

# Possible contribution of GNSS to the definition of the ITRF2020 scale based on the Galileo satellite PCOs

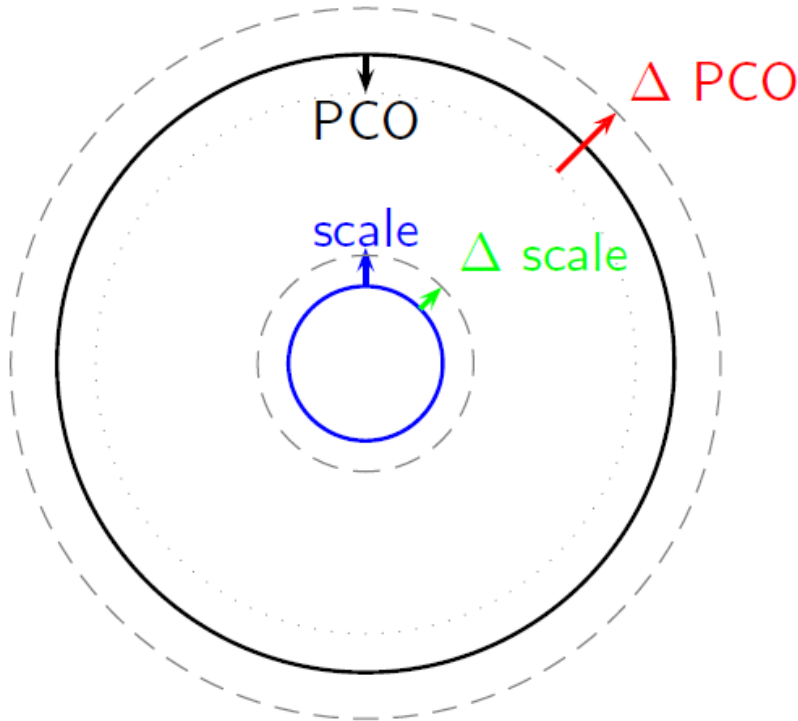
## Part 1

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2. October 2019, Paris

# Relation PCO and scale determination

Why do we need calibrated antennas?



- PCO to Scale:  
*[Zhu et al. 2002]*  
1m  $\hat{=}$  -7.8 ppb  
1 ppb  $\hat{=}$  -0.13 m
- PCO's: -4 m  $\Delta$  PCO
- Stations: 20 cm offset

# Antenna calibrations

## Situation IGS14.atx

GNSS	Frq	Sat.	Rob.
GPS	L1	estimated	calibrated
	L2		
	L5	unknown	
GLO	G1	estimated	calibrated
	G2		
	G3	unknown	
GAL	E1	calibrated	L1
	E5a		L2
	E5b		
	E5		
	E6		

GNSS	Frq	Sat.	Rob.
BDS	B1	unknown	L1
	B2		L2
	B3		
QZSS	L1	calibrated	
	L2		
	L5		unknown

unknown    estimated    calibrated    approx.

Rob. : roboter receiver antenna calibrations

# Satellite calibrations

## Galileo antenna pattern

- Disclosed by GSA for all Galileo satellites (IOV and FOC)
- Last eight satellites were disclosed in time for the repro 03
- Disclosed for QZSS (regional, not part of the repro)

Satellite	Estimated	Calibrations.	Differences
E101 (IOV)	95	83.7	11.3
E102 (IOV)	95	92.4	2.6
E103 (IOV)	95	82.4	12.6
E201 (FOC)	105	90.7	14.3
E202 (FOC)	105	86.4	18.6
E203 (FOC)	110	92.6	17.4
E204 (FOC)	110	75.3	34.7
Average	-	-	15.9

- Before release of the pattern Galileo relied as GPS and GLO on estimations [Steigenberger et al., 2016]
- Chamber calibrated PCOs differ by 15 cm from the estimates
- **Scale issue between GAL and GPS/GLO!**

# Antenna calibrations

## ANTEX for reprocessing 03?

GNSS	Frq	Sat.	Rob.	Cha.
GPS	L1	estimated	calibrated	unknown
	L2	estimated	calibrated	unknown
	L5	unknown	calibrated	unknown
GLO	G1	estimated	calibrated	unknown
	G2	estimated	calibrated	unknown
	G3	unknown	calibrated	unknown
GAL	E1	calibrated	L1	unknown
	E5a	calibrated	L2	unknown
	E5b	calibrated		unknown
	E5	calibrated		unknown
	E6	calibrated		unknown

GNSS	Frq	Sat.	Rob.	Cha.
BDS	B1	approx.	L1	unknown
	B2	approx.	L2	unknown
	B3	approx.		unknown
QZSS	L1	calibrated		unknown
	L2	calibrated		unknown
	L5	calibrated		unknown

unknown    estimated    calibrated    approx.

