Assessment of Reservoir processes induced by geothermal utilization at Reykjanes, SW-Iceland, inferred from interferometric analysis of satellite images and gnss geodesy 2005-2018

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**Abstract**

We study local deformation induced by geothermal utilization of the high-temperature Reykjanes system, SW-Iceland, since 2006 when a new 100 MWe power plant began operation. Using interferometric analyses of synthetic aperture radar (InSAR) images acquired by the Envisat, TerraSAR-X and Sentinel-1 satellites, time series of deformation have been determined for the 2005-2008, 2009-2016 and 2015-2018 time periods, respectively, complemented by Global Naviation and Satellite System (GNSS) data.

Surface displacements above the geothermal reservoir have been estimated from InSAR data at coherent pixels. Time-series of range change in the satellite line-of-sight (LOS) indicate a continuous deflation, with the highest rate observed for the 2005-2008 study period, where the main deformation area (about 4 km long by 2.5 km wide) is aligned along the Reykjanes fissure swarm, in the vicinity of the power plant. From 2009, the deformation zone narrowed to a 2-km wide circular subsidence bowl centered on the well field. Maps of approximate vertical and east displacement rates were inferred for each time period from the InSAR data. A total subsidence of about 285 mm together with horizontal contraction towards the centre of deflation of up to about 210 mm were calculated for the 2006-2017 period.

The average ascending and descending LOS velocities, derived at coherent pixels from each time series, are used to invert for the characteristics of the deformation source, modeling the reservoir as a body of simple geometry within an elastic half space. In the 2005–2008 period, the best fitting model is obtained for a near-horizontal ellipsoidal source at about 2.2 km depth, contracting at a rate of −7.3×105 m3yr−1. Modeling results for the periods 2009–2016 and 2015-2017 indicate a decrease in the rate of volume change down to −1.5×105 m3yr−1 and −0.9×105 m3yr−1, respectively, for a best-fitting point pressure source situated at about 1-km depth.

Similarities were found between the pattern of the decline in the modeled rate of volume change and the rate of pressure drop measured in observation wells at 1625 m.b.s.l., until the end of 2015. From 2015, minor pressure increase was however reported at that depth, while a continued pressure decline together with cooling were measured between 2009 and 2017 at 925 m b.s.l. Using production data as well as an analysis of the reservoir structure and of the rock properties, we find that the shallow deformation modeled since 2009 can be attributed to a combination of compaction under pressure decrease and thermal contraction of the rocks within or near a steam cap. This steam cap was formed in the topmost part of the reservoir (800–1200 m depth) in response to a sudden 3 MPa pressure drop associated to high rates of fluid extraction within the two-three first years of production.

The use of in-situ pressure/temperature measurements combined with ground deformation inferred from InSAR and GNSS observations provides valuable opportunities to monitor the detailed response of the Reykjanes reservoir to new production and reinjection strategies.