Application of adjoint method to a two-degree-of-freedom fault model: an identical twin experiment using synthetic afterslip data

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We apply adjoint method to a simplified fault model to make an identical twin experiment of estimation of initial values of simulation variables and frictional parameters. We model a fault in two cell-like faults, which is equivalent to a two-degree-of-freedom spring-slider system [Mitsui et al., 2008JPGU]. We use quasi-static equations of motion of each cell, rate- and state-friction law [Dieterich(1979)] and slowness law as time evolution law of state variables. We use adjacent two cells and set parameters of cell 1 and 2 so as to generate earthquakes and afterslips, respectively.

We set initial values as follows; V_1=3.60cm/yr, V_2=3.60cm/yr, theta$_1$=$1.25*10^{-3}$yr, theta$_2$=$2.50*10^{-3}$yr, a_1-b_1=-$3.0*10^{-4}$, a_2-b_2=$3.0*10^{-4}$. With this condition, we perform a simulation over earthquake generation cycles. Earthquakes occur at every about 100 years at cell 2. At cell 1, an afterslip occurs for a few years just after each earthquake.

We select one earthquake and consider the following about 10 years when an afterslip is observed. We call this period 'test period'. In this case the true initial values are given by V_1=$6.59*10^{-7}$m/s, V_2=$3.91*10^{-9}$m/s, theta$_1$=$7.34*10^3$s, theta$_2$=$2.96*10^5$s. We record slip velocity of cell 1 at every $5.0*10^{-2}$yr during the test period. We generate synthetic data set by adding normally distributed errors (variance $1.0*10^{-18}$m^2/s^2) to the synthetic error-free velocity.

Next we apply adjoint method to the synthetic data set to estimate initial values (twin experiment). We start the search of the initial values from V_1=$1.66*10^{-6}$m/s, V_2=$4.01*10^{-9}$m/s, theta$_1$=$7.44*10^3$s, theta$_2$=$3.06*10^5$s. A cost function converges after about five iterations. The estimated initial values are V_1=$6.61*10^{-7}$m/s, V_2=$3.50*10^{-9}$m/s, theta$_1$=$7.38*10^3$s, theta$_2$=$3.05*10^5$s. Only the value of V_{1} agrees with the true value very well. This is because assimilated data set have only V_{1} components.

We study two more cases and in our poster we will present 3 cases; 1) initial values are estimated, 2) frictional parameters are estimated, and 3) both are estimated.