Three-Method Absolute Antenna Calibration Comparison

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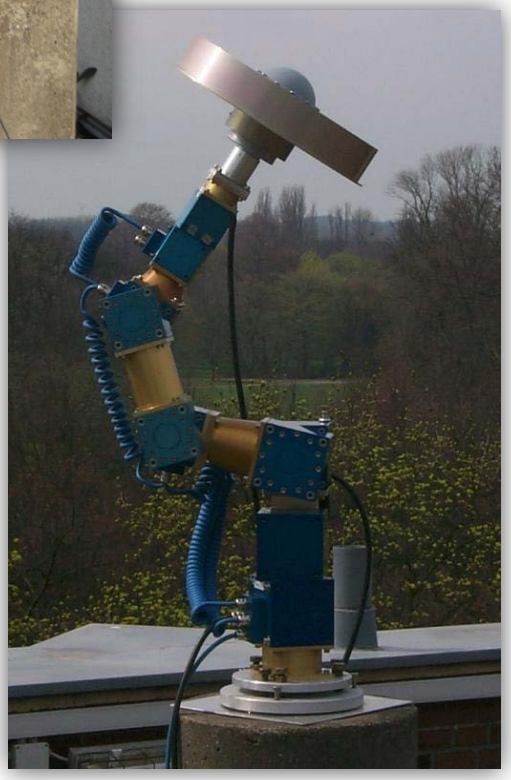
Outline

- Goals of Three-Method Comparison
- Overview of Methods
  - Geo++ robot in field
  - Uni of Bonn robot in anechoic chamber
  - NGS robot in field
- Comparison
  - Antennas tested
  - Results
- Conclusions and Future Work

Goal of Study

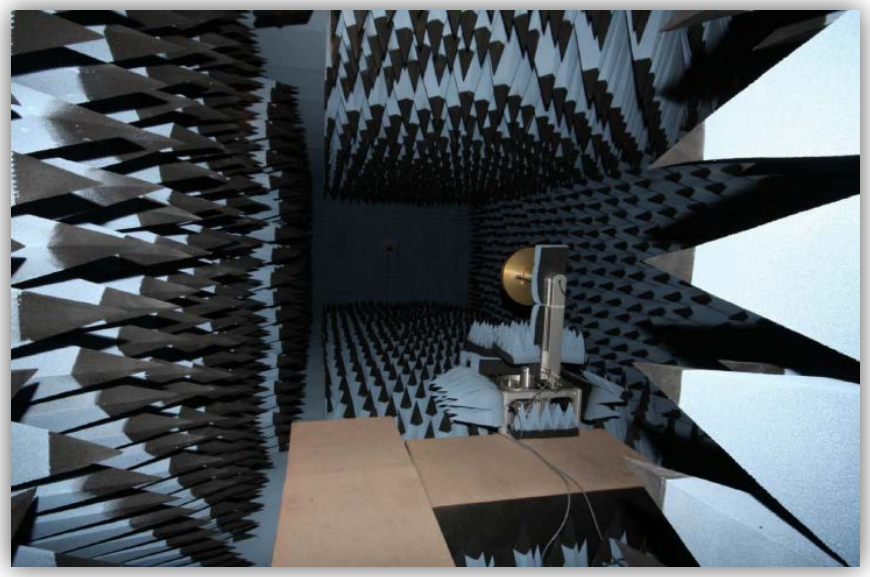
- NGS to demonstrate agreement with approved IGS calibration institutions
  - Send same antenna to 3 institutions
  - **individual** calibrations
- For multiple absolute calibration methods/institutions to contribute to IGS ANTEX:
  - Establish compatibility (matching results)
  - Understand any differences
- Evaluate different types of multi-frequency antennas
  - **Geodetic** (chokering or other multipath-rejecting reference station antenna)
  - Survey-grade (small, compact, often susceptible to near-field effects)

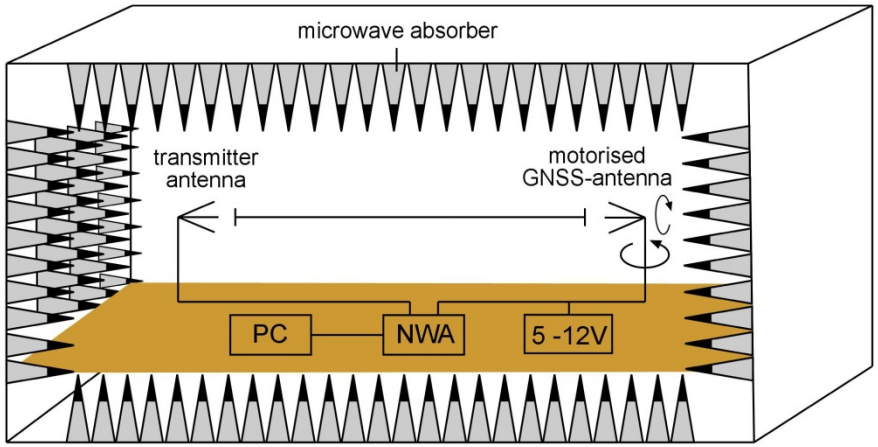


Geo++ GmbH

- Contributing to IGS since 2006
  - Operational since 2000
  - Similar robots at Hannover and Berlin contribute to IGS
- Robot in field
  - 3-axis, 5 degrees of freedom
  - Pivot point (~ L1/L2 PCO) remains fixed in space
- All-in-view GNSS signals, JAVAD TRE_G3T receiver
- Data analysis
  - Short baseline
  - Undifferenced phase data
  - Kalman filter

University of Bonn





- Approved by IGS AWG in 2010 (no calibrations in igs08.atx yet)
- Robot in anechoic chamber
  - 2-axis
  - Antenna boresight remains fixed in space
- Simulated signal (sine wave at carrier frequency)
- Network analyzer sends and receives

NOAA / NGS

- Robot in field
  - Corbin, VA
  - 2-axis
  - PCO not fixed in space
- All-in-view GPS signals
- Data analysis
  - Short baseline
  - Septentrio AsteRx receiver (both antennas)
  - Time-differences of single-differenced phase
  - Unfiltered

For specifics, see poster "Absolute Antenna Calibration at the National Geodetic Survey"

Antennas in Comparison

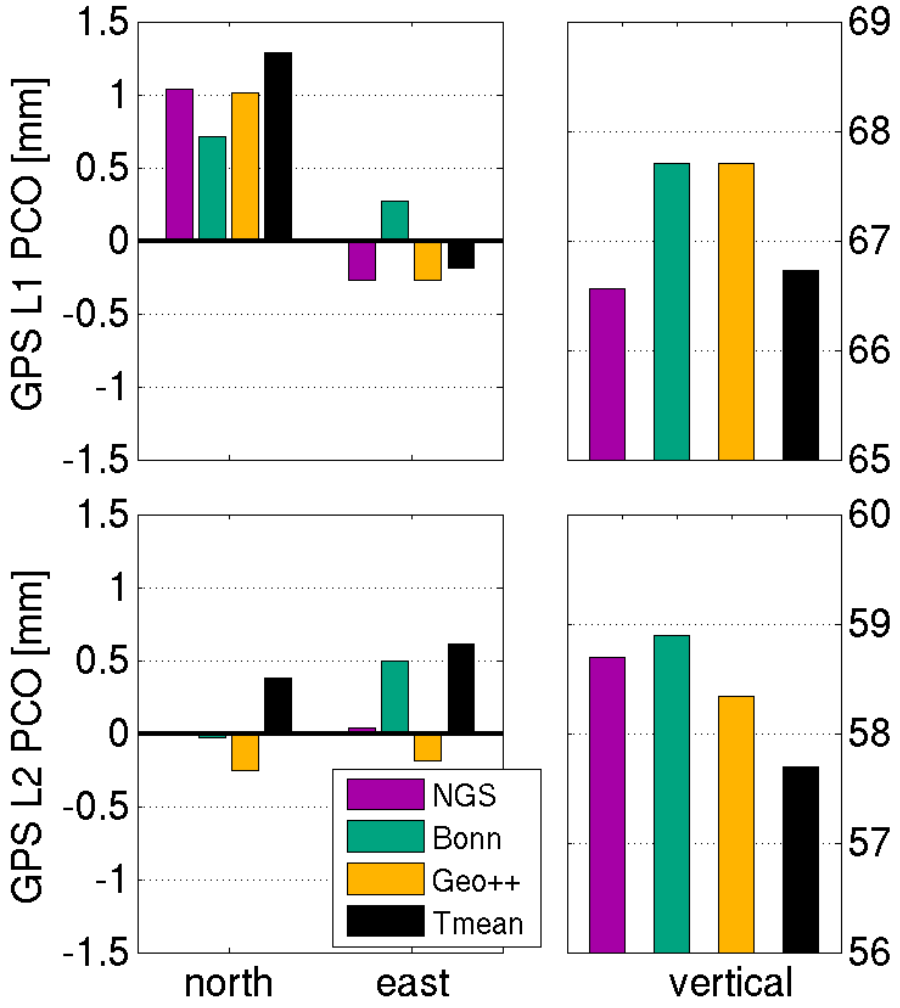
Trimble GNSS chokering	Trimble Zephyr 2 with groundplane	Topcon PG-A1 rover with groundplane
TRM59800.00	TRM55971.00	TPSPG_A1+GP
Full GNSS	Full GNSS	GPS/GLONASS
17 in IGS network	17 in IGS network	0 in IGS network
3 samples	1 sample	1 sample

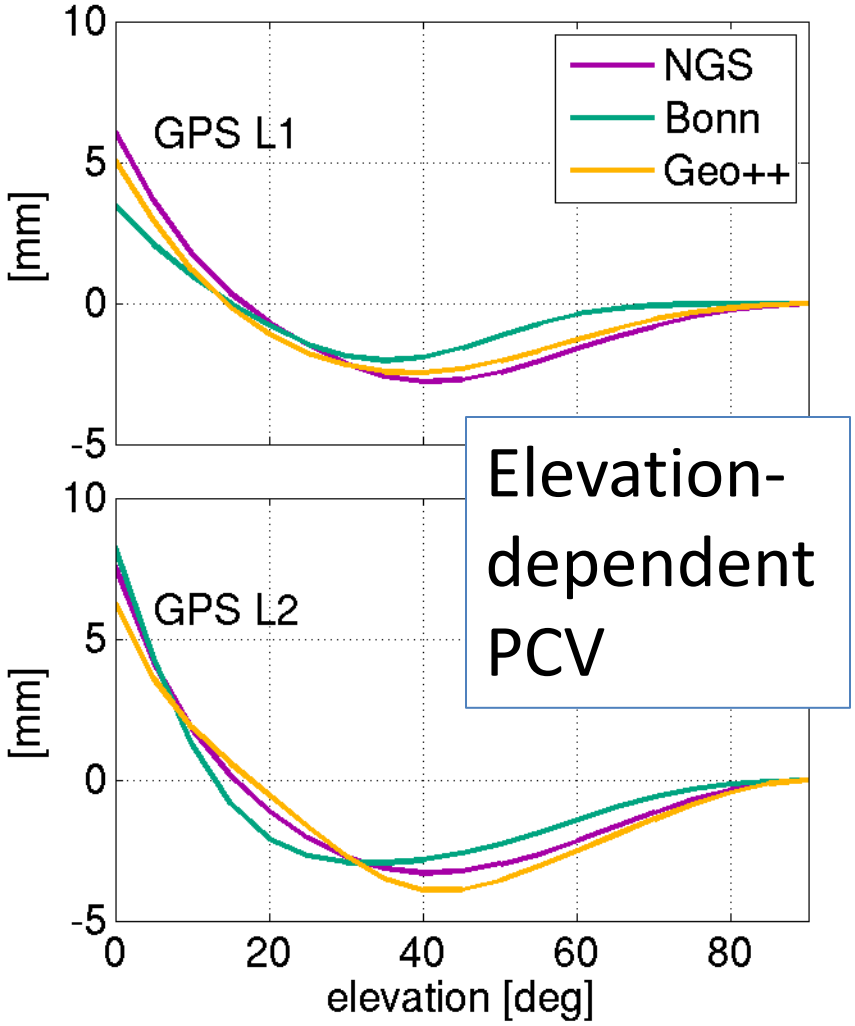
GPS L1/L2 only for this presentation.

Trimble Zephyr 2 (TRM55971.00)

One antenna sample tested

Trimble Zephyr 2 (TRM55971.00)



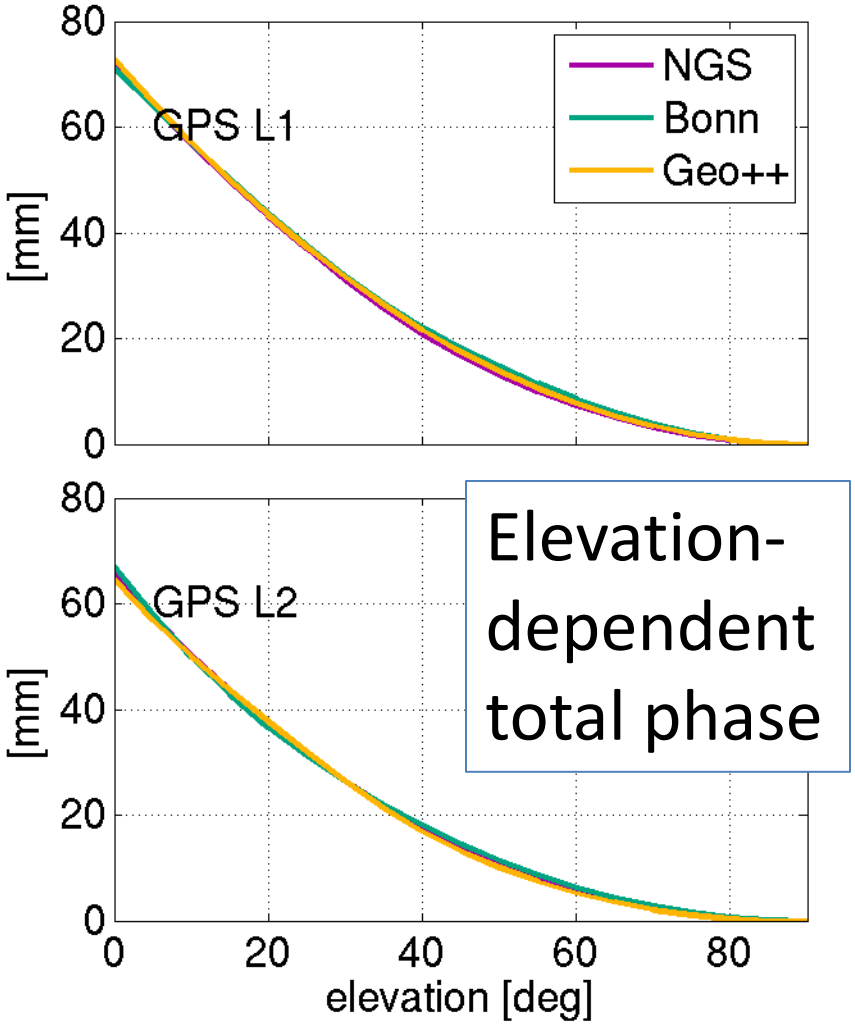


Elevation-dependent PCV

Trimble Zephyr 2 (TRM55971.00)

Convention for comparison:

- Add together PCO and PCV into total antenna phase center
- Reduce to antenna ARP
- Maintain condition that total phase = 0 mm at zenith

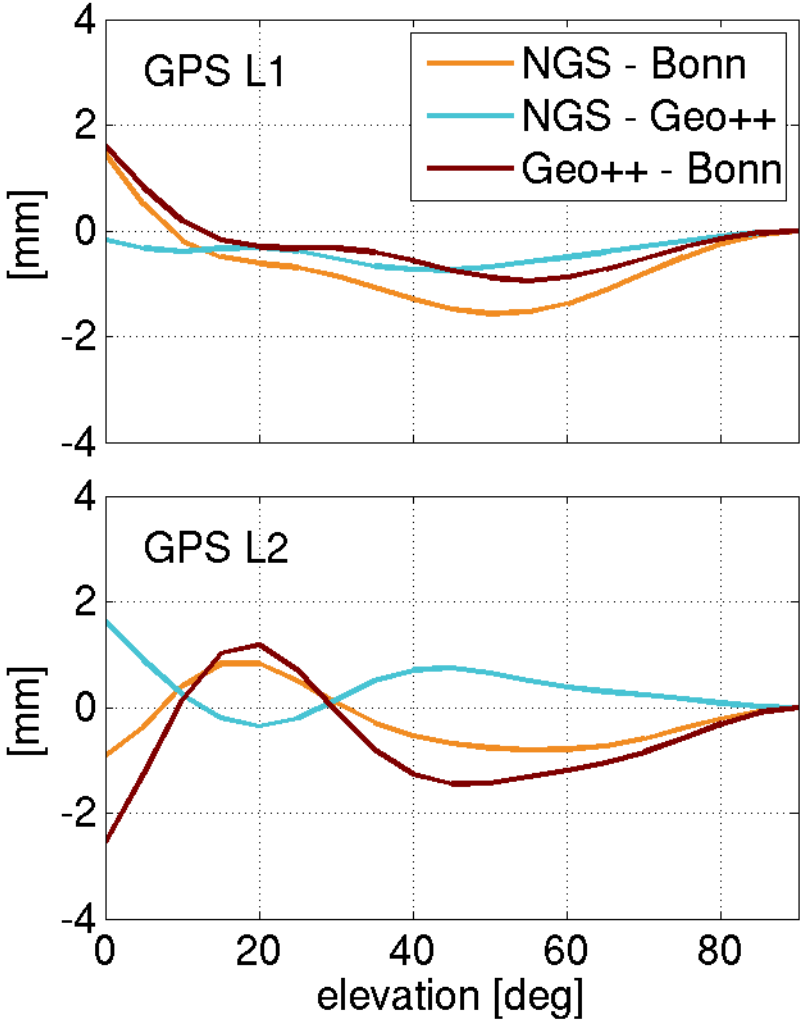


Trimble Zephyr 2 (TRM55971.00)

Differences in purely elevation-dependent PCV:

- <= 1 mm
  - L1 above 10°
  - L2 except for bump at 20° and 45°
- < 2 mm for L1 & L2

L1 pattern size = 70 mm

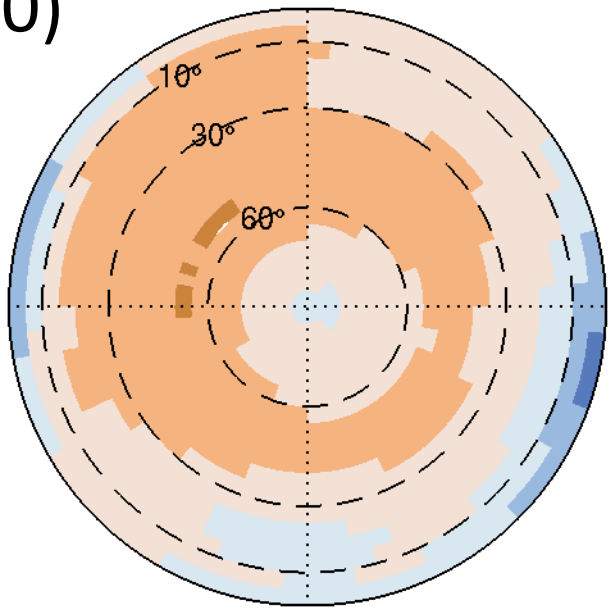


L2 pattern size = 65 mm

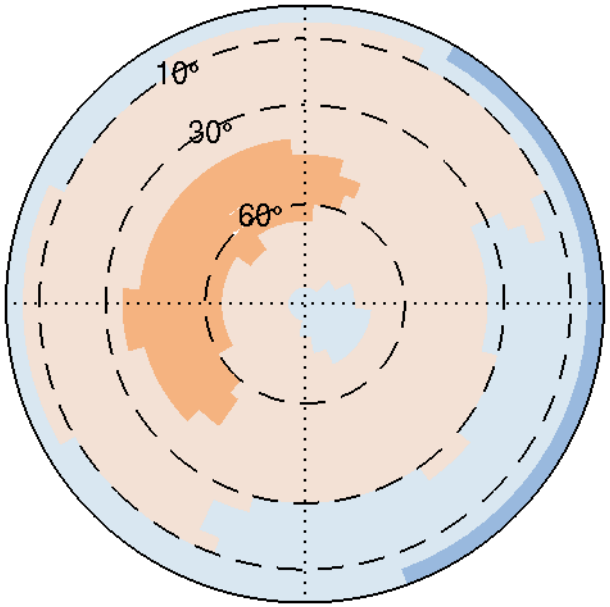
Trimble Zephyr 2 (TRM55971.00)

