TEMPORAL VARIATIONS IN MARTIAN SWISS CHEESE TERRAIN. J. P. Knightly[1], M. S. Fusco[1], K. Farnsworth[1], V. F. Chevrier[1] [1]University of Arkansas Center for Space and Planetary Sciences (Edward Durell Stone House North (STON) 346½ North Arkansas Avenue, Fayetteville, AR, 72701 USA), jknightl@uark.edu.

Introduction: Swiss Cheese Terrain, comprised of Swiss Cheese Features (SCFs), refers to groups of pit-like features in the south polar ice cap of Mars. First described in 2000 [1], SCFs are pits driven by sublimation of a CO_2 ice top layer and ending at a water ice subsurface layer [1]. Sizes (in surface area) vary from less than one square meter to hundreds of thousands of square meters with depths varying ~ 0 - 10s meters. The SCFs are generally steep, such that the topology often resembles the inverse of a mesa or butte (Fig. 1). SCFs have previously been reported to increase in area, however this is the first study to systematically investigate SCF's changes over multiple years at several locations across the south polar cap. We present new results in our continuing investigation of SCF's.

Figure 1: Example of a SCF dubbed "Happy Face", seen with exposed CO_2 and water ice (left) and fresh deposition of dust (right).

Methods: The images chosen for our study were taken by the High Resolution Imaging Science Experiment (HiRISE) camera aboard the Mars Reconnaissance Orbiter [5]. We disregard Mars Observer Camera (MOC) images of Swiss Cheese Terrain, due to poor resolution in the Martian south polar cap.

For analysis, we selected 10 locations across the Martian south pole, encompassing 103 SCFs, and ranging ~ 1 - 10,000 m^2 in area. Swiss cheese features that were near circular, isolated from clusters, and highly imaged (multiple images over multiple years), were chosen for analysis due to ease of detection and measurement. Furthermore, due to lack of imaging during southern hemisphere winters, images used were obtained during southern hemisphere spring-fall with gaps during the southern winters.

Areas are measured through the use of Photoshop or GIMP, where the outer edges of the SCFs are manually selected and the number of pixels counted using the histogram tool. Pixel areas are transformed to square meters using the pixel scale available from the HIRISE images. Several options for edge fitting algorithms or neural networks could be adapted to the automation of area measurement in the future [6], however finding the appropriate parameter space for accurate measurement is nontrivial.

Results: We find SCFs are increasing over the course of 6 Martian years, with lesser evidence of seasonal change within individual years. The majority of features appear to show a reasonably smooth growth pattern, with no major spikes. However, some locations show a sharp spike in growth between Mars Years 31 and 32 (Fig. 2). Over the sampled locations, all SCFs are growing in area. This suggests more CO_2 ice is being sublimated than deposited.

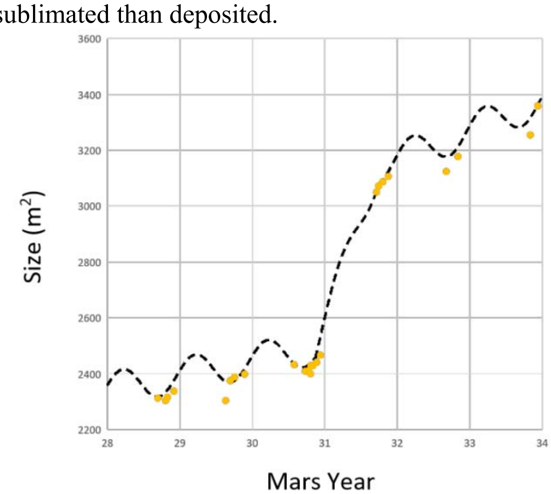

Figure 2: Seasonal size of "Happy Face" between MY 28-34, showing a large departure in typical seasonal sizes between MY 31-32.

We find that SCF's at high southern latitudes (>89 degrees) exhibit slower growth rates. This is thought to be the result of lower angle of incidence in the immediate polar region, resulting in less daytime heating and lower sublimation rates. Area growth for SCFs across the entire cap fit to an exponential growth regime.

The growth of the SCFs is measured in terms of a linearized change in surface area over time, with the slope dA/dt being the least squares linear fit to the full time range of the data (Fig. 3). In the simplest (assume circular SCF) case, this suggests a nonlinear increase in the radius of the Swiss Cheese based on its size. Small SCFS grow rapidly in terms of percent change in area but slowly in terms of absolute change in area, while large SCFS grow slowly in terms of percent change in area but rapidly in absolute terms. This may partially arise from the geometry. If the SCFs may be described as changing mainly along its sloped edges (ring of radial change dr added to the existing radius per year), the size of the shell (with constant dr) compared to the total area becomes smaller as the area gets larger. However, our data appear to show dr increases as a function of r, which we have not yet explained. From the empirical power law relationship between dA/dt and A, we may derive an equation (see: eq. 1) describing A(t), where t is the age of a feature assuming the environmental conditions governing its growth have not changed.

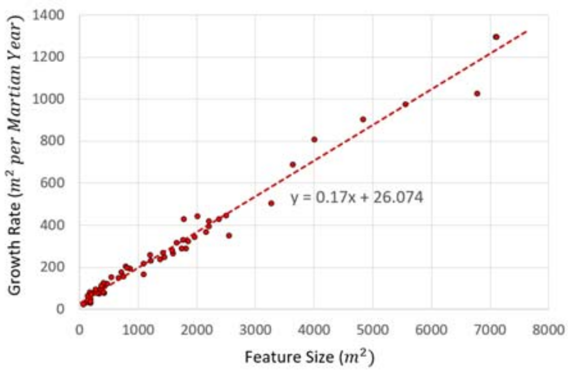

Figure 3: SCF growth rate as a function of feature size.

Discussion: Changes in the sizes of SCFs are governed by sublimation and deposition processes and the environmental conditions affecting them [2-4]. There is strong evidence of year-over-year pit growth, implying a warming (not in equilibrium) state for the Martian south pole over the course of nearly a Martian decade. In addition, we find some indication of seasonal variability, as sublimation rates are highly temperature dependent.Other factors that affect the sublimation rate include, include albedo changes, local topology, and Martian latitude and longitude.

During the process of measuring and characterizing SCFs, a thin veneer of freshly deposited dust was observed across several images at different SCF sampling locations. Further investigation revealed dust deposition across SCFs occurred on multiple occasions throughout the six Mars-year period. In conjunction with the noted jump in SCF expansion between MY 31-32, we began investigating connections between dust storm activity and SCF growth rates (Fig. 4).

Surface temperature conditions on the south polar cap were simulated using the Mars Climate Database (MCD) under dusty and low dust conditions, as well as to calculate temperature ranges for MY 28 through 32 (Fig. 4). Dust storm conditions were found to result in substantially warmer temperatures that could lead to increased CO_2 sublimation rates. In addition, a search of climate records in the MCD and weather reports generated by Malin Space Science Systems using Mars Reconaissance Orbiter Mars Color Imager (MARCI) observations found a 9% increase in southern hemisphere dust storm activity during the jump year between MY31-33, including a significant regional event in MY32. It was found that most south polar dust activity occurs in spring to early summer prior to peak regional heating. We propose that an increase in atmospheric heating as a result of dust storm activity is partly responsible for the observed increase in growth rates of SCFs.

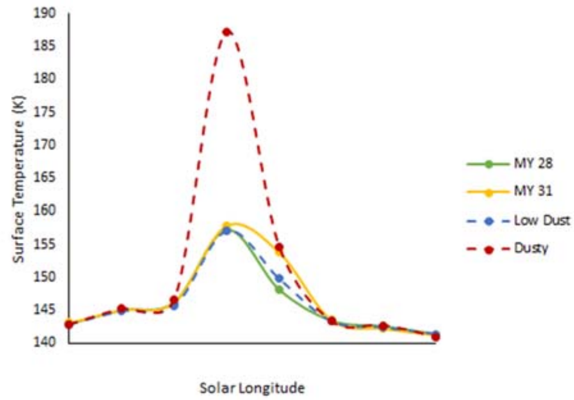

Figure 4: Temperatures at "Happy Face" in MY 28 and 31, and the predicted temperatures under low dust and high dust scenarios (Source: Mars Climate Database).

Conclusions: Across most of the South Polar Cap, Swiss Cheese terrain follows similar growth behavior through time. In addition, yearly area variations are larger than seasonal variations and greater fluctuations in area are observed during southern hemisphere autumn. A large departure in inter-annual SCF growth rates were observed between MY 31-32. Dust storms create warmer surface temperatures and faster CO_2 sublimation rates, leading us to propose that dust storm activity may have increased SCF growth rates during this "jump year."

References:

[1] Thomas, P. C. et al., 2000, *Nature 404 (6774): 161–4.* [2] McKeown, et al., 2017, *LPSC XLVIII*, Abstract #1330 [3] Guno, Xin et al., 2010, *JGR* 115 *[4] Byrne, S. and Ingersoll, A. P., 2002, AAS, 34:837 [5] Fusco, M. S. et al, 2018, LPS XLIX, #2682. [6]* McEwen, S. et al., 2002, *JGR*, 112, E05S02 [7] Li, C. et al., 2010, *IEEE Trans. Image Processing*, vol. 19 (12), pp. 3243-3254 [8] Becerra, et al., *AGU* F2013 abstract #P41A-1913