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Temporal deformation in the Hellisheiði geothermal field and its adjacent Húsmúli injection field explained by poroelastic modelling

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Crustal deformation allows us to monitor and understand critical properties of exploited geothermal systems around the world. The Hellisheiði high-temperature geothermal field (in 2011: 303MW_e and 133MW_{th}) in SW Iceland has been previously studied using Global Navigation Satellite Systems (GNSS) and Interferometry Synthetic Aperture Radar (InSAR) data between 2011 and 2015. These studies characterized the subsidence rate related to the extraction of fluids in the Hellisheiði area, as well as a 4-month uplift at the start of injection of geothermal fluids in the Húsmúli area. This uplift was accompanied by significant seismicity culminating with two M_L >3.5 earthquakes felt in the surrounding region.

We carry out further analysis of GNSS and InSAR data between 2011 and 2019 that show a total of three uplift events, separated by periods of subsidence or little deformation in the Húsmúli area. The deformation episodes seem to correlate with heightened seismic activity despite the continued decrease of injected mass flow rate in the original injection boreholes.

Here we use a finite element poroelastic model (COMSOL Multiphysics) to relate the extraction and injection of the adjacent Hellisheiði and Húsmúli areas to the ground deformation within the same time span. We assume that the boreholes can be represented by three point-injector sources: one of negative mass flow rate in Hellisheiði, and two of positive mass flow rates in (west and east) Húsmúli. The three sources are necessary to explain the deformation observed between 2011 and 2019. The poroelastic model presents insights into the temporal response of geothermal systems from extraction/injection, changes in exploitations and variability in permeability all of which induce heightened strain and stress in the fractured Húsmúli region. We investigate if poroelastic effects may be responsible for triggering transient earthquake swarms and to what degree poroelasiticy can explain the spatially and temporally complex uplift and subsidence. We suggest this study offers new insights into the Hellisheiði geothermal system that are transferable to geothermal systems around the world.