Institut für Erdmessung | National Geodetic Survey | Topcon Positioning Systems | Leibniz Universität Hannover

# A Global Collaboration to Enhance GNSS Receiver Antenna Calibration: The IGS Antenna Ring Campaign

- **EGU General Assembly 2024** -
*G2.2 :: Terrestrial Reference Frames*

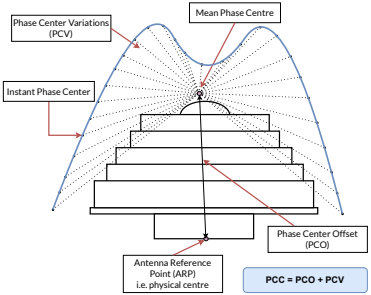
**T. Kersten**[Γ], A. Bilich[†] I. Sutyagin[‡], S. Schön[Γ]

[Γ]Institut für Erdmessung, Leibniz University Hannover
[†]National Geodetic Survey, NOAA/NOS
[‡]Topcon Positioning Systems, Livermore

## GNSS receiver antenna calibration

**What does this mean?**

- Characterization of GNSS receiver and satellite antennas
- No certification through standards (IEEE, ISO, etc.)
- International *commitment* to achieve the *highest quality* for global products, such as for positioning, frequency transfer, satellite orbits, and troposphere estimates






**International GNSS Service (IGS)**

- Federation, over 200 self-funded agencies, universities and research centres, worldwide
- Providing free and open access to highest precision GNSS products (Orbits, biases, clocks, etc)
- Coordination by committee: IGS Antenna Committee

## Phase Centre Correction requirements

**Phase centre corrections (PCC) need to be**

- *Accurate* – prerequisite for high quality GNSS applications and products
- *Cross-validated* – evidence and proof of the scientific method of GNSS calibration

**Receiver antenna calibration sets and IGS**

- Since GPS week 1400 (Nov. 2006), IGS applies absolute calibration values
- Change of IGS processing procedures to multi GNSS
- Robot method developed 1998/1999 by Uni Hannover & Geo++ (Menge et al., 1998)
- Chamber method by University of Bonn (Görres et al., 2006)

Menge et al. (1998). *Results of the absolute field calibration of GPS antenna PCV*, **ION GPS 1998**
Görres et al. (2006). *Absolute calibration of GPS antennas: Laboratory results and comparison with field and robot techniques*, **GPS Solut 10(2):136-145**

## Phase Centre Correction requirements

**Phase centre corrections (PCC) need to be**

- *Accurate* – prerequisite for high quality GNSS applications and products
- *Cross-validated* – differences of *robot* and *chamber*, updates of PCCs

**Receiver antenna calibration sets and IGS**

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# IGS receiver antenna ring calibration and validation campaign (IGS ringCalVal)

## Motivation and procedure

- Historically, receiver antenna PCC mainly by one institution/method (Geo++/robot)
- Currently, IGS approved facilities: Geo++, IfE (both robot) and University of Bonn (chamber)
  - **Question 1:** How to cross-validate results from different facilities?
  - **Question 2:** Rules and requirements to integrate new facilities?

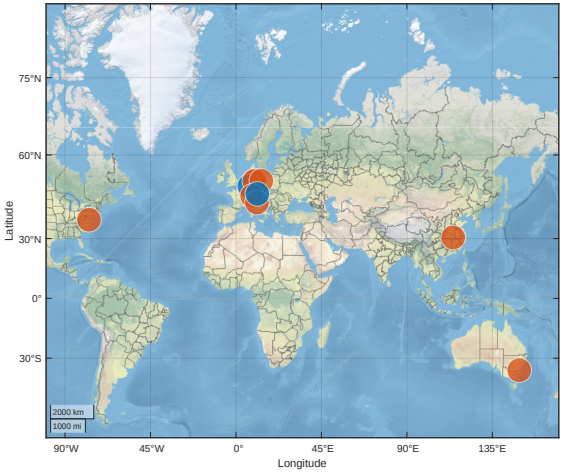
## Independent methods and setups

- *Different robots and approaches:* National Geodetic Survey (NGS), Topcon Italy, ETH Zurich, GNSS Research Center Wuhan (GNSS-RC)
- *Same robots – different approaches:* Geo++, Inst. f. Erdmess. (IfE), GeoScience Australia (GSA)
- *Anechoic chamber:* Uni Bonn, German Aerospace Center (DLR) Oberpfaffenhofen

