Differences between GPS receiver antenna calibration models and influence on geodetic positioning

Q. Baire , W. Aerts, C. Bruyninx , E. Pottiaux and J. Legrand
Royal Observatory of Belgium (ROB)

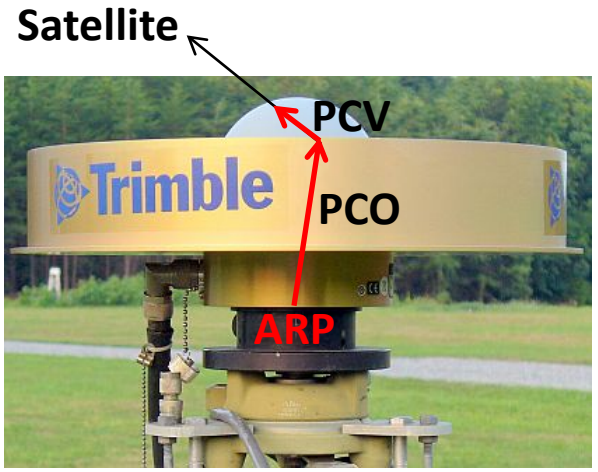
Outline

- Individual antenna calibration methods
- Methodology
  - Precise Point Positioning
  - Data sets
- Impact on computed station position
- Summary and conclusions

Phase Center Correction (PCC)

- Computed GPS station position: Antenna Reference Point (ARP)
- GPS signal measured at the virtual phase center of the receiving antenna
- Phase center corrections = Difference between ARP and phase center of the antenna
- Determined by the calibration and divided in 2 parts:
  - Phase center offset (PCO): independent of satellite position
  - Phase center variation (PCV): depend on the azimuth and elevation of the satellite over the antenna

$$PCC(\alpha,z) = PCO + PCV(\alpha,z)$$



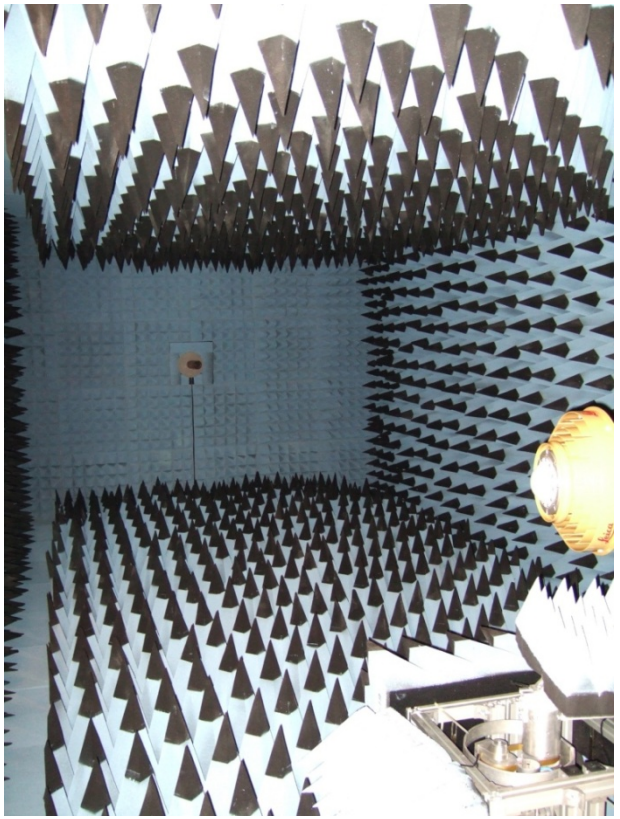
Individual calibration methods

Robot calibrations

➡ Geo++(D)

Also NGS(USA), Ife(D), SendStadt Berlin(D)

Anechoic chamber calibrations



➡ Uni-Bonn(D)

Individual calibration methods

Robot Calibrations	Anechoic chamber calibrations
Use real GNSS signals	Use generated sine wave
Only observed signals	Any frequency
GNSS receiver	Vector Network Analyzer
Multipath mitigated by intelligent positioning sequence	Multipath mitigated by the chamber
Used to generate type mean calibrations in the IGS	Can be used to generate type mean calibrations since the igs08.atx

How to compare 2 calibrations

$\Delta PCC(\alpha,z) = (PCO_1 - PCO_2) + (PCV_1(\alpha,z) - PCV_2(\alpha,z))$

But PCV are not aligned:

- Geo++: Zenith PCV = 0
- Uni-Bonn: PCV = direct phase measurement

To compare:

