OVERVIEW OF NEAR-SURFACE ATMOSPHERIC PROCESSES AT JEZERO FROM MEDA OBSERVATIONS

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Introduction: Perseverance landed on Jezero with the most complete suite of environmental sensors sent to date to another planet. These sensors are on the Mars Environmental Dynamics Analyzer (MEDA), MastCam-Z, SuperCam spectrometers and, finally, several microphones [1,2,3]. MastCam-Z, the rover engineering cameras, and MEDA's SkyCam combined measure the dust opacity and physical aerosol properties on time scales from seconds to diurnal, seasonal, and annual. MEDA's atmospheric sensors characterize surface pressure, air temperature at three heights, surface temperature, night time relative humidity, wind speeds and directions, and radiative fluxes. This is a summary of MEDA observations to date.

Temperature cycle: While showing some response to surface temperature changes with location and the associated variations in thermal inertia, Fig. 1a shows that the air temperature has changed little as a function of Ls since landing [4], and its seasonal trend is more stable than other missions, similar to VL1's behavior.

MEDA shows in Fig 1b the ability to track the evolution of temperatures at four heights: the surface, 85 cm, 145 cm, and an atmospheric layer spanning from about rover height m to 200 m, with a contribution peak at 40 m day and night. This opens up the ability to measure the vertical distribution of the thermal signatures from dust devils, as well as the associated changes in buoyancy. This observation

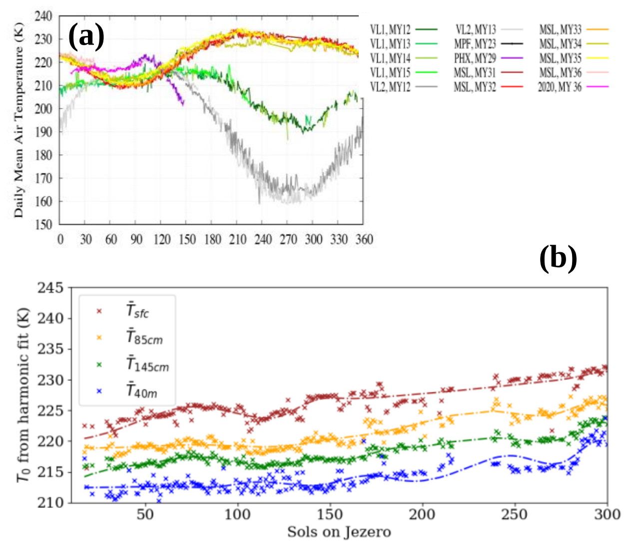

Figure 1. ***(a)*** *Average sol temperature for Viking Landers VL1, VL2, Mars Pathfinder MPF, Phoenix PHX, Curiosity MSL and M2020.* ***(b)*** *Evolution of MEDA daily average temperatures at 4 heights.*

helps identify the passage of convective plumes, when the density at low heights coincides with the density at 40 m, see Figure 2, and sometimes separate those above 40 m from lower ones. Following the time when the signal of convective plumes enables and its relation to dust events, allows to link convective cells to the passage of dust devils [5]. Figure 2 shows the density at several heights during the passage of a dust object.

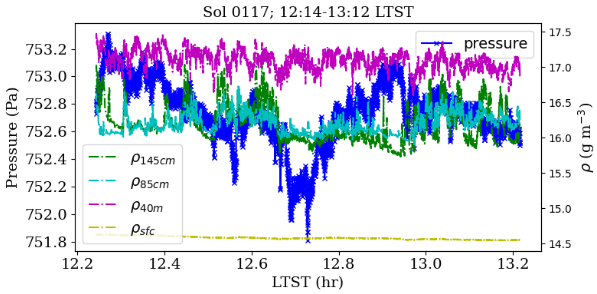

Figure 2. Air density estimates in g/m^3 at the surface (olive green), 85cm (blue), 145cm (green), and 40m (magenta) above the surface overlaid with surface pressure (blue symbols) during the passage of a pressure eddy drop. It shows the vertical signature of the passage of convective plumes vertical mixing and reduce the density differences from 40 m (green) to that at 145cm and 85cm (red).

