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GNSS-based scale realization by integrating LEOs

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Abstract. The phase center offsets (PCOs) of the transmitting antennas of GPS satellites in the z-direction are highly correlated with the terrestrial scale when they are estimated simultaneously. Due to the uncertain PCOs of the GPS satellites launched before Block-III, the GNSS technique was not involved in the realization of the scale. On the contrary, the GPS PCOs in the z-direction (z-PCO) are estimated by introducing the scale determined by other geodetic techniques. Two approaches to realizing a pure GNSS-based scale are raised by using low Earth orbiters (LEOs) and Galileo, respectively. In the LEOs-based approach, the scale is realized by integrating LEOs with the GPS in processing in which the z-PCO, orbits, station coordinates, and some other parameters are estimated jointly. Based on the well-calibrated transmitting and receiving antennas of Galileo, a Galileo-based scale was derived in the third re-processing of the International GNSS Service (IGS).

To study the LEOs-based approach, the GPS observations obtained by six LEOs and ground networks with different numbers of stations in 2019 and 2020 are used in the processing. The scale of the ground networks is not constrained. By adding six LEOs, the correlation coefficient between the z-PCO and the scale is reduced significantly (from about 0.85 to 0.30). For GPS satellites operated in 2019 and 2020, excluding GPS III, their estimated z-PCOs have an average difference of -231 mm compared to the IGS values and the corresponding scale to the IGS14 reference frame is +1.89 part per billion. The improvement due to different numbers of LEOs and the impact of the accuracy of LEO z-PCO on the estimation are studied. More LEOs decorrelate the GPS z-PCOs and the scale more efficiently. A one-millimeter accuracy of the z-PCOs of the LEOs is required to achieve a one-millimeter scale. For validation, a comparison and cross-check study of the LEOs- and Galileo-based approaches is done. Both approaches agree well with each other in the realized scale and the estimated z-PCO. Thanks to the long-term available data of LEOs, the LEO-based approach has an advantage in the real-data-based processing backward in time over the Galileo-based one. A twelve-year scale is realized by using the two satellites of the GRACE mission. We will discuss the scale and the impact of the z-PCO of GRACE in a dedicated way.

Overall, we will present the scale realized by using six LEOs and their subsets, the scale comparison between the LEO-based and the Galileo-based methods, and a long-term scale based on the real data of the GRACE mission in 12 years. The above-mentioned result and conclusions will be discussed in detail.