Global Elastic Response Simulation

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We compute theoretical seismic waves for realistic three dimensional (3-D) Earth models and recent large earthquake using Spectral-Element Method (SEM) and compare them with the observed seismic waves. We calculate synthetic seismic waveform for 2011 Tohoku earthquake (Mw9.0) using fully 3-D Earth model and compare with observation. Comparison is done for synthetic seismic waveforms with precision 5 seconds and 1 second. Our results indicate that the earthquake source mechanism of this event can be well modeled by our finite rupture model with 1 second precision

Keywords: Synthetic seismograms, 3-D velocity structure of the Earth, Spectral Element Method

1. Synthetic seismograms for 2011 Tohoku earthquake

We have calculated theoretical seismograms for a realistic Earth model using the SEM [1] and finite rupture model. The earthquake which we have selected is the magnitude 9.0 March 11, 2011 Tohoku earthquake. Because of the size and proximity to coastal areas of this earthquake, it caused serious damage to coastal northern Japan, especially due to an extraordinary large tsunami. There are many studies of the rupture mechanism of this event, using various types of observation, such as seismic waves, crustal movement and tsunami heights (e.g., Lees et al., 2011) [2]. Here we use the earthquake rupture model of Tsuboi and Nakamura (2013) [3], which used teleseismic seismic waves to establish a seismic rupture model, to compute theoretical seismograms and compare them with observed seismograms. This earthquake rupture model represents this event with 597 subevents along a 500 km earthquake fault. It may be better to use geodetic measurements, such as crustal deformation to grasp images of the entire source rupture mechanism. However, since we are interested in the very beginning of the earthquake rupture initiation process, it might be better to use a source rupture model determined solely by seismic wave observations. Also, it is now generally agreed that the fault responsible for this earthquake is almost 500 km long and the maximum slip along the fault is about 50 m. Our model agrees with other studies with regards to these points. Figure 1 shows a comparison of theoretical seismograms with the observation for seismographic stations in Inchon, South Korea (epicentral distance 13.9 degree), Matsushiro, Japan (epicentral distance 5.6 degree), Taipei, Taiwan (epicentral distance 23.9 degree) and Yuzhno-Sakhalinsk, Russia (epicentral distance 7.5 degree). Duration of these theoretical seismograms is 7 minutes. Figure 1 shows the first 100 seconds of rupture, because the observed seismograms saturate due to the large size of this earthquake at some station. We compared one second precision theoretical seismograms, computed by the K computer in Kobe, Japan, with lower precision theoretical seismograms and confirmed that the agreement between the observed and theoretical seismograms has improved. We have computed theoretical seismograms with 5 seconds precision using the Earth Simulator 2. We used 1014 CPUs (127 nodes) of the Earth Simulator 2 and computed theoretical seismograms with a precision of about 5 seconds. Figure 1 shows agreement of the theoretical seismograms with the observed seismograms is greatly improved for 1.2 seconds precision simulations compared with 5 seconds simulations, especially for the very early part of the rupture. This should help us to understand the rupture initiation process of this extraordinary large earthquake.

2. Implications for future directions

When we are able to calculate at least 10 minutes duration theoretical seismograms, we would like to compare the March 9, 2011, foreshock with the March 11, 2011, main shock. It is well known that the 2011 Tohoku earthquake was preceded by a magnitude 7.3 foreshock 2 days before the main shock. It is difficult to answer the question if we could tell that there should be magnitude 9 earthquake in the future when we had magnitude 7.3 foreshock on March 9, 2011. It also is difficult to answer the question why the March 9 earthquake ended with a magnitude 7.3 whereas the March 11 earthquake became a magnitude 9.0. To address these questions it may be helpful if we get theoretical seismograms with 1 seconds precision at epicentral

