TEMPERATURE AND ULTRAVIOLET ALBEDO CORRELATIONS IN THE LUNAR POLAR REGIONS: IMPLICATIONS FOR WATER FROST. P. O. Hayne[1], K. D. Retherford[2], [3]E. Sefton-Nash, [3]D. A. Paige, [1]Jet Propulsion Laboratory, California Institute of Technology (Paul.O.Hayne@jpl.nasa.gov), [2]Southwest Research Institute, [3]University of California, Los Angeles.

Introduction: The Moon's permanently shadowed regions (PSRs) are distinguished by their unusually low ultraviolet albedo and "red" spectral slope, consistent with highly porous regolith and the presence of ~1–2% water frost by area at the surface [1, 2]. Although these UV features are broadly correlated with known cold traps, a systematic study of their distribution with respect to temperature has not been performed. In this study, we use temperature data from the Diviner Lunar Radiometer [3] and UV albedo maps from the Lyman-Alpha Mapping Project (LAMP) [4], to investigate the detailed relationships between the diverse lunar thermal environments and the apparent surface water frost distribution.

Data and Methods: After more than four years in orbit aboard the Lunar Reconnaissance Orbiter (LRO), Diviner has acquired multi-spectral brightness temperature data with excellent spatial and temporal resolution over the full diurnal and seasonal cycles [5]. We used these data to derive annual maximum, minimum, and mean temperatures with a spatial resolution of ~240 m (Fig. 1). Similarly, LAMP continues to build its statistical sample of the nightside UV albedo, with greatest coverage over the poles. For this study, we used LAMP data published on the NASA Planetary Data System, as well as a proprietary dataset soon to be publicly released. Each of the maps is re-sampled to the same polar stereographic grid for direct comparison of individual spatial pixels. Here we focus on the south polar region, but have performed a similar analysis for the north.

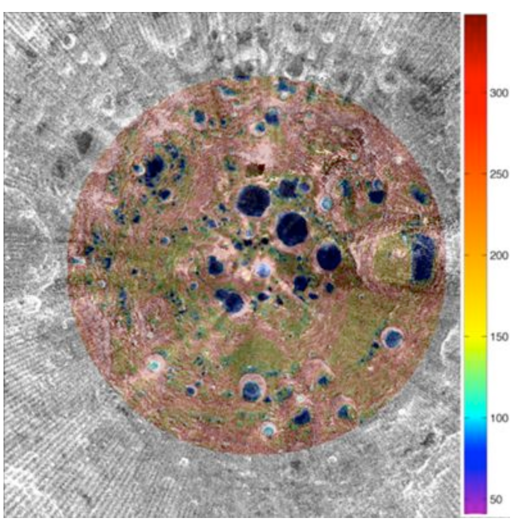

Figure 1: Overlay of Diviner annual maximum temperature (colors: 40-350 K) and Ly-α albedo from LAMP (grayscale) for the south polar region of the Moon. The outer edge of the Diviner map lies at 82.5°S.

Results: The LAMP data show an obvious trend of decreasing Ly-α albedo with decreasing temperatures (Fig. 1), as noted previously [1, 2]. The correlation coefficient for Ly-α albedo and annual maximum temperature T_{max} is $R \approx 0.21$ for all points, which is quite high considering the noise in the LAMP data. When compared to annual average temperature T_{avg}, the correlation with albedo is only slightly less, with $R \approx 0.18$. As noted by [1], this apparent temperature-porosity correlation may be attributed to the development of "fairy castle" structures at the regolith surface due to electrostatic effects in the PSRs. We also note that the degree of correlation Ly-α albedo with annual minimum temperature T_{min} and with $T_{max} - T_{min}$, are both significantly lower at $R \sim 0.01$. This suggests that the high porosity in the cold traps is not due to thermal cycling or unusual low-temperature mechanical properties.

Correlation coefficient, R:

	Ly-α	H_2O Ratio
T_{max}	0.21	-0.07
T_{mean}	0.18	-0.12
T_{min}	0.01	-0.19
$T_{max} - T_{min}$	0.01	-0.02

Table 1: Correlation coefficients for LAMP and Diviner data in the lunar south polar region >80°S. The negative correlation of H_2O ratio and temperature indicates greater apparent frost abundance at lower temperatures.

