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Ground deformation around Bárðarbunga, Iceland: Aftermath of the 2014-2015 Lateral Dyke, Caldera Collapse and Major Effusive Eruption Event

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The largest instrumentally recorded ground deformation event in Iceland occurred during 2014-2015 within the Bárðarbunga volcanic system. A 48-km-long lateral dyke propagated away from the caldera, followed by a six-month-long effusive eruption at the far end of the dyke, during which the Bárðarbunga caldera gradually collapsed by 65 meters. We study ground deformation in the volcanic system after these events, in order to provide an improved understanding of the deformation that follows the rifting and the caldera collapse, and distinguish signals induced by visco-elastic responses to magma withdrawal from those related to renewed melt supply.

We observe ground deformation using Interferometric analysis of Synthetic Aperture Radar (InSAR) and GPS geodesy. We analyze Sentinel-1 satellites interferograms spanning the time 2015-2017 to observe the overall deformation field. InSAR time series analysis is implemented to reduce atmospheric noise and derive average velocity fields over the area. The observed deformation is a superpostion of several processes, including glacial isostatic adjustment (GIA) and steady plate movements in addition to the viscous and magmatic process we seek to study. We correct for GIA and plate boundary deformation to reveal excessive displacement rates we attribute to the deformation after caldera collapse around Bárðarbunga caldera and post-rifting relaxation in the dyke area. The movements are attributed to visco-elastic response of the Earth, which results in gradual recovery of the area and high displacement rates after the events.

The deformation due to post-caldera collapse relaxation is modelled with magma withdrawal from a spherical point source embedded in a visco-elastic rheology under a fully elastic layer with the RELAX software. We removed 2 km3 from a spherical source at 10 km depth, assuming the elastic layer was 7 km thick (corresponding to the brittle-ductile transition). We assume in initial model that visco-elatic half-space has viscosity of 5 x 1018 Pa s. The shear modulus is set to 30 GPa. Directly above the source, the post-caldera collapse relaxation induces gradual subsidence directly above the source, which decays at the beginning and reverts to uplift in 1.3 years in our preliminary model. The deformation signal produced in surrounding areas also gradually changes from subsidence to uplift. This may explain the elevated earthquake activity at Bárðarbunga caldera since December 2015. Importantly, the model predicts outward radial displacement, which is similar to the pattern observed from GPS and InSAR observations acquired between 2015 and 2017 northwest of Bárðarbunga, that could be interpreted as magma recharge of the source. The maximum horizontal displacement velocity appears at 5.5 km distance from the caldera, which can explain around 50% of the high observed horizontal velocity at KISA GPS point.

Our preliminary modeling suggests that the viscous response to large-scale deformation events can create inflation-like deformation fields without direct addition of new melt to the system. We note that the temporal behavior and vertical deformation is different from a static spherical magmatic inflation source, but both models would serve to increase the pressure within a magma body beneath Bárðarbunga caldera.