RAPID DUST STORM EXPANSION WITHIN THE ACIDALIA CORRIDOR, MARS, DURING THE INITIAL GROWTH PHASE OF THE PLANET-ENCIRCLING DUST EVENT OF 2018. J. H. Shirley[1] , A. Kleinböhl[1], D. M. Kass[1], N. G. Heavens[2], J. T. Schofield[3], D. T. McCleese[4], L. J. Steele[1], S. Piqueux[1], and the MRO-MCS Science Team. [1]JPL-California Institute of Technology, 4800 Oak Grove Dr., Pasadena CA 91109 USA. [2]Space Science Institute, Boulder, CO USA. [3]Retired, Pasadena, CA, USA, [4]Synoptic Sciences, Pasadena, CA, USA. (James.H.Shirley@jpl.nasa.gov)

Introduction: Local and regional-scale dust storms occur every year on Mars. Occasionally, such storms grow and coalesce, to become global in scale. The mechanisms responsible for dust storm growth beyond the regional scale are not well understood. The periods of transition, from regional to planet-encircling scale, are thus a focus of intense scientific interest. Rapid expansion of a regional dust storm occurred between ~1 June and 9 June 2018 (L_s 186.2°–189.8°). This storm initiated a planet-encircling dust event that lasted for several months thereafter. The triggering regional dust storm began within the previously-recognized 'Acidalia storm track' [1, 2] on Mars (Fig. 1).

For this study, we employ dayside MRO-MCS vertical profiles of atmospheric dust extinction to illustrate and describe the evolution in space and time of this first strong dust lofting episode of the global storm. The MCS instrument is uniquely suited to this task, as it resolves aerosols and temperatures in the lower and middle atmosphere (to altitudes > 80 km) with 5 km vertical resolution.

Mars Climate Sounder (MCS) Observations: MCS is an infrared 9 channel limb staring radiometer [3]. The retrieval algorithm produces vertical profiles of temperature, dust, and water ice extinction versus pressure [4]. MCS rides on the Mars Reconnaissance Orbiter (MRO) spacecraft, in a near-polar sun-synchronous orbit with a local mean solar time of 3 AM/PM at the equator.

Figure 1 illustrates the trajectories of the five dayside orbital ground tracks over the 'Acidalia Corridor' study area that comprise the data analyzed. The data available clearly and unambiguously reveal the evolution of the triggering storm, in latitude, in altitude, and in time (Fig. 2).

Evolution of the Storm: Below we describe salient features of the atmospheric dust distribution for each day observed. We begin with a description of pre-storm conditions as recorded on 29 May 2018. Figure 2 illustrates cross-sections of atmospheric dust extinction for 29 May and for the additional dates and orbit tracks indicated in Fig. 1.

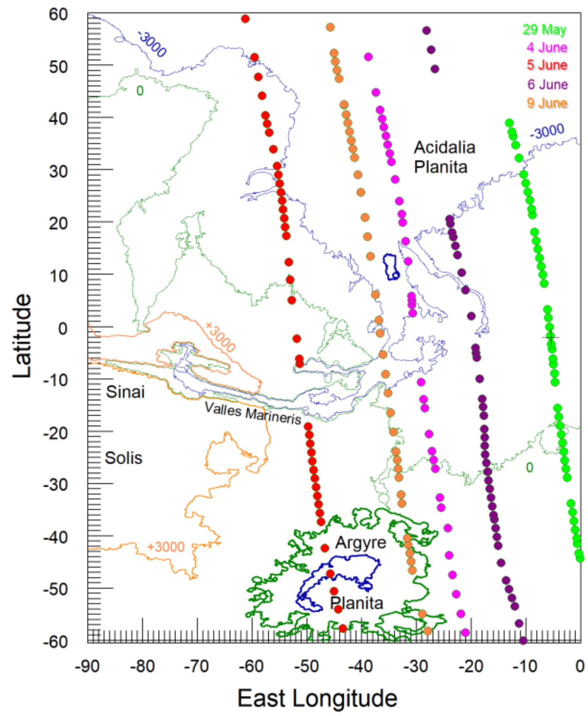

Figure 1. The 'Acidalia Corridor' study area. The locations of MCS retrievals of atmospheric temperatures and aerosol opacities are shown by color-coded dots corresponding to the dates provided in the legend. Simplified topographic contours at 3000 m intervals are provided for reference.

Pre-storm conditions. The dust distribution on 29 May (Fig. 2, top) is representative of typical conditions at this season on Mars. A relatively symmetric 'bulge' of dust lies over the equatorial latitudes. This is the zone of convergence and upwelling of the twin equinoctial 'Hadley Cell' meridional circulation cells that are normally present at this season. Dust present in the lower atmosphere may be carried aloft by this circulation. The peak altitude of the dust attained on 29 May is a little under 40 km. For reference, peak altitudes of dust resolved in MCS observations during past regional-scale dust storms rarely exceed ~45 km in altitude.

June 4, 2018. A significant vertical expansion of the equatorial dust 'bulge' of May 29 is evident in the dust extinction cross-section for this date, rising to >50 km altitudes in a range of latitudes north of the equator. (Gaps at lower altitudes near the equator in this figure are indicative of very high atmospheric dust opacities, which may prevent accurate retrievals of dust extinctions from lower altitudes). Dust rising higher than ~40 km in altitude is observed only within and above the Acidalia Corridor on this date.

