

GPS z-PCO and GNSS-based scale determined by integrated processing with LEOs and Galileo

Wen Huang^{1,2}, Benjamin Männel¹, Andreas Brack¹, Harald Schuh^{1,2}

1: GFZ German Research Centre for Geosciences, Department 1, Potsdam,
Germany

2: Technical University of Berlin, Institute for Geodesy and Geoinformation
Technology, Berlin, Germany

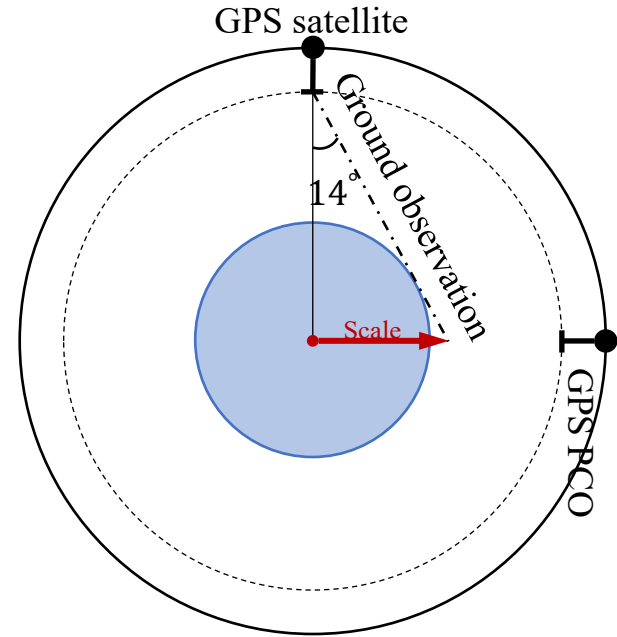
European Geosciences Union General Assembly 2021

Outline

- Introduction
- Two calibration methods
- GPS z-PCO estimation by integrating LEOs
- Comparison and cross-check between two methods
- Conclusions

Correlation between GPS z-PCO and scale

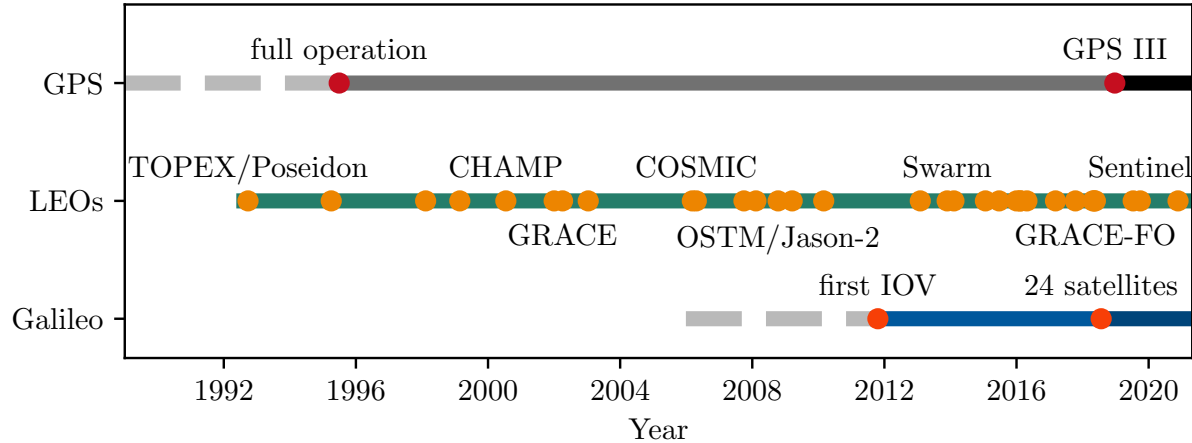
- Issue:
 - Unavailable PCO calibration before GPS III
- Zhu et al. (2003)
 - 13 cm z-PCO error leads to 1ppb scale difference
- In joint estimation:
 - correlation coefficient 0.85



