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On the Impact of a Quadratic Acceleration Term in the Analysis of Position Time Series

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The analysis of Global Navigation Satellite System (GNSS) position time series generally assumes that each of the coordinate component series is described by the sum of a linear rate (velocity) and various periodic terms. The residuals, the deviations between the fitted model and the observations, are then a measure of the epoch-to-epoch scatter and have been used for the analysis of the stochastic character (noise) of the time series. Often the parameters of interest in GNSS position time series are the velocities and their associated uncertainties, which have to be determined with the highest reliability. It is clear that not all GNSS position time series follow this simple linear behaviour. Therefore, we have added an acceleration term in the form of a quadratic polynomial function to the model in order to better describe the non-linear motion in the position time series. This non-linear motion could be a response to purely geophysical processes, for example, elastic rebound of the Earth's crust due to ice mass loss in Greenland, artefacts due to deficiencies in bias mitigation models, for example, of the GNSS satellite and receiver antenna phase centres, or any combination thereof. In this study we have simulated 20 time series with different stochastic characteristics such as white, flicker or random walk noise of length of 23 years. The noise amplitude was assumed at 1 mm/y-[U+F06B]/4. Then, we added the deterministic part consisting of a linear trend of 20 mm/y (that represents the averaged horizontal velocity) and accelerations ranging from minus 0.6 to plus 0.6 mm/y2. For all these data we estimated the noise parameters with Maximum Likelihood Estimation (MLE) using the Hector software package without taken into account the non-linear term. In this way we set the benchmark to then investigate how the noise properties and velocity uncertainty may be affected by any un-modelled, non-linear term. The velocities and their uncertainties versus the accelerations for different types of noise are determined. Furthermore, we have selected 40 globally distributed stations that have a clear non-linear behaviour from two different International GNSS Service (IGS) analysis centers: JPL (Jet Propulsion Laboratory) and BLT (British Isles continuous GNSS Facility and University of Luxembourg Tide Gauge Benchmark Monitoring (TIGA) Analysis Center). We obtained maximum accelerations of -1.8±1.2 mm2/y and -4.5±3.3 mm2/y for the horizontal and vertical components, respectively. The noise analysis tests have shown that the addition of the non-linear term has significantly whitened the power spectra of the position time series, i.e. shifted the spectral index from flicker towards white noise.