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Potential for a GNSS-based Determination of the Terrestrial Scale

A. Villiger[1], F. Dilssner[2], P. Rebischung[3], R. Dach[1], F. Zimmermann[4], H. Kuhlmann[4], A. Jäggi[1]

[1] Astronomical Institute of the University of Bern, Bern, Switzerland
[2] European Space Operations Centre (ESOC), Germany
[3] Institut National de l'Information Géographique et Forestière, Laboratoire LAREG, France
[4] Institut für Geodäsie und Geoinformation, Universität Bonn

Contact: arturo.villiger@aiub.unibe.ch

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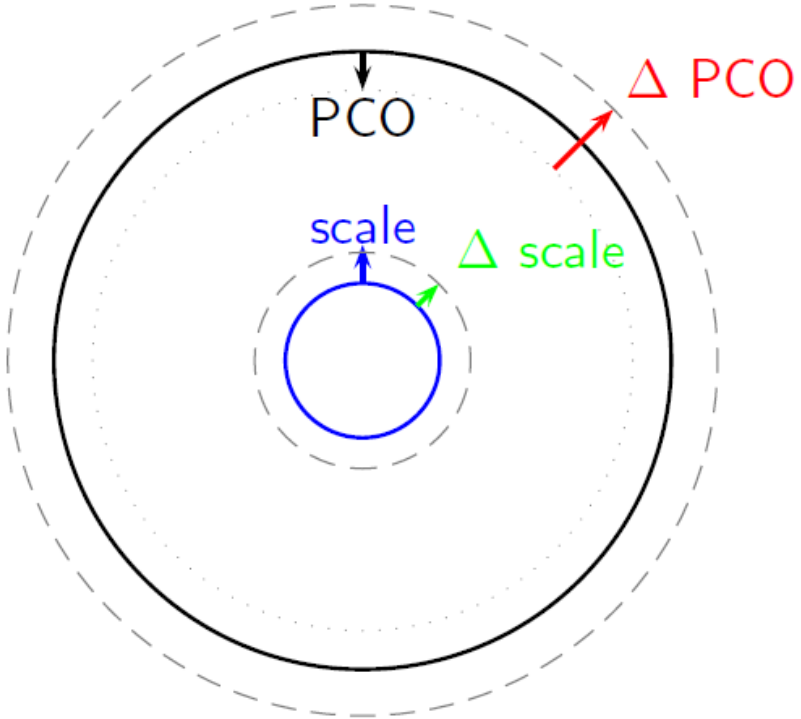
AIUB CODE

Scale determination

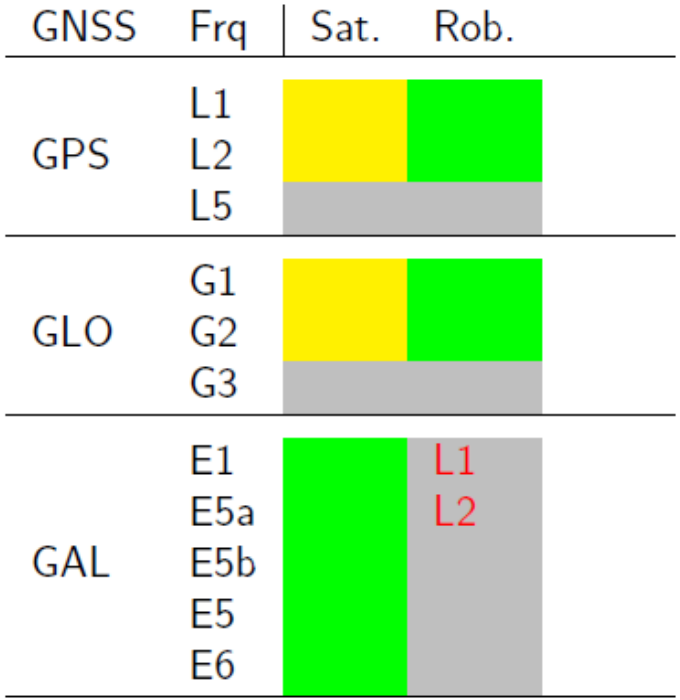
Why do we need calibrated antennas?

