FROST HALOS ON THE SOUTH POLAR RESIDUAL CAP OF MARS P. Becerra[1], S. Byrne[1], Adrian J. Brown[2]. [1]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ. 85721. USA. becerra@lpl.arizona.edu. [2] SETI Institute, 189 Bernardo Ave., Suite 100, Mountain View, CA. 94043. USA.

Introduction: The CO_2 ice South Polar Residual Cap (SPRC) may be a sensitive indicator of the interannual variability of the martian climate. Imaging of the martian south polar region by HiRISE *[1]*, and CTX *[2]* found that many of the scarps and pits that compose the so-called "Swiss cheese terrain" *[3]* of the SPRC exhibited a bright "halo" (fig.1) around their edges during midsummer of Mars Year (MY) 28 *[4]*. The MY28 southern summer included a global dust storm at ~Ls 260 that could have altered the thermal environment of the SPRC such that these halos formed from sublimation differences in the terrain. Our goal is to understand the climatic difference at the south pole between MY28 and other years through the detailed study of the surface changes that took place, namely CO_2 frost falos on the edges of swiss cheese features.

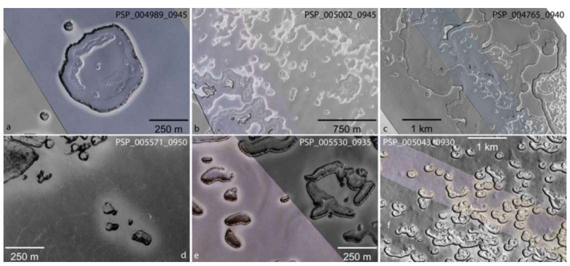

Fig. 1. Examples of HiRISE images of "swiss-cheese" terrain on the SPRC exhibiting halos.

Observations: We examined ~200 CTX images, and ~600 HiRISE images covering the entire area of the SPRC. We analyzed about 20 CRISM spectral products of selected sites were halos were observed. We also looked at ~175 MOC images with swaths that overlapped those of HiRISE images with halos, in order to search for halo appearances in previous years. Our entire dataset spans seven different Mars years and the entire south polar summer in each year.

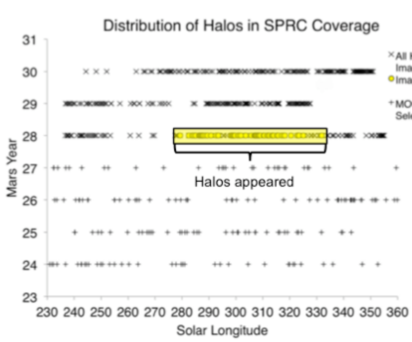

Fig. 2. Temporal distribution of all HiRISE images examined to constrain the timing of the appearance of halos.

Timing and Location: We found halos only on images taken during MY 28, and only at a specific time of the year (Ls 280 – 330). This suggests that specific environmental conditions (e.g. the global dust storm of 2007) have to be met in order for these features to appear. MY25 also included a global dust-storm although at a much earlier season. Thus the seasonal timing of these storms has measurable effects on the later appearance of the SPRC.

Brightness and size: We measured the variation of brightness and width of the halos with orientation of the pit walls. The average Lambert albedo of the halos in the HiRISE RED band is about 0.58. Their average HWHM from a Gaussian fit to brightness vs. distance from the wall ranges from 20 to 50 m. 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 points to a connection between halo formation and insolation, as north-facing scarps receive more sunlight. The dependence in brightness with aspect however, could be due to more directly illuminated sections of the SPRC, that tilt downward as they approach the walls of the pits.

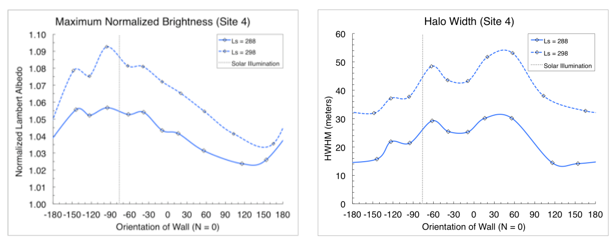

Fig. 3. Top: Example of the variation of the maximum brightness, and maximum width of the halos with orientation of the pit walls (north aspect = 0º) for a typical area of the SPRC where halos were seen.

Composition and Grain Size: CRISM data have been used in both poles to determine CO_2 and H_2O ice grain sizes *[5,6]*. We have examined the available full resolution CRISM over the halo regions with two objectives: 1) To rule out any compositional differences between the halo and the surrounding terrain, that could indicate that a difference in water ice contamination was responsible for the halos, and 2) To look for CO_2 ice grain size differences between the halos and the surrounding plateau that could be the cause of the albedo difference. Generally, larger grain sizes mean darker ice at visible wavelengths.

The initial analysis revealed a uniform cover of CO_2 ice at the halos and the surrounding terrain (fig. 4), evidenced by the absorption features at 1.43 and 2.28 μm, and the lack of broad absorption bands at 1.5 and 3 μm, which indicates a lack of any water ice *[5]*.

