An application of reversible-jump MCMC method for simultaneous determinations of 1-D velocity structures and hypocenters around a fault (I): Formulation

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Locations of earthquakes are one of the fundamental information in seismology. To determine hypocenters, a one-dimensional (1-D) velocity model, such as the JMA2001 1-D velocity model [Ueno et al., 2002], is routinely used. In the case of local seismic swarm activities, such as aftershocks of a large earthquake, a local 1-D velocity model is often constructed. Although a single 1-D velocity model was conventionally adopted for the source area of the swarm, it was reported that two or more 1-D velocity models can accurately estimate location of hypocenters when earthquakes occur at around a structural boundary [e.g., Sakai et al., 2004]; that is, seismic velocities change across the source area. Since such structural boundary often act as a slip plane of a large earthquake, preliminary understandings for the earthquake and monitoring of its aftershocks will improve by utilizing several local 1-D velocity models.

A 1-D velocity model is generally constructed based on seismological and/or geological knowledge [e.g., Sakai et al., 2004]. Three-dimensional analyses, i.e., tomographic inversion, would detect those heterogeneous structures if a large amount of seismological observations were obtained. In other words, with small dataset of seismic records, it is difficult to know a presence of structural boundary and velocity structures of each seismological/geological unit around a fault without obvious surface exposure of them. Therefore, in our series of presentation (this study and Shiina and Kano [this meeting]), we propose a Bayesian-based approach for simultaneous determination of hypocenters of earthquakes and 1-D velocity structures around a fault. Additionally, our approach assigns each station to a specific velocity model.

This study uses a reversible-jump Markov chain Monte Carlo (rj-MCMC) method to estimate 1-D velocity models and hypocenters of earthquakes. In an analysis of seismic velocity structure of Earth’s interior, the rj-MCMC method can change a number of discrete units, i.e., grid, block, or layer, and investigate P- and S-wave velocities of the discrete units. Bodin and Sambridge [2013] adopted this method to estimate a two-dimensional velocity structure. Based on their formulation, we developed the rj-MCMC approach; layered velocity structures and hypocenters are simultaneously determined when given a number of 1-D velocity models.

In this presentation, we will summarize formulations of the developed method in detailed. An application of this method for synthetic data sets will be summarized by Shiina and Kano [this meeting].

