Outline of the Earth Simulator Project

1. Mission and Basic Principles of the Earth simulator

The Earth Simulator was developed for the following aims. The first aim is to ensure a bright future for human begins by accurately predicting variable global environment. The second is to contribute to the development of science and technology in the 21st century. Based on these aims, the principles listed below are established for the projects of the Earth Simulator.

1) Each project should be open to researches in each research field and to the public, rather than it is confined within the limited research society.
2) In principle, the research achievements obtained by using the Earth Simulator should be promptly published and returned to the public.
3) Earth project should be carried out for peaceful purposes only.

2. Earth Simulator Research Project

The allocation of the Earth Simulator resources for each research field in FY2013 was decided to be as shown in Fig. 1. There are three project categories in the Earth Simulator resource allocation. The projects are shown in Table 1 and 2.

1) Proposed Research projects:
   We accept and select applications for the research projects of the earth science field which is included Climate Change, Solid Earth, Natural Disasters, etc.
2) Contract Research projects:
   The projects using the Earth Simulator focus on research commissioned by public organizations such as the government.
   - The Program for Risk Information on Climate Change (SOUSEI).
   - The Program for Creating Innovation by Sharing Advanced Research Facilities (The Strategic Industrial Use)
   - Consignment Study (JST/CREST, KAKENHI, etc.)
3) JAMSTEC Research projects:
   The Earth Simulator is also used for research projects organized by JAMSTEC, international and domestic collaboration projects and the execution of urgent jobs in the time of natural disasters. In addition, fee-based usage of the Earth Simulator is included in this category.

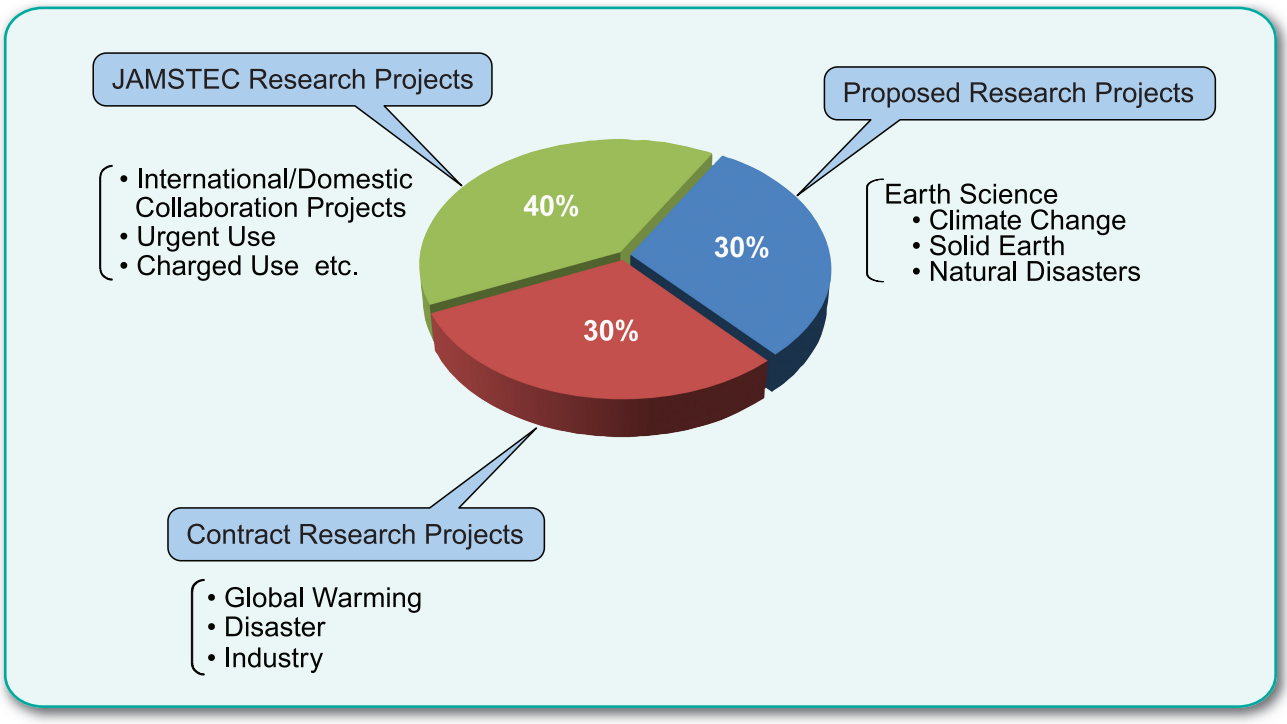

Fig. 1 The Allocation of Resources of the Earth Simulator in FY2013

Table 1 Proposed Research Projects in FY2013

Earth Science (24 projects)

