Real-time automatic uncertainty estimation of GNSS-based coseismic fault model: a case study of 2019 Yamagata-Oki earthquake

*Keitaro Ohno[1], Yusaku Ohta[1], Hiroki Muramatsu[2], Satoshi Abe[2]

1. Research Center for Prediction of Earthquakes and Volcanic Eruptions, Graduate School of Science, Tohoku University, 2. Geospatial Information Authority of Japan

Rapid understanding of the magnitude of large earthquakes and their associated fault dimensions are extremely important. Since 2012, Geospatial Information Authority of Japan (GSI) and Tohoku University are jointly developing the GEONET real-time analysis system (REGARD). REGARD estimates two types of coseismic fault models in real time, which are slip distribution on the plate interface and single rectangular fault model, using permanent displacement data based on the real-time GNSS analysis. Currently, REGARD adopt the maximum likelihood approach to obtain the optimum model for both types of coseismic fault models. The system, however, has the problems to be solved in single rectangular fault model estimation. For the single rectangular fault model estimation, the problem is the non-linear. Thus, the obtained results strongly depend on the initial values of the fault parameters. Furthermore, it is difficult to estimate the quantitative estimation of the obtained fault parameters because the obtained result and its uncertainties also depend on the initial values of the parameters and assumed Green’s function.

Based on these backgrounds, we developed the method for the real-time uncertainty estimation of the single rectangular fault model using full Bayesian inversion approach. We adopted the MCMC (Markov Chain Monte Carlo methods) to obtain the posterior probability density function (PDF) of the unknown fault parameters. One of the advantages in the MCMC, dependency on the initial value is relatively small compared with current REGARD system.

One of the challenge issues for using MCMC in real time is how to assume the 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 investigated the automatic determination of these parameters in real-time. 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 optimized the developed code and adopted the OpenMP for the parallelization for the calculation.

In this presentation, we applied the developed method to the 2019 Yamagata-Oki earthquake based on the actual time series from the REGARD and post-processed time series (Q3 solution). We used permanent displacement of 50 sites near the focal area. The length of the Markov chain is 1×10^7 samples and calculation time is approximately 108 seconds. To stabilize the solution, we introduced a prior information from the earthquake early warning (EEW) system. We gave a priori distribution for the fault location based on the EEW information. We also gave the constraint in the direction of the fault dipping based on the aftershock distribution in the case of the Q3 solution.

The result from the REGARD, the developed method successfully obtains the fault model (Figure (a)) even though the value of the variance reduction is not high (~50%) because of the signal to noise ratio of the obtained displacement field was low. The obtained fault model (median value) clearly shows the east-dipping fault. This result basically consistent with the characteristic of the aftershock distribution. In contrast, the marginal PDF clearly shows the trade-off between the fault area and the slip amount. It suggests that the only onshore GNSS data cannot constraint these parameters. These result clearly suggest that our developed method can contribute to estimate the fault model and its uncertainties in real-time. The result from the Q3, the we gave the a prior information for the direction of the fault dipping. Both of the fault dipping direction (east and west dipping), obtained fault model can explain the data (Figure (b)). This result also suggest that the difficulty of the determination of the fault geometry only from the onshore GNSS data. In the presentation, we will discuss how to obtain the more reliable fault model in real time.

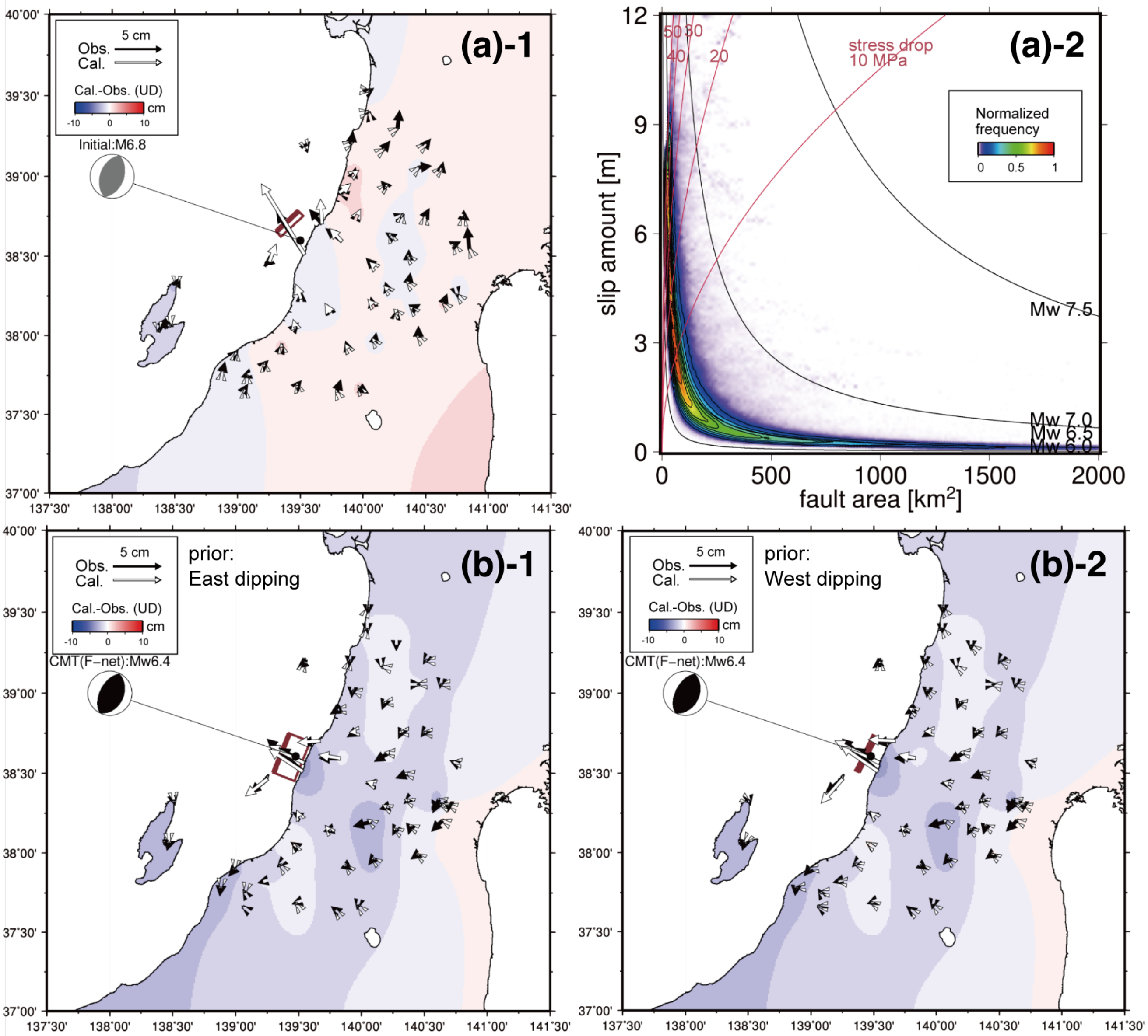

Figure (a) Results used the data from REGARD. 1: Estimated fault (median). 2: Marginal PDF between fault area and slip amount.
(b) Results used the data from Q3 solution. Estimated fault (median) with prior PDF of strike [1: east dipping, 2: west dipping].