EnKF estimation of frictional properties and slip evolution on a LSSE fault and the changing slip deficit rate on a megathrust fault

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With EnKF(Ensemble Kalman Filter), we are developing a system of real-time estimation of frictional properties and slip evolution on LSSE(long-term slow slip event) faults together with the slip deficit rate of the megathrust existing at the up-dip portion of the LSSE faults from the observed GNSS data, through numerical experiments. In the present system, the state vector to be forecasted and updated includes slip rates, state variables and frictional parameters on a LSSE fault, and the slip deficit rate in the megathrust fault. The first 3 parameters are constrained by a RSF(rate and state friction) law and data, but the last one is only by data in a kinematic way. Nishikiori and Hirahara (2017) have shown that the system with EnKF has successfully estimated the slip deficit rate together with frictional properties and slip evolution on the assumed Bungo-Channel LSSE fault for the station distribution corresponding to the GEONET one. So far, we have mainly examined the case of the constant slip deficit rate of the locked megathrust fault, assuming a short and stationary period in the Nankai earthquake cycle.
Several simulation studies have suggested the activity of LSSE is changing during the megaquake cycle, and the real-time monitoring of LSSE activity is important for understanding the stress state of the megaquake fault. Hirahara and Nishikiori (2018) have preliminarily examined the effect of changing deficit rate of the locked region. This study is an extension of theirs. A time series of slip deficit rate derived from a simple simulation of the Nankai earthquake cycle with a RSF law produces shorter reoccurrence time and larger slip rate of the Bungo-Channel LSSE fault toward the occurrence of Nankai megaquake. Based on this simulation model, we produce the simulated deformation rate data at GEONET stations. Then we try to estimate the changing slip deficit rate of the Nankai earthquake fault together with frictional parameters and slip evolution on the LSSE fault. Here, we define v_lock=V_lock -Vpl, and assign Vpl=6.5cm/yr. We can correctly trace the v_lock around -6cm/y during almost locked period. However, when v_lock is larger than -4 cm/yr, our system can not trace v_lock and underestimate the value. Then other parameters become to be also estimated as values deviated from the true ones. Therefore, we try to apply covariance inflation to enlarge the error covariance of the forecast state vector. There are two types of covariance inflation to enlarge the error covariance of the forecast vector. One is multiplicative inflation, where the forecast vector is artificially enlarged. Another is additive inflation, where we add random perturbation to the analysis vector in the previous time step, and obtain the forecast one in the next time step. In the latter one, the perturbation is not added directly to the forecast vector but to the analyzed one in the previous time step, so that the dynamical balances are kept when the next forecast is obtained. We use the approach of additive inflation of covariance. Then, we can correctly estimate the value of v_lock as well as other parameters up to a high value of v_lock around 25 cm/yr. We discuss such problems of abrupt breaks when we encounter in applying our system in numerical experiments.

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