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Long GPS coordinate time series: multipath and geometry effects

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Within analyses of Global Positioning System (GPS) observations, unmodelled sub-daily signals are known to propagate into long-period signals via a number of different mechanisms. In this paper, we investigate the effects of time-variable satellite geometry and the propagation of an unmodelled multipath signal that is analogous to a change in the elevation dependant phase centre of the receiving antenna.

Multipath reflectors at H=0.1 m, 0.2 m and 1.5 m below the antenna are modeled and their effects on GPS coordinate time series are examined. Simulated time series at 20 global IGS sites for 2000-2008 were derived using the satellite geometry as defined by daily broadcast orbits, in addition to that defined using a perfectly repeating synthetic orbit.

For the simulations generated using the broadcast orbits with a perfectly clear horizon, we observe the introduction of a time variable bias in the time series of up to several centimeters. Considerable site to site variability of the frequency and magnitude of the signal is observed, in addition to variation as a function of multipath source. When adopting realistic GPS observation geometries obtained from real data (e.g., those that include the effects of tracking outages, local obstructions, etc.), we observe concerning levels of temporal coordinate variation in the presence of the multipath signals. In these cases, we observe spurious signals across the frequency domain, in addition to what appears as offsets and secular trends. Velocity biases of more than 1mm/yr are evident at some few sites. The propagated signal in the vertical component is consistent with a noise model with a spectral index marginally above flicker noise (mean index -1.4), with some sites exhibiting power law magnitudes at comparable levels to actual height time series generated in GIPSY.

The propagated signal also shows clear spectral peaks across all coordinate components at harmonics of the draconitic year for a GPS satellite (351.4 days). When a perfectly repeating synthetic GPS constellation is used, the simulations show near-negligible power law variability highlighting that subtle variations in the GPS constellation can propagate multipath signals differently over time, producing significant temporal variations in time series.

We conclude that the time variable nature of GPS observation geometry and satellite orbits combined with a multipath signal that is manifested as an elevation dependant bias can introduce a spurious signal that is a potential significant contributor to flicker noise present in GPS time series. Further, the spurious signal also makes a potential significant contribution to the energy present at frequencies related to the draconitic year and harmonic thereof observed in GPS analyses.