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Probabilistic source inversion using body wave coda from a single seismic station (InSight)

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On December 19th, 2018, a seismometer was placed directly onto the surface of a planetary body for the first time since the Apollo missions. In this study we focus on characterizing source mechanisms of potential marsquakes using only a single station, an approach that went out of fashion on Earth because of the abundance of seismic stations.

Method: Our method fits the waveforms of seismic body waves, specifically the P- and S-wave train, including depth phases reflected at the surface above the event. We use the seismic waveform database Instaseis to generate synthetic waveforms up to frequencies of 1 Hz in combination with a Markov-Chain Monte Carlo sampler. We restrict our model space to double-couple sources, expressing the focal mechanism in three unique orientation angles: strike(ϕ), dip(δ) and rake (λ). The waveform match is estimated using a correlation-coefficient based likelihood function as described by [1].

Synthetic test on Mars Data: We test the method on synthetic seismograms for Mars, including modelled noise as described in the Mars blindtest [2, 3]. For these tests, we used different velocity models to create the synthetic seismograms, to test the effect of the a priori unknown velocity structure of Mars. Based on these examples, we show that (1) two out of three orientation angles can be obtained to high accuracies. The third orientation angle has a bimodal probability density function for many events. (2) the event depth can be constrained to less than 5 kilometer, depending on the event magnitude and therefore signal-to-noise ratio.

Test on Earth Data: We tested the method on earthquakes of magnitude 5.5 to 6 recorded on single seismic stations in teleseismic distance. This magnitude range has a similar signal-to-noise ratio as a magnitude 4 on Mars, due to the presence of microseismic noise on Earth. The results are compatible with the results of our synthetic Mars test.

References: **[1]** Stähler, S. C., and K. Sigloch. (2016) *Solid Earth* 7 (6): 1521–36. doi:10.5194/se-7- 1521-2016. **[2]** Clinton, J. F., et al (2017). *Seismological Research Letters* 88 (5): 1290–1302. **[3]** Mimoun, D., et al (2017). *Space Science Reviews* 211 (1–4): 383–428. doi:10.1007/s11214- 017-0409-x.