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Seismicity associated with 2018 and 2020 hydraulic stimulations at EGS in Helsinki, Finland, shows limited earthquake interaction: Implication for seismic hazard assessment

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In this study we investigate the statistical spatio-temporal characteristics induced seismicity associated with two stimulation campaigns performed in 2018 and 2020 in a 6.1 km deep geothermal well near Helsinki, Finland as part of the St1 Deep Heat project. We aim to find out whether the seismic activity is passively responding to injection operations, or whether we observe signatures of significant stress transfer and strong interactions between events. The former suggests stable relaxation of seismic energy proportional to hydraulic energy input, while the latter includes stress transfer as an additional source of stress perturbation, hence implying larger seismic hazard.

The selected catalogs from 2018 and 2020 stimulation contained in total 60,814 and 4,368 seismic events, respectively, recorded during and after stimulation campaigns and above the local magnitude of M -1.5. The analyzed parameters include magnitude-frequency b-value, correlation integral (c-value), fractal dimension (D-value), interevent time statistics, magnitude correlation, interevent time ratio and generalized spatio-temporal distance between earthquakes. The initial observations suggest significant time-invariance of the magnitude-frequency b-value, and increased D and c-values only at high injection rates, the latter also guiding the rate of seismicity. The seismicity covering the stimulation period neither provide signatures of magnitude correlations, nor temporal clustering or anticlustering. The interevent time statistics are generally characterized with Gamma distribution (close to Poissonian distribution), and the generalized spatio-temporal distance suggest very limited triggering (90% of the catalog was classified as background seismicity). The observable parameters suggest the seismicity passively respond to hydraulic energy input rate with little to no time delay, and the total seismic moment is proportional to total hydraulic energy input. The performed study provides the base for implementation of time-dependent probabilistic seismic hazard assessment for the site.