Deficiencies of Phase Center Models: assessing the impact on geodetic parameters

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Introduction

Status Quo of Multi-GNSS network processing

- lack of GNSS receiver antenna calibration values for new signals and systems from ROBOT due to development of the space segment (Beidou, Galileo, etc.) and constellation of several GNSS (consistency problems for field approach)
- CHAMBER & ROBOT accepted and used in EPN/IGS network processing (mixture)
- individual antenna patterns of both approaches available [Bruyninx and Legrand, 2017]

Challenge and scope of study

- differences of several millimetres in calibration sets present [Aerts et al., 2013]
- *rule-of-thumb* (<1 mm) between patterns used to estimate impact (justified?)
- uncertainties at the antenna characterisation lead to inconsistencies depending on the data processing scheme [Kersten et al., 2015]
- impact on geodetic estimates evaluated in [Kersten and Schön, 2016] for PPP

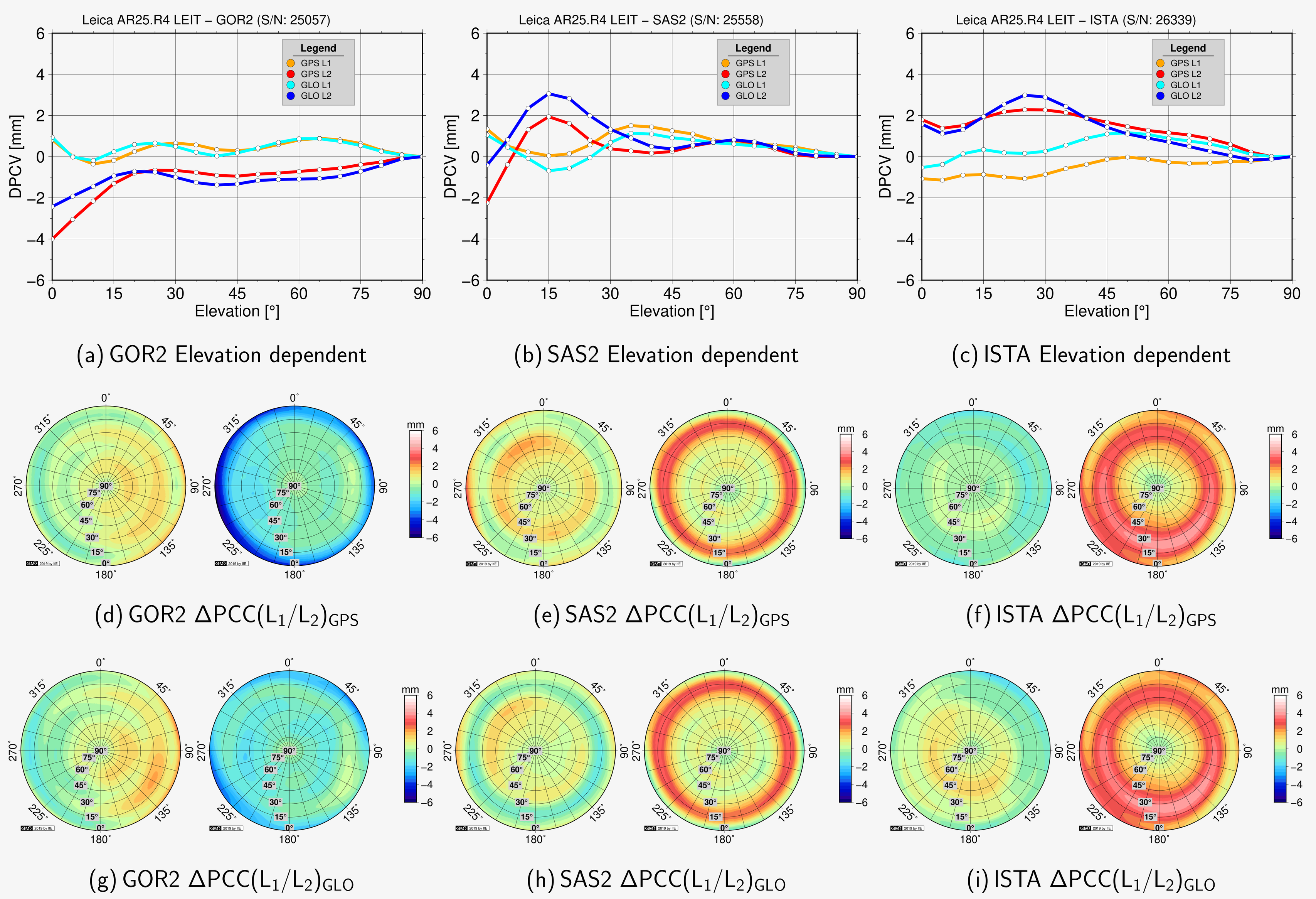
Questions

- Impact on geodetic estimates in network solution (where the errors are mapped into)?

