INDIVIDUAL CALIBRATION ANTENNA PCC MODELS: DIFFERENCES AND THEIR IMPACT ON TROPOSPHERIC ESTIMATES: LEIAR25 CASE STUDY

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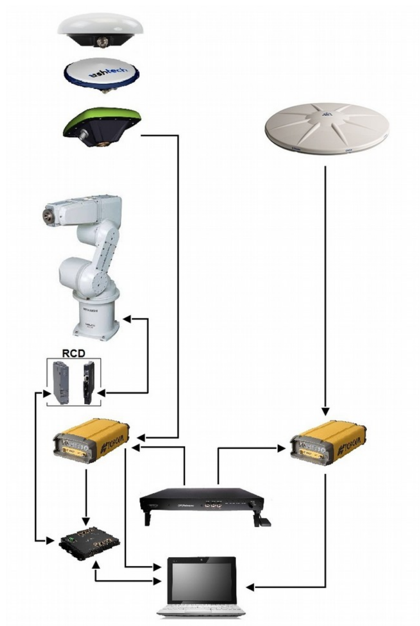
Motivation

- study connected with GRAVEr project focused on the development and implementation of field calibration procedure for multi-frequency and multi-system GNSS antennas
- preparation for antenna calibration for receiving new signals from developed and modernized GNSS constellations
- develop the method of verification and validation of calibration results
- investigate the impact of differences in GNSS antenna calibrations models on the quality of the tropospheric estimate series for climate applications;



Comparison of robot and chamber calibration techniques

Robot calibration (GEO++)

- uses **real satellite signals** in the natural environment, taking into account signal strength and all disturbing effects
- it is usable **only for available signals**;
- **strong multipath** from surrounding objects, so more demanding post-processing needed to mitigate;
- **long duration** of observation
- **variable** environment

Anechoic chamber calibration (UniBonn)

- uses **„artificial” signal** in the form of generated sine wave
- any frequency available to calibrate;
- **weak multipath** effect
- **short duration** of observation
- **stable** environment

Data and Method

- data collected at **19 EPN stations** were processed with **NAPEOS** software;
- PPP and Zero-differenced network solution utilizing **ESA** precise satellite **orbits and clocks** were used;
- The first solution was obtained by applying the **IGS type-mean** Phase Center Correction (PCC) models. In the second and third solutions PCC models from **individual field robot calibration and calibration in anechoic chamber** were used;
- All three solutions were processed several times – using **GPS only**, **GPS+GLONASS**, **GPS+Galileo** and **multi-GNSS** (GPS+GLONASS+Galileo) observations;
- In order to validate and assess the quality of the GNSS solutions, tropospheric estimates obtained from solutions were compared to **ERA-Interim** reanalysis derived ZTDs.

Detailed parameters of solutions.

