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Detecting temporal changes in shallow subsurface structures by auto correlation analysis of coda waves

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Seismic interferometry using ambient noise records has been successfully used to detect temporal changes in a subsurface velocity structure. So far, velocity changes have been found to be associated with large earthquakes and volcanic eruptions [e.g. Sens-Schoenfelder and Wegler (2006); Brenguier et al. (2008)]. Though coda waves, which may contain more body waves than ambient noises, will be better to detect reflected waves from interfaces at depths, we can not help waiting earthquakes. But at regions with high seismicity, it may be possible to monitor subsurface structures. Though seismic interferometry using downhole array records is very efficient to detect temporal changes in shallow subsurface [e.g. Sawazaki et al., (2009)], it requires borehole records. In this study we propose to use auto-correlation function of coda waves recorded at surface receivers to detect subsurface velocity structures. And we apply this method to the 2011 Tohoku-Oki earthquake, with which velocity changes have been reported to be associated by Wu and Peng (2011) and Nakata and Snieder (2011). So the purpose of this study is to validate the auto-correlation analysis of coda waves for monitoring.

We use KiK-net stations in the Pacific side of Northern Honshu (from Aomori to Chiba). At each station, records from earthquakes of M smaller than 7.0 which occurred at depths of 20-60km off Pacific region in 2010 and 2011. Two horizontal component acceleration records at the surface are used. In the frequency range of 1-20Hz, normalized auto correlation function of the record is calculated for a 10.24 s?long coda waves starting from the 1.5 times the direct S-wave travel time. We repeat such calculations 20 times by sliding time windows by 1 s. Normalized auto correlation functions are stacked with respect to different time windows. Aligning the stacked normalized auto correlation functions along time, we try to find changes in arrival times of phases in the auto correlation functions. Focusing on shallow depths, we deal with phases in lag times of less than 1s. According to the results, temporal variations are found at some stations. Especially, clear phase delays are found at stations along the coast in Iwate and Ibaraki. And this change is associated with the mainshock. Amounts of phase delays are in the order of 10% on average with the maximum of 30%. This method seems to have an accuracy of about a few percent, which is much larger than methods using earthquake doublets [e.g. Poupinet et al. (1984)]. So this method might be applicable to detect larger changes. In spite of these disadvantages, this method is still attractive because it can be applied to records on the surface without boreholes.

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Keywords: seismic interferometry, auto correlation function, coda wave