Seasonal variations of sub-surface seismic velocities observed by the SEIS-InSight seismometer on Mars

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Abstract

The SEIS seismometer deployed at the surface of Mars in the framework of the NASA-InSight mission has been continuously recording the ground motion at Elysium Planitia for more than one martian year. In this work, we investigate the seasonal variation of the near surface properties using both background vibrations and a particular class of high-frequency seismic events. We present measurements of relative velocity changes over one martian year and show that they can be modeled by a thermoelastic response of the Martian regolith. Several families of high-frequency seismic multiplets have been observed at various periods of the martian year. These events exhibit repeatable waveforms with an emergent character and a coda that is likely composed of scattered waves. Taking advantage of these properties, we use coda waves interferometry to measure relative travel-time changes as a function of the date of occurrence of the quakes. While in some families a stretching of the coda waveform is clearly observed, in other families we observe either no variation or a clear contraction of the waveform. Measurements of velocity changes from the analysis of background vibrations above 5Hz are consistent with the results from coda wave interferometry. We identify a frequency band structure in the power spectral density, that can be tracked over hundreds of days. This band structure is the equivalent in the frequency domain of an autocorrelogram and can be efficiently used to measure relative travel-time changes as a function of frequency. The observed velocity changes can be adequately modeled by the thermoelastic response of the regolith to the time-dependent incident solar flux at the seasonal scale. In particular, the model captures the time delay between the surface temperature variations and the velocity changes in the sub-surface. Our observations could serve as a basis for a joint inversion of the seismic and thermal properties in the first meters below InSIght.

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AGU FALL MEETING

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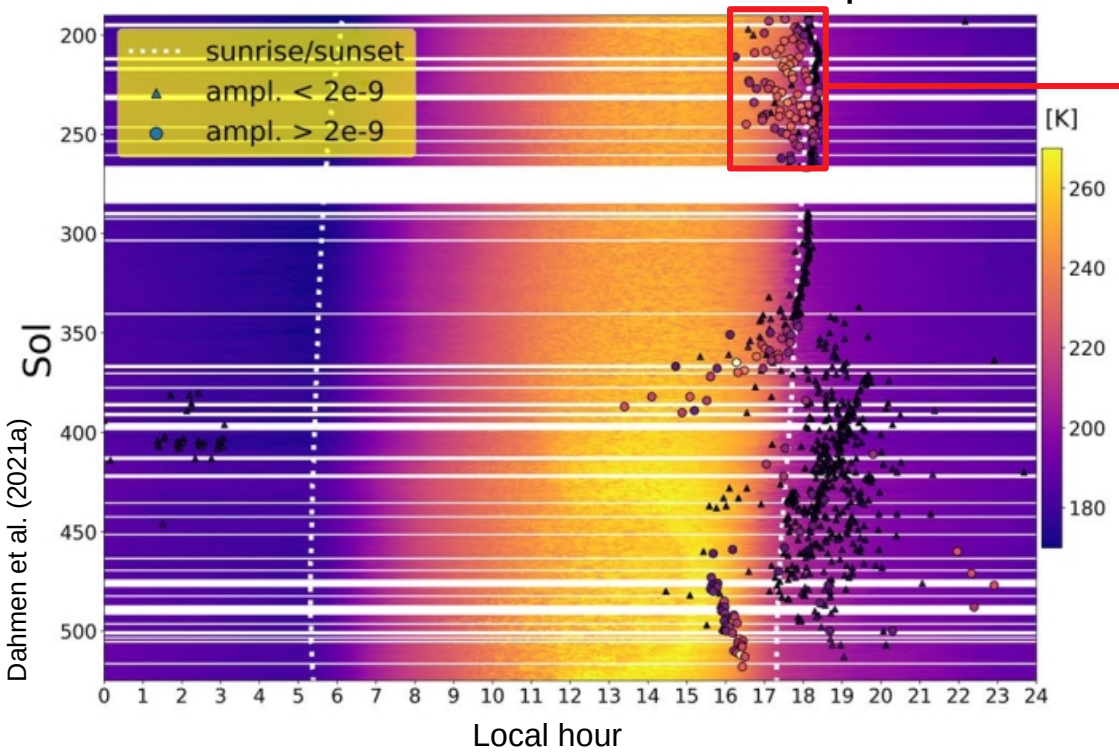
CONTEXT AND MOTIVATION

Previous studies succeed to apply seismic interferometry methods to InSight-SEIS data on Mars for crustal Imaging applications (*Suemoto et al., 2020; Deng & Levander, 2020; Compaire et al., 2021a; Schimmel et al., 2021; Knapmeyer-Endrun et al., 2021*).

