Large Impacts on the Moon: Rays, Halos, and Melts

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Introduction: The Diviner instrument aboard LRO acquires radiometric measurements of reflected and emitted radiation of the Moon in 9 spectral channels. Over 5.5 years of data have been compiled into a 0.5° resolution global dataset with a 0.25 hour local time resolution providing a global perspective of the surface energy balance of the Moon [1]. Impact craters are found to modify regolith thermophysical and radiative properties over large distances. The thermal signature of Tycho is asymmetric, consistent with an oblique impact coming from the west and rays require material with a higher thermal inertial than nominal regolith. The modification of the regolith by the formation of the Orientale basin is observable over a substantial portion of the western hemisphere despite its age (~ 3.8 Gyr), and may have contributed to mixing of highland and mare material on the margin of Oceanus Procellarum where the gradient in radiative properties at the mare-highland contact is broad (~ 200 km).

Tycho Crater: Tycho represents one of the most significant thermal anomalies in the nighttime IR observations with minimum temperatures, T_{min}, exceeding the zonal average by > 30 K. Conversely, high reflectance material within and surrounding Tycho reduces the maximum temperatures, T_{max}. As a result, the relative temperature difference (T_{max}/T_{min}) experienced by Tycho and the adjacent terrain is reduced relative to the rest of the highlands (Fig 1). The T_{max}/T_{min} values display an east-west asymmetry resulting from higher T_{min} on the eastern wall and higher reflectance and thermal inertia materials distributed to a greater extent to the east. The warmer nighttime temperatures on the eastern wall cannot be entirely attributed to the western wall being in shadow in the afternoon. Nighttime brightness temperatures display anisothermality in the Diviner IR channels that also shows a strong east-west asymmetry. Anisothermality, seen for example by differencing channel 6 and 8 nighttime temperatures, results from mixtures of warmer and cooler temperatures within Diviner's field-of-view and is diagnostic of the presence of rocks [2]. The greater anisothermality observed on the eastern crater wall indicates a greater abundance of high thermal inertia materials and the elevated anisothermality is distributed to a greater extent eastward outside of the crater (Fig 1).

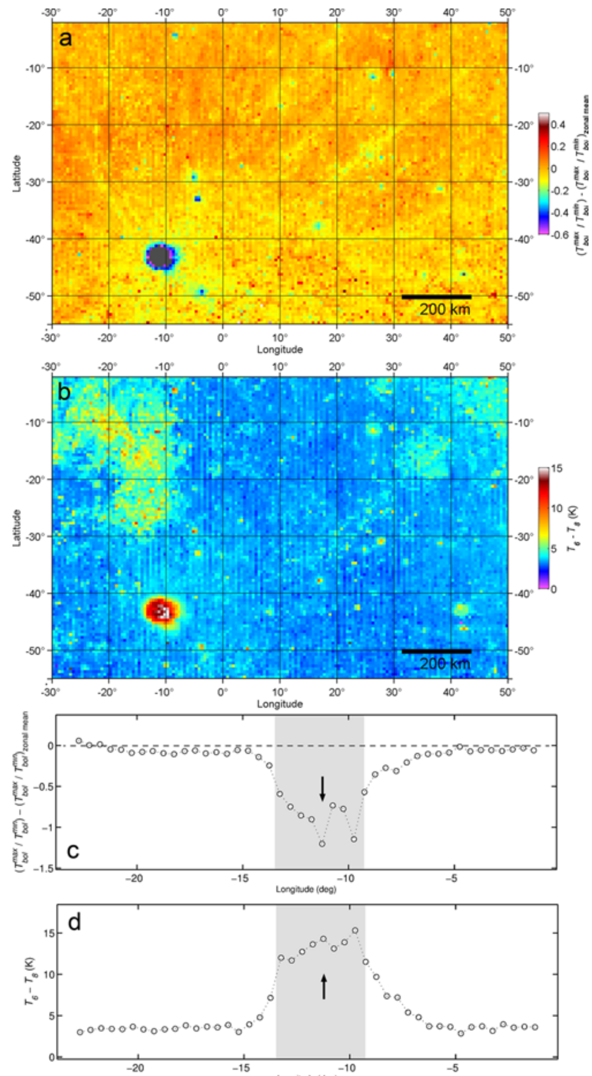

Figure 1: Maps of (a) T_{max}/T_{min}, and (b) nighttime anisothermality (T_6-T_8), and E-W profiles across Tycho of (c) T_{max}/T_{min}, and (d) T_6-T_8. Shading indicates crater interior and arrow the central peak.

Tycho displays some of the most extensive rays visible in the Diviner data. Rays are observable as thermal anomalies in nighttime temperatures indicating a contrast in thermophysical properties in addition to having a higher reflectance. Bandfield et al. [2] modeled rock abundances from anisothermality observed in Diviner nighttime temperatures. The rock abundance estimates do not show an enhancement of rock concentration in the rays and they are indistinct in the $T_6 - T_8$ maps. The thermal skin depth for a basaltic rock under lunar diurnal conditions is ~ 0.5 to 1 m indicating the thermal contrast of the ray must largely result from objects primarily smaller than this size.

