Integrated Predictive Simulation System for Earthquake and Tsunami Disaster

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1. Outline of the Project

The aim of this research project (2005–2010) is to develop an integrated simulation system for the prediction of earthquake and tsunami disasters using the Earth Simulator, which covers the entire multi-scale processes related to earthquakes, such as tectonic stress accumulation due to relative plate motion, earthquake generation, seismic wave/tsunami propagation, and building oscillation [1]. The computer simulations are combined with a large number of observed data from the nation-wide seismic and GPS networks for realistic prediction. The developed simulation system will make a major contribution toward the reduction of earthquake and tsunami disasters.

In 2005 we introduced facilities for computation, such as PC clusters (2 × 64core Opteron processors) and data servers (48core G5 processors with 15 TB storage and 8core Opteron processors with 20 TB storage), and made fundamental design of the entire system. In 2006–2007, integrating six existent basic models, we develop three coupled simulation sub-systems for earthquake generation, strong ground motion/tsunami propagation, and building oscillation. We also develop a platform and data grid which support coupled simulations and parallel data management. In 2008–2010 we will integrate the three coupled sub-systems into the final unified system, and make simulations for the prediction of earthquakes and tsunami disasters in realistic scenarios.

2. Contents of Research Work

The integrated simulation system to be developed in this projects consists of six basic simulation models (plate motion, crustal stress accumulation, dynamic fault rupture, seismic wave propagation, tsunami wave propagation, and building oscillation), three data analysis programs (geodetic data, seismic activity data, and strong ground motion data), and a platform which supports coupled simulations and parallel data management, as shown in Fig. 1. Prototype models and programs have been already developed and tested on the Earth Simulator for all of the basic simulation models and data analysis programs except tsunami wave propagation.

In the first phase of this project (2005–2007), we develop a simulation model for tsunami generation and propagation. We develop three coupled simulation sub-systems for earthquake generation, strong ground motion/tsunami propagation, and building oscillation. Each of the three coupled simulation sub-systems consists of closely related two or three of the six basic simulation models. We also develop a platform and data grid which support coupled simulations and parallel data management.

In the second phase of the project (2008–2010), we will integrate three coupled sub-systems into the final unified system, and make simulations for the prediction of earthquakes and tsunami disasters in realistic scenarios.

Our project team has the following five research groups:

(1) Matsu'ura Group (Graduate School of Science, The University of Tokyo)
- Simulations for crustal stress accumulation due to plate motion
- Predictive simulations for earthquake generation

(2) Furumura Group (Earthquake Research Institute, The University of Tokyo)
- Simulations for seismic wave propagation in a 3D realistic medium
- Simulations for tsunami generation and propagation

(3) Okuda Group (Research Center for Artifact Engineering, The University of Tokyo)
- Development of a platform for coupled simulations and parallel data management