GPS L1 differences

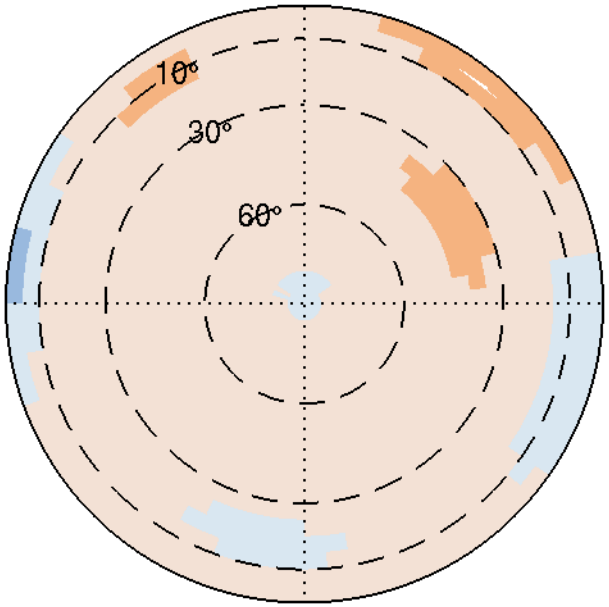
NGS – Bonn

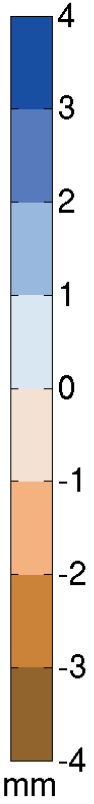


Geo++ - Bonn



NGS – Geo++

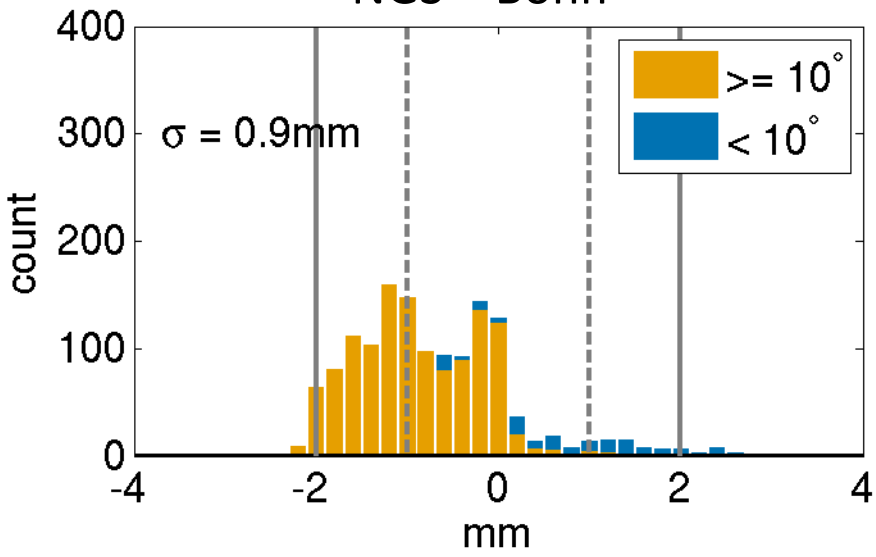




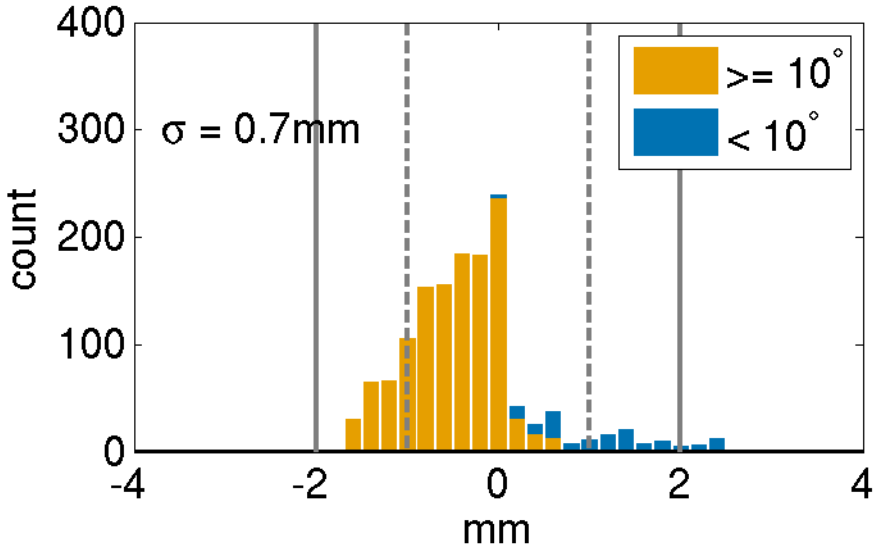
Trimble Zephyr 2 (TRM55971.00)

GPS L1 differences

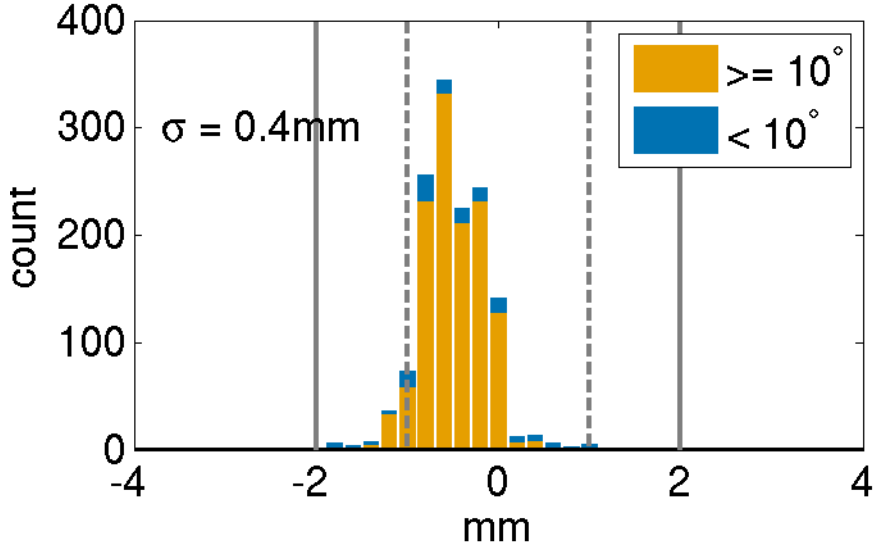
NGS – Bonn



Geo++ - Bonn



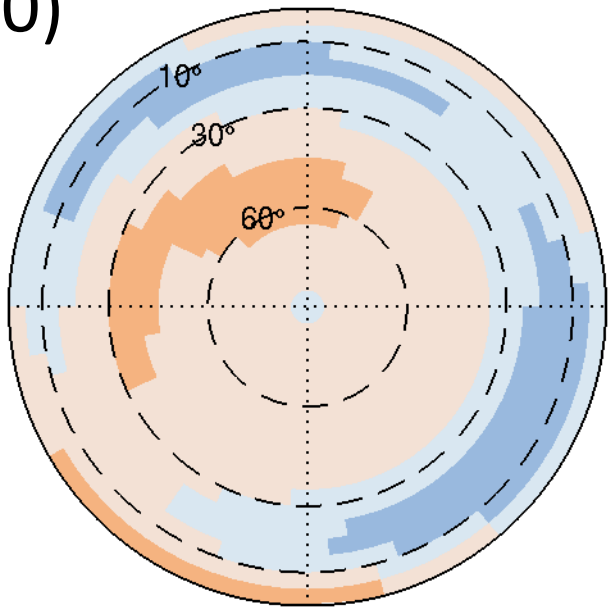
NGS – Geo++



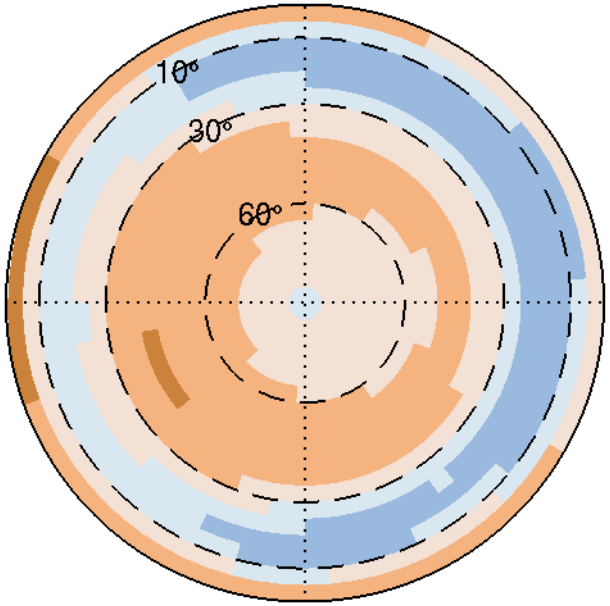
Trimble Zephyr 2 (TRM55971.00)

GPS L2 differences

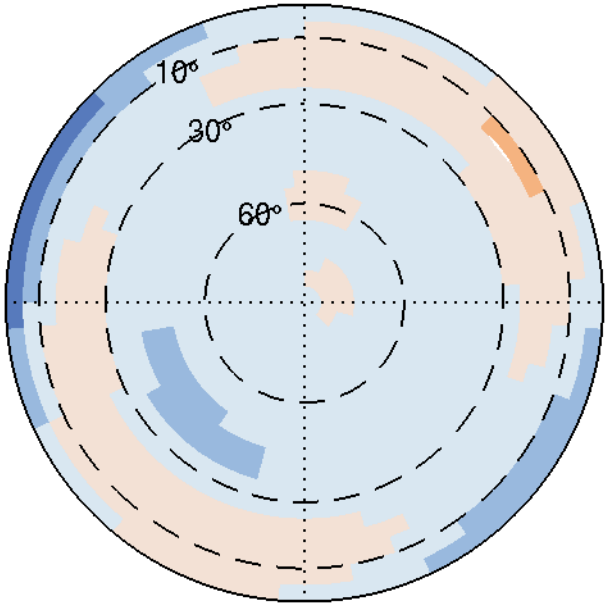
NGS – Bonn

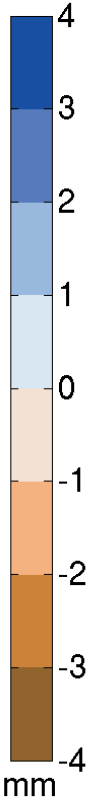


Geo++ - Bonn



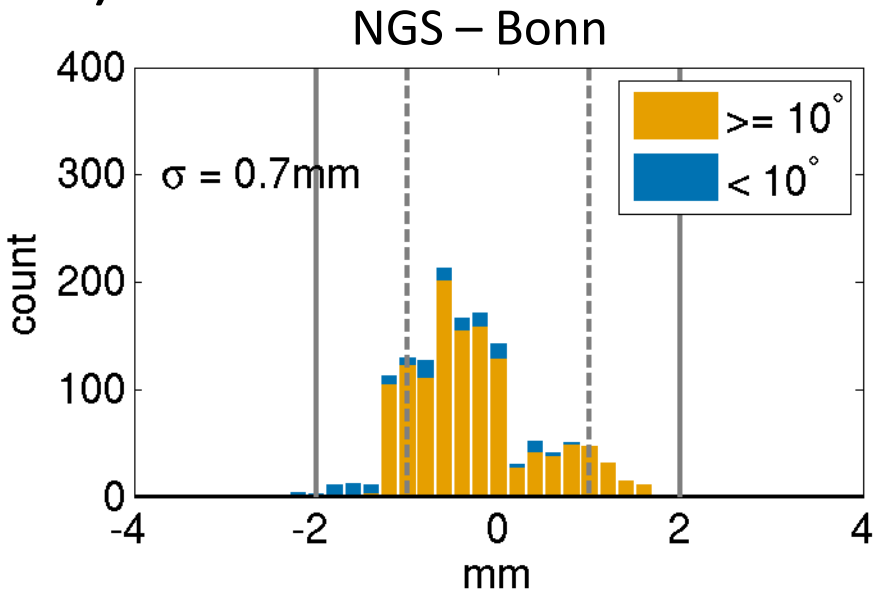
NGS – Geo++

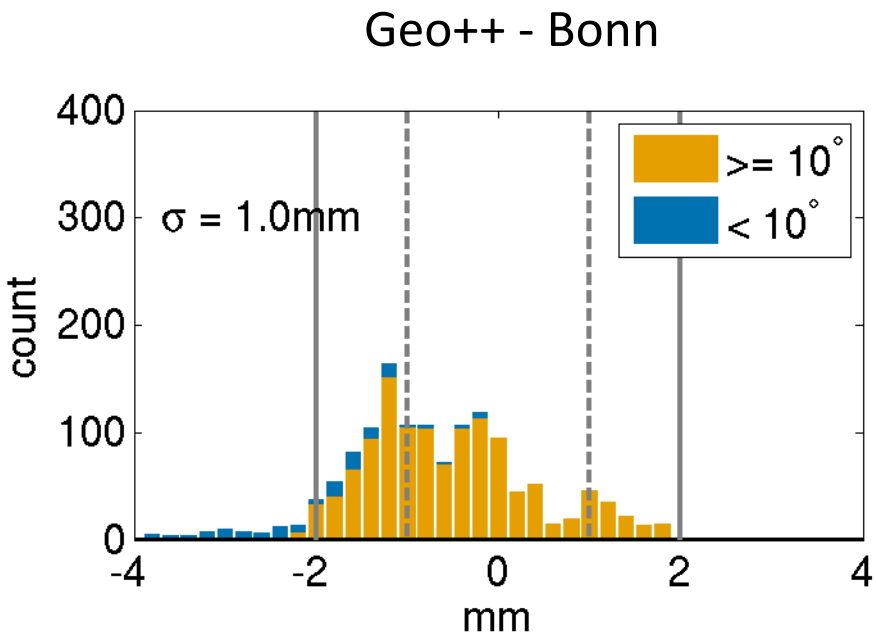


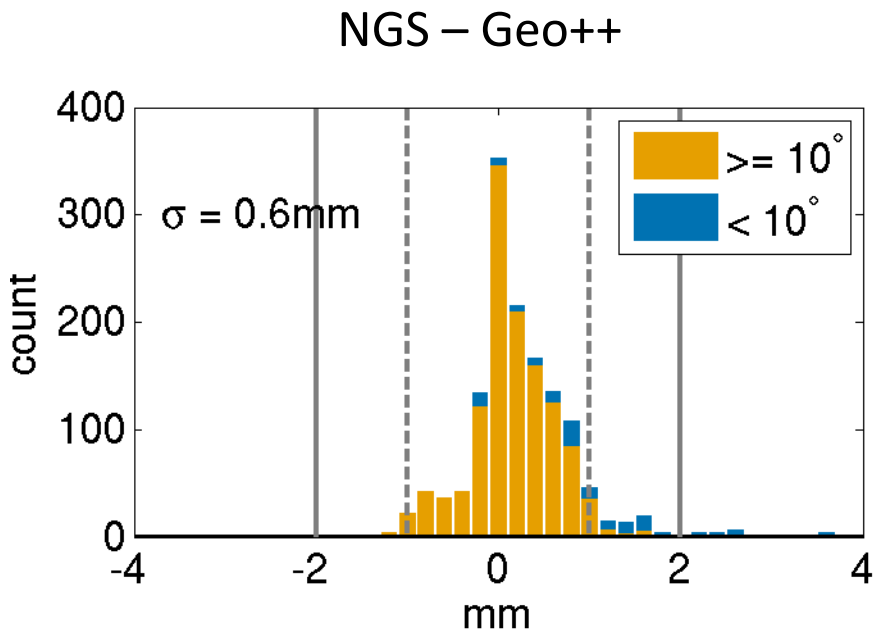


Trimble Zephyr 2 (TRM55971.00)

GPS L2 differences







Trimble Zephyr 2 *Summary*

- Most of inter-method differences < 1 mm
- Exceptions to the 1mm rule:
  - L1 below 10° elevation
  - L2 below 30° elevation
- Majority of differences are < 2 mm (independent of azimuth and elevation)

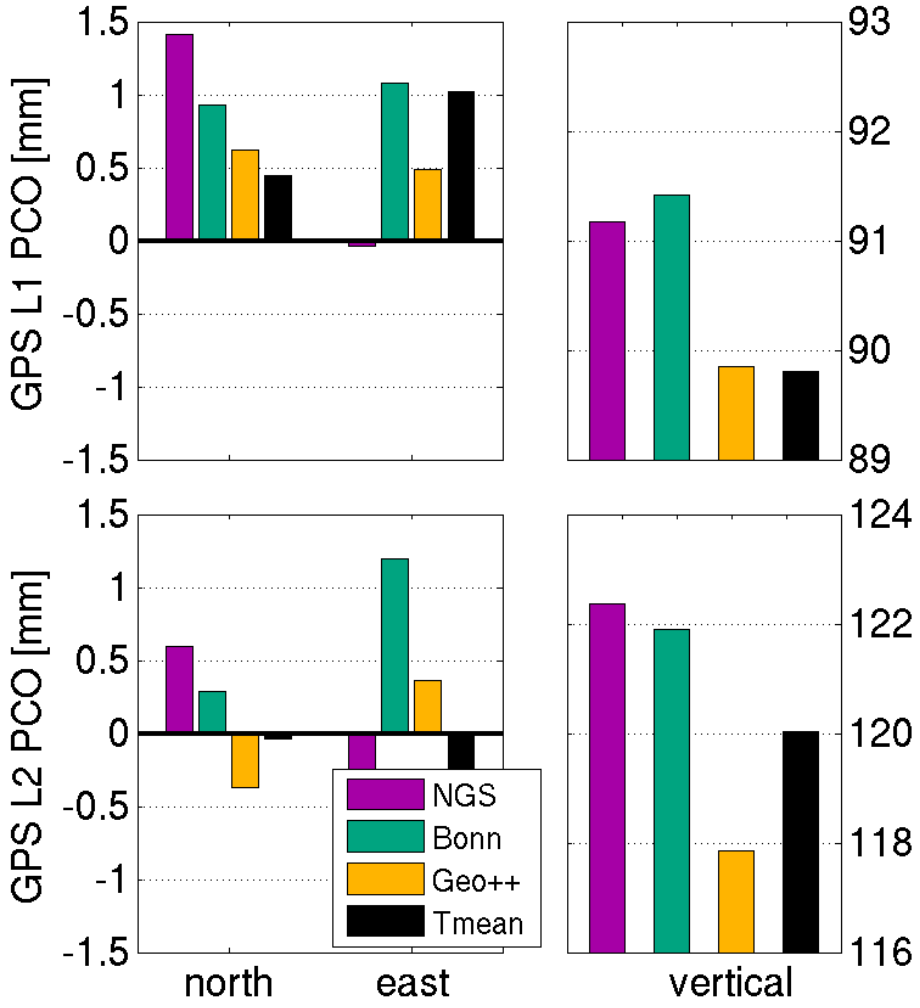
Trimble GNSS Chokering (TRM59800.00)

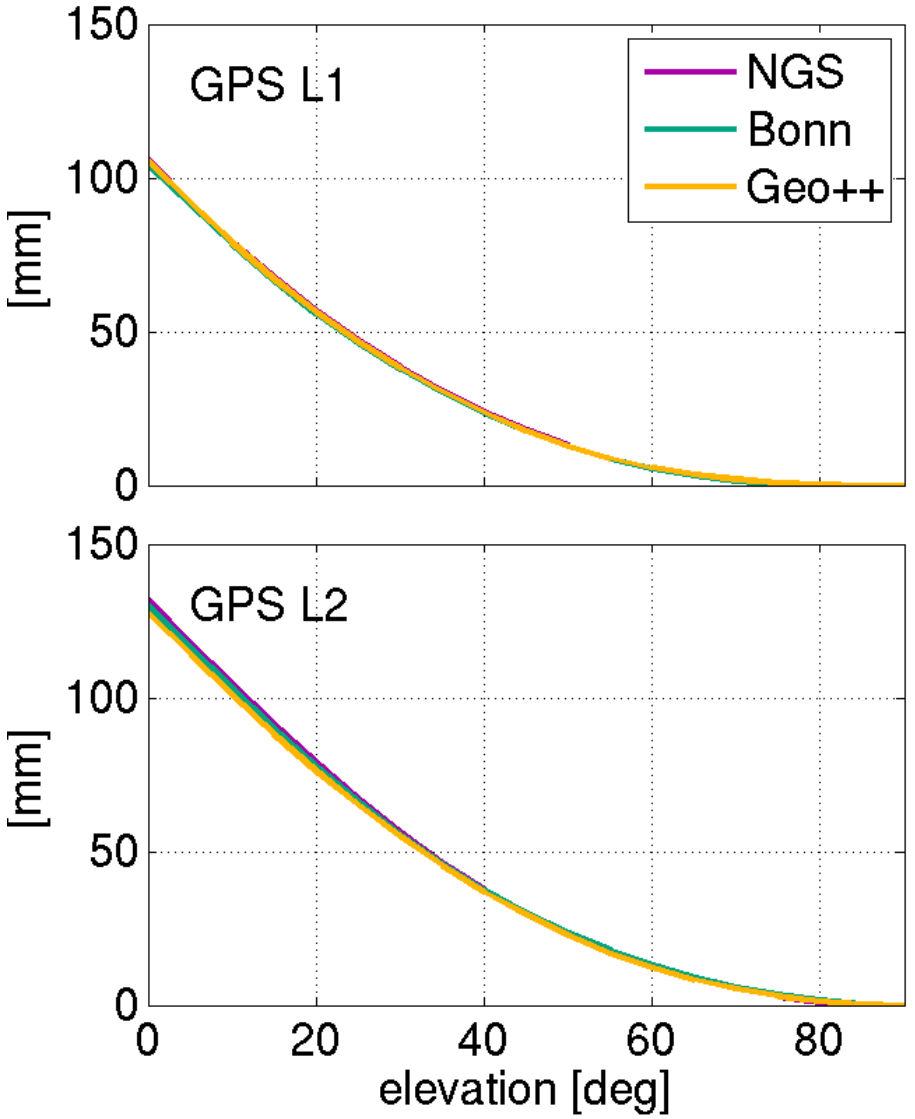
Three antenna samples tested

Trimble GNSS chokering (TRM59800.00)

Serial # xxxx371

1





Trimble GNSS chokering (TRM59800.00)

