Geophysical signatures of magma chamber replenishment

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Many volcanic eruptions are shortly preceded by new magma injection into a pre-existing, shallow (< 10 km) magma chamber, causing convection and mixing between the incoming and resident magmas. These processes may trigger dyke propagation and further magma rise, inducing long-term (days to months) volcano deformation, seismic swarms, gravity anomalies, and changes in the composition of volcanic plumes and fumaroles, eventually culminating in an eruption. Although new magma injection in shallow magma chambers is a potentially hazardous event, its occurrence is still not systematically detected and recognized. Here we present the results of numerical simulations of magma chamber replenishment by buoyant magma of deeper origin, and the associated gravity changes, seismicity, and ground deformation. Synthetic gravity changes and ground deformation patterns are then inverted with classical methods, to check their capability to detect the source of signals. The results show that the invaded shallow chamber may be not revealed by inversion of ground deformation, as a consequence of non-homogeneous pressure changes resulting into substantial deviations from usual simplifying assumptions when inverting the data. While ground deformation patterns and volcanic seismicity tend to illuminate the deeper regions of the magmatic system, gravity changes are controlled by the shallow system where gas expansion dominates. These results suggest that i) classic simplifications in data inversion techniques may be largely inadequate for magmatic systems, and ii) more robust inversions require joint use of a variety of data including gravity changes.