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Lunar rotation measurement using orbital observations by LRO

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We use orbital observations by the Lunar Reconnaissance Orbiter (LRO) to study Moon's rotation. Our current knowledge on the rotation of the Moon benefits largely from the long history of continuous Earth-based Laser Ranging (LR) to retroreflectors on the Moon's surface. However, spacecraft in orbit about the Moon also collected extensive high-resolution laser altimeter data. In this paper, we demonstrate that this data can be used to track the slight variations in the orientation of the rotation axis and the rotation rate.

The Lunar Orbiter Laser Altimeter (LOLA) delivered topographic measurements of the lunar surface for over more than seven years. The laser profiles, acquired from the polar orbit of LRO, converge at the poles leading to a high density of measurements in these regions. In order to perform our measurements of the lunar rotation we construct with help of LOLA footprints reference digital terrain models (DTMs) at the lunar poles with a grid size of 15 meters. These reference DTMs are obtained by iterative co-registration of individual profiles to the DTMs constructed from other profiles in the same area. In this iterative process we remove the offsets of the profiles caused by residual mis-modelling in LRO orbit reconstruction, LOLA pointing, and rotation state of the Moon. After about twenty iterations the final DTMs are free of artifacts and benefit from internally consistent laser profiles. Finally, we compute the inertial coordinates of the nominal LOLA footprints and solve for the rotation parameters required to bring them in agreement with the reference DTMs. In particular, we solve for instantaneous values (at the time of the LOLA measurements) for the right ascension and declination of the rotation axis, as well as the rotation angle of the Moon. Since the rotation affects both lunar poles in the same way we can disentangle the estimates from orbit and pointing corrections. Furthermore, we make use of a smoothing constraint resulting from the relatively slow rotation of the Moon compared to the short LRO orbit period of approximately two hours.

In our initial results, based on more than 10 million LOLA footprints (6166 profiles) from the lunar North Pole, we demonstrate the recovery of small oscillations in the orientation of the lunar rotation axis (in the order of ten arc seconds) in agreement with models obtained from the lunar LR data.