GeoFEM kinematic earthquake cycle modeling in the Japanese Islands

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Abstract

We review GeoFEM kinematic earthquake cycle modeling in the Japan Islands. Before performing a full FEM modeling of earthquake cycle based on a laboratory derived friction law, we examine the viscoelastic response in a 3-D heterogeneous medium to the subduction of slabs and interplate earthquakes mainly based on a kinematic framework (Savage[1]), employing a parallel FEM code, GeoFEM, which has been developed for large-scale simulation in solid-earth problems and will run in the "Earth Simulator". We construct two 3-D heterogeneous viscoelastic FEM models with the elastic crust and subducting slabs and the viscoelastic mantle wedge in northeast and southwest Japan, respectively. Considering the coseismic and viscoelastic response of large interplate earthquakes which actually occurred in the past, we simulate long-term and recent crustal deformation due to the subducting Pacific and Philippine Sea plates and compare with the observed ones.

Introduction

We are developing a FEM(Finite Element Method)-based software to simulate the whole earthquake cycle of large interplate earthquakes in a realistic 3-D heterogeneous viscoelastic medium at a subduction zone. The module includes a laboratory derived friction law (Ruina[2]) and is a module of GeoFEM which is developed under the project 'Earth Simulator' (Iizuka et al.[3]). This software is still under development, especially in the implementation of friction law on plate interfaces or faults using a master-slave method. Accordingly, we review GeoFEM kinematic earthquake cycle modeling in the Japan Islands, which is supplementary to the review of earthquake cycle simulation by Kato et al.[4] in this workshop. Before performing a full FEM modeling of earthquake

cycle based on a laboratory derived friction law, we examine the viscoelastic response in a 3-D heterogeneous medium to the subduction of slabs and interplate earthquakes mainly based on a kinematic framework (Savage[1]), employing a parallel FEM code, GeoFEM, which has been developed for large-scale simulation in solid-earth problems and will run in the "Earth Simulator". We construct two 3-D heterogeneous viscoelastic FEM models with the elastic crust and subducting slabs and the viscoelastic mantle wedge in northeast and southwest Japan, respectively (Fig.1). Then we simulate long-term crustal deformation in two regions and compare with the geodetic observations by conventional and GPS instruments.

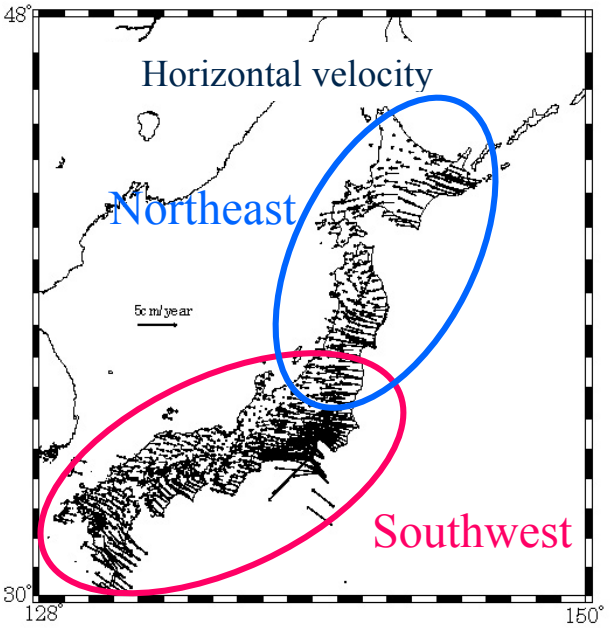

Figure 1. GPS horizontal rate field observed by GEONET, and two modeling regions, northeast and southwest Japan.

Northeast Japan

In the northeast Japan model, we perform a simulation during recent 100 years. We consider the westward subduction of the Pacific plate along the Kuril-Japan trench with a rate of 8cm/yr and the eastward subduction of the Amurian plate along the eastern margin of the Japan Sea with a rate of 1 cm/yr. And we give the slips on the plate interface according to the sizes and the occurrence times for all recoded interplate earthquakes with the magnitudes greater than 7.4. We assume the subducting slabs have full coupling in the locked plate interface down to a depth of 60 km along the Kuril-Japan trench and 30 km in the Japan Sea. Comparing the long-term geodetic observation data with the simulated ones, we found a possible existence of a great slow slip or afterslip event with the size of

Mw=8.4 off the Sanriku region early in the 1900's, which has not been recorded. See the details by Suito et al. [6] in this meeting.

