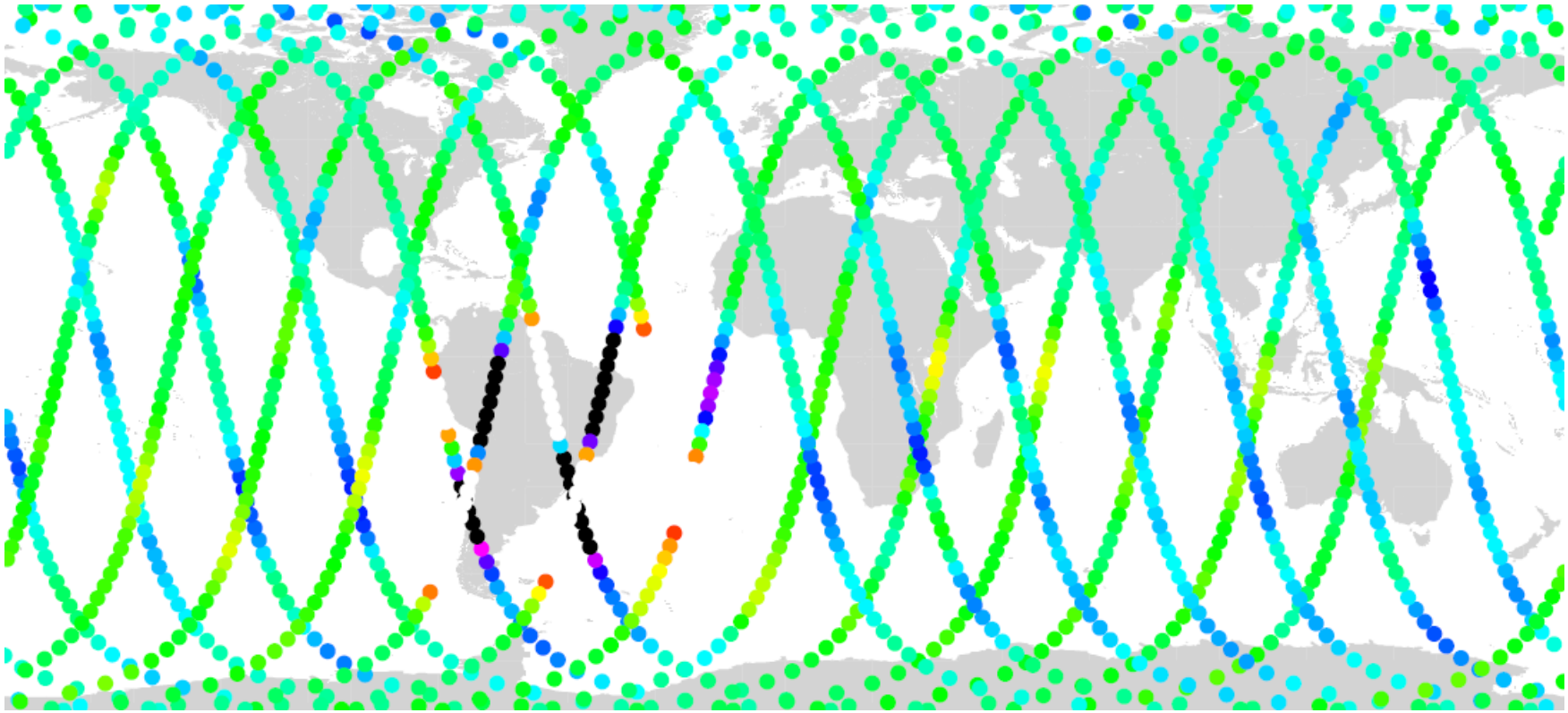


600 s interval linear adjustment (small amplitudes)



Amplitudes of a few centimeters are frequent

Smaller geographic effects



Visualisation of the smaller amplitude effects (green corresponds to 0)

to be studied ….