Booklet for External Review

March 2006

Department of Earth and Planetary Science

Graduate School of Science

The University of Tokyo

Contents

1 Purpose of the Review

1.1 Objectives

Department of Earth and Planetary Science, the University of Tokyo was established in April 2000 by merging and reorganizing previously existed four Earth and planetary science-related departments, Earth and Planetary Physics, Geology, Mineralogy, and Geography, aiming at promoting researches and education at an international standard. Recent progress in the earth and planetary sciences required us to reconstruct old division of graduate course education, which was based mainly on the scientific tools such as model simulation, observation, and analysis. However, the present-day Earth and planetary science-related problems, such as climate change, prediction for earthquakes, exploration of planets, development of new materials, and search for the origin of life, can be understood by combining approaches from all aspects of each problem. For example, we need to combine observation, analysis of data, development of more sophisticated models, chemical analysis, comparison with geological records, and so on in order to understand the global climate change. It is also required to understand the behavior of the Earth and planetary systems, which has complicated evolution history with interactions among various subsystems including the Sun, magnetosphere, atmosphere, ocean, biosphere, crust, mantle, and core.

On the basis of above concepts, the new department was divided into five fields, Atmospheric and Oceanic Science group, Space and Planetary Science group, Earth and Planetary System Science group, Solid Earth Science group, and Geosphere and Biosphere Science group. Each group has its own research objective and educational program, and at the same time, they are closely related with each other. The Earth and Planetary System Science group was constructed especially to take the role of interaction among other groups. On the other hand, scientific achievement with these concepts should be supported only by undergraduate education with various scientific tools, and therefore, current two undergraduate programs, Earth and Planetary Physics Program, and Geological Science Program which includes Geology and Mineralogy Course and Geography Course have been retained.

Since the reorganization, the new department has strongly promoted science and education, obtaining scientific achievement described in Chapter 4, and awarded 430 master's and 200 doctor's degrees along with 250 Bachelor's degrees. During these six years we have two large changes in the educational system; one is the "COE program" and another is the reorganization of the undergraduate programs. The 21st Century Center of Excellence (COE) program "Predictability of the Evolution and Variation of the Multi-sphere Earth System" is a special program started in 2003, and is on the extension of the purpose of the establishment of the department. In 2006, we are plannng to reorganize half of the undergraduate programs: the Geological Science Program will be changed to "Earth and Planetary Environmental Science" Program. The university itself has changed in 2004 from National University to National University Corporationwith more autonomy and independence, which forces us to carry out sciences more acceptable for public requirements, and we have paid much time for public service and outreach activities.

The previous external review committee required us to respond to their comments within 2 to 3 years, and suggested us to have next review after 7 to 10 years. Regarding the former suggestion, we have once tried to prepare our responses when the COE program was just starting, but Dr. I. Kushiro, the previous committee chair, suggested us to carry out the next external review with the response and with including the progress of the COE program. We think it is now good time to have an external

review and ask a committee to evaluate the scientific activity, educational achievement, our system including science, education, and management of the department. It will give us a guide for coming several years.

1.2 Breif summary of previous external review

The last external review was held to ask advice for the new department, and many of recommendations were on the plan itself. The following is concise summary and recommendations by the committee report including comments on the construction of the new department.

(1) The reorganization of Department of Earth and Planetary Science is strongly recommended.
(2) The new department should consolidate in a single location by constructing a new building.
(3) The decrease in number of Research Associate is serious. Diminishing the distinction between Research Associates and postdoctoral fellows and term appointments are recommended.
(4) High quality technical support is essential.
(5) Although the qualities of most faculty members are high, some are in reasonable national level. The latter should make efforts to improve the activity.
(6) The new department plan is well, but may present minor organization problems. The department should have periodic review.
(7) The relationship between Affiliated Institutions should be strengthened.
(8) Employment of foreign and female faculty members is recommended.
(9) Administrative duty should be decreased to increase the time for research.
(10) Education should be revised.
(10-1) The undergraduate education should include both earth and planetary physics and geological basic survey or experimental sciences for both programs.
(10-2) The masters degree education should give broad-based survey courses in the first semester, the curriculum should be interdisciplinary, students should have a mutli-member advisory panel, and masters theses should be designed to emphasize developments of a student's critical faculties.
(10-3) The doctoral students should have an advisory committee including members from outside, the advisory committee should assess the student's progress and knowledge at the middle stage of the course, and the theses should be written in English.
(10-4) More emphasis should be placed to develop communication skills both in Japanese and English at all levels of the curriculum.
(11) Faculty with experience in geochemistry should be added.
(12) A report should be presented in 3 years to show the establishment of the new department.

2 Organization

2.1 Personnel changes

The personnel changes are summarized in the table below. We have appointed twenty four members in these six years; eight professors, eleven associate professors including three lecturers, and five research associates. The total number of faculty members was 58 at the beginning of the department, but has been decreased to 54 because of the government's policy for the reduction in personnel ceiling.

All the appointments were done through open announcement. For each appointment, a selection committee was made, which comprises of members of the corresponding group and one each from other groups. The tentative decision by the selection committee was further discussed by the committee made up of all professors, where final decision is made.

Although the number of applicants varied depending on the research field and position, the average numbers are 5 to 10 for professors, 20 to 30 for associate professors, and almost 50 for research associates, suggesting severe competition for all the appointments. About two thirds were from the outside the department for professors, associate professors, and lecturers, and four of five were from JSPS research fellows and one from outside for research associates. It is worth mentioning that we have employed one foreign professor from CALTECH and one young female professor, which has been recommended by the last external review committee.

Eleven members who belonged to the department in 2000 moved out getting promotion. All the changes shown above indicate the mobility of our organization, which holds the activity of the department.

Date	Name	Rank*	
Apr. 1, 2000	OZAWA, Kazuhito	P	From Institute for Study of the Earth's Interior, Okayama University
Apr. 1, 2000	HIBIYA, Toshiyuki	P	From Associate Professor, Department of Earth and Planetary Science, The University of Tokyo
May. 16, 2000	NAKAMURA, Hisashi	AP	From Research Associate, Department of Earth and Planetary Science, The University of Tokyo
Jun. 16, 2000	TADA, Ryuji	P	From Associate Professor, Department of Earth and Planetary Science, The University of Tokyo
Jun. 30, 2000	KITA, Kazuyuki	RA	To Research Center for Advanced Science and Technology, The University of Tokyo
Jul. 1, 2000	URABE, Tetsuro	P	From Geological Survey of Japan
Sep. 1, 2000	TAKAGI, Masahiro	RA	From Department of Earth and Planetary Science, The University of Tokyo （JSPS Research Fellow）

* P: Professor, AP: Associate Professor, L: Lecturer, RA: Research Associate

Date	Name	Rank	
Oct. 16, 2000	KOIKE, Makoto	AP	From Solar-Terrestrial Environment Laboratory, Nagoya University
Mar. 31, 2001	ASHI, Jyuichiro	RA	To Ocean Reseach Institute, The University of Tokyo
May 31, 2001	KURITA, Kei	AP	To Earthquake Reseach Institute, The University of Tokyo
Jun. 30, 2001	SUZUKI, Yasunori	RA	Resigned
Jul. 1, 2001	TANAKA, Hidemi	L	From Department of Geo/Biosphere Science, Ehime University
Jul. 16, 2001	NAGAHARA, Hiroko	P	From Associate Professor, Department of Earth and Planetary Science, The University of Tokyo
Aug. 1, 2001	YAMAGISHI, Akihiko	P	From Department of Science, Hokkaido University
Nov. 16, 2001	MASUMOTO, Yukio	AP	From Research Associate, Department of Earth and Planetary Science, The University of Tokyo
Dec. 1, 2001	Kirschvink, Joseph L.	P	From California Institute of Technology
Mar. 31, 2002	NAKAMURA, Masato	AP	To Institute of Space and Astronautical Science
Apr. 1, 2002	NIWA, Akihiro	RA	From Department of Earth and Planetary Science, The University of Tokyo （JSPS Research Fellow）
Apr. 1, 2002	SAKURABA, Ataru	RA	From Department of Earth and Planetary Science, The University of Tokyo （JSPS Research Fellow）
Apr. 16, 2002	IDE, Satoshi	L	From Earthquake Research Institute, The University of Tokyo
May 31, 2002	ENDO, Kazuyoshi	RA	To Institute of Geoscience, University of Tsukuba
Jul. 16, 2002	TAJIKA, Eiichi	AP	From Research Associate, Department of Earth and Planetary Science, The University of Tokyo
Oct. 1, 2002	YOKOYAMA, Yusuke	L	From Institute of Geophysics and Planetary Physics, Lawrence Livermore National Laboratory
Mar. 31, 2003	HAYASHI, Kanji	AP	Retired
Mar. 31, 2003	Kirschvink, Joseph L.	P	To California Institute of Technology
Apr. 1, 2003	YOKOYAMA, Takaaki	AP	From Radio Astronomy Division, National Astronomical Observatory of Japan
Apr. 1, 2003	SUNAMURA, Michinari	RA	From National institute of Advanced Industrial Science and Technology

Date	Name	Rank	
Apr. 1, 2003	TACHIBANA, Shogo	RA	From Department of Earth and Planetary Science, The University of Tokyo （JSPS Research Fellow）
Mar. 31, 2003	MATSUDA, Yoshihisa	AP	To Tokyo Gakugei University
Mar. 31, 2003	IMAI, Akira	RA	To Faculty of Engineering, Kyusyu University
Mar. 16, 2004	FUNAMORI, Nobumasa	AP	From Lecturer, Department of Earth and Planetary Science, the University of Tokyo
Apr. 1, 2004	NAKAJIMA, Kengo	AP	From Research Organization for Information Science and Technology
May 31, 2004	SUGITA, Seiji	RA	To Graduate School of Frontier Sciences , The University of Tokyo
Sep. 30, 2004	SASAKI, Sho	AP	To National Astronomical Observatory of Japan
Apr. 1, 2005	YOSHIKAWA, Ichiro	AP	From Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency
Mar. 31, 2005	YASUDA, Ichiro	AP	To Ocean Reseach Institute, The University of Tokyo
Oct. 1, 2005	SATO, Kaoru	P	From Division for Research and Education, National Institute of Polar Research

2.2 Faculty Members

All the faculty members belonging to the department in January 2006 are listed below.

Name	Rank*	Speciality
Atmospheric and Oceanic Science Group		
SATO, Kaoru	P	Atmospheric Dynamics, Middle Atmosphere Sciences
HIBIYA, Toshiyuki	P	Ocean Dynamics
YAMAGATA, Toshio	P	Ocean-Atmosphere Coupled Dynamics, Large-scale Ocean Dynamics, Geophysical Fluid Dynamics
KOIKE, Makoto	AP	Atmospheric Environmental Science
NAKAMURA, Hisashi	AP	Climate dynamics; Atmospheric general circulation; Large-scale air-sea interaction
MASUMOTO, Yukio	AP	Atmosphere and Ocean Circulation Dynamics

* P: Professor, AP: Associate Professor, L: Lecturer, RA: Research Associate

Name	Rank	Speciality
TAKAGI, Masahiro	RA	Dynamic meteorology, Planetary fluid dynamics
NIWA, Yoshihiro	RA	Physical Oceanography
Space and Planetary Science Group		
SUGIURA, Naoji	P	Planetary Science
TERASAWA, Toshio	P	Physics of magnetospheres around the earth, planets, and sun
HOSHINO, Masahiro	P	Space Physics
MIYAMOTO, Masamichi	P	Planetary Material Science
IWAGAMI, Naomoto	AP	optical remote sensing of planetary atmospheres
HIYAGON, Hajime	AP	planetary science, isotope cosmochemistry, meteoritics
YOKOYAMA, Takaaki	AP	Solar and Astrophysical Plasma Physics
YOSHIKAWA, Ichiro	AP	Planetary airglow
MIURA, Akira	RA	Space plasma physics
MIKOUCHI, Takashi	RA	Planetary Science, Mineralogy, Meteoritics
YAMAMOTO, Takashi	RA	Solar-Terrestrial Physics
Earth and Planetary System Science Group		
TADA, Ryuji	P	Earth System Dynamics, Paleooceanography, Paleoclimatology, and Sedimentology
NAGAHARA, Hiroko	P	Petrology, Cosmochemistry
HAMANO, Yozo	P	Dynamics and Evolution of the Earth and Planetary Interiors
ABE, Yutaka	AP	Planetary System Physics (Planetary evolution, Planetary atmosphere, Planetary climate)
KAYANNE, Hajime	AP	Earth System Science (coral reef, coast, carbon cycle, global change, paleoenvironment)
TAJIKA, Eiichi	AP	Earth and planetary system science
MATSUMOTO, Jun	AP	Physical Geography, Climatology
YOKOYAMA, Yusuke	L	eochemistry, Palaeoclimatology, Palaeoceanography
TACHIBANA, Shogo	RA	Experimental geo- and cosmochemistry
Solid Earth Science Group		
OZAWA, Kazuhito	P	Petrology
KIMURA, Gaku	P	Tectonics and Structural Geology

Name	Rank	Speciality
GELLER, Robert	P	Seismology
MATSU'URA, Mitsuhiro	P	Earthquake Physics and Tectonics
IKEDA, Yasutaka	AP	Tectonic geomorphology, Active tectonics
IWAMORI, Hikaru	AP	Dynamics of Earth's Interior, Petrology
FUNAMORI, Nobumasa	AP	High-pressure mineral physics
IDE, Satoshi	L	Earthquake Source Physics
TANAKA, Hidemi	L	Material Seismology, Structural Geology
SAKURABA, Ataru	RA	Geodynamics,Planetary dynamos,Geomagnetism
SHIMIZU, Ichiko	RA	Structural Geology, Rock Rheology
FUKAHATA, Yukitoshi	RA	Tectonophysics, Geothermics
MOCHIZUKI, Eiji	RA	
Geosphere and Biosphere Science Group		
URABE, Tetsuro	P	Chemical Geology, Economic Geology, Hydrothermal activity, deep biosphere
TANABE, Kazushige	P	Paleobiology & Paleoecology
MATSUMOTO, Ryo	P	Sedimentary Petrology
MURAKAMI, Takashi	P	Environmental Mineralogy
YAMAGISHI, Akihiko	P	Clay Science
OJI, Tatsuo	AP	Invertebrate paleobiology Evolutionary paleoecology
KOGURE, Toshihiro	AP	Mineralogy, Material Science
SUGIYAMA, Kazumasa	AP	Crystallography, Mineralogy, Material Science, Synchrotron Radiation
OGIHARA, Shigenori	RA	Organic Geochemistry
SUNAMURA, Michinari	RA	Geomicrobiolgy, Microbial ecology
COE		
NAKAJIMA, Kengo	AP	Computational Fluid Dynamics, Parallel Computing, FEM, Numerical Linear Algebra, AMR

3 Education

3.1 Principles

Department of Earth and Planetary Science covers extremely wide research area. Spatially, the area covers the solid earth including crust, mantle, and core, the fluid earth including ocean and atmosphere, biosphere that extends along the boundary between the solid and liquid parts of the earth, and their assemblage, the earth system. The area further extends into solar system including its planets, satellites, and planetary space. Temporally, the area ranges from more than 4.6 Giga years ago before the birth of the solar system through the present to the future. The research methods are also highly various. The methods include field survey and observation that are essential to recognize and describe the diversity and complexity of the nature, experiment, analysis, and theory that are indispensable to extract universality from the observed diversity and complexity, and modeling and simulation that are useful to understand the observed diversity and complexity under the unified concept of the earth system. Recent rapid advance in science and technology surrounding the earth and planetary science is now gradually making it possible to capture the earth as a system composed of the solid earth, its surface environment, and surrounding planetary space that interact one another in a complicate fashion, and treat its history of formation and evolution as well as future prediction of its behavior as a temporally sequential manner. In order to support and further develop this major trend in the earth and planetary science, it is necessary to keep providing researcher-oriented, engineer-oriented, and research administrator-oriented experts of the earth and planetary science with high specialties. Besides, such experts should be armed with a wide scope, highly sophisticated technical knowledge and ability, and an international way of thinking. On the other hand, new fields for application of earth and planetary science such as prevention of geo-hazards, environmental protection, and diagnosis of environments emerge, and demands for experts with a wide scope and highly sophisticated technical knowledge and ability also increases among the general public and industries.

Department of Earth and Planetary Science organized its educational system of undergraduate and graduate programs with taking the above described state into consideration in 2000 when the department was born by merging the four departments; Department of Earth and Planetary Physics, Department of Geology, Department of Mineralogy, and Department of Geography. The new department set the aim of its education to bring up science researchers with wide scopes, deep technical knowledge, and high creativity, as well as science engineers with wide and firm technical knowledge who can satisfy various social demands. The new department classified subjects into introductory, basic, and advanced categories, which allows students to understand the curriculum structure easily and to choose appropriate subjects in appropriate orders. In undergraduate program, the new department conducted its education that puts emphasis on understanding and acquiring the basic concepts and skills with a strong belief that wide scope and sophisticated technical knowledge is attained only after the firm understanding of the basic concepts and skills. As fot graduate program, the new department prepared a master course curriculum that allows to take combination of basic and advanced subjects for the students who aim to be science researchers, and combination of introductory and basic subjects for the students who aim to be science engineers, in order to nurture wide scope and sophisticated technical knowledge. In addition, the new department prepared a doctor course curriculum that nurture high creativity capable of utilizing the wide scope and sophisticated technical knowledge learned during the

master program.