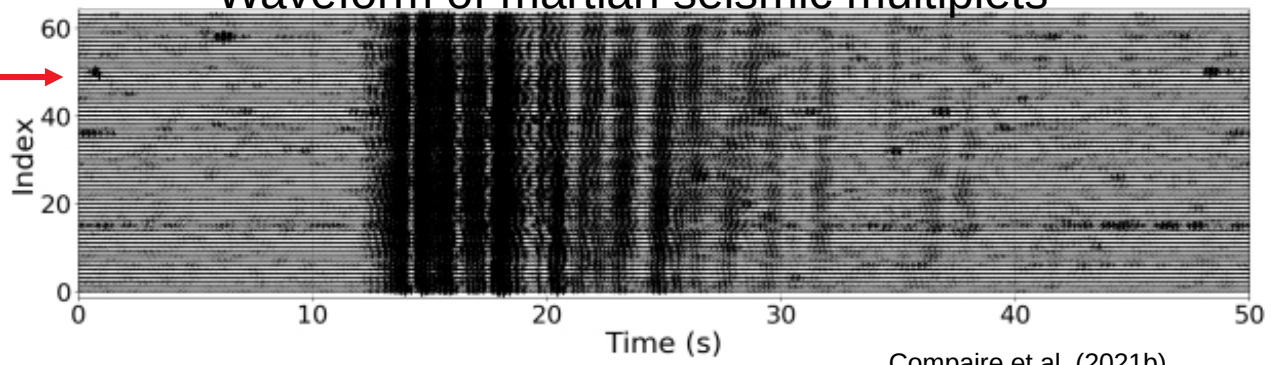
A continuous monitoring of the seismic velocities on Mars using the seismic ambient noise is motivated by the detection of thermally induced high frequency seismic multiplets (Dahmen et al., 2021a) presenting a strong stretching of their waveforms across the mission time-line.

Distribution of the seismic multiplets



Dahmen et al. (2021a)

Waveform of martian seismic multiplets



Compaire et al. (2021b)

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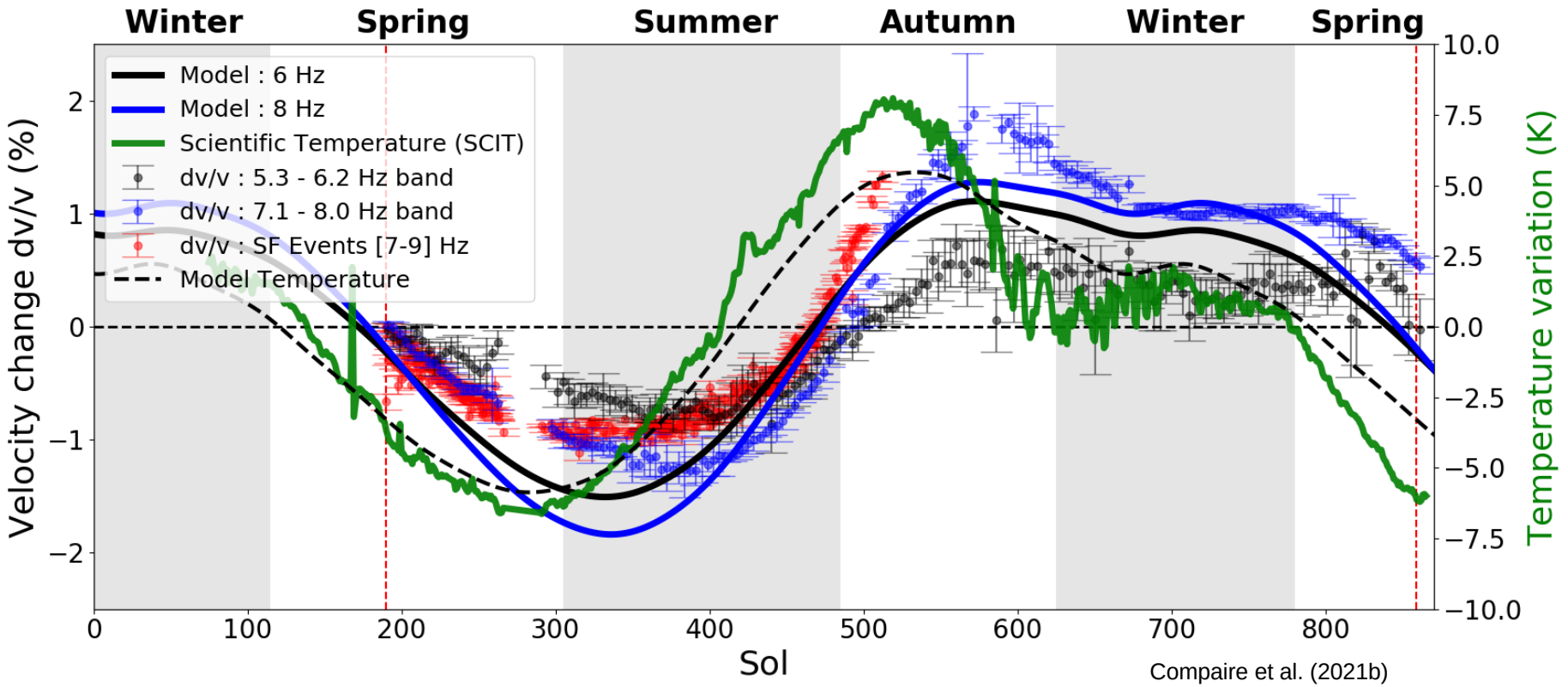
KEY RESULTS

