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Bi-directional reflectance, surface roughness, and shadowing over the lunar south pole

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Abstract

Three years of continuous observations by the laser altimeter (LOLA) on the Lunar Reconnaissance Orbiter (LRO) spacecraft have provided unique data on spatial scales of 5 m and above for the reflectance, surface roughness and topographic shadowing over the south polar region of the Moon.

1. Introduction

Since the launch of LRO in June 2009 the LOLA instrument has acquired over 5.6×10^9 altimeter observations, many with measurements of the return laser pulse energy at 1064 nm, used to derive bi-directional reflectance, and the spreading of the laser pulse used to estimate the surface roughness [1]. Because of the large number of altimetric observations and the density of the ground tracks in the high latitudes a digital elevation model of these regions at 10-meter spatial resolution and less than 1-meter internal radial accuracy has been developed. These measurements have been acquired both inside and outside of permanently shadowed craters and enabled lighting conditions and shadowing to be studied for the present and past lunar orientations.

1.1 Polar elevation model

The altimeter data has enabled detailed a topographic map of the high southern latitudes in regions that are of high interest for possible future landing sites by several nations and organizations. A recent map of one of these regions near the pole that receives considerable sunlight is shown in Figure 1. It is a small rectangular area approximately 1.6 km on a side about 12 km from the south pole. Contours are at 1-meter intervals. The central region is approximately flat, undulating, and potentially a safe landing site surrounded by slopes of 10 to 20 degrees.

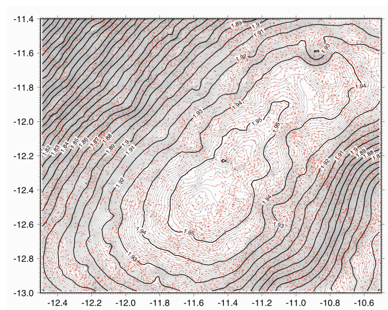

Fig 1 A small area approximately 12km from the south pole showing the LOLA measurements within the area.

1.2 Polar surface roughness

We derive surface roughness from the altimeter in two ways; (1) by measuring the spreading of the laser

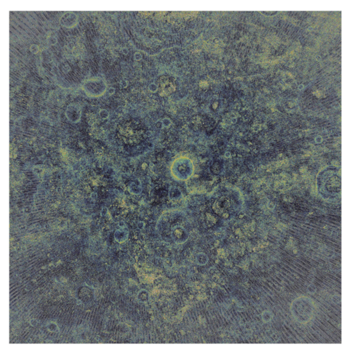

Fig 2 Surface roughness variations over a 10-degree area surrounding the south pole. Shackleton crater is in the center. Most craters show a greater roughness on their rims than in their interior.

pulse over the size of the laser spot on the surface (5 m) and (2) by looking at the altimeter residuals to a plane through 5 adjacent spots that removing most of any regional slope. Roughness at the 5 to 25 m scale clearly identifies craters, frequently by their rims which are rougher than the surrounding area. The Shackleton [1] crater has a most pronounced greater roughness on the rim, possible due to mass movements on the sloping sides of the crater [2].

1.3 Bi-directional reflectance

Reflectance is expressed as a radiance factor *(I/F)* which is defined as the ratio of the measured radiance *I* to the radiance *F* of an ideal diffusive surface in vacuum with 100% reflectance under the same solar illumination.

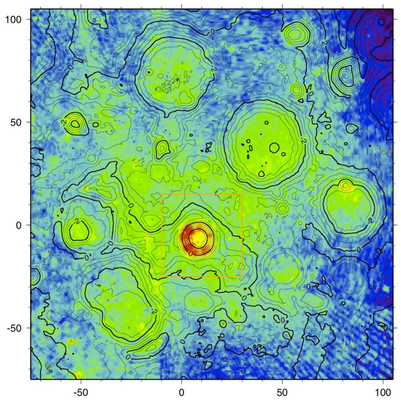

Fig 3 Bi-directional reflectance at 1064 nm over a 200 km square region at the south pole. Shackleton crater is in the center and shows anomalous brightness compared to the surrounding region.

Observations represent active reflectivity at 1064 nm during Shackleton Spring 2010. Figure 3 shows bi-directional surface slopes over baselines comprising footprints from 2 successive shots with a minimum cross-track dimension of 10 m and a maximum along-track dimension of 90 m. Shackleton's floor is clearly darker than the walls but brighter than the surrounding terrain [2]. Other small areas within craters also show brightening. Cause of brightening is at present unknown but most likely the result material on the crater walls sliding down to the crater floor and exposing a fresh surface that has not undergone weathering from solar radiation.

2. Summary and Conclusions

The high spatial resolution and radial accuracy LOLA observations of the lunar south polar region show higher reflectance in some permanently shadowed craters but not all, and roughness that is frequently greatest on the crater rims. The selection of future robotic landing sites from altimetry and imaging data will need to contend with limited sunlight even at high elevations and being in close proximity to high slopes as well as areas of high roughness.

References

[1] Smith, D.E. et al, Initial observations from the Lunar Orbiter Laser Altimeter, Geophys. Res. Lett., 37, L18204, 2010.

[2] Zuber et al, Constraints on the volatile distribution within Shackleton crater at the lunar South Pole, Nature, 2012, accepted.