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Refined event location and lowered uncertainties in temporal variation of seismic velocity: tackling down the spatial and temporal correlation between elastic and hypocentral parameters in full 4D local earthquake tomography of a geothermal site

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Temporal variations of the elastic properties of the rocks within a geothermal reservoir have been documented during injection and production phases, using time-repeated 3D local earthquake tomography, LET (e.g. Calo et al., 2011, Gunasekera et al., 2003). However, the magnitude of the variations could be so small that their effects can be masked by observational errors. A common way to reduce the uncertainties in the tomographic models is based on the minimization of the difference between arrival-times of events occurred in the same rock volume, i.e. the so-called Double-difference. In this way: (a) position of the hypocenters is tightly constrained, and (b) residuals in the observed P and S arrival-times are strongly associated with the perturbation of the elastic model more than the perturbation of the hypocentral parameters. Such techniques have been applied to refine the location of the induced seismicity, assuming a time-invariant elastic model between the couples of events. However, this assumption should be carefully considered within the framework of the induced seismicity, where rocks in a geothermal reservoir are heavily stressed and their elastic properties are supposed to change in time.

In this study, we investigate the effect of a refined event location on the uncertainties in the velocity model during an injection phase at Soultz geothermal site. First, we perform two synthetic tomographic experiments using travel-times in a given two-phases 3D seismic model, adding a Gaussian noise with a known standard deviation. In the first test, we only use as observed data the absolute P and S arrival times. The tomographic inversion is performed using the trans-dimensional Monte Carlo approach. In the second test, we expanded the Bayesian formulation including the Double-Differences in the data-set. Finally, we present the results for the inversion of the field measurement using a Double-Difference approach with a weighted time-length scale.