# MULTITEMPORAL OBSERVATIONS OF IDENTICAL ACTIVE DUST DEVILS ON MARS WITH THE HIGH RESOLUTION STEREO CAMERA (HRSC) AND MARS ORBITER CAMERA (MOC).

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**Introduction:** Dust devils on Mars are suggested to be an important factor to loft dust in the martian atmosphere and to replenish the background dust haze [1]. [2] estimated that dust devils contribute to as much as half of the global dust suspension into the martian atmosphere based on a global study of dust devil track occurrence. The lifetime of Martian dust devils is one important parameter needed for the estimation of dust lifting rates. Earth based field observations have revealed that smaller dust devils (< 100 m) are more frequent than larger ones (> 100 m) [e.g., 3, 4], and that smaller dust devils collapse relatively quickly. Most terrestrial dust devils have a maximum duration of not more than a few minutes [5, 6]. Although large dust devils occur relatively rarely, several observations have been reported where large dust devils were active for more than 30 min up to several hours [e.g., 6-9]. [8] observed a large stationary dust devil, which lasted more than 4 h as well as large (height of ~760 m) migratory dust devils with durations of 7 h, traveling distances of about 65 km. Lifetimes of martian dust devils are rarely documented. [10] derived an mean minimum lifetime of 13 min for 12 dust devils with an average diameter of ~185 m. [11] measured average minimum lifetimes of 2.83 min for 533 dust devils with an average diameter of ~20 m. In this study [12], we made a global search of multitemporal imagery acquired within 12 h of the same surface areas using Mars Orbiter Camera –Wide Angle (MOC-WA) and High Resolution Stereo Camera (HRSC) for the presence of active dust devils to constrain the lifetimes of martian dust devils. Although several image pairs of HRSC and MOC-WA imagery covering the same region within the time constraints have been identified, only one image pair contained active dust devils [12].

**Observations:** Active dust devils were observed in Syria Planum in MOC-WA and HRSC imagery acquired on the same day with a time delay of ~26 min (Figure 1). The images which contained active dust devils were acquired at Coordinated Universal Time (UTC) of 2005-09-11T10:07:45.63 (MOC-WA image S1000175) and 2005-09-11T10:31:33.10 (HRSC image h2131_0000). In the MOC-WA image, 13 dust devils have been identified in agreement with the published number of [13]. The HRSC image strip crosses these coordinates and due to the higher resolution, 26 dust devils and 2 dust plumes have been identified. The unique operating technique of the HRSC allowed the measurement of the traverse velocities and directions of motion. Large dust devils observed in the HRSC image could be retraced to their counterparts in the earlier acquired MOC-WA image [12].

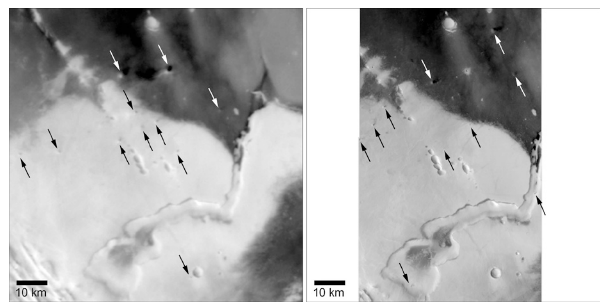


**Figure 1.** Parts of the overlapping images with several active dust devils (arrows) identified in MOC-WA image S1000175 (A) and HRSC image h2131_0000 (B) in the Syria- Claritas region.

A number of dust devils observed in HRSC images can be correlated to their probable counterparts in the MOC-WA image. We define a positive correlation of identical dust devils as ‘‘retraced’’ if the direction of motion, traverse velocity, diameter, and height can be correlated from one dust devil to the former one (for further information see [12]). Figure 2 contains the most straightforward examples for retracing. Dust devil h1 is large (diameter ~823 m, height ~1.6 km), and traveling in a northeastern direction. Its speed and direction can be most easily extrapolated to the location of dust devil m1 (diameter ~970 m, height ~1.15 km). In addition both diameters and heights are very similar. Based on our criteria dust devil h1 can be retraced to dust devil m1. Dust devil h2 (diameter ~820 m, height ~660 m), whose velocity is less certain, is most easily retraced to the position of dust devil m3 (diameter ~760 m, height ~880 m). The larger error associated with one measurement of the horizontal speed of dust devil h2 might be due to the fact that the dust devil appears to be breaking up in the HRSC image. However, both horizontal speed measurements of h2 are in the range of m3 as well as the direction of motion.

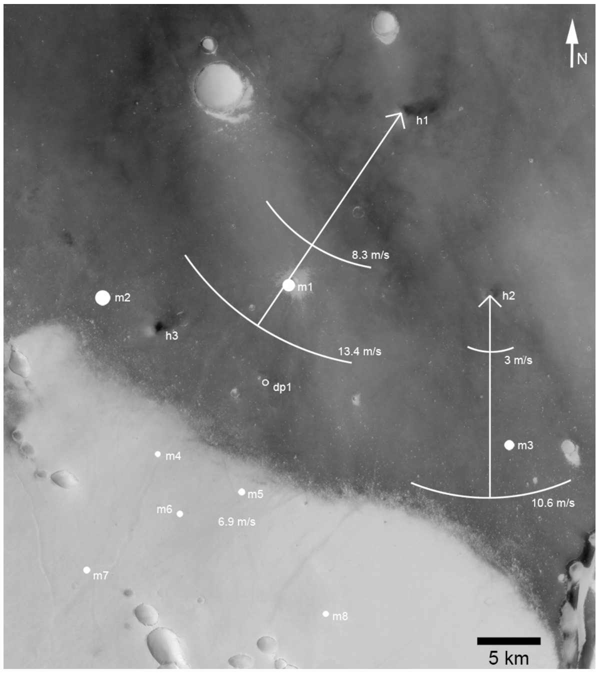


**Figure 2.** Retracing of dust devils h1-m1 and h2-m3. The direction of motion is indicated by white lines with arrows and measured speeds by circle arcs of the dust devils h1 and h2. Two speeds are indicated by the arced lines, because speeds were measured from the S2-channel to ND-channel and ND-channel to S1 channel. For additional information see [12].

