STUDYING MARTIAN TURBULENCE USING HIGH FREQUENCY PRESSURE FLUCTUATIONS OBSERVED BY INSIGHT AND PERSEVERANCE

N. Murdoch[1] (naomi.murdoch@isae-supaero.fr), A.E. Stott[1], A. Spiga[2], O. Temel[3], A. Chatain[4], T. Bertrand[5], S. Maurice[6], B. Chide[7], C. Newman[8], D. Banfield[9], J. Pla-Garcia[10], R. Garcia[1], M. Gillier[1], M. De La Torre Juarez[11], A. Chavez[11], A. Munguira[11], R. Hueso[12], A. Sanchez Lavega[12], G. Martinez[13], L. Lange[2], J. Rodriguez-Manfredi[10], R. Wiens[14], P. Lognonné and D. Mimoun[1]

[1]*ISAE-SUPAERO, 10 ave E. Belin, 31400 Toulouse, France,* [2]LMD, Paris, France, [3]Royal Observatory of Belgium, Belgium, [4]South West Research Institute, CO, USA, [5]Paris Observatory, France, , [6]IRAP, Toulouse, France, [7]LANL, NM, USA, [8]Aeolis Research, Chandler, AZ, USA, [9]Cornell University, NY, USA, [10]Centro de Astrobiología (CSIC- INTA), Madrid, Spain, [11]JPL /California Institute of Technology, Pasadena, CA, USA., [12]Universidad del País Vasco (UPV/EHU), Bilbao, Spain, [13]Lunar and Planetary Institute, Houston, TX, USA, [14]Purdue, IN, USA, [15]IPGP, Paris, France.

Introduction: Different types of turbulent regimes exist in the atmosphere, particularly in the planetary boundary layer (PBL), the lowermost part of the atmosphere. This is the part of the atmosphere that is in contact with the planetary surface and is of critical importance for the mixing of heat, momentum, dust, and a variety of chemical species between the surface and atmospheric reservoirs [1]. Given that all Mars landers have to pass through and operate in the Martian PBL, understanding this part of the Martian environment is also extremely important for the in-situ exploration of the red planet.

Space missions have provided valuable pressure, wind and temperature data allowing the Martian turbulence to be studied (e.g., [2-4]). Here we use a spectral approach to analyse data from the InSight and Perseverance meteorological sensors [5-6], and the SuperCam microphone [7-8]. This method allows us to investigate how the pressure and wind fluctuations, and thus PBL processes, vary as a function of frequency, or spectral range.

High frequency atmospheric measurements: The InSight pressure sensor [5] is capable of acquiring data up to 20 Hz and operated continuously for long periods of time in order to support the interpretation of the seismological data. The InSight pressure were at a higher frequency than any previous measurements and have shown unexpected behaviour in the pressure fluctuations. For example, the spectral slope seems to contradict the theoretical predictions (Kolmogorov theory) for the cascade of the inertial range [9].

The SuperCam Microphone onboard the Mars 2020 Perseverance rover is located at a height of 2.1 m above the ground on the front of the SuperCam instrument (Fig 2; [7-8]). With its high sampling frequency (up to 100 kHz), the SuperCam microphone can be used to probe the Martian atmosphere at even higher frequencies than the InSight pressure sensor. The SuperCam microphone can, therefore, complement the lower frequency wind and pressure measurements and provide a window into previously unexplored regimes of Martian atmospheric science.

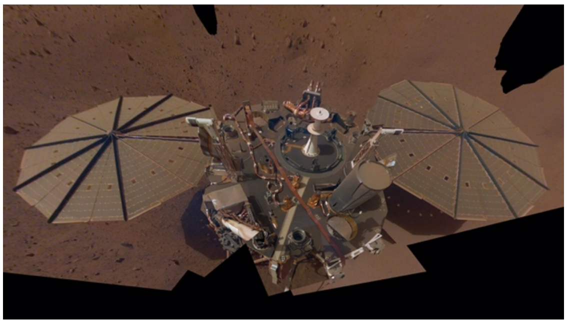

Figure 1: The Insight lander. Credits: NASA/JPL-Caltech.

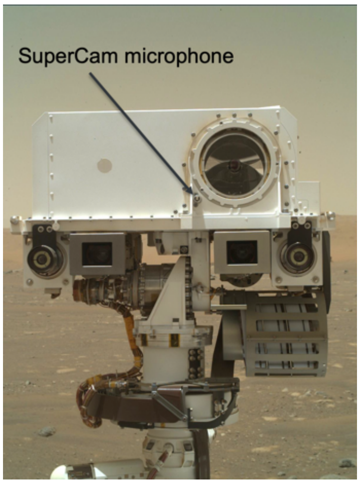

Figure 2: The SuperCam instrument, including the microphone, on the surface of Mars. Credits: NASA/JPL-Caltech.

