Stress coupling between magmatic and hydrological systems during explosive eruptions

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Multiparametric geophysical data of the July 29, 2008 Vulcanian explosion at the andesitic Soufrière Hills Volcano (SHV) in Montserrat (West Indies) shows a statistically significant increase in gravity accompanying dilatational volumetric strain as a result of conduit opening and initiation of explosive activity. The peak gravity increase coincides with maximum decompression of the shallow plumbing system as a result of conduit emptying.

Syn-eruptive mass and volume changes in the shallow magmatic plumbing system can be excluded as a source for the gravity transient. Instead, we propose a dynamic response of an aquifer to the eruption leading to a change in the water table as the cause for the transient. First order approximations support this hypothesis by indicating that the required hydraulic head changes are realistic. The mechanisms which induce changes in the hydraulic conditions of the aquifer and thereby affect the pore pressure are still to be investigated but may include seismic excitation and volumetric strain changes or a combination of both. Although cause-effect relationships between magmatic activity and hydraulic head changes have previously been proposed at several volcanoes, the quantitative understanding of this coupling is incomplete. Here, we present results from a hydrogeophysical study using a suite of finite-element models of the sub-surface stress transfer accompanying the July 29, 2008 Vulcanian explosion at SHV. The models simulate porous flow through an aquifer as a result of changing stress conditions by conduit evacuation. Resultant poro-elastic effects are then solved numerically to test whether the gravity transient can be explained purely by a mass variation or also by ground deformation caused by pore-pressure changes in the aquifer. The quantitative investigation of stress transfer at active volcanoes permits new insights on complex interactions between subsurface reservoirs which may be exploited in the future for pre-eruptive hazard assessment.