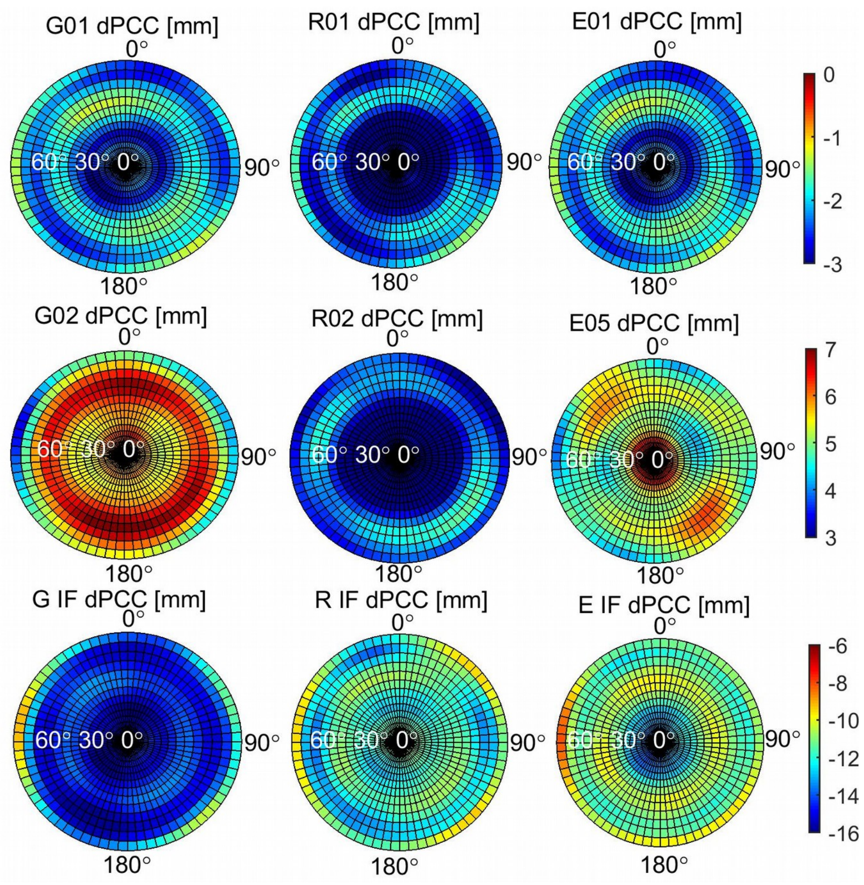
Processing variant	Standard Precise Point Positioning (PPP)	Zero-differenced network solution
Utilized GNSS systems	GPS-only GPS+GLONASS GPS+GLONASS+Galileo	GPS-only GPS+Galileo
Basic observables	Undifferenced carrier phases & pseudoranges;	
Processed time span	1Y 2017	2Y 2017-18
Phase ambiguity fixing	Float ambiguities solution	Fixed ambiguities solution
Orbit & clock products	ESA precise final orbit and clock (30 s) products;	
Ionospheric delay	1st order effect: accounted for dual frequency ionosphere-free linear combination; 2nd order effect: no corrections applied;	
Tropospheric delay	Zenith dry delay computed using the Saastamoinen model with pressure and temperature from the GPT model; the resulting zenith delay is mapped using the dry GMF mapping function; Wet delay estimated using the wet GMF mapping function; Tropospheric estimates computed with 1h interval	
Ocean loadings	Computed for FES2004 model using ONSALA ocean loading service;	
Tidal displacement	In accordance with IERS2010 (Petit and Luzum 2010);	
Satellite clock correction	2nd order relativistic correction for non-zero orbit ellipticity (-2*R*V / c) applied;	
Observation weighting	Carrier phase: 10 mm sigma (for zenith); Pseudorange: 1 m sigma (for zenith); Sigmas increase with increasing zenith angle using the function (1 / cos(z));	
Others	Observation sampling rate: 5 minutes Elevation angle cut-off 5° Antenna PCC models: IGS14 type-mean calibration, individual robot calibration, individual chamber calibration	

