THE DISTRIBUTION AND LIFETIMES OF DUST DEVIL TRACKS IN HIRISE IMAGES. Rachel Hausmann[1,2] Ingrid J. Daubar[1], Matthew Chojnacki[3], Lujendra Ojha[4,] Matthew Golombek[1], Ralph Lorenz[5], James Wray[6], Kevin Lewis[4]. [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA (rbhausmann@gmail.com) [2]Oregon State University, [3]University of Arizona. [4]Johns Hopkins University. [5]Johns Hopkins University APL. [6]Georgia Institute of Technology.

Introduction: Dust devils may significantly contribute to the amount of dust in the Martian atmosphere [1]. Thus quantifying the amount of dust raised by dust devils is critical to understanding the martian dust cycle. Dust devil activity on Mars can be inferred by the tracks they form when surface dust is entrained and removed or disturbed, exposing a substrate with a contrasting albedo and/or grain size.

Motivation: The objectives of this study are to: (1) investigate the global distribution of dust devil tracks (DDTs), (2) measure DDT lifetimes at various sites and investigate any trends, and (3) examine the spectral differences in Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [2] data between fresh DDTs and their surroundings in order to estimate the thickness of dust removed by track formation using the method of [8].

Part 1- Spatial Distribution of DDTs: No thorough search of DDTs in High Resolution Imaging Science Experiment (HiRISE) [3] images has been done before, although it has been attempted with other datasets [e.g., 1, 4] and at limited locations [e.g. 5]. HiRISE's 25 cm/pixel images allow detection of much smaller DDTs at a wide variety of locations and seasons.

Approach: To identify occurrences of DDTs we searched all HiRISE images acquired from November 21st, 2014 to May 6th, 2018 and span L_S 237º in Mars year 32 to L_S 171º in Mars year 34. The visual search was done at the thumbnail resolution using the default stretch, so very faint DDTs or those smaller than ~5 m in width may not be resolved.

Results: Out of 15,764 images, 912 (5.8%) contained dust devil tracks (Fig.1). Of the 912 images, 174 (19%) were located between 90°N to 45°N, 94 (11%) between 45°N and 0°N, 224 (25%) between 0° and -45°S, and 418 (46%) between -45 and -90°S. 71% of the HiRISE images searched that contain dust devil tracks are in the southern hemisphere and 29% in the northern hemisphere.

Discussion: [1] also found more DDT's in the southern hemisphere than the northern and concluded that the latitudinal dependency of DDTs is a result of two principal factors: (1) orbital asymmetries result in a more energetic dust devil season in the southern hemisphere than in the north and (2) dust layer asymmetries that result in fewer DDTs forming in the northern hemisphere than in the south.

Spatial biases exist in the HiRISE dataset because images tend to be targeted in geologically active, relatively dust-free areas (Fig. 1). Additionally, seasonal trends in targeting exist, for example, the high northern latitudes are not imaged during the northern winter when they are in darkness. These biases will need to be taken into account as we continue to analyze this dataset.

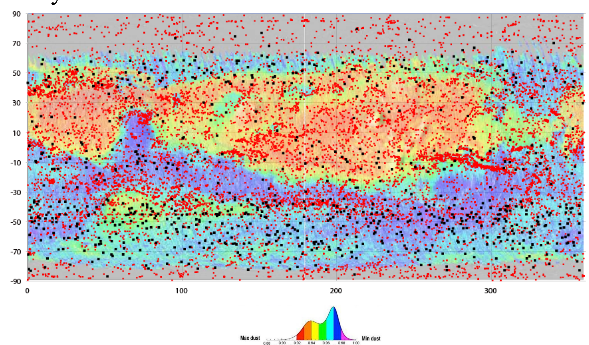

Fig. 1. *TES Dust Cover Index [6] map showing 912 HiRISE images containing dust devil tracks (black squares) and the 14,852 images in the same time period that do not contain dust devil tracks (red squares).*

Part 2- Fading rate of DDTs:

Methods: To understand the fading rates, and thus lifetimes, of DDTs on Mars, we selected sites with: (a) a minimum of 3 overlapping noise-free HiRISE images taken within 3 months, (b) images taken close enough in time to see a dust devil track appear between subsequent images (therefore constraining the formation time), (c) features that can be robustly identified between images, and (d) areas that are not saturated with DDTs. We measured the change in brightness of a surface sample inside a dust dust devil track ratioed to a background surface in successive images to yield relative albedo, using the method of [7,8]. The relative albedo is plotted against the time that image was taken. A linear fading rate is assumed and extrapolated to a relative albedo of 1 to estimate the lifetime of the DDT (Fig. 3).

Results and Discussion: We have measured the fading of dust devil tracks at 12 sites around Mars. DDT lifetimes range between 58 and 279 Earth days. Our preliminary results suggest that (1) higher elevation sites tend to have longer lifetimes and (2) southern hemisphere dust devil tracks take longer to fade (Fig. 2). (1) indicates that atmospheric density plays a role in the fading of DDTs. The implications of (2) are not yet obvious, but in the southern summer, the surface receives 40% more solar energy that drives atmospheric motion and dust devil formation than in the northern summer [1]. It's possible that more dust devils, and generally more eolian activity from a less stable atmosphere may prolong DDT fading in the southern hemisphere.

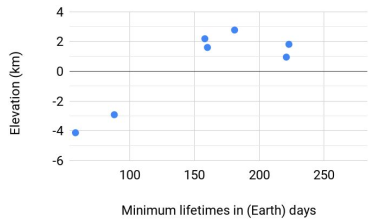

Fig. 2. *(Above) Minimum lifetime in (Earth) days of dust devil tracks vs. site elevation on Mars.*

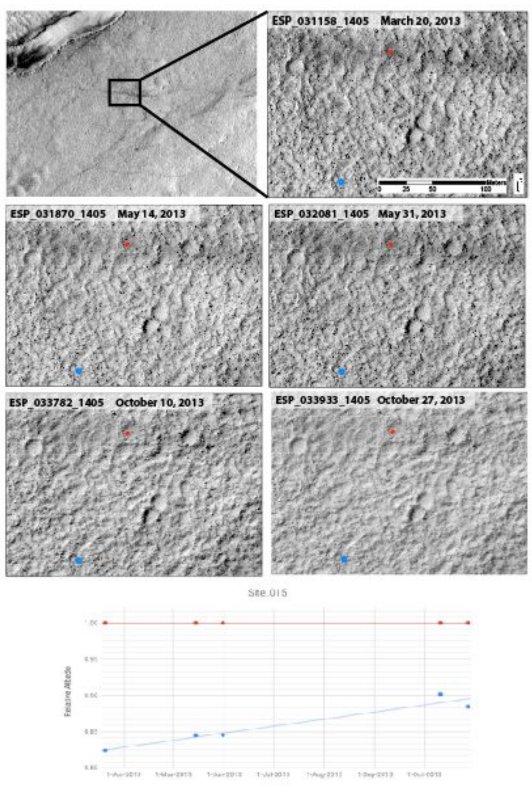

Fig. 3. *(Top) Example dust devil track (DDT) in five successive HiRISE images. (Bottom) Relative albedo plotted over time of a sample from within the dust devil track (red) ratioed to a background sample (blue) and the best fit linear function describing its fading. Estimated minimum lifetime of 221 days is calculated to be when A_rel=1, i.e. when the DDT brightens to match the albedo of the surroundings.*

Part 3- Spectral Analysis:

Methods: We examined spectral differences between fresh DDTs and their surroundings in order to estimate the thickness of dust cover removed by track formation. For each DDT, average spectra of the DDT was normalized by average spectra from a background region (BK) that lacks DDTs. The largest difference in the reflectance spectra between DDT and BK occurs at 700 nm, which can be correlated to dust cover thickness [9].

Results: The spectral reflectance difference was computed at one of the sites where the fading rate has also been measured (Fig. 4). At 700 µm, the maximum difference in the reflectance between DDT and background is ~0.09. Given this minimal spectral contrast, we can only put a lower bound of 1×10^{-4} gm/cm^2 on the dust removed by the dust devil [9]. If the amount of material in this layer covered the surface as a continuous fill, it would be 0.3 µm thick, assuming 3 g/cm^3 density. If those deposited particles instead are present as a fluffy, porous layer with 50x lower density, then the layer would be a minimum of ~16 µm thick.

The lifetime of this site was measured to be 158 Earth days. Combining the dust thickness removed to form the track with the amount of time it takes to disappear yields a dust deposition rate at this site is between 0.69µm/year and 37µm/year, comparable to previously measured rates [8, 10].

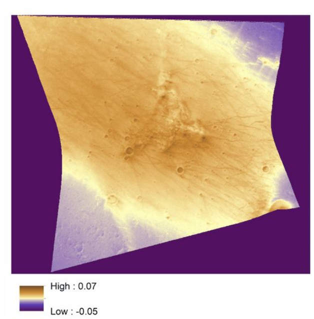

Fig. 4. *Analysis of site at 45.93°S, 9.525°E showing spectral contrast between the DDT and the background. The maximum contrast between DDT and the background is <0.1, which based on [8] implies dust lofting of <1X10^{-4} gm/cm^2.*

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