## Calibration samples

- Geodetic grade antennas: 4 x choke ring antennas, 1 x Zephyr II, 1 x rover antenna

# Worldwide partners and coordinators




Möllers, A. (2024)

## Agencies & Methods: Robot and Chamber

1. National Geodetic Survey (US)†
2. Topcon Livermoore (US/IT)†
3. Institut für Erdmessung (DE)†
4. Geo++ (DE)
5. ETH Zurich (CH)
6. GNSS-RC Wuhan (CN)
7. Geoscience Australia (AU)
8. University of Bonn (DE)
9. DLR Oberpfaffenhofen (DE)

† Coordinators

Möllers, A (2024). *Multi-GNSS antenna corrections and GNSS reference stations*, **B.Sc. thesis, Leibniz University Hannover**

# Facilities within the IGS ringCalVal 2023/2024

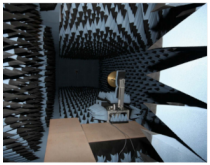

ETH-Zürich, CH


NGS, Virginia, US


Geo++, Garbsen, DE


GSA, Canberra, AU


GNSS-RC, Wuhan, CN


Uni Bonn, DE


DLR-IKN, Oberpfaffenhofen, DE


LUH-IfE, Hannover, DE


Topcon, IT

# Current status by April 10th, 2024

| Region | Method | Institution | TPSCR.G5C | TPSG5_A1 | JAVRINGANT_DM | TRM57971.00 | LEICA25.R3 | HXCCGX601A |
|---|---|---|---|---|---|---|---|---|
| Australia | robot | GSA - Geoscience Autralia | 9 | 9 | 1 | 1 | 9 | 9 |
| China | robot | GNSS Research Center of Wuhan University (WHU-GNSSRC) | 8 | 8 | 3 | 3 | 8 | 1 |
| Europe | chamber | DLR German Aerospace Centre Institute of Communications and Navigation | 5 | 5 | 8 | 8 | 4 | 7 |
| | | Uni Bonn | 4 | 4 | 9 | 9 | 3 | 8 |
| | robot | Geo++ GmbH | 3 | 3 | 7 | 7 | 2 | 6 |
| | | TOPCON AGRICULTURE S.R.L. | 1 | 1 | 5 | 5 | 5 | 4 |
| | | ETH Zurich | 6 | 6 | 4 | 4 | 6 | 3 |
| | | LUH-IfE | 2 | 2 | 6 | 6 | 1 | 5 |
| USA | robot | NGS/NOAA | 7 | 7 | 2 | 2 | 7 | 2 |

**Legend**

1:= last stop in rotation

antenna(s) not arrived/calibrated

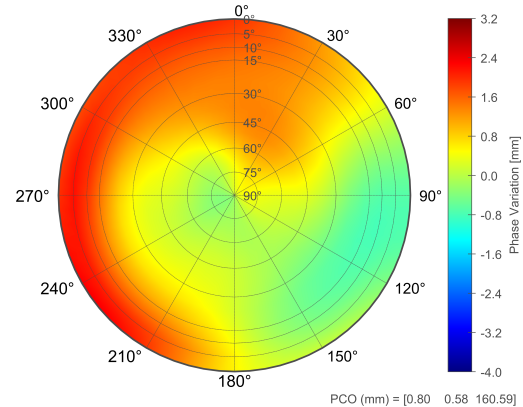
antenna(s) under testing/calibration

waiting position for receiving antenna(s) as next

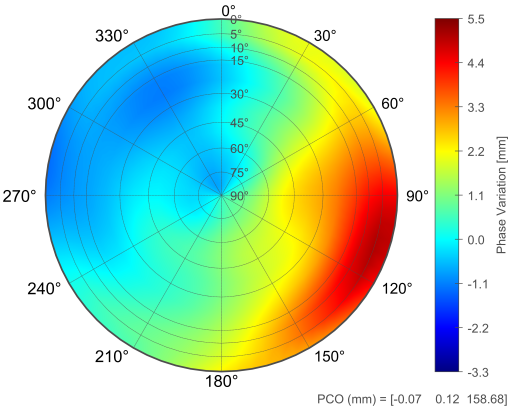
finished testings/calibration

# Initial results of LEIAR25.R3 NONE (IfE - NGS - TPS)

## Reference: IGS_2290




(a) ΔPCC, G01 (IGS-IFE)




