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GPU 計算による 2011 年東北地方太平洋沖地震の地震動大規模シミュレーション GPU-accelerated large-scale simulation of seismic wave propagation from the 2011 Tohoku-Oki earthquake

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The Tohoku-Oki earthquake on March 11, 2011 (MJMA 9.0) generated strong shaking reaching the maximum intensity (seven) on the JMA's scale and caused devastating tsunamis with run-up heights exceeding 30 m. Such mega-thrust earthquake was not expected to occur along the plate interface off the northeastern Japan. Thus it is very important to study this event for understanding the geophysical condition of the generation of mega-thrust earthquake, the characteristics of the induced strong ground motions, and the mechanism of the excitation of the large tsunamis.

The ground motion records of this event are quite important data for the quantitative studies on the earthquake source and the induced damages. However, modeling of the ground motions is not a simple task because of the strong lateral heterogeneity in and around the Japan trench: all of steeply varying topography, oceanic water layer, thick sediments, crust with varying thickness and subducting oceanic plate can affect the seismic waves radiated from suboceanic earthquakes [1,2]. Thus the structural model is an important factor in the study of waveform modeling.

The modeling of the ground motion induced by this event is a computational challenge: large memory size and fast computing devices are required because the huge fault size of the earthquake (about 500 km x 200 km) imposes a very large domain size for the simulation. For example, for a finite-difference domain of 960 km long, 480 km wide and 240 km deep and for a grid spacing of 0.15 km, a quite large grid size of 6400 x 200 x 1600 or 33 billion of grid points are necessary.

Therefore, we need to develop numerical methods that can precisely incorporate the effects of the heterogeneous structure including the land-ocean topography. Further, we need to confirm the feasibility of the methods in the case of large-scale problem: the computation must be done within a tolerable time.

Thus, in this paper we use a 3-D finite-difference time domain (FDTD) method [3,4]. In the method we implement the schemes to incorporate the land and ocean-bottom topography, oceanic layer and other lateral heterogeneity. In order to simulate the wave propagation with a large grid size, we adopt the GPU (graphics processing unit) computing to our finite-difference program. We use the TSUBAME supercomputer in Tokyo Institute of Technology which has a peak performance of 2.4 peta-flops. Currently, we have succeeded to simulate the wavefield from the whole fault of 2011 Tohoku-Oki earthquake by using 1000 GPUs of the TSUBAME supercomputer with 33 billion of grid points and a grid spacing of 0.15 km. We present the results of the simulation of the wave propagation based on a preliminary source model of the 2011 Tohoku-Oki earthquake.

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[4] Okamoto et al., in GPU Solutions to Multi-scale Problems in Science and Engineering, Yuen, D. et al. (Eds.), 250 p., Springer, due February 29, 2012. (ISBN 978-3-642-16404-0)

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