Educational concept described above has been maintained since the start of the new department and the department continued efforts to strengthen and improve its educational system. For example, the department realized emergence of new and attractive research fields such as “co-evolution of life and environment of the earth” and “planetary environment”, and decided to reorganisze one of its undergraduate program, Geological Science Program into Earth and Planetary Environmental Science Program from FY 2006. It is intended to show the difference in basic educational concept and methods of investigation between Geological Science Program and Earth and Planetary Physics Program clearer for students, and to strengthen the educational system of the two programs in order to organize, manage, and carry out its basic education in more effective and consistent way. At the same time, the department reorganized curriculum of the graduate program. In this way, the educational system of the department will be renewed and move to a new system from FY 2006, which afford much better link between two undergraduate programs as well as between undergraduate and graduate programs, especially master prpgram.

In the new educational system of undergraduate programs, Earth and Planetary Physics Program puts emphasis on understanding of basic physics and applied mathematics approaches, whereas Earth and Planetary Environmental Science Program puts emphasis on understanding of basic material science and natural history approaches. The renewal of curriculum of graduate program was carried out based on the principle that 2 years of master program, or 3 years including the first year of doctor program, is used to learn basic knowledge common to all areas of earth and planetary science as well as basic knowledge of specific research field that is essential to conduct its own research spontaneously. While 3 years of doctor program will be used to nurture originality and creativity that are essential to promote cutting-edge sciences.

(a) Undergraduate Programs

As is described above, the methods of earth and planetary science have a wide variety ranging from field survey-observation, experiment-analysis- theory, and modeling-simulation. Consequently, it is impossible to teach all of these basics during the last 2 years of specialized program of undergraduate school. Thus, the department decided to maintain two undergraduate programs; Earth and Planetary Physics Program that puts emphasis on education of basic physics and applied mathematics, and Earth and Planetary Environmental Science Program that puts emphasis on education of basic material science and natural history. With the progress in earth and planetary science, new and attractive research fields have emerged, for example, “co-evolution of life and environment of the earth” and “planetary environment”. In addition, necessity rose to clarify the difference in educational concept and methods of investigation between Earth and Planetary Physics Program and Geological Sciences Program to students. For these reasons, the department decided to reorganize one of its undergraduate programs, Geological Sciences Program into Earth and Planetary Environmental Science Program and to unify two courses, which are Geology and Mineralogy Course and Geography Course, into one from FY 2006. At the same time, drastic reorganization of the curriculum was conducted in Earth and Planetary Environmental Science Program to put more emphasis on basic education of field survey, visual observation of geological materials, and to include more elements of chemistry and biology relevant to earth and planetary science. Concurrent with this reorganization, the department also conducted reorganization of curriculum of Earth and Planetary Physics Program to put emphasis on basic education of physics and applied mathematics, compliment subjects which were not covered in previous curriculums of the two courses as well as to eliminate overlapping subjects, and to strengthen

the linkage between the two programs by setting introductory and basic subjects common to both programs.

(b) Master Program

Education in master program aims to nurture researcher-oriented and engineer-oriented experts with wide scope and deep knowledge on specific science fields, which should be built on firm education of basic physics and applied mathematics in Earth and Planetary Physics Program and basic material science and natural history in Earth and Planetary Environmental Science Program. The department recognizes the fact that more than 60% of students getting into the master program came from outside the two undergraduate programs, many of which did not have any background of earth and planetary science. For this reason, the department set introductory subjects in its master program curriculum so that the students without any earth and planetary science background can learn basic knowledge common to all the specific fields of earth and planetary science. In addition, the department selected basic subjects which are especially useful to learn basic knowledge of the specific research fields relevant to conduct advanced researches in the doctor program and arranged these subjects in the way that allows systematic acquisition of the basic knowledge on specific research fields.

(c) Doctoral Program

Education in doctor program aims to encourage flexible and creative way of thinking founded on wide scope and deep knowledge on specific research field acquired during the master program so as to nurture researchers with creativity and internationality who have ability to carry out their original researches and present and discuss the results in international community. In order to attain this objective, the department puts special emphasis on seminars and colloquiums in its doctor program curriculum so as to effectively extract autonomy of students. Students are also required to publish at least one full-paper in English in an international journal before submitting a doctoral thesis so as to nurture the ability to express opinions to international community. In case this requirement is not satisfied, the department requires writing a doctoral thesis in English. In addition, the department cooperates with 21st Century Earth Science COE Program “Predictability of the Evolution and Variation of the Multi-scale Earth System” to establish “the Predictive Earth science course” within the doctor program, in which COE special lecture series by leading foreign scientists, education on advanced computer literacy by COE teaching staffs, and English for Scientific Researchers by foreign assistants are conducted. Furthermore, the COE Program has introduced International Internship.

3.2 Statistics and facts

(a) Master Program and Doctoral Program

Number of Students (As of April 1)

	Master Course	Doctoral Course
FY2000	189	179
FY2001	212	175
FY2002	211	171
FY2003	189	179
FY2004	174	167

Number of Degrees Awarded

	Master's Degree	Doctor's Degree	
		Course Doctor	Dissertation Doctor
FY2000	69	34	8
FY2001	88	36	5
FY2002	103	31	8
FY2003	90	45	5
FY2004	80	30	2

(b) Undergraduate Programs

Number of Students (As of April 1)

	Earth and Planetary Physics	Geosciences	
		Geology	Geography
FY2000	69	32	15
FY2001	69	31	17
FY2002	61	29	17
FY2003	62	21	17
FY2004	69	21	17

Number of Bachelor's Degrees Awarded

	Earth and Planetary Physics	Geosciences	
		Geology	Geography
FY2000	32	15	8
FY2001	35	10	7
FY2002	27	18	5
FY2003	28	8	6
FY2004	31	10	5

4 Research Activities

4.1 Objectives and Achievements

Research objectives and achievements during these six years are shown below by groups.

(a) Atmospheric and Oceanic Science group

Objective

Our planet Earth is unique simply because it is covered by moisture evaporated from the ground and oceans. Since the oceans of this planet occupy more than 70% of the global surface, this planet is sometimes called an "aqua-planet". Water absorbs radiation from the Sun quite effectively and has a large specific heat; it releases/absorbs large latent heat by changing its phase. In addition, it is extremely solvent and fluid. It is all those characteristics that have introduced rich daily weather, seasonal changes and climate variations into our planet. Another unique evolution of our civilization is due to those natural changes of our environment; building a society less vulnerable to natural disasters has been a major motive for our evolution. Now, anthropogenic effects appear to have crucial impact on those variations after the industrial revolution.

This group will be devoted to high-level education as well as research on those oceanic and atmospheric phenomena of various space and time scales from breaking internal waves to centennial global climate changes. The efforts will contribute to enhancing our basic knowledge on predictability of oceanic and atmospheric phenomena of great societal concern. To be more specific, this group, through data analysis, analytical methods, global modeling and field observations when necessary, encourages development of our understanding of oceanic and atmospheric flows and turbulence, ocean-atmosphere coupled phenomena generating climate variations, circulation of various oceanic and atmospheric substances such as ozone, carbon and fresh water.

In order to fulfill above purposes, we introduce the following four research subgroups and proceed to realization of world leading research and education in the realm of oceanic and atmospheric science.

- Atmospheric Physics

The atmospheric phenomena observed on Earth and other planets range over various scales and involve various physical processes, such as dynamical, radiative and cloud physical ones. With a special emphasis on the dynamical process, this group will devote their efforts to enhancing research and education of atmospheric physics. In particular, the atmospheric phenomena ranging from the general circulation to the micro-scale phenomena are investigated using analytical methods, numerical models and various dataset. Our definite objective is to make clear dynamical mechanisms working in the troposphere and/or the middle atmosphere as well as to advance the predictability study. Outcomes from this group will be particularly beneficial to the general society. In addition, the group wishes to contribute to planetary science by clarifying unknown mechanisms of various interesting phenomena in other planets.

- Physical Oceanography

This research group will devote their major efforts to understanding as well as educating various physical processes such as eddy-eddy interaction, eddy-mean flow interaction and turbulent

mixed-layer dynamic in the ocean. Those processes that are crucial to accurate modeling of the large-scale ocean general circulation are clarified through analytical and numerical study as well as analysis of in situ and remote sensing data. Areas of current particular interest are interaction between mesoscale eddies and global ocean currents and parameterization of diapycnal mixing processes caused by breaking internal waves, and advanced modeling of the ocean surface mixed layer to be embedded in next-generation general circulation models.

- Climate Dynamics

  This research group focuses on understanding climate variations on seasonal-to- centennial time scales. Particular emphasis is laid on roles of the ocean on climate. Phenomena to be addressed actively in cooperation with the world climate research community are, for example, interannual variations such as El Nino/Southern Oscillation, variations of the Kuroshio and their link with the Pacific climate changes, decadal/interdecadal climate events and variations of the oceanic lateral and meridional circulation. Developing various tools from simple conceptual models to realistic general circulation models including ocean-atmosphere coupled models as well as stand-alone ocean models, major physical processes causing climate changes will be clarified in order to enhance predictability of those phenomena with vast societal impact. Synthesis of global ocean-atmosphere data with models is also encouraged in this group in order to produce high-level researchers needed in this field.

- Ocean-Atmosphere Material Circulation Physics

  This group is devoted to studying as well as educating circulation of substances in the atmosphere and oceans using observational methods, data analyses and models of various degrees of freedom. On the atmospheric side, major targets are to study composition, distribution, chemical transformation and variability of atmospheric constituents such as ozone and so-called greenhouse gases. Addressed on the oceanic side are the oceanic thermohaline processes, water-mass formation and circulation of oceanic substances such as fresh water, salt, nutrients and carbon. This group will interact actively with other three groups which provide information on ocean-atmosphere flow field with its variability.

Acheivement

During the last 6 years, the AOS group has conducted research through data analysis, analytical methods, global modeling and field observations to clarify dynamic processes over a wide range of space and time scales, namely, from global scales to micro-scales scales in both oceans and atmospheres. Research activities of each subgroup for the last 6 years are summarized below.

- Atmospheric Physics

  Dynamics of large-scale earth atmospheric circulation has been examined. First, for the formation mechanism of the Okhotsk High, causing abnormal summertime coolness to Japan, it was shown that downward effects of upper level blocking in association with a Rossby wave-train propagating from Europe are essential for the cold surface high development through acting on the thermal contrast between Siberia and the Okhotsk. Similar amplification mechanisms are important for the Siberian High. Second, it was shown that the summertime development of the subtropical highs over the eastern oceans is due to the response to the local low-level land-sea thermal contrasts, which is opposed to the conventional knowledge, i.e., remote monsoon effects. Third, we introduced a new concept of three-dimensional teleconnection via a Rossby wave-train to the stratospheric dynamics. It was shown that lower-stratospheric wavy disturbances occasionally cause localized tropospheric circulation

anomalies. We also identified the local source of a Rossby wave packet causing the unprecedented Antarctic ozone hole split that occurred in September of 2002. Fourth, we made an analysis for the Southern Hemisphere data, showing that a surface baroclinic zone anchored by a mid-latitude oceanic frontal zone is essential for the formation of a storm track and associated polar front jet, which is counteracted by a subtropical jet enhanced with the Hadley cell in winter. We have proposed that the extra-tropical tropospheric general circulation must be reinterpreted from a viewpoint of the mid-latitude ocean-atmosphere interaction. The counterintuitive characteristics of the North Pacific storm track activity can be understood reasonably in this framework also.

Dynamics of planet atmosphere, in particular, Venus one has been studied as well. Using a spherical linear model of Venus atmosphere, we examined dynamics of thermal tides, in terms of dependence of their structures on various parameters, and of their influence on the atmospheric super-rotation. A general circulation model for the Venus atmosphere has been developed to elucidate the effects of thermal tides on the formation of atmospheric super-rotation. Results suggest that thermal tides can induce a realistic mean-zonal wind, which is stronger than expected by conventional linear theories. These theoretical implications have contributed significantly to the plan and design of the instruments for the Venus Climate Orbiter mission (PLANET-C) promoted by JAXA. Furthermore, so as to establish the unified theory of the planet atmosphere, stability of the mean-zonal flow in the cyclostrophic balance has been examined. Traditional baroclinic instability theory was generalized to show the existence of baroclinic instability modified by the centrifugal force in the lower atmosphere of the Venus. A radiative transfer model has been developed, allowing us to make comparative study of various planet atmospheres, such as general circulation under various conditions.

- Physical Oceanography

Global mapping of diapycnal mixing rates in the thermocline is essential to improve the ability of global overturning circulation models in predicting future climate changes. During the last 6 years, we have been involved in the theoretical/observational studies to clarify the global distribution of diapycnal mixing rates in the deep ocean. For this purpose, we first carried out a series of numerical experiments to see how the energy supplied from the semidiurnal internal tides and traveling atmospheric disturbances cascades through the local internal wave spectrum down to dissipation scales. It has been found that the energy transfer is dominated by wave-wave interaction termed parametric subharmonic instability which occurs only equatorward of 30˚ of latitude so that diapycnal mixing rates in the thermocline should be strongly latitude-dependent. Actually, this numerical prediction has been confirmed through the XCP (expendable current profiler) surveys of finescale vertical shear of horizontal velocity carried out over a large area in the Pacific Ocean, the Indian Ocean, and the North Atlantic Ocean. Recently, based on internal wave-wave interaction theory, we have succeeded in extrapolating the results from the XCP surveys to obtain a global map of the intensity of diapycnal mixing. The obtained map clearly demonstrates that regions of high mixing rates (mixing hotspots) are limited to the prominent topographic features at latitudes between 20˚ and 30˚ where the available semidiurnal internal tide energy can be efficiently transferred to dissipation scales by parametric subharmonic instability. We are now assessing the validity of this map by carrying out direct microscale measurements at several key locations using TurboMap-D, the first domestic micro-scale profiler. At the same time, we are incorporating the obtained distribution of diapycnal mixing rates into the global circulation model to predict the meridional overturning circulation accurately.

Besides, using a three-dimensional, primitive equation numerical model that takes into account realistic topography, we have carried out numerical simulation of the transient response of the Kuroshio

leading to the large meander formation. It has been found that baroclinic instability enhanced over the local topographic feature, Koshu-Seamount, located ~ 200 km to the south of Cape Shiono-misaki, is the dominant mechanism for the rapid amplification of the Kuroshio meander leading to the large meander formation.

- Climate Dynamics

Using observational data such as in situ buoy data, reanalysis data, and satellite data and various models ranging from a simple model to GCMs (general circulation models), tropical air-sea interaction has been studied. In particular, the role of intraseasonal oscillations in the IOD (Indian Ocean Dipole), the relationship between the ENSO (El Niño-Southern Oscillation) and the IOD, and the unique teleconnection associated with the IOD are investigated. Furthermore, as part of CGCM (coupled GCM) validation, the effect of IOD on the interannual variation of East African short rain is examined. More recently, the decadal modulation in the IOD is investigated. It is shown that the variations in the Indonesian Throughflow and the Mascarene High play an important role in determining the heat budget of the tropical Indian Ocean, and thus the decadal modulation. Also, the mechanism of the subtropical dipole mode of the Indian Ocean, which is closely associated with the fluctuations in the Mascarene High, is clarified.

The variations in near-surface circulation of the warm pool region of the tropical Indian and Pacific Oceans are investigated using a high-resolution OGCM and observational data. In particular, it is shown that intraseasonal oscillations that appear as a form of various equatorial waves are more dominant compared with the previously focused seasonal variation in the eastern equatorial Indian Ocean. These intraseasonal oscillations also affect the circulation in the Indonesian Seas via coastal Kelvin waves that propagate along the Indonesian coast. Moreover, the forced Rossby waves in the southern subtropical Indian Ocean, the generation of instability eddies off the coast of Mindanao Island in the western tropical Pacific and their intrusion into the Indonesian Seas, and the coastally trapped waves around Australia that incorporate the effect of mid-latitudes into the tropics are shown to influence the circulation in the warm pool region.

On the other hand, in the tropical Pacific, the existence of “El Niño Modoki”, which is different from the well-known El Niño, is revealed from observational data analysis, and its unique structure and teleconnection are clarified. In addition, a detailed analysis of the generation mechanism of the warm anomaly that destroys the Mindanao Dome revealed an existence of a basin-scale seasonal air-sea interaction, “Annual ENSO”, which is associated with seasonal variations in the southern oscillation, wind stress, sea level, and outgoing long-wave radiation. It is also demonstrated that the decadal variation in the characteristics of ENSO is explained by changes in the relative amplitude of the annual ENSO mode and the interannual ENSO mode. Moreover, an importance of processes in the South Pacific for the decadal ENSO-like variability is shown for the first time.

