PREDICTING SIGNATURES OF DUST DEVILS RECORDED BY THE SUPERCAM MICROPHONE. N. Murdoch[1], R. Lorenz[2], B. Chide[1, 3], A. Cadu[1], A. Stott[1], S. Maurice[3], R.C. Wiens[4] and D. Mimoun[1]. [1]ISAE-SUPAERO, Toulouse, France, [2]JHU-APL, Maryland, USA, [3]Institut de Recherche en Astrophysique et Planétologie (IRAP), Toulouse, France, [4]Los Alamos National Laboratory (LANL), Los Alamos, USA. (naomi.murdoch@isae.fr)

Introduction: On the 18th of February 2021 the Mars 2020 Perseverance rover will land on Mars in the Jezero crater [1]. The SuperCam Microphone [2] is located at a height of 2.1 m from the ground on the front of the SuperCam instrument [3,4] and has a bandwidth from 100 Hz to 10 kHz. The primary science objective of the SuperCam Microphone is to support the SuperCam LIBS investigations by providing additional information about the physical properties of the LIBS targets [5, 6]. However, the SuperCam Microphone will also be used for atmospheric science investigations such as determining the wind speed and direction [7] and monitoring Perseverance-induced mechanical noise. A dedicated standalone recording mode allows passive monitoring of the acoustic environment for up to 167 s in a row.

Convective vortices form when warm air close to the surface starts to rise and begins to rotate in turn generating a pressure depression in the vortex center [8]. The passage of a convective vortex is often identified with a barometer as a sharp dip in the local pressure, however, vortices also generate other observables such as temperature increases, wind speed increases and changes in the wind direction over a short time scale [e.g., 9, 10], and even ground deformation signals [11,12,13]. Numerous convective vortices (called dust devils when they transport dust particles) have been detected by previous Mars missions [e.g. 14, 15]. Studying these vortices provide an excellent way of studying the atmospheric Planetary Boundary Layer; a crucial step in understanding the climate of a planet [16].

Convective vortices also generate acoustic waves in the infrasound band [17, 18], but these signals are outside the frequency range of SuperCam Microphone. In addition, vortices may also lead to saltating particles [19], although it is unlikely that many particles reach the height of SuperCam to impact it directly. The variations of atmospheric pressure will cause a small change in the acoustic impedance but we anticipate that dominate vortex signal on the SuperCam Microphone will be the pressure fluctuations induced by the wind dynamic pressure.

First we model the winds associated with a passing vortex, then we make use of the SuperCam Microphone wind calibration results obtained in the Aarhus Martian chamber [7] to predict the typical signatures that we expect to see on the SuperCam Microphone during a vortex encounter. We then compare this to a terrestrial sound recording of a convective vortex before discussing how the SuperCam Microphone can complement the MEDA instruments [20] to investigate Martian convective vortices in more detail.

Modelling the dust devil winds: We model the variation of the tangential wind speed during a vortex encounter following [21, 22]. In this model the tangential wind in a vortex, V_t can be described as follows:

$$V_t = \Gamma \frac{r_{dd}/r^2}{1+(r/r_{dd})^2}$$

where r is the distance to the vortex center and r_{dd} is the radius of the convective vortex. Γ is given by:

$$\Gamma = \sqrt{(2\,\Delta P_o\, r_{dd}^2/\rho_a)}$$

where ΔP_o is the vortex core pressure drop and ρ_a is the air density.

The observed wind speed during a vortex encounter is then a combination of the background wind speed (assumed also to be the vortex advection speed) and the observed vortex wind speed (Fig 1).

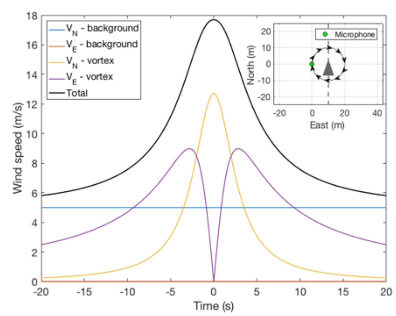

Fig. 1. Wind speed variations during an example vortex encounter. Vortex parameters: ΔP_o = 5 Pa, r_{dd} = 10 m, ρ_a = 1.55e-2 kg m^{-3}, background wind speed = 5 m/s, clockwise vortex rotation, with a closest approach distance of 10 m.

Microphone wind calibration: To estimate the signal generated on the SuperCam Microphone, we use the wind calibration results obtained in the Aarhus Martian chamber (Fig. 2 and [7]). Note that, because the Martian chamber may have generated additional noise sources (e.g., the wind-generating fan), this calibration will have to be performed again on Mars using MEDA.

