

Multiple orbit surface waves excited by the great Sumatra earthquake and directivity effects of the finite moving source

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The great Sumatra earthquake occurred on December 26, 2004, generated a series of multiple orbit surface waves circumventing the Earth. A broad-band seismic array, F-net, deployed and operated by NIED, Japan, has recorded the clear Rayleigh wave trains which circle around the Earth more than 5 times. The observed multiple orbit Rayleigh waves are the most prominent in a period range between 200 and 300 seconds, which corresponds to an extremum in a group-velocity dispersion curve, producing the Airy phase with conspicuous amplitude. The group speed of the fundamental mode Rayleigh wave at 240 seconds are about 3.6 km/s for PREM, and thus the Rayleigh wave packets circle around the Earth at nearly 3 hours. The clear Rayleigh wave phases up to R11, which travels around the Earth more than 5 times, are clearly observed, and some surface wave disturbances, corresponds to the later arrivals, can be still seen in the later time.

The observed surface waves are compared with synthetic seismograms computed by the summation of the normal modes for PREM working with the Harvard CMT solution. Despite the significantly large rupture area as well as the long rupture duration of the Sumatra event, the normal-mode synthetic waveforms with a point source approximation successfully reproduced the series of long-period multi-orbit surface wave trains observed by the F-net array. This is mainly because that the Japanese islands are located in a nearly perpendicular direction to the fault strike. For the later-arrival surface waves, e.g., after R11, the effects of lateral heterogeneity due to long propagation distances (over 200,000 km) become conspicuous, and thus the synthetic waveforms become less correlated with the observed ones even in the long period range. Such effects of the lateral heterogeneity are also apparent from the results of surface wave ray tracing in laterally heterogeneous dispersion maps for Rayleigh waves.

The multiple orbit surface waves have also been observed in seismic records of global broad-band stations provided by the IRIS DMC. In the global seismic records, the effects of directivity of the finite moving source are clearly observed. According to preliminary analyses of the source processes for the Sumatra event (e.g., Yamanaka, 2004; Yagi, 2004; Chen, 2005), the fault rupture initiated in the south eastern end of the fault area and moved toward the north-western end of the fault. The effects of the moving source are clearly seen as the larger Rayleigh-wave amplitudes radiated northwestward, and smaller amplitudes toward the southeast; e.g. the amplitude of R2 observed in station NWA0 in the southeast of the source is much larger than that of R1; R3 in station AAK in the northwest of the source, is larger than R2. Such effects of the directivity on observed surface waves are useful for rough estimations of fault parameters, i.e., a fault length and a rupture velocity. Further studies on the source mechanisms using the long-period surface wave records will be necessary for revealing the source processes of the gigantic event.