Various phenomena in the Atlantic Ocean are also studied. The generation and propagation mechanism of a lens-like eddy called “Meddy” are investigated. Also, seasonal and interannual variations of the Angola Dome and its relation to climate modes in the tropical Atlantic are examined.

Finally, the small meanders of the Kuroshio south of Kyushu, which trigger the large meander of the Kuroshio, are successfully reproduced by a high-resolution North Pacific basin model. It turns out that the generation of the small meander is strongly dependent on the vorticity generation at the Tokara Strait and associated with anticyclonic eddies that propagate northward along the Kuroshio path in the East China Sea.

Above results contribute significantly to an enhancement in our understanding of climate variability

and an improvement its predictability. Our original ocean-atmosphere CGCM has also been developed, and it is successful in reproducing air-sea coupled phenomena such as the ENSO and the IOD.

- Ocean-Atmosphere Material Circulation Physics

This research group has been studying key processes of transport and chemistry controlling spatial and temporal variations of atmospheric ozone (O3) and aerosols, which play critical role for climate and air quality changes. First, three major sources of tropospheric reactive nitrogen have been investigated by aircraft measurements and their impacts on ozone chemistry have been evaluated. In the tropics, it was found that lightning NO production caused by convection over land significantly increases reactive nitrogen levels in the free troposphere (FT). It was also discovered that convection over the ocean has opposite impact by pumping air with lowers levels of O3 and its precursor species up to the FT. In the mid-latitudes upper troposphere, aircraft emissions are considered to be large sources of reactive nitrogen. Aircraft measurements were carried out over the North Atlantic Flight Corridor region and the first quantitative estimate of large-scale impact was made. In the mid-latitudes, anthropogenic emission is the greatest source of reactive nitrogen and its impact over East Asian countries has also been studied. Because of a rapid growth in air traffic and anthropogenic emission rate in East Asia in recent years, these results provide important scientific bases for evaluation on their impacts. Second, transport processes of air influenced by anthropogenic emissions over East Asia have been studied. In late-spring, vertical transport in a quasi-stationary frontal zone over central China efficiently export pollutants to western Pacific. This process was confirmed by enhancements of various anthropogenic species in the FT from aircraft measurements. The results obtained by these studies clearly show an importance of systematic understanding of locations of anthropogenic emissions and those where vertical transport is active. Third, in the stratospheric research, an evidence of redistribution process of reactive nitrogen (gravitational sedimentation of nitrogen containing aerosols and their evaporation at lower altitudes), which is one of the key processes to elongate the period of polar O3 loss in spring, was obtained from aircraft measurements over the Arctic.

Several new progresses have been made in oceanic material science as well. Oceanic material circulation processes in the North Pacific were studied by observations and modeling, in order to elucidate oceanic carbon cycle and marine ecosystem. In cooperation with other oceanographic laboratories, intensive oceanic observations of current, water, heat etc were carried out. As a result, it is revealed that North Pacific Intermediate Water characterized by intermediate salinity minimum is formed by the direct transport from subarctic to subtropical gyres and that a part of the intermediate water returns to subarctic gyre and forms intermediate temperature maximum water. Anthropogenic carbon transport was estimated based on the observation. Theories about this cross-gyre process considering strong tidal mixing and diapycnal transport around the Kuril Islands were proposed.

(b) Space and Planetary Science group

Objective

We, the space and planetary science group, have conducted research and education to comprehensively understand both the unique and the common characteristics of elementary physical processes, structures, compositions, and dynamics in various regions of planets, planetospheres, the heliosphere, and space, and also the interactions among those regions. To accomplish these objectives,

we have systematically combined theoretical means including numerical simulation, observational means including in-situ observations by artificial satellites and planets, planetary orbiters, sounding rockets, balloons, ground equipment, as well as simulation experiments in ground laboratories. This group consists of five subgroups, “Space Physics”, “Magnetospheric Physics”, “Observational Planetology”, “Comparative Planetology”, and “Planetary Material Science”.

Acheivement

The two subgroups of space physics and magnetospheric physics among those in the Space and Planetary Group have the closest relation and share research interests in various plasma processes (heating/acceleration/transport/mixing processes, magnetic reconnection, Kelvin-Helmholtz instability, ballooning mode instability, auroral formation process in the regions of shocks, current sheets, and velocity shear layers). Following the decade of 1990’s when the studies in Japan led the worldwide research activity in this field based on the successful projects such as Geotail satellite, these 6 years between 2000 and 2005 were the period when the deep and mature research developments were obtained. It is now common view not only in this field but also in the neighboring fields such as astronomy and astrophysics, that the heliosphere is an ideal in situ laboratory, in which one can study various plasma processes keeping a high level of generality. For example, studies of heliospheric shocks and relating phenomena have been closely related to the cosmic ray origin processes which are thought to occur in supernova shock environments. The achievements on elementary shock acceleration processes by the members of this subgroup attracted a keen attention from astrophysical community especially after 1995 when the nonthermal X-ray features was identified in supernova remnants, and thus contributed to enhance a cross-disciplinary research interaction. Similarly, studies of magnetic reconnection in the earth’s magnetosphere have provided a firm basis for understanding of magnetic energy releases in cosmic events such as solar flares and pulsar/magnetar magnetopheres. For several international workshops on magnetic reconnection held in these 6 years the members of this subgroup played the major role in their organizations through an intensive collaboration with researchers of laboratory fusion as well as those of astrophysical plasmas. A remarkable event occurred in December 2004, where a giant flare in a magnetar, namely a strongly magnetized neutron star, some 10kpc away directly affected the earth’s environment via an extremely strong gamma ray flux. The research achievement for this extreme event by the members of this subgroup obtained a worldwide attention.

In the area of planetary explorer, it was quite unfortunate that “NOZOMI” (PLANET-B) spacecraft had to give up its injection into orbit around Mars due to unrecoverable malfunctions of communication and propulsion systems. During its interplanetary cruising period, however, NOZOMI brought a number of new scientific results, such as measurement of lunar albedo and interactions of interplanetary- heliosphere gas. From these studies, three students earned doctorates successfully. As for ongoing project, the members of this subgroup have developed a near-infrared telescope for Venus Climate Orbiter (Planet-C) project as well as ground-based infrastructure for cooperative observations. It is noted that during the initial ground-based optical observation of oxygen molecules in the Venus atmosphere these members found a significant enhancement of oxygen intensity around the anti-solar point, suggesting the adiabatic or chemical heating there.

The members of the subgroups, Comparative Planetology and Planetary Material Science, have developed techniques of isotopic and trace element analyses using Secondary Ion Mass Spectrometry (SIMS) and obtained fruitful results for meteorites and their constituents, e.g., in the studies of stable isotopes (e.g., O-isotopic study of refractory inclusions and chondrules, Mg and Si isotopic studies to

understand evaporation/ condensation processes, studies of isotopic heterogeneity in the early solar system using Ca and Ti isotopes), early solar chronology (chronological studies using various short-lived nuclides, such as 26Al-26Mg, 53Mn-53Cr, 10Be-10B, 41Ca-41K, 60Fe-60Ni systems), and studies of rare earth elements (REEs) and trace elements (e.g., study of condensation and fractionation processes of REEs and other elements in refractory inclusions). In addition, these members also have obtained good results for thermal histories of asteroids and meteorite parent bodies, detailed cooling history of chondrules in unequilibrated chondrites formed in the early stage of evolution of primitive solar system, spectral changes by the differences in metamorphic temperature or in oxygen-fugacity for the diffuse reflectance spectra of meteorites on the basis of high-temperature heating experiments,evaluation of Fe-Mg and Ca diffusion coefficients that are fundamental variables for calculation of the cooling rate, and application of micro laser Raman spectroscopy to Martian meteorites. Especially, formation models of many Martian meteorites were proposed by using crystallization experiments and detailed mineral analyses in terms of crystallization of magmas. Heating experiments of shocked plagioclase in Martian meteorites revealed their shock metamorphism and subsequent thermal metamorphism, which could apply to lunar materials. Furthermore, direct evidence was discovered for the formation of achondrite meteorites by partial melting of carbonaceous chondrites.

(c) Earth and Planetary System Science group

Objective

The Earth system is complex and is consisted with several subsystems such as the atmosphere, the ocean, the solid Earth, and the biosphere. Geological events that we observe are controlled ultimately by external forcing, such as the one from the sun and from the interaction within the subsystems. Formation of the present conditions of the Earth and other planets were also depends on the unique evolutional pathways that they have been gone through. Some of the phenomena in the Earth system are common in other planetary systems and hence the knowledge we gather on the Earth could be applied to study planetary systems. The current status of the Earth is strongly influenced by human activities due to the emission of greenhouse gasses which may cause significant irreversible changes in the future Earth system. The role of the humanosphere on the Earth's environmental systems is therefore to be investigated.

Our aim of research and teaching activities are to understand the Earth and other planets as a system composed of closely coupled subsystems. Interactions of amongst subsystems are typically focused and instability of the systems have also been evaluating. Sample collections and observation campaigns at the field, data analysis, laboratory experiments and geophysical modeling are all important approaches to achieve our aim hence we have conducted the researches using these measures. The group consisted with 4 subgroups entitled as "Analysis of the Earth and Planetary System", "Evolution of the Earth and Planetary System", "Dynamics of the Earth and Planetary System" and "Dynamics of the Earth Surface Environment".

Acheivement

The sub groups of Earth and Planetary System Science group are closely linked and interacted effectively depending on the research subjects. In the body of the report which follows, therefore, we introduce the overviews of our research activities not by group by group but the topics.

- Origin and evolution of the solar system and the early Earth

As the Earth is a part of the solar system, we have been focusing on the interaction between evolution of the solar system and physical and chemical behavior of its constituents to understand entire history of the early Earth system. The subject includes, (1) how the solar system was born and had been evolved to form diverse planets, (2) how the early Earth had been evolved to constitute its present state, (3) what were the timescales of the evolutions of the early solar system and the early Earth, and (4) whether the evolution proceeded by necessity or by random chances.

Regarding the beginning of the solar system, we found down-to-Earth evidence of the formation of the sun in a star-cluster forming region using isotopic geochemical fingerprints which is the live 60Fe, short-lived radionuclide formed only in stars. The estimated abundance of 60Fe in the initial solar system is consistent with predictions for nucleosynthesis in a supernova explosion just before the solar-system formation. The finding shows that neighboring massive stars would have affected the formation of the solar system and its later evolution.

In order to evaluate the interaction between condensed materials and the radiation field and its evolution time scale of the early solar system, time scale of gas-solid reactions were studied by evaporation and condensation experiments on major planetary materials such as magnesian silicates and metallic iron. We obtained evaporation and condensation rates of metallic iron as a function of temperature and pressure of iron gas.

We will integrate the experimental results and hoping to develop the chemical evolution model of planetary materials including kinetics of phase transitions in a multi-phase and multi-component system. These results enable us to develop a quantitative model on the evolution of the solar nebula including condensed phase.

The evolution time scale of the early solar system and the relationship between gas and solid were studied by chemical and isotopic analyses of primitive chondrites. The results revealed that high-temperature chondrule -forming events lasted for ca. 2 million years over a wide range of the early solar system and that kinetic condensation of supersaturated melt droplets explains the chemical diversity of chondrules. These findings provide constraints on the time-dependent distribution of condensed materials, which formed diverse planets in the later stage, in the early solar system.

Regarding the evolution of the planets, the core formation, large-scale differentiation of the interior of planets was studied by using the constraints from Hf-W radiometric age. Modeling on the core formation, in which time scales of accretion, metal-silicate separation, oxidation, and reduction are compared, shows that the accretion time scale of Earth-forming proto-planets should have been shorter than 10 million years if oxidation and reduction processes were sluggish.

Most prominent feature of the Earth is the existence of liquid water. We have studied the evolution of the Earth with the particular interests on the presence of liquid water, which played important roles in the origin and evolution of terrestrial life. We identified the critical parameters of which terrestrial planets in the solar system obtained their own characteristics. We modeled the evolution of atmosphere of proto-planets during the planet-forming stage and showed that the evolutional pathways of atmosphere would be quite different between planets with and without an ocean and hence the escape of atmosphere is significantly enhanced by the presence of the ocean. This mechanism seems to be employed to explain well the difference of atmospheric compositions between Earth and Venus. We also showed theoretically that the potential of the substantial water contents of the Earth-forming materials during the passive stage of the disk evolution. We further indicated that the dry planet (ie. lesser amount of water) have a wider stability field of liquid water than those covered with the ocean.

- Evolution of the Earth system during the Archean and Proterozoic

It has been known that the major regime shifts have been occurred during these eons for the Earth system that has been seen in the various geological evidences. Irreversible evolution had been taken place during these periods as is categorized as one of the major transition for the Earth system in its history. The key issue that we should answer is to identify the mechanisms of the changes. That includes understanding the process, cause and the timing of the changes.

The magnetic field of the Earth which is generated and maintained by the dynamo effect in the outer core had become stronger since 2.6 Ga although there have been only a limited number of paleomagnetic data. Our measurements for Archean and early Proterozoic samples shows that the magnetic field strength was comparable to the one that we observe in the present level at ca. 3.5 Ga followed by the period of weakening of the strength gradually with time by ca. 2.6 Ga when the level is characterized as its sudden increase, and has been maintained at the same level until the present.

The marked rise of oxygen level in the atmosphere was occurred in the late Archean-early Proterozoic period as is categorized as one of the most significant events for the surface environments of the Earth system. Global glaciation so called "the snowball Earth" event would have also occurred in the same timing and hence we have been trying to untangle the mechanisms related to the problem of the evolution of life. We have been investigating the early Prorerozoic sedimentary rocks using sedimentological and geochemical approach under the collaboration with the group leading by the Prof. J. Kirschvink at California Institute of Technology. We have so far found the evidence of mass-independent isotopic fractionation of sulfur, which can be attributed to a existence of the reducing atmosphere, in the lowermost section of the Huronian Supergroup, Canada whereas the record of emergence of oxygen in atmosphere was found as the manganese anomaly in the upper part of the same sedimentary sections. These results provide a constraint on the timing and the process of the rise in the level of the atmospheric oxygen. Other studies such as paleomagnetic measurements on the rocks, carbon isotopic analysis on the sedimentary rocks and Re-Os radiometric dating have been also carrying out to reveal more comprehensive picture of the Earth during this period

Modeling studies on the process of the initiation of the snowball Earth status have been studied. Combined analyses of both climate models and the carbon cycle models indicated that the decrease in the volcanic CO2 degassing accompanied with the increase of the productivity in the ocean were responsible to trigger the snowball Earth in the late Proterozoic.

Comparisons of the other planetary climate system have also been made and the Martian climate system was investigated. We found that there are multiple steady states in the Martian climate system as is found in the terrestrial climate system. We also showed that the atmospheric pressure in the Martian system is strongly controlled by the presence of the polar ice cap and the climate jump would have occurred owing to the atmospheric escape and/or the obliquity variations.

- Changes in the Earth system during the Phanerozoic

The research topics enveloped within this subject cover the clarifications of the interactions between the surface environment and the dynamics of the interior of the solid Earth. Since relatively large number of geological evidences is available for this period, we are conducting geological investigations together with the geophysical modeling work to better understand the nature of interactions among the Earth's subsystems.

Modeling of the core-mantle interaction showed that fall of stagnant slabs into the lower deep mantle is responsible for the mantle dynamics during this eon. The Cretaceous superchron is one of the major targets for our study when the no reversal of the magnetic field has been occurred for ca. 40

million years. The cause of this geomagnetic chron has been investigating employing the powerful computational resource, the Earth Simulator. We are expecting to obtain the results to be clues to understand the mechanisms.

The biosphere had been experienced major changes during this period and repeated explosive evolution and mass extinction events were occurred. They could have been triggered by changes in the surface environments and/or the regime shifts in internal dynamics of the solid Earth. Relating to this subject, we have been intensively investigating the K/T-boundary mass extinction event triggered by the sudden changes of the surface environments induced by the asteroid impact. Detailed studies have been carried out to understand the incidents in particular for the first several months after the impact. The joint geological field survey between Japan and Cuba has been undergone and analyses of core samples taken by the Inter Continental Drilling Project (ICDP) from Mexico have been also made.

In order to understand the impact of variability of the solid Earth on the climate system, we have started the international projects entitled as "A research on the evolution and variability of Asian Monsoon and its linkage to tectonics (IGCP-476)". We synthesized the processes of uplift events of Himalaya-Tibet and evolution of Asian monsoon, and found that the uplift of Himalaya-Tibet played critical roles both in strengthening of the Asian Monsoon system and desertification of inland Asia.