Orientale Basin The thermal signature of the Orientale basin (Fig. 2) demonstrates the wide spread influence the impact event has had on the regolith properties in the western hemisphere. The basin, defined by the Cordillera ring, covers an area of $\sim 700,000$ km^2. The warmest nighttime temperatures are associated with a lobe of the Montes Rook Formation that extends beyond the Cordillera scarp in the southwest corner. This area also corresponds to higher $T_6 - T_8$ nighttime anisothermality indicative of elevated concentrations of rocks consistent with the presence of impact melt (arrow in Fig. 2b). Deposits exterior to the basin are collectively named the Hevelius Formation [3]. The inner facies are comprised of continuous deposits forming an annulus of material $\sim 300 - 600$ km wide. The deposits of the inner facies are discernible in Diviner data as a region of relatively uniform, low $T_6 - T_8$ anisothermality from the Cordillera ring extending radially outward to a digitate outer margin that roughly corresponds to the contact mapped by Scott et al. [3]. This annulus of low anisothermality, most prominent in the south and east, is also found to be a region of low radar return [4] implying the unit is related to the radar-dark halos observed around other sizeable craters.

The mare-highland boundary of western Oceanus Procellarum was likely modified by the impact event. Diviner visual brightness (Fig. 2) shows a gradation in reflectance over a distance of ~ 200 km across the mare-highland boundary. T_{max} values also mirror the gradient in radiative properties. In contrast, the gradient in thermophysical properties (e.g. $T_6 - T_8$ anisothermality and T_{min}) appear relatively narrow and abrupt by comparison (within one or two map pixels, $\sim 20 - 40$ km) and occurs at the low side of the visual brightness gradient at ~ 0.06. The broad transition in radiative properties is consistent with ejecta from Orientale mixing with pre-existing, proto-Procellarum basalts (e.g. [5]).

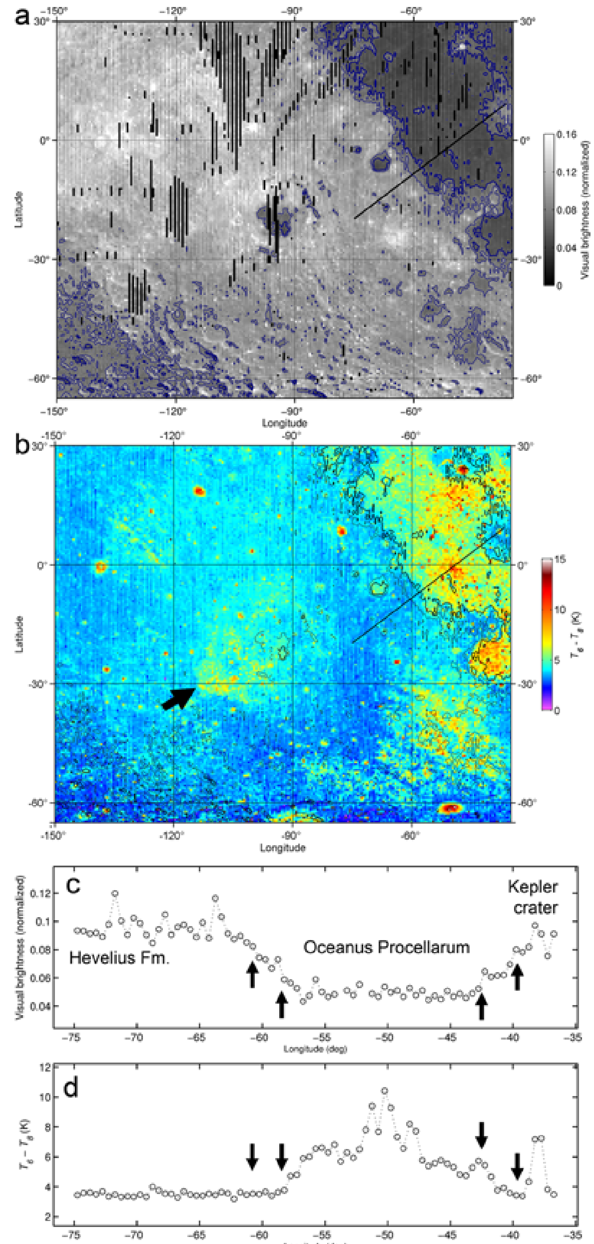

Figure 2: Diviner maps centered on Orientale:(a) visual brightness (VB) (b) nighttime $T_6 - T_8$. Contours are VB = 0.06 and 0.08. Line is location of profiles in (c) and (d) with arrows showing the location of VB contours.

References

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