GNSS robot field calibrations

- GPS/GLONASS/Galileo (L1/E1, L2, L5/E5) calibrations for method ROBOT *now available*
- GNSS patterns provided – among others – by Institut für Erdmessung (IfE)
- presentation of IfE solutions provided in EGU contributions #EGU2019-14173 [oral] and #EGU2019-14143 [poster] in EGU session G1.3 (Tuesday, April 9th 2019)

Comparison of Robot (Geo++®) versus Chamber (BONN)



(a) GOR2 Elevation dependent (b) SAS2 Elevation dependent (c) ISTA Elevation dependent

(d) GOR2 $\Delta PCC(L_1/L_2)_{GPS}$ (e) SAS2 $\Delta PCC(L_1/L_2)_{GPS}$ (f) ISTA $\Delta PCC(L_1/L_2)_{GPS}$

(g) GOR2 $\Delta PCC(L_1/L_2)_{GLO}$ (h) SAS2 $\Delta PCC(L_1/L_2)_{GLO}$ (i) ISTA $\Delta PCC(L_1/L_2)_{GLO}$

Figure 1: Differences of GPS and GLONASS patterns obtained by ROBOT (GEO) and CHAMBER (BONN), exemplary shown for high grade geodetic GNSS-antennas of individual EPN stations using the comparison strategy from [Schön and Kersten, 2013], elevation dependent differences (a–c), azimuthal-elevation dependent differences for frequencies of GPS (d–f) and GLONASS (g–i).

Input and findings

- 25/19 [available/operational] antennas have multiple indiv. calibrations (Bonn, Geo++®)
- comparison of antenna patterns show frequency dependent deviations of several millimetres, max. deviations in elevation displayed in Tab. 1 (columns abs(ΔL1/L2))
- azimuthal variations higher than indicated by NOAZI differential patterns (cf. Fig. 1(i))
- differences in up-component of up to 4–6 mm (at L2 frequencies in most cases)
- in most of studied cases: differences at elevations below 20° present (cf. Fig. 1(a-c), Fig. 3)

Evaluation with EPN stations - processing scheme

Research subject

- BKG stations (16) from Germany (cf. Fig. 2) and Turkey (1) with individual ROBOT & CHAMBER patterns (cf. Tab. 1) for DOY006–010, 2019
- LDB2 (Lindenberg, Brandenburg) as reference station (star strategy)
- medium baseline lengths: 200–600 km (LDB2–ISTA: 1670 km)

GNSS data processing

- Bernese 5.2 and consistent CODE products [Dach et al., 2015]
- troposphere: VMF, 1 hour resolution
- ambiguity resolution: QIF and L3/L5/L3 with SIGMA
- separate solutions with ROBOT or CHAMBER patterns
- comparison to set-up ROBOT