- Quaternary environmental changes

Quaternary is the period of the last ca. 2 million years when the surface environment has repeatedly experienced dramatic changes. The existence of the huge ice sheets are characteristic features during this periods and the atmosphere, ocean and other partitions of the surface environments have been varied in harmony with waxes and wanes of the large ice sheets. Various components of the Earth's surface have been interacted each other in complex manners and hence it is the key to address to the problems for Quaternary using system scientific approaches.

To understand overall process of the surface environment, geophysical modeling is one of the better measures to outline the system. We developed the box model to describe marine biogeochemical carbon cycle for the last 300 kyrs. Atmospheric-Ocean and Ocean-Terrestrial biosphere interactions are considered in the model. It successfully reconstructed the oceanographic environmental changes and suggested possible mechanisms of drawdown of the atmospheric CO2 during the glacial which was the result of the lower surface productivities in the upper ocean leading to the lowering of carbonate flux to the deep sea which causes enhancements of sea water alkalinity.

Oceanic sediments serve various information to understand the past environments. We have collected the deep sea sediment cores and reconstructed the paleoenvironments using various proxies. Marginal seas are particularly targeted where terrestrial-oceanic interactions are expected to be preserved. We found the record of correlated variations of the Asian monsoon as well as the path of westerly in the deep sea cores from the Japan Sea with the rapid and repeated changes in North Atlantic climates during the last ice age as is known as "Dansgaard-Oschgar cycle (DO cycle)". Similar variations of the Asian monsoon in the present interglacial are also seen in the cores. The results suggested that the teleconnection of the rapid climate changes from the North Atlantic to the East Asia have been made via the atmosphere. The study of spatial variations of the rapid climate change is important to understand future global climate changes and hence further investigations on the cores are undertaken using biomarkers analyses. Mid to low latitude climate changes related to the high latitude glacial fluctuations are also actively studied by sea-level change and glacial rebound studies. More direct information for the polar region environmental changes have been collected using sediment cores retrieved from the Southern Ocean as well as the dating of glacio-geological remains using the

Terrestrial Cosmogenic Nuclides system.

High resolution paleoceanographic records at the low latitude can be recovered and we collected living as well as fossil corals from the Western Pacific. Our temperature and salinity reconstructions showed El Niño related large shift in sea surface temperature (SST) and the results obtained from the South China Sea indicated that the SST in this region was dominantly controlled by the Asian monsoon variations. A novel approach to reconstruct palaeo Sea Surface Salinity (SSS) was established by our group and it successfully reveals the regional distributions of palaeo precipitations related to ENSO. Radiocarbon in the coral skeletons is the proxy of the paleo upwelling and water mass distributions. Our group is now trying to understand the mechanisms of ENSO as well as the Indian dipole phoenomina using above mentioned approach combined with the climate models.

Geomagnetic studies during the Quaternary have been also conducted using volcanic rocks and lake sediments. Combined with the data taken at the sea-floor geomagnetic observatory with high resolution lake sediments records could separate the signal due to the changes in physical status of the core. We are trying to set up the numerical method to disclose the physical property of the fluid core which is in the turbulent status .

As briefly described in this part, our group studied the Quaternary environmental changes using interdisciplinary approaches. The most of the samples were collected from the Western Pacific but the eastern Pacific as well as Antarctic samples have been studied. Geophysical modeling are always employed to understand reconstructed high resolution data sets and they revealed the role of each components in the Earth systems quantitatively.

- Response of ecosystem and human activities to the global change

One of the major questions for the Earth and planetary system science in shorter time scale, typically less than a decade, is to evaluate the degree of impact of the human activities as well as the future changes on the ecosystems. We have targeted on the studies of the recent monsoon variations as well as changes in coral reefs using fieldwork-based approaches.

On the mechanism of present Asian monsoon climate, seasonal evolution of Asian monsoon is explained not from a simple meridional migration of the ITCZ. Seasonal, intraseasonal and diurnal variability of Southeast Asian monsoonal rainfall and water cycle has been analyzed and differences of monsoon climate between the Indian and Indochina monsoon have been revealed. Recent delay of the end of the Baiu season and the winter-time more prominent climatic contrast between the cloudy Japan Sea side and the sunny Pacific Ocean side in Japan has been pointed out in the seasonal changes of Japan occurred in the latter half of the past century.

As for the linkage between climatic environment and Earth surface phenomena in Asia, triggering factors of the mass blooming of flowers in the tropical rain-forest in the Malay Peninsular is not related to the El Niño event as previously believed, but to the coincidence of the low night time temperature and low humidity events caused in a particular synoptic conditions. The rice production variations in Bangladesh in the past 40 years are found to have no clear relationship with rainfall variations, unlike the situations in India and other monsoon countries. Instead, they are closely related with the flood regimes that is which the increase in the productions are observed in the dry season just after a large flood events. The influence of large flood events on rice productions extended to the succeeding rainy season which enhancement of the rice productivities are also found. Therefore, repeated occurrences of recent large floods have been responsible for the recent long-term increase in rice production in the region.

Mechanisms of self-sustainability of coral reefs have been studied through fieldwork-oriented

approach. We conducted a time-series observation of degradation and recovery of corals after the bleaching events by global warming. Measurements of changes in community metabolism and CO2 flux by using a newly developed continuous monitoring system for CO2, total inorganic carbon and alkalinity are also accompanied. We found two major changes in the corals reefs after the campaigns namely a shift in coral reef community after the bleaching and the role of the coral reef from sink to source of CO2 due mainly to the decrease in community's metabolisms.

We have also been conducting the to assess vulnerability of atoll islands in the Pacific for future sea-level rise due to on going global warming. Combined efforts have been made to investigate this problem by various experts from areas of ecological sciences, coastal engineering, anthropology and the Earth system science. We discovered that the formation and sustainability of atoll islands are constrained mainly by two physical oceanographic factors namely sea level changes and calcium carbonate production of coral and foraminifera.

In the course of our research activities in this subject, we have been proposing countermeasures and adaptation strategies.

(d) Solid Earth Science group

Objective

Our group studies the Earth's interior, which consists of the crust, mantle, outer core and inner core. Strictly speaking, our group's name might appear slightly inaccurate, as the liquid outer core is included in the scope of our research. However the use of the term "solid" ("kotai" in Japanese) is traditional as a way of distinguishing research on the Earth's interior from research on oceanic and atmospheric science ("ryutai" or "taiki kayou" in Japanese), or on space and planetary science.

The Earth's interior is a large-scale complex system, whose component regions differ greatly, both physically and chemically. Our group studies the structure, composition and state of the Earth's interior, with the aim of achieving a better and more unified understanding of the various geophysical, geochemical, and geological processes operating on different temporal and spatial scales, and their interaction.

Our group is divided into six subgroups: Structure of the Earth's Interior, Dynamics of the Earth's Interior, Magma Dynamics, Global Tectonics, Dynamic Geomorphology, and Earthquake Physics. The first three subgroups mainly focus on structure and processes in the deep interior. The central topic of their research is how the structure of the Earth's interior controls dynamic processes and how the dynamic processes affect the Earth's internal structure. These subjects are addressed from the viewpoints of seismology, geodynamics and material science.

The latter three subgroups focus mainly on structure and processes near the Earth's surface. Their central research topic is the construction of theories to explain complexity and diversity in tectonic structure and crustal activity including earthquake occurrence, volcanic eruption and mountain building. These subjects are being addressed from geophysical, geological and geomorphological points of view.

Another key research topic is the thermo-mechanical coupling between dynamic processes in the mantle and dynamic processes in the crust. The Dynamics of the Earth's Interior, Magma Dynamics and Global Tectonics subgroups are collaborating to address this subject.

As Solid Earth Science covers diverse research fields. graduate education in Solid Earth Science is being conducted in collaboration with many faculty members from the Earthquake Research Institute and Ocean Research Institute, as well as a few faculty members from other Schools and Institutes.

- Structure of the Earth's Interior

  The goal of this subgroup is to determine the structure (density, compressibility, rigidity, viscosity, pressure, and temperature), composition, and state of the Earth's interior. The main approaches used by this group are seismological observations and high-pressure laboratory experiments on minerals. In order to obtain the most accurate possible models of the structure of the Earth's interior, we are directly analyzing seismic waveforms, as opposed to using only secondary data such as travel times or surface wave phase velocities. In order to analyze seismic waveforms we need efficient and accurate methods for calculating synthetic seismograms. Our subgroup has developed such computational techniques, and now is in the process of applying them to actual data to invert for 3-D Earth structure. Determining the Earth's 3-D structure has important implications for geodynamics. In order to be able to interpret these data properly, we need better knowledge of the behavior of minerals at the pressures and temperatures in the Earth's interior. We are studying mineral physics experimentally using facilities such as SPRING-8.

- Dynamics of the Earth's Interior

  From a dynamical point of view the Earth's interior consists of three coupled convective systems in the fluid outer core, the subsolidus mantle and the outermost solid shell. In the outer core magnetohydrodynamic motions generate the geomagnetic field. In the mantle, in addition to the global-scale thermal convection which is responsible for plate tectonics, there exist local-scale thermal plumes that cause hot-spot volcanism. At and near the Earth's surface, global plate motions, with accretion of new plate areas at oceanic ridges and consumption of old plate areas at oceanic trenches, are driven by gravitational forces arising from the thermal contraction associated with cooling. This subgroup aims to quantitatively understand the dynamic processes of these convective systems and the mechanism of interaction between them, namely the viscous, magnetic and topographic coupling at the core-mantle boundary and the viscous and thermo-mechanical coupling between plates and mantle convection, through the analysis of geophysical and geological data and large-scale computer simulation based on geophysical and geochemical models. This work is being carried out in collaboration with the Structure of the Earth's Interior and Magma Dynamics subgroups.

- Global Tectonics

  Tectonics is concerned with the nature and causes of the large-scale deformation of the lithosphere, ranging from the large deformations seen in mountain belts at plate boundary zones to the long wave deformation of plate interiors. Microscopic scale deformation is also very important to understand the basic processes of tectonics. Sea floor tectonics is a science of the Mesozoic and Cenozoic, whereas continental tectonics takes us back to the Archean. Among the major objectives of this subgroup are understanding how the lithosphere shortens, extends and flexes, and how bulk deformations are accomplished in the brittle upper crust, the ductile lower crust and in the lithospheric portion of the mantle. Areas of current particular interest are the tectonics of convergent margins and their evolution throughout the Earth's history.

- Magma Dynamics

  Magma is a product of melting of the Earth's (and planetary) interiors, which plays an important role in material and energy transport, and hence in the evolution of the Earth and planets. The research targets of this group range from the microscopic scale (e.g., behavior of elements and molecules in magma), to global scale phenomena related to magma generation, such as mantle convection-melting

systems. Consequently, a wide spectrum of methods and approaches are used: for example, spectroscopic observations of solid and melt, field surveys and sampling of rocks, high-pressure and temperature experiments, and numerical modeling of the processes. We are analyzing the role of magma in the Earth and planetary systems by combining all available methods and data.

- Dynamic Geomorphology

  The formation and evolution of the Earth's landforms continues to be one of the most important subjects in Earth science, but these processes are not yet fully understood. A deeper understanding of the Earth's morphology is a key to understanding geologic processes acting on other planets, because most observational data for the planets consists of surface morphology that was obtained by remote-sensing methods. The topography of the Earth's surface is controlled by both endogenic processes (plate interaction, magmatic activity, etc.) and by exogenic processes (weathering, erosion, etc.). As topographic features of increasingly larger length scales are considered, properties such as density, temperature, and rheology at progressively greater depths in the Earth's interior become important. Therefore, understanding of the Earth's morphology requires a multi-disciplinary collaboration by scientists from many different fields of Earth science. This subgroup consists of researchers from geomorphology, marine geology, and solid Earth physics. By combining geological/geophysical observations and modeling, we are seeking to understand the Earth's morphology from an essentially new point of view.

- Earthquake Physics

  The scientific goal of earthquake physics is the understanding of the physical process of earthquake generation, which consists of tectonic loading due to relative plate motion, quasi-static rupture nucleation, dynamic rupture propagation and stopping, and fault lithification and healing. In order to achieve this goal, our subgroup is conducting research and education on the mechanics of earthquakes, physics of earthquake rupture, crustal deformation due to faulting, theory and application of geophysical data inversion, and computer simulation of earthquake generation cycles. Graduate education in earthquake physics is being conducted in collaboration with faculty members from the Earthquake Research Institute. Research on computer simulation is being carried out in collaboration with the Crustal Activity Modeling Group of the Earth Simulator Project of the Ministry of Education, Culture, Sports, Science, and Technology and the Microscopic Simulation Group of ACES (APEC Cooperation for Earthquake Simulation).

Acheivement

- Structure of the Earth's Interior

  Our subgroup focused on developing and then applying new methods in the fields of seismology and mineral physics. In the former field, we developed several accurate and efficient numerical algorithms for computing synthetic seismograms in heterogeneous and irregular media. These algorithms are based on the fundamental theoretical results for optimally accurate numerical operators published by our group in the 1990s. We have released free software (available by downloading on the internet) for computing synthetic seismograms in spherically symmetric transversely isotropic Earth models. We are now applying our methods for forward and inverse modeling to inversion of observed seismic waveforms for the structure of the D" region (the region immediately above the Core-Mantle Boundary). In the field of mineral physics, we carried out in situ experimental studies using X-ray diffraction and Raman scattering spectroscopy in melts as well as in solid samples. These experiments

led to the discovery of pressure induced structural changes in silicate melt and phase transformation in dioxides.

- Dynamics of Earth's interior

  We investigated the mechanism of magmatic and metamorphic activity in the Earth's interior from the points of view of geology and physical chemistry. The dynamics and state of the Earth's interior were examined using information recorded in igneous and metamorphic rocks. We focused on field observations of magmatism and metamorphism, a simulation of mass flux in subduction zones, and a fundamental study of global scale water circulation. We also investigated the dynamics of the core. Numerical simulations for three-dimensional convection of a rotating spherical liquid metal were carried out. In particular, we tried to elucidate the characteristic features of rapidly rotating conducting fluid by analyzing linear and nonlinear magnetoconvection in the presence of a uniform magnetic field. We found some important phenomena such as the emergence of convective modes with peculiar equatorial symmetry, and magnetization of anticyclonic convection cells near the equatorial plane.

- Magma Dynamics

  During the last 6 years we quantitatively investigated the behavior of magma generation and fractionation on the basis of observation on natural systems. In researches on magma differentiation, understanding of the dynamics of crystal transport in melt has been deepened through investigation of crystal redistribution in sheet-like intrusions. In research on magma generation, mass balance equations for open magma system have been formulated to facilitate extraction of useful information from natural systems. This approach was applied to mantle peridotites and the role of material influx in magma generation was quantitatively evaluated. Additionally, conditions and the ascent process of the lithosphere and its relationship to magma generation have been quantitatively clarified by examining the spatial variation of pressure and temperature history of a peridotite complex. These results, have established a basis for comprehensive understanding of the dynamics of magma generation through coupling among material and thermal transport.

- Global Tectonics

  We focused on plate boundary processes at subduction zones. Integrated studies of geophysical observations in subduction zones and geological/material analyses of on-land fossil plate boundary rocks of accretionary complexes reveal factors controlling the up-dip limit of seismogenic zones. We also investigated the thermodynamics of solid-fluid interfaces and the diffusion process of faults in terms of visualization of pore structures and experiments. The purpose of this study was to reveal the effects of dehydration of the slab and H2O fluid diffusion on the transition between brittle and ductile deformation. We also developed descriptive methods for analyzing core samples obtained by drilling into fault rocks, and estimated the energy budget of recent earthquakes. A proposal for drilling at the seismogenic plate boundary of the Nankai Trough led by this subgroup was highly ranked by the Science Evaluation Committee of the Integrated Ocean Drilling Program in 2004 and is now ready to begin operations. Thus we made quite significant progress during this period.

- Dynamic geomorphology

  We investigated the rate of crustal shortening over the northeast Japan arc in the Quaternary by using data on fault geometry, surface deformation, and regional uplift. The geologic rate of crustal

shortening that we obtained is one order of magnitude smaller than the geodetically observed rate, implying that large decoupling events (comparable in magnitude with the 2004 Sumatra-Andaman earthquake) are necessary to release the large strain accumulated within the arc in the last ~100 years. This is being confirmed by recent paleoseismological studies. We also made progress in clarifying the topographic evolution of active orogenic belts from a geophysical viewpoint, through such studies as morphogenetic processes in convergent plate boundaries, effects of crustal deformation and denudation on the thermal structure of an orogen, theoretical displacement fields due to a dislocation in a multiple-layered viscoelastic medium, and inversion analyses based on ABIC (Akakike's Bayesian Information Criterion).

