JST Basic Research Programs

C R E S T

(Core Research for Evolutional Science and Technology)

Annual Report for Research Work in the fiscal year 2005

Research Area :

High Performance Computing for Multi-scale and Multi-physics Phenomena

Research Theme

Integrated Predictive Simulation System for Earthquake and Tsunami Disaster

Name of Research Director, Belonging and Title:

Mitsuhiro MATSU'URA, Graduate School of Science, The University of Tokyo, Professor.

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§1. Outline of Research Work

This is the first integrate simulation system for prediction of earthquake and tsunami disasters using the Earth Simulator, which covers entire multi-scale processes related to earthquakes, such as tectonic stress accumulation due to relative plate motion, earthquake generation by dynamic fault rupture, seismic wave/tsunami propagation, and oscillation of buildings. The simulations are complimented by large number of observational data sets obtained through nation-wide network of seismic instruments and GPS etc. Developed system will make a major contribution toward the reduction of earthquake and tsunami disaster

In FY.2005, we introduced facilities for computation, such as PC clusters (2 x 64core Opteron processors) and data servers (48core G5 processors with 15TB storage, and 8core Opteron processors with 20TB storage), and made fundamental design of the entire system. In FY.2006 and FY.2007, we are going to integrate existing fundamental models, and develop three new coupled simulation codes for earthquake prediction, strong ground motion/tsunami propagation and oscillation of buildings, respectively. We also develop a platform and data grid which supports integrated coupled simulations and parallel data management. In FY.2008, FY.2009 and FY.2010, we will integrate three coupled simulation models into the final system, and make simulations for prediction of disasters by earthquakes and tsunami according to realistic scenarios.

§2. Content of Research Work

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

In the 1st phase of this project (FY.2005-2007), simulation model for tsunami wave propagation will be developed. We develop three coupled simulation models for earthquake prediction, strong ground motion/tsunami propagation and oscillation of buildings. Each of three coupled simulation model consists of closely-related two or three of the six fundamental simulation models. We also develop a platform and data grid which supports integrated coupled simulations and parallel data management.

In the 2nd phase of the project (FY.2008-2010), we will integrate three coupled models into the final system, and make simulations for prediction of disasters by earthquakes and tsunami according to realistic scenarios.

We have following five research groups:

(1) Matsu'ura Group

- Simulations crustal stress accumulation due to plate motion
- Simulations of prediction of earthquake generation

(2) Furumura Group

- Simulations of seismic wave propagation
- Simulations of tsunami generation and wave propagation

(3) Okuda Group

- Development of a platform which supports integrated coupled simulations and parallel data management

(4) Ichimura Group

- Coupled simulations between seismic wave propagation and oscillation of buildings

