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Automated width measurements of Martian dust devil tracks

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ABSTRACT

Studying dust devils is important to better understand Mars climate and resurfacing phenomena. This paper presents an automated approach to calculate the width of tracks in orbital images. The method is based on Mathematical Morphology and was applied to a set of 200 HiRISE and MOC images of five Mars quadrangles, which were Aeolis, Argyre, Noachis, Hellas and Eridania. Information obtained by our method was compared with results of manual analysis performed by other authors. In addition, we show that track widths do not follow a normal distribution.

1. Introduction

Dust devils are whirlwinds made visible by entrained dust and sand. They are upward moving, spiraling flows caused by heating of near-surface air by insolation. The term *dust devil* is used to refer to sustained, particle-loaded convective vortices to distinguish them from vortices that form in the same way but are too weak to pick up materials and become visible (Balme and Greeley, 2006). They have been studied on Earth for more than a century (Baddeley, 1860; Brooks, 1960), were first observed on Mars in the 1970s in orbital images taken by the Viking orbiters (Thomas and Gierasch, 1985) and can achieve miles in width and height. The knowledge about dust devil activity contributes to the understanding of Martian climate, geology and surface modification which is essential to plan future robotic and manned missions (Atreya et al., 2006; Balme et al., 2003; Balme and Greeley, 2006; Ferri et al., 2003; Metzger et al., 1999; Rennó et al., 2000; Toigo et al., 2003). In addition, wind is the only surface-shaping factor that is known to presently be active over a short geological timescale on Mars (Örmo and Komatsu, 2003).

Information such as approximate width, orientation and area coverage about dust devils can be inferred from the analysis of their tracks (Hess, 2012). Such tracks are mostly dark filamentary features originated by differences in photometric properties of the surface, perhaps caused by removal of fine-grained material (Reiss et al., 2010).

Most of the works regarding analysis of dust devils tracks in digital images use a manual method. There are hundreds of high resolution images depicting Martian surface being taken and the amount of information on them grew at a rate greater than the human capability to analyze and extract relevant information from these products to characterize the planet under study. As examples of the difficulty in analyzing manually so many images, Balme et al. (2003), Fisher et al. (2005), Cantor et al. (2006), Örmo and Komatsu (2003), Drake et al. (2006), and Whelley and Greeley (2006, 2008), had to search for tracks in (3000), (8116), (1238), (1700), (1734) and (6002; 167,254) Mars Orbiter Camera (MOC) images, respectively; Stanzel et al. (2008) searched in (23) High Resolution Stereo Color (HRSC) images and Towner (2009) did that in (3079) Thermal Emission Imaging System (THEMIS) images.

We have previously proposed and evaluated automatic methods for detecting dust devil tracks in digital images (Statella et al., 2012), for inferring their direction of movement (Statella et al., 2014) and for estimating extensively the albedo contrast with their neighborhood (Statella et al., 2015). In this paper we present a method for calculating the mean width of tracks identified in Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) and Mars Reconnaissance Orbiter (MRO) High Resolution Imaging Science Experiment (HiRISE) images which is automated. Our approach is based on Mathematical Morphology.

2. Image datasets

A search for MOC narrow angle and HiRISE images with solar longitudes ranging between 180° and 360° (a few images out of

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Table 1
Summarized information about the image dataset.

	Lat°	Lon°	Ls°	Width (pixels)	High (pixels)
Min	−14.47	0.70	134.17	138.00	179.00
Mean	−53.39	156.06	300.56	2754.85	2457.47
Max	−64.80	358.80	353.90	9058.00	7526.00

that range we knew beforehand containing tracks were also considered as part of the dataset) containing tracks of dust devils has been performed in the regions Aeolis, Noachis, Argyre, Eridania and Hellas.

More than a thousand images have been searched and a total of 124 images (75 MOC narrow angle panchromatic band and 49 HiRISE red band) showing dark dust devil tracks were initially considered. In order to decrease the processing time (mainly because of the larger size of HiRISE images) and discard irrelevant information (like regions with no tracks) the images have been trimmed to its regions of interest (HiRISE images were also resampled by a factor of 1/3), making it a set of 200 images: 90 MOC and 110 HiRISE (a number of HiRISE scenes were trimmed into two or more regions of interest). After the trimming procedure, the final dataset was distributed as follows: 4 MOC and 1 HiRISE images depicting regions in the Aeolis quadrangle, 20 MOC and 19 HiRISE images depicting regions in the Noachis quadrangle, 16 MOC and 55 HiRISE images depicting regions in the Argyre quadrangle, 26 MOC and 19 HiRISE images depicting regions in the Eridania quadrangle and 24 MOC and 16 HiRISE images from the Hellas quadrangle. Table 1 summarizes some characteristics of the images. The spatial resolution of HiRISE images before resampling is either 0.25 m (~90% of the images) or 0.50 m while the MOC spatial resolution varies from 1.43 m to 8.75 m (mean ~ 5 m).

In Table 1, Ls° stands for *solar longitude* which refers to the Mars–Sun angle, measured from the Northern Hemisphere spring equinox where Ls = 0°. Fig. 1 shows the distribution of the initial set of 124 images (white circles) according to their center coordinates in the planetocentric system. The base map is the Mars Orbiter Laser Altimeter (MOLA) image layer of the Mars Global Digital Dune Database.

