Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

STT59-P01 Room:Convention Hall Time:May 20 18:15-19:30

Accumulation of earthquake scenarios towards the construction of simulation database

Mamoru Hyodo[1]*, Takane Hori[1]

[1]JAMSTEC/SeismoLP

In recent years, earthquake cycle simulations based on plate motions and rock friction laws have been utilized for studies on the earthquake preparation process and repetition pattern of the earthquake which occurs in the plate boundary near the Japanese Islands (e.g., Hori et al., 2004, Nakata et al., 2012, etc.). In these studies, the target earthquakes are mainly events occurred in the past. Through the trial-and-error correction in the distribution of frictional property on faults, many forward simulations are carried out until the basic repetition patterns or magnitudes of target earthquake is reproduced. Then, for expecting the future repetition of target earthquakes, the extension of simulations for some tuned parameters might be utilized. However, an natural earthquake is a highly nonlinear problem with huge degrees of freedom, and the modeling error of forward simulations of earthquake cycles is generally large due to the simplicity. For this reason, "deterministic future prediction" is theoretically impossible through the above strategy based on the reproduction of old events.

That is, for the purpose of practical earthquake prediction, we need the prediction framework which can reflect the real-time observation data (such as crustal deformation) without large time lag, and can perform sequentially with increasing data. In order to realize such prediction, we propose the construction of a simulation database consisted of a large number of simulation results (scenarios) with various simulation models or model parameters. If such database is established, with the increase of realtime observation data, simulation results in the database are sequentially accessed and utilized to compare with observed data by likelihood evaluation. Then, the extrapolation of scenarios with higher likelihood values is regarded as the tentative prediction based on the last observation data. The large advantage of this prediction concept is that the resultant predictions have high flexibility according the real-time observation data.

Due to the recent development of domestic High Performance Computing Infrastructures(HPCI), such as K (RIKEN) or ES2 (JAMSTEC), within several days, we can calculate 100-1000 scenarios of quasi-dynamic earthquake cycle simulations, with moderate discretization (about 1km cell) of the plate interface (about 300kmx800km area). Now, for the Nankai Trough region where the next earthquake occurrence is anticipated, many earthquake scenarios with various frictional parameters are tried, and simulation database is under construction towards the establishment of earthquake prediction system.

In the presentation, we will introduce the more details of simulation database and the concept of our prediction system.

Keywords: High Performance Computing, earthquake cycle simulation, database, prediction system, realtime data

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

STT59-P02 Room:Convention Hall Time:May 20 18:15-19:30

Cause of Significant scattering of teleseismic P-wave near Japan Trench as Inferred by Large-Scale Numerical Simulation

Takuto Maeda[1*], Takashi Furumura[2], Kazushige Obara[1]

[1]ERI, The University Tokyo, [2]CIDIR, The University of Tokyo

We found a significant scattered wave train in Japan after the arrival of near-vertical incidence of P-wave of the Off West Coast, New Zealand Earthquake (Mw7.6) in 2009 by using a dense, high-sensitive seismograph network (Hi-net) operated by NIED. The scattered wave train is dominant in the vertical component at period band of 20-50 s with a propagation velocity of 3.5 km/s. It propagates cylindrically to west from Kanto area, central Japan. This signal contains only low-frequency components and no local earthquakes were reported at that time. All of these facts suggest that the observed wave train is a scattered wave originated nearfield by incoming P wave from distant earthquake.

To locate the conversion point of the scattered waves, we first separated scattered wave train from large-amplitude direct waves. Firstly, we stacked seismic traces along the wavefront of the direct waves to cancel out the scattered wave propagating from different direction to each station to make a clear direct wave packet. Then, the stacked trace is subtracted from the raw seismogram to enhance scattered waves. By analyzing the subtracted traces based on an array data processing technique, we located the scatterer at around the Boso triple junction of three plates, southeast of Kanto area.

To clarify what kind of structure develops such large scattered waves, we conducted a finite difference method simulation of seismic wave propagation using high-resolution subsurface structure model with topography and bathymetry. Simulation results revealed that strong scattered waves are generated along the Japan Trench, and are guided to the direction normal to the trench axis due to the reverberation between seafloor and the Pacific plate boundary. In addition, the reverberation of scattered waves in thick (~9000 m) seawater column above the Boso triple junction enhance and elongate the scattered waves significantly, which explains observed feature of scattered waves.

Acknowledgements: This study is supported by the Strategic Programs for Innovative Research field 3 "Projection of Planet Earth Variations for Mitigating Natural Disasters", by MEXT Japan. We used computer resources of the K computer by RIKEN-AICS.

Keywords: Seismic wave scattering, subduction zone, numerical simulation, high performance computing, array analysis

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

STT59-P03 Room:Convention Hall Time:May 20 18:15-19:30

Computation of teleseismic waves for large earthquake using Spectral-Element Method

Seiji Tsuboi[1*], Takeshi, Nakamura[1], Mikito, Furuichi[1]

[1]JAMSTEC

We calculate broadband synthetic seismograms with the finite source propagation model for a realistic 3D Earth model using the spectral-element method. Source model we used is that of Lee et al (2011), which uses teleseismic waveform, strong motion seismograms and GPS measurements. We use the Earth Simulator 2 of JAMSTEC to compute synthetic seismograms using the spectral-element method. The simulations are performed on 1014 processors, which require 127 nodes of the Earth Simulator 2. We use a mesh with 200 million spectral-elements, for a total of 13 billion global integration grid points. This translates into an approximate grid spacing of 2.0 km along the Earth's surface. On this number of nodes, a simulation of 30 minutes of wave propagation accurate at periods of 3.5 seconds and longer requires about 7 hours of CPU time.

