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Source mechanism solutions of low frequency Martian events based on body wave coda from a single seismic station

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On the 26th of November 2018, NASA's InSight lander successfully touched down on the Martian ground in Elysium Planitia. The lander transported among other instruments a single three-component broadband seismometer to measure seismic events and subsequently determine the seismic activity level and eventually the internal structure of Mars. In this study we focus on characterizing the source mechanisms of the highest-quality marsquakes detected so far: The events with highest SNR occurred on sols 173 (S0173a, May 23rd 2019) and 235 (S0235b, July 27th 2019) with $M_w > 3.5$, showing clearly polarized P and S waves. The InSight MarsQuake Service has estimated their distances to be around 27 degrees, nearby the Cerberus Fossae Graben system. Two more events, S0183a and S0325b have less clear body wave phases and locations, but are also interpreted to be related to it.

We have developed a grid-search based method to fit synthetic waveforms to the observed first arriving P and S wave trains. The four source parameters we invert for in this study are the three unique orientation angles of the source mechanism, strike (φ), dip (δ) and rake (λ), and the depth of the event. Synthetic seismograms are generated by computing Green's functions based on the epicentral distance determined by the InSight MarsQuake Service (MQS) and radially symmetric velocity models. These Green's function are then convolved with a source time function including an estimated global body wave attenuation to obtain realistic seismograms.

The two high-quality event recordings originating from the Cerberus Fossae (CF) fault system were analyzed. Multiple velocity models, frequency bands and window lengths around the arriving phases were used to explore the non-uniqueness in the inverse problem of the inherently ambiguous single-station data. We found that using plausible structural models based on geophysical modeling, the first 10-15 seconds of the waveforms can be fit, constraining the source mechanism and depth, but that the estimation of the uncertainty remains challenging.

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