MARTIAN ATMOSPHERIC INDUCED MICRO-SEISMIC NOISE GENERATION: LARGE EDDY SIMULATIONS

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Introduction: Even in the absence of quakes, the surface of planets with atmosphere or ocean is subject to continuous vibrations generated by the fluids envelops circulations and turbulences, generating the so-called micro-seismic noise. We here, in the frame of the 2016 InSight seismic project to Mars, estimate this micro-seismic noise by modeling the interaction of large eddies on the Martian subsurface.

Ground deformation model: Atmospheric pressure fluctuations generate ground deformations, which in turn produce either a ground acceleration or a ground tilt, both of which detected by seismometer located on a planetary surface. Rough estimations of this noise have been already proposed [1]. By using the elastic loading theory, the response of the ground can be computed for different wind regimes, assuming that the wind is associated to the mean phase velocity of the atmospheric loading perturbations [2,3]. The results shows that the upper, low rigidity layers, are mainly seen when the wavelength of the pressure perturbation is comparable to their thickness and as a consequence, that the ground sensitivity is relatively flat and of the order or below 1 nm/microbar of displacement over the InSight VBB seismometer bandwidth (5 mHz-5 Hz).

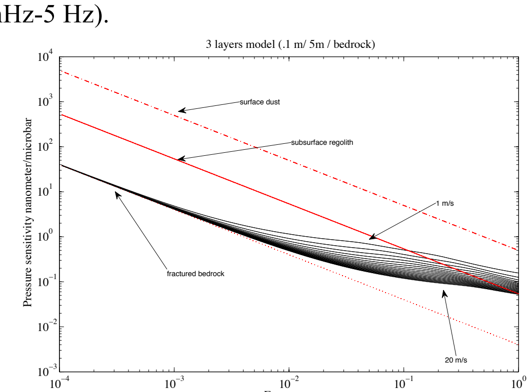

Figure 1. Three layers vertical ground deformation transfert function. Densities, Vp, Vs of the layers are (1800 kg/m^3, 300 m/s;100 m/s; 1800 kg/m^3; 1000 m/s; 300 m/s;2300 kg/m^3;2700 m/s;1000 m/s) and thickness of the two first layers are 10 cm and 5 m, the last being a semi-infinite half space.

Large Eddy Simulation: Constant wind models are generally used for estimating this seismic noise. In order to get more realistic models, we have used Large eddy simulations (LES) [4] of the pressure and wind fields in one of the Insight possible landing sites (Lat, Lon: 1.48, 138.96, Altitude: -2.6 km), for a mean wind of 5 m/s over the boundary layer, corresponding to a mean wind of about 2.5 m/s at 2 meter height, generating wind burst up to 15 m/s and with about 1.5 m/s of variance. Such conditions are comparable with the average conditions in non storms conditions of the landing site.

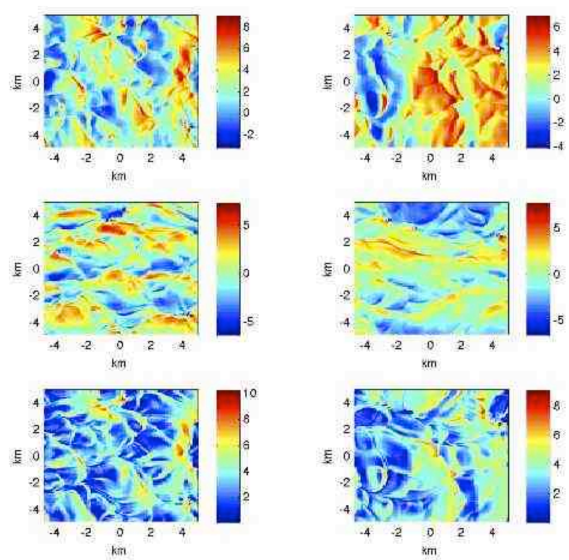

Figure 2 Wind conditions from LES (top is zonal wind, middle is the meridional wind and bottom the wind amplitude for a forcing zonal wind). All color amplitudes are in m/s, while distance are in km. The two snapshots are at 12h and 15h local time.

These LES capture local pressure disturbances (Figure 3) such as dust devils and models also the eddies generated acoustic noise at frequencies larger than 0.1 Hz. The comparison with the observed Pathfinder or Viking pressure noise has also been done, suggesting that the later was also recording the dynamic wind pressure, in addition to the static pressure. Pressure and LES data have been used to estimate the direct noise acting on the SEIS and to design the WTS in order to reduce these wind induced noise to a level below the instrument noise requirement for 80% of operation condition. But in additon, these provide the first precise estimations of the true martian micro-seismic noise, which is directly related to the interaction of the Martian surface with the planetary boundary layer.