- Earthquake Physics

  We systematized inversion theory for geophysical data sets, and applied this theory to geodetic data for the 1923 Kanto earthquake to estimate the co- and inter-seismic slip distribution. This systematized theory was also applied to one cycle of the Nankai earthquake and we reconstructed the slip history along the plate boundary. We derived the basic equations for the physical process of earthquake generation and developed a simulation model for prediction of crustal movement using the "Earth Simulator" supercomputer. We also studied the stress field and energy budget during co-seismic slip along a fault on the basis of seismic data analysis, and explained the complexity of various sizes of earthquake hypocenters in terms of a fractal model.

(e) Geosphere and Biosphere Science group

Objective

This group will conduct research and education on the formation of geosphere materials, the evolution of the geosphere, the origin and evolution of life, and the fundamental processes of geosphere-biosphere interactions. This research will be based mainly on field observation, analysis of geological, mineralogical, and paleontological samples, and laboratory experiments using various techniques such as transmission electron microscopy, scanning electron microscopy, atomic force microscopy, electron probe and energy dispersion X-ray microanalyses, X-ray diffraction analysis, gas- and ICP-mass spectrometry, gas-chromatography, and amino-acid and DNA sequence analyses. The methodology and objectives of study in this group are, therefore, partly common with those in other groups, especially those of earth and planetary system science and of solid earth science, but we have a stronger intention to explore the interdisciplinary field between Earth Science and Biological Science than the other groups. Our research field has also an intimate relationship with human activity, since it focuses on the co-evolution between geosphere environments and life.

To perform our research and education, our group consists of five subfroups as described in detail below. Of course these subgroups are expected to collaborate intimately for the objectives of the group.

- Evolution of Geosphere Environments

  This subgroup aims to reconstruct the environmental evolution of the geosphere (the combination of the lithosphere, hydrosphere, and atmosphere) based on both field observations and laboratory experiments, from the viewpoint of sedimentology and geochemistry. This subgroup's work has the overall aim of clarifying the interrelation of the geosphere, biosphere, and the Earth's interior throughout the 4.6 billion years of the Earth's history. One of the important projects in this subgroup is

to present a general model of the short-term and long-term evolution of the geosphere, in terms of bio-productivity change, development of sedimentary basin and carbonate precipitation, and formation/dissociation of marine gas hydrates.

- Geosphere Material Science

  This subgroup will focus on the structure of materials (mainly minerals) at the Earth's surface, their formation mechanisms, and the fundamental processes of interaction between geosphere materials and solutions. This research will be investigated on the nanometer scale by X-ray diffraction analysis, electron microscopy, and related techniques. Currently important subjects are 1) crystal-chemical properties of geosphere materials such as zeolite, 2) atomic-resolution transmission electron microscopic studies of minerals and their fine structures, 3) fundamental dissolution and weathering reactions of silicate minerals and their effects on elemental transport, and 4) weathering in the Precambrian and the evolution of the atmosphere.

- Chemical Evolution of Geosphere and Biosphere

  This subgroup will study the origin and evolution of the chemical condition of the geosphere and biosphere in relation to the evolution of life, through the analysis of the origin of chemical variation of constituents of the geosphere and biosphere, processes and mechanism of transportation, concentration, and dispersion of materials, and microbial activity and organic production of geosphere and biosphere materials.

- Biosphere Material Science

  This subgroup will focus on the elemental reaction mechanisms between biological and inorganic materials down to the atomic and molecular level in order to better understand the origin of life and the interactions between life and the environment in the geosphere and biosphere. A specific focus involves study of organic-inorganic interactions and interface structures between biomolecules and crystals in the process of biomineralization.

- Paleobiology

  This subgroup will focus on biological aspects of extinct organisms based on comparative analysis of fossils and extant organisms. Its major goals are to better elucidate the tempo, mode and mechanism of morphological evolution of life throughout the Earth's history, and the role of life in the formation and evolution of the geosphere. Currently important subjects are 1) Study of early evolution and phylogeny of marine invertebrates with sufficient fossil record based on embryological, molecular biological, and paleontological data, 2) Life history of extant and fossil organisms using shell growth lines and stable isotopes, 3) Paleontological consideration on recovery of bio-diversity after mass extinction, and 4) Evolution of predator-prey relation after the "Mesozoic Marine Revolution".

Acheivement

- Evolution of Geosphere Environment

  This subgroup has been conducting the studies of the following subjects. (a) Elucidation of the mechanism and environmental change of the boundary events through the Upper Proterozoic to Paleozoic. Alborz Mountains of Iran and Yantze Gorge area of southern China are the main targets of our study. As a highlight, we proposed a model for the transition from the "Snow-ball earth"mode to "Cap carbonates" based on detailed field works and integrated geochemical studies.(b) Gas hydrate and

related phenomena such as methane seeps and chemosynthetic communities along the active margin have been intensively studied by several cruises and submersible dives. We identified ocean floor gas hydrates and magnificent methane plumes, ~600 m high, in the eastern margin of Japan Sea for the first time in Asia. (c) We developed new technique to identify and characterize archea and bacteria in modern and geologic sediment samples. We defined diversification and evolution of microbes. All these studies are combined and integrated to develop an innovative hypothesis of methane hydrate induced, catastrophic environmental change through the Earth history.

- Geosphere Material Science

  We have carried out researches into (1) structures and formation mechanisms of geosphere materials and (2) fundamental processes of solution-geosphere material interactions. (1) We have analyzed the atomic clusters in quasicrystals, glasses and oxide melts and developed the systematic understanding of complex structures. The crystal structures of the zeolites with organic cations were also systematically studied so as to realize the three-dimensional structural interaction based on the charge transfer and hydrogen bonding. (2) Dissolution/weathering of minerals have been applied to quantitative estimation of the evolution of atmospheric carbon dioxide and oxygen in the Precambrian by using the results of experiments, field work and simulation. We have carried out dissolution experiments of Fe-bearing silicates under oxic and anoxic conditions, and analyzed the differences in processes, rates and element redistribution between the two conditions. We have proposed a new model of oxygen evolution based on the results. To quantitatively estimate uranium transport at the Earth's surface, we have examined the relationships of solutions and the formation of secondary uranium minerals, and found the formation is related to weathering. The results reveal the mechanisms of long-term uranium transport in the field.

- Chemical Evolution of the Geosphere and Biosphere

  Geo-microbiology is one of the hottest topics in earth and planetary science and is strongly recommended by the previous external review committee to incorporate into our Geosphere and Biosphere Science group. In our subgroup, we aimed to understand the interlink between earth system and microbes living not only on the surface but also within the subsurface of the earth. Our research objectives during the last 6 years were: 1). Development of detection and quantification method for environmental microbial cells, 2). Exploration for microbes in deep-sea hydrothermal vents and sub-vent biosphere, and 3). Investigation of organic-chemical reaction under experimental hydrothermal condition. These topics include: 1).Visualization and quantification of microbes in natural environments that are essential for the comparison with chemical factors. We introduced several microbial detection methods based on the molecular and optical microscopic techniques and developed three novel methods to visualize and quantify microbial cells in specific seawater and marine sediment. 2). From 2000 to 2004, we led "Archaean Park Project: International Research Project on Interaction Between Sub-Vent Biosphere and Geo-Environments", which funded by the Ministry of Education, Culture, Science and Technology (MEXT), as the chief scientist of the project. We planned and conducted total 12 research cruises at Suiyo seamount in the Izu-Bonin Arc and Southern Mariana Trough backarc spreading center. As the result, we have been finding scales, structures, phisico-chemical environments, and microbial ecosystems in the both deep-sea hydrothermal systems. During these surveys, we conducted aseptic seafloor drilling using Benthic Multicoring System (BMS) and successfully recovered contamination-free cores for the first time in the world, and, 3). Experimental synthesis of low-molecular organic compounds which can be used as nutrients by hydrothermal microbes and experimental investigation on the behavior of microbial cells under hydrothermal condition have

beenconducted. We modified Seyfreid-type hydrothermal reaction system and developed an accumulator sampling device for time-series sampling from the reaction vessel, and demonstrated decomposition of cells and synthesis of organic materials at the hydrothermal condition.

- Biosphere Material Science

  Our subgroup has been interested in the properties of clay minerals relevant to chirality. We took the following two approaches on this topic: (1) to examine a possibility of chiral discrimination when the interlayer space of a smectite-type clay mineral is modified by chiral ionic molecules and (2) to obtain an evidence for the chiral structure of kaolinite crystals. As for the first approach, it has been revealed that an intercalation of a certain kind of metal complex forms a stereo-regular adsorption layer when it is intercalated into the interlayer space of a smectite clay. The conclusion has been derived from the fact that there is a remarkable difference in the adsorption amounts between an pure enantiomer and a racemic mixture of the same metal complex. This is most prominent when a metal complex possesses bulky ligands with low positive charge. These properties arise mainly from the stereochemical effects in the intermolecular interaction of intercalated molecules. The network structure of a phyllosilicate surface is believed to be an important factor for the occurrence of such effects. As a practical application, a clay ion-exchanged with a chiral metal complex has been shown to exhibit a remarkable ability of recognizing an adsorbing molecule. As for the second approach, the morphology of a kaolinite crystal has been investigated using electron back-scattered diffraction and high resolution of scanning electron microscopy. It has been intended to derive the crystal structure of a kaolinite crystal from morphological characteristics. On the other hand, in order to understand organic-inorganic interaction that is the fundamental of biomineralization, we made a series of the experiments to grow calcium carbonates and phosphates on organic thin films and several new insights were obtained from the experiments. The Electron back-scattering diffraction (EBSD) system was introduced to analyze polymorphs and crystallographic orientation of the crystals precipitated on the organic films. Furthermore, functions of intracrystalline proteins extracted from natural biominerals were investigated in collaborations with other groups in the University of Tokyo. Besides, fine structures in many clay minerals and related materials were elucidated mainly by using atomic-resolution transmission electron microscopy, the result of which were published in many papers and presented several international conferences.

- Paleobiology

  The Paleobiology subgroup has been conducting a variety of research on the topics of phylogeny, paleoecology and paleobiology based on the material of marine invertebrates and marine and terrestrial vertebrates. The main results include: (1) Paleobiological studies on the ammonoids (Mollusca; Cephalopoda), which had flourished since middle Paleozoic up to the end of the Mesozoic, provided following results, such as their comparative anatomy, developmental characteristics, morphological evolutionary features and high-level phylogenetic relationship, (2) Sclerochronological study on Holocene bivalves on the daily scale has clarified their response to the changes of marine environments as the change of their life history traits, (3) An overseas research on the marine Cretaceous in the northeastern Pacific coastal regions is currently in progress, and a synthesized chronostratigraphy and tempo-spatial distributions of marine biota is now being clarified, (4) Predator-prey interactions, an important factor for driving animals' evolution, were traced in the fossil records, and as a result, the start of shell-crushing predation is concluded to have intensified since the Paleogene, the timing much later than previously thought, (5) Studies of recovery after the mass extinction, based on the materials

of echinoderms, elasmobranches and trace fossils, have clarified geographically different timings in their recovery, (6) Development of the stalked crinoids were observed for the first time, and the phylogenetic implications were discussed.

4.2 Visiting Researchers

Numbers of visiting researchers who were supported by governmental or JSPS are listed below. The number of short-time visitors who stayed in our department just for one day is not summarized here.

	Period of stay : Less than 1 month	Period of stay : More than 1 month
FY2000	12	4
FY2001	5	2
FY2002	9	1
FY2003	23	7
FY2004	13	12

4.3 Patents obtained by the faculty members

Recently, we are encouraged to obtain patents, and although many of us are engaged in basic sciences, some members earned patents. Followings are the list of patents we obtained.

Inventor	Title	Patent Number
Kimoto, H., Kayanne, H., Nozaki, K. and Kudo, S.	Continuous gas extractor and free carbon dioxide and free total inorganic carbon analyze by use of the extractor	JP,3587724,B
Kayanne, H., Ikeda, Y., Nozaki, K. and Miyajima, T.	Methodology to suppress CO_2 generation from degradation of organic matter in water	JP,3714611,B
Sunamura M., Maruyama A., Kubo M. and Kurane R.	Organic coated filter and its application for monitoring microorganisms.	JP,2000-333668,A
Sunamura M., Maruyama A. and Kurane R.	Method for detection and quantification of microorganisms in solid structures	JP,2002-291499,A
Maruyama A., Higashihara T., Kitamura K., Sunamura M. and Kurane R.	Methods for assessing polluted and natural environment by molecular analysis	JP,2003-038199,A
Maruyama A., Higashihara T., Iizuka T., Miyako C., Kitamura K. and Sunamura M.	Novel oil degrading bacteria	JP,2004-159599,A

Inventor	Title	Patent Number
Yamagishi A., Tanaka I., Ogawa T. and Kutsuna H.	Compounds, Column packing materials, chromatographic columns, chromatogram, and methods of optical resolution	JP,2005-010112,A
Yamagishi A., Takushoku K. and Tamura K.	Odor sensors and its fabrication	JP,2004-184124,A
Yamagishi A., Tamura K. and Miyajima N.	Chiral dopants, liquid crystal materials including the corresponding chiral dopants and display devices	JP,2004-35627,A
Yamagishi A., Tamura K. and Sato H.	Syntheses of photo-responsive metal complexes with dibenzoylethnato ligands as a chiral dopant	2005-037051
Yamagishi A., Tamura K. and Sato H.	Photo-responsive chiral dopants and their application for memory devices	2005-037052

5 The 21st Century COE Program

Since the October of 2003 the Department of Earth and Planetary Science has urged the 21st Century COE program “Predictability of the Evolution and Variation of the Multi-sphere Earth System” to create a new research field “predictive Earth science” in cooperation with Earthquake Research Institute, Center for Climate System Research, and Ocean Research Institute. Our endeavor to establish an advanced research and educational center for predictive Earth science was highly valued by the COE Interim Evaluation Committee in 2005.

5.1 Purpose of the COE Program

The purpose of Earth and planetary science is to understand the present state and dynamics of the Earth and planets, their surrounding ocean and atmosphere and interplanetary space, reveal the past evolution history of the Earth, planets and life, and predict the future variation of the multi-sphere interactive Earth system. The method of research in Earth and planetary science is manifold, which includes field research and observation to understand diversity and complexity of nature, experiment, data analysis and theory to extract universal laws from diversity and complexity, and modeling and computer simulation to comprehend the total behavior of the Earth system. In order to advance such a manifold research and education in Earth and planetary science, we proposed the COE program for predictability of the evolution and variation of the multi-sphere Earth system.

The goal of our COE program is to create a new research field of predictive Earth science, and establish an advanced research and educational center that can promote the quest for predictability of the evolution and variation of the Earth system. Our planet has a unique, 4.6-billion-year history of evolution and variation due to necessity and contingency. By comparing actual Earth history based on geological records and virtual histories based on computer simulation, we can verify this necessity and contingency—that is, the predictability and unpredictability—of large-scale variations in the Earth’s past. Given this, and assuming Earth system stability for some perturbations, we might be able to predict future Earth system variations within a particular degree of uncertainty by integrating observations and computer simulations (Figure 5-1).

5.2 Structure for Promoting the COE Program

Twenty-two academic staffs in Department of Earth and Planetary Science, Earthquake Research Institute, Center for Climate System Research and Ocean research Institute compose a structure for promoting the COE program (Figure 5-2). The leader of the structure is Professor Toshio Yamagata at Department of Earth and Planetary Science. For education, all the academic staffs contribute to the establishment of an advanced course for predictive Earth science. For research, the 22 academic staffs take responsibility to promote the three research projects for the evolution of the Earth system, the dynamic process of the Earth’s interior, and the variation of the Earth’s environment in cooperating with seven COE post-doctoral fellows.

5.3 Products of the COE Program

Over the three years from 2003 to 2005 we have urged the COE program to establish an advanced research and educational center for the predictability of the evolution and variation of the multi-sphere Earth system, which is one of the most important scientific subjects in the 21st Century, and to create a new research field “predictive Earth science”. In a research aspect, for example, we have accomplished the state of the art for various problems such as the reproduction of the ice age cycle by a global climate model, the development of the computer simulation model for crustal activity in and around Japan, and the reproduction of the climate changes in the20th Century and the prediction of the global warming in the 21st Century associate with a global climate changes. In an educational aspect, we have established an advanced sub-course for predictive Earth science, and introduced an oversea internship system in the doctoral course of Department of the Earth and Planetary Science. Our endeavor to establish an advanced research and educational center for predictive Earth science was valued very high by the COE Interim Evaluation Committee in 2005.

5.3.1 Products in research

(a) Reproduction of the Ice Age Cycle by a Global Climate Change Model

A research group in CCSR has succeeded in reproducing the observe ice age cycle by using a global climate change model (Figure 5-3). They have also performed the computer simulation for the climate in the ice ages or the warm age by using an ocean-atmosphere global circulation model.

(b) Development of the Simulation Model for Crustal Activity in and around Japan

A research group in Department of Earth and Planetary Science has developed a prototype of the computer simulation model for crustal activity in and around Japan (Figure 5-4). By using this simulation model they performed the predictive simulation for the earthquake generation cycle at the source region of the 1968 Tokachi-oki earthquake. They have also revealed tectonic loading mechanism at plate boundary zones through the comparative study between the plate subduction zone in northeast Japan and the plate collision zone in Himalaya.

