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An iterative inversion technique to improve single station event locations on Mars

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The InSight mission will deploy a single seismic station on Mars in November 2018. The main task of the Marsquake Service (MQS) within the project includes detecting, characterisation of seismicity and managing the marsquake catalogue. Together with the Mars Structural Service, we will use observed seismicity to improve our knowledge of the Martian structure, which in turn will be used to refine our catalogue. In preparation for the mission, we continually calibrate our single-station location algorithms, using a priori 1 and 3D structural models. Target synthetic waveforms are generated using AxiSEM/Instaseis and combined with realistic Martian noise. For the inversion, seismic phase travel times are computed for a wide range of plausible structural models. However, our knowledge on the interior structure of Mars is limited, which in turn affects our ability to locate events accurately.

In this study, we present an iterative inversion method for computation of Martian structural models and the ensuing revision of event locations. We first locate seismic multiple events using manual identification of clearly observed seismic phases, including estimate of timing uncertainty. In the inversion for event distance, we use differential arrival times for a large suite of a priori initial models. These models are built considering a one-dimensional average crust and current estimates of bulk mantle chemistry and areotherm. Then, we invert for the interior structure employing the arrival times for the picked phases, and generate an updated suite of models. Predicted travel times from these updated models are subsequently used to revise the initial phase picks (relabeling mis-identified phases, selection of additional phases) and relocate the events. We repeat this procedure for each additional and new entry in the travel time database (modified or new phases and/or additional events) to improve event locations and radial models of Mars' interior.

In order to test our approach, we simulate the operational conditions we will encounter in practice using synthetic waveforms, including noise, for a realistic event catalog of 120 events, with magnitudes between 2.5 and 5.0 and double-couple source mechanisms only. The waveforms and event catalog are hosted at the ETH servers, and are publicly accessible via FDSN web services.