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# Seismic velocity reduction after the 2011 Tohoku-Oki earthquake using repeating earthquake

TAKAGI, Ryota[1*], UCHIDA, Naoki[1], OKADA, Tomomi[1], HASEGAWA, Akira[1]

[1]RCPEV, Graduate School of Sci., Tohoku Univ.

We used repeating earthquakes data to estimate velocity change in the overriding plate from Kanto to Hokkaido region associated with the 2011 M9.0 Tohoku-Oki earthquake. Because repeating earthquakes occur as the repeating slips on the same patch on the Pacific plate with the same source mechanism at different time, waveform data of repeating earthquake is suitable for detecting temporal change in subsurface structure.

First, we performed the moving window cross-spectral analysis for vertical component of seismograms of 54 repeating earthquake sequences. Before the analysis, data were filtered with a band-pass window of 1-10Hz. To align the arrival time of P-wave, we used cross-correlation for the P-wave in a 5-sec time window centered by computed arrival time according to the 1-D structure of JMA2001 [Ueno et al., 2002]. After aligning the P-wave, we computed cross-spectra for the moving time window with a length of 2-sec at every 0.1 sec to measure time-shift between a pair of repeating earthquakes. For pairs of repeating earthquakes that are both before the 2011 Tohoku-Oki earthquake, the time-shifts are almost zero from direct P-wave to S coda. In contrast, for pairs before and after the earthquake, the time delay gradually increases with lapse time. This result indicates the velocity decrease after the 2011 Tohoku-Oki earthquake. For example, at a Hi-net station (N.KAKH) near the Oshika Peninsula, the time delay linearly increase just after P arrival to about 0.02 sec in 40 sec for an repeating earthquake sequence of which epicentral distance is 232 km. From the slope of the time delay, the amplitude of velocity reduction is about 0.05 %. The time delay does not always show linear increase with lapse time. The behavior of the time delay seems to depend on the location of event-station pair, which means heterogeneous distribution of velocity change.

Secondly, we only used the information of direct part of a seismogram to estimate the location of the velocity reduction. This is because the time-shift in direct part simply reflects the velocity change only along a direct ray path in contrast to the complex path of coda waves. One problem for using the direct part is an error of origin time. However, because the errors of origin times are identical at all stations, we can estimate the relative delay in many stations for a pair of repeating earthquakes that can be used for the estimation of the spatial variation of time-shift in direct part. In order to evaluate the spatial variation of time-shift for a pair of repeating earthquakes, we subtract a median of the time-shifts of direct P-wave for all stations from the time-shifts of P and S-wave at every station. From the result of all repeating earthquake sequences, we can recognize clear relative time-delay of about 0.01 sec for S-wave by in both the fore-arc and back-arc region from Fukushima to Iwate prefecture. Furthermore, we estimated spatial distribution of the S-wave velocity change by a tomographic inversion method using the time-shift as input data. In this inversion method, we solved slowness changes in three-dimensional blocks and the errors of the origin times simulatenously. The ray path is computed by using the JMA2001. As a preliminary result, a major slowness increase (velocity decrease) of 0.05 % is estimated in upper crust in Tohoku region from Fukushima to Iwate prefecture. The receiver-side velocity reduction 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.