GALE ATMOSPHERIC EVOLUTION ALONG THE FIRST TWO YEARS ON MARS OF USING REMS-MSL DATA

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Introduction

The Rover Environmental Monitoring Station (REMS) [Gomez-Elvira, 2012] is part of the Mars Science Laboratory payload. It has been operating regularly from the beginning of the mission (sol 10), recording data of pressure, air temperature, surface brightness temperature, relative humidity, ultraviolet radiation and wind during 5 sec every hour plus a number of extended sessions (from several minutes to 2 -3 hours) distributed along the sol following science requirements.

Over more than two years, REMS has been witness of the Mars atmosphere evolution at Gale crater. Due to its location, close to the Mars Equator, and its particular morphology, the atmoshphere has some characteristic conditions as described by Rafkin (2016) and Pla-Garcia (2016). During most of the Mars year, it appears isolated from the main and regional circulation with only few episodes of air intakes from the crater surroundings,namely around southern summer.

The purpose of this presentation is to show the general evolution of the parameter mentioned above along two Martian years. The idea is to give a global view. Others presentations are more focused in specific features detected during this period.

Operation

REMS has been operative most of the sols. Only at the beginning some small issues related with its memory management marked it sick. Daily operations are defined by the MSL-ENV group, which establish the distribution of the extended sessions each sol. REMS' basic operation aim isto record 5 minutes each hour, and a number of additional hours are available depending of the power and memory resources of the rover. Statistically, the period with a greater number of extended sessions goes from 1200 to 1600 LMST

Pressure

Figure 1 shows the evolution of pressure (Haberle 2014; Harri, 2014) along the different Mars seasons: two periods are highlighted: i) Southern autumn and winter with smooth variations oinpressure, and its corresponding relative maximum at the end of autumn and annual minimum at the end of the winter –both related to the sublimation and deposition of the southern CO_2 polar cap -, and ii) the spring and summer (dust storm season) where the evolution shows a lot of fluctuations, even the pattern of a remote dust storm could be seen in dots in the second year. All seasons refer to the Southern hemisphere.

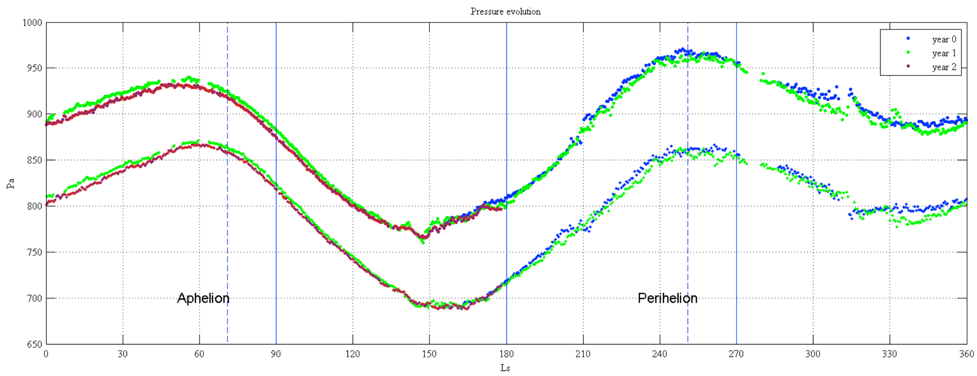

Figure 1. Evolution of daily maximum and minimum pressure over the first two years of the MSL mission

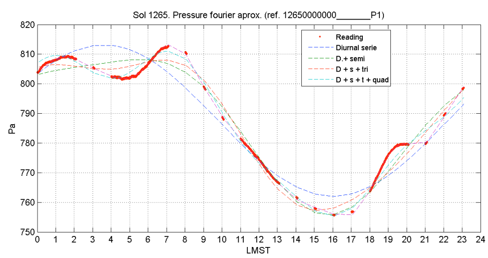

Figure 2. Representative pressure evolution along a sol. It shows how the evolution of the first mode fit maximum and minimum of pressure and how the semidiurnal and followings (related two local conditions) are approaching to the readings.

Making a fit of the data by a Fourier series, we can see that the mean value is clearly driven by the global planet evolution and represent circa 90% of the pressure value and the rest is controlled by local conditions.

The early morning and late evening fluctuations are controlled by higher modes, which means that are driven by the local conditions. The shape of theseq two fluctuations also change along the Martian year.

values.

