CO_2 FROST HALOS ON THE SOUTH POLAR RESIDUAL CAP OF MARS P. Becerra, S. Byrne, and the HiRISE Team. Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, USA, becerra@lpl.arizona.edu.

Introduction: Imaging of the martian south polar region by the Mars Reconnaissance Orbiter's (MRO) High Resolution Imaging Science Experiment (HiRISE) [1], and Context Camera (CTX) [2] found that a large number of the scarps and quasi-circular pits that compose the so-called "Swiss cheese terrain" of the CO_2 ice South Polar Residual Cap (SPRC) exhibit a bright "halo" around their edges in certain seasons (fig.1b,c). Our study of these features is motivated by the fact that investigating the martian halos will help constrain the mass balance of the SPRC, and therefore contribute to an accurate description of the recent climate history of Mars.

Observations: We examined nearly 200 CTX images of the martian SPRC taken throughout southern summer, and found halos in ~30%, the majority between L_s 285-310, located mostly in the southernmost latitudes of the SPRC (~85ºS-90ºS). No halos were seen in images taken after ~L_s 320º (fig.1d), indicating that their appearance coincides with the darkening of the pit walls, and that their formation is a highly seasonal process.

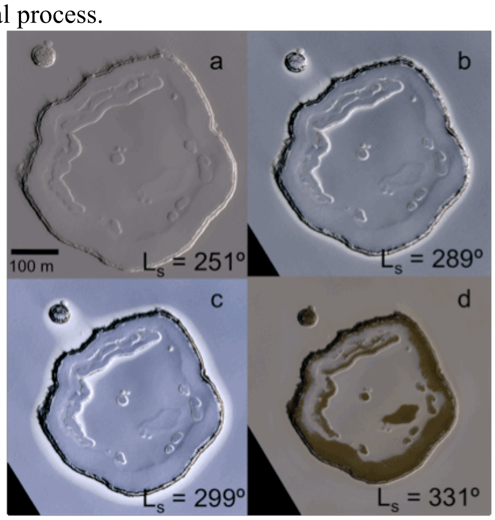

Figure 1. Portion of four HiRISE images showing a circular pit (~500km wide) on the SPRC at different times. In images b and c, a bright halo of frost (arrows) is clearly visible around the edge of the pits.

Halo brightness decreases with distance from the pit rim. To characterize the widths and brightnesses of these halos we fit a half-Gaussian function to radial brightness profiles around the circumference of the pits. We use this to calculate the maximum lambert albedo and the width (FWHM) of the halo as a function of the orientation of the pit walls (figure 2 shows the width and brightness of the halo seen in figure 1).

We find that there is about an 8% albedo difference between the halos and the surrounding material. In addition, the brightest parts of the halo appear adjacent to the sun-facing walls of the pit, while the widest portions occur off of north-facing walls. This fact suggests that the brightest sections of the halos follow the sun around in the sky diurnally, and the widest sections occur adjacent to the walls that spend the most time in sunlight.

The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [3] aboard MRO, also monitored this area and revealed a uniform cover of CO_2 ice, which shows that the halos are composed of CO_2, and rules out spatial variations in dust, or water ice, as causes for the albedo difference seen by HiRISE.

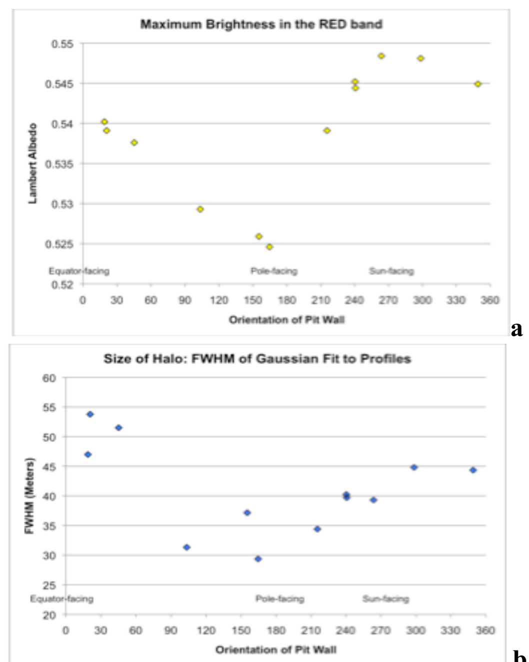

Figure 2. (a) Maximum brightness of halo in the HiRISE RED Band vs. orientation of the pit wall. **(b)** size of halo (FWHM) vs. orientation of pit wall.

Brown et al. [4] reported a decrease in CO_2 grain sizes from ~7cm to ~5mm in the period between L_s 200º – 310º. We constructed a simple reflectance model based on the theory of Hapke [5], and found that there is a ~10% albedo difference between 7cm grains and freshly deposited 1μm grains. This led to the inference that the halos are exposures of fresher, fine-grained CO_2 ice that is brighter than the older surrounding ice.

Model: Our hypothesis (fig.3) is that there is condensation, or slower sublimation of CO_2 ice occurring in areas close to the walls of the scarps. This is caused by a rise in the partial pressure of CO_2 gas in the local atmosphere, due to a faster sublimation rate from the sloped walls that receive sunlight at lower incidence angles. This effect is diminished far from the walls, by the diffusion and dilution of the excess CO_2 into the surrounding atmosphere.

