INSIGHT SHORT PERIOD SEISMOMETERS DETECTION OF DUST DEVILS ON MARS.

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Introduction: The Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission touched down successfully on the Martian surface on the 26th of November 2018 in the Elysium Planum region. InSight has a suite of geophysical instruments including both seismometers and atmospheric instrumentation [1]. The seismometer package (SEIS) includes two three component sensors: a short period seismometer (SP) and a very broadband seismometer (VBB) on a levelling platform [2] that is designed for on-ground operation. The atmospheric instrument package, known as the Auxiliary Payload Sensor System (APSS), comprises of a pressure sensor, air temperature sensor and two wind sensor booms (TWINS) [3]. As the SP sensors do not need to be level to operate, they were switched on along with the APSS instrumentation while SEIS was still on the lander deck prior to the deployment on the surface of Mars.

During this time the SPs have been used to examine atmospheric phenomena and the lander dynamics. It was predicted prior to landing that sharp pressure drops associated with vortices, forming "dust devils" (if of sufficient strength to loft Martian particles or dustless devils if not), would be visible in both the pressure signal measured by the APSS and in the seismic signal measured by the SP sensors. It was also predicted that distant dust devil signals not observed by the APSS pressure sensor might be observed in the seismic signal [4,5,6,7,8].

Modelling: The expected seismic signal caused by dust devils can be modelled using two different theories of Lorenz [4] and Sorrell [9,10]. Both models account for the deformation of the surface ground as perturbed by the dust devil to produce a vertical displacement and tilt on a seismometer, detected respectively by the vertical and horizontal axes of the SP.

The Sorrells' model calculates the quasi-static ground displacement generated by pressure fluctuations, assuming that such pressure fluctuations are plane waves propagating at the ambient wind speed. The model assumes a homogeneous half-space to give a vertical ground velocity and surface tilt proportional to the pressure fluctuations. Following the formulation given in [5] Figure 1 shows the expected vertical velocity signal and the absolute tilt that would be measured by the SP seismometers for a given arbitrary dust devil pressure signal. The pressure signal is modelled following [11] as $\Delta P(x) = [(2/\pi)\arctan(r^2)]$, where $r = 2x/D$ (taken from [8]), $x = c\times t$, t is time from closest approach, c is the wind speed and D is the distance of closest approach = 5 m. The vertical acceleration and tilt responses are calculated using the Sorrell model with a wind speed of 5 m/s, an S-wave velocity of 100 m/s, a P-wave velocity of 200 m/s and a bulk density in the upper regolith of 1000 kg/m^3. These values have been chosen as representative of predicted values for Elysium Planitia, to demonstrate the expected waveforms measured by the SP sensors due to ground deformation.

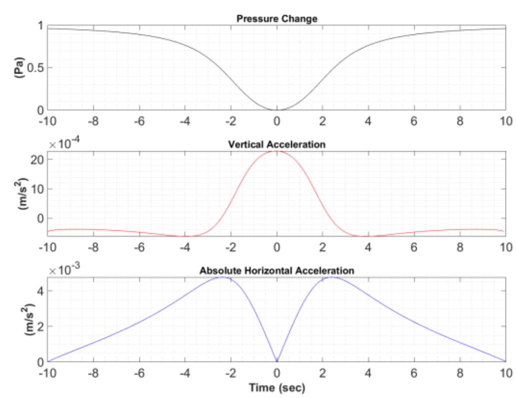

Figure 1 : Example of ground vertical and horizontal acceleration for a simple dust devil pressure signal.

Lorenz models a dust devil as a negative point load traveling across an elastic half-space in a straight line at a constant speed. The model then computes the tilt caused by the ground deformation on a seismometer. Modelling a dust devil as a negative point load limits this technique to small and distant dust devils. Figure 2 shows the Lorenz predicted North/South, East/West and absolute predicted tilts for the same given arbitrary dust devil pressure signal used in Figure 1. In this case the formulation from [12] was followed with a scaling factor of 1, a dust devil velocity of 10 m/s, a closest approach of 5 m and an azimuthal direction of 120°. A companion abstract to this abstract [13] goes into greater detail of the Lorenz model.

