A PRELIMINARY INTERPRETATION OF THE FIRST RESULTS FROM THE REMS SURFACE PRESSURE MEASUREMENTS OF THE MSL MISSION. R.M. Haberle[1], J. Gómez-Elvira[2], M. de la Torre Juárez[3], A-M. Harri[4], J.L. Hollingsworth[1], H. Kahanpää[4], M.A. Kahre[1], F. J. Martín-Torres[2], M. Mischna[3], C. Newman[5], S.C.R. Rafkin[6], N. Rennó[7], M.I. Richardson[5], J.A. Rodríguez-Manfredi[2], A.R. Vasavada[3], M-P Zorzano-Mier[2], and the REMS/MSL Science Teams. [1]NASA/Ames Research Center, Moffett Field, CA 94035 (Robert.M.Haberle@nasa.gov), [2]Centro de Astrobiología (INTA-CSIC), Madrid, Spain, [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA 91109, [4]Finnish Meteorological Institute, Helsinki, Finland. [5]Ashima Research, Pasadena CA 91106, [6]Southwest Research Institute, Boulder CO 80302, [7]University of Michigan, Ann Arbor, MI 48109.

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 description of the instruments is described elsewhere [1]. Here we focus on interpreting the first 90 sols of REMS operations with a particular emphasis on the pressure data. Companion papers at this meeting discuss other aspects of the REMS data.

REMS Observation Strategy: All REMS instruments acquire data at 1Hz during a given sampling interval. In "Background" mode, REMS data have been acquired for 5 minutes at the beginning of every hour. In "Extended" mode, additional data have been acquired typically in one-hour blocks. The number of extended blocks varied from sol-to-sol depending on plan complexity, data volume, and power availability. On some sols only a few extended blocks were possible, but on others as many as eight were uplinked. Thus, the REMS daily downlink varied from ~2 to ~9 hours of 1Hz data per sol.

The REMS Pressure Sensor: The Finnish Meteorological Institute provided the REMS pressure sensor. Centro de Astrobiologia (INTA-CSIC) integrated it into the REMS payload88. The sensor, a capacitance device based on the Barocap® technology developed by Vaisala Inc., consists of two oscillators: Oscillator 1 has two "high-resolution Barocaps" (type RSP2M) while Oscillator 2 has both a "high resolution" and a "high stability Barocap" (type LL). The RSP2M Barocaps have short response times (~1 s) with very high precision on this time scale (~ 0.2 Pa) and are best suited for the study of short-term phenomena (e.g., dust devils, see Fig 1). The LL Barocap is more accurate and stable. Its absolute accuracy of < 3 Pa and zero-drift of < 1 Pa/year make it ideal for the study of the CO_2 cycle (see Fig 4). Oscillator 1 was used during the first few sols of operations for calibration and was not used again during the first 90 sols. Oscillator 2 provides the science data reported here.

Results: Pressure data reveal information about meteorological phenomena on a variety of time and spatial scales. The smallest scales of interest are convective vortices, which appear as sharp pressure drops of up to several Pascals over the course of tens of seconds (Fig 1). In some instances, these pressure drops are anti-correlated with temperature fluctuations. These signatures are similar to those seen by other Mars landers that have been interpreted as dust devils [2,3]. However, dust devils in Gale have not been observed from orbit as often as REMS is detecting them, which suggests that the Gale convective vortices are relatively dust free[4].

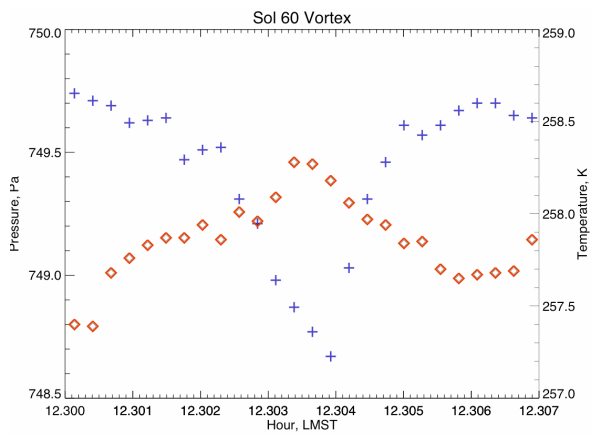

Fig 1. Pressure (blue) and air temperature (red) variations for a vortex on Sol 60.

The next phenomena of interest are the regional circulation systems forced by the crater itself. Models predict strong upslope/downslope (katabatic) flows in Gale, which should affect the daily pressure cycle [5]. An example or the total pressure cycle is shown in Fig 2. Note that the magnitude of the variation is almost 90 Pa, which is about 12% of the daily average. Also, while the first four tidal harmonics provide a good fit to the shape of the curve, there are higher order features that leave significant residuals. General circulation models do not reproduce these features, while higher resolution mesoscale models do. Thus, some of these higher order features are most likely due to the katabatic wind system.

