Seismic imaging of crustal structures by a trans-dimensional coda-wave analysis

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Seismic waves at high frequencies (>1Hz) usually show incoherent and complex wave trains due to medium random inhomogeneity and inelasticity. Multiple lapse time window analysis (MLTWA) is one of the frameworks for a separate estimation of scattering and intrinsic 1/Q values (e.g., Fehler et al. 1992). This approach analyses the spatiotemporal variation of the normalized energies from direct S-wave to coda wave, and gives a relatively stable estimation of 1/Q values. A single station approach of MLTWA (e.g., Hoshiba 1993) has been applied for large scale seismic networks to estimate spatial variations of scattering and intrinsic 1/Q values (e.g., Carcole and Sato, 2010). However, the MLTWA usually assumes horizontally uniform 1/Q in data-fitting. Then, we should take into account of the spatial variations of 1/Q in MLTWA to estimate these structures. To achieve this aim, this study generalized the MLTWA under the Bayesian framework in dimension-variable space for an adequate estimation of scattering and intrinsic 1/Q structures.
This study partitioned the study area by means of the discrete Voronoi tessellation, and assumed that each Voronoi cell is characterized by constant scattering and intrinsic 1/Q values. We evaluate the misfit of the normalized energy of the MLTWA for all Voronoi cells, and define the posterior probability under the Bayesian framework. We applied the reversible jump Markov Chain Monte Carlo (Green, 1995) to conduct a parameter sampling under the posterior probability with changing the number and spatial layout of Voronoi cells. This trans-dimensional sampling in dimension-variable parameter space would generate uniform structure areas under the information of input data, and would estimate seismic structure with an adequate spatial resolution for input data. We applied this method for seismic data at the outer-rise region off Tohoku area. This observation (Obana et al. 2012) covered a large outer-rise earthquake (Mw7.6) and its aftershocks that occurred soon after the 2011 Tohoku-Oki earthquake. The single station analysis of MLTWA gives weak intrinsic attenuation (1/Q ~ 1/1000) at all stations and some high scattering stations with 1/Q ~ 1/300. However, this result could not give clear insights on the origins of strong scattering due to the sparse seismic network. The trans-dimensional analysis of this study found the weak intrinsic attenuation (1/Q ~ 1/1000) as with the single station approach, and imaged two anomalies of strong scattering 1/Q. One of strong scattering is imaged at the northern part of seismic network. This is almost located at the epicenter of the Mw7.6 event. Another one is imaged at high activity area of aftershocks at the south of seismic network. This result suggests coda-wave analysis has sensitivity for fractured structures due to seismic activity, and the trans-dimensional analysis is effective to extract spatial variations of inhomogeneity and inelasticity.

Keywords: coda wave, MCMC, wave scattering, wave attenuation, outer rise

