INVESTIGATION ON PUTATIVE EXPLANATION FOR SEIS/INSIGHT UNKNOWN EVENTS FROM ROCK AVALANCHES AND ROCKFALLS AND COMPARISON WITH ALPINE CASES

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Motivations For the past year, the SEIS/InSight seismometer has been recording Martian seismic activity. Some rather unusual signals have been recorded, notably numerous events peaking at 2.4 Hz (Fig. 1, the origin of which is still elusive. Here we discuss the possibility that slope instabilities (rock falls, avalanches) may be the cause of some detected events.

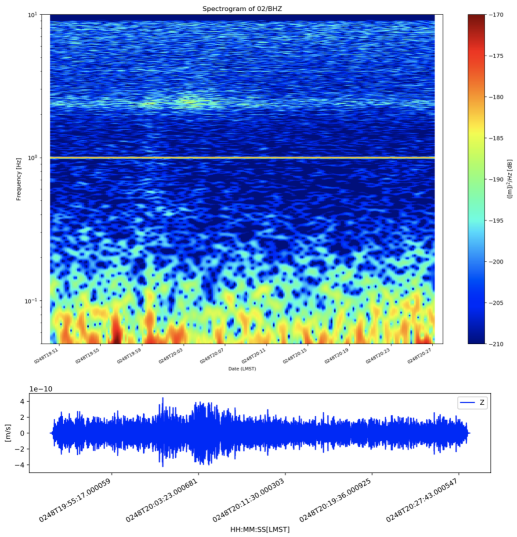


Figure 1: Example of a 2.4Hz event detected by SEIS.

As a matter of fact, from large landslides to small dust avalanches, mass wasting are active on Mars [1]. Dust avalanches, also known as slope streaks, appear as dark or bright features on steep slope and occur in wide regions with high albedo and low thermal inertia [2]. Despite numerous studies, there is as yet no consensus on their underlying mechanism. Many authors have proposed dry spreading of fine dust, whereas some others suggest wet processing during springs discharge involving salty groundwater. Many of those studies have been performed from interpretations of geomorphics features by comparing knowing processes occurring on Earth. Numerous studies have been conducted in order to understand their emplacements and potential implications in regards to landslide dynamics, triggering mechanisms and surface properties [3]. Meanwhile, in recent years, the study of landslides on Earth by seismology has grown, with investigations inverting for terrestrial landslide properties based on simple models with good success [4, 5]. Rock avalanches and rock falls may generate distinct source functions due to their respective mechanisms. On Earth, as exemplified by cases in the Alps, these seismic events have specific characteristics that strongly differ from earthquakes and tremors (Fig. 2).

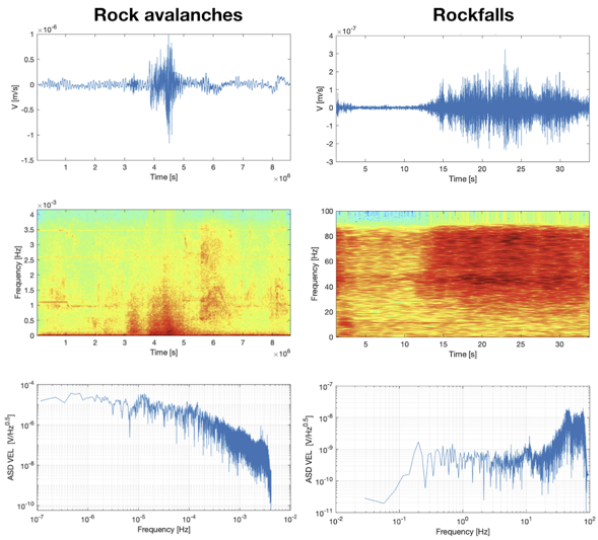


Figure 2: Seismic records of terrestrial example of rock avalanche (Italian Alps, in 2004), and rockfall (Swiss Alps in 2014).

Methods While the model of avalanche is based on the depth-averaged assumption after Saint-Venant equations, the rock fall source function is computed from empirical consideration based on terrestrial examples. The source is considered as a point force at the surface as we integrate the applied force downwards over the evolving mass (Fig 3).

The seismic waves generation is computed from a fast Green function with a model summation method. Such approach have been proven to be robust for examples in the Alps [6, 5]. The velocity models are obtained after geological considerations after [7], around the landing site where active mass wasting have been identified. All models present an Airy phase (Fig. 4).

