Temporal Contrast Changes in Dark Slope Streak on Mars. H. Chilton[1, 2] and C. Phillips[2], [1]California State University Fullerton, 800 N. State College Blvd., Fullerton, CA 92831-3599, [2] SETI Institute, 189 Bernardo Ave, Suite 100, Mountain View, CA 94043.

Introduction: Dark slope streaks on Mars, first observed in Viking images, provide insight into one of the most active and dynamic processes observed on the planet's surface. While various formation models have been suggested [1][2][3], dust avalanches seem to best explain streak origin and characteristics [4][5]. New dark streaks are observed to have the greatest contrast to their surroundings while older streaks have less contrast, suggesting that streaks fade over time. One theory for this is atmospheric dust fallout slowly raising the albedo of the surface exposed by the dust avalanche, resulting in increased streak albedo over time until the streak becomes indistinguishable from the surrounding surface. Dark streaks provide a more obvious and discernible rate of atmospheric dust fallout, and as such analysis of these streaks offers the potential to provide key insights in regional and global atmospheric dust deposition and surface processes. Constraining aspects of the dust cycle on Mars will also develop and expand models of present, past, and future climate on the planet.

Methods: In this study, we attempt an initial evaluation of changes in streak brightness relative to surroundings, with a first order correction for incidence angle[6] based on MOLA data. CRISM images were first identified for spatial overlap and large temporal span, and then further selected for those image sets with well-matched viewing geometries. Locations included Nicholson Crater, the Nestus Valles area, the Naktong Vallis area, Lycus Sulci, and others.

We focused on 1 micron wavelength CRISM images, corresponding to band 434, in order to reduce atmospheric interference. From here, brightness (observed radiance divided by solar irradiance at Mars divided by pi) values were collected along individual streaks, with measurements at a number of identified locations along the streak length and alongside at points of similar elevation to streak measurements to establish a consistent and average contrast ratio. Further, special care was taken to ensure the MOLA INA value for on-streak and off-streak did not vary by more than a degree so as to avoid skewing from topographic features and maintain a consistent comparison. Both on-streak and off-streak values were divided by the cosine of their respective local MOLA incidence angles to correct for brightness variation due to solar flux and topographic angles. These measurements were then repeated for overlapping images, establishing local and overall averages for the rate of change in this contrast ratio. As an additional check for data skewing, we compared these ratios with the more basic areoid correction.

Additionally, an error check was done by doing a full pixel analysis of a streak. For this check, two points off-streak were used for each point on-streak, one on each side of the feature to further balance any possible skewing.

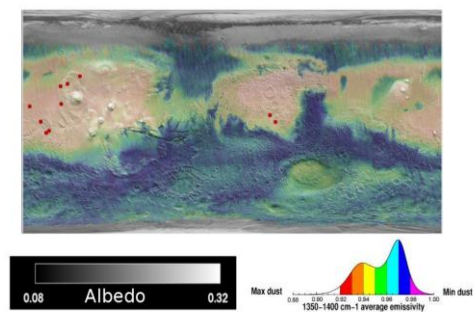

Illustration 1: Albedo and dust map of Mars with streak sites located by red dots. Image altered from MARS Global Data Sets, http://www.mars.asu.edu/data/

Streak Contrast Ratios and Ratio Change: Of eight locations analyzed, more than 50 streaks were looked at over 22 images and several years. No distinct pattern of fading was apparent from the image sets, and in fact many showed more complex progressions.

South Nestus Vallis showed the simplest fading, with the darkest streak brightening, or fading, the quickest and the lowest contrast streak fading the slowest. The former, at a contrast ratio of 0.81100 in 2008 and 0.89250 in 2010 showed a change in contrast ratio of 0.04853 per Earth year (Ey^{-1}). The later, at a contrast ratio of 0.94322 in 2008 and 0.96466 in 2010, showed a change in contrast ratio of 0.01277 Ey^{-1}. The average for all three streaks over 613 days was a change in contrast ratio of 0.02878 Ey^{-1}.

The Eastern Amazonias and Nicholson Crater sites showed examples of some streaks fading while other streaks showed little to no fading or even a slight reversal to darkening. The Eastern Amazonias darkest two streaks did have the greatest change in contrast ratio, but similar ratios did not change by the same degree indicating fading rate is not entirely dependent on contrast ratio. At Nicholson Crater, over half the streaks no fading or even slight darkening instead of fading, although darkening values plotted within the range of error. Overall averages for these two sites were a change in contrast ratio of 0.04545 for Eastern Amazonias, where the darkest streak had a contrast ratio of 0.90880 Ey^{-1}. This is moderately close to the values from South Nestus Vallis, for which the three streaks measured showed simple and progressively increased fading with increased contrast ratio. Nicholson Crater, however, had an average change in contrast ratio of 0.06594 Ey^{-1} from mid to late 2008, where the greatest change in an individual streak contrast ratio was 0.16846 Ey^{-1} from an initial ratio of 0.94197. From late 2008 to 2010, the all-streak average dropped to a change of 0.00560 Ey^{-1} where the same individual streak had a change in contrast ratio of -0.00222, which would suggest darkening but is within the range of error. This negligible change is over a much longer period of time and concurrent with other streaks at Nicholson and elsewhere showing fading. That particular streak, using a full pixel analysis, had an error of about 0.0171 from a contrast ratio of 0.96308 from the first image used of the site.

Western Lycus Sulci showed an average fading of 0.05275 Ey^{-1}, with the darkest streak having a 0.94470 contrast ratio the first six months then a contrast ratio of 0.08464 Ey^{-1} five months later. Streak 4, which was darkest in the most recent image with a contrast ratio of 0.93994, was the brightest streak in the oldest image at a contrast ratio of 0.98713 and was the median contrast ratio in the intermittent image at 0.98076. This is a particularly striking case of an individual streak changing both whether it faded or darkened, but also the relative contrast compared to nearby streaks.

Lycus Sulci proper, Pettit Crater, and Greater Tharsis locations all showed consistent darkening, with contrast ratio changes of -0.01603 Ey^{-1}, -0.01258Ey^{-1}, and -0.007122 Ey^{-1} respectively. Lower Naktong Vallis, with three images, one from 2007, one from 2008, and the last in 2010, initially showed darkening of contrast ratio by 0.03094 Ey^{-1} then a small degree of fading by 0.00354 Ey^{-1}.

Discussion: About half of the streak locations showing brightening and the other half showing either brightening then darkening or just darkening. While most locations show many of the darkest streaks fading the quickest and brightest streaks fading the slowest, this does not apply to an overwhelming proportion. While images that show all streaks as darker than prior images may be expressing an unaccounted for effect influencing the contrast of the area, including atmospheric effects, the demonstration at some sites of relative streak contrast ratios changing order (when ranked darkest to brightest) support that there are more dynamic aspects involved than simple streak fading.

One possible explanation for all these observed trends is streak reactivation. Not only would this allow for streak darkening, but reactivation may occur along sheer planes above those of initial streak formation, resulting in a lower momentum flow which is able to remove less dust and thus results in less contrast than a fresh streak. This could also explain instances where streak contrast has changed very little, where the timing of the images have allowed dust deposition to bring the reactivated streak close to the contrast ratio of the earlier image. This would also explain why no indisputable trend was seen between initial contrast ratio and rate of fading; while some streaks may demonstrate this, the inclusion of localities with reactivated streaks would noise over these results. It may even be possible to tie together fading rates, such as those at South Nestus Vallis and Eastern Amazonias, and identify smaller scale or older reactivation.

Given the small sampling, regional trends are unreliable, although we do note the clumping of brightening values along the Southern and Eastern Amazonias and that both Lycus Sulci sites showed darkening overall. Further sites within these areas would be preferential to look at in regards to this. Additionally, no connection was seen with dust storm season, between Solar Longitude 180 and 360, nor could we find any evidence of other effects from orbital parameters outside of the corrections already used.

Observing both more sites and more overlapping images would greatly help establishing a relationship for fading and possibly validate this idea of reactivation. In addition, we will be continuing to do full pixel error analyses of key streaks, comparing images from other instruments to look for changes in streak shape and interior, and other checks as we can find.

Conclusions: Dust deposition and streak fading is more complex than a linear, uninterrupted brightening process. Even if images where all streaks show darkening are being influenced by an unaccounted for parameter, the lack of a relationship between contrast ratio and rate of change of that ratio and particularly the changing of order of the darkest streaks at locations indicates a more dynamic process. Streak reactivation offers an explanation that covers all the trends we saw in the data. Steps in increasing the number of sites and the number of overlapping images will greatly help in further defining this, as will steps in image comparison to identify possible changes in streak shape and interior.

References: [1] Morris (1982) *JGR, 87,* 1164-1178. [2] Ferguson and Lucchita (1984) *NASA Tech. Memo., TM-86246,* 188-190. [3] Miyamoto, H. et al. (2004) *JGR, 109,* E06008. [4] Sullivan, R. et al. (2001) *JGR, 106,* 23607-23633. [5] Baratoux, N. M. et al. (2006) *Icarus, 183,* 30-45. [6] Brown, A. et al. (2010) *JGR, 115,* E00D13.