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The impact of GNSS multipath errors on ZTD estimates based on PPP

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Multipath is a large systematic GNSS error source which can bias the Zenith Total Delay (ZTD) estimation of Precise Point Positioning (PPP). In this paper, we explore the magnitudes and systematics of the errors caused by multipath in ZTD estimates. We apply several process noise models based on an Extended Kalman Filter (EKF) and study whether those models are capable of partly mitigating the multipath error. Simulated data, generated with a commercial GNSS simulator, is thereby used to study the impact of multipath signals. All results are based on PPP solutions for which ambiguities are resolved (PPP-AR) and since the simulations provide us reference data, the degradation of ZTD accuracy can be studied in different scenarios where the multipath errors come from different reflection sources. The results reveal that the magnitude of ZTD errors due to multipath reaches millimeter to centimeter order, depending on the chosen scenario. In order to mitigate the effect of multipath errors on ZTD estimates, we study the use of the Continuous Wavelet Transform (CWT). We compute Code-minus-Carrier (CMC) observations and apply a CWT with the purpose to detect the periods during which multipath errors are affecting the observables. Once those periods are identified, it might be possible to mitigate the multipath error by using different process noise models or different function representations for the unknown parameters. In particular, we focus on the random walk model, the first-order Gaussian-Markov model, a noise-overbounding approach and a B-spline representation. We discuss how effective those models perform and reveal whether there is the possibility to improve troposphere estimates which would otherwise be biased by multipath effects. Although all our findings relate to PPP post-processing, the suggested approaches can be mapped to real-time applications since multipath errors mitigation is done epoch wise with the help of an EKF.