Preliminary Interpretation of the Meteorological Environment Through Mars Science Laboratory Rover Environmental Monitoring Station Observations and Mesoscale Modeling.

J. Pla-García[1,2], S. Rafkin[1], F.J. Martín-Torres [3], M.-P. Zorzano[2], J. Elvira-Gómez[2] and the REMS and MSL Science team

[1]*Southwest Research Institute, Boulder CO 80302, USA*
[2]*Centro de Astrobiología (CSIC-INTA) Carretera de Ajalvir, km.4, 28850 Torrejón de Ardoz, Madrid, Spain*
[3]*Instituto Andaluz de Ciencias de la Tierra, CSIC-UGR, Armilla, Granada, Spain*

Abstract:

In this study the Mars Regional Atmospheric Modeling System (MRAMS) has been applied to the Gale Crater region, the landing site of the Mars Science Laboratory (MSL) Rover Curiosity. The landing site is at one of the lowest elevations in Gale, between the crater rim and the ~4 km high central mound known as Mt. Sharp. As Curiosity heads toward its long term target of Mt. Sharp, the meteorological conditions are expected to change due to the increasing influence of topographically-induced thermal circulations that have been predicted by numerous previous studies [1, 2, 3, 4]. The types of perturbations of pressure, air and ground temperature and wind measured by the Rover Environmental Monitoring Station (REMS) [5] have never been observed at other locations and these data provide a great opportunity to test the models at the most meteorological interesting area measured to date. We provide a comparison of MRAMS predictions (pressure, air temperature, winds and ground temperature) to the REMS data available at the location of the Rover for sols 21-25 (when first regular REMS measurements were obtained, L_s=163), sols 51-55 (L_s=180), sol 215 (L_s=270) and sols 348-352 (L_s=0), in order to provide a baseline of model performance.

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. [5].

In an effort to better understand the atmospheric circulations of the Gale Crater, the Mars Regional Atmospheric Modeling System (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 1). 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 [6, 7]. Figures 2 and 3 are comparison examples of model predicted pressure and ground temperature compared to the diurnal cycle measured by REMS in sols 348-352 (L_s=0).

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 [8] 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.

2. Comparisons MRAMS-REMS:

The model does appear to be doing a reasonable job representing the meteorological conditions. Pressure and ground temperature provide the most robust parameters with which to test the model predictions. Modeled pressure variations at L_s=0 (Figure 2) indicate that the baseline global pressure is reasonably accurate (note we did a 60hPa bias correction, indicative of errors in the parent GCM which controlls the global pressure value, problem solved with the new GCM inputs of the last simulations not included in this abstract), as is the amplitude of the diurnal pressure cycle. Besides the dominant diurnal and semi-diurnal tide, both the model and observations show higher frequency variations in pressure.

The cause of these perturbations is unclear. In the model, there is no noticeable relationship between upslope/downslope flows and the pressure. These circulation have no noticeable affect on pressure, as determined by looking at the pressure signal for various locations within the crater and classifying the wind regimes. Pressure is not observed to change when winds change direction.

Daytime ground temperatures are in good agreement with observations, but the model nighttime ground temperatures are warmer (Figure 3). Comparisons were done before the new offset characterization of the GTS was released. With that correction, REMS ground temperature measurements for air temperatures bellow -50ºC go up till 4ºC.

Model air temperatures (Figure 7) are noticeably warmer than the observations during the evening (under investigation). Part of this discrepancy is due to the height of the first model atmospheric level that sits 14-m above the ground. In a strong nocturnal inversion, the model will produce a warmer temperature than at a height of ~1.5m where the REMS temperature sensors are located. There is work in progress to extract the 1.5-m temperature extrapolated from the model using Monin-Obukhov surface layer physics.

2.2 Topographic winds at Gale:

In the model, a katabatic flow that adiabatically warms as it descends originates on the north rim of the crater (Figure 4). There is a sudden increase in air density around 22.55 LMST at landing site. The air is only a few K colder than the surrounding environment at the point of origin. By the time it reaches the crater floor, it is approximately the same temperature as the surrounding air. There are numerous convergence boundaries and some turbulent mixing that may also keep the temperatures warmer than would be expected by pure radiative equilibrium arguments. Therefore, the unexpectedly warm observed temperatures as well as the noticeably thermal perturbations at night (Figure 7) may be caused by mixing from intermittent nocturnal turbulence and by changes in local air mass.

