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Thermal extremes in permanently shadowed regions at the lunar south pole

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Abstract

Permanently shadowed regions (PSRs) persist at the lunar poles due to the Moon's low axial tilt and may offer conditions suitable for long-term stability for volatiles [1]. Here we present new bolometric temperature maps constructed from more than three years of observations by LRO's Diviner Lunar Radiometer Experiment. These data prompt discussion regarding thermophysical properties of regolith and the consequences for the potential presence and stability of volatiles in PSRs.

1. Introduction

Crater interiors and other topographic depressions that form PSRs act as cold traps. Evidence from recent observations of the lunar poles by instruments aboard NASA's Lunar Reconnaissance Orbiter is focused on isolating potential signatures of such volatiles, following the detection of water and other volatiles after the LCROSS impact into Cabeus crater [2].

However, the body of results to date yields a relatively inconclusive answer to the question of volatile abundance at the surface, with most techniques indicating either a very thin veneer of water ice frost [3] or signatures that may also represent freshly exposed/weathered regolith [4, 5, 6].

Diviner's complete spatial coverage of the South Pole, with many repeat observations, allows high-resolution quantification of diurnal, seasonal and total thermal extremes.

2. Method

Diviner radiance measurements acquired between between July 5th 2009 and February 25th 2013 were projected onto a lunar terrain model derived from measurements by the Lunar Orbiter Laser Altimeter (LOLA). We calculate bolometric temperature, the wavelength-integrated radiance in all seven thermal Diviner channels expressed as the temperature of an equivalent blackbody [8]. Data were corrected for field of view effects before gridding onto a 240m per pixel polar stereographic grid between 90°S and 82.5°S. Statistics are calculated for each grid cell, including the maximum (Figure 1) and minimum bolometric temperatures observed, as well as the total thermal range (Figure 2).

Diviner channels 8 (50 – 100 μm) and 9 (100 – 400 μm) are most sensitive to surface temperatures of 43 – 69K and < 43K, respectively [7]. The coldest PSRs exhibit temperatures close to the sensitivity threshold of channel 9 and thus bolometric temperatures become dependant predominantly on the brightness temperature of the longest wavelength channels.

3. Results

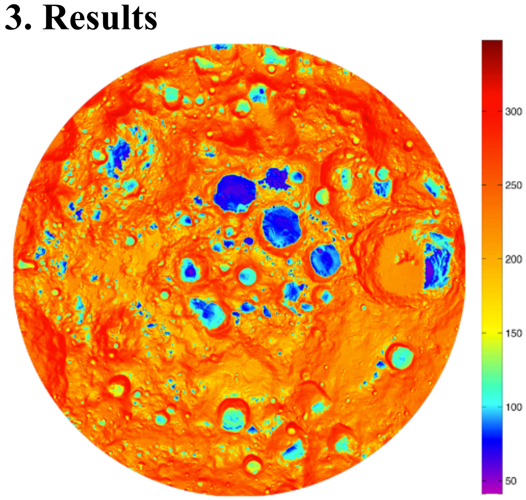

Figure 1: Maximum bolometric temperature (K), south pole to 82.5°S.

Many PSRs show maximum bolometric temperatures < 100K throughout the year and there are many significantly colder than this.

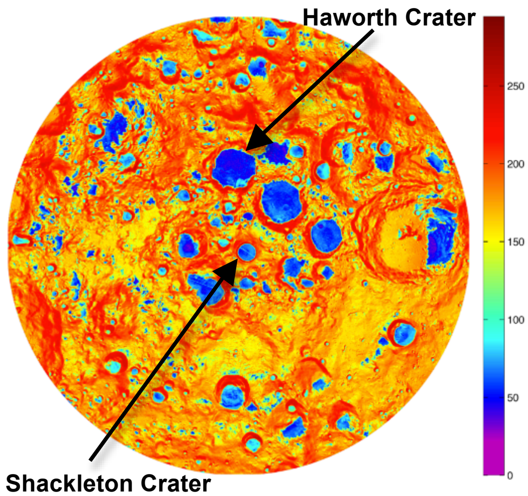

Figure 2: Bolometric temperature range (max-min) (K), south pole to 82.5°S.

A variety of thermal behaviors are observed for south pole PSRs, indicating a range of thermophysical properties for surface materials. Some of the coldest maximum bolometric temperatures observed reside in Haworth crater (Figure 2) and appear never to exceed ~40K. This is also the region with the lowest temperature range, indicating a persistently stable thermal regime. Doubly shadowed regions also exhibit similar cold and stable thermal regimes. They typically lie within small diameter craters inside PSRs and are shielded from minor thermal emissions from PSR surfaces by the crater rim.

4. Correlation with albedo

Recent 1064nm albedo measurements by LOLA indicate that there is some correlation between high albedo and low temperatures. However, not all cold places are bright, and many bright places are also warm. Plausible causes of high 1064nm albedo (as well as low ultraviolet albedo as measured by the Lyman-Alpha Mapping Project, LAMP) include regolith brightening by mass-wasting, the effects of space weathering at low temperatures or minor amounts of surface ice [3,5]. Comparison of bright LOLA albedo measured in Shackleton Crater (Figure 2) with albedos from a broad crater population sampled from PSRs and equatorial regions indicates that surface volatiles are not necessarily required to explain high albedo PSRs [4]. Further investigation requires isolation of super cold areas and correlation of bolometric temperature with albedos from both LOLA and LAMP albedo. Consideration of sub-pixel effects is important since limited surface expression of volatiles i.e. a sparse surface or sub-surface distribution, may have little effects on apparent albedo at the scale of measurement footprints.

5. Acknowledgements

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6. References

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