EXPLORING THE THERMAL BEHAVIOR OF CRATERS WITH PERMANENT SHADOWED AREAS IN THE NORTH POLE OF MERCURY

Bertoli S.[1], Cambianica P.[1], Martellato E.[1], Cremonese G.[1], Lucchetti A.[1], Pajola M.[1], Munaretto G.[1], Massironi M.[2], Simioni E.[1],

[1] INAF, Osservatorio Astronomico di Padova, Padova, Italy; [2] Department of Geological Sciences, University of Padova, Padova, Italy;

Introduction: The Mercury polar regions host Permanent Shadowed regions (PSRs), which are constantly in shadow (due to the planet's small obliquity, [1]), and can thus reach very low temperatures [2]. These conditions could have allowed the long-term survival of water ice, as suggested in the 90s after the discovery by Earth based radar observations of radar bright material located within the PSRs [3,4]. This hypothesis was later confirmed through the comparisons with the signal from icy satellites and Mars's polar cap [5], hydrogen concentration on PSR measured from MESSENGER mission [6], and thermal models [7]. The morphological analysis of those craters in [8] highlights some interesting features within the craters that could be ascribed to the presence of water ice. In this work we show the results obtained by applying a shape-based thermophysical model [9] to 1) characterize the thermal environment, 2) predict the evolution of the analyzed craters [8], and 3) understand if the PSRs thermal conditions could affect the occurrence and evolution of specific landforms.

Methods: Two different methodologies are used to explore the thermal behavior of craters located in the north pole of Mercury. First, we characterize the morphology of the considered craters focusing on specific morphologies. We start our evaluation from the [8], focusing in specifying morphologies and how they can be connected with the thermically aspect. Secondly, in order to evaluate the possible implication of the temperature on these morphologies, we performed a thermal analysis. To investigate the thermal environment of the analyzed craters we applied a shape-based thermophysical model [9]. The 3D thermal model computes the surface and subsurface temperature of each facet of a 3D mesh as it evolves over time. Temperatures are calculated considering the direct insolation, the multiple scattering of visible and infrared radiation, the infrared emission, and the effect of terrain shadowing on each facet by other facets of the geometry. The model is based on the raytracing technique and treated the Sun as a disk due to the proximity of Mercury to the Sun, hence the large areal coverage of the Sun in Mercury's sky.

Having considered the Sun as a disk makes shadow and penumbra modeling more complete in terms of heat flux calculation, since the actual morphology of a crater strongly affects the final amount of insolation received from a geometry element.

Preliminary results*:*

Morphological analysis: The first type of morphologies concerns the fractures present in the PSRs within Fuller and Jimenez craters. These have been classified as "Landforms of Uncertain origin" by [8], because their morphogenesis cannot be unambiguously defined at the available resolution. Most of these structures seem to be aligned with four nearby outcropping rocks. These rocks (350 m long, following the main axis) have an asymmetrical shape, characterized by an elongated (and less sloping) shape in one direction, and a shorter (and steeper) shape in the opposite direction. One hypothesis explaining the formation of these landforms is that the ice in the subsurface could act as permafrost. For instance, on the Earth, permafrost forms when ground is frozen for more than two years [10]. Previous studies (e.g., [7,12]) highlighted that craters with PSRs have a characteristic lag deposit on their floor, defined as dark carbon rich-material, representing the leftover of sublimated ice. This layer could act as a permafrost active layer, which flows and produces cracks on the surface, when assuming that the freeze cycle in penumbra areas is affected by heat transfer from the nearby permanently illuminated area [13]. Alternatively, we cannot exclude the possibility that fractures could instead form from the cooling of impact melt material and/or volcanic infilling. In fact, many of those kinds of fractures have been observed on Mercury [14]. Such melt deposits are in general smooth, (with many downs to no overlaying craters), and characterized by distinct contacts, as in the case of the northern portion of Fuller's and Jimenez's floor. The second type are the landslides. There are large landslides in the Fuller, Jimenez, and Yoshikawa craters that partially cover the floor. These are particular landslides that develop after the formation of craters and are referred as "rockslides" (per [15]). In order to verify the occurrences of the rockslide, we computed the proportion of the crater area occupied by it. Our result is slightly lower than the value found by [16] (25% vs. 28.3%) for thirty-eight craters located below 76°N latitude. This can be explained by changes in temperature. The thermal weathering rate [17] causes the regolith layer to react differently, which may result in varying volumes of regolith that are susceptible to failure. The effectiveness of weathering may be reduced in the areas of the Hermean polar craters that are permanently shaded, causing the decrease of the probability of later landslides.