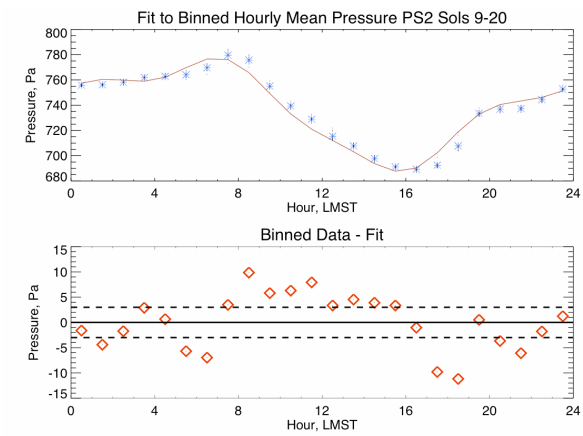

Fig 2. Top: Fit to Sols 9-20 binned hourly mean pressure using the first four tidal harmonics (red line). Bottom: Difference between the data and the fit. Dashed lines signify the accuracy limits.

At still larger scales, the REMS pressure data show strong global thermal tides (Fig 3). The amplitude of the tide is much larger than seen by previous landers. This is due to MSL's near-equatorial location where classical theory predicts a strong tidal response to solar heating [6]. The observed phases are also consistent with classical theory.

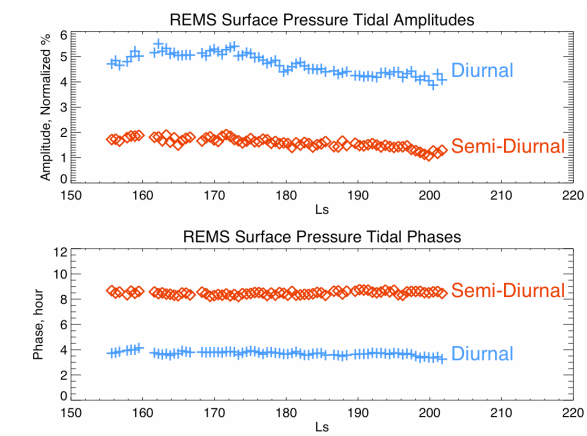

Fig 3. Diurnal and Semi-Diurnal tidal amplitudes (top) and Phases (bottom) at Gale Crater for the first 90 sols.

Tidal amplitudes are strongly coupled to atmospheric heating and dust loading. The observed dust opacities at Gale were declining during this period [7], which may partly explain the decline in observed tidal amplitudes. However, the diurnal tide is also strongly modified by the non-migrating Kelvin wave, whose amplitude is expected to be waning at this season [8].

At the very largest scales, the pressure data reveal information about the global atmosphere/cap system. The daily averaged surface pressures systematically increased during the first 90 sols (Fig 4). This increase, which was first observed during the Viking mission [9], is due to the sublimation of CO_2 from the retreating south polar cap.

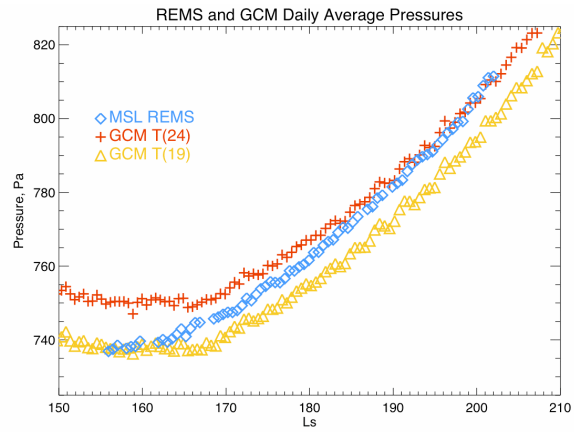

Fig 4. Daily average surface pressures: REMS (blue); GCM with T(24) (red) and T(19) (yellow).

For comparison Fig 4 includes predictions from the Ames GCM using two different model layer temperatures to extrapolate to the actual elevation: one at ~5 m above the surface, T(24), and one at ~1 km above the surface, T(19). The model predictions agree well with the observations, but show a slower increase with time. This may be due to an underestimate of the CO_2 sublimation rates, a misrepresentation of the true temperature structure, and/or some combination of the two.

As the data accumulate it may also be possible to address the question of the stability of the South Polar Residual Cap [10]. This will require careful assessment of the impact of the crater circulation on surface pressures, the extrapolation technique, as well as the thermal environments of other landers.

Conclusions: The REMS pressure measurements are providing a valuable data set for the study of a broad range of meteorological phenomena. The sensor is performing well, is well calibrated, and quite stable. Given the long life of the MSL mission, the REMS pressure data set may ultimately become the best we have from the surface of Mars.

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