MARS SPRING SEASONAL ICE CLEANING AS DETECTED BY PLANET FOUR PROJECT.
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Introduction: Evolution of seasonal deposits from CO_2 jets in the martian polar areas has been in focus of Mars Reconnaissance Orbiter (MRO) HiRISE for the past 6 martian years. Here we report on statistical evidence for seasonal ice surface brightening events that have been previously noted in MRO HiRISE and CRISM seasonal monitoring data [1].

The idea of seasonal ice cleaning originally appeared in the formulation of a model for creation of seasonal CO_2 jets and martian araneiforms by H. Kieffer [2]. Kieffer's model postulated that seasonal CO_2 jets are the result of a solid-state greenhouse effect acting on the seasonal semi-translucent layer of CO_2 ice. For the ice to be translucent, it has to be cleared from dust that deposits together with CO_2 in fall and winter. Kieffer proposed, that dust grains get heated by the sunlight, create a pocket of sublimed gas around themselves, and this way are able to move downward with the help of gravity, eventually clearing the whole slab of the seasonal dust.

Recent observations by MRO's Mars Climate Sounder show that the winter atmosphere of Mars is relatively clean of dust [3], and thus the seasonal ice layer in the southern hemisphere might be created free of inclusions. Then there is no need for the mechanism of ice cleaning. However, in this work we argue that the ice cleaning still happens in the southern polar regions during local spring, however, at the later stage of seasonal surface development than was originally proposed.

Method: We use HiRISE images analyzed in the framework of the project Planet Four with the help of citizen scientists. Observational data that were used cover southern polar targets where CO_2 jets are active in early spring. Citizen scientists were asked to mark dark deposits created by these eruptions. Their markings were cleaned, clustered and recorded in a catalog published in [4]. We use this catalog of all clustered citizen scientists markings separating 7 selected regions of interest (ROIs). Detailed description of Planet Four project and pipeline created for its data analysis can be found in [4].

For each HiRISE image in every of the 7 analyzed we have created a histogram of length of all fans marked by the citizen scientists. Examples of such fan size distributions for ROI Ithaca for three L_s are shown in Fig. 1. We determine the position of maximum of size distribution from the best fit Weibull to avoid being fooled by spikes in separate histogram bins. The position of the maximum shows the most probable fan length.

Example from Ithaca: We plot most probable fan length vs L_s in Ithaca ROI in Fig. 2 (top panel). The bottom panel shows sub-frames from HiRISE images corresponding to the strongest variations in the most probable fan lengths: decrease from L_s =180° to 189° and increase from 189° to 199°. One can see that the decrease corresponds to the general change of color and appearance of blue halos around dark fan deposits. Few new fans appeared between L_s=189° and 199°. From the size distribution histograms in Fig. 1, one can see that the relative number of large fans is larger at L_s=199°, which is visually confirmed in HiRISE images (Fig. 2 bottom panel).

Results: Analysis of fan size distributions for 7 ROIs showed that the dark deposits shrink between L_s=180° and 240° revealing brighter CO_2 ice in its peripheries. This creates an illusion of bright halos around darker central parts of the jet deposits. The timing of the observed size reduction is consistent with the hypothesis of cleaning the top of CO_2 ice layer from dust and regolith mix imposed over it during jet eruptions. Vie

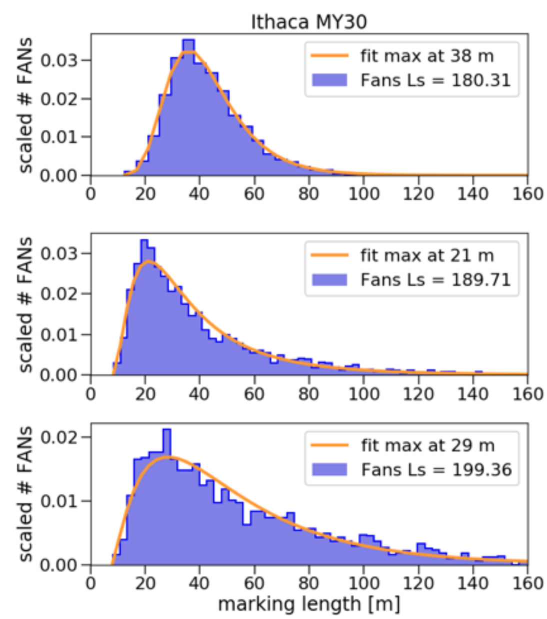

Figure 1: Ithaca fan lengths size distribution for 3 L_s from spring of martian year 30 (MY30): L_s = 180°, 189°, and 199°. Sub-frames of HiRISE images that were used to create these histograms are shown in the bottom panel of Fig. 2

wed on the larger scale the reduction of dark deposits' sizes will result in general surface brightening.

