Uncertainty Quantification for Inhomogeneous Frictional Features in a Slow-Slipping Fault Based on a Large-Scale Four-Dimensional Variational Data Assimilation

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Dynamics of slipping motion of a fault largely depends on spatial inhomogeneous frictional features on the fault. Thus, it is essential to estimate the spatial frictional features from the observations of the slipping motion and to identify essential parts of frictional features that contribute to the main motion of the slipping by quantifying uncertainties involved in the estimated frictional features.
Data assimilation (DA) is a Bayesian-based numerical technique that, from limited observational data, enables us to estimate unobservable quantities together with their uncertainties by evaluating a posterior probability density function (PDF). However, “curse of dimensionality” makes the evaluation impossible easily when applying conventional DAs to large-scale simulation models used in the solid Earth science. To avoid this problem, we proposed a variational DA method that enables us to obtain estimates together with their uncertainties within a practical computational time and resources. Our method, in which a second-order adjoint method is implemented, does not depend on the number of degrees of freedom (NDF) involved in a given simulation model to obtain uncertainties, whereas the conventional DAs needs computational cost proportional to an exponential order of NDF.
This study applies our new DA method to a fault model that mimics slow-slipping region along the Bungo Channel. The fault model employs a rate-and-state dependent friction law, in which the frictional parameters are spatially dependent. Due to this feature, NDF of this fault model is so large that the conventional DAs cannot be applied. Through applying our DA method to the fault model using synthetic data of slip velocity on the fault, we investigate the estimates of frictional features and their uncertainties, and subsequently, we quantify the relation between the slow-slipping motion and the uncertainties of frictional features.

Keywords: Uncertainty quantification, Frictional feature

