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Simultaneous estimation of frictional parameters on earthquake and afterslip rapture areas using an adjoint method(II)

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How we assimilate observational information into earthquake generation cycle simulation is one of the key issues for properly predicting spatio-temporal evolution of megathrust earthquakes and the associated afterslips along subduction zones.

We have recently targeted reducing uncertainty of frictional properties on the earthquake and the accompanied afterslip surfaces in the earthquake cycle simulation, introducing empirical information on crustal deformation data into the theoretical time series of the slip velocities.

Kano (2011) developed an adjoint method to specify the frictional properties on the afterslip surfaces of the 2003 Tokachi-oki earthquake. His identical twin experiments demonstrated that the adjoint method was a good candidate of efficiently estimating the frictional properties on the afterslip surfaces in the earthquake cycle simulation. Moreover, Kano (2011) found that the estimation of all the frictional parameters on the afterslip surfaces required the early phase of the slip velocity evolution.

For further improving the earthquake cycle simulation, it would be necessary to extend the adjoint method to identify all the frictional parameters on earthquake slip surfaces, covering the early phase of the slip velocity evolution. In addition, it would be better to perform the data assimilation of the earthquakes and afterslips in one time frame, because earthquakes and afterslips along subductions could not be a simple cause-effect sequence, but could interact in time and space.

We develop an adjoint backward method with reusing the adaptive time steps which the forward calculation of the slip velocity on the rupturing surfaces (the fifth order Runge-Kutta method; Press et al., 1993) employs.

The new adjoint method adaptively changee the time steps, so that the method enables to estimate the frictional properties on the slip surfaces even in their slip velocities changing in different time scales.

We design two identical twin experiments for obtaining frictional parameters on the slip surfaces, having quite differnt slip velocities.

(1) Continuous data assimilation of the early phase ($dV/dt>0$; V is the slip velocity) and the decaying phase ($dV/dt<0$) of the slip velocity data:
The identical twin experiment reveals that the empirical data should be assimilated into the acceleration part of the slip velocity ($dV/dt>0$) as well as the decaying part ($dV/dt<0$) in the time series for adequately estimating all the frictional parameters (a, b, and L). In addition, our sensitivity analyses illustrates that the sensitivities (dV/da, dV/db, dV/dL) intensify along the accelaration part.

(2) Simultaneous data assimilation of the earthquake and afterslip rupturing velocity data:
The data assimilation window spans one earthquake cycle including one earthquake and the associated afterslips. The identical twin experiment begins with the initial model having its frictional parameters purterbed by 5 to 10 percents from the assumed true model. In consequence, we can fix all the frictional parameters within one percent error range of the assumed parameter values. This means that the solution in this adjoint method can iteratively converge close to the true values when the initial (background) frictional parameters adequately set within 5 to 10 percent range of the true model.

Keywords: earthquake cycle simulation, frictional coefficient, adjoint method, data assimilation