CLASSIFICATION AND ANALYSIS OF HIGH RESOLUTION DUST DEVIL TRACKS ON MARS.

P. Horton[1], [1]Arizona State University School of Earth and Space Exploration, Tempe, AZ 85251 (pahorton@asu.edu).

Introduction: Martian dust devils create ephemeral surface features that briefly reveal the underlying substrate materials [1]. These tracks are useful in determining wind direction and speed as well as an explanation for unique surface features. While global analysis has been done on Dust Devil Track (DDT) regions using the Narrow Angle Mars Orbiter Camera (MOC-NA), analysis using the High Resolution Imaging Science Experiment (HiRISE) has been limited to individual regions of interest [2]. To provide a high resolution global overview of DDTs on Mars, this work has identified areas with high dust devil activity, classified the type of DDT, and derived wind patterns from the tracks. Identifying these images will help inform future work on the effects of dust devils and their tracks on the global climate of Mars through dust injection and surface heating.

Background: Dust devils are formed by near-surface heating resulting in an upward moving spiral flow of air that creates a vortex of upward moving sand or dust [1]. This phenomenon is common on Earth and was first identified on Mars in 1985 with Viking orbiter images [3]. These images revealed about 100 active dust devils averaging in height from 1 to 2.5 kilometers [3]. While these initial observations indicated that Mars dust devils often are much larger than their terrestrial counterparts, higher resolution orbiting cameras and lander missions have shown a large variation in the size distribution of martian dust devils [1]. Based on observations from these newer missions, evidence has shown that smaller dust devils are extremely common and have a similar morphology to terrestrial dust devils [1].

Dust devils leave streaks of surface albedo contrast with widths on the scale of the diameter of the dust devil. The characteristics of these DDTs vary from region to region depending on the wind patterns and the underlying substrate materials. Reiss et al. [4] described three categories of DDTs: Dark Continuous DDTs (DC-DDT), Bright DDT, and Dark Cycloidal DDT. The most common type is DC-DDT, described as a relatively curvilinear path with a darker albedo than the undistributed surface. Bright DDTs are similar in structure to dark continuous DDTs except the albedo of the path is lighter than the undisturbed surface. Finally, the rarest type is dark cycloidal DDT, which has a similar albedo contrast to DC-DDTs but a spiral, looping path. These categories were previously used to produce global maps of DDTs using MOC-NA data [4]. This work aims to provide similar analysis using the much higher resolution HiRISE imager.

Previous work on analyzing DDTs with HiRISE data has been limited to region of interest studies. In particular, one such work analyzed DDTs at the InSight landing site to measure wind patterns using HiRISE images [2]. The objective of this work is to conduct similar analysis across Mars to provide a global overview of high resolution DDTs.

Approach: To collect all HiRISE images containing DDTs this work utilized an existing inventory of DDTs [5] derived from all HiRISE images containing metadata tags mentioning dust devils. From there, each image was sorted into three categories: active dust devils, sparse DDTs, and dense DDTs. Images with active dust devils include images containing active dust devils but no visible DDTs. The distinction between sparse and dense is determined by the percentage of the image covered in overlapping DDTs. Images with more than 10% of the region covered in overlapping DDTs were categorized as dense.

After all the images have been sorted, the DDTs in each image were labeled based on the categories by Reiss et al. [4]. To measure wind direction, dense images were gridded into 256 by 256 pixel regions. Within each region, the most prominent DDTs were labeled and their orientation was recorded. For images with a high DDT density, the top three most prominent DDTs in each grid were recorded. The measured DDTs in each region were combined to provide an overall measurement of DDTs in the region.

Results: Of the 60 images in the initial data set, 13 contain active dust devils, 32 contain sparse DDTs, and 15 contain dense DDTs. Table 1 shows the distribution of images in the data set. Dark encompasses both continuous and cycloidal DDTs as the two usually appear together. None was added to classify images that do not contain any visible DDTs.

