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An attempt to detect seismic velocity change due to tidal strain based on autocorrelation analysis of ambient noise

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Recent studies using noise correlation method report temporal changes in seismic velocity associated with occurrence of large earthquakes and volcanic activities or seasonal variations (e.g. Titi et al., 2012; Hobiger et al., 2012). These temporal changes of the structure can be interpreted as the damage in near surface due to strong motion or the static stress change due to coseismic slip on the fault or volcanic crustal deformation. A few field experiments of in situ seismic velocity measurements detected seismic velocity changes of 0.1%˜0.5% due to tidal strain (e.g. Reasenberg & Aki, 1974; Yamamura et al., 2003). In frequency band, these active experiments using piezoelectric transducer or air gun as sources with dominant frequency of 1kHz or 30 Hz are not always consistent with seismic interferometry which have reported temporal changes. Using dilation and compression by tidal force as an external force, we examine seismic velocity changes due to applied stress based on autocorrelation function (ACF) analysis of ambient noise.

We use the vertical component of continuous seismic data (100Hz sampling) at 118 Hi-net stations in the northeastern Japan from 1 January to 31 December 2010. To remove signals from natural earthquakes, we use data with amplitudes less than a threshold value, which is set to be five times the median of 1 year RMS calculated every 10 min, and apply one-bit normalization. The data is filtered at frequency band of 1-2Hz, 2-4Hz. ACFs are calculated every 10 minutes.

To detect small velocity changes due to tidal stress in 103 Pa order, we need to select data in relatively calm day. We measure time delays by applying cross correlation analysis for the mean ACF in 2010 and daily ACFs. Correlation coefficients and time delays are calculated by shifting a time window of 2.56 s during the lag time of 1.28-10 s. For a homogeneous medium in which seismic velocity constantly increases or decreases, we estimated daily seismic velocity changes from the relation between lag time and delay time. In order to enhance the temporal resolution of the CCF, we interpolate with a sampling frequency of 800 Hz.

We compute tidal synthetic volumetric strain at each station using GOTIC2 program (Matsumoto et al., 2001) in estimated calm days. We define tidal strain with a value more than 5.0x10-9 and less than -5.0x10-9 as dilational and compressional episodes respectively, and we stack ACFs in each period. We call the ACF stacked in dilational episode DACF and that in compressional episodes CACF. We estimate the time delay of DACF for CACF only when the correlation coefficient is larger than 0.99.

Focusing on seismic velocity changes obtained stably, we select stations which estimated error of seismic velocity changes is smaller than 0.01%. At the frequency band of 2-4 Hz, we measure seismic velocity changes at 27 stations, and summarize them in a histogram. Velocity changes are distributed in -0.06±0.06%, and the peak shows -0.01%. It can be thought that seismic velocity decrease in dilation, our result may show velocity changes due to tidal strain. However the weighted average of seismic velocity changes is estimated -0.006±0.005%, which show our methods cannot always give meaningful result. On the other hand, at the frequency band of 1-2 Hz, we measure velocity changes at 45 stations. At this frequency band, velocity changes are distributed in -0.14±0.09%, and the weighted average of seismic velocity changes is estimated 0.0±0.004%. These results may show that our method cannot detect seismic velocity changes due to tidal stress.

In comparison with previous studies, we cannot detect clear seismic velocity changes corresponding to tides. There may be difference of frequency band between previous study and our study as a cause, so we will analyze at higher frequency band.

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Keywords: seismic interferometry, autocorrelation function, ambient noise, earth tide, temporal seismic velocity change