The Variation of Martian Dust Devil Lifetime with Surface Temperature and Pressure.

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Introduction: Dust devils occur in arid desert landscapes on Earth, and are especially active on Mars today. The formation of dust devils is primarily controlled by insolation at the surface causing instability and convection in the near-surface (>10 m) boundary layer [1]. Dust entrained in dust devils can influence the Martian climate significantly and can cause near-surface warming by increasing the atmospheric opacity [3]. Recent work [4] has attempted to constrain dust devil lifetimes from repeat visible imagery, finding that dust devils forming at locations of higher elevations and those within the southern hemisphere typically have longer lifetimes. Here we build on their work by modeling surface temperatures and pressures at the locations of constrained dust devil locations from [4] to explore possible trends with dust devil lifetimes.

Methods: Using Dust Devil Track (DDT) data from [4], we used a one-dimensional planetary thermal model, KRC [2] within JMARS [5] to model the surface temperatures at dust devil track locations throughout the year. Standard KRC inputs were used (TES albedo, thermal inertia, etc.) The elevation at each location was used to derive the local surface pressure assuming a constant scale height of 11 km and the surface pressure at 0 km elevation to be 610 Pa.

HiRISE Observation	Latitude	Longitude	Min lifetime (Earth days)
PSP_003689_1650	-14.625	175.519	218
ESP_032188_2070	26.625	62.812	178
ESP_054007_2330	52.524	178.041	156
ESP_036536_2360	55.564	150.602	110
ESP_021870_1315	-48.113	242.442	181
ESP_016973_1330	-46.734	20.146	542
ESP_030802_1405	-39.303	111.217	551
ESP_048523_1275	-52.351	157.776	223
ESP_026996_2300	49.526	325.294	107
ESP_033456_1255	-54.278	12.909	110
PSP_005456_1650	-14.634	175.527	1217
ESP_022762_1335	-45.934	9.534	158
ESP_031158_1405	-39.302	111.217	543
ESP_057301_1520	-27.718	272.512	159
ESP_057357_1385	-41.175	187.414	261
ESP_057267_1265	-53.144	125.421	197
ESP_057279_1275	-52.290	157.690	428

Table 1. *Dust Devil Track (DDT) lifetimes as observed by HiRISE [4].*

Results: The majority of DDTs cluster at their respective hemisphere's summer time (L_s 270 and 90) near 300 and 260 K in Fig. 1.

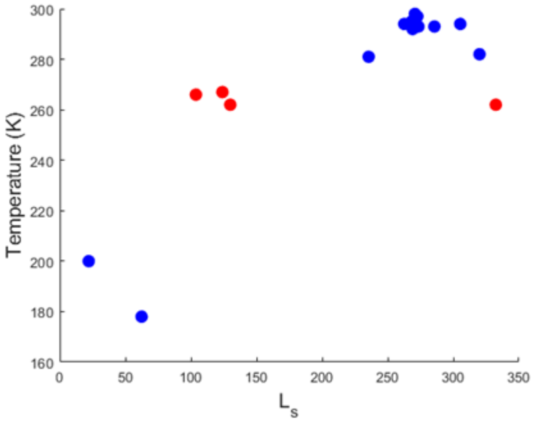

Figure 1. *DDT temperatures at the times of their constraining image from [4] (0 = southern autumn, 90 = southern winter, 180 = southern spring and 270 = southern summer). Red dots are in the north, blue dots are in the south.*

The northern hemisphere locations are lower on average than locations in the southern hemisphere; this can perhaps be attributed to perihelion causing warmer summers in the south.

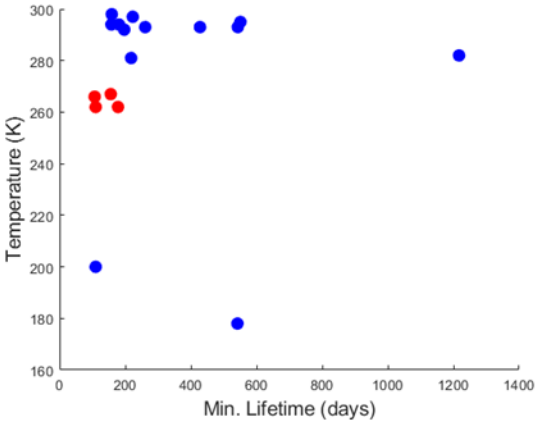

Figure 2. *DDT temperatures versus minimum lifetimes (Earth days). Red dots are in the north, blue dots in the south.*

Most DDTs seem to cluster between 260 and 300 K, with lifetimes between 150 and 600 days (Earth days). The temperature of the four Northern DDT's (in red) are around 260 - 265 K while the southern hemisphere temperatures are generally above 280 K in Fig. 2.

