Atmospheric Optical Depth estimation over Syrtis Major and Arsia Mons region of Mars using Mars Color Camera on-board Indian Mars Orbiter Mission. Manoj K. Mishra, Prakash Chauhan*, Ramdyal Singh and A. S. Kiran Kumar, Space Applications Centre, Indian Space Research Organization, Ahmedabad – 380015, India (*prakash@sac.isro.gov.in)

Introduction: The atmosphere of Mars is dominated by dust activity leading to considerable atmospheric optical depth (AOD) varaibility, often in the range 0.1-1.0. This happens due to presence of large amount of reddish airborne dust and other aerosols. This optical depth can be estimated from the brightness of shadows with the so called "shadow method". We have used MCC data of Mars Orbiter Mission to estimate AOD at two diffrenet locations on Mars using the algorithm described by Hoekzema et al. 2011 [1]. Mars Color Camera (MCC) has been developed at Space Applications Centre of ISRO. MCC is operating in the visible range (0.4-0.7) and provides the images of Mars in varying resolution depending on the orbital geometry [2]. From the proposed orbit of 272 km x 72000 km around Mars, the camera is returning high quality visible images of Mars and its environments. Currently MCC is providing information on the events like dust storms, dust devils, morphology etc.

Data: In peresent work we have used radiance data over *Syrtis Major Region* (figure 1) and *Arsia Mons Region* (figure 2) aquired by MCC on 27 September 2014 and 27 December 2014, respectively. The solar longitude for the images shown in figure 1 and figure 2 are equal to 203.57 and 260.38, respectively. For each pixel of images, values for elevation, solar incidence, emission, and phase angles are available.

Theory: Shadows obviously contain information about the atmospheric optical depth of the overlying atmosphere. If the optical depth becomes larger, then the brightness difference between a shadowed and a nearby sunlit region becomes smaller. The translation of this difference into an optical depth is what we named the "shadow method". An estimate of optical depth is given as follows

$$AOD_{shad} = -\left(\frac{\mu_0 \mu}{\mu_0 + \mu}\right) \ln\left(\frac{I_{sunlit} - I_{shad}}{I_{sunlit}}\right)$$

μ_0, μ are the cosines of solar and of emission angle. I_{shad} is the average intensity that was measured for the analyzed pixels in shadow and I_{sunlit} is that average for the pixels of the sunlit comparison region.

Results: We present the results of shadow method retrieved from MCC image. These are from regions in and around the Syrtis major and cover altitude range of about 1.5 km. Figure 1, 2 shows examples of shadowed regions in white and the sunlit comparison regions in black. Each region in shadow is paired to a nearby sunlit one. Each pair yields an estimate of the optical depth. All were manually selected. We used MCC image co-registered with MOLA DEM, the analysed pixels in the images correspond to the same location on Mars. The altitude that we assign to analyzed region is the average altitude of sunlit comparison region, not of the shadowed one. We selected shadowed regions with less than a few hundred meters altitude difference with the sunlit comparison regions and it typically is 100 - 200 m. Table 1 shows AOD retrievals for 11 sample regions representd by pair of black (sunlit) and white (shadow) lines in Syrtis Major reion (figure1). The average value of AOD is equal to 0.577, 0.652 and 0.719 for red, green and blue regions, respectively. Table 2 shows AOD retrievals for 6 sample regions representd by pair of black (sunlit) and white (shadow) lines in Arsia Mons region (figure 2). The average value of AOD is equal to 0.181, 0.194 and 0.2 for red, green and blue regions, respectively.

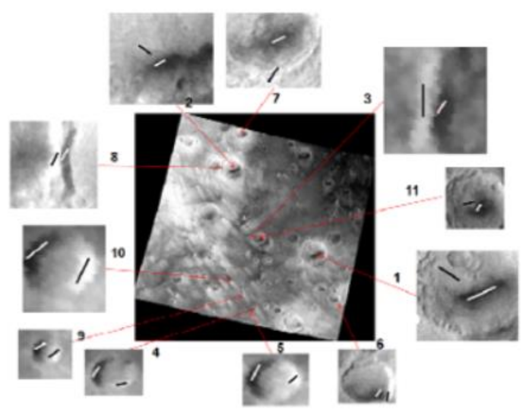

Figure 1. MCC image showing Syrtis major region extended from 113.47 °E to 125.88 °E and 15.11 °S to 26.74 °S. The region shown in image covers area almost equal to 700 X 650 km^2. Image is overlaid with a sample of 11 analyzed regions each represented by a pair of black and white line. Black lines denote analysed sunlit pixels and white ones analyzed pixels in shadow. Each pair is used for a shadow method estimate of optical depth AOD_{shad} .

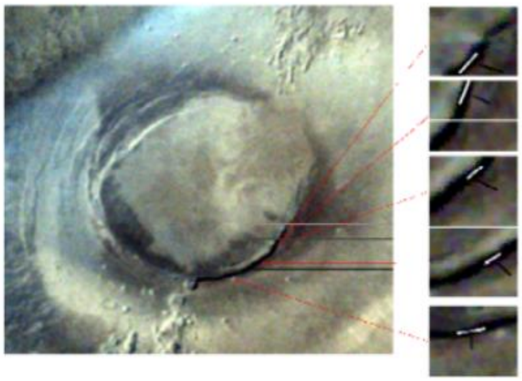

Figure 2. MCC image showing Arsia Mons extended from 112.17 ^{o}W to 118.27 ^{o}W and 7.3 ^{o}S to 11.19 ^{o}S. Image is overlaid with a sample of 6 analyzed regions each represented by a pair of black and white line. Black lines denote analysed sunlit pixels and white ones analysed pixels in shadow. Each pair is used for a shadow method estimate of optical depth AOD_{shad} . The orange colour box encompassing all 6 analyzed regions covers area almost equal to 65 X 50 km^{2}.

The analysis of AOD data for two different regions cleraly beings bout AOD dependence on the altitude of the feature, as in case of Arsia Mons, the AOD values are relatively smaller, when compared to Syrtis major region of Mars.

Table 1: Aerosol optical depth retrievals for 11 sample regions representd by pair of black (sunlit) and white (shadow) lines in figure1. SRN refer to sample region number shown in figure 1.

SRN	Elevation (m)	AOD (Red)	AOD (Green)	AOD (Blue)
1	693	0.630	0.690	0.811
2	744	0.636	0.720	0.796
3	465	0.621	0.677	0.687
4	1666	0.479	0.556	0.607
5	1648	0.479	0.565	0.625
6	1432	0.520	0.609	0.647
7	1233	0.560	0.712	0.894
8	807	0.602	0.624	0.653
9	1600	0.548	0.659	0.702
10	1442	0.536	0.609	0.713
11	218	0.737	0.756	0.770
Average AOD_{shad}		0.577	0.652	0.719

Table 2: Aerosol optical depth retrievals for 6 sample regions representd by pair of black (sunlit) and white (shadow) lines in figure 2. SRN refer to sample region number shown in figure 2.

SRN	Elevation (m)	AOD (Red)	AOD (Green)	AOD (Blue)
1	17208	0.180	0.188	0.198
2	17250	0.172	0.193	0.203
3	17306	0.190	0.192	0.193
4	17451	0.192	0.193	0.196
5	17478	0.169	0.205	0.208
6	17208	0.180	0.188	0.198
Average AOD_{shad}		0.181	0.194	0.200

References:

[1] Hoekzema N. M. et al. (2011) *ICARUS, 214*, 447–461.

[2] Kiran Kumar A.S & Chauhan P, (2014), *Current Science*, 1096-1097