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A preliminary study of level 1A data processing of a low–low satellite to satellite tracking mission

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ABSTRACT

With the Gravity Recovery and Climate Experiment (GRACE) mission as the prime example, an overview is given on the management and processing of Level 1A data of a low–low satellite to satellite tracking mission. To illustrate the underlying principle and algorithm, a detailed study is made on the K-band ranging (KBR) assembly, which includes the measurement principles, modeling of noises, the generation of Level 1A data from that of Level 0 as well as Level 1A to Level 1B data processing.

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1. Introduction

The present work is a continuation of a mission study commissioned by the National Space Science Center of the Chinese Academy of Sciences. The objective of the mission study is to understand various technological as well as scientific aspects of a prospective low–low satellite to satellite tracking (LL-SST) gravity mission in the post Gravity Recovery and Climate Experiment (GRACE) Follow On era, with laser interferometry replacing the microwave ranging in tracking of the range rate variation between two satellites. In China, this prospective mission acquires extra significance of being a stepping stone to another planned mission aiming to detect gravitational wave in space [1].

As part of the feasibility study, a preliminary study is also made on the data structure and management of a LL-SST mission, including both the GRACE type mission using microwave ranging as well as the more advanced type using laser interferometry. The present work is extracted from a report of the study. We will outline a possible basic framework for Level 1A (L1A) data management for future LL-SST mission in China. To illustrate the working principles underlying the 1A data analysis, a more detailed study is made on the K-band ranging (KBR) assembly, with a view that more detailed and comprehensive study including other payloads will be made in future when we have a more concrete plan for the future development of satellite gravity in China. It should be remarked that the materials presented here are not entirely original and appropriate references will be given throughout. Despite of this lack of originality, we feel perhaps it is still useful, particularly for the aerospace industries and the satellite gravity user community in China, to go public our study.

As far as the background of the present work is concerned, very scant knowledge on the details of 1A data processing of the GRACE mission is available in the references [2,3]. Some peripherally related work in this area may also be found in the Chinese references [4–6] together with some discussion on raw data processing [7]. In this work, we will have to start from the basics, build the mathematical models for the payloads ourselves in order to do further analysis and simulations.

The layout of the present work may be given as follows. At first, we give an overview of the data management and processing procedure of a LL-SST mission. The basic framework for the Level 1A data analysis is also reviewed. And then, we present the detailed studies on KBR assembly including the measurement principles, productions of Level 0 (L0) and Level 1A data, noise modelings as well as the processing from Level 1A to Level 1B data. Remarks and future plans are summarized in the last section.

2. Overview of the data management and processing

The main theme of the present work is to give a brief overview of the preprocessing procedures from the L1A to L1B data products of a LL-SST mission, with the GRACE mission as our concrete example. Basically, the preprocessing procedures consist of noise calibration of payloads, identification of anomalous instrumental and environmental events, filtering out errors in data transmission and corrections of biases and systematics. This will enable us to separate out signals from noises and systematics, and then generate the Level 2 (L2) data for scientific purposes. Before doing so, let us first give an overview of the data management of the GRACE mission.

The data products of the GRACE mission are divided into the following three levels [8–11] (see Fig. 1).

a) L0 data (raw data) products: Except for the GPS occulation data, all the raw instrument data is collected by the on board data handling (OBDH) system and transmitted through the S-band channel to the GRACE Raw Data Center (RDC) at Deutsches Zentrum für Luft und Raumfahrt (DLR). In each downlink pass from each satellite, the telemetry data is further divided into two streams, namely, the science instrument data and the spacecraft housekeeping data. Both will and are stored in the rolling archives in the RDC, which are the L0 data product files. The L0 data files contain the unscaled binary instrument data with description headers, which will be documented permanently at the GRACE Science Data System (SDS) centers at Jet Propulsion Laboratory (JPL) and GeoForchungs Zentrum Potsdam (GFZ).
b) L1 data products: The L1 data comprises the KBR assembly data, science instruments (accelerometer (ACC), star camera assembly (SCA) and GPS) data, housekeeping data and intermediate ancillary data, which is further divided into L1A and L1B data products. The L1A data results from the nondestructive processing applied to the L0 data. The L0 binary is converted to engineering units with time tags, editing and quality control flags added. In general, except for the bad data packets, the transition between L0 data to L1A data is reversible. The L1B data results from the destructive irreversible processing applied to both the L1A and L0 data. The L1B data contains the intersatellite biased range, range rate and range acceleration, the non-gravitational accelerations from each satellite, the pointing estimate and orbits.
c) L2 data (science data) products: The L2 data is the science data product generated from L1 B and other ancillary data. Through JPL and GFZ, the monthly Earth gravity field is released in the form of spherical harmonic coefficients, and the mean or static gravity field is also produced by combining several months of data. Some groups also distribute the value-added products (like mass anomalies or water layer) based on the L2 data, which is called the L3 data products [12].

The overview of the GRACE data processing flow is summarized in the flow chart in Fig. 1. The processing from the L0 data product to the L1B data product is called the L1 data processing or preprocessing, which mainly assess the performance of the payloads. The aim of the data preprocessing is to produce, from the calibrated instruments data (L0 and L1A), all the necessary input data (L1B) for the derivations of the monthly time-variation of the Earth's gravity field and mean gravity fields. These involve several processing steps for each instrument (reversible and irreversible), like units conversion, removing the effects from possible anomalous instrumental or environmental events and compressing the propagated instrumental errors which include the time tag corrections,