MARTIAN WIND SENSING WITH SEISMOMETERS AND MICROPHONES

A. E. Stott[1], *(alexander.stott@isae-supaero.fr)*, **N. Murdoch**[1], **R. F. Garcia**[1], **M. Gillier**[1], **D. Mimoun**[1], **A. Spiga**[2], **R. Lorenz**[3], **D. Banfield**[4], **T. Bertrand**[5], **B. Chide**[6], **A. Chavez**[7], **M. De La Torre Juarez**[7], **R. Hueso**[8], **G. Martinez**[9], **L. Mora Sotomayor**[10], **A. Munguira**[8], **S. Navarro**[10], **C. Newman**[11], **P. Pillieri**[12], **J. Pla-Garcia**[10], **J. A. Rodriguez-Manfredi**[10], **A. Sanchez-Lavega**[8], **D. Viudez Moreiras**[10], **N. Williams**[7], **S. Maurice**[12], **R. C. Wiens**[13], **P. Lognonné**[14]

[1]ISAE-SUPAERO, Université de Toulouse, FR, [2]LMD, Paris, FR, [3]Johns Hopkins APL, MD, USA, [4]NASA Ames, CA, USA, [5]Paris Observatory, FR, [6]LANL, NM, USA, [7]JPL /California Institute of Technology, Pasadena, CA, USA., [8]Universidad del País Vasco (UPV/EHU), Bilbao, Spain, [9]Lunar and Planetary Institute, Houston, TX, USA, [10]Centro de Astrobiología (CSIC- INTA), Madrid, Spain, [11]Aeolis Research, Chandler, AZ, USA, [12]IRAP, Toulouse FR, [13]Purdue, IN, USA, [14]IPGP, Paris, FR

Introduction: The wind plays a major part in the processes shaping Mars to this day [1]. The coupling of the wind with the dust cycle, for example, is of great importance for the atmospheric dynamics [1]. To that end, high quality measurements of the Martian wind are of significant interest. Dedicated wind sensors have provided in situ measurements of the wind on the Martian surface. However, other sensitive instruments offer complementary and new information on the wind and turbulence. Here, we will demonstrate how InSight's seismometer [2] and Perseverance's microphone [3,4], can be used for wind analysis in planetary applications.

Background: The NASA InSight and Perseverance missions have each carried wind sensors which operate at up to 1 or 2sps (samples per second) respectively [5,6]. InSight's TWINS instrument [5] has functioned effectively throughout its over 3-year mission so far. However, power constraints due to dust deposition on the solar panels have meant measurements are scarce for the second Martian year of operation. On the other hand, the Perseverance rover's MEDA instrument [6] has acquired data for around an Earth year so far. Other instruments deployed on Mars missions are also sensitive to the wind. For example, the seismometer on InSight [2] and the microphone on the SuperCam instrument suite for Perseverance [3,4]. These have respectively recorded vibrations due to wind forcing or pressure fluctuations, and so offer a new way to examine the Martian atmosphere.

The InSight seismometer: The InSight seismometer is capable of sensing vibrations of 1.5E-10 m/s^2/rtHz at 0.4Hz and records at up to 100sps [7]. This makes it an ideal tool to observe the dynamic forcing due to the wind. Fig. 1 shows the signal power (RMS envelope) of the seismic data for the first 700 sols compared to the wind speed level measured by TWINS. There is a clear correlation

