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Modelling surface roughness and rocks in LRO Diviner observations

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Abstract

The Diviner Lunar Radiometer Experiment on NASA's Lunar Reconnaissance Orbiter (LRO) observes radiance in 7 infrared spectral channels from which brightness temperatures of the lunar surface are derived. In general, Diviner's surface footprint contains small scale variations in temperature. This anisothermality results in different observed brightness temperatures in Diviner's individual channels. A three-dimensional heat diffusion model is used to explore anisothermality in Diviner observations resulting from surface roughness and rocks at multiple length-scales and illumination conditions.

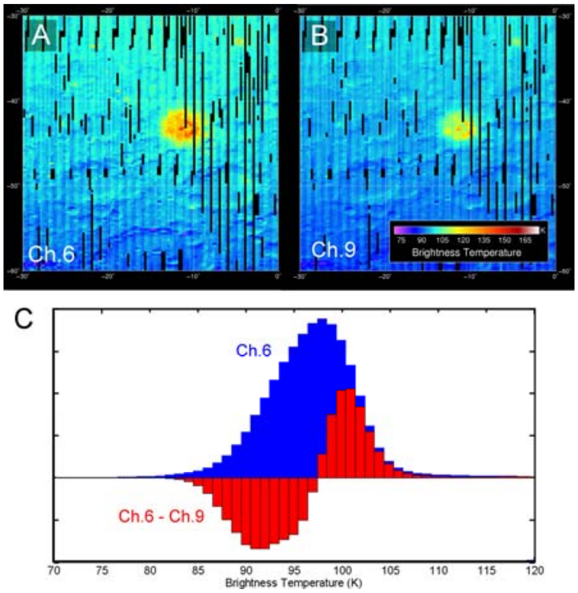

Figure 1: Diviner nighttime brightness temperature map of A) channel 6 and B) channel 9. The quasi-circular warmer feature is Tycho crater. C) Histogram of channel 6 and 6 – 9 temperatures.

1. Introduction

The Diviner instrument is systematically mapping the global thermal state of the Moon [1]. The highly insulating nature of the surface, the lack of an appreciable atmosphere to buffer surface temperatures, and slow rotation allow daytime temperatures to nearly equilibrate with solar flux. Therefore daytime temperatures are influenced by topographic effects and radiative properties. Nighttime temperatures are determined by the radiation of sensible heat stored in the subsurface during the day and therefore are sensitive to the thermophysical properties of the regolith [2]. In general, Diviner's surface footprint contains small scale slopes, shadows, and rocks causing the brightness temperatures in Diviner's individual infrared channels to vary with wavelength (anisothermality) depending on the distribution of sub-footprint-scale temperatures as warmer temperatures have an increased proportional influence on brightness temperature and radiance at shorter wavelengths [3]. Figure 1 shows anisothermality in Diviner nighttime observations. The warmer, quasi-circular feature is the crater Tycho which has excavated large blocks of rocky material.

2. Heat Diffusion Model

We employ a three-dimensional heat diffusion model that balances incident solar radiation with infrared emission and conduction into the subsurface to explore lateral anisothermality in Diviner observations resulting from surface roughness and rocks at multiple length-scales and illumination conditions. This model builds upon previous explicit finite difference one-dimensional layered thermal models like [2] and includes ray tracing of illumination so that slope effects and shadowing at different solar incidence angles can be explored for arbitrary surface geometries.

3. Anisothermality

Roughness generally increases with decreasing scale [4], and therefore Diviner should be most sensitive to the smallest scale capable of maintaining lateral anisothermality. We explore the smallest scale over which roughness is still expressed as anisothermality as a function of solar incidence in daytime temperatures and how anisothermality is influenced by rock sizes in nighttime temperatures.

3.1 Daytime

Daytime temperatures are influenced by slope and shadow effects. Figure 2 demonstrates the dependence on solar incidence angle on anisothermality. The increase in anisothermality and scatter in the data at higher incidence angles results from the increased fractional coverage of shadowed surfaces and increased dependence of phase angle on observed brightness temperatures. The curves show results using a similar model to [5], with a Gaussian slope distribution for a range of rms slopes and employing statistical functions for shadowing [6].

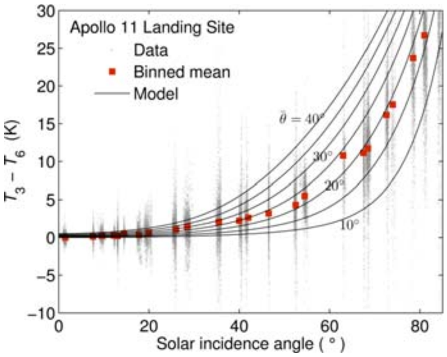

Figure 2: Diviner, channels 3 – 6, daytime observations of the Apollo 11 landing site and modeled temperatures.

3.2 Nighttime

Modeled anisothermality resulting from rocks in nighttime temperatures using our three dimensional heat diffusion model is shown in Figure 3. Nighttime surface temperatures are sensitive to rocks as they can remain warmer than the surrounding regolith throughout the lunar night. Rocky areas will therefore exhibit higher brightness temperatures at shorter wavelengths due to the non-linearity of the Planck function. Larger rocks provide a larger reservoir of sensible heat and remain warmer than smaller rocks of comparable thermophysical properties. As the rocks cool during the long lunar night, anisothermality decreases as temperature differences between rocks and the rock-free regolith diminish.

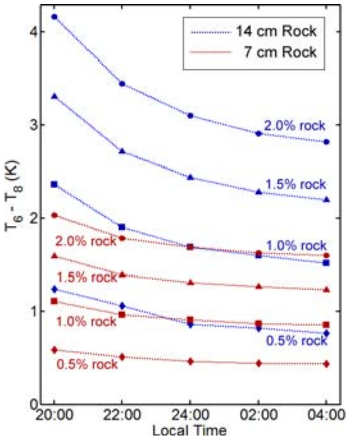

Figure 3: Modeled Diviner channels 6 – 9 brightness temperatures as a function of surface area fraction of rocks and local time for two rock diameters.

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