Geophysical Research Abstracts, Vol. 9, 04870, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-04870

Gravity, deformation, and seismic signals due to pre-eruptive magma chamber / volcanic conduit dynamics

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Magma movement in the sub-surface environment produces variations in the gravity and stress fields which can be relieved by volcanic monitoring networks. Understanding the relationships between observed quantities and magmatic processes is one crucial step towards the comprehension of volcanic processes out of direct observation, and towards a more reliable evaluation of the short-term volcanic hazard. We have numerically simulated the dynamics of convection and mixing in replenished magma chambers and dykes, and have analyzed the associated gravity changes, deformation of country rocks, and seismic signals . Numerical simulations are carried out by solving the 2D, transient, multicomponent dynamics of compressible magma with properties depending on local composition, phase distribution, pressure and temperature conditions. The investigated systems are a phonolitic magma chamber and feeding dyke filled with trachyte, designed to be representative of possible conditions at Campi Flegrei, and a vertical, compositionally stratified, gravitationally unstable dyke inspired to conditions at Stromboli. The numerical results describe the time-space evolution of flow variables and magma composition and properties, and provide the mass/density distribution determining the gravity signal, as well as the time-space dependent stress representing a source for rock deformation and seismicity. This source is intimately related to the internal magma dynamics. A first order investigation of the propagation of pressure transients through the country rocks allows the determination of the amplitude and frequency distribution of the expected seismic and deformation signals. The results show that the simulated convection and mixing dynamics produce measurable changes in monitored geophysical quantities. In particular, the simulated arrival

of light magma batches in a shallow chamber is found to produce negative gravity anomalies of the order of a few tens of μgal, and maximum vertical deformation of mm to cm size depending on the specific conditions for the simulations. The associated seismic signal displays a characteristic period around 15 s, in a range of simulated conditions in terms of chamber geometry and magmatic overpressure driving inflow of magma into the chamber. Conversely, the simulated dynamics in the two-layer dyke produces gravity changes of < 10 μgal, dominant radial rock deformations of the order of 1 mm close to the dyke, and a seismic signal with dominant period around 50 s. The combination of geophysical data analysis and numerical simulation of magma dynamics should contribute substantially in the next years to our understanding of the pre-eruptive volcanic processes, and lead to a more confident evaluation of the short-term volcanic hazard.