EGU21-5138
https://doi.org/10.5194/egusphere-egu21-5138
EGU General Assembly 2021

Stochastic modelling of injection-induced seismicity in the Cooper Basin enhanced geothermal system

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Fluid-injections under high pressures into deep "hot" rock formations are routinely performed during the development of Enhanced Geothermal Systems (EGS). Such fluid-injections, which aim to enhance the permeability in the targeted rock formation, can induce intense microseismicity and in some cases even larger magnitude earthquakes. A characteristic of injection-induced seismicity is its spatial migration with time, which is considered indicative of pore-pressure diffusion and the geometry of the stimulated volume in which permeability is enhanced. Understanding the details of earthquake migration during stimulation operations is particularly important for the design of EGS, the management of operations, as well as for the mitigation of hazardous induced earthquakes. Herein, we develop a stochastic model to map the spatiotemporal evolution of injection-induced seismicity. The model is based on the well-established Continuous Time Random Walk (CTRW) theory that has widely been applied in nonlinear transport phenomena in complex heterogeneous media. Within this context, we describe the spatiotemporal evolution of injection-induced seismicity with an appropriate master equation and the time-fractional diffusion equation. Application of the model to two stimulation experiments in the Cooper Basin (Australia) EGS shows that induced seismicity migrates slowly with time away from the injection points according to a subdiffusive process, with waiting times between the successive earthquakes drawn from a broad probability density function with asymptotic power-law behavior. Moreover, we show that the solution of the time-fractional diffusion equation adequately describes the propagation of induced seismicity in time and space, showing a peak of earthquake concentration close to the injection point and a stretched exponential decay for the concentration of distant events. The results demonstrate that the CTRW model can efficiently describe nonlinear diffusion of injection-induced seismicity during stimulation operations in EGS.

Acknowledgements

The research project was supported by the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the "2nd Call for H.F.R.I. Research Projects to support Post-Doctoral Researchers" (Project Number: 00256).