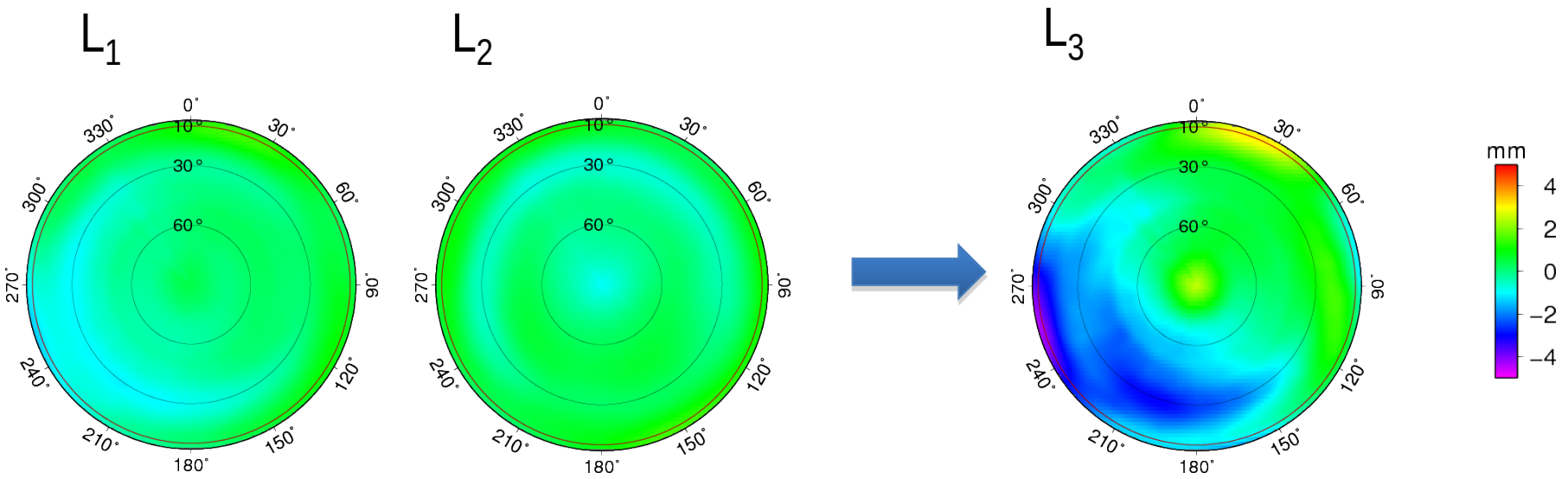
- Shift Uni-Bonn PCC ->Zenith PCV= 0
- PCC(α,z) equivalent to PCC(α,z) + constant for all directions (for positioning)

Adding a constant: no position offset

- Only station clocks affected
- Equivalent to adding cable length

Individual calibration on L_3

- Differences of PCC between Geo++ and Uni-Bonn calibrations for a Trimble antenna on L_1 and L_2 and the resulting L_3 calibration



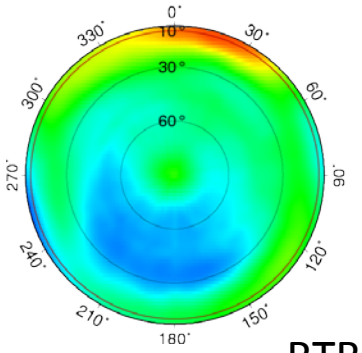
- Differences on L_1 and L_2 at the mm level but amplified in L_3
- In this study: only L_3 used

Individual calibration models

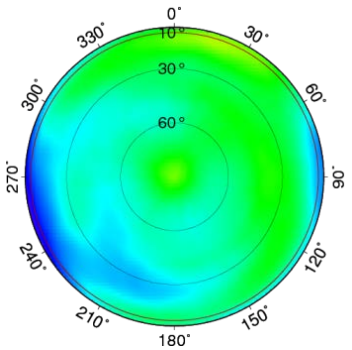
PCC differences between Geo++ and Uni-Bonn

- Six antennas installed at ROB.
- Each individually calibrated by both GEO++ and Uni-Bonn.

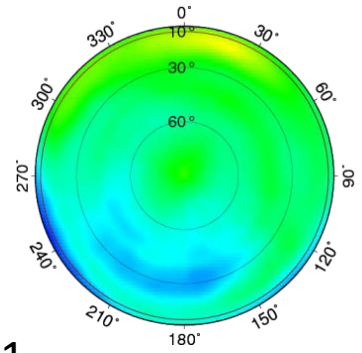
RTBT 3

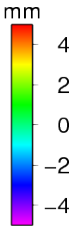


RTBT 2



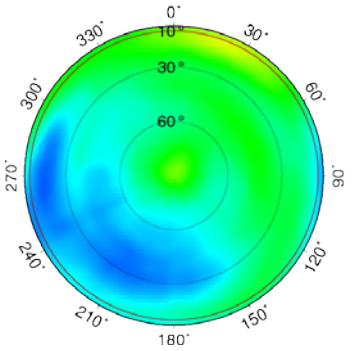
RTBQ 1



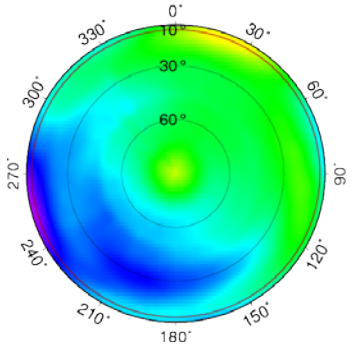


5 Trimble TRM59800.00 NONE

RTBR 3

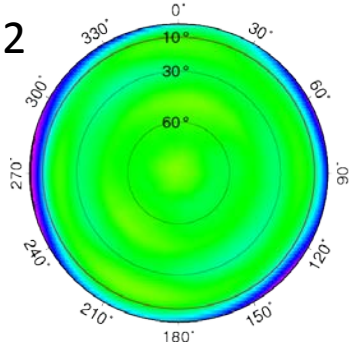


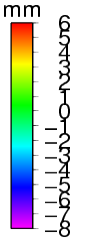
RTBS 1



1 Leica LEIATR25.R3 NONE

RTBR 2





- What is the impact of the calibration model on computed station position ?

Individual calibration models

PCO differences between Geo++ and Uni-Bonn

- Six antennas installed at ROB.
- Each individually calibrated by both GEO++ and Uni-Bonn.

