3D seismic wave simulation for understanding seismological features of 3 different families of Martian convective vortices

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Abstract

Convective vortex (i.e. whirlwind) is a typical phenomenon on Mars caused by diurnal variations of atmospheric temperature. When it is strong enough to lift up dusts, it is called "dust devil" vortex. As demonstrated on the Earth [1], a convective vortex which deforms the nearby ground as it moves around can generate seismic waves, allowing us to constrain the subsurface structure. NASA's InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) mission has been conducting seismological and meteorological observation on Mars since the end of November, 2018 [2]. The first estimation of the Martian internal structure was done using the InSight seismic data concerning convective or dust devil vortices and HP^3 hammering (e.g. [3]). On the other hand, the elastic properties of the regolith (such as Young's modulus) was constrained by combining the pressure profiles related to the vortices and the excited seismic signals [4].

This study focuses more on the phenomenon itself. From the InSight data, it turned out that the seismic signals caused by the vortices can be categorized into 3 different families such as "Spike type", "High Frequency Oscillations (HFO)", and "Complex type (i.e. combination of Spike and HFO types)" (e.g. [5]). However, it is not clear that what makes differences in seismological features and what kind of factor is dominant to characterize them. In order to understand these, we conducted 3D seismic wave simulations under various conditions.

As for seismological modeling, the previous studies succeeded to reproduce the overall features for a reference dust devil whose track information, pressure profile, wind data, and seismic data were all tied with each other (e.g. [2] [5]). Based on their models, we conducted parameter studies (e.g. input pressure model, internal structure model, track geometry and moving speed of a vortex) in order to evaluate their respective influences on the characterization of the seismic signals by the Martian vortices.

As a result, we found that the track geometry and the moving speed of a vortex plays an important role to characterize the resulting seismic signals. Basically, for a given vortex trajectory, as a source moves faster, the resulting signals become more spike-shaped. Also, regarding the distance of the track from the seismic station, it turned out that the oscillated signals were more likely to be generated for the farther distant cases. In the presentation, we show how seismic signals by the Martian convective (or dust devil) vortices can be modeled and discuss the consistency between the synthetics and the data.

References

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