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Evaluation of Gravitational Field Models Based on the Laser Range Observation of Low Earth Orbit Satellites† ⋆

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Abstract The Earth gravitational field model is one of the most important dynamic models in satellite orbit computation. Several space gravity missions made great successes in recent years, prompting the publishing of several gravitational filed models. In this paper, two classical (JGM3, EGM96) and four latest (EIGEN-CHAMP05S, GGM03S, GOCE02S, EGM2008) models are evaluated by employing them in the precision orbit determination (POD) and prediction. These calculations are performed based on the laser ranging observation of four Low Earth Orbit (LEO) satellites, including CHAMP, GFZ-1, GRACE-A, and SWARM-A. The residual error of observation in POD is adopted to describe the accuracy of six gravitational field models. The main results we obtained are as follows. (1) For the POD of LEOs, the accuracies of 4 latest models are at the same level, and better than those of 2 classical models; (2) Taking JGM3 as reference, EGM96 model's accuracy is better in most situations, and the accuracies of the 4 latest models are improved by 12%-47% in POD and 63% in prediction, respectively. We also confirm that the model's accuracy in POD is enhanced with the increasing degree and order if they are smaller than 70, and when they exceed 70, the accuracy keeps constant, implying that the model's degree and order truncated to 70 are sufficient to meet the requirement of LEO computation of centimeter precision.

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1. INTRODUCTION

The gravitation of the Earth suffered by the Earth satellite is divided into two parts, one is the central gravitational force and the other is the non-spherical gravitational perturbation that arises from the irregular shape and uneven mass distribution of the Earth. The Earth gravitational filed model is introduced for the sake of describing this irregular, uneven gravitational field. In recent decades, new gravitational field models have been raised one after another along with the enriching observational measure and the increasing geodesic precision. Several space gravity projects, such as CHAMP (CHAllenging Minisatellite Payload)[1], GRACE (Gravity Recovery and Climate Experiment)[2] and GOCE (Gravity field and steady-state Ocean Circulation Explorer[1]), have achieved full implementation in the new century. Particularly, the time before the launch of CHAMP in 2001 is called the pre-CHAMP era, in which the gravitational field models were basically based on the ground-based measurements of satellites, such as SLR (Satellite Laser Ranging), DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite) and some GPS data. Both the precision and the resolution are limited. After the launch of CHAMP, gravity satellites were generally equipped with the GPS receiver, onboard accelerometer, inter-satellite microwave ranging system (for GRACE), gradiometer (for GOCE), etc. The precision and spatial resolution of gravity inversion were significantly improved.

This paper will study the following six gravitational field models: JGM3, EGM96, EIGEN-CHAMP05S, GGM03S, GOCE02S and EGM2008, focusing mainly on the precision orbit determination (POD) with the SLR data of LEO satellites, to test the precision of different models, and to provide a support for the selection of gravitational field models in the precision orbit determination and prediction of LEO satellites. In geodesy, several approaches are applied to estimating the precision of gravitational field model, e.g. by evaluating the precision of the geoid and gravity anomaly using independent data, including the the GPS leveling[3], etc. In this paper, the model precision will be evaluated by the orbit perturbation of LEO satellites, since the accuracies of orbit determination and prediction for specific target satellites can also serve as an evaluation of the gravitational field model[4].

The six gravitational field models and the four satellites as test targets will be introduced in Section 2. In Section 3, using the SLR data of CHAMP, GFZ-1 and SWARM-A as the observational data, we perform POD under the above-mentioned 6 gravitational field models and estimate the accuracies of these models in orbit determination. We also use the GRACE-A satellite to analyze the accuracy difference between different models in orbit prediction. The conclusion and discussion will be given in Section 4.

[1] http://www.esa.int/Our_Activities/Observing_the_Earth/GOCE