Serial # xxxx409

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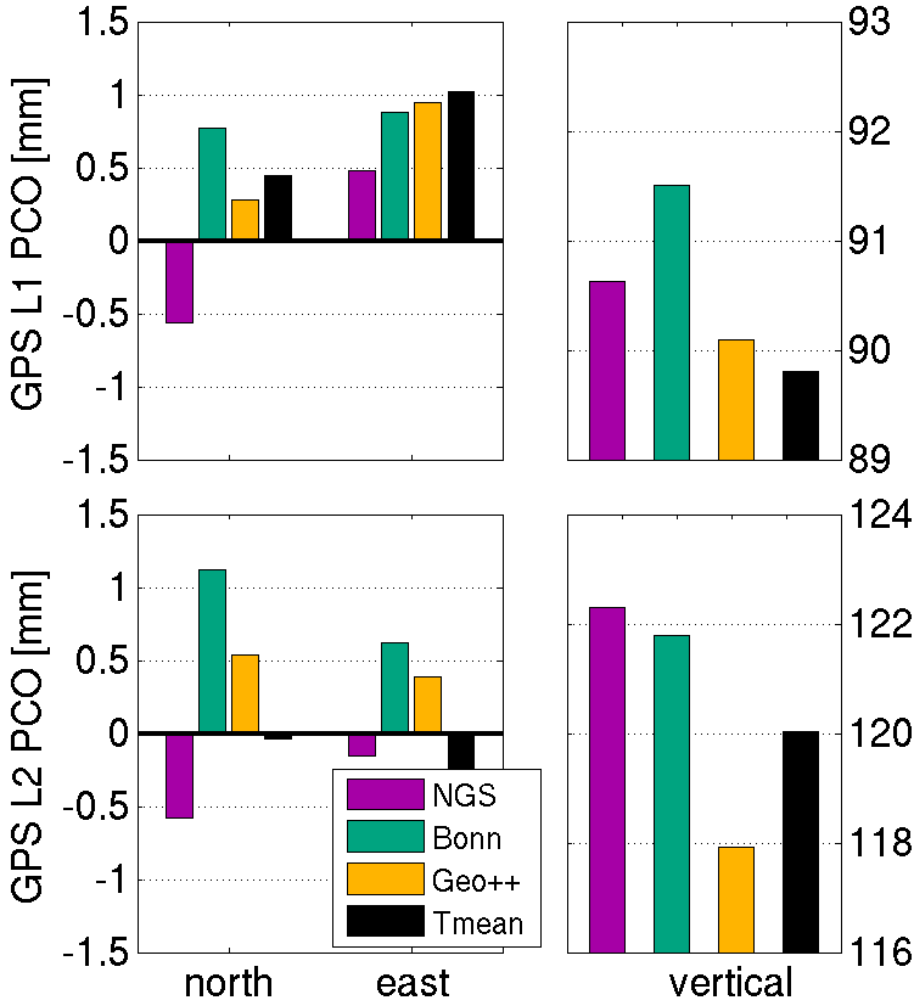
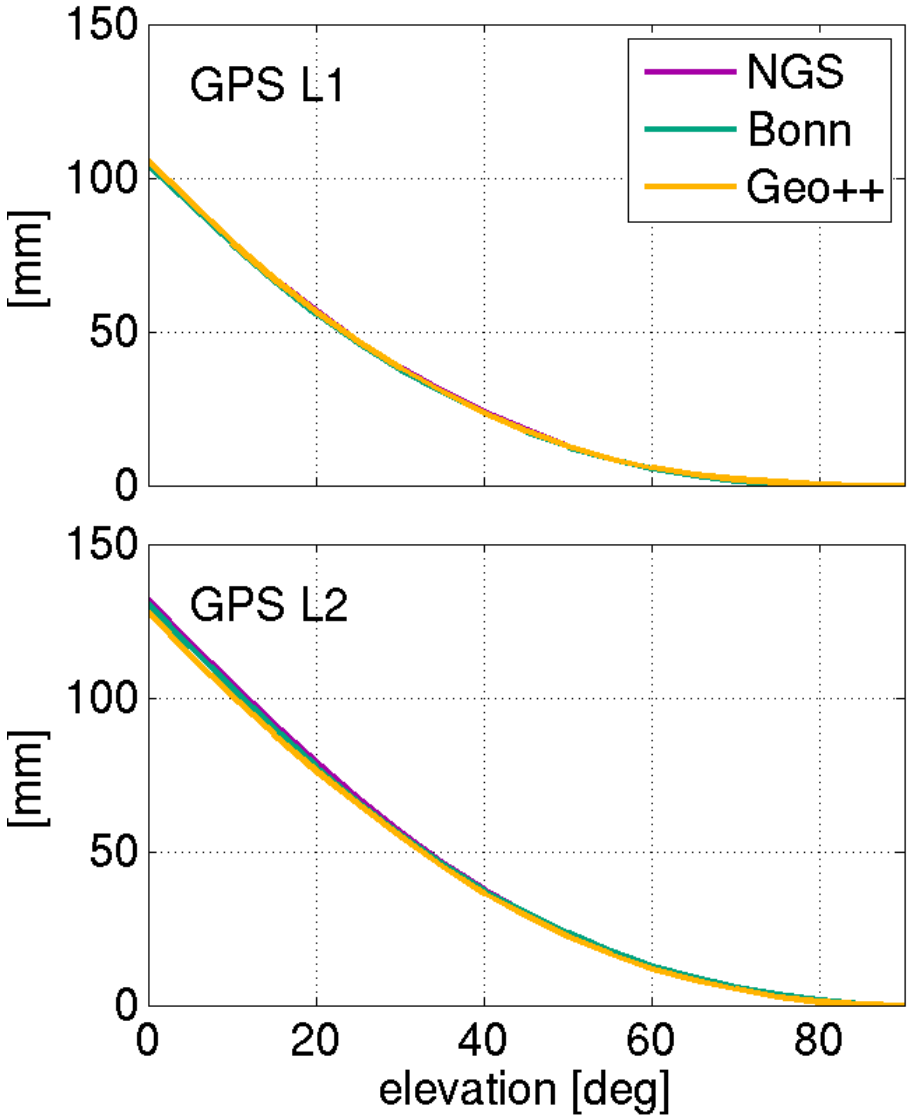
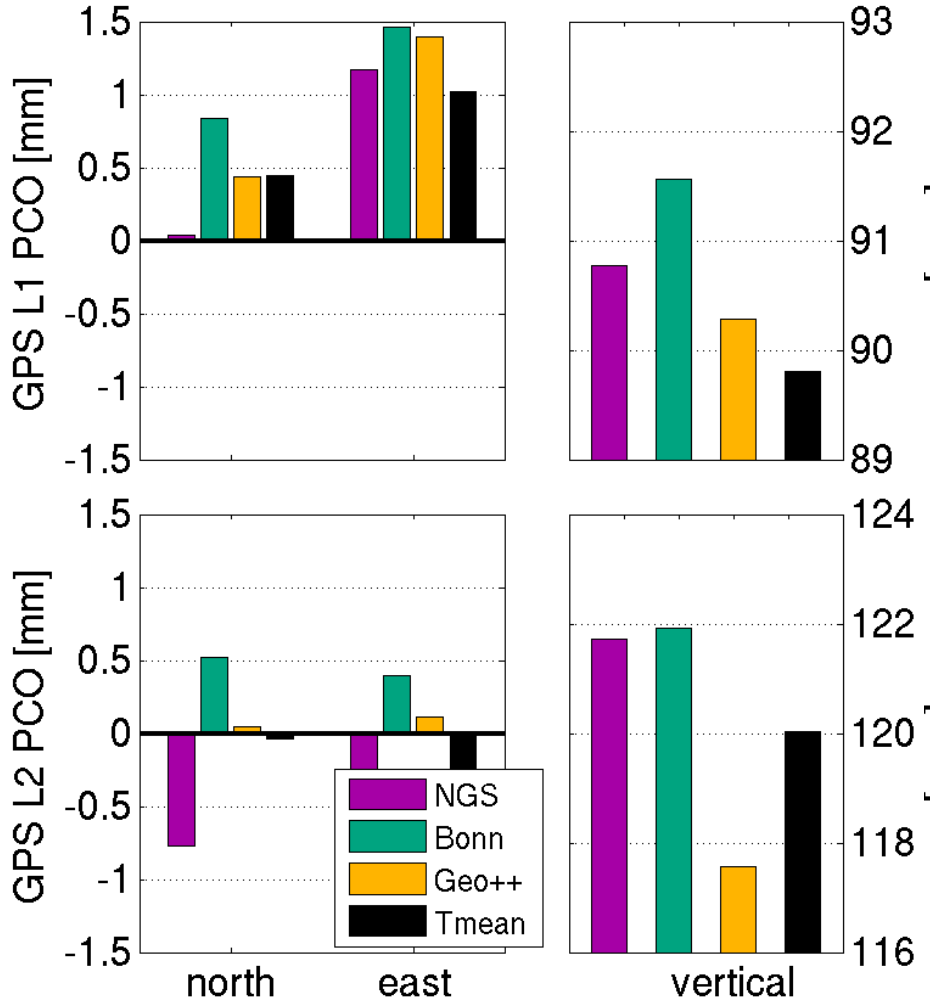


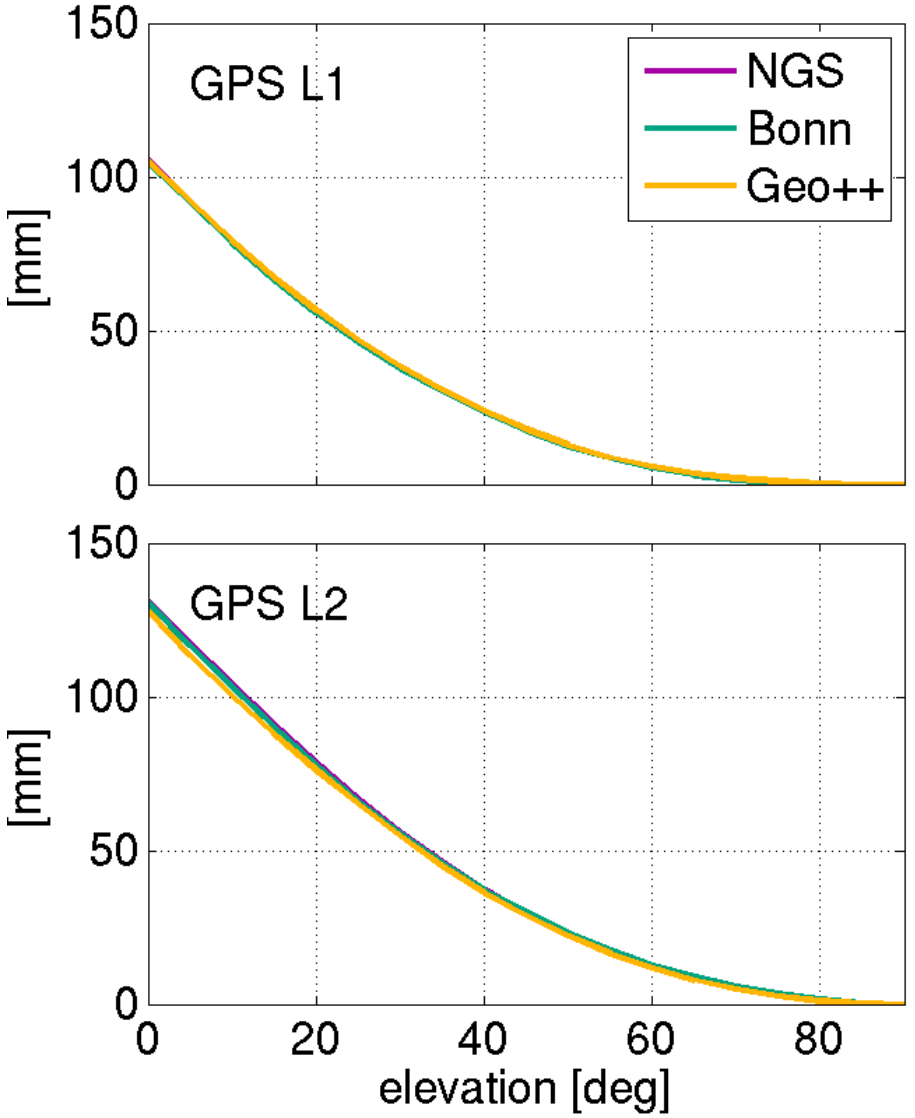


Trimble GNSS chokering (TRM59800.00)

