Interpretation of the Meteorological Environment Changes Experienced By MSL During Mission Traverse Using REMS and MRAMS

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Abstract:

This work aims to examine the atmospheric pressure, ground and air temperatures and relative humidity obtained by REMS on its journey from the MSL landing site to its current position on the slopes of Mount Sharp. It seeks to extend the work done by Pla-García et al. [1] and Rafkin et al. [2], studying the evolution of the meteorology during the rover's traverse. The results help to better understand the martian meteorology inside Gale Crater, revealing changes in pressure and temperature driven by the change in altitude of the rover and meteorological cycles, and confirming the hypothesis of Rafkin et al. [2] about the existence of a pocket of cold air at the bottom of the crater.

1. Introduction

The Rover Environmental Monitoring Station (REMS) on the Mars Science Laboratory (MSL) Curiosity rover consists of a suite of meteorological instruments that measure pressure, temperature (air and ground), wind (speed and direction), relative humidity, and the UV flux. A detailed description of the REMS sensors and their expected performance can be found in Gómez-Elvira et al. [3]. Curiosity landed on Mars in a shallow area of Gale Crater, near Mount Sharp, a topographically and meteorologically complex area of great scientific interest. Since then, Curiosity has traveled more than 27 kilometers, climbing almost 600 meters on its way up Mount Sharp.

2. Methods

We report 3289 sols observations performed by REMS from Martian Year (MY) 31 to 36 for air temperature (Figure 1), surface temperature (Figure 2), daily mean atmospheric pressure (Figure 3) and daily mean relative humidity (Figure 4).

In an effort to better understand the different meteorological environments observed inside Gale crater, MRAMS was applied to the landing site region using nested grids with a spacing of 330 meters on the innermost grid that is centered over the landing site (Figure 5). MRAMS is ideally suited for this investigation; the model is explicitly designed to simulate Mars' atmospheric circulations at the mesoscale and smaller with realistic, high-resolution surface properties. The model is run for 4 sols with 4 grids and then the 3 additional grids are added and run for at least 3 more sols. Initialization and boundary condition data are taken from a NASA Ames GCM simulation with column dust opacity driven by zonally-averaged TES retrievals. Vertical dust distribution is given by a Conrath-v parameterization that varies with season and latitude.

3. Results

Surface pressure drops when climbing Mt Sharp (Figure 6) since the atmosphere column above a unit area shortens as altitude [4].

MRAMS model results are shown to be in good agreement with observations (Figures 7 and 8) when considering the uncertainties in the observational data set. The good agreement provides justification for utilizing the model results to investigate the meteorological environment changes experienced by the rover during mission traverse.

As expected, both REMS and MRAMS show during nighttime air temperatures up to 10 K warmer for recent years (MY35-36) compared to postlanding years (MY31-32), when the rover was exposed to cold air masses at the crater floor (Figure 7), and lower pressure (Figure 8).

During MY31-32 (first and second MSL years), the rover was in the crater floor, completely exposed to the strong N-W downslope (mostly dynamically driven) winds from Peace Vallis during Ls 225-315 [2]. The overturning circulation aloft due to upslope winds during daytime through rims and Mt. Sharp creates an intense subsidence area in the crater floor area (, Figure 9), suppressing the PBL [5]. During the MY33 (third MSL year), the rover was climbing the slopes of crater Mt Sharp (Figure 6) and was less exposed to the high subsidence area and to the strong N-W downslope wind flow. This new environment condition should favor the dust devil activity. After MY34 (fourth MSL year), the rover could be much more exposed to "free" (and putative wet) atmosphere, that is, outside Gale crater floor air masses that could explain, among others, the relative humidity increment during mission traverse (Figure 4).

