LUNAR POLAR ILLUMINATION CONDITIONS DERIVED USING KAGUYA LASER DATA
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Introduction: The lunar polar regions experience unusual illumination conditions that make them attractive candidates for future exploration and possible use. The small angle between the Moon's spin axis and the ecliptic plane result in locations that are permanently shadowed as well as some that are nearly continuously illuminated. We have used the Kaguya laser-altimeter derived topography to comprehensively characterize the illumination conditions at both poles of the Moon for the first time.

The Data: This detailed illumination study became possible with the release of the Kaguya laser-derived topography data set. Kaguya was a JAXA lunar orbiter, launched in 2007, which mapped the Moon from a 100 km polar orbit for 2 years. Kaguya (known as SELENE before launch) carried an extensive suite of instruments that conducted a comprehensive study of the lunar surface [1]. The primary data set used in this study is the polar Digital Elevation Model (DEM) derived from the laser altimeter experiment. The laser altimeter on Kaguya used a 1064 nm laser firing at 1 Hz (with a corresponding along track spacing of ~1.6 km). Spot size on the lunar surface was 40 m and the vertical accuracy was 5 m. These data were used to produce a 500 m/pixel spatial resolution DEM covering from 85° S to 90° [2].

Technique: We are able to simulate where is illuminated on the lunar surface for a chosen value for Sun position. We have used a Kaguya-derived DEM to generate simulations of a diverse range of lunar polar illumination conditions.

Results: Specifically we have addressed four topics: 1. Clementine Comparison, 2. Permanent-shadow, 3. Seasonal variations, & 4. Illumination profiles for key sites.

Clementine Comparison: We ran multiple simulations using solar positions that correspond to a Clementine UVIS image. An example is shown in Figure 1. We find that the Kaguya DEM can be used to predict illumination conditions with a high degree of confidence. In fact we think that this is the first data set of sufficient quality to be used for conditions where this is not an image to provide ground truth.

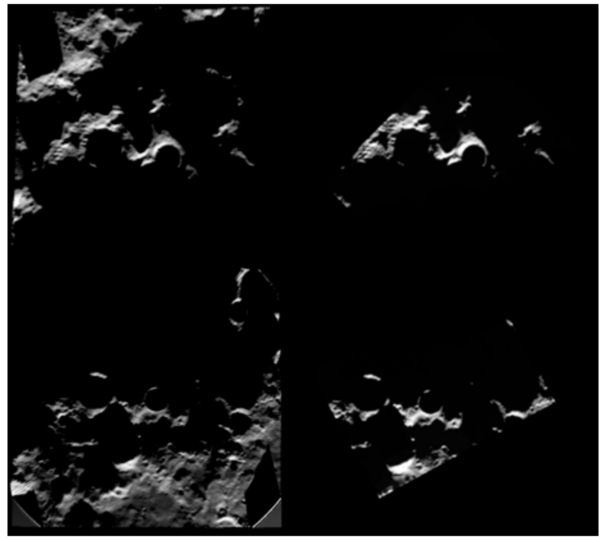

Figure 1. Comparison between two Kaguya-derived simulations and actual Clementine images of the region near Shackleton crater. Earth is towards the top of the images. The Sun direction for the top images is 15°W and for the bottom images is 167°E. The Kaguya DEM can be used to accurately predict the illumination conditions.

Permanent Shadow: We used the Kaguya DEM to calculate areas of permanent shadow and also those areas which are also Earth shadowed. Figure 2 shows the results for the south pole. We calculate there to be 5058 km^2 of permanent shadow (shown in red & yellow in Figure 2), 44% of which is also Earth shadowed (shown in red). There is a total of 10520 km^2 of areas that are always hidden from Earth (blue & red), of which 79% are NOT in permanent Sun shadow (blue).

Seasonal Variations: We have used the data to investigate seasonal variations in the illumination conditions. Even though the Sun only varies 3° in elevation during a year there are significant variations between summer and winter. Initially we produced a quantitative illumination map over the course of an entire year. Next quantitative illumination maps were made for seven lunar days. Day 1 had mid-winter for the northern hemisphere at the middle of the day, whilst day 7 has mid-summer at the middle of the day. The maps for days 1 & 7 for the North Polar Region are shown in Figure 3. Similar maps were made for the South Polar Region.

