Simultaneous retrieval of the lunar solid body tide and topography from laser altimetry

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The Moon is periodically deformed by the tidal forces exerted on it by the Earth and the Sun. The tidal Love number $h_2$ describes the magnitude of the radial component of these deformations at the monthly frequency, which have an amplitude of up to $\sim 10$ cm. Like the potential Love number $k_2$, $h_2$ depends on the density and rheological properties of the materials in the lunar interior and their distribution. We analyze $> 3.6 \cdot 10^9$ measurements of the Lunar Orbiter Laser Altimeter (LOLA) obtained during the 27-month circular orbit phase of the Lunar Reconnaissance Orbiter (LRO) at 50 km altitude, when LOLA reached global coverage. We simultaneously invert these observations for the Love number $h_2$ and a global topographic model. The topography is parametrized as an expansion in 2D cubic B-spline basis functions, which are defined on a global equirectangular grid. This parametrization is more computationally efficient than an expansion in spherical harmonics, but still allows for a high smoothness. To deal with data gaps, we constrain the solution by minimizing the second derivative of the topography. We find that the $h_2$ solution depends on the choice of resolution of the equirectangular grid. We determine the accuracy for each investigated resolution (from 6 km to 1 km at the equator) from a Monte Carlo simulation using 100 synthetically generated sets of observations. The topographic signal in the synthetic data follows a power law extrapolated from the real lunar topography. At large scales, the topography is generated using a spherical harmonic expansion, at smaller scales it is generated using Gaussian process regression. Finally, we use the inverse of the root-mean-square $h_2$ obtained from the Monte Carlo simulation as weights for determining a weighted mean of the $h_2$ results for different grid resolutions. The final result of $h_2 = 0.0386 \pm 0.0022$ agrees within one standard deviation with a previous result obtained from the same data, but utilizing crossover points of LOLA profiles. This validates the method of simultaneous inversion for tides and topography, especially with regard to future laser altimeter experiments at other planetary bodies, such as Mercury and Ganymede. However, our result also confirms a discrepancy between laser altimeter measurements of $h_2$ and the $k_2$ result of the Gravity Recovery and Interior Laboratory (GRAIL) mission, which needs to be resolved through better modelling of the lunar tidal response.