Air temperature

The air temperature sensor (ATS) is quite close to the rover body and its measurement are affected by thermal contamination from the rover, as well as by electronic noise. Nevertheless, the general behavior of the sensor follows the pattern seen in the GTS. There are two clear periods in the Mars year: spring and summer with temperatures more stable and small

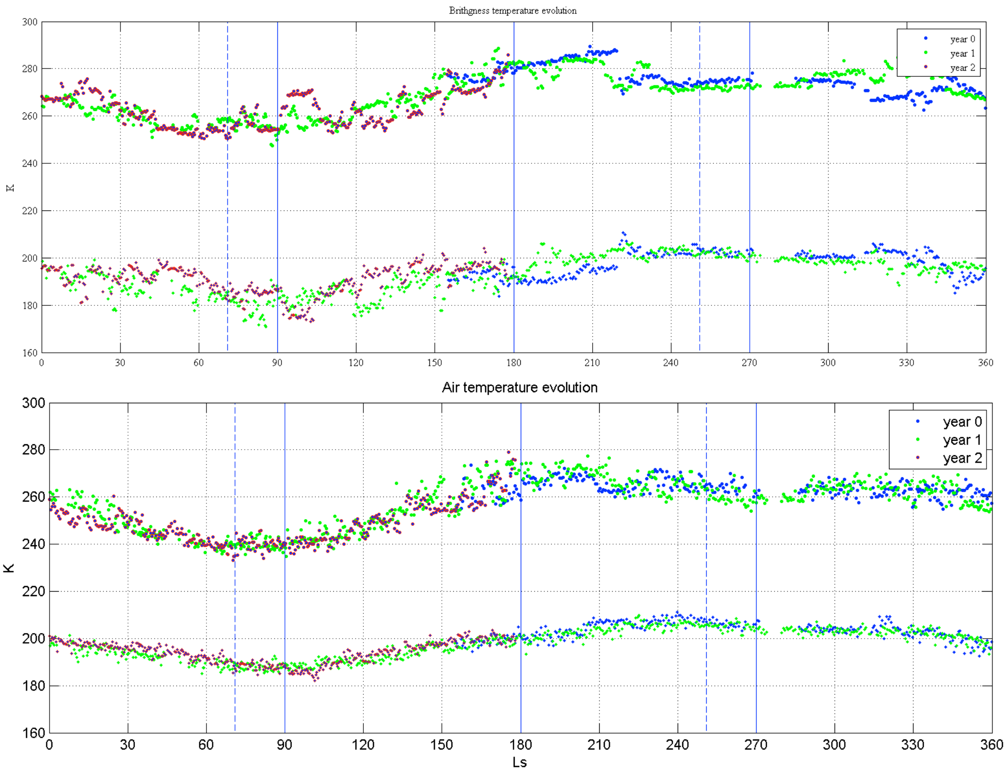

Figure 3. Ground brightness temperature (top) and air temperature (bottom). The Ground Temperature and Air Temperature sensors are quite dependent of the noise generated by the conditioning electronics, mainly during night. To mitigate this issue the values have been fitted by a Fourier serie of 8 terms and with a 1 sol period. The maximum and minimum values shown in the graphics correspond to those of the fitting curve.

Ground Brightness Temperature

The ground brightness temperature evolution is shown in Figure 3, and a number of features can be observed on it: i) maximum temperature has a narrow range of variations, from circa 250 to 290 K; ii) similarly for the minimum spanning from 170 to 210 K; iii) the second part of the year, spring and summer, maximum and minimum are quite stable; iv) the oscillations (not seen in air data) are driven by the soil materials and their thermal inertia (Hamilton 2014, Martinez 2014), and v) the surface type determines the difference between maximum and minimum.

The mean temperatures are totally dominated by the planetary cycle and the first mode (daily cycle) determines maximum and minimum values. The ground conditions produce oscillations around those

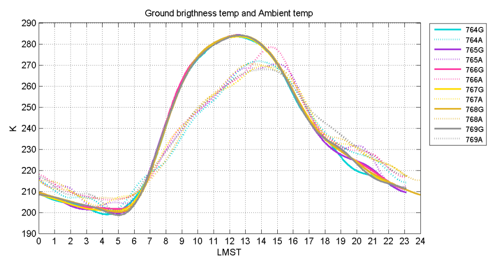

Figure 4. Typical evolution along several sols of ground and air temperatures (MSL kept its position in this period). Typically the maximum temperatures of ground and air are shifted by 2 hours and usually the air minimum is higher than the ground one.

variation of maximum and minimum temperatures, and the rest of the Mars year.

