ACCUMULATION AND REMOVAL OF DUST ON CURIOSITY'S MARS HAND LENS IMAGER (MAHLI) CALIBRATION TARGET ASSOCIATED WITH THE PLANET-ENCIRCLING DUST EVENT OF 2018.
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Introduction: In June and July of 2018, a planet-encircling dust event enveloped Mars. The event fully reached Gale crater and Curiosity on Sol 2083 (16 June 2018). The rover continued to operate, and its instruments recorded many of the effects of the storm, including increased atmospheric opacity, warmer temperatures, and less extreme diurnal temperature swings [1]. Documented by the imagers on the rover were mobilization of surface fines, including sand-sized particles. The Mars Hand Lens Imager (MAHLI) was deployed and acquiring data on Sol 2083 as the storm conditions reached Gale crater. On this occasion and for several months thereafter, MAHLI recorded both sand grain motion between the acquisition of stereo images, and dust accumulation on various pieces of hardware. These *in situ* measurements provide a unique opportunity to study dust accumulation and removal. Here we report on dust accumulation patterns on the MAHLI calibration target, to better understand characteristics and properties of dust mobility and settling on a vertical target before, during and after a significant martian dust event.

Instrument: MAHLI is a 2-megapixel color camera with a macro lens that can focus on targets at working distances from 2.1 cm to infinity [2]. MAHLI was designed to provide data regarding the stratigraphy, grain-scale texture, structure, and morphology of geologic targets. With a best resolution of 14–18 µm pixel, in practice MAHLI can resolve individual grains down to very fine sand [3], discriminating them from unresolvable coarse silt-sized or smaller grains (silt grain sizes as defined by [4], <=62.5 µm diameter). Relevant to this work, MAHLI images resolve aggregates and clods of dust grains, as well as sand grains that have moved along the surface [5].

Approach: Many studies have assessed dust settling from the atmosphere (e.g., [6-8]). In this case, we chose to examine the MAHLI calibration target, a target that was affixed vertically to the housing of the rover's robotic arm shoulder azimuth actuator lower to the ground than the rover deck. Near-vertical mounting worked well for preventing dust accumulation on the Viking lander camera calibration targets [9] and, other than during the 2018 dust storm, has also worked well for MAHLI. The calibraton target is designed specifically to reveal differences in camera response, so the behavior of the color swatches (the same as those for the MER Pancams and MSL Mastcams [2]) and black/white fiducial markings under standard illumination is well-known and photometrically characterized. This yields a well-modeled background against which dust accumulation can be measured.

An unavoidable limitation of this approach is that only a snapshot of target dustiness is obtained on a given sol, and there are no data for many intervening sols that typically pass before the calibration target is reimaged. Thus, results are limited to those sols for which the team was able to schedule the necessary arm activities required for imaging the calibration target, yielding a limited record of the dynamic process of dust accumulation and removal.

Methodology: We utilized two different methods to estimate dust cover. Firstly, we determined dust cover by converting each image to 8-bit greyscale, determined the reflectance of areas with no dust cover, and compared areas of cover with areas of no cover. Secondly, and as a check on this method, we manually counted the pixels covered by visible dust aggregates on black areas of the calibration target; this manual method yielded a coverage estimate within 5% of the other method.

Results: To date, our efforts have concentrated on calibration target images acquired at the beginning of the dust storm (sol 2082), at the point where atmospheric opacity had returned to pre-dust storm levels (sol 2161) and a few months after the dust storm had ended (sol 2248). Figure 1 shows a portion of the calibration target imaged on these three sols.

The calibration target was imaged on sol 2082, just as the dust storm had begun to redden the atmosphere (resulting in the redder cast to the image in Figure 1, top). At the time the image was acquired, dust aggregates covered an estimated 4% of the target. By comparison, on sol 2161, immediately after the storm, at the time the image was acquired the target was covered 43% by dust aggregates resolvable by MAHLI (Figure 1 middle). By sol 2248, the vast majority of the dust was gone; < 1% of the target was covered (Figure 1 bottom).

