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A Trial for Detecting the Temporal Variation in Seismic Velocity Accompanied by a Slow Slip Event using Seismic Interferometry of Ambient Noise

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Seismic interferometry is one of the most effective techniques to detect temporal variations in seismic velocity before or after a large earthquake. Some previous studies have been reported on seismic velocity reduction due to the occurrence of large earthquakes (e.g., Wegler et al., 2009; Yamada et al., 2010) as well as preceding them (e.g., Lockner et al., 1977; Yoshimitsu et al., 2009). However, there have only been a few studies thus far which attempt to detect seismic velocity changes associated with slow slip events (SSEs). In this study, we focus on applying seismic interferometry to ambient noise data from ocean bottom seismometers (OBSs) deployed near a subduction zone.

Between the end of January 2011 and the largest foreshock occurring on March 9th that precedes the March 11, 2011 Tohoku-Oki earthquake, SSEs and low-frequency tremors were detected offshore Miyagi Prefecture (Ito et al., 2013, 2015; Katakami et al., 2016). We applied our seismic interferometry analysis using ambient noise to recordings from 17 OBS stations that were installed in the vicinity of the 2011 Tohoku-Oki earthquake source region, and only considered the recordings from before that major earthquake.

All the OBSs are short-period seismometers with three components which have an eigenfrequency of 4.5 Hz. These OBSs were deployed offshore Miyagi Prefecture between November 2010 and April 2011. Before proceeding with the seismic interferometry analysis, we needed to estimate the two horizontal components of the original deployment orientation for 13 OBSs in (we could not estimate them for 4 OBSs). To obtain the OBS orientation, we used particle orbits of some direct P waves from selected tectonic earthquakes, in order to extract one vertical and two horizontal components. Then, the seismic interferometry analysis consisted of the following steps. First, we applied a band-pass filter of 0.25-2.0 Hz and one-bit technique to the ambient noise signal. Second, we calculated auto-correlation functions (ACFs) for the radial and transverse components using a 5-s time window with lag time from -30 s to 30 s, sampled at intervals of 0.1 s. Using either seven or sixteen days of continuous waveform records or the entire time period, we can construct either a 7-day ACF, a 16-day ACF, or a reference ACF. Finally, we calculated the Correlation Coefficients (CCs) between the 7-day ACF or the 16-day ACF and the reference ACF.

There are three important points in our results. First, during the occurrence of the SSE, the values of the CCs decrease. Second, the changes in the values of the CCs display regional differences across the OBS network. Third, the locations of the stations for which the drop of the CC from a value of 1.0 is large corresponds to the seafloor region above the rupture area of the largest foreshock, whereas the locations of the stations for which the drop from the CC of the previous period is large corresponds to the seafloor above the slip area of the SSEs detected before that foreshock.