4. Figures:

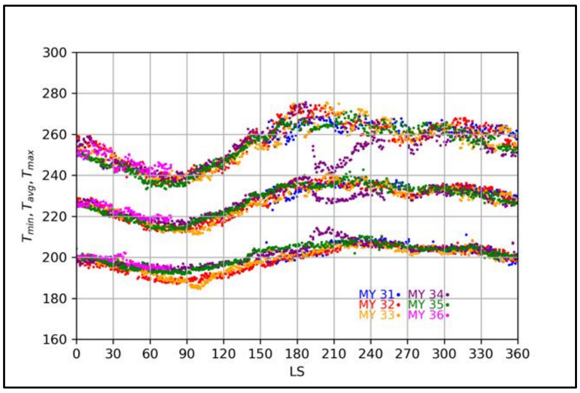

Figure 1: Interannual and seasonal evolution of daily maximum, average and minimum air temperature during the first 3289 sols of the Mars Science Laboratory mission. Color code is used to represent different Martian Years.

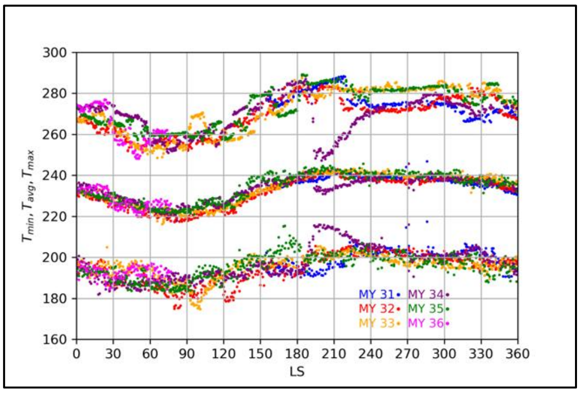

Figure 2: Same as Fig. 1, but for surface temperature.

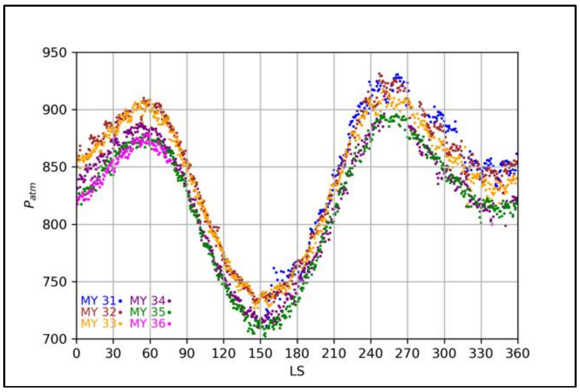

Figure 3: Same as Fig. 1, but for daily mean atmospheric pressure.

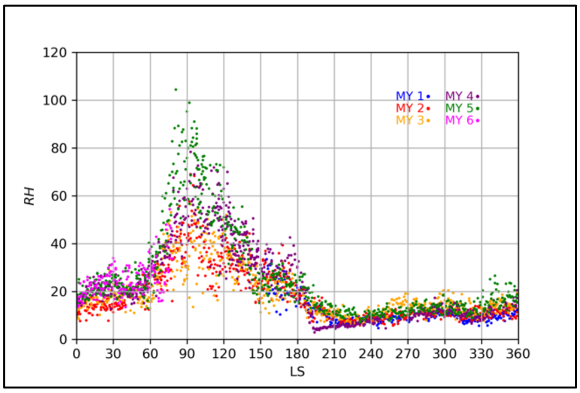

Figure 4: Same as Fig. 1, but for daily mean relative humidity.

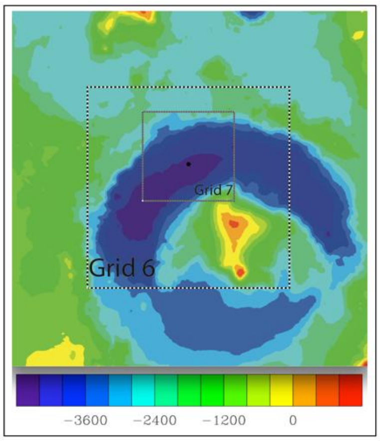

Figure 5: Horizontal Grid Spacing applied to landing site region: 330 meters for Grid 7 and 980 meters for Grid 6. The black dot is the Curiosity location.

