THE ALBEDO OF FLOORS OF REGIONS IN PERMANENT SHADOW: COMPARING DIVINER DERIVED ALBEDO TO SHADOWCAM IMAGES. Ireland, S. M.1, P. G. Lucey2, J.-P. Williams3, Prasun Mahanti4, M.A. Chertok1. 1University of Hawaii at Manoa, Honolulu HI, USA, ireland@hawaii.edu, 2University of California at Los Angeles, Los Angeles CA, USA, 3Arizona State University, Tempe AZ, USA.

Introduction: Albedo is a fundamental property of planetary surfaces. It provides insights into the composition of the surface, the degree to which a surface has been exposed to space weathering, and it controls in part the amount of energy absorbed from the Sun or other sources that contribute to the surface temperature.

Albedo is tricky to measure with imagers. Imagers respond to radianc, in part due to albedo but also due to the photometric effect of lighting on highly variable topography. Spectacular full Moon images minimize the effect of photometry and topography by observing near zero phase, where shadows and shading are minimized, but zero phase not available to nadir viewing imagers in orbit at non-equatorial latitudes.

The problem is exacerbated in permanently shadowed regions (PSRs), where instead of benefiting from an assumption that the light source (the Sun) is a point source, lighting is more analogous to a sports stadium, where the light source has limited extent in elevation, but very large extent in azimuth. Developing just such models are on-going [e.g. 1].

To support validation of models that can yield albedo in PSRs, we have developed an empirical method to derive relative spatially-resolved albedo variations in PSR Lunar Reconnaissance Orbiter Diviner observations [2]. This method relies on the fact that most of the lunar surface is in radiative equilibrium with its lighting environment owing to the extreme insulating properties of lunar regolith [3]. As a result, the temperature of the surface is in part controlled by albedo because albedo affects how much of the incident illumination is absorbed by the surface. We have found that the ratio of Diviner’s measurement of solar radianc in its visible-near IR bands to its far IR bands is proportional to local surface albedo and from this relationship we have produced an albedo map of the interior of several large PSR surfaces. Quantitatively, with modest simplifying assumptions, the ratio of the visible to infrared radianc of the floor is $L_{PSR, vis}/L_{PSR, IR} = \frac{A_{wall}[A_{PSR, vis}/(1-A_{PSR, vis})]}{A_{wall}}$, where $L_{PSR, vis}$ is the visible radianc measured by Diviner’s solar channels, $L_{PSR, IR}$ is the thermal radianc measured by Diviner’s far infrared bands, $A_{wall}$ is the albedo of the wall illuminated by the Sun that shines into the PSR, and $A_{PSR, vis}$ is the albedo of the crater floor in PSR. The equations shows that the ratio is a function both of the wall and floor albedos. However, for each small floor surface element evaluated, the wall albedo is averaged over the large solid angle subtended by the wall, so we assume the wall albedo is constant. The function $A/(1-A)$ is not linearly related to $A$, but over a reasonable range of albedos, less than 50%, it is only weakly nonlinear and the floor reflectance relative to wall albedo can be derived from fitting the data using the simple model.

Data: Diviner Channel 1 (400-3000 nm) and Channel 8 (50 to 100 microns) [1] observations acquired over various portions of the mission were used in this analysis. Radiance values were extracted for a grid of small surface elements for each of several PSRs over various 1-year periods during the mission. The first year (2009-2010), where the orbit of LRO passed near the pole, featured many orbits passing over Haworth crater enabling the results shown here. The latitude and longitude range defining Haworth is 86.2°S-88.3°S and 19.6°W-28.9°E.

Method: Haworth crater was divided into a grid of 125x125 pixels corresponding to a spatial sample of about 500 m/pixel. Every Diviner data point falling within each grid square was extracted. A linear fit to the visible and far IR data was computed, and the ratio reported out as the slope. A fit is required because the far IR radianc sometimes includes a background of minor residual cooling of the surface in the absence of radiative load. A plot of the two radiances for a single grid element is shown in Figure 1, with its fit superimposed. Because actual nighttime data occurs so frequently and can dominate the derived slope, data with visible radianc values below 0.02 watts/m² are excluded.

![Figure 1. Correlation of Diviner solar band (Channel 1) with Diviner far infrared thermal radianc (Channel 8) for a lat-lon bin. The slope is proportional to PSR albedo for that surface element.](1629.png)

Results: The Diviner-derived map of the floor of Haworth is shown in Figure 2a. A ShadowCam [4] mosaic of the Haworth interior is shown in Figure 2b. For context, LOLA laser reflectance [5] and LOLA DEM
[6] shaded relief are also shown. There appear to be three, or possibly four, albedo units, defined using the context from ShadowCam: Floor material, crater material, wall material, and low albedo material. The floor is relatively low albedo, with modest variation, some of which could be artifacts of the image creation process. Crater deposits are often bright, and high albedo seems confined to pole-facing slopes. Some Haworth wall deposits are also bright, with intricate albedo textures as seen in ShadowCam images. Regions exterior to Haworth have been grayed out as these areas included high radiance from illuminated surfaces that invalidated the fits (the relationship between illuminated solar and IR radiance differs from that in shadow). The small “islands” of data outside the crater were not illuminated in the first year, and are not all PSR.

Discussion: The derivation algorithm has clearly revealed variations in albedo well above the noise level within the Haworth PSR. These units are associated with morphological features within Haworth that include steep slopes that may have exposed fresh material through mass wasting. The patterns on the northwest wall of Haworth are complex, but we have not yet compared these with control craters at lower latitudes to assess if they are unusual.

It is clear from inspection that the quality of the albedo data within the PSR far exceed that of the LOLA laser reflectance at this scale. However, LOLA benefits from absolute calibration of its data to normal albedo; we expect that our ultimate data products will be scaled to large averages of LOLA data, for example, averaging the floor of Haworth.

These results are complementary to ShadowCam images where the effect of albedo is muted by the effects of indirect lighting [7]; together the date sets will improve understanding of the materials within PSRs.


Figure 2. Result for south polar Haworth crater. Upper left: Diviner-derived relative albedo. Upper right: ShadowCam radiance. Lower left: LOLA DEM Hillshade. Lower right: LOLA laser reflectance-derived 1064 nm normal albedo.