

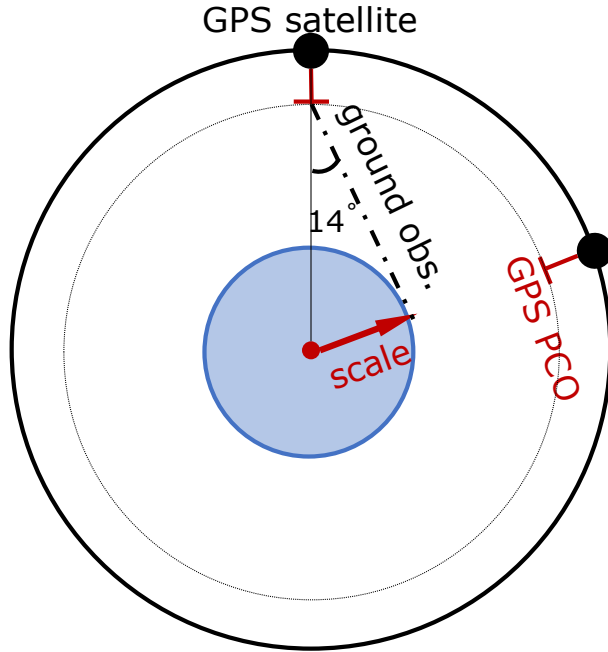
LEO-based solution of GPS PCOs and impact on terrestrial scale

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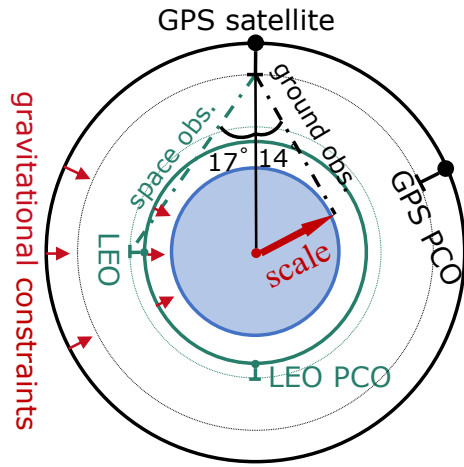
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GPS z-PCOs and GNSS-based scale



- Issues:
 - $z\text{-PCO}^{\text{GPS}}$ are highly correlated with the scale:
 - 13cm $z\text{-PCO}^{\text{GPS}} \rightarrow 1$ ppb scale (Zhu et al. 2003)
 - 0.85 correlation coefficient (Huang et al. 2022)
 - $z\text{-PCO}^{\text{GPS}}$ (before Block III) given by the manufactories were not convincing (Ge et al. 2005)
- Solution of the IGS:
 - estimating GPS z-PCOs by introducing scale determined by VLBI and SLR
 - scale is propagated to users and applications

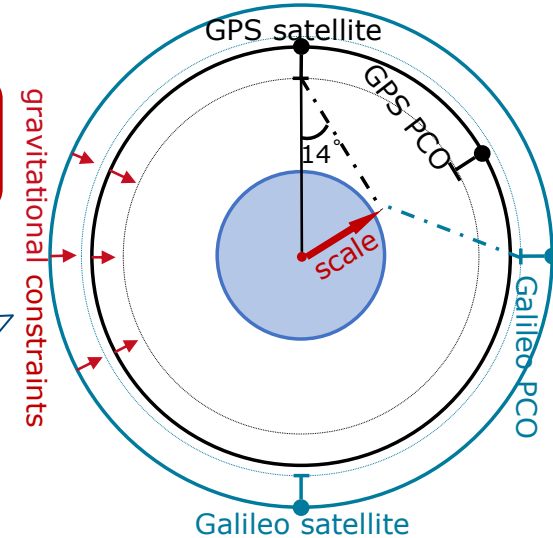
Two methods for z-PCO^{GPS} and GNSS-based scale