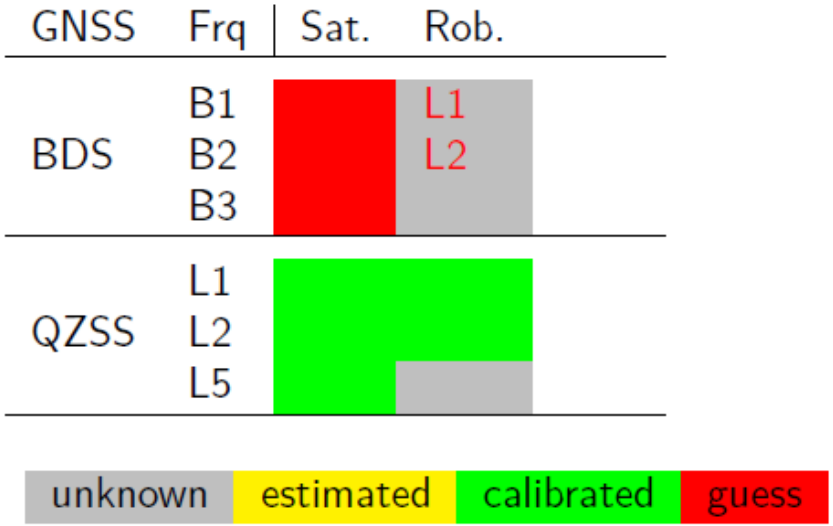


- PCO to Scale:
  [Zhu et al. 2002]
  1m ≙ -7.8 ppb
  1 ppb ≙ -0.13 m
- PCO's: -4 m Δ PCO
- Stations: 20 cm offset

Current status of antenna calibrations

Overview IGS14

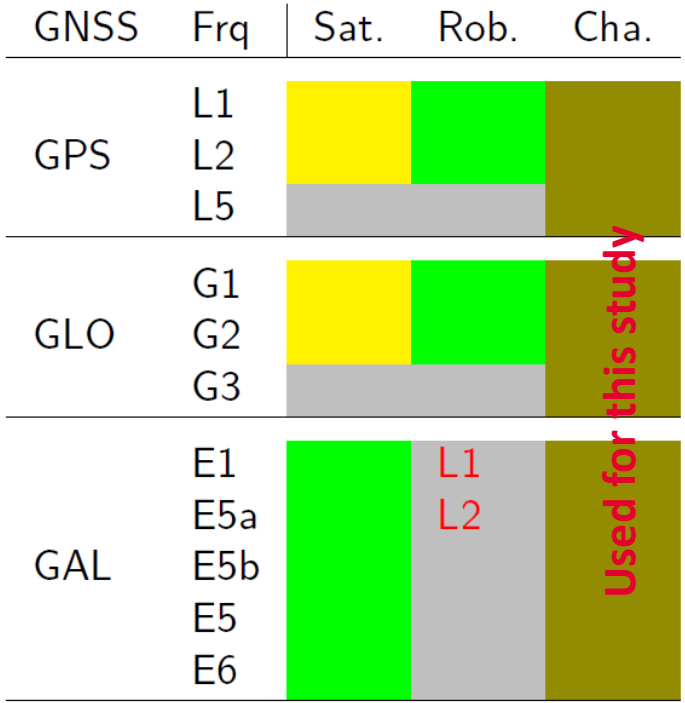


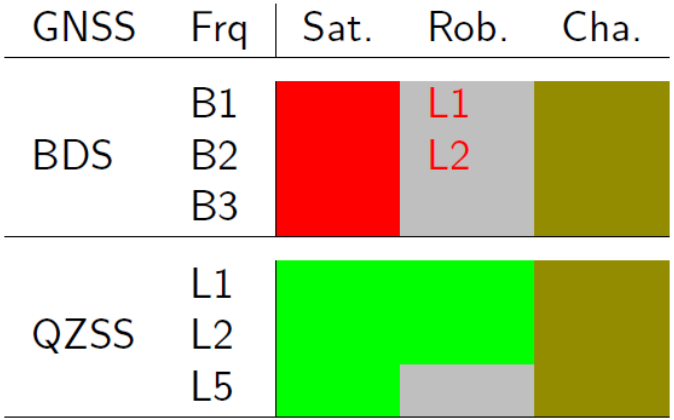


Rob. : roboter calibrations

Current status of antenna calibrations

Overview chamber calibrations





Rob. : roboter receiver antenna calibrations
Cha. : chamber receiver antenna calibrations