Serial # xxxx068

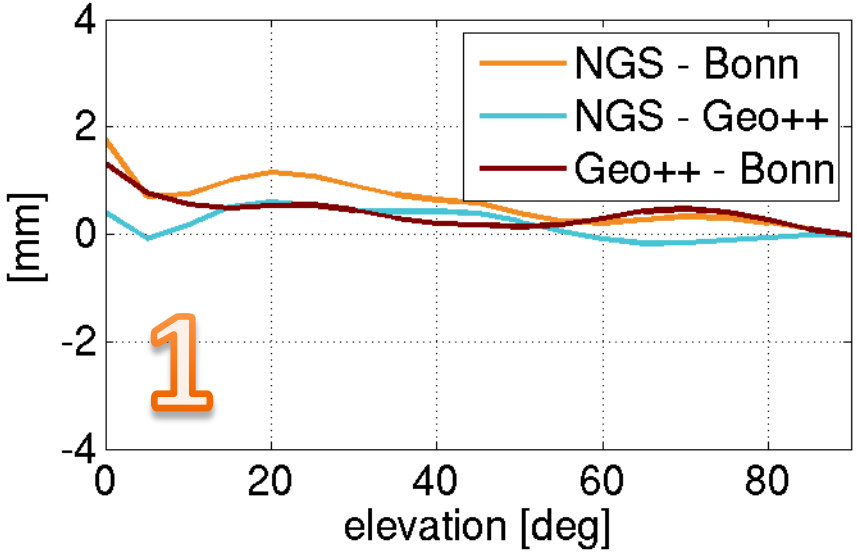
3

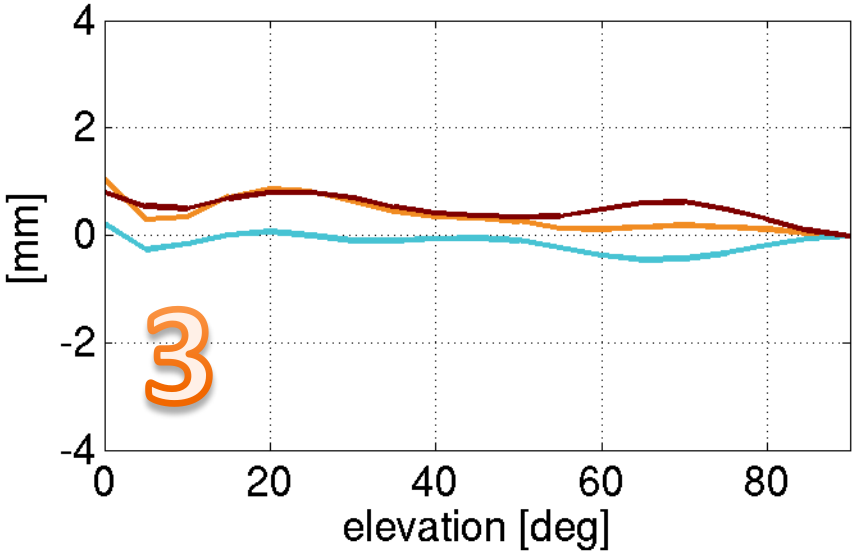


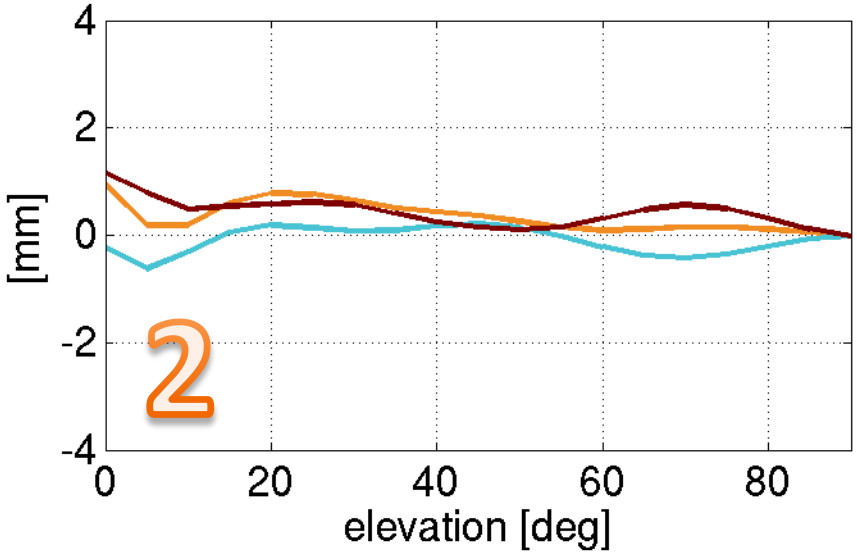


GPS L1 elevation-dependent differences

L1 pattern size = 130 mm

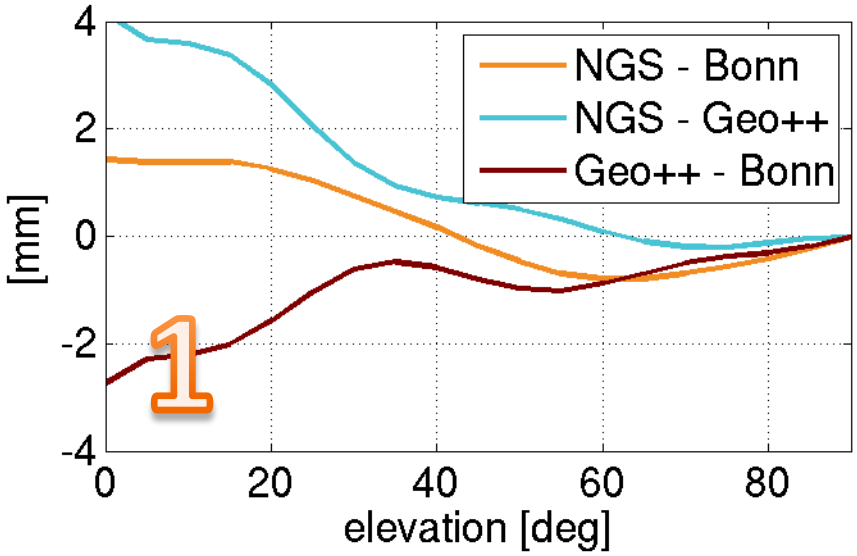


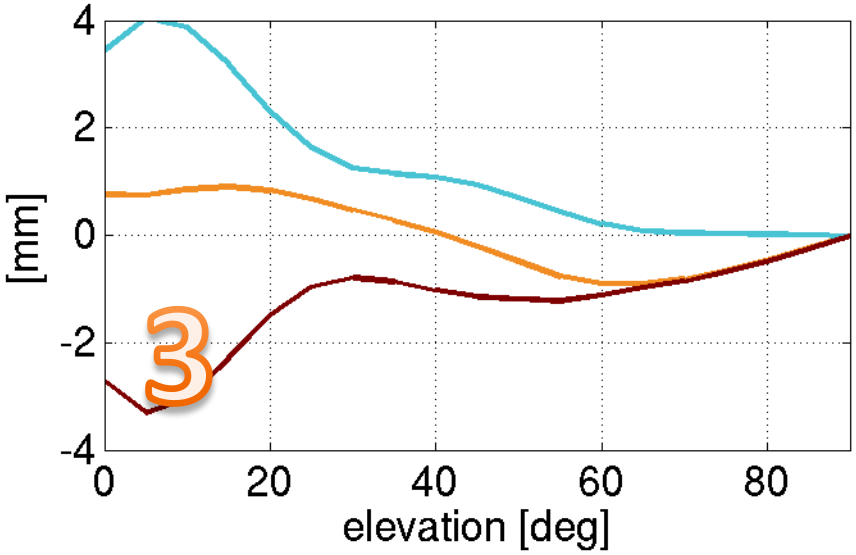


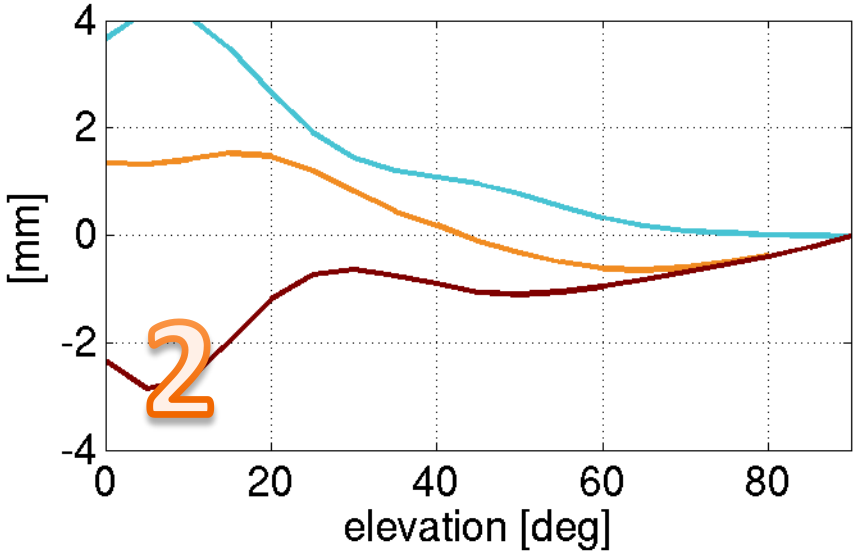


GPS L2 elevation-dependent differences

L2 pattern size = 100 mm





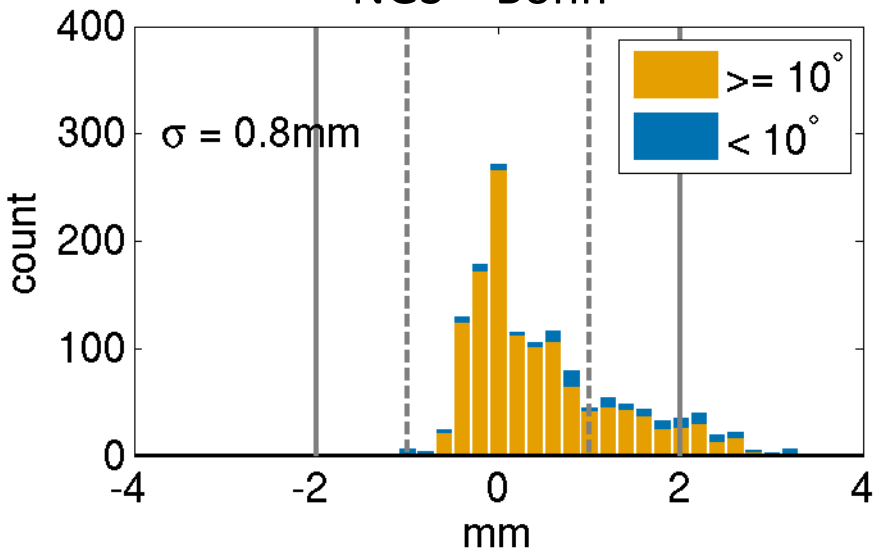


Trimble GNSS chokering

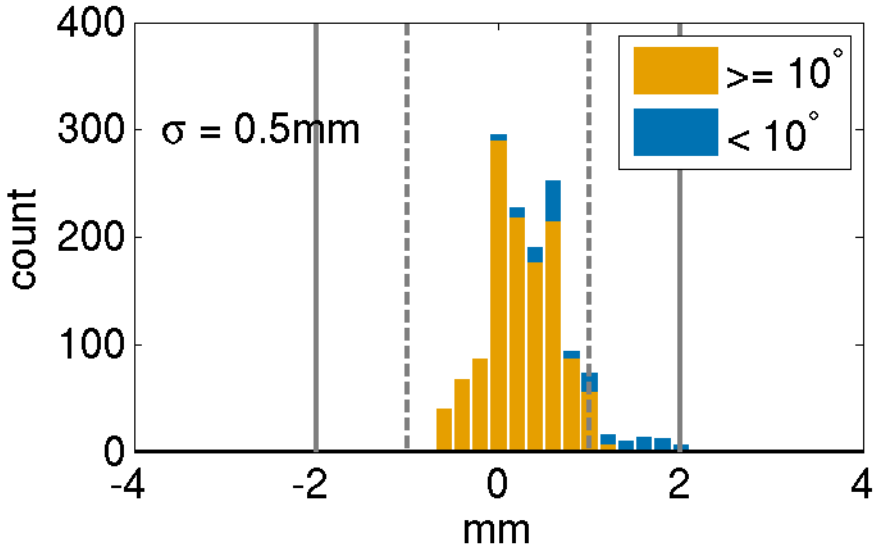
GPS L1 differences

L1 pattern size = 130 mm

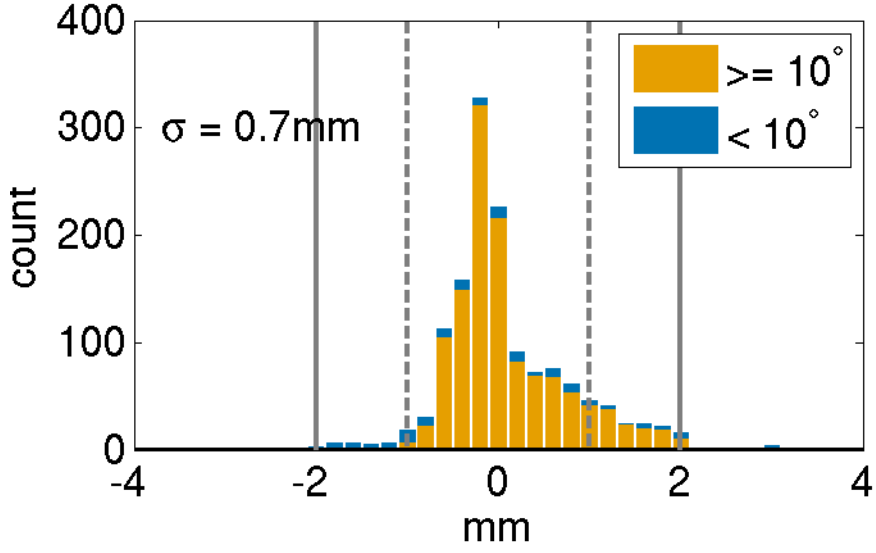
NGS – Bonn



Geo++ - Bonn



NGS – Geo++

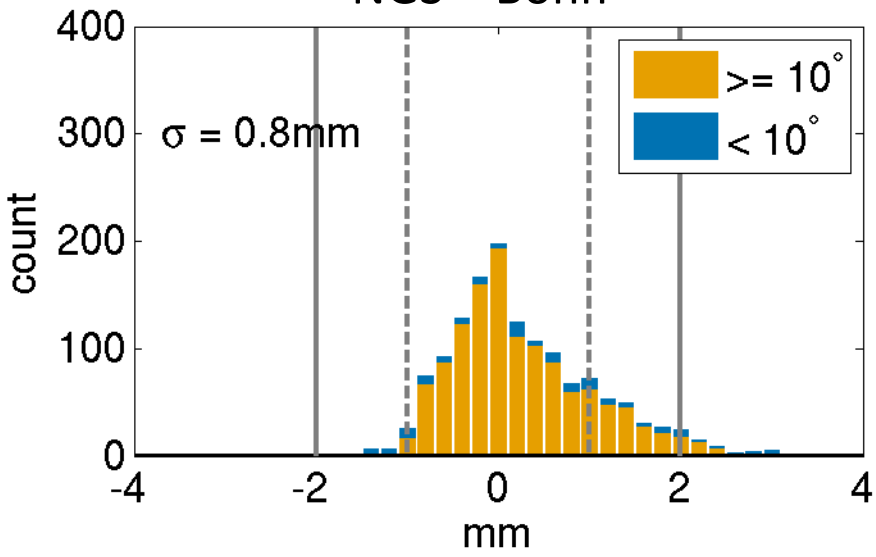


Trimble GNSS chokering

GPS L1 differences

L1 pattern size = 130 mm

NGS – Bonn



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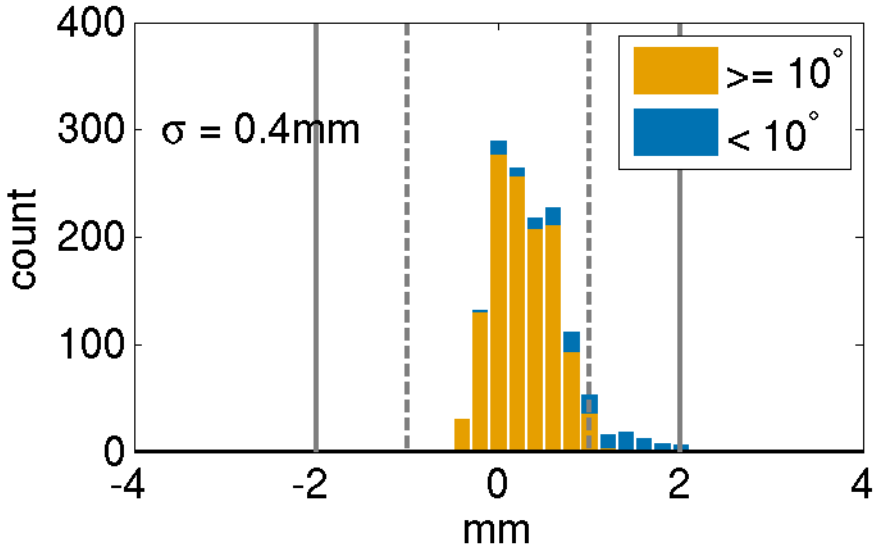

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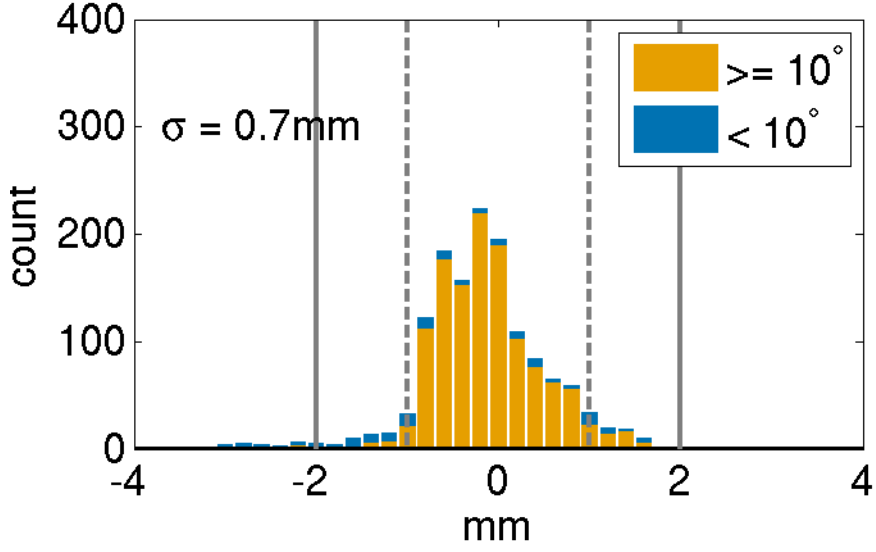
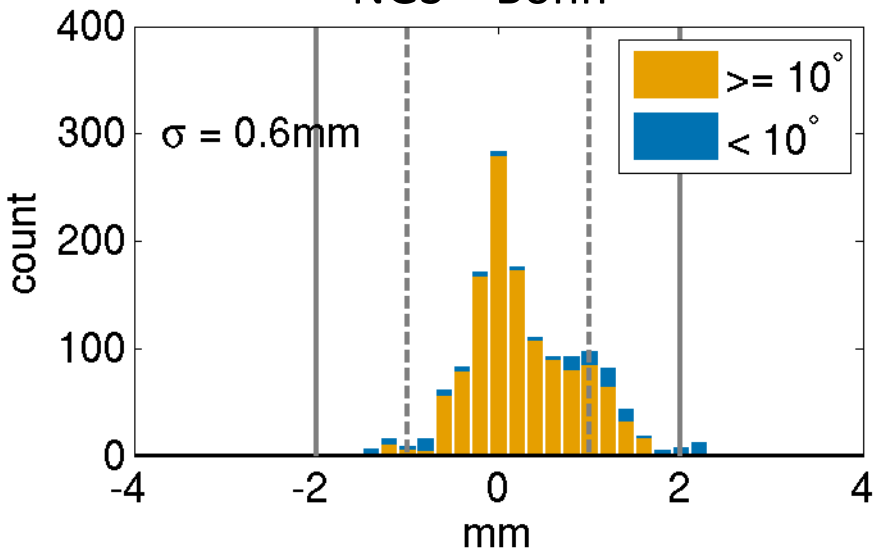