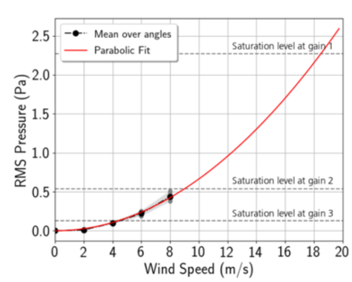

*Fig. 2. The SuperCam Microphone wind speed calibration [5]. The RMS pressure (in the 100-500 Hz bandwidth) is given by 6.6e-3 * wind speed squared. Saturation levels for the 3 highest microphone gains are reported. At gain 0 (not displayed here), the saturation is reached at 4.4 Pa that corresponds to a speed of 27 m/s*

Results: Simulations of signals from typical vortices [14, 23] can be seen in Fig. 3 (left) for varying closest approach distances. The largest amplitude signal occurs when the microphone is in the vortex 'wall' (closest approach, $r_{min} = 1\ r_{dd}$). If the microphone always remains outside of the vortex wall ($r_{min} > r_{dd}$), we see a smooth increase then decrease of signal amplitude. However, if the microphone passes inside the vortex ($r_{min} < 1\ r_{dd}$) a double peak is observed. In the case of a direct encounter when the center of the vortex passes directly over the microphone ($r_{min} = 0$) the vortex winds disappear entirely at the closest approach before increasing again until the microphone reaches the opposite side of the vortex. The amplitude variation between the double peaks and the point of closest approach is directly linked to the closest approach distance of the vortex.

We note also that the vortex rotational direction also plays a role in the observed signals depending on whether the vortex wind and background winds are aligned or opposed (Fig. 3, right).

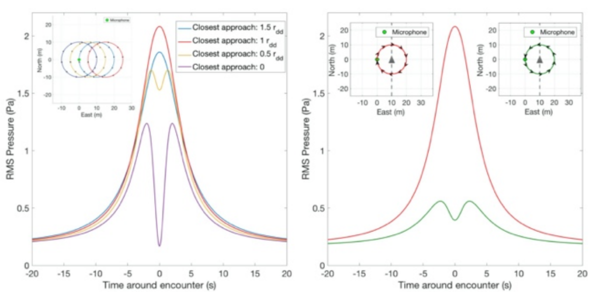

Fig 3. Simulated SuperCam Microphone vortex signals. (Left) Influence of the closest approach distances. (Right) Influence of the direction of vortex rotation. The vortex parameters are the same as in Fig. 1.

We can compare these simulation results to a terrestrial sound recording of a convective vortex (Fig. 4). The microphone (not the SuperCam Microphone) signal rises appreciably during the vortex encounter, and the double peak indicates that the calm 'eye' of the vortex passed very close to the sensor, with the stronger winds at the vortex 'wall' giving a stronger microphone output.

Discussion: Our modelling demonstrates that the SuperCam Microphone has the potential to observe and characterize convective vortices, if an encounter occurs during the short (167 s) microphone recording periods. The form of the vortex signals will provide an indication of the closest approach distance of the vortex. In addition, once an in-situ wind speed calibration has been performed with the MEDA instruments, the SuperCam Microphone will also be able to provide measurements of the vortex wind speeds during the encounter.

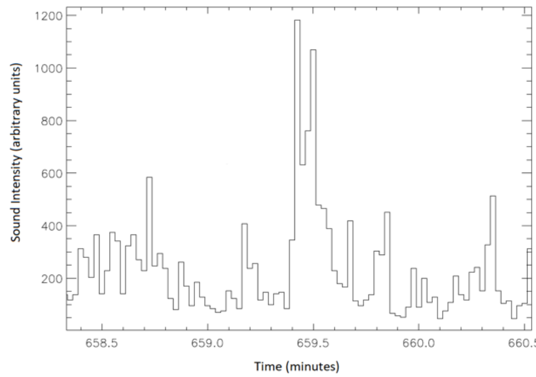

Fig 4. The sound level recorded during a vortex encounter at Goldstone Dry Lake, California USA in June 2014. The measured core pressure drop was 1.1 hPa.

The SuperCam Microphone vortex measurements will be very complementary to the MEDA measurements: with a bandwidth of 100 Hz to 10 kHz, the SuperCam Microphone will provide additional information about the rapid wind fluctuations associated with vortices (the MEDA wind sensor, located at a height of 1.5 m from the ground has a maximum sampling frequency of 2 Hz and a resolution of 0.5 m/s in the wind velocity; [20]). The MEDA pressure sensor (resolution of ± 0.5 Pa; [20]) will, however, be invaluable to confirm the vortex events and to provide information on the vortex wind direction (this may be possible also with the SuperCam Microphone, but would require a dedicated calibration campaign; [7]).

The InSight mission [13] and its high performance pressure sensor [24] are currently unveiling new atmospheric phenomena at Mars, in a higher-frequency range than ever before (up to ~10 Hz; [25]). The SuperCam Microphone measurements will extend our atmospheric observations to higher frequencies (> 100 Hz), offering a window into previously unexplored Martian atmospheric science.

References: [1] Farley et al., (2020), [2] Mimoun et al. (2021), [3] Maurice et al. (2021), [4] Wiens et al., (2021), [5] Murdoch et al., (2019), [6] Chide et al. (2019), [7] Chide et al., (2021), [8] Rafkin et al., (2016), [9] Schofield et al. (1997), [10] Kahanpää et al, (2004), [11] Lorenz et al., (2015), [12] Lognonné et al. (2019), [13] Banerdt et al., (2020), [14] Murphy et al., (2016), [15] Lorenz et al. (2020), [16] Spiga et al., (2021). [17] Schmitter (2010); [18] Lorenz and Christie (2015), [19] Neakrease et al., (2016), [20] Rodriguez-Manfredi et al., (2021), [21] Vatistas (1991), [22] Kurgansky et al., (2016), [23] Spiga et al., (2020), [24] Banfield et al., (2018), [25] Banfield et al., (2020).