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Joint inversion of muographic and gravimetric data with a Bayesian formalism for the 3D density imaging of volcanoes

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We present a method to jointly invert muographic and gravimetric data to infer the 3D density structure of volcanoes, using the puy de Dôme volcano (French Massif Central) as proof of principle.

Muographic and gravimetric data are two independent measurements that are sensitive to density distributions. The gravimetric inversion allows to reconstruct 3D density variations but the process is well-known to be ill-posed leading to non unique solutions. Muography provides 2D images of mean densities from the detection of high energy atmospheric muons crossing the volcanic edifice. Several muographic images can be used to recontruct 3D density distributions but the number of images is generally limited by instrumentation and field constraints.

The joint inversion of muographic and gravimetric data is expected to improve the resolution of the inversion (Jourde et al. 2015). Such inversions have already been applied to active volcanoes (Nishiyama et al. 2013, Rosas-Carbajal et al. 2017). Here, we jointly invert gravimetric and muographic data using a linear inversion scheme with a Bayesian formalism (Tarantola 2005). This approach takes into account the data errors and a priori information on the density distribution with a spatial covariance so that smooth models are obtained. Once the data errors and the a priori averaged density are properly identified, the inversion result is tuned by two hyperparamters: the standard-deviation of the a priori density and the spatial correlation length. We explore these two hyperparameters in a systematic way and use L-curves and Cross Validation Sum of Squares (CVSS) criteria to help determining the optimal set of hyperparameters.

We use the puy de Dôme volcano (French Massif Central) as a proof of principle as high quality data are available for both muography (Le Ménédeu et al. 2016) and gravimetry (Portal et al. 2016). We show the advantages and limits of the method using a synthetic model based on the topography and acquisition geometry of the puy de Dôme volcano, as well as real data.