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Traveltime tomography using reflection seismic data and uncertainty analysis by initial model randomization

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The seismic tomography is one of useful technique to estimate velocity distribution using natural earthquakes or active seismic survey data, but inverted results have uncertainty which depends on a initial model, a source-and-receiver geometry, and so on. A Monte Carlo uncertainty analysis by the initial model randomization is one method to evaluate the uncertainty of a velocity model estimated by tomographic inversion. This method provides the velocity structure model and the spatial distribution of error range by calculating an average and a standard deviation of all tomography results from hundreds initial models. We adopted this method in order to evaluate our results from the refraction traveltime tomography using the reflection seismic survey data, and applied this analysis to some simulated and field data sets. In our refraction traveltime tomography, a LTI method is used to calculate theoretical travel time, and a SIRT is used to update the velocity model based on differences between observed and theoretical traveltime. One example of our uncertainty analysis using seismic data acquired on a 42km-long survey line with 1152 receivers (25-50m spacing) and 712 shots (vibrator and explosive shots) across the western marginal faults of Kitakami lowland, northeast Japan. The reconstructed velocity structure averaged from 500 random initial models shows reasonable spatial variation with high reliability above 3-4km in depth, and it corresponds to geological interpretation by a reflection seismic profile. In contrast, the deviation around faults and velocity boundaries shows locally high value. It means that distribution patterns of the deviation implicitly indicate the structural character such as drastic velocity changes or geological complexities. Additional analysis about convergences of the deviation and the velocity show that at least 100-200 initial models are required for the stable reliability analysis. In order to evaluate a spatial resolution, a checkerboard resolution test is one choice, because this uncertainty analysis method gives no information about the resolution.

Keywords: Refraction traveltime tomography, reflection seismic survey, initial model randomization, uncertainty analysis