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Combination of space geodetic techniques with atmospheric and local ties. A simulation study

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Atmospheric ties are understood as corrections for parameters such as the zenith delays, the gradient vector components, and the mapping factors, that refer to the atmosphere aloft co-located geodetic observing systems. Atmospheric ties may be induced by the different location of the stations, different signal frequencies, technique-specific issues, the time difference, or a combination thereof. In this work, we explore the benefit of combining tropospheric parameters in addition to station coordinates via local ties, utilizing atmospheric ties. To this end, we have carried out Monte Carlo simulations employing the actual observation geometry, that is, Global Navigation Satellite System (GNSS), Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), and Satellite Laser Ranging (SLR) satellite orbits, and the actual Very Long Baseline Interferometry (VLBI) schedules. The simulation setup comprises of a turbulence model for the troposphere, Markov processes for the clocks, and an elevation- and system-dependent white noise for the observations. The simulator is additionally driven by ray-traced delays computed from state-of-the-art reanalysis numerical weather model, ERA5. The simulation of SLR observations is based on the cloud cover tensors from ERA5. After the single-technique geodetic analysis, the technique-specific normal equations are stacked to estimate station coordinate offsets, velocities, and seasonal signals combining or not the tropospheric parameters. We found that the multi-technique combination employing atmospheric ties greatly facilitates the accurate estimation of zenith delays and gradient components, especially under sub-optimal observation geometry (SLR and VLBI); the improvement is at the level of 80% in terms of scatter reduction. Moreover, it was found that atmospheric ties is a powerful tool to stabilize the combined solution; for instance, 1 cm bias in the height component of the local tie at the GNSS station introduces a 5.5 mm height bias in the combined solution employing only local ties, whereas, the bias is reduced to 4.0 mm should accurate atmospheric ties be additionally introduced.