Development of “real-time” uncertainty evaluation algorithm for the estimated coseismic fault model using MCMC approach

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Rapid understanding of the magnitude of large earthquakes and their associated fault dimensions are extremely important. Since September 2012, Geospatial Information Authority of Japan (GSI) and Tohoku University are jointly developing the GEONET real-time analysis system (REGARD). REGARD system rapidly estimates two types of coseismic fault models, which are slip distribution along the plate interface and single rectangular fault model, using permanent displacement field based on the real-time GNSS tine series. Currently, REGARD adopted the maximum likelihood approach to estimate the optimum model. The system has two points to be improved. As first point, it is difficult to estimate the quantitative uncertainty estimation of the obtained result because of the estimated result should contain both of the observation error of the real time GNSS and modeling error caused by the model settings. Understanding of such uncertainties quantitatively based on the data is important for evaluation of the result for disaster response. Second point, the problem is non-linear to estimate the single rectangular fault model in REGARD. Thus, the result strongly may depend on the initial values of the fault parameters. It is necessary to find the global minimum quickly for real-time use.

Based on these backgrounds, we are developing coseismic fault model estimation system using MCMC (Markov Chain Monte Carlo methods), which is probabilistic approach based on Bayesian statistics. MCMC does not specify one maximum likelihood value, but estimates the posterior probability density function (PDF). In addition, dependency on the initial value is relatively small by searching unknown parameters over a wide range randomly. In this study, we focus on the development the algorithm to estimate the single rectangular fault model deduced from permanent coseismic displacement field in real-time. We adopted basic Metropolis Hasting method as sampler and utilized parallel tempering approach to improve the sampling efficiency. One of the challenges for using MCMC in real time is how to make search settings, such as initial value, walk distance, variance of likelihood function, and Burn-in, which are generally decided by the try and error. We suggest a method of deciding these values automatically using scaling law and original sampling flow. Other challenging issue is calculation time. In generally, the calculation cost of MCMC is problem for the real-time purpose. To improve the performance of the MCMC we adopted OpenMP for the parallelization of the computing.

We applied this approach to the 2011 Tohoku-Oki earthquake, 2016 Kumamoto earthquake, and 2016 Fukushima-Oki earthquake using the actual permanent displacement time series from REGARD. In each estimations, we got 1×10^6 samples and obtained posterior PDF within 30 seconds. To emphasize, this algorithm could estimate the magnitude as distributions based on the data. Especially in Tohoku-Oki earthquake, obtained results clearly shows the tradeoff between the fault area and the slip amount. This result suggests that the onshore GNSS data cannot constrain them, which are extremely important factors for precise near-field tsunami forecasting.
In our presentation, we will show the more detail characteristic of the algorithm. We are working on development of it for single rectangular fault model aiming at actual operation. Furthermore, we will expand this approach to not only the single rectangular fault but also the slip distribution along the plate interface.

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