ALBEDO AND THERMAL INERTIA AT JEZERO CRATER DURING THE FIRST 350 SOLS OF THE MARS 2020 MISSION

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Introduction: We use measurements from the Mars Environmental Dynamics Analyzer (MEDA) instrument [1] to obtain albedo and thermal inertia (TI) during the first 350 sols of the Mars 2020 mission. MEDA is one of the seven scientific instruments onboard M2020 [2]. It includes six sensors measuring the environmental conditions at Jezero Crater, Mars (77.5945°E, 18.3628°N, -2656m).

MEDA's Thermal Infrared Sensor (TIRS) and Radiation and Dust Sensor (RDS) are providing novel measurements of radiative fluxes [3–4], allowing for the first in situ estimation of the net radiative balance on Mars [5]. These measurements include TIRS' downwelling atmospheric IR flux (6.5–30 μm), upwelling IR flux emitted by the surface (6.5–30 μm), surface-reflected solar flux (0.3–3 μm), and RDS' downwelling solar flux (0.2–1.2 μm).

Along with TIRS' ground temperature, these measurements allow the direct estimation of broadband albedo (0.3–3 μm) and TI at spatial scales of a few m^2 without the need for numerical models.

Environmental Context: MEDA's nominal measuring strategy consists of 1 Hz measurements taken during 1h-5min-long blocks starting at even/odd full hour local mean solar times (LMST) on even/odd sol numbers (Fig. 1).

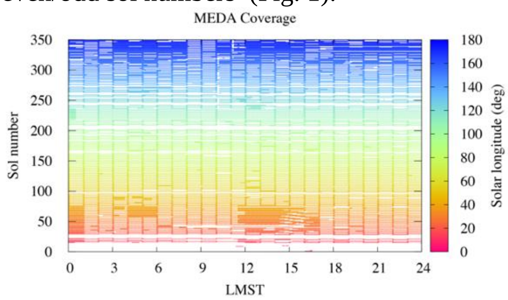

Figure 1. MEDA coverage during the first 350 sols of the M2020 mission.

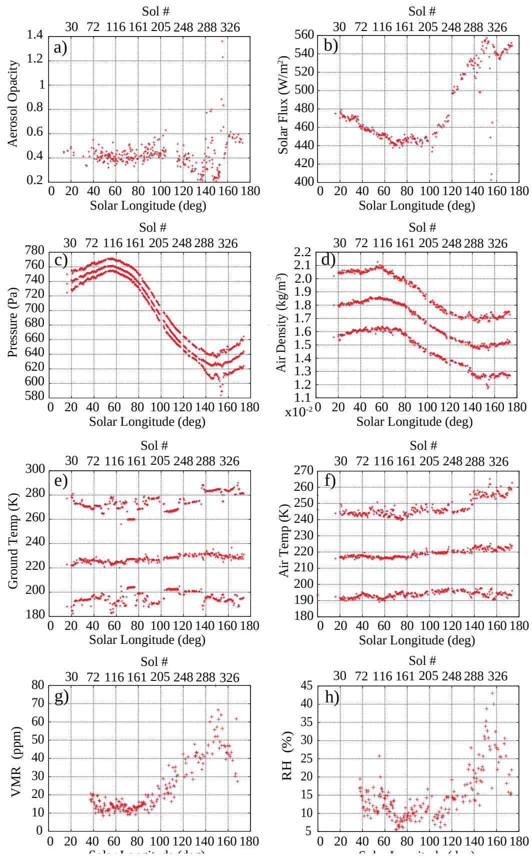

Figure 2. **(a)** Aerosol opacity at 880 nm; **(b)** Daily max downwelling solar flux (0.2–5 μm); **(c–d)** Daily max, mean and min atmospheric pressure and air density at 1.4 m; **(e–f)** Daily max, mean and min atmospheric air temperature at 1.4 m and ground temperature; **(g)** Daily max atmospheric relative humidity at 1.4 m; **(h)** Nighttime (04:00-06:00) water vapor VMR at 1.4 m. First 350 sols of the M2020 mission.

Fig. 2 shows the environmental conditions at Jezero Crater during the first 350 sols of the M2020 mission. This period covers most of the northern spring and summer, with solar longitudes (Ls) ranging from 5° to 175°.

Most notably, a regional dust storm hit Jezero Crater on sol 313 (Ls ~153°) and lasted for a few sols, strongly altering the environmental conditions.