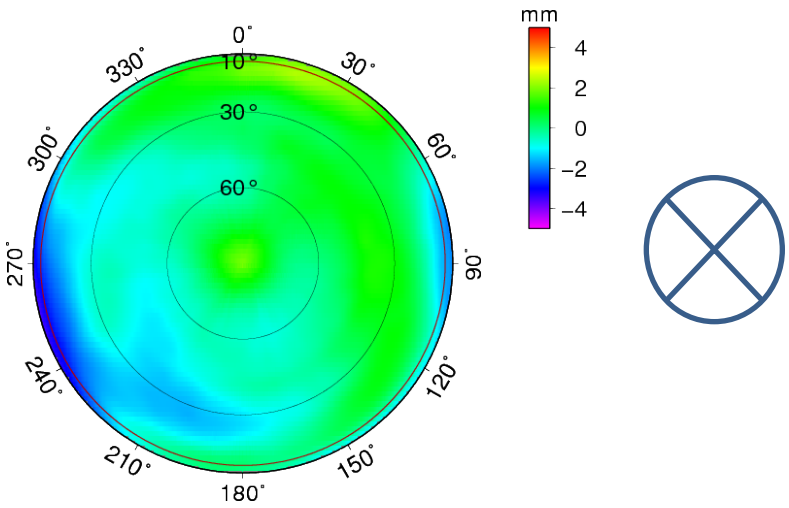
Station	North ΔPCO (mm)	East ΔPCO (mm)	Up ΔPCO (mm)*
RTBR 2	0.1	0.0	8.3
RTBT 2	0.7	1.0	-5.3
RTBT 3	1.4	0.6	-6.5
RTBQ 1	1.3	0.5	-6.3
RTBR 3	1.2	1.0	-5.0
RTBS 1	1.5	1.4	-3.7

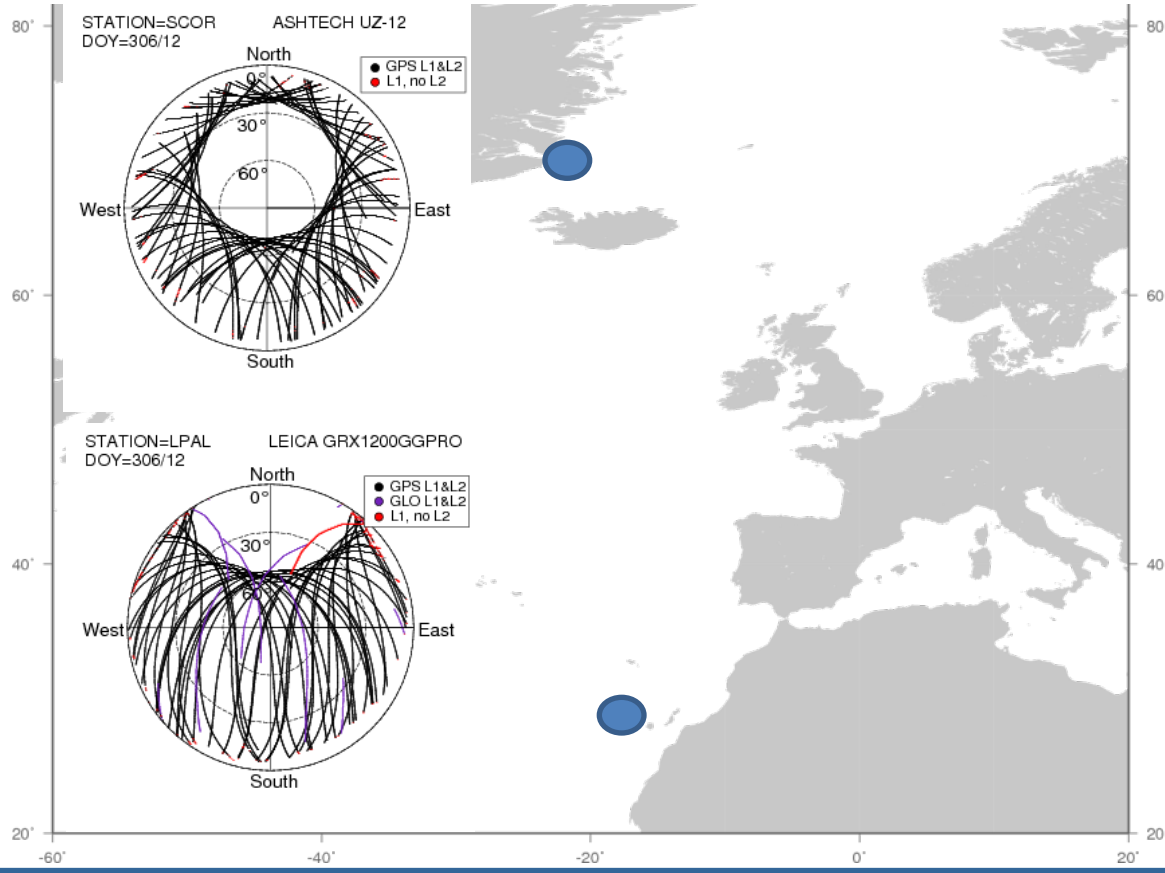
(*) PCO of Uni-Bonn adapted for zenith PCV = 0 (approximation: horizontal neglected)

- What is the impact of the calibration model on computed station position ?

How to estimate the impact on computed station position

- Impact on computed station position not direct:
  - PCO+PCV (PCC) will affect each satellite differently at each epoch