The MRAMS mesoscale model predictions of slope flows for Gale Crater seem to be in general agreement with REMS observations: timing and direction of incoming wind, wind variability during the day and fixation at night to the same orientation, and indications of turbulent mixing of different masses of air with different temperatures. Wind speeds predictions show a diurnal pattern with the strongest winds at night, regardless of season. The windiest season is northern winter, L_s=270 (Figure 5). Moreover, this season is the only one in where downslope winds can flush out crater air mass and where northern hemisphere air make it into the crater in a massive push of cold air (Figure 6). Studying potential temperature we can tell how the warm air from south overrides the crater and gravity waves are formed in the north rim. Unfortunately for this season (L_s=270) we have only a few REMS observations data, due to a problem with rover active computer and solar conjuntion.

The daytime is generally the least windy time, although wind gusts associated with turbulence, as indicated by the subgrid scale turbulent kinetic energy (not shown) can be strong (10.3 m/s in Ls=270 and 6.9 m/s in L_s=163). Wind direction is complex and varies with season (Figure 8). This is due to the interaction of the numerous local flows with the seasonally-evolving larger-scale circulations. For example, the surface winds at different seasons look similar, but there are subtle differences in the strength and location of the local circulations.

3. Figures:

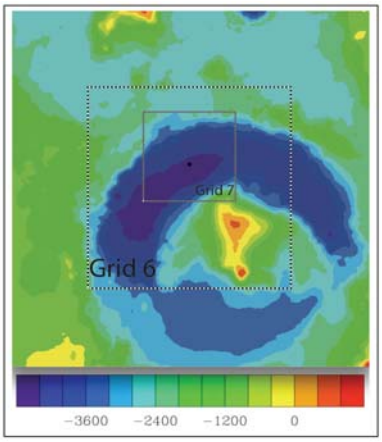

Figure 1: Horizontal Grid Spacing applied to landing site region: 330 meters for Grid 7 and 980 meters for Grid 6. The black dot is the Curiosity location.

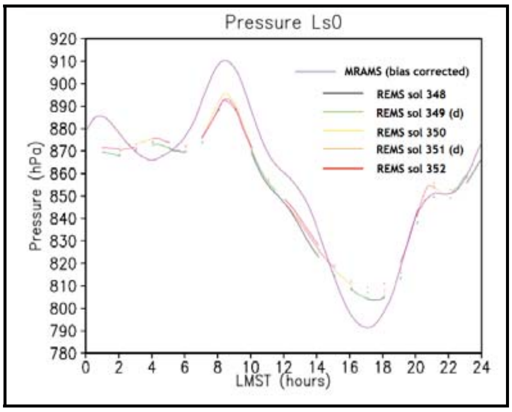

Figure 2: Comparison of MRAMS model predictions to the diurnal pressure cycle measured by REMS in sols 348-352 (L_s=0).

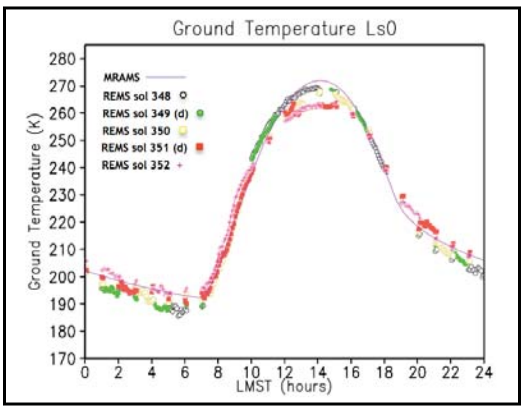

Figure 3: Comparison of MRAMS model predictions to the diurnal temperature cycle measured by REMS in sols 348-352 (L_s=0). “d” are rover driving sols

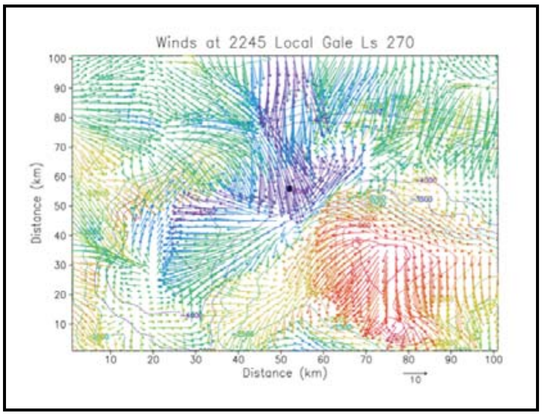

Figure 4: MRAMS model predictions of night winds (katabatic) colored by potential temperature for sol 215 (L_s=270). The black dot is the Curiosity location.