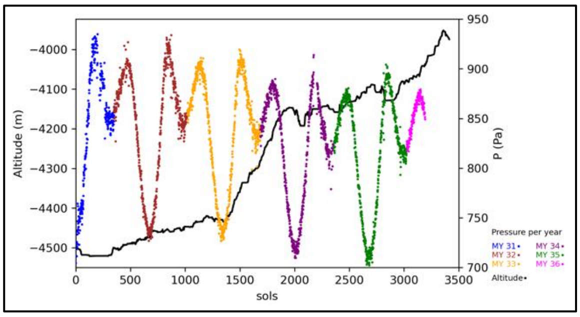

Figure 6: Seasonal evolution of daily mean atmospheric pressure vs elevation changes during the first 3289 sols of the Mars Science Laboratory mission. Color code is used to represent different Martian Years in the pressure.

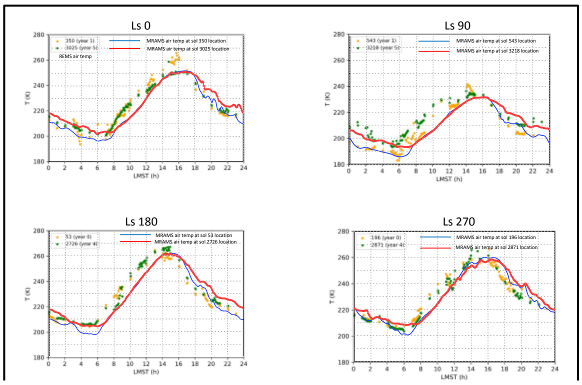

Figure 7: MRAMS model predictions and REMS observations of diurnal air temperature at solstices and equinoxes of MSL years 0-1 (MY31-32) vs MSL years 4-5 (MY35-36). As expected, air temperature during nighttime is up to 10 K warmer at years 4-5 locations (600 m higher in elevation compared to landing site), far away from the cold air masses of the crater floor.

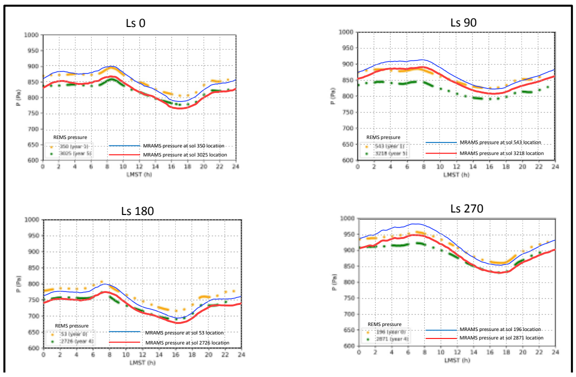

Figure 8: Same as Fig. 8, but for daily mean atmospheric pressure.

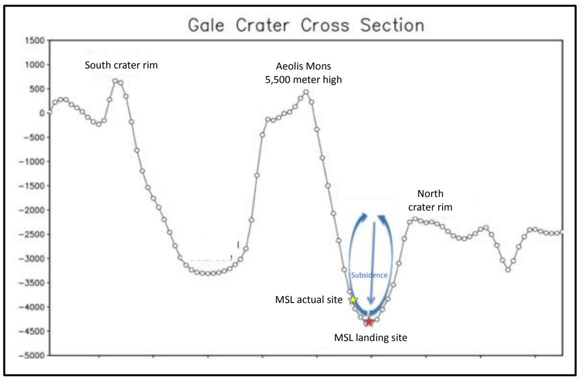

Figure 9: Subsidence area near MSL landing site.

5. References:

[1] Pla-Garcia et al. (2016), Icarus. [2] Rafkin et al. (2016) [3] Gómez-Elvira, J., et al. (2012), Space Science Reviews, 170(1-4), 583-640. [4] Pascal, Blaise (1648) Oeuvres completes. [5] Moores et al. (2015). Icarus, 249, 129-142.