Illumination analysis of Louth Crater and its relation with ice deposits. M. Mantegazza[1] and M.G. Spagnuolo,[1]
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Introduction: In the Martian north polar regions there are over 10 ice deposits contained in the interior of different craters. One of these deposits is found in Louth Crater. Louth is a 36 km diameter crater 1.5 km depth. It is located at ~70.2°N 102.3°W and represents one of the most southern water ice deposits. Its interior contains a ~10 km diameter ice mound placed near the center of the crater floor, slightly shifted to the north. Previous works describe the morphology, composition [1] and models the mass balance of the ice mounds [2]. However, the origin of this ice deposits in still poorly understood mainly because of the most-equatorward position. In previous works it was proposed that inner-crater ice mounds developed under unique atmospherics conditions in what is known as "cold traps" [3]. An alternative hypothesis argues that these equatorward ice deposits might be related with a more extensive ice cap [4]. Most geological evidence point to a model of atmospheric deposition of water vapor in the center of the crater [1]. Moreover, the offset position of the ice mound was attributed to depositional process, aeolian activity and sublimation [1].

In this work we explore the relation of illumination and solar energy with the position of the ice mound inside Louth crater. We explore three hypotheses of formation: i) the ice mound represents a residual North Polar Cap deposits ii) it was formed in the center of Louth crater and shifted to the north or iii) it was formed at its present offset position from the center. We analyzed the shadows distribution in Louth Crater and the solar energy in order to evaluate if the north ice mound region represents a low illumination region that defines ice precipitation.

Methods: For the illumination analysis we use the MarsLux code [5] using MOLA DEM [6] downsampled to 600 m/px (Figure 1A). Based on the topography and orbitals parameters the code calculates shadows and illumination for each pixel along a period of time. In this work we analyzed 1 Martian year (MY30) with a time-step of hour.

The ice deposits are controlled mainly by topographic, atmospheric and orbital conditions. In this work we present three different approaches in order to test the effects of topography and orbital parameters. In the first one we calculated the illumination in the present conditions, using the actual topography and a Martian inclination axis of 25.19° ("Present Crater").

To analyze the effects of topography we generate a new DTM without the ice mound. We produced a new DTM (with the same resolution) but with a typical bowl shape crater floor ("Empty Crater"). To create

this new topography we first mapped the limits of the ice mound based on HiRISE and CTX images. Then we extracted those points from the original topographic grid. Finally using an interpolating polynomial technique of different topographics profiles we reconstruct the crater floor, filling the grid again with the interpolated points. (Figure 1B).

To analyze the impact of orbital parameters we use the MarsLux code but modified the inclination axis up to 60°. In this way we wanted to examine the illumination under a past high-obliquity orbital conditions ("Past crater").
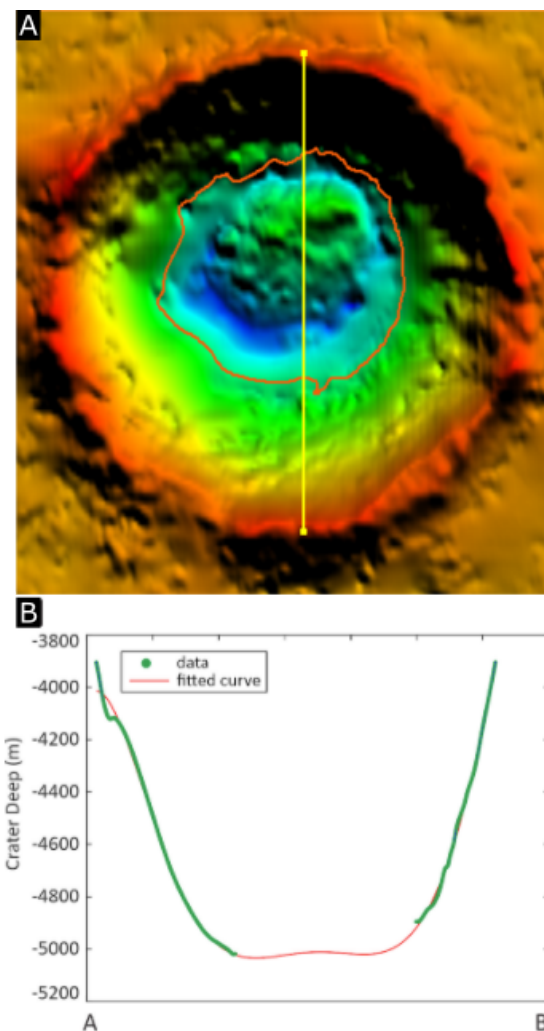
Figure 1: *Example of topography removal method. A) DTM MOLA downsampled to 600 m/px of Louth Crater. The orange polygon represents eliminated area. The yellow N-S line is one of the topographic profile as an example. B) Profile reconstruction by polynomial interpolation.*

Finally a statistical analysis was made to generate maps of mean, maximum and minimum illumination, together with a number of hours in total darkness. This study was made annually and seasonally to be able to quantify the radiation variation along one Martian year.

