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Spatio-temporal monitoring seismic wavefield by recovering broadband signal in dense seismograph network

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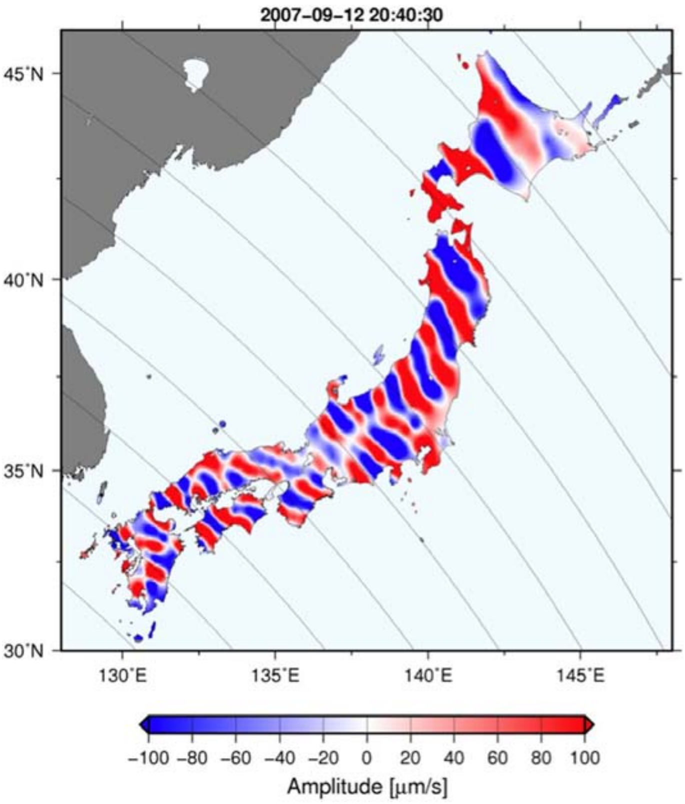

Introduction

High-sensitive seismograph network (Hi-net) with average station separation of 20 km is installed in Japan (Okada, et al., 2004). Despite of their main target of small earthquake observation enriched in high-frequency component, low-S/N and large dynamic range observation system enables us to observe long period seismic waves of far-field earthquakes. Here, we study the capability of the high-sensitive seismographs as a broad-band seismometer. Then, a couple of wave phenomena due to the inhomogeneity of the earth medium observed by dense networks are introduced.

Recovering broadband record from high-sensitive records

The Hi-net have velocity seismograph with natural frequency of 1Hz. Since they do not reproduce true ground motion in low frequency band of <1 Hz, we recover a broad band seismic record by applying simulation filter to the observed seismogram (e.g., Kanamori et al., 1999). This is a second-order, recursive time domain filter; we can recover broadband signal with relatively small computational cost.

We applied the filter to seismic records of the 2007 off Sumatra earthquake of Mw 8.5. Cross-correlating the recovered trace with closest F-net broadband trace shows that we can recover the true ground motion of the period of 2-100 s by the filter. However, the longer limit of the period band depends on the incident amplitude. For the case of the aftershocks of the earthquakes of magnitudes 7.0 and 6.0, the maximum period of reconstruction of broadband signal were 20 s and 10 s, respectively.

Another limitation on recovering broadband record is saturation of the seismometer for near field observation. For the case of west off Fukuoka earthquake of Mw 6.6, we have poor recovery of broadband records for stations with epicenter distance of less than 300 km. For these stations the simulated broadband records do not match the synthetic trace. Since the maximum stroke of the mass movement of the pendulum in velocity seismometer in Hi-net is 0.2 cm (Obara et al., 2005), the maximum incident acceleration to the seismograph is limited to be smaller than 3.95 gal (Shiomi et al., 2005).

Spatial monitoring of seismic wavefield

Since the simulated broadband records with dominant period of >10 s have longer wavelength of surface waves than the average station separation, we can visually monitor the spatial coherence of seismic wavefield.

We studied spatio-temporal pattern of phase in the records of the 2007 off Sumatra earthquake by mapping the phase onto map for the period band of 20-50 s. We observe quite coherent surface waves which propagate along the great circle path. However, at the later elapsed time, an inversely polarized surface waves along the wave front are observed (Figure). An array analysis region by using 120 stations in mid Japan region to clarify the constituents of the inverse polarization from their arrival directions. We found that they consists of two different wave packets having slightly different arrival directions each other, probably due to scattering at the distant place from Japan. Due to interference of two signals, we observed such an inverse polarization. This effect is conceptually same with the Moire effect in optics (Takasaki, 1970).

Besides, for 2009 New Zealand earthquake of Mw 7.2, an existence of a clear scattered waves after the incidence of P wave in Japan at same period band is found by spatial monitoring of the seismic wavefield (Maeda et al., 2009). From array analysis and comparison with the numerical simulation, these scattered waves are originated from the triple junction off the SE Boso peninsula. A shape of the Pacific slabs, bathymetry, and low-velocity of thick sediment on the junction are the possible cause of these scattered waves.

As shown in these two examples, investigation of spatial coherence seismic phase enables us to directly monitor the effect of topography, and inhomogeneity on the propagation seismic waves.

Keywords: seismic wave propagation, seismic wave scattering, broadband seismogram