The important differences between the two models are the Sorrell model models the vortices as a straight line front at which there is a step change in pressure; whereas the Lorenz model models the dust devil as a negative point load. The Sorrells model is therefore likely to be more physically accurate in the near field than the Lorenz model. Sorrells' model also includes the effect of wind, that the Lorenz model omits. The Sorrell model includes a formulation for the vertical motion induced by the ground deformation from the dust devil, however, since the vertical motion is small compared to the tilt induced the Lorenz model ignores this vertical ground deformation. For the Martian surface however, since the vertical motion is expected to be much less noisy, the vertical motion maybe visible.

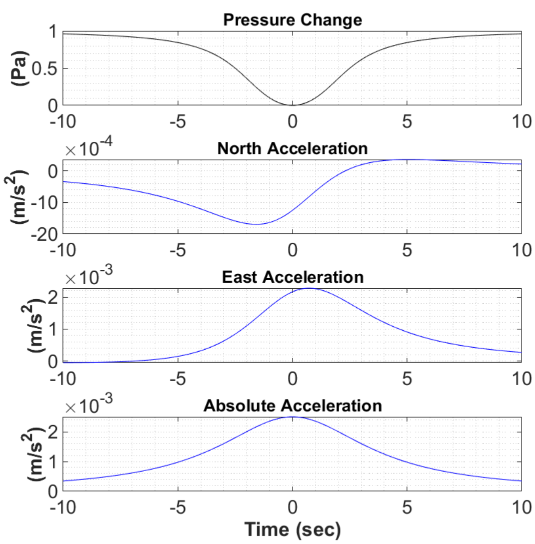

Figure 2 : Example of the expected acceleration signals on the SP sensors from the Lorenz model for a simple dust devil pressure signal.

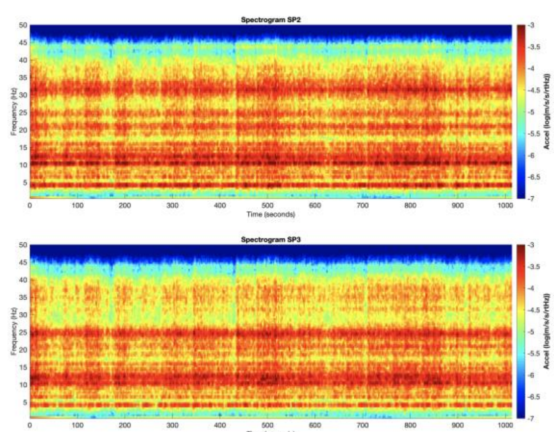

Figure 3 : Spectrograms of the acceleration signals from the two horizontal-axis SPs taken from Sol 4, 16:06:47 LTST

As well as responding to disturbances of the ground from dust-devil vortices, the SP seismometers will also be sensitive to direct atmospheric perturbations of the lander deck. It may be possible to delineate the signals observed on the SP sensors from the two different pathways - through the atmosphere and through the ground. The pathway through the lander deck can be modelled by accounting for the lift and drag forces acting on the lander directly.

SP observations: SP observations were made during the first 35 sols of the mission before the VBB started operations. Figure 3 shows a spectrogram from the two horizontal components of the SP most sensitive to tilt. To observe the dust devil signal from the SP sensors requires their output to be mapped from the sensing directions to the lander site frame of reference. The SP velocity outputs are bandpass filtered from 5 - 200 s periods to capture the maximum signal content from prospective dust devils.

Conclusion: We will present results from these observations, their fits to the Sorrell and Lorenz models and an estimation of the additional aerodynamic contribution to the SP response, including possible buoyancy effects from the pressure drop. The model fits will allow some constraints to be placed on the atmospheric properties around the Insight lander as well as estimates of transit vector of the dust devils.

References:

[1] Banerdt W. B. et al. (2013) *LPSC 44*, Abstract #1719. [2] Lognonné P. et al. (2019) *SSR*, in press. [3] Banfield D. et al. (2019) *SSR*, 215, 4. [4] Lorenz R. et al (2015) BSSA, 105. [5] Murdoch et al. (2017a) SSR ; [6] Murdoch et al., (2017b); [7] Mimoun et al. (2017); [8] Kenda et al. (2017) SSBMD [9] Sorrells, 1971; [10] Sorrells et al, 1971 [11] Vasistas et al., 1991 [12] Lorenz et al. (2016) Icarus 271 [13] Murdoch et al, (2019) LPSC.