Impact on parameters

- position, troposphere, ambiguities

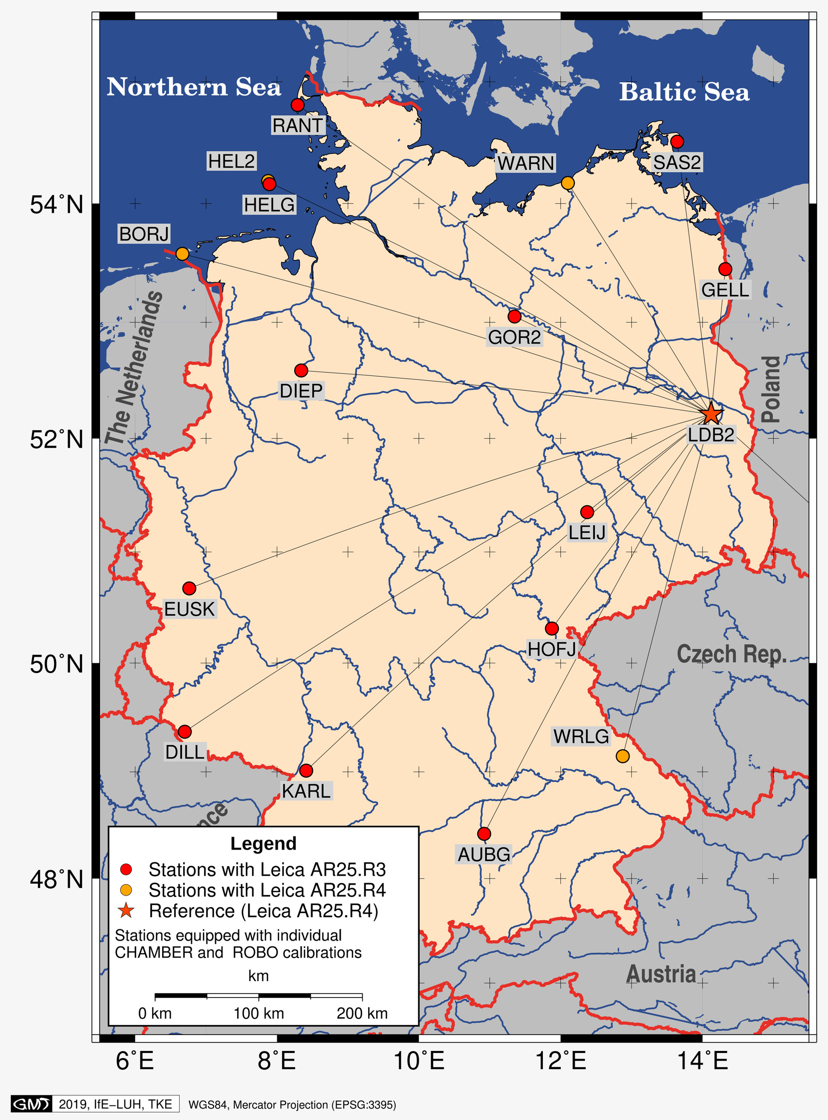
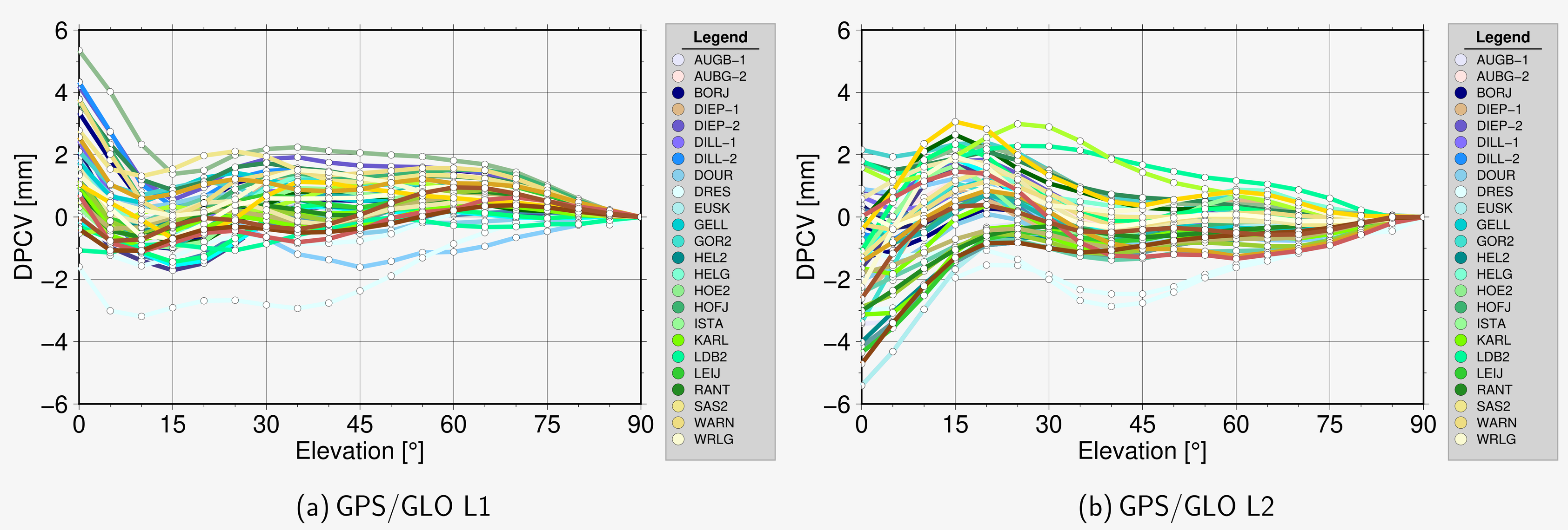


Figure 2: Distribution of EPN stations used in this study

Table 1: Summary of IGS/EPN stations equipped with conical choke ring antenna (LEIAR25, Rev. 3&4, w/o radome LEIT) which provide individual calibration sets for CHAMBER (BONN) and ROBOT (GEO), *BKG:* BKG - Department of Geodesy, *FSW:* BKG Geodetic Observatory Wettzell, *ROB:* Royal Observatory of Belgium.

