Investigating the propagation of periodic errors into GNSS coordinate time series

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In precise satellite positioning, notably GPS, it has often been considered that unmodelled periodic systematic error effects can largely be mitigated by data averaging, ie by choosing a suitable duration of data processing window. However, by considering the effect of ocean tide loading on continuous GPS height estimates formed from 24 hour sessions on a baseline between Alice Springs and Karratha, Australia, it is apparent the mitigation mechanism is somewhat more involved than one of simple data averaging. For instance, we found that failing to model S2 tidal loading of 1 cm amplitude can result in an artificial semi-annual signal of amplitude greater than 0.5 cm in the resulting height time series, ie an admittance of greater than 50 %. From GPS simulation studies, we attributed such long period data artefacts to the repeating satellite geometry (Penna and Stewart, 2003). Here we further investigate these simulations, to further understand the effects of the repeating satellite constellation geometry, and the mechanism causing large admittances.

To gain a rudimentary understanding of the effect of unmodelled periodic errors when the least squares technique is used to estimate heights using GPS data, we considered a very simple GPS positioning analogy. A single ground point was considered to be subject to a periodic displacement, and observations were continuously made to a pseudo satellite (constrained to 2-d motion for simplicity) that orbited the point with a particular repeat period (one sidereal day for the GPS case). We simulated 5 years of data and formed height time series, with the same dominant periodicities detected as for both the real and simulated GPS time series. Furthermore, we concentrated on deriving these periodicities analytically, and showed that each unmodelled periodic error source results in 11 output periods (that matched the data simulations), due solely to the adoption of a first order linearization process for the least squares functional model. We found the admittance to be a function of the data processing window, the amplitude and period of the unmodelled periodic error, and the satellite repeat period. The periods arising in the output height time series were found to depend on the periods of the unmodelled systematic error and the satellite repeat period. Our expressions can also be extended to GLONASS and Galileo analogies, to help to further our understanding of data artefacts and time series noise, and provide increased confidence and understanding of the geophysical interpretation of GNSS height time series.

Reference

Penna N. T. and M. P. Stewart (2003). Aliased tidal signatures in continuous GPS height time series, Geophys. Res. Lett., 30(23), 2184, doi:10.1029/2003GL018828, 2003.