	Active	Sparse	Dense
Dark	0	18	15
Bright	4	0	0
None	9	14	0
Total	**13**	**32**	**15**

Table 1: Classification of DDTs in HiRISE data set

For the 15 images with dense DDTs, wind direction measurements were performed. Fig. 1 shows an example of two wind direction measurements. The HiRISE images shown are subsections of a larger HiRISE image. The rose plot shows a histogram of DDT orienta-

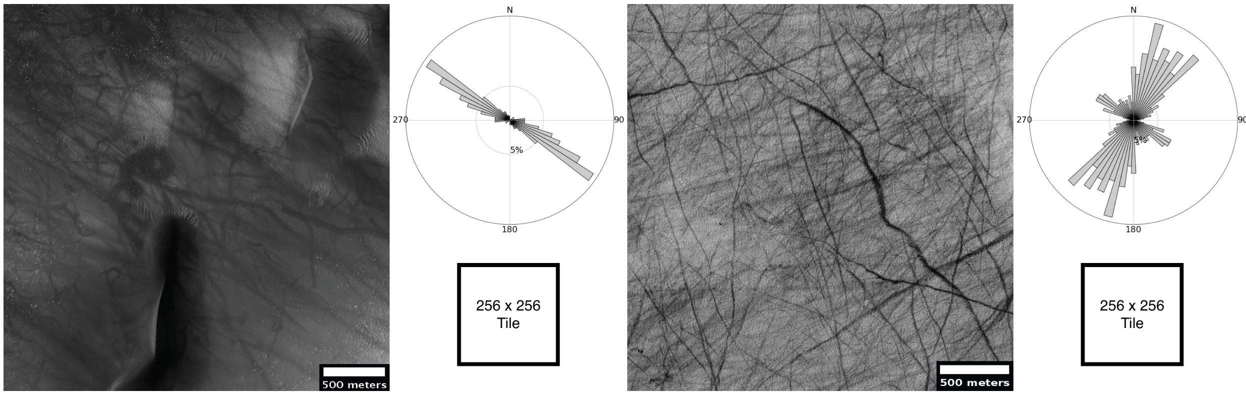

Figure 1: DDT Orientation Histograms for the Southern Noachis Region (Left: ESP_012252_1245) and Sisyphi Planum (Right: ESP_031083_1180). Images from HiRISE (NASA/JPL/University of Arizona)

tions for the dominant DDTs in the gridded version of each full size image. The size of a 256 x 256 grid tile is shown for scale.

Discussion: The distribution and albedo of DDTs provides key information about their life cycle. All of the images containing active dust devils feature less than a 5% brighter DDT, with most having no albedo change. This is surprising as we would expect to see a distinct DDT for an active dust devil. These active dust devils may not remove enough dust for a noticeable albedo change. When there is an albedo change, the DDT is bright compered to the undisturbed surface. The most surprising observation is that no images of active dust devils exist associated with a dark DDT even though they are the most abundant DDT.

Images containing sparse DDTs either contained the occasional dark DDT or no DDTs at all. Bright DDTs did not appear in any of these images or the images with dense DDTs. Evidence from this work shows that bright DDTs may fade quickly after their formation. This is supported by the lack of visible bright DDTs without the presence of an active dust devil.

Finally, all of the images containing dense DDTs contained dark continuous DDTs. Given the abundance of DDTs in some of these images and the lack of active dust devils, evidence points towards dark DDTs take much longer to fade than bright DDTs. This aligns with previous theories that bright DDTs fade sub-annually [4]. The majority of dark DDTs were continuous but some images, such as the one shown on the left in Fig. 1, contain cycloidal DDTs. In the figure, the cycloidal DDT is seen as a curvy, phone cord-like trail, near the center of the image. These features are likely rare because they require high turbulence to push the dust devil in multiple directions. The edge of the dune may account for wind patterns that produced the cycloidal DDT in this image.

The track orientation of the images with dense DDTs gives us information about local wind patterns. In Figure 1, the left example shows relatively consistent track patterns in the Southern Noachis Region. Almost all of the tracks in the region are pointing in the NW to SE direction. This is may be due to the hilly region providing channels for wind to blow through creating a relatively consistent wind pattern, but further analysis is needed. In comparison, the right example shows somewhat inconsistent tracks patterns in the Sisyphi Planum. Because the area is relatively flat and open, the wind direction is less consistent so the tracks have a less uniform alignment.

Summary and Conclusion: By utilizing HiRISE images (0.3 m/pixel), much finer DDTs can be detected when compared with MOC-NA (6 m/pixel) data. From the HiRISE images, this work documented that brighter DDTs fade faster than darker DDTs and confirm that dark continuous DDTs are the most abundant. The high resolution imaging also enables us to perform wind pattern analysis using DDT orientation. This is important for understanding local wind patterns for future Mars missions and understanding how dust affects the Mars climate.

Future work can be done by confirming the bright DDT fading theory by comparing a region's images over time. Additionally, wind patterns can be measured as a function of season by counting the number of new DDTs and analyzing orientation patterns.

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