ATMOSPHERIC THERMAL FORCING AT GALE CRATER, MARS.

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Introduction: The atmospheric thermal forcing (LW↓) is one of the terms comprising the surface energy budget on Mars (Fig. 1). This term depends on the vertical profile of temperature, which, in turn, depends on the vertical distribution of dust and water ice aerosols, and of CO_2 and H_2O molecules [1].

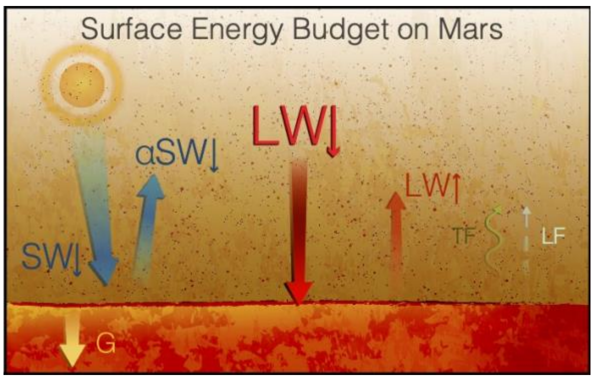

Figure 1*. Schematic of the surface energy balance on Mars, where G represents the ground heat flux, SW↓ the downwelling solar radiation flux, αSW↓ the reflected solar radiation, where α is the Lambertian surface albedo, LW↓ the downwelling thermal atmospheric radiation, LW↑ the upwelling thermal radiation flux emitted by the surface, TF the sensible heat flux, and LF the latent heat flux. The arrows are not to scale.*

Although LW↓ is typically one order magnitude lower than the primary, solar forcing (an exception to this occurred during the global dust storm in Martian Year (MY) 34), its variations at different timescales provide important information about changes in atmospheric temperatures and in the column abundances, vertical profiles and optical properties of dust and water ice aerosols [2–4].

Due to the lack of direct ground-based measurements on Mars, LW↓ has typically been obtained using numerical models [3]. More recently, this term has been indirectly obtained from interannual to diurnal timescales using measurements from the Mars Science Laboratory (MSL) mission [4].

Objective: Here we continue the study presented in [4] and discuss the diurnal variability of LW↓ through sol 2500 of the MSL mission in light of potential processes causing such variability.

Atmospheric Thermal Forcing at Gale: The interannual and seasonal variability of the optical depth and daily maximum LW↓ is shown in the top and middle panels of Fig. 2, while the diurnal variability of LW↓ is shown in the bottom panel.

To a first approximation, changes in atmospheric dust opacity govern interannual and seasonal variations in LW↓, in agreement with results from numerical models [3–4]. Surprisingly, the diurnal variation in LW↓ shows two local maxima, the first in the 7–10 LMST period and the second in the 15–19 LMST period, while previous modeling efforts predicted only the 15–19 LMST peak [3,5].

Even though LW↓ values between 7 and 10 LMST present large uncertainties ranging between ~20 and 100% depending on solar longitude (Ls) [4], the 'am' peak stands for most of the analyzed sols regardless of the season and MY. This increases the confidence that it can actually occur.

Discussion on the diurnal variability in LW↓: We hypothesize that the 7–10 LMST peak could be caused by enhanced dust opacity near the surface occurring in the morning. Three independent investigations provide indirect evidence supporting this hypothesis.

First, it has been found that Ls ~270° is the time of the year with the highest amount of dust inside Gale crater as measured by line-of-sight-extinction measurements from the Curiosity's navigation cameras [6]. This is interesting, as the daily maximum LW↓ occurs mostly between 15–19 LMST throughout the year except near Ls ~270°, when it occurs between 7–10 LMST (see empty triangles in the middle panel of Fig. 2).

Second, preliminary analyses of UV fluxes measured by MSL suggest intrasol variations in atmospheric opacity, with largest values occurring in the early morning [7]. Moreover, 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 [8].

Third, different models have been used to simulate MSL-measured ground temperature, all of them resulting in slightly too cold values in the morning [9–11]. Since these models do not predict the 'am' diurnal peak in LW↓, it is plausible that underestimated simulated values of the net energy flux into the ground between 7 and 10 LMST cause the mismatch between models and measurements.