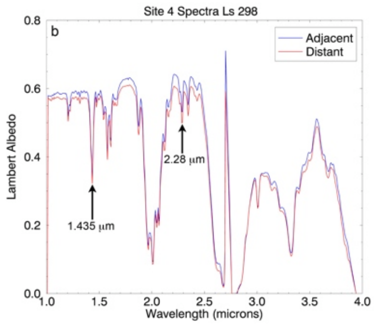

Fig. 4. CRISM infrared spectra of halos (adjacent), and surrounding plains (distant). The spectra of both locations are nearly identical. Absorption bands characteristic of CO_2 ice are indicated.

Differences in the depths of absorption bands between the halos and the surroundings would be indicative of differences in apparent grain sizes of the ice *[5]*. Figure 5 shows a map of an area in which halos were seen, color-coded to indicate relative differences in the ratio of the albedo at the 1.43 μm absorption band, to that at 1.35 μm (a “flat” portion of the spectrum where no absorption is observed). We observed that in areas where halos appear, CO_2 ice absorption bands are deeper than in the surrounding areas. This indicates larger minimum apparent grain sizes *[5,6]* within the halos, and indicates that a simple model of increased brightness caused by fine grain deposition forming the halos is not supported by the data.

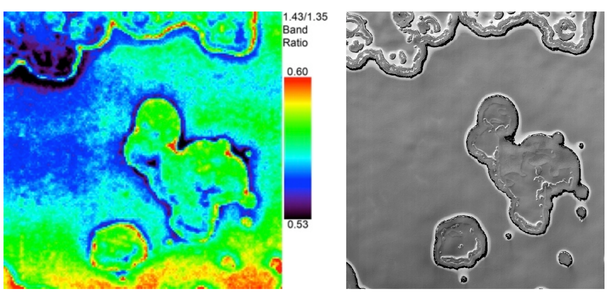

Fig. 5. Left: CRISM band ratio map of a site in which halos where seen. Right: HiRISE image of the same site (PSP_004989_0945). The halos are clearly visible near the edges of the pits, and match the lower band ratios, indicative of a deeper 1.43 μm band, and larger grain sizes.

Since water ice absorbtion bands are not observed in the CRISM data, and it appears as though ice grain size differences are not the main cause of the albedo contrast, we are forced to consider dust differences between the halos and the surrounding terrain as the most likely cause for the appearance of halos. However, spatial variation in dust contamination should be detectable using HiRISE bands ratios, and in the slope of the CRISM visible band spectra. Initial analysis of this data shows no ‘red’ slopes associated with the pits, implying a lower dust ratio within the halos (Fig. 6).

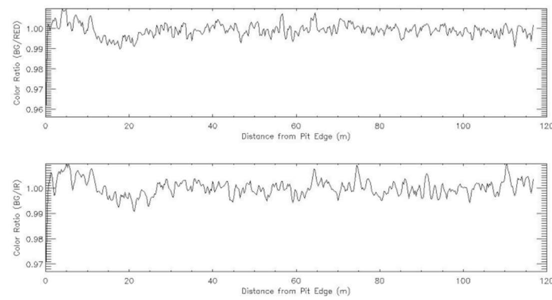

Fig. 6. Distance from pit edge profiles of BG/RED and BG/IR HiRISE band ratios. Surrounding terrain brightness is normalized to 1.

Hypothesis of formation: Width and brightness measurements suggest a relationship between insolation and halo occurrence. During polar day, sloped surfaces receive more direct sunlight than flat surfaces in the SPRC. Thus, a higher sublimation rate of CO_2 ice would be expected from the walls of swiss cheese pits, than from the surrounding terrain. Our original idea *[7]* was that this difference in sublimation could increase the mixing ratio of CO_2 in the local atmosphere and cause less ice ablation from the adjacent surfaces. This would result in fresher, smaller-grained ice exposed in the halos. However, this theory requires further investigation after our finding of higher minimum apparent grain sizes in halo regions.

An alternative explanation is that, because of the global dust storm at ~ Ls 260 that year, dust was deposited uniformly over the SPRC, but vigorous CO_2 sublimation from sloping pit walls created a “sublimation wind”, that allowed for less dust to be deposited in adjacent areas. This would result in bright, near-pure CO_2 ice halos, within a darker, dust contaminated SPRC. This theory is consistent with the overall darker albedo of the SPRC compared to other years; however, it remains to be reconciled with the visible color data.

Future Work: The exact response of the SPRC to global dust storms of differing seasonal timing is still unknown. We are carrying out further analysis of the CRISM visible and infrared dataset using Hapke mixture modeling in order to constrain dust contamination that could cause brightness differences. We are performing reflectance modeling of ice-dust mixtures which will test the hypothesis mentioned above, in order to determine the characteristics of dust-ice snowpacks that could cause the albedo variations we have observed, and thereby better understand the processes that could have led to these halos.

References: *[1]* McEwen et al. *JGR* 112, (2007). *[2]* Malin et al., *JGR* 112, (2007). *[3]* Clancy, et al., *JGR* 105, (2000). *[4]* Thomas, et al., Icarus 203 (2009) *[5]* Brown et al., *JGR* 115, (2010). *[6]* Brown et al. *JGR* 117 (2012) *[7]* Becerra et al. XLIII LPSC Abs. 2513