How to estimate the impact on computed station position

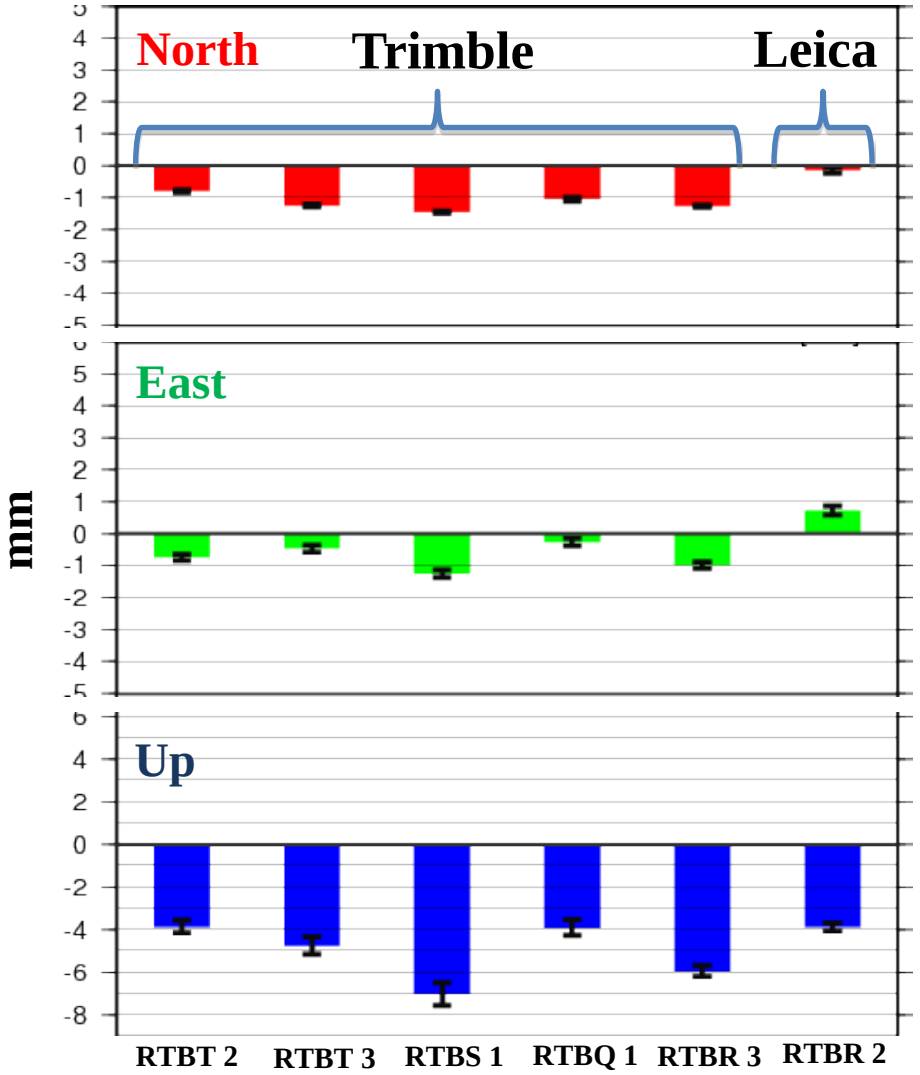
- Daily RINEX files
- 2 Precise Point Positioning:
  - Identical processing options (10° elevation cut-off, satellite antenna calibrations, orbits and clocks, etc…)
  - 2 different receiver antenna calibrations:
    - Geo++
    - Uni-Bonn

➡ Daily Position offsets

Final position offset = Mean daily position offsets (100 consecutive days)

Rebischung et al., *IGS08: the IGS realization of ITRF2008*, GPS Solution, vol. 4, issue4, pp. 483-494, 2012.

Position offsets for Brussels



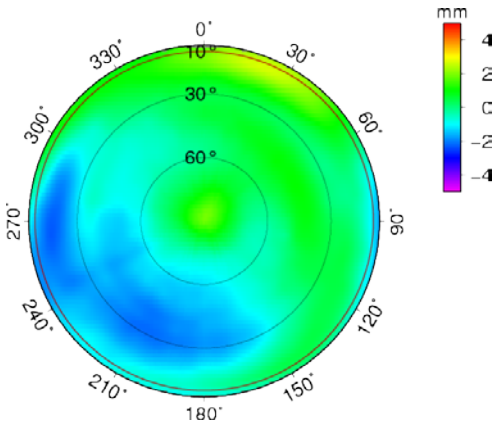
- Horizontal:
  - Trimble: -1 mm in the North and between 0 and -1 mm in the East
  - Leica: -0.1 mm in the North and 0 and -1 mm in the East
- Vertical:
  - Between -4 and -7 mm

Latitude dependency of the position offsets

- On a globally distributed set of stations (IGS08 core stations)
  - Assumption: all stations equipped with the same antenna
  - PPP for 2 antennas (using Geo++ and Uni-Bonn calibrations)
  - Position offset as function of latitude