Trimble GNSS chokering

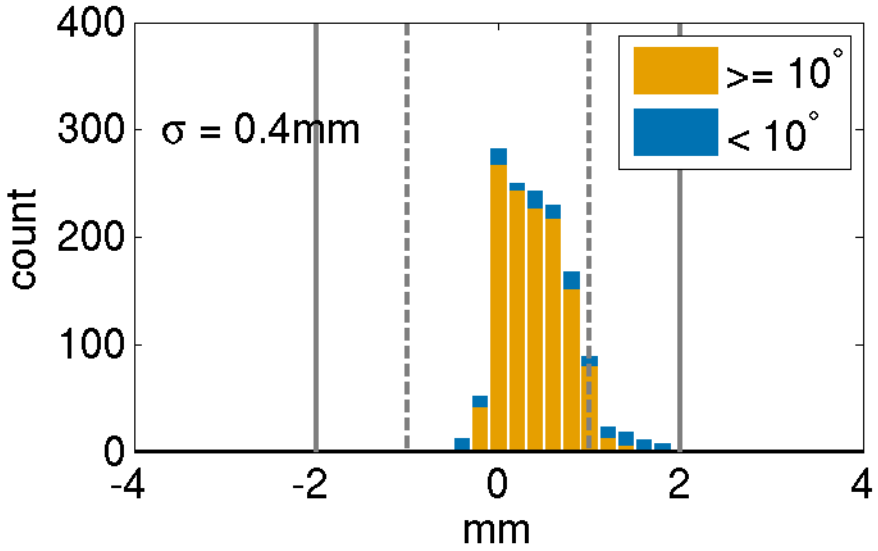
GPS L1 differences

L1 pattern size = 130 mm

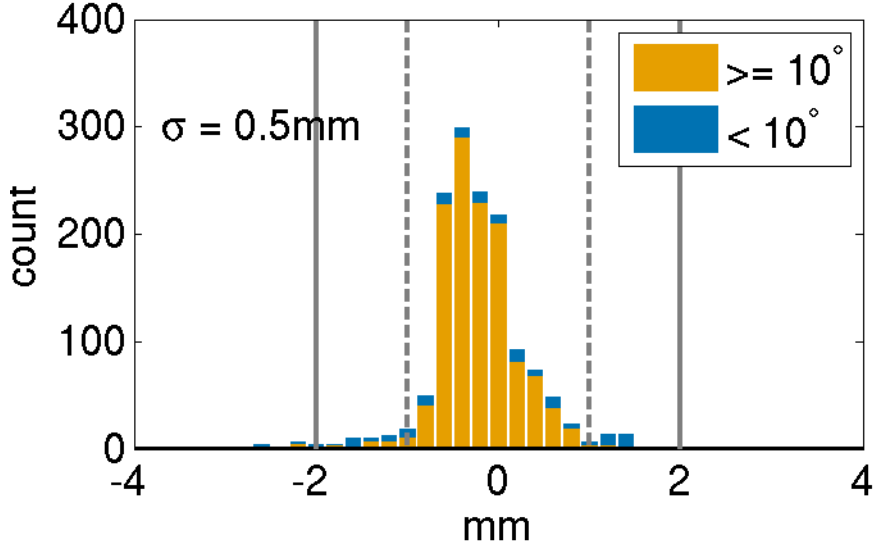
NGS – Bonn



Geo++ - Bonn



NGS – Geo++

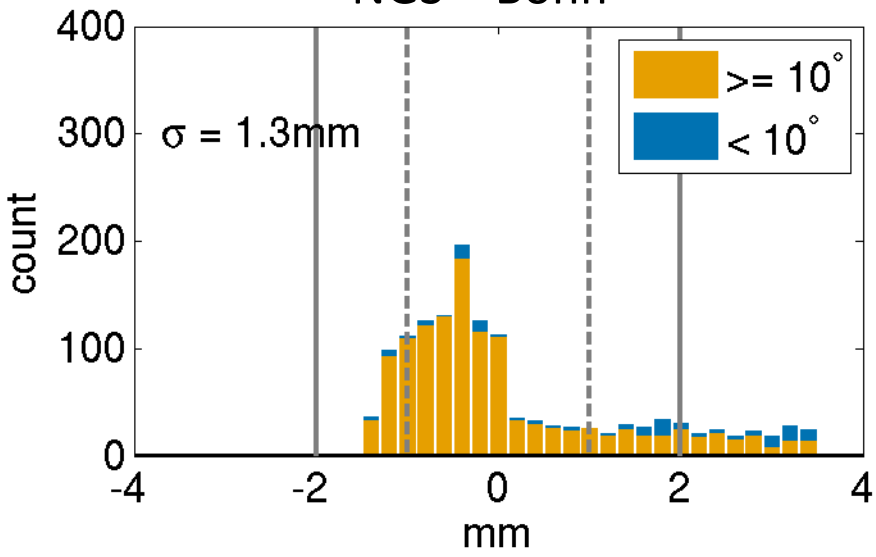


Trimble GNSS chokering

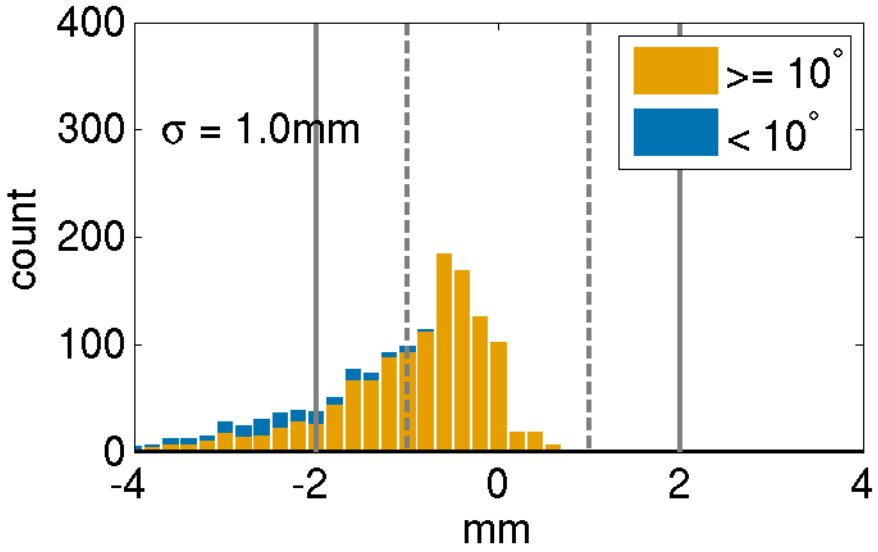
GPS L2 differences

L2 pattern size = 100 mm

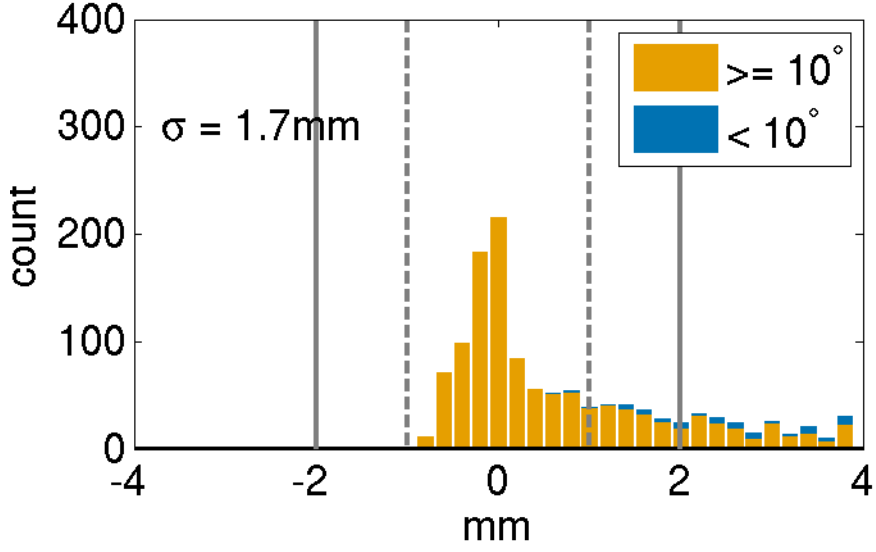
NGS – Bonn



Geo++ - Bonn



NGS – Geo++



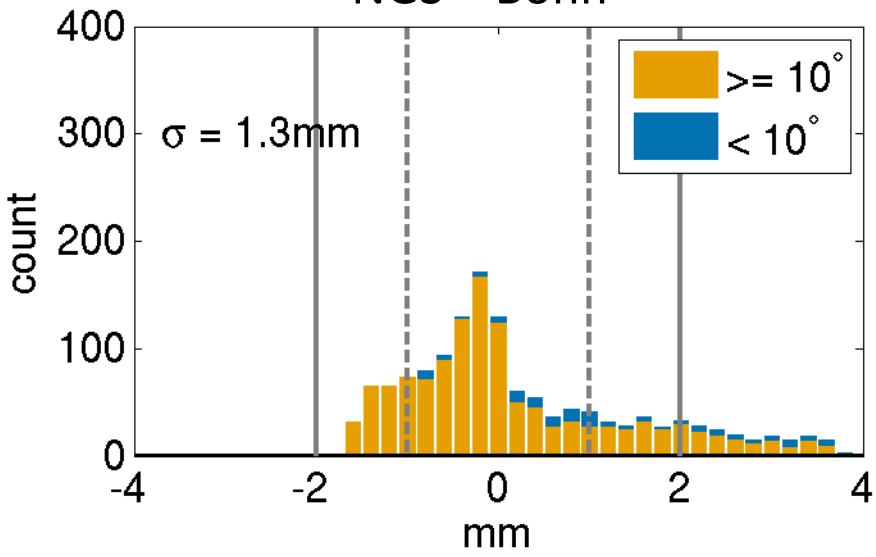
Trimble GNSS chokering

GPS L2 differences

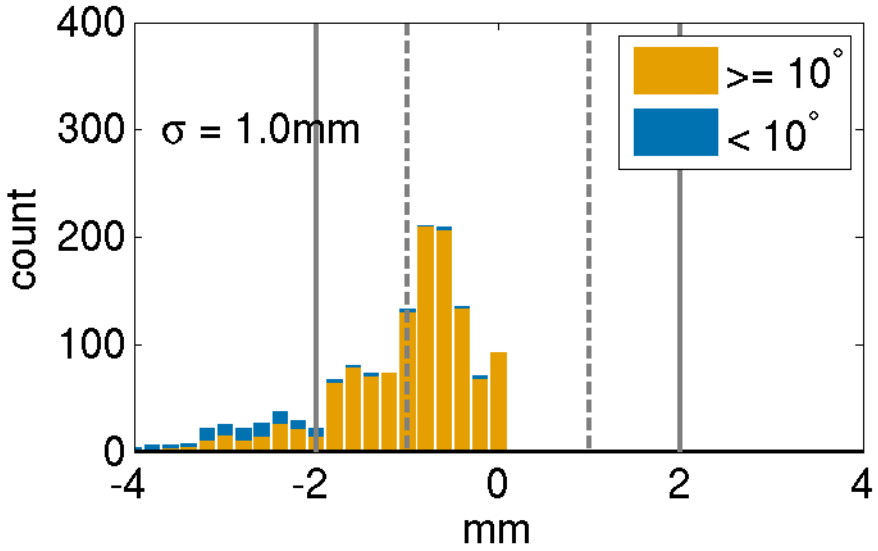
2

L2 pattern size = 100 mm

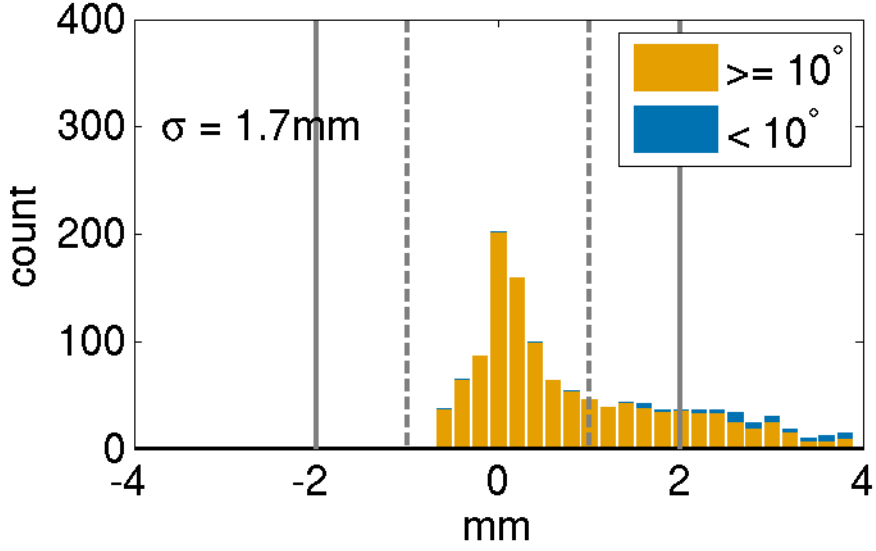
NGS – Bonn



Geo++ - Bonn



NGS – Geo++

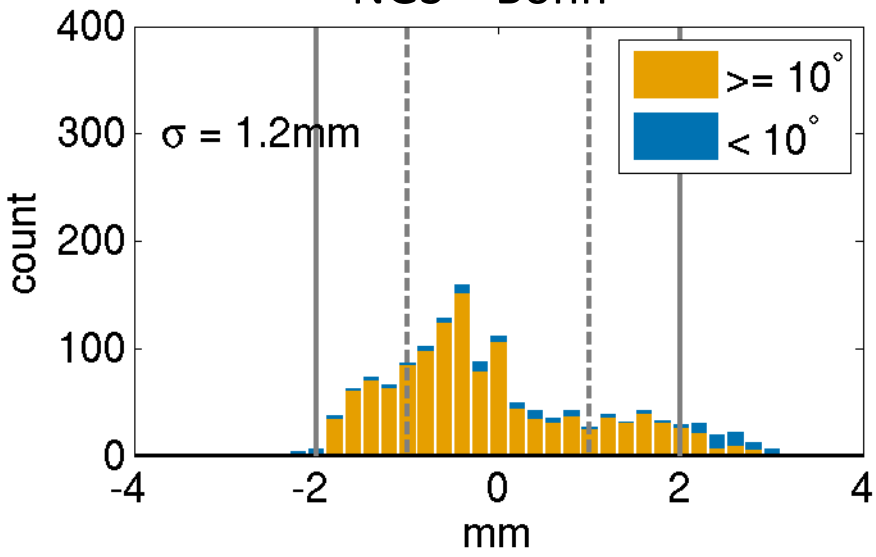


Trimble GNSS chokering

GPS L2 differences

L2 pattern size = 100 mm

NGS – Bonn



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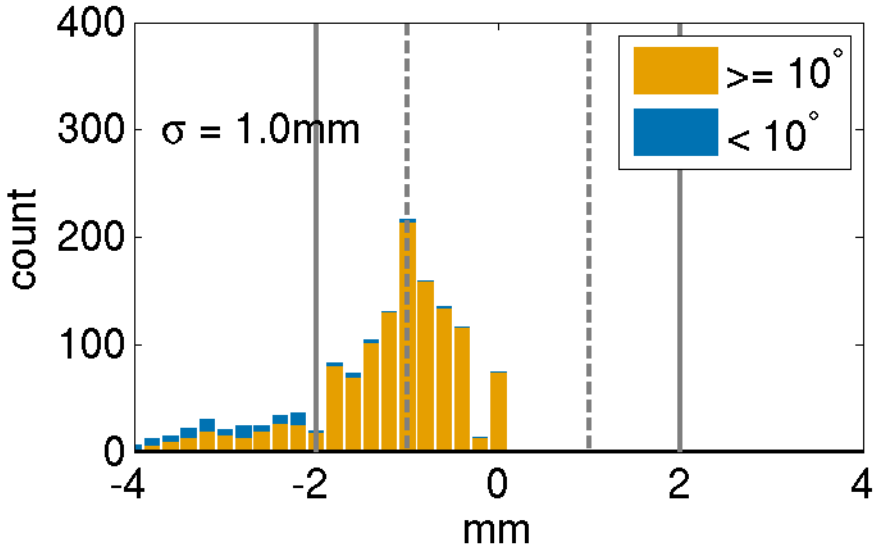
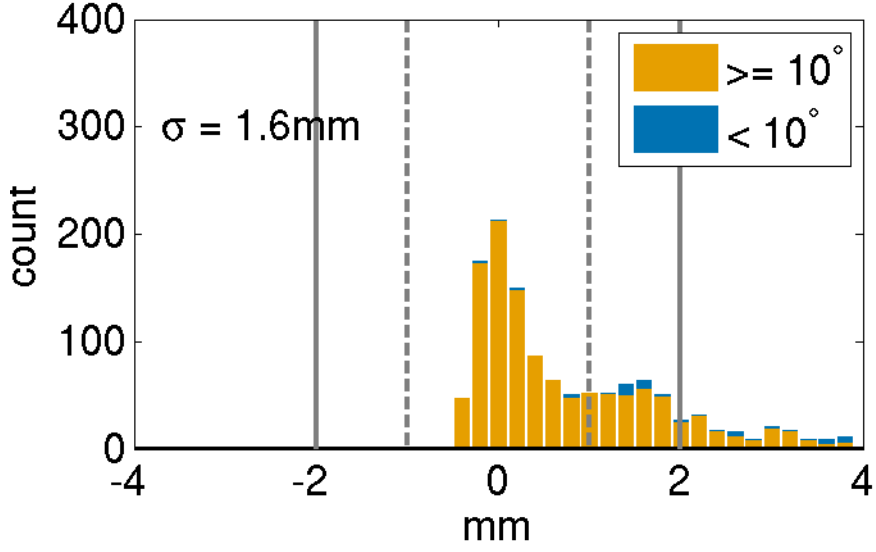


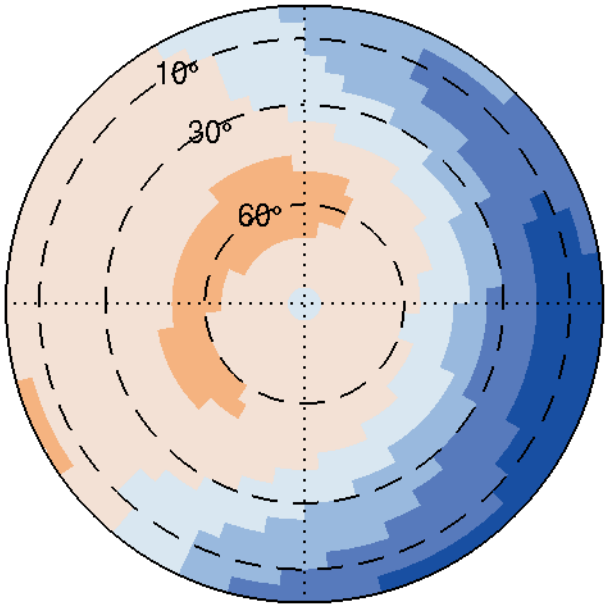
NGS – Geo++



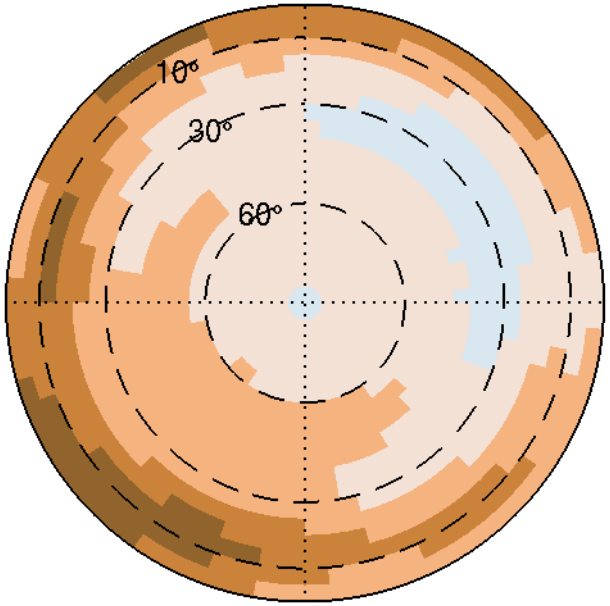
Trimble GNSS chokering

GPS L2 differences

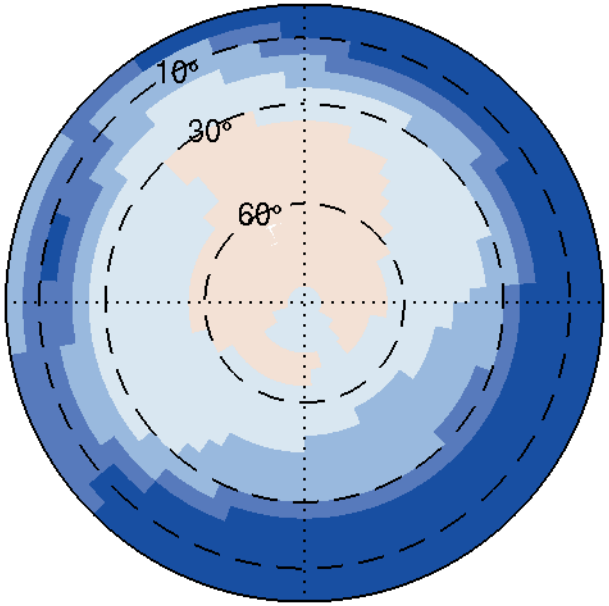
NGS – Bonn

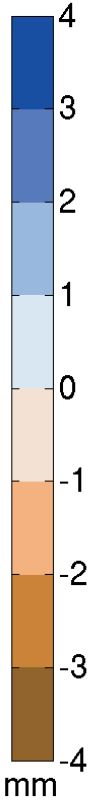


Geo++ - Bonn



NGS – Geo++

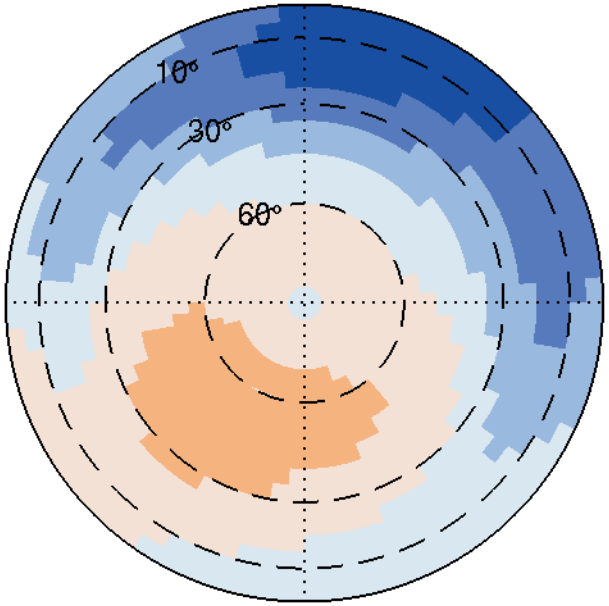




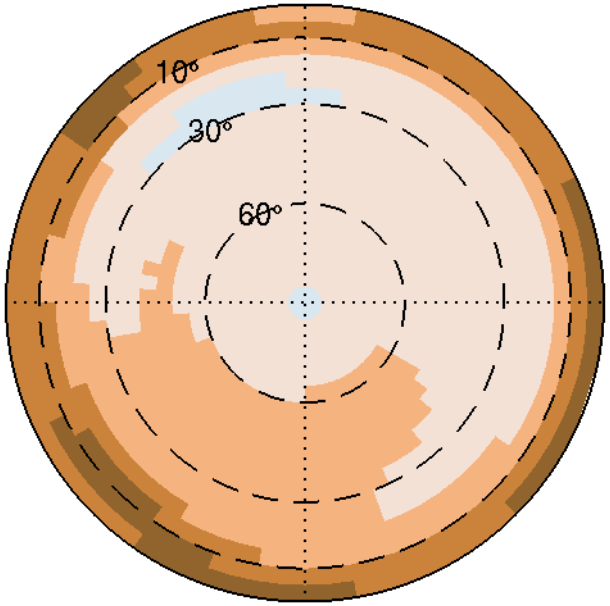
Trimble GNSS chokering

GPS L2 differences

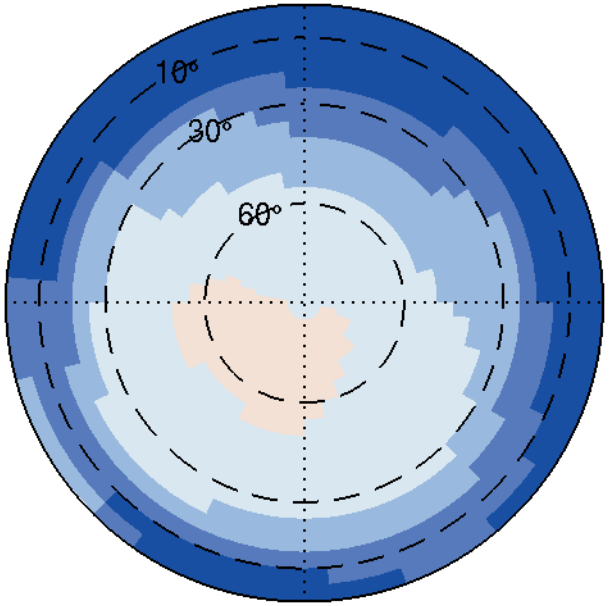
NGS – Bonn

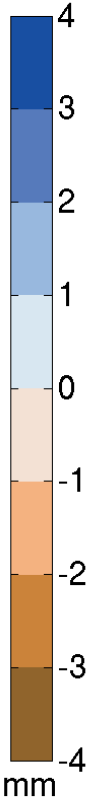


Geo++ - Bonn



NGS – Geo++

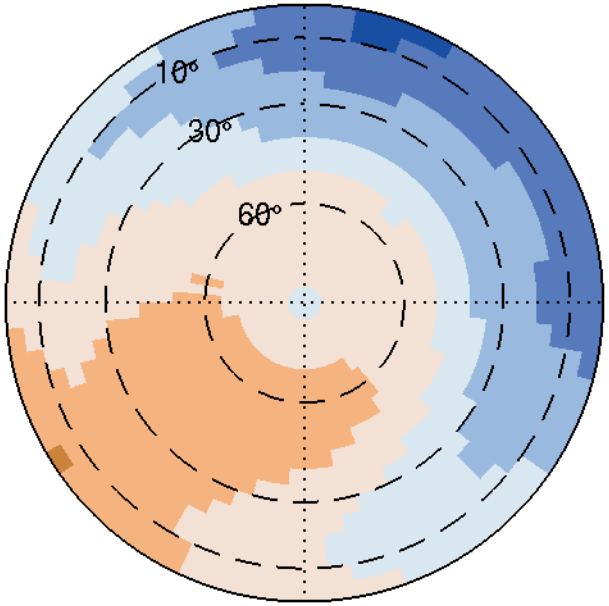




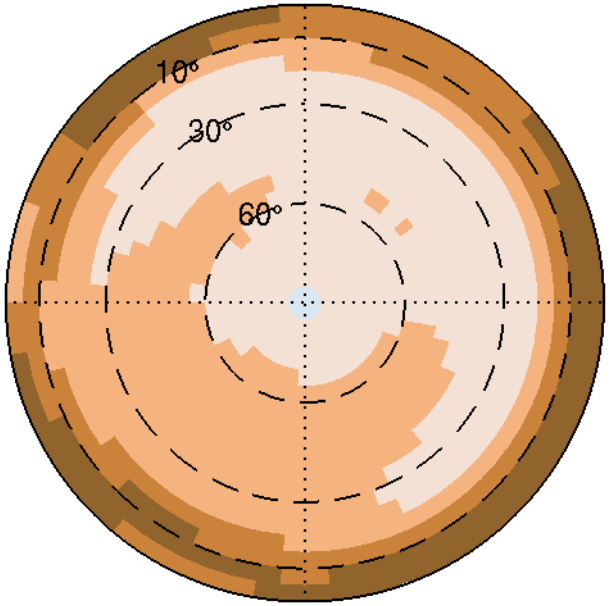
Trimble GNSS chokering

GPS L2 differences

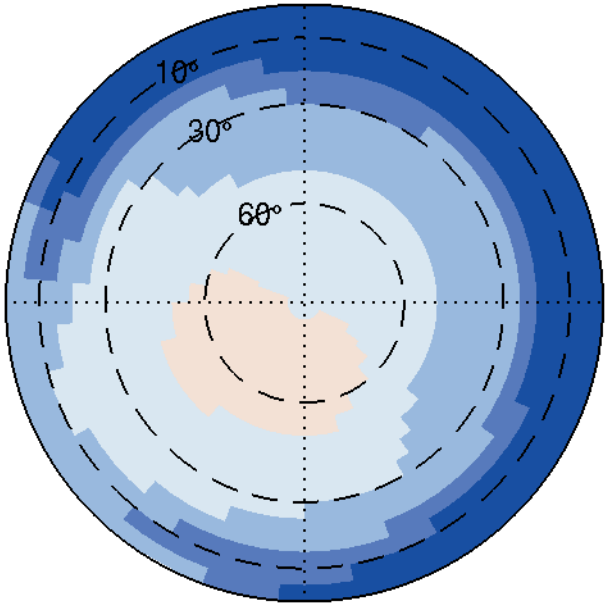
NGS – Bonn

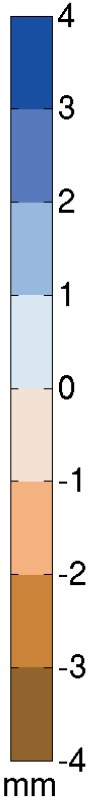


Geo++ - Bonn

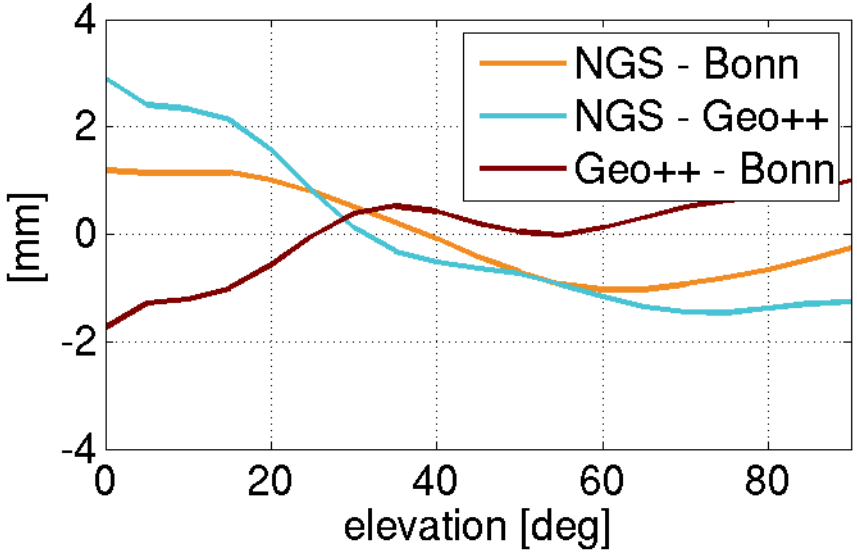


NGS – Geo++



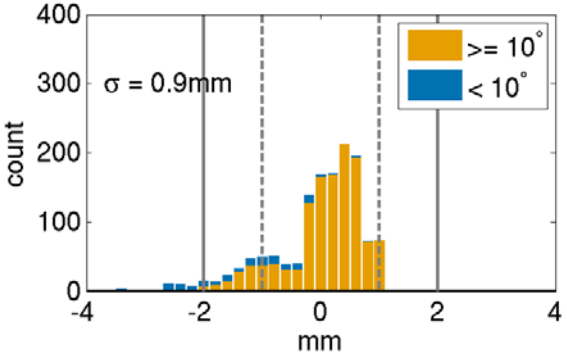


In-depth Exploration of Chokering L2 Differences

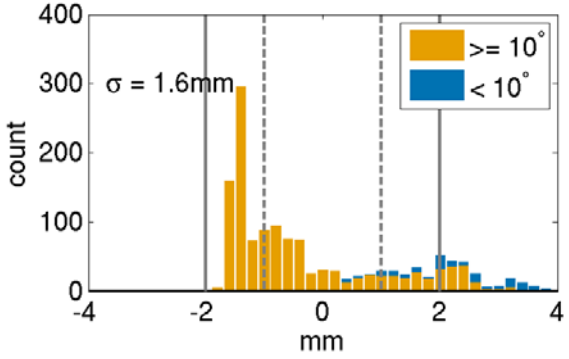


- Systematic differences
- Is there a simple explanation?

