SURFACE ROUGHNESS WITHIN LUNAR SOUTH POLAR COLD TRAPS. L. O. Magaña[1], P. Prem[1], A. N. Deutsch[2], C. I. Fassett[1], A. Stickle[1], A. C. Martin[1], H. M. Meyer[1], B. D. Byron[3], K. E. Mandt[1], K. D. Retherford[4,5], K. R. Stockstill-Cahill[1] [1]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA (lizeth.magana@jhuapl.edu), [2]NASA Ames Research Center, Mountain View, CA, USA, [3]NASA Jet Propulsion Laboratory, Pasadena, CA, USA, [4]Southwest Research Institute, San Antonio, TX, USA, [5]University of Texas at San Antonio, San Antonio, TX, USA.

Introduction: Permanently Shadowed Regions (PSRs) at the lunar poles are known to experience temperatures cold enough to harbor volatiles over geologically long time scales. Evidence of condensed water ice has been observed through various instruments onboard the Lunar Reconnaissance Orbiter (LRO) and the Chandrayaan-1 spacecraft [e.g., 1, 2]. Additional volatile species may exist within cold traps including CO_2, NH_3, SO_2, and others [3], though these species have so far only been observed within Cabeus crater [4, 5].

In this work we investigate surface roughness differences between five south polar cold traps of interest (Faustini (87.18° S, 84.31° E), Shoemaker (88.14° S, 45.91° E), Haworth (87.45° S, 354.83 E), an unnamed region (86.73° S, 22.00° E), and Cabeus (85.33° S, 317.87° E)) and their respective surrounding regions. These cold traps are all in crater interiors, or low-lying terrain. We test whether roughness changes can be attributed to the presence of condensed volatiles with-in cold traps, or whether roughness changes are better explained by other factors such as mass wasting, impact melt, or ejecta.

Methodology: Surface roughness represents the deviation from the mean topography. We utilize published roughness maps [Fig. 1; https://pds-geosciences.wustl.edu/lro/lro-l-lola-3-rdr-v1/lrolol_1xxx/data/lola_gdr/] from LRO's Lunar Orbiter Laser Altimeter (LOLA). Roughness R at the center of each laser shot is calculated as,

$$R = \sqrt{\frac{1}{n-v}\sum_{i=1}^{n} {z_i}^2}$$

where n is the number of LOLA spots (5), v is the number of degrees of freedom (3), and z is the height residual for a given spot. Noise is given by the mean statistical observations and is ~0.15 meters.

Roughness values within polar cold traps are compared to the roughness of their surrounding regions at 1-km, 240-m, and 40-m [Fig. 1]. Cold traps are identified through LRO's Diviner Lunar Radiometer Experiment (Diviner) as regions where annual maximum temperatures remain below 110 K. A p-value test is performed to test if cold traps and their surroundings are statistically different. A p-value <0.05 indicates two statistically distinct populations. We consider three scenarios that may influence roughness differences including mass wasting, the presence of condensed volatiles, and the presence of impact melt and/or hummocky ejecta [Fig. 2].

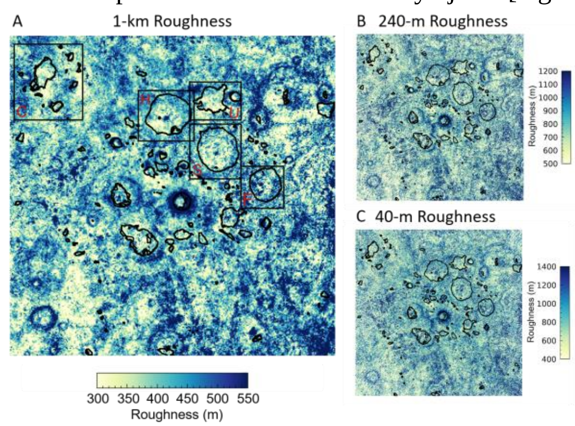

Figure 1: South pole roughness maps at a) 1-km (LDRM_40S_1000M), b) 40-m (LDRM_85S_40M), and c) 240-m (LDRM_75S_240M) scales derived from LOLA observations. Cold traps are outlined, regions of interests are labeled, and their respective surrounding regions are boxed.

Mass Wasting. Mass wasting is the process by which material moves downward on crater walls, resulting in local smoothing. Slopes steeper than ~20° may promote mass wasting [6]. To rule out the smoothing effects of mass wasting, we also compared only regions with slopes less than 10°.

