# DETERMINATION OF PERMANANTLY SHADOWED TERRAIN IN THE LUNAR POLAR REGIONS.

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**Introduction:** Imaging of the Moon by Clementine has allowed our first quantitative look at the illumination in the lunar polar regions [1]. This has shown that several regions exist at the south pole that receive almost continuous sunlight and also that there are large areas that received no illumination for the duration of the Clementine mission. While the imaging coverage at the north pole is less extensive, a qualitative analysis of Clementine data [2] indicated that portions of the floors of craters as far out as 10° from the pole may be in permanent shadow.

Both missions that have imaged the lunar poles, Clementine and Lunar Orbiter, acquired data during summer in the northern hemisphere (and therefore winter in the southern hemisphere). In order to expand our knowledge of the polar illumination conditions (i.e. for lighting conditions that we do not have imagery of, e.g. summer in the southern hemisphere) it is necessary to use techniques other than image analysis.

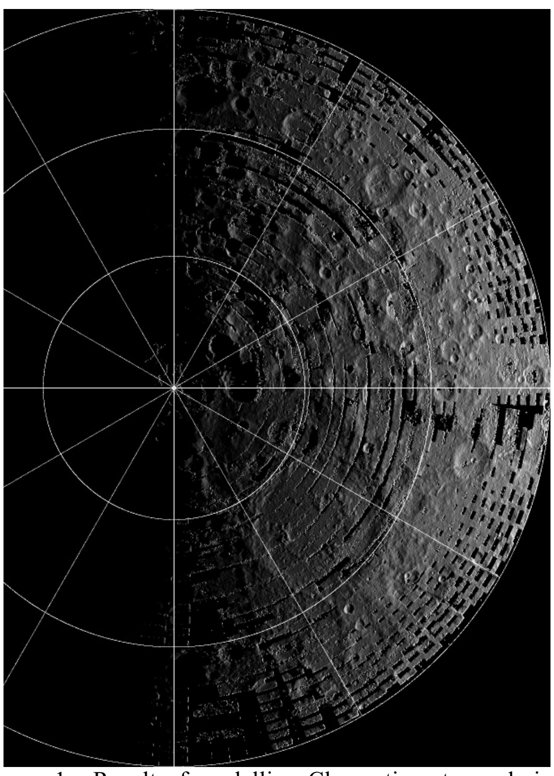

Figure 1. Result of modelling Clementine stereo derived topography data of the Moon's southern polar region. Mosaic extends from 60° to 90° S. 0° longitude is at the top. Sun direction is 90° E.

One method of investigating the illumination at the poles for lighting conditions for which there is no imagery is modelling of topography data. Topography data of the lunar poles exists from both earth based radar measurements [3] and Clementine stereo analysis [4]. Modelling illumination using these datasets showed promising results when comparing the output of simulations with actual imagery [5]. Figure 1 shows the result of simulating illumination using Clementine stereo derived topography.

**Crater Simulations:** In order to do detailed analysis of permanent shadow in craters near the poles, higher resolution topography than currently exists is desirable.

Fortunately the shape of simple craters on the Moon has been well studied and the shape of a crater can be determined as a function of its diameter [6]. Simple crater parameters (such as depth, rim height, rim width etc) can be expressed in the form $\mathbf{a=D^b}$ where 'a' is a crater parameter, 'D' is crater diameter, and 'b' is a known constant. We are therefore able to generate realistic crater profiles to be modelled. Figure 2 shows the half-profile of a 20 km crater superposed onto a 1738 km sphere.

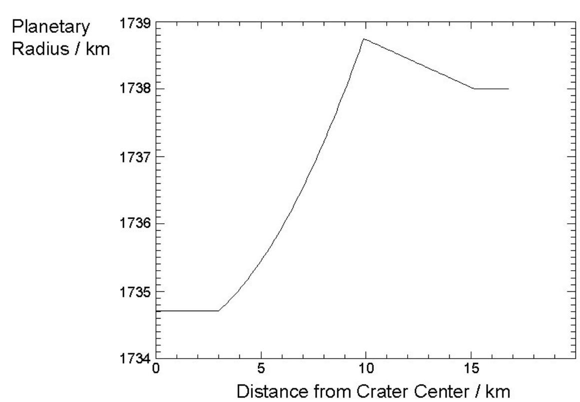


Figure 2. Half profile of a simple 20 km lunar crater. Vertical exaggeration is approximately 3x.

Many simulations were conducted to investigate how the amount of permanent shadow inside an impact crater varied as a function of different parameters (size, latitude, and season). Four different sizes of simple craters (2, 5, 10, and 20 km) at latitudes ranging from 80° to 90° (in 1° increments) were studied.

