LUNAR HYDRATION MEASUREMENTS BY LRO/LAMP. A. R. Hendrix[1], T. K. Greathouse[2], K, D. Retherford[2], K. E. Mandt[2], G. R. Gladstone[2], D. E. Kaufmann[3], D. M. Hurley[4], P. D. Feldman[5], W. R. Pryor[6], S. A. Stern[3]; [1]Planetary Science Institute, Tucson, AZ, arh@psi.edu; [2]Southwest Research Institute, San Antonio, TX; [3]Southwest Research Institute, Boulder, CO; [4]Applied Physics Laboratory, Johns Hopkins University, Laurel, MD; [5]Johns Hopkins University, Baltimore, MD; [6]Central Arizona College, AZ

Introduction: Lunar hydration signatures have been observed by a handful of instruments and, while still not well understood, represent an exciting prospect. Future missions are being planned to locate and exploit lunar water. In the meantime, we utilize the unique measurements from the current Lunar Reconnaissance Orbiter (LRO) mission to study this phenomenon. The Lyman Alpha Mapping Project (LAMP) onboard LRO senses a strong water absorption edge indicating hydration in small abundances in the permanently shadowed regions [1] as well as on the lunar dayside [2]. In this study, we seek to confirm and strengthen the dayside LAMP hydration results [2] by using additional data (not available during that earlier study) and supplementary methods.

Background: Several observations have pointed to water and hydrated species on the Moon. *Vilas et al.* [3] first suggested the presence of water-bearing minerals (indicated by the presence of the broad 0.7 μm charge transfer band in oxidized iron) near the lunar south pole from Galileo Solid State Imager (SSI) broad band spectra. Data from the Moon Mineralogy Mapper (M^3) on Chandrayaan-1 measured the spectral signatures of adsorbed water (near 3 μm) and hydroxyl (near 2.8 μm), finding them to be strongest at high latitudes and at several fresh craters [4]. *Clark et al.* [5], in a re-processing of the M^3 data, showed that the water-related absorptions appear also at lower latitudes. The M^3 detections were verified using Cassini Visual and Infrared Mapping Spectrometer (VIMS) data [6] and Deep Impact data [7], which showed the OH and H_2O absorptions to vary with temperature (related to time of day); the Deep Impact data also found that the diurnal changes in hydration are stronger in mare regions than in highlands regions. A likely scenario (e.g., [8][9]) is that solar wind protons interact with the lunar regolith, reacting with iron oxide (FeO) to form H_2O. The adsorption coefficient of H_2O could be variable based on temperature (the highlands being cooler than the maria due to their higher visible albedo) or composition (ilmenite in the maria versus silicates in the highlands), either of which could result in the different diurnal hydration changes in the maria and highlands [10]. Similarly, the diffusion time of implanted solar wind can vary as a function of composition and temperature, which might produce the spatial and temporal variations [11]. More laboratory work is required to understand these observations.

LRO/LAMP Data: LRO LAMP has been making measurements of the lunar nightside, dayside and atmosphere since September 2009. The LAMP instrument [12] is a photon-counting imaging spectrograph. The entire passband is 57–196 nm, in the far-UV (FUV) spectral region. For dayside measurements, the instrument is operated in “pinhole” mode, with the entrance aperture reduced by a factor of 736. The instrument was usually nadir-pointed in LRO’s characteristic 50-km lunar orbit of the prime mission and provided ~500 m resolution during that phase of the mission. In 2011, LRO’s orbit was modified to an elliptical orbit that results in up to ~2 km resolution when at the north pole and ~300 m at the south pole.

To determine the lunar FUV reflectance, we divide the LAMP data from any selected region by the full-disk solar spectrum from SORCE SOLSTICE [13], taken for the day of each observation and convolved to agree with the LAMP resolution and line spread function. Sample LAMP reflectance spectra are shown in Fig. 1.