	Project Name	Name of Project Representative	Professional Affiliation of Project Representative
1	Understanding Roles of Oceanic Fine Structures in Climate and its Variability	Hideharu Sasaki	ESC, JAMSTEC
2	Simulations of Adaptation-Oriented Strategy for Climate Variability	Keiko Takahashi	ESC, JAMSTEC
3	Development of a High-quality Climate Model for Global Warming Projection Study	Akira Noda	RIGC, JAMSTEC
4	Simulations of Atmospheric General Circulations of Earth-like Planets by AFES	Yoshiyuki Hayashi	Graduate School of Science, Kobe University
5	Study on the Diagnostics and Projection of Marine Ecosystem Change Associated with Global Change	Sanae Chiba	RIGC, JAMSTEC
6	Study of Cloud and Precipitation Processes Using a Global Cloud-system Resolving Model	Masaki Sato	RIGC, JAMSTEC / Atmosphere and Ocean Research Institute, The University of Tokyo
7	Study on the Predictability of Climate Variations and Their Mechanisms	Yukio Masumoto	RIGC, JAMSTEC
8	Simulation and Verification of Tropical Deep Convective Clouds Using Eddy-permitting Regional Atmospheric Models	Kozo Nakamura	RIGC, JAMSTEC
9	Improved Ocean State Estimation by Using a 4D-VAR Ocean Data Assimilation System	Shuhei Masuda	RIGC, JAMSTEC
10	Global Elastic Response Simulation	Seiji Tsuboi	DrC, JAMSTEC
11	Simulation Study on the Dynamics of the Mantle and Core in Earth-like Conditions	Yozo Hamano	IFREE, JAMSTEC
12	Numerical Simulation of Seismic Wave Propagation and Strong Ground Motions in 3-D Heterogeneous Media	Takashi Furumura	Center for Integrated Disaster Information Research, Interfaculty Initiative in Information Studies, The University of Tokyo/Earthquake Research Institute, The University of Tokyo
13	Development of Advanced Simulation Tools for Solid Earth Sciences	Mikito Furuichi	IFREE, JAMSTEC
14	Numerical Simulations of the Dynamics of Volcanic Phenomena	Takehiro Koyaguchi	Earthquake Research Institute, The University of Tokyo
15	Space and Earth System Modeling	Kanya Kusano	Laboratory for Earth Systems Science, JAMSTEC
16	Numerical Experiments with Multi-models for Paleo-environmental Problems	Ayako Abe	Atmosphere and Ocean Research Institute, The University of Tokyo
17	Model-observation Integration Study of the Middle-atmosphere Dynamics using a High-resolution Climate Model and the Antarctic PANSY Radar	Shingo Watanabe	RIGC, JAMSTEC
18	Predictability Variation in Numerical Weather Prediction	Takeshi Enomoto	Disaster Prevention Research Institute, Kyoto University
19	Computational Science of Turbulence in Atmospheric Boundary Layers	Takashi Ishihara	Graduate School of Engineering, Nagoya University

	Project Name	Name of Project Representative	Professional Affiliation of Project Representative
20	A Large-Scale Self-Organizing Map for Metagenome Studies for Surveillance of Microbial Community Structures	Toshimichi Ikemura	Nagahama Institute of Bio-Science and Technology
21	Generation Mechanism of the Banded Structures Observed in the Jovian-type Planetary Atmospheres	Shin-ichi Takehiro	Research Institute for Mathematical Sciences, Kyoto University
22	Study on the Real-time Ensemble Seasonal Prediction System and its Application	Swadhin Behera	APL, JAMSTEC
23	Analysis of Global Ecosystem Ecology by Fragment Molecular Orbital(FMO) Method	Tadashi Maruyama	BioGeos, JAMSTEC
24	Mercury Magnetosphere Simulator Using Global 3D EM PIC Code for Bepi Colombo	Cai, DongSheng	Faculty of Engineering, Information and Systems, University of Tsukuba

JAMSTEC: Japan Agency for Marine-Earth Science and Technology
IFREE: Institute for Research on Earth Evolution
ESC: The Earth Simulator
RIGC: Research Institute for Global Change
DrC: Data Research Center for Marine-Earth Sciences
APL: Application Laboratory
BioGeos: Institute of Biogeosciences

