SEISMIC DETECTION OF MASS WASTING ON MARS WITH SEIS/INSIGHT: A LOONY ATTEMPT?

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Motivations Mass wasting is a common active process observed on Mars. From large landslides to small dust avalanches, also known as slope streaks, they contribute to the landscape dynamics [1, 2]. 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, 4]. In recent years, the study of landslides by seismology has grown, with investigations inverting for terrestrial landslide properties based on simple models with good success [5, 6, 7].

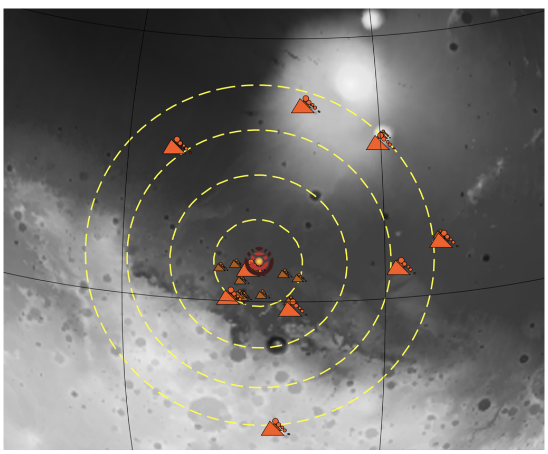

Figure 1: Localization and distances of identified mass wasting features (avalanche signs) around the landing site (InSight icon). Large red icons correspond to active mass wasting. Small brown icons are associated with observed mass wasting features with no orbital evidence for ongoing activity. Yellow dashed circle represent epicentral distances $\Delta = \{5°, 10°, 15°, 20°\}$ which correspond to ∼300, ∼600, ∼900 and ∼1200 km respectively.

As InSight has landed on Mars with a seismometer (SEIS), we wish to investigate the possibility to capture and analyse seismic source due to mass wasting processes. We analyzed the orbital data around 20° of epicentral distance of SEIS in order and identified several areas with active gravity-driven transport (Figure 1). Some of them are close to the seismometer (less than 100 km) making their detection likely. Therefore we are investigating the mandatory conditions for their detection with SEIS and on the potential inference on their physical properties (i.e., duration and frictional properties) along with other geomorphic metrics such as their runout and their volume that can be derived from remote-sensing [4].

Methods We based our analysis on a continuum theory in order to generate synthetic seismic source due to gravity-driven sediment transport based on [2, 8, 9, 4]. The model of avalanche is based on the depth-averaged assumption after Saint-Venant equations accounting for the curvature of the topography and on various frictional behavior for the source term [4]. Example for a martian slope streak is shown on Figure 2. According to our simulations, the typical duration of the event is of about 25 minutes for a 2 km runout slope streaks based on [2, 9, 4]. Volume involve are around 20,000-40,000 m^3 with a total drop height higher than 1 km (Figure 2).

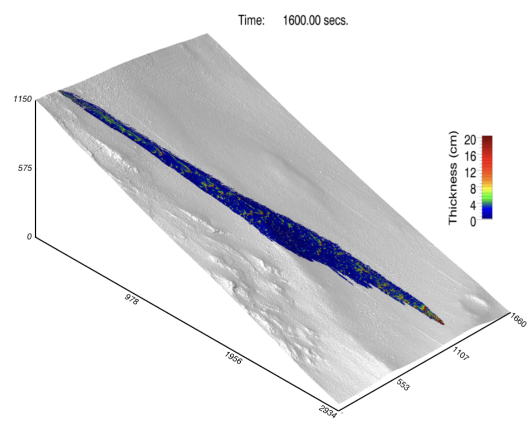

Figure 2: Continuum numerical simulation of a martian dust avalanche over a DTM generated from HiRISE stereo pair; after [8].