Condensed Volatiles. Temperatures within cold traps are sufficiently cold to support condensed volatiles over geologically long time scales. The presence of condensed volatiles may serve to reduce surface roughness [7-9]. Since roughness values cannot be directly compared from one region to the next, we compare polar roughness ratios (inside crater/outside crater) with six equally sized (~40 km - 55 km diameter) equatorial craters of similar pre-Nectarian age. These are Morozof F (4.92° N, 1130.20° E), Rosenberger C (52.28° S, 42.20° E), Van Maanen (36.03° N, 128.18° E), Fraunhofer E (43.20° S, 61.57° E), Brisbane (49.20° S, 68.76° E), and Asclepi (55.19° S, 25.52° E).

Further, observations from LRO's Lyman-Alpha Mapping Project (LAMP) UV spectrograph are sensitive to the presence of condensed volatiles; high Off-band/On-band ratios are consistent with the presence of water ice [1]. We therefore investigate possible correlations between surface roughness and LAMP Off-band/On-band ratios.

Impact Melt and Ejecta. Other processes that can affect surface roughness within our regions of interest include impact melt and hummocky ejecta. Impact melt serves to subdue roughness within craters while hummocky ejecta would enhance roughness outside of craters. We test whether impact melt and ejecta could be affecting the measured roughness by analyzing images from the Lunar Reconnaissance Orbiter Camera (LROC), where available.

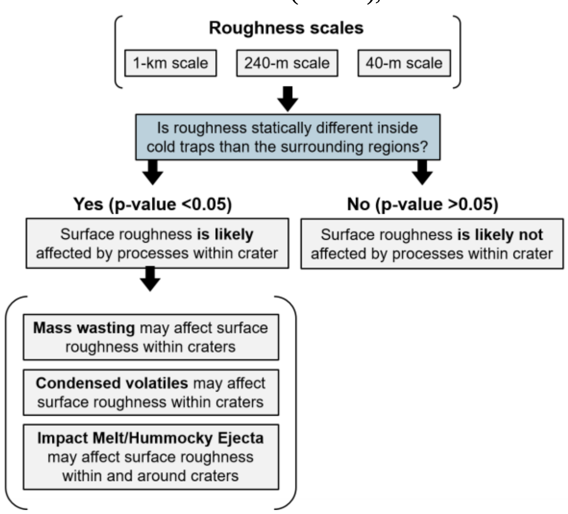

Figure 2: Flow chart demonstrating the scenarios considered and methodology utilized in this study.

Preliminary Results: LRO LAMP, LOLA, LROC, and Diviner observations are studied in conjunction to understand the surface roughness characteristics of five cold traps of interest at the lunar south pole, and how mass wasting, condensed volatiles, impact melt, and/or hummocky ejecta may be affecting the surface roughness. Through this preliminary study we find that [Fig. 3]: 1) Surface roughness values at 240-m and 40-m scales do not change significantly when entering cold traps, suggesting that condensed volatiles do not appear to affect roughness at these scales; 2) Surface roughness at 1-km scales is reduced within both cold traps (polar craters) and equatorial craters relative to surrounding regions, suggesting that mechanisms other than condensed volatiles may be responsible; 3) Regions with high LAMP Off-band/On-band ratios (consistent with the presence of H_2O) have roughness values that are reduced from those in the surrounding regions, suggesting that condensed volatiles may nonetheless play a role in controlling surface roughness. We will discuss potential causal relationships for this correlation in future work.

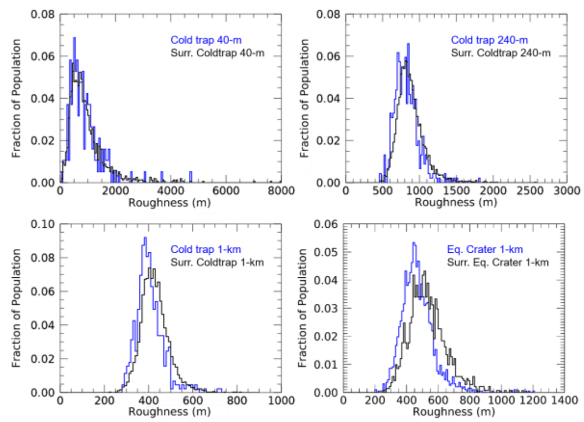

Figure 3: Mean roughness distribution within craters (blue) and their surrounding regions (black).

Previously, [8] found subdued 50-200-m surface roughness in cold traps in Scott E crater and [9] found subdued 360-m surface roughness inside 9 of 12 polar cold traps. The five cold traps studied here are different from the sites analyzed by [8] and [9], so if subdued roughness observed by [8] and [9] is due to the presence of sequestered volatiles, our new results highlight the heterogeneity of volatile abundance and distribution across the poles.

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