Constraining interplate frictional parameters using limited terms of observation data; a preliminary test for data assimilation

Noa Mitsui[1]; Takane Hori[2]; Shin'ichi Miyazaki[3]; Kazuyuki Nakamura[4]

[1] IFREE,JAMSTEC; [2] IFREE, JAMSTEC; [3] Kyoto Univ.; [4] ISM

Stress and slip on a fault during seismic cycle crucially depend on frictional properties on the fault. Once we have a set of initial conditions and frictional parameters, the evolution of the stress and slip are determinable. Since the system may be initialized with a certain set of frictional parameters by performing a simulation over several seismic cycles, it is more crucial to constrain frictional parameters than initial conditions. Frictional parameter estimation may be achieved by fitting data to a numerical model. This procedure is known as data assimilation. Although data assimilation is often used to estimate initial conditions in other society such as meteorology, we apply it for frictional paratemer estimation.

One of difficulties in our problem is that measurements are strictly limited in time compared with earthquake recurrence periods. However durations of transient slip events such as afterslip and slow slip events are at most several years and are recently observed by, for example, dense GPS networks. Thus we first intend to estimate frictional parameters in afterslip and slow slip segments. Once we have parameters there, it might be possible to constrain frictional parameters in asperities by considering interactions among asperities, afterslip segments and other segments.

We use two-degree-of-freedom fault cell model as the simplest one that contains interaction of stress changes due to fault slips. We define time series of cumulative displacement at fault cells as data. Then, using the sum of the squared residuals between the data and the calculated values for a frictional parameter set, we evaluate how good the parameter set is. The results are; 1) In the case of data with two coseismic terms or more, interseismic slip does not fully contribute to the residual estimation, because residual is small, if recurrence times of earthquakes are the same even for the case of different parameter set, 2) In the case without coseismic terms, the amount of displacement and the duration of afterslip or slow slip events are useful to constrain the possible parameter ranges except for the critical slip distance in rate- and state-friction law, L in the case of afterslip at steady state, and 3) even one afterslip or slow slip event is useful. Moreover we find out; 4) Data without any clear unstable slip can exclude the parameter range that produce unstable slip in the limited terms of used data, and 5) slip history on the another area can be useful to constrain the possible parameter range, because the fault slip with frictional parameters can change another fault slip behaviors. On the estimation of frictional parameters using large-degree-of-freedom continuum-approximated fault cell models, results 4) and 5) suggest that A) the number of possible solutions do not increase as many as that of the degree-of-freedom, and stress responses to fault slip among the fault cells become to be strong constraint of frictional parameters, and that B) every data on all areas and for all terms can be useful for the estimation of frictional parameter in the system that fault slip causes stress change everywhere, except the case that data have no information about the frictional parameter. A) and B) suggest that realistic estimation of interplate frictional parameters will be possible through appropriate processes according to individual problems.

Particle filter with sequential importance sampling, which is one of data assimilation method, can be done using our aforementioned simulation method with a little improvement in calculation of likelihood. Thus we can easily establish the prototype model of data assimilation method and verify the availability of data assimilation of earthquake gemneration cycle model.