Episodes of magmatic fluid injection into hydrothermal systems and caldera unrests. The case of Campi Flegrei (Italy)

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The isotopic signatures of many fumaroles from volcanoes, and in particular from calderas, indicate that the feeding hydrothermal systems are recharged by a mixture of shallow waters, of meteoric or marine origin, with magmatic fluids. In the few cases where long time series of chemical and isotopic compositions of the fumarolic vents are available, the data suggest that the mixing processes occur during short periods during which large amount of magmatic fluids are injected in the hydrothermal system. In this frame Campi Flegrei is the best studied case. Since 1980, the fumarole compositions and their variation in the time are known together with the seismic activity and the ground deformation of the caldera. On the base of an accurate analysis of the long geochemical time series, i.e. variations in the main component of the fumaroles as well in the minor gas species and in their isotopic composition, we recognised that thirteen episodes of injection of magmatic fluids into the hydrothermal system occurred from 1980 to 2012. The sudden arrive of the magmatic fluids causes the pressurization of the hydrothermal system and in turn pulsed ground uplift episodes and earthquakes, a process which well explain the correlation in the time among geochemical and geophysical signals. The process was simulated with a physical numerical model able to treat energy and fluid dynamics in a hydrothermal system characterised by bi-phase (vapor and liquid) and bi-component (water and carbon dioxide) fluids. The model was constrained by the flux of CO2 and of thermal energy measured at the surface as well as by the rock properties of the volcanic products filling the caldera. The results indicate that each episode of magma degassing involve an amount of fluids of the same order of magnitude as that involved in medium-small size eruptions. Furthermore the cumulative curve of the masses injected in each episode shows an inversion in 2000 which divides a preliminary period of decrease in the flux of magmatic fluids from the present phase of increasing activity, suggesting the beginning of a new unrest phase at Campi Flegrei. The approach used here is potentially a powerful tool for quantifying the evolution of hydrothermal systems undergoing magmatic fluid injections. This opens the door to accurately detecting and correctly interpreting early signals of volcanic unrest in potentially hazardous caldera settings.