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Joint inversion for shallow crustal discontinuities from high-frequency waveforms of microearthquakes

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The waveforms of microearthquakes are of high frequency and complicated. They contain many phases secondarily generated at crustal interfaces and at small-scale inhomogeneities. They are highly sensitive to focal mechanisms and thus very different for each station of local networks. However, with a large number of clustered microearthquakes, the reflected/converted waves present in waveforms can serve for detecting prominent discontinuities within the crust. With a dense network of sensitive seismic stations and a good azimuthal distribution, it is possible to retrieve a depth of these discontinuities and map their lateral variations. The standard microseismic monitoring is routinely investigated for source parameters; however, an analysis of shallow crustal structure is often missing, though it can contribute to, e.g., mitigation of induced seismic hazard.

The structure studies based on microseismic data are specific. The depth of discontinuities is modelled using several independent tools provided by refraction and reflections seismics combined with the earthquake source analysis. We use ray tracing for calculating traveltimes of converted and/or reflected phases, analysis of focal mechanisms and radiation patterns for converted/reflected phases, full waveform modelling using the discrete wavenumber method for comparing synthetic full wavefields with observed data, alignment of traces and their stacking for amplifying studied phases, and a grid search method for the inversion. Joint interpretation of more phases converted/reflected from the same interface increases the stability of retrieved results and enhances the robustness of the inversion. If phases are well visible and separated in time, the processing is confined to vertical components of the SP/PS conversions and the PPP reflections. Otherwise, it is combined with the PS conversions and/or the SSS reflections detected on horizontal components or supplemented by the analysis of the total vector in absolute values which also includes horizontal components. A novel concept for extracting crustal structure from high-frequency waveforms of local microearthquakes is demonstrated on natural seismicity in the West Bohemia swarm region, the Czech Republic. Clustered seismicity in West Bohemia indicates a strong-contrast interface at depths of 3.5-6.0 km, which is in agreement with previous profiling and might be related to trapping of fluids ascending from the mantle.

References:

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