

EGU21-6836, updated on 28 Jan 2022

<https://doi.org/10.5194/egusphere-egu21-6836>

EGU General Assembly 2021

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Ensemble Kalman Filter estimates shear stress and seismic slip rates in synthetic laboratory experiment

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Our ability to forecast earthquake events is hampered by limited information of the state of stress and strength of faults and their governing parameters. Ensemble data assimilation methods provide a means to estimate these variables by combining physics-based models and observations taking into account their uncertainties. In this study, we estimate earthquake occurrences in synthetic experiments representing a meter-scale laboratory setup of a straight-fault governed by rate-and-state friction. We test an Ensemble Kalman Filter implemented in the Parallel Data Assimilation Framework, which is connected with a 1D forward model using the numerical library GARNET. A perfect-model test shows that the filter can estimate shear stresses, slip rates and state θ acting on the fault even when simulating slip rates up to m/s and can thus be used for estimating earthquake occurrences. We assimilate shear stress and slip-rate observations, representing measurements obtained from shear strain gauges and piezoelectric transducers sensors, and their uncertainties acquired at a small distance to the fault in the homogeneous elastic medium. In this study we evaluate how the Ensemble Kalman filter estimates the state and strength of the faults using these observations, and assess the relative influence of assimilating various observations. The results suggest that the data assimilation improves the estimated timing of the earthquake occurrences. The assimilation of the shear stress observed in the medium improves in particular the estimates of the state θ and the shear stress on the fault, while assimilating observations of velocity in the medium improves the slip-rate estimation.