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Bulk density of the lunar crust in high resolution

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Abstract

We used gravity data from the Gravity Recovery and Interior Laboratory (GRAIL) mission and topography derived from Lunar Orbiter Laser Altimeter (LOLA) data to determine the bulk density of the lunar crust. The resulting map has a grid space of 0.75°. Utilizing the crustal density, Bouguer anomalies can be calculated in an enhanced accuracy and resolution, with which a sophisticated view can be taken on lunar impact basin subsurface structures.

1. Introduction

The gravity field of the Moon is known in an unrivaled spatial resolution. The tracking data from GRAIL's primary and extended mission have resulted in a gravity field with a resolution of harmonic degree 1500 [2], which is equivalent to ~ 4 km in the spatial domain.

While the low-order gravity field is affected by deep interior structure, the short-wavelength gravity is mostly affected by local topography [4]. For getting insights about the mass distribution below the surface, Bouguer anomalies are calculated. To subtract the right portion of gravitational contribution from the terrain, the correct density of the upper crust must be applied.

Since seismic experiments were completed in 1977, we use remote sensing data to obtain new findings about the inner structure of the Moon. By analysis of the correlation between the gravity field and topography, lateral variations of density in the upper crust can be determined [6].

We apply the most recent gravity data to obtain maps of the crustal density in the highest possible spatial resolution.

2. Method

We use the lunar gravity model GL1500E, which is available with a resolution of harmonic degree 1500 [2]. Since the measurement noise becomes larger with higher degree and may affect the accuracy of the analysis (Fig. 1), we only used the coefficients up to degree 600.

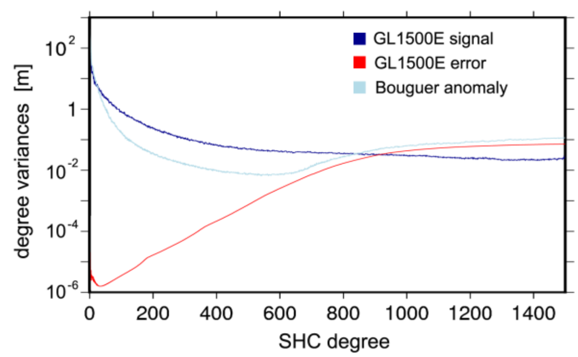

Figure 1: Power spectrum of the gravity signal (dark blue), measurement noise (red) and Bouguer anomaly (light blue)

For estimating variations of the bulk density in the upper crust, we applied the same method as Wieczorek et al. [6]. Our model assumes a constant density with depth and only seeks for lateral variations. The goal is to compute crustal density for each of approx. 115.000 grid elements.

To eliminate flexural rigidity of the lithosphere [4] as well as the sensitivity of the data to the crust-mantle boundary [6], we considered spherical harmonic coefficients larger than degree 150, only.

The higher degree expansions show strong correlation with the terrain. We take advantage of this fact for estimating the density of the crust: the observed short wavelength gravity field should be equal to the Bouguer correction [5] plus the measurement error – if the correct density was used for calculating the Bouguer correction. If a wrong density was used, a too small / large portion of gravity from terrain gets subtracted and the terrain is mapped in the resulting Bouguer anomalies. Hence, finding the Bouguer anomalies which are least correlated with the overlying terrain, the correct density was applied.

A topographic map was created using data from Lunar Orbiter Laser Altimeter (LOLA). We truncated the data set in the spectral domain to the same expansion as the gravity data. Both, gravity field and topography, were referenced to the Principal Axis (PA) lunar reference system.

3. Results

We calculated the bulk density of the lunar crust and created global maps (Fig. 2). The grid has a spacing of 0.75° (22.5 km at the equator). The bulk density of each grid point was calculated using a circular analysis region with a radius of 1.5° (45 km at the equator). The gravity field was corrected for the elevation, where it was measured, down to the mean radius of the topography of each analysis region.

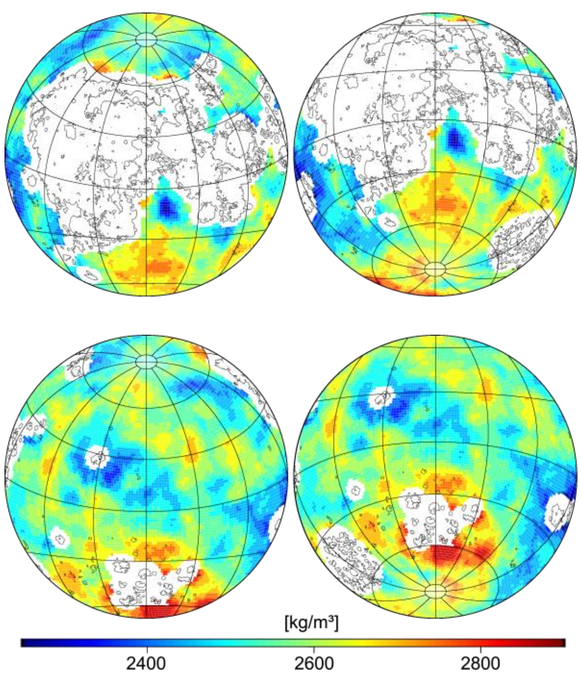

Figure 2: Top: bulk density of the lunar nearside crust for the northern (left) and southern hemisphere (right). Bottom: crustal density of the lunar farside for the northern (left) and southern hemisphere (right). The maps are given in Lambert azimuthal equal-area projection.

We are concerned about mare basaltic units, known to have a much higher density than the underlying crust [1]. We used maps of lunar Maria [3] to identify and exclude regions with a contribution of more than 2.5 % of mare basalt (depicted in white).

4. Summary and Conclusions

We processed high resolution gravity data in combination with topography to map the bulk density of the upper lunar crust. The results are in good agreement with earlier maps of bulk density in [6], but maps of this study are available in a higher spatial resolution.

We will use the high-resolution gravity data and apply the determined crustal density to recompute global Bouguer anomalies of the Moon.

Acknowledgements

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