Simulation of long-period ground motions for the 2011 Tohoku earthquake (Mw9.0) using large-scale parallel computing

*Kentaro Kasamatsu[1], Kenichi Kato[1]

1.Kobori Research Complex INC.

In the 2011 off the Pacific coast of Tohoku Earthquake (Mw9.0), long-period earthquake ground motions were recorded all over Japan including KiK-net Konohana in Osaka. It is important to clarify the reproducibility and the propagation characteristics of long-period ground motions to improve the S-wave velocity model of deep sedimentary layers and predict ground motions of the large earthquake occur in Nankai troughs. To simulate the earthquake ground motion for all over Japan, we developed a parallel computing program using 3D finite difference method based on domain decomposition. We simulated the earthquake ground motions of the March 11 main shock using the developed program, and examined the reproducibility of earthquake ground motions at periods from 2 to 10s in the Metropolitan area.

For effective parallel calculations of earthquake ground motions using 3D finite difference method, we deployed 3 computers equipped with 2 CPUs made by Intel (E5-2690v3, 12 cores) and memory cards of 192Gbyte in each node. We connected 3 nodes using the InfiniBand of 40Gbps transmission speed and constructed the calculation environment that enabled 72 parallel computing with inter-node communication using MPI. The parallel calculation was based on the 3D domain decomposition to utilize a large number of cores which were equipped in each node effectively, and used MPI in intra-node communication as well. We checked the parallel efficiency by simple examples. Scalability was approximately 15 times in case of 32 processes. When we used another PC cluster (16 nodes, 2 CPUs, 8 cores), scalability was approximately 60 times in case of 64 processes. Overall execution time was shortened approximately as expected.

We simulated long-period earthquake ground motions of the March 11 main shock using pseudo point-source model (Nozu, 2012) for the purpose of examining the applicability of point-source at periods from 2 to 10s. Source time functions were triangle type and the number of time window was 1. Dip angle was 90 degrees for all point-sources. Rise times were set based on the corner frequencies of Nozu (2012). We used S-wave velocity model of deep sedimentary layers of Headquarters for Earthquake Research Promotion (2012). The calculational domain was East-West 300km, North-South 600km, and vertical 100km. We digitized the model with grid of 0.2km for horizontal and 0.1km to 1.0km for vertical. Total number of grids was approximately 1,600 million, and duration time was set to 300s with the time interval of 0.005s. We finished calculation of 60001 steps in less than two days. When we compared observed and simulated earthquake ground motions at periods from 2 to 10s, shapes of the spectra were well reproduced although amplitudes at periods from 6 to 10s were underestimated in the metropolitan area likely due to the point-source modeling. Surface waves (T=6-10s) generated around south of Ibaraki Prefecture propagated toward the metropolitan area were almost reproduced except for amplitude. Continuously, we are going to adjust the source model of the March 11 main shock, and investigate the propagation characteristics of long-period ground motions. In addition, we will implement the developed program in the Earth Simulator.

Keywords: parallel computing, finite difference method, the 2011 off the Pacific coast of Tohoku Earthquake, long-period ground motion