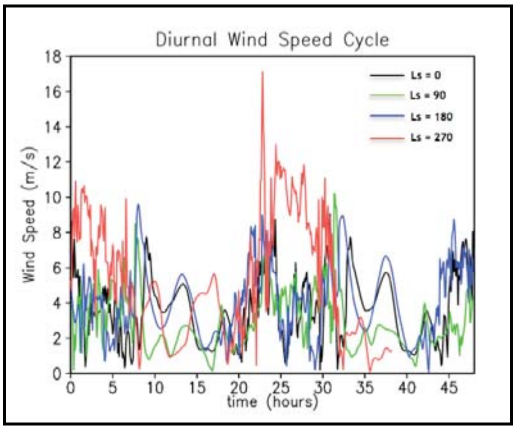

Figure 5: MRAMS model predictions of diurnal wind speed (2 sols) for all seasons.

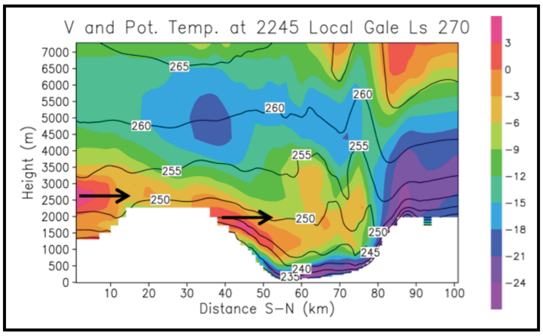

Figure 6: Winds colored by potential temperature in cross section. Strong downslope (katabatic) winds at L_s=270 along north rim during the night.

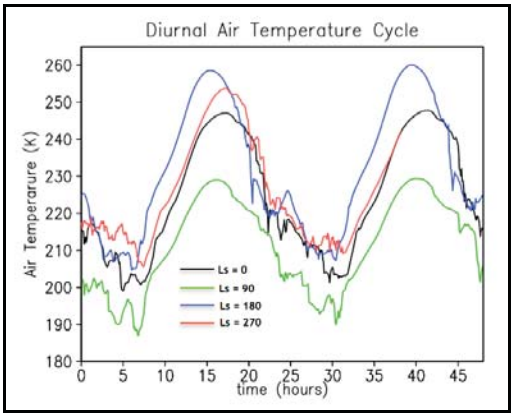

Figure 7: MRAMS model predictions of diurnal air temperature (2 sols) for all seasons.

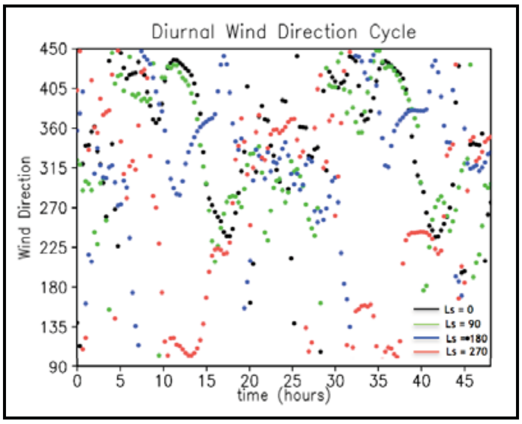

Figure 8: MRAMS model predictions of diurnal wind direction (2 sols) for all seasons.

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References:
[1] Rafkin, S. C. R., and T. I. Michaels (2003), J. Geophys. Res., 108(E12), 8091. [2] Michaels, T. I., and S. C. R. Rafkin (2008), J. Geophys. Res.-Planets, 113. [3] Toigo, A. D., and M. I. Richardson (2003), J. Geophys. Res., 108(E12), 8092. [4] Tyler, D., J. R. Barnes, and E. D. Skyllingstad (2008), J. Geophys. Res.-Planets, 113(E8). [5] Gómez-Elvira, J., et al. (2012), Space Science Reviews, 170(1-4), 583-640. [6] Rafkin, S. C. R., R. M. Haberle, and T. I. Michaels (2001), Icarus, 151, 228–256. [7] Rafkin, S. C. R., M. R. V. Sta. Maria, and T. I. Michaels (2002), Nature, 419, 697–699. [8] Haberle, R.M., Murphy, J.R., Schaeffer, J., 2003. Icarus 161, 66–89.