Rob. : roboter receiver antenna calibrations

Cha. : chamber receiver antenna calibrations

In 2018 an IGS call was made asking for chamber calibrations

- Calibrations from 8 institution (chamber calibrations from Bonn)
- University of Bonn participated contributing more than 250 individual calibrations
- First test campaign could be made showing the potential of using Galileo for the scale determination

IGS AC Analysis Workshop 2019:

- Test using robot calibrations were presented
- Geo++ presented first multi-GNSS calibrations (robot) and delivered shortly after a set of > 35 antenna / radom calibrations

# Receiver antenna calibrations

	Geo++ (robot)	BONN (chamber)
Individual	-	~250
Type-mean	37	35

- Which one shall be used?

- *IGS chose to use robot calibrations and extend it by chamber calibrations (>5 individual calibrations) at the IGS AC Workshop in Potsdam, 2019*

# Consistency of the multi-GNSS calibrations

## Average of station specific biases (2017-18)

ISTP: Inter-system translation bias: vector between GPS and another

GTRP: troposphere bias between GPS and another GNSS

GNSS	Sol.	IGS14	Galileo Scale		
		ISTP	ISTP	ISTP	GTRP
GLONASS	ROB	-1.22	-0.88	0.80	-0.4
	CHA	-3.58	-0.73	1.29	-0.5
GALILEO	ROB	6.31	0.58	0.43	0.11
	CHA	7.40	1.08	0.21	0.44

nadir dependent consistency

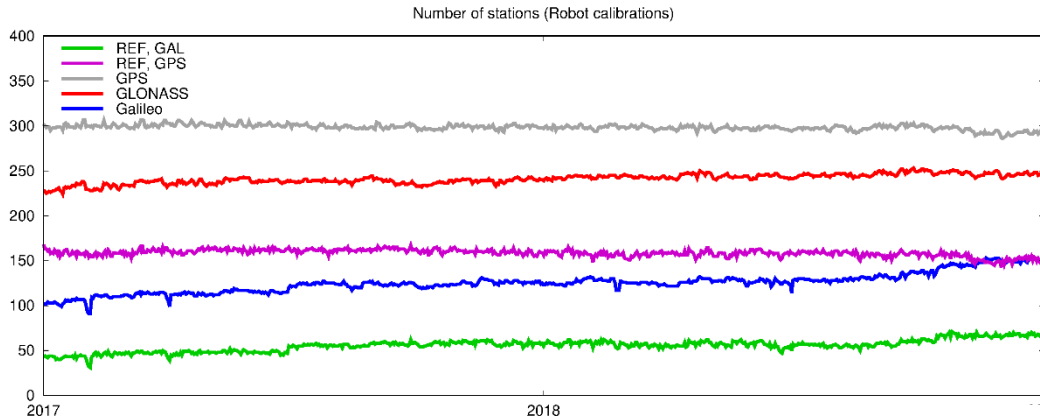
→ Robot calibration consistent to ITRF 2014

→ When adjusting scale to either robot or chamber calibrations the consistency is below 1.5mm for GLONASS and Galileo → **good**



