MARTIAN DUST DEVILS OBSERVED SIMULTANEOUSLY BY IMAGING AND BY METEOROLOGICAL MEASUREMENTS. H. Kahanpää[1,2], M. T. Lemmon[3], D. Reiss[4], J. Raack[4,5], E. Mason[3] and M. Battalio[3], [1]Finnish Meteorological Institute, P.O. BOX 503, FI-00101, Helsinki, Finland, henrik.kahanpaa@fmi.fi, [2]Aalto University / School of Electrical Engineering, Espoo, Finland, [3]Texas A&M University / Department of Atmospheric Sciences, College Station, Texas, USA, [4]Westfälische Wilhelms-Universität / Institut für Planetologie, Münster, Germany, [5]The Open University / School of Physical Science, Milton Keynes, UK.

Abstract: The Mars Science Laboratory rover (MSL) has observed dust devils simultaneously by imaging and by meteorological measurements. We use this data to determine meteorological properties of these Martian dust devils, such as tangential wind velocities at the edge of the optically detected vortex core. Preliminary data of this survey was presented in the European Planetary Science Congress 2017 [1]. The first numerical results will be shown in this presentation.

Introduction: Dust devils on Mars were first detected in images taken by the Viking orbiters [2]. Since then dust devils have been imaged by several Mars orbiters and landers (reviews of these observations are given in [3] and [4]). In addition, Mars landers with meteorological instrumentation have detected abrupt changes in wind direction and transient pressure dips interpreted as being caused by passing convective vortices [5][6][7][8][9][10][11][12]. However, the connection between the vortices detected in the wind and pressure data and the optically detected dust devils has remained unclear. For example, it has not been known if the vortices detected by meteorological means lifted dust or not. As a consequence, the meteorological properties of Martian dust lifting vortices have been poorly constrained. The reason for this is that dust devils have so-far not been observed simultaneously by both imaging and by meteorological measurements on Mars.

Methods:

Instrumentation. The MSL rover Curiosity [13] carries a suite of environmental sensors called REMS (Rover Environmental Monitoring Station) [14]. REMS includes sensors for measuring atmospheric pressure, wind speed and direction, air temperature, ground temperature, relative humidity and UV radiation flux. Nominally REMS performs 5-minute long measurement sessions with 1 Hz sampling rate, starting on every Martian hour. Furthermore, one hour long "extended measurement sessions" are performed by REMS at varying times of the sol. The image sequences used in this study were photographed by MSLs Navigation Cameras (Navcam) [15].

Measurement strategy. A campaign of imaging Dust Devil Search Movies was initiated soon after Curiosity landed in Gale crater on August 6, 2012 [16]. These movies consisted of 4 to 24 frames pointed towards North. 249 such movies had been taken up till sol 1520 (14th November 2016) but only two dust devil had been detected in them [16][17]. However, a dust devil was identified in South/South-West direction in a multispectral sequence taken by Curiosity's Mast Camera (Mastcam) on sol 1520 [17]. Since then Navcam dust devil surveys have been performed in all directions. In these surveys two images are taken in each direction to identify moving features. It soon appeared that dust devils could be seen in abundance in directions ranging from South-West through East to North-East, i.e. in the foothills of Aeolis Mons, the central mountain of Gale crater [17]. Circa 28 minute long "dust devil movies" have been taken by Navcam in these directions. Each movie consist of 30 images grouped into 15 "pairs". Images belonging to the same pair are separated by circa 25 seconds while the interval between two pairs is circa 118 s. REMS extended measurement sessions have been scheduled to cover these movies whenever possible.

Data processing. We examine the "long dust devil movies" with simultaneous REMS coverage to find dust devils that pass by MSL concurrently with abrupt drops in the atmospheric pressure recorded by REMS. Then we determine the distances of closest encounters and translation velocities of these dust devils using the images. These parameters are further used together with the measured pressure curve to calculate the pressure depression at the optically detected edge of each dust devil. The tangential wind velocity at this core edge, were dust is probably lifted, is calculated using the first-order postulate that dust devils are in cyclostrophic balance [18]. The data processing methods are validated using reference data measured on our own planet [19][20][21].

Results: 25 "long dust devil movies" with simultaneous REMS coverage were imaged by Navcam between sol 1588 (23th January 2017) and sol 1758 (17th July 2017). 15 dust devils that passed by MSL concurrently with pressure drops were identified in these image sequences. An example of these observations is

shown in Figures 1 and 2. The meteorological properties of these dust devils will be discussed in the presentation.

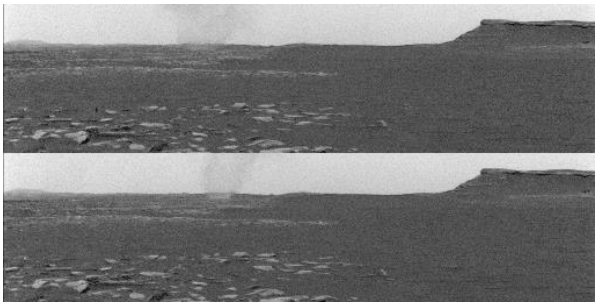

Figure 1: Navcam images showing a dust devil on sol 1633. The lower image was taken 26 s after the upper. (Images originally published in [1])

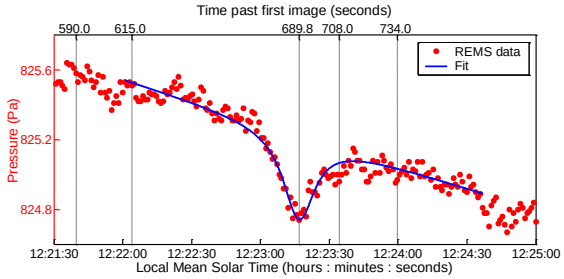

Figure 2: REMS pressure data measured when the dust devil shown in Figure 1 passed by MSL. (Originally published in [1])

Summary and Conclusions: Our observations prove that the "transient daytime pressure drops" detected by Mars landers can be caused by dust devils, as has been postulated since these phenomena were first detected by Mars Pathfinder [7][8]. This is also the first study where tangential wind velocities of optically observed Martian dust devils are determined using in situ data. The results will be used to constrain the threshold wind velocity required for dust lifting in a Martian convective vortex. Knowledge on this threshold value helps in parametrizing the amount of dust lifted by dust devils in numerical models of the Martian atmosphere.

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