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Estimating the Geocenter from GNSS Observations

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The satellites of the Global Navigation Satellite Systems (GNSS) are orbiting the Earth according to the laws of celestial mechanics. As a consequence, the satellites are sensitive to the coordinates of the center of mass of the Earth. The coordinates of the (ground) tracking stations are referring to the center of figure as the conventional origin of the reference frame. The difference between the center of mass and center of figure is the instantaneous geocenter.

Following this definition the global GNSS solutions are sensitive to the geocenter. Several studies demonstrated strong correlations of the GNSS-derived geocenter coordinates with parameters intended to absorb radiation pressure effects acting on the GNSS satellites, and with GNSS satellite clock parameters. One should thus pose the question to what extent these satellite-related parameters absorb (or hide) the geocenter information.

A clean simulation study has been performed to answer this question. The simulation environment allows it in particular to introduce user-defined shifts of the geocenter (systematic inconsistencies between the satellite's and station's reference frames). These geocenter shifts may be recovered by the mentioned parameters – provided they were set up in the analysis. If the geocenter coordinates are not estimated, one may find out which other parameters absorb the user-defined shifts of the geocenter and to what extent.

Furthermore, the simulation environment also allows it to extract the correlation matrix from the a posteriori covariance matrix to study the correlations between different parameter types of the GNSS analysis system. Our results show high degrees of correlations between geocenter coordinates, orbit-related parameters, and satellite clock parameters. These correlations are of the same order of magnitude as the correlations between station heights, troposphere, and receiver clock parameters in each regional or global GNSS network analysis. If such correlations are accepted in a GNSS analysis when estimating station coordinates, geocenter coordinates must be considered as mathematically estimable in a global GNSS analysis. The geophysical interpretation may of course become difficult, e.g., if insufficient orbit models are used.