EXPLORATION POTENTIAL FOR HIGHLY ILLUMINATED POINTS AT THE LUNAR POLES USING KAGUYA, LOLA, AND LROC DATA SETS. D. P. Quinn[1], J. T. S. Cahill[2], D. B. J. Bussey[2], J. A. McGovern[2], P. D. Spudis[3], H. Noda[4], and Y. Ishihari[4], [1]The University of North Carolina at Chapel Hill, Dept. of Geological Sciences, 104 South Road, Mitchell Hall, CB #3315, Chapel Hill, NC 27599, USA [2]The Johns Hopkins University Applied Physics Laboratory, [3]Lunar and Planetary Institute, [4]National Astronomical Observatory of Japan, (davenquinn@unc.edu).

Introduction: The lunar poles experience extreme variations in illumination conditions due to a low axial tilt [1]. Shadows cast by polar topography allow for areas of permanent shadow and near-permanent sunlight within close proximity. These characteristics make these regions particularly attractive for exploration (manned or robotic) and possible resource utilization.

Permanently shadowed ‘cold traps’ where temperatures can be less than 40 K [2], may contain deposits of water ice and other volatile materials. Water, if available in significant quantities, could support a long-term human presence. In close proximity to these extremely cold locales, points of near-continuous illumination offer favorable conditions for powering surface operations. These locations offer extended periods of sunlight and earth communication, and reasonably stable surface temperatures [3]. These factors have the potential to simplify the challenges faced during future exploration of the lunar poles.

Background on Polar Lighting Studies: The extent of permanent shadow and near-continuous illumination over the lunar poles has been previously modeled with several data sets (e.g., [3-8]). This includes studies with actual Clementine optical data [3, 5] and by computing illumination models from radar derived digital elevation maps (DEMs) [4, 7]. More recent lighting models have used laser altimetry data collected by the Selene/Kaguya to simulate polar lighting conditions and integrate/reconcile these models with optical data sets [6, 8]. The recent availability of the Lunar Orbiter Laser Altimeter (LOLA) dataset from the Lunar Reconnaissance Orbiter (LRO) has allowed refinement of the initial illumination models derived from topographic data sets. The LOLA instrument collects topographic data at finer spatial scales (10-240 meters/pixel) than previous altimeters, and derived illumination models contain more information. Recent work [9] exploits LOLA’s data characteristics constructing illumination models and provides a perspective of both lunar poles at 240 meters/pixel. However, despite derivation from data with higher resolutions these more recent models show points of near-continuous illumination consistent with those initially observed in [3-5]. Here, we integrate/reconcile LOLA and Kaguya lighting models of both poles and begin to exploit these maps in ways applicable for engineering and exploration activities.

LOLA and Kaguya Illumination Modeling: The LOLA illumination model was composed using the methods from [6]. Illumination maps are generated for a specific Moon-Sun geometry by tracing rays from the Sun to each point on the gridded terrain dataset. These shadow maps are generated at 12-hour intervals for the year 2020. Maps of mean illumination are constructed by summing modeled shadows over time (Fig. 1). These maps show the locations of near-continuous illumination as well as the extent of permanent shadow. Modeling with LOLA topography suggests the extent of predicted permanent shadow has increased from previous estimates, but the locations and characteristics of highly illuminated points are consistent with the results of previous studies [1-4].

Permanent Shadow: The estimated extent of permanent shadow increases substantially at both poles with modeling based on LOLA topography. Within 10° of the South Pole, an area of 18,603 km^2 (6.46% of the total area) is permanently shadowed. At the North Pole, new models suggest 14,752 km^2 in permanent shadow, relative to the previous estimate of 6,176 km^2 [6]. LOLA-derived models also show small, discontinuous areas of permanent shadow not shown in previous studies. This is likely the cause of increased estimates of permanent shadow extent.

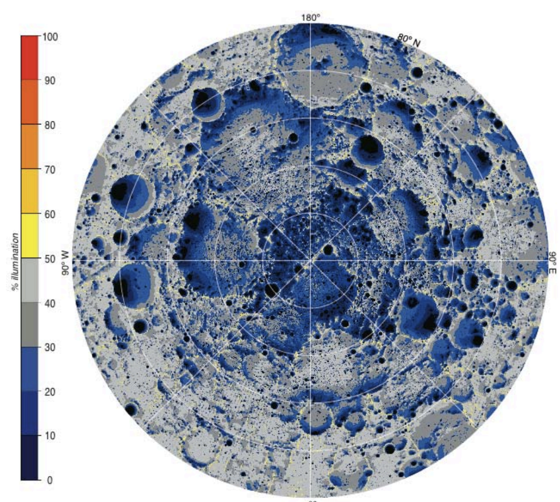


Fig. 1. Illumination map of the lunar South Pole derived from LOLA topography (year 2020).

Locations of Near-Continuous Illumination: New models suggest points illuminated ~90% of the year at both poles. Locations of near-continuously illumination predicted based on LOLA topography corroborate those found in previous optical studies [3,6]. Areas on the South Pole with the most continuous illumination are located near the western rim of Shackleton crater (~89.8º S) and the peak of Malapert Mountain (~85° S) are the (Table 1). At the North Pole, the rims of Whipple and Aepinus craters (both north of 88º N) have the most sustained lighting (Table 2).