Reprocessing 3: will include multi-GNSS calibrations from roboter calibrations

Motivation

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- In June 2019 GSA released the chamber calibrated PV and PCO for the last 8 Galileo FOC satellites

  → full constellation with calibrated PV and PCOs available!

- Galileo shall be included into IGS reprocessing effort for the next ITRF solution:
  - What about the receiver antenna calibrations?
  - Are the estimated PCO for GPS and GLONASS compatible with the Galileo PCOs?
  - If not, how can we address this issue?

  → Can we use Galileo to define a GNSS scale?

Dedicated test campaings

Overview

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- For the IGS AC Workshop 2019 dedicated test solutions were created to address those issues
- Based on:
  - **Chamber calibrated receiver antennas**
  - The final reprocessing will be based mainly on robot calibration provided by Geo++ and extended by chamber calibrations (they were not available at the time of the test solution)
- **Test solutions:**
  - **COD: 2017 / 2018 (GE, G, E)**
  - **ESA: 2017 / 2018 (GE, G, E)**

Chamber calibrated receiver antennas

TRF scale contribution from GNSS?

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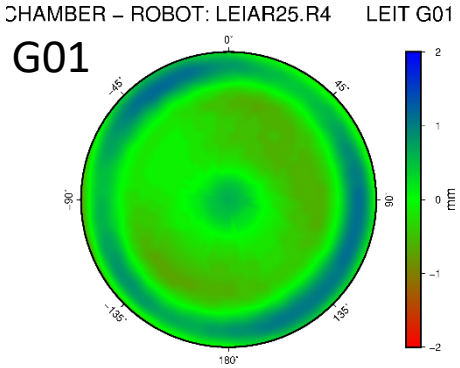
- Creation of type-mean antenna pattern from chamber calibrations (more than 250 individual calibrations)→ 37 type-mean calibrations (covering ~49% of the IGS network)
- Differences between robot and chamber calibrations?
- Comparison of satellite PCO and scale determination using robot or chamber calibrated ground antennas

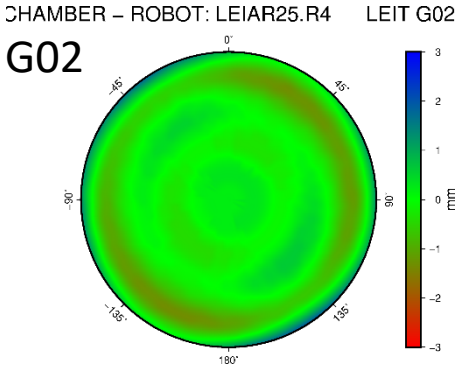
Case study:

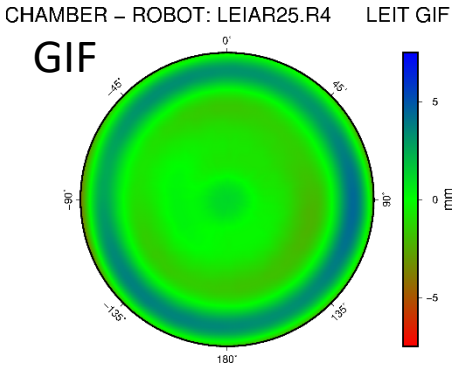
- Study on the scale determination using data from 2017-2018
- GPS/Galileo solution (COD / ESA)

