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Constraints on the quality of source localization and characterization with Time Reverse Imaging imposed by the array design, the complexity of the velocity model and the signal-to-noise ratio

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Time Reverse Imaging (TRI) is a method to localize and characterize seismic sources that uses the whole waveform. Because no identification of individual events is needed, it is especially suited for datasets with quasi-simultaneous events or a low signal-to-noise ratio, for example in non-volcanic tremor applications, microseismic event localizations or non-destructive testing problems. In recent years, large passive seismic networks have become more frequent and imaging methods are able to produce high quality three-dimensional velocity models. To exploit the capabilities of TRI it is essential to know the influence of the station distribution, a complex velocity model and a high degree of noise on the localization results and the source characterization possibilities.

TRI uses seismograms that are obtained from field measurements. Alternatively, for example for testing purposes, seismograms can be obtained with a forward simulation. TRI then consists of three steps: the reversal of the traces in time, the back propagation of the time reversed wavefield and the elimination of artifacts impinged by the velocity structure. The accuracy of TRI focusing strongly depends on the quality of the velocity model and on the distribution of stations at the surface. Therefore, we perform 3D elastic synthetic simulations of wave propagation with several velocity models for the forward and backward propagation steps.

Different station distributions are systematically tested for their ability to allow the backwards propagating wavefield to focus at the initial source location and retrieve source characteristics. Parameters like station density, array aperture and the symmetry of the array in relation to the source location are investigated. The influence of the complexity of the velocity model is shown. Additionally, the capability of the method to work with noisy data is tested with different signal-to-noise ratios. Simulations were performed with different source depths and source types.

This study will be of help for designing arrays or using data from an existing array for TRI. It will provide guidelines to evaluate if a certain station distribution is beneficial and if the velocity structure and noise level will allow the method to be successful.