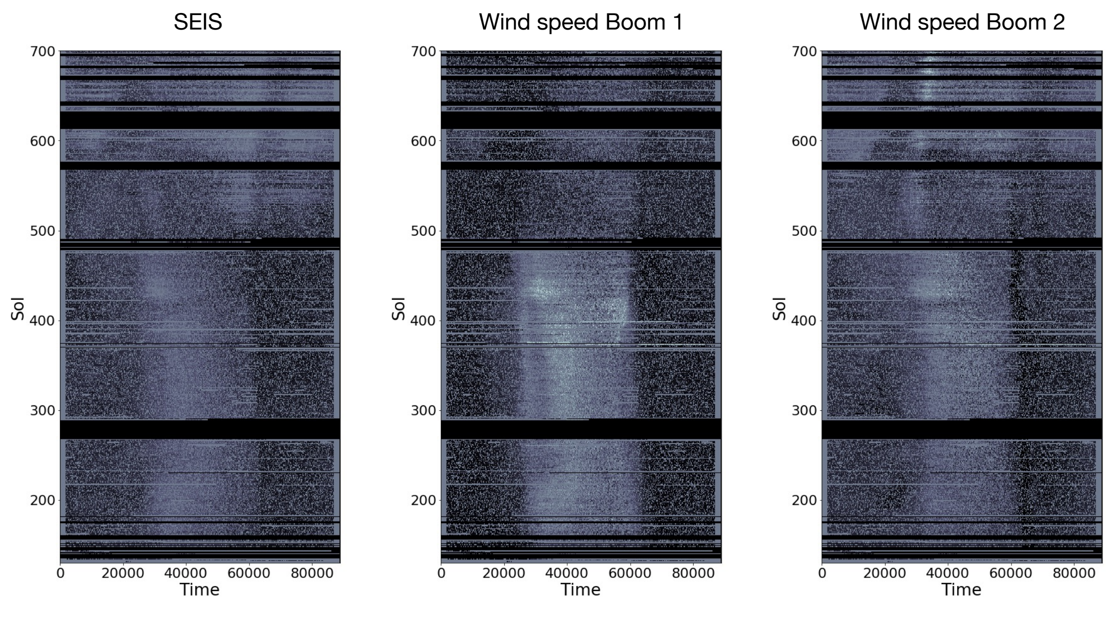

Figure 1: Comparison of InSight seismometer velocity RMS (0.4-1Hz bandwidth) signal to the wind speed retrieval from both TWINS booms. All signals are normalised.

between the two. This relationship was described in [8], where the sensitivity of the seismic data to the wind speed was shown to vary over the Martian sol and seasons. As pointed out in [9], the change in relationship is correlated to the type of turbulence and not just the wind speed, in fact, it follows the patterns identified in [10]. This is understood by the fact that the seismometer measures the vibrations due to wind forcing which, in turn, depend directly on the turbulent flow.

The seismometer typically records at 20sps and can record at up to 100sps, higher than the 1sps of TWINS. Moreover, the TWINS sensor relies on a calibration grid and complex retrieval algorithm [5]. As a result, combining the seismic data with the wind data from TWINS can lead to improved wind estimates in terms of sampling rate and resolution.

The buildup of dust on the solar panels has led to power constraints becoming tighter throughout the second Mars year of operations. As a result, the atmospheric sensors have not been able to operate for the entire time, while the seismometer has been operated almost constantly. This highlights the prospect of using the InSight seismic data to provide an estimate of the Martian wind when the atmospheric sensors were not recording. This would bolster the InSight wind catalogue to an almost continuous 2 Martian years of data.

The Perseverance microphone: The microphone on the SuperCam instrument suite senses the sound pressure, which is the deviation from static/ambient pressure. As a result, it is sensitive to the wind and its variability [1,11,12]. This is demonstrated in Fig. 2, which shows the RMS of a microphone recording overlayed with the wind speed from the MEDA instrument for the same period.

The microphone can record at up to 100ksps or, more usually, at 25ksps, both above what is required for atmospheric observations. As a result, the microphone RMS can be combined with the MEDA wind sensor to estimate the wind speed at much shorter time intervals than the MEDA wind sensor alone. This is exemplified in Fig. 2 where the microphone derived RMS exhibits more rapid fluctuations. In fact, the microphone is directly sensitive to the variation in the wind speed, as well as the wind speed itself. This has been observed on Earth in [12] which showed the output of unshielded microphones to be best correlated to the product of the mean and standard deviation of the wind, according to the turbulent conditions. Therefore, the microphone can be used both for high frequency wind estimation and to directly provide information on the wind speed variation, both helpful to study turbulence.