3. Method

The basic input for our method for calculating the width of tracks is a binary image containing the tracks. In such image, a dust devil track pixel is assigned to the value 1 (white) and all the background pixels are assigned to the value 0 (black). Therefore, a previous step in which dust devil tracks had been detected is needed. The tracks in each one of the 200 images had been automatically detected using the method proposed by Statella et al. (2012). It was the first automated method proposed for detecting dust devil tracks. The global accuracy in the detection was 92% ± 5%. A review of papers regarding the manual analysis of dust devil tracks is fully provided in Statella et al. (2012) as well as detailed information on the automated method developed by the authors. In Fig. 2 we show examples of the detection of tracks. Fig. 2(A) and (C) are original images HiRISE PSP_006163_1345 and MOC M10-01206, respectively. The HiRISE image has spatial resolution of 0.25 m and its size is 4415 × 7184 pixels. The MOC image has spatial resolution of 5.55 m and its size is 363 × 829 pixels. Both images are from the Argyre region. Fig. 2(B) and (D) are the results of the detection. They are examples of the binary images adopted as input for our method.

For measuring tracks width in digital images we have used a Mathematical Morphology tool called granulometric analysis.

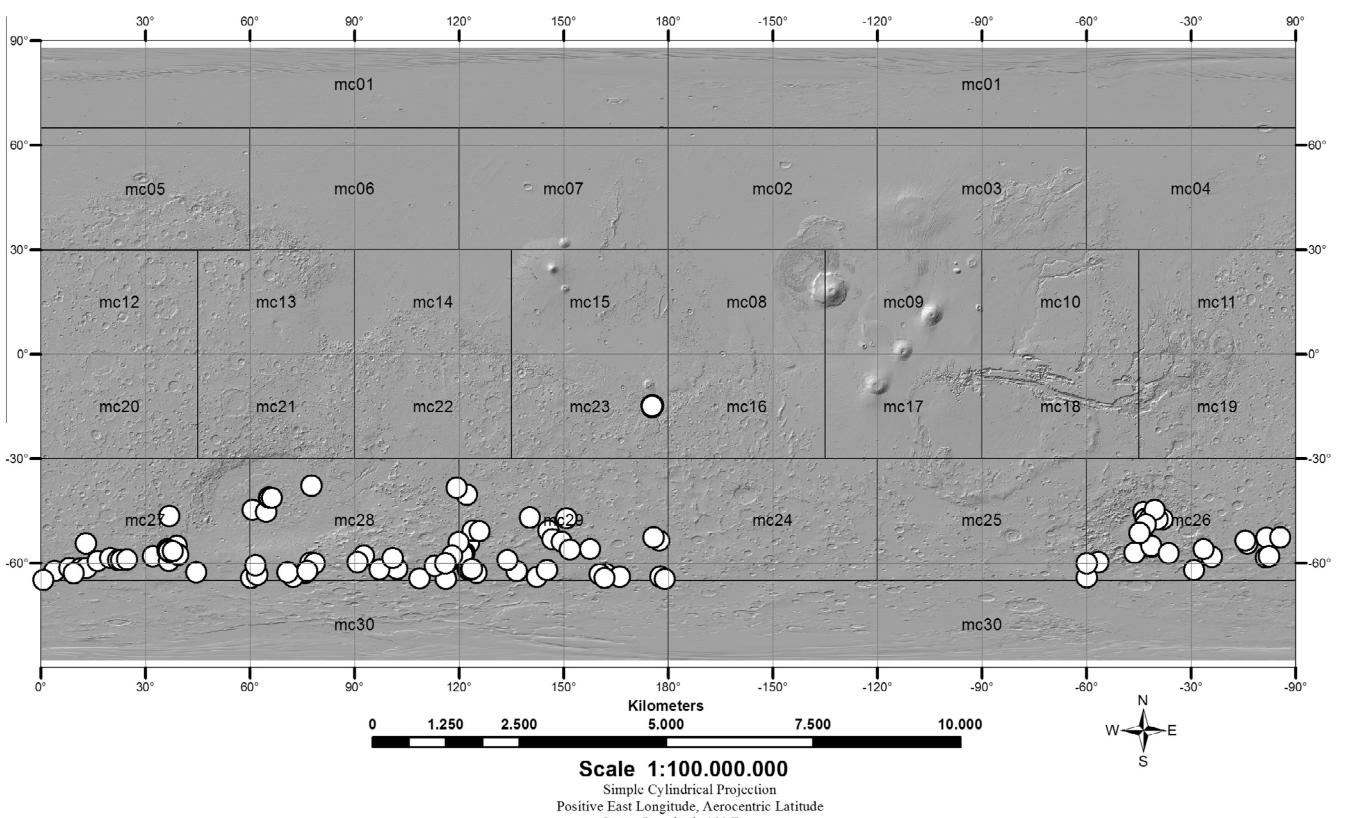

Fig. 1. Distribution of the initial image dataset in the Mars Charts (MC): Aeolis (MC23), Argyre (MC26), Noachis (MC27), Hellas (MC28) and Eridania (MC29). The white circles represent the center coordinates of the scenes. Image credits: R.K. Hayward, K.F. Mullins, L.K. Fenton, T.M. Hare, T.N. Titus, M.C. Bourke, A. Colaprete, P.R. Christensen.