Geophysical Research Abstracts
Vol. 21, EGU2019-7163, 2019
EGU General Assembly 2019

Mars Structure Service: Single-station and single-event marsquake inversion for structure using synthetic Martian waveforms

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The InSight lander successfully delivered geophysical instrument package on the Martian surface on November 26th, 2018, including a broadband and a short-period seismometer (Seismic Experiment for Interior Structure, SEIS). The seismic instrument package is specifically designed to record marsquakes and meteoritic impacts in Martian conditions. Routine operations are split into two services: the Mars Structure Service (MSS) and the Marsquake Service (MQS), which are responsible for defining structure models and seismicity catalogs, respectively. The first "deliverable" of the MSS will be a model based on the events detected during the first 3 months of seismic monitoring of the mission, for which only a few quakes might be expected based on current estimates of Mars seismic activity. To test our approach of determining the interior model of Mars and to prepare the InSight science team for data return, we made use of a "blind test" time series for which the Marsquake parameters (location, depth, origin time, and moment tensor) and interior model were unknown to the group at large.
In preparation for the mission, the goal was to develop mature algorithms to handle the data as efficiency as possible. Synthetic seismic waveforms were computed in a 1D mantle model with a 3D crust on top using AxiSEM and Salvus. The time series were created by adding seismic noise that relies on pre-landing estimates of noise generated by the sensors, electronic system, environment, and nearby lander.
To characterize what we could learn about Mars interior structure with only one station and with the first seismic event, we performed inversions of a synthetic data following a blind test process, where the interior model was unknown to all team members carrying out data analysis and inversion.
We detail and compare the results of this "blind test" using different methods including inversion of surface wave dispersion data, body waves travel times, and the waveforms themselves. We have used mainly Bayesian techniques to obtain robust probability density functions of interior structure parameters. The effects on the retrieved model distributions of fixing mars quake location and origin time are investigated, as is the effect of using fixed Vs flexible parameterizations. To allow for tighter constraints, we also test the use of priors based on thermodynamically-constrained models together with seismic observations, as well as seismic confirmation/rejection of models purely based on thermodynamical modelling. These techniques considered here form a large part of the planned modeling of the MSS that will be ultimately employed with the first recording of a seismic event by InSight.