Convective Vortices and Seasonal Variations in the REMS Pressure Data.

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Introduction: The Rover Environmental Monitoring Station (REMS) aboard the Mars Science Lab (MSL) has been collecting meteorological data at Gale Crater since August of 2012 [1]. The pressure sensor included in the REMS package is ideal for investigating short timescale phenomena such as convective vortices, or dust devils, as well as seasonal pressure changes at the landing site.

Background dust in the Martian atmosphere plays a role in atmospheric and surface heating [2]. It is thought dust devils, which are convective vortices capable of lifting dust, could be the main contributor to background dust in the atmosphere [3]. Assessing this contribution requires determining the frequency and conditions under which dust devils occur. Convective vortices have been detected at Gale Crater during the first 100 sols of the mission [4, 5]. We have expanded on those findings by examining REMS pressure measurements from the first 440 sols of the MSL mission to detect convective vortices. It should be noted that due to suppression of the planetary boundary layer at Gale Crater, convective vortices in the region are primarily dustless [4, 6]. The signature of a convective vortex stands out in a series of pressure data as a temporary drop of up to a few pascals that lasts anywhere from a few seconds to about a minute [7, 8, 9]. Sometimes these pressure drops are accompanied by temporary increases in temperature. An example of a convective vortex signature that we have detected from Sol 158 of the mission is shown below in Figure 1.

Seasonal pressure changes that occur globally on Mars are linked to the deposition and sublimation of CO_2 ice caps at the northern and southern poles [10, 11]. Observations in recent years suggest that the southern CO_2 ice cap may be shrinking [12], which would cause global surface pressures to rise over time as additional CO_2 remains in the atmosphere. There have been attempts to detect such pressure increases over time by comparing pressure measurements from the Viking, Phoenix, and Curiosity missions [13, 14]. These studies have adjusted the pressure data sets given the different elevations of the landing sites. However, they do not account for differences in latitudes and longitudes for each site. We are modeling the seasonal pressure changes at these landing sites using a 3D General Circulation Model (GCM) in order to demonstrate the spatial dependence of surface pressure.

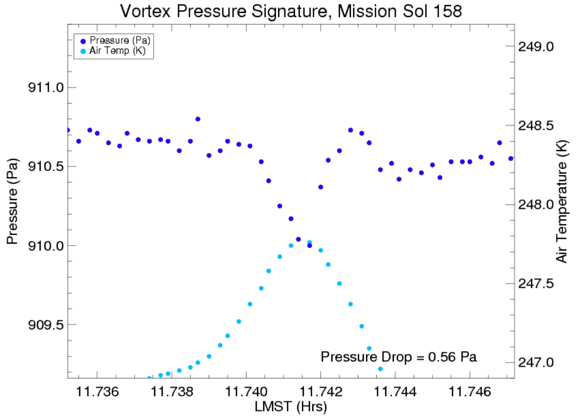

Fig 1: Example of a convective vortex signature in the REMS data.

Methods: We are examining pressure measurements taken by the REMS-P RSP2M-type sensors (sampling frequency 1 Hz) to detect convective vortex signatures over 440 sols. First, we identify pressure drops that are at least 3σ below a fitted temporal trend and that last for more than two seconds. Those drops are then evaluated by eye to confirm which signatures are convective vortices. It is important to note that identifying these events by eye introduces some ambiguity regarding where the threshold of detection lies. Pressure drops must exceed the peak to peak noise of the sensor, ~0.2 Pa, do be considered detections. We calculated each drop magnitude as the difference between the event minimum pressure and the average of ten pressure values immediately before and after the event.

Additionally, we investigate the dependence of seasonal pressure changes on latitude and longitude. Using a 3D GCM with a resolution of 5° x 6° [15], we produce daily average surface pressures over one

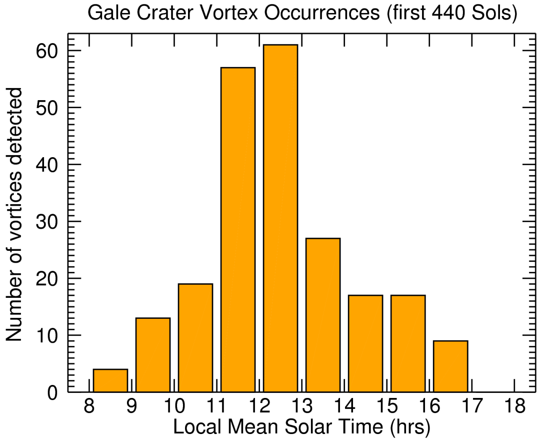

Fig 2: Histogram of convective vortices detected as a function of LMST.

Mars year for the Viking Lander 2 (47.67 °N, 134.28 °E), Phoenix (68.22 °N, 234.25 °E), and Curiosity (4.49 °S, 147.42 °E) landing sites.

