INVESTIGATION OF THE DIURNAL VARIATION OF SURFACE PRESSURE IN GALE CRATER.

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Introduction: Pressure data is of particular interest when studying atmospheric circulation as it provides insight into atmosphere dynamics at different scales. It is representative of the mass of gas in the atmospheric column above the surface as well as allows monitoring of pressure-gradient driven local circulations. With Mars Science Laboratory (MSL), unprecedented surface pressure diurnal variations have been measured by the Rover Environmental Monitoring Station (REMS) instrument. Mainly driven by the thermal tides, pressure data recorded at the beginning of surface operations showed variations of about 10% from the daily mean [1]. This range of pressures is almost twice as large as that predicted by the NASA Ames General Circulation Model (GCM) [1]. One of unique aspects of the MSL mission compared to the previous landed missions is the environment of its landing site: a 5 km deep, 150 km wide crater with a central mound. Because Curiosity sits at the bottom of this crater, it is likely that topography-generated local circulations, which are not resolved by global circulation models, will have a significant impact on the pressure signal recorded by REMS. Using the high resolution capabilities of the Mars Regional Atmospheric Modeling System (MRAMS) [2], we investigate the effects of Gale crater's topography on the pressure signal with both idealized and realistic simulations where the boundary conditions are taken from the Ames GCM.

Methodology: MRAMS is a non-hydrostatic mesoscale model with nested computational grids which allows spatial resolution on the order of a km at the site of interest. This makes MRAMS particularly appropriate to study the topographically induced buoyancy circulations that may enhance the surface pressure variations in Gale. We ran a five-grid/2963m-resolution simulation focused on Gale crater, using realistic topography, dust loadings and NASA Ames GCM's runs at solar longitude Ls 150° to provide initialization and boundary conditions at the edges of the mother-grid. The results, presented in figure 1, show a diurnal pressure range of 80 Pa at MSL's landing site, which is consistent with REMS records [1]. Also shown in figure 1 is the pressure trace outside the crater at a higher elevation, which has a much reduced daily variation. The normalized pressure variations (not shown) are also enhanced at the bottom of the crater as was found in [3]. The increase in diurnal pressure range at the bottom of Gale compared to outside the crater can be attributed to several factors: a) the large (~5km) elevation difference between the landing site and outside the crater, b) the crater circulation itself due to upslope/downslope winds [4], and c) the interaction of the crater circulation with large scale atmospheric circulations.

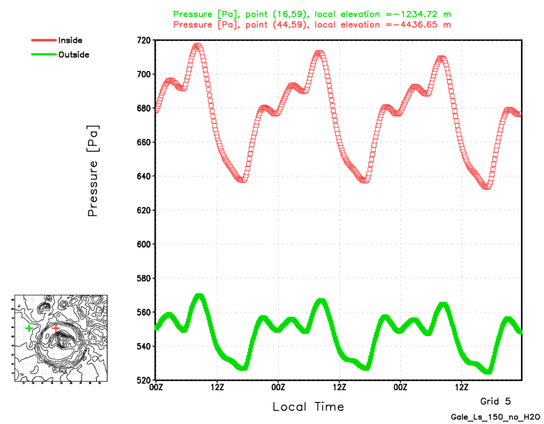

Figure 1: Comparison of the pressure inside and outside the crater as predicted by MRAMS

In order to isolate b) from factors a) and c) we set-up an idealized simulation with simplified topography such that the elevation at the bottom of the crater is the same as it is far away from the crater (see figure 2). Thus, the topography is flat over the entire modeling domain except for a single crater, which has roughly the same dimensions as Gale (5km deep, 150 km in diameter, but no central mound). On the flanks of the crater, the topography slopes linearly from 5 km elevation at the rim to 0 km at 3 crater radii from the rim. This allows a direct comparison of the pressure signals inside and outside the crater. We also arbitrarily turned off the thermal tide by removing the longitudinal variations in solar heating. Thus, all longitudes at a given latitude experience the same phase of the diurnal cycle, i.e., the sun rises and sets everywhere at the same time. By eliminating the tide, the circulation within the crater is purely the result of buoyancy forces.