Average illumination maps provide a macroscopic view of the lunar polar environments however, more detailed analysis of specific locations and determining the potential to navigate from one area of interest to another considering lighting limitations is fundamental toward evaluating the plausibility of polar exploration. Analysis of lighting over time is the first step toward this goal (Fig. 2). Analysis of local topography, and more detailed illumination models considering optimum height for energy capture are currently being explored. These data will aid in the development of mission constraints for future exploration.

Conclusions: Here we report a more complete characterization of points of near-continuous illumination and evaluate their exploration potential. On-going work includes improvements to lighting models using ~2-3 hour modeling intervals (consistent with LROC data coverage) and illumination modeling at multiple receiving heights from the lunar surface to determine and detail optimum solar array capture height variations. This variety of approaches will allow detailed multi-instrument knowledge of conditions spacecraft will encounter.

References: [1] Ward, *Science* 189, 377 (1975); [2] Paige *et al.*, *Science* 330, 479 (2010); [3] Bussey *et al.*, *Geophys. Res. Let.* 26, 1187 (1999); [4] Margot *et al.*, *Science* 284, 1658 (1999); [5] Bussey *et al.*, *Nature* 434, 842 (2005); [6] Bussey *et al.*, *Icarus* doi: 10.1016/j.icarus.2010.03.028 (2010); [7] Zuber, Garrick-Bethell, *Science* 310, 983 (2005); [8] Noda *et al.*, *Geophys. Res. Let.* 35 (2008); [9] Mazarico *et al.*, *Icarus* doi: 10.1016/j.icarus.2010.10.030 (2010).

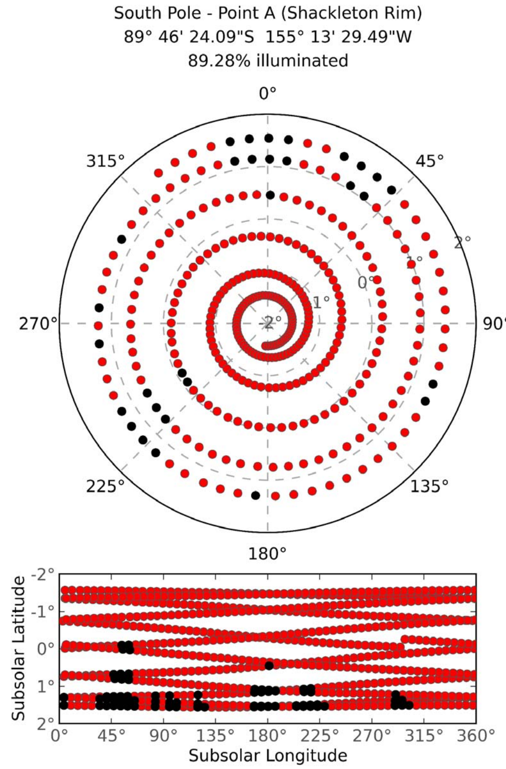


Fig. 2. Illumination on the western rim of Shackleton crater (Point A) over time. Red points represent lit periods, black represent shadowed.

Table 1. The bar charts show illumination over the lunar year 2020 for locations on the South Pole.

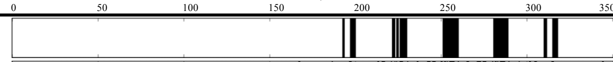
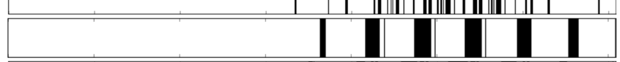
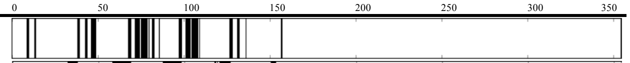
Location	Position	Illumination	Max. Shadow (Days)	Lighting Conditions Over the Lunar Year (Days: 0, 50, 100, 150, 200, 250, 300, 350)
Malapert Mountain	85º 18' 21.74" S 36º 59' 8.75" E	89.6%	9.5	
Point A (Shackleton)	89º 46' 24.09" S 155º 13' 29.49" W	89.3%	3.0	
Point B	89º 26' 4.2" S 136º 42' 4.88" W	86.5%	10.0	
Point C	88º 40' 6.55" S 68º 0' 31.93" W	83.8%	11.5	
Point D	88º 48' 44.89" S 123º 35' 2.98" E	88.0%	5.5	

Table 2. The bar charts show illumination over the lunar year 2020 for locations on the North Pole.

Location	Position	Illumination	Max. Shadow (Days)	Lighting Conditions Over the Lunar Year (Days: 0, 50, 100, 150, 200, 250, 300, 350)
Whipple Rim	89º 20' 38.55" N 131º 34' 34.06" E	90.3%	4	
Aepinus Rim	88º 2' 57.94" N 117º 48' 45.63" W	89.0%	11