

**MARTIAN DUST DEVILS OBSERVED BY MARS COLOUR CAMERA ONBOARD MARS ORBITER MISSION.** Ramdayal Singh and A. S. Arya, Space Applications Center, Indian Space Research Organisation, Ahmedabad – 380 015, India. (ram@sac.isro.gov.in)

**Introduction:** Dust devils on Mars are whirlwinds resulting from sunlight, warming the ground, causing convective rising of air. Observations of these dust devils over the Martian environment provide significant information about wind directions and interaction between the surface and atmosphere. Martian dust devils typically a kilometre in diameter and altitude of 10 kilometres. Dust devils on Mars were first detected in images taken by the Viking orbiters [1]. On Mars, dust devils are frequently observed with orbital image data [1, 2, 3, 4, 5, and 6]. Dust devils are important boundary layer processes for energy transport and their contribution to the atmosphere's dust load [7, 8].

The Mars Science Laboratory rover (MSL) has also observed dust devils simultaneously by imaging and by meteorological measurements. Dust devil processes represent the drops in transient daytime pressure [9]. Knowledge of the threshold transient wind velocity from MSL helps in parametrizing the amount of dust lifted by dust devil in numerical models of the Martian atmosphere.

Understanding dust devils is important for exploration of Mars. Dust related studies are main concern for the current and upcoming Martian missions.

**Mars Colour Camera:** Mars Colour Camera (MCC) developed at Space Applications Centre of ISRO. MCC is operating in the visible range (0.4-0.7 $\mu$ m) and provides the images on the varying resolution depending on the orbital geometry [10]. Form the proposed orbit of 272 km x 72000 km around Mars, the camera is returning high quality visible images of Mars and its environment.

**Data:** Martian dust devils from MCC observed during Solar Longitude of 256.83° at 12:08:56 UTC on 07 November 2016 with 25.52 m resolution at spacecraft altitude of 490.66 km. Figure i shows the MCC observation of Dust Devils which is observed on 7 November 2016. In present work we have used top of atmosphere reflectance (I/F) data shown in Figure ii (A, B) [11], acquired by MCC on 7 November 2016.

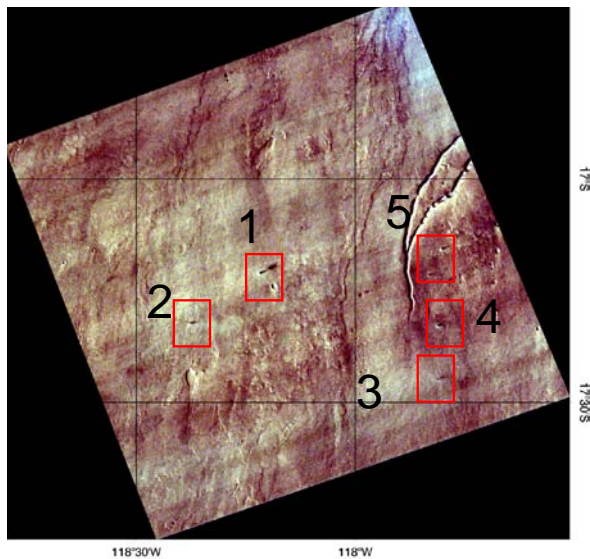
**Theory:** Altitude of dust devil have been estimated using shadow method [12]. Using shadow method and sun-sensor geometry the altitude of dust devils has been observed. The uncertainty is due to off nadir angle of Mars Colour Camera. The information of shadow length, solar zenith angle, satellite zenith angle and estimated dust devil height is tabulated in Table 1. The shadow method works well if the sun is not too high in the sky and with images that have very high spatial resolution [13].



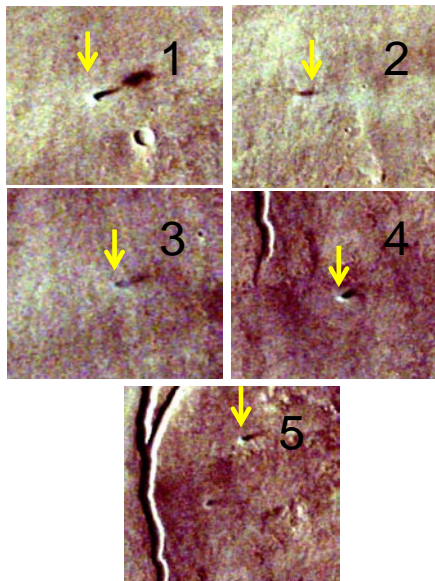
**Figure i:** MCC observation of Dust Devils on 7 November 2016.

**Table 1:** Summary of Dust Devil height computation. Dust Devils are observed on 7 November 2016 MCC Datasets.

Dust Devil No.	Shadow Length SL ~Pixels	Pixel Resolution in image plane (m)	Solar Zenith Angle, SZ (°)	Sensor Zenith Angle, VZ (°)	Approximate Dust Devil Height (km)	Uncertainty (km)	First Order Estimation of Dust Devil Height using Shadow Length (km)
1	90	25.52	40.0	11.5	1.93	~0.24	$1.93 \pm 0.46$
2	50	25.52	39.8	10.8	1.06	~0.23	$1.06 \pm 0.24$
3	43	25.52	40.3	14.8	0.93	~0.31	$0.93 \pm 0.29$
4	34	25.52	40.3	14.4	0.74	~0.30	$0.73 \pm 0.22$
5	20	25.52	40.4	14.0	0.43	~0.29	$0.43 \pm 0.13$



**Figure ii (A) :** A unique swarm of five dust devils detected in single frame of MCC image of 7 November 2016 in the southern hemisphere of Mars during the summer season.



**Figure ii (B):** 1. A large dust devil with S-shaped shadow. 2. A medium sized dust devil with a tilted dust column. 3. A smaller dust devil with shorter shadow & 4, 5: Well developed medium scale dust devils having bright spectacular dust column with an elongated sharp shadow. The dust devil column is strongly tilted to the right which is reflected in the shadow.

**Result and Discussion:** Dust devils are whirlwinds that result from solar warming of the ground, prompting convective air to rise into the atmosphere. The dust devils on Mars are relatively in larger number. Mars Colour Camera (MCC) onboard Mars Orbiter Mission (MOM) captured this spectacular weather phenomenon on 7 November 2016 at 12:08:56 UTC with spatial resolution of ~25 m at a spacecraft altitude of ~490 km in the southern hemisphere of Mars. This is an exclusive observation as five dust devils are captured in a single frame of Mars Colour Camera. The time of MCC imaging corresponds to solar longitude (Ls) of  $256.83^\circ$ , which corresponds to Southern Summer season on Mars. First dust devil (No. 1) is most evident as depicted in the Figure ii (A, B). Altitudes of dust devil have been estimated using Sun sensor geometry and shadow method. The altitude of these dust devils varies from ~0.5 to 1.9 km. The image represented in Figure ii (A, B). is the top of atmosphere reflectance (I/F).

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