Local Area Earthquake Simulation

Solid earth simulation is performed in three scales; global (core, mantle), regional (crust deformation around Japan), and local (Southwest Japan, Northeast Japan). The history of earthquakes at Northeast and Southwest local area in Japan has been well studied by many seismologists. They forecast a large earthquake in the near future at Southwest Japan. The earthquake generation process (quasi-static earthquake cycle and dynamic rupture) and seismic wave propagation simulation in a three-dimensional heterogeneous medium are performed at the local scale. Local area earthquakes analysis requires complex and large-scale simulation. Simulation of the Northeast and Southwest Japan earthquakes is tried in order to develop a simulation method of the earthquake generation process and to address issues such as earthquakes disasters. A simulation of the generation and cycle of earthquakes requires rigorous nonlinear analysis of the complex fault network. To perform such analyses, contact problems under the rate-state friction-fault constitutive law, which is highly nonlinear (ill-conditioned and stiff), must be solved using a large-scale finite element method (FEM), where parallel computation is essential. In this study, we have developed an effective way to analyze large-scale parallel contact problems using the iterative solver and the augmented Lagrange method (ALM), which is used to improve matrix conditions. Using the explicit integration method, conventional for rate-sate friction law problems, requires a very wide range of time steps (from milliseconds to years) and very large simulation steps. A new implicit integration method has been developed to reduce the number of simulation steps and computation time. In order to simulate a solid earth system on the scale of a local area of Japan, many different models should be parallelized, coupled and integrated on advanced parallel computers. However, the development of such applications is very difficult for non-specialists in computer science. Therefore, the parallel coupler in GeoFEM has been developed to enable solid earth models to be easily parallelized and coupled. Modeling and mesh generation for solid earth structures is important to accurately reproduce the complicated internal structures such as crust, mantle, and fault networks. The Northeast and Southwest Japan area FEM model has been developed using a sophisticated mesh generation method through collaboration with a geophysicist. Techniques for parallel visualizing of 3D unstructured physical fields is highly useful for handling the voluminous results of large-scale FEM simulation. We have also developed parallel cross-section and iso-surface fitting modules for used with the GeoFEM platform.

Using the simulation system incorporating these new methods, at 1st step, simulation of the Northeast Japan area is being performed as 2 million nodes model on ES. As 2nd step, simulation of 1944 Southwest Japan earthquake will be done via large-scale simulation on ES.

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