(4) Ichimura Group (Graduate School of Science and

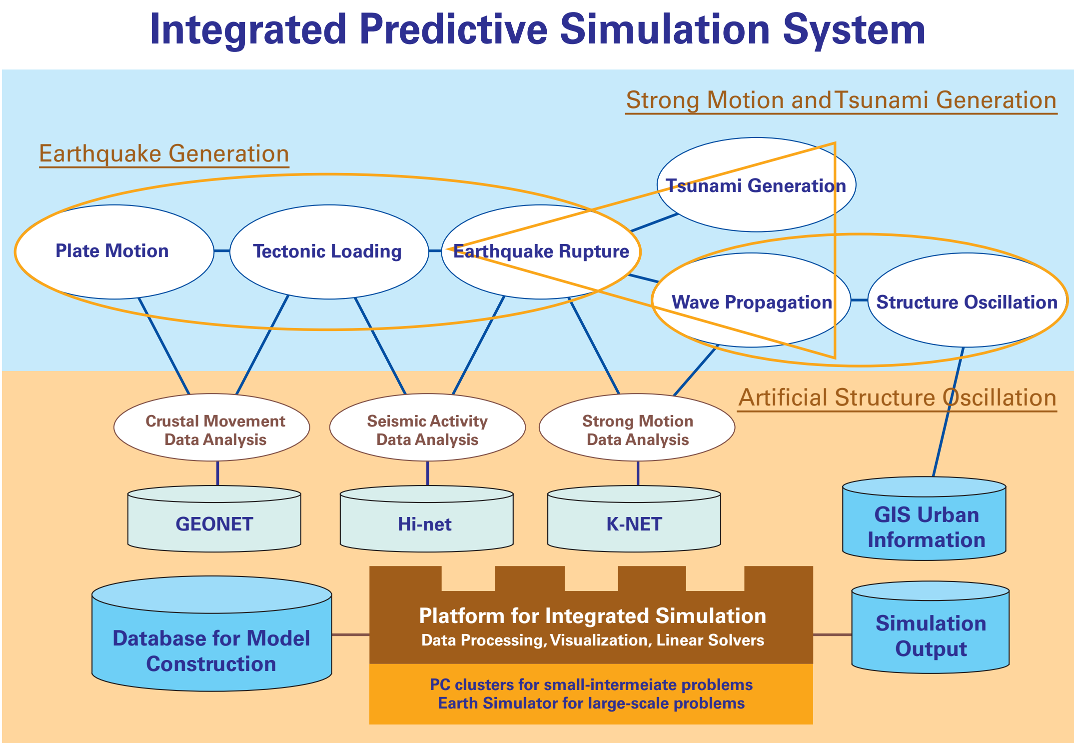

Fig. 1 Overview of Integrated Predictive Simulation System for Earthquake and Tsunami Disaster [1].

Engineering, Tokyo Institute of Technology)
- Coupled simulation of seismic wave propagation and building oscillation

(5) Nagashima Group (Faculty of Science and Engineering, Sophia University)
- Coupled simulation of seismic wave propagation and oil-tank sloshing

(6) Fukuyama Group (Solid Earth Research Division, National Research Institute for Earth Science and Disaster Prevention)
- Coupled simulation of dynamic fault rupture and seismic wave propagation

3. Progress in 2005

Matsu'ura Group and Furumura Group in Tokyo University have installed PC clusters with 64core Opteron processors. A data files server with 48core G5 processors and 15 TB storage has been installed in National Research Institute for Earth Science and Disaster Prevention (Fukuyama Group). Geographical Survey Institute (GSI), collaborating with Matsu'ua Group in Tokyo University, has also installed a data file server with 8core Opteron processors and 20 TB storage. Construction of a grid system that connects the four institutions has been initiated. Each group started preliminary studies and tuning up the basic simulation models shown in Fig. 1.

In Matsu'ura Group, advanced simulation models for crustal deformation and stress accumulation at plate boundaries have been completed for large-scale coupled simulations [2]. A prototype system for inversion analysis of geodetic data in and around Japanese Islands has been developed under collaboration with GSI [3]. The prototype system has been applied to Kanto Region, and the diversity in stress release mode at the North American-Philippine Sea plate interface has been revealed, as shown in Fig. 2.

In Furumura Group, strong ground motion simulations for the 2004 Chuetsu Niigata earthquake and the 2005 off Miyagi prefecture earthquake have been conducted on the Earth Simulator with an accurate subsurface structure model of Japanese Islands and the fault-slip model estimated from seismic waveform inversion, as shown in Fig. 3. The simulation results were compared with observed waveform data in K-NET and KiK-net of NIED to demonstrate the efficiency and validity of the large-scale simulation of seismic wave propagation [4]. Strong ground motion simulation for the 1944 Tonankai earthquake have been also carried out with a realistic model of subsurface structure, and the amplification of seismic waves in Kanto Region has been evaluated [5].

In Okuda Group, the fundamental design of data reservoir for hierarchical analysis, multi-hierarchical visualization modules, library for coupled simulation, and library for parallel iterative solvers, have been conducted [1].

In Ichimura Group, a methodology for constructing a numerical city model based on GIS/CAD data has been developed. Earthquake disaster simulation has been conducted by using a prototype numerical city model. A basic numerical shaking-table test was also conducted to evaluate the oscillation of large-scale complicated structures [6].