ID	used	Station	Country	Class	Serial	abs(Δ L1) [mm]	abs(Δ L2) [mm]	Operator	Network
AUBG	y	Augsburg	Germany	B	725552	4.3	1.4	BKG	EPN
BORJ	y	Borkum (Island of Borkum)	Germany	A	726365	3.4	0.7	BKG	EPN, ITRF2014
DIEP	y	Diepholz	Germany	B	725268	4.2	1.8	BKG	EPN
DILL	y	Dillingen	Germany	B	725266	4.3	0.9	BKG	EPN
EUSK	y	Euskirchen	Germany	A	725299	1.7	1.2	FSW	EPN
GOR2	y	Gorleben	Germany	B	1831170	0.8	4.0	BKG	EPN
HEL2	y	Helgoland Island	Germany	B	726209	5.2	2.3	BKG	EPN
HELG	y	Helgoland Island	Germany	A	726342	3.4	0.8	BKG	EPN, ITRF2014
HOFJ	y	Hof	Germany	B	10211018	0.9	3.1	BKG	EPN
ISTA	y	Istanbul	Turkey	B	726339	1.1	1.8	FSW	EPN
KARL	y	Karlsruhe	Germany	A	725092	1.1	4.3	BKG	EPN, ITRF2014
LDB2	y	**Lindenberg**	Germany	B	725072	0.6	3.0	BKG	EPN
LEIJ	y	Leipzig	Germany	B	09390011	2.8	1.3	BKG	EPN, IGS
RANT	y	Rantum / Island Sylt	Germany	B	726365	3.8	1.1	BKG	EPN
SAS2	y	Sassnitz Island of Rugia	Germany	B	725558	1.5	2.3	BKG	EPN
WARN	y	Rostock-Warnemuende	Germany	A	09050002	2.6	1.4	BKG	EPN,IGS,ITRF2014
WRLG	y	Bad Koetzting	Germany	B	10240009	1.1	4.7	FSW	EPN
DOUR	n	Dourbes	Belgium	A	9300021	1.7	2.0	ROB	EPN
GELL	n	Gellin	Germany	B	170027	1.3	3.4	BKG	EPN
DRES	n	Dresden	Germany	A	170015	1.6	3.0	BKG	former EPN
HOE2	n	Hoernum (Island of Sylt)	Germany	A	725267	0.9	1.3	BKG	former EPN



(a) GPS/GLO L1 (b) GPS/GLO L2

Figure 3: Deviations of ROBOT versus CHAMBER antenna patterns for studied EPN station equipment for GPS and GLONASS, frequency L1 (a) and frequency L2 (b).

Discussion of results

- Table 2 shows negligible variations for 6 out of 17 processed stations
- topocentric position deviations up to sub-millimetres
- additional marginal deviations of similar order detected on ZPD/ZTD for stations in Tab 2, for other stations strictly zero
- findings match previous studies of our group, due to correlations of parameters, antenna effects are projected not only to the position domain
- findings strongly rely on GNSS processing strategy

Table 2: Deviations of position for studied antennas and stations in a 24h daily batch mode between DOY006–010, 2019. The table lists only those stations, showing marginal differences between the processing sets using either CHMABER or ROBO antenna calibration patterns.

ID	ΔN [mm]	ΔE [mm]	ΔU [mm]
AUBG	0.01	-0.05	0.10
EUSK	-0.01	-0.01	0.02
KARL	0.05	0.06	-0.25
RANT	-0.10	-0.05	0.02
SAS2	0.67	-0.33	0.78
WARN	0.01	0.00	0.01

Conclusions and challenges

Conclusions - observation domain

- receiver antenna pattern's impact studied for selected stations of EPN network providing individual calibrations sets of both methods
- calibration patterns of ROBOT & CHAMBER in general agreement (cf. Fig. 3), however, deficiencies present above the *1 mm rule-of-thumb*
- deviations of frequency comparison on L1/L2 match in most of the cases >2 mm at elevation ranges <20°,
- outliers below 20° elevation, values of up to 6 mm are present (cf. Fig. 1, Tab. 1) and are mapped mainly into the up-component at those elevations
- deviation of the individual patterns obtained from both methods do agree better than individual patterns in comparison to a type mean

Conclusions - parameter domain

- impact on geodetic parameters for baselines of 200–1670 km identified (coordinates, ambiguities, troposphere), however, magnitudes are negligible

Challenges

- antennas for this study are of the same kind (homogeneous set-up), an inhomogeneous set-up (as typical for EPN/IGS) even more interesting but currently not available

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