Observation and simulation of the regional-distance S-PL wave from the very deep (h=680 km) Mw 7.9 Ogasawara Islands earthquake of 2015 May 30

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Deep earthquakes in the subducting Pacific slab frequently produce anomalously large ground motions over Japan along the east coast of Honshu due to an efficient slab waveguide effect for high-frequency (f >1 Hz) signals caused by multiple forward scattering in heterogeneous and high-Q slab.

A recent observation of the Mw 7.9 earthquake beneath the Ogasawara Islands on 2015 May 30 at 680 km depth, produced an anomalously large shock over Japan with a distinctive pattern of ground motion with significantly stretched shaking intensity contours from the hypocenter to northern Honshu along the Pacific seaboard, demonstrated a typical pattern of the deep Pacific slab events.

However, the observed waveforms of regional distances (D=1000-2000 km) recoded by the F-net broadband, strong motion instruments indicate that the large ground acceleration arises from relatively low-frequency (f < 1 Hz) S-wave pulses and following low-frequency (f < 0.1 Hz) signals with long tails. The arrival of the slab-guided high-frequency signal was very late and weak compared with ordinary slab events. Such an anomalous wavefield may arise due to the very great depth of this event, about 100 km deeper than other seismicity in the vicinity.

Numerical simulation of seismic wave propagation employing the 3-D finite-difference method with a detailed structural model of the Pacific slab subduction zone shows how the deep source affects the regional wavefield. The results of the simulation demonstrate that the S waves radiating from the very deep (h=678 km) source out of the slab travel upwards and impinge on the crust at around 1000 km epicentral distance with similar slowness to P in the crust to produce strong S-to-P conversions at the free surface. The converted P waves are trapped in the crust with multiple Moho and surface reflections interfering to produced a long-period PL wave. Such a PL wave developed from a very deep source can travel substantial distances with successively supply of S wave from depth to the crustal waveguide for distances to 2000 km. Also the incidence of the S waves with the same slowness as the PL wave traveling in the crust makes a shear-coupled PL (S-PL) wavetrain with long-period (T=5-10 s). Later, weak slab-guided S waves from the very deep event are also transferred injected into the crust and continue as an Lg wave traveling in the crustal waveguide.

Though the S-PL wave is often noticed in the teleseismic (D=50-60 deg.) records as a dispersed long-period (T=20-30 s) wavetrains following the S and SS waves, this study demonstrates that the S-PL wave can be also developed in the regional distances (D=10-20 deg.) from very deep sources. However, the visibility of the regional S-PL phases depends strongly on the development of the high-frequency slab-guided waves, which can entirely override the regional seismic wavefield along the slab. The clear observation of the regional S-PL wave from the very deep earthquake beneath Ogasawara Island is because this event occurred out of the main slab.

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