Keywords: Theoretical seismic waves, Spectral-Element Method

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

STT59-P04 Room:Convention Hall Time:May 20 18:15-19:30

Three-dimensional numerical modeling of temperature, fluid flow and heat flow associated with subduction of curved slabs

Yingfeng Ji[1*], Shoichi Yoshioka[2]

[1]Department of Earth and Planetary Science, Graduate School of Science, Kobe University, [2]Research Center for Urban Safety and Security, Kobe University

In order to simulate distributions of temperature and fluid flow associated with subduction of a curved slab, we constructed a three-dimensional thermal convection model. We assumed that slab extends with time in a given shape with velocity of 6cm/year, dip angle of 10 deg. for 10 million years. We investigated the relation concerning shape of slab upper surface, subduction direction, distributions of temperature and fluid flow, and surface heat flow for various types of curved slabs. The results revealed a very likely relation between temperature distribution and upper surface shape of a slab, and composite subduction angle which is a compound of a dip angle and slab gradient slope angle along subduction direction. Not only thermal field, but also flow velocity differed greatly on each side of a curved slab. A bent slab leads to a complex fluid flow around it. The results also exhibited how oblique subduction performs in such a curved slab. Although symmetric slab shape models are constructed, oblique subduction resulted in some asymmetric patterns of interplate temperature and heat flow distributions. Isotherm on the plate interface appears to be dragged to the direction of oblique subduction, and low heat flow anomaly appeared on the descent slope of the subducting slab. Most of these simulated results are related to the composite subduction angle. The slab surface shallower than a depth of 60 km has a corresponding relation with surface heat flow distribution above it, whereas the effect gradually disappears when it is deeper than 60 km. Cooling effect associated with subduction is generally related to slab length from the model surface and the composite subduction angle. Large bent slab shape also has a negative effect on cooling down as compared with a flat one .

Keywords: curved slab, temperature, fluid flow, heat flow, numerical simulation

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

STT59-P05 Room:Convention Hall Time:May 20 18:15-19:30

Numerical simulation of geodynamo with HPCs

Takehiro Miyagoshi[1*], Yozo Hamano[1]

[1]IFREE/Jamstec

Since magnetohydrodynamic (MHD) numerical geodynamo simulations in three-dimensinal spherical shell with super computer were started, about 18 years have passed. Many useful results have been obtained by the present. For example, MHD dynamo solution in nonlinear process, reproduce of magnetic dipole field like the Earth, and reversal of magnetic polarity. Inside the core cannot be observed directly, so knowledge from numerical simulations is very useful to understand core convection and geodynamo.

However, physical properties or non-dimensional parameters are very different from them in the Earth's core, due to limitation of present super computers. To understand the realistic core convection and geodynamo, physical properties or parameters, especially viscosity or Ekman number, should be closed to the real value in numerical simulations.

Factors from outside the core, not inside the core, for example climatic change, probably affect geomagnetic field variation, but this point is seldom considered in numerical simulations. To understand geomagnetic field variation and predict it, those factors are important.

In next generation HPCs, coupling geodynamo simulation with mantle convection simulation may become actual. Of course, then the parameters in each simulations are restricted. However, useful results are probably obtained to understand the connection among surface, mantle, and core activity.

We will talk about the directivity of geodynamo simulation studies associated with development of next generation HPCs.

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

STT59-P06 Room:Convention Hall Time:May 20 18:15-19:30

Development of a simulation code for a growing planet with core formation in 3D

Mikito Furuichi[1*], Takashi Nakagawa[1]

[1]Japan Agency for Marine-Earth Science and Technology, Institute For Research on Earth Evolution

This talk introduces our developed a new numerical code for solving the Stokes flow in 3D to investigate the global core formation process in the planetary interior. The formation of a metallic core is widely accepted as the major differentiation event during planetary formation. In our simulation, the growing planet with the impact events and global sinking of the dense metal-rich material over long time scale are captured in the Stokes flow regime.

In order to simulate the core formation process in 3-D, we employ the spherical Cartesian approach. The surface of the material c is captured by the distribution of color functions. The dynamical boundary as a free surface is mimicked by surrounding low viscosity material with zero density, so-called sticky air. The viscosity of the sticky air varies laterally, depending on the neighbouring viscosity of planetary surface. Self-gravitating force is obtained by solving the gravity potential equation. For solving the momentum and continuity equations, we developed an iterative Stokes flow solver, which is robust to problems including jumps in the viscosity contrast. Our solver design consists of an inner and outer solver utilizing a strong Schur complement preconditioner and the Arnoldi type Krylov subspace method preconditioned with geometric multigrid method (GMG). We enhance the robustness of the inner solver for the velocity problem with a mixed (quad-double) precision Krylov kernel calculation. As the high precision calculation method, we employ the double-double precision algorithm which has high arithmetic intensity and is faster than normal quad arithmetic using a register or cache memory. Our mixed precision method improves the convergence of Krylov method without significantly increasing the calculation time.

All of our numerical algorithms are designed for the parallel-vector architecture especially for the Earth Simulator 2 (ES2). Our careful implementation of SOR smoother enables to achieve 34% of the peak performance of ES2 at the finest level of GMG. In the simulation with a grid size of $256*256*256$, our solver achieved 910.3Gflop using 8 nodes (13.9% of peak performance) which involves the cost for idling CPU for multigrid operations.

Keywords: core formation, Stokes flow, mantle convection, double-double method, Krylov subspace method