(b) ΔPCC, G02 (IGS-IFE)

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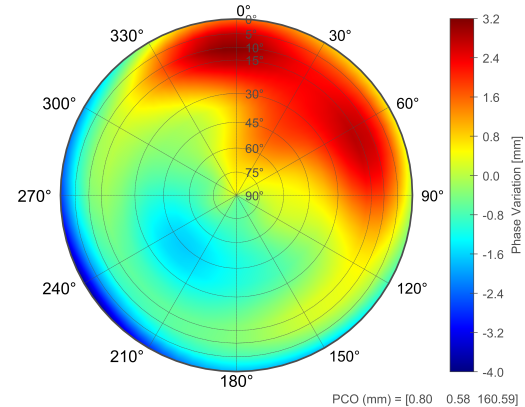
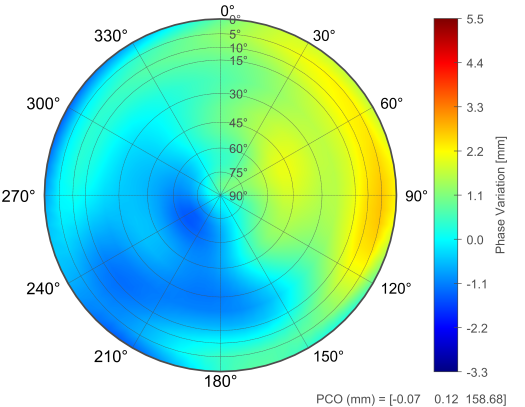



(c) ΔPCC, G01 (IGS-NGS)




(d) ΔPCC, G02 (IGS-NGS)

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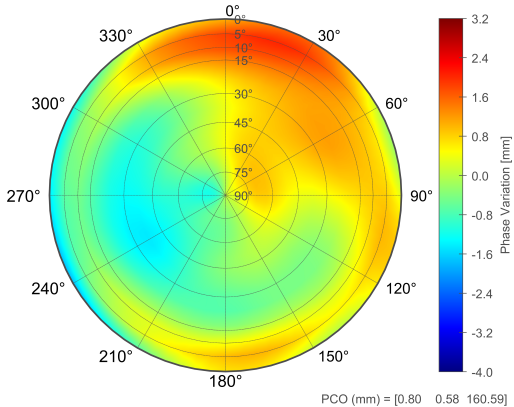
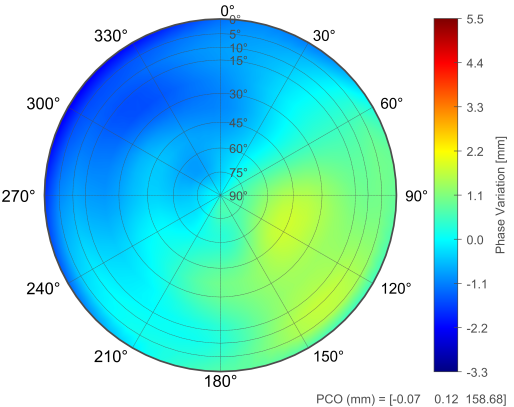



