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Pre-eruptive development of the stress field at Eyjafjallajökull (Iceland): Constraining driving forces of the 2010 magma intrusion using Moment and Stress Tensor Inversion of volcanic earthquakes

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The Eyjafjallajökull stratovolcano is located at the western border of the Eastern Volcanic Zone in South Iceland, west of Mýrdalsjökull (Katla). Since the settlement of Iceland, three eruptions have been documented in Eyjafjallajökull before 2010, in 920, 1612 and 1821-1823.

Following three episodes of persistent microearthquake activity in the 1990s, seismicity raised again throughout 2009 under the northeastern flank of Eyjafjallajökull and culminated in an intense earthquake swarm in February-March 2010. Simultaneous inflation observed by GPS and InSAR confirmed magma accumulation within the volcano, heralding the subsequent eruptions.

In early March 2010, the permanent seismic network around the volcano was augmented by additional sensors to enhance hypocentral earthquake locations and to improve the liability of focal mechanisms. Earthquake locations revealed more than one accumulation zone at shallow depth (3-5 km) beneath the northeastern flank throughout March 2010. These clusters migrated eastwards during the week prior to the Fimmvörðuháls flank eruption on 21. March. The 14. April summit eruption was preceded by a short seismic cluster beneath the central part of the volcano. A Stress Tensor Inversion based on high quality focal mechanisms indicates a horizontal orientation of the first principle stress axis during the intrusion phase prior to the flank eruption. This stress state results in E-W striking reverse faulting. Contrary, the stress field flips to a purely vertically orientated first principle stress axis shortly before the summit eruption, resulting in normal faulting mechanisms and evidencing the final ascent of the magma.

A subsequent Moment Tensor Inversion of the strongest events revealed slight positive isotropic components, suggestively due to gas or magma ascent, and further stabilized the double-couple components of our focal mechanism. This improvement significantly enhanced our Stress Tensor Inversion results and allowed insights into the driving forces of the plumbing system beneath Eyjafjallajökull. As the timing of the stress change coincides with the reversal point between inflation and deflation of the volcano, the near-realtime analysis of the stress development can be a valuable tool for the early identification of a final magma ascent towards the surface.