Results: Figure 2 shows the annual hours of total shadow for the three different sets. From a total of 16516 hours, the interior of Louth crater received maximum of ~9500 hours of darkness.

Figure 2 shows that the shadows are what were expected for a northern crater, but some areas stand out for anomalously low energy. It is observed that there is a clear "self-shadowing" process by the ice mound (Figure 2A). The area enclosed between the mound and the northern crater wall has the lowest energy and the larger amounts of hours in full darkness.

The results of the illumination map for the "Empty crater" do not show any large anomaly except for a "triangular" less illuminated area that match with the elongated shape of the mound (Figure 2B and C arrow). This is also seen even in a high-obliquity scenario. The shadow pattern results very similarly but the amount of energy received is lower (Figure 2B and   C).

Conclusions: Based on our analysis we agree with [1] that there could be a self-regulating process where the ice mound itself cast a shadow in its northern area. This might facilitate the preservation of the northern part either by preventing ablation and/or promote precipitation of water ice.

Our results show a favoring condition in the "Empty Crater" scenario where the mound might have started to grow form the North-East and extended to the South-West in accordance to the ages reported by [1] . Finally the high-obliquity scenario provides lower values of illumination at the area but no significant changes in the patterns of shadows.

References: [1] Brown A. J. et al. (2008) *Icarus*, 196, 433–445. [2] Bapst J. et al. (2018) *Icarus*, 308, 15–26. [3] Conway S.J. et al. (2012), *Icarus*, 2020, 174-193. [4] Fishbaugh, K. E., and J. W. Head (2000),J.G.R., 105(E9), 22,455–22,486. [5] Spagnuolo et al. (2019) *E&SS*, 6, 146-155. [6] Smith, et al. (2001). J.G.R. 106(E10), 23689–23722.
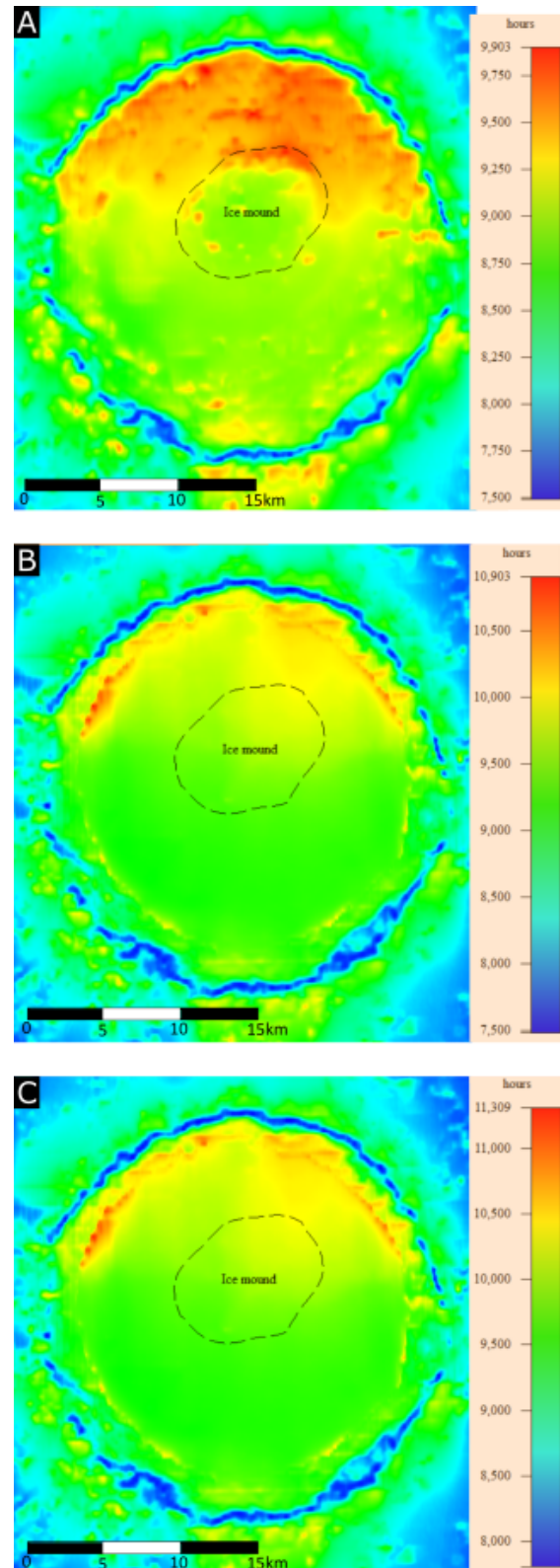
Figura 2: *Map of # of annual hours of total shadow for: A) Present Crater, B) Empty Crater and C) Past Crater. In dashed line it's delimited the ice mound limit.*