The seismic waves generation is based on [7], that is a calculation of fast Green function with a discrete frequency wavenumber method. The model solves the elastodynamic equations in a horizontally layered half space (Fig. 3). The source is considered as a point force at the surface as we integrate the applied force F downwards over the evolving mass:

$$F = \sum_{\text{flow}} \rho h g_\theta \left(\mu \frac{u_x}{\|u\|}, \mu \frac{u_y}{\|u\|}, -1 \right), \qquad (1)$$

where ρ is the density (i.e. 1600 kg m^{-3}), h the flow thickness, g_θ the acceleration due to gravity accounting for the bottom topography curvature, $\mathbf{u} = (u_x, u_y)$, the velocity in the local plane frame and μ the friction coefficient (see [9, 4] for details on μ).

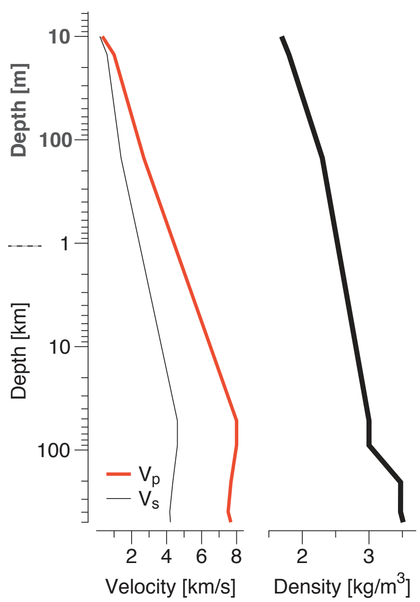

Figure 3: Martian structure model used in this work.

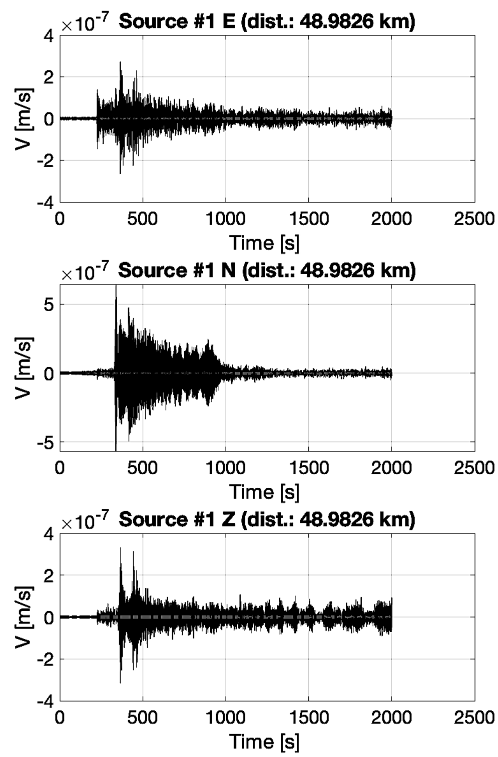

Figure 4: 2.5Hz synthetic seismograms for a simulated slope streak localized at ~50 km away from the lander.

Discussion As the wind and thermal shield (WTS) is planned to be deployed by the end of January 2019, the noise level floor is currently (as of January 10) unknown once shielded. Nonetheless, preliminary results based on synthetic seismograms show that mass wasting events (i.e., slope streaks) in the vicinity of the landing site generated motion amplitudes of 10^{-7} m s^{-1} as shown in Figure 4. Triggering conditions, multi-sources dispersion, frictional behavior, distal and azimuthal effects are being investigated and will be discussed in regards to the detectability with SEIS, accounting for the landing site environmental seismic noise and sub-surface structure (i.e., attenuation factor). Additionally, time series of orbital observations (from CTX, HiRISE and CaSSIS sensors) have been requested and will be used along with the modeling for investigating the dynamics of the ongoing mass wasting processes in Elysium Planitia. Finally, the triggering conditions will be investigated in regards to climatic conditions so as to focus on zones favorable to mass wasting [10].

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