ILLUMINATION OF THE LUNAR POLES FROM LUNAR ORBITER LASER ALTIMETER (LOLA) TOPOGRAPHIC DATA. E. Mazarico[1,2], LOLA Science Team[1]; [1]NASA Goddard Space Flight Center, Code 698, Greenbelt, MD, USA; [2]Oak Ridge Associated Universities, NASA Postdoctoral Program.

Introduction: The goal of the Lunar Reconnaissance Orbiter (LRO) mission is to provide high-resolution datasets to help plan the future exploration of the Moon. In addition to the scientific interest of permanently shadowed regions (PSRs) **[1-3]**, the polar regions are regarded as a desirable location for an outpost because of the supposed existence of areas of permanent sunlight **[4-5]**. Until recently [**6**], the topography at high latitudes was not precise enough to model the illumination conditions with a good level of confidence over timescale appropriate for mission planning. In addition, spacecraft imagery was limited spatially and temporally (the Clementine mission could only observe the Southern Winter). [6] restricted their study to 85°S.

New data from the Lunar Orbiter Laser Altimeter (LOLA) **[7]** and the LRO Camera (LROC) **[8]** can help settle this issue. We use preliminary LRO data products to model the lighting conditions of the lunar polar regions, survey and characterize the extremes: permanently shadowed regions (PSRs) and points of high average illumination. Our region of interest (ROI) is larger than previous studies **[4-5]**, extending to ~80°S.

Here, we present preliminary results that indicate that several sites in the South Pole region have very high average illumination, and continuous sunlight for months at a time.

Method: Previous studies usually used a raytracing approach to the illumination problem. At each timestep, all the points in the considered region are surveyed by calculating if rays emitted from the light source intersect the surrounding grid elements. While precise, it is too slow to conduct large-scale simulations relevant to average illumination conditions over multi-decadal timescales. For example, results from **[6]** are based on 1000 days, significantly less than the 18.6 year node precession period.

We follow and expand on **[9]**, and use the "horizon method". The illumination condition at any given point is assessed by comparing the elevation of the light source to the elevation of the horizon in its direction. The illumination calculations are separated in two steps. First, the elevations of the horizon of every point in the ROI in a number of directions are stored in a database. This step is very time-consuming, but only needs to be computed once. The calculations are made based on maps in gnomonic projection, so that direction is conserved. Straight lines represent line-of-sight and are used to calculate the elevation and distance of the obstructing topography. In addition, because the sub-solar latitude is always small (<1.6°), its gnomonic projection is at a great distance from the poles, so it is seen in the same direction over the whole ROI. This allows the database to be organized in "elevation

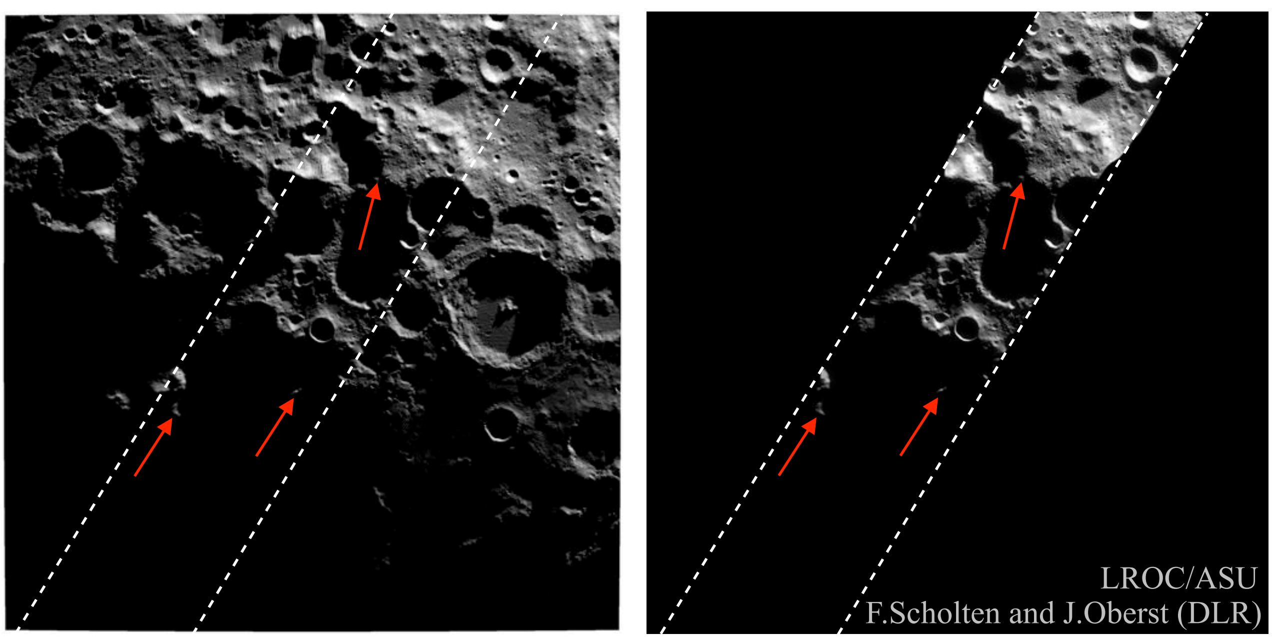

Figure 1. Validation of our method by comparison of a model output (left) with an LROC Wide-Angle Camera (WAC) South Pole image strip taken on Sep. 28, 2009 (right). A photometric function **[11]** was used (the observer is looking straight down on the South Pole). Note the good agreement of the small sunlit "islands" (arrows), which demonstrates the good quality of the LOLA topography. The region shown extends to ~80°S.

maps”, which contain the elevation of the horizon from each ROI point in the same gnomonic ‘azimuth’. In the second step (at each desired epoch), the database is used to obtain an interpolated elevation map, in the actual Sun direction. It is then simply compared to the Sun elevation (from each ROI point). We treat the Sun as an extended source, and calculate its visible area, assuming a linear horizon between the two adjacent elevation maps in the database. In order to avoid artifacts during interpolation, we use 720 directions ($\Delta\theta$=0.5°).

