Observations and Simulations of Martian weather, a perspective with data from MSL curiosity.

Iñaki Ordonez-Etxeberria *(inaki.ordonez@ehu.es),* **Ricardo Hueso, Agustín Sánchez-Lavega**.
Dpto. de Física Aplicada I, Escuela de Ingeniería de Bilbao, Universidad del País Vasco, Plaza Ingeniero Torres Quevedo, 1, 48013, Bilbao, Spain.

Introduction:

Since the beginning of the exploration of Mars, there have been several missions that carried meteorological instruments in order to measure the Martian weather and define its climate. In-situ measurements of pressure and temperature on the surface of Mars have been obtained by the two Viking Landers (VL), the Mars Pathfinder Lander, the Phoenix Mars Lander and the Mars Science Laboratory (MSL) rover, and recently compared (Martinez et al., 2016). This mission landed in Mars in the Gale crater at 4.5º S and has been compiling meteorological data for more than 2 Martian years with the REMS (Rover Environmental Monitoring Station) instrument (Gómez-Elvira et al., 2012).

On the other hand, different General Circulation Models (GCM) adapted or fully developed for Mars allow predicting and simulating the weather conditions, including the meteorology of the landing points of each surface mission. One of these GCMs allows retrieving atmospheric data for particular conditions from a dedicated website: The Mars Climate Database MCD (Millour et al., 2015; see: http://www-mars.lmd.jussieu.fr/mcd_python/). In this work, we compare results from this model with observations of air temperature and pressure made by the REMS instrument and other landers at a variety of positions and seasons over Mars.

REMS data

REMS carries several meteorological sensors, among them the Pressure Sensor (PS) and the Air Temperature Sensor (ATS) instruments sample these variable with a cadence of 1 second over different observing runs of 5 min. to 1 hour (Gómez-Elvira et al., 2012). Early publications of REMS data showed the seasonal behavior of the atmospheric pressure subject to the CO2 annual cycle of sublimation/condensation in the polar caps (Harri et al., 2014), periodic atmospheric tides of global and local scales (Guzewich et al., 2016), and events of fast drops of pressure of about 1 Pa of a few seconds, generally interpreted as the local effect of a passing warm convective vortex or dust devils (Gómez-Elvira et al., 2014; Harri et al. 2014; Steakley and Murphy, 2016; Kahanpää et al., 2016; Ordonez-Etxeberria et al., 2016).

Comparative of pressure and temperature:

We compared the pressure response from REMS data over 2 Martian years with the results from the MCD model for a standard year (Figure 1). The MCD model and REMS data agree on the magnitude of pressure and its seasonal and daily evolution. There a few particular epochs where mismatches between the model and the measurement are bigger. Close to sol 300, during summer time, there is a larger daily variation of pressure in the REMS data than that produced by the MCD model. This pattern repeats again in the REMS data over the second year. Other differences between the measurements and the model occur during winter, when the maximum daily pressure values observed are systematically higher than those produced by the MCD model.

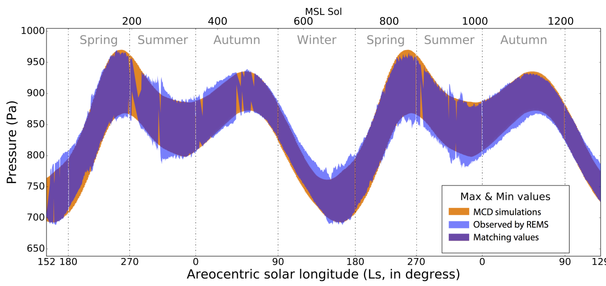

Figure 1: Comparison between REMS pressure observations obtained during two Martian years and simulated pressure from the MCD model for the location of the Gale crater.

Figure 2 shows the comparison of observed and modeled air temperatures. Data from the ATS sensor show a smaller daily variation than results from the MCD model. A possible interpretation of this difference is that the low resolution albedo map used by the MCD may result in smaller heating over the day and larger temperature variations from the model.

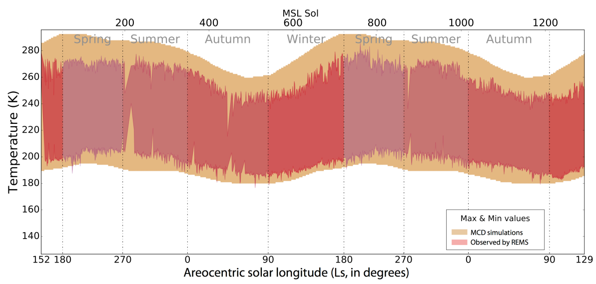

Figure 2: Same as figure 1, using air temperature.

