Estimation of spatio-temporal changes of seismic scattering property associated with the 2008 Iwate-Miyagi Nairiku earthquake from sparse modeling of seismic ambient noise CCFs

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In recent years, spatial distributions of seismic velocity and/or seismic scattering property changes associated with volcanic activities and earthquakes have been investigated by linear least-squares inversions using seismic ambient noise cross-correlation functions (CCFs) and sensitivity kernels (e.g., Obermann et al., 2013; Obermann et al., 2014). However, spatial distributions of medium changes are not easily estimated in the regions where only a small number of stations are set up. Here, we use sparse modeling (L_1 norm regularization) to estimate model parameters for a small data set (e.g., Tibshirani, 1996), and evaluate the minimum number of stations for these studies. We apply the sparse modeling to the 2008 M_w 6.9 Iwate-Miyagi Nairiku earthquake that occurred on 14 June 2008, and estimate the spatial distribution of seismic scattering property changes from decoherence (waveform changes) data of seismic ambient noise CCFs. Since we have enough seismic stations, we can compare the results from the sparse modeling and those from an ordinary linear least-squares inversion with L_2 norm regularization which has been widely used to solve linearized problems.

Seismic ambient noise CCFs were calculated at 0.5-1 Hz band for the pairs among 17 Hi-net stations during the years of 2007 and 2008. We firstly calculate decoherence values between reference CCFs (Jan-Dec, 2007) and target CCFs in two time periods of May 1 to June 13 (Period I) and June 15 to July 31 (Period II) in 2008, respectively. We then calculate the differences of decoherence values of Period I and Period II, and use them as observed decoherences. Totally, 450 observed decoherence values are analyzed. Finally, we divide the study area into 63 small cells with a size of $0.15^{\circ}\times 0.15^{\circ}$ and estimate scattering coefficient changes, Δg, for each small cell by comparing the observed and synthesized decoherence values. Here, we estimate synthesized decoherence values using 2-D decorrelation kernels (Margerin et al., 2016).

The result from the linear least-squares inversion with L_2 norm regularization shows that large Δg values are estimated around the epicenter of the main shock. The region of the largest Δg value is located at the south of the epicenter also from the sparse modeling. The maximum Δg value is about 0.035 km^{-1}, which is almost equivalent to the total scattering coefficient at this region. To know a minimum number of stations for the estimation, we selected the stations which locate within 30 km, 40 km, and 50 km from the epicenter (5, 7, and 13 stations, respectively), and conducted the same estimations for each case using the sparse modeling. We confirmed that 7 stations were necessary to recover the similar result.

The regions with large Δg values are well correlated with the region where large peak ground acceleration and large seismic velocity decreases are obtained (Takagi et al., 2012; Hobiger et al., 2014). This consistency suggests that strong motion by the main shock introduce not only large seismic velocity decreases but also large seismic scattering property changes in the shallow medium at the south of the epicenter. The sparse modeling will be useful to locate a change region of seismic scattering property changes from a sparse seismic network with several seismic stations.

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Keywords: sparse modeling, seismic scattering property change, Iwate-Miyagi Nairiku earthquake, seismic interferometry