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Meteorological Circulations at Gale Environment Through Rover Environmental Monitoring Station (REMS) Observations and Mesoscale Modeling (MRAMS)

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Abstract

Gale Crater, in which the Mars Science Laboratory (MSL) landed in August 2012, is the most topographically complex area visited to date on Mars. The meteorology within the crater may also be one of the most dynamically complex meteorological environments, because topography is thought to strongly drive the near-surface atmospheric circulations. The Rover Environmental Monitoring Station (REMS) [5] has provided some clues on the nature of the local meteorology strongly influenced by the complex topography, as predicted by numerous previous studies. The types of perturbations of pressure, air and ground temperature and wind measured by REMS 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. In an effort to better understand the atmospheric circulations of the Gale Crater, the Mars Regional Atmospheric Modeling System (MRAMS) [6] 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. We provide a comparison of MRAMS predictions for pressure, air temperature, winds and ground temperature, to the REMS data available at the location of the Rover for sols 51-55 (L_s=180), sols 195-199 (L_s=270), sols 348-352 (L_s=0) and sols 541-545 (L_s=90), in order to provide a baseline of model performance. Pressure and ground temperature provide the most robust parameters with which to test the model predictions (Figures 2 and 3).

2. Circulations at Gale

Simulations with MRAMS indicate thermal and wind thermal signatures associated with slope flows, katabatic winds, and nocturnal mixing events that are consistent with the rover environment monitored by REMS. Some pressure structures are shown both in model and observations during L_s=270 at night, and could be related to strong downslope winds (Figure 3). Potential temperature studies allows thermal comparison of air at different altitudes, showing evidence for two distinct air masses—one in the bottom of the crater (a relatively cold dense air mass) and one on the plateau, that produces minimal interaction with one another during L_s=0, 90 and 180. Warm air from south overrides the crater and gravity waves are formed in the north rim (Figure 5). An exceptional case is season L_s=270, when colder air from north plateau (downslope winds) can flush out crater air mass and northern hemisphere air make it into the bottom crater in a massive push of cold air (Figures 4 and 5). If there are indeed two distinct air masses, there are strong implications for dust, water vapor and chemical (including methane) cycles within Gale Crater. The air within Gale should be drier and less dusty due to more limited mixing with the environment and limited dust lifting due to dust devils during L_s=0, 90 and 180. There are strong indications that there is a complex interplay between circulations over a large range of spatial and temporal scales. In particular, the modeling will demonstrate that global (Hadley cell), regional (Mars dichotomy) and local (Gale crater) circulations must all be considered in order to explain the observational data. Complex crater circulations result from adding all scales of motion (Figure 6).

3. Figures

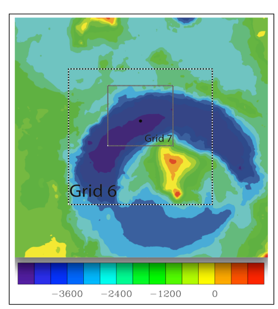

Figure 1: Horizontal Grid Spacing applied to landing site. The black dot is Curiosity landing site location.

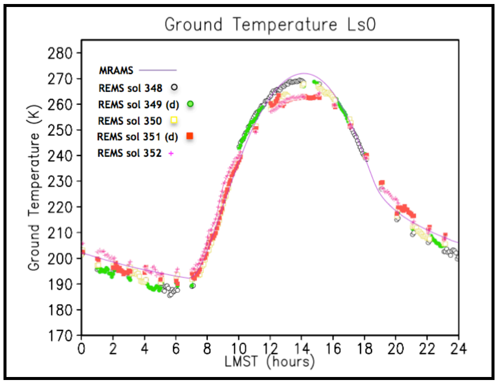

Figure 2: Comparison of MRAMS predictions to Gale diurnal temperature cycle measured by REMS in sols 348-352 (Ls=0). "d" are rover driving sols.

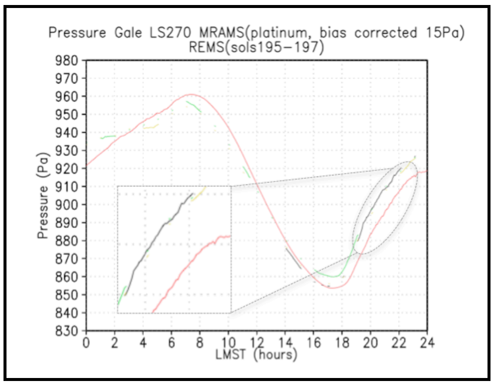

Figure 3: Comparison of MRAMS predictions to the diurnal pressure cycle measured by REMS in sols 195-197 (L_s=270).

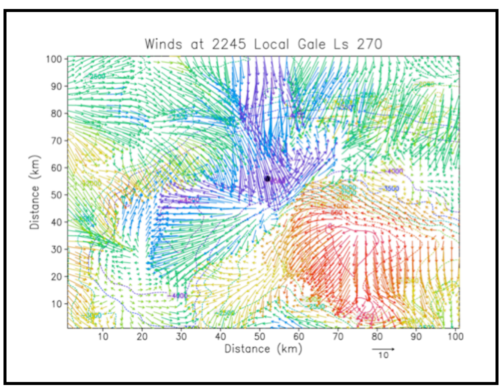

Figure 4: MRAMS model predictions of night winds (katabatic) colored by potential temperature for sol 197 (Ls=270). The black dot is the Curiosity location.

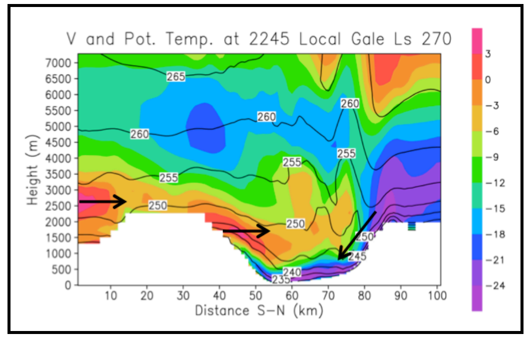

Figure 5: Winds colored by potential temperature in cross section. Strong downslope (katabatic) winds at Ls=270 along north rim during the night.

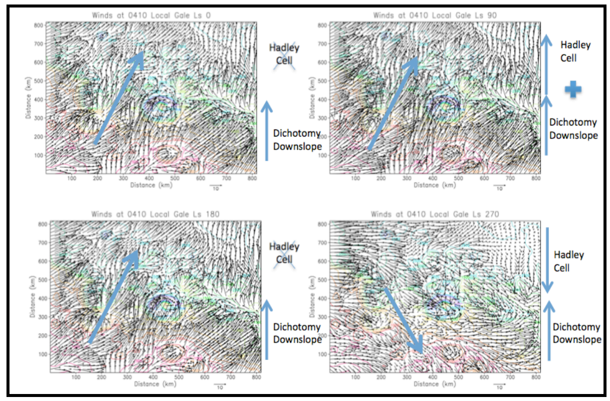

Figure 6: Multiscale scenario. Air flowing into crater originates from Southern Hemisphere for all seasons except Ls=270 where global winds (northern) are fighting against regional dichotomy (downslope) winds during the night.

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.