ALBEDO OF PERMANENTLY SHADOWED REGIONS (PSR) AT THE LUNAR SOUTH POLE. M. A. Riner[1], P. G. Lucey[1], G.A. Neumann[2], D.E. Smith[3], M.T. Zuber[3], D.B. J. Bussey[4], J. T. S. Cahill[4], E. M. Mazarico[2], Hawaii Institute of Geophysics and Planetology, University of Hawaii, Manoa, 1680 East-West Rd., Honolulu, HI 96822, USA, (mariner@higp.hawaii.edu); [2]NASA Goddard Space Flight Center, Code 698, Greenbelt, MD 20771, USA; [3]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, USA; [4] The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA.

Introduction: Due to the only very slight tilt in the Moon's spin axis relative to the Sun, topographic depressions near the lunar poles can experience permanent shadow and may serve as cold traps, harboring water ice and/or other volatile compounds [1,2]. Permanently shadowed regions (PSRs) provide an opportunity to understanding the amount, nature and transport of volatiles on the Moon and may also be a potential resource for human exploration.

Neutron spectroscopy has detected the presence of enhanced hydrogen at the lunar poles [3,4,5] but the distribution and chemical state of the hydrogen is not well known. LCROSS measurements showed the presence of water and other volatiles in one PSR (Cabeus crater) [5] and radar observations of some polar craters are consistent with significant quantities of buried ice [6]. The LRO UV spectrometer LAMP detected low UV albedos in many lunar PSRs some of which have UV colors consistent with the presence of a small amount of surface frost [7]. Anomalously bright areas in the coldest portions of the north pole of Mercury has been detected at 1064 nm using the Mercury Laser Altimeter strongly indicating the presence of water frost [8,9]. Using LOLA (Lunar Orbiter Laser Altimeter) reflectance measurements, Zuber et al. [10] reported the locally anomalous reflectance of the south polar crater Shackleton, also suggesting the presence of surface frost.

We calibrated the LOLA reflectance data set to physical units of normal albedo (the reflectance of a spatially resolved surface element observed at zero phase, relative to a Lambert surface illuminated normally also observed at zero phase angle). Data are gridded to 8 km resolution below 80 degrees latitude (N and S) and 1 km resolution at the poles.

Results: We sampled 124 PSRs, and 124 craters of similar size in the equatorial region (Figure 1). The albedo of the measured PSRs is 0.35 ± 0.03 (1σ) compared to 0.33 ± 0.02 (1σ) for 124 low latitude craters sharing roughly the same crater size distribution. Some PSRs show reflectance values significantly higher than seen at the equator, with four locations 4 sigma from the equatorial mean.

Near the pole the LOLA track density is high so we can sample the data to a finer grid and verify the results of [10] that Shackleton exhibits substantial variation in interior brightness. We compared the maximum value of its normal albedo to the maximum normal albedo of 175 craters between 20 and 30 km [11, 12] with measurable reflectance anomalies on their walls due to mass wasting. In this case we estimated the normal albedo from high resolution Kaguya imagery by regressing Kaguya Multiband Imager data on LOLA normal albedo to use data with similar spatial sampling. Figure 2 shows the distribution of maximum normal albedos for that population and also indicates the maximum normal albedo of Shackleton. We also compared the normal albedo of the floor of Shackleton to the floors of the control population (Figure 3)

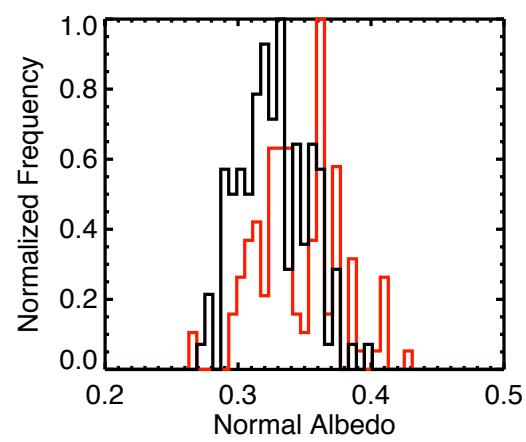

Figure 1: Frequency of normal albedo values for 124 PSR craters (red) and low latitude farside lunar highlands craters (black) with the same approximate size distribution.

Discussion: Some, but not all, PSRs have anomalously high reflectances relative to similar geologic features at low latitudes. The most apparent anomalously bright surfaces are the floors of the three large permanently shadowed south polar craters Shoemaker, Faustini and Haworth (Figure 4). These craters are also clearly anomalous in the UV, and Faustini and Haworth exhibiting UV color consistent with a small amount of water frost.

Shackleton's maximum normal albedo is typical of similar craters suggesting mass wasting dominates the reflectance of its walls. The floor of Shackleton how-

ever is brighter than almost all equatorial craters of similar size, supporting the suggestion of [10] that frost may be present on the floor.

