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Deformation of Grímsvötn volcano, Iceland, 1992-2014: Constraints on magma flow in relation to eruptions in 1998, 2004 and 2011

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A time series of ground deformation at Grímsvötn volcano, Iceland from 1992 to 2014 reveals deformation due to plate movements, glacial-isostatic uplift in response to the melting of the Vatnajökull ice cap, annual changes due to snow loading and magma movements. GPS measurements have been made at one nunatak, conducted intermittently since 1992 and continuously since 2004. During this period eruptions have occurred at Grímsvötn in 1998, 2004 and 2011. The component of displacement related to magma movements is obtained after the time series are corrected for signals due to other processes. Uplift and displacement away from the caldera occurs between eruptions at a rate of few cm/yr, interrupted by sudden co-eruptive subsidence and displacement towards the caldera (up to half a meter). This inflation/deflation pattern suggests deformation driven by pressure change in an upper crustal magma chamber, similar to other highly active calderas in Iceland such as Askja and Krafla. A simple model of pressure change variation in a magma chamber at shallow depth, with variable inflow between eruptions and outflow during eruptions can explain the observed deformation pattern. The erupted volume of magma in the 2011 eruption is about 10 times larger than the inferred co-eruptive volume change, attributed to compressibility of magma in the chamber. The magma compressibility is inferred to have remained constant during the 2011 eruption, as about constant scale factor is found during that eruption between eruption rate and displacement rate. This scale factor is, however, about five times lower for the 2004 eruption. This difference implies higher compressibility of magma in the shallow Grímsvötn magma chamber during the 2011 eruption compared to 2004, assuming the active part of the Grimsvötn magma plumbing system remained the same in both eruptions.