Nonlinear Attenuation Caused by the Wave Interaction in the Near Surface

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Strong seismic waves produced dynamic stresses that bring the shallow subsurface into nonlinear frictional failure. Therefore, when the dynamic stress of one type of waves is strong enough to reach the frictional failure, the structure cannot hold other types of waves, and hence these waves have to be attenuated. Physically, the anelastic strain rate increases with increasing dynamics stress, and the dynamic stress is proportional to the difference between total strain and anelastic strain. To the first order with frictional rheology, the effective friction bounds the resolved horizontal acceleration. This hypothesis can be tested at single-station seismograms. We select five earthquakes as examples for examining the effect of the nonlinear attenuation: 1992 Mw 7.3 Landers earthquake, 2008 Mw 6.9 Iwate-Miyagi earthquake, 2011 Mw 9.0 Tohoku earthquake, 2015 Mw 8.3 Coquimbo Chilean earthquake, and 2016 Mw 7.0 Kumamoto earthquake. The strong Rayleigh waves generated by the Tohoku earthquake brought rock beneath MYGH05 station into frictional failure, and the high-frequency S waves simultaneously arrived at the station suppressed. We discover the similar wave phenomena occurred at the Coquimbo Chilean earthquake. In the example of the Iwate-Miyagi earthquake, we find that the P and S waves are nonlinearly attenuated. For this example, the boundary of the observed horizontal and vertical acceleration is close to the gravity acceleration since cohesion of near-surface rock is relatively small. During the Kumamoto earthquake sequence, two strong waves hit at a station within 30 hours and modified the condition of the friction.

