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# Close-up to the stimulation phase of a EGS geothermal site: mapping the time-evolution of the subsurface elastic parameters using a trans-dimensional Monte Carlo approach

Nicola Piana Agostinetti (1) and Marco Calo' (2)

(1) Geophysic section, School of Cosmic Physics, Dublin Institute for Advanced Studies, Dublin, Ireland (piana@cp.dias.ie),
(2) Department of Earth and Planetary Science, University of California, Berkeley, CA, USA (calo@seismo.berkeley.edu)

Stimulation of geothermal wells through hydraulic injections is the most common way to increase secondary porosity in hot-dry rock geothermal reservoir. As worldwide documented, injection of over-pressurized fluids in the subsurface creates a diffuse pattern of microseismicity confined to the portion of crustal volume around the injection well. Such "pseudo"-natural seismicity can be a valuable source of information about the elastic properties of the rock in the volume directly below the geothermal site and about their time-evolution during fluid injection. Classical methods (e.g. Local Earthquake Tomography, LET) have been applied to image how the rocks interact with the flow of over-pressurized fluids. Repeating the LET computation using consecutive set of events produces a time-series of P-wave velocity models which can be analyzed to catch the time-variation of the elastic properties. Such approaches, based on a linearized solution of the tomographic inverse problem, can give a qualitative idea of the behavior of rocks, but they cannot be used to quantify such interaction, due to the well-know issues which affect LET results, like the strong link between the "final" and the "starting" model (i.e. the "final" model must be a small-perturbation of the the "starting" model), model paramterization, damping of the covariance matrix, etc.. Also, the robustness of the retrieved models can not be easily assessed due to the difficulties to determine the absolute errors on the Vp parameters themselves. Thus, it can be challenging to understand if the fluctuations in the elastic properties remain or not within the estimated errors.

In this study we present the results of a full 4D local earthquake tomography obtained with the P- and S-wave arrival times of 600 seismic events recorded in 2000 during the stimulation of the GPK2 well of the Enhanced Geothermal System located in Soultz-des-Forestes (France). We focus on the initial stage, when the injection rate has been increased abruptly from 30 l/s to 40 l/s. Such operation lasted less than 13 hours and generated a large number of events, almost evenly time-distributed. Such stage has been analyzed in details using a linearized tomographic inversion code imroved with a post-processing (WAM) which highlighted the fluctuations in the Vp velocity near the well-head over a few hours time-scale and a few hundreds meter spatial-scale (Calo' et al, GJI, 2011). The approach adopted (LET+WAM) provided a rough estimation of the distribution errors in the models that resulted unsatifactory to assess the reliablity of some important velocity variations observed over the time. Solving the LET inverse problem using a trans-dimensional Monte Carlo method gives us now the possibility to fully quantify the errors associated with the retrieved Vp and Vp/Vs models and enable us to evaluate the robustness of the fluctuations in the elastic properties during the injection phase.