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Deep magma movements at volcanoes and their geophysical signatures

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Magma movements in sub-surface volcanic environments produce variations in the stress and gravity fields that translate into signals recorded on the Earth surface as ground deformation, seismicity, and gravity changes. In the classical approach such signals are inverted to constrain the position and force vs. time history of a point source or of an extended homogeneous source with simple geometrical characteristics. Here a forward approach is described, consisting in modelling the time-space-dependent magma dynamics in complex magma chambers + dykes systems. Magma properties are described in terms of local P-T-X conditions by employing compositional-dependent models from the literature or appositely developed. Magma convection and mixing occurs as a consequence of the initial system configuration in terms of distribution of magma composition and volatile contents (H2O and CO2), that in some cases may result in gravitational instabilities triggering magma movements. The calculated time-space-dependent stress distributions at system domain boundaries, and the time-space-dependent density distributions in the simulated domains, provide the input for the calculation of gravity field variations and ground displacements over a large frequency range from 10-3 to 10 s-1. Such an approach allows monitored quantities to be consistently related to a variety of potentially hazardous processes, such as the arrival of new magma batches in a shallow magma chamber, the mixing of compositionally different magmas, the process of volatile exsolution, the ascent of magma along volcanic conduits or dykes, etc.