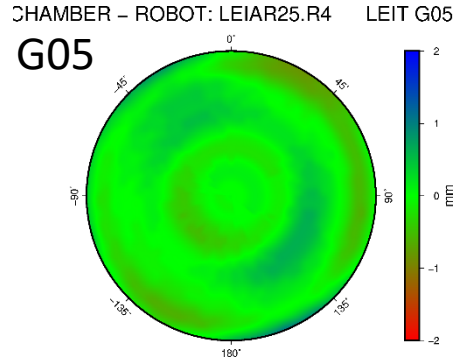
Chamber vs. robot calibrations

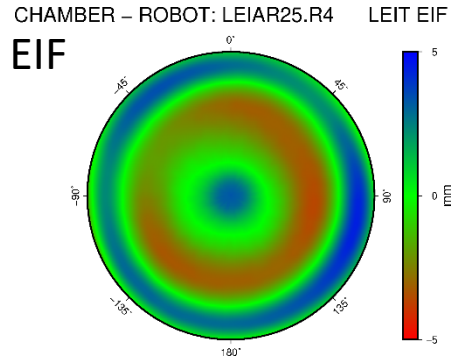
Comparison: GPS PV: BONN – Geo++











PCO IF	IGS14	Geo++	BONN
GPS	150.96	150.07	150.77
GAL	152.05	146.47	148.31

Comparison receiver antenna PCOs

IF Galileo - GPS (PCO up [mm])

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		ETH Zürich[1]	IGS14 (L1/L2)	BONN
JAV_GRANT-G37	NONE	6.7	-1.3	
JAV_RINGANT_G3T	NONE	-10.6	+1.2	-7.6
SEPCHOKE_B3E6	SPKE	-8.0	+4.7	
TRM57971.00	NONE	-2.94	-1.7	-5.2
		Geo++	**IGS14 (L1/L2)**	**BONN**
LEIAR25.R4	LEIT	-3.6	1.09	-2.45

[1] [Willi et al. 2019, open access, https://doi.org/10.3929/ethz-b-000332282]

Consistency of antenna calibrations

Based on ESA solutions

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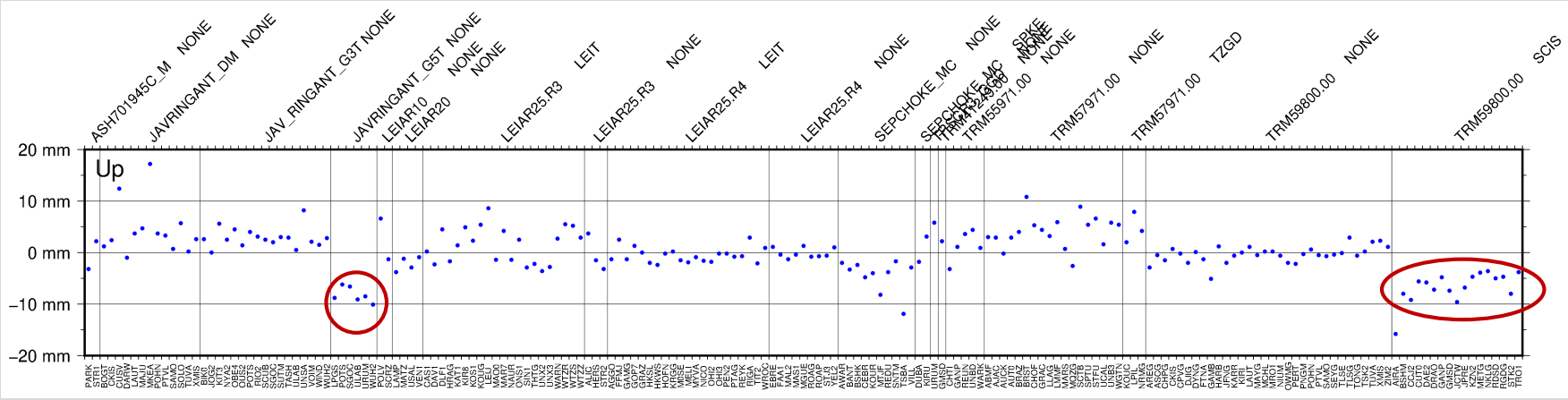
Systematic errors between GPS and Galielo (E1/E5a) only solutions:

- Systematic differences for some receivers
- Robot calibrations have to be tested and, if needed, to be adjusted!



NB: The solutions were differenced after having brought them to a common origin, orientation and scale.
Station position differences are thus shown up to an unknown global translation, rotation and scale factor.

