Development of trans-dimensional source inversion with geodetic data

*Hisahiko Kubo[1], Wataru Suzuki[1], Akemi Noda[1], Shin Aoi[1]

1. National Research Institute for Earth Science and Disaster Prevention

In this study, we develop a new approach to estimate the static slip distribution from geodetic data by the trans-dimensional inversion, which estimates the dimension of model parameters as well as values of model parameters. The trans-dimensional inversion has been recently applied in the geophysical field (e.g. Agostinetti and Malinverno 2010; Bodin et al. 2012; Hawkins and Sambridge 2015; Kubo et al. 2016 JpGU) including the source inversion (e.g. Dettmer 2014). An advantage of this approach on the source inversion is that it does not require the smoothing constraint on slips as the prior information. The smoothing constraint is widely used in the source inversion to obtain stable and physically reasonable solutions; however, the use of the smoothing constraint significantly reduces the resolution of the source inversion. In the case of the biased and/or sparse station distribution, the source inversion with this constraint is likely to produce the solution largely affected by the prior information. Another advantage is that the posterior distributions of model parameters directly produced by sampling methods such as Markov chain Monte Carlo (MCMC) method are useful for the estimation of model uncertainties.
We assume the linear observation equation: the static slips on fault are linearly related to the static displacement at receivers via Green's functions. For simplicity, the errors of the observation equation are assumed to follow a Gaussian distribution and to be independent of each other. We model the static slip distribution on fault by a variable number of Voronoi cells. Unknown parameters are the number of Voronoi cells, the locations of Voronoi cells on fault, and slip values of Voronoi cells. We impose the non-negative constraint on this inverse problem following the procedure of Fukuda and Johnson (2008) and Kubo et al. (2016 GJI). To obtain the distribution of the model parameters, we employ the reversible jump MCMC method (Green 1995), which selects the action in each sampling step from four candidates: birth of Voronoi cell, death of Voronoi cell, move of Voronoi cell, and slip change of Voronoi cell. To improve the efficiency of the probabilistic sampling and the search range of parameter spaces, we use the parallel tempering algorithm (e.g. Sambridge 2013) in the ensemble sampling. For Green's functions, we calculate the theoretical static displacements caused by a unit slip on each subfault assuming a homogeneous elastic half-space (Okada 1992).
We apply this newly-developed approach to real GNSS data of the 2015 Gorkha, Nepal, earthquake (Galetzka et al. 2015; Kubo et al. 2016 EPS). Because the station distribution is sparse in this event, the GNSS data are expected to have a limited resolution of fault slips. We found that the conventional source inversion with the smoothing constraint produces the unsharp slip distribution where slips are widely distributed over the assumed fault. On the other hand, our new approach produces the sharp slip distribution that has large slips north of Kathmandu and no slip at the other places. The data fit of this approach is better than that of the conventional approach. This result demonstrates that the introduction of the trans-dimensional approach to the source inversion leads to the acquisition of the source model composed of only meaningful slips that are necessary to explain the data. The estimated posterior distributions in the large slip region suggest that the variation of slips is small in the area surrounded by several stations and large in the area far from stations, which is consistent with our intuitive understanding of the source process inversion.

Keywords: Source inversion, Trans-dimensional inversion, Geodetic data