Methodology to Obtain Albedo and TI: We obtain broadband albedo (0.3–3 μm) using TIRS' measurements of reflected solar flux (0.3–3 μm) and RDS' measurements of downwelling solar flux (0.2–1.2 μm). To convert RDS fluxes to TIRS' range, we use the radiative transfer model COMIMART [6]. Additionally, we correct for the effects of dust deposition on the RDS' upward looking channels, which on average decreased measured fluxes by ~5% prior to the dust storm.

We obtain thermal inertia by solving the heat conduction equation for homogeneous terrains using MEDA measurements of the surface energy budget as the upper boundary condition (Fig. 3). For each sol when the rover was parked, we obtain TI by minimizing the difference between measured and numerically simulated values of the diurnal amplitude of ground temperature (Fig. 4).

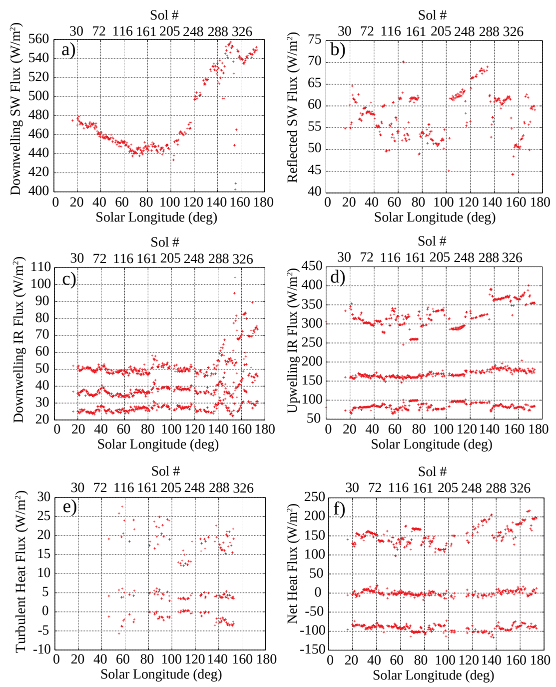

Figure 3. Surface energy budget across the first 350 sols of the Mars 2020 mission. **(a–b)** Daily max downwelling and surface-reflected solar flux (0.2–5 μm); **(c–d)** Daily max, mean and min downwelling atmospheric IR flux, and upwelling IR flux emitted by the surface (6–80 μm); **(e)** Daily max, mean and min turbulent heat flux; **(f)** Daily max mean and min net heat flux into the ground.

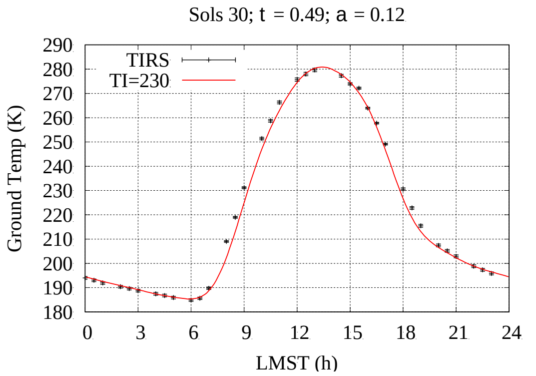

Figure 4. Ground temperature on sol 30 as measured by TIRS (black) and as obtained by solving the heat conduction equation for homogeneous terrains using MEDA measurements of the surface energy budget as the upper boundary condition (red curve). TI = 230 $Jm^{-2}K^{-1}s^{-1/2}$ (tiu) provides the best match.

Shortwave and longwave radiative fluxes in Fig. 3 are measured by TIRS and RDS, while the turbulent heat flux is derived using wind speed, pressure, and air and ground temperature measurements in combination with similarity theory [5].

We note that the field of view (FoV) of the two downward-looking TIRS channels, which measure ground temperature and reflected solar radiative flux, covers an area of a few m^2, but most of its signal comes from a smaller area corresponding to center of the FoV. This results in ground temperatures that, unlike for the Mars Science Laboratory Ground Temperature Sensor [5], adjust very well to homogeneous terrains (Fig. 4).

Albedo: Fig. 5 shows 5min-averaged values of broadband albedo (0.3-3 μm) for the first 350 sols of the M2020 mission as a function of LMST and rover's yaw (0° indicating North; 90° East; -90° West; and ±180° South). Only values when the solar zenith angle (SZA) is below 60° are included (SZA = 0° indicates local zenith), resulting in local mean solar times (LMST) between 07:00 and 17:00.

