THE MARS SCIENCE LABORATORY DUST STORM CAMPAIGN

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Introduction: The Mars Science Laboratory (MSL) Curiosity rover has a capable suite of instruments to monitor the meteorology of Gale Crater. The Rover Environmental Monitoring System (REMS) contains instruments to measure air pressure, temperature (both air and ground), relative humidity, wind speed and direction, and ultraviolet flux [1]. Although REMS is the only dedicated instrument for meteorological measurements, several of the MSL's other instruments obtain useful information on the environment. Specifically, the Mast Camera (MastCam) [2] and Navigation Cameras (NavCam) [3] routinely take image sequences to measure atmospheric opacity and search for clouds and dust devils, while the Chemical Camera (ChemCam) observes the sky in a passive mode to measure atmospheric gas concentrations and aerosol opacity as well [4].

This combination of instruments and measurements is the most robust and long-lasting meteorological monitoring on the surface of Mars since the Viking Landers. This provides us with the opportunity to observe and document large regional and global dust storms, if and when they occur, from the surface in concert with orbiters observing from above. In an effort to pre-plan rover activities in the event of a large dust storm, the MSL Environmental Science Theme Group created the Dust Storm Campaign (DSC).

Dust Storm Campaign Plan: The DSC utilizes all existing environmental monitoring sequences from REMS, MastCam, NavCam, and ChemCam at increased frequency to monitor potentially rapid changes in weather conditions.

Nominally, REMS is active for 5 minutes at the top of each hour and has a series of 1-hour duration "extended blocks" throughout a given sol. These extended blocks typically occur every 6 hours at rotating times, with additional targeted blocks occurring at other times of day. When the DSC is initiated, these background extended blocks occur every 3 hours. If nighttime temperatures become sufficiently warm during a storm, additional extended blocks are added at night to observe winds. Typically, cold nighttime temperatures preclude accurate wind direction and speed measurements. Similar cadence increases occur in other observations sequences including daily MastCam atmospheric opacity measurements during the growth stage of a large dust storm and weekly passive ChemCam observations of atmospheric gases and aerosols.

Additionally, uniquely-planned observations will be conducted to monitor the surrounding surface and the rover deck for "change detection". Similar observations were conducted during the "Bagnold Dunes Campaign" [5] where dedicated observations searched for signs of saltation and dune movement.

Campaign Triggers: The DSC can be initiated either through consensus of the Environmental Science Theme Group or by a given day's Environmental Science Theme Group Science Team Lead (i.e., the person participating in daily operational planning). Weather conditions both globally and within Gale Crater are monitored for changes that could initiate the DSC. Atmospheric opacity changes both in Gale Crater (via MastCam atmospheric opacity image sequences and REMS ultraviolet flux) and at the Opportunity rover's location (Meridiani Planum) are monitored daily for sudden increases. Changes in the amplitude and phase of atmospheric pressure tides (specifically the diurnal and semidiurnal tides) are indicative of both local and global atmospheric dust loading. Helpfully, orbiting instruments such as the Mars Climate Sounder and Mars Color Imager onboard the Mars Reconnaissance Orbiter also provide notice of growing dust storms.

Large Regional Dust Storm MY33 L_s = 217-227: On September 5th and 6th, the Environmental Science Theme Group was notified by the Mars Climate Sounder team that a regional dust storm was developing in the southern hemisphere mid-latitudes [6]. After discussion, the DSC was initiated on MSL Sol 1455 (September 8th, 2016). By Sol 1458 it was clear that the storm was beginning to diminish and would not become a global dust storm, and the DSC was suspended on Sol 1460. While atmospheric opacity did not immediately increase within Gale Crater, additional dust did drift over MSL during the decay stage of the storm. This increased opacity over Gale forced an increase in diurnal pressure tide amplitude by Sol 1460, while the semidiurnal tide responded quickly to global aerosol loading and ex-

ceeded 15.5 Pa amplitude on Sol 1454, a threshold only rarely exceeded to date during the mission. The tide phases also saw rapid variations, typical of large dust storms in previous Mars years.

Future Work: The Environmental Science Theme Group will continue to monitor conditions for the remainder of the canonical dust storm season of Mars Year 33 and may initiate the DSC again during this year.

References:

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