Quantitative Uncertainty Estimation for the Coseismic Fault Model and its Slip Heterogeneity Using Real-time GNSS Data

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Earthquakes beneath the sea-floor possibly generate tsunamis. Typically, tsunamis caused by large interplate earthquakes will strike near-field coasts within several minutes to an hour. Thus, the rapid estimation of the coisesmic fault beneath the sea-floor is extremely important for the rapid estimation of the resulting tsunami. After the 2011 Tohoku-Oki earthquake, several researches have stressed on the advantages of real-time GNSS data for rapid earthquake size estimation and its utilization for tsunami early warning. In contrast, when we only adopt the onshore real-time GNSS data, resolution of the estimated coseismic fault model in the offshore region will degrade. Quantitative understanding of the such uncertainties will directly relate to uncertanties of the estimated tsunami height.

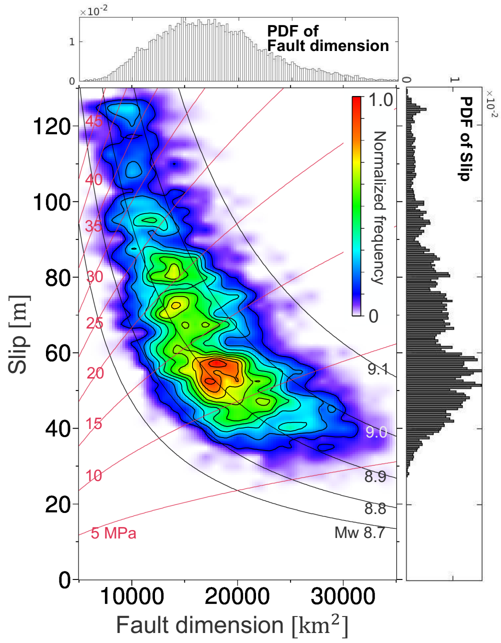

Figure 1. Posterior PDF between the fault dimension and the amount of slip. The thin black and red line denote the expected line of Mw and the stress drop value, respectively. The upper and right histograms represent the PDFs of fault dimension and slip amount, respectively.

Based on these backgrounds, we try to estimate the quantitative uncertainty estimation for the coseismic fault model deduced from permanent displacement field by the real-time GNSS data. We estimate two different types of coseismic fault model (single rectangular fault and slip distribution model along the plate interface) using Bayesian inversion approach. In Bayes' theorem, prior probability density function (PDF) is updated to the posterior PDF by considering the observation data in the form of a likelihood function. We construct a discrete representation of the posterior PDF by sampling with a Markov Chain Monte Carlo (MCMC) method. In addition, considering utilization in real time, we make sampling more efficient using Parallel-tempering approach: the samples can be obtained more effectively compared with single chain MCMC because of a parallel search by the PDF family being annealed by different temperatures. We applied this method to the 2011 Tohoku-Oki earthquake. For the single rectangular fault model, estimated posterior PDF clearly shows the trade-off between the fault dimension and the slip amount (Figure 1). For the slip distribution model, we divided into 482 sub—faults along the subducting plate interface. Without appropriate a priori information in the each sub—faults, it is difficult to obtain the reasonable result within realistic computation time even though the using of the parallel tempering approach. This result clearly shows the a priori information will be very important for the rapid convergence of the analysis. Thus we will also discuss how to implement the appropriate a prior information for the real-time purpose.