Geophysical Research Abstracts
Vol. 17, EGU2015-13344, 2015
EGU General Assembly 2015

Geodetic observations of deep re-equilibration of magmatic systems accompanying the Hekla 2000 and Eyjafjallajökull 2010 eruptions, Iceland

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Volcano geodesy most easily displays deformation from shallow deformation sources. However, with the expansion of geodetic networks and observations systems, there is growing evidence for far-field deformation at some volcanoes, indicating deeper processes within theses magmatic systems. We reflect here on crustal deformation from two recent eruptions in Iceland, the Hekla 2000 and Eyjafjallajokull 2010, which show signs of pressure changes at various crustal depths accompanying the eruptions. These eruptions were of similar eruptive volumes, approximately 0.2 km3, and were accompanied by crustal deformation relating to shallow dike and sill emplacements, in addition to more subtle and widespread crustal deformation caused by magma withdrawal. The crustal deformation associated with the Hekla 2000 eruption was captured by various geodetic methods, including continuous and episodic GPS, dry-tilt (i.e. short leveling lines), borehole strain, and InSAR. Continuous GPS data show deformation at >50 km from Hekla. We derive new deformation estimates from the episodic GPS network, and model the GPS displacements with previously published dry-tilt, InSAR, and borehole strain measurements in a formal joint inversion. While most of our data indicate a deep source of magma withdrawal ($\sim$20 km depth for a spherical source, or a pipe-like structure that reaches up to shallower depths), data from the borehole strain station closest to Hekla cannot be readily explained with a deep source. The borehole strain data at Hekla has good short-term resolution but poor long-term resolution, while the GPS, tilt, and InSAR measurements span a longer time interval. Therefore, we suggest the geodetic data from the Hekla 2000 eruption can best be interpreted with spatio-temporal progression of pressure changes in the magmatic system such that the co-eruptive signal was from a shallower ($\sim$10 km) source, which was followed by magma transport from deep to shallower depths before, during and after the eruption.

For the Eyjafjallajokull 2010 eruption, we observe a wide-spread (>60 km from Eyjafjallajokull) deformation field with motion towards the volcano from an extensive network of episodic and continuous GPS stations. The distant continuous GPS stations clearly show that the time of deformation exceeds the eruptive period by several months, indicating that these stations are recording deep re-equilibration of the magmatic system under Eyjafjallajokull. Both volcanoes indicate a certain time-progression of deformation, where the deeper (>10 km) parts of the magmatic systems re-equilibrate in response to the shallower co-eruptive pressure decrease.