Ensemble Kalman Filter estimation of frictional parameters and slip evolution on L-SSE faults : application to the Bungo Channel L-SSE fault

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We have been developing a real-time estimation system of frictional properties and slip evolution on long-term slow slip event (L-SSE) faults from the observed GNSS data with the ensemble Kalman filter (EnKF), a sequential data assimilation method, which has been developed in atmosphere and ocean sciences. Nishikiori(2018) and Hirahara and Nishikiori(2019) executed identical twin numerical experiments for the Bungo Channel L-SSE with the effect of the locking Nankai megathrust fault and showed the potential for estimating the frictional parameters and slip evolution on the L-SSE fault together with the assumed constant slip deficit rate of the megathrust fault.

Now we are trying to apply our method to actual GEONET data. Here, we give our progress report. First, we introduced the actual geometry of the Philippine Sea plate interface instead of the flat square plane previously assumed. For this actual geometry, we constructed a frictional model with the slip deficit the megathrust fault referring to the GNSS-A observation (Yokota et al., 2016) to produce the L-SSE similar to the observed Bungo Channel L-SSE. Then we compared the synthetic displacement rates in GEONET stations from this model with the observed ones including trend components and found the discrepancy between them, which might be due to large slip concentration in the shallow portion of L-SSE fault caused by the slip deficit of the locked Nankai fault. And we found also that we need to select the initial ensemble members in a narrower space around the true parameters than those proposed in previous studies to execute stable EnKF estimates without breaks. Therefore, we used the slip rate histories on the L-SSE fault as data, which were kinematically obtained from the detrended GEONET data (Yokoi, personal communication). We analyzed the data from the year 2009 to the time just before the 2011 Tohoku earthquake. With the grid search, we obtained some pairs of frictional parameters that minimize the sum of squared residuals of the observed and the simulated slip rates in all cells within the circular L-SSE patch during only the period of the 2010 L-SSE occurrence. With the initial ensemble members constructed from such pairs of frictional parameters, the frictional parameters are successfully updated to converged values without breaks. The discrepancy of the observed and the estimated slip rates in the L-SSE patch cells is large at the early period of the L-SSE occurrence, but thereafter becomes smaller in the L-SSE occurrence period. Further, we examined the forecast capability of slip evolution based on the analyzed parameters in some data assimilation times. During the early period of L-SSE occurrence, the forecast slip rates are different from the observed ones, but the analyzed parameter values around the time of maximum slip rate correctly forecast the ending time of the L-SSE.

Thus, this is the first study where we successfully applied our EnKF method to the actual data for the L-SSE fault. There are, however, left some problems to be solved. First, we should consider the use of the actual displacement rate data observed in GEONET stations. Or we might need to use displacement data. Secondly, we need to use the data including the trend components to estimate also the slip deficit rates in the locked Nankai fault existing at the updip portion. In this case, we might consider the effect of inland block motions as in Nishimura et al. (2018). Third, we applied only to the 2010 L-SSE data. The Bungo Channel L-SSEs have recurred several times, which have slightly different slip evolution and recurrent times. Our frictional model at present is simply uniform and would be extended to include inhomogeneity.

Keywords: Ensemble Kalman Filter, Slow Slip Events, Rate and State Friction Law, Slip Evolution, Bungo Channel L-SSE