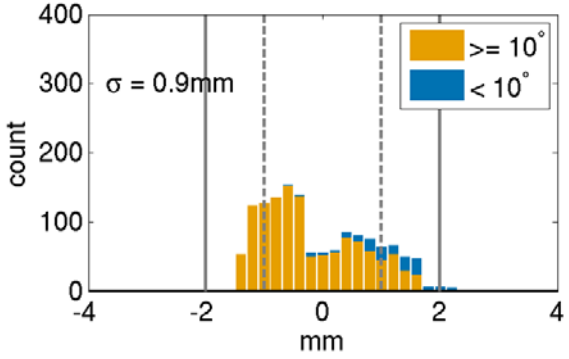
Geo++ - Bonn



NGS – Geo++

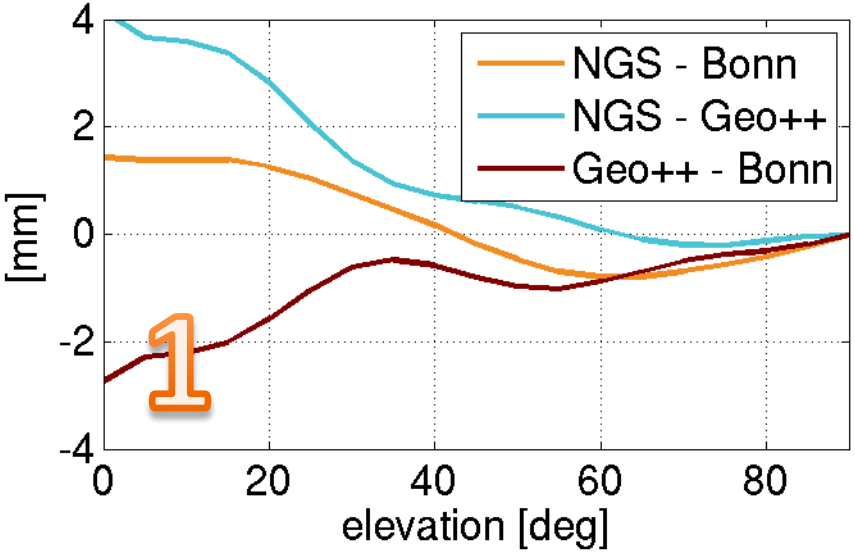


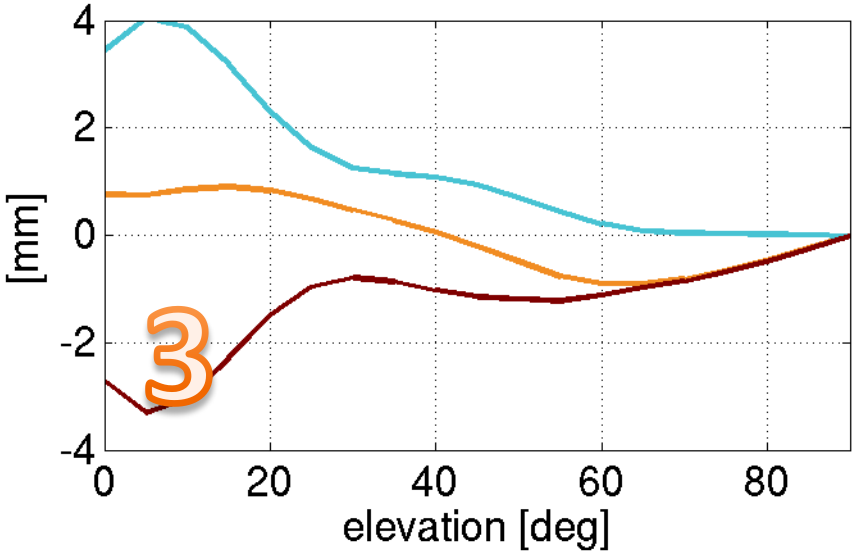
NGS – Bonn

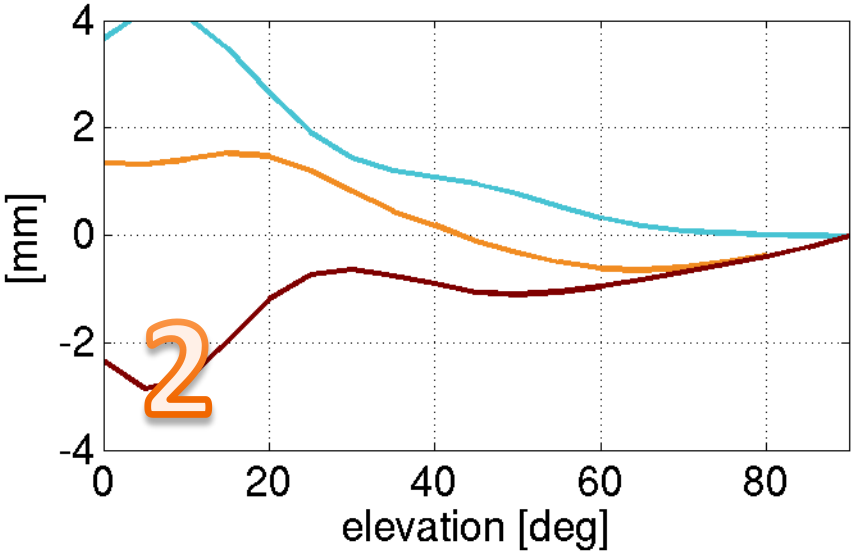


GPS L2 elevation-dependent differences

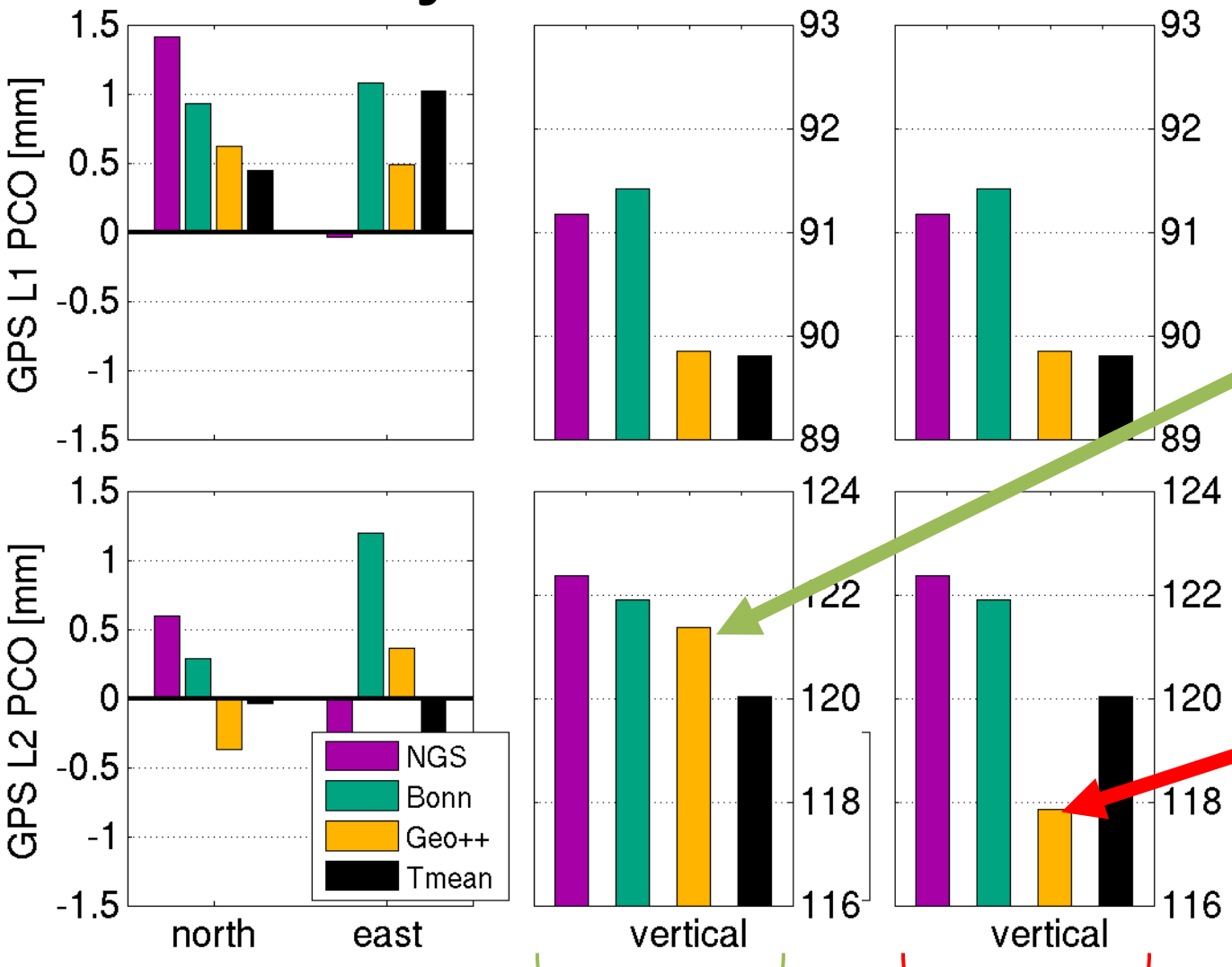
… drift with respect to elevation angle is consistent with error in vertical PCO







Adjust Vertical PCO



Add 3.5 mm to be consistent with other solutions

Original PCO

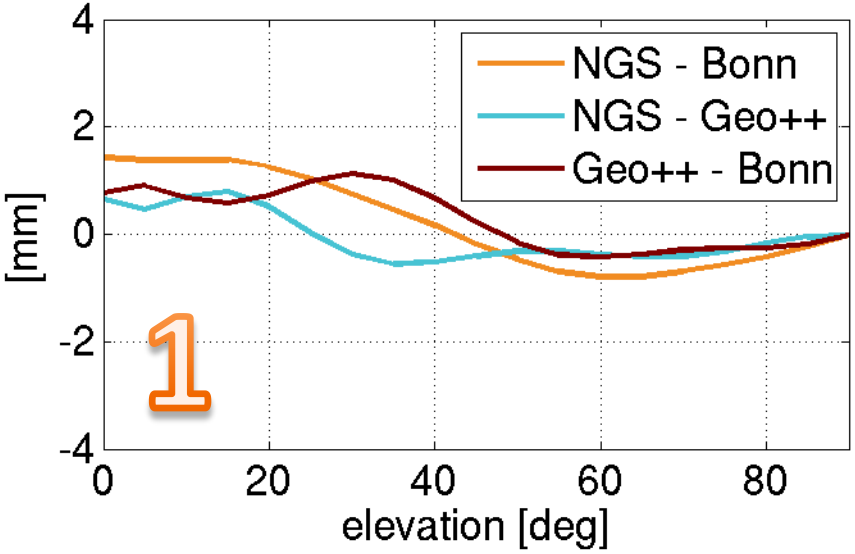
Modified Geo++ Vertical

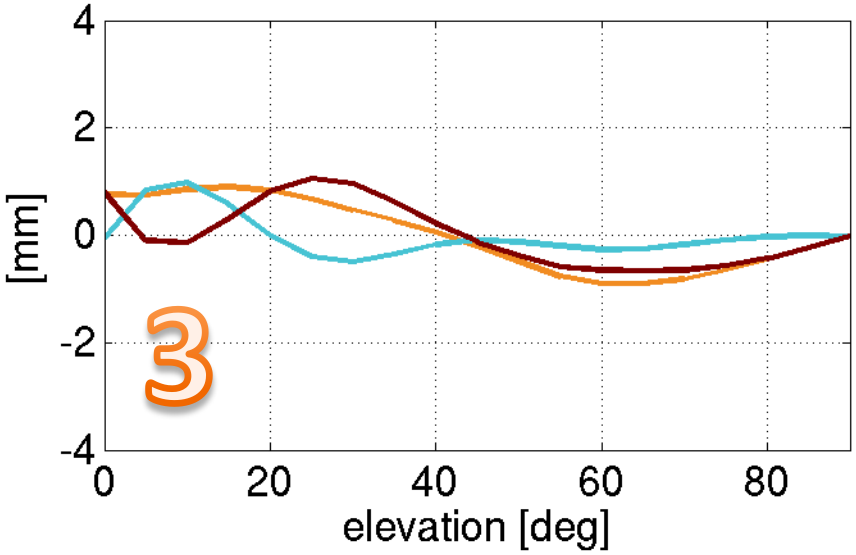
Estimated

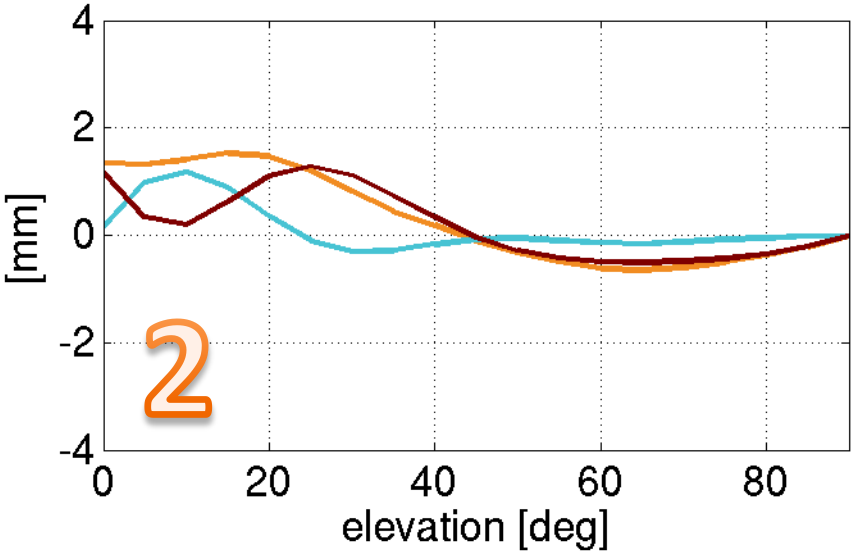
GPS L2 elevation-dependent differences

Changing vertical PCO of one or more solution creates agreement:

- Shown here: add 3.5 mm to Geo++
- Same effect from:
  - -4 NGS, -2 Bonn
  - -2 NGS, +2 Geo++





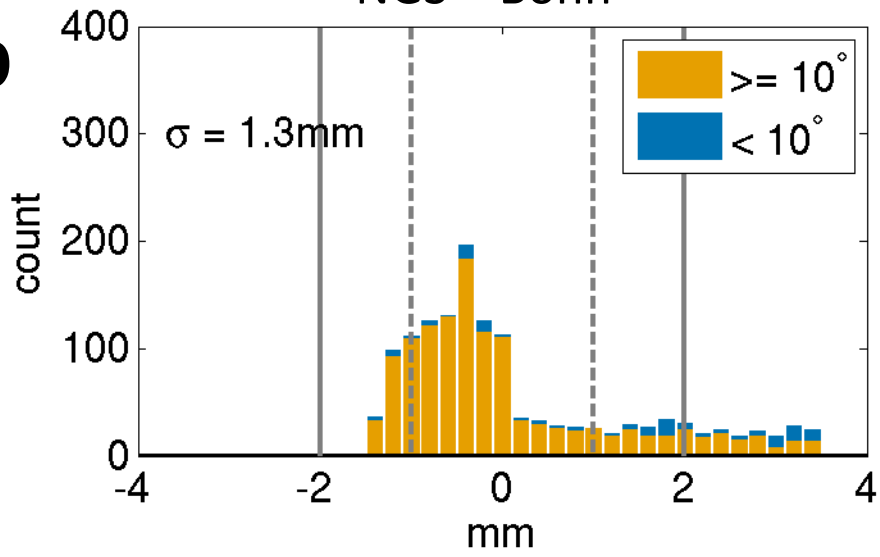


Trimble GNSS chokering

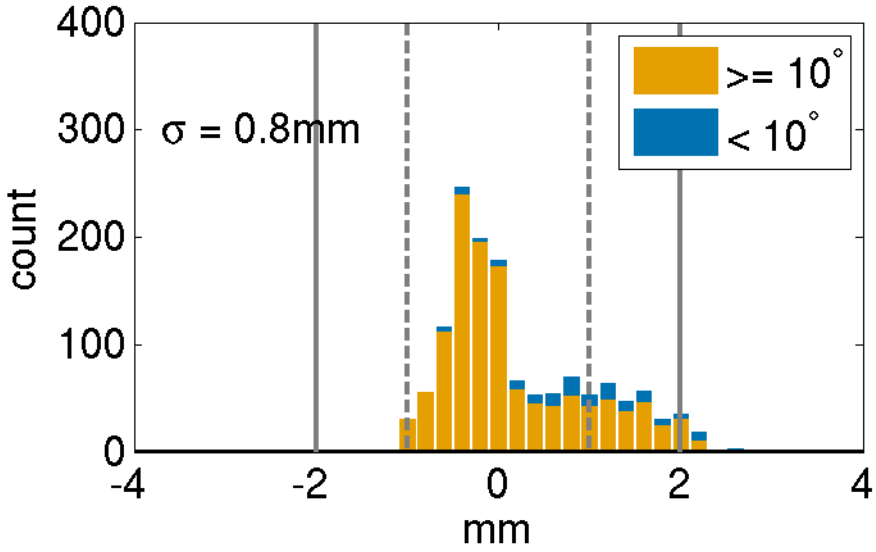
GPS L2 differences with adjusted vertical PCO

1

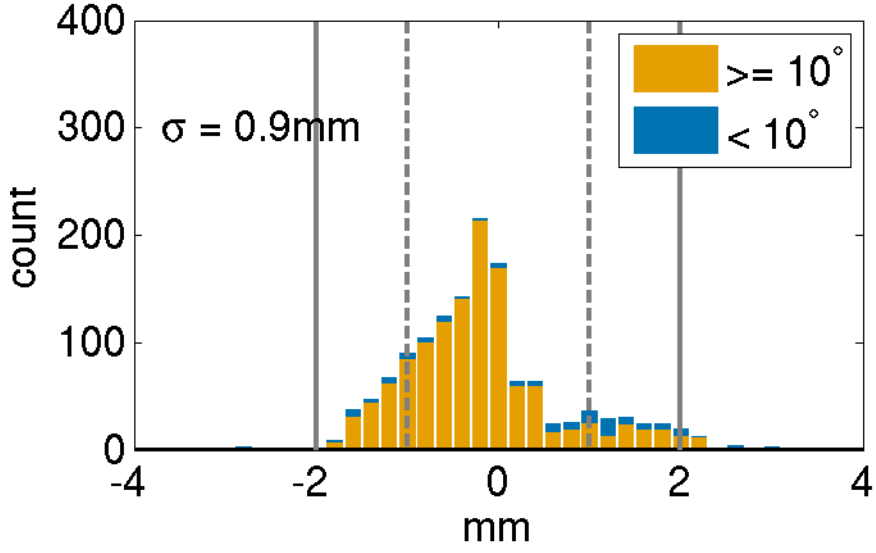
NGS – Bonn



Geo++ - Bonn



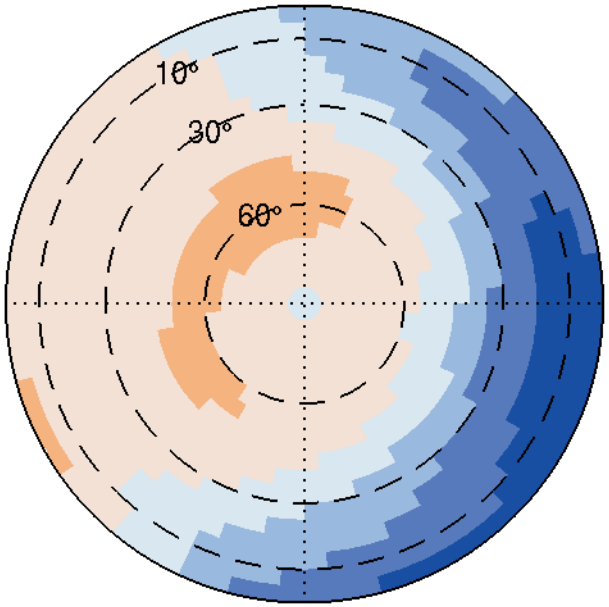
NGS – Geo++



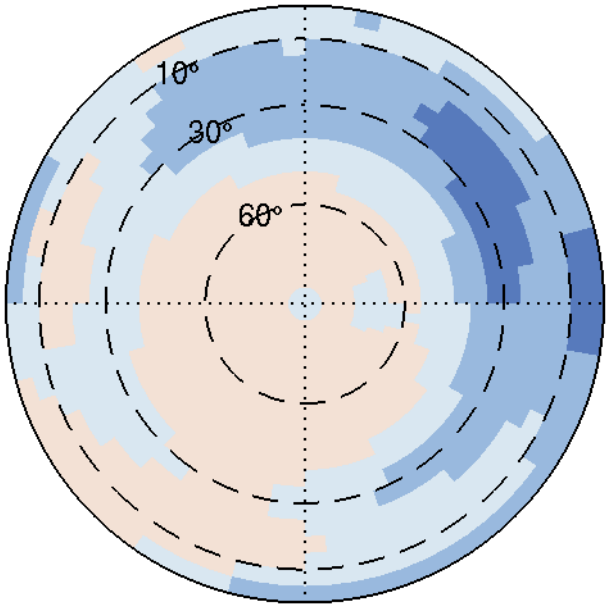
Trimble GNSS chokering

GPS L2 differences with adjusted vertical PCO

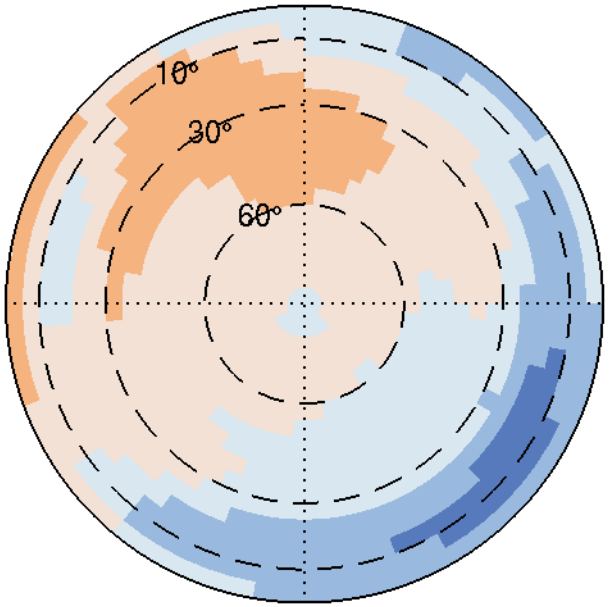
NGS – Bonn

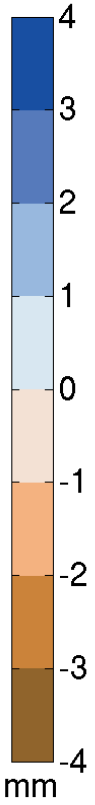


Geo++ - Bonn



NGS – Geo++





Trimble GNSS Chokering *Summary*

- Good agreement for L1 (sub-mm)
- Less ideal L2 agreement, differences are:
  - Systematic (same trends across samples)
    - Trends consistent with vertical PCO error
    - Area of active research for AWG
  - < 2 mm above 30° elevation (not 10°)
  - < 3-5 mm in the 0-20° range

