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Lunar topographic roughness maps from Lunar Orbiter Laser Altimeter (LOLA) data: Scale dependence and correlation with geologic features and units

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ABSTRACT

We present maps of the topographic roughness of the Moon at hectometer and kilometer scales. The maps are derived from range profiles obtained by the Lunar Orbiter Laser Altimeter (LOLA) instrument onboard the Lunar Reconnaissance Orbiter (LRO) spacecraft. As roughness measures, we used the interquartile range of profile curvature at several baselines, from 115 m to 1.8 km, and plotted these in a global map format. The maps provide a synoptic overview of variations of typical topographic textures and utilize the exceptional ranging precision of the LOLA instrument. We found that hectometer-scale roughness poorly correlates with kilometer-scale roughness, because they reflect different sets of processes and time scales. Hectometer-scale roughness is controlled by regolith accumulation and modification processes and affected by the most recent events, primarily, geologically recent (1–2 Ga) meteoritic impacts. Kilometer-scale roughness reflects major geological (impact, volcanic and tectonic) events in earlier geological history. Young large impact craters are rough, and their roughness decreases with age. The global roughness maps revealed a few unusually dense clusters of hectometer- and decameter-size impact craters that differ in their morphology and settings from typical secondary crater clusters and chains; the origin of these features is enigmatic. The maps can assist in the geological mapping of the lunar maria by revealing contacts between volcanic plain units. The global roughness maps also clearly reveal cryptomaria, old volcanic plains superposed by younger materials, primarily crater and basin ejecta.

1. Introduction

Laser altimeter instruments onboard orbital planetary missions significantly advanced our knowledge of the Moon, Mars, Mercury. Topographic maps derived from the laser altimeter data are widely used in geological studies. In addition to the topographic maps, synoptic maps of topographic roughness can be useful. There are a few reasons, why in some circumstances the use of roughness maps is essential for geologic studies.

First, roughness maps provide a convenient large-scale overview of small-scale textures. To map regional variations of textures solely with topographic maps, a geologist constantly needs to switch from large scale to small scales, which is time-consuming and inconvenient. Roughness maps give a generalized overview of texture variations at large scale.

Second, roughness maps help to focus on typical topography rather than on peculiar features. When we look at topographic maps and images, our eyes see the most prominent features and often miss background textures. For example, when we look at the lunar highlands, we see the distinctive impact craters, and it is very difficult to ignore craters and focus on intercrater textures. Properly designed roughness maps display the most typical topographic textures and ignore rare features.

Finally, roughness maps utilize the exceptional internal precision of laser altimeter data. The precision of the range determination along each spacecraft orbit is much higher than the accuracy of orbit knowledge, and the accuracy of the topographic maps is much worse than the internal precision of the original measurements. In addition, the gaps between orbit tracks are often wider than the distance between elevation measurements along the orbit, and the effective resolution of the topographic maps is worse

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