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Adjustable box-wing model for solar radiation pressure impacting GNSS satellites

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GNSS satellites are at a distance from the Earth where the solar radiation pressure is the main non-gravitational orbit perturbation. While the solar radiation impacting the satellites is simple to model, the perturbing acceleration depends on the structure of the satellite and on the optical properties of each surface facing the Sun. Furthermore the satellite is constantly changing its orientation with respect to the Sun to maintain its nominal attitude, making the modelling of solar radiation pressure a complex task. Other important though smaller effects are caused by deviations of the satellite from nominal attitude, Earth radiation pressure and thermal re-radiation forces.

To compensate for solar radiation pressure and other smaller effects, the IGS Analysis Centers usually estimate empirical parameters which fit best the tracking data obtained from a global network of GNSS ground stations. This has allowed computing orbits at an accuracy level of 2.5 cm for GPS and of 5 cm for GLONASS. The Center for Orbit Determination in Europe (CODE) estimates five (three constant and two periodic) parameters in a satellite - Sun fixed reference system and pseudo stochastic pulses once per revolution in the radial, along-track and cross-track directions.

There are also accurate physical models for the mentioned non-conservative forces affecting the GNSS satellites such as the ROCK models for GPS satellites. However, current models fail to predict the real orbit behaviour with sufficient accuracy, mainly due to deviations from nominal attitude, from inaccurately known optical properties, or from aging of the satellite surfaces.

In this context an analytical box-wing model has been derived based on the physical interaction between the solar radiation and a satellite consisting of a bus (box shape) and solar panels. Furthermore some of the parameters of the box-wing model can be adjusted to fit the GNSS tracking data, namely the optical properties of the satellite surfaces. Additionally a parameter related to a rotation angle bias of the solar panel array around its rotation axis was included in the box-wing model.

For this study GNSS orbits are generated based on one year of tracking data from the global IGS network and involving the box-wing model implemented into the Bernese GPS Software, with the processing scheme derived from the one used at CODE. Using this year of data the correlation between the box-wing and orbit parameters was studied, as well as their daily variability and formal errors. The quality of the orbits using the box-wing model is analyzed by computing prediction and overlaps errors, and by comparing them to the orbits obtained by using the CODE empirical model.