

3-D Viscoelastic FEM Modeling of Kinematic Earthquake Cycle in Northeast Japan

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Introduction

It is well known that large thrust-type earthquakes have occurred along the plate boundary around the Japan Islands with a recurrence interval of 100 to 150 years. For long-term prediction of the earthquakes, it is necessary to construct an adequate earthquake cycle model along with a continuous observation of seismic activity, crustal deformation and investigation of the historical documents. Now, we developed GeoFEM module under the collaborative work between Nagoya University and RIST. In this study, we simulate an earthquake cycle and its associated geophysical phenomena in northeast Japan using GeoFEM based on the kinematic model to evaluate the crustal deformations and stress changes in inland region.

Tectonics in Northeast Japan

In northeast Japan, the Pacific plate is subducting beneath the North American (or Okhotsk) plate accompanied by great interplate earthquakes along the Japan and Kurile Trench. Various types of large interplate earthquakes have occurred along the southern region of the Japan Trench. For examples, the 1933 Sanriku Oki earthquake whose mechanism is normal fault (Kanamori, 1971) and the 1994 Sanriku Haruka Oki earthquake, which is accompanied by the large after-slip (Heki et al., 1997). It is considered that the seismic coupling in this region is about 30 to 70 % (Kawasaki et al., 1998, Le Pichon et al., 1998, Ito et al., 2000). In comparison with Japan Trench, huge interplate earthquake ($M > 8$) have occurred along the Kurile trench with a recurrence interval of about 110 years. In this region, interplate earthquakes have occurred continuously filling up the non-rupture region. On the other hand, Eurasian (or Amurian) plate is subducting beneath the North American (or Okhotsk) plate with a subducting rate less than 1 cm/yr roughly in eastward at the eastern margin of the Japan Sea. Recently, large earthquakes have occurred around this region, for example the 1993 Hokkaido Nansei Oki earthquake and the 1983 Nihonkai Chubu earthquake.

Problems on an Earthquake Cycle Modeling in Northeast Japan

In order to construct an earthquake cycle model of northeast Japan, we investigate the following problems.

1) Estimation of the backslip distribution

During an interseismic period, strain accumulates due to drag of the subducting Pacific plate. Accumulated strain is released by the large interplate earthquakes. Hence, to understand the generation of interplate earthquake, it is important to know the spatio-temporal variation of interplate coupling.

II) A series of earthquakes along the Kurile Trench

Since 1952 Tokachi Oki earthquake, huge interplate earthquakes have occurred continuously along the Kurile Trench in different segments for a few decades (Figure 1). In order to construct an earthquake cycle, it is important to know the interaction of the interplate earthquakes, which occurred in different segments. To examine the interaction of the earthquakes, we simulate this series of earthquakes, and evaluate the stress changes and crustal deformations.

III) A seismic gap in the eastern margin of the Japan Sea

In the eastern margin of the Japan Sea, large earthquakes have occurred in each segment (Figure 1). We investigate the stress changes caused by the subduction and interplate earthquake, which occurred in the Japan Trench, and evaluate the relationship with the occurrence of the earthquake in the eastern end of the Japan Sea.

IV) Modeling of the earthquakes for the past 100 years

Finally, we simulate earthquake actually occurred in northeast Japan for the past 100 years, and evaluate the stress changes and crustal deformations in inland regions and plate boundary, comparing with the present GPS data.

Preliminary Modeling

We will construct a detailed structure model (about a few millions DOF), and execute the large-scale parallel computation using Fujitsu VPP 5000 at Computation Center of the Nagoya University. However, since our study and GeoFEM are under construction, we only show the results of the preliminary computation using 1 PE. We construct 3-D viscoelastic FEM model, which has about 40 thousands DOF in northeast Japan (Figure 2). Our model consists of the elastic crust and plate, and the viscoelastic upper mantle wedge with the Maxwell time of 5 years. The whole model space is 1150*1350*200 km. Before starting the simulation of an earthquake cycle, we estimate a backslip rate during the interseismic period based on the Backslip Model proposed by Savage (1983) using forward modeling. In this presentation, a variety of computed spatio-temporal patterns on displacement field will be demonstrated in detail, in comparison with the observed ones.