It is possible that the UV characteristics and the LOLA reflectance anomalies are a phenomenon of the microtexture of the surface rather than frost. In one scenario, space weathering may operate somewhat differently at very low temperatures. Solar wind gases are probably enhanced in the permanently shadowed regions (the solar wind irradiates the polar shadow due to the terrestrial magnetotail). Returned lunar soil outgases rapidly above lunar noontime temperatures of 400K so PSR soil probably retains gas more effectively never having experience high temperatures. During micrometeorite impact gases are released and the higher possible gas content may contribute to more vesicles in agglutinate glasses, increasing their reflectivity.

In another scenario, the mobility of volatile species may change the complex, highly porous, interconnected, immediate surface of lunar regolith, sometimes called "fairy castle" structure. The specific effects of volatile mobility on the fairy castle structure and the resulting optical effects are not well understood.

Conclusions: Some of the permanently shadowed regions at the lunar south pole show reflectance anomalies that may indicate the presence of surface frost. A large sample of permanent shadow and equatorial craters of similar size show that some PSRs are several sigma from the mean of the equatorial control population. Large flat-floored craters in permanent shadow in particular appear bright relative to their surroundings as is the floor of Shackleton. While frost is one explanation, 1064 nm anomalies reported here and the UV anomalies could be due to the influence of low temperature on space weathering.

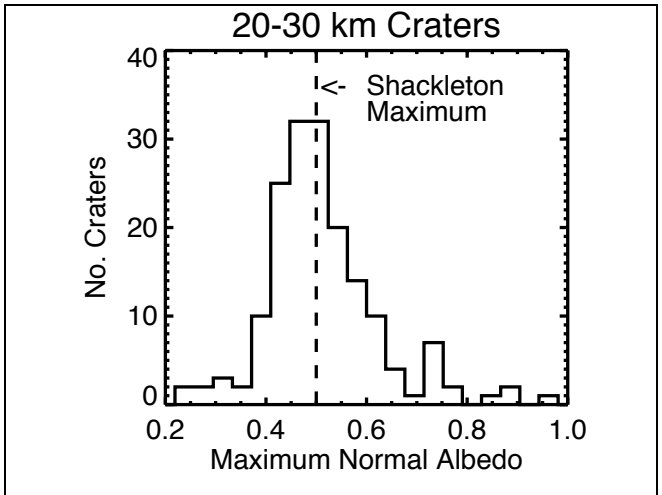

Figure 2: The maximum normal albedo of Shackleton relative to similarly preserved 20-30km craters.

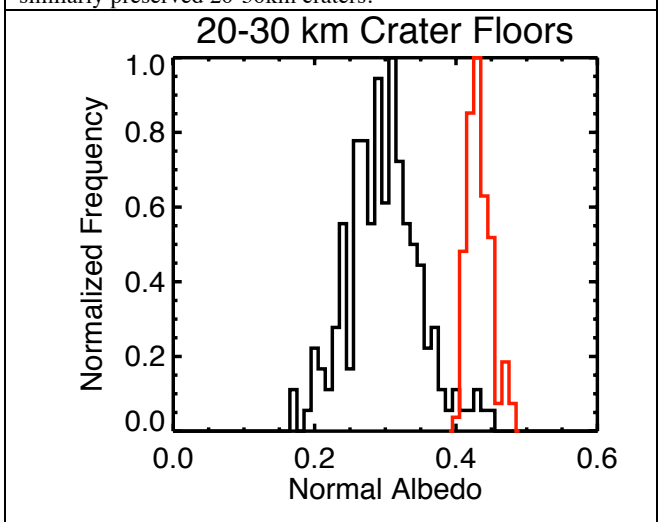

Figure 3: The normal albedo of Shackleton floor (red) and the median normal albedo of the floors of similarly preserved 20-30km craters.

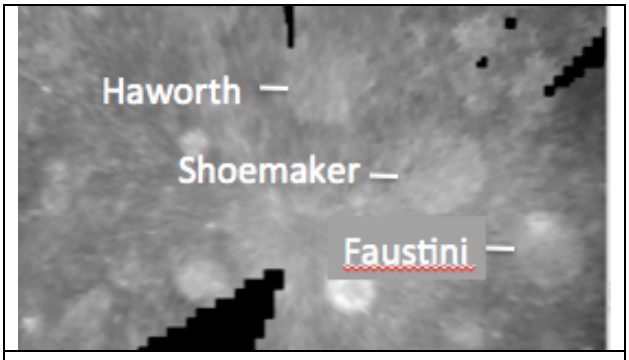

Figure 4: South pole normal albedo from LOLA. The large permanently shadowed craters indicated show anomalously high albedos relative to their surroundings.

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