(c) Reproduction of the Climate Change in the 20th Century and the Prediction of the Global Warming in the 21st Century

A research group in CCSR has developed a global model to simulate climate changes in the time-scale of several hundred years with the highest resolution in the world. With this computer simulation model they have reproduced the climate change in the 20th Century and predict the global warning in the 21st Century (Figure 5-5).

5.3.2 Products in education

In order to quest for the predictability of the evolution and the variation of the multi-sphere interactive Earth system we need to combine various research methods from field research and observation to modeling and computer simulation under the common concept of predictive Earth science. For this purpose we have constructed a system to foster coming generation scientists in Earth and planetary science by establishing a new course of predictive Earth science and introducing the support systems of COE research assistant and overseas internship.

(a) The predictive Earth science course

From the April of 2004 we started the course of predictive Earth science as an advanced course common to the five special fields of Ocean & Atmosphere, Space & Planets, Earth and Planetary System, Solid Earth, and Geosphere & Biosphere. In this course we provide doctoral-course students with COE special lectures, teaching of advanced computer literacy, teaching of scientific English, and advanced lectures of predictive Earth science (Figure 5-6).

- COE Special Lecture Series

  From the April of 2004 we started the COE special lecture series by overseas invited leading scientists in the predictive Earth science course. The titles of the lectures are: Tectonics and Climate Evolution in Asia by Prof. Peter Clift and Prof. John Chappell, Thermodynamics for the Evolution of the Earth's Core by Prof. Stephane Labrosse, Three Lectures on the Pliocene Paradox (An Ice-Age Perspective on Global Warming) by Prof. George Philander, and Geodynamic by Prof. Dan Mckenzie.

- Teaching of Advanced Computer Literacy

  Since the importance of large-scale computer simulation increase more and more in predictive Earth science, we started the lecture of parallel computer programming and the related exercise of advance computer science by COE Associate Professor Kengo Nakajima.

- Teaching of Scientific English

  In order to enhance the ability of graduate students in scientific communication skill in English we started the exercise of scientific English by Professor Robert Geller and three professional teaching assistants from the April of 2004.

(b) The System of Overseas Internship

In order to enhance the internationality of graduate students through the experience in research at overseas universities or research institutes, we introduced the overseas internship system. During the period from the October of 2003 to the March of 2006 16 graduate students have visited overseas universities or research institutes to progress their researches.

(c) Employment of COE Research Assistants

We introduced the system of COE research assistant from the October of 2003. At present 45 excellent doctoral-course students are employed as COE research assistants, who are the core students in the predictive Earth science course.

5.4 International Meetings and Publications

For reference we list the COE international symposium and workshop held for 2003-2005 and the published matters below.

5.4.1 COE International symposium and workshop

International Symposium on Predictability of the Evolution and Variation of the Multi-scale Earth System, January 8 - 9, 2004, Sanjo Conference Hall, University of Tokyo.

International Workshop on Evolution and Predictability of the Earth System, July 9, 2004, University

Museum, University of Tokyo.

International Workshop on Geodynamics: Observation, Modeling, and Computer Simulation, October 14 - 15, 2004, Sanjo Conference Hall, University of Tokyo; October 16, 2004, Earthquake Research Institute, University of Tokyo.

International Workshop on Variability and Predictability of the Earth Climate System, January 26 - 27, 2005, Sanjo Conference Hall, University of Tokyo.

International Workshop on Energetic Particle Phenomena in Magnetosphere, March 3 - 5, 2005, Lecture Room 807A, Science Bldg 1, University Tokyo.

International Symposium on Predictability of the Evolution and Variation of the Multi-sphere Earth System, September 21-22, 2005, Sanjo Conference Hall, University of Tokyo.

5.4.2 Publications

The 21st Century COE Program: Predictability of the Evolution and Variation of the Multi-sphere Earth System, Report on the products for 2003-2004, The 21st Century Earth Science COE Program, University of Tokyo, 2005.

Predictability of the Evolution and Variation of the Multi-sphere Earth System, in The 21st Century COE Program in Tokyo University: Wisdom toward the Future, Chapter 7-4, pp237-244, Nikkei BP, 2006 (in Japanese).

Proceedings of 2003 International Symposium on Predictability of the Evolution and Variation of the Multi-scale Earth System, The 21st Century Earth Science COE Program, University of Tokyo, 2004.

Proceedings of 2004 International Workshop on Evolution and Predictability of the Earth System, The 21st Century Earth Science COE Program, University of Tokyo, 2004.

Proceedings of 2004 International Workshop on Geodynamics: Observation, Modeling, and Computer Simulation, The 21st Century Earth Science COE Program, University of Tokyo, 2005.

Proceedings of 2004 International Workshop on Variability and Predictability of the Earth Climate System, The 21st Century Earth Science COE Program, University of Tokyo, 2005.

Proceedings of 2005 International Symposium on Predictability of the Evolution and Variation of the Multi-sphere Earth System, The 21st Century Earth Science COE Program, University of Tokyo, 2005.

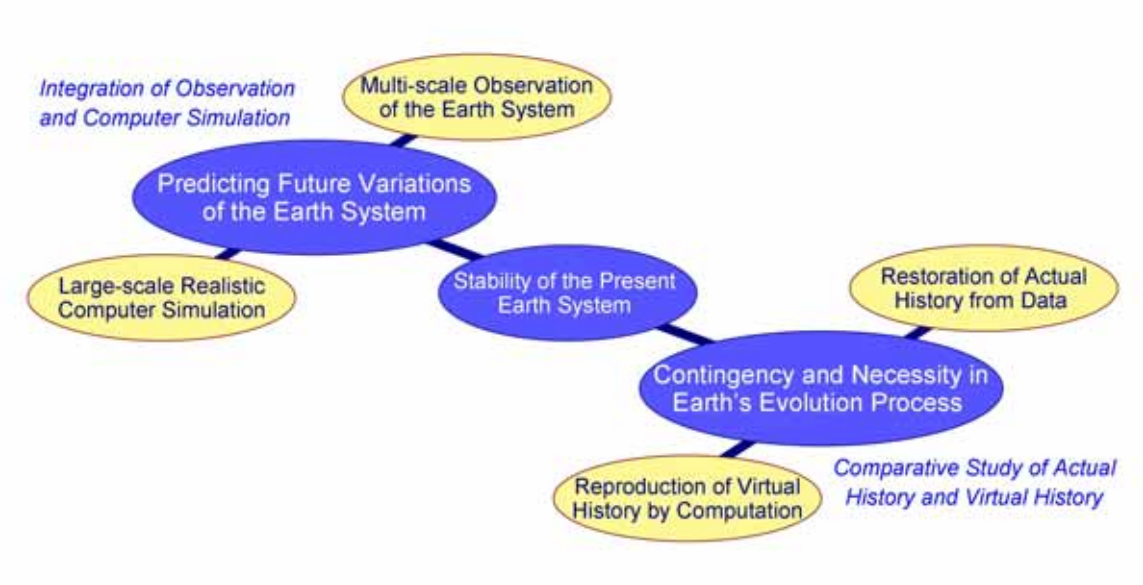

Figure 5-1. The basic concept of predictive Earth science: a science to investigate whether future Earth system variations are predictable or not by comparing observations and computer simulations.

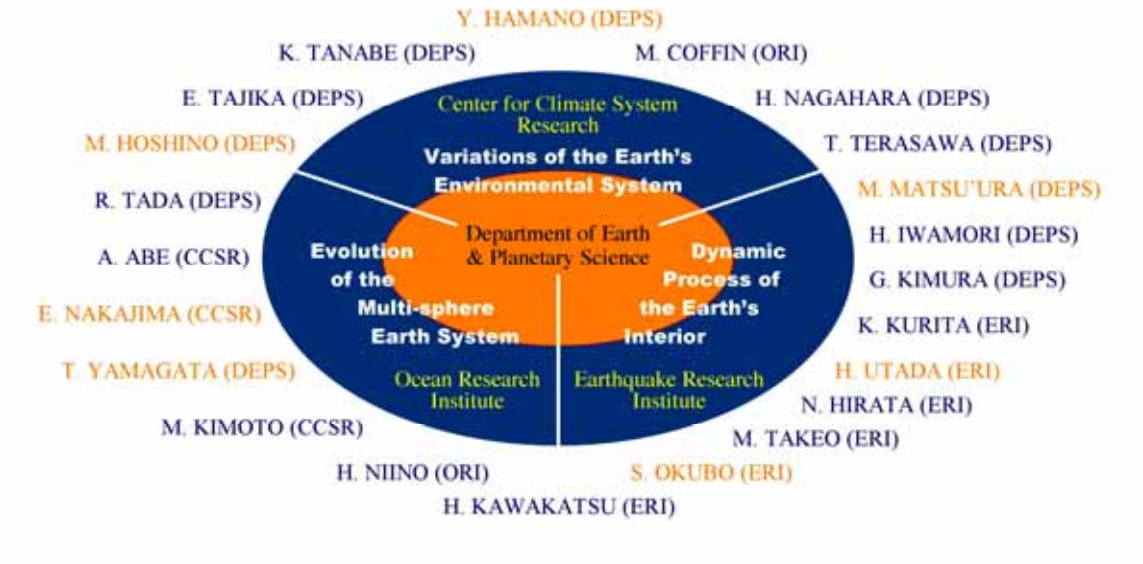

Figure 5-2. Structure for promoting the COE program. DEPS: Department of Earth and Planetary Science, ERI: Earthquake Research Institute, CCSR: Center for Climate System Research, ORI: Ocean Research Institute.

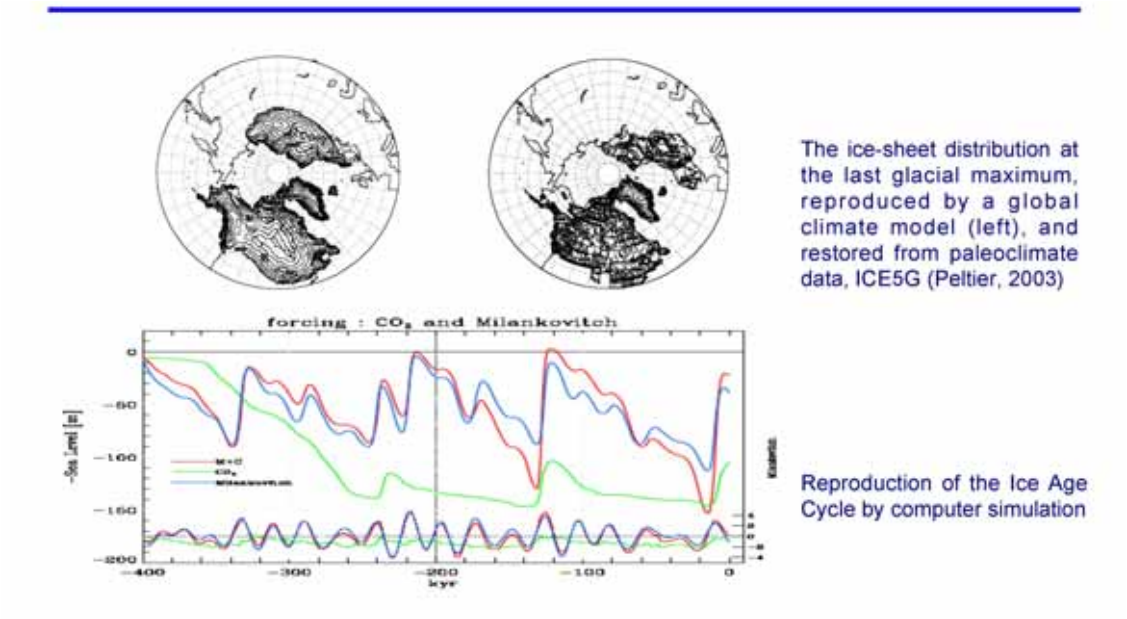

Figure 5-3. Reproduction of the ice age cycle by a global climate change model.

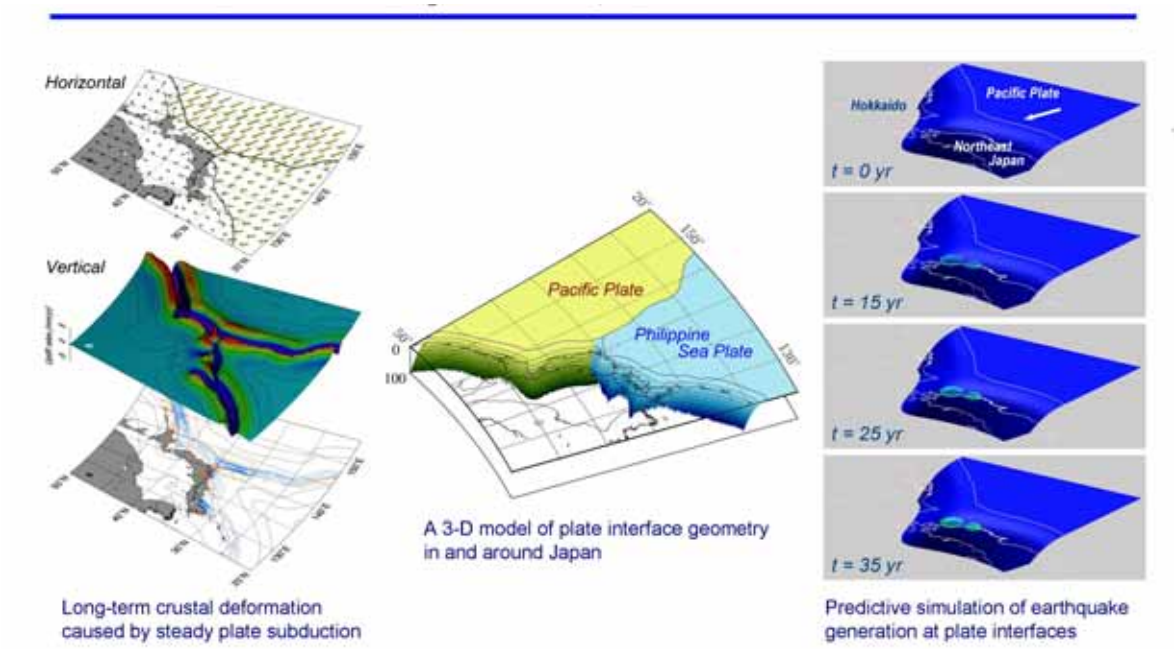

Figure 5-4. Development of the computer simulation model for crustal activity in and around Japan.

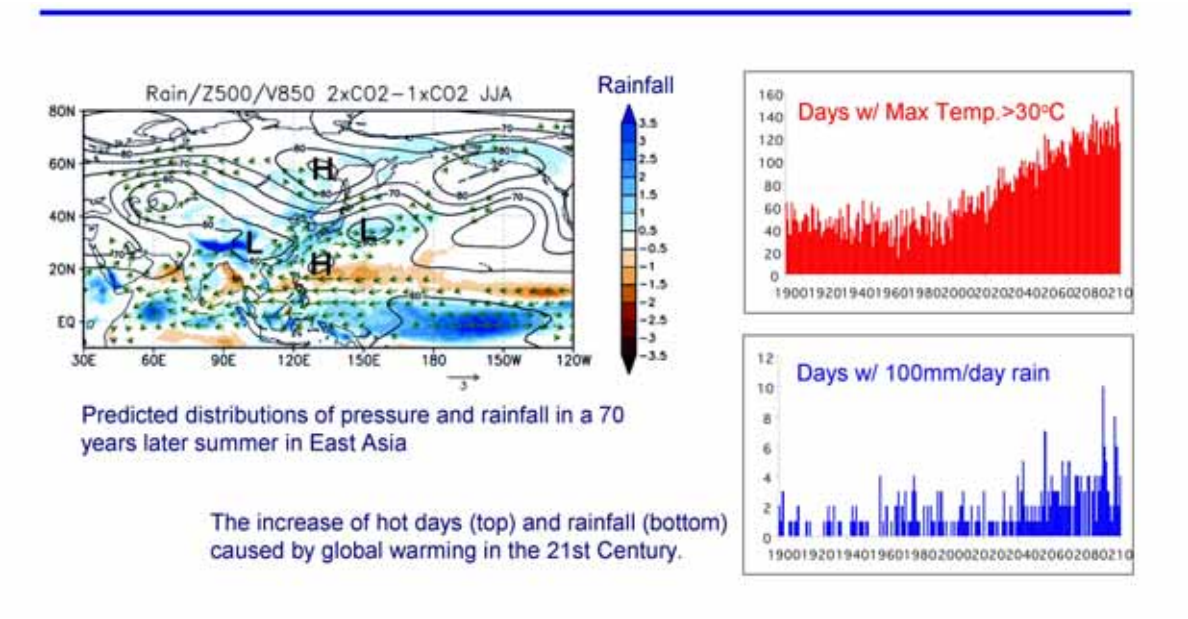

Figure 5-5. Reproduction of the climate change in the20th Century and the prediction of the global warming in the 21st Century.

