LABORATORY INVESTIGATIONS INTO A PHOTOMETRIC ORIGIN OF THE DIURNAL VARIATION OF THE WATER-RELATED 3-MICRON BAND ON THE LUNAR SURFACE. Gwendolyn T. Robbins¹, Charles A. Hibbitts¹, David T. Blewett¹, and Karen Stockstill-Cahill¹, ¹Johns Hopkins Applied Physics Laboratory, Laurel, MD (gwendolyn.robbins@jhuapl.edu),

Introduction and Background: Water on the surface of the illuminated Moon is not understood. Remote-sensing observations from the UV through IR show that, for the illuminated surface, spectral absorption features are deeper (stronger) at high latitudes than at the equator. At the equator and mid-latitudes, these signatures of water are weakest during the hot noontime hours and strongest during the mornings and evenings [1,2,3,4]. These spectral characteristics are interpreted as greater water abundance at high latitudes and a dynamic process at lower latitudes where water is repeatedly made through solar wind implantation, then thermally lost when the surface warms, to again be created and retained as the surface cools. For the IR, using the absorption constant for water-ice, and assuming Beer’s Law (no scattering, i.e. that the reflected illumination interacts with each OH only once), a 12% band requires ~100 layers of contiguous water molecules, and due to the non-linear nature of light absorption, a decrease to an 8% band suggests about half the water is lost. Given about half the available $10^{22}$ oxygen atoms can be bound to implanted solar wind particles to form OH [5], then at saturation due to solar wind bombardment about $10^{17}/\text{cm}^2$ OH can be formed [6]. Given that the 3-μm absorption may be consistent with about a few hundred ‘layers’ of OH [i.e. 1], it is possible that, assuming an average spacing of about 2Å between each oxygen, a total path length of about 40 nm (100 layers*2Å *2) could be all that is required to achieve the observed band depth. This depth is consistent with the thickness of the alteration rind on lunar grains as well as consistent with the penetration depth of solar wind protons after also accounting for their subsequent diffusion into the grain rims [7]. Thus, a single layer of grains with solar-wind derived OH-rich rims may account for the 3-μm feature.

However, there is an unresolved dilemma with this proposed process for explaining the observed diurnal variation in the water-related 3-μm feature. Whereas the change in the strength of the absorption band occurs on a two-week diurnal timescale, replenishment of OH through the protons from the solar wind occurs at a rate several orders of magnitude slower; it takes approximately 100 years to saturate the upper 100 nm with protons, or several tens of years to repopulate the surface in protons to replenish the observed loss of OH. Thus, if solar wind implantation is too slow to replenish the diurnal OH spectral feature, a different hypothesis is needed. We propose that the majority of this spectral variation is a photometric effect; not evidence for a change in the abundance of OH, but due to how the solar illumination interacts with the grains’ surfaces, and specifically due to the fact that the OH is contained in a rind in grains’ surfaces (Fig. 1).
Procedures: We simulated the illumination conditions of the Moon at equatorial morning to noon to evening and measured the bidirectional reflectance of nominally anhydrous powdered anorthosite (highland analog) that was artificially weathered to create a hydrous rind that exhibits a water-related 2-μm absorption feature (to simulate the solar wind induced 3-μm band). We needed a 2-μm feature instead of the 3-μm features because the spectrometer available to us, a Spectral Vista Systems fiber-fed point spectrometer (SVC), senses from the visible to 2.5-μm. In order to create this material, we crushed and ground anorthosite as a water-rich slurry (grinding in air did not itself enable enough moisture to bound onto the grains to induce a 2-μm band and instead was used as an anhydrous reference). Upon completion, the grains were dried in air. Reflectance measurements were obtained with the goniometer facility at APL (Fig. 2). The sample was spread onto a metal plate to about 1-cm thickness. A 1-m metal support was connected to the goniometer pointing towards the sample. Our light source was then connected to a fiber optic cable 1 m long and colimated with a lens. The fiber optic cable was attached parallel to the metal support. This enabled us to vary incidence angles while keeping the illumination source close to the sample for highest signal. The SVC was placed approximately 15 cm above the sample, facing downwards simulating a spacecraft nadir perspective. A diffuse gold spectral reference was used because gold does not possess spectral features in the 2-μm region. The reflectance spectrum at each angle is an average of 10 acquisitions. The process was repeated at 20, 30, 40, 50, 60, and 70 degrees incidence angle.

Results: As expected from the model (Fig. 1A) The band depth shows no trend with increasing incidence angle (Figs. 3 and 4). Repeated measurements generated the same results. Using this model, between each incidence angle there is little change in reflectance. Variation appears to be primarily noise, but each angle’s normalized signal strength is virtually identical.

Implications and Conclusions: We have obtained reflectance spectra indicating that there is no correlation between the depth of a hydration band and incidence angle for a particular surface that is composed entirely of grains with hydrated rims. This relationship is consistent with the concept presented in Figure 1. We will next test the scenario depicted in Figure 1b, for which only the upper few grains, which are continually exposed to solar wind, possess hydration rims and the deeper grains are desiccated, possessing no 2-μm band, simulating a lack a 3-μm band just beneath the upper most grains on the lunar surface.