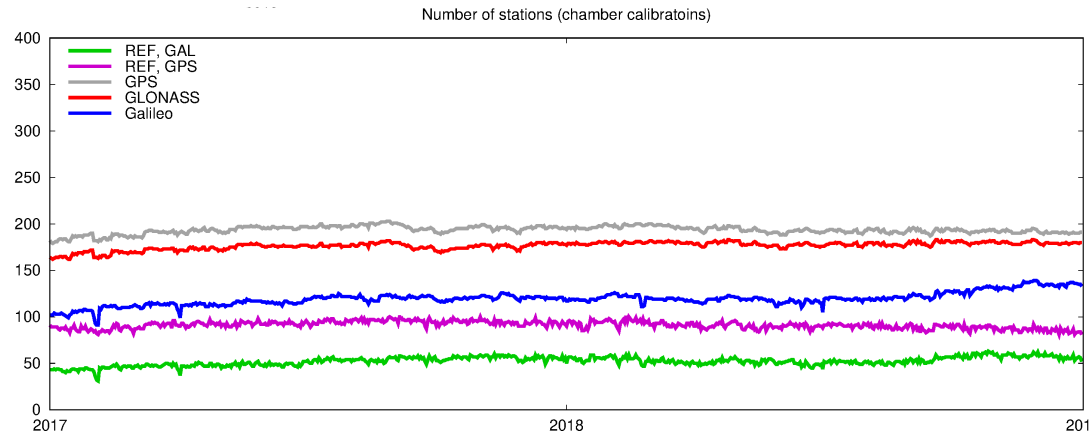
# Coverage

## Used stations in CODE's contribution



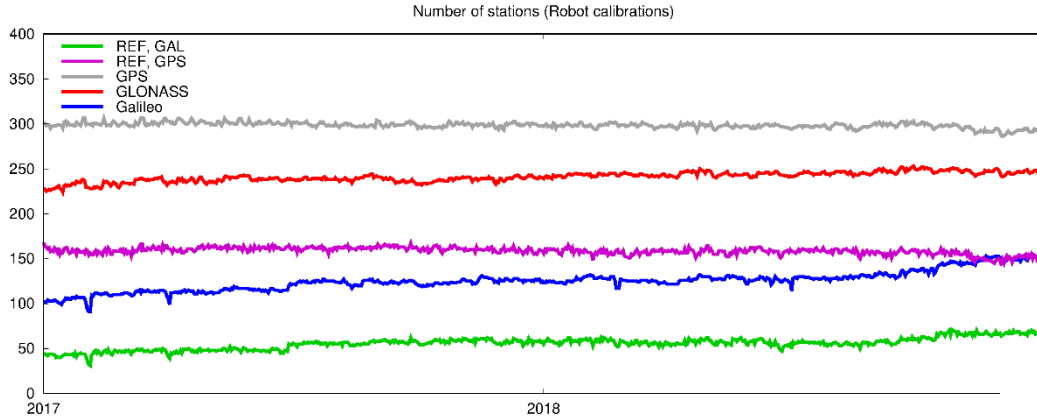
← Robot calibrations

Chamber calibrations →

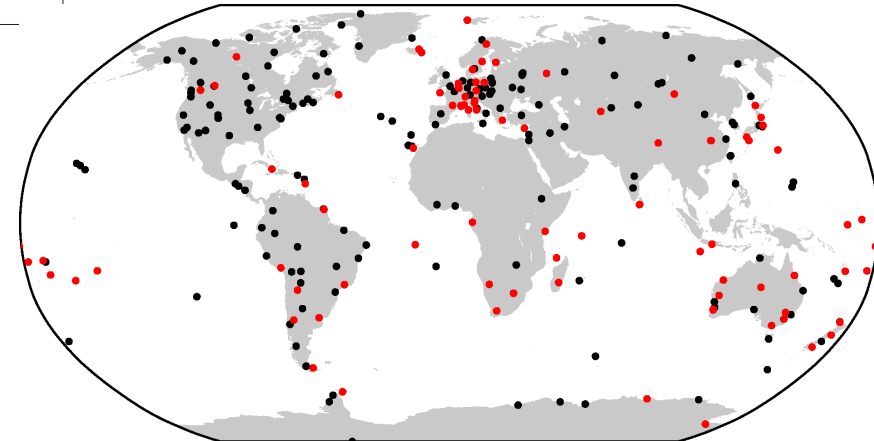


# Coverage

## Used stations in CODE's contribution

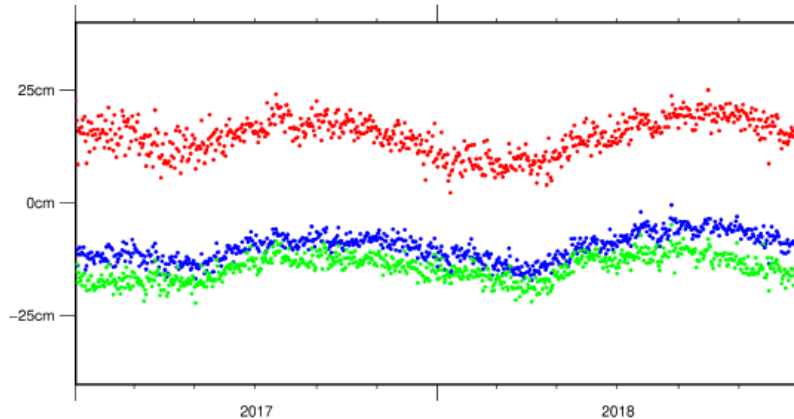


← Robot calibrations

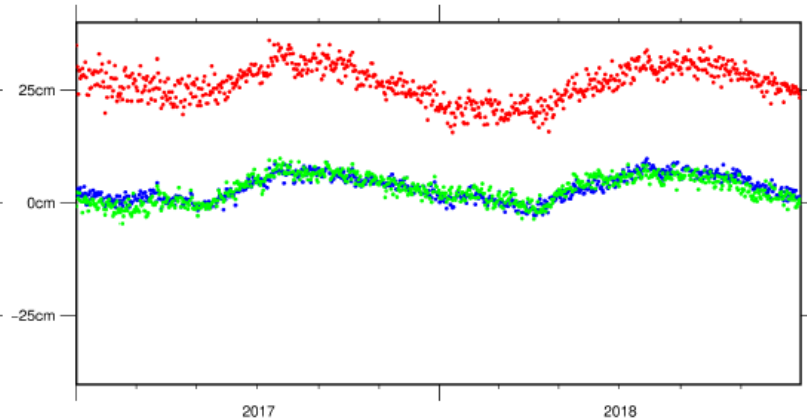


# Scale determination

Code solution: ITRF 2014 scale fixed



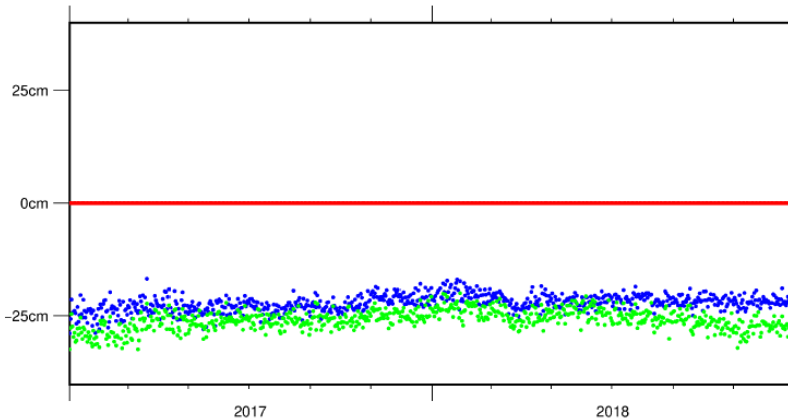
(a) Chamber calibrations: Scale fixed to ITRF 2014.



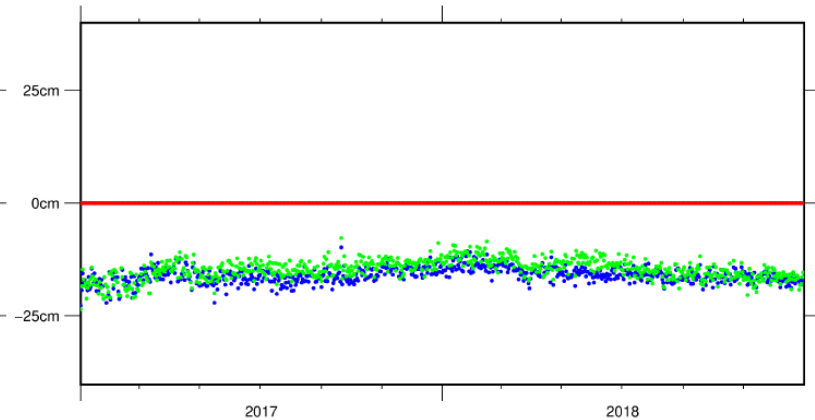
(d) Robot calibrations: Scale fixed to ITRF2014.

# Scale determination

Code solution: Galileo PCO fixed



(c) Chamber calibrations: Scale fixed to GAL PCO.



(f) Robot calibrations: Scale fixed to GAL PCO.

# Scale determination

## CODE solutions only!

	Solution	scale [ppb]	amplitude [ppb]	phase [degree]	RMS [ppb]	
2017-2018	CHA, GAL fixed	1.03	0.28	329	0.12	
	CHA, GPS fixed	-0.62	0.29	338	0.11	
	CHA, GLO fixed	-1.02	0.30	323	0.11	
	ROB, GAL fixed	1.51	0.32	323	0.12	← Repro03
	ROB, GPS fixed	0.26	0.29	328	0.08	
	ROB, GLO fixed	0.23	0.33	317	0.10	
2010	IVS	0.68	0.28	245		} [Altamimi et al. 2016]
	ILRS	-0.68	0.11	258		
	IDS		0.06	204		