Hardware characteristics of the test stations

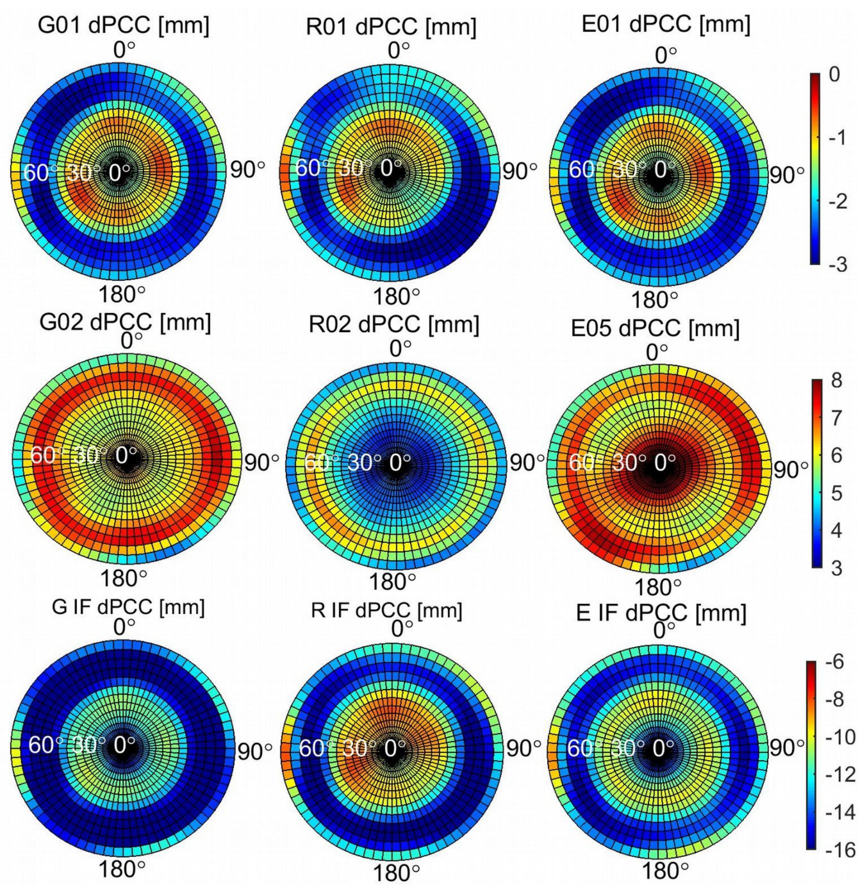
No.	Station	Network	Station hardware	
			Antenna type	Receiver type
1	AUBG	EPN	LEIAR25.R4 LEIT	LEICA GR25
2	BORJ	EPN	LEIAR25.R3 LEIT	JAVAD TRE_3 DELTA
3	DIEP	EPN	LEIAR25.R4 LEIT	LEICA GR25
4	DILL	EPN	LEIAR25.R4 LEIT	LEICA GR25
5	DOUR	EPN	LEIAR25.R3 NONE	SEPT POLARX4
6	EUSK	EPN	LEIAR25.R4 LEIT	LEICA GR25
7	GELL	EPN	LEIAR25.R4 LEIT / LEIAR25.R3 LEIT	LEICA GR25
8	GOR2	EPN	LEIAR25.R4 LEIT	LEICA GR25
9	HEL2	EPN	LEIAR25.R3 LEIT	LEICA GR25
10	HELG	EPN	LEIAR25.R4 LEIT	JAVAD TRE_G3TH DELTA
11	HOFJ	EPN	LEIAR25.R4 LEIT	LEICA GR25
12	ISTA	EPN	LEIAR25.R4 LEIT	LEICA GR25
13	KARL	EPN	LEIAR25.R4 LEIT	JAVAD TRE_3 DELTA
14	LDB2	EPN	LEIAR25.R4 LEIT	LEICA GR25
15	LEIJ	EPN	LEIAR25.R3 LEIT	JAVAD TRE_G3TH DELTA
16	RANT	EPN	LEIAR25.R4 LEIT	JAVAD TRE_G3TH DELTA
17	SAS2	EPN	LEIAR25.R4 LEIT	JAVAD TRE_G3TH DELTA
18	WARN	EPN	LEIAR25.R3 LEIT	JAVAD TRE_G3TH DELTA
19	WRLG	EPN	LEIAR25.R3 LEIT	LEICA GR25

Azimuth and elevation dependent PCC differences obtained by comparison of chamber and