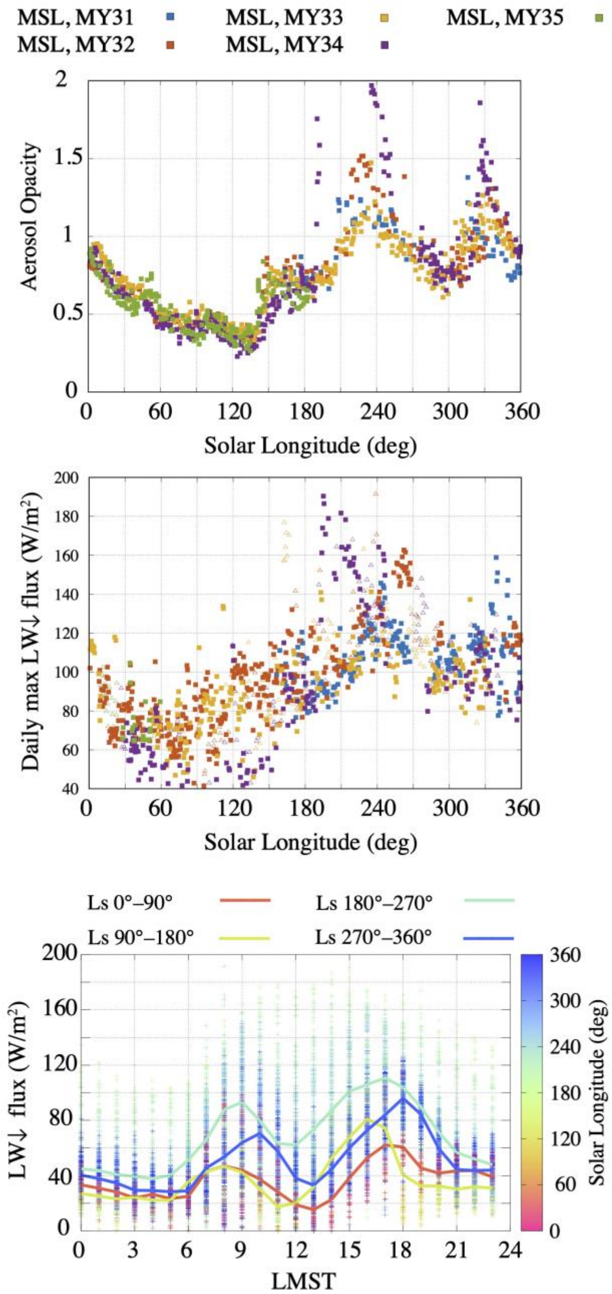

***Figure 2. (Top and Middle)** Evolution of the optical depth and daily maximum LW↓ as a function of season and MY. The y-axis ranges in the top panel varies only between 0 and 2 to magnify dust variation outside the global dust storm in MY 34. The daily maximum LW↓ typically occurs in the 7–10 (empty triangles) or 15–19 (solid squares) LMST period. **(Bottom)** Diurnal variation of LW↓ as a function of LMST using color code for Ls. For reference, the thick, colored lines represent seasonal hourly averages LW↓ flux.*

Ongoing Work: We are testing the hypothesis that the 7–10 LMST peak could be caused by enhanced dust opacity near the surface by following two independent approaches. First, we are analyzing diurnal variations in dust opacity at Gale crater using UV measurements [7]. Second, we are performing numerical simulations using the University of Helsinki/Finnish Meteorological Institute 1D model [3] with the twofold objective of improving the accuracy of simulated outputs (e.g., ground temperature or relative humidity), and validating aerosol radiative properties necessary to match solar and atmospheric thermal fluxes obtained in [4]. These analyses are important to better understand dust transport and settling processes, and to improve predictive capabilities of numerical models. Moreover, we plan to extend these comparisons with the Mars Weather Research and Forecasting model [12], MRAMS [13] and LMD mesoscale model [11].

Additionally, the Mars Environmental Dynamics Analyzer (MEDA) onboard the Mars 2020 mission [14] will directly measure the atmospheric thermal forcing for the first time on Mars using its Thermal Infrared Sensor (TIRS) [15]. We plan to compare results between both missions to shed light on the diurnal variation in LW↓ at both locations.

Acknowledgments: This research was supported by Jet Propulsion Laboratory grant number 1449038 and LPI/USRA 976 Subaward No. Subk00011877.

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