LUNAR MASS WASTING EVENTS USING MINI-RF RADAR M-CHI DECOMPOSITION. S. L. Pérez-Cortés\textsuperscript{1}, A. M. Bramson\textsuperscript{1}, E. G. Rivera-Valentín\textsuperscript{2}, C. A. Nypaver\textsuperscript{3}, R. Melikyan\textsuperscript{4}, G. W. Patterson\textsuperscript{2}, A. K. Virkki\textsuperscript{5}, P. A. Taylor\textsuperscript{6}, M. C. Nolan\textsuperscript{3}, M. A. Slade\textsuperscript{7}; \textsuperscript{1}Purdue University, West Lafayette, IN (sperezco@purdue.edu), \textsuperscript{2}Johns Hopkins Applied Physics Laboratory, \textsuperscript{3}Smithsonian Institution, Center for Earth and Planetary Studies, National Air and Space Museum, \textsuperscript{4}University of Arizona, \textsuperscript{5}University of Helsinki, \textsuperscript{6}NRAO, \textsuperscript{7}NASA JPL/Caltech.

**Introduction:** Mass wasting is the downslope movement of material driven by gravity. The first evidence of lunar mass wasting deposits was reported in Apollo 10 images, resulting in suggestions of creeps, slumps, debris flows, and rock falls on the Moon [1]. Since the launch of NASA’s Lunar Reconnaissance Orbiter (LRO) in 2009, some studies have investigated the distribution of mass wasting events on the Moon [2], but their formation mechanisms remain unclear.

Radar observations are useful for studying mass wasting events because they are sensitive to wavelength-scale “roughness” or “blockiness” within its penetration depth, which, on the Moon, is typically <10x the wavelength. Therefore, radar can characterize mass wasting material in a different way than visible images (Fig. 1). Previously, we investigated the material properties of mass wasting sites using their backscattered power in the same sense circular (SC) and opposite- sense circular (OC) polarization in the S-band (12.6 cm, 2380 MHz) following [3]; however, we did not identify trends with respect to mass wasting event or geological setting (i.e., craters vs. tectonic) [4]. Here, we follow-up on that initial study with additional polarimetric characterization.

**Methodology:**

*Mapping:* We mapped more than 300 landslides across the nearside maria (Fig. 2) in the Java Mission-planning and Analysis for Remote Sensing (JMARS) tool. We used [2] as a guide, while also identifying new mass wasting events that were not previously mapped in [2].

**Figure 2:** Location of the landslides covered by this study shown by red polygons.

We then used monostatic S-band observations from LRO’s Mini-RF instrument to study the scattering properties of the areas with landslides and their surroundings. Mini-RF is a hybrid-polarimetric radar, whose measurements allow for the calculation of Stokes parameters (\(S_1, S_2, S_3, S_4\)), which describe the total backscattered power (\(S_1\)) and the power in linear (\(S_2, S_3\)) and circular polarizations (\(S_4\)). These parameters can be used to derive “child products” such as Circular Polarization Ratio (CPR) and the degree of linear polarization (DLP) [5] following:

\[
CPR = \frac{S_3 - S_4}{S_3 + S_4}
\]

\[
I_p \text{ DLP} = \sqrt{\frac{s_2^2 + s_3^2}{I_p}}
\]

CPR is a first-order approximator of near-surface, wavelength-scale “roughness” [5–9]. For a circular transmitting radar, DLP is a good indicator of subsurface structure, as well as rough, bouldery surfaces [10]. For this study, we are using the polarized intensity (\(I_p\)) instead of \(S_1\) (average intensity that includes the polarized and the unpolarized components) to avoid uncertainty related to normalization factors [11]. Together, these two parameters can be used to investigate surface and subsurface properties [9].
Additionally, we also analyzed mapped landslides using m-$\chi$ (m-chi) decomposition technique [7]. This product characterizes the intensity contribution from three scattering regimes simultaneously via a false-color RGB image following:

$$\begin{align*}
R &= \left[ \frac{mS_1(1+\sin2\chi)}{2} \right]^\frac{1}{2} \\
G &= [S_1(1 - m)]^\frac{1}{2} \\
B &= [mS_1(1-\sin2\chi)]^\frac{1}{2}
\end{align*}$$

where red (R) indicates even bounce, green indicates depolarized backscattering (G) and blue indicates odd bounce (B) [7]. The decomposition method is named m-$\chi$ due to its dependence on the degree of polarization, $m = \sqrt{\frac{S_2+S_0+S_1}{S_1}}$, and the degree of circularity $\sin2\chi = -S_4mS_1$.

**Preliminary results:** Most lunar landslides are in areas that show high CPR and high DLP (Fig. 3), which is suggestive of wavelength-scale complexity at the surface, as well as buried rough structures. The landslides are distinguishable from their surroundings in m-$\chi$ products (Fig. 3). Most rockslides appear yellow, but primarily green, indicating they are dominated by depolarized, with some contribution from even bounce returns. This may suggest an increase in abundance of randomly oriented scatterers several wavelengths in size. Meanwhile, rockfalls seem to be dominated by yellow, but primarily red, indicating mostly even bounce scattering representative of their bouldery surfaces. These distinctions are most noticeable in simple and complex craters, where we can distinguish parts of the landslide body (scarp vs. toe). In tectonic settings, most of the rockfalls are predominantly yellow, suggesting a roughly equal combination of depolarized and even bounce scattering.

**Acknowledgments:** Mini-RF data can be found in the PDS. We thank the Mini-RF Team for their feedback. SLPC is supported by the NSF-GRFP.

**References:**

[4] Pérez-Cortés et al. (2023) LPSC LIV Abstract #2492