Studying martian dust storms, clouds, and associated meteorology using observations from Indian and foreign satellite missions

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Dust and water ice are the two major constituents in the Martian atmosphere, which significantly affect its climatic system. The dust activities over Mars could be ranging from dust devils, i.e., a few meters across, to dust storms, i.e., thousands of kilometers or more. The occurrence of dust storm events can modulate the global weather and climate by influencing the radiation budget and interacting with the primary circulation. The impact also strongly depends upon its vertical structure. Therefore, in the present study, we analyzed the aerosol profiles and associated atmospheric features during a dust storm event in early Martian southern summer based on the observations from Mars Colour Camera (MCC) onboard the Indian Mars Orbiter Mission (MOM) during October 11 and October 20, 2014 (Figure 1a). The dust storm is found to be a local-scale in nature (area calculated ~ 4.68×10^5 km^2), happened within the north-eastern portion of the Lunae Planum region on October 11, 2014, which is observed to be relatively larger during October 20. Analysis of dust and water ice extinction and temperature profile derived from the observations of Mars Climate Sounder (MCS) onboard Mars Reconnaissance Orbiter (MRO) is carried out before, during and after the dust storm period. Dustiness is found to have increased drastically at the HATDM (High Altitude Tropical Dust Maximum) layer but with a temporal delay of ~2°L_S after the dust storm disappearance (here L_S is the areocentric solar longitude). The delayed variation consequently explained the convective boundary layer growth during the dust storm scenario and is also exclusively reflected in the increased heating rate at different levels of the atmosphere. The vertical mixing time scale of dust is also found to be effective in a global dust storm scenario, which indicated a similar mechanism irrespective of the spatial extension (regional or global) of a dust storm. On the other hand, the clouds play an important role in controlling the water vapor profile; consequently, they influence transport and exchange of water with ground reservoirs and could be used to track the water vapor transport over a synoptic-scale. Again, the clouds are mostly present in the middle atmosphere, where they can interact with the dustiness. The dust and water ice are linked mechanistically by the ability of dust particles to nucleate water ice clouds, or it may modulate the air temperature by heating/cooling of itself, which consequently impacts the clouds present in the atmosphere. Therefore, we aimed to investigate the clouds over the entire tropical and subtropical latitudes over Mars. The thick clouds appear as a belt over the tropical latitude and are popularly known as Aphelion Cloud Belt (ACB), due to its appearance in the aphelion season (L_S = 0 –180°). Analysis of water ice column opacity suggests its spatial extension of nearly -20 –40°N during L_S ~ 45 –135°, wherein the three phases of ACB are identified. The cloud belt shows a northerly movement within the three phases of it, where an influence of upper-tropospheric dustiness is evident. Further, the tropical clouds are primarily dominated by the orographic clouds over the highly elevated terrains or volcanos, e.g., Olympus Mons and Arsia Mons (Figure 1b). The cloud appearance over these volcanos are found to be strongly controlled by the air temperature during the aphelion period and is more influenced by the elevated dustiness and by the circulation pattern during the perihelion period.

Keywords: dust storms, clouds, Lunae Planum, Aphelion Cloud Belt , Arsia Mons , Olympus Mons

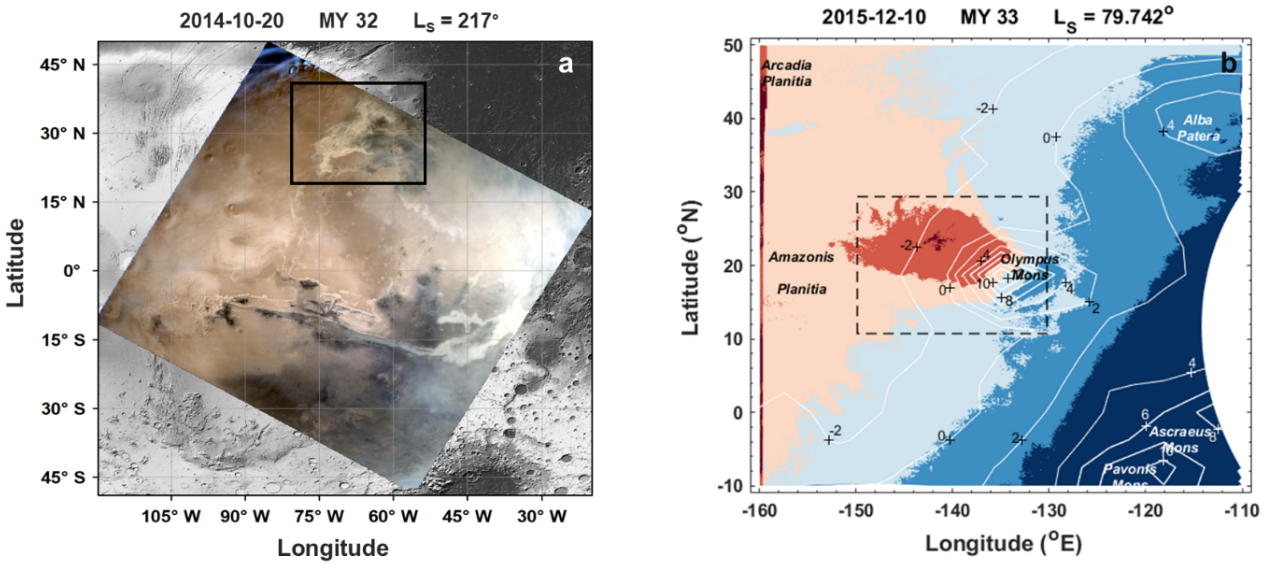

Figure 1. MOM/MCC images: (a) of visible band on October 20, 2014, i.e., Ls ~ 217°, MY 32 showing a small-scale dust storm event within the far north of the Lunae Planum region (marked by solid rectangle), (b) of blue band on December 12, 2015, i.e., Ls ~ 79°, MY 33 showing water ice clouds observed over the western sides of calderas of Olympus Mons and nearby region (marked by dashed rectangle).