Interpreting the kinetic energy spectrum: Turbulent kinetic energy can be generated by buoyancy driven convection and by wind shear [11]. Once generated, the eddies experience non-linear interactions as they cascade into smaller and smaller eddies by an inertial mechanism. Eventually, at the very small scale, viscous forces

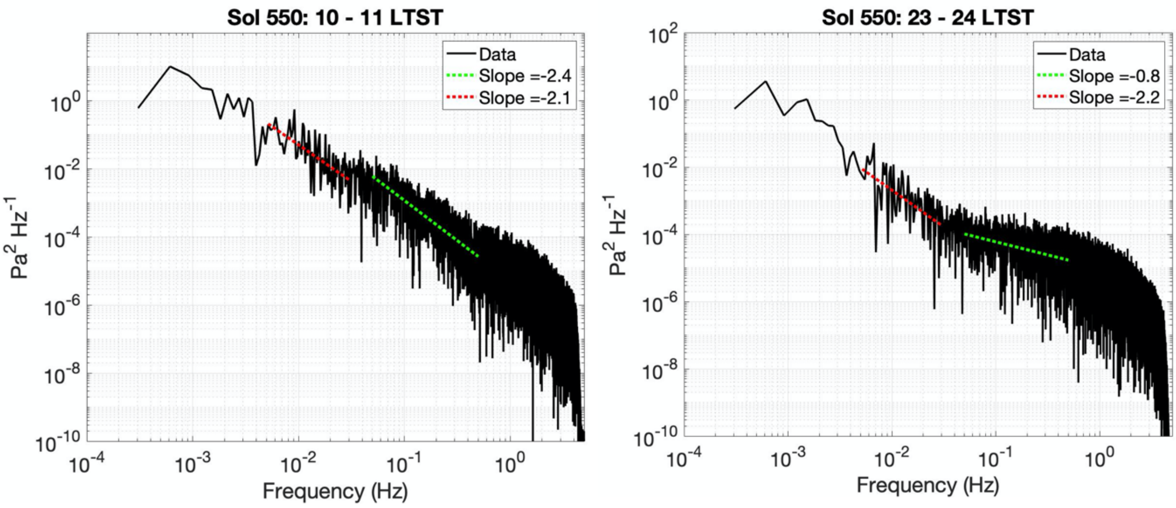

Figure 3. Power spectral densities (PSDs) of the pressure fluctuations on InSight sol 550 in the periods 10 - 11 Local True Solar Time (left), and 23 - 24 Local True Solar Time (right).

become important and the eddies are dissipated [12]. The PBL kinetic energy spectrum can be viewed, therefore, as a superposition of several components that exhibit different spectral slopes. The different components will become dominant at different length scales, at different local times and at different heights above the surface.

Results: Here we first analyse the spectral characteristics of the pressure as measured by InSight, as a function of both local time (Fig. 3) and season. In doing so we attempt to isolate the different turbulent regimes, in addition to explaining why the spectral slopes of the pressure data appear to contradict the theoretical predictions [9]. These results allow us to probe the diurnal and seasonal trends of the atmospheric dynamics at the InSight landing site and how these trends are influenced, for example, by wind jets [4,12], dust storms [10], or variations in near-surface wind belts due to changes in Hadley circulation with dust forcing [13-14].

Next we turn to the even smaller scales. We will present the first observations of the Martian dissipative regime thanks to the SuperCam microphone. The length scale and timescale at which the viscous dissipation should become significant on Mars are theoretically estimated to be 0.02 m and ~0. 45 seconds, respectively [1,15]. The dissipation regime of the Martian atmosphere should, therefore, be observable at frequencies above 2 Hz. There are some indications of a possible regime change at this frequency range in the InSight pressure data (Fig. 3 and [9]), however, this is at the very limits of the instrument capabilities and should be interpreted with care [9]. We demonstrate that this theoretical prediction of a regime transition close to 2 Hz is confirmed by the SuperCam acoustic data ([16]; Fig 4).

Conclusions and Discussion: Using a spectral approach we investigate the turbulent behaviour of the Martian atmospheric. The InSight data, particularly the pressure sensor, are used to study diurnal and seasonal atmospheric dynamics. In addition, using the SuperCam microphone we can now study Martian turbulence on new, previously inaccessible, scales. Investigations into how the high frequency spectral slope and regime transitionsvary with wind speed, wind direction, local time and season are ongoing as we collect more data.

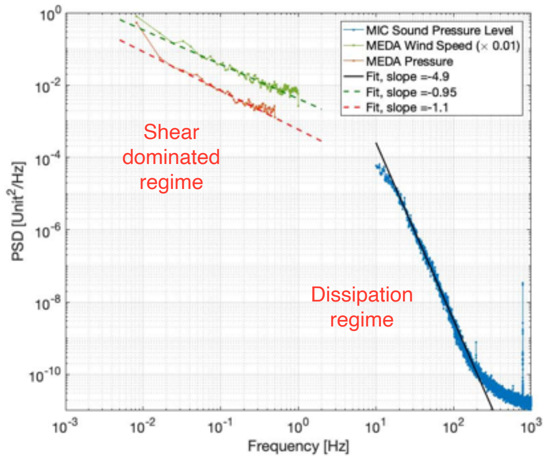

Figure 4. The PSD calculated for Perseverance's sensors; the SuperCam microphone (in Pa^2/Hz over 167 s), MEDA pressure (in Pa^2/Hz) and MEDA wind data (in (m/s)^2/Hz). Modified from [16].

As we go forward, in addition to studying the diurnal and seasonal effects, comparing the Mars 2020 and InSight data sets can provide information about the effects of topographical forcing [12,17] in the two different landing sites, where regional circulation is expected to be quite different [18-19]. Furthermore, differences in aerodynamical roughness length change the wind gradient and can create additional shear production of turbulence, and thermal inertia differences will also affect the turbulence kinetic energy level; a lower thermal inertia will result in stronger temporal gradients of surface temperature and thus an enhanced turbulent mixing.

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