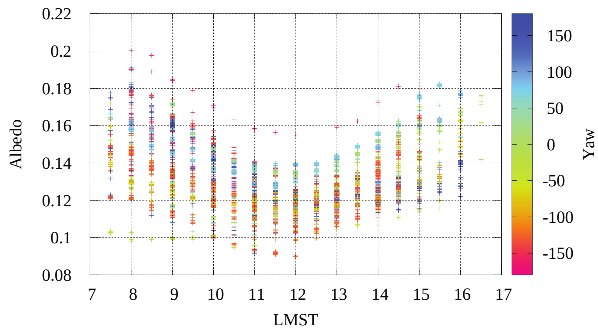

Figure 5. Albedo values measured by MEDA for the first 350 sols of the mission as a function of LMST and rover's yaw (color bar). We note that TIRS' FoV is pointed +75° with respect to the rover's yaw.

Regardless of the rover pointing and type of terrain, the albedo shows a strong non-Lambertian behavior, with lowest values around local noon.

Fig. 6 shows near-noon (i.e., daily minimum) albedo values as a function of Ls and sol number, together with the TIRS' FoV for the sols with highest and one of the lowest albedos (sols 125 and 282). Interestingly, the regional dust storm which occurred between sols 313 and 319 (Ls~155°) decreased the albedo dramatically, producing the lowest measured albedos up to sol 350 (the rover was parked on sols 287–328). Dust lifting and sand transport occurred during the storm, and we are investigating the potential processes for such a decrease in albedo.

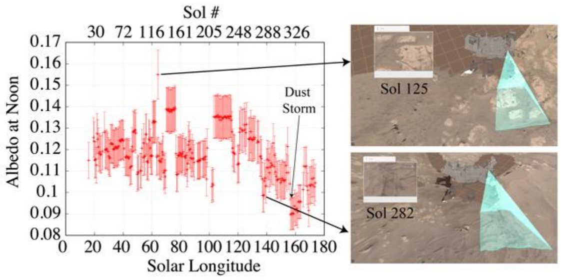

Figure 6. (Left) Near-noon albedo values for the first 350 sols of the M2020 mission. **(Right)** FoV of MEDA measurements of reflected solar flux corresponding to the terrains with the highest (sol 125) and one of the lowest (sol 282) albedo values. Note that the lowest albedo values were achieved on sols 319-323, right after the peak of the regional dust storm.

Comparison to satellite estimations: Lambertian values at Jezero in the 0.3–2.9 µm range retrieved from satellite by TES with a ~300 km^2 spatial resolution are ~0.15. These retrievals are made at 14:00 LTST (MGS was on a polar orbit). For comparison, MEDA-derived albedo values at 14:00 LMST are typically lower than 0.15 (see Fig. 5). This discrepancy is likely explained by the different spatial resolution between both datasets and the Lambertian assumption, and it is subject of ongoing investigations which also include OMEGA observations [7].

Thermal Inertia: Fig. 7 shows TI values across Perseverance's traverse only for sols when the rover was parked. TI values range between 200 and 630 tiu, with the lowest and largest TI values on sols 106 (sand) and 125 (bedrock), respectively.

On sols when the rover was parked in the same location (e.g., sols 138–152 or 211–237), MEDA-derived TI values typically vary less than ~5%, indicating that the method to obtain TI is robust.

Comparison to satellite estimations: Fig. 8 shows TI values derived from THEMIS (squares) and MEDA (circles). While THEMIS values range between 200 and 450 tiu, MEDA values are in the 200–630 tiu range. Departures between both data sets are likely caused by the different spatial resolution (10^4 m^2/px for THEMIS, and a few m^2 for MEDA).

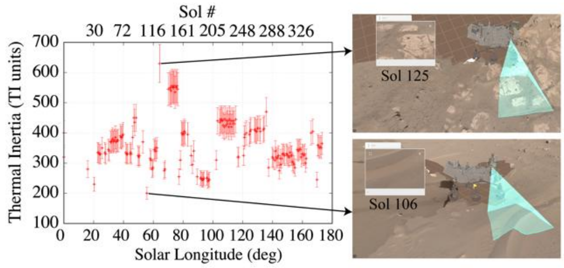

Figure 7. (Left) Thermal inertia values for the first 350 sols of the M2020 mission when the rover was parked for an entire sol. **(Right)** FoV of MEDA measurements of ground temperature on sols 106 and 125, corresponding to the terrains with the lowest and highest TI values.

