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Numerical modelling of crustal deformation due to fluid extraction and re-injection in the Hengill geothermal area in South Iceland

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Several high temperature geothermal energy production fields are currently harnessed in Iceland. One of these is located at the Hengill triple junction, where the oblique plate motion along the Reykjanes peninsula is partitioned between the E-W oriented transform along the South Iceland Seismic Zone (SISZ) and spreading across the Western Volcanic Zone in SW Iceland. The Hengill volcano is a high temperature geothermal area that is utilized by the Hellisheiði and Nesjavellir power plants. The regions around the power plants are subject to surface deformation due to several processes. These include the motion of the Earth's crust due to plate spreading, co- and post seismic deformation due to earthquakes in the South Iceland Seismic Zone and deformation due to water and steam extraction and wastewater re-injection near geothermal power plants.

We measure surface displacement in the Hengill area using both GPS and InSAR data. The former are obtained from four continuous and more than 15 campaign GPS stations in the area, with time-series starting after two M6 earthquakes on 29 May 2008 in Ölfus - the westernmost part of the SISZ. The InSAR data consist of 10 images taken by the TerraSar-X mission, starting October 2009. The InSAR time-series has a temporal resolution of 1 to 3 images per year, taken at an incidence angle of approximately 30° from the vertical.

In the InSAR data we can see a clear subsidence signal in the proximity of the power plants with a maximum of $\sim$24 mm/yr in Line-of-Sight direction (LOS) at Hellisheiði, after correcting for plate motion. The subsidence is elongated in NNE-SSW direction and possibly related to the orientation of the Hengill fissure swarm. In addition to subsidence, we observe an uplift signal of ca. 10 mm/yr in LOS west of the Hellisheiði site, potentially due to wastewater re-injection in the area. The area of maximum uplift is located close to the epicenters of two M4 earthquakes that occurred in October 2011.

We run numerical simulations using the Finite Element Method to model the poroelastic response of the crust to the fluid extraction and re-injection at the power plants, based on Biot's equations. The equations are solved implicitly using the code Defmod. We include the real extraction and injection rates, obtained from the power plant operator. These rates induce pressure change in the system and consequently drive the flow of pore fluids and the deformation. Preliminary results show that the observed surface deformation can in parts be explained by this effect. We use an iterative scheme to reduce residuals by parameter variation to gain a better understanding of the geometry and hydraulic parameters of the geothermal reservoir as well as the properties of the local crust.