EXPLORING THE EFFECT OF SMALL-SCALE TOPOGRAPHY ON SURFICIAL TEMPERATURES AT THE LCROSS IMPACT SITE. C. W. Hayes[1], D. A. Minton[2], J. L. Kloos[3], and J. E. Moores[1], [1]Centre for Research in Earth and Space Science, York University, Toronto, ON, [2]Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, West Lafayette, IN, [3]Department of Astronomy, University of Maryland, College Park, MD.

Introduction: As we enter the new era of lunar exploration, there has been increased interest in the permanently-shadowed regions (PSRs) that exist near the Moon's poles. PSRs are of scientific interest because, in the absence of direct solar illumination, they can maintain extremely low temperatures (<110K) over geologically long timescales [1, 2]. This means that they can act as "cold traps" where volatile molecules like water can remain stable instead of rapidly sublimating away as they do elsewhere.

Because the sublimation rate of ice in a vacuum is strongly dependent on temperature, temperature maps are a powerful tool for assessing the total area available for the cold-trapping of various volatile species. Since 2009, the Diviner Lunar Radiometer Experiment onboard the Lunar Reconnaissance Orbiter has been constructing global temperature maps of the lunar surface, allowing us to determine the spatial extent of the largest PSRs for the first time.

Although the resolution of Diviner's polar temperature maps (240 meters/pixel) is sufficient for examining large-scale trends in temperature, these maps are necessarily averaging over fine details at smaller scales. It has been shown that so-called "micro cold traps" below the resolution of orbital datasets outside of the large PSRs can significantly impact the Moon's total cold trapping area [3], so it is reasonable to assume that a similar effect takes place within the PSRs themselves, creating "micro ultra-cold traps" that could expand the area available for the cold trapping of highly volatile molecules. We will be examining this effect at the Lunar Crater Observation and Sensing Satellite (LCROSS) impact site, as doing so allows us to link modeled and observed abundances of different volatile species.

Methods:

Terrain upscaling. Our terrain maps are derived from the 240 m pix^{-1} Lunar Orbiter Laser Altimeter (LOLA) polar digital elevation models (DEMs). We first extract a 10-pixel by 10-pixel region surrounding the LCROSS impact site from the south polar DEM, then upscale it to our target resolution of 1 m pix^{-1} using bivariate spline interpolation.

The interpolation process creates a perfectly smooth surface, which is not representative of real-world conditions. To approximate the lunar surface in a more realistic manner, we use the interpolated terrain as an input to the Minton et al. [4] Cratered Terrain Evolution Model (CTEM), which generates a cratered terrain with an appropriate equilibrium crater size-frequency distribution (SFD). We have truncated the upper limit of the equilibrium SFD to prevent the production of craters that would be visible at the original resolution of the DEM. The version of the CTEM used here also does not include a crater ray model.

Illumination. As there are a number of illumination sources incident upon the lunar surface at any given point, it would be computationally infeasible to model them all. Instead, we choose to focus on the dominant sources: direct solar illumination for the non-PSR terrain and singly-scattered sunlight and infrared emissions from directly-illuminated surfaces for the PSR terrain.

The terrain visible from the impact site (the "light-scattering terrain") is determined by assessing whether a line of sight exists between the impact site and all non-PSR terrain within 400 km using the 240 m pix^{-1}

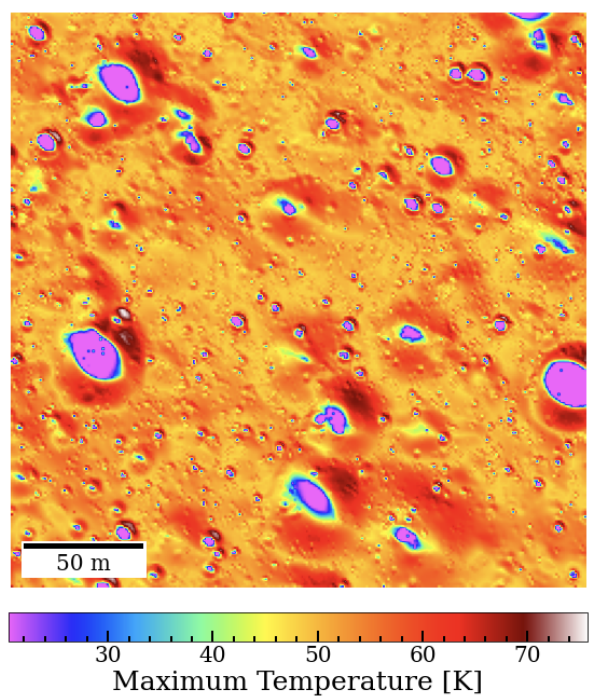

Figure 1. *Maximum temperatures experienced by the 240 metre Diviner pixel containing the LCROSS impact site at a resolution of 1 m pix^{-1}.*

LOLA south polar DEM. Using the "horizons method" [5], we generate two types of horizons: "absolute horizons" for the light-scattering terrain, used to determine direct solar illumination; and "local horizons" for the upscaled PSR terrain, which quantify the extent to which the upscaling process affects the visibility of the light-scattering terrain. The horizons are integrated into a geometric illumination model with the Sun as an extended source, though the effects of limb darkening are ignored.