Scale study CODE (2017-2018)

PCO (system-wise, Z-component)

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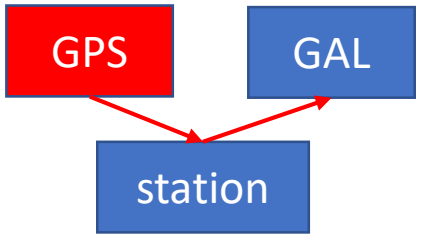

	Robot calibrations [cm]		Chamber calibrations [cm]	
	GPS	Galileo	GPS	Galileo
GPS PCO fixed	-	-0.2 ± 1.8	-	+24.7 ± 1.3

Scale study (2017-2018)

PCO (system-wise, Z-component)

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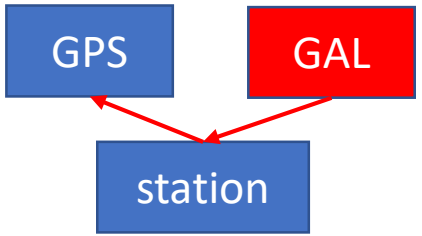
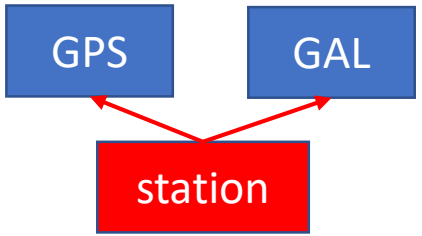


	Robot Calibration [cm]		Chamber Calibration [cm]	
	GPS	Galileo	GPS	Galileo
GPS PDO fixed	-	-0.2 ± 1.8	-	+24.7 ± 1.3
Gal PCO fixed	-0.6 ± 2.5	-	-22.0 ± 2.1	-

Scale study (2017-2018)

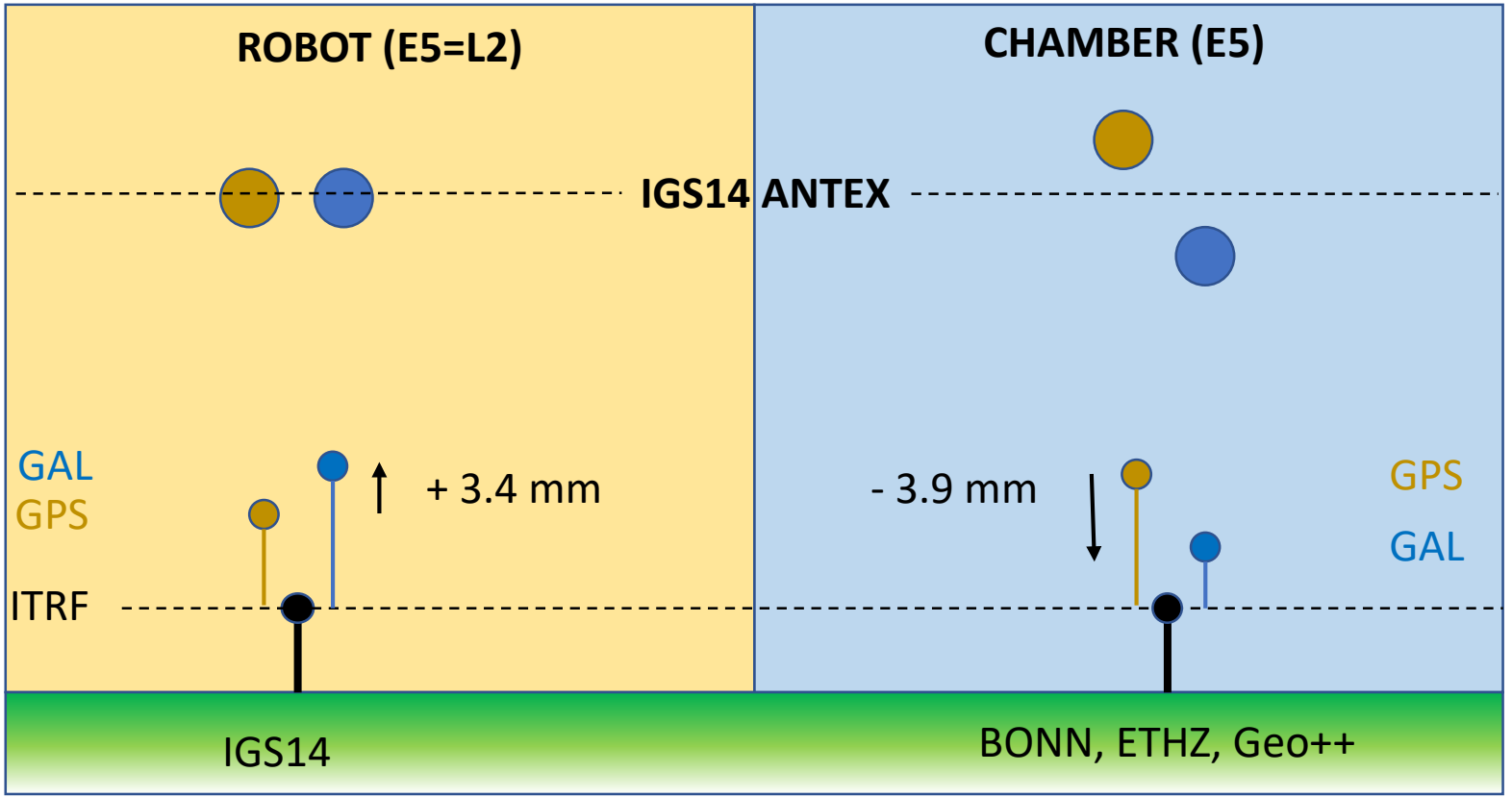
PCO (system-wise, Z-component)



