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An elastic 3D Finite-Element-Model for Grímsvötn, Iceland

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Deformation models are an important tool to study and monitor active volcanoes. However, in many cases models are strongly simplified either due to a lack of data or for the sake of speed and computational demands. The assumption of a magma body embedded in a homogeneous elastic half-space for example neglects the topography and heterogeneous crustal structures found at some volcanoes. This oversimplification can lead to a poor representation of individual systems and result in erroneous estimates of deformation source parameters like the location and geometry of a magma chamber. The Finite Element Method (FEM) is a powerful tool to include complex heterogeneous structures and existing data sets into deformation models in order to create more realistic representations of individual volcanic systems.
In this study, the FEM-software COMSOL was used to build a three-dimensional elastic model of the subglacial volcano Grímsvötn, Iceland, accounting for the steep topography at the caldera rim, using a digital elevation model, as well as crustal heterogeneity. The elastic structure developed for this model is based on a density-structure, a seismic-velocity-structure and a pressure-dependent relation between the dynamic and static elastic moduli. The main feature of the elastic structure is a weak material (static shear modulus of G_{stat}=0.6-9.8 GPa from 1 km above to 2 km below sea level) filing the caldera, which is surrounded by a stiffer, ring-like structure underneath the caldera rim (G_{stat}=1.6-18 GPa from 1 km above to 2 km below sea level). The source parameters and geometry of forward models including the topography and elastic structure (individually and combined) were varied to fit the deformation observed at the nunatak GPS station GFUM, located at the caldera rim, during the last eruption (2011). While the topography has limited influence at the deformation at GFUM, the elastic structure requires the magma chamber to be significantly deeper than previous models suggested.