DIURNAL VARIATIONS IN ATMOSPHERIC OPACITY AT GALE CRATER, MARS. A. Vicente-Retortillo[1,2], G. M. Martínez[3,2], M. T. Lemmon[4], N.O. Renno[2] and J. A. Rodríguez-Manfredi[1], [1]Centro de Astrobiología (CSIC-INTA), Torrejón de Ardoz, Spain (adevicente@cab.inta-csic.es), [2]University of Michigan, Ann Arbor, MI, USA, [3]Lunar and Planetary Institute, Universities Space Research Association, Houston, TX, USA, [4]Space Science Institute, College Station, TX, USA.

Introduction: Dust aerosols exert an important influence on the thermodynamic processes that take place in the Martian atmosphere [1,2]. In addition, atmospheric dynamics control the spatial and temporal evolution of suspended dust abundance [3]. The analysis of intrasol variations in the amount of suspended dust can shed light into dust lifting, transport and settling processes. This knowledge is important to improve numerical models and to better understand the Martian atmosphere.

Atmospheric opacity has been measured by the Mars Science Laboratory mission using Mastcam and Navcam images, and REMS UV measurements. Mastcam images of the Sun are typically acquired every few sols, allowing the study of seasonal and interannual variations [4]. In addition, sol-to-sol variations in atmospheric opacity have been studied with the REMS UV sensor, showing an excellent agreement with Mastcam opacities [5]. Navcam and some Mastcam images are acquired with an elevation angle of few degrees with respect to the site, allowing the determination of the line-of-sight extinction within Gale Crater. Interestingly, the analysis of more than 100 line-of-sight images during the first 2556 sols of the mission showed morning/afternoon variations in the extinction [6,7].

Here we examine REMS measurements aiming to show and discuss temporal variations in atmospheric opacity on timescales shorter than one sol. REMS performs measurements every hour during the first five minutes, complemented with extended measurement sessions of one hour.

REMS UV measurements: The Rover Environmental Monitoring Station includes a sensor that measures ultraviolet radiation in six different bands between 200 and 380 nm [8].

REMS UV measurements depend on several factors:
- Solar zenith angle [5,9].
- Solar azimuth angle [9].
- The field of view, which is affected by the presence of rover elements (mainly the mast and masthead of the rover) [10] and by the geometry adopted in the construction of the sensor [8].
- Rover tilt and orientation.

- The amount of dust deposited on the window of the photodiodes [9,11].
- Temperature, which can affect the spectral response of the sensor.
- The position of the robotic arm.

These factors introduce notable difficulties in the analysis of intrasol variations in atmospheric opacities, as shown in Fig. 1.
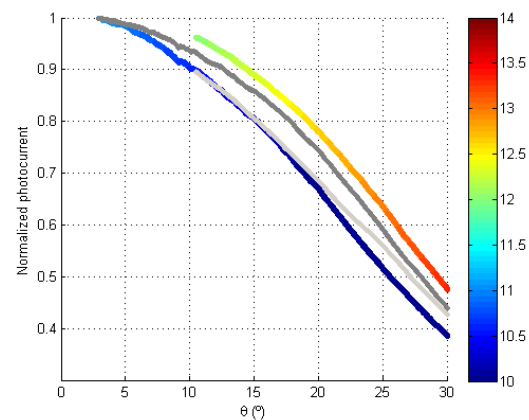

Figure 1. Normalized photocurrents of the UVABC (colored indicating LMST) and UVE (dark (AM) and light (PM) gray) channels as a function of solar zenith angle on sol 91. Measurements of both channels show different behavior due to the factors mentioned before.

Figure 1 shows the measurements of two REMS UV channels (UVABC, colored as a function of Local Mean Solar Time, and UVE, in dark (AM) and light (PM) gray) on sol 91 of the MSL mission as a function of the solar zenith angle relative to the rover frame. UVE values are higher during the morning, whereas UVABC values are higher in the afternoon; in addition, AM/PM differences are relatively small for the UVE channel and decrease as the solar zenith angle approaches 30º, whereas UVABC AM/PM differences are larger and their relative difference increases as the solar zenith angle increases. These different behaviors are caused by some of the factors listed before (mainly angular, but also temperature responses), which are different for each channel [9], and which need to be disentangled to determine diurnal variations in atmospheric opacity as measured from the REMS UV sensor.

