Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SSS24-P02 Room:Convention Hall Time:May 20 18:15-19:30

Time-lapse change in seismic velocity after the 2011 Tohoku-Oki earthquake estimated using ambient noise record

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We detected temporal velocity change after the 2011 Tohoku-Oki earthquake using ambient noise interferometry. We used a seismic array in Iwate prefecture, which is equipped by Tohoku University. The array consists of 10 broadband sensors. Minimum and maximum separations of the array are 2.4 km and 18 km, respectively. Vertical component data of nine stations from January 2010 to December 2011 are used. After removing earthquake according to data amplitude, we computed normalized cross spectra for each day.

In the case of isotropic incidence of ambient noise, normalized cross spectra can be modeled by the Bessel function $J_0(kr)$, where k is the wavenumber and r is the separation distance [Aki 1957]. By fitting the Bessel function, we measured average phase velocity for each frequency. From average cross spectra before the earthquake, the phase velocities at 0.4, 0.8, 1.2 Hz are estimated as 3.183, 2.985, 2.878 km/s, respectively. After the earthquake, they are 3.176, 2.978, 2.863 km/s. Therefore, velocity decreases at 0.4, 0.8, 1.2 Hz are 0.22, 0.22, 0.52%, respectively. The phase velocities at other frequencies also show decrease after the earthquake. Especially, in the frequency range of 0.4-1.2 Hz, velocity decrease tends to be proportional to frequency.

The cross spectra for the case of anisotropic incidence of ambient noise also can be modeled by expanding the azimuthal distribution of incident wave amplitude in a Fourier series [Harmon et al., 2010]. When we modeled the noise source distribution by the fourth order expansion, the phase velocities at 0.4, 0.8, 1.2 Hz before the earthquake are 3.181, 2.980, 2.855 km/s, respectively. After the earthquake, the phase velocities are estimated as 3.173, 2.972, 2.842 km/s, which means velocity decrease by 0.24, 0.27, 0.46%.

Keywords: Seismic velocity change, Seismic interferometry, The 2011 Tohoku-Oki earthquake