Using Coda Wave Interferometry in the seismic multiplets and a frequency-based approach of Passive Image Interferometry in the ambient seismic noise we detect a strong seasonal variation of the seismic velocities, consistent between the two datasets. We can model these variations as a **thermoelastic response of the martian regolith** due to changes in the thermal forcing by the Sun. The model reproduce quite well the **positive correlation** and the time-delay with the surface temperature as well as the high amplitude of the velocity perturbation.



Compaire et al. (2021b)

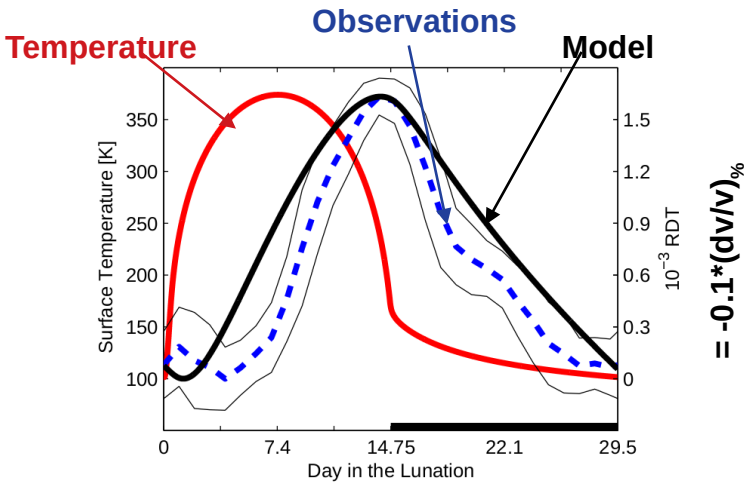
DISCUSSION

Interest for the InSight mission

- This observation provides a link between the thermal and elastic properties of the martian subsurface under InSight and opens the way to a joint inversion of the velocity and thermal conductivity profiles,
- Our model also allows us to put some constraints on the nature of the seismic ambient noise recorded at InSight.

Comparison with the Moon

- *Sens-Schönfelder and Larose (2008)* observed a clear **anti-correlation** between the surface temperature on the Moon and apparent velocity changes of the order of 0.1-0.2%,
- To explain their observations they invoke the temperature dependence of elastic moduli,
- On Mars, this effect is expected to affect only marginally the seismic properties of the martian regolith (perturbations of the order of 0.01-0.02%),
- The contrasting observations between Mars and Moon is important topic for future investigation on the mechanical properties of extraterrestrial regoliths.



(Sens-Schönfelder and Larose, 2008)

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