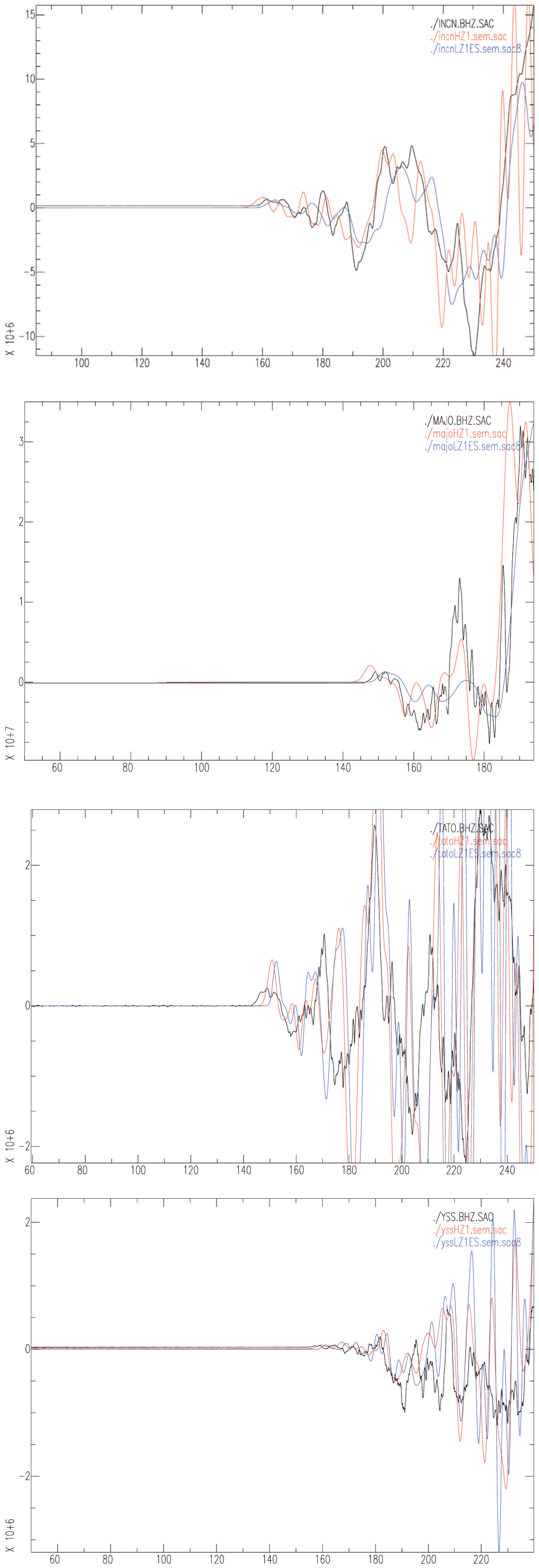

Fig. 1 Comparison of theoretical seismograms with 1.2 seconds precision (red traces) and 5 seconds precision (blue traces) with observations (black traces) for seismographic stations in Inchon, South Korea (epicentral distance 13.9 degree), Matsushiro, Japan (epicentral distance 5.6 degree), Taipei, Taiwan (epicentral distance 23.9 degree) and Yuzhno-Sakhalinsk, Russia (epicentral distance 7.5 degree), from top to bottom. Vertical component broadband velocity seismograms are shown. Horizontal axis is time in seconds and vertical axis is digital count. About two minutes duration of data are shown.

distances around 30-40 degrees, because the P-wave observed at these distances is less affected by very heterogeneous shallow crustal structure. We believe that theoretical seismograms with 1 seconds precision should help us to study the earthquake generation process quantitatively.

References

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全地球弾性応答シミュレーション

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スペクトル要素法により現実的な 3 次元地球モデルに対する理論地震波形記録を 2011 年東北地方太平洋沖地震（Mw9.0）に対して計算した。計算は地球シミュレータの 127 ノードを用いて、周期約 5 秒の精度で行った。理論地震波形は、有限断層震源過程モデルに対して計算し、周期 1 秒の精度で京コンピュータを用いて計算した結果と共に、観測と比較した。その結果、この地震の震源過程モデルは周期 1 秒の短周期でも観測波形を良く説明出来ることが分かった。

キーワード : 理論地震波形記録, 3 次元地球内部構造, スペクトル要素法