Pressure cycle: The pressure cycle is following its seasonal pattern and some more focus has been set on the amplitude of pressure tides. They respond to changes in opacity (Fig. 3a) measured by the SkyCam, MCAM-Z and the engineering cameras. A first noticeable difference was the smaller amplitude of Jezero's diurnal tide when compared with Gale [6] or Viking [7,8], Fig. 3b. While the behavior at Jezero was reasonably well predicted by the models intercompared in [9], there are differences in the amplitude and especially the timing of the disruptions caused by dust storms, and also to the seasonal cycle of the polar cap sublimation and growth peaks.

Another visible difference appears in the comparison to the pressure cycle observed by Curiosity's Rover Environmental Monitoring Station (REMS) at Gale during the same period. This difference is largely due to the local characteristics of how the lateral hydrostatic adjustment to the topography interacts with the exchanges of air mass between the interior and exterior of the basin [10]. On Gale the amplitude of the diurnal pressure tide remained larger than the semidiurnal pressure tide. Both were slightly higher than that of MEDA, the diurnal had a different response to a dust storm near L_s~150º, and the convexity of the semidiurnal tide had opposite sign at Jezero than over Gale between L_s~30 and L_s~140º.

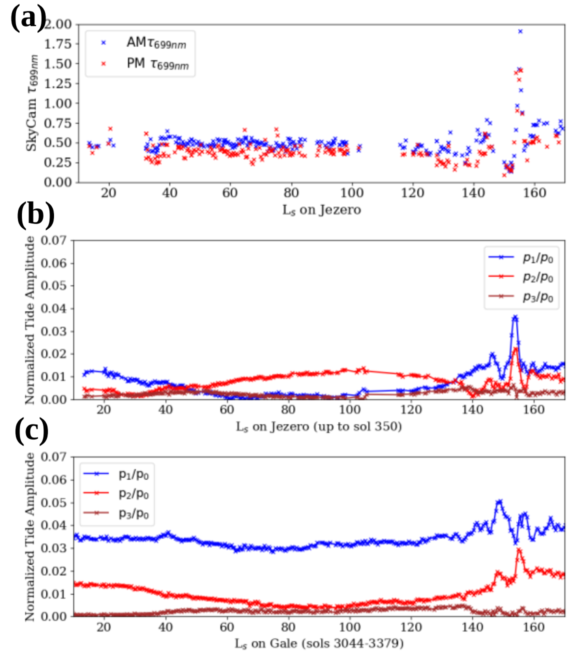

*Figure 3. Temporal evolution from L_s 10º to 170º for **(a)** Diurnal cycle of aerosol opacity at 699 nm before noon (blue) and after noon (red); **(b)** response of the normalized diurnal, semidiurnal, and terdiurnal tide to the dust cycle on Jezero; and **(c)** same pressure tide amplitudes at Gale.*

Aeolian Processes: MEDA wind observations [see 5] are consistent with the model predictions [8,11] that daytime and nighttime wind directions respond to different mechanisms. The most frequent wind orientation during daytime is consistent with the regional models of synoptic scale winds. At night the local Jezero slope topographic flows seem to dominate over the synoptic meteorology.

The two different wind regimes leave a different mark in the average wind speeds, shown in Figure 4, and the times when the wind is most unstable (top of Figure 4). During the daytime convective regime, that is between ~9 am LTST and ~15 LTST, wind speeds are intense and so are their standard deviations. However, the strongest winds appear in the evening transition, around 15 to 18 LTST, as the surface is cooling down. After a calm period of about 2 hours, new jets form and last from around 20 LTST to midnight and into the early hours of the new sol. These nighttime winds don't seem to generate as strong fluctuations as those driven by daytime convection.

Jezero's abundance of eddy pressure signatures and wind surges accompanied by dust lifting stands out from other Mars locations [11]. Jezero accumulates a high frequency of dust devils, and dust clouds rising and flying over the rover. This characteristic of Jezero is providing new aspects of the physical processes involved in active dust lifting.

