LRO-LAMP OBSERVATIONS OF LUNAR SOUTH POLE PERMANENTLY SHADED REGIONS. K. E. Mandt[1], T. K. Greathouse[1], K. D. Retherford[1], G. R. Gladstone[1], A. R. Hendrix[2], A. F. Egan[3], D. M. Hurley[4], P. D. Feldman[5] and W. R. Pryor[6], [1]Southwest Research Institute, Space Science & Engineering, PO Drawer 28510, San Antonio, TX 78228 kmandt@swri.org, [2]Planetary Science Institute, Los Angeles, CA, [3]Southwest Research Institute, Boulder, CO, [4]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, [5]Johns Hopkins University, Baltimore, MD, [6]Central Arizona University, Coolidge, AZ.

Introduction: The Permanently Shaded Regions (PSR) of the Moon are of great interest as potential locations for future in situ exploration and sample return studies. Of particular interest are illumination conditions within the PSRs [1] and the potential volatile content within the PSR's [2-6]. We have conducted a study of Lunar Reconnaissance Orbiter (LRO) Lyman Alpha Mapping Project (LAMP) [7] observations covering more than three years to evaluate illumination conditions and volatile inventory as a function of lunar season.

Mapping the South Pole in Ultraviolet: The LAMP team has created a local area mapping software package to evaluate targeted regions of the moon. This tool is capable of producing data cubes of up to 20°x20° degree (latitude and longitude) spatial coverage with square surface sampling as small as 250 m x 250 m. These data cubes consist of surface maps at 69 independent wavelengths (55.57-193.57 nm at 2 nm resolution) covering the entirety of the LAMP bandwidth. Figure 1 illustrates the average albedo of the South polar region of the moon at Lyman-α wavelength bin (119-125 nm).

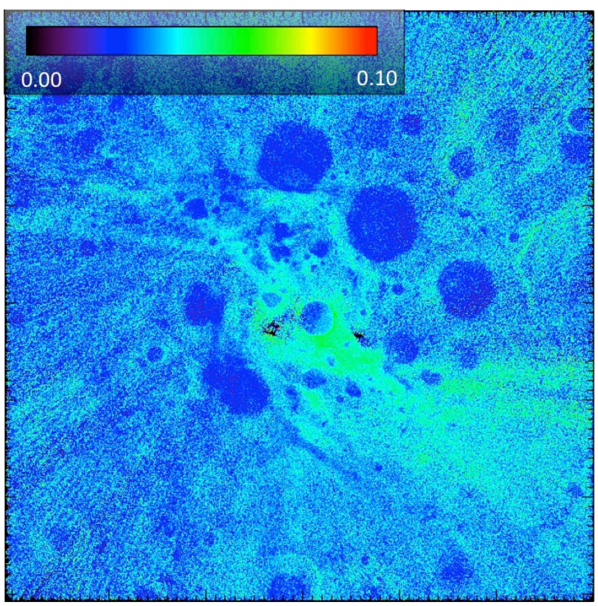


Figure 1: Average Lyman-α albedo of the south polar PSR's as measured by LAMP between September 2009 and October 2013 at 500 meters per pixel.

In Figure 1, the PSRs are the portions of the map that have a lower UV albedo than their surroundings. A lower albedo for PSRs is generally true across the entire wavelength range covered by LAMP [6]. Nighttime maps of the lunar PSRs show that sunlight scatters into the interiors of the PSRs for particular lunar orbital geometries, highlighting features observed in topographic maps. Figure 2 compares a Lunar Orbiter Laser Altimeter (LOLA) topographic map of Haworth Crater with a LAMP map of the crater in the longer wavelengths (155-190 nm) produced using data taken during the southern lunar summer months. This longer wavelength band is most sensitive to scattered sunlight and/or surface water frost signatures. Several smaller craters located inside the PSR are distinctly illuminated by the scattered sunlight showing that ultraviolet light scatters into the PSRs during the southern summer months.

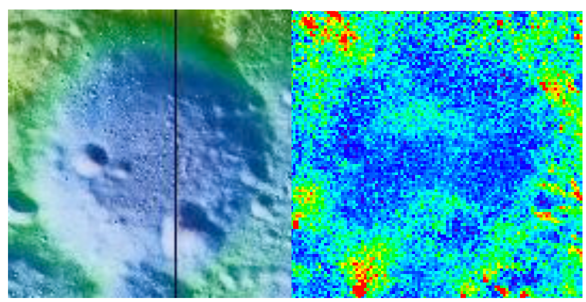


Figure 2: LOLA Topographic map of Haworth Crater (left) compared to LAMP map of Haworth Crater in the wavelengths range of 155-190 nm.

Figure 3 shows LAMP maps of Shoemaker Crater in the same wavelength range (155-190 nm) for each of the four southern lunar seasons. When compared to the LOLA topographic map in Figure 4, it is clear that different features are highlighted during different seasons. In fact, only the top left portion of the crater does not appear to be exposed to scattered sunlight at any point during the entire year. The variability in exposure to very small amounts of scattered sunlight within the PSRs may lead to complex spatial variability in the volatile content of the PSRs that is difficult to resolve with LAMP's limited spatial resolution and counting statistics. However, we can evaluate the temporal variability in the average spectrum of the

PSR interior to study the influence of scattered sunlight on volatile retention within the PSRs.

