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Perspective

Gravity Recovery and Climate Experiment (GRACE) Mission in the Study of Solid Earth

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DESCRIPTION

NASA and the German Aerospace Center collaborated on the GRACE mission (Gravity Recovery and Climate Experiment). From its launch in March 2002 through the conclusion of its science mission in October 2017, twin spacecraft gathered precise measurements of the Earth's gravitational field anomalies. Launched in May 2018, the GRACE Follow-On (GRACE-FO) is a continuation of the mission using very similar gear. Two identical satellites are part of the GRACE programme, which is tracking in a north-south orientation. The K-band Ranging (KBR) equipment of the GRACE mission can detect minute variations in the intersatellite distance with a micrometre level of accuracy. The exceptional accuracy of the gravity data generated by GRACE is largely due to the interaction of the special satellite configuration and the precise measurements system. When compared to static solutions based on previous gravity models, the precision of static solutions has improved by more than an order of magnitude with the utilisation of GRACE data gathered over a decade. The temporal gravity variations observed by GRACE also enable a previously unheard-of understanding of time-varying changes in mass over vast spatial scales.

Despite the GRACE system's impressive performance, numerous flaws in its instrumentation have a severe impact on its spatial and temporal resolution. The principal flaws include low spatial resolution, temporal aliasing issues, and inconsistent observation quality in various directions.

First, the observation of GRACE is not sensitive to the variation of gravity signals in the west-east direction because of the north-south tracking pattern and near-polar orbit. The gravitational spherical harmonics' zonal (latitudinal) coefficients are therefore more precise than their sectorial (longitudinal) values. This issue can be avoided by using an alternative orbital configuration, such as a pendulum-type, cartwheel-type, or Bender-type.

Second, the low spatial resolution of the GRACE solution is mostly caused by the discrepancy between the satellite ground track and the precision of the satellite sensors. In particular, September 2004's orbital repeat period for GRACE is approximately 61/4, and this month's geoid height error for the temporal gravity model is about one order of magnitude lower. Making ensuring that the orbits are constructed to avoid short recurrence periods is one technique to increase the spatial resolution. Additionally, improving spatial resolution can be accomplished by raising observation accuracy. Fortunately, a laser interferometer ranging system will take the place of the KBR system soon, and its precision is predicted to be at the nano-scale level. Additionally, the drag-free compensation technique can be used to effectively estimate non-conservative perturbation.

Third, temporal aliasing errors have two different causes. One reason for the temporal aliasing inaccuracies is because GRACE temporal solutions and real mass variations have different time resolutions. For instance, the final GRACE monthly outputs may alias the high frequency temporal signals in hydrology, atmosphere, and ocean. Furthermore, the effects of these signals cannot be averaged during the computation of the monthly temporal signal since the variation period of the K1 and S2 main ocean tide waves is larger than one month. The second reason is that correcting that aliasing can result in more errors. Using background geophysical models like ocean tide models and non-tidal models, the mass variations of the ocean and atmospheric systems are eliminated during the processing of GRACE data. Unfortunately, the earlier geophysical models were not entirely accurate, and these flaws could have an impact on the GRACE results as well.

The models specifically include observation error, ocean tide model error, and non-tidal model error, which may or may not be independent. For both the KBR and laser interferometer ranging systems, the range rate errors' noise levels are the same. To determine temporal gravity field models for both existing and upcoming GRACE-type missions, and to evaluate the effect of background geophysical models on these models.

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