Imaging spatiotemporal evolution of slow slip events using a geodetic inversion method based on hierarchical Bayesian modeling

Jun'ichi Fukuda[1]; Shin'ichi Miyazaki[2]; Tomoyuki Higuchi[3]; Teruyuki Kato[4]

[1] ERI, Univ. of Tokyo; [2] ERI; [3] Inst. Stat. Math.; [4] Earthq. Res. Inst., Univ. Tokyo

The large-scale continuous GPS networks have recorded aseismic deformation transients caused by aseismic slip on plate interfaces. Segall and Matthews [1997] developed a geodetic inversion method to infer space-time distribution of fault slip and slip velocity from a set of geodetic time series. Their method is based on Bayesian state space modeling in which prior information about temporal smoothness of slip velocity is employed. In this framework, temporal smoothness of slip velocity is governed by a hyperparameter, which is assumed to be a constant. Under this assumption, rapid changes of slip velocity are temporally oversmoothed, whereas estimated slip velocity during steady-state periods is excessively oscillatory due to undersmoothing. Consequently, estimated slip velocity is obscured due to the oversmoothing/undersmoothing problems. For example, it may be difficult to image the nucleation of slow slip events or rapid decays in the very early stage of postseismic slips.

In order to solve this problem, we developed a geodetic inversion method in which the hyperparameter is treated as a time-varying stochastic variable. To estimate temporal variation of the hyperparameter, we employ hierarchical Bayesian approach. Specifically, we introduce prior distribution for the hyperparameter, which describes time-dependence of the hyperparameter, and employ a Bayesian method to infer the time-varying hyperparameter.

We applyed the new inversion method to transient deformation observed by GPS in October 2002, caused by a slow slip event which occurred off the east coast of the Boso peninsula. The results were compared with those obtained by the conventional method. Space-time distribution of slip velocity estimated by the conventional method is temporally oversmoothed during the aseismic slip event, whereas it is excessively oscillatory before and after the event due to undersmoothing. In contrast, the new inversion method does not suffer from these oversmoothing/undersmoothing problems. These results demonstrate that introducing the time-varying hyperparameter is effective to solve the oversmoothing/undersmoothing problems and consequently enables us to reconstruct detailed image of slow slip events.