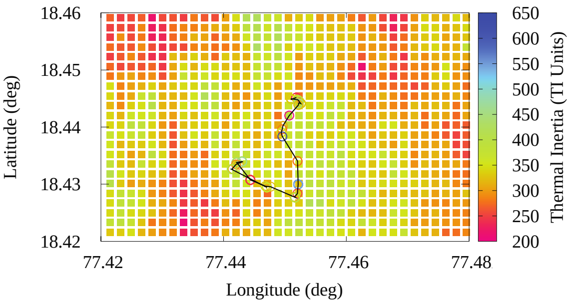

Figure 8. Thermal inertia map retrieved from THEMIS (squares) and MEDA (circles). The black line represents the rover's traverse for the first 350 sols.

Thermophysical Surface Units: Comparison of thermal inertia and albedo can provide insight into the characteristics of the surface materials, and it can be used to delineate and characterize different surface units.

Fig. 9 shows combined values of TI and albedo for the first 350 sols of the M2020 mission. In general, there is a positive correlation between both quantities, although there are clusters of points that deviate from this behavior (e.g., low albedo and medium TI). Interesting relationships among the values and surface materials are identified. These analyses are subject of ongoing investigations.

Summary and Conclusions: MEDA's novel measurements of the net radiative balance at the surface of Mars (Fig. 3) allow for the direct estimation of thermal inertia and broadband albedo across Perseverance's traverse.

Depending on the type of terrain, near-noon albedo values vary between 0.09 and 0.16 (Fig. 6), while thermal inertia varies between 200 and 630 tiu (Fig. 7).

Regardless of the type of terrain and rover geometry, the albedo shows a strong non-Lambertian behavior, (Fig. 5) with lowest values near noon when the solar zenith angle is lowest (sun closest to zenith).

Comparison of thermal inertia and albedo values derived from MEDA and satellites indicate significant departures likely caused by the different spatial resolution of both datasets (Fig. 8).

Analyses of correlations between thermal inertia and albedo values can be used to delineate different surface units (Fig. 9).

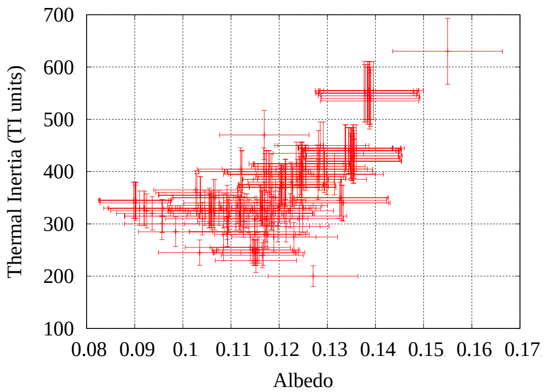

Figure 9. Thermal inertia and albedo during the first 350 sols of the M2020 mission.

References: [1] Rodriguez-Manfredi, José Antonio, et al. "The Mars Environmental Dynamics Analyzer, MEDA. A suite of environmental sensors for the Mars 2020 mission." *Space science reviews* 217.3 (2021): 1-86. **[2]** Farley, Kenneth A., et al. "Mars 2020 mission overview." *Space Science Reviews* 216.8 (2020): 1-41. **[3]** Sebastián, Eduardo, et al. "Radiometric and angular calibration tests for the MEDA-TIRS radiometer onboard NASA's Mars 2020 mission." *Measurement* 164 (2020): 107968. **[4]** Apestigue, Víctor, et al. "Radiation and Dust Sensor for Mars Environmental Dynamic Analyzer Onboard M2020 Rover." *Sensors* 2022, 22, 2907. **[5]** Martínez, G. M., et al. "The surface energy budget at Gale crater during the first 2500 sols of the Mars Science Laboratory mission." *Journal of Geophysical Research: Planets* 126.9 (2021): e2020JE006804. **[6]** Vicente-Retortillo, Álvaro, et al. "A model to calculate solar radiation fluxes on the Martian surface." *Journal of Space Weather and Space Climate* 5 (2015): A33. **[7]** Vincendon, Mathieu, et al. "Mars Express measurements of surface albedo changes over 2004–2010." *Icarus* 251 (2015): 145-163.