Analysis of Frost Inside and Around Dokka Crater in the North Polar Region of Mars

A. Luspay-Kuti[1], A. Kereszturi[2], V. F. Chevrier[1], [1]Arkansas Center for Space and Planetary Sciences (MUSE 202, UARK Fayetteville, AR 72701, USA; aluspayk@uark.edu), [2]Collegium Budapest Institute for Advanced Study (H-1041 Budapest, Szentharomsag u. 2.)

Introduction: Present day morphology in the north polar region of Mars plays an important role in understanding the climatic fluctuations forced by orbital changes, and the paleoclimatic characteristics of the planet. Based on theoretical computations and observational evidences, the latitudinal distribution of water ice on Mars varies according to the orbital changes on geologic timescales [1, 2]. One of the H_2O ice related phenomena in the north polar region are the frost outliers. It has been shown that in several craters (e.g. Korolev, Louth) there are high albedo deposits/events (HAEs) even during the summer, when they are already separated from the residual cap itself [3-8].

The intent of this work is the analysis of such frost outliers in and around Dokka crater. Dokka is 50 km in diameter, located at 77°N, 214°E. Its interior is presumably a remnant of a former polar cap with larger extension, so it could provide valuable information about the past Martian conditions.

Methods: For the analysis, we used bolometric brightness temperature and Lambert albedo data from MGS TES. Five different geological units could be outlined in and around the crater (Fig. 1): crater interior deposit (CID, CIDS), non-crater frost patches (NFP, NFP 2), and undulating crater ejecta (UCE). Besides that, four main regions were chosen in the surroundings of Dokka crater at different latitudes: above Dokka (AD; 213-215°E, 78.0-78.5°N), inside Dokka (ID; 213-215°E, 77.0-77.5°N), near Dokka (ND; 218-220°E, 77.0-77,5°N), and below Dokka (BD; 213-215°E, 75.8-76.3°N), as well as three reference regions, without summertime frost inside: BDW (208-210°E 75.8-76.3°N), DW (208-210°E 77.0-77.5°N) and ADW (208-210°E 78.0-78.5°N). The size of the analyzed regions was chosen to be small enough to be homogenous, but large enough to have reasonable data from different solar longitudes.

Discussion: The annual albedo variation of four chosen regions is presented in Fig. 2. Note that in the regions ID, AD and ND, a re-brightening can be observed roughly between Ls 87° and 138°. In a previous work, we showed that the characteristic temperatures (215 K at ID, AD and ND; 10-20 K lower compared the

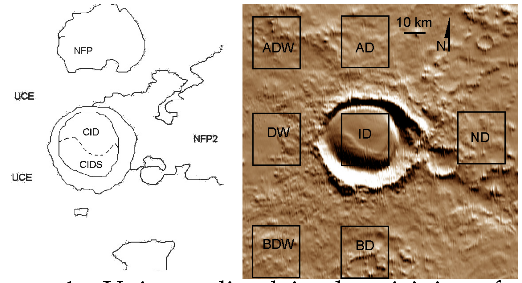

Figure 1: Units outlined in the vicinity of the Dokka crater (left), and the analyzed terrains on a MOLA shaded topography map (right).

rest of the surroundings) this time were too high for CO_2 to be present, and the cause of the re-brightening must be H_2O ice [9]. Moreover, these values were also too high for the deposition of newly formed H_2O.

[10] proposed a conceptual model for the explanation of the HAE phenomena in crater interiors. According to their model, the characteristic albedo trend of craters with a fully or partially exposed water ice body inside follows the H_2O/CO_2 frost sublimation/deposition, and this albedo change can be divided into four, well defined phases: 1. CO_2 frost sublimation, 2. H_2O frost sublimation during the afternoon, 3. H_2O deposition, 4. CO_2 deposition.

Based on our results, Dokka matched well with the proposed conceptual model, and our data support their findings. The BD region is frost-free in this early/mid summer season, and its albedo stays low around the value of 0.20-0.25 in the frost/ice-free periods. While the summertime re-brightening is most apparent in ID showing AM/PM HAEs, the same, but less prominent trend can be observed in the case of regions ND and AD (Fig. 2).

