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GRAIL gravity field determination using the Celestial Mechanics Approach – status report

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Abstract

The NASA mission GRAIL (Gravity Recovery And Interior Laboratory [1]) inherits its concept from the GRACE (Gravity Recovery And Climate Experiment) mission to determine the gravity field of the Moon. The use of inter-satellite Ka-band range-rate (KBRR) observations enables data aquisition even when the spacecraft are not tracked from the Earth [2]. The data allows for a highly accurate estimation of the lunar gravity field on both sides of the Moon, which is crucial to improve the understanding of its internal structure and thermal evolution. In this presentation we discuss our latest GRAIL-based lunar gravity fields generated with the Celestial Mechanics Approach using the Bernese Software.

1. Orbit and gravity field

We present our most recent AIUB lunar gravity fields based on the data of GRAIL primary mission (PM) phase, covering the period March to May 2012. Gravity field recovery is realized in the framework of the Celestial Mechanics Approach [3], using a development version of the Bernese GNSS Software [4] along with Ka-band range rate (KBRR) data series as observations and the dynamic GNI1B positions provided by NASA JPL as pseudo-observations.

Apart from normalized spherical harmonic coefficients up to degree $n = 200$, also arc-specific parameters like initial state vectors and appropriately spaced empirical parameters (pseudo-stochastic pulses and empirical accelerations) are set up as common parameters for all measurement types. The latter shall compensate for imperfect models of non-gravitational forces. In this respect, we present our advances towards a more realistic model of solar radiation pressure using empirical accelerations in appropriate directions. We compare our results with the most recent lunar gravity field models released by other groups [5, 6] (see Fig. 1), as well as their consistency with topography induced gravity. We show that the lunar gravity field can be recovered with a high quality by adapting the Celestial Mechanics Approach, even when using pre-GRAIL gravity field models as a priori fields.

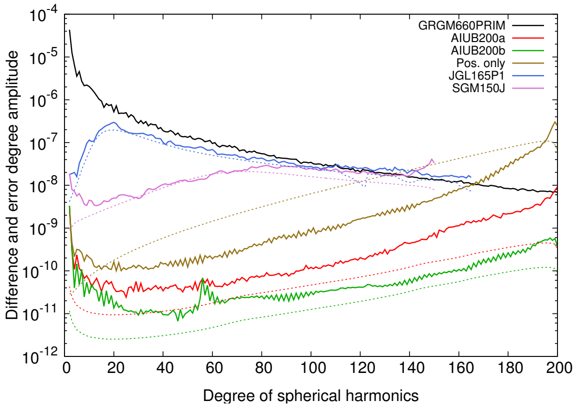

Figure 1: Left: Difference degree amplitudes (solid) and formal errors (dashed) of our preliminary degree-200 solutions based on the a priori field GRGM660PRIM (up to d/o 200, red, and 660, green) compared to pre-GRAIL solutions. The brown curve represents a position-only solution, showing that KBRR observations improve the solution over nearly the full spectral domain.

Fig. 2 shows the free-air gravity anomalies derived from AIUB200a using a Moon reference radius of 1738 km.

2. Doppler data processing

As a further extension of our processing, the GNI1B positions are replaced by the original Doppler observations of the Deep Space Network (DSN) to allow for a completely independent determination of the lunar gravity field using the Celestial Mechanics Approach. Fig. 3 shows the current status of our pre-fit Doppler

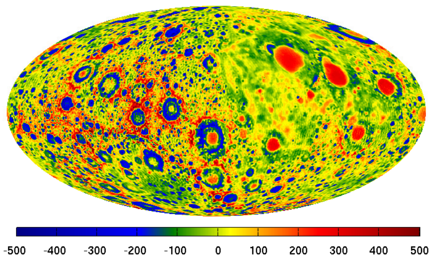

Figure 2: Free-air gravity anomalies on a 0.5° x 0.5° grid (Mollweide projection centered around 270°, with the nearside on the right).

residuals based on GNI1B-derived orbits of GRAIL-A and GRAIL-B and the Doppler data. Observations are screened for outliers by setting a threshold on the residuals and by applying an elevation cutoff at 25°. We present our latest results about DSN data modeling and orbit determination in the Bernese Software.

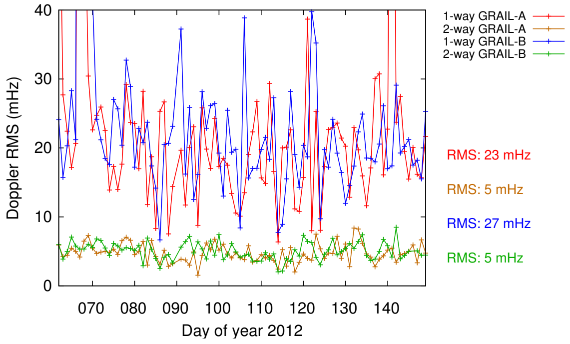

Figure 3: Daily RMS of one-way and two-way Doppler residuals for both GRAIL-A and GRAIL-B over the PM.

3. Summary and Conclusions

In conclusion, AIUB200 already represents an alternative solution for the lunar gravity field from GRAIL data obtained using an independent software. We have compared our solution to the first official NASA GRAIL solution GRGM660PRIM and evaluated it in terms of the correlations to the topography-induced gravity fields (always above 0.98 up to degree 169). We will present our most recent solution, where further improvements are demostrated from the optimisation of the parametrisation and non-gravitational force modeling. Although convenient for the initialization of GRAIL data processing, the use of the dynamic GNI1B positions is not entirely satisfactory. The ongoing implementation of DSN Doppler data processing into the Bernese GNSS Software will allow us to contribute a fully stand-alone solution.

Acknowledgements

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