Performance of the Selected Geopotential Models with the Empirical Accelerations in the Aspect of GOCE Satellite Orbit Computation

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Introduction: Beginning in the second half of 2009, the gravity field measurements - Satellite Gravity Gradiometry measurements (SGG) and the Satellite to Satellite Tracking data (SST) are transmitted by the Gravity field ardently - State Ocean Observation Explorer (GOCE) to the ground segment of the mission. An important role in the processing of these kinds of data plays the knowledge of the satellite orbit, which estimation is based on the SST observations. The presented work is a part of an orbital research of the GOCE satellite. The aim of this research is to use the SST and SGG measurements in the process of the satellite orbit improvement. This work includes a comparison of selected gravity field models in an aspect of GOCE orbit computation. Such comparison can be helpful in selecting the proper geopotential model for the mentioned process of orbit improvement.

Research and results: In order to perform the comparison of selected geopotential models, the various variants of the GOCE orbit were computed and then compared with a reference orbit in the J2000 initial reference frame. These 1-day variants differ from each other with the satellite motion model. The reference orbit is the 1-day GOCE satellite orbit delivered by European Space Agency (ESA) and it is known as the reduced-dynamic Precise Science Orbit (RD PSO). This orbit with a sampling interval of 10 sec., has the centimeter-level accuracy and is expressed with respect to the ITRF2005 reference frame. Thus, this reference orbit was transformed into J2000 reference frame using given quaternions. The basic tool used in this work is the Toit orbit Processor system (TOP), which enables determination of a satellite orbit in the field of gravitational and non-gravitational disturbing forces. The TOP software is based on the Cowell numerical integration method of 8th order. All GOCE orbits were computed using a fixed initial state vector at the epoch 53156.162883 MJD (11 October 2009 23h 15m 45s 61s UTC). This vector can be described in terms of the following keplerian elements: semi-major axis, eccentricity, argument of perigee, mean anomaly, inclination, and right ascension of ascending node.

Table 1. GOCE differences between the 1-day computed orbit and the J2-day reference orbit - RD PSO data. The differences between the satellite altitudes are given in metres, the orbital velocities - in m/s, and the orbital frequencies - in rad/s. The reference orbit is selected as the result of the best model, which gives the minimum difference in the three empirical acceleration components. It is shown when the value of the RMSD was obtained in the coordinate system, which has a smaller amount of empirical acceleration.

Table 2a. Two variants of the RMSD values for the selected comprehensive geopotential model. The parameters are compared against the RD PSO data. The means of the RMSD values are given in Table 3.

Measure of distance between the computed orbit and the reference one

General form of the empirical acceleration model used in this work

\[ \mathbf{a}_e = \mathbf{a} \left[ \frac{\mathbf{r}}{\mathbf{r}^3} \right] + \mathbf{a}_v \left[ \frac{\mathbf{v}}{\mathbf{v}^3} \right] + \mathbf{a}_f \left[ \frac{\mathbf{f}}{\mathbf{f}^3} \right] + \mathbf{a}_g \left[ \frac{\mathbf{g}}{\mathbf{g}^3} \right], \]

\[ \mathbf{a}_e = \mathbf{a} \left[ \frac{\mathbf{r}}{\mathbf{r}^3} \right] + \mathbf{a}_v \left[ \frac{\mathbf{v}}{\mathbf{v}^3} \right] + \mathbf{a}_f \left[ \frac{\mathbf{f}}{\mathbf{f}^3} \right] + \mathbf{a}_g \left[ \frac{\mathbf{g}}{\mathbf{g}^3} \right] + \mathbf{a}_m \left[ \frac{\mathbf{m}}{\mathbf{m}^3} \right] + \mathbf{a}_e \left[ \frac{\mathbf{e}}{\mathbf{e}^3} \right]. \]

Summary: The selected geopotential models were compared in terms of the GOCE satellite orbit computation in the aspect of the reference orbit - RD PSO orbit. Taking into account the linear and non-linear model of empirical accelerations, it is clear that the older geopotential models work better (especially GGM03S, GIA05, EGM96) with RMSD below 132 m (the newer ones for example EGM96, EGG93, GRIM4S4 with RMSD values at the level 153 m). This question is not so well understood. In fact, RMSD value depends on the work of given geopotential model with the empirical accelerations, which absorb some extent of the errors of this model. It seems that the absorption of errors is more efficient in case of the older geopotential models. The newer models are more accurate and more precise (by more right "in" the error absorption. What's more, the absorption efficiency increases after the given geopotential model truncation at the low-wave length part. However, the efficiency of the error absorption for the non-linear model of empirical accelerations is very low. This is evident in the comparison of difference between the RMSD values for the linear non-linear model of empirical accelerations. The proposed non-linear model contains, among others, numerous pericentral components of which the biggest impact have ones with the periods close to 1 day the length of orbit arc. This feature was noticed for GGM03S with the four considered here empirical accelerations.