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High resolution surface deformation measurements in Iceland's Northern Volcanic Zone: Unraveling multiple deformation sources using InSAR and GPS

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We study crustal deformation in the Krafla and Theistareykir volcanic systems in the Northern Volcanic Zone of Iceland. Krafla experienced a major rifting episode in 1975-1984, and is also the site of a 60 MW geothermal power station. About 20 km to the north-west of Krafla, Theistareykir is mainly known for its geothermal activity, and plans exist to use the area for geothermal energy extraction. Previous studies have shown several deformation signals in the area, including continuous subsidence of the Krafla caldera, intrusive activity in the Theistareykir central volcano and a broad uplift signal to the north of Krafla. Poor spatial and/or temporal resolution in measurements used during previous studies have made it difficult to correctly identify and separate different signals. Here we present results from a combined study of InSAR and GPS data, which yields deformation maps over wide areas around Krafla and Theistareykir with unprecedented resolution. This allows us to not only obtain new constraints on previously identified displacements, but also reveals a subsidence source at Bjarnarflag geothermal field, in the southern part of Krafla's central volcano.

We used Interferometric Synthetic Aperture Radar (InSAR) time series analysis covering the period 1992-2010, and over 10 years of Global Positioning System (GPS) measurements in the area. For the InSAR analysis, we applied the StaMPS method to analyse data from the ERS-1/2 and the Envisat missions. This resulted in a relative surface displacement map in the radar line-of-sight (LOS) with high spatial resolution and signal-to-noise ratio. GPS measurements provide highly accurate measurements in three dimensions with respect to an absolute reference frame. Campaign GPS measurements in Krafla and Theistareykir have been performed for over 10 years, with an increasingly dense network of stations. In the fall of 2011, we installed a continuous GPS station in both the Krafla and Theistareykir area to further increase our monitoring capabilities. We processed all GPS data using the GAMIT/GLOBK software, which yielded absolute deformations and yearly deformation rates.

Our results show subsidence inside the Krafla caldera averaging up to 10-15 mm/yr between 1992-2010, which are attributed to pressure decrease in the shallow magma chamber and the geothermal exploitation in the area. Intersecting this signal we see a narrow band of subsidence which follows the central part of the Krafla fissure swarm. We attribute this subsidence to post rifting deformation and plate spreading. We also see subsidence at the Bjarnarflag geothermal field, which between 1992-2010 has an average subsidence rate of approximately 10 mm/yr. In and around Theistareykir, we see a complex interaction of deformations. A 30 km broad signal consisting of uplift and eastward movement is present in our results, from Theistareykir extending to the east. This broad signal is intersected by the narrow subsidence band along Krafla's fissure swarm, creating a two lobed feature in our results. Furthermore, an intrusion in 2007-2008 underneath the central volcano of Theistareykir resulted in a 7-8 cm uplift of the area, which is superimposed on the east lobe of the broad deformation pattern.