Data & Results: The topographic elevation models we use are preliminary LOLA data products, with a grid resolution of 240m. We validated our modeling against ray-tracing models **[10]** and against spacecraft imagery **[8]**. The agreement with LROC WAC images is very good over all solar longitudes (e.g., Figure 1). The average illumination conditions over the South Pole region were calculated over four lunar precession cycles (i.e., ~74 years) with a timestep of 6 hours. The areas identified as PSRs are shown in Figure 2. The agreement with Kaguya results **[6]** is generally good (polewards of 85°S), although we find a larger total area (above 88°S, 3680km^2 vs 2750km^2). Near the South Pole, we find areas of very high illumination (75-88%) similar to **[4,5,6,9]** (Figure 3). We also find that, at very low altitude above the surface (~10m), a small location near the Shackleton rim can offer >95% average illumination (for continuous periods of ~200 days most years). We also use our model with the Earth as a “light source”, in order to determine visibility conditions (Figure 4). The Shackleton region is not ideal (~60%), but Mons Malapert is the southernmost area of potential continuous communication relay.

Conclusion: The LOLA data enables precise modeling of the illumination conditions in the lunar polar regions, and can define the architecture of future exploration. Thanks to its speed (once the database has been created), our method also facilitates the integration of illumination in mission planning [**12**].

References: **[1]** Bussey et al., GRL, 1999. **[2]** Margot et al., Science, v284, 1999. **[3]** Nozette et al., JGR, 2001. **[4]** Bussey et al., Nature, v434, 2005. **[5]** Zuber and Garrick-Bethell, Science, v310, 2005. **[6]** Noda et al., GRL, 2008. **[7]** Smith et al., Sp.Sc.Rev., 2009. **[8]** Robinson et al., Sp.Sc.Rev., 2009. **[9]** Garrick-Bethell et al., LPSC, 2005. **[10]** Stubbs and Wang, LPSC. 2010. **[11]** Gaskell et al., Met. Plan. Sc., v43, 2008. **[12]** Johnson et al, NASA HRPIW, 2010.

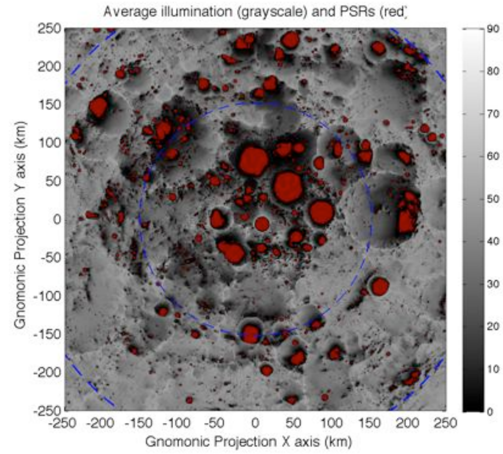

Figure 2. Permanently Shadowed Regions (PSRs, in red), over a map of the average illumination over 4 precession cycles. The dashed circles indicate 80°S and 85°S.

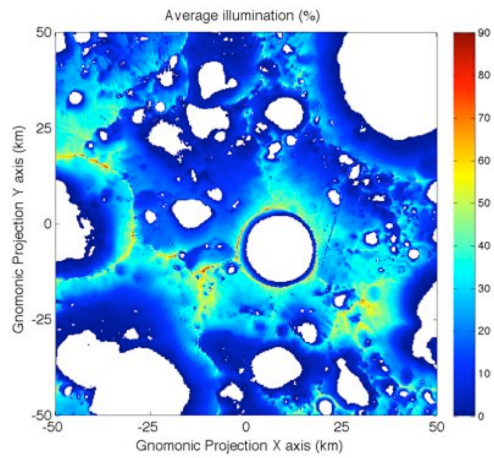

Figure 3. Average illumination near the South Pole (~88°S). PSRs are shown in white.

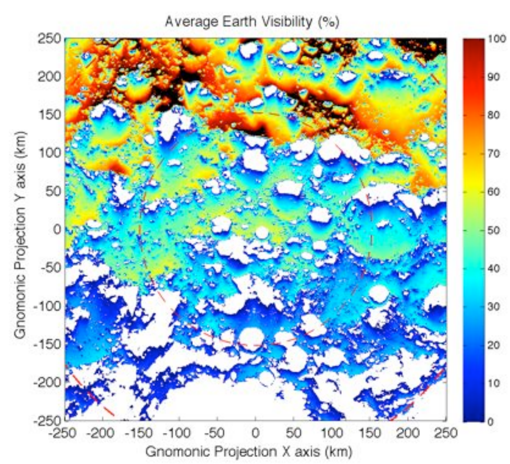

Figure4. Average Earth visibility (in percent) in the South Pole region (~80°S). Areas continuously visible are in black; areas never visible are in white. The axes are gnomonic projection coordinates (in km).