(5) Nagashima Group

- Coupled simulations between seismic wave propagation and sloshing of tanks

(6) Fukuyama Group

- Coupled simulations between dynamic fault rupture and seismic wave propagation

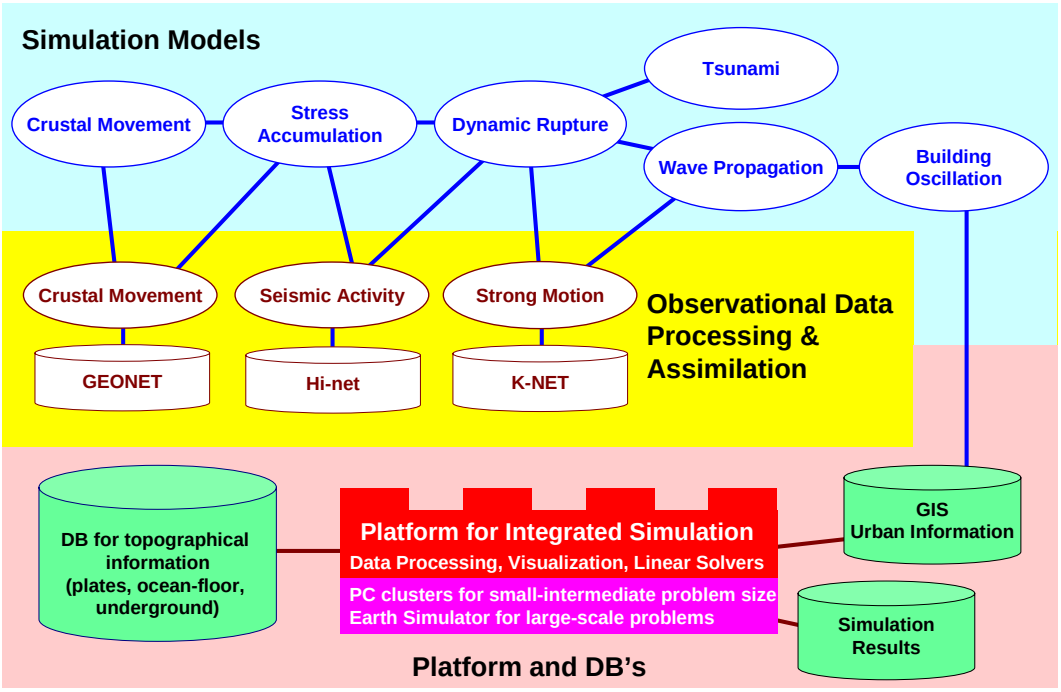

Fig.1 Overview of Integrated Predictive Simulation System for Earthquake and Tsunami Disaster

Progress in FY.2005

Each of the University of Tokyo, and ERI/University of Tokyo has installed PC clusters with 64core Opteron processors. A data files servers with 48core G5 processors and 15TB storage has been

installed to National Research Institute for Earth Science and Disaster Prevention (NIED). Geographical Survey Institute (GSI), collaborating with the University of Tokyo also installed a data file server with 8core Opteron processors and 20TB storage. Construction of a Grid system which connects four institutions, has been also initiated. Each group started preliminary studies and tuning up fundamental simulation models according to Fig.1

In Matsu'ura Group, advanced simulation models for crustal deformation and stress accumulation at plate boundaries have been developed for large-scale coupled simulations. Prototype system of analysis and assimilation of geodetic data around Japanese Islands has been developed under collaboration with GSI. Developed system has been applied to Kanto Region and validated, as shown in Fig.2

In Furumura Group, strong ground motion simulations for the Chuetsu earthquake in 2004 and the Off Miyagi prefecture earthquake have been conducted on the Earth Simulator with an accurate subsurface structure model of Japanese Islands (resolution of 0.25-1km) and source-slip model for the earthquake, as shown in Fig.3. Simulation results are compared with observed waveform in K-NET and KiK-net of NIED and network of seismic intensity meters (SK-net), which demonstrates efficiency of the large-scale simulation of seismic wave field, and provides significant improvement of the simulation model. Strong ground motion simulations for the 1944 Tonankai earthquake have been carried out with detailed model of subsurface structure of western Japan, and seismic behavior in Kanto Region has been evaluated.

In Okuda Group, the data structure and fundamental design of data reservoir which supports the hierarchical analysis, multi-hierarchical visualization modules, library for coupling and library for parallel iterative solvers, have been conducted.

In Ichimura Group, a prototype of methodology for construction of numerical simulation model of city with pertinent setting has been developed through the discussion on data structure of numerical simulation city model, which is constructed from GIS/CAD data. A numerical simulation city model has been constructed and earthquake disaster simulation was conducted. A basic discussion on numerical shaking table test was also conducted to estimate seismic behavior of large-scale complicated structure.

In Nagashima Group, two types of prototype software packages were developed. One is a structural analysis program based on the finite element method (FEM) for dynamic response of thin-walled structures. The other is a program for potential flow analysis by FEM, which can calculate the dynamic response of liquid with free surface. Validity of each code has been evaluated for linear problems. Moreover, numerical methods for fluid-structure interaction have been surveyed.

In Fukuyama Group, preliminary design for coupling interfaces for transition processes from accumulation tectonic stress to dynamic rupture, and generation of seismic wave by dynamic

rupture.