	Robot Calibration [cm]		Chamber Calibration [cm]	
	GPS	Galileo	GPS	Galileo
GPS PCO fixed	-	-0.2 ± 1.8	-	+24.7 ± 1.3
Gal PCO fixed	-0.6 ± 2.5	-	-22.0 ± 2.1	-
ITRF 2014 fixed	+1.4 ± 3.6	+1.9 ± 4.7	-10.9 ± 3.4	+12.7 ± 4.6

Scale study (2017-2018)

Impact of IF-PCO values



Scale study (2017-2018)

Scale w.r.t ITRF 2014 – GAL/GPS fixed

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Solution	IGS14 ANTEX	Chamber
GPS PCO fixed	**2.58 mm**	-3.00 mm
GALILEO PCO fixed	2.09 mm	**7.27 mm**
Difference GAL-GPS	**+0.49 mm**	**+10.27 mm**
	VLBI	**SLR**
ITRF 2014[1]	+4.4 mm	-4.4 mm

1 ppb $\cong 6.4\ mm$

→ **Chamber calibrations: scale of +4.7 mm (+7.3 with a priori value 0)**

[1] [Altamimi et al. 2016, J. Geophys. Res.]

SINEX combination

ESA / COD (2017 & 2018)

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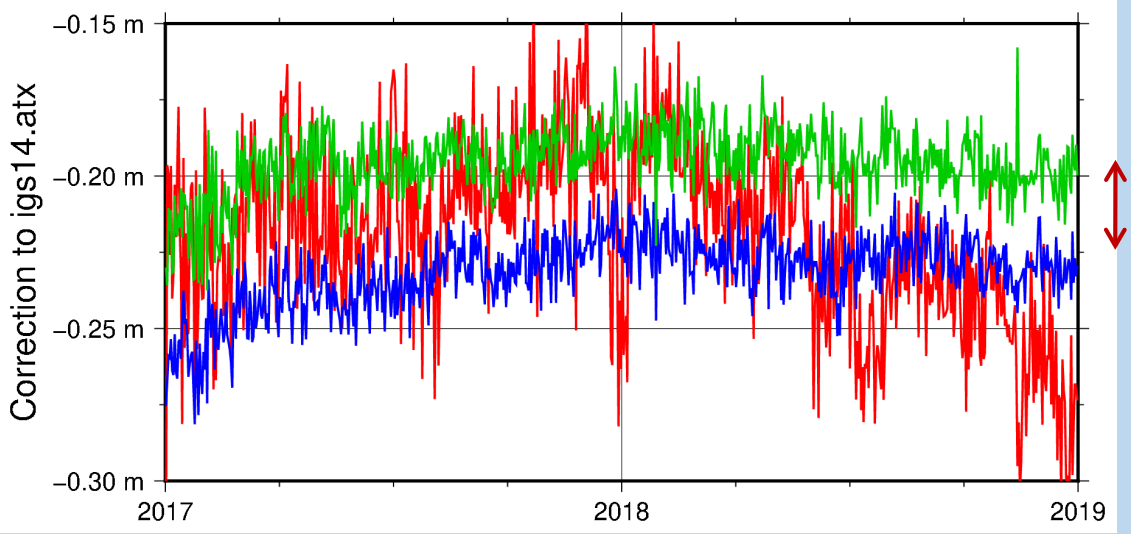
Fix Galileo satellite z-PCOs; solve for an average correction to igs14.atx GPS satellite z-PCOs