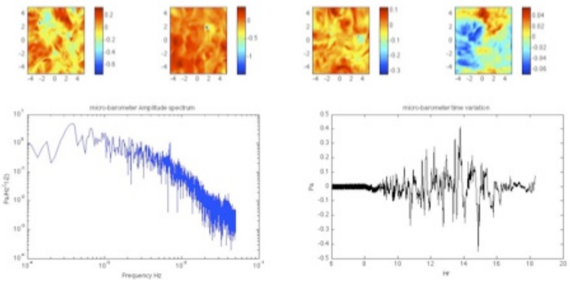

Figure 3. Top, LES results of the pressure field for 4 snapshots every 1h30. Amplitudes are in Pa and the X and Y units are in km (± 5 km). Bottom left, Amplitude spectrum of the pressure fluctuation in the middle of the area. Bottom right, time variation of the pressure, from 6am to 18 am Martian local time, with a mean 5 m/s wind. Space resolution is 100 m and time resolution is 10 sec.

Modeling results are shown on **Figure 4**. The slope of the vertical noise is about f, while the slope on the horizontal at long period is about $1/f^2$, as the vertical and horizontal noise are mainly velocity flat and tilt generated respectively. In the normal modes frequencies, the obtained noise remains below the InSight instrument noise, but the extrapolation suggests that the instrument will be able to detect such ground microseismic noise at about 0.1 Hz. Larger LES will be performed to increase frequency resolution and space resolution, in order to achieve the modeling or modeling extrapolation done to 1Hz, as the later is strongly related to the spatial and time coherency of the eddies, which is expected to decrease with increasing frequencies. Several publications however shows that the turbulence power is reaching a maximum at about 0.1 Hz and then decrease again as $f^{2/3}$ [5]. We expect therefore that this signal will peak at about 0.1 Hz and then decrease, likely below the requirement sensitivity (e.g. 10^{-9} $ms^2/Hz^{1/2}$) in the short period body waves bandwidth [0.5-2.5 Hz], with the possible exception of storm periods.

Pressure decorrelation and subsurface inversion: The pressure ground acceleration will offer the possibility, by using joint pressure and seismic measurement, to constrain the upper subsurface and likely the thickness of the low velocity mega-regolith. This pressure effects is also likely the source of the planetary seismic humm, which minimum amplitude been already estimated with global circulation models [6], but which might get extra-excitations through the globally distributed large eddies. Last but not least, as the Insight pressure sensors will operate continuously with the same sampling rate as the VBB sensor. Pressure decorrelation, as demonstrated on several Earth seismic data [7], will be performed in order to correct the seismic detected waveforms from this environemental signal. Field Tests have been conducted with that respect with VBB seismometers and prototype of the WTS and microbarometers in Reunion Island, on Mars analogue fields. Finaly and through the infrasounds acquisition, InSight will enable to detect for the closeby impacts (e.g. at a few 100 kms of distance), the impact associated airburst [8] and to therefore better constrain, with an additional arrival time, the epicentral distance of these events.

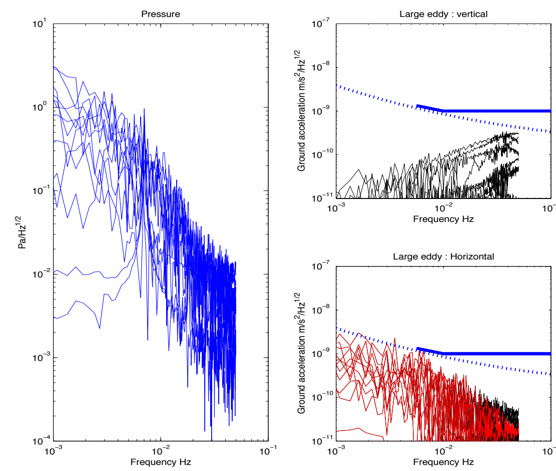

Figure 4. Modeling results up to 0.05 Hz of the microseismic vertical noise (black curves, top right) and horizontal noise (red curves, bottom right), each spectrum corresponding to one Mars hour of signal between 6 and 18hr local time. The associated pressure fluctuations are on the left figure. Solid blue and dashed curves are the InSight SEISmometer requirement and capacity, and the pressure signal will therefore exceed the capacity at about 1 Hz, enabling its detection and further inversion and correction by the InSight micro-barometer.

References: [1] Lognonné and Mosser, 14, 239-302, Survey in Geophysic, 1993 [2] Sorrells, G.G, et al., 1971. *Geophy. Jour. R. Ast. Soc.*, 26:83-98. [3] Sorrells, G.G, and T.T. Goforth, *Bull. Seis. Soc. Am. 63:1583-1601.* [4] Spiga et al, (2010), Quarterly Journal Royal Meteorological Society, 136, 414-428 [5] Tillman et al., 1994, J. Atmos. Sci. 35, 2346–2355. [6] Lognonné and Johnson, Treatrise in Geophysics, 10, Planets and Moons », editor G.Shubert, chapter 4, 69-122, Elsevier, 2007 [7] Beauduin et al, Bull. Seism. Soc. Am., **86**, 1760-1769,1996 [8] Burleigh et al, Icarus, 217, Issue 1, p. 194-201., 2012