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Rupture Complexities of Fluid Induced Microseismic Events at the Basel EGS Project

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Microseismic data sets of excellent quality, such as the seismicity recorded in the Basel-1 enhanced geothermal system, Switzerland, in 2006-2007, provide the opportunity to analyse induced seismic events in great detail. It is important to understand in how far seismological insights on e.g. source and rupture processes are scale dependent and how they can be transferred to fluid induced micro-seismicity.
We applied the empirical Green's function (EGF) method in order to reconstruct the relative source time functions of 195 suitable microseismic events from the Basel-1 reservoir. We found 93 solutions with a clear and consistent directivity pattern. The remaining events display either no measurable directivity, are unfavourably oriented or exhibit non consistent or complex relative source time functions.
In this work we focus on selected events of $M \sim 1$ which show possible rupture complexities. It is demonstrated that the EGF method allows to resolve complex rupture behaviour even if it is not directly identifiable in the seismograms. We find clear evidence of rupture directivity and multi-phase rupturing in the analysed relative source time functions. The time delays between consecutive subevents lies in the order of $10\,ms$. Amplitudes of the relative source time functions of the subevents do not always show the same azimuthal dependence, indicating dissimilarity in the rupture directivity of the subevents. Our observations support the assumption that heterogeneity on fault surfaces persists down to small scale (few tens of meters).