Discussion: Surface brightening of seasonal ice in spring has been previously noted in HiRISE and CRISM seasonal monitoring data [1]: HiRISE-measured reflectance of the top surface of two selected locations in the southern polar regions increases between L_s=200° and 240° (see Fig. 2 in [1]). The increase shows a correlation with CRISM reflectance at 1.14 micron (CRISM analog for mean surface albedo), no correlation with water absorption band strength and a weak correlation with CO_2 absorption band strength. The authors concluded that the observed surface brightening is some unknown surface process that exposes more fresh CO_2 ice.

Our analysis of 7 ROIs in Southern polar regions confirms the existence of the surface brightening event and proves that on a small scale it is the creation of bright halos around previously existed dark CO_2 jet deposits.

There are two possible scenarios that might explain the brightening: fresh deposition of CO_2 frost, or revealing of CO_2 ice that was previously covered by the fan deposits from jets. The bright halos are observed by HiRISE in local afternoon. This means the top ice layer had ample time to be warmed by the sunlight and any thin CO_2 layer would have sublimed. The fresh deposition of CO_2 frost seems unlikely. We believe the second scenario is more probable. Model results show that in framework of Kieffer's model, dust can sink through 0.5 m of CO_2 ice in 10 to 60 Sols (5°-30° of L_s) with strong dependence on the dust particle shape [5]. These calculations were done for lat=75° and earlier time in spring. Later in spring the process is probably more efficient. The timing of the brightening event slightly varies between the different ROIs, probably because of latitude and related to it differences in local insolation conditions in spring.

Our analysis proves that this surface process is active in multiple locations around the Southern polar regions, probably everywhere that dark deposits are created by the jetting process.

References: [1] Pommerol, A. et al. (2011) JGR, 116 (E8); [2] Kieffer, H.H. et al. (2006) Nature, 442; [3] Bicas_2018 [4] Aye, K.-M. et al. (2019), Icarus. 319; [5] Portyankina, G. et al. (2010) Icarus 311.

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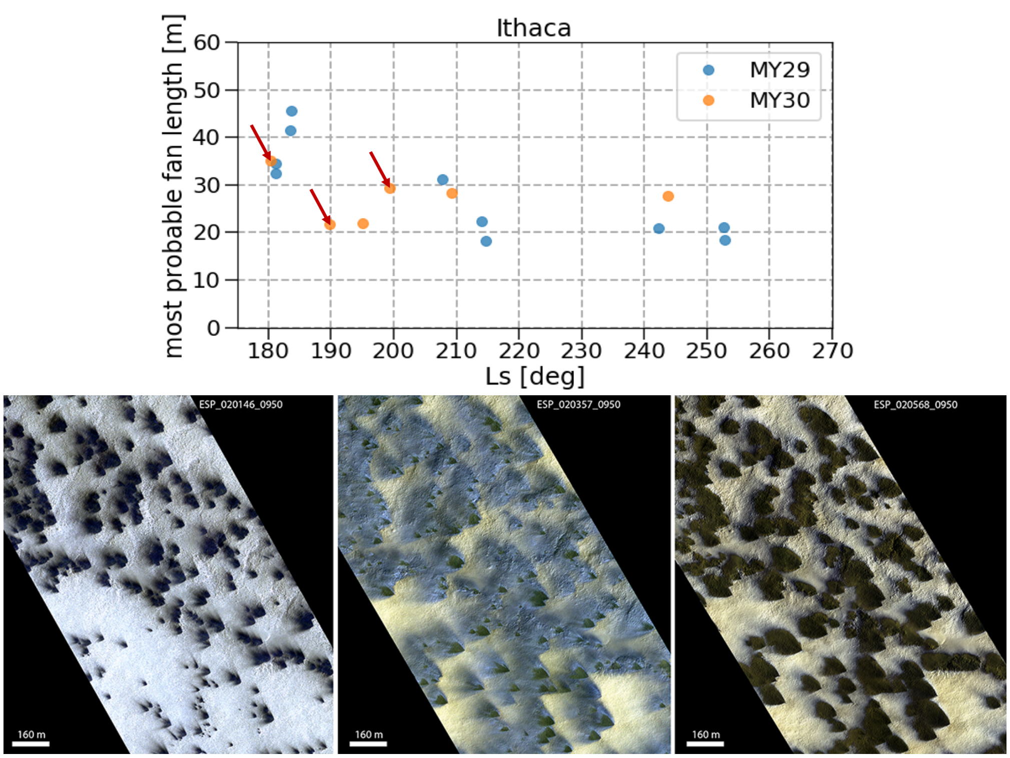

Figure 1: **Top**: Most probable fan length in Ithaca vs L_s during spring of MY29 and MY30. Red arrows mark data points derived from HiRISE images shown in the bottom panel. **Bottom**: Sub-frames of HiRISE color images ESP_020146_0950, ESP_020357_0950, and ESP_020568 taken in Ithaca at L_s=180°, 189° and 199° respectively. The decrease in the fan length between Ls = 180° and 189° is due to development of bluish halos around formerly existed dark fans.