Real-time uncertainties evaluation of coseismic fault models and Tsunami inundation deduced from GNSS observations

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Rapid understanding of the magnitude of large earthquakes and their associated fault dimensions are extremely important from the viewpoint of immediate tsunami prediction. 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 time series. In November 2017, the Cabinet Office, Government of Japan, commenced operation of the system for estimation of tsunami inundation and damage. The system is to be adopted as part of the Disaster Information Systems (DIS). The system has been developed based on the results from "The research group of real-time estimation for tsunami inundation" including utilization of the results from the REGARD system.

The REGARD system, however, has a problem that it is difficult to estimate the quantitative uncertainty of the estimated result because of the obtained result should contain both of the observation error of the real-time GNSS time series and modeling error caused by the assumed model settings. Understanding of such uncertainties quantitatively based on the data is important for evaluation of the result for disaster response.

Based on these backgrounds, we develop the method which estimate the coseismic slip distribution and its estimation uncertainties using MCMC (Markov Chain Monte Carlo methods). In the slip distribution model estimation, we focus on Nankai area in Japan where megathrust earthquakes have repeatedly occurred. We utilize the simulated Hoei type earthquake by Todoriki et al. (2013). We divided into 2951 rectangular subfaults along the subducting plate interface and designed Quadtree-like sampling flow by 4-step sequential segmentation. As the result, we successfully obtain the expected slip distribution and its uncertainty as the 95%C.I. of posterior PDF.

Furthermore, we assess how the uncertainty of the fault model estimation can affect the results of the tsunami inundation. Firstly, we extracted the 300 slip distribution models which has the same variance reduction value (99.51%). Based on the extracted models, we calculated the tsunami inundation for Kochi city. In the most models, the inundation area was the same as the result of the assumed fault slip model. However, the several cases clearly show the larger inundation. This result clearly suggest that the obtained tsunami inundation will have large diversity even though we use the results from high VR value models.

Furthermore, we propose visualization procedure which shows the risk of the tsunami inundation as the map with the probability. Firstly, we classify the slip distribution models by the MCMC approach using k-means approach. Secondly, we extracted the median value as the "possible scenario" from each cluster. Finally, we calculate the tsunami inundation using each "possible scenario" and then, we count the number of the tsunami inundation at each inundation point for all of the "possible scenario". The obtained map reflect the uncertainties of the tsunami inundation caused by the uncertainties of the coseimsic fault estimation using the real-time GNSS data. The map may be useful to understand the possible "worst case" scenario based on the observation.

Keywords: GNSS, Real time, Tsunami inundation

