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Joint inversion of gravity and muon tomography data on unstructured meshes

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We are developing joint inversion methods for gravity and muon tomography (muography) data to apply to the imaging of volcanoes. Muography provides estimates of the average density along solid angular lines of sight and, as such, has similarities to seismic tomography with straight rays. Because of the difficulties involved in collecting muography data, there are generally a very limited number of positions at which the muon receiver system is located. For our field survey example, data has so far only been collected at a single location. Hence, the muography data can provide only an essentially 2D image of the volcano and joint inversion with gravity data is required to provide interpretable 3D results. Furthermore, muography data generally presents horizontal or shallow dipping lines of sight, and gravity data generally provides poor depth resolution compared to laterally. Therefore, the two types of data provide complimentary information and a joint inversion is expected to provide improved results over independent inversions.

Puy de Dôme is a volcano located in the French Massif Central ancient volcanic zone. The question central to this work is to determine the maximum density of the magma conduit in the volcano to provide support for a hypothesis regarding its formation. To assess this question, we are considering three different types of joint inversion. First, a minimum-structure-style inversion approach, on a mesh of space-filling cells, is performed, for which we use unstructured meshes to honour the large topography variation. The resulting density models are combined with 2D interpolated sections to generate a 3D geological model of Puy de Dôme. The geological model comprises wireframe surfaces of tessellated triangles that represent contacts between rock units. A second type of inversion can then determine the densities inside each of those rock units, as required to best fit the measured muography and gravity data. Finally, a third type of inversion can be performed, with the densities of the rock units fixed and the geometries of the wireframe surfaces changed by the inversion algorithm to best fit the measured data.