Previous LAMP Analyses: The presence of a strong water absorption edge in the far-UV (near 165 nm) allows the study of lunar hydration by LAMP: To map the presence and strength of the water feature in the LAMP data, *Hendrix et al*. [2] made a straight line fit to each reflectance spectrum in the 164-173 nm range, where the presence of any water is expected to most strongly affect the slope and determined the slope of that line, after photometrically correcting using the Lommel Seeliger term $\mu_0/(\mu+\mu_0)$. For comparison, *Hendrix et al.* [2] also studied the slopes in the 175-190 nm range, where the slope is not expected to change due to hydration effects. Past analyses of LAMP dayside data (e.g. [2][14]) have shown that spectral slopes in the 175-190 nm region are good indicators of weathering and composition. (e.g., Fig. 1). *Hendrix et al.* [2] found a relationship between the 164-173 nm slope and time-of-day (Fig. 2), with steeper (redder) slopes (consistent) with increased hydration) earlier and later in the day, and at higher latitudes. Near noon, the slopes were the bluest. The slopes in the 175-190 nm range showed no relationship with time-of-day.

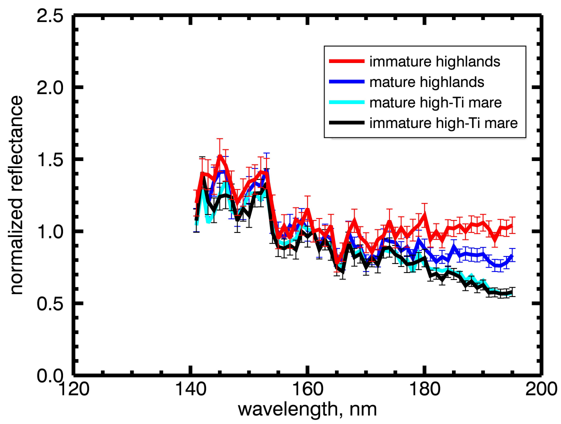

Figure 1. LAMP spectra of representative lunar terrains: a mature highlands region (13°N, 145°E), an immature highlands region (Jackson crater, 19°N, 193°E), a mature high-Ti (11.17N, 314.44 E) and an immature high-Ti (9.88°N, 311.66°E) region. Mare regions are bluer than highlands regions; in the highlands, more weathered regions are bluer than less-weathered regions at wavelengths longer than ~160 nm.

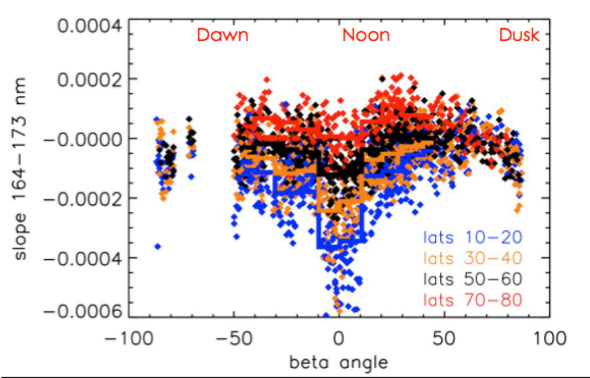

Figure 2. Spectral slope (units of nm^{-1}) vs. beta angle of straight lines fit to LAMP spectra in the 164-173 nm range. Negative beta angles correspond to morning, positive beta angles correspond to afternoon. Just four latitude bins are shown, to reduce clutter. Average slopes in each 10° beta angle range (up to 50°) are overplotted as thick lines.

Preliminary Results: Preliminary results indicate that, as in our earlier study [2], small abundances (~1%) of hydration are detected using the FUV absorption feature, and the abundance varies over the course of a day. In this study, we consider latitude and terrain type. We show models of different mixture types (e.g., intimate mixtures, monolayer models) to understand the nature of the hydration. Far-ultraviolet wavelengths are sensitive to the uppermost ~100 nm of the lunar regolith, suggesting that the hydration sensed by LAMP on the lunar dayside is surficial and transient.

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