DOUR LEIAR25.R3 NONE



HELG LEIAR25.R4 LEIT



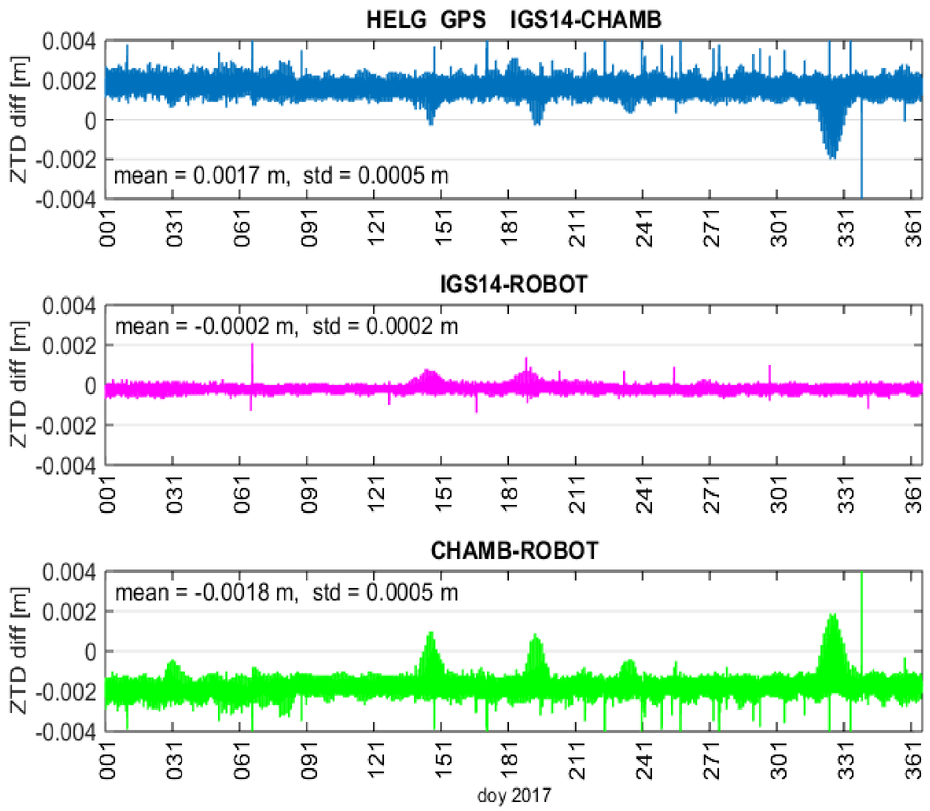
dPCC within the same azimuth:

- L1: max 4 mm
- L2: max 10 mm
- IF: max 20 mm

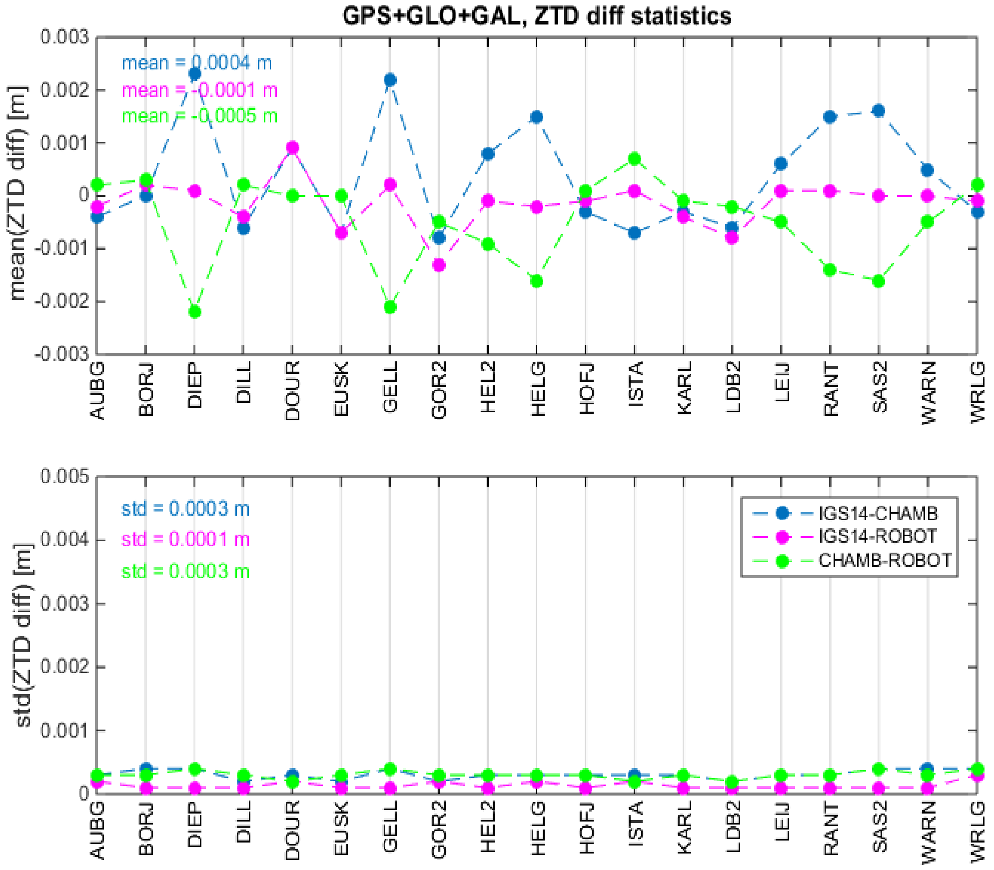
dPCC within the same zenith angle:

- L1: max 3 mm
- L2: max 3 mm
- IF: max 5 mm

Standard PPP solution:



Time series of ZTD differences for station HELG; GPS-only processing.



Mean and standard deviation of ZTD differences between variants for GPS+GLO+GAL processing for 19 stations over 1 year of data.

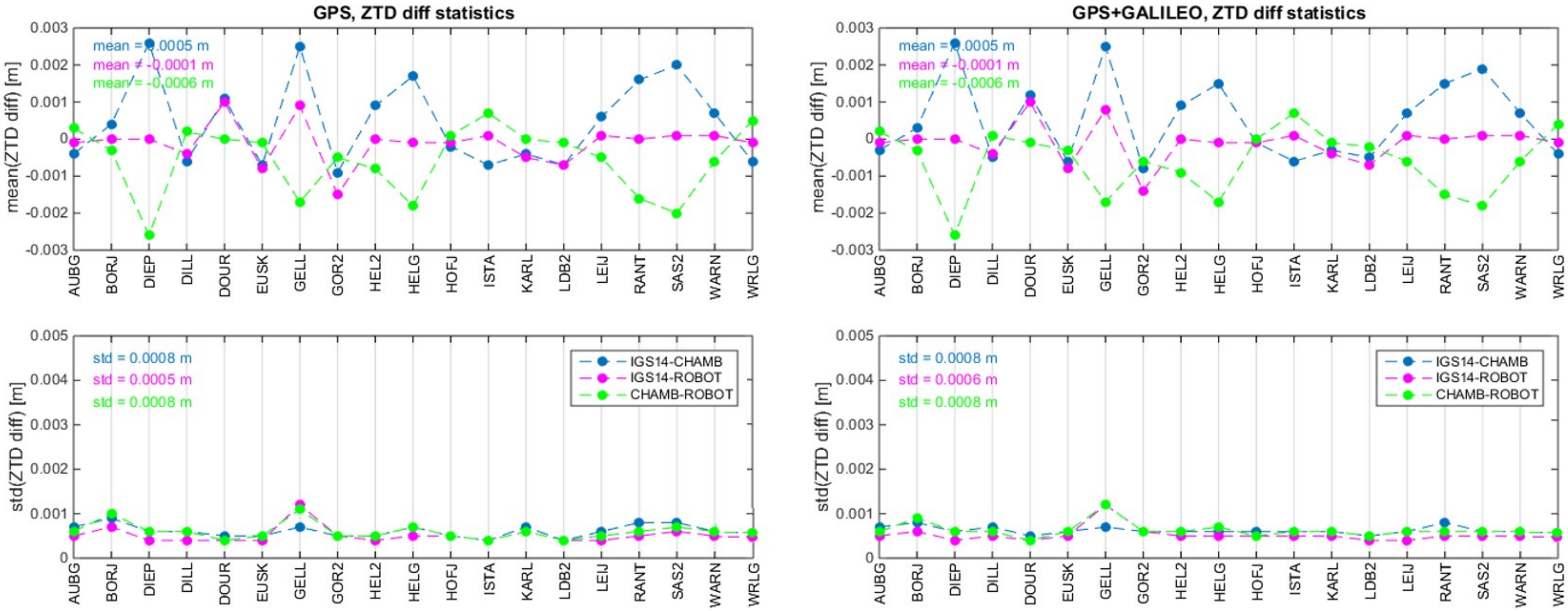
Statistics of ZTD differences for 3 selected stations. Differences between antenna calibration variants for GPS-only, GPS+GLONASS and GPS+GLONASS+Galileo processing