TRM59800.00 NONE

SN: 54146



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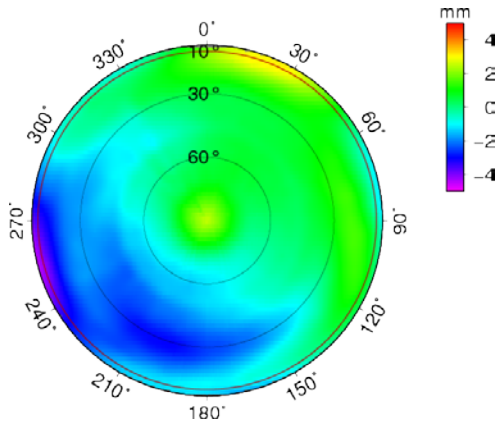
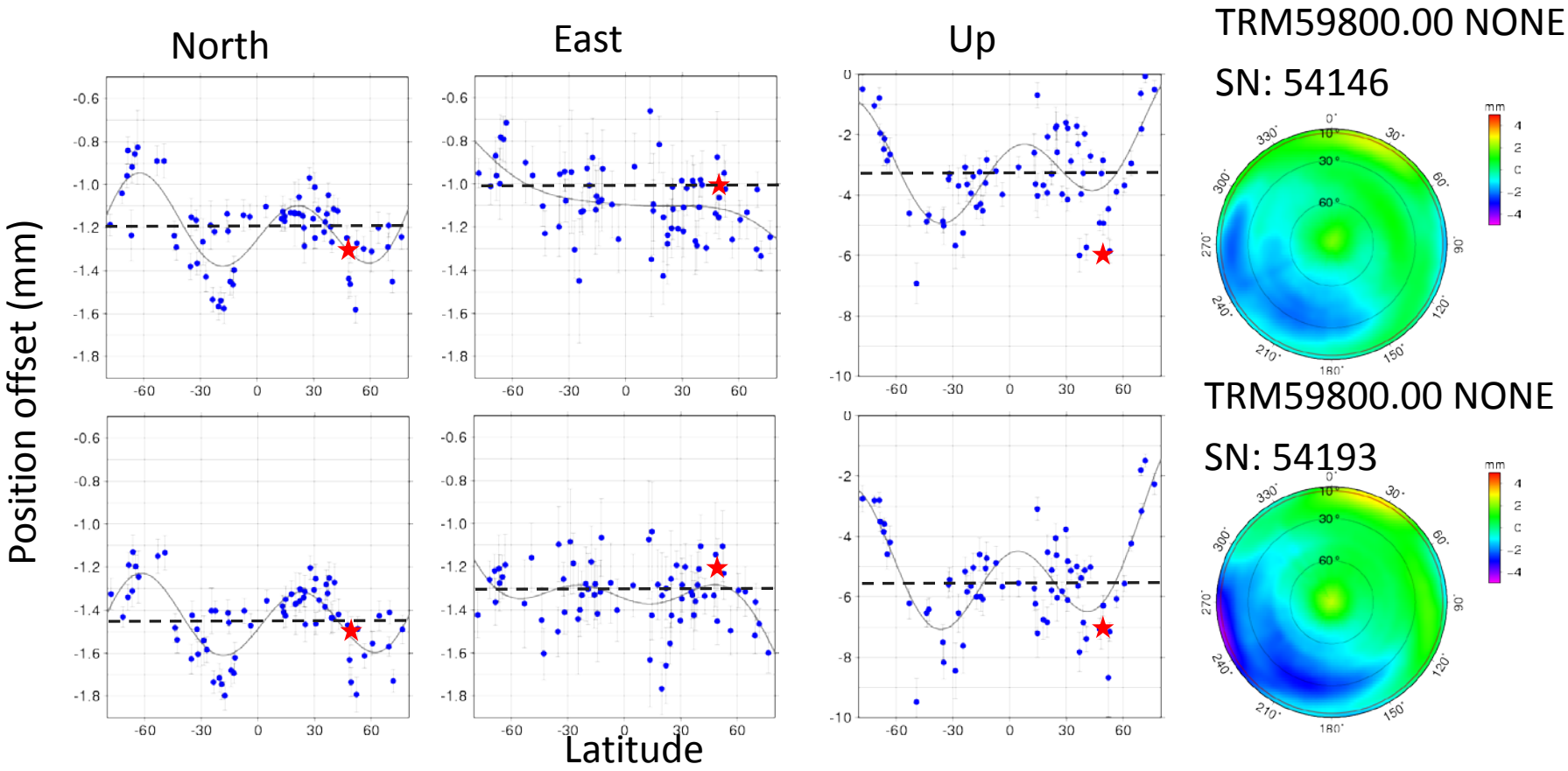
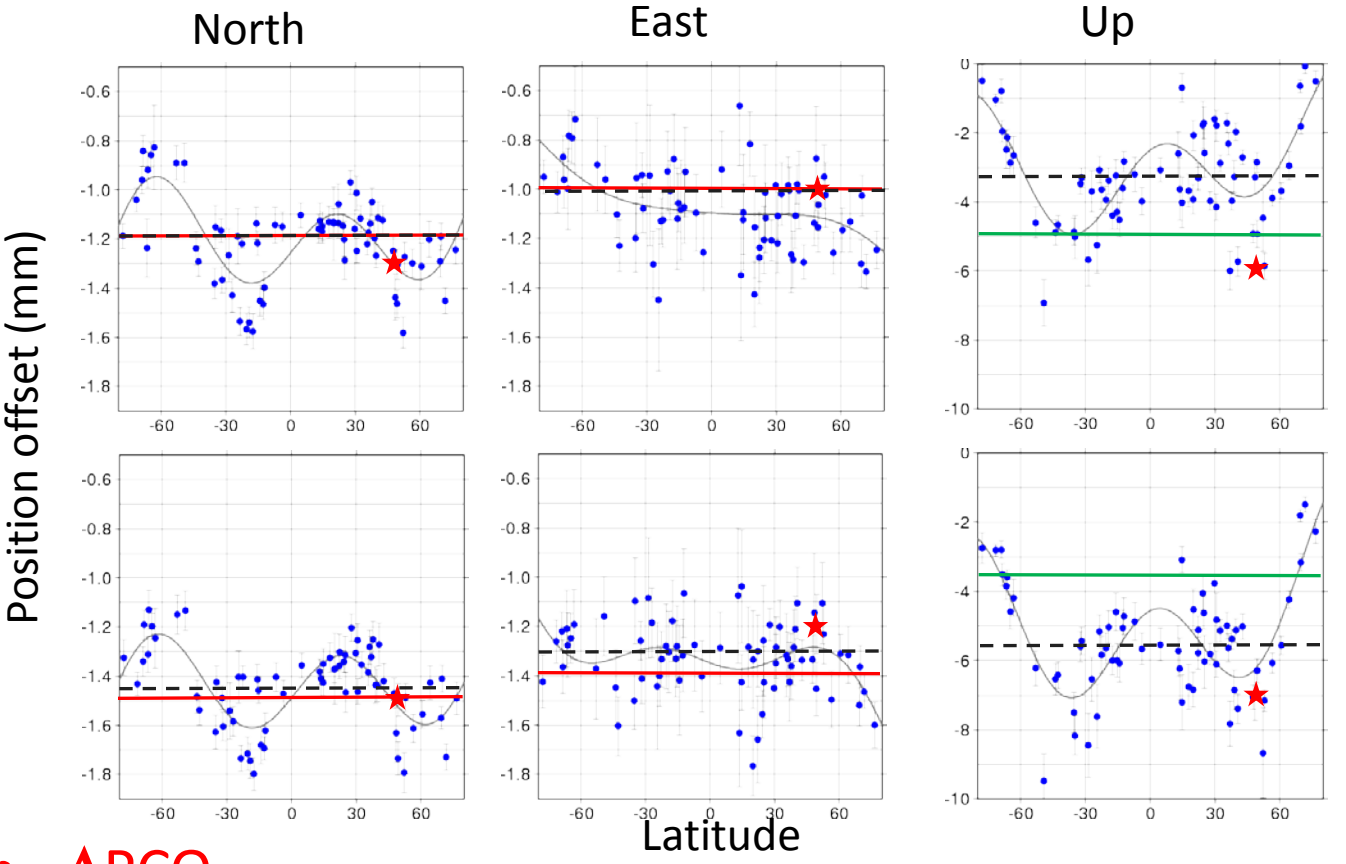