Corresponding system-wise  
Z-PCO correction

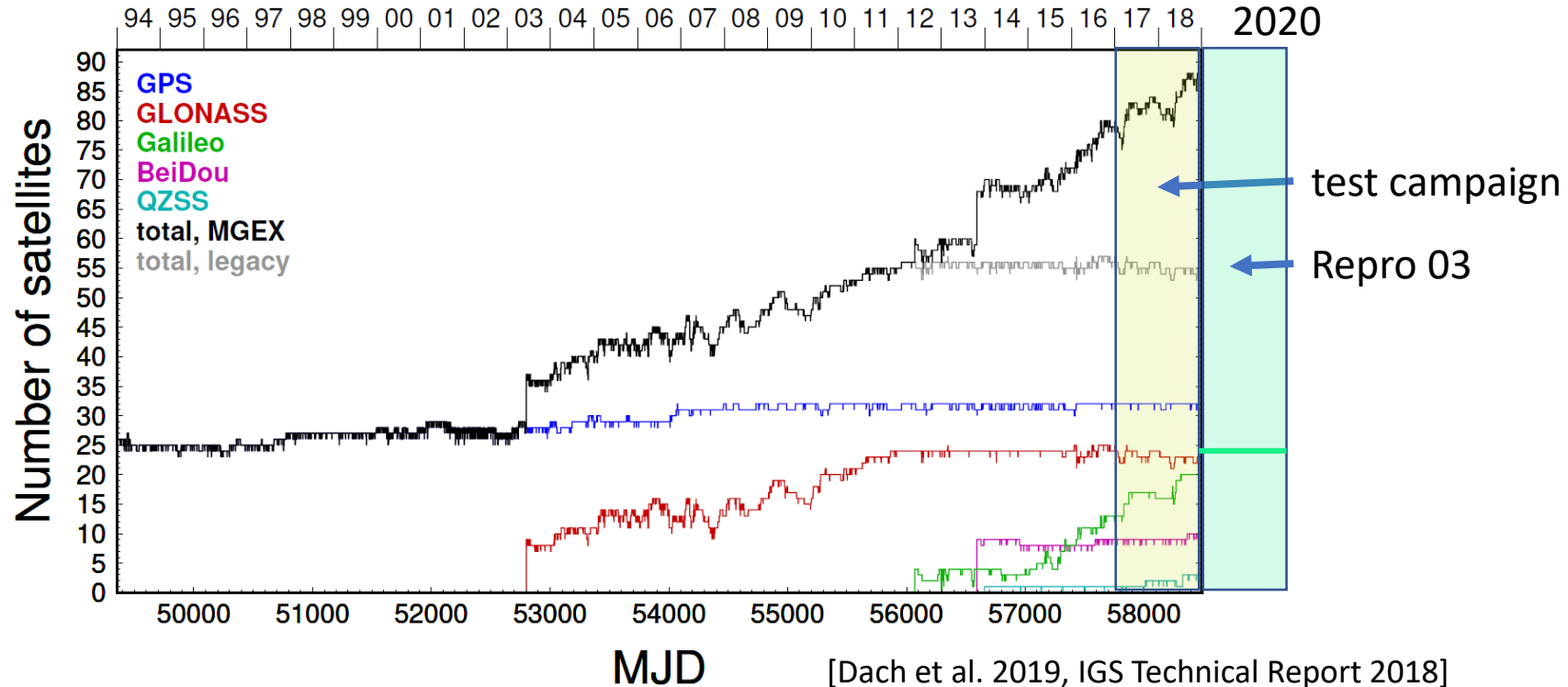


	Fixed	GPS	ROB GLO	GAL	GPS	CHA GLO	GAL
GPS		-	-3.5	22.5	-	-6.1	25.8
GLO		5.4	-	23.1	4.0	-	31.6
GAL		-16.2	-15.3	-	-22.1	-25.8	-

## Changes w.r.t. IGS14.atx:

- time-dependant GLONASS PCOs (in x and y)
- Time-dependant z-PCOs (jumps > 10cm)
- Update of the most recent GLONASS satellites (z-PCO)
- GPS and GLONASS z-component changed to fit chamber calibrated Galileo antenna pattern (~ -16cm)
- GPS Block III also (manufacturer PCOs, no PV)
- multi-GNSS receiver calibrations (mainly from Geo++)
  - update of several receiver antennas

# Satellite availability



# Used ANTEX for test repro (2017-2018)

Changes w.r.t. IGS14.atx:

- time-dependent GLONASS PCOs (in x and y)
- multi-GNSS receiver calibrations (mainly from Geo++)

→ IGS AC Workshop: two year test campaign ( 2017-2018) to evaluate the potential of a GNSS scale and estimate Galileo-scale PCO's for GPS and GLO