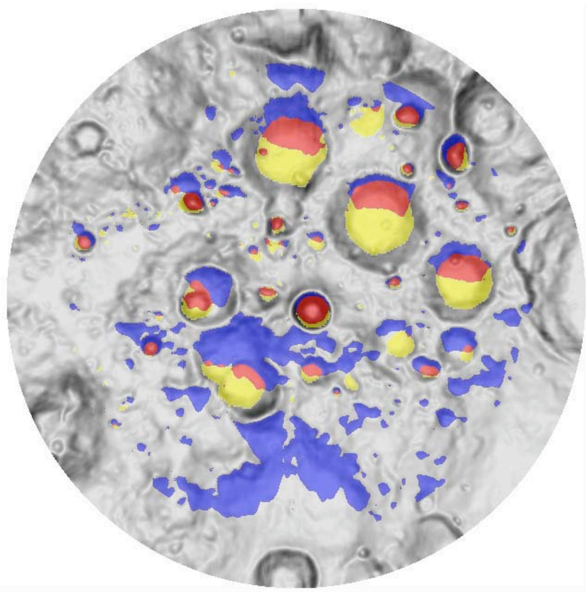

Figure 2. A map of permanent shadow within 4° of the South Pole. Areas shown in red and yellow are permanently shadowed from the Sun. Areas in blue and red are permanently Earth shadowed. Areas in red are also shadowed from both the Sun and the Earth.

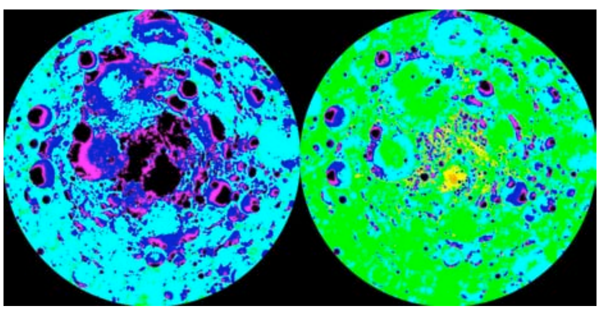

Figure 3. Quantitative north-pole illumination maps for summer (left) and winter (right).

Illumination Profiles: We used the seasonal-variation maps to identify regions that receive the most illumination near both poles. For the south pole the four areas that receive the most illumination were found to be the same areas that were previously identified by analysis of Clementine UVVIS images [3]. For these regions of maximum illumination we determined detailed illumination profiles. These show the amount and duration of the eclipse periods. Additionally they show the maximum single amount of time that they receive contiuous illumination. We have found places near the south pole that are illuminated continuously for more than four months around mid-summer. Figure 4 shows the illumination profile for two areas near Shackleton. These are collectively illuminated for over eight continuous months around mid-summer and greater than 94% of the time overall.

Kaguya also carried a HDTV camera that acquired stunning HD movies of the lunar terrain passing below the spacecraft. Figure 5 shows a single frame from one of these movies. It covers the south polar region including Shackleton and de Gerlache craters. This image also shows the four areas near the south pole that we identified as receiving the most illumination. They appear to correspond to small local topographic highs.

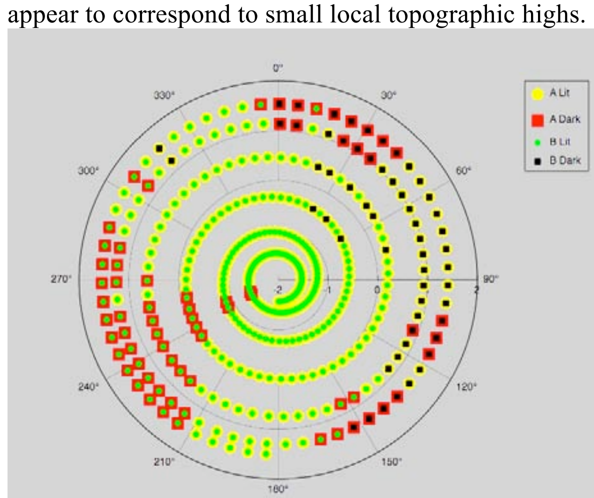

Figure 4. Detailed illumination profiles for two areas near Shackleton crater.

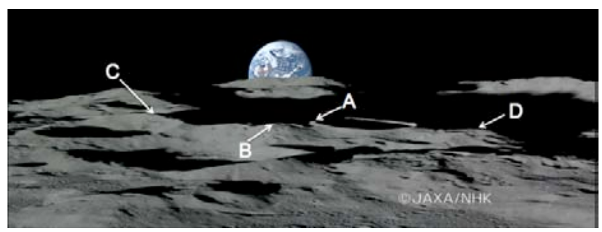

Figure 5. Kaguya HDTV image of the south polar region showing the areas that receive the most illumination.

Conclusions: The Kaguya DEM has proved to be a major asset in trying to understand the illumination conditions at the lunar poles. We have used this topography product to comprehensively characterize the lunar polar illumination conditions. New data now being obtained by LRO will increase our understanding of polar lighting conditions.

References:

[1] Kato M. (2008) *Adv. Space Res.,*, 42, 294–300. [2] Noda et al., (2008) *GRL*, 35, L24203. [3] Bussey D.B.J. (1999) *GRL,* 26, 1187-1190.