Monitoring temporal changes in seismic velocity around Shinmoe-dake with seismic interferometry

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Stress changes and fluid migrations due to earthquakes or volcanic eruptions greatly affect the seismic velocity in situ. By investigating the temporal and spatial change of the subsurface structure, temporal changes of the stress field and the fluid distribution can be constrained. Recently, many groups has reported spatial and temporal changes in seismic velocity associated with these events(e.g. Brenguier et al., 2008) using the technique of monitoring the seismic velocity with seismic interferometry (SI). In this study, we apply SI to the seismograms near Shinmoe-dake and report the temporal change in seismic velocity related to the eruption in Jan. 2011.

We analyzed continuous seismic records from May 1, 2010 to Apr. 30, 2017 at two V-net stations, which were deployed by National Research Institute for Earth Science and Disaster Resilience (NIED) around Shinmoe-dake. Each station has a broadband seismometer at the surface and a high-frequency seismometer (1 Hz) at the bottom of a borehole (depth ~200 m). In this study, we estimated the temporal changes in seismic velocity for 2 types of seismometer pairs. One is Vertical array (VA) composed of seismometers at the same station and has about 200 m scales vertically, and the other is Cross-hole array (ChA) with the same type of the seismometers at different station pairs with horizontal separation distance of about 10 km typically.

First, we calculated the cross-correlation function (CCF) for every day. After the detrending and the tapering, a one-day seismogram was bandpass-filtered from 2 to 8 Hz for VA and from 0.3 to 0.6 Hz for ChA. Moreover, we corrected the seismometer’ s response to VA because the sensor types are different. We devided the seismogram into 81.92-sec (163.84-sec) segments for VA (ChA) and this segment was detrended and tapered again. After 1-bit normalization and spectral whitening, we calculated the CCF for each segment and stacked them for obtaining the one-day CCF.

Next, we estimated the temporal changes in the seismic velocity using the travel-time differences between the reference CCF and CCF stacked for 5 days before and after 2 days. Here, the reference CCF was obtained by stacking one-day CCF for 1 month on may in 2010. For VA (ChA), we shifted the time window of 2.56 s (10.24 s) from -5 s to 5 s (from -40 to -20 s, and from 20 s to 40 s) and measured the delay times for each window. We set the threshold for the absolute value of the delay time (VA: 0.2 s, ChA: 1.0 s) and the correlation coefficient (VA: 0.7, ChA: 0.5). Choosing the data based on the threshold, we determined the slope and the intercept by linear fitting.

We found two features in the temporal change of seismic velocity. The first was the change due to the eruption. This was detected clearly only for VA. Because the frequency range and the relative location of seismometers were different between VA and ChA, the depth sensitivity of VA might be too shallow to detect the signal. The change in seismic velocity due to the eruption could be located in the deeper part where VA has no sensitivity.

The second was the periodic change detected by both VA and ChA. In Kyushu region, Qing-Yu Wang et al. (2017) reported that the change in seismic velocity due to the strong rainfall in Jul. was remarkable. The precipitation affects the shallow aquifer more strongly, so the result for VA showed the clear change correlated with the precipitation.

In this study, we monitored the seismic velocity around Shinmoe-dake with SI. By investigating the seismic wave extracted from SI spatially with more stations, we are going to infer the spatial variations of the temporal change associated with the eruption. Furthermore, we will remove the change of seismic velocity due to precipitation and estimate the velocity change due to the eruption in 2011 more exactly.

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