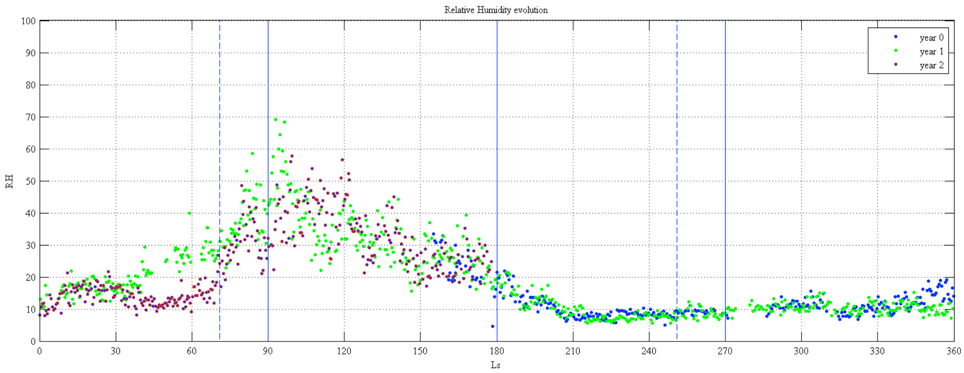

Figure 5. Humidity relative data .At each reading period, the data after the 3 first seconds is taken as representative for the full period. After that there is a self heating of the sensor and the values are not so reliable.

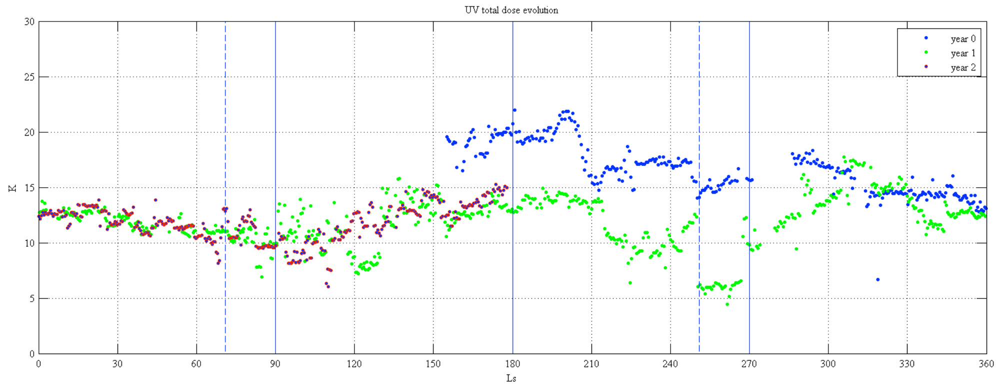

Figure 6. Ultraviolet total dose maximum readings. The dots values in the plot are the maximum reading each sol without any correction. This representation could be misleading because in many sols the UV field-of-view is blocked by the rover arm manipulator and unfortunately happen in most of the cases at the time of maximum irradiation, or is affected by the RSM shadow. Nevertheless, we believe that is enough to have a picture of the global evolution.

The curves show a high degree of repeatability, in global terms. The two years have a similar pattern. Maximum temperatures in the second half of the year are relatively high, circa 260 K. The minimum temperatures of the year correspond to the end of autumn. Minimum temperatures have lower variations than the maximum because the electronic noise is quite high under these conditions and the fit takes medium values.

Relative humidity

Relative humidity(Harri 2014) shows two periods too. Nevertheless, it needs to be considered that there is a correlation between relative humidity and air temperatures. At low temperatures, the capability of the Mars atmosphere to absorb water is small and that causes those high values in the first part of the year.

All the variability of data duringthe first part of the year and the difference between year 1 and 2 are in line with the GT Sensor during the same period of time. Ground temperatures in year 1 were lower than in year 2, and all is related with the different type of soils that MSL goes over.