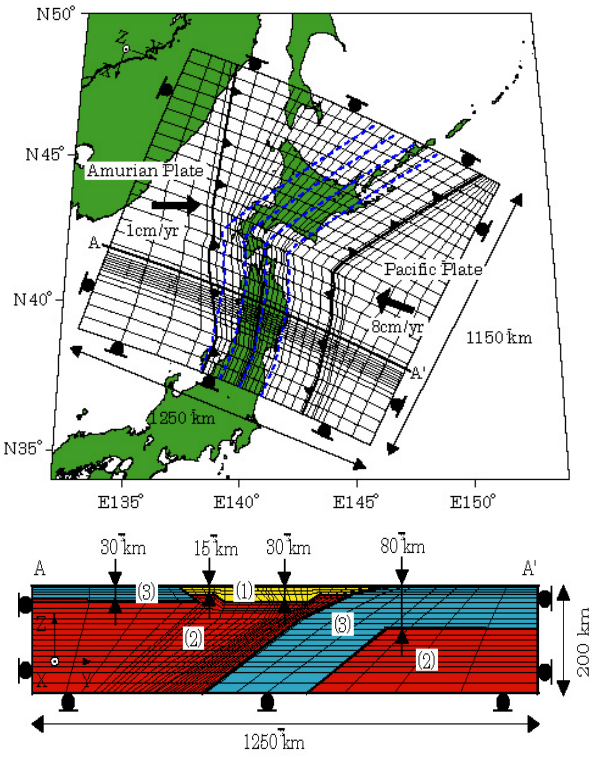

Figure 2. FEM meshes in northeast Japan model: Horizontal (upper) and vertical ones (lower) In the lower figure, crust (1) and plates (3) are elastic, and upper mantle (2) is Maxwell solid medium.

Southwest Japan

In southwest Japan, we consider the westward subduction of the Pacific plate along the Japan trench and the northwestward subduction of the Philippine Sea plate along the Nankai trough with a rate of 4-6 cm/yr and the eastward motion of the Amurian plate. The great interplate earthquakes along the Nankai trough have repeatedly occurred with a recurrence time of 90 – 150 years. We consider the sequence of great interplate earthquakes in recent 300 years. We assume the full coupling in the locked interface down to a depth of 30 km. Then we compare the present crustal deformation with the simulated one and examine the stress perturbations on inland faults. As pointed out by Sagiya et al.[4], there is the complicated crustal deformation in central Japan (Fig.1), where a high strain rate belt is especially striking. Sagiya et al. [5] called this deformation zone as the NKZ (Niigata-Kobe tectonic Zone). This observed field is well explained with our viscoelastic model but not with elastic ones. See the details by Hyodo et al.[7] in this meeting.

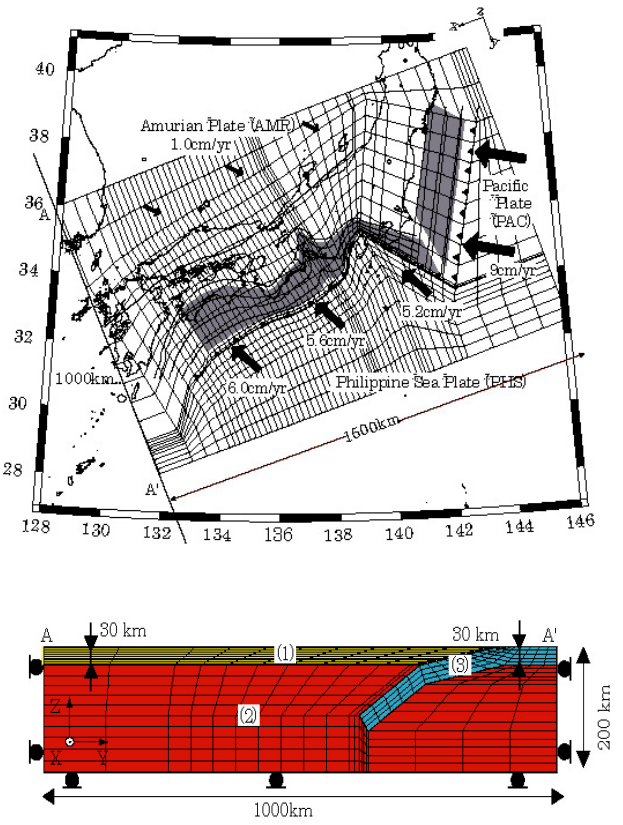

Figure 3. FEM meshes in southwest Japan model: Horizontal (upper) and vertical ones (lower)

Acknowledgments

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