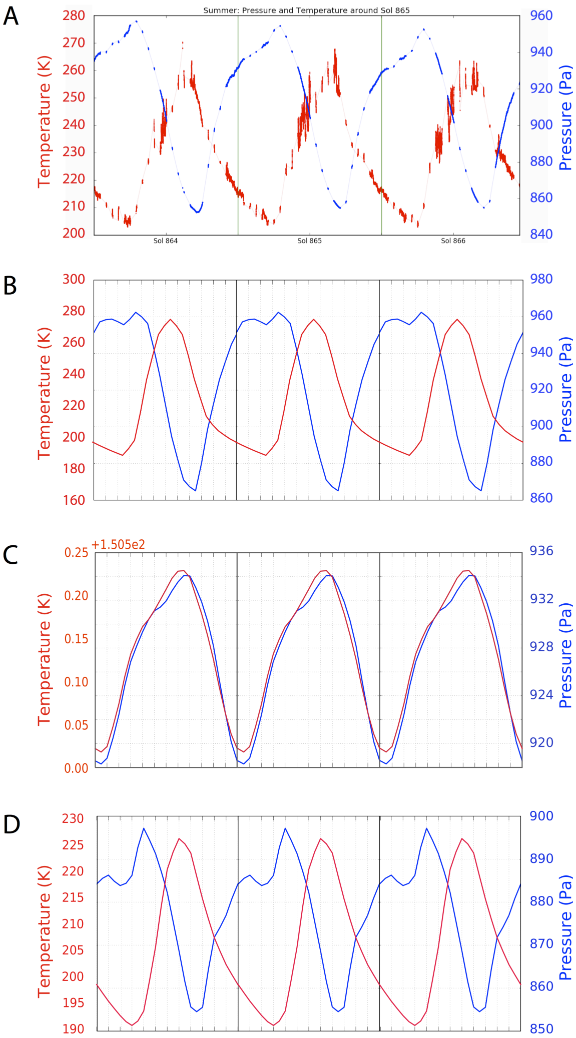

Figure 3: Comparison of diurnal pressure and air temperature response for three consecutive sols (from 864 to 866, Ls 270º). Panel A corresponds to in situ observations from REMS ATS and PS sensors. Panel B is the result, for the same sols and place as panel A, from the MCD model. C and D correspond to the MCD response to the same sols in Phoenix and Mars Pathfinder locations respectively.

Figure 3 presents a comparison o the diurnal cycles of pressure and temperature during the transition from Spring to Summer at the winter solstice in the north hemisphere at solar longitude 270º. The observed signal from REMS and the result from the MCD model, for the same Ls, at the landing points of MSL show reasonable agreement but fine scale variations show relevant differences in both fields. The daily temperature variation of 60 K observed in REMS data is caused by the local insolation cycle which also affects the pressure through the global solar tide. Panels C and D show the results of pressure and temperature over the same set of sols but for the location of the Mars Phoenix Lander (68º N, 125º W) and Mars Pathfinder (19.3º N, 35.6º W). A systematic comparison of MCD simulations and data from those missions is under way, although Mars Pathfinder only obtained meteorological data for 83 sols and Mars Pathfinder for 151 sols. A systematic comparison with the much longer signal recorded by the Vikings Landers (2245 sols for VL1 and 1050 sols for VL2) is also underway.

Sudden pressure drops on Gale crater:

We have also run a systematic search of sudden pressure drops over the REMS data analyzing the first 1293 sols (Ordonez-Etxeberria et al., submitted). Here we summarize the main results from that study. About 1 diurnal pressure drop per sol are found in the REMS data with a clear seasonal evolution and higher number of events in Spring and Summer. They are concentrated at local hours close to noon, when the thermal difference between the warm ground and the air is large. Interannual variability is also found. Additionally, unexpected nocturnal events of sudden pressure drops similar to those found during the diurnal hours were found. These events cannot be warm convective vortices and their origin must be linked to atmospheric turbulence caused by the local topography and the global circulation. These nocturnal pressure drops are highly concentrated in Spring and Summer which provides an important hint to study their origin.

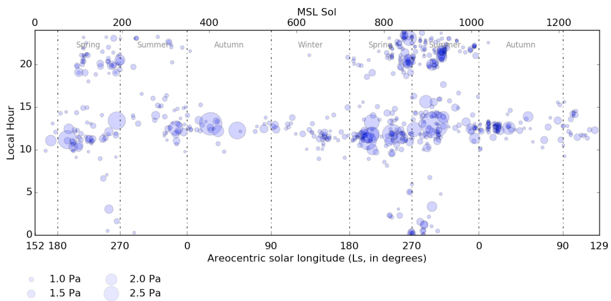

Figure 4: Distribution of pressure drops (nocturnal and diurnal) during the first 1293 sols, depending on the local time. The size of the balloons indicates the intensity of each event. A strong seasonality of the nocturnal can be observed during Spring and Summer seasons.

We interpret this seasonality as a consequence of the nocturnal circulation inside Gale crater during Spring and Summer. Detailed simulations with the MRAMS model (Rafkin et al., 2001) show that Summer at Gale crater is an unique season with a different global circulation (Pla-Garcia et al., 2016; Rafkin et al., 2016). Surface winds are affected by a combination of motions at different scales. The hemispheric dichotomy between the northern and southern hemispheres plays an important role at Gale crater situated in the limit between the South hemisphere high-lands and the North hemisphere low-lands. During the diurnal hours the dominating flow goes from North to South and reverses at night. However, the global Hadley cell circulation at Summer competes with this flow producing an overriding flow from the North that brings cold wind inside the crater. The competition between both flow patterns results in higher levels of surface turbulence during night.

Conclusions:

- The REMS data is one of the most extensive records of atmospheric data on the Mars surface. A comparison of this data with data gathered by previous space missions at other locations allows to better address the global meteorology at the surface of the planet. Together, those spacecraft measurements constitute a ground-truth that General Circulation Models of Mars should aim to reproduce.
- REMS data is globally well reproduced by the GCM of the LMD institute. However, REMS data and results from the MCD show some interesting differences that may allow improving the model or understanding the key features producing these differences (local surface albedo, small scale circulation, role of the Planetary Boundary Layer, etc…).
- The particular sols in which REMS and MCD data show mismatches could correspond to special local events such as a dust storm passing close-by or the effects of short-term atmospheric instabilities. This systematic comparison provides, therefore, an excellent tool to find these unexpected environment events.

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