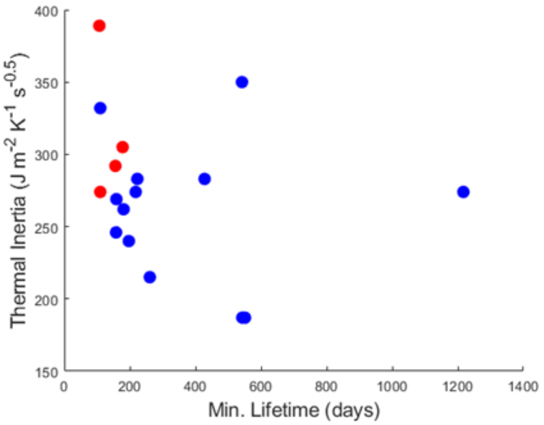

Figure 3. *Thermal inertia of DDT locations with minimal lifetime. Red dots are in the north, blue dots are in the south.*

The thermal inertia of these DDT locations varies from just above 200 $J\ m^{-2}\ K^{-1}\ s^{-0.5}$ to just below 400 $J\ m^{-2}\ K^{-1}\ s^{-0.5}$ with minimal lifetimes of around 200 days in Fig. 3. There is no observable trend between DDT lifetime and surface thermal inertia, at least at the relatively coarse TES thermal inertia resolution.

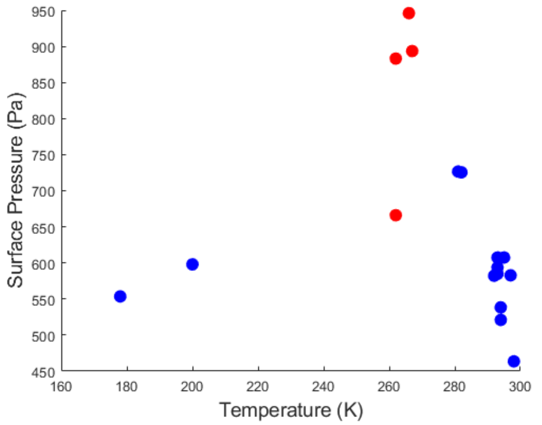

Figure 4. *DDT temperatures versus average surface pressure. Red dots are in the north, blue dots are in the south.*

The DDT locations that attain the highest surface temperatures are also the regions of the lower surface pressure, as is expected for regions in the southern hemisphere (Fig.4).

Discussion: Dust devil formation can act as a positive feedback system during the summer, when insolation is highest [6]. While the DDTs last less than a Martian Year, the observed track lifetime is far longer than terrestrial dust devils. This discrepancy is either due to limitations in repeat HiRISE coverage or due to the substantially lower atmospheric pressure of Mars relative to the Earth. Lower atmospheric pressure at locations of higher elevations can also explain longer DDT lifetimes at these locations.

These 17 observations are only a small subset of the 798 images taken by HiRISE [4] but may still be indicative of the overall results that show most dust devils occur in the southern hemisphere during the summer [3, 4, 6]. Additionally, modeled temperatures wll probably be underestimated due to near-surface heating caused by increased dust opacity from dust lifted by the dust devil.

Dust devils can alter surficial geology and affect surface albedo, which could lead to long-term effects on the Martian climate through the changing rate of surface heating [6]. More observations and real time data are needed especially in active dust devils versus DDT's to get a true understanding of the nature and patterns of dust devil formation and the consequences they pose to future missions be it manned or robotic. Higher resolution studies using THEMIS can help with further constraining martian DDT lifetimes with surface thermophysics.

References: [1] Ryan, J. A. and Carroll, J. J. (1970) *JGR*, *75*, 531-541. [2] Kieffer, H. H. (2013) *JGR*,118. [3] Towner, M. C. (2009) *JGR*, *114*. [4] Hausman, R. et al. (2019) *LPSC L*, Abstract # 2132. [5] Christensen P. R. et al. (2009) *AGU*. [6] Balme, M. and Greeley, R. (2006) *JGR*, *44*.

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