Development of trans-dimensional waveform inversion to estimate 1D layered underground structure model

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Some previous studies tried to estimate 1D layered underground structure models based on the waveform modeling of small events (e.g., Ichinose et al. 2003; Kakehi 2004; Asano and Iwata 2009) to obtain reliable Green's functions used in earthquake source inversions. In this study, we develop a new approach of the estimation of 1D structure model from waveform data using the reversible jump Markov chain Monte Carlo (rjMCMC) method (Green 1995). The trans-dimensional inversion using the rjMCMC method has recently found applications in geophysics (e.g. Malinverno 2002; Agostinetti and Malinverno 2010; Bodin et al. 2012; Dettmer et al. 2014; Hawkins and Sambridge 2015). In the rjMCMC method, the number of model parameters is one of the variables in the inverse problem, and therefore the parsimony of the solution can be determined by data and is not imposed by user (Gallagher et al. 2009; Agostinetti and Malinverno 2010). Because in this method there is no necessity of strong prior information (e.g. layer number and initial structure model), the flexibility of the proposed approach in this study is expected to be high. Another advantage is that ensembles of models produced by the MCMC approach are useful for the estimation of model uncertainties. The uncertainty information of structure model could be used in the introduction of synthetic errors to source inversions as the uncertainties of Green's functions.
The geometry of layers is described by a variable number of Voronoi nuclei (e.g. Bodin et al. 2012). For simplification, errors of the observation equation are assumed to follow a Gaussian distribution and be independent from each other. Unknown parameters are the number of layers, thickness of each layer, Vs of each layer, and hyper-parameter which represents the scale factor of the errors. Vp and density of each layer are calculated from Vs by the empirical relations of Brocher (2005). The attenuation characteristics (Qp, Qs) are calculated from Vs following the procedures of Kawabe and Kamae (2008) and Koketsu et al. (2009). Synthetic waveforms are calculated using the discrete wavenumber method (Bouchon 1981) and the reflection/transmission matrix method (Kennett and Kerry 1979). In the trans-dimensional sampling of structure models, we use the parallel tempering algorithm (e.g. Sambridge 2013) to improve the efficiency of the probabilistic sampling and the search range of parameter space.
In this presentation, we will show the results of the applications of the newly developed approach to synthetics and real data to show the validation and usefulness.

Keywords: Trans-dimensional waveform inversion, Estimation of 1D structure model, Reversible jump MCMC method