Results: Figure 3 shows the results of this idealized simulation. As it

is clearly evident, there is a significant diurnal pressure variation of ~ 12 Pa (peak-to-peak) at the grid point in the bottom of the crater. During the day, the crater circulation exports mass and surface pressure falls. The minimum surface pressure occurs at ~ 4PM.

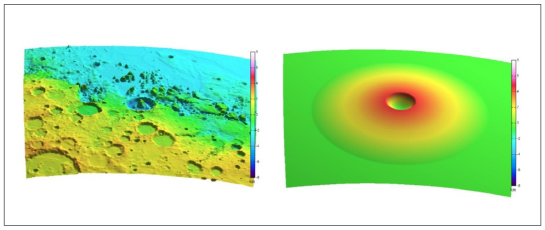

Figure 2 : Topography at Gale crater, before and after modifications

At night downslope flows return air to the bottom of the crater and surface pressures increase with maximum pressures occurring shortly after midnight. The phase of this pressure variation, again due entirely to the crater circulation, is almost the same as the thermal tide (which is not included in this simulation). Thus, we expect that the crater component and the global thermal tidal component will interact constructively and increase the amplitude further.

Note that outside the crater, at a point ~7 crater radii away from the rim and 2.5 crater radii from the bottom of the outer slopes , there is a daily pressure variation that is out of phase with the pressure variation inside the crater. This is due to two factors. The first is related to the export/import of mass from the crater itself. During the day air flows out of the crater to the surrounding plains and increases the surface pressure. The opposite occurs at night. This affect decreases with distance from the crater. The second is due to the rigid upper boundary condition. MRAMS is a sigma-z coordinate model and the upper boundary condition sets vertical velocities to zero at the top. This leads to a “pressure-cooker” effect since, for example, heated air during the day cannot expand upward, interior pressures must increase.

To the extent that the pressure trace outside the crater (the green curve in figure 3) is due to the “pressure-cooker” effect, we can place an upper limit on the crater circulation induced daily pressure range of ~20 Pa.

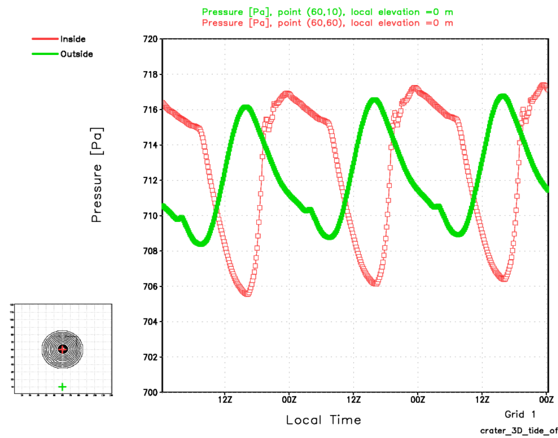

Figure 3: Pressure signal inside and outside the idealized crater, when the solar longitudinal variation of the sun is disabled

Conclusions: The simulations we perform here are highly idealized and only meant to demonstrate that slope flows associated with a crater with the approximate dimensions of Gale will indeed produce a significant diurnal pressure variation. In our simulations the peak-to-peak amplitudes are somewhere between 10-20 Pa, depending on how one removes the pressure-cooker effect. Furthermore, these flows are synchronized with the daily heating cycle and so they produce a phase that is similar to the diurnal thermal tide. Thus, we hypothesize that the large diurnal pressure variation measured by the REMS experiment is due to the enhancement of an already large diurnal variation due to the global thermal tide by a localized buoyancy-driven upslope/downslope circulation generated by the topography of Gale Crater itself.

References: [1] Robert M. Haberle et al. (2014) *Preliminary interpretation of the REMS pressure data from the first 100 sols of the MSL mission*, JGR,119, 440-453. [2] Scot Rafkin et al. (2001), *The Mars Regional Atmospheric Modeling System: Model description and selected simulations,* Icarus, 151, 228–256. [3] Daniel Tyler Jr. et al. (2013) *Mesoscale Modeling of the Circulation in the Gale Crater Region: An Investigation into the Complex Forcing of Convective Boundary Layer Depths,* MARS 8, 58-77. [4] Ashwin R. Vasavada et al. (2012) Assessment *of Environments for Mars Science Laboratory Entry, Descent, and Surface Operations*, Space Sci rev 170, 793-835