Previous approach

- GPS z-PCO estimation
 - Ground-station-based POD solution;
 - network scale is constrained to the a priori coordinates (e.g., no-net-scale to the ITRF)
 - e.g., Schmid et al. (2016)
 - GPS-based scale realization
 - Ground-station-based POD solution;
 - GPS PCOs are fixed to the a priori values (e.g., IGS ANTEX)
 - e.g., Rülke et al. (2008)
- z-PCO or scale has to be constrained to the a priori information
 - The a priori information is derived by the other techniques, e.g., VLBI and SLR

Update of the situation



- GPS: PCO calibration available for block III satellites
- LEOs: Ground measured or calibrated PCOs (long history)
- Galileo: PCO calibration available (short history)

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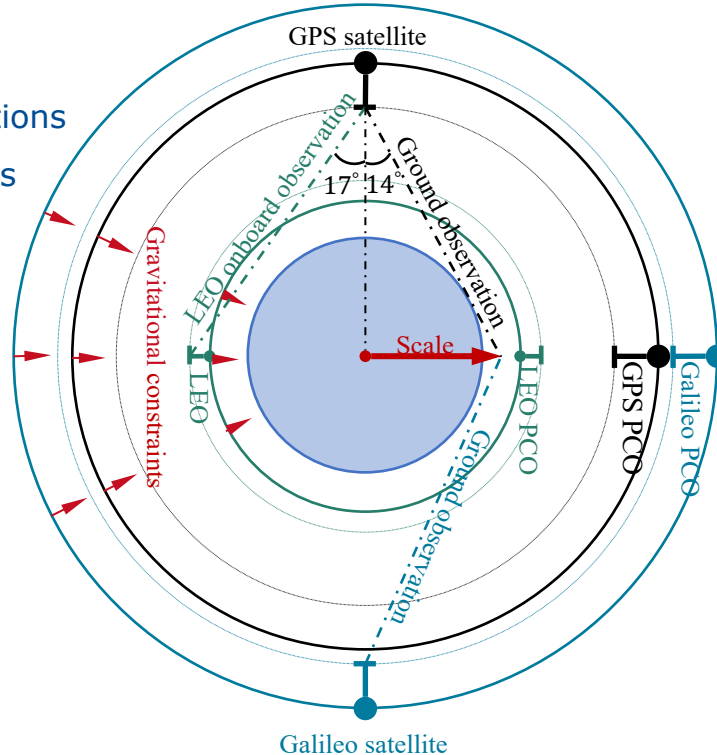
Two methods based on LEOs and Galileo

LEO-based method

- Space- and ground-based observations
- Linked by space-based observations
- Fixed LEO PCOs
- Available LEOs depending on time
- Larger bore-sight angle

Galileo-based method

- Ground-based observations only
- Linked via multi-GNSS stations
- Calibrated Galileo PCOs
- 24 satellites but short history



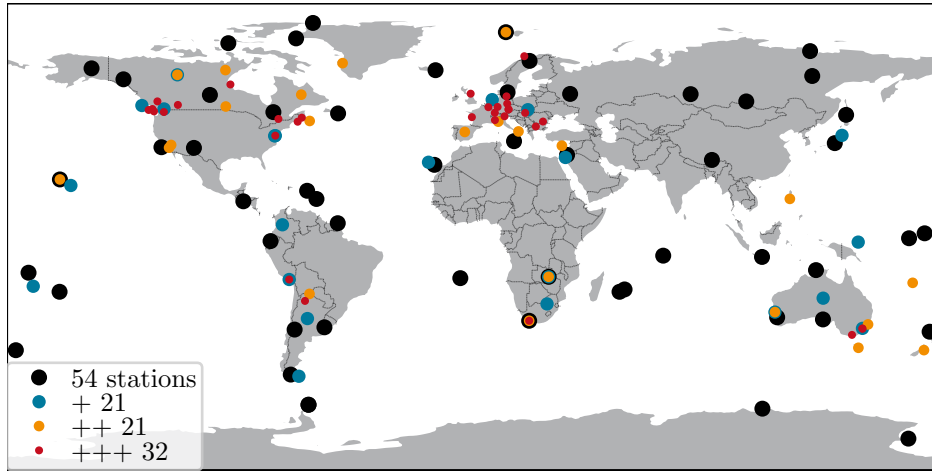
Both methods

- Scale is not constrained
- Gravitational constraints due to the orbital dynamics
- Calibrated PCOs/PVs of ground station receiver antennas