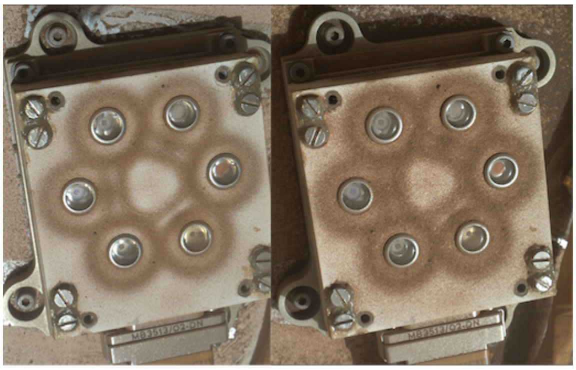

Figure 7. Images taken by MALHI on sols 660 (left) and 1041 (right). Independently of the different lighting conditions, it is clear that the amount of dust accumulated is growing with time. (Credit: NASA/JPL-Caltech/MSSSW)

Ultraviolet Radiation

The REMS UV sensor has 6 photodiodes [Gómez-Elvira, 2012]: total dose, UVA,B,C,D and E. It is located on the rover deck, close to the SAM inlet and exposed to dust deposition. In fact, several episodes of sensor cleaning have been detected during these two years. Figure 6 show the evolution of total dose without applying any correction factor. As in previous cases there is a clear difference in the curves: in the two first seasons there is a similar evolution in the first and second year, and in the other seasons the UV variation is large (episodes of dust deposition and cleaning too) due to the dust content of the atmosphere (Mason, 2017).

Wind

Due to damage that possibly occurred during landing landing the wind sensor has had its capabilities reduced, with only the front-facing wind sensor boom able to be used. Winds approaching from the hemisphere to the rear of the rover are strongly perturbed by the remote sensing mast before they reach this boom. Winds are thus placed into two groups: those coming from the 'rear' of the rover, and those coming from the rover's 'front.' For rear winds it is only possible to identify whether wind comes from over the left or right 'shoulder' of the rover, and no wind speed is retrieved. In the case of front winds, both speed and more accurate directions are retrieved.

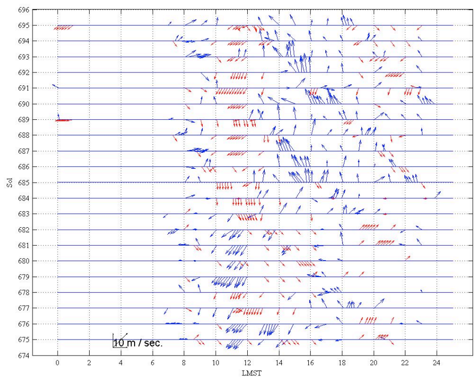

Figure 8. A summary of wind sensor results for sols 675 to 695 (month 6 of year 1). Red arrows indicate that most winds in each 5 minute period came from the rear of the rover and show only wind direction (with an error of +/-45°) with no information about speed. Blue arrows indicate that the dominant winds came from the hemisphere to the front of the rover, and indicate wind direction (statistically, the mode over the 5 minute period) and speed. The lack of information during cold periods (overnight) is due to electronic noise of the conditioning electronics that makes the sensor signal unusable.

Figure 8 shows the dominant wind vectors in 5 minute periods over 21 sols. Red arrows indicate rear winds and blue front winds. Since landing, MSL has faced ~SW/S/SSE in the majority of sols, including sols 683-695 in Figure 8. Midday winds were generally from ~N at this point in the mission, hence they appear as red arrows (indicating 'rear' winds) in these sols, with the arrows turning blue in the afternoon as the wind changes to come from ~S. However, in sols 675-the rover faced between ~NE and SE, allowing the wind speed and a more accurate wind direction to be retrieved for winds at this time of day

Once the rover has entered in the area closer to Mount Sharp, the terrain is more abrupt and apparently it has more influence in the local wind directions that measure the sensor. Newman et al. (2017) shows that winds measured during the Bagnold Dunes campaign, the first *in situ* measurement of winds in an active dune field on another planet, are consistent with mesoscale model predictions of a strongly daytime upslope / nighttime downslope flow on the slopes of Mount Sharp around local (southern) summer solstice. Wind speed has a typical Weibull distribution with an evolution from seasons as reported by Viúdez-Moreiras (2017) in another abstract of this workshop

Conclusions

REMS sensors have been recording the variations of the main Martian atmosphere parameters for two (Martian) years, since the beginning of Mars Science Laboratory mission. In these two years a a strong interannual repeatability is observed, with a "calmer" first half of the year and a second half in which the atmosphere appears to be more active.

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