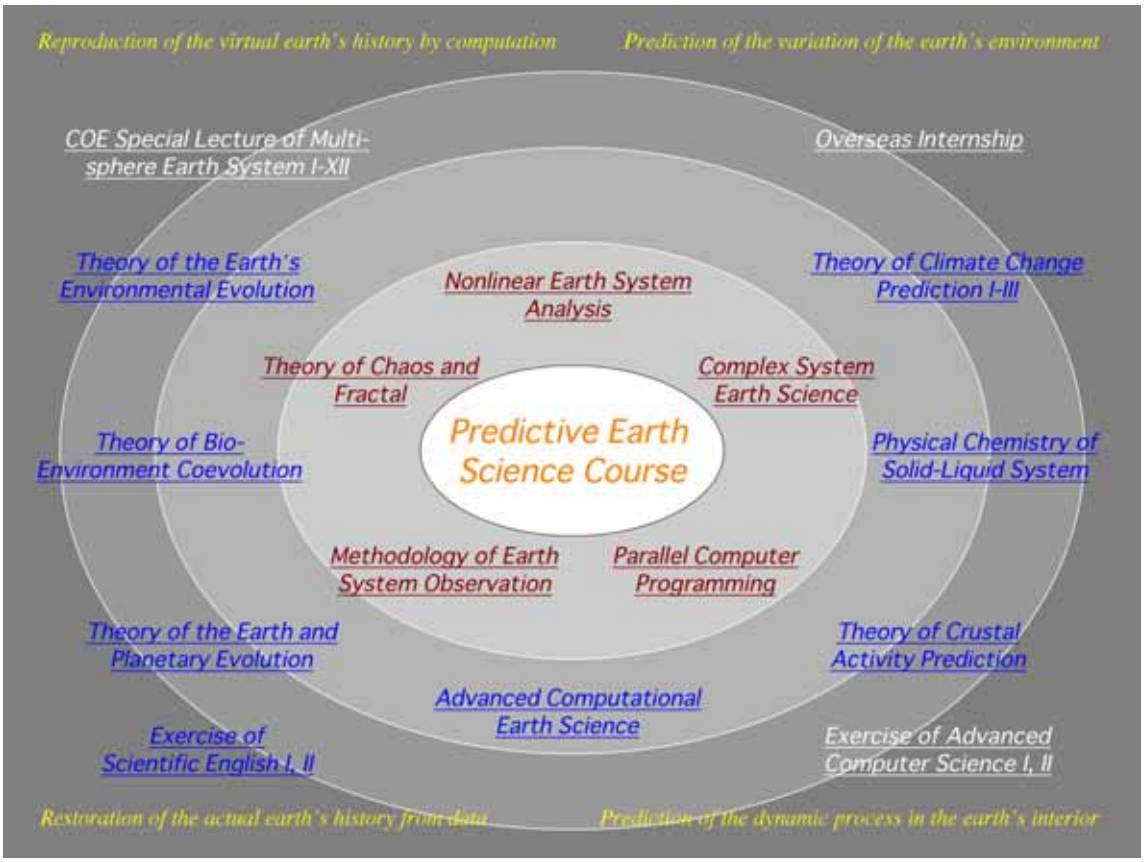

Figure 5-6. The curriculum of the predictive Earth science course

6 Response to the Previous External Review

6.1 Organization

The first point of the last external review is the construction of a new department by merging four earth and planetary science-related department to be capable of giving researches and education as an international standard of Earth and planetary sciences. We have successfully done it by overcoming the differences in scientific tools and educational systems inherited from the old four departments, which was achieved through the efforts by all the faculty members and supporting staffs. Three of five groups are mixtures of members from different old departments and have different educational backgrounds. They periodically have seminars to get mutual understanding, and graduate students continuously learn different way of thinking and different research tools to reach a common scientific goal. This was supported by the educational system for graduate course, which enables students to learn basics of other tools and way of thinking. After six years, all the students belonging to our department are educated in the new system, and they understand the policy of the department well.

The second point by the previous external review committee is the consolidation to one place, which was achieved last March. We were so fortunate to gather into a location with new building constructed next to building 1 of the Faculty of Science. Most of scientific and educational parts of Geosciences were moved to the new building, which enabled us to promote well organized science and education along with mutual communication. The space was enlarged and most laboratories now have enough space to carry out experiments. Unfortunately, the space was not full enough, and educational part of the undergraduate programs remained in another two areas; the Earth and Planetary Physics Program is in the building #3 in the Asano area, and the Geological Science Program (now Earth and Planetary Environment Program) in the building #4, which is located just next to the building #1 and which is close enough to have daily contact between faculty members and students.

The third point is about the decrease in number of research associates. This problem has, unfortunately not been solved, or yet getting worth. Japanese government has kept a policy to decrease the number of governmental employees, and national universities are not exceptions. The total number of faculty members (and also supporting staffs) continues to decrease, and will decrease further. Because we can employ either a professor, an associate professor, or a research associate with the position of professor, but cannot employ a professor with the position of research associate, we have no choice but should decrease a number of research associates. This is one of the most serious problems for us as well as the problem shown next and budget cut by the government.

The fourth point is an increase of the supporting staff members, which is in the quite same situation as above. The number of supporting staff is decreasing seriously, and we have to employ temporal staffs with parttime contracts. Although this is a general trend of Japanese universities, we were fortunate to make up for two vacant positions of technicians after April 2006; one will engage in transmission electron microscopes, and another will engage in ion microprobe and mass spectrometer. Both of them have master's degree at chemistry, and are expected to contribute significantly to our research.

The fifth problem is internationality of our sciences. Now all faculty members write papers in English to submit them into international journals, which is clear in the list of publications during 2000-2005 (Chapter 8).

The sixth point is about reorganization of the department. We think we are still in the course of construction, and therefore have not yet seriously considered the reorganization of the department in the

future. The decrease of the faculty members, however, may force us to reorganize the department in several years.

The seventh point is cooperation with affiliated institutions. The relationship between those institutions has been strengthened mostly through the education system and the COE program. About one third of the graduate students belong to the affiliated institutions, Earthquake Research Institute, Ocean Research Institute, Center for Climite System Research, and the Institute for Solid State Physics of the University of Tokyo and Japan Aerospace Exploration Agency, and therefore, the education system has been constructed and organized by a committee consisting of members from all the institutions in addition to the core faculty members. The oral presentation for entrance examination and for master and doctor theses is done at a meeting where both faculty members and graduate students attend. The final decision of pass or fail of the entrance examinations for the masters and doctoral courses and those of masters and doctoral theses are made at meetings gathered by all the faculty members, where each thesis is introduced. The interaction between the affiliated institutions has been strengthened through these processes. Furthermore, the COE program is promoted by the core part of the department and Earthquake Research Institute and Ocean Research Institute, which makes the interaction active.

The eighth point is the promotion of appointment of foreign and female faculty staffs. This has been satisfactorily done in these six years. Just before construction of the department, Robert J. Geller was promoted to a professor, who is the only one permanent foreign professor in the Faculty of Science, the University of Tokyo, and we have appointed Joseph L. Kirshvink from CALTECH from 2001 to 2003 as a professor. Also Hiroko Nagahara was promoted to a professor in 2001 we have appointed Kaoru Sato in 2005 as a professor, who is as young as 43 years old. The Earth and Planetary Science is the only department that has two female professors in the Graduate School of Science. The increase in number of foreign or female professors are important to enlarge the diversities of science or way of thinking, and particularly to encourage foreign or female graduate students.

The ninth point is to ensure the time for research. This problem has not been improved or rather worsened. The decrease in the faculty members, supporting staff, and budget due mainly to the governmental policy and social requirement for universities make us spend much time for administration or social activities. Although all of them are important activities, the increase of these activities reduces time for research.

6.2 Education

(a) Undergraduate Programs

In the previous review, the committee recommended mandatory cross-fertilization between the physics/applied mathematically based program and the geologically based program. They also pointed out the importance in the experience of the basic experiments.

Just following this recommendation, both the Earth and Planetary Physics Program and Geological Sciences Program modified their curriculum including the introduction of some cross-program lectures, however, such treatment was not enough. Therefore, the department started consideration of more thorough change. From FY2006, the Geological Sciences Program is reorganized into the Earth and Planetary Environmental Science Program and unified two courses in Geological Sciences Program, Geology and Mineralogy Course and Geography Course, into one. Simultaneously, drastic reorganization of the curriculum is conducted in Earth and Planetary Environmental Science Program to

put more emphasis on basic education of field survey, visual observation of geological materials, and to include more elements of chemistry and biology relevant to earth and planetary science. Concurrent with this reorganization, the department also conducted reorganization of curriculum of Earth and Planetary Physics Program to put more emphasis on basic education of physics and applied mathematics. Exercises and experiments are expanded, and lecture courses are refined and reduced. Several subjects which were not covered in previous curriculums of the two programs was added, and the linkage between the two programs was strengthened by setting introductory and basic subjects common to both programs which afford much better link between two undergraduate programs, while too much overlapping between two programs was eliminated.

(b) Master Program

In the previous review, the importance of the master program was emphasized. In particular, the committee pointed the need to ensure smooth assimilation of students from diverse backgrounds and to widen students' horizons and recommended to make compulsory to take general introduction subject for all students. They also raised some concern over the number and relatively specialized nature of master level subjects, and relative deficit of interdisciplinary subjects. They advised team teaching for the larger introductory subjects as well as periodic rotation of teaching staffs so that the same staffs will not teach the same subjects for too long periods. The committee pointed the need of less narrow academic approaches in the early stage of the master program and of arrangement of an advisory staff for career counseling. Furthermore, the committee recommended to delay the time limit for students to fix their themes of master thesis to the end of the summer semester of their first year and widen the types of the theme so that master course will not become merely a preparation stage for the doctor course.

The department organized the curriculum to ensure smooth assimilation of students from diverse backgrounds and to widen students' horizons. The subjects are classified into introductory, basic, and advanced categories, which allows students to understand the curriculum structure easily and to choose appropriate subjects in appropriate orders. As basic category subjects, undergraduate-level basic subjects and interdisciplinary introductory subjects are prepared as common subjects between the master and undergraduate programs. Most of these basic subjects are given by team teaching. On the other hand, periodic rotation of teaching staffs is not adopted because of limitation in number of staffs who can teach certain subjects. However, the department keeps paying attention to the results of evaluation of each subject by students to avoid potential bad effect mentioned by the committee. To avoid narrowing the academic approach in a too early stage, the department utilizes an advisory scheme in which the supervisors of the students are determined through the repeated interview with more than two faculty staffs in related research field within about three months after the examination. Besides, each research group provides students with a chance to present their progress report and organizes their advisory committees to widen their horizon.

In the new curriculum starting from FY2006, we reexamined the basics necessary to bring up both researcher-oriented and engineer-oriented experts with a wide scope, highly sophisticated technical knowledge and ability from the viewpoints of five research fields. The number of subjects is drastically decreased by eliminating too-much specialized contents. The department thus provides the program so that students can learn a systematic basement for their future research in a relatively short time as well as widen their horizon. In addition, the new curriculum introduces some new interdisciplinary subjects and flexible series of special lectures that can be used to present specialized contents.

The idea of delaying the time limit for students to fix their themes of master thesis to the end of the summer semester is not adopted. It is because job-hunting efforts by students generally start from December or January of the first year and usually last for several months, and delay in the start of master thesis work by half a year will unreasonably shorten available time for such students to work on their master theses. Even for those students who plan to go to doctoral program, half a year delay may have unfavorable influence on the preparation of application to JSPS DC-1 fellowship whose application deadline is early June in the second year of master course.

(c) Doctoral Program

In the previous review, the committee recommended that students should have an advisory committee including membership from outside their immediate research group. According to the recommendation, the advisory committee should be responsible for assessing the student's progress and an oral examination on the thesis proposal at the 18-month stage. The committee recommended the doctoral theses should be mandatory written in English.

In most research groups, an advisory committee is organized for each doctoral student, and students present their progress report in the middle of their second grade of the doctoral course. The advisory committee commonly includes membership from outside their immediate research group. The department requires the doctoral candidate to give oral presentation of the outline of the thesis two months before the submission. The presentation is examined by 6 to 20 members of the faculty including membership from outside their immediate research group. Only the candidates who passed this examination can submit their theses. In addition, the candidates are required to have more than one full research paper accepted in international journals as the principal author before submitting their thesis. In case this requirement will not be satisfied, the department requires writing a doctoral thesis in English. In most cases, theses are written in English even if the former requirement is satisfied.

6.3 Research

(a) Atmospheric and Oceanic Science group

The external review committee pointed out that the situation of the department distributed among widely separated buildings would severely hamper teaching and collaborative research. In the AOS group, three associate professors moved from the old science building to the new central science building on April 1, 2005, so that all the faculty members in the AOS group can be consolidated in a single location. This brought the AOS group significant improvement in the efficiency of teaching as well as cooperative research.

Following a recommendation from the external review committee, during the last 6 years, the AOS group has strengthened cooperative research with the Affiliated Institutions. For example, in one of the 21st-century COE program starting from 2003, the Climate Dynamics subgroup (the core research group for the program) has collaborated with a group in the Center for Climate System Research as well as in the Ocean Research Institute, and designed together a number of successful international symposia and workshops for climate changes, global warming, and paleoclimate. Furthermore, the Physical Oceanography subgroup has been involved in a cooperative research project (“Advanced parameterization of physical processes in the ocean and atmosphere” for a next-generation climate model using the Earth Simulator) with a group in the Ocean Research Institute since 2002, and the

Ocean-Atmosphere Material Circulation Physics subgroup has collaborated with a group in the Research Center for Advanced Science and Technology for several national and international research projects, such as the IMPACT experiment (http://noysun1.atmos.rcast.u-tokyo.ac.jp/IMPACT/) and NASA's GTE/TRACE-P aircraft experiment (http://www-gte.larc.nasa.gov/gte_fld.htm#TRACE).

The Department of Earth and Planetary Science received a recommendation from the external review committee to encourage recruitment of more female faculty in order to introduce fresh thinking and greater diversity. In the AOS group, we have hired one female faculty, Dr. Kaoru Sato, as a full professor of Atmospheric Physics since October 1, 2005. She is actually a second female full professor in the Department of Earth and Planetary Science.

The external review committee recommended that the local computational resources (workstations an network) should be upgraded and the space for the shared equipment should be improved in terms of ventilation. The computer room for the AOS group has been doubled to one large research room (about 60 m2) since April 1, 2005, as the new science building becomes available. This new room is equipped with a powerful air-conditioning system, to keep the air in the room cool and fresh, and with the Gigabit Ethernet and the optical fiber network connections. In addition, due to wide distribution of the inexpensive high-performance computers and our effort for getting competitive funds, our computer facility has been continuously updated and reinforced appropriately. Together with the super-computer at the university computer center, the available cpu resources are almost enough for our research purposes. However, there is still an issue for securing the disk spaces to save quite large amount of data that are used in the AOS group.

(b) Space and Planetary Science group

Research activity of this group in the past 6 years has been at a high level as the detail was described in the previous chapter.

The previous review committee pointed out that this group should not only cooperate more closely among group members but also actively explore cooperation with other groups and related research facilities and institutes both inside and outside the university (e.g., Laboratory for Earthquake Chemistry, Earthquake Research Institute, Institute of Space and Astronautical Science, National Astronomical Observatory of Japan). Following these suggestions, the members of this group have tried to expand their research activities with higher efficiency during these 6 years. These efforts have been gradually realized as exchanges of group members, who moved in (Associate Professors: Takaaki Yokoyama and Ichiro Yoshikawa) and out (Research Associate Seiji Sugita and Associate Professor Sho Sasaki) from/to National Astronomical Observatory of Japan, Institute of Space and Astronautical Science, and Graduate School of Frontier Science. This group is also trying to cooperate with Institute of Astronomy, Institute for Cosmic Ray Research, and High Temperature Plasma Center in both research and educational aspects.

The previous external review committee also suggested that it is beneficial and important to promote a big science mission under the collaboration with the Institute of Space and Astronautical Science (ISAS/JAXA). In fact the link to ISAS has been well-developed appeared to be mutually appreciated. Specifically, in the collaboration of the Geotail magnetosphere mission, several members at the University of Tokyo and Dr. Yoshikawa at ISAS (Associate Researcher at that time, now Associate Professor in our group) made a great contribution to the detection of an intense cosmic gamma-ray burst, for which the Geotail science team received the highest evaluation from General

Council on Science and Technology in fiscal year 2004. For ongoing programs, such as Solar-B (the third solar physics satellite with the launch schedule in 2006), SELENE (a lunar science satellite with the launch schedule in 2007), Planet-C (a Venus orbiter for the study of the planetary climate with the launch schedule in 2010), and BepiColombo Mercury mission (the first Euro-Japan joint mission to investigate Mercury), the participation of our group member has become crucial.

