Adjoint tomography and its application to the seismic wave-speed structure beneath Japanese Islands

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Powerful supercomputers enable us to simulate a seismic wavefield using three-dimensional (3D) structure and seismic waveform inversion based on wave theory has become feasible recently to clarify the realistic Earth structure. Adjoint tomography is a method of waveform inversion using the gradient of the misfit function obtained by interaction between a forward and an adjoint wavefield. Wave-speed model is updated by a gradient method, such as the steepest descent method, until the misfits between observed and theoretical waveforms become small. Adjoint tomography has applied to the Californian region (Tape et al. 2009), the Australian region (Fichtner et al. 2009), Europe (Zhu et al. 2013), East Asia (Chen et al. 2015), and other regions. In terms of the 3D structure beneath Japanese Islands, we have the results of the seismic tomography based on ray theory, or layered model by the NIED J-SHIS to predict strong motions. We are working on construction of the realistic wave-speed model beneath Japanese Islands by using adjoint tomography to reproduce observed seismograms and to predict strong motions for future earthquakes. We have obtained the model of the 3D structure beneath the Kanto region, Japan. We picked up the waveforms with a high S/N ratios from the broadband seismograms observed by NIED F-net. The earthquakes were selected between 4.5 and 5.5 for moment magnitude from the F-net earthquake catalog. Almost events occurred at the upper boundary of the subducted Pacific and Philippine Sea plates, and some events occurred in the upper crust of the overriding plate. We used the travel-time tomography result (Matsubara and Obara 2011) as an initial model with considering no ocean, no attenuation structure in the forward and adjoint simulations for 130 sec duration. The minimum period was 2.6 sec for the initial model. We used the spectral element method to calculate forward and adjoint wavefields (e.g. Peter et al. 2011). Large computing was conducted on the Riken’s K computer; it takes approximately 4,000 node hours for each iteration. The inversion involved 3 iterations for the period range 5-20 sec after 4 iterations for the period range 10-20 sec. The new wave-speed model shows the low wave-speed area corresponding to the Kanto basin in the shallower part, and the low wave-speed zone associated with the subducting Philippine Sea plate at around the depth of 35 km. The new wave-speed for the shear wave includes local changes of 10 % with respect to the initial model. These results may be affected by initial structure and source model, number of stations, and the difference between ray theory and wave theory. We are planning to use not only land observations but also ocean-bottom observations to construct the reference structure beneath Japanese Islands.
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