Data/System		GPS			[GPS+GLO]			[GPS+GLO+GAL]	
Calibration model	IGS14-CHAMB	IGS14-ROBOT	CHAMB-ROBOT	IGS14-CHAMB	IGS14-ROBOT	CHAMB-ROBOT	IGS14-CHAMB	IGS14-ROBOT	CHAMB-ROBOT
		DILL			DILL			DILL	
mean(ZTD diff) [m]	-0.0005	-0.0003	0.0002	-0.0007	-0.0004	0.0003	-0.0006	-0.0004	0.0002
std(ZTD diff) [m]	0.0002	0.0001	0.0003	0.0002	0.0003	0.0004	0.0002	0.0001	0.0003
		HELG			HELG			HELG	
mean(ZTD diff) [m]	0.0017	-0.0002	-0.0018	0.0015	-0.0002	-0.0017	0.0015	-0.0002	-0.0016
std(ZTD diff) [m]	0.0005	0.0002	0.0005	0.0005	0.0002	0.0005	0.0003	0.0002	0.0003
		KARL			KARL			KARL	
mean(ZTD diff) [m]	-0.0004	-0.0004	-0.0001	-0.0004	-0.0004	0.0000	-0.0003	-0.0004	-0.0001
std(ZTD diff) [m]	0.0003	0.0001	0.0003	0.0003	0.0001	0.0003	0.0003	0.0001	0.0003

Statistics of ZTD differences for 3 selected stations. Differences between data variants

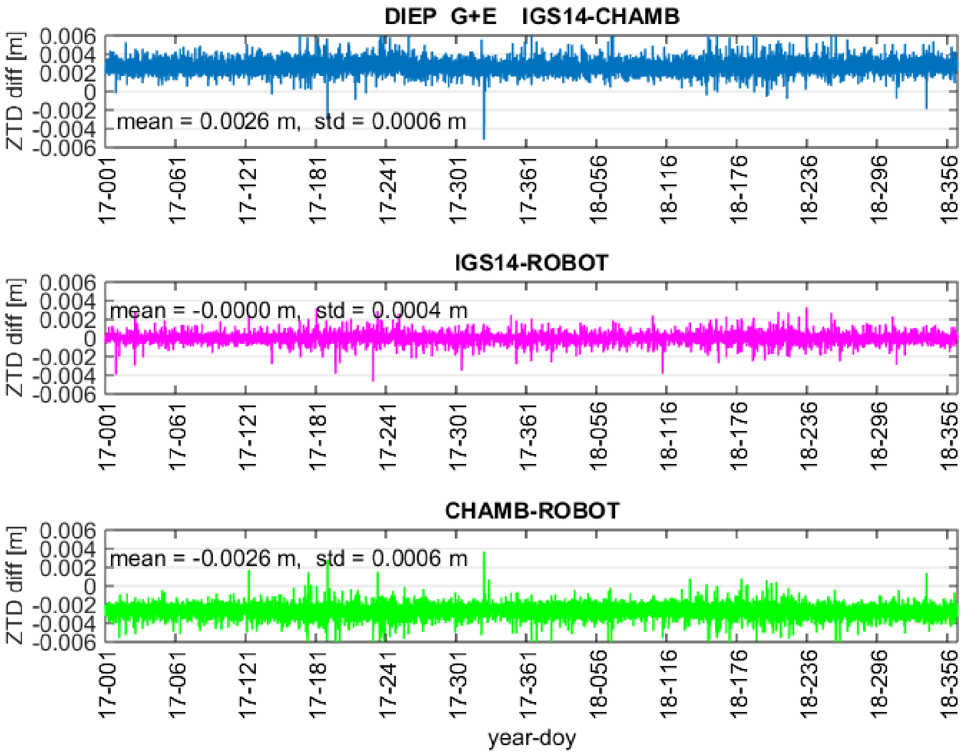
Calibration model	IGS14	CHAMB	ROBOT
Data/System			
		DILL	
mean(ZTD diff) [m]	-0.0007	-0.0008	-0.0007
std(ZTD diff) [m]	0.0020	0.0021	0.0019
		HELG	
mean(ZTD diff) [m]	0.0000	-0.0002	-0.0001
std(ZTD diff) [m]	0.0130	0.0133	0.0130
		KARL	
mean(ZTD diff) [m]	0.0000	-0.0001	0.0000
std(ZTD diff) [m]	0.0014	0.0014	0.0014