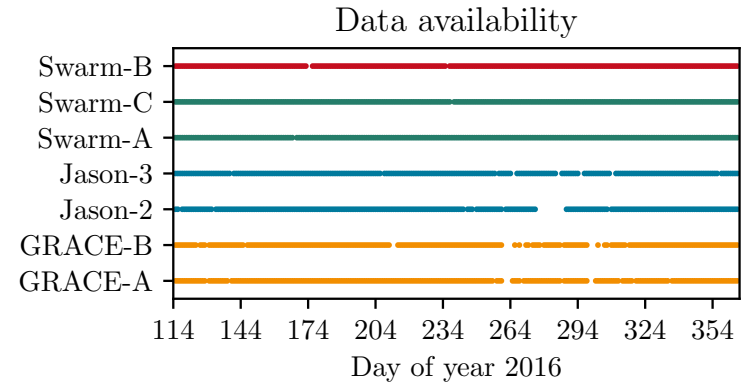
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LEO-based study for 2016



Four ground station networks with more stations step by step (54, 75, 96, and 128 stations)



Seven LEOs used

Four schemes for processing

System-specific z-PCO corrections and scale

A: no-net-scale; z-PCO agree to the a priori values

B: no-net-scale; z-PCO biased by adding LEOs

C: scale free; z-PCO varies due to different networks

D: scale free; consistent z-PCO for different networks due to the LEOs

Scheme	LEOs	Stations	Correlation	z- Δ PCO [mm]	Scale [ppb]
A	0	54	0	-4.7 ± 42.1	0
		75		$+2.2 \pm 30.7$	
		96		-4.2 ± 29.6	
		128		-3.8 ± 28.4	
B	7	54	0	-99.6 ± 26.12	0
		75		-76.3 ± 26.0	
		96		-72.3 ± 55.6	
		128		-62.3 ± 47.3	
C	0	54	0.85	$+234.9 \pm 105.0$	-1.77 ± 0.88
		75	0.85	$+37.6 \pm 146.5$	-0.24 ± 1.16
		96	0.86	-99.7 ± 126.7	$+0.81 \pm 1.02$
		128	0.84	-55.1 ± 101.0	$+0.42 \pm 0.87$
D	7	54	0.30	-254.8 ± 56.7	$+1.80 \pm 0.43$
		75	0.36	-258.1 ± 55.1	$+1.91 \pm 0.43$
		96	0.40	-262.7 ± 53.7	$+1.90 \pm 0.61$
		128	0.43	-255.2 ± 52.3	$+1.86 \pm 0.53$

