DUST DEVIL TRACK SURVEY AT THE INSIGHT LANDING SITES: IMPLICATIONS FOR THE PROBABILITY OF SOLAR PANEL CLEARING EVENTS. D. Reiss[1] and R. D. Lorenz[2], Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany, [2]Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD 20723, USA.

Introduction: The InSight robotic lander is scheduled to land on Mars in September 2016. InSight was designed to perform the first comprehensive surface-based geophysical investigation of Mars [1]. Passage of vortices may have a number of influences on the geophysical measurements to be made by InSight. Seismic data could be influenced by dust devils and vortices via several mechanisms such as loading of the elastic ground by a surface pressure field which causes a local tilt [e.g. 2]. In addition, the power supply of the InSight instruments is provided by solar arrays. Solar-powered missions on Mars like the Sojourner rover in 1997 were affected by a decline in electrical power output by 0.2-0.3 % per day caused by steadily dust deposition on its horizontal solar panel [3]. The solar-powered Mars Exploration Rovers (MERs) Spirit and Opportunity experienced similar dust deposition rates [4] which led to steady power decrease over time endangering longer rover operation times. The much longer operation times of the rovers were made possible by unanticipated 'dust clearing events' of the solar arrays by wind gust or dust devils [5]. Recent studies imply that dust devils are primarily responsible for those recurrent 'dust clearing events' [6]. In this study we investigate the potential frequency of intense dust devil occurrences at the InSight landing site regions, which are able to remove dust from its solar panels. We analyzed newly formed dust devil tracks within a given time span using multi-temporal HiRISE image data covering the same surface area. Based on these measurements we will give encounter rate predictions of intense (high tangential speed and high pressure drop) dust devils with the InSight lander.

InSight landing site region: In 2013, four final landing site ellipses in Elysium Planitia located between 133.8°-139.5°E and 2.8-5°N (Fig. 1) were selected [7]. Within this region we analyzed multi-temporal HiRISE images covering the same surface area within a relatively short time period. In total, 8 image pairs were available at the start of the analysis (Fig. 1; Ids 1-8). Newly formed dust devil tracks were identified and mapped, and the width, length, and azimuth of each dust devil track was measured.

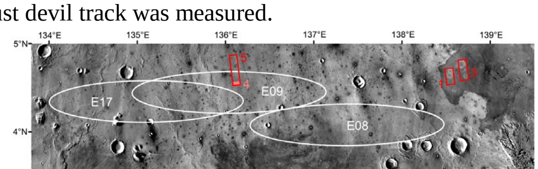

Fig. 1. The final four InSight landing ellipses (white color; E05, E08, E09, and E17) in Elysium Planitia (based on [7]). Frames and identitiy numbers (Ids 1-8) show areas of HiRISE stereo pairs (red) and overlapping surface area of two HiRISE images (pink).

Results: In total, 557 dust devil tracks were identified in 8 image pairs acquired between March 2010 and February 2014. No active dust devils in these image pairs were observed.

Morphology. Fig. 2 shows an example of a typical newly formed DDT. The DDTs in the study region are relatively straight which is also expressed in their low mean sinuosity of 1.03 (standard deviation = 0.004). The sinuosity is lower compared to mean values of ~1.3 and ~1.08 measured by [8] in Russell and Gusev crater, respectively.

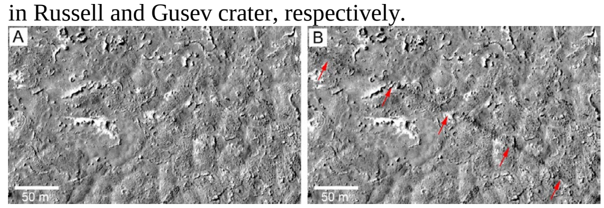

Fig. 2. Example of observed track formation between HiRISE images. A: HiRISE image ESP_016942_1845 at LS=61.30°. No tracks visible. B: HiRISE image ESP_018010_1845 at LS=97.83°. The new NW-SE oriented dust devil track has a width of 5 m. Images were acquired 81 sols (martian days) apart.

Track widths. Measured DDT widths vary from 1 – 30 m with a mean and median width for all measured DDT of 3.99 m and 3.08 m (standard deviation = 3.13), respectively. Fig. 3 shows the histograms of all measured DDTs. In general, narrower DDTs occur much more frequently as broader ones, i.e. the size distribution is strongly skewed. This can simply be explained by size-frequency distributions of dust devils: On Earth and Mars, smaller dust devils occur more frequently than larger ones [e.g., 9, 10], hence narrower DDTs should be expected to occur more frequently as larger ones. [11] suggested the size distribution of Martian dust devils may be described by a power law with a differential exponent of -2: fuller discussion of this question is found in [12] and [13]. As discussed in these papers, the break in frequencies occurring at DDT widths that we observe here between 1 – 2 m and 2 – 3 m (Fig. 3) can be explained by limitations of DDT identification due to the spatial image resolution of around 30 cm/pixel (i.e. a poor detection efficiency at small sizes, rather than a low abundance).

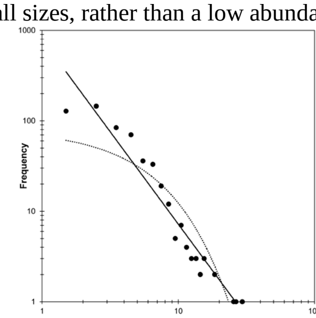

Fig. 3. DDT frequency versus DDT widths (black circles). Solid line is a power law fit with an exponent of -2.04 which follows the trend well. Dotted line is an exponential fit which is not in agreement with the measured data.