Simulations were conducted to determine the amount of permanent shadow in a crater during a lunar day (708 hours) by running the model several times, the only parameter changing being subsolar longitude. Seasonal variations were investigated by allowing the subsolar point to move 1.5° above and below the equator. The finite radius of the Sun was also allowed for. Figure 3 shows the results of a single simulation.

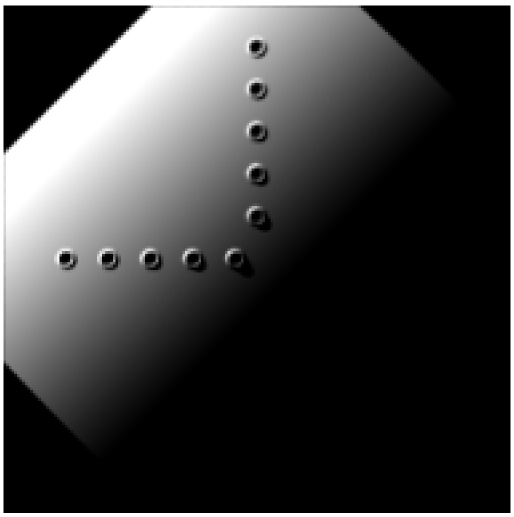

Figure 3. This shows the results for a single run of the simulation for 20 km craters superposed onto a 1738 km sphere. The sun direction is from the upper left.

By averaging the results of several simulations, that vary only in illumination direction, we can produce a map that indicates the percentage time a place on the surface is illuminated during a lunar day. It is thus possible to see which portions of the interiors of the craters are permanently shadowed.

**Results:** Figures 4 & 5 show the results from 3 series of simulations for 20 & 5 km craters respectively.

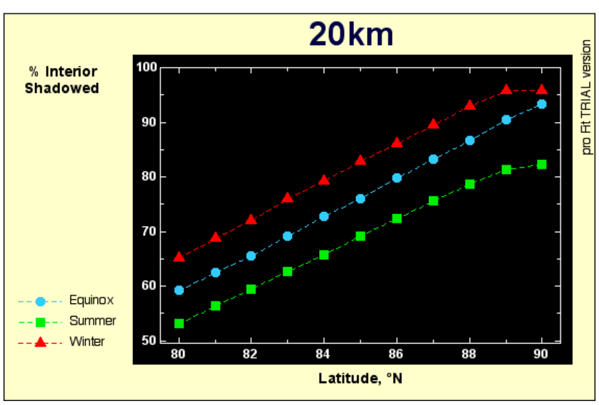


Figure 4. The graph shows the results for three sets of simulations (corresponding to summer, equinox, and winter) for 20 km craters. It shows the percentage of the interior of the crater that was shadowed during a lunar day.

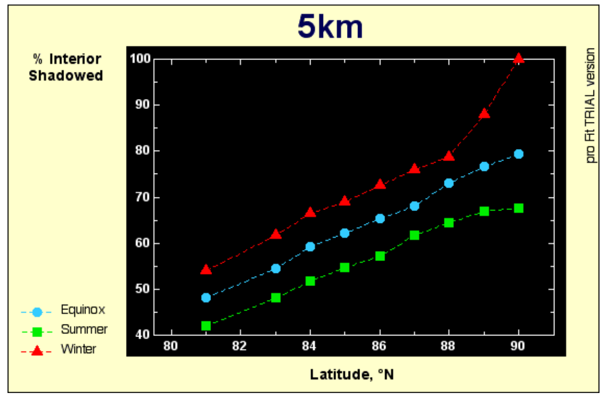


Figure 5. These data show the results of simulating the illumination conditions for 5 km craters near the lunar pole to determine the amount of permanent shadow in their interiors.

Key results so far include:

- At a given latitude, large craters have a higher proportion of their interiors shaded than smaller craters.
- Seasonal variations appear to be independent of crater size, the amount of darkness during a day in winter versus summer differs by about 15%.
- Craters as far out as 10° from the pole can still have significant amounts (> 50% for 20 km craters) of permanent shadow.

**Future Work:** Results from this study will help to understand the nature of the permanent shadow at the lunar poles, hence permitting the production of new darkness maps. Comparison of this map with results from the Lunar Prospector neutron spectrometer [7] will put constraints on the location of ice deposits.

**References:** [1] Bussey D. B. J. et al. (1999) *GRL*, *26*, 1187-1190. [2] Bussey D. B. J. et al (1999) *LPSC XXX*, Abs. # 1731. [3] Margot J. L. et al (2000) *IEEE Trans. Geo. Rem. Sens.*, *38*, 1122-1133. [4] Cook A. C. et al. (2000) *JGR* , *105*, 12023-12033. [5] Bussey D. B. J. et al. (2001) *LPSC XXXII*, Abs. # 1907. [6] Pike R. J. (1977) *Impact and Explosion Cratering*, 489-509. [7] Feldman W. C. (2000) *JGR, 105*, 4175-4196.