Table 2 Collaboration Projects in FY2013

System/Application Optimizations of Hetero Super Computer System in JAMSTEC : RIKEN
Implementation Agreement between ESC/JAMSTEC and DOPS/IFREMER on Simulation Research Using the ES: IFREMER
ESC-NERSC Performance Evaluation for HPC : NERSC
Ultra High Resolution Simulation for the Safety of International Transportation on the Sea : Kobe University
Study on the Evaluation Techniques of Vortex-Induced Vibrations for the Design of Risers : The University of Tokyo, NME, MHI
Collaborative Research on the Sophistication of the Computational Simulation Software toward Constructing the Platform for the Leading Industrial Research and Development : Institute of Industrial Science, The University of Tokyo
Forecasting Thunder Cloud : JAXA
Rapid Change of the Arctic Climate System and its Global Influences : NIPR
Numerical Simulations of Scalar Transfer Across Wind-driven Air-water Interface : Kyoto University

3. System Configuration of the Earth Simulator

The Earth Simulator (ES2) is the upgrade system of the previous Earth Simulator, which has significantly contributed to the development of a simulation culture in the area of earth science and related technical fields, and introduces new features to bring accurate and high-speed analysis and projections of global-scale environmental phenomena. The current ES is also used to product numerical simulations for advanced research fields that are beyond the scope of other computing systems. By the examination at the time of procurement, the average performance of real application benchmarks exceeded the first system's twice (Table 3).

Table 3 Real Application Benchmarks Performance

Application	ES initial (# of CPUs)	ES current (# of CPUs)	Speed up
PHASE	135.3 sec (4096)	62.2 sec (1024)	2.18
NICAM-K	214.7 sec (2560)	109.3 sec (640)	1.97
MSSG	173.9 sec (4096)	86.5 sec (1024)	2.01
SpecFEM3D	96.3 sec (4056)	45.5 sec (1014)	2.12
Seism3D	48.8 sec (4096)	15.6 sec (1024)	3.13

Harmonic Mean of Speed up Ratio : 2.22

ES2 is in the independent network environment and can be used via the Internet under advanced security protection (Fig. 2). In the Earth Simulator network, there are ES2, Login Servers, User Disks, Terminals and other servers. The current ES2 is a highly parallel vector supercomputer system of the distributed-memory type, and consisted of 160 processor nodes connected by Fat-Tree Network. Each Processor nodes is a system with a shared memory, consisting of 8 vector-type arithmetic processors, a 128-GB main memory system. The peak performance of each Arithmetic processor is 102.4Gflops. The ES as a whole thus consists of 1280 arithmetic processors with 20 TB of main memory and the theoretical performance of 131Tflops. All of the software available on the ES2 system are designed and developed so that users can fully and readily exploit the outstanding performance of the world's largest vector-type computer. ES2 is basically a batch-job system. Network Queuing System II (NQSII) is introduced to manage the batch job. The L batch queue is majored for a production run. The nodes allocated to a L batch queue are used exclusively for that batch job to estimate the job termination time and to make it easy to allocate nodes for the next batch jobs in advance. The batch job is scheduled based on elapsed time instead of CPU time to an efficiency job execution. The job can use the nodes exclusively and the processes in each node can be executed simultaneously. As a result, the large-scale parallel program is able to be executed efficiently.

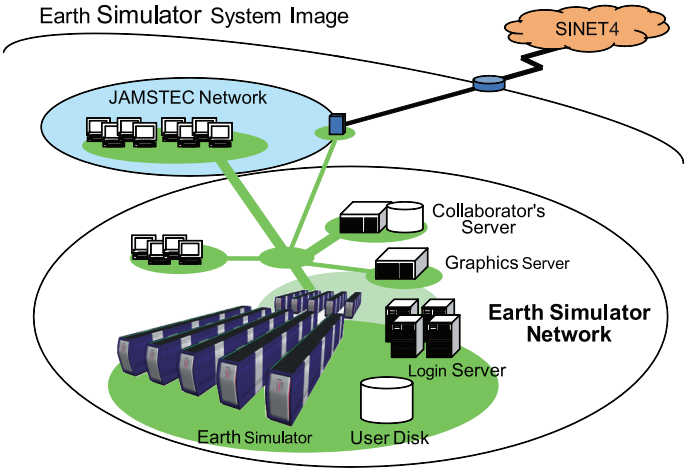

Fig. 2 ES System Outline