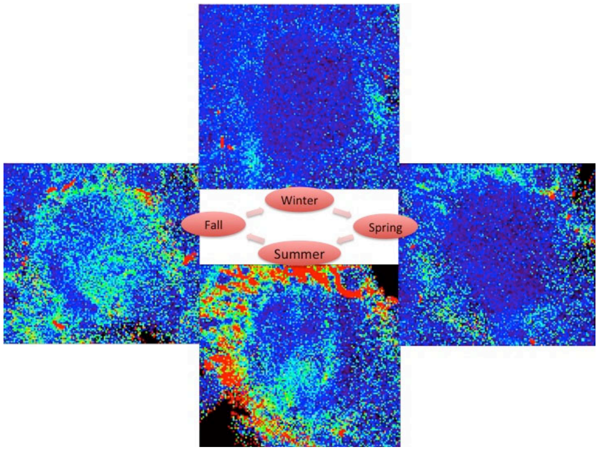


Figure 3: Maps of average LAMP albedo in the wavelength range of 155-190 nm for Shoemaker Crater during the four southern seasons.

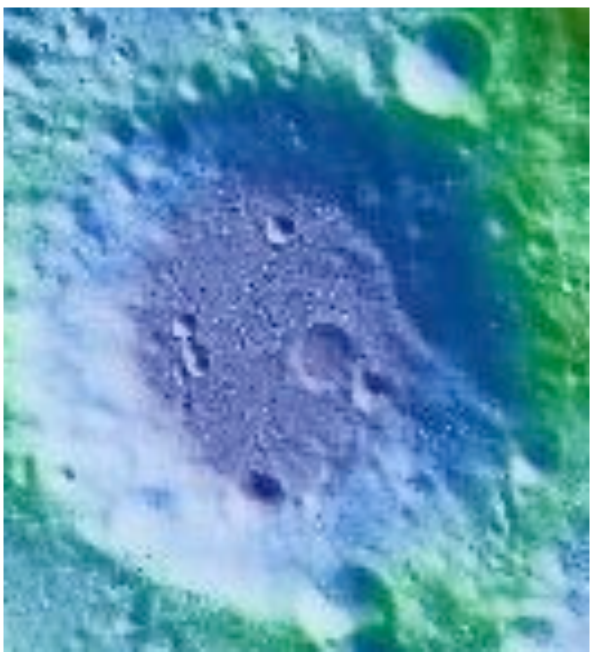
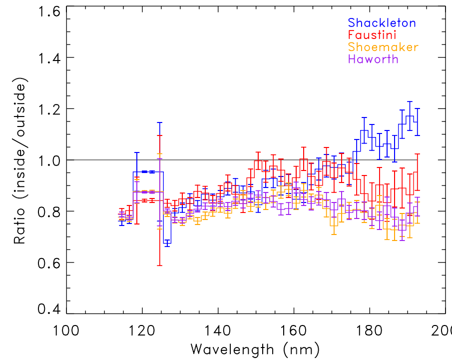


Figure 4: LOLA Topographic map of Shoemaker Crater.

Spectral studies: As demonstrated in [6], evaluations of the LAMP spectral data require restricting observations by solar zenith angle to ensure that scattered sunlight does not contaminate albedo determinations in the wavelengths greater than 155 nm. The maps shown in Figures 2 & 3 include data that is excluded from spectral studies only because the goal for these maps is to illustrate observations of sunlight scattered into the PSRs. When we restrict the data to solar zenith angles greater than 91 degrees our spectral evaluations are limited to winter (Figure 5) and spring (Figure 6) timeframes. These spectra include the data used in [6] and the LAMP datasets delivered to the PDS and are relatively free of contamination due to scattered sunlight.



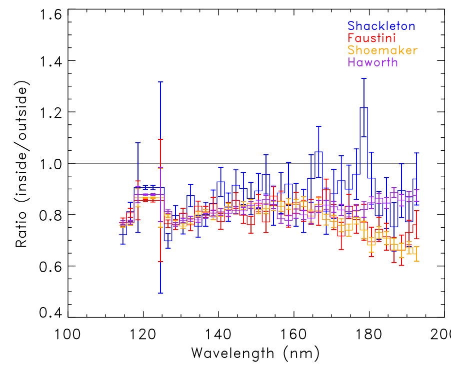


Figure 5: Ratio of the average LAMP albedo for the PSR interior to the average albedo of the region between -80^{o} to -90^{o} S measured during the Lunar winter (top) and spring (bottom).

Figure 5 shows the ratio of the average spectrum inside each of the PSRs to the spectrum of the entire region between the pole and -80^{o} latitude, including the PSRs. In all cases except for Shackleton, the PSR has a lower albedo (i.e. ratio < 1) than the south polar region across all wavelengths. With the exception of Shoemaker, the relative albedo inside each of the PSRs seems to vary with time. Future refinements to these analyses are now in progress. The next delivery of LAMP maps to the PDS will include quality flags regarding the solar zenith angle filtering criteria.

References: [1] Mazarico, E. et al., (2011) *Icarus* 211, 1066-1081. [2] Haruyama J. et al., (2008) *Science, 322,* 938–939. [3] Zuber M. T. et al. (2012) *Nature, 486,* 378–381. [4] Thomson, B. J. et al. (2012) *GRL, 39*, L14201. [5] Miller R. S. et al. (2012) *JGR, 117*, E11007. [6] Gladstone, G. R. et al. (2012) *JGR, 117*, E00H04. [7] Gladstone, G. R. et al. (2010) *SSRv, 150*, 161–181. [8] Smith, D. E. et al. (2010) *SSRv, 150,* 209-241.