DUST DEVILS AND CONVECTIVE VORTICES OBSERVED BY MARS 2020 PERSEVERANCE.

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Summary: An important and perhaps dominant source of dust in the martian atmosphere, dust devils play a key role in Mars' climate. Datasets from previous landed missions have revealed dust devil activity, constrained their structures, and elucidated their dust-lifting capacities. However, each landing site and observational season exhibits unique meteorological properties that shape dust devil activity and help illuminate their dependence on ambient conditions. The recent release of data from the Mars Environmental Dynamics Analyzer (MEDA) instrument suite onboard the Mars 2020 Perseverance rover promises a new treasure-trove for dust devil studies. In this study, we sift the time-series from MEDA's Pressure Sensor (PS) and Radiative and Dust Sensors (RDS) to look for the signals of passing vortices and dust devils. We detected 309 vortex encounters over the mission's first 89 sols. Consistent with predictions, these encounter rates exceed InSight and Curiosity's encounter rates. The RDS time-series also allows us to assess whether a passing vortex is likely to be dusty (and therefore is a true dust devil) or dustless. We find that about one quarter of vortices show signs of dust-lofting, although unfavorable encounter geometries may have prevented us from detecting dust for other vortices.

The present abstract provides a summary version of a study already accepted for publication to the "Planetary Science Journal" and posted here - https://arxiv.org/abs/2109.04601.

Introduction: The Mars 2020 Perseverance rover landed on 2021 February 18 (L_s = 5.6° -- http://www.tinyurl.com/MarsClock) at the Octavia E. Butler Landing site within Jezero Crater on Mars. The primary goals of the mission are to seek signs of extant and extinct life and collect rock and soil samples for a future return to Earth by acquiring imaging, spectroscopy, and other measurements to characterize Martian soils, rocks, atmosphere, and other aspects of the environment [1]. To address these goals, the rover carries seven scientific instruments, as well as a sample acquisition and caching system. These instruments involve the Mars Environmental Dynamics Analyzer (MEDA) suite including sensors to measure environmental variables air pressure and temperature (the pressure and temperature sensors, PS and ATS respectively) and up/downward-welling radiation and dust optical depth (via the Radiation and Dust Sensor RDS). This instrumentation enables, among other investigations, the exploration of aeolian processes [2].

Small-scale, dry, and dust-laden convective vortices, dust devils, act as a key if ephemeral aeolian transport mechanism on the surface of Mars, lofting a significant fraction of the dust in the martian atmosphere [3]. As a boundary layer phenomenon, convective vortices register in meteorological datasets as short-lived (few to tens of seconds), negative pressure (~1% of the ambient pressure) and positive temperature (few to several degrees K) excursions. If carrying dust (i.e., are true dust devils), the vortices can also register as positive or negative excursions in measured insolation [4]. The precise conditions that allow a dustless vortex to become a dust devil are not clear but likely depend on the availability of dust and the vortex wind speeds, and understanding the relationships between a vortex's pressure and wind profiles and its dust content is critical for accurately estimating the contribution of dust devils to the martian atmospheric dust budget, key to Mars' climate.

The initial release of data from Mars 2020's MEDA PS (pressure) and RDS (radiation and dust) instrument provide an opportunity to explore these relationships in a novel locale on Mars. In this study, we analyze the MEDA data from the Mars 2020 Perseverance mission released on 2021 Aug 20 to assess the rates of vortex and dust devil occurrence.

Methods: The analysis presented here closely follows that employed in [5]. For the present study, we analyzed pressure time-series from the PS instrument available from NASA PDS (https://pds-atmospheres.nmsu.edu/PDS/data/PDS4/Mars2020/mars2020_meda/), the data set labeled ``data_derived_env'' (see [2] for details). To recover vortices, we applied a matched filter with a Lorentzian profile to the pressure time-series, estimating the encounter's duration and depth ΔP. Then we turned to the RDS time-series and, for the time-spans when an encounter occurred, we estimated the largest fractional excursion against the local average $\max(F - \overline{F})/\overline{F}$ to assess the dust optical depth during each encounter. Fig. 1 shows representative pressure and RDS signals for one vortex with ΔP = 5.7 Pa. Panel (a) shows a negative pressure excursion, while (b) shows excursions in the amount of sunlight reaching the RDS sensors: some sensors saw decreases (from the dust devil's shadow), while others saw increases (reflection of sunlight by the dust).

