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Data assimilation of earthquake generation cycle model on 2-D fault with interseismic data

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The need has long been recognized for a quantitative model that uses observational data such as crustal deformation to forecast earthquakes so that the effects of future earthquakes can be mitigated. To forecast earthquakes based on a physical model, we need to fit the model parameters and variables to observational data. In short, data assimilation is necessary.

The recurrence times of large earthquakes range from decades to centuries, but we have accurate and continuous GPS data of crustal deformation for only the last 15 years and intermittent data (e.g., leveling) for only the last 100 years. Therefore, we need to investigate how model parameters can be constrained by using observational data only from within this limited period.

Mitsui et al. (2009, Zishin) examine how the interplate frictional parameters are constrained using the limited periods of data with two-degree-of-freedom fault cell model as the simplest one that contains interaction of stress changes due to fault slips. They showed that estimation of frictional parameters will be possible in the case that the slip feature of the data has the information to specify the parameters even if the data period is shorter than the earthquake cycle.

Actually, earthquake generation cycles are complicated spatio-temporally, thus a 2-D or 3-D forecast model with a large number of degree of freedom is needed. Therefore we have to check how the estimation of parameters depends on the degree of freedom of the model.

We consider 2D planar square fault 25.6km on a side in an infinite uniform elastic medium. The fault plane is discretised with many equal-area square cells 100m on a side and each with uniform slip. The frictional stress acting on the fault is assumed to obey the composite rate- and state-dependent friction law (Kato and Tullis, 2001). The spatial distribution of A-B and L are assumed to be a constant value (-0.5MPa, 1cm) in a circular patch with a radius of 6km, and (-1.0MPa, 10 cm) for the outside of a patch. We assume that the fault is loaded at a constant rate so that slip occurs at a slip rate Vpl=10cm/yr in the x-direction. This makes earthquake cycle that contains earthquake in the patch and afterslip out of the patch with the recurrences of 11yr.

We assume the abovementioned parameter setting as a solution, and perform data assimilation test using a synthetic slip history with artificial noise at several point in and out of the patch as observational data. Practically, earthquake cycle simulations are done with having each different frictional parameters, and calculate the likelihood distribution in the parameter space with slip histories of simulation result and that of solution by using a statistical index. We assume that the parameters in the patch are fixed and only that out of the patch are changed uniformly. We examine how data period changes the likelihood distribution of frictional parameters. Mitsui et al. (2009, SSJ fall meeting) showed that parameters can be estimated by using the data at the point of the rim or the out of the patch, if we use the data at the latter half of the interseismic term. In this study we verify how result is robust with the position of the observation point or with the value of the solution.

Keywords: earthquake generation cycle, crustal deformation, numerical simulation, data assimilation, friction law