IMPROVED LOLA ELEVATION MAPS FOR SOUTH POLE LANDING SITES: ERROR ESTIMATES AND THEIR IMPACT ON ILLUMINATION CONDITIONS. Michael K. Barker[1], Erwan Mazarico[1], Gregory A. Neumann[1], David E. Smith[2], Maria T. Zuber[2], James W. Head[3], [1]NASA Goddard Space Flight Center, Greenbelt, MD 20771, [2]Department of Earth, Atmospheric, and Planetary Sciences, MIT, Cambridge, MA, 02139, [3]Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912.

Introduction: Multiple national and international public- and private-sector organizations are actively planning to send robotic and human explorers to the south pole of the Moon. Mission design studies require accurate, precise, and high-resolution maps of surface height, slope, and roughness both outside and within permanently shadowed regions [1 – 4]. To that end, we present new high-resolution (5 m/pix) topographic models of 4 high-priority lunar south pole landing sites based exclusively on laser altimetry data acquired by the Lunar Orbiter Laser Altimeter (LOLA) onboard the Lunar Reconnaissance Orbiter (LRO). These new LOLA DEMs (LDEMs) are substantially more realistic than the old versions and will be useful to constrain higher-resolution topographic models derived from imagery, which are not as well controlled geodetically and which can be hindered by shadows. A major advantage of this process is that, for the first time, we can estimate realistic LDEM height uncertainties and their effect on illumination conditions. We presently focus on the 4 highest-priority south pole candidate landing sites for NASA's Artemis program, Sites 1, 4, 7, and 11 in [5]. We consider the LOLA data within 16x16 km square regions surrounding each site. The primary differences between previous studies [1 – 3] and ours is that we use the LDEM itself as the reference DEM for adjusting tracks, we run illumination simulations at a higher resolution (5 m/pix vs. 40 and 20 m/pix), and we perform a detailed analysis of LDEM height uncertainties and their impact on illumination conditions.

Track Adjustments: We iteratively adjust the LOLA tracks to the LDEM in a self-consistent fashion. The whole process is repeated 5 times in total, each time starting from a new LDEM computed with the best-fit track adjustments from the previous iteration. Track adjustments converge towards zero and their dispersion decreases with each iteration. After the final iteration, we remove a small percentage (~0.1%) of outliers based on their abnormally high residuals and high slopes relative to local terrain. The track adjustment and cleaning process remove the vast majority of artifacts visible in the hillshade and slope maps. The resulting track geolocation uncertainty is ~10 – 20 cm horizontally and ~2 – 4 cm vertically, reduced by over ~10x from the initial uncertainties arising from the LRO orbit reconstruction process (Mazarico et al. 2018).

LDEM Height and Illumination Uncertainties: Natural terrain slope variations and sub-pixel sampling cause the uncertainty in LDEM surface height Z to be larger than the track geolocation error. We developed a method to estimate surface height uncertainty in the new LDEMs that circumvents the infeasible computation of the full error-covariance matrix of the LDEM. Instead, we use the fractal nature of lunar topography to build a more computationally manageable statistical ensemble of 100 "clones" with similar error properties as the data. We use this ensemble to study height and slope uncertainty, as well as the uncertainty in illumination conditions. The LDEM height and slope uncertainties are similar across all the sites with a typical RMS Z error ~ 0.30 – 0.50 m and a typical RMS slope error ~ 1.5 – 2.5° per pixel. Maps of the RMS Z and slope errors can serve as weight maps for the LDEMs when constraining traverse studies and stereo or shape-from-shading techniques. We compute predicted illumination conditions at each site during using a horizon method similar to [5]. The simulations are run independently for the new LDEM and for each of the clones. Surface height errors translate to near-field horizon elevation errors and variations in illumination conditions in the clones (Figure 1). These variations can be useful when examining the feasibility of different landing sites.

References: [1] De Rosa, et al. (2012). PSS, 74, 224. [2] Gläser, P., et al. (2014). Icarus, 243, 78. [3] Gläser, P., et al. (2018). PSS, 162, 170. [4] Heldman, J. L., et al. (2016). Acta Astronautica, 127, 308. [5] Mazarico, E., et al. (2011). Icarus, 211, 1066. [6] Mazarico, E., et al. (2018). PSS, 162, 2.

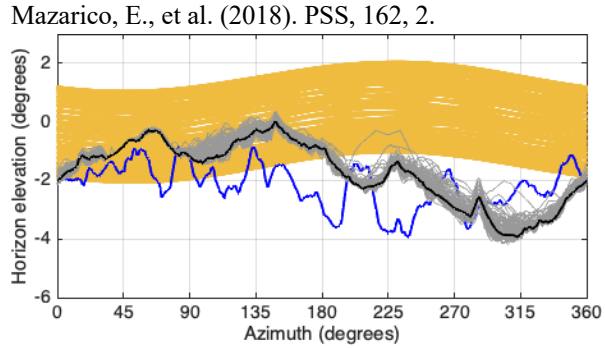

Figure 1 – Horizon elevation due to near-field topography as viewed from a pixel at Site 1 in the new LDEM (black) and 100 clones (gray). Horizon elevation due to far-field topography (blue). Sun position over 18.6 years (orange).