IMPROVED NIGHTTIME TEMPERATURE MAPS FROM LRO DIVINER WITH A MODEL FOR TOPOGRAPHIC REMOVAL. T. M. Powell[1] (tylerpowell@ucla.edu), T. Horvath[1], V. Lopez Robles[1], J.-P. Williams[1], P. O. Hayne[2], C. L. Gallinger[3], B. T. Greenhagen[4], D. S. McDougall[5], and D. A. Paige[1], [1]University of California, Los Angeles, [2]University of Colorado, Boulder, [3]University of Western Ontario, [4]Johns Hopkins University Applied Physics Laboratory, [5]Brigham Young University.

Introduction: The Diviner Lunar Radiometer Experiment on the Lunar Reconnaissance Orbiter (LRO) has been mapping the emitted infrared radiation of the Moon since July 5, 2009 [1]. Diviner has since collected over 500 billion radiometric measurements with excellent spatial and local time coverage. Diviner data has been used to create global maps of surface temperature, derived thermophysical properties, and composition. However, the most recently published global maps [2,3,4] use data collected from the start of the mission until 2016. Since that time, Diviner coverage has improved substantially.

We compile the full ~12 years of Diviner data to produce updated maps of nighttime brightness temperature, bolometric temperature, and derived regolith temperature and rock abundance. The greater data volume results in improved spatial and local time coverage and better signal-to-noise ratios. In addition, we employ several key improvements to our data processing method: 1) Angular offset errors in instrument pointing have been corrected, resulting in improved localization of Diviner measurements; 2) past effective field of view (FOV) modeling [5] used to determine the center of each Diviner observation accounting for topography and spacecraft motion has been optimized to produce sharper maps; and 3) curve fitting of nighttime temperatures is used to interpolate temperatures at a uniform local time. The resulting maps are noticeably sharper than previous data products. We estimate a ~2-3 times increase in the effective resolution of Diviner maps.

Nighttime temperature maps are valuable because they are diagnostic of the thermophysical properties of the surface. However, differences in temperature can also be caused by topography, so it is often desirable to remove these effects. In this work, we present a model for topographic subtraction which accounts for scattered and emitted radiation from surrounding surfaces.

Model for Topographic Removal: Topography and latitude influence lunar surface temperatures in several ways. Local slope and latitude determine the amount of direct solar illumination incident on a surface. Previous Diviner maps [4] have implemented a simple correction for slope where: 1) the effective latitude of a particular pixel is shifted from that of a flat surface by the north-south component of the slope; and 2) the effective local time is shifted by the east-west component of the slope.

Additionally, surrounding topography can scatter and emit radiation onto a surface, causing more heating than would be expected for a region with flat surroundings. The total amount of land emission received is determined by the emission from each pixel within the FOV weighted by incidence angle i and integrated over all spherical angles Ω: $Q_{LAND-IR} = \int \epsilon\sigma T^4 \cdot \cos i \, d\Omega$, where ϵ is emissivity, σ is the Stefan-Boltzmann constant, and T is the temperature of each pixel [6]. This can be approximated as $Q_{LAND-IR} = \epsilon\sigma T_{LAND}^4 \cdot f_{LAND}$, where the land factor f_{LAND} describes the amount of land within the FOV (weighted by $\cos i$), and T_{LAND} is an equivalent scene temperature which produces the same total emission as the entire scene.

We use the SLDEM 2015 topographic map [7] to calculate f_{LAND} and T_{LAND} for each pixel. Figure 1 shows an example for the Apollo 17 landing site. A horizon profile is constructed by finding the maximum elevation angle in 10° azimuth angle increments. This is used to calculate f_{LAND} and to find sunset and sunrise times. T_{LAND} is calculated by averaging the emission received from pixels in 10° azimuth angle and 1° elevation angle increments. These parameters are input into a 1-dimensional thermal model [4] to determine the expected temperature of each pixel. The temperature anomaly (ΔT) is the difference between the Diviner observations and the model temperature.

Results: Figure 2 shows ΔT for an example region with progressively increasing levels of topographic removal: A) latitude correction, B) simple slope correction, and C) land scattering and emission correction. Most large-scale topographic features are removed by a simple slope correction. However, many smaller features, most notably bowl-shaped craters, remain warmer than their surroundings. These features mostly vanish when scattering and emission is accounted for, indicating that the elevated temperature in many bowl-shaped craters is due to topographic effects, and does not necessarily indicate a difference in thermophysical properties. These improved temperature maps better isolate differences in thermophysical properties by largely removing topographic effects.

References: [1] Paige et al. (2010) *Space Sci. Rev. 150*, 125-160. [2] Bandfield et al. (2011) *JGRP, 116*. [3] Williams et al. (2017) *Icarus 283*, 300-325. [4] Hayne et al. (2017) *JGRP, 122,* 2371-2400. [5] Williams et al. (2016) *Icarus, 273*, 205-213. [6] Aharonson et al. (2006), *JGR, 111*, E11007. [7] Barker et al. (2016) *Icarus, 273*, 346-355.