**Dust calculations:** The duration of active dust devils is one important parameter, in addition to the size, frequency and dust flux which will lead to better estimations of dust entrainment by dust devils into the martian atmosphere. The contribution of total entrained dust amounts into the atmosphere by larger (>300 m in diameter) dust devils is difficult to determine due to the unknown frequency of different dust devil diameters in the study region. However, from Earth it is known that smaller dust devils occur much more frequently compared to rarely observed larger dust devils. The same relationship was observed for martian dust devils [11, 14]. The size-frequency distribution for dust devils on Earth and Mars is highly debated and seems to follow either an exponential [15, 16] or a power law function [17]. Using both functions and scaled dust fluxes, as well as lifetimes for different diameters, we estimated the percentage contribution of small (<100 m in diameter), medium (>100– 300 m) and large (>300–1000 m) dust devils to the total dust injection by dust devils into the atmosphere. Based on the size-frequency distribution observed in Gusev crater [11] scaled to larger dust devil diameters (1000 m) we calculated the number of dust devils in 10 m bins from 1 to 1000 m using both an exponential [15] as well as a -2 power law function [17]. For the dust flux we scaled measurements from Gusev crater (Fig. 10 in [18]) assuming a linear decrease to larger dust devil sizes from $10^{-4}$ kg/m$^2$/s for a diameter of 1 m to $10^{-7}$ kg/m$^2$/s for a diameter of 1000 m. For the lifetimes of dust devils we assumed a 0.62 power law based on the minimum average lifetimes of 2.83 min for 19 m in diameter [11], 13 min for 185 m in diameter [10] and 26 min for 700 m in diameter dust devils derived from the probable retraced dust devils in this study. The 0.62 power law function was used, because it gives the best fit to the limited available data of lifetime–diameter relationships, and we note that the function is very uncertain. The results for the exponential size-frequency relationship indicate that smaller dust devils (<100 m in diameter) contribute ~55%, medium dust devils (>100–300 m in diameter) ~44%, and large dust devils (>300–1000 m in diameter) ~1% to the total injection of dust by dust devils into the atmosphere. Results for the power law function indicate a contribution of ~23% (<100 m in diameter), ~24% (>100–300 m in diameter), and ~53% (>300–1000 m in diameter), respectively.

**Conclusions:** (1) Active dust devils in the Syria-Claritas region on Mars imaged by two different orbiter cameras with a time delay of ~26 min were identified. Some larger dust devils (>300–1000 m in diameter) in the later acquired image could be correlated to their previous counterparts in the earlier acquired image. Our results imply that larger dust devils have much longer lifetimes than smaller dust devils on Mars as it is the case on Earth. (2) Estimates of the contribution of large dust devils (>300–1000 m in diameter) indicate that they may contribute to ~50% of dust entrainment by dust devils into the atmosphere compared to the dust devils <300 m in diameter given that the size-frequency distribution follows a power-law. If the size-frequency distribution of dust devils follow an exponential function there contribution is insignificant. (3) Observations of large dust devils (>300–1000 m in diameter) on Mars indicate that their occurrence is regionally clustered [13]. Therefore, their contribution to the dust entrainment by dust devils might be regionally limited. In a global context the contribution of medium sized dust devils (>100–300 m in diameter) could be more significant.

**References:** [1] Balme M. and Greeley R. (2006) *Rev. Geophys, 44,* RG3003. [2] Whelley P.L. and Greeley R. (2008) *JGR*, 113, E07002. [3] Carroll J.J. and Ryan J.A. (1970) JGR, 75, 5179-5184. [4] Snow J.T. and McClelland T.M. (1990) JGR, 95, 13707-13721. [5] Idso S.B. (1974) Am. Sci. 62, 530–541. [6] Sinclair P.C. (1969) J. Appl. Meteorol., 8, 32–45. [7] Flower W.D. (1936) London Meteorol. Off. Prof. Notes 5, 1–16. [8] Ives R.L. (1947) Bull. Am. Meteorol. Soc. 28, 168–174. [9] Williams N.R. (1948) Bull. Am. Meteorol. Soc. 29, 106–117. [10] Stanzel C. et al. (2008) Icarus, 197, 39-51. [11] Greeley R. et al. (2006) JGR, 111, E12S09. [12] Reiss D. et al. (2011) Icarus, 215, 358-369. [13] Cantor B.A. et al. (2006) JGR, 111, E12002. [14] Greeley R. et al. (2010) JGR, 115, E00F02. [15] Kurgansky M.V. (2006) Izvestiya Atmos. Oceanic Phys., 42, 319–325. [16] Pathare A.V. (2010) Icarus, 209, 851–853. [17] Lorenz R.D. (2009) Icarus 203, 683–684. [18] Neakrase L.D.V. and Greeley R. (2010) Icarus, 206, 306-318.