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Checking the validity of superimposing analytical deformation models

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The displacement field due to magma movements in the subsurface is commonly modelled using the solutions for a point source (Mogi, 1958), a finite spherical source (McTigue, 1987), or a dislocation source (Okada, 1992) embedded in a homogeneous elastic half-space. When the magmatic system is represented by several sources, their respective deformation fields are summed, and the assumption of homogeneity in the half-space is violated.

We have investigated the effects of neglecting the interaction between sources on the surface deformation field. To do so, we calculated the vertical and horizontal displacements for models with adjacent sources and we tested them against the solutions of corresponding numerical 3D finite element models. We implemented several models combining spherical pressure sources and dislocation sources, varying the pressure and the relative position of the sources. As examples we also considered models adapted from Soufrière Hills Volcano (Montserrat, West Indies) and the Dabbahu rift segment (Afar, Ethiopia).

For certain conditions, we found combining analytical sources can cause an error of up to 300%, mostly due to the source spacing. For the error to be neglected (<5 %), the analytical sources should be separated by at least 3 radii when the sources are superposed, and by more than 9 radii for juxtaposed sources.