Non-linear and plastic soil response in the greater Tokyo area during the 2011 Tohoku-Oki earthquake

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Strong ground motion from earthquakes can induce dynamic strains large enough for the shallow subsurface to respond non-linearly and cause permanent velocity changes. We investigate the behavior of the near-surface in the greater Tokyo area during the 2011 M_w 9.0 Tohoku-Oki earthquake sequence using continuous records from 234 seismometers of the Metropolitan Seismic Observation network (MeSO-net). This network, which was deployed in shallow 20-m depth boreholes, recorded large strong ground motions during the main event. For each MeSO-net station, we compute the near-surface response using the single-station cross-correlation technique between vertical and horizontal components, every 6 hours for 2.5 months around the main event. Comparing each near-surface response against a pre-event reference, we find shallow (~100 m) seismic velocity drops up to 10% during the mainshock. The amplitude of the coseismic velocity drop increases with increasing ground shaking and decreasing V_{S30}, which is the S-wave velocity in the upper 30-m of the ground. Furthermore, the waveforms experience a loss of coherence that recovers exponentially over a time. While most of the velocity changes recover within a few days, we also find permanent changes at stations that experienced liquefaction and the strongest ground motions. The ambient seismic field captures the coseismic velocity changes in the shallow structure and the following healing process, and can be used to detect permanent damage.

Keywords: Ambient seismic field, Tohoku-Oki earthquake, Earth's response, Seismic interferometry, Strong ground motion