Zero-differenced network solution (2017-2018):

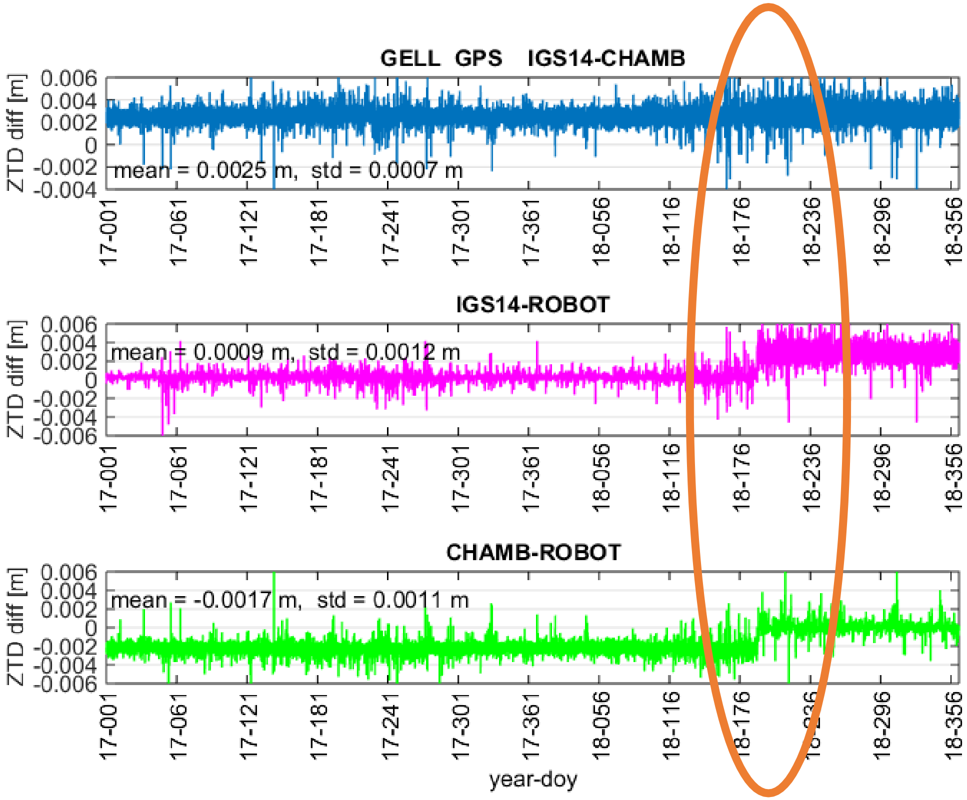


Mean and standard deviation of ZTD differences between variants for GPS only processing (left) and GPS+Galileo processing (right) over 2 years of data.