Water frost exhibits a strong absorption in the short wavelength region of LAMP UV spectra, such that the ratio f_{H2O} of albedo "off band" (155–190 nm) to "on band" (130–155 nm) is proportional to water content [1, 6]. In contrast to the Ly-α albedo, this ratio is negatively correlated with all of the temperature parameters (Table 1). In this case, the correlation is strongest for T_{min}, followed by T_{avg}. Though more work is needed to understand this relationship, it may be consistent with a diffusive process driving water to the coldest of the cold traps [7], especially if they remain in communication with the subsurface [8]. If the lunar surface is populated by many small-scale "micro cold traps", this could result in a general increase in f_{H2O} toward the pole similar to the hydrogen abundance pattern from neutron data [9].

We isolated portions of the T_{max} vs. f_{H2O} scatter plot (Fig. 2) in order to map regions with both extremely low temperatures and high apparent water abundance. Fig. 3 illustrates the spatial distribution of these units, which is quite patchy. In particular, Shoemaker crater stands out, as do many other small craters with ~5° of the pole. However, other craters with similar environments such as Faustini and Haworth, show a pattern of much lower UV water band depth. Cabeus crater, where the LCROSS impact excavated material with ~5% water ice by mass [10], shows a patchy distribution of high apparent water frost.

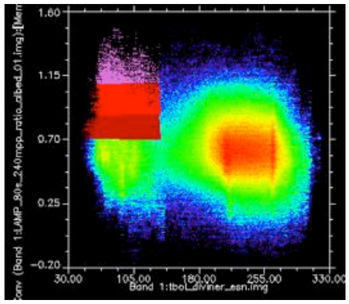

Figure 2: Scatter plot of LAMP water band depth (f_{H2O}) vs. Diviner annual maximum temperature (T_{max}), with three regions of interest highlighted. These ROIs are mapped in Fig. 3.

Conclusions: Surface brightness temperatures from Diviner and UV albedo maps from LAMP reveal significant correlations: 1) high Ly-α albedo (possibly due to porosity) is highly correlated with the lowest annual maximum temperatures, but not with temperature range or minimum annual temperature; 2) UV water band depth is most strongly correlated with regions with low minimum and mean annual temperatures, but less so with annual maximum temperature; 3) the distribution of high apparent surface water frost among the coldest craters is patchy, indicating processes independent of temperature may influence the transport and deposition of surface frost.

References: [1] Gladstone G. R. et al. (2012), *JGR*, *117*, E00H04, doi:10.1029/2011JE003913. [2] Retherford K. D. et al. (2012) *LPSC*, [3] Paige D. A. et al. (2010), *Space Sci. Rev.*, *150*, 125. [4] Gladstone G. R. et al. (2010), *Space Sci. Rev.*, *150*, 161–181. [5] Sefton-Nash E., et al. (2013) 44th LPSC, Abs. 2617. [6] Hendrix A. R. et al. (2012), *JGR*, *117*, E12001, doi:10.1029/2012JE004252. [7] Watson K. et al. (1961), *JGR*, *66*, 3033. [8] Schorghofer N. and Taylor G. J. (2007), *JGR*, *112*, E02010, doi:10.1029/2006JE002779. [9] Hayne, P. O. (2013). *BAAS* 45, #9, 107.3. [10] Colaprete A. et al. (2010), *Science*, *330*, 463, doi:10.1126/science.1186986.

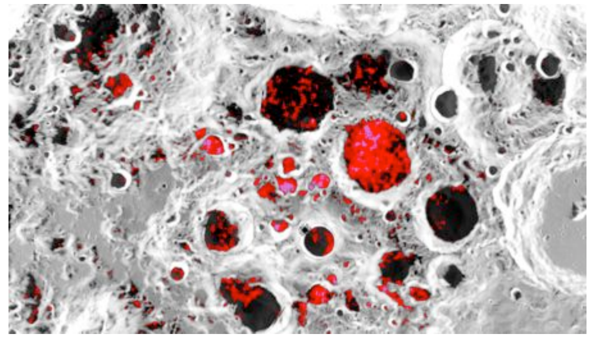

Figure 3: Surface material with high UV water band depth from LAMP and Diviner T_{max} < 130 K is indicated by shades of red in this south polar map. The background grayscale image is Diviner T_{max}, a subset of Fig. 1.