Bayesian estimation of physics-based models of fault slip evolution

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Recent development GNSS and other geodetic networks makes it possible to capture transient crustal deformation due to slow, aseismic, slip on plate boundary faults with high resolution in both space and time. Many previous studies have modeled slow fault slip using a kinematic approach, in which the spatial distribution and temporal evolution of slip is determined to reproduce geodetic observations without adopting any mechanical constraints. Although the kinematic approach is convenient, it does not provide direct information on the mechanisms governing the evolution of slow slip. In this study, we develop a method to estimate parameters and initial conditions of physics-based models of fault slip evolution, in which the evolution of slip is governed by the rate- and state-dependent friction law. In this method, unknowns to be estimated include fault friction parameters and initial state and slip rate.

In order to quantify uncertainties of the model, we adopt a Bayesian approach and estimate the posterior probability density function (PDF). In general, estimating posterior PDFs of computationally intensive forward models are difficult because a large number of forward calculations are required. This also applies to our case. We reduce the computational demands by developing surrogates of the posterior PDF. In this approach, we first obtain a function approximation to the posterior PDF by fitting a surrogate function to the posterior probability densities calculated for sample points in the model parameter space. Then a Markov chain Monte Carlo method is used to sample the surrogate posterior PDF. By using this approach, we obtain the posterior PDF within a realistic computation time. In the presentation, we show applications to slow slip events and compare results obtained from several surrogate models.

Keywords: Bayesian inference, slow slip, GNSS

