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Analytical magmatic source modelling from a joint inversion of ground deformation and focal mechanisms data

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Seismicity and ground deformation represent the principal geophysical methods for volcano monitoring and provide important constraints on subsurface magma movements. The occurrence of migrating seismic swarms, as observed at several volcanoes worldwide, are commonly associated with dike intrusions. In addition, on active volcanoes, (de)pressurization and/or intrusion of magmatic bodies stress and deform the surrounding crustal rocks, often causing earthquakes randomly distributed in time within a volume extending about 5-10 km from the wall of the magmatic bodies. Despite advances in space-based, geodetic and seismic networks have significantly improved volcano monitoring in the last decades on an increasing worldwide number of volcanoes, quantitative models relating deformation and seismicity are not common. The observation of several episodes of volcanic unrest throughout the world, where the movement of magma through the shallow crust was able to produce local rotation of the ambient stress field, introduces an opportunity to improve the estimate of the parameters of a deformation source. In particular, during these episodes of volcanic unrest a radial pattern of P-axes of the focal mechanism solutions, similar to that of ground deformation, has been observed. Therefore, taking into account additional information from focal mechanisms data, we propose a novel approach to volcanic source modeling based on the joint inversion of deformation and focal plane solutions assuming that both observations are due to the same source. The methodology is first verified against a synthetic dataset of surface deformation and strain within the medium, and then applied to real data from an unrest episode occurred before the May 13th 2008 eruption at Mt. Etna (Italy). The main results clearly indicate as the joint inversion improves the accuracy of the estimated source parameters of about 70%. The statistical tests indicate that the source depth is the parameter with the highest increment of accuracy. In addition a sensitivity analysis confirms that displacements data are more useful to constrain the pressure and the horizontal location of the source than its depth, while the P-axes better constrain the depth estimation.