Determining temperatures. To find the surficial temperatures, we use a modified version of the Schörghofer et al. [6] one-dimensional thermal model. To improve the model's performance in the low temperature regime often seen in PSRs, we modify it to include the temperature- and depth-dependence of density, heat capacity, and thermal conductivity from Martinez & Siegler [7].

Results: We find that the upscaled terrain experiences a wide range of thermal environments, ranging from minimums near 20 K in small, doubly-shadowed craters that are shielded from singly-scattered sunlight, to maximums near 75 K (see Figure 1). By the time of the conference, we anticipate having a more robust analysis of the implications that this thermal environment has on the potential distribution of volatile species and how it compares with the measurements made by LCROSS.

We can validate our results against Diviner measurements of the impact site by using a linear mixing model of Planck spectra to determine what temperature Diviner would measure if it were to observe our simulated terrain. That comparison is presented in Figure 2, where we can see generally close agreement between our model and Diviner measurements. We do slightly undermodel the temperatures, particularly for subsolar longitudes between 230–360°, which we attribute to the fact that we do not include the secondary illumination sources that dominate when the primary sources are absent.

Conclusions: We have modeled surficial temperatures at the LCROSS impact site at a resolution of 1 m pix^{-1} through realistic illumination of an upscaled LOLA DEM. We find that the upscaled terrain experiences a wider range of temperatures than is found in Diviner measurements, suggesting that the total area of the Moon's surface available for the cold-trapping of highly volatile molecules is larger than is implied from Diviner temperature maps.

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References:

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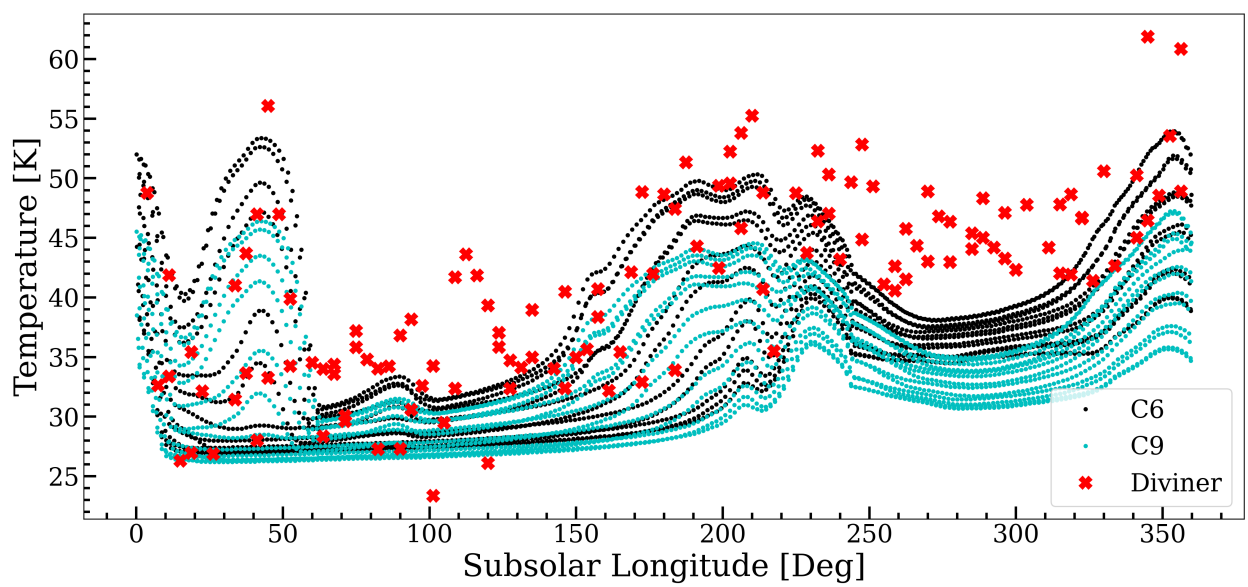

Figure 2. *Comparing measured Diviner temperatures of the LCROSS impact site (red) and modeled Diviner Channel 6 and Channel 9 temperatures of our upscaled surface (black and cyan, respectively).*