Estimation of frictional properties and slip evolution on the Long-term SSE fault with Ensemble Kalman Filter -numerical experiments-

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Long-term Slow Slip Events (LSSEs) occur on the plate interface beneath the source regions of the interplate large earthquakes. They are stress-release processes on the plate interface. The activity of SSE possibly changes before large interplate earthquakes and SSEs may directly trigger them. Hence, it is important to know the frictional properties and predict slip evolution on SSE faults. Our final goal is to estimate slip evolution and frictional parameters with the Ensemble Kalman Filter (EnKF), one of data assimilation methods, and then to give some insight into the occurrence of large interplate earthquakes. In this paper, we consider the Yaeyama and the Bungo Channel LSSEs and construct simple models which reproduce SSEs. We perform numerical experiments on estimation of frictional parameters on the fault through EnKF with LSSE model.

At first, we describe the numerical experiments for Yaeyama SSEs in the Ryukyu region, southwest Japan, (recurrence interval: 6 months, duration: 1 month). We set a dipping fault embedded in a homogeneous elastic half space. The friction on the fault was assumed to obey a rate-and state-dependent friction law, and the slowness law of state evolution. The constructed simple model has a circular velocity-weakening (A-B <0) patch (radius R=30km) on the fault plane with the frictional parameters so that R / Rc = 0.4 (Rc: critical nucleation radius). Then, we generated synthetic observed data where we added random numbers to the displacement rates at the ground simulated from the model, and performed EnKF estimations of the frictional parameters A and L on the fault plane and B-A on the patch along with the slip velocities and the state variables.

In this method, when the temporal change of observation becomes large, the innovation (residual of observation and forecast) also becomes large and the forecasted values are greatly updated. Hence, the forecasted values approach the true values during SSEs. However, it was found that we need observational data including several SSE cycles for accurate estimation. On the other hand, since the forecasted values are greatly updated during SSEs, numerical calculations frequently stop. This is an entirely different problem from the estimation ability of EnKF, and is troublesome for numerical experiments assuming various distributions of the observation points, for example. This problem is caused by the rapid temporal change of the observation values during the short duration of SSEs, and therefore we thought that it is avoidable in the assimilation for LSSEs with larger duration times. In addition, it was found that the poorer (e.g., the low density, and the heterogeneous distributions, etc.) distributions of observation points are, the slower are the conversion rates of estimated values to the true ones. It is difficult to observe Yaeyama SSEs with the poor distribution of observation points due to the sea area.

Based on the above experiments, to apply EnKF, the regions of SSEs should satisfy the following conditions:
1. SSEs have been observed more than once
2. The duration of SSEs is long
3. The distribution of observation points

Therefore, we target at the Bungo Channel LSSEs and construct a simple model (the patch radius

R=40km, R/Rc=0.9) which reproduces the LSSEs (recurrence interval: 7 years, duration: 1 year). We perform numerical experiments similar to the Yaeyama case. The results show that if the duration of SSEs is sufficiently longer than the assimilation step, updating is moderately performed and calculation does not stop. As long as we use a very simple model, we can estimate the frictional parameters on the Bungo Channel LSSE fault with considerable accuracy for the actual GNSS station distribution (GEONET).
In our current model, frictional parameters are uniform on the SSE patch. We need to perform numerical experiments for verifying the feasibility of this method when setting more complicated models and increasing estimated parameters.

Keywords: Ensemble Kalman Filter, Slow Slip Events

