Tests of daily time variable Earth gravity field solutions for precise orbit determination of altimetry satellites

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Introduction

This study aiming on precise orbit determination of altimetry satellites makes use of current GFZ daily gravity field products 2002 to 2015 based on radial base functions (RBF) in comparison to the use of a time variable gravity field model (EIGEN-6S4). Since some days are missing in the GRACE data and in order to reach consistency for the precise orbit determination, monthly RLOA solutions have been interpolated to fill these gaps. Moreover, since the geopotential coefficients of low degrees are better determined using Satellite Laser Ranging (SLR) observations to geodetic satellites like Lageos, Sta. Afrika and Asia from GRACE observations, these terms are co-estimated in the RBF solutions by using a priori SLR-derived values up to degree and order 2.

Precise orbits for all satellites Envisat (2002-2012), Jason-1 (2002-2013) and Jason-2 (2008-2015) have been computed over the given time intervals using this approach and compared with the orbits obtained when using a dedicated gravity field model such as EIGEN-6S. An analysis of the root-mean-square values of the fits of SLR and DORIS observations and the orbit arc overlaps will allow us to draw a conclusion on the quality of the RBF solutions and to use these new trajectories for sea level investigations and geophysical applications.

Generation of daily time variable Earth gravity field solutions

Besides ‘standard’ RLOAa monthly gravity field solutions that have been generated within the frame of the GRACE Science Data System (Dahle et al. 2012) also ‘alternative’ monthly gravity field solutions based on radial base functions (RBF) have been developed and reanalyzed. RBF projects the potential of a surface layer on the Earth’s reference ellipsoid onto the spherical Earth in a consistent way. Therefore, the gravity field is represented by an exponential radial function (Guiraud et al. 2014). In this way the approximation of the potential of a surface layer becomes consistent with the Earth’s ellipsoidal shape.

The relation between the GRACE satellite observations and the Gravity field solution is given by polynomial functions (Guiraud et al. 2014). One way to express these functions is a spherical harmonic expansion. However, this method has some limitations as it can handle only up to degree 500. Therefore, we use an alternative method for the gravity solution generation. The core of this approach is a Radial Basis Function (RBF) that can handle high-order coefficients. The advantage of RBF is the compact support of the basis functions which means that the basis functions are non-zero only around their center, whereas the spherical harmonics have a global support. The RBF is a non-orthogonal expansion of the potential of a surface layer, which can be easily adapted to the Earth’s ellipsoid. As a result, the approximation of the potential of a surface layer becomes consistent with the Earth’s ellipsoidal shape.

The description of precise orbit determination tests

We have made use of GFZ new daily gravity field solutions based on the radial base functions (RBF) obtained from GRACE observations over the time interval from 2002 to 2015, as compared to a time-variable gravity field model (EIGEN-6S4) for precise orbit determination of altimetry satellites using the algorithms and other background models for precise orbit determination as described by Rudenko et al. (2012). Since some daily solutions are missing in the GRACE RBF solution and in order to reach a better quality for the precise orbit determination, daily solutions obtained by the interpolation over a few months of RLOAa were used for missing days. Moreover, since the geopotential coefficients of low degrees are better determined using SLR observations to geodetic satellites like Lageos, Sta. Afrika and Asia from GRACE observations, these terms are co-estimated in the RBF solutions by using a priori SLR-derived values up to degree and order 2.

Conclusions

1. Precise orbits of three altimetry satellites (Envisat, Jason-1 and Jason-2) have been derived using EIGEN-6S4 time variable gravity field model and GFZ RBF daily time variable gravity field solutions over the total time interval 2002-2015.
2. Generally speaking, for each satellite, the quality of the orbits based on EIGEN-6S4 model and RBF solutions show rather similar behavior.
3. The mean values of RMS fits of SLR observations are 0.5-1.5 m smaller when using the EIGEN-6S4 model as compared to RBF solutions.
4. There is a minor impact on the RMS fits of DORIS observations for all three satellites when using RBF gravity field solutions instead of EIGEN-6S4 gravity field model.
5. Two-day arc overlaps indicating the internal consistency of the orbits seem to be more sensitive to changes in the gravity field model. Envisat orbits derived from the EIGEN-6S4 model are generally more consistent that using the RBF solutions. The mean values of the arc overlaps in the radial, cross-track and along-track directions by about 7%, 2% and 5%, accordingly, smaller for the Envisat orbit based on the EIGEN-6S4 model as compared to these derived using RBF solutions. However, using GFZ RBF gravity field solutions allows us to get rid from such outliers and generally improves arc overlaps of Jason-1 in the radial and along-track directions by about 9% and 8%, accordingly, and along-track arc overlaps of Jason-2 by about 14%.
6. Numerous activities are presently undertaken at GFZ within the Precise Orbit Determination Test (PODT) project in order to improve the quality of RBF gravity field solutions.

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