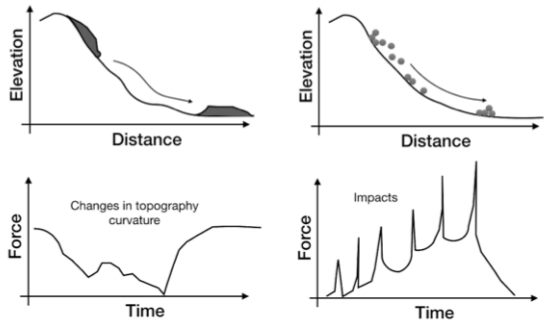
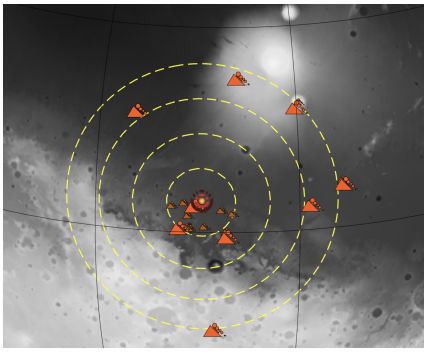


Figure 3: Schematic force history for rock avalanches and rock falls.

a)



b)

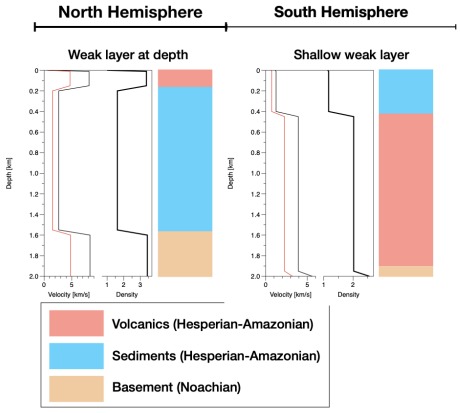


Figure 4: (a) Identified slope instabilities around the InSight lander (rockfall icons). Dashed circles represent epicentral distances from 5° to 20°. (b) Velocity model considered after [7].

Results The resulting seismograms are shown in Fig. 5. They highlight that rock avalanches and rockfalls show low frequency cutoff depending on the velocity model. Rock falls can generate pseudo mono-chromatic seimic signal when accounting for weak layer at depth, as considered near the landing site [7]. We observed a frequency shift with respect to the alpine cases, (towards lower frequencies on Mars). This might be due to the lower gravity inducing a lower velocity and hence a lower energy in the high frequency content. The velocity model, still under investigation for Mars, is also an important open issue that have a strong impact on the resulting signal.

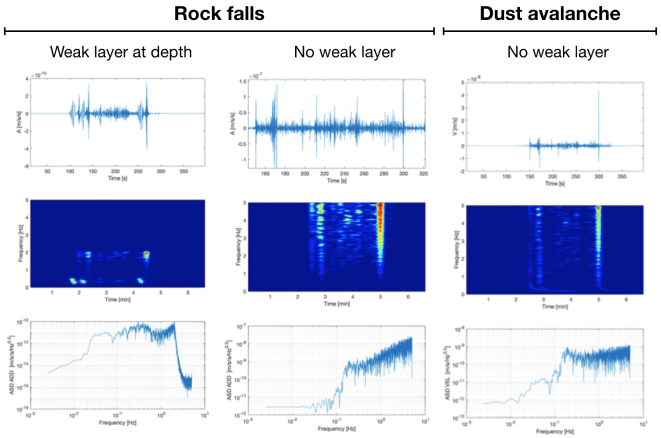


Figure 5: Synthetic seismograms from rockfalls and dust avalanches located at 50 km away from the landing site accounting for various velocity models.

Summary The repetitive 2.4Hz detected events could be explained by mass wasting as soon as they are located in close range (<100 km) from the lander to be detectable. Their systematic occurrence is compatible with the thermal conditions that favor their triggering from thermoclasty on steep slopes. Such conditions are observable around the landing site.

References: **[1]** D. Baratoux et al. "The role of the wind-transported dust in slope streaks activity : Evidence from the HRSC data". In: *Icarus* (2006). **[2]** N. Schorghofer et al. "Slope streaks on Mars: Correlations with surface properties and the potential role of water". In: *Geophys. Res. Lett.,29(23)* (2002). **[3]** A. Lucas et al. "Frictional velocity-weakening in landslides on Earth and on other planetary bodies". In: *Nature Comm.,5:3417* (2014). **[4]** C. Hibert et al. "Slopes instabilities in the Dolomieu crater, la Reunion island: from the seismic signal to the rockfalls characteristics". In: *J. Geophys. Res. - Earth Surface, 116, F04032* (2011). **[5]** P. Favreau et al. "Numerical modeling of landquakes". In: *Geophys. Res. Lett., 37, L15305* (2010). **[6]** A. Lucas. "Dynamique des glissements de terrain par modelisation numerique et teledetection : Application aux exemples martiens". In: *Ph.D. Thesis, IPGP, Paris, France* (2010). **[7]** L. Pan et al. "Crust stratigraphy and heterogeneities of the first kilometers at the dichotomy boundary in western Elysium Planitia and implications for InSight lander". In: *Icarus* (2019).