Thermal analysis: In Fig. 1 an example of the obtained results is shown. The illumination and incident flux maps are then supplied as input to the thermal model to calculate the surface and subsurface temperatures.

Conclusion and future works: In this work, we have analyzed two craters located in the north pole of Mercury and characterized by the presence of Permanently Shadowed Regions (PSRs) within their floor. In particular, based on [8], we selected specific morphologies (e.g., fractures and landslides), whose origin and evolution could be connected to the specific temperature conditions of the hermean poles, and ultimately explained by the presence of water ice (eventually under a deposit lag). The next step will be the application of the thermal model presented by [9] to these specific structures, in order to evaluate the possible implication of thermal conditions for the long-term evolution of these craters.

Acknowledgements: The study has been supported by the Italian Space Agency (ASI-INAF agreement no. 2020-17-HH.0).

References: [1] Margot J.-L. et al. (2012), JGR:Planets, V. 117. [2] Susorney H. C. M. et al. (2021), The Planet. Sci. J., V. 2., p. 97 [3] Harmon and Slade (1992), Science, V. 258(5082), pp. 640–643 [4] Harmon et al. (2011), Icarus, V. 211, pp. 37-50. [5] Butler et al. (1993), JGR, V. 98, pp. 15003 – 15023. [6] Wilson et al. (2019), JGR:Planets, V. 124, pp. 721 – 733. [7] Paige et al. (2013), Science, V. 339, pp. 300 – 303. [8] Bertoli et al. (2022), 44th COSPAR Scientific Assembly, Abstract B4.5-0014-22 [9] Cambianica P. et al (2022), 44th COSPAR Scientific Assembly, Abstract B4.5-0012-22 [10] Dobinski, W. (2011), Earth-Science Rev., V. 108, pp. 158 – 169. [11] Syal M. B. et al. (2015), Nature Geoscience, V. 8., pp. 352 – 356. [12] Filacchione G. et al. (2022), EPSC Abstracts V. 16, EPSC2022-191, 2022 [13] Xiao Z. et al. (2014b), JGR:Planets, V. 119, pp. 1496 – 1515. [14] Crudes D. M. and Varnes D. J. (1996), Landslides Eng. Pract, V. 24, pp. 20–47. [15] Brunetti M. T. et al. (2015), Icarus, V. 260, pp. 289 – 300. [16] Molaro J. L. et al (2015), JGR:Planets, V. 120.

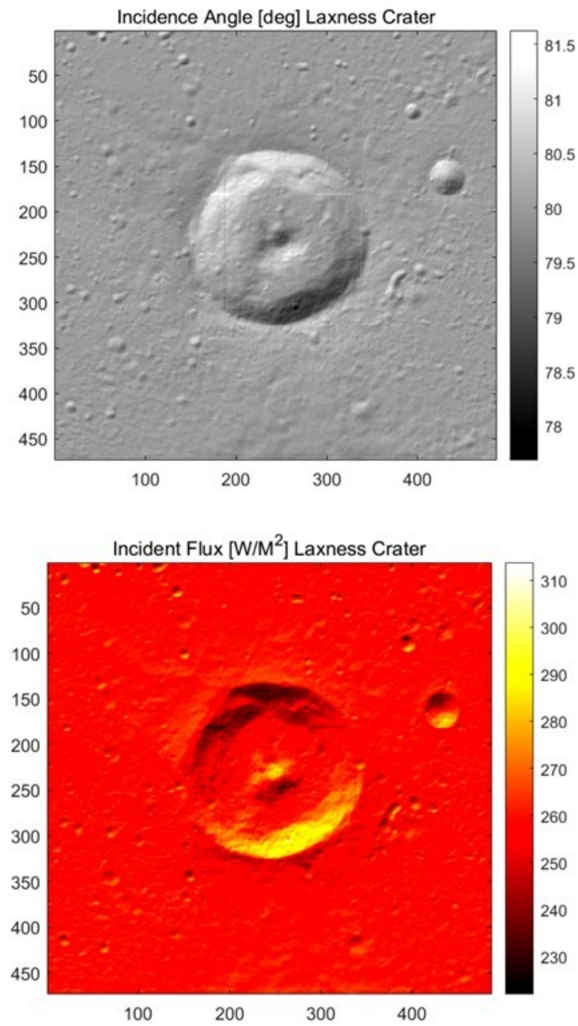

Fig. 1: The two images show the preliminary step of the thermic part applied on Fuller crater. The first image shows an example of the illumination map, the second image the incident flux map.