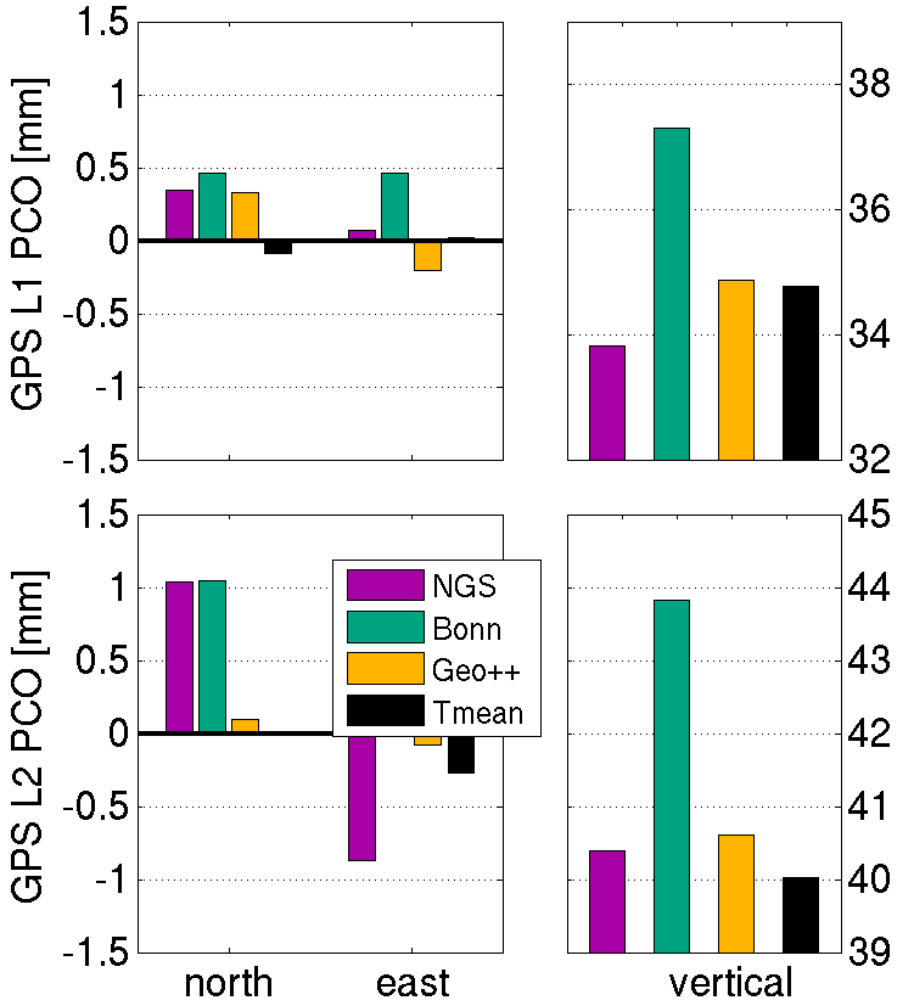
Conclusions

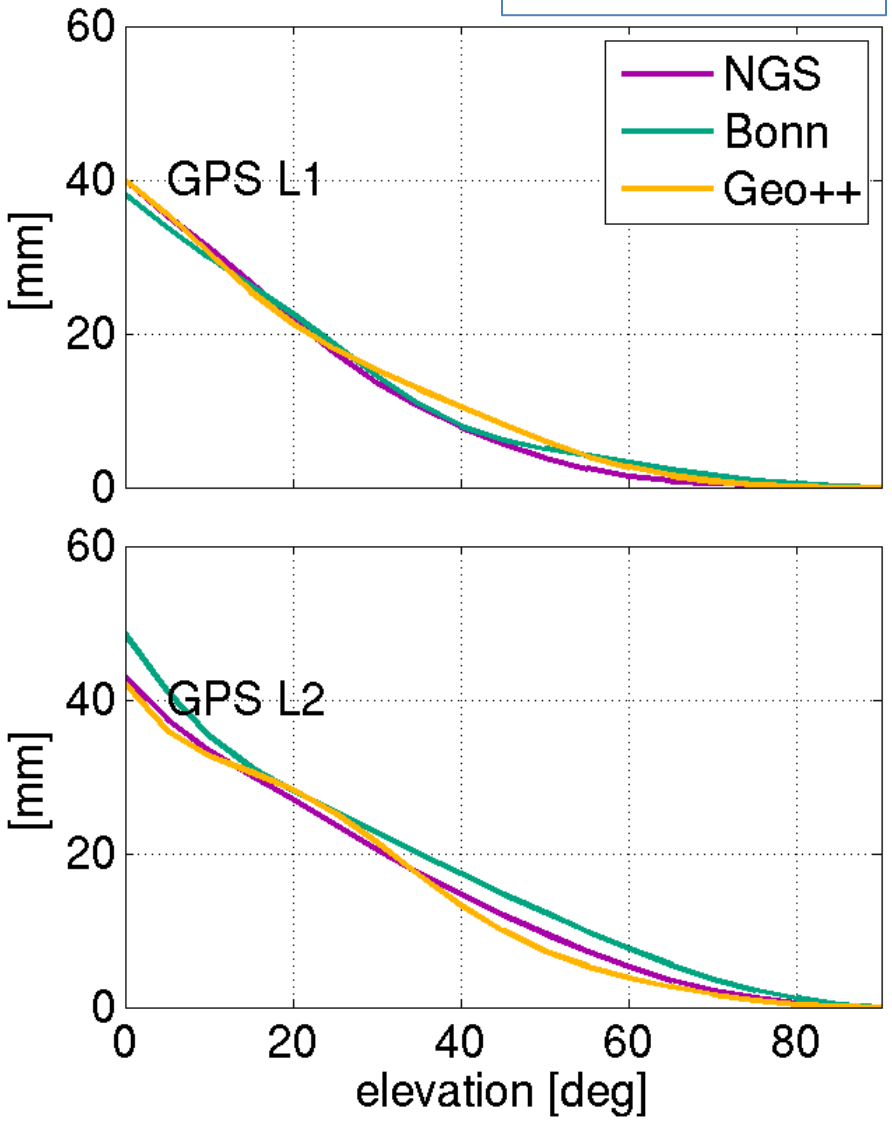
- NGS has demonstrated agreement with Geo++ and Bonn for IGS-quality antennas ...
- AWG active research to continue
  - Source of vertical PCO mis-estimation
  - Calibration effects on position
  - Near-field effects (robot, antenna mount) on calibration

Topcon PG-A1 with groundplane (TPSPG_A1+GP)

Topcon PG-A1 (TPSPG_A1+GP)

Elevation-dependent PCV

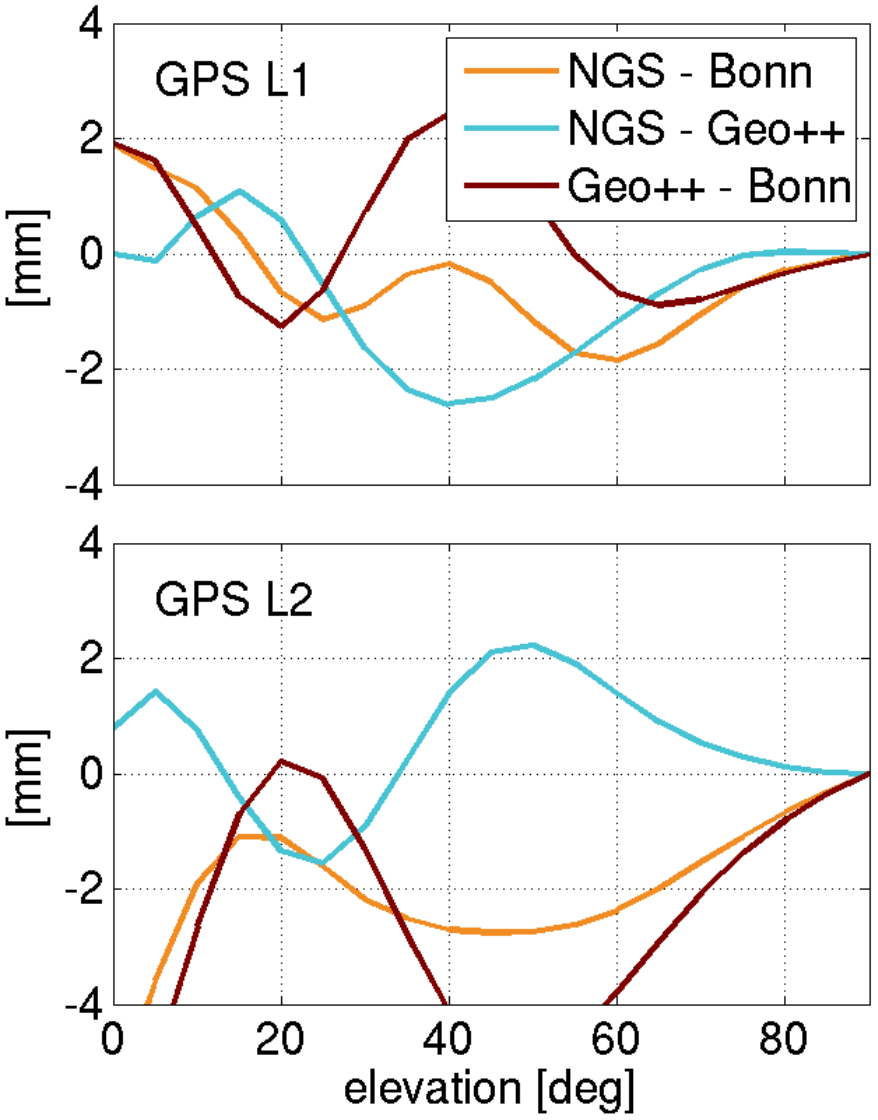




Topcon PG-A1 (TPSPG_A1+GP)

Differences in purely elevation-dependent PCV:

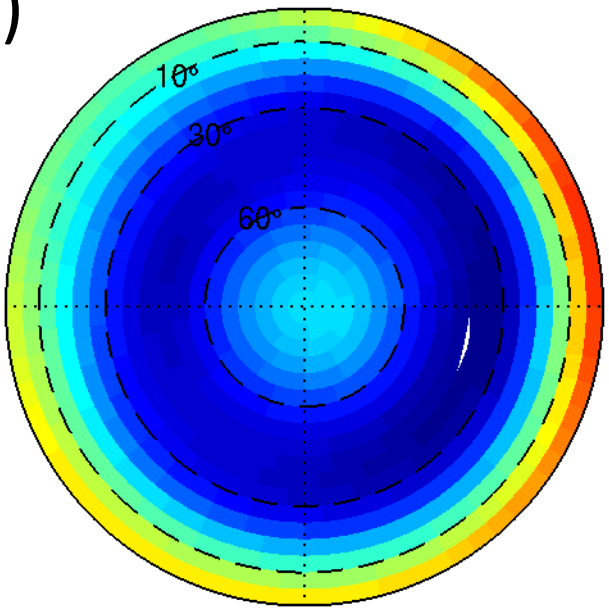
- L1 ± 2 mm
- L2 ± 4 mm w/ bias
- Extremely variable
- Differences in L2 PCV are larger than PCV themselves



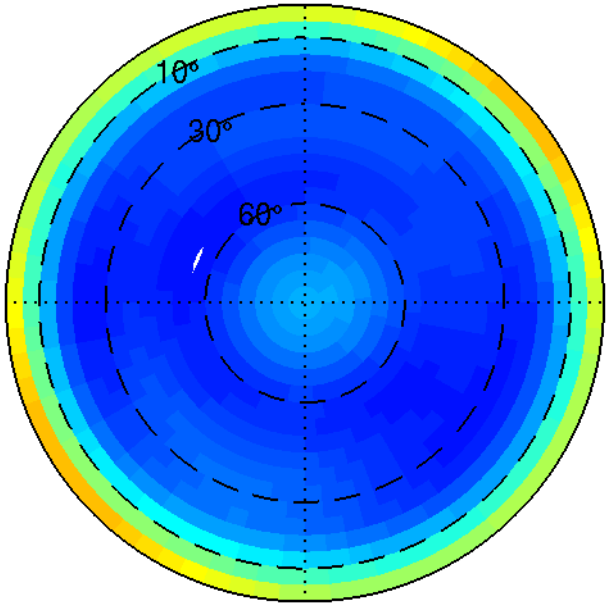
Topcon PG-A1 (TPSPG_A1+GP)

GPS L1 PCV

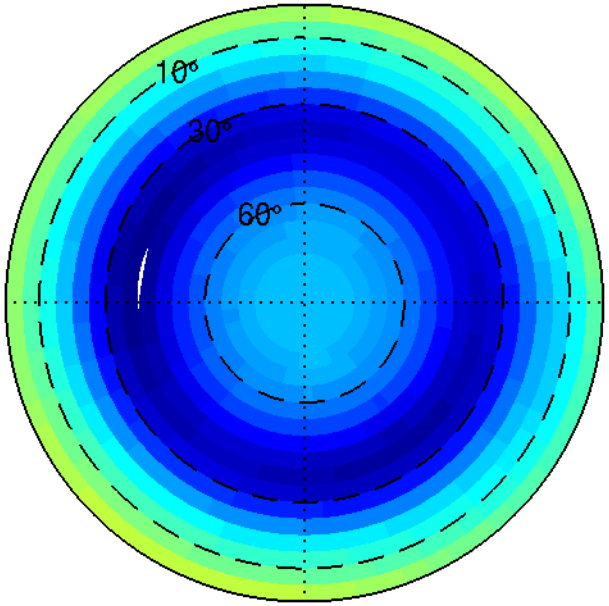
NGS

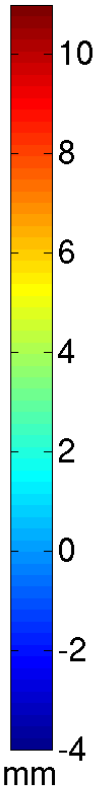


Geo++



Bonn

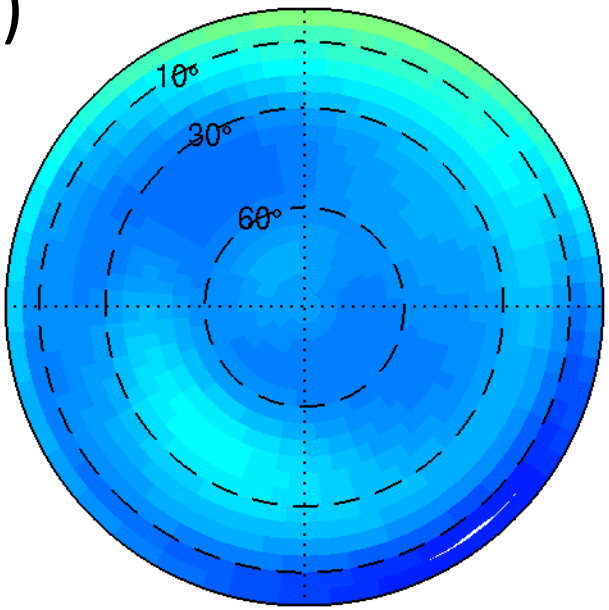




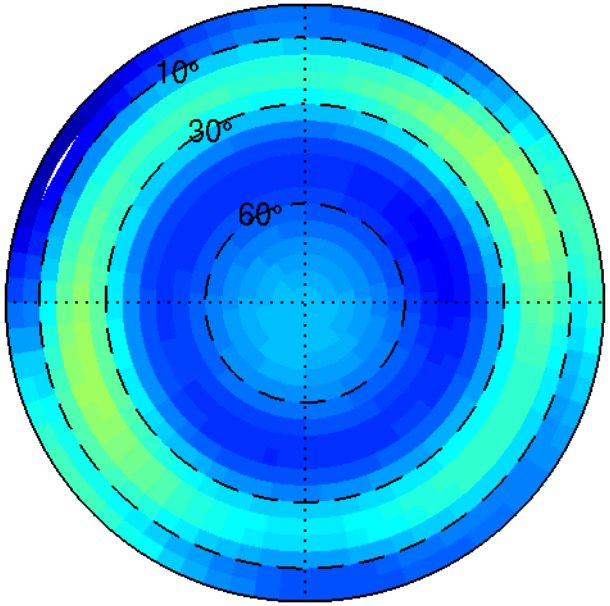
Topcon PG-A1 (TPSPG_A1+GP)

GPS L2 PCV

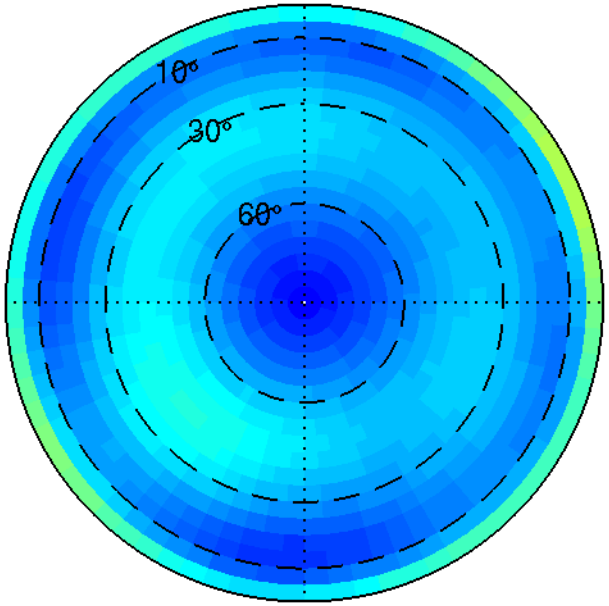
NGS

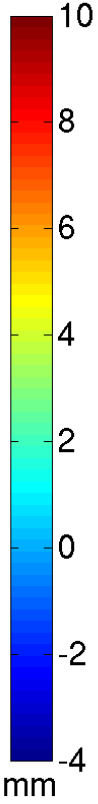


Geo++



Bonn

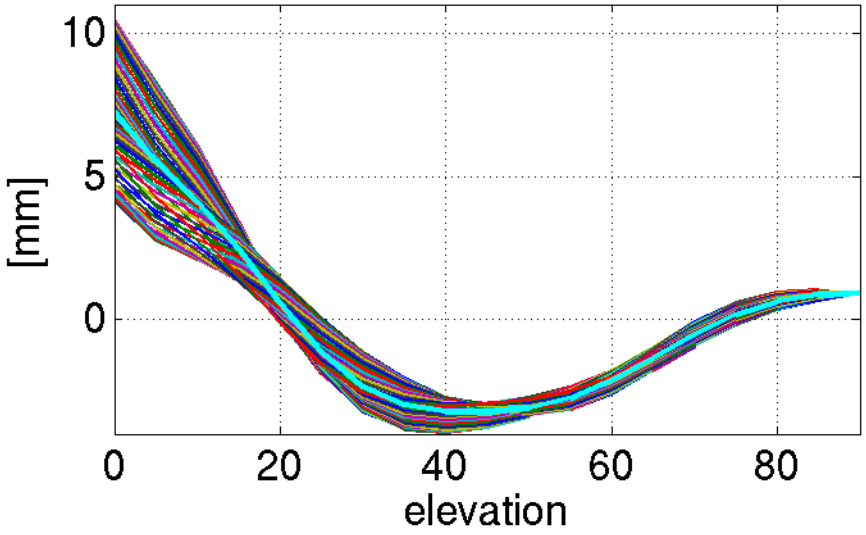




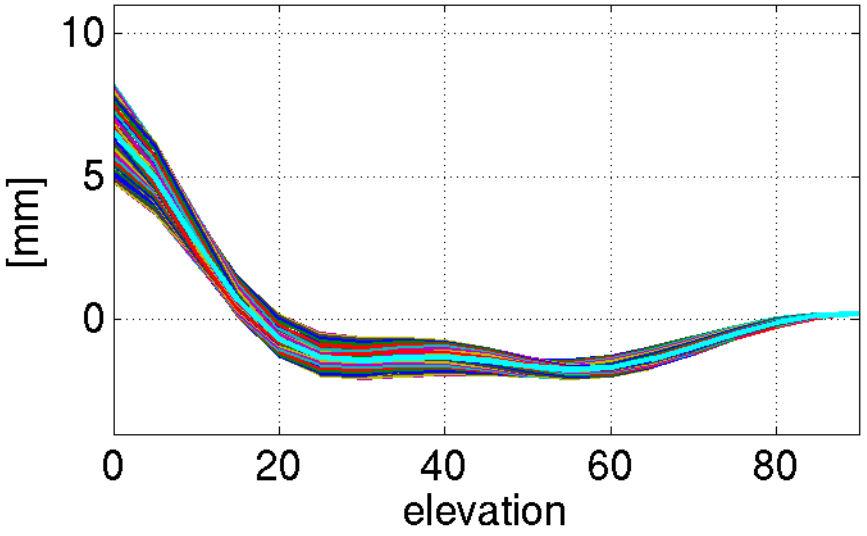
Topcon PG-A1 (TPSPG_A1+GP)

