DUST DEVIL HORIZONTAL VELOCITIES AND DIRECTIONS OF MOTION ON MARS DERIVED FROM CRISM AND CTX/HIRISE OBSERVATIONS. D. Reiss[1], A. Spiga[2] and G. Erkeling[1], [1]Institut für Planetologie, Westfälische Wilhelms-Universität, Münster, Germany, [2]Laboratoire de Météorologie Dynamique, Université Pierre et Marie Curie, Paris, France.

Introduction: Early field observations suggested that dust devils travel across the surface with horizontal velocities and in directions which, to first order, correspond to ambient wind fields (e.g., 1-3). The more recent and detailed field measurements of [4] showed that dust devil ground velocity is in agreement with boundary layer winds a few tens of meters above the surface, and that dust devil direction closely matches ambient wind directions. These results suggest that the horizontal motion of terrestrial dust devils can be used as a proxy for ambient wind speeds and directions a few tens of meters above the surface [4]. As pointed out by those authors, there should be no physical reason why this relationship would differ on Mars. Preliminary tests using a few measurements indicated indeed a broad agreement between dust devil horizontal velocities [5] and directions of motion [6] with ambient wind speeds and directions predicted at the height of the measured dust devils through Global Climate Models [GCMs].

Here, we introduce a new technique to derive horizontal speeds and directions of motion for martian dust devils using image data from the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) [7] together with time delayed surface observations by the CTX and/or HiRISE. This is the first time this combination of instruments on board MRO is used to retrieve the characteristics of dust devils. We compare our dust devil horizontal speed and direction of motion to the monthly climatologies released in the Mars Climate Database (MCD) [8,9] derived from General Circulation Model (GCM) predictions.

Method: While the CTX and HiRISE (red channel) instruments image the same spot on the martian surface at nearly identical times, CRISM uses a specific imaging technique which results in larger time offsets to the other imaging instruments onboard MRO. The CRISM instrument uses an active pointing device, a gimbaled sensor system enabling that a target can be tracked with long exposure time. During an observation the center of a surface target is imaged in forward looking, nadir, and backward looking angles in flight direction commanded by the Gimbal Motor Electronics (GME) unit (for further details see [7]). This imaging technique results in positive and negative time offsets (± 1 minute) from the center of the surface target to the simultaneously in flight direction scanning HiRISE and CTX instruments. We calculated the exact acquisition time of the center of dust devils in CRISM raw images using the start and stop time of the image acquisition in combination with the image line position of the dust devil center. For each CRISM image line the exact spacecraft clock time is recorded in tabular files, hence the time elapsed after the image start time can be calculated. Imaging times of the equivalent dust devils in CTX or HiRISE images were read out in the ISIS image viewer QView after ISIS3 processing. We did a systematic dust devil survey based on all available CRISM center targeted (FRT, HRS, and HRL) VNIR browse images available at PDS Geoscience Node released until 01 October 2012.

Results: In total, 47 dust devils were identified in 26 CRISM images which have counterparts in CTX and/or HiRISE. For 44 of the dust devils we were able to measure their horizontal speeds. Figure 1 shows one example from Gusev crater. Horizontal speeds of dust devils range between ~4 to ~25 ms^{-1} with an average speed of ~12 ms^{-1}. For more than two-third (73%) of the dust devils the horizontal speed was less than 15 ms^{-1}. Measured horizontal speeds are in good agreement with previous measurements on Mars derived from HRSC data [6,10].

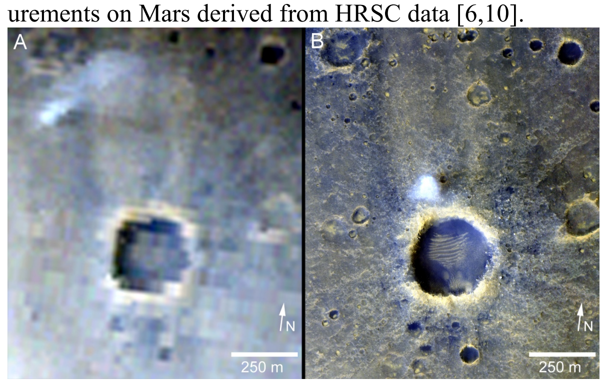

Figure 1. Example of a coordinated CRISM and HiRISE observations at Gusev crater. (A) CRISM image FRT0001D8DC_07_IF124S with a ~50 m in diameter dust devil. (B) The same dust devil as observed in A imaged by HiRISE (ESP_021925_1650) ~34.2 s later. The dust devil moved ~415 m between the CRISM and HiRISE observation indicating a horizontal speed of ~12.1 ± 1.6 ms^{-1}. The dust devil moved in southeast direction.

We compared our measured dust devil horizontal velocities and directions of motion to the monthly climatologies released in the MCD derived from GCM predictions. In general, the dust devil horizontal velocities and directions of motion are in good agreement with the predicted MCD horizontal wind speeds at the top of the dust devil heights (Fig. 2) and MCD horizontal wind orientations (Fig. 3). However, some dust devil horizontal velocities (id 28-30, and 32 in Fig. 3) and directions of motion (id 28-30 in Fig. 4) show a large offset to the MCD wind speed and wind orientation predictions at times the dust devils occurred. Fortunately, these dust devils occurred near the

Phoenix landing site (id 28-30) and at Gusev crater (id 32) which allows us to compare the offsets with lander/rover observations.