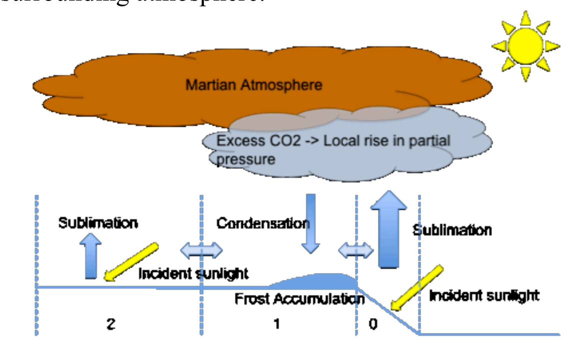

Figure 3. Schematic of the model for the formation of the SPRC halos. Model surfaces/cells labels: 0-slope, 1-adjacent, 2-distant.

The objective of the model is to describe the annual cycle of accumulation and ablation of CO_2 ice on a model surface like the one shown in fig.3, and track the diffusion of the excess CO_2 sublimated from the sloped surface (cell 0 in fig.3), in order to expose the differences between the accumulation rates of a flat surface adjacent to the scarp (cell 1 in fig.3), and one distant from the scarp (cell 2 in fig.3). If less ice is ablated from an adjacent surface than from a distant one, then the former would expose younger, smaller-grained, and brighter ice, revealing a halo.

The model calculates the sublimation rate and accumulated mass of CO_2 of a surface cell (fig.4a) via an energy balance equation that balances incident solar radiation with emitted infrared surface radiation, taking into account the slope of the surface. Sublimation and condensation at the surface affect the partial pressure of CO_2 gas in the near-surface atmosphere. We then solve a diffusion equation to track changes in the local partial pressure of atmospheric CO_2 due to the extra input of CO_2 from the slope. The difference in thickness of deposited frost between surfaces 1 and 2 of fig.3 is shown in fig.4b.

Between L_s 280º and 320º the sun is well above the horizon, and net ablation is occurring on all surfaces. However, since the ice on surface 0 sublimates faster, it produces a rise in the local CO_2 partial pressure and so a rise in the condensation temperature on surface 1, slowing the ablation of ice at this site. As older ice is being exposed at surface 2 it should be coarser grained and so darker. Several mm of extra frost accumulates in cell 1 (compared to cell 2) close to the equinoxes; however, the cell 1 to cell 2 difference in ablation during the halo season is only several microns. It is unknown how thick the brighter material needs to be to be visible to HiRISE; however, some experimental work has hinted that perhaps only a very small difference in accumulated frost is needed to produce the observed brightness contrast between surfaces 1 and 2 [6]. In addition, in the case of dust obscuring bright ice, experiments indicate that as little as 17 μm of dust is required to mask bright white material [7].

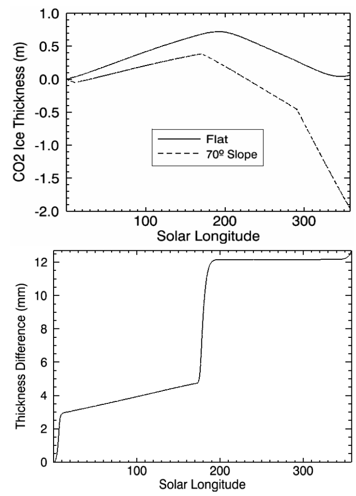

Figure 4. (a) Annual CO_2 ice accumulation of two surfaces at 87ºS. Dashed line: 70º north-facing slope (cell 0 in fig.3). Solid line: Flat surface (cells 1 and 2) **(b)** Difference in frost thickness between an adjacent surface (cell 1), and a distant one (cell 2).

Preliminary Conclusions: (a) The halos are composed of fine-grained CO_2 and are not compositionally different than their surroundings. (b) The albedo difference is most likely due to a difference in the grain sizes of exposed ice. (c) The seasonal occurrence of the halos is connected to the increased sublimation rate from adjacent slopes, which are subject to diurnal variations in insolation.

Future Work: We are coupling a model for grain growth with our Hapke reflectance model in order to be able to match a certain ice age with a certain brightness. With this we will know the albedo of ice exposed from different depths and know how much of an ice thickness difference is needed between surfaces 1 and 2 to produce the observed albedo contrast. We are also extending our current frost accumulation model to include multiple surface scattering and atmospheric emission, in order to more accurately simulate the radiation balance.

References: [1] McEwen et al. *JGR* 112, E05S02 (2007) [2] Malin et al., *JGR* 112, E05S204 (2007) [3] Murchie et al., *JGR* 112, E05S203 (2007) [4] Brown et al., *JGR* 115 E00D13 (2010) [5] Hapke, Cambridge Univ. Press. (1993) [6] Portyankina, G., 5th Mars Polar Science and Exploration Conf., Abs. # 6021 (2011) [7] E. M. Fischer, C. M. Pieters, Icarus 102, 185 (1993).