GPS L1 PCV

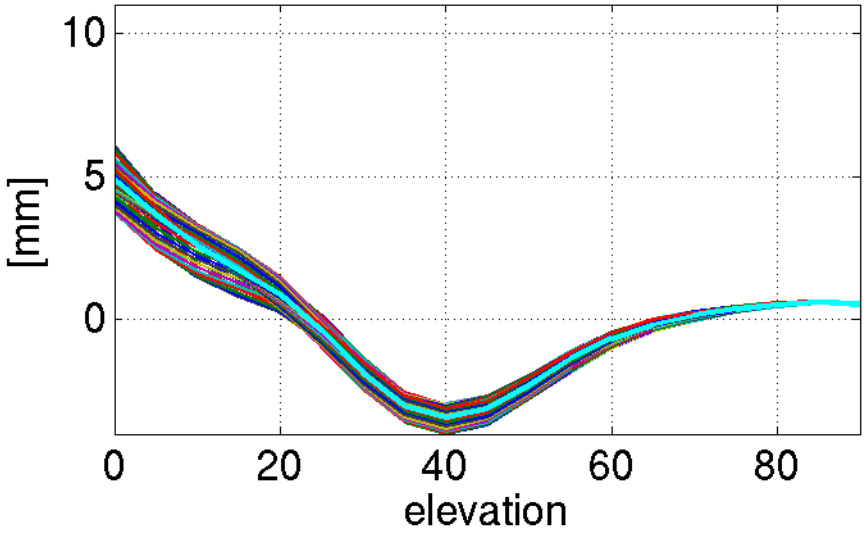
NGS



Geo++



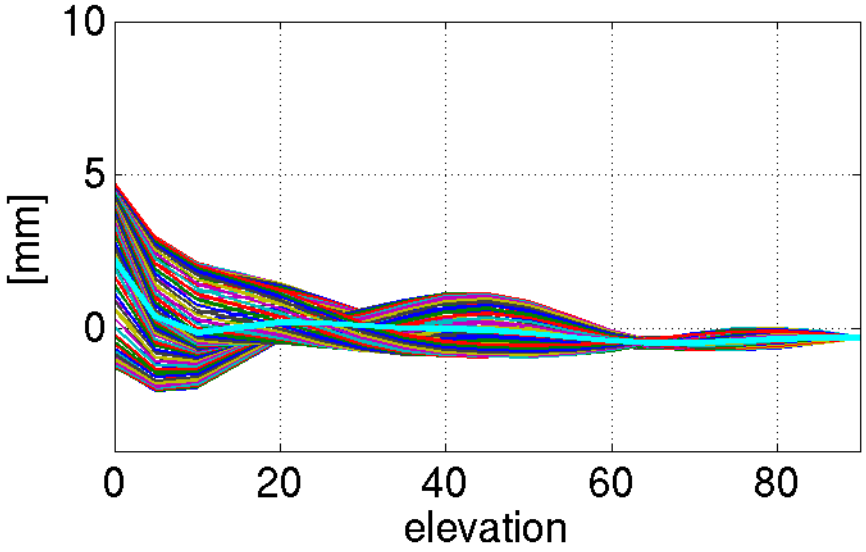
Bonn



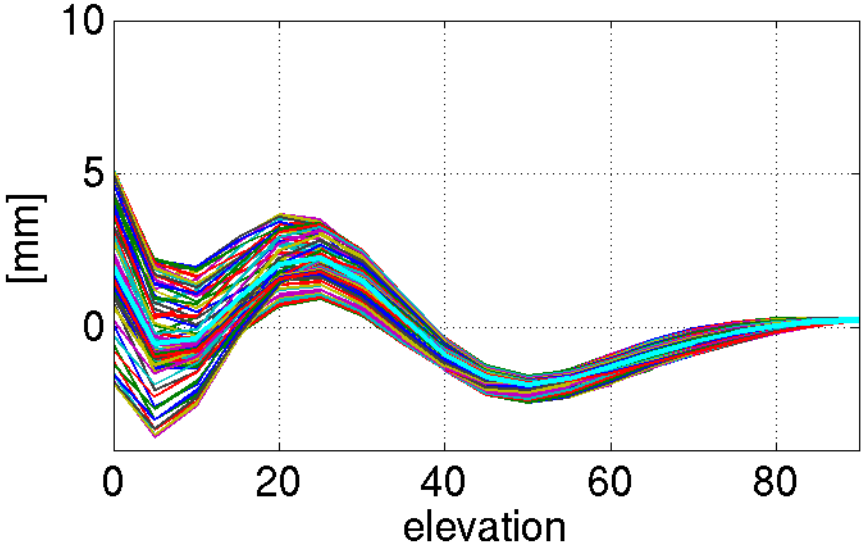
Topcon PG-A1 (TPSPG_A1+GP)

GPS L2 PCV

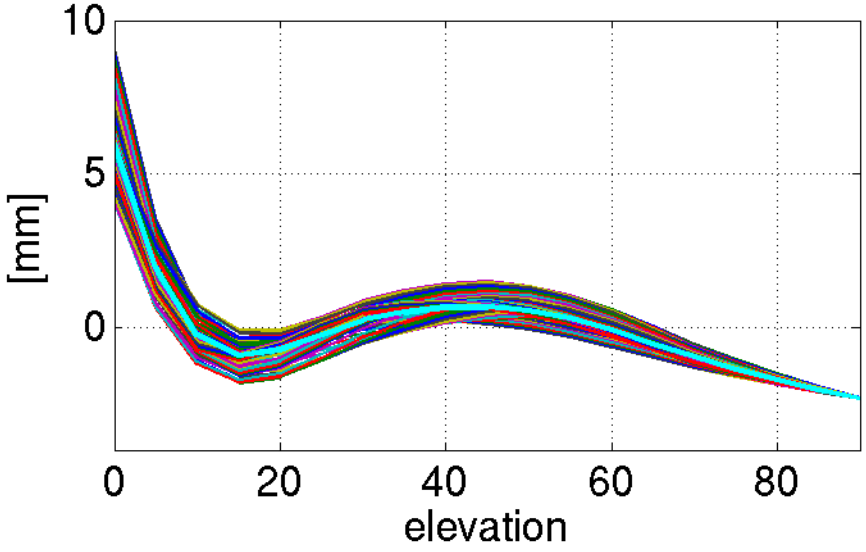
NGS



Geo++



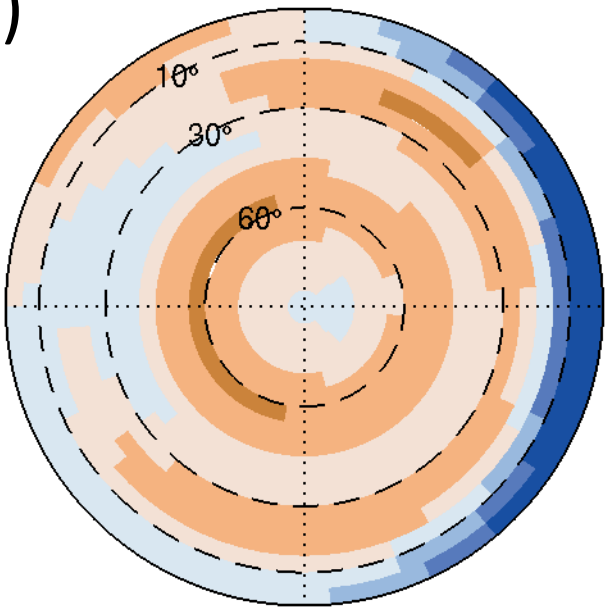
Bonn



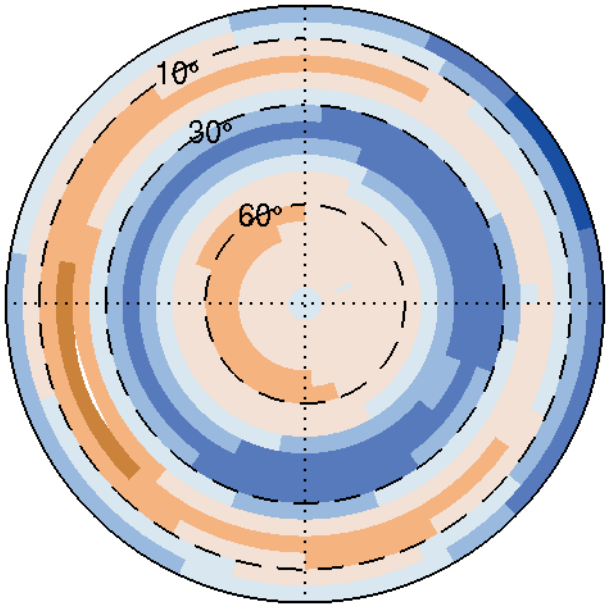
Topcon PG-A1 (TPSPG_A1+GP)

GPS L1 differences

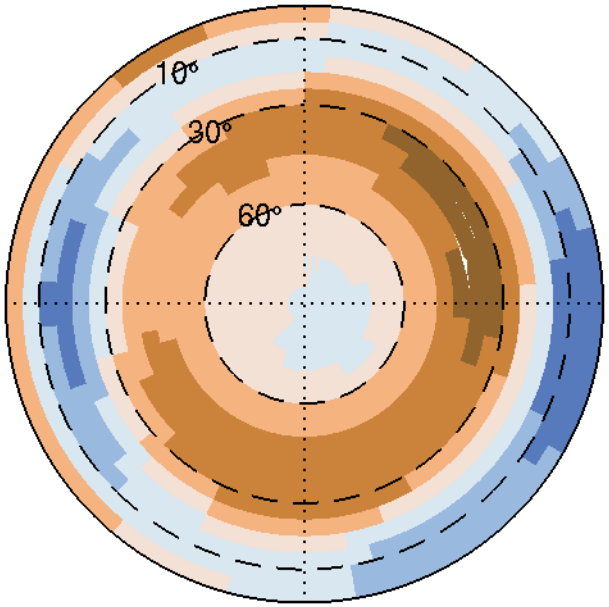
NGS – Bonn

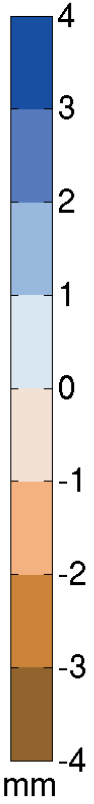


Geo++ - Bonn



NGS – Geo++

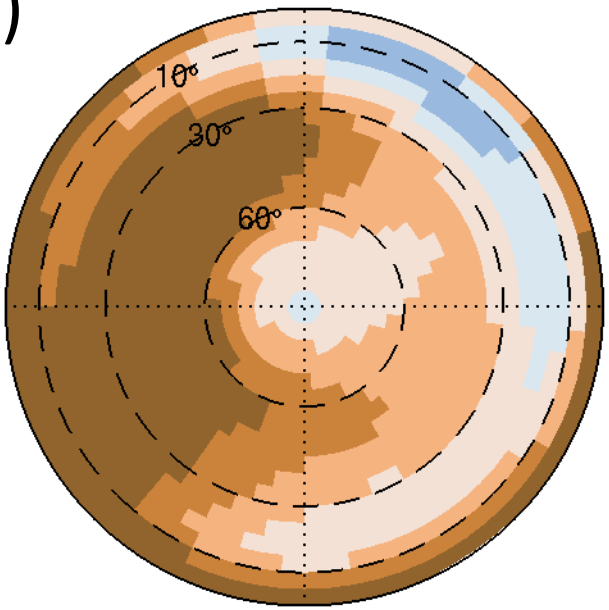




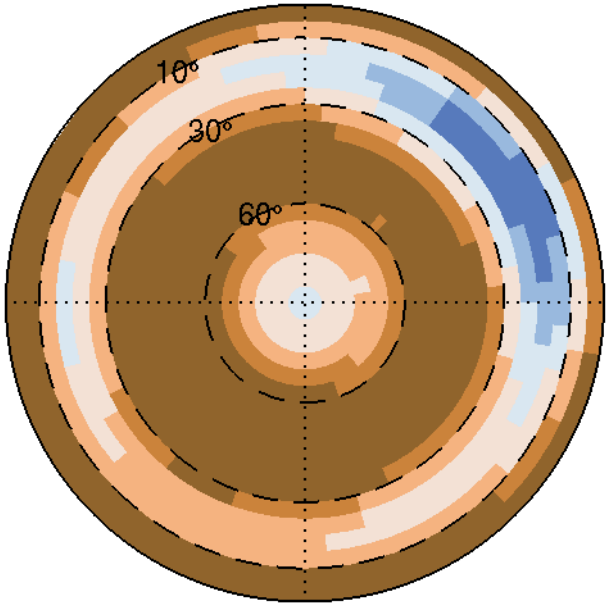
Topcon PG-A1 (TPSPG_A1+GP)

GPS L2 differences

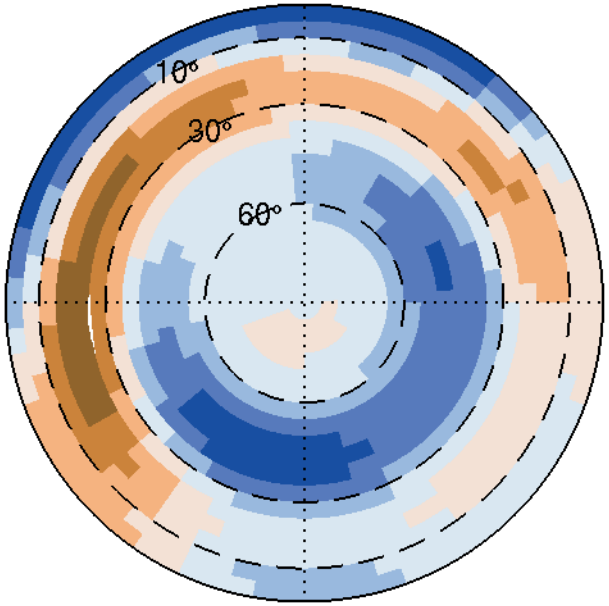
NGS – Bonn

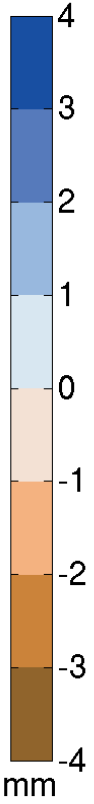


Geo++ - Bonn



NGS – Geo++

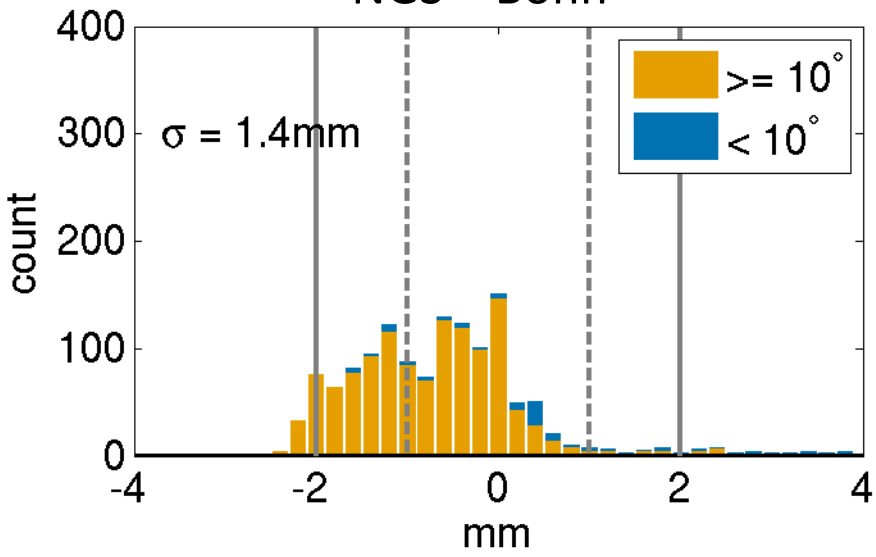




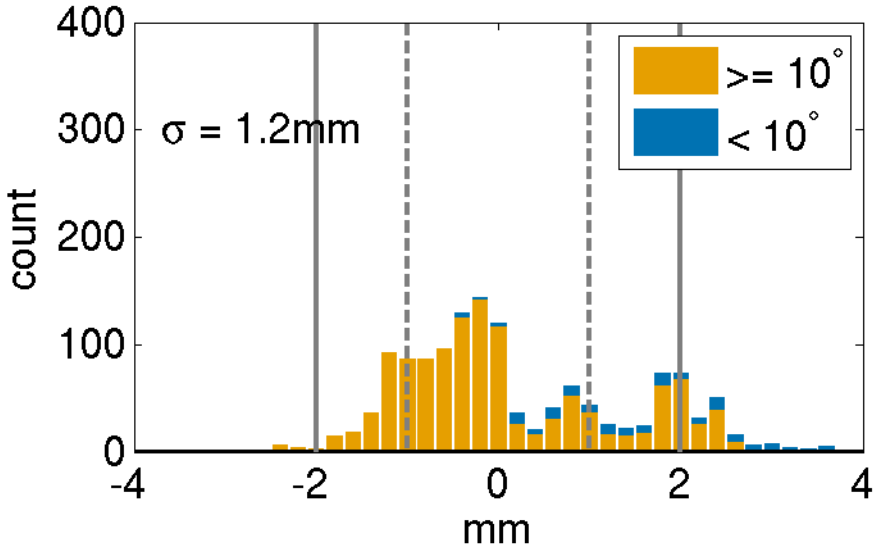
Topcon PG-A1 (TPSPG_A1+GP)

GPS L1 differences

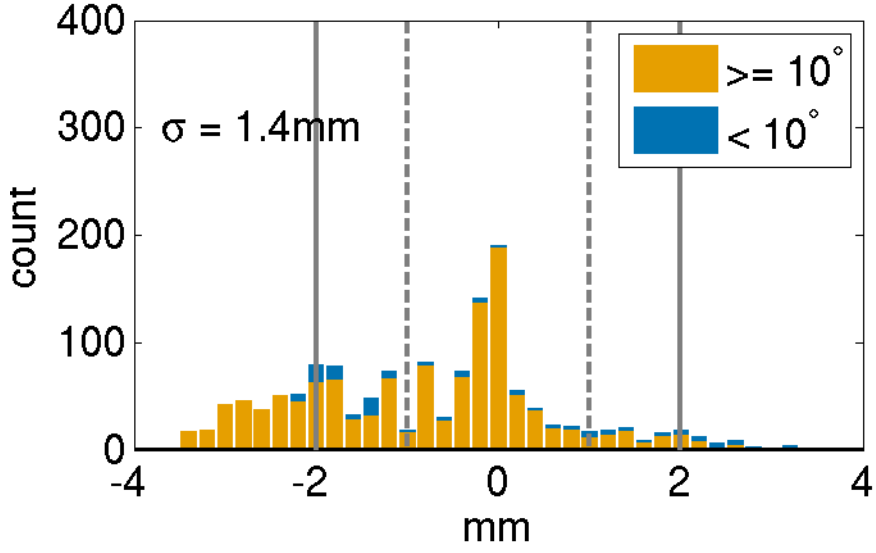
NGS – Bonn



Geo++ - Bonn



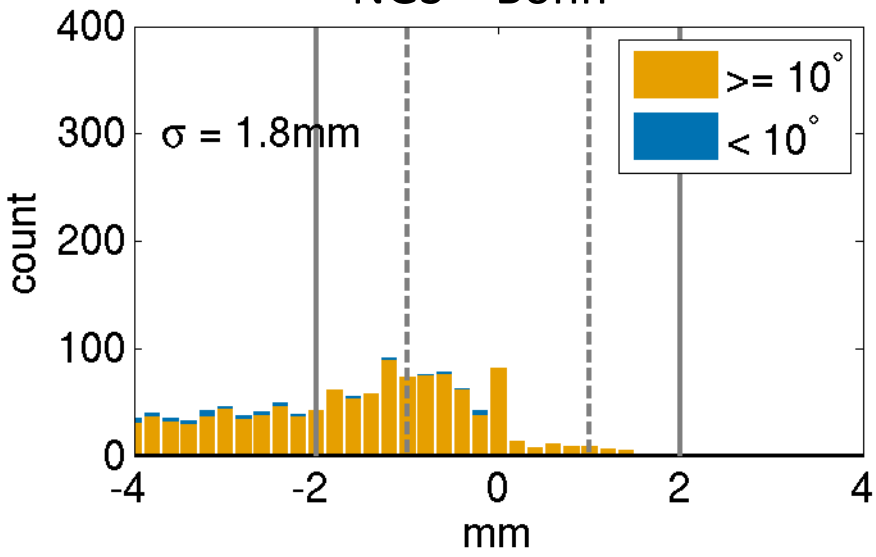
NGS – Geo++



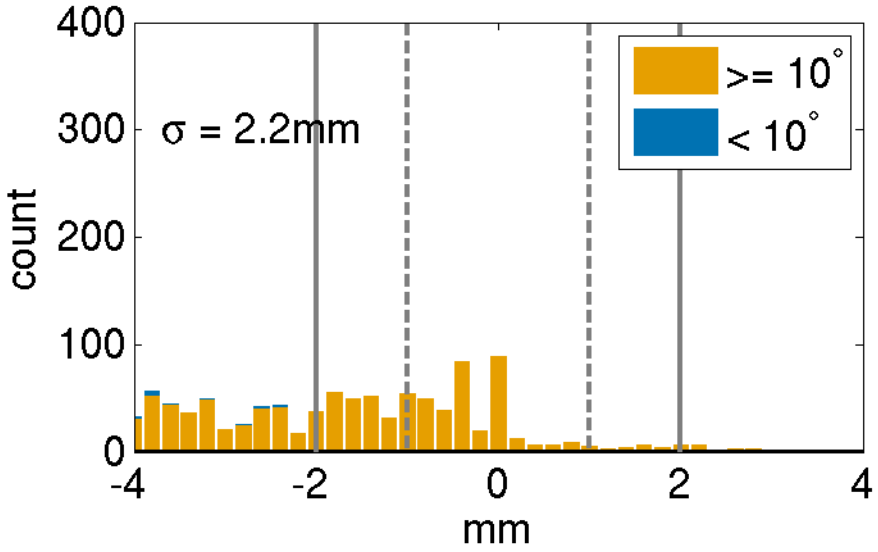
Topcon PG-A1 (TPSPG_A1+GP)

GPS L2 differences

NGS – Bonn



Geo++ - Bonn



NGS – Geo++