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Changes of acoustic transmittivity of a natural fault caused by earthquake rupture

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A number of studies have revealed that seismic properties of crust are changed by the occurrence of large earthquakes (e.g., Li et al., 2007). Most of these studies, however, focus on the changes of travel time. In contrast, some experimental studies find fairly large changes of the amplitude of the transmitted wave due to the changes of physical state of the slip interface (e.g., Pyrak-Nolte et al., 1990; Nagata et al., 2008). In this study, we investigate the amplitude of the seismic waves that have passed through a fault plane before and after the occurrence of a large earthquake on the plane.

We use the waveform data obtained by the temporary seismic observation following the 2004 Mid-Niigata Prefecture Earthquake (e.g., Sakai et al., 2005; Kato et al., 2005). Kato et al. (2005) relocated 1055 aftershocks which occurred from at 18:00 on October 24 to 24:00 on November 25. In this study, we look for changes of the transmittivity of the fault plane caused by a Mw5.6 earthquake on November 8 (target event).

We define clusters of events; each cluster has at least 2 events before and after the target event in a small cell of 2 x 2 x 2 km^3, where we assume that ray path is the same for all the events in each combination of station and cluster. As detailed below, we estimate the transfer function before and after the target event, respectively. We assume that the transfer function does not change within the period before and after the target event. First, we take the spectral ratio between the seismograms for different events in the cluster captured at the same station. By fitting the spectral ratio with a ratio of two omega square spectrum models with different corner frequencies, we obtain the source spectrum for each of the two events. Now, by dividing the observed spectrum by the estimated source spectrum, we obtain the transfer functions for the combination of the station and event cluster. These transfer functions include path effects, site effects and the possible effect of physical state of the rupture plane. We compare these transfer functions before and after the occurrence of the target event. For easy comparison, we use the amplitude of transfer function averaged over 10-30 Hz. We define the ratio of this quantity before and after the target event for each ray path and call it ' change index '.

The change index shows fairly large scattering. Then we group the ray paths by the distance from the target event and take the geometrical average. For ray paths that have passed the extension of the target event's rupture plane within about 10km from the hypocenter, the reduction of the transfer function was more pronounced as the crosspoint is closer to the hypocenter. In particular, the reduction for the group of ray paths closest to the hypocenter of the target event exceeded the data scattering. Thus, we believe that we could detect the change of physical state on this fault plane.