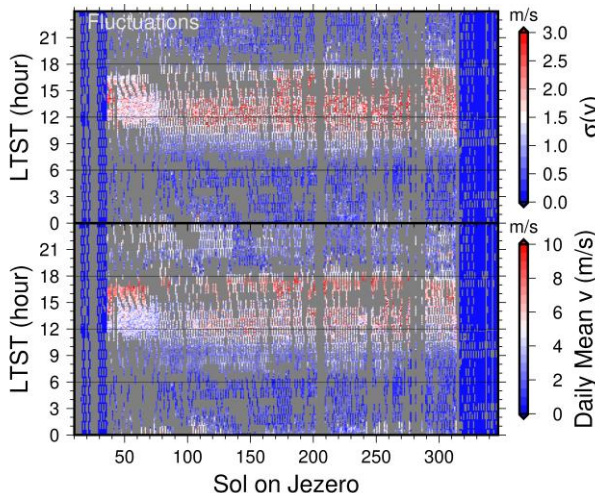

*Figure 4. **Top**: observed wind speed fluctuations, measured as standard deviation of wind speeds, and; **Bottom**: 5-minute averaged wind speeds marking different dynamical regimes in daytime and evening.*

Local hydrological cycle: The Local hydrological cycle combined with the radiation cycle are key components of astrobiological models for Mars, as well as processes that affect alteration and geochemistry. MEDA relative humidity measurements follow an approach that can be compared to similar sensors flown to other locations on Phoenix and Curiosity's REMS. SuperCAM adds information on total water column that can be compared to surface MEDA's observations. As of this writing Jezero appears as a drier location even under a higher water column content.

Another observation is a night time humidity cycle with several peaks that was not predicted [11] and could be related to wind transport of water or to exchanges with the surface. Understanding the potential reasons for this result requires a longer data record that enables to separate what are robust, long lasting effects that could be associated to latitude, altitude, or topography, and what may be seasonal effects. Therefore more constant monitoring is needed and key in helping constrain what mechanisms are more intense at Jezero than at Gale. Thus far, the lower nighttime relative humidity at Jezero for the same period raises the possibility of a more active diurnal exchange process between the atmosphere and the surface rather than this effect being purely seasonal or latitudinal influence.

Radiative cycle: The ability to regularly measure opacities several times every sol with the Radiation and Dust Sensor (RDS) is not only capturing the evolution of atmospheric opacity, but offers a color index that can separate ice from dust aerosols. It has unveiled that the morning hours meet a slightly more opaque atmosphere in the morning hours than in the afternoon since M2020 landed [figure 3a and reference 12]. The photodiodes on the RDS, covering from the UV into the near IR have found signatures of early morning clouds [13]. The Thermal Infrared Sensor (TIRS) has confirmed those as well and the Thermal Infrared signatures of the evolution and possible growth of night time clouds.

Additional, channels on the TIRS enable to measure in-situ the radiative energy balance at the surface, its albedo on a small scale, and provide ground validation to satellite measurements over Jezero.

Energy balance estimates combined with measurements of wind speeds and temperature profiles are also being used to infer the diurnal cycle of eddy heat fluxes. The turbulent parameters associated to this heat diffusivity are required to model the exchanges of heat between the surface and the atmosphere that force the local dynamics and transport near the surface.

Summary and Future Work: Jezero is reinforcing the different types of environments that one can find on Mars. It is exhibiting unique temperature and pressure cycles attributable to a combination of topographic and latitudinal effects. The ability to capture vertical temperature profiles is enabling for the first time to explore the vertical response of the atmosphere to passing eddies and how the boundary layer responds to different atmospheric dust loads. All of it on a region of Mars where we might land again in the future, thereby providing useful information for the engineering and design of future mission to Jezero. Being at a different location from InSight's and Curiosity, it forms a network of comparable atmospheric sensors that capture how the large-scale circulation simultaneously affects different parts of the red planet. A longer data record and the diverse sensors on MEDA is becoming useful to understand how the global circulation impacts the processes observed at different latitudes and longitudes.

Last, Perseverance's instruments inform the context of other instruments data, the rover engineering activities, and Ingenuity helicopter flight decisions. We hope that MEDA and Perseverance sensors enable novel measurements that we are only starting to discover, like now possible to measure the response of near-surface vertical temperature profiles to dust events, or to the full solar cycle, the cycles of net radiative balance at the surface, or more technical in-situ observations as ground truth for orbital instruments, like direct estimation of thermal inertia and broadband albedo across Perseverance's traverse, or the evolution of magnitudes relevant for Monin-Obukhov parameterizations.

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