Methodology: The methodology to analyze diurnal variations in dust opacity can be summarized in the following steps. First, we use a Monte-Carlo radiative

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transfer model [10] to calculate he radiance as a function of atmospheric opacity. Then, we simulate the photocurrent applying empirical functions that simulate the effects of the angular response [9], of the masthead and mast of the rover [10], dust deposition [9,11], and of the remaining factors. Therefore, the comparison of measurements within a given sol requires an accurate knowledge of those factors.

A case study: sols 91-100: The effects of the factors enumerated before are minimized when comparing measurements at the same time of the sol performed on sols with the same rover position.

In this study we focus on sols 60 to 100, when the rover remained still at Rocknest. In particular, we analyze the end of this period, when an increase in opacity from 0.6 to 1.2 was observed between sols 91 and 100 [5].

Table 1 compares the UV measurements at 11 LMST on sol 91 with its counterparts on sols 94, 99 and 100 for the six UV channels. The evolution of the ratios is virtually identical for the six channels, indicating the high reliability of these measurements.

Channel\Sol	94 (0.67)	99 (1.03)	100 (1.20)
UVA	0.988	0.808	0.766
UVB	0.987	0.802	0.756
UVC	0.985	0.801	0.756
UVD	0.989	0.802	0.755
UVE	0.990	0.811	0.769
UVABC	0.991	0.811	0.768

Table 1. Ratio between UV measurements at 11 LMST on selected sols and those on sol 91. The values in parenthesis indicate the atmospheric opacity [5].

Figure 2 shows the ratio between the UV measurements on the selected sols (94, 99 and 100) and a reference value calculated as the mean between sols 88 and 93. The values at 9-11 LMST show the significant increase in opacity between sols 94 and 100.

Hourly values suggest particularly high opacity values (corresponding to low normalized UV values) at 6 LMST on sol 99: radiation was even smaller than on sol 100, when the opacity around noon was significantly higher than on sol 99. The analysis of hourly REMS UV values can potentially allow the identification of variations in opacity that could not be recorded in previous studies.

The ratio increases during the morning. This behavior is expected, since the ratio between measurements on two sols with higher opacity during the second sol increases with solar zenith angle. However, we observe that the increase on sol 99 was larger than on sol 100. This suggests that at least part of the change within each sol is caused by variations of opacity in intrasol time scales.
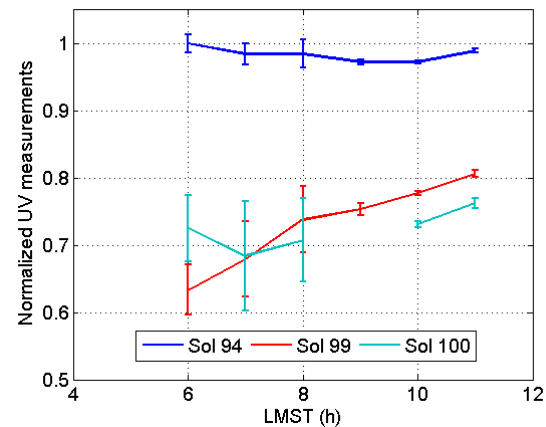

Figure 2. Ratio between the UV measurements on sols 94, 99 and 100, and the hourly mean value of sols 88-93. The values and the error bars represent the mean and standard deviations of the ratios calculated with the six channels.

These results suggest that opacities in the early morning during periods of enhanced dust opacity might be higher than at noon. This would support the behavior of opacity during the MY 34 Global Dust Storm observed with Mastcam and Navcam, when morning values were higher than in the afternoon [6].

In a future work we plan to study intrasol variations in atmospheric opacity throughout the MSL mission by applying the approach described in the methodology (and the approach followed in the case study when possible), and to further analyze the frequency and amplitude of these variations.

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