Latitude dependency of the position offsets

- Latitude dependent model (spherical harmonics) computed
- Horizontal range: 0.4 mm
- Vertical range: 3.5 mm



Latitude dependency of the position offsets



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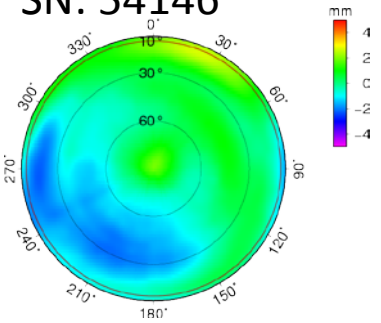

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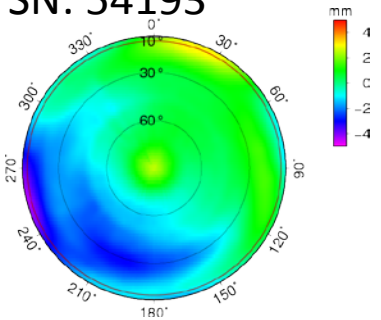
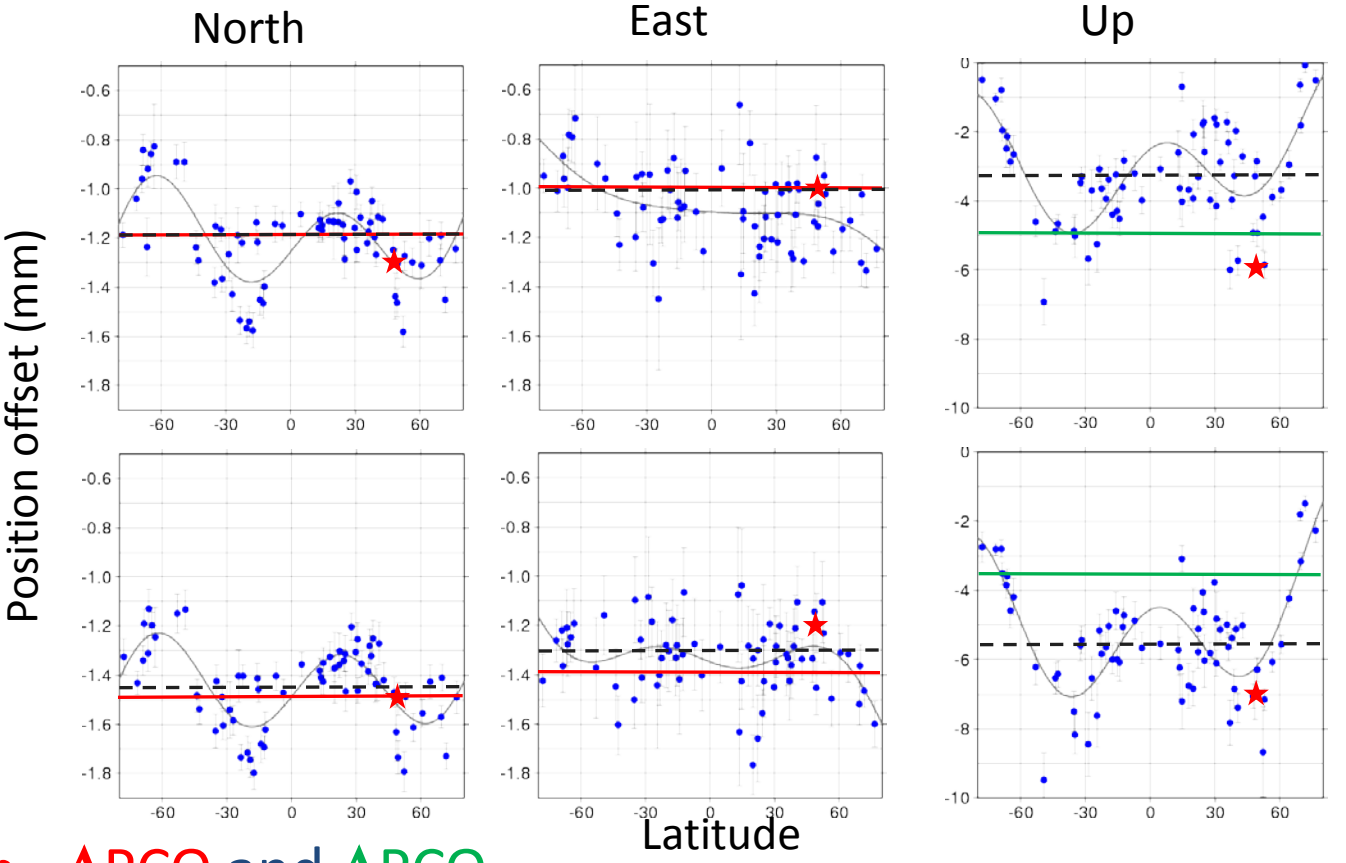