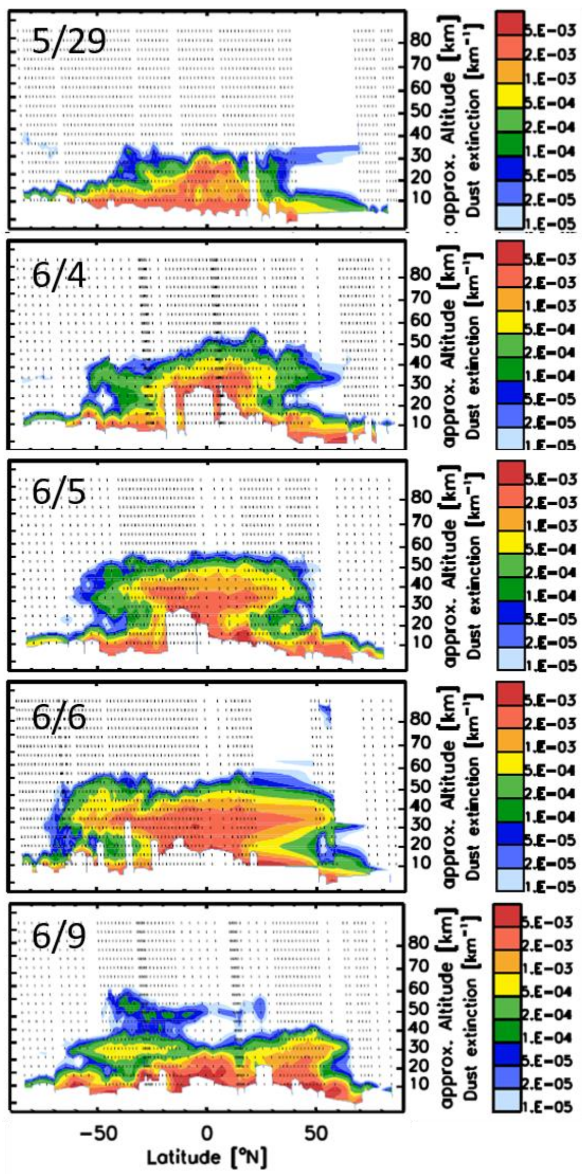

Figure 2. Cross-sections illustrating MCS atmospheric dust extinction (km^{-1}) for the orbital trajectories of Fig. 1 on the indicated dates in 2018. Black marks indicate the locations of retrieved profiles.

June 5, 2018. A well-defined anvil-shaped dust distribution has developed by this date. Dust with extinction $\geq 1x10^{-4}$ extends from ~50° S to >50° N. Upwelling of dust at the equator, followed by latitudinal spreading at altitude in both north and south, is strongly indicated.

June 6, 2018. A significant further expansion in latitude of the main dust feature has occurred by this date. The dust clouds now extend more than 120° in latitude. Dust is present at altitudes of nearly 60 km nearly everywhere above the Acidalia Corridor. A significant expansion of the high altitude dust in longitude (not shown) has begun by this date. The spreading is likely due to strong tropical jet stream winds.

June 9, 2018. The anvil-shaped dust feature has begun to collapse. Peak altitudes have fallen back to ~40 km over much of the northern portion of the study area. Even so, by 9 June, an extended, 50-km altitude dust haze attributable to this storm (not shown) has fully encircled the planet. (The global storm did not officially attain planet-encircling status until 8 days later, on 17 June (L_s=194.9)).

Discussion: 'Intensification' of atmospheric Hadley cell circulations at Mars has often been proposed as a key factor contributing to the growth beyond the regional scale of planet-encircling dust storms [5-8]. The existence of this circulation, in a globally averaged sense, is widely recognized, but disagreements exist regarding the symmetry and scale of the flows. Few direct observations of the precise locations, scale, timing, and evolution of Hadley cell flows have been reported. MCS retrievals of atmospheric dust extinction, when used as a 'tracer' for meridional flows, may be able to address some of the open questions in this area.

The cross-sections of Fig. 2 document the evolution of a regional dust event and the subsequent transport of the dust. The morphology observed is consistent with the occurrence of a brief episode of intensification of meridional flow cells that was highly localized in longitude. The confinement in longitude of this episode likely resulted from the strong topographic relief of the Acidalia Corridor as illustrated in Fig. 1.

References: [1] Cantor, B. A. et al., (2014), 8th Intl. Conf. on Mars, Abs. #1316. [2] Wang, H. & M. Richardson (2015), Icarus 251, 112. [3] McCleese, D. et al. (2007), JGR 112, E002790. [4] Kleinböhl, A., et al. (2009), JGR 114, E10006. [5] Haberle, R. (1986), Science 234, 459. [6] Murphy, J. et al. (1995), JGR 100, 26,357. [7] Wilson, J. et al. (2008), Mars Atmos. Modeling and Obs. Conf., Abs. # 9023. [8] Shirley, J. (2017), Plan. Sp. Sci. 141, 1.

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