**(e)** ΔPCC, G01 (IGS-TPS)



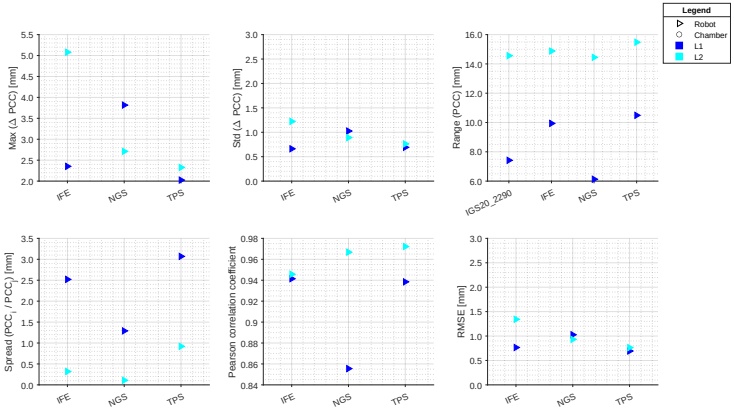

**(f)** ΔPCC, G02 (IGS-TPS)

# Initial results of LEIAR25.R3 NONE (IfE - NGS - TPS)

**Reference: IGS_2290**
(type mean)

**Scalar metrics (Kersten et al., 2022)**

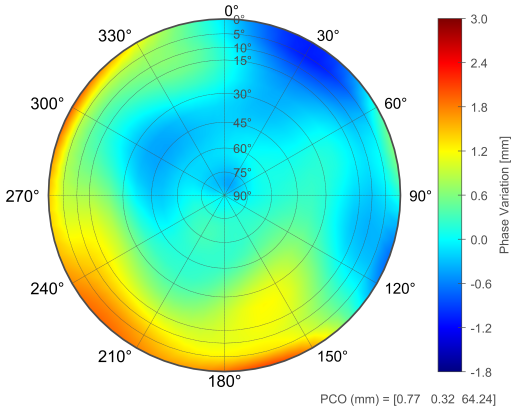
- Max (ΔPCC)
  $max|\Delta PCC|$
- Standard deviation
  $\sigma_{\Delta PCC}$
- Range
  $r_{PCC} = max(PCC) - min(PCC)$
- Spread
  $s_{\Delta PCC} = |(r_{PCC_j} - r_{PCC_i})|$
- Correlation coefficient: overall similarity between two patterns (Pearson correlation coefficient)




Kersten et al. (2022). *Comparison concept and quality metrics for GNSS antenna calibrations*, **J GEODESY 96:48**

# Initial results of TRM57971.00 NONE (IfE - NGS - TPS)

## Reference: IGS_2290

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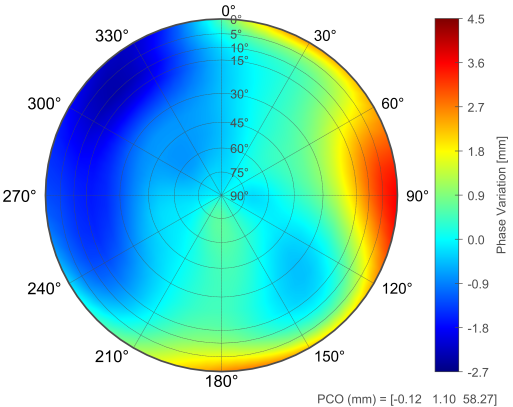


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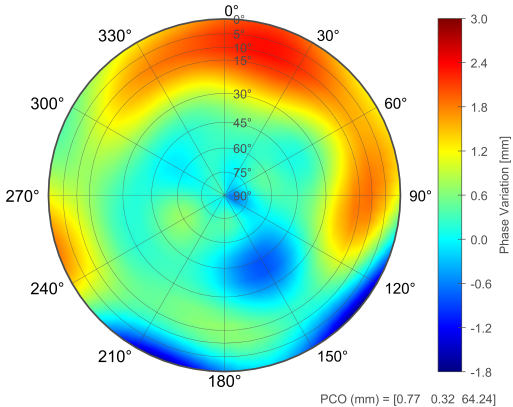


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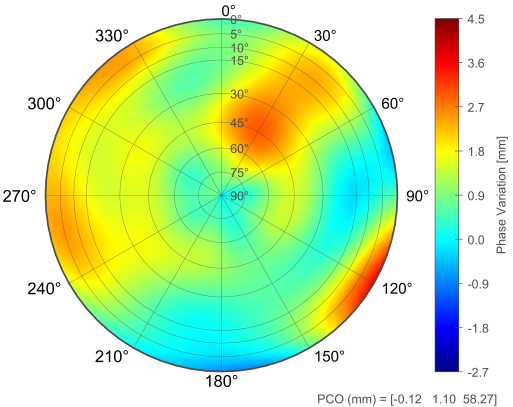


(d) ΔPCC, G02 (IGS-NGS)

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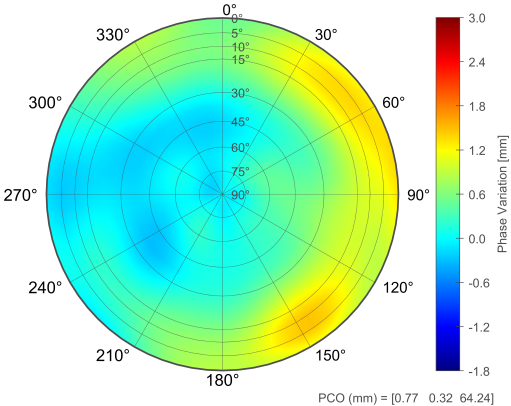