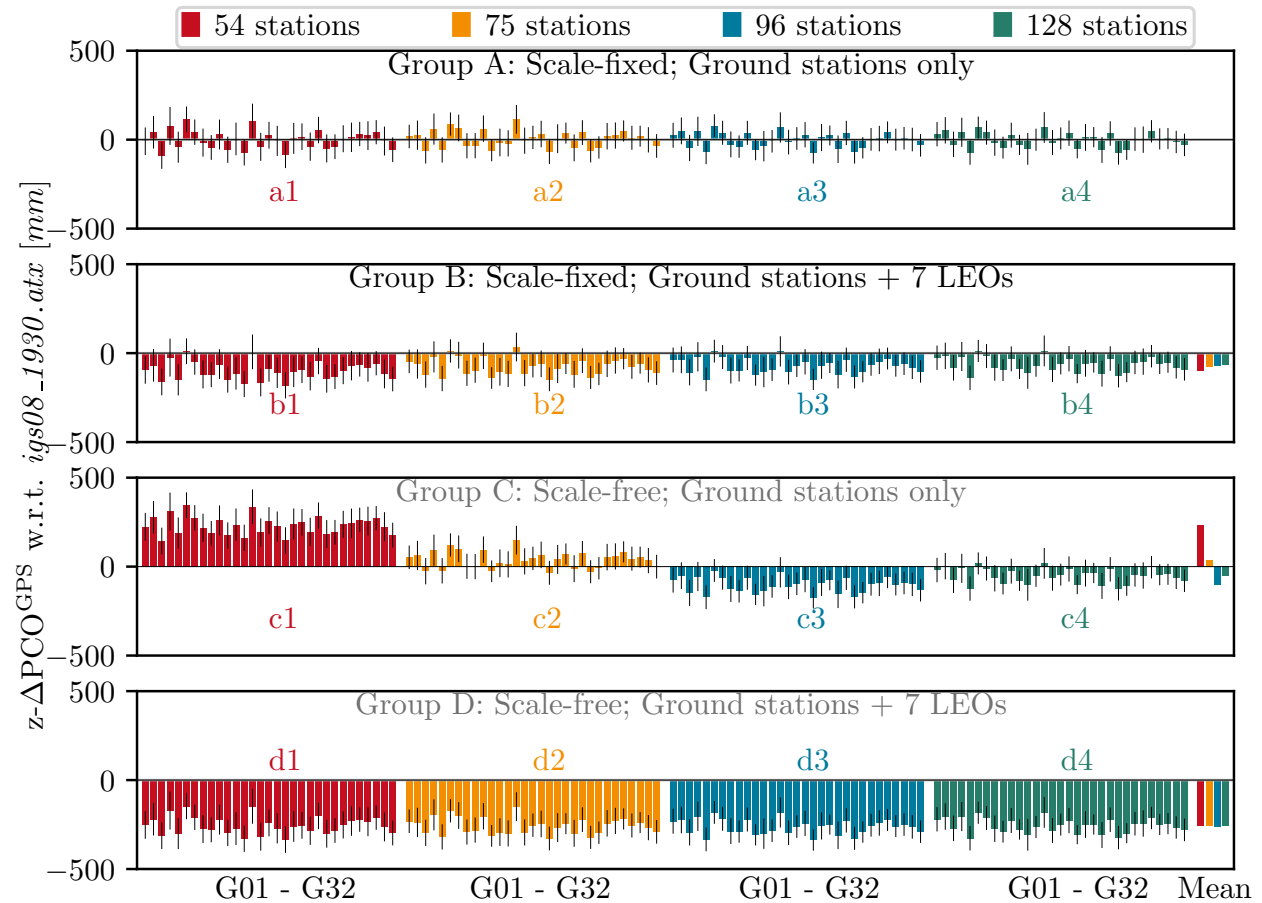
Satellite-specific z-PCO corrections

A: no-net-scale; z-PCO agree to the a priori values

B: no-net-scale; z-PCO biased by adding LEOs

C: scale free; z-PCO varies due to different networks

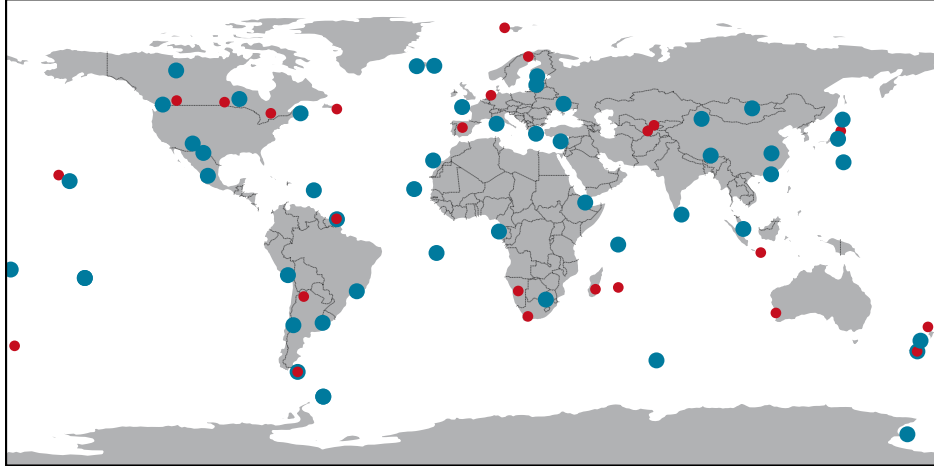
D: scale free; consistent z-PCO for different networks due to the LEOs