Convective Vortex Detections and Discussion: We have identified approximately 200 convective vortices in the first 440 sols of the MSL mission. Most vortex events occurred between the hours of 12:00 and 13:00 local mean solar time (LMST). Figure 2 shows the distribution of events over the time of day. The pressure sensor typically collected data in 5 or 60 minute intervals, and most of the 60 minute sets were taken from 11:00-12:00 or 12:00-13:00 LMST. Thus, our detections are biased to those time intervals. In general, we would expect vortices to occur in the late morning and afternoon, once there has been sufficient heating of the surface to induce convection. Pressure drops of these vortices ranged from 0.2 to 2.83 Pa with an average of 0.57 Pa. The distribution of pressure drops is plotted in Figure 3. Vortices were most commonly detected during southern spring (L_s 180-270). The MSL mission began at L_s 150.6 and has not yet been operating for a full Mars year. Once this happens, we will produce a more complete analysis of the seasonal variations in vortex activity.

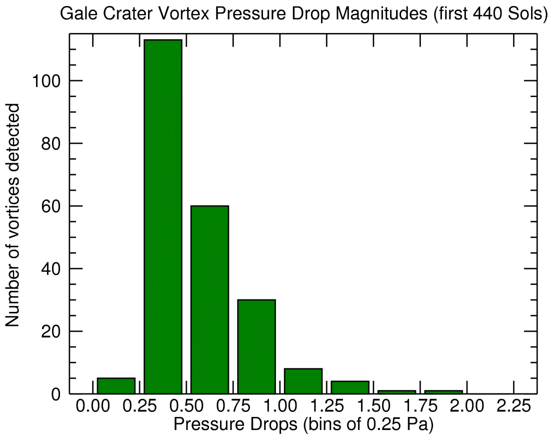

Fig 3: Histogram of convective vortices detected as a function of their pressure drop.

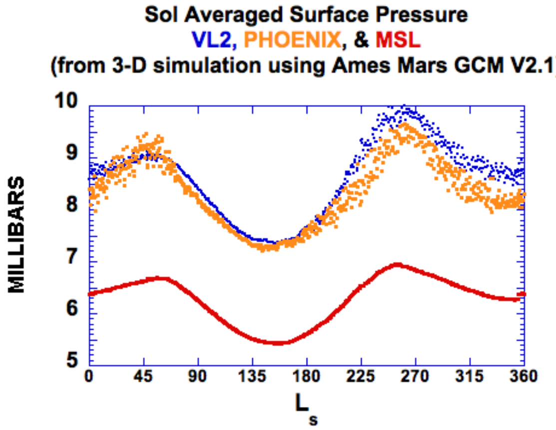

Fig 4: Simulated daily averaged surface pressures at the Viking Lander 2, Phoenix, and Mars Science Lab landing sites.

As part of future work, we plan to examine whether atmosphere-surface energy exchange correlates with our detected convective vortex activity. This will be done using a 1-D climate model to quantify surface heat flux and atmospheric dust load at the time each vortex occurred. Local albedo and topography variations in the regions where these vortices occurred would also be worth examining.

Seasonal Pressure Discussion: We present the three simulated annual pressure trends from the Viking Lander 2, Phoenix, and MSL landing sites in Figure 4. Each data point in the figure represents the average surface pressure for one Martian sol as determined by our 3D GCM. There are noticeable differences in the pressure trends, especially when comparing the MSL landing site to the other two locations. We suspect that each pressure trend is effected by local elevation, location on the planet, and local topography and weather. We are currently using the 3D GCM to quantify these contributions in order to accurately compare the pressure trends over space and time. The additional effects of local topography and weather could be better examined in the future using a mesoscale model. In addition to determining what “scaling factor” can be applied to make two pressure data sets comparable, we must also examine how that scaling factor my change on a sol to sol basis. Such accuracy is necessary in order to assess whether climate change is detectable in the pressure signatures from landing missions. Future work will also include the use of our 3D GCM to quantify how much additional CO_2 must be added to the atmosphere in order to detect the change in the REMS data.

References: [1] Gomez-Elvira et al. (2012) *Space Sci. Rev., 170,* 583-640. [2] Kahn et al. (1992) *“The Martian dust cycle,”* chapter from *Mars*, 1017-1053. [3] Basu et al. (2004), *JGR*, *109*, E11006. [4] Kahanpää et al. (2013) *LPSC*, *44*, Abstract #3095. [5] Harri et al., (2014) *JGR*, *119*, 82-92. [6] Tyler and Barnes (2013) *Int. J. Mars Sci. Explor.*, *8*, 58-77. [7] T.J. Ringrose et al. (2007) *Planet. & Space Sci.*, *50*, 2151-2163. [8] Renno et al. (2000), *JGR*, *105*, 1859-1865. [9] Murphy and Nelli (2002), *JGR Letters*, *29*, 23. [10] James et al. (1992) *“The seasonal cycle of carbon dioxide on Mars,”* chapter from *Mars*, 934-968. [11] Zurek et al. (1992) *“Dynamics of the atmosphere of Mars,”* chapter from *Mars*, 835-933. [12] Thomas et al. (2009) *Icarus*, *203*, *issue 2*, 352-375. [13] Haberle and Kahre (2010) *Int. J. Mars Sci. Explor. 5*, 68–75 . [14] Haberle et al. (2014), *JGR Planets*, *119*, JE004488. [15] Nelli et al. (2010) *JGR*, *115*, E00E21.