Poroelastic aquifer responses to crustal strain and their use in volcano monitoring

Due to their poroelastic nature, aquifers respond to crustal strain with changes in pore pressure and groundwater flow patterns. Well water level changes associated with volcanic unrest can therefore be interpreted as a result of hydrological responses to crustal deformation, and so could provide important constraints on the subsurface processes causing this strain.

We developed numerical models that simulate crustal deformation due to different volcanic strain sources and the dynamic aquifer response. The models are applied to two case studies. The first concludes that pre-eruptive well level changes at Usu volcano (Japan) in 2000 were induced by the pressurization of both the magma chamber and a large, shallow hydrothermal system. The second case study simulates water level changes in the Belham valley on Montserrat, 2004-2006. In this case, the aquifer responds to both gradual and rapid transient strain sources associated with the eruption of Soufrière Hills Volcano (Montserrat): repeated lahar sedimentation leads to an increasing sediment load and thereby rising aquifer pressures, while a dome collapse induced a short-term water level drop.

The presented models are a significantly improved tool for the interpretation of well level signals in volcanic areas that can provide valuable constraints for volcanic strain sources and thereby complement other monitoring systems.