A seismic wavefield estimation in a dense seismograph network: An optimization for the MeSO-net

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MeSO-net (Metropolitan Seismic Observation network) is a dense seismograph network deployed in and around Tokyo, Japan [Kasahara et al., 2009; Sakai and Hirata, 2009]. Station separation of the MeSO-net is about 5 km on average and ~2 km at the densest area. Recently, some reconstructing method of seismic wavefield in such dense seismograph networks have been developed [e.g., Langston, 2007; Kano et al., 2017]. Kano et al. [2017] proposed a wavefield imaging method based on the data assimilation: they demonstrated the reconstructions of wavefield up to ~1 Hz using the MeSO-net. Their method can simultaneously determine layered structures and location of the hypocenter. Seismic wave gradiometry (SWG) method is also well known as another method for estimating 2D seismic wavefield. The SWG method has low computational cost and can apply to observations without assumptions of hypocenter and structural heterogeneity. Therefore, the SWG method will be useful for monitoring wavefield and investigating ground motions without source data as prior information.
We adopt the SWG method developed by Maeda et al. [2016] to estimate seismic wavefield within the MeSO-net. In this method, amplitude and its spatial gradients of seismic wave at grid points are estimated from observed amplitude at surrounding stations. Interpolation coefficients used for the estimation are determined by the weighted least squares technique and are only depended on a grid-station distance.
In order to optimize the interpolation coefficient, we perform the analysis based on numerical modeling. The finite difference modeling, the OpenSWPC [Maeda et al., 2017], is used to simulate seismic waves at any grid points and sites of which locations correspond to the MeSO-net stations. For the simulated waveforms, we adopt bandpass filter of 0.1-0.2 Hz which is lower than the upper-limit frequency of our numerical modeling, ~0.25 Hz. Then, we synthesize waveform at a grid point from simulated ones at surrounding sites by the SWG method. As the weighting function imposing to the least square, we assume the 2D Gaussian form with respecting to the grid-station distance. The 2D Gaussian weight is characterized by the lengths in two orthogonal axes, long and short arms, and a rotation angle of the short axis in the clockwise direction from the north. The ” optimization” in this study is to find the three parameters which maximize the three-components cross-correlation coefficient between the SWG-synthesize and the simulated waveforms at the grid point. We investigate the parameters by the grid search technique.
We carry out the numerical simulations for hypocenters of 12 directions with 30 degree interval. The hypocenters are located at a depth of 10 km and a distance of 150 km from the center of the MeSO-net. In this case, the determined Gaussian weight realize the highest reproducibility of the seismic wavefield for wave incidence from an arbitrary direction. The obtained Gaussian weights mark small and isotropic shapes near the central area of the MeSO-net, whereas they mark large and elliptical shapes around edges of the network. These shapes of the optimum weight would represent the configuration of the MeSO-net stations and demonstrate that the high-reproducible area of seismic waveform is expanded. Moreover, we confirmed that the accuracy of the seismic wavefield estimation can improve when selecting the interpolation coefficients coinciding with the incoming direction of the seismic waves.

Keywords: Seismic wavefield, Seismic wave gradiometry, MeSO-net