Track lengths. Many DDT run out of the HiRISE image, hence the complete length of the DDT can not be measured. Fig. 4 shows the complete (filled black squares) and incomplete (open red circles) DDT lengths versus DDT widths.

Although there is a broad scattering in the results, a trend for increasing DDT lengths versus DDT widths can be seen. Such a relationship of increasing lengths with increasing widths (likely comparable to dust devil diameters) would be expected due to the fact that larger dust devils have longer durations [14] who suggested an empirical correlation for both Earth and Mars data of $t=40d^{0.66}$, where t is the longevity in seconds and d the diameter in meters. The exponent allowed by the data may be between about 0.5 and 0.75, with 0.66 as a best guess round number (there exists large scatter in the data). The track length data in Fig. 4, where the full tracks were observed, are described by the least-squares fit $L=181d^{0.71}$. The exponent here is reassuringly consistent with the longevity exponent of 0.66 in the expression by [14].

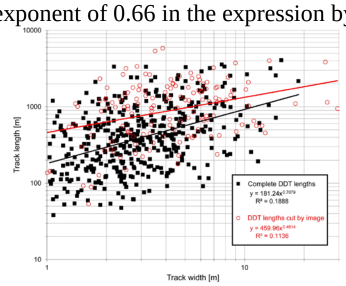

Fig. 4. DDT lengths versus DDT widths. Complete DDT lengths are shown by black filled squares (n=415). Incomplete DDT lengths are shown by red open circles (n=142).

Frequency and seasonal variations. Seasonally most image pairs cover solar longitudes (L_S) between 51° and 93° (northern spring), except for one covering L_S=215°-250° (northern autumn). The frequency of newly formed DDTs per square kilometer per sol (ddt km^{-2} sol^{-1}) varies between 0.002 and 0.08 (Fig. 5). However, within the last three acquired image pairs with a frequency of 0.002–0.005 ddt km^{-2} sol^{-1} a strong fading of already existing DDTs occurred, indicating suppressed dust devil activity probably caused by increased dust deposition. We compared the seasonal DDT formation rate to the Dust Devil Activity (DDA) index (Fig. 4), which is defined as the flux of energy available to drive dust devils [15]. It is related to the surface sensible heat flux and thermodynamic efficiency and generally increases with the depth of the convective planetary boundary layer, the difference between air and surface temperatures and the surface wind stress. Input parameters for the calculation of the DDA index were derived from the the Mars Climate Database (MCD version 5.1) [16]. The seasonal DDA index was calculated in L_S=10° steps and averaged from 5 daily calculations between 9-17 local time. Although the available multitemporal HiRISE data is so far limited to certain seasons, the DDA index indicates an average seasonal DDT formation rate around 0.04 ddt/km2/sol.

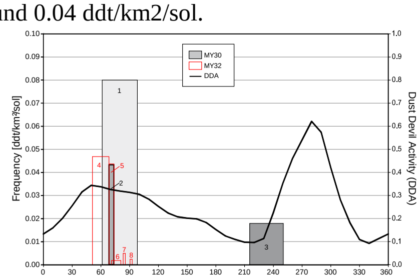

Fig. 5. Seasonal DDT frequency of the analyzed image pairs in comparision to the Dust Devil Activity (DDA) index of [15].

Solar panel clearing predictions: The formation of DDTs is of operational interest, in that InSight is solar-powered, and the accumulation of dust on its solar panels may influence the amount of data the lander can send back, and ultimately the operational lifetime of the lander itself. By multiplying the track widths by the track lengths, we obtain a DDT area formation rate (e.g. for the Id1 data, we find a total of 1.6 km^2 of DDTs formed by 396 DDTs in a 61km^2 survey area over 81 sols) of about 0.0003 km^2/km^2/sol. Inverting this implies that a given spot on the surface may be cleared of dust once in 3000 sols (i.e. every ~5 Mars years). Based on the measurements of Ids 1-5 (Ids 6-8 show fading of tracks) and the seasonal DDA index (Fig. 5), the average seasonal DDT formation rate is around 0.04 ddt/km^2/sol. After normalization of track widths (Fig. 3), lengths (Fig. 4), and using the average DDT formation rate of 0.04 ddt/km^2/sol we calculated an average DDT area formation rate of about 0.00007 km^2/km^2/sol for the InSight landing site regions, which implies that InSight's solar panels may be cleared of dust in average once in ~15000 sols (i.e. every ~22 Mars years). In so far as clearing dust from a solar panel is in principle the same process as the formation of a DDT (i.e. the removal of a layer of dust [17, 18]), then the DDT formation rate we have observed is not favorable for expecting any reversal of dust accumulation on InSight's solar panels since the recurrence interval of ~22 martian years is much longer than the expected mission duration. The main reason for this very long recurrence interval is the small dust devil size population observed from DDTs. On the other hand, we have not yet had the opportunity to observe the DDT formation rate at the season at which dust devil activity would be expected to be highest based on the DDA index from L_S ~250°-320° (Fig.5). Finally, the total encounter rate of the InSight lander with less intense dust devils (not able to remove significant amounts of dust) and dustless vortices will be much higher. Orbital obervations showed that only 14% of active dust devils leave tracks [19]. Measurements of DDT formation rates with HiRISE [8] and the comparison to observed active dust devils by Spirit rover [10, 20] in Gusev crater implies a ratio between 1/500 and 1/110 [8]. This ratio even does not include dustless vortices, which indicates that the total encounter rate of vortices with the InSight lander might be several 100 factors higher than our predictions for intense dust devils.

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