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Isotropic and anisotropic changes in S-wave velocity in shallow subsurface associated with the 2016 Kumamoto earthquake sequence, Japan

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We detect isotropic and anisotropic S-wave velocity changes and their long-term recovery near the source area of the 2016 Mw7.0 Kumamoto earthquake, Japan. We apply the stretching technique to deconvolved waveforms of 8 KiK-net vertical seismogram pairs that are installed near the source area. By rotating EW and NS components every 10 degree, we search both isotropic and anisotropic S-wave velocity changes in the depth from 0 to 300 m. The average S-wave velocity (the isotropic component of S-wave velocity) decreases by 1 % to 6 % within 1 day after the mainshock. This velocity reduction strongly correlates with the horizontal maximum dynamic shear strain (MDS) excited by the mainshock. The Anisotropy Coefficient (AC: the amplitude of azimuthal perturbation of the S-wave velocity) increases by 0.2 % to 0.7 % within 1 day after the mainshock except for 1 station. The change of the polarization direction distributes within 10 degree for most of the stations. The increase of the AC has a weak negative correlation with MDS. Both of the isotropic and the anisotropic velocity changes recover as time lapses, while the recovery does not complete within 1 year for most of the 8 stations. We hypothesize that both of the reduction of the average S-wave velocity and the increase of the AC are induced by growth of cracks. Applying a stronger dynamic shear strain would induce growth of larger number of cracks and reduce average S-wave velocity. To increase the AC, on the other hand, the cracks oriented to the fast Vs direction must grow selectively: if all the cracks oriented to arbitrary directions grow by the same degree, the AC may not change. According to the theory of fracture mechanics, the stress intensity factor K near the tip of the crack is proportional to the applied stress and to squared root of the crack length. This indicates that the threshold stress necessary to grow the crack is weaker for the longer cracks. Consequently, if the relatively longer cracks are oriented along the fast Vs direction and relatively shorter cracks are oriented randomly, only the longer cracks should grow selectively under the certain range of external stress, which may increases the AC. If the ground motion is considerably strong, not only the longer cracks but also the shorter cracks should grow, and consequently the AC may not change significantly. This could be the reason why a weak negative correlation between the increase of the AC and the MDS is observed.