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Coseismic and postseismic wave velocity changes caused by large crustal earthquakes in Japan

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Using Passive Image Interferometry (PII), we analyzed coseismic and postseismic changes of seismic wave velocities caused by the following earthquakes which occurred in Japan between 2004 and 2011: The 2005 Fukuoka ($M_W 6.6$), 2007 Noto Hantō ($M_W 6.6$) and 2008 Iwate-Miyagi Nairiku ($M_W 6.9$) earthquakes, three earthquakes in Niigata Prefecture (2004 Mid-Niigata, $M_W 6.8$; 2007 Chūetsu Offshore, $M_W 6.6$; 2011 Nagano/Niigata, $M_W 6.2$), as well as the 2011 Tohoku earthquake ($M_W 9.0$) in the four regions of the other earthquakes. The time series of ambient noise used for the different earthquakes spanned from at least half a year before the respective earthquake until three months after the Tohoku earthquake.

Cross-correlations and single-station cross-correlations of several years of ambient seismic noise, which was recorded mainly by Hi-net sensors in the surrounding areas of the respective earthquakes, are calculated in different frequency ranges between 0.125 and 4.0 Hz. Between 10 and 20 seismometers were used in the different areas. The cross-correlations are calculated for all possible station pairs. Using a simple tomography algorithm, the resulting velocity variations can be reprojected on the actual station locations. The cross-correlation and single-station cross-correlation techniques give compatible results, the former giving more reliable results for frequencies below 0.5 Hz, the latter for higher frequencies.

Our analysis yields significant coseismic velocity drops for all analyzed earthquakes, which are strongest close to the fault zones and exceed 1 % for some stations. The coseismic velocity drops are larger at higher frequencies and recover on a time scale of several years, but the coseismic velocity drops do not completely recover during our observation time. Velocity drops are also visible in all areas at the time of the Tohoku earthquake. Furthermore, we measured seasonal velocity variations of the order of 0.1 % in all areas which are, at least for frequencies above 0.5 Hz and for the areas in the central to northern part of Japan, consistent for all sensors of an area and correspond to seismic velocity maxima in autumn.