Separation of temporal variation in transfer function of ACROSS source using Independent Component Analysis

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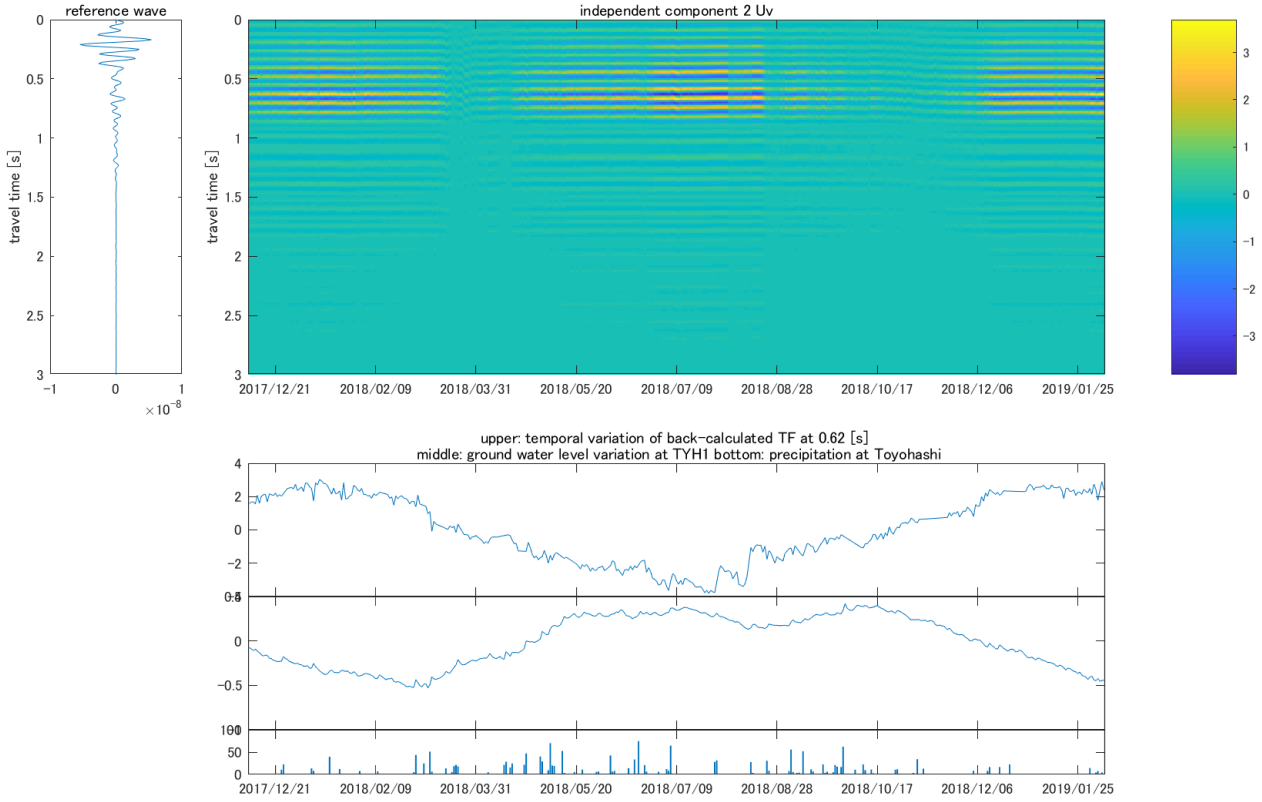
ACROSS source is a vibration source that can generate seismic wave of constant frequency band by accurately controlled rotation of eccentric weight. This source can gain a signal with high signal-to-noise ratio by taking advantage of stable operation for long period. Therefore, it is suitable for continuous monitoring of the propagation property of seismic wave. The ACROSS source is used for monitoring temporal variation of seismic velocity in many studies. Ikuta et al. (2002) reported that observed velocity change was caused by multiple factor such as rainfall and strong motion by earthquake. In this study, we applied Independent Component Analysis (ICA) for the observation data using the ACROSS vibrations in Mikawa Observatory of Nagoya University in Toyohashi City, Aichi Prefecture. We try to separate independent variation in order to research influence of each factor to the temporal variation of transfer function

ICA is a method to extract statistically independent signal from the mixing of multiple signals. By an assumption that the variation of transfer function by each factor is independent and observed variation of transfer function is linearly mixed by these variations, we can extract variation by each factor using ICA.

In this study we used fourteen-month long data for monitoring temporal variation of transfer function at stations around the ACROSS source installed at Mikawa Observatory of Nagoya University. There are six components in the transfer function: up-down, north-west, and east-west components by vertical excitation (Uv, Nv, and Ev component) and those components by horizontal excitation (Uh, Nh, and Eh component). For our analysis, we synthesized horizontal component at seismometer which is parallel to the vibration direction using Nh and Eh, named Hh. Uv and Hh component mainly include P and S wave, respectively. For the analysis, we used transfer function in frequency domain and performed data whitening and dimension compression as a preprocessing. Data whitening maximizes the performance of signal separation by ICA. Dimension compression is made by Principal Component Analysis to reduce noise that may be included less important components. We applied ICA to the preprocessed transfer function and succeeded to obtain independent components. Among many methods of ICA, we adopted AMUSE method (Tong et al., 1991, Nemoto and Kawakatsu, 2005) that is often applied to time series signals.

Independent components obtained by ICA show same temporal variations but show difference in travel time part in Uv and Hh. Comparing each independent component with ground water level data, independent components show high correlation with ground water level variation. The temporal variation of this independent component mainly appeared in later wave.


reference wave
travel time [s]
×10^-8
independent component 2 Uv
travel time [s]
2017/12/21
2018/02/09
2018/03/31
2018/05/20
2018/07/09
2018/08/28
2018/10/17
2018/12/06
2019/01/25
upper: temporal variation of back-calculated TF at 0.62 [s]
middle: ground water level variation at TYH1 bottom: precipitation at Toyohashi