Toward a full 4D seismic tomography: a case study of an active mine

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Rock elasticity in the subsurface can change in response to natural phenomena (e.g. massive precipitation, magmatic processes) and human activities (e.g. water injection in geothermal wells, ore-body exploitation). However, understanding and monitoring the evolution of physical properties of the crust is a challenging due to the limited possibility of reaching such depths and making direct measurements of the state of the rocks. Indirect measurements, like seismic tomography, can give some insights, but are generally biased by the un-even distribution (in space and time) of the information collected from seismic observations (travel-times and/or waveforms). Here we apply a Bayesian approach to overcome such limitations, so that data uncertainties and data distribution are fully accounted in the reconstruction of the posterior probability distribution of the rock elasticity. We compute a full 4D local earthquake tomography based on trans-dimensional Markov chain Monte Carlo sampling of 4D elastic models, where the resolution in space and time is fully data-driven. To test our workflow, we make use of a “controlled laboratory”: we record seismic data during one month of mining activities across a 800x700x600 m volume of Kiruna mine (LKAB, Sweden). During such period, we obtain about 260 000 P-wave and 240 000 S-wave travel-times coming from about 36000 seismic events. We operate a preliminary selection of the well-located events, using a Monte Carlo search. Arrival-times of about 19 000 best-located events (location errors less than 20m) are used as input to the tomography workflow. Preliminary results indicate that: (1) short-term (few hours) evolutions of the elastic field are mainly driven by seismic activation, i.e. the occurrence of a seismic swarm, close to the mine ore-passes. Such phenomena partially mask the effects of explosions; (2) long-term (2-3 days) evolutions of the elastic field closely match the local measurements of the stress field at a colocated stress cell.