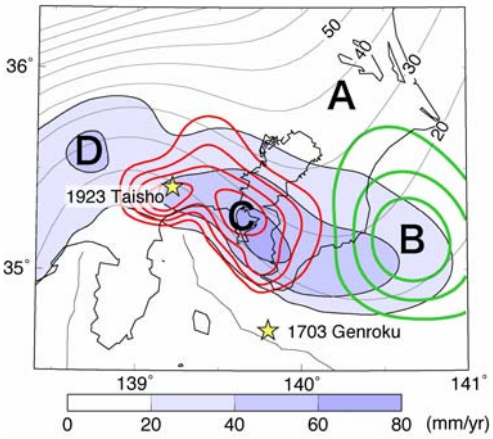

Fig.2 Pattern of stress release at boundary of North America-Philippine Sea plates based on Geodetic data inversion

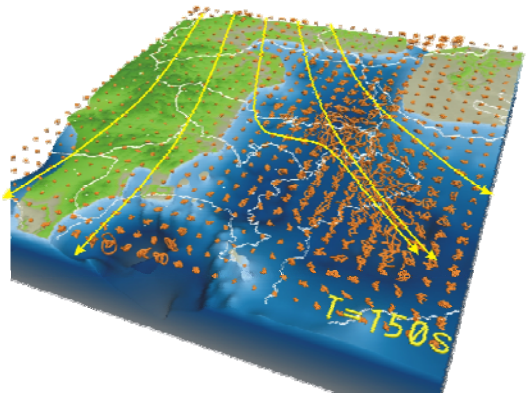

Fig.3 Computer Simulation of the 2004 Chuetsu Niigata Earthquake using the Earth Simulator

Current Status

This project started in October, 2005. We introduced facilities for computation, such as PC clusters (2 x 64core Opteron processors) and data servers (48core G5 processors with 15TB storage, and 8core Opteron processors with 20TB storage), and made fundamental design of the entire system. We started to construct a Grid system which connects four institutions. Each research group is conducting preliminary study using existing simulation models and makes further development on existing models.

§3. Formation of Research Work

Research Director

Mitsuhiro Matsu'ura, Professor

Graduate School of Science, The University of Tokyo

The aim of our research group is to reproduce and predict the chain process from tectonic stress accumulation due to relative plate motion to earthquake generation in and around Japan through the large-scale computer simulation integrating observed data and theoretical models on the Earth Simulator.

Main Research Collaborators

Takashi FURUMURA, Associate Professor

Earthquake Research Institute, The University of Tokyo

We will conduct computer simulation of seismic wave propagation and generation and propagation of Tsunami. Following the dynamic rupture propagation simulation for the earthquake, we will study seismic wave propagation in heterogeneous structure and generation of strong ground motion on ground surface by means of the FDM method. The results of simulation are combined with oscillation simulation of man-made constructions. The results of the earthquake generation simulation is also used for Tsunami simulation based on FEM with a use of structure model of ocean bottom and proper physical parameters of crust and sedimentary layers.

Hiroshi OKUDA, Professor

Research Into Artifacts, Center for Engineering, The University of Tokyo

The hierarchical platform for coupled simulations is constructed, which effectively executes the large-scale coupled simulation that unites the observation data with the model calculation on the earth simulator. The system also supports the exchange of data among the programs and the visualization of large-scale data.

Tsuyoshi ICHIMURA, Associate Professor

Graduate School of Science and Engineering, Tokyo Institute of Technology

Fast and accurate models for coupling of oscillation of buildings and strong ground motion by seismic wave propagation will be developed.

Toshio NAGASHIMA, Associate Professor

Faculty of Science and Technology , Sophia University

Industrial plants along coast lines contain various types of facilities, such as pipes and tanks for oil storage. In this study, fast and accurate computational models, which simulates dynamic response of such facilities against seismic wave, will be developed.

Eiichi FUKUYAMA, Senior Researcher
Solid Earth Research Group,
National Research Institute for Earth Science and Disaster Prevention.

Codes for dynamic rupture simulations by boundary integral methods and for wave propagation simulations by finite-difference methods are coupled, and realistic earthquake simulations based on physical processes of earthquake generations will be conducted.

§4. Publication of Research Results

（4－1） Publication of Thesis (The original Work)

① Number of Publications (0 times-Domestic, 0 times-International)

（4－2） Patent Application

① Cumulative Number

1) Patent Applications in the fiscal year 2005 (Domestic- 0 Cases, Oversea- 0 Cases)
2) Cumulative number of Patent Applications for the research period of CREST
(Domestic- 0 Cases, Oversea- 0 Cases)
3) Details for this fiscal year
   a) Domestic Application (0 cases)
   b) Oversea Application (0 Cases)