References

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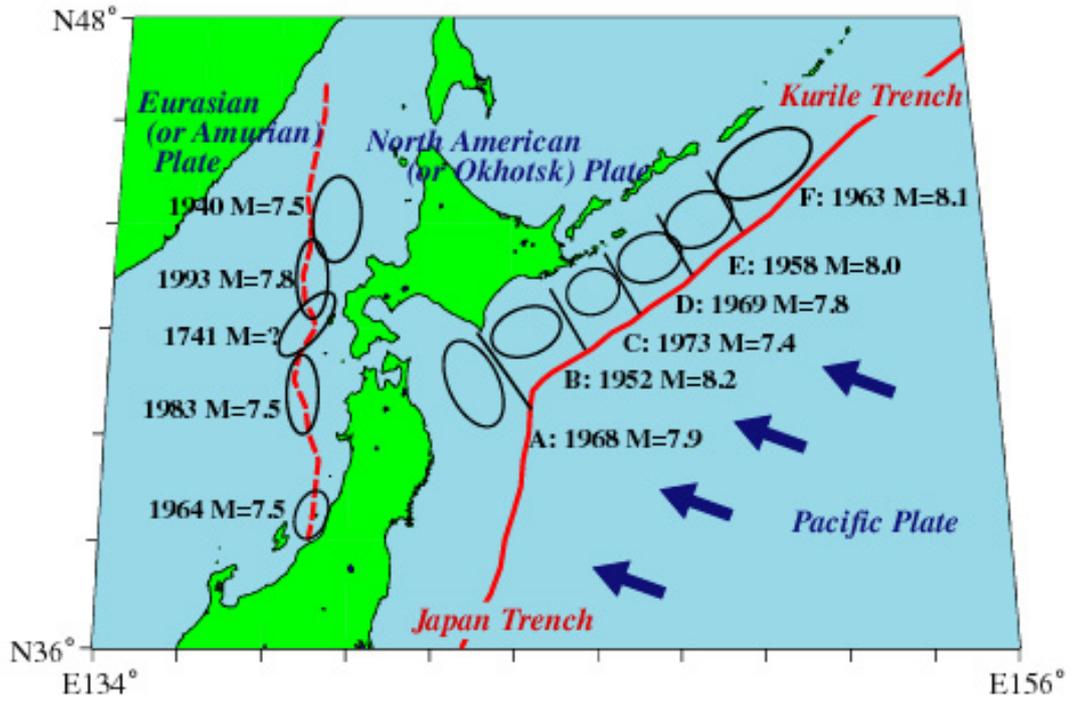


Figure 1: Distribution of the source region of large earthquakes along the Kurile Trench, the Japan Trench and the eastern margin of the Japan Sea.

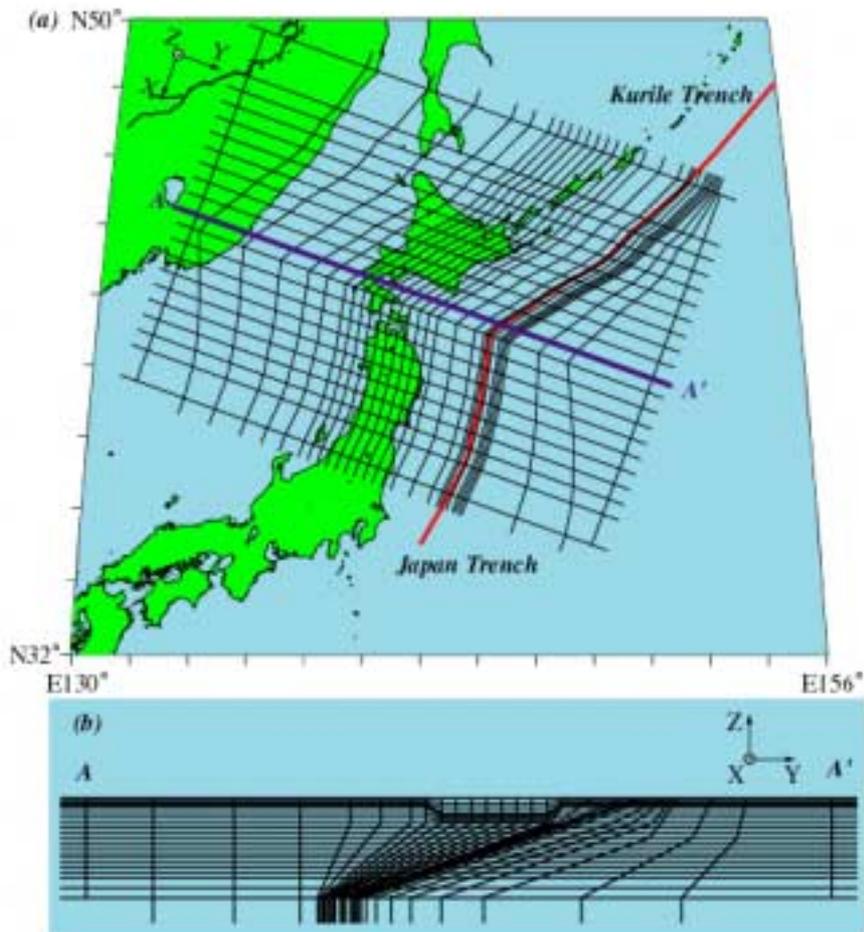


Figure 2: FEM meshes used in this study. (a) FEM mesh on the horizontal view in northeast Japan. (b) FEM mesh in the vertical section along the line A-A' in Fig. 2(a).