- ΔPCO

Latitude dependency of the position offsets



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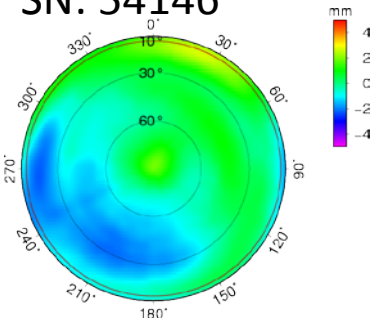

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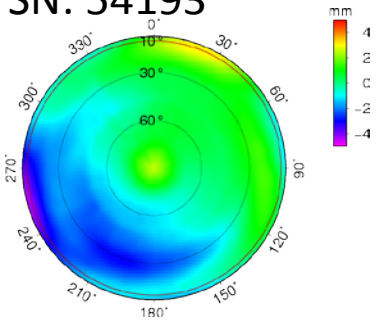
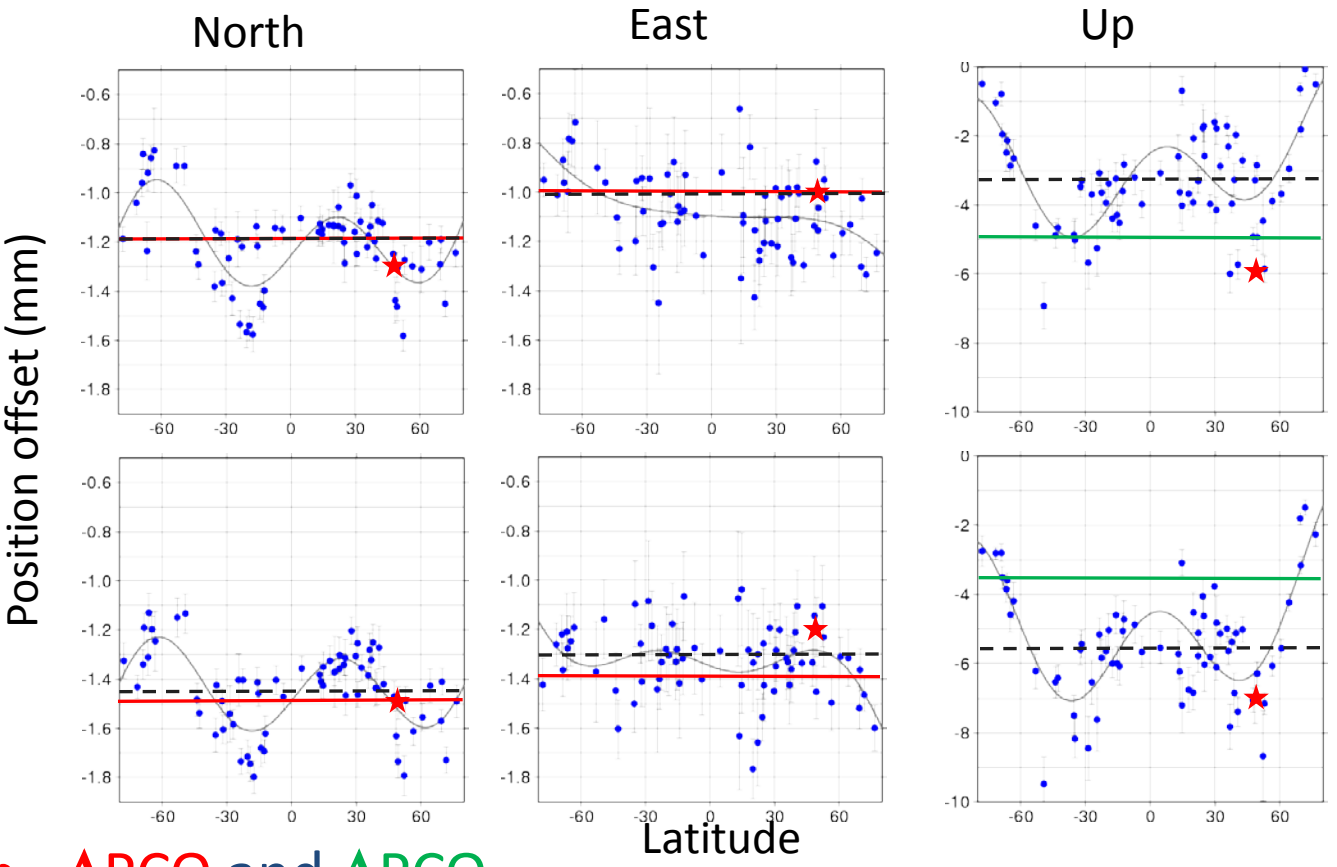


- ΔPCO and ΔPCO

Latitude dependency of the position offsets



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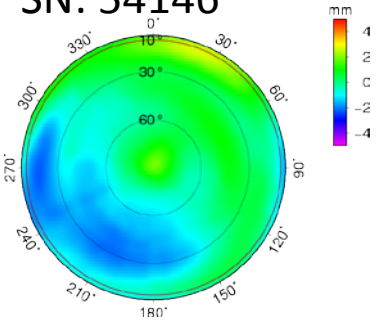

