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A perturbative approach for the modelling of short-term fluid-driven ground deformation episodes on volcanoes: the case of Campi Flegrei caldera (Italy)

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We developed a numerical time-dependent inverse method, which allow retrieving the flow rate of fluids injection in hydrothermal systems by using the observed ground deformation. We demonstrate that, under general assumptions, a perturbative approximation, around a steady state, of a thermo-fluid dynamics system, allows the use of a simple linear approach based on numerical Green's function. The thermo-fluid dynamics modelling has been performed in a 3D permeability and porosity model and has been used for computing both the steady state and the Green's function. Moreover, we model ground deformation by computing the elastic response to the injection of pressurized hot volcanic fluids (CO_2/H_2O mixture) at depth, taking into account both the poroelastic and the thermoelastic strains. The method has been applied to an area of particular geophysical interest, also characterized by a high volcanic risk: the Campi Flegrei caldera. The first step consisted in determining the shape and the positions of the fluid injection source. The forward modelling has shown that using a NW-SE elongated source with a length of about 2 km, placed at about 2600 m of depth and in the middle of the caldera, we can reproduce the actual spatial ground deformation pattern observed at Campi Flegrei. The method has been tested on a synthetic dataset, showing the capability of retrieving the flow rate pattern over temporal intervals up to about 25 years. We have applied the method to a single ground deformation episode at the Campi Flegrei caldera, which showed a clear correlation with episode of degassing and, subsequently, we extended the method to the interval 1987-2013, during which the volcano has shown, repeated episodes of unrest, evidenced by both geophysical and geochemical data. Applying the inverse method we found a good agreement between the measured and the estimated temporal deformation pattern. Results indicate a tight correlation between short-term ground uplift episodes and fluid injection rates in the last 25 years at Campi Flegrei.