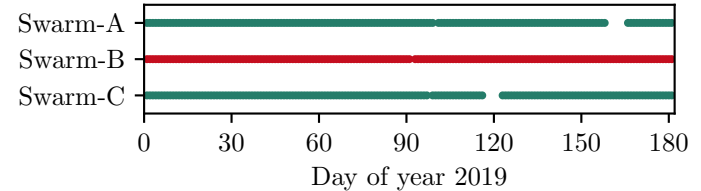
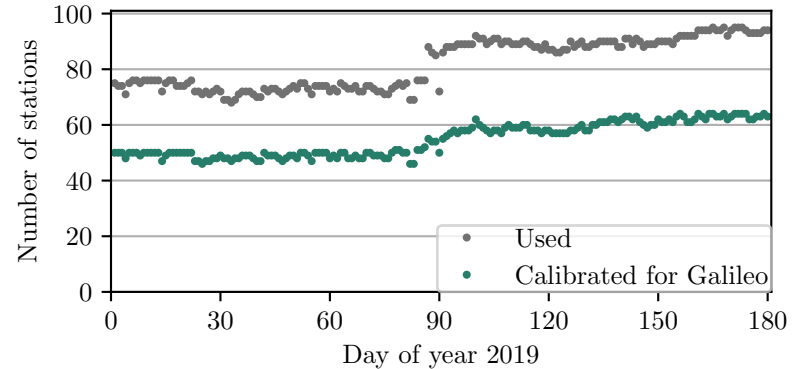
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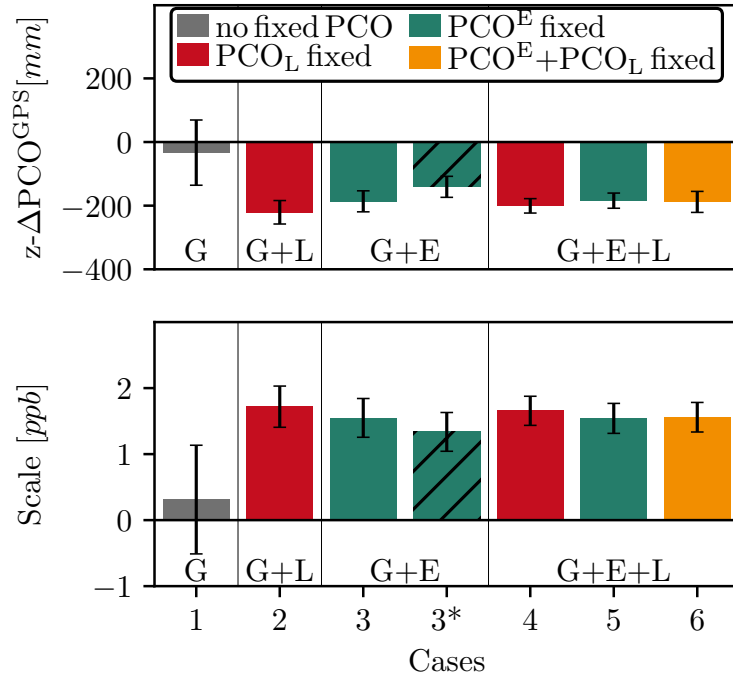
Processing strategy



- First half of 2019
- 24 Galileo and 3 Swarm satellites used
- More than 75 stations observing GPS(G) and Galileo (E) for each day
- Most of the stations are calibrated for Galileo (blue dots)



