MARTIAN DUST PARTICLE SIZE DURING THE 2018 PLANET-ENCIRCLING DUST STORM AS MEASURED BY THE CURIOSITY ROVER.

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Introduction: The Mars Science Laboratory (MSL) Curiosity rover conducted a dedicated science campaign to study the 2018 Mars planet-encircling (or "global") dust storm [1]. The campaign involved ~100 martian sols of an increased cadence in meteorological observations lasting from early June (L_s ~ 188°) through mid-September (L_s ~ 248°). Due to the Curiosity rover's radioisotope thermoelectric generator power source, science operations were not precluded by the reduced sunlight during the storm. One of the focuses of the science campaign was to retrieve dust particle properties to understand dust-lifting properties in global dust storms and dust properties more generally. General results from Curiosity's dust storm science campaign are detailed in [1].

Several previous works have discussed retrievals of dust particle effective radii from Curiosity observations. [2] shows the seasonal cycle as viewed from ChemCam passive sky observations and finds a seasonally-varying cycle in dust particle effective radius from ~0.5-2 μm, with a clear link to opacity (i.e., higher dust optical depth is associated with large dust particle effective radius). [3] shows comparable dust particle effective radius (~0.5-2 μm) over the seasonal cycle retrieved by the upward-looking Rover Environmental Monitoring System (REMS) ultraviolet (UV) photodiode sensors.

Methodology: We employ four independent observations with three of the rover's instruments to derive dust particle effective radius during the dust storm.

The first observation is the "tau" observation with the Mast Camera (Mastcam). This observation has been used on Curiosity and previous landed missions to derive column-integrated aerosol opacity using direct solar images by the rover's cameras [1,4]. The tau observation sequence includes images with the two solar filters on Mastcam at 440 and 880 nm. The spectral slope of opacity between these two filters is dependent on the dust particle effective radii. Mastcam tau observations were conducted nearly every sol of the dust storm science campaign, including multiple measurements on several sols.

The second observation also utilizes Mastcam and is termed a "sky survey". A Mastcam sky survey involves multi-wavelength near-Sun imaging and a series of images at increasing azimuthal angles in the anti-Sun direction to complete as much of the scattering phase function as possible. The scattering phase function of dust is dependent on the dust particle effective radius. The atmospheric opacity is measured concurrently during the sequence. Mastcam images are radiometrically calibrated before analysis [5]. Seven Mastcam sky surveys were conducted during the dust storm campaign, with an eighth just before the campaign (when the storm was active elsewhere on the planet). Data from Sol 2097 was not used due to the extremely high opacity (~8) and resulting poor retrieval fit.

As described by [2], ChemCam passive sky observations can retrieve dust particle effective radii. Six ChemCam passive sky observations were taken during the dust storm, with a seventh taken just prior.

Lastly, measurements performed by the REMS UV sensor can also be used to retrieve dust aerosol particle size. In particular, the dust effective radius can be estimated by analyzing REMS UV measurements conducted when the Sun is temporarily blocked by the masthead or the mast of the rover [3]. Furthermore, REMS UV measurements have been used to study the amount of dust deposited on the sensor, quantified by means of a Dust Correction Factor (DCF) [6]. During the global dust storm, the ratio of the DCF from different channels changed, indicating a change in dust particle size (Figure 1).

Results: All four observations provide cross-validation to our retrieved dust particle sizes. REMS UV retrievals show that dust particle effective radii was > 2 μm, but does not have sufficient sensitivity to discriminate larger particle sizes. The two Mastcam observations and the ChemCam observation show that the largest dust particle sizes ever seen on Mars occurred during the storm. Mastcam and ChemCam show that dust particles were > 4 μm and may have exceeded 5 μm during the height of the storm (Figure 2). Dust particle size was closely tied to dust opacity during the storm, with pre-storm values near climatologically-typical values of 1-1.5 μm near L_s ~ 180° [2,3] before rapidly increasing in-step with opacity to 4 μm or greater. As the storm progressed, mean dust particle size declined and returned to more seasonal values of ~2 µm near Sol 2140 (L_s ~ 230°).

No direct dust lifting was seen by Curiosity within Gale Crater during the storm [1], implying that these extremely large particles (by martian standards) were advected from dust-lifting regions outside of Gale. [7] suggests that dust was advected into Gale from the west and southwest from Hesperia Planum and Tyrrhena Terra, both hundreds to thousands of kilometers away. [8] shows that 4-5 µm radius particles sediment out of the atmosphere at velocities of 1-10 km/sol, depending on altitude, implying rapid transport and strong upward motion was present to advect such large dust particles.

References:

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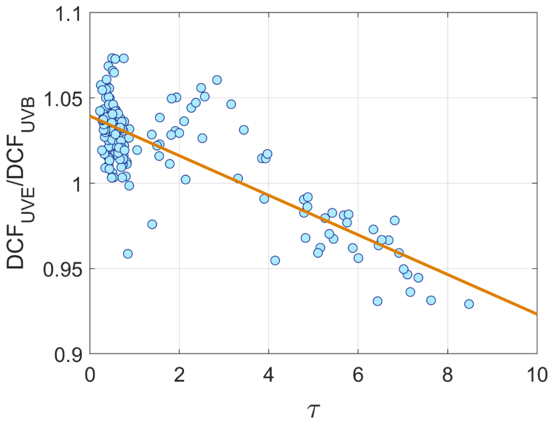

Figure 1. Ratio between UVE and UVB channels (UVB measures at shorter wavelengths [9]) DCF as a function of atmospheric opacity during MY 34. The change of this ratio with opacity suggest that there is a change in dust particle size.

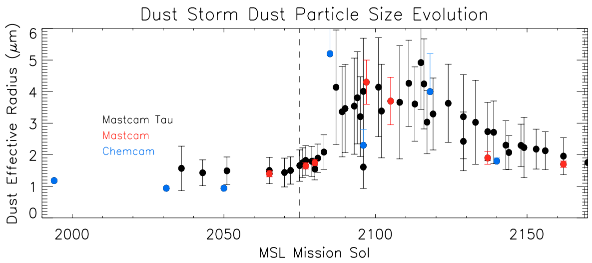

Figure 2. Retrieved dust particle effective radii from Mastcam tau observations (black), Mastcam sky surveys (red), and ChemCam passive sky observations (blue). Dashed vertical line indicates the start of the MSL dust storm campaign.