With the high reputation about the level of our faculty member, we are continuing the effort to maintain the high level of education and research among national universities. As stated above, in the last two appointment processes we could select two Associate Professors with the extremely high-quality talents. Currently, we are in the stage of selecting another Associate Professor, and we believe that a new high-talented researcher will join our group soon.

The previous external review committee noted an anxiety about maintaining the infrastructure of the laboratory experiment, but it was not possible to be solved only by the effort within our group members. After transformation into National University Corporations with a new system of executive decision and budget distribution, it is supposed to become more difficult to secure the maintenance budget of large experiment equipments such as SIMS (Secondary Ionization Mass Spectrometer). To enhance and expand our research activity, it is necessary to maintain strategically the experiment equipment as the effort of the Department as a whole.

(c) Earth and Planetary System Science group

The previous external reviews advised 4 major points namely (1) the group's role to activate department's ability to tackle interdisciplinary topics, (2) the study of linkage between the Sun's activity and the Earth's climate, (3) employment of the faculty members who received the PhD other than the University of Tokyo, and (4) enhancement of the field to study the cryosphere. We have set up and been continuously conducting collaborative projects actively within and outside of the Earth and Planetary Science departments as was described in the previous sections. We believe our department's activity has been much more enhanced due to our interactions. Under the collaboration of the National Institute of Polar Research as well as the Department of Nuclear Engineering and Managements, we are successfully able to quantify the trace amount of cosmogenic radionuclides in ice cores. Our preliminary results suggested that 36Cl in the ice cores clearly records 11 year cycles of the sun's activity. In 2002 and 2003, we appointed new faculty members who received the PhD from ANU (Australian National University) and Osaka University respectively. The lecturer appointed in 2002 is studying sea-level histories and the environmental changes in Antarctica that allows our group's ability to correlate low to mid latitude climate changes to the high latitude environmental events.

(d) Solid Earth Science group

The following is a list of the recommendations addressed directly to our group, or addressed to the department as a whole, but with a significant role for our group.

a. Research and teaching in the solid earth sciences would be enhanced by the inclusion of geochemistry.
b. Strengthening of experimental work will be needed to make a major contribution in areas such as the exploitation of synchrotron facilities.
c. A potential weakness is the isolation of the current work from observational studies.
d. It would be desirable to have a more coherent development of the Solid Earth component of the Graduate School of Science to provide a focused program that is internationally competitive and can sustain the reputation of The University of Tokyo.

e. The general directions of the components are well defined but some of the cross linkages should be reinforced.
f. It is important that a geochemical component be introduced either by future faculty appointments or by collaborations with geochemists in other institutions.
g. It would also be desirable for the work on the solid earth to have increased interaction with material scientists.

Response of our group:

The Solid Earth Science Group is subdivided into six subgroups, which are distinguished by their respective scientific targets and methodology. An appropriate balance between observation, experiment and theory is critical in research and educational activities being carried out by our group, as pointed by 1999 external review. Responding to the recommendations of the external review, two new faculty members joined our group in 2002. Their work links theory and observation in earthquake physics and global tectonics. An experimental mineral physicist was also promoted to associate professor in 2004. A Research Associate specializing in core magnetohydrodynamics was appointed in 2003. Research collaboration among the subgroups in the Solid Earth Science group has become stronger since the merger of the four old departments in April 2000, especially since the opening of the second phase of the No. 1 Building of the Faculty of Science in the spring of 2005 allowed almost all of our faculty and students to be physically contiguous. Research collaboration with affiliated institutes of the university: ERI (the Earthquake Research Institute), ORI (the Ocean Research Institute) and LEC （Laboratory for Earthquake Chemistry） has improved through collaboration on research projects such as the COE (Center of Excellence), Earthquake Prediction, and IODP (Integrated Ocean Drilling Program).

Collaboration with ERI, ORI, and ECI in education in solid earth science has improved greatly at both the graduate and undergraduate levels.

The external review recommended inclusion of or collaboration with geochemists and material scientists. As the number of faculty positions in our group is limited, we are strengthening our collaboration with geochemists at other institutions.

(e) Geosphere and Biosphere Science group

The principal scientific interest and the purpose of the education and research of the Biosphere and Geosphere Science group are to elucidate the evolution of the environment of the earth surface through the earth history from the view points of the interaction between biosphere and geosphere. It is critically important to enhance the collaboration with the experts of the inorganic and organic geochemistry and geomicrobiologists, in addition to the studies based on such conventional disciplines as sedimentology, stratigraphy, palaeontology, and mineralogy. The evaluation committee also pointed out that reinforcement of the geochemistry and microbiology field would fulfill the concept of our group. Seriously considering the evaluation, we invited a distinguished geochemistry-based expert and bioscience based microbiologist to our group. We would proudly conclude that our group has become a unique and leading part of the Department and even in an Earth and Planetary Science community in Japan as a group to develop the geoscience discipline toward the biogeoscience.

7 Plans for the Next Six Years

7.1 Organization

The largest theme will be the reorganization of group structure in our department. During these five years (2000-2005) the importance of the evolutional asepects of the Earth system including the biosphere has increased more and more in Earth and planetary science. The success of the 21st Century COE program “Predictability of the Evolution and the Variation of the Multi-Sphere Earth System” would indicate a direction of reorganizing the research and educational system of our Department. One of the most serious problems in the reorganization is the continuous decrease in number of faculty members, especifically that of research associates. It will make the retention of the present system difficult in several years. The total number of faculty members will decrease from 54 to 51 in three years, which is seven less than that at the beginning of the department. Although the size of each group is varied, the average number is 10 with 4 to 5 professors. This means that the each subgroup consists of one professor and one associate professor or research associate. Further decrease of total numbers means that one subgroup may have only one professor, which seems not to work. In this situation, we have to start discussing about the structure of groups. The present structure is, however, suitable for the promotion of present-day Earth and planetary sciences, and therefore, it will be necessary to strengthen relationship further with affiliated institutions for the reorganization of groups.

We will keep current appointment system of open competition to select most appropriate faculty members. The problem of decreasing staff members will last in coming years, which must be supported by funding from outside. The largest theme is the reorganization of group structure. The continuous decrease in the number of faculty members, specifically that of research associates will make the retention of the present system difficult in several years. The total faculty members number will decrease to 51 in three years, which is seven smaller than that at the beginning of the department. Although the size of the groups is varied, the averaging number is 10 with 4 to 5 professors. These numbers mean that the each small group consists of one professor and one associate professor or research associate. Further decrease of total numbers mean that one small group may have only one professor, which will do not work. Thus, we will have to start discussing the structure of groups. The present structure is, however, suitable for the promotion of present day Earth and planetary sciences, reorganization will require strengthening of the relationship between affiliated institutions.

We will keep current appointment system of open competition to get good members. The problem of decreasing stuff members will last in coming years, which must be supported by funding from outside.

7.2 Education

The Department of Earth and Planetary Science is planning to reform curriculum for the undergraduate programs, particularly, Earth and Planetary Environmental Science Program, and also curriculum for the graduate program in FY 2006. The drastic reform for Earth and Planetary Environmental Science Program is linked to the reorganization of the former Geological Sciences Program by merging its two courses and intended to strengthen basic educations in field survey and observation of geologic material and to include more elements of chemistry and biology relevant to

earth and planetary science. The department is also conducting curriculum reform for Earth and Planetary Physics Program to put more emphasis on basic education of physics and applied mathematics, compliment subjects that were not covered in previous curriculums of the two programs, as well as eliminated overlapping subjects, and strengthen the linkage between the two programs by setting introductory and basic subjects common to the two programs.

The renewal of curriculum of graduate program lays the foundation on basic education in the two undergraduate programs: basic physics and applied mathematics approaches in Earth and Planetary Physics Program and learning basic material science and natural history approaches in Earth and Planetary Environmental Science Program. Basic principles of the new curriculum are that the 2 years of master program, or 3 years including first year of doctor program, will be used to learn basic knowledge common to all areas of earth and planetary science as well as basic knowledge of specific research field that is essential for students to conduct researches on their own and that the doctor program is intended for students to nurture originality and creativity that are essential to promote cutting-edge sciences. According to these principles, introductory subjects, which allow for students graduated from undergraduate programs other than earth and planetary sciences to learn basic knowledge common to all specific fields of earth and planetary science, and basic subjects, which are especially useful to aquire basic knowledge of the specific research fields to conduct advanced research, are carefully reorganized in each research field by sorting out from the current subjects as well as adding new subjects if necessary. Most of introductory subjects are carefully organized such that more than two staffs are able to teach, which is intended to prevent students from getting into a specific field in very early stage of master course. Moreover, seriously taking the current situation that sufficient cutting-edge subjects have not been provided in doctor program, “Prediction in Earth Science Course”, COE special lecture series by leading foreign scientists, education on advanced computer literacy by COE teaching staffs, and English for Scientific Researchers by foreign assistants are to be extended so as to develop cutting-edge subjects that prospect the future of earth and planetary science in cooperation with 21st Century Earth Science COE Program “Predictability of the Evolution and Variation of the Multi-scale Earth System”,.

In this way, the department will launch the renewed educational programs for both the undergraduate and graduate courses from FY 2006, which has been developed on the basis of accumulation of experience and information during the last 6 years since its inauguration. After FY2006, educational effects of the new curriculum will be closely monitored through class evaluation by students, accumulating feedback from undergraduate students entering their third year and from successful candidates for the master course, and follow-up surveys on graduate students, which is exploited for further improvement of our educational system. The department is particularly keeping eyes on the drastic curriculum reform made for the undergraduate program of Earth and Planetary Environmental Science by conducting thorough surveys on outcome of new classes and exercises to make step-by-step improvements every year and by strengthening teaching staffs for subjects related to biological fields, which are one of the most important elements of Earth and Planetary Environmental Science Program.

7.3 Research Activities

(a) Atmospheric and Oceanic Science group

We believe research activities in the AOS group during the last 6 years went very smoothly as was

planned. The total number of published papers reaches about 240, most of which appeared in leading international journals. Five faculty members were awarded for their outstanding scientific achievements. The faculty members in the AOS group have also given, in total, about 60 invited talks in the international conferences and symposia, and accepted nearly 20 visiting scientists from all over the world, thus enhancing international interactions. Furthermore, under the supervision of the faculty members, 16 graduate students received D.Sc. degree and 27 graduate students received MS degree.

The primary goal of the AOS group is to produce achievements at a high international level in each subgroup's research as well as cooperative research not only between the AOS subgroups but also with the Affiliated Institutions (the Ocean Research Institute, the Center for Climate System Research, the Research Center for Advanced Science and Technology), national institutions (the Japan Aerospace Exploration Agency, the National Institute of Polar Research, the National Institute for Environmental Studies, etc), and foreign institutions (University of Hawaii, University of Washington, Princeton University, Seoul National University, Yonsei Univesity, Ocean University of China, etc). Through these research efforts, the AOS group aims to enhance knowledge on predictability of oceanic and atmospheric phenomena of great societal concern and provide leading figures in various fields of oceanic and atmospheric sciences.

(b) Space and Planetary Science group

We will keep the high level of the education and research activities based on our past 6 year's successful achievement. In this section, each research subgroup's objective is briefly described.

- Space Physics and Magnetospheric Physics

These groups will promote education and research from both theoretical and observational aspects. First, we are going to revisit the presently major paradigm for the particle acceleration mechanism, i.e. the acceleration of captured particles in a coherent electromagnetic field. The turbulent scattering effect as well as the reaction effect will be taken into account in this new project. The other research subject is a study of plasma physics including the relativistic and radiative effects. The development of theories on the dynamics of such high-energy plasmas is still under a progress although they are considered to be important recently. We will promote an inter-disciplinary collaboration with astrophysics and laboratory-physics groups on this subject. For the observational researches, we will take part in the SOLAR-B project to challenge the problems on the solar magnetic activities. We will also analyze the state-of-the-art magnetospheric data from the spacecraft including the SELENE satellite and prepare for the science by the future coming missions, e.g. the USA MMS mission , the Japanese SCOPE mission, and so on. The GEOTAIL data is still keeping its importance and is used for the long-term variation of the magnetosphere.

- Observational Planetology

As for the observational planetology, preparation and realization of extreme UV imaging of the Earth's magnetosphere should be the main target in the first half of coming 6 years. At the same time, preparation of the Venus mission should be advanced further. About the ground-based observation of Venus, those at Mauna Kea (where much more nights with clear sky may be expected than in Japan) should be performed in parallel to those in Japan. The development of the UV and visible sensors to be onboard the Mercury mission scheduled in early 2010s starts after setting up the fabricating and testing facilities.

- Comparative Planetology and Planetary Material Science

  In the fields of Comparative Planetology and Planetary Material Science, we will further develop our isotopic and trace element studies using SIMS to better understand the origin and evolution of early solar system materials. In order to financially support these studies, we will raise competitive funds from outside of the university. In addition, more detailed studies of reflectance spectra for meteorites and asteroids on the basis of both experimental and theoretical methods are needed for the future exploration of asteroids. A newly developed computer simulation for estimating cooling rates is applied to Martian meteorites and combination with Mars exploration data will greatly contribute to the promotion of Mars science. Employment of frontier analytical methods in material sciences should be planned to better understand planetary materials. As the NASA Stardust comet sample return mission will be back in 2006, variable returned planetary materials will be available in near future. Therefore, preparation for analysis of such planetary materials is necessary. As our next research target, we are also planning studies of various phenomena in the early solar system and the star formation regions, such as dust formation, electromagnetic interactions, and so on. Since understanding of these phenomena is the inter-disciplinary field of space physics and physics of magnetosphere, this will encourage our collaborative studies and will increase activities of the Space and Planetary Science Group as a whole.

- General concern

  It should be noted, however, that there is a growing concern about the difficulty in obtaining permanent research positions for graduate students, in spite of their important roles in keeping the high level research activity of the Space and Planetary Science Group for these 6 years. While this problem is far beyond what the group alone could contribute to solve, the group members recognize the importance of making appeals to the public for the improvement of job conditions for young scientists.

(c) Earth and Planetary System Science group

Our group was newly established to tackle the various interdisciplinary topics of Earth and planetary science when the Department of Earth and Planetary Science was reorganized its structure in 2000. The areas include the studies of interactions amongst the subsystems of the Earth in various timescales, planetary system evolutions, and the formation of the planets.

Due to the nature of our group, we have been actively collaborating with other groups and institutions depending on the research subjects. Hence we have been playing a pivotal role to produce internationally competitive scientific activities by the departmental staffs and we believe that the group achieved successfully these original aims.

We also encourage students to develop scientific perspectives that have not only single ended approach but also 2 or more alternatives to address their scientific problems. The alumni of our group are active in various fields after they developed their “system scientific perspectives” while they were in our group.

To promote the Earth and planetary system sciences, we published the book entitled as “Evolutions of Earth and Planetary Systems” in 2004. The book has been well accepted and it covered most of the aspects of Earth and planetary system sciences. We are trying to keep this momentums going and hoping to achieve cutting edge sciences of the Earth and planetary science field in our future activities.

(d) Solid Earth Science group

The sold earth science group will follow the following general guidelines for our future research.

a. The research objectives and subgroups will remain substantially the same for the next five years.

b. Research will be primarily conducted by each individual faculty member, but interaction and collaboration among the individual researchers and subgroups will be encouraged through seminars, and discussion.
c. Our group encourages its members to collaborate with other institutes of the university and with external institutions.
d. Our group encourages members to take leadership roles in international and domestic scientific programs.

The specific plan of each subgroup is as follows:

- Structure of the Earth's Interior

For the past few years we have developed optimally accurate numerical operators for simulation of seismic wave propagation in arbitrarily heterogeneous media with irregular boundaries. We are now focusing on applying these methods to inversion of seismic waveform data for global-scale Earth structure, with the D" layer (immediately above the core mantle boundary) and the mantle transition zone under the western Pacific and East Asia as the study regions. We also are seeking to apply our computational methods to problems arising in seismic exploration for oil and gas. We will also continue to develop new algorithms and software, and to release publicly available free software. In the field of high temperature-high pressure mineral physics, over the past few years we have succeeded in securing external funding for the necessary equipment for a state-of-the-art laboratory. We plan to use this equipment over the next few years to conduct experiments that will significantly augment present experimental data in high pressure-high temperature mineral physics. We also will work on developing original experimental methods. We plan to conduct collaborative research with theoreticians working on first-principles calculations.

- Dynamics of Earth's interior

This subgroup will conduct studies to better integrate and understand the geological processes occurring at subduction zones (seismicity, magmatism-metamorphism, deformation of arcs, orogeny, growth of continents). Based on the understanding we obtain from these studies, we aim to better understand the global circulation of materials. As for the dynamics of the core, which is in an ultimate turbulent state, it is uncertain to what extent our knowledge based on previous numerical simulations is really applicable to core dynamics. We will study MHD turbulence in a rapidly rotating fluid, mainly making use of large-scale simulation of magnetoconvection of a less viscous (low Prