

GLOBAL DISTRIBUTION OF DUST DEVIL TRACKS IN HIRISE IMAGES. Ingrid J. Daubar¹, Matthew Chojnacki², Rachel Hausmann³, Lujendra Ojha⁴, Matthew Golombek³, Ralph Lorenz⁵, James Wray⁶, Kevin Lewis⁷. ¹Brown University, Providence, RI (Ingrid_Daubar@brown.edu). ²University of Arizona, Tucson, AZ. ³Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA. ⁴Rutgers University, NJ. ⁵Johns Hopkins University APL, Laurel, MD. ⁶Georgia Institute of Technology, Atlanta, GA. ⁷Johns Hopkins University, Baltimore, MD.

Introduction: Dust devil tracks (DDTs) are the traces across the surface left behind by the passage of dust devils (atmospheric vortices carrying dust) [e.g. 1]. Although not all dust devils leave behind tracks, (on average as low as only ~14% of them do [2]), and DDTs themselves fade on timescales of months [3], DDTs can still provide a method of studying the occurrence of this atmospheric phenomenon over time and space, as the tracks remain visible orders of magnitude longer than the dust devils themselves.

Here we provide results from the first thorough search of DDTs in High Resolution Imaging Science Experiment (HiRISE) [4] images, although it has been attempted with other datasets [e.g., 1] and at limited locations [e.g. 5, 6]. HiRISE's 25 cm/pixel images that span over a decade at Mars allow detection of much smaller DDTs at a wide variety of locations and seasons.

Methods: To identify occurrences of DDTs, 21,477 HiRISE images were searched – 34% of all HiRISE images taken to date. This range spans all images acquired between MRO orbit 35,000–55,000; from January 13, 2014 to April 21st, 2018; between L_s 76° in Mars year 32 to L_s 163° in Mars year 34. A visual search was done at the reduced “thumbnail” resolution using the default stretch, so this method would not necessarily detect all DDTs with limited albedo contrast with the surrounding surface, or those smaller than ~5 m in width. Both dark and bright DDTs were included, although they are not distinguished in the dataset. Dust devils caught in action were identified as well.

Surface properties at the locations of those images were sampled from global datasets in JMars [7], taking the average value across the HiRISE footprint. See below for specific data sampled. In most cases these low-resolution maps have pixel scales orders of magnitude larger than HiRISE, so these should be considered local estimates, not on the scale of the identified DDTs.

In order to compensate for the targeting biases inherent in the HiRISE observations (e.g. concentrations of imaging near geologically active, relatively dust-free areas and landing sites, as seen in Fig. 1), we correct for the observed statistics by considering only percentages of images in a given bin of surface property value, for example, which were identified as containing DDTs. Thus they may not represent true absolute fractions of DDT occurrences, but in comparison to each other they should indicate trends that depend on that particular surface characteristic. Biases remain, however – for example, multiple images taken at the same location may contain DDTs.

Results: Out of the 21,477 images searched, 798 (3.7%) contained dust devil tracks (Fig. 1). Only 20 images with active dust devils were identified (0.093%); analysis has not yet been performed on this very sparse dataset. The DDT dataset was examined for the following trends, in addition to others that will be presented.

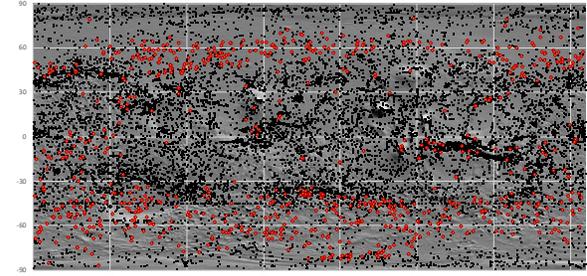


Fig. 1. Global map of Mars showing locations of 21,477 HiRISE images with DDTs (orange) and those without (black). Plotted on map of MOLA shaded relief [14].

Latitude. DDTs have a strong latitudinal preference for polewards of -60° and $+60^\circ$ (Fig. 2), avoiding equatorial regions, as was also seen by [8] in MOC images over much smaller regions. The higher frequency of DDTs in the south also agrees with previous studies [8] that attribute this to more energetic Hadley cell circulation in the southern summer, and less dust accumulation in the north.

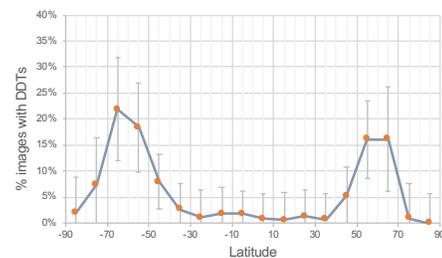


Fig. 2. Occurrence of DDTs with latitude.

Season. The exact time of formation of the DDTs is not known, but because DDTs fade over timescales of several months [3], we assume that the season in which we observed them is roughly that of their formation.

We find that DDTs have a strong seasonal preference for L_s ~250–320° (southern summer) and when regional and planet-encircling dust storms are most common [9, 13] (Fig. 3). This matches other studies in the literature [1, 5, 8] and is also related to atmospheric circulation. When only equatorial latitudes $\pm 30^\circ$ are considered, activity in general is lower, and the seasonal trend disappears (Fig. 3).

These seasonality trends are not necessarily that of dust devil activity or track creation, rather when preserved DDTs are most apparent. Nevertheless, our recorded peak of DDT detections are also near the peak of the Gusev crater dust devil season (perihelion), as observed by the Spirit rover [10].

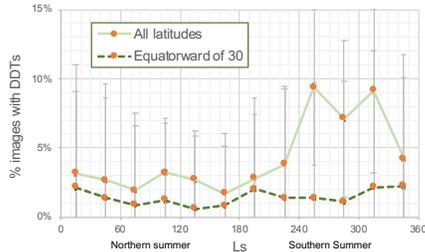


Fig. 3. DDTs with martian season, for all latitudes (solid light green line) and for equatorial latitudes (dark green dashed line).

Elevation. Elevation measurements were sampled from the MOLA 128 ppd global grid [14]. The very lowest elevations on Mars (-8 to -6 km) show significantly more DDTs, but above -5 km we do not see significant variation with elevation (Fig. 4), although the statistics at elevations >5 km are sparse. This contrasts with previous studies that found no dependence of DDTs with elevation [8,11].

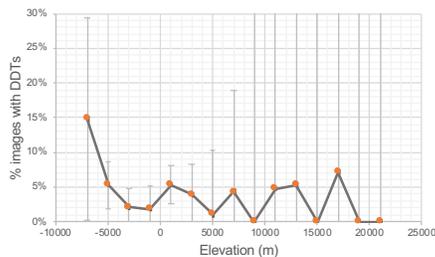


Fig. 4. DDTs with elevation (MOLA [14]).

Thermal inertia (TI) vs. Albedo. Thermal inertia was sampled from the THEMIS 100 m global mosaic [15] where available, and the lower-resolution 8 ppd TES elsewhere [16]. Albedo was sampled from the TES 8 ppd albedo map [16].

Although DDTs tend to occur at all thermal inertias, we find a higher frequency of DDTs among lower albedo regional units. DDTs are far more common in the “Unit B” surface type identified by [12] (Fig. 5). This is a fairly common type of (kilometer-scale) surface unit defined by relatively high thermal inertia and low albedo, interpreted as consisting of mixed sand, rocks, and bedrock. This is a somewhat surprising result, as DDTs might be expected to be more common in areas like Putzig’s Unit A, high albedo areas that are interpreted to consist of bright unconsolidated fines [12]. One possible explanation is that those deposits of fines may be significantly thicker than the layer removed to form a DDT. For example, Unit A includes broad dusty regions

like Tharsis that have stacks of dust deposits. Instead, DDTs seem to be more likely to form in regions with thin layers of dust deposits overlying material with larger grain sizes or even bedrock, rather than in thick deposits of dust that do not provide either a grain size or albedo contrast with depth that is required to make tracks visible.

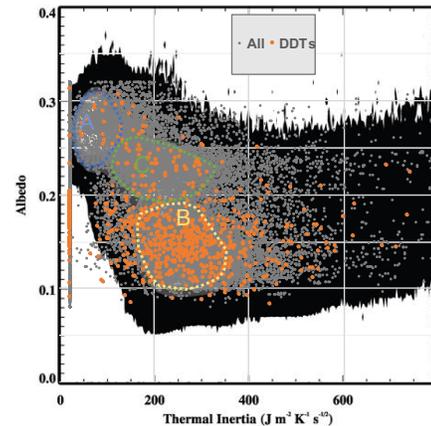


Fig. 5. DDTs with Thermal Inertia [15, 16] and Albedo [16], plotted over surface units defined by [12].

Conclusions. In the first global survey of dust devil tracks in HiRISE images, we find that DDTs tend to form most often near -60° and $+60^\circ$ latitude, during the summer when solar heating is at the maximum in each hemisphere, but much more commonly in the southern hemisphere. These results agree with previous, more limited, studies. We find significantly more DDTs at the lowest elevations, perhaps indicating atmospheric pressure does in fact play a part in their formation. DDTs are most common in the thermal inertia–albedo unit B. These characteristics allow us to identify the conditions under which DDTs form and are preserved most readily.

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References: [1] Reiss et al. (2016) *SSR* 203:143–181. [2] Cantor et al. (2006) *JGR* 111, E12002. [3] Hausmann et al. (2019) *LPSC*, 2964. [4] McEwen, A.S., et al. (2007) *JGR* 112, E05S02. [5] Verba C. A. et al., (2010) *JGR* 115 E09002. [6] Tamppari, L. K., et al. (2020) 7th Mars Polar Sci. Conf., Abs. 6011. [7] Christensen et al. (2009) *AGU Fall*, Abs. IN22A-06. [8] Whelley and Greeley (2008) *JGR* 113, 1–12. [9] Cantor et al. (2019) *Icarus*. **321**, 161–170. [10] Greeley, R. et al. (2006) *JGR* 111, 1–16. [11] Balme et al. (2003) *JGR* 108, 5086. [12] Putzig et al. (2005) *Icarus* 173, 325–341. [13] B. Cantor (2007) *Icarus*. 186, 60–96. [14] Zuber, M. T., et al. (1992) *JGR* 97 (E5): 7781–97. [15] Christensen, P. R., et al. (2004) *SSR* 110: 85–130. [16] Christensen, P. R., and H. J. Moore (1992), in *Mars*, ed. H. H. Kieffer, et al., pp. 686–729, U Arizona Press, Tucson, AZ.