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Real-Time Magnitude Determination and Ground Motion Prediction using Optical Fiber Distributed Acoustic Sensing for Earthquake Early Warning

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Distributed Acoustic Sensing (DAS) is ideally suited for the challenges of Earthquake Early Warning (EEW). These distributed measurements allow for robust discrimination between earthquakes and noise, and remote recordings at hard to reach places, such as offshore, close to the hypocenters of most of the largest earthquakes on Earth. In this study, we propose the first application of DAS for EEW. We present a framework for real-time strain-rate to ground accelerations conversion, magnitude estimation and ground shaking prediction. The conversion is applied using the local slant-stack transform, adapted for real-time applications. Since currently, DAS earthquake datasets are limited to low-to-medium magnitudes, an empirical magnitude estimation approach is not feasible. To estimate the magnitude, we derive an Omega-squared-model based theoretical description for acceleration root-mean-squares (rms), a measure that can be calculated in the time-domain. Finally, peak ground motions are predicted via ground motion prediction equation that are derived using the same theoretical model, thus constituting a self-consistent EEW scheme. The method is validated using a composite dataset of earthquakes from different tectonic settings up to a magnitude of 5.7. Being theoretical, the presented approach is readily applicable to any DAS array in any seismic region and allows for continuous updating of magnitude and ground shaking predictions with time. Applying this method to optical fibers deployed near on-land and underwater faults could be decisive in the performance of EEW systems, significantly improving earthquake warning times and allowing for better preparedness for intense shaking.