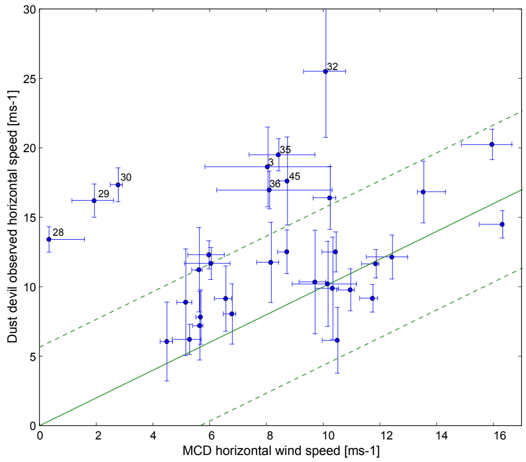

Figure 2. Dust devil horizontal velocities versus MCD horizontal speeds at the top of the dust devil heights.

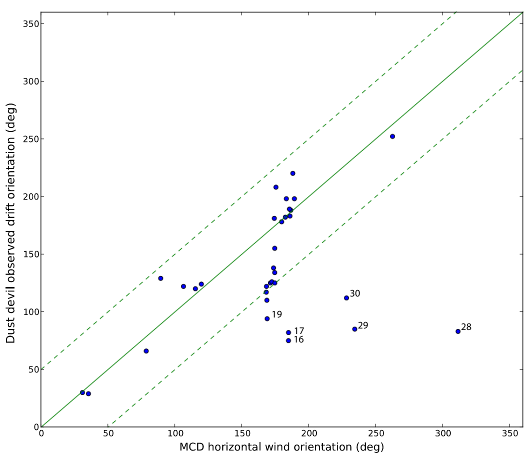

Figure 3. Dust devil directions of motion versus MCD horizontal wind orientations.

Gusev crater: The horizontal velocity of dust devil 32 is with ~25.5 ± 4.7 ms^{-1} much higher than the predicted ambient wind speed with ~10 ± 1 ms^{-1} although the direction of motion is in very good agreement with the predicted MCD wind orientation. A large dataset of dust devil horizontal velocities was derived from MER-A (Spirit) image sequences at Gusev crater [11]. The horizontal velocities range between ~0.1 and ~27 ms^{-1} (n=498), but the median speeds around 2 ms^{-1} are relatively low [11]. Although, most of the horizontal velocities measured by [11] are much lower, it shows that our dust devil horizontal velocity is not out of range. Interestingly, another dust devil in Gusev crater was observed (Fig. 1) which shows a horizontal velocity of ~12.1 ± 1.6 ms^{-1} and a direction of motion toward southeast, both in very good agreement with the MCD model predictions.

Phoenix landing site: Three active dust devils were observed about 2.5 km north of the Phoenix landing site. At the observation time of CRISM/CTX on 2008-10-16 the Phoenix lander was still active which allows us to compare our results with lander observations. The three dust devils observed by CRISM and CTX occurred at L_S = 142.83° and moved with a horizontal velocity of ~15 ms^{-1} in eastward direction. This is in contradiction to the MCD predictions with a horizontal wind speed of ~2 ms^{-1} and a wind orientation to the west. However our results are consistent with the landing site observations at the time of the dust devil occurrence. Wind measurements at the landing site show relatively high wind speeds in eastward direction [12]. Based on mapping of dust devil tracks and wind streaks from orbital datasets, [12] found a predominant wind direction of WNW or ESE and suggested that dust devils move more likely in eastward direction due to the wind direction measurements after L_S = 120°. In addition, [13] surveyed the Surface Stereo Imager (SSI) dataset mounted on the Phoenix lander for active dust devil passages. A total of 76 active dust devils were detected during L_S = 125° - 142° [13]. Although it was difficult to determine the exact travelling direction of these dust devils due to the lack of clear landmarks the most likely direction of motion was suggested to be toward the east [13]. Our measurements show that all three dust devils move toward the east supporting the suggested travel directions of [12] and [13]. Orbital data show evidence for passing of weather systems consisting of condensate clouds over the Phoenix landing site after L_S = 111° [12-14] suggesting that regional weather phenomena are responsible for our offsets between dust devil observations and predicted model results.

Conclusions: Our results show that dust devils on Mars move with ambient wind fields confirming previous studies on Mars [5,6] and Earth [4]. They also indicate that dust devils on Mars move with a horizontal speed which equals boundary layer wind speeds, hence faster than near surface winds in agreement with terrestrial results [4]. We introduced new method for measuring horizontal speeds and directions of motion of larger scale active features on Mars (e.g., dust devils, dust storms). The combination of this method with simultaneous measurements like dust devil tangential velocity derivations from HiRISE color images [15] and/or current landing site dust devil observations in Gale crater would lead to a much better understanding of dust devil processes on Mars.

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