≈ 3.6 cm ↔ 0.28 ppb / 1.8 mm in terresrial scale

- ESA GE5c solutions
- ESA GE7c solutions
- CODE GE5c solutions

Consistency of antenna calibrations

Based on ESA solution

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Systematic errors between GPS and Galielo (E1/E5a) only solutions:

- Systematic differences for some receivers
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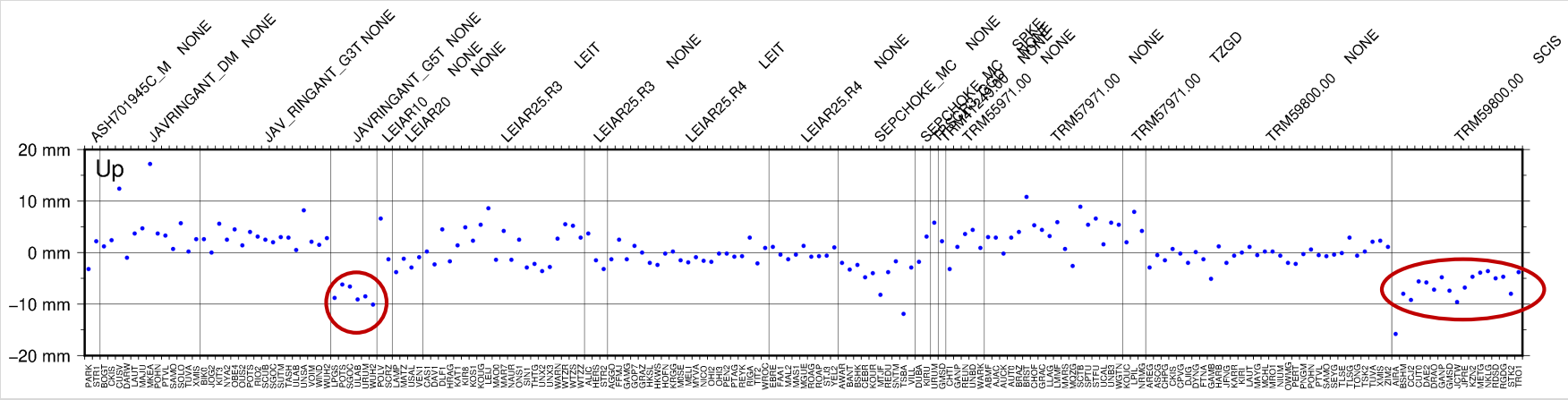

NB: The solutions were differenced after having brought them to a common origin, orientation and scale.
Station position differences are thus shown up to an unknown global translation, rotation and scale factor.

Outcome / outlook

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Calibrations:

- Reprocessing will be based mainly on robot calibrations
- Including E1/E5 calibrations
- Chamber calibrations for Galileo

Satellite PCO

- GPS/GLO PCO (z-component) rescaled to Galileo
- Based on SINEX combination from various AC contributions

Receiver PCO

- Comparison of GPS and Galileo only solutions
- Adjustment of PCO (z-component) if needed for Galileo