Six cases for comparison and cross-check

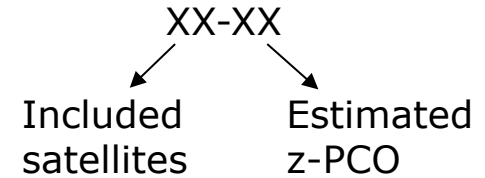
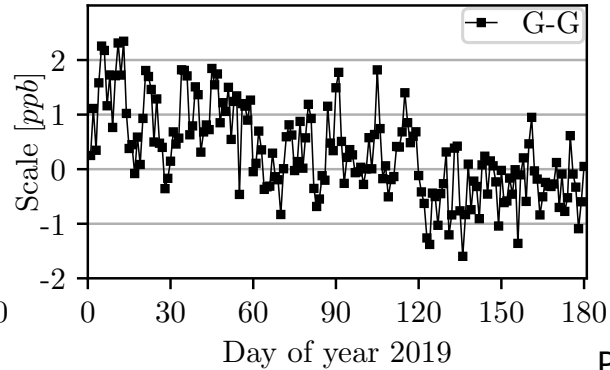
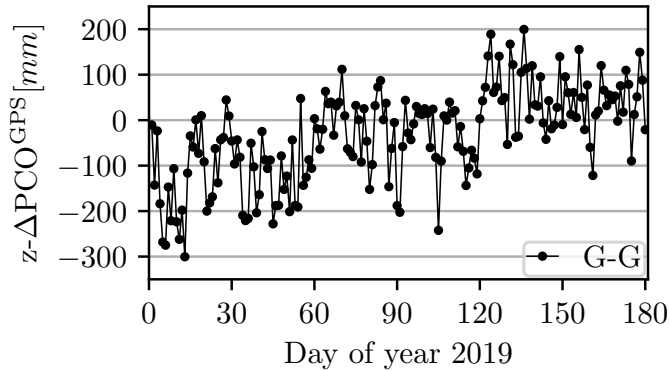


Huang et al. 2021

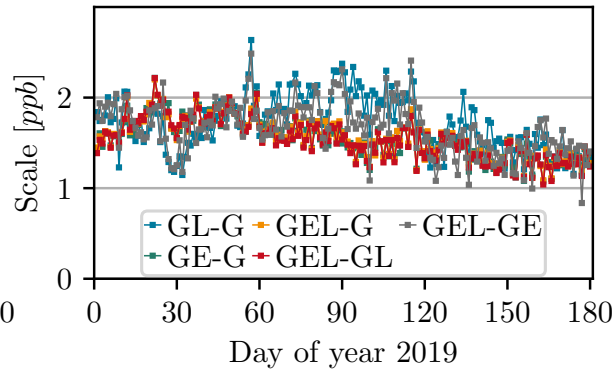
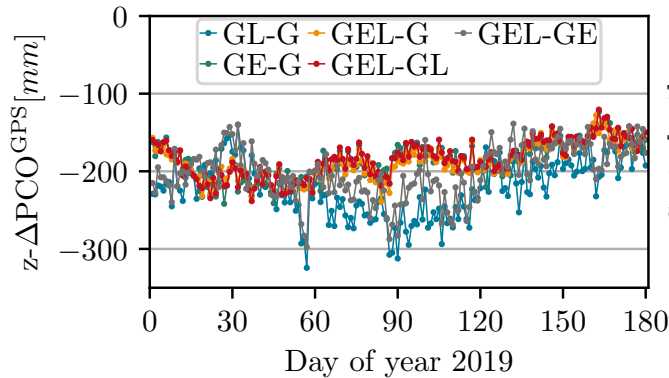
Case	Sat.	Fixed PCO	Correlation coefficient between $z-\Delta PCO$ and scale		
			GPS	Galileo	LEOs
1	G	-	0.87	-	-
2	G+L	L	0.52	-	0
3	G+E	E	0.13	0	-
3*	G+E	E	0.54	0	-
4	G+E+L	L	0.56	0.56	0
5	G+E+L	E	0.13	0	0.09
6	G+E+L	E+L	0.12	0	0

- Both methods can decorrelate the GPS z-PCO and the scale
- Both methods agree with each other:
 - -186 and -221 mm of GPS z-PCO correction
 - +1.55 and +1.72 ppb of scale
- Galileo-based solution is stronger due to more satellites
- Case 3* includes three Galileo satellites only

Time series of the cases



Please notice the axis scale difference



- large variations for G-G
- Galileo PCO-fixed solutions are more stable due to more satellites
- Trend needs further study

Conclusions

- GPS z-PCO is calibrated by two methods. An independent GNSS-based scale is achievable.
- The correlation coefficient between the GPS z-PCO and the scale is reduced from 0.85 to 0.3 by including seven LEOs.
- The correlation coefficient between the GPS z-PCO and the scale is reduced to 0.13 by including the current constellation of Galileo with 24 satellites.
- The LEO-based and Galileo-based solutions agree with each other with small differences in the GPS z-PCO corrections and the scale.
- Due to the larger number of Galileo observations, the Galileo-based method leads to more precise and stable results.
- The trend of the time series of the Galileo-based solution needs further investigation.

References

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