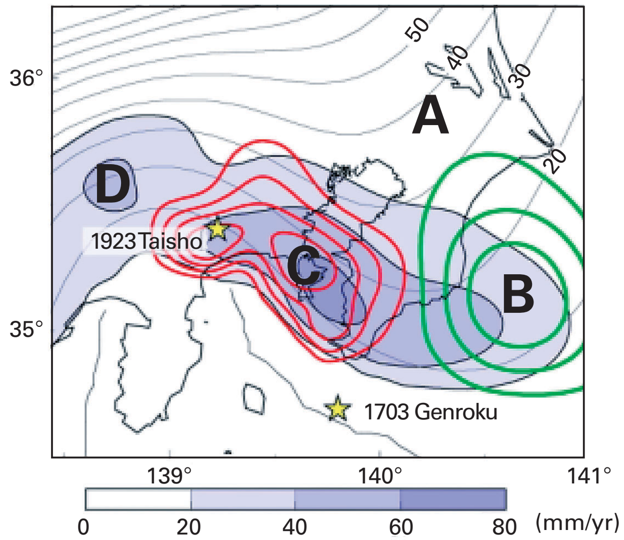

Fig. 2 Partitioning the NAM-PHS plate interface based on difference in stress release mode [3]. A) steady slip without stress accumulation, B) intermittent stress release by slow slip events, C) sudden stress release by large interplate earthquakes, and D) tectonic stress release by inelastic crustal deformation. The blue color-scale contours show the interseismic slip-deficit rates. The red contours at 2 m intervals show the coseismic slip of the 1923 Kanto earthquake. The green contours at 5 mm/yr intervals show the average slow-slip rates estimated from the slip distribution of the 1996 and 2002 east off-Boso events. The stars indicate the epicenters of the 1703 Genroku-Kanto earthquake and the 1923 Taisho-Kanto earthquake.

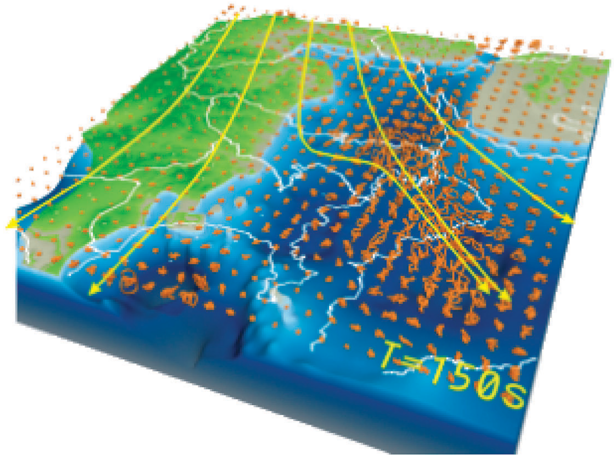

Fig. 3 3D simulation of seismic wave propagation for the 2004 Chuetsu Niigata earthquake using the Earth Simulator [4].

In Nagashima Group, two types of prototype software packages have been developed. One is a structural analysis program based on the finite element method (FEM) for dynamic response of thin-walled structures. Another is a program for potential flow analysis by FEM, which can calculate the dynamic response of liquid with free surface. The validity of each code has been tested for linear problems [1].

In Fukuyama Group, the fundamental design of coupling interfaces for transition processes from tectonic stress accumulation to dynamic rupture propagation with seismic wave radiation has been carried out.

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観測・計算を融合した階層連結地震・津波災害予測システム

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プレート沈み込み帯に位置する我が国の地震・津波災害の軽減に資するために、プレート運動による地殻応力の蓄積を経て大地震が発生し、地震波が構造物を揺らし、津波が海岸部を襲うまでの一連の過程を「地球シミュレータ」上で再現・予測する観測・計算融合の階層連結型高精度シミュレーション・システムを世界に先駆けて開発する。平成17年度は、設備と既存要素モデルの整備並びに全体システムの基本設計を行った。平成18–19年度には、既存要素モデルを結合して、地震発生予測シミュレーション、強震動／津波予測シミュレーション、人工構造物振動予測シミュレーションを実施する。また、これと並行して階層連結プラットフォームを構築する。

平成20–21年度には、これら3つのサブシステムを更に階層連結して全体システムを構築し、実シナリオに即した地震・津波災害予測の統合シミュレーションを試みる。