Discussion: What was the primary mechanism responsible for cleaning dust off the target? One hypothesis is that the cleaning agent is the impingement of

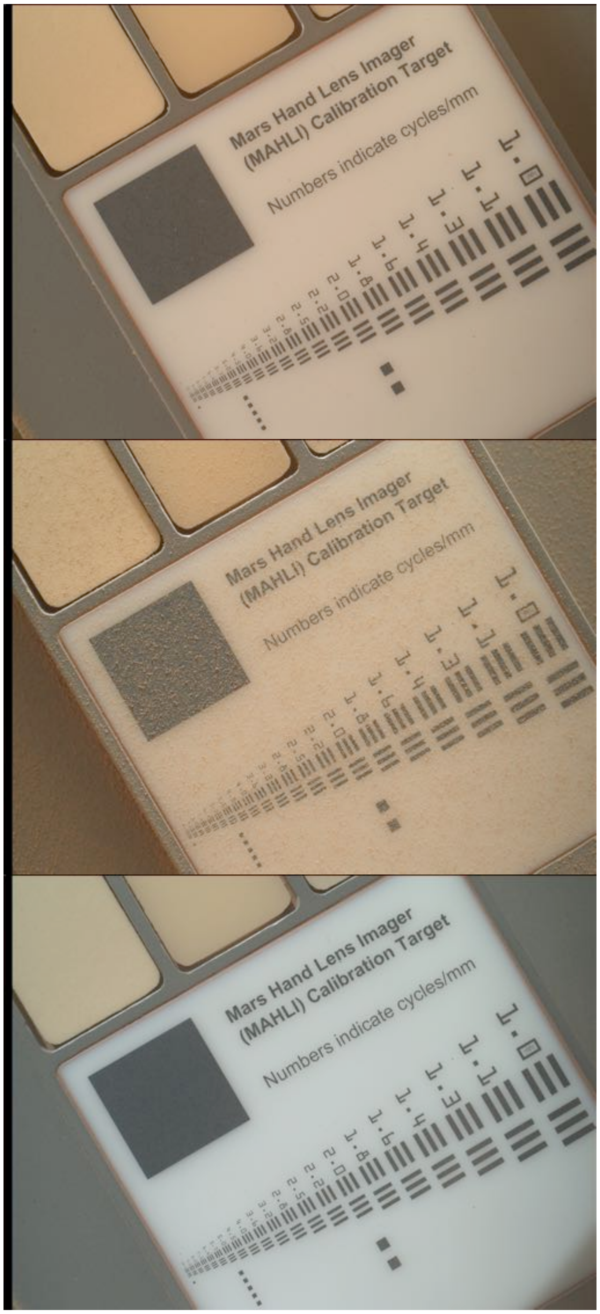

Figure 1. Portion of the MAHLI calibration target as imaged by MAHLI on sol 2082 (top; 2082MH000 3710010802206C00), sol 2161 (middle; 2161MH0003710010802780C00) and sol 2248 (bottom; 2248MH0003710010803300C00).

windblown sand. Previous cleaning of the calibration target occurred during the traverse across the Bagnold sand transport corridor between sols 1493-1675 (18 October 2016 to 23 April 2017). The fact that sand grains were found on the Spirit solar panels [10] and trapped inside the Mastcam-100 baffle are evidence that these grains can bounce to a significant height. These grains could easily reach the height of the MAHLI calibraton target, dislodging dust. Much of the dust observed on the target on Sol 2161 may have appeared in a relatively short period of time. It is possible, too, that some dust continued to accumulate thereafter, by airfall then sticking to dust already plastered to the calibration target.

The rover attitude with respect to prevailing winds likely was an influential factor. This changed during the period of this experiment with changing rover heading from drive to drive, and with changing wind directions according to the weather. The vertical positioning of the calibration target may be particularly susceptible to deposition when facing into the wind, if the winds are dust-laden. On the other hand, saltating sand would also have been mobilized and impinged on the target in that case. It is possible that the dust storm was of sufficient magnitude to overcome any cleaning effects by sand.

Our next steps are to assess all MAHLI calibration target images for dust accumulation, yielding a model of dust accumulation and loss over the duration of the mission to date. We will use rover attitude data to estimate in which cases the rover was facing into or away from the prevailing winds, although we note that the intervening sols between image acquisition may make this particular part of the problem too unconstrained. In addition, we are exploring the use of MAHLI color data to estimate the fractional coverage of dust on the calibration target and measure changes in dust cover during the mission [5].

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