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Inference of fault friction parameters by inversion of postseismic geodetic data

Jun'ichi Fukuda[1*], Kaj M. Johnson[2], Naoyuki Kato[1]

[1]ERI, University of Tokyo, [2]Indiana University

Current afterslip modeling efforts in the geodetic community are moving away from a purely kinematic approach, in which slip is estimated using standard inversion methods, towards dynamic models that incorporate stress boundary conditions and fault rheology. Previous studies have modeled geodetic postseismic time series data as a response of a fault to instantaneous stress and velocity changes due to an earthquake using a single-degree-of-freedom spring-slider model or a 2 D fault in an elastic half-space with a steady-state velocity strengthening or rate- and state-dependent friction laws. These models assume that initial conditions on the fault immediately after the earthquake are determined from steady-state sliding before the earthquake and an instantaneous stress step corresponding to the earthquake. The purpose of this study is to examine effects of (1) the spring-slider assumption, (2) friction laws, and (3) initial conditions on estimates of the friction parameter $(a-b)¥sigma$ by inverting simulated postseismic geodetic time series.

In this study, we use a 1D fault model in an elastic medium with a steady-state rate-strengthening or rate-and-state friction laws to generate synthetic data sets. We then invert the synthetic data sets for the friction parameter $(a-b)¥sigma$ using a single-degrees-of-freedom spring-slider model with a steady-state rate-strengthening friction law. The results of the inversions show that the spring-slider models overpredict $(a-b)¥sigma$ assuming realistic range for coseismic stress change. Alternatively, if we assume true $(a-b)¥sigma$, small coseismic stress change and large patch size is required to fit the data. Furthermore, spring-slider model with true model parameters significantly overpredicts displacements during the early period of afterslip because spring is too compliant during the early period. This suggests that the misestimation of model parameters are due to the assumption of constant spring stiffness, which is equivalent to assuming that the size of the slip patch does not vary with time. Therefore it is important to incorporate temporal variability of spring stiffness in order to estimate the friction parameter correctly. We thus develop an inversion method to simultaneously estimate the friction parameter and time-varying spring stiffness using a particle filter. We also investigate effects of friction laws and initial conditions on estimates of the friction parameter.