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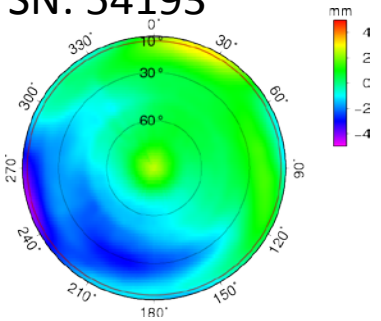
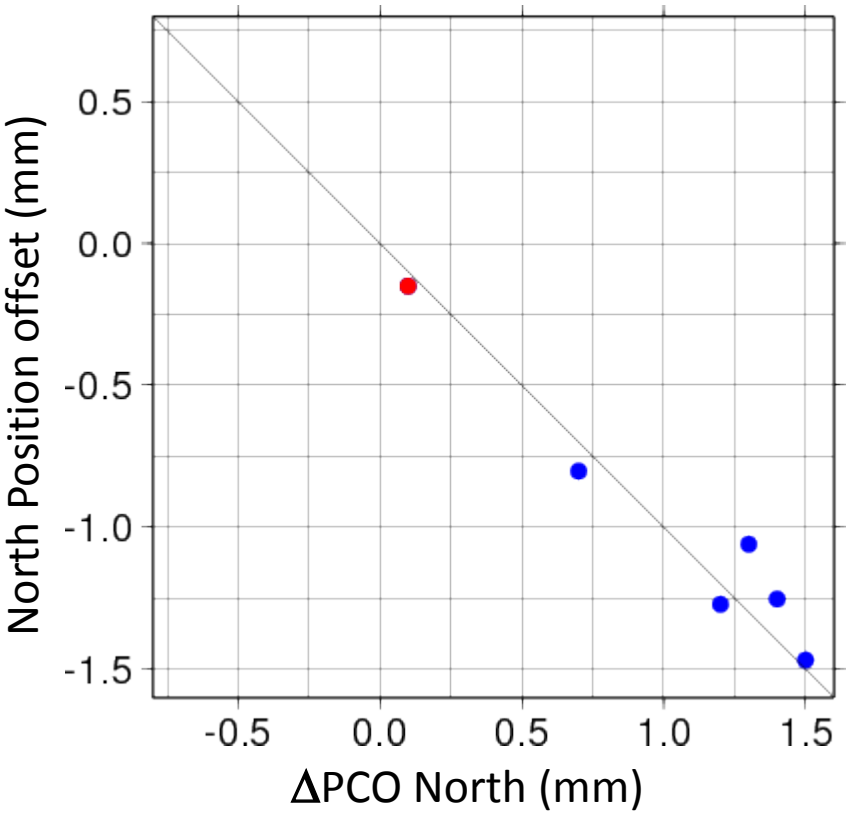


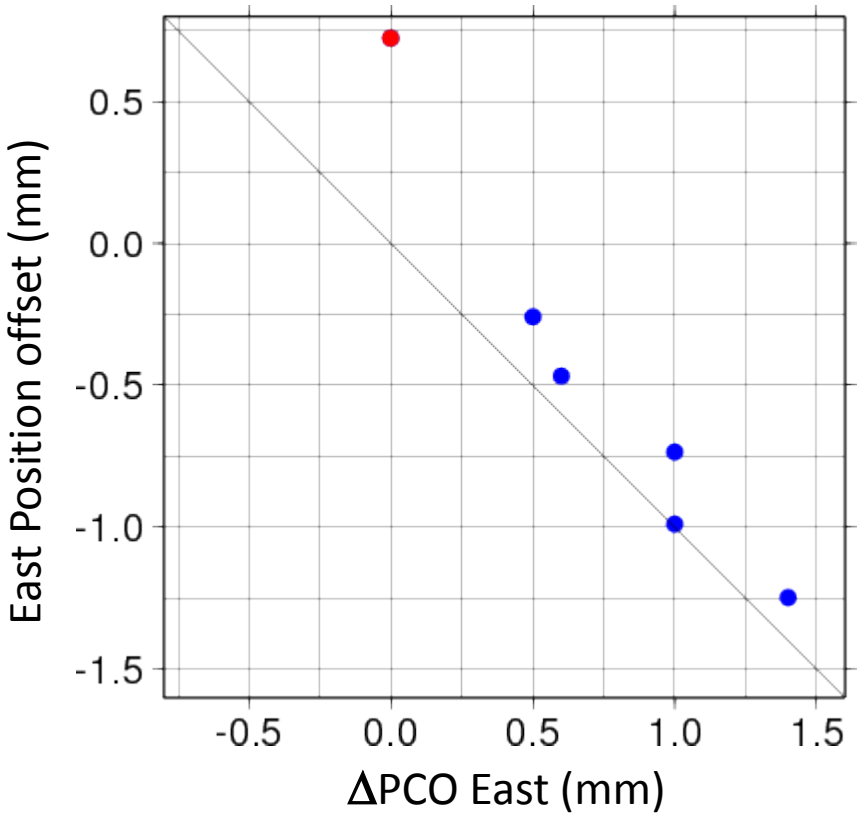
- - ΔPCO and ΔPCO
- -ΔPCO = Mean horizontal offset ±0.1 mm
- Latitude dependency weak
- Up component ?

Position offsets for Brussels

Link with the ΔPCO

- Differences of PCC (PCO+PCV) in all three component
- Link between ΔPCO and horizontal component position offset ?
  - Differences between igs08.atx and igs05.atx seem to show similar behaviour





Summary

- Station positions computed with Geo++ and Bonn calibrations for 6 antennas in Brussels:
  - Horizontal position offsets
    - Reach 1 mm and differences between Trimble and Leica antenna
  - Vertical position offsets
    - Between 3 and 7 mm
- Station positions computed with Geo++ and Bonn calibrations for 2 antennas on a globally distributed set of stations:
  - Weak latitude dependency position offsets
  - Horizontal position offsets
    - $-\Delta$PCO = Mean $\pm$0.1 mm and variations of 0.4 mm to the mean
  - Vertical position offsets
    - Variations of 3.5 mm to the mean

Summary

- Impact of different calibration models on the computed station position not yet fully understood:
  - Up component ?
  - Which level of agreement to reach between receiver antenna calibrations for positioning ?