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Ground Motion Prediction Equations as proxy for monitoring and interpreting induced-seismicity data

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Sub-surface operations (e.g., gas storage, CO_2 sequestration,. . . .) and exploitation for energy production, such as geothermal energy, may originate various environmental risks. Science4CleanEnergy, S4CE, is a multi-disciplinary project (H2020-EU.3.3.2. - Low-cost, low-carbon energy supply) aimed at understanding the underlying physical mechanisms underpinning sub-surface geo-energy operations and to measure, control and mitigate their environmental risks.
Of great relevance is the seismic risk due to the induced and triggered seismicity associated with field operations. In general, a key aspect of seismic hazard mitigation is the reliable estimation of the expected ground motion values for damaging earthquakes. Although well-established techniques based on simple point-source or extended faults model do exist for estimating the ground motion, they are useful in case of strong earthquakes and, basically in post-event periods. On the other hand, the analysis of the induced seismicity requires a near-real time monitoring able to capture the evolution of the system toward a critical status to avoid adverse consequences. In this case, the empirical ground-motion prediction equations (GMPEs) represent a fast and effective tool. GMPEs are empirical equations that correlate a strong ground motion parameter, such as peak-ground motion acceleration (PGA), peak-ground motion velocity (PGV) or spectral ordinates (Sa) at different structural periods, with magnitude and source-to-site distance through coefficients that must be inferred from the analysis of the available waveforms.
In the framework of the S4CE project, we investigate if the GMPEs can have twofold usefulness. Indeed, aside from their use as a fast and easy tool to estimate the ground motion, once magnitude and source-to-distance are known, they could be used for monitoring field operations and their impact on the environment. The idea is to use the earthquakes recorded during the field operations to infer and/or update the coefficients of a reference GMPE with the aim of refining the estimation of the ground motion and reduce the associated uncertainties. However, as each of the coefficients of the GMPE is empirically correlated with properties concerning both the propagation medium and the source, a time dependent analysis of their evolution could allow the monitoring of the status of the reservoir. We show the results of a synthetic test that reproduces the seismic activity (seismicity rate, minimum and maximum magnitude, etc. . .) induced by fluid injection and recorded at a local seismic network. To simulate the temporal variation of the propagation medium due to the field operations, for each earthquake, waveforms are computed by modifying physical parameters with time. Peak-ground motion parameters are then used for testing the sensitivity of the GMPEs' coefficients to the temporal variations of the propagation medium.

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