PRELIMINARY ANALYSIS OF SMALL-SCALE TURBULENCE AT THE INSIGHT LANDING SITE ON MARS.

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Introduction

NASA's InSight lander is the first seismology station sent to Mars, where it has been studying the interior structure of the planet since November 2018. To interpret possible "marsquakes" and other observations correctly, it carries a weather station that measures pressure (PS) and near-surface winds (TWINS) at high frequency (Banfield et al. 2020). One aspect of Martian meteorology that is poorly understood is small-scale turbulence. By observing at such high frequency, Insight provides a unique dataset that can be used to study Mars small-scale turbulence.

We have used InSight wind and surface pressure measurements to study atmospheric turbulence around the lander. In particular, the turbulent structure functions quantify correlations in wind speed and direction between different locations. These can reveal information about the type of turbulence that occurs in the Martian atmosphere, such as the kinetic energy cascade rate, the direction of energy transfer as a function of length scale, and (under suitable assumptions) the kinetic energy spectrum.

This type of analysis ideally requires a network or grid of weather stations but it turns out that, when the average wind speed is faster than typical turbulent motions, we can estimate the structure functions from a single measurement using the "frozen turbulence" hypothesis (Taylor, 1938; Byrne & Zhang, 2013). Therefore it is possible in principle to measure these structure functions using the InSight wind and pressure observations.

Velocity structure functions

We focused on observations from sol 19 of the mission, after Banfield et al. (2020). The sol 19 wind observations are well suited to this analysis, particularly during the nighttime, when the ratio between the kinetic energy of the mean flow and the kinetic energy of the eddies is large, which is a requirement for the frozen turbulence hypothesis to apply (Fig. 1).

We computed the second- and third- order structure functions during sol 19 between 0200-0500 and 1000-1500 local mean solar time (Fig. 2).

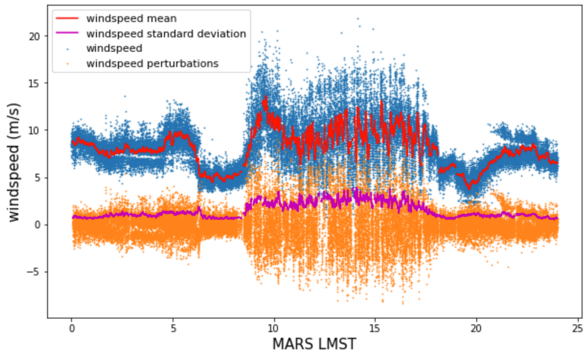

Fig. 1. Wind speeds during sol 19. Blue dots are individual observations, red and purple are the running mean and standard deviation over a 130s window, and orange dots are individual deviations from the running mean.

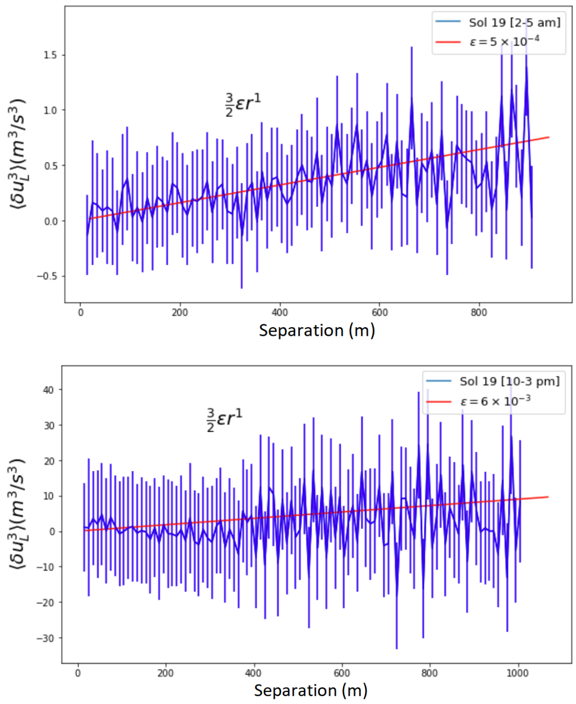

Fig. 2. Preliminary third order longitudinal structure functions computed for InSight sol 19 for 2–5 AM LMST (top) and 10 AM – 3 PM LMST (bottom). Note the different values of ϵ in the fitting function.

The third order structure functions showed a reasonable fit to a linear fitting function $\langle \delta u_L^3 \rangle \propto \epsilon r$, but with a sign for ϵ indicative of upscale energy transfer, which was quite surprising. Further work is required to ascertain whether this is real, in particular by averaging over many different sols. The energy injection rate ϵ was significantly larger during the daytime than the nighttime, consistent with our understanding of Mars' boundary layer.

Pressure structure functions

Pressure structure functions focused on the later sol 186, which falls within a long unbroken period of pressure observations at 10 Hz. The 2nd order pressure structure function is $\Pi(r) \propto \rho^2 \epsilon^{4/3} r^{4/3}$ for isotropic, homogeneous turbulence. Figure 3 shows the measured 2nd order pressure structure function for a short period during sol 186. The pressure time series is sampled at 10 Hz, while the wind speeds are measured at 1 Hz, so there is less noise in the pressure structure function than in the wind structure function. There is a small range where the slope is close to $r^{4/3}$, around 100m separation, but the fit is not yet convincing, and further analysis of other times of day and other sols is needed to build up adequate statistics.

Conclusion

Preliminary analysis of Insight wind and pressure observations under the frozen turbulence hypothesis have been presented. Further work is required to investigate how these functions vary over different sols, as well as systematically examining how they vary at different times of day and year.

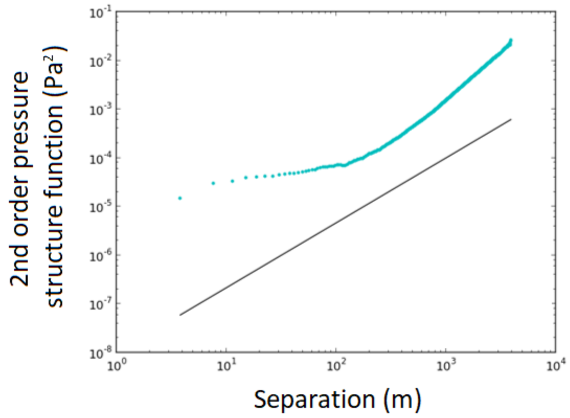

Fig. 3. Preliminary 2nd order pressure structure function during sol 186. Blue shows the structure function and black a line with slope $r^{4/3}$.

References

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