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# Earthquake tomography on volcanoes with a probabilistic regularization approach

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Muon radiography of volcanoes aims at estimating the density of rocks constituting the volcanic edifice from muon fluxes. Earthquake tomography aims at estimating the seismic velocity of the same rocks from the travel times of seismic waves. Muon radiography and earthquake tomography are inverse problems that share some similar features - muon flux variation and travel time may be both written as the integral of elementary flux variations or travel times across elementary volumes of rocks that are sampled by muon trajectories or seismic rays.
In this talk we will present our experience in seismic tomography, emphasizing on the aspects that may be later used in muon radiography. In both cases the whole volume of the volcanic edifice may be incompletely or insufficiently sampled by muon trajectories or seismic rays. Inferring parameters characterizing elementary volumes from an integral measure therefore leads to evidence trade-offs between this parameters. These trade-off relations feature the correlation existing between the parameters, which is inherent to the nature of the inverse problem. Incomplete or insufficient sampling and trade-offs lead to find unphysical parameter values, which may spread over trajectories or rays. Noise may therefore propagate along these trajectories or rays, from poorly sampled elementary volumes to neighbouring elementary volumes due to the integral nature of the muon flux variation or seismic travel time, lowering the resolution of the parameter estimation.
Mitigating the problems due to the incomplete sampling of the studied volume is performed by regularizing the inversion. In this talk we will follow a probabilistic, bayesian approach for performing this regularization, in the frame of seismic tomography. We therefore perform the Maximum a posteriori Probability (MAP) estimation of the model parameters. Data and parameters are assumed to follow a gaussian distribution, and a priori information is used to limit the values taken by parameters to physical intervals. The correlation between parameters is explicitely taken into account by defining correlation kernels and correlation lengths. Optimal standard deviation and correlation length are found by minimizing a cost function. It leads to find the minimal-norm model fitting the data. It will be shown that (1) introducing a limited bias in the estimation strongly limits its variance, (2) contrarily to what is often thought, increasing the correlation length does not lead to bias the model and to lower the resolution –instead, using the optimal correlation length leads to increase the resolution by solving the bias-variance trade-off (improving the physical value of the parameter while reducing the noise).

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