Zero-differenced network solution (2017-2018):

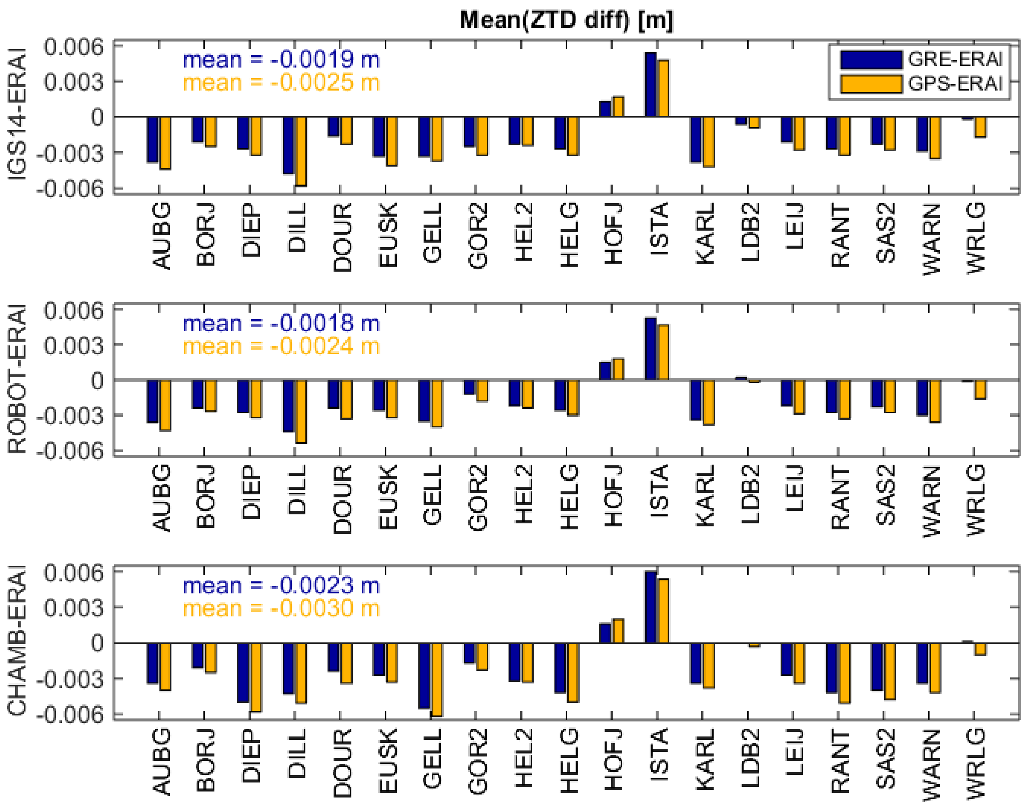


Time series of ZTD differences for station DIEP, GPS+Galileo processing.



Time series of ZTD differences for station GELL, GPS processing.

Mean ZTD differences between PPP [GPS+GLO+GAL] solution and ERA-Interim (navy blue) as well as ZD network solution (GPS-only) and ERA-Interim (orange), for 2017.



Summary and conclusions

- Overall, the mean standard deviation of **ZTD differences is higher for differences between variants using observations from different satellite systems** than for variants using different antenna calibration models. However, the impact of applying individual calibrations is not negligible. The results depend on the equipment (receiver and antenna) of the stations;

- Validation against data from climate reanalysis confirms that **all approaches provide high-quality tropospheric delays**;

- The mean bias between ZTD from GNSS processing and ERA-Interim depends on the processing options (antenna model calibration) and varies from -6.2 mm to -0.2 mm, except two stations: ISTA and HOFJ with the bias 5.6 mm and 1.8 mm respectively. Negative mean ZTD bias for almost all comparisons suggests that ZTDs achieved from the ERA Interim reanalysis are drier than those obtained from GNSS reprocessing. For stations ISTA and HOFJ the reason of positive mean ZTD bias between GNSS and ERA-Interim needs further investigation.

- Based on the mean ZTD differences, it can be concluded that **[GPS+GLO+GAL] processing variant is closer to ERA-Interim than GPS only processing variant**. At the same time, ZTD estimates obtained from variants using **ROBOT and IGS14 calibration are also slightly closer to estimated from ERA-Interim** than estimates from variant with calibration in anechoic chamber.

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