Future network missions: Both atmospheric and geophysical science goals desire a network of observatories on Mars (e.g. [13,14]). As we present here the sensors for both can aid each other's goals and so should be proposed together. The atmospheric measurements are essential to determine whether a signal is of seismic origin or not [8,9] and to determine the seismicity [9]. As shown here though, the seismometer contributes directly to atmospheric science goals. Microphones, on the other hand, look at the highest frequency variation in the atmosphere. Furthermore, they are relatively cheap and straightforward to operate. The sensor and its electronics are relatively lightweight and can be operated at lower sampling rates (down to the 1sps range) to reduce downlink volume in continuous operations.

Conclusion: We have demonstrated that seismometers and microphones are suitable tools to analyse the wind on Mars, in combination with dedicated wind sensors. In this way we are able to extend the InSight wind catalogue and also shine a light on turbulence in terms of forcing. The SuperCam microphone, on the other hand, provides a look at the high frequency scales of the Martian atmosphere along with a direct sensitivity to the variability. The fact that each instrument is complementary while also being sensitive to a particular aspect of the Martian wind means that they not only provide robustness but also offer estimation quality and additional information on turbulence. The use of data processing, such as through machine learning, will enable the separation of these facets.

We propose that future network missions should accommodate both atmospheric and seismology goals together in order to maximise the possibilities

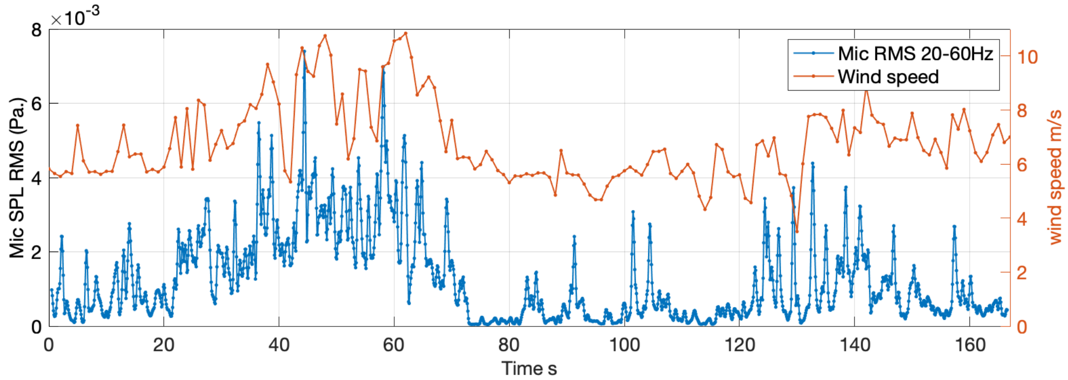

Figure 2: A plot of the RMS of the microphone signal compared to the wind speed measured by MEDA.

for both communities. The sensors are sensible payloads to attach to missions, for example the sample return landers, to maximise scientific return.

References:

[1] Newman et al. Science Advances in print ,2022
[2] Lognonné et al. SSR, 2019
[3] Mimoun et al., SSR, Submitted 2022
[4] Maurice et al., SSR, 2021
[5] Banfield et al., SSR 2018
[6] Rodriguez-Manfredi et al. SSR, 2021
[7] Lognonné et al., Nature Geo., 2020
[8] Charalambous et al. JGR Planets 2021
[9] Stott et al. in prep. 2022
[10] Chatain et al. GRL, 2021
[11] Maurice et al., Nature, 2022
[12] Morgan and Raspet, JASA, 1992
[13] Stähler et al., Low-Cost Science mission concepts, 2022
[14] Parfitt et al. EPSC, 2021