EnKF estimation of the viscoelastic deformation and the viscosity

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Following large earthquakes, postseismic crustal deformations are often observed for more than years. They include the afterslip and the viscoelastic deformation of the crust and the upper mantle, activated by the coseismic stress change. The viscoelastic deformation gives the stress change on the neighboring faults, hence affects the seismic activity of the surrounding area, for a long period after the large earthquake. So, estimating the viscoelastic deformation after the large earthquakes is important.

In order to estimate the time evolution of the viscoelastic deformation after a large earthquake, we also need to know the viscoelastic structure around the area. Recently, the Ensemble Kalman filter method (EnKF), a sequential data assimilation method, starts to be used for the crustal deformation data to estimate the physical variables (van Dinther et al., 2019, Hirahara and Nishikiori, 2019). With data assimilation, we get a more provable estimation by combining the data and the time-forward model than only using the data. Hirahara and Nishikiori (2019) used synthetic data and showed that EnKF could effectively estimate the frictional parameters on the SSE (slow slip event) fault, addition to the slip velocity. In the present study, I applied EnKF to estimate the viscosity and the inelastic strain after a large earthquake, both the physical property and the variables.

First, I constructed the forward model simulating the evolution of the viscoelastic deformation, following the equivalent body force method (Barbot and Fialko, 2010; Barbot et al., 2017). This method is appropriate for applying EnKF, because the ground surface deformation rate is represented by the inelastic strain at the moment, and the history of the strain is not required. Then, we applied EnKF based on the forward model and executed some numerical experiments using a synthetic postseismic crustal deformation data.

In this presentation, I show the result of a simple setting. I assumed the medium to be two layers with a homogeneous viscoelastic region underlying an elastic region. The synthetic data is made by giving a slip on a fault at time $t = 0$ and simulating the time evolution of the ground surface deformation. For assimilation, I assumed that the slip on the fault and the stress distribution just after the large earthquake is known. Then we executed the assimilation every 30 days after the large earthquake. I found that I can get a good estimation of the viscosity after $t > 150$ days.