Results: We detected 309 vortex encounters over the Mars 2020 mission's first 89 sols. As with previous studies the histogram of ΔP-values follows a power-law with an index of about -3 (i.e., a vortex with ΔP=0.5 Pa appears eight times as often as a vortex with ΔP=1 Pa). As shown in Fig. 2, about one quarter of the encounters showed statistically significant RDS

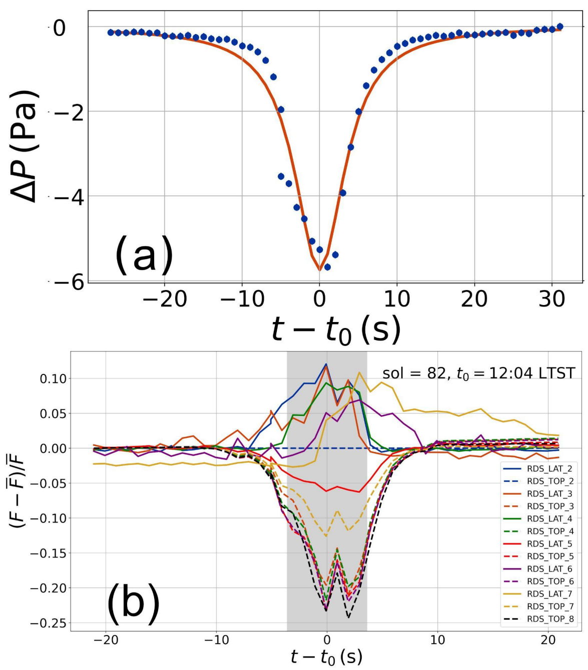

Fig 1. (a) A model fit (solid orange line) to the deepest vortex (blue dots) discovered on sol 82. (b) RDS time-series collected during the vortex encounter on sol 82 at 12:04 LTST. Each line reflects a specific RDS sensor.

excursions, consistent with lofted dust. Among those excursions, the average is about 2%, similar to results from a field study that monitored insolation excursions for terrestrial dust devils [4], ranging between 10 parts-per-million up to about 8%.

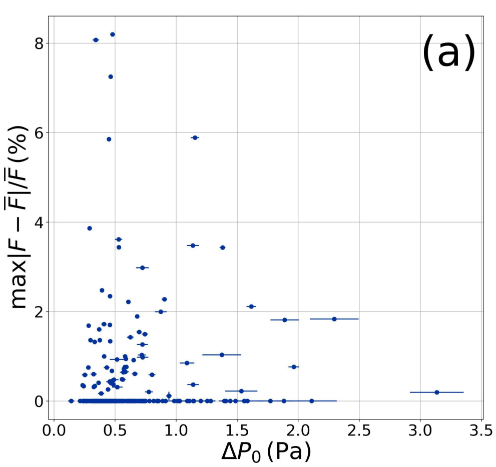

Fig. 2. RDS excursions for the vortex encounters.

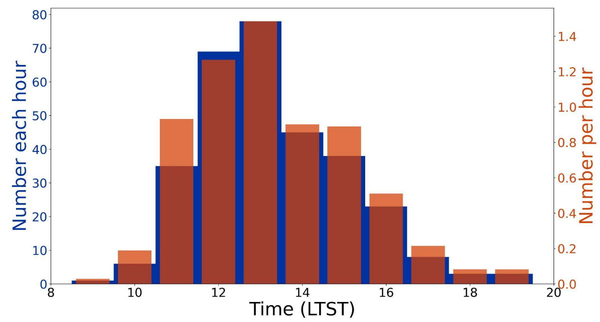

Fig. 3. The blue bars show the total number of vortex encounters that took place during that hour over the whole 89 sol dataset, while the orange bars show that number divided by the total number of hours during that period.

Discussion and Conclusions: Fig. 3 shows the hourly rate of vortex encounters during each sol. At least for the seasons observed so far, these results corroborate predictions [6] that vortex activity at Jezero would exceed activity at Gale Crater, the exploration site for the Mars Science Laboratory rover (MSL) Curiosity, and likely at the landing site for the InSight mission. [7] reported per-hour encounter rates for Curiosity of typically 0.5 per hour (when it was not zero), while [5] reported encounter rates for InSight of about 0.4 per hour (although there is some disagreement with other studies [8]).

As additional data are made available and processed from Perseverance, additional insights can be gleaned. Auspiciously, [6] predict higher encounter rates for mission sols 90 and onward. Analysis of wind data, once processed, may constrain wind speed thresholds for vortex dust lifting, and analysis of thermal and temperature data from Perseverance may elucidate conditions for vortex formation.

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