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, it is important to estimate the viscoelastic deformation after the large earthquakes.

In order to estimate the prospective time evolution of the viscoelastic deformation after a large earthquake, we 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). By assimilating the observational data to the time-forward model, we get a more provable estimation 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 velocities. In this study, I applied EnKF to estimate the viscosity and the inelastic strain after a large earthquake, both the physical property and the variables.

I employed the BIEM-based equivalent body force method (Barbot and Fialko, 2010; Barbot et al., 2017) as the forward model simulating the evolution of the viscoelastic deformation. In this method, the viscoelastic region is discretized into cuboid cells with uniform strain and stress. The time derivative of the inelastic strain is represented by the value at the moment, and the history is not required. So, this method is appropriate for applying EnKF. With this method, we can calculate the displacement rate on the ground due to the inelastic strain of a cuboid cell is calculated as the form of green function times the strain at the moment. Then, based on the forward model, I constructed a method to estimate the time evolution of the deformation and the viscosity from the displacement on the ground surface, using the EnKF method.

In this presentation, I show an assimilation experiment using the synthetic ground displacement, called as the twin experiment. I set a simple model where the medium consists of two layers of a homogeneous viscoelastic region with viscosity $\eta = 10^{18}$ [Pa s] underlying an elastic region. I set a fault in the elastic layer and give a slip at time $t = 0$, and calculated the time evolution of the ground surface displacement. I add a Gaussian noise on the displacement and set as the synthetic observation data. 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 earthquake ($t = 0$) to estimate the strain and the viscosity. I found that I can get a good estimation of the viscosity after $t > 150$ days.

Keywords: postseismic deformation, viscoelastic rebound, Ensemble Kalman Filter