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アジョイント法による地震断層面・余効すべり面摩擦パラメータの同時推定
Simultaneous estimation of frictional parameters on earthquake and afterslip rapture areas using an adjoint method

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Recent developments of numerical and observational techniques in seismology and geodesy enhance our ability of drawing more realistic pictures of thrust-type earthquake generation cycles along subduction zones. Forward integrations of the equation of motion with the rate and state friction law (the frictional parameters; A, B, and L) allow to simultaneously depict the multi-time scale ruptures on a fault plane, namely, an earthquake and the associated afterslips. In addition, the denser GPS network such as the GEONET array provides more detailed information of the crustal deformation due to earthquakes. In consequence, for improving our earthquake cycle model, it is expected to assimilate the observational information on the crustal movement into the earthquake cycle model through adjusting the frictional parameters on both earthquake and afterslip surfaces.

In this couple of years, opportunities for the application of the data assimilation technique rapidly increased. However, we still face difficulties. First, few assimilation approaches are successful to simultaneously estimate all the frictional parameters on the earthquake and afterslip planes. An earthquake and the associated afterslips can be in a cause-effect sequence; therefore, their frictional parameters on both surfaces should be simultaneously obtained. However, it is difficult to simultaneously perform data assimilation of the earthquake and afterslips due to their widely-separated time constants (from a few seconds to more than a year). Second, we still make a trial-and-error method to find out an adequate assimilation time window. It is crucial to properly assess the data assimilation window for most efficiently evaluating the frictional parameters.

To tackle the first problem, we develop an adjoint backward technique with adaptive time steps based on the fifth-order Runge-Kutta forward integration (Press et al, 1993). We then apply the adjoint technique for the synthetic ”twin” experiments in which the known true model is tried to be recovered with assimilating the artificial observed data into the iterative model. The synthetic twin experiments show that our adjoint technique with adaptive time steps can estimate all the frictional parameters (A, B, and L) on the earthquake fault plane as well as the afterslip areas even in different time scales.

To find an adequate assimilation time window, we plot and analyze the sensitivities of the slip velocity (V) in terms of the parameters (A, B, and L) on the earthquake and afterslip surfaces. It suggests that the assimilation time window should cover at least that of the acceleration phase of the slip velocity ($dV/dt>0$).

We note that our results account for the possibility of estimating the frictional parameters on earthquake and afterslip surfaces in the theoretical framework. Therefore, we need to develop our adjoint method for more detailed earthquake cycle models with the real observational data.
Keywords: assimilation, adjoint method, earthquake cycle, afterslip, frictional parameter