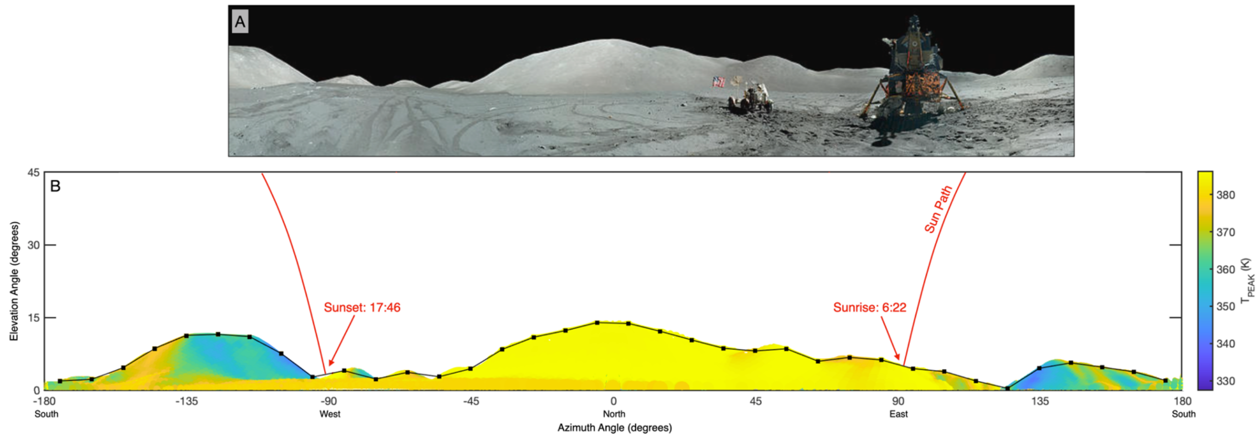

Figure 1. A) A panorama taken at the Apollo 17 landing site (30.772˚E, 20.191˚N) and B) a panorama of the same region constructed using the SLDEM 2015 topographic map [7]. Peak temperatures are calculated assuming radiative equilibrium with solar illumination. The horizon profile (black line) and peak temperatures are used to calculate f_{LAND} and T_{LAND}, which describe the amount of scattered and emitted radiation that contribute to the energy balance at the Apollo 17 landing site. The horizon profile is also used to calculate the sunrise and sunset times.

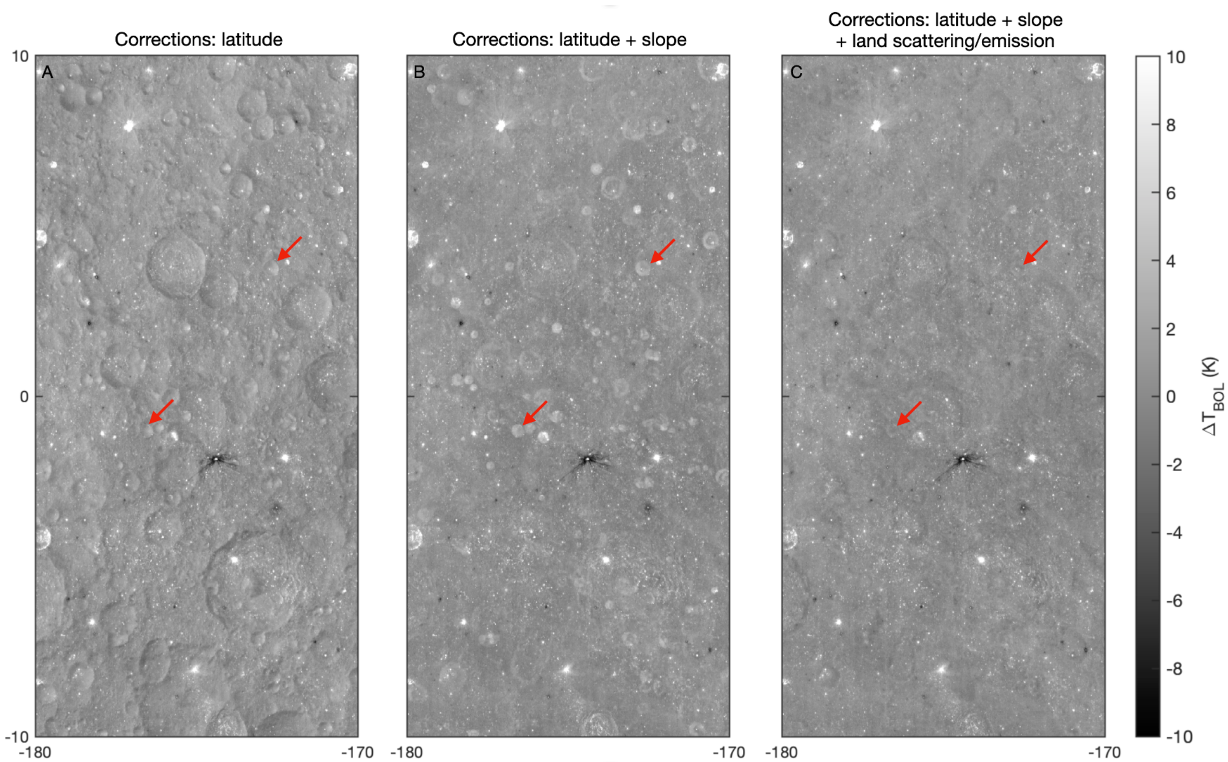

Figure 2. An example region showing the midnight bolometric temperature anomaly with different levels of topographic removal: A) correction for latitude, but no topography correction; B) correction for latitude and slope angle, but not for surrounding topography; and C) a correction for latitude, slope angle, and surrounding topography. The red arrows show examples of bowl-shaped craters which remain warmer than their surroundings when only slope and latitude are accounted for. These features mostly vanish when scattering and emission from surrounding topography is included.