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# Polar illumination conditions analysed with LROC images

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## Abstract

The Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC) and Narrow Angle Cameras (NAC) provide synoptic and high-resolution imaging of the polar regions, respectively. Image sequences collected over time provide the means to create movie sequences, illumination maps, verify illumination models, and identify small nearly continuously illuminated peaks to aid future polar exploration. With the LROC dataset, we have identified regions that are illuminated for over 90% of the year and small illuminated peaks that are 10's of meters wide in regions predicted to be in shadow.

## 1. Introduction

The rotation axis of the Moon is tilted by only 1.5° with respect to the ecliptic plane (compared to the Earth's 23.5°), leaving some areas near the poles in permanent shadow, while other nearby regions remain sunlit for the majority of a year. Each of these regions provides a unique environment for future human and/or robotic exploration. Theory, radar data, neutron measurements, Diviner, and LCROSS observations suggest volatiles may be present in cold traps in permanently shadowed regions [1-3]. Near to these shadowed regions are illuminated massifs, some of which remain illuminated for a majority of the lunar year. These regions of near permanent illumination are prime locations for future lunar outposts due to their benign thermal conditions and near constant accessibility to solar power, as well as their proximity to potential lunar resources in nearby cold traps. The images acquired by LROC provide a high-resolution dataset for unambiguously delimiting between shadowed and illuminated regions, prime locations for future robotic and human explorers.

## 2. Multi-temporal mapping

LRO's 50-km polar orbit enables images of each pole to be acquired every ~2 hours during normal spacecraft and instrument operations (average time between WAC observations thus far is 2.3 hours, including spacecraft and instrument disturbances). The WAC 90° field of view (monochrome mode) allows for a 104-km region within 2° degrees of the pole to be acquired at a pixel scale of 100 m. This repeat coverage enables the creation of illumination movies, which allow us to visualize how lighting conditions at each pole change over a year. The same frames are also collapsed into illumination maps (one for each pole). The images are first converted into binary images, which delimit regions that are illuminated and those in shadow. The binary illumination frames are stacked in map space, and at each pixel the percentage that pixel is illuminated is recorded in an illumination image (Figure 1). Brighter regions denote areas with extended illumination while dark areas remain in shadow for most or all of the year.

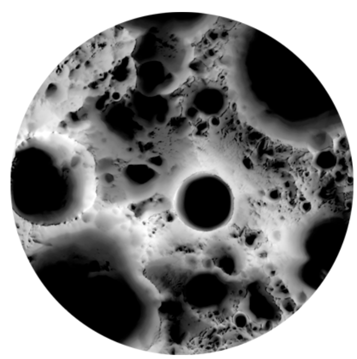

Figure 1: South pole illumination map derived from over 1,700 WAC images.

## 3. High resolution mapping and model validation

The NAC provides high-resolution (0.5 to 1.5 m pixel scale) images of select regions around the poles. Due to the NAC's 2.85° field of view (5.7° combined) broad scale multi-temporal mapping is limited. However, during each poles respective summer solstice, when shadows are at a minimum, the NACs acquire 100s of images that are used to create meter scale maps of the illuminated terrain. During the winter months, a majority of the region is in shadow, so NAC imaging is focused on previously identified illuminated peaks that stay illuminated for a majority of the year [4-6].

Due to its high resolution, the NAC images can be used to validate previous illumination studies that used lower-resolution topographic models (240-500 m pixel scale) [4-6]. NAC images revealed several cases where small regions of the surface were illuminated when previous models predicted they would be in shadow (Figure 2 and 3). Similarly, NAC images have also shown some regions in shadow at times in which models showed them illuminated.


Figure 2: LROC NAC images of small illuminated peak in regions thought to be in shadow. Left to right: M125982889R, M121428595R, M125487442R.

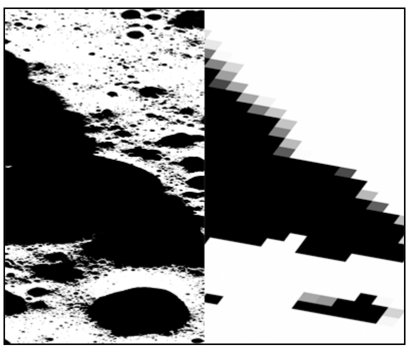

Figure 3: Left- LROC NAC image (M123851228R) with hard stretch to unambiguously delimit illuminated and shadowed regions. Right- LOLA illumination simulation (240 m pixel scale).

## 4. Impact on future exploration

Future polar explorers, both human and robotic, will need to consider the regional illumination conditions. Previous studies have focused on locating small illuminated massifs with long periods of illumination [4-6]. Alternatively, surface mobility can also extend the amount of time polar explorers are illuminated. This method is also advantageous thermally since the entire human and/or robotic explorer would have access to solar energy. With the high spatial resolution provided by the WAC and the NAC, *regions* of extended illumination are identified. For a case study, we examined a 2.25-$km^2$ region surrounding the most illuminated massif identified in previous publications (89.4° S 223° E) [4-5]. Over a year-long period this region remained illuminated 92% of the time (Figure 4).

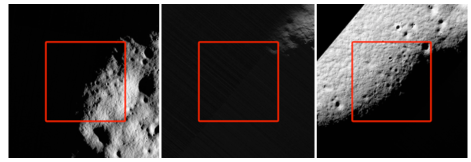

Figure 4: Detailed look at the illumination conditions of a 2.25 $km^2$ region (red box). Left to right: M108578776, M117228165, M121951177.

## 5. Summary and Conclusions

The Moon's slightly tilted axis provides a unique opportunity for regions near the vicinity of the pole to be permanently shadowed while other nearby regions can have extended periods of sunlight. Illumination in these regions has been previously studied with Clementine UVVIS data and topographic models from laser altimeters. LROC compliments this analysis with higher resolution data (up to meter scale) that can unambiguously identify these regions. Together, the NAC and the WAC can enhance our knowledge of the lighting conditions at the pole and provide a new dataset planning future science and exploration missions to the polar regions.

### References


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