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# Interpreting LRO Diviner observations of fine-scale lunar surface thermal variability

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## Abstract

The Diviner Lunar Radiometer Experiment on NASA's Lunar Reconnaissance Orbiter (LRO) has been mapping the global thermal state of the Moon since July of 2009. The instrument has acquired thermal emission data in nine spectral channels spanning a wavelength range from 0.3 to 400 microns [1]. Surface temperatures are found to exhibit extreme spatial variability. We employ a 3-D regolith heat flow model to aid in interpreting measured brightness temperatures.

## 1. Introduction

All bodies in the Solar System exchange thermal energy with their environment and investigating their surface energy balance allows us to develop an understanding of how planetary regoliths store, and exchange heat. Diviner is providing the first systematic observations of the global thermal state of the Moon (Figure 1) and its diurnal and seasonal variability providing the ability to characterize the lunar thermal environment, one of the most extreme of any planetary body in the solar system due to the lack of an appreciable atmosphere to buffer surface temperatures [2]. This provides an opportunity to study heat flow dominated by solar forcing in the upper most part of a planetary body with negligible atmosphere and understand what the observed surface temperatures imply about the thermal state of the regolith.

## 2. Brightness Temperatures

An example of Diviner data is show in Figure 1 depicting a map of daytime thermal emission for the south polar region of the Moon. The mapped quantity is the bolometric brightness temperature, a measure of the spectrally integrated flux of infrared radiation emerging from the surface, and is computed from the measured brightness temperatures in the Diviner infrared channels. For the purposes of quantifying the overall heat balance of the surface and comparing with available models, the bolometric brightness temperature is the most fundamental and interpretable measurable quantity. In the general case where Diviner's surface footprint contains small scale slopes, shadows, or rocks, the brightness temperatures in Diviner's individual infrared channels may vary with wavelength depending on the distribution of sub-footprint-scale temperatures, spectral emissivities and photometric properties and therefore the bolometric brightness temperature cannot be interpreted in terms of a unique surface

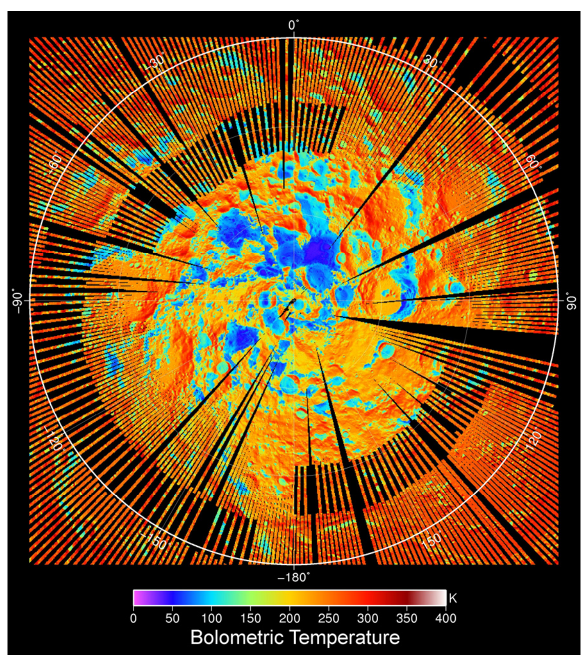


Figure 1: Diviner measured daytime bolometric brightness temperatures of the lunar south pole binned at 240 m pix$^{-1}$ in polar stereographic projection using data acquired during the period of 10/17/2009 to 11/13/2009.

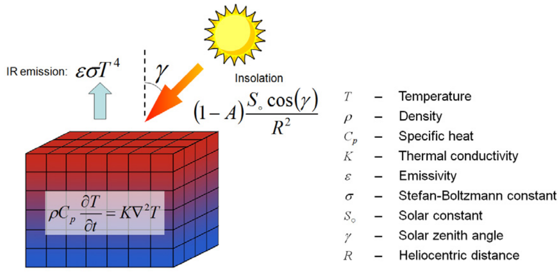


Figure 2: Diagram depicting three-dimensional heat flow model.

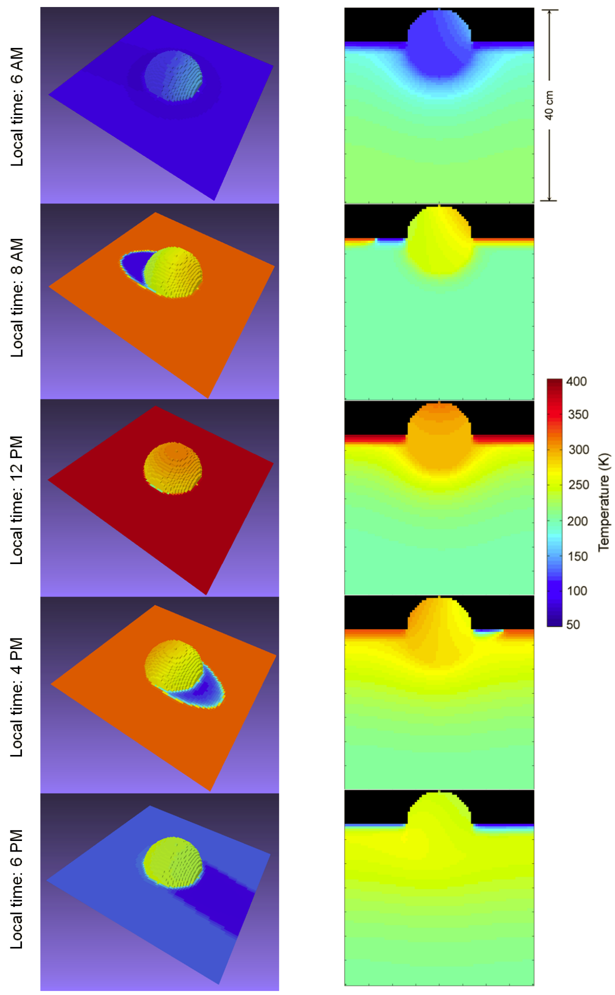


Figure 3: Model with topography and ray tracing demonstrating shadow and slope effects on daytime surface temperatures with 81×81×81 node model and 14 cm diameter spherical rock protruding from surface.

temperature. With a three dimensional regolith heat flow model, we explore how slope effects and rocks within a scene affect observed brightness temperatures. How surface roughness and rocks at different length-scales influences brightness temperature observations is not well understood and is important to quantify for interpretation of thermal data sets.

## 3. Heat Flow Model

Our 3-D heat flow model (Figure 2) builds upon previous explicit finite difference one-dimensional layered thermal models like [3] and [4]. These models balance incident solar radiation with infrared emission and conduction into the subsurface. Our model is extended to three-dimensions and includes ray tracing of illumination from the Sun and to an observer so that arbitrary geometries can be explored and model results tied to Diviner observations.

## 4. Results

Results are shown in Figure 3 using thermophysical properties of the regolith selected to match Apollo heat flow experiments [4] and include a 2 cm thick low density surface layer, $\rho$ =1250 kg m$^{-3}$, atop layers increasing in density to $\rho$ = 1900 kg m$^{-3}$ and temperature dependent thermal conductivity and specific heat. The model has an embedded 14 cm spherical rock ($\rho$ = 3000 kg m$^{-3}$) to demonstrate how shadows and slopes result in more complex daytime temperatures and observed temperatures will vary with viewing geometry relative to the sun angle.

## References

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