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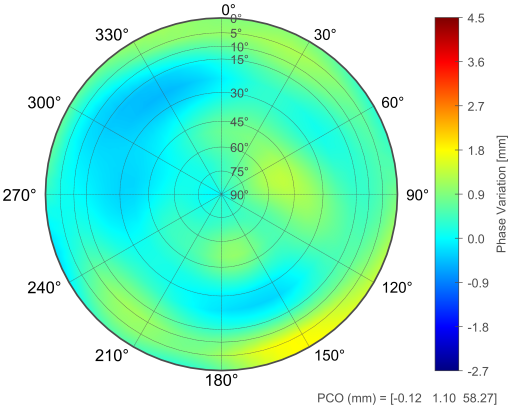


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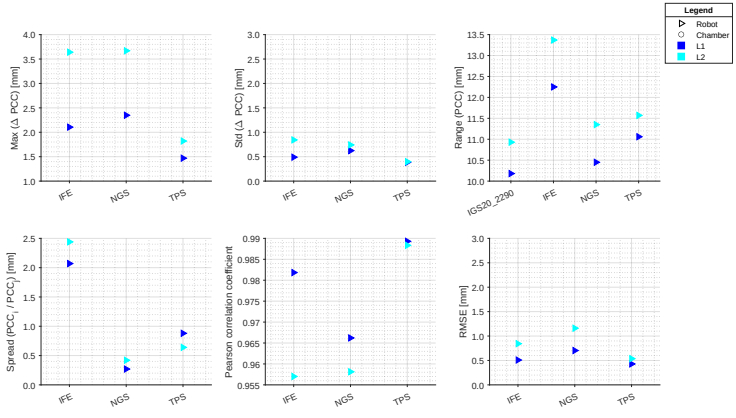


Kersten et al. (2022). *Comparison concept and quality metrics for GNSS antenna calibrations*, **J GEODESY 96:48**

## Summary and future work

### Summary

- Overview on on status of IGS ring calibration for receiver antenna calibrations among nine institutions and six different geodetic antenna designs
- Finalise the campaign by exchange the last antennas (three samples)
- Testing of calibration sets and evaluation among all contributors (here: IfE/NGS/Topcon)

### Future work

- Comparison and impact of PCCs, cf. methods by Kröger et al. (2022) and Kersten et al. (2022)
- Collect results from calibration facilities (ongoing)
- Currently under investigation and available later: Open source toolbox on Gitlab
- Present further results and details of all partners at IGS workshop in summer 2024 Bern

Kröger et al. (2022). *How Do Different Phase Center Correction Values Impact GNSS Reference Frame Stations?*, **REFAG 2022**
Kersten et al. (2022). *Comparison concept and quality metrics for GNSS antenna calibrations*, **J GEODESY 96:48**

**Tobias Kersten, Andria Bilich, Igor Sutyagin & Steffen Schön**
**Institut für Erdmessung**
Schneiderberg 50
D-30167 Hannover, Germany
phone +49-511-762 5711
web http://www.ife.uni-hannover.de
mail kersten@ife.uni-hannover.de

Leibniz University Hannover
Institut für Erdmessung

National Geodetic Survey

TOPCON

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Görres, Barbara, James Campbell, Matthias Becker, and M. Siems (2006). "Absolute calibration of GPS antennas: Laboratory results and comparison with field and robot techniques". In: *GPS Solut* 10.2, pp. 136–145. DOI: 10.1007/s10291-005-0015-3.

Kersten, Tobias, Johannes Kröger, and Steffen Schön (2022). "Comparison concept and quality metrics for GNSS antenna calibrations". In: *Journal of Geodesy* 96.7. DOI: 10.1007/s00190-022-01635-8.

Kröger, Johannes, Tobias Kersten, Yannick Breva, and Steffen Schön (2022). "How Do Different Phase Center Correction Values Impact GNSS Reference Frame Stations?" In: *IAG International Symposium on Reference Frames for Applications in Geosciences (REFAG 2022), October 17-20, Thessaloniki, Greece*.

Menge, Falko, Günter Seeber, Christian Völksen, Gerhard Wübbena, and Martin Schmitz (1998). "Results of the absolute field calibration of GPS antenna PCV". In: *Proceedings of the 11th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GPS 1998), September 15 - 18, Nashville, TN, USA*. Institute of Navigation (ION), pp. 31–38.