VORTEX AND DUST DEVIL ACTIVITY ON JEZERO CRATER FROM MARS2020/MEDA DATA AND PHYSICAL CHARACTERIZATION OF SELECTED EVENTS

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MEDA

The Mars 2020 Perseverance rover landed in Mars in February 2021 in Jezero crater at 18.4ºN. The Mars Environmental Dynamics Analyzer (MEDA) instrument [1] on Mars 2020 measures environment parameters such as air pressure, horizontal winds, air temperature at different levels, surface temperature from its infrared emission, and the presence of dust from photodiodes pointing in different directions. MEDA acquires data typically over 50% of a full sol with a cadence of 1 Hz in most sensors and 0.5 Hz in a few cases. After more than 360 sols in Mars, the data allows to explore the changing dynamics of the Martian atmosphere from northern Spring (Ls=6º, sol 1) to northern Autumn Equinox (Ls=180º, sol 361) and beyond.

Vortices, Dust Devils and other pressure drops

Predictions before landing [2] suggested that Jezero is a location where intense vortices and frequent dust devils form. MEDA data, as well as dust devil surveys and movies obtained by the different cameras on Perseverance, confirm those predictions with frequent observations of vortices and dust devils [3].

The passage of convective vortices close to Perseverance produces pressure drops of varying duration and intensity that are characterized from MEDA data and follow a daily cycle with activity peaking at noon. Distinct weak vortices of 0.3-0.5 Pa start in the morning at 08-09 am and they increase in number and strength as the sol progresses, with some pressure drops larger than 6 Pa close to noon on particular sols. The typical duration of the pressure drop is 30 s but there are long events that exceed durations of 100 s. Figure 1 shows an example of a long duration event.

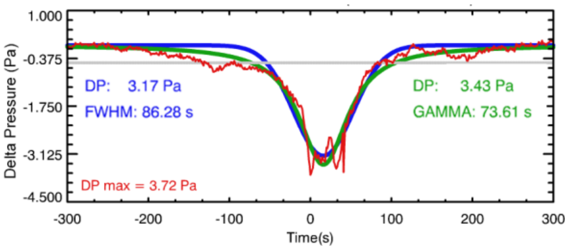

Figure 1: A long and intense pressure drop found on MEDA pressure data (red curve) and its fit with a Gaussian (blue) or Lorenzian function (green) with relevant physical parameters. The horizontal grey line shows a common detection threshold in vortex studies of 0.5 Pa.

Besides vortices, there are long pressure drops where the combination of pressure and winds show strong turbulence, and where the multi-sensor characterization of the local environment by MEDA suggests the passage of the boundaries of convective cells [3]. These long and turbulent pressure drops also peak in their activity close to noon. In most sols, night-time pressure drops are only found irregularly and are much weaker than the daytime activity.

We will discuss the seasonal variation of the daily cycle of vortices and convective cells. In addition, short clusters of vortex and pressure drops are also concentrated in particular ranges of sols, meriting a comparison of the location of these clusters with the properties of the varying terrain covered by Perseverance in its traverse over Jezero.

Dust Devils

Many of the vortices detected in pressure show a simultaneous drop of light detected by the photodiode dust sensors that point to the top. These events constitute close encounters with dust devils. We find a clear relation between the strength of the vortices from the intensity of the pressure drop and the frequency in which they bring dust. At noon, when vortices are more intense and frequent (1.1 event with $\Delta P>0.5$ Pa per hour), up to a 25% of all vortices with a pressure drop larger than 0.5 Pa have detectable dust. Disregarding local time constrains, at least 78% of all events with $\Delta P>2.0$ Pa are dusty, as well as all events with a pressure drop $\Delta P>3.2$ Pa. The largest drop in light from the RDS Top 7 detector occurred for a vortex with $\Delta P=4.5$ Pa and a duration of 100 s that showed a decrease of 25% of the light measured by the photodiodes in the top of the rover. The example shown in Figure 1 was accompanied by a reduction in the signal measured by the RDS Top 7 detector of 8%.

Windy vortices and geometry of encounters

Intense pressure drops also show their signature in winds. Due to operational constrains, the wind sensors are not always on and obtaining data when the rest of MEDA is working. Nonetheless, there is a long number of vortices detected in pressure and with simultaneous wind data that allows constraining the geometry of the encounter. Figure 2 shows an example of one of these events with a wind intensity profile that is compatible with a near direct encounter of the vortex with Perseverance.

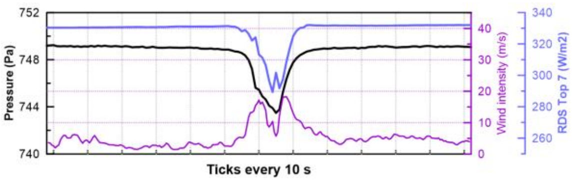

Figure 2: An example of a dust devil detected with an intense pressure drop (black curve, left axis), a strong decrease of light in the RDS Top 7 detector (blue line rightmost axis) and winds (purple line and right axis). The double peak structure of the winds and small central values are indicative of a very close encounter.

In close encounters with vortices like the case shown in Figure 2, the combination of pressure drop duration and background wind intensity outside the vortex allows to characterize the vortex diameter, which in this case is about 20 m. In the statistical analysis of dust devils with simultaneous wind data, the distance scale measured by this metric lies in the range of 10-400 m, with a median value of 60 m [3].

Multi-sensor characterization of dusty windy vortices

The sample of dust devils with good wind data offers an excellent opportunity to characterize specific events. Individual events can be examined in comparison with models of drifting vortices [4] that largely constrain the physical characteristics of individual vortices such as their diameter, distance at closest approach and true pressure drop at their centers. Some of the closest approaches have clear counterparts in the temperatures measured by the 5 Air Temperature Sensors located in different locations of the rover's mast and its front. These thermal counterparts generally imply higher temperatures of +5 K with respect to their environment.

We will present examples of the multi-sensor characterization of selected dust devils including dust devils passing right through Perseverance, tangential passes in which one wall of the vortex passes over Perseverance, and more distant passages of large and very dusty events.

Comparison with LES simulations and activity during a dust storm

MEDA is producing a treasure trove of observations of vortices and dust devils. The distinct different response of dust devils during a recent dust storm [5] will be discussed in comparison with the seasonal evolution of vortex activity.

Finally, in order to gain further insight on convective vortices and convective cells, we are comparing the pressure drops detected in the MEDA pressure data with results from a Large-Eddy Simulation using the MarsWRF model of Jezero crater with 10 m resolution, where convective cells and vortices are observed [3].

While the vortices and dust devils here studied are only those that pass close enough to Perseverance to cause a detectable pressure perturbation, additional dust devils are detected at a range of distances from MEDA photodiodes and the different imaging instruments. The inter comparison of those rich datasets, available only for Jezero, will undoubtfully help to advance our understanding of the role of dust devils in the Martian dust cycle.

References:

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