While both the conceptual model of [10] and the previous studies identify and deal with craters with HAEs, there has not been emphasis on these adjacent, non-crater frost patches before, however, as seen in Fig. 2, they show a very similar behavior. In Fig. 2 it is also apparent that the HAE shows much more significantly in the case of ND (within NFP 2) than at AD (within NFP). Consequently, these NFPs must also consist of a large amount of previously deposited H_2O ice, just like the crater interior, and the HAE could be caused by dust thermally sinking into the H_2O

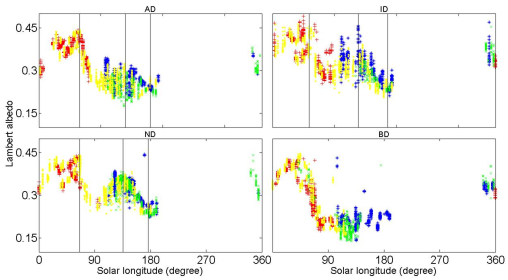

Figure 2: Albedo variation for three Martian years (blue: MY24, red: MY25, green: MY26, yellow:MY27) in and around Dokka crater. The lines indicate the different albedo phases, according to [10].

ice, or falling into cracks between the grains [11], in accordance with [10].

Investigating the basic properties of the NFPs, we found that they had frost-free parts inside them, mostly appearing at the south facing slopes - regions that are more exposed to solar insolation (Fig. 3). This latter phenomenon appears in the albedo trends as well. Our results show that in case of the NFPs (AD and ND), the scattering of data is caused by the mixture of frosted and defrosted areas within the analyzed regions, and the effect is more defined at AD, having more frost-free parts than ND, while in the ID region, it is the two types of units (CID and CIDS) that cause the scattering.

The origin of ice deposits inside the crater and the NFPs could be the same, i.e. resulting from a more advanced polar cap in the last high-obliquity period, as it is supposed for craters with HAEs [10], or they might have formed as a result of a smaller climatic change in the recent past. Either way, surprisingly we observe these HAEs in those specific regions outside the crater, and not everywhere in that latitude (e.g. AD has a summertime frost cover, while ADW does not). This fact clearly excludes the possibility that the reason for the frost could be the meridional difference. Moreover, since there is no apparent variance in the surface relief of the areas, it is very unlikely that an uneven topography could cause the observed phenomenon.

We have also noticed a rather unusual appearance of the NFPs in km scale, both in case of the Dokka crater, and another crater (89°E, 77°N) at high latitude, having no ice in the western side, but an eastward frost extension processing from the crater. It appears as if the ice had been deposited in a wind-blown tail.

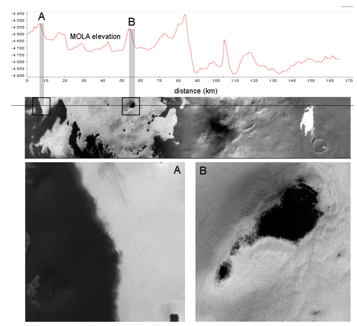

Figure 3: MOLA based topographic profile (top), CTX image B01_010187_2569 (middle), and two magnified insets (A, B), where the frost-free areas coincide with south oriented slopes.

Conclusions: Our results show that the proposed conceptual model of [10] can also be well adopted to the NFPs showing HAEs in the vicinity of Dokka crater, and this well-defined albedo trend can be indicative of summertime H_2O ice not only in craters, but in case of outliers near the craters. This ice coverage is eroding, mainly on the southward oriented slopes that exhibit stronger insolation, resulting frost-free parts within the outliers. Subsequently, the water ice coverage in these units outside the Dokka crater is presumeably thinner, while the craters with HAEs contain a thick water ice body [6, 10].

The observed appearance of frost located in a rather eastward direction could be the effect of wind mechanism. We presume that either the deposition of materials that favor freezing in these regions might had happened formerly, under different climatic conditions, resulting in a thicker ice cover than in the adjacent places at the same latitudes, or the ice grains themselves were brought there by the wind, and were deposited in these leeward places.

Acknowledgement: This work was supported by the Climatic Planetomophology project at Eotvos University [12].

References:
[1] Ward W. (1992) in *Mars*, pp. 298-320. [2] Head J. et al. (2003) *Nature* 426, 797-802. [3] Garvin J. & Frawley, J. (1998) *GRL* 25, 4405-4408. [4] Garvin J. et al. (2000) *Icarus* 144, 329-352. [5] Kieffer H. & Titus T. (2001) *Icarus* 154, 162-180. [6] Armstrong, J. et al. (2005) *Icarus* 174, 360-372. [7] Brown A. et al. (2008) *Icarus* 196, 433-445. [8] Armstrong, J. et al. (2007) *GRL* 34, 1202. [9] Kuti A. (2009) *40th LPSC*, #1006. [10] Xie H. et al. (2008) *P & SS* 56, 887-894. [11] Langevin Y. et al. (2005) *Science* 307, 1581-1584. [12] Mizser A. & Kereszturi A. (2007) *38th LPSC*, #1523.