Vector-wave envelopes on the free surface of 2-D random elastic media: Markov approximation and finite difference simulations

Kentaro Emoto[1]; Haruo Sato[1]; Takeshi Nishimura[1]

[1] Geophysics, Science, Tohoku University

Short-period seismograms well reflect scattering effect caused by random inhomogeneities in the solid earth. For P-waves, the apparent duration of observed seismogram is broadened and the amplitude of transverse component is excited with travel distance increasing. In order to explain such characteristics of short-period seismograms, it is useful to treat statistically wave propagation in random media. The Markov approximation is one of powerful stochastic methods for the direct synthesis of vector-wave envelopes in random inhomogeneous media when the wavelength is shorter than the correlation distance. Seismic receivers are usually installed on the free surface. It is necessary to synthesize vector-wave envelopes on the free surface and to evaluate quantitatively the effect of the free surface for more realistic estimation of the velocity fluctuation of the earth.

By using the angular spectrum representation, Emoto et al. (2008) synthesized the vector wave envelopes on the free surface of a 3-D random elastic medium characterized by a Gaussian autocorrelation function (ACF) on the basis of the Markov approximation, where wide-angle scattering and PS conversion are neglected. In the present study, we verify the validity of the Markov approximation by a comparison with finite difference (FD) simulations in 2-D random elastic media.

We numerically solve velocities and stresses by the staggered grid method. The accuracy is the 4-th order in space and the 2nd order in time. The width of the model space is 100 km and the length is 117 km: the medium is homogeneous between z=-17 km and z=0 km, and inhomogeneous between z=0 km and z=100 km. The random inhomogeneous medium is characterized by the Gaussian ACF with a correlation distance of 5 km, an RMS fractional velocity fluctuation of 5 %, average P and S-wave velocities of 6 km/s and 3.46 km/s, respectively. We put a Kupper wavelet (2Hz) as the vertical incident plane P-wavelet at z=-7 km. We place 20 receivers with a 5 km interval on the free surface at z=117 km. We conduct FD simulations of wave propagation for 100 different realizations of random media. For each realization, we take the average of the square of synthesized waveforms and apply a moving average in time with duration 0.25 s. Next we average the resulting mean square (MS) envelopes over the whole realizations. As a result, the maximum MS envelope of the horizontal component is as large as 10 % of that of the vertical component. The peak delay times of the horizontal- and vertical-component are 1.0 s and 0.5 s, respectively.

From the comparison of MS envelopes derived by using the Markov approximation with those of FD simulations, both components are well fitted each other from the onset to the peak. After 2.4 s the Markov envelope becomes a little bit smaller than the FD envelope in the horizontal component. It is due to the contribution of wide-angle scattered waves which are neglected in the Markov approximation. From these results, we conclude that the Markov approximation is accurate from the onset to around the peak; however, it gives a little smaller coda envelope because of the breakdown of the forward scattering approximation.