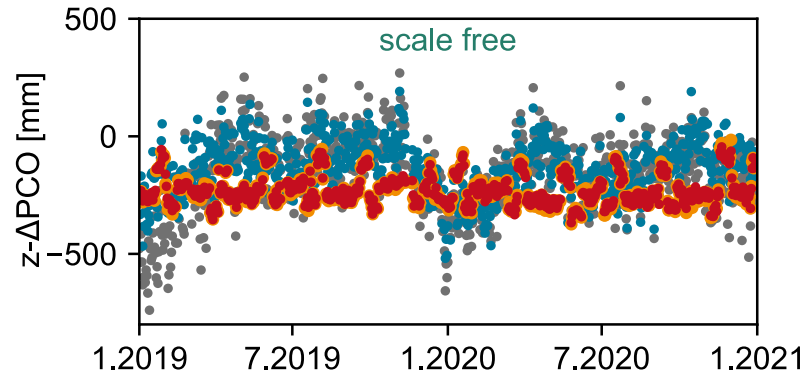
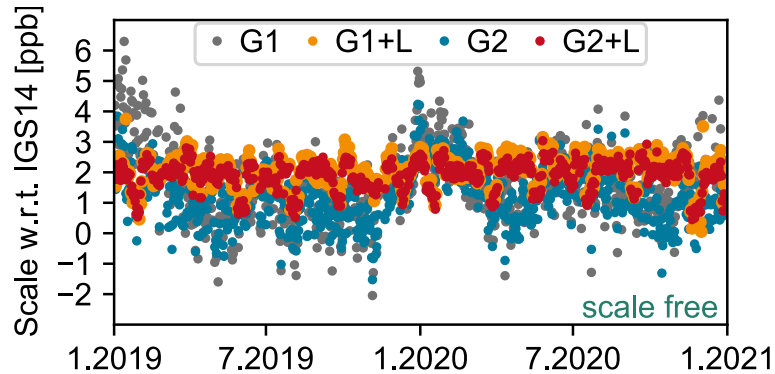
- based on LEOs:
 - ground calibrated PCOs and gravitational constraint
 - fast movement and larger bore-sight angle
 - **historical data for long term study**

No-net-scale condition **NOT** applied
→ **GNSS-based scale**

- based on Galileo:
 - scale based on Galileo is propagated to GPS z-PCOs (Villiger et al. 2020)
 - GPS z-PCO: -160.0 mm
 - IGS repro3 derived a Galileo-based scale



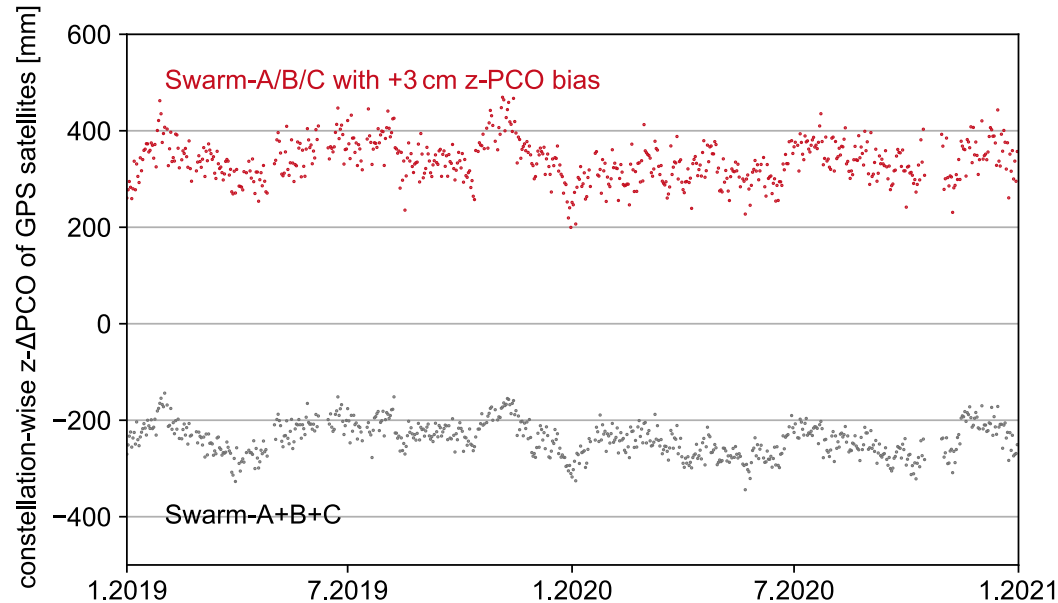
LEO-based solution



- G1 and G2: networks with different numbers of stations
- L: six LEOs (GRACE-FO, Jason-3, Swarm)
- scale free: NNS not applied

stations only → large variation
LEO-based → consistent
effective decorrelation

Requirement on the z-PCOs of LEOs



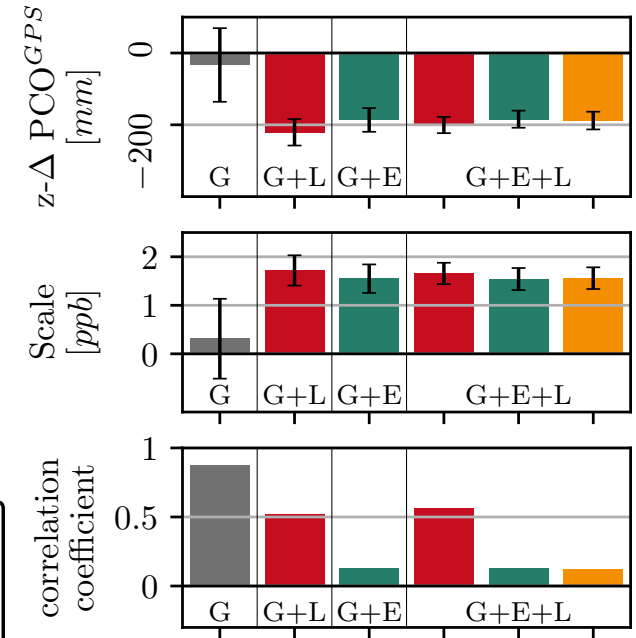
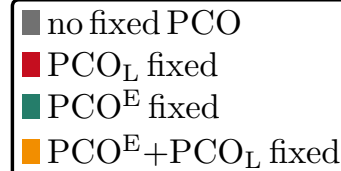
+3 cm z-PCO of LEOs leads to

- -574 mm z- Δ PCO^{GPS}
- +4.27 ppb scale (+27mm)

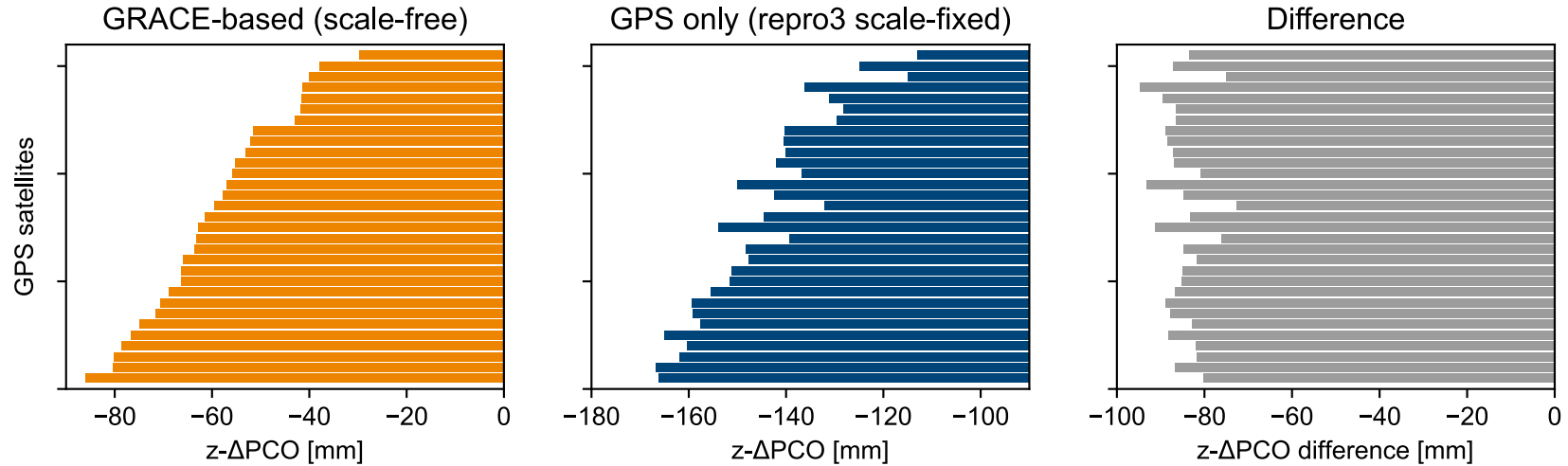
**1 mm accuracy of z-PCO^{LEO}
to achieve 1 mm scale;**
agrees with the simulation
study by [Glaser et al. \(2020\)](#)

Cross-check of both methods

- first-time validation of the LEO-based method
- G: GPS (32); E: Galileo (24); L: Swarm (3)
- scale free: NNS not applied
- **good agreement**
- Galileo solution dominating due to the larger number of satellites (24 vs. 3)



Satellite-specific z-PCO^{GPS}



- 12-year processing: GRACE (2), GPS(51), and level 1&2 stations (100-130) of Repro3
- satellites with 2000+ daily solutions
- sorted by z-PCO^{GPS} corrections in GRACE-based solution (same sequence in all subplots)
- **satellite-specific corrections**
 - 5 cm difference between satellites in maximum
- both solutions agree with each other with an offset (accuracy of z-PCO^{GRACE} ?)

Conclusions

- By integrating LEOs, $z\text{-PCO}^{\text{GPS}}$ values are calibrated without introducing the scale of other geodetic techniques.
- A GNSS-based scale is achieved by including Galileo or LEOs. Both methods agree well with each other. The LEO-based method has advantage in long-term study back in time.
- A 1-mm accuracy of the LEO $z\text{-PCOs}$ is required for the GGOS goal (1 mm scale).
- Satellite-specific $z\text{-PCO}^{\text{GPS}}$ is proposed based on the long-term study.

Thank you for your attention!

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