**LRO MULTI-INSTRUMENT STUDY OF ILLUMINATION CONDITIONS AND PHYSICAL PROPERTIES OF THREE LUNAR SOUTH POLE PERMANENTLY SHAPED REGIONS.** K. E. Mandt¹, E. Mazarico², T. K. Greathouse³, K. D. Retherford¹, G. R. Gladstone³,4, B. Byron³,4, D. M. Hurley¹, A. M. Stickle¹, G. W. Patterson¹, A. R. Hendrix⁵, J.-P. Williams⁶, Y. Liu⁷, and M. Lemelin⁸. ¹Johns Hopkins University Applied Physics Laboratory, Laurel, MD (Kathleen.Mandt@jhuapl.edu), ²Goddard Space Flight Center, ³Southwest Research Institute, San Antonio, TX, ⁴University of Texas at San Antonio, ⁵Planetary Science Institute, Los Angeles, CA, ⁶University of California at Los Angeles, ⁷Lunar Planetary Institute, Houston, TX, ⁸York University, Toronto, Canada.

**Introduction:** The south pole of the Moon is an area of great interest for exploration and scientific research because many low-lying regions are permanently shaded (PSRs) and are likely to trap volatiles for extended periods of time, while adjacent topographic highs can experience extended periods of sunlight. A primary goal of the Lunar Reconnaissance Orbiter (LRO) mission [1] is to characterize the spatial and temporal variability of water on the Moon, with a focus on the PSRs. The physical properties of the regolith within the PSRs as well as the temporal variability of illumination are of critical importance for achieving this goal. We have compiled observations from multiple LRO instruments to conduct a comparison with far ultraviolet (FUV) observations made by the Lyman Alpha Mapping Project (LAMP) [2] to evaluate illumination at the lunar south pole (within 5° of the pole).

**LRO-LAMP Mapping:** LAMP observations are made through passive remote sensing in the FUV wavelength range of 57-196 nm using reflected sunlight during daytime observations and reflected light from the IPM and UV-bright stars during nighttime observations [2,3]. Observations in the FUV can provide information about surface frost and porosity of the regolith [3].

In this study we focused on the region within 5° of the south pole, (Fig. 1) and produced maps using nighttime data taken between September 2009 and February 2014. Summing over long time periods is necessary to obtain sufficient signal to noise. We show here several of the maps produced for this study, including brightness and albedo in the “Off Band” [3], or 155-190 nm, where we are able to observe scattered sunlight at low solar zenith angles (SZA). To isolate scattered sunlight observed by LAMP from reflected light by the interplanetary medium (IPM) and UV-bright stars we subtract the albedo measured with a SZA > 91° from the albedo mapped using all observations.

LAMP observes scattered sunlight in the three largest PSRs during nighttime observations: Haworth, Shoemaker, and Faustini. We focus on these craters for comparisons with other LRO datasets and with an illumination model [4]. We resample the datasets and model to the LAMP map resolution and search for correlations that may provide useful information on surface properties within the PSRs.

**Additional LRO Observations:** We compared the LAMP maps with observations by LRO Diviner, Mini-RF, and the Lunar Orbiter Laser Altimeter (LOLA). Diviner has measured the minimum, average and maximum temperature of the top few cm of regolith [5]. The temperature varies with illumination conditions and is directly relevant to the stability of water in the PSRs. Mini-RF measures the Circular Polarization Ratio (CPR) of the upper meter(s) of the surface. High values can be interpreted either as ice or increased surface roughness [e.g., 6]. Finally, LOLA normal albedo measurements can be used to infer ice or other properties such as porosity and grain size of the top few microns of regolith [7].

Therefore, each dataset provides unique information about surface properties, but some results could be interpreted in multiple ways. In order to determine what information is available in these datasets about properties within the PSRs, we conducted a multivariate pair-
wise correlation study of these datasets and the illumination model [4]. The combined datasets for Haworth are shown in Fig. 2.

Figure 2: Comparison of LAMP maps of scattered sunlight with other LRO datasets for Haworth: (a) slopes from LOLA topography; (b) elevation from LOLA topography; (c) LAMP excess albedo showing scattered sunlight; (d) 1064 nm phase function; (e) 174 nm phase function; (f) 184 nm phase function; (g) LOLA normal albedo; (h) West-looking Mini-RF CPR; (i) East-looking Mini-RF CPR; (j) Minimum temperature; (k) Average temperature; (l) Maximum temperature from Diviner.

Illumination Model: Modeling using topographic data has provided estimates of PSR extent and percent illumination of sunlight peaks [4]. This work is also designed to estimate the thermal balance in PSRs based on scattered sunlight, which varies diurnally and seasonally. The model first calculates the amount of sunlight scattered into the PSR and then determines the amount scattered to LRO using a wavelength-dependent phase function. The initial model results used the phase angle for the LOLA wavelength of 1064 nm, but we have added simulations for phase functions relevant to LAMP wavelengths of 174 and 184 nm [8]. A more detailed model is in development that uses the location of LRO to predict the illumination that LAMP should observe is in development. Preliminary results of this model for all three PSRs are illustrated in Fig. 3.

Figure 3: Illumination conditions predicted to be observed by LAMP at specific time periods of operation for LRO for Haworth (left), Shoemaker (center) and Faustini (right).

Results: In our statistical study, we calculated the Pearson correlation coefficient for each pairs of data and the probability that the datasets are not correlated, or the p-value. If the p-value is less than 0.01 we conclude the probability that the datasets sets are correlated.

We first found that the original illumination model does not correlate with the LAMP observations of scattered sunlight, leading to the newer model and more studies. The LAMP scattered sunlight observations correlate very well with the Diviner maximum temperature, in agreement with the idea that scattered sunlight would heat the upper layer of regolith.

The correlation study provided interesting results for comparisons with LOLA. The LOLA normal albedo correlates well with the maximum temperature and the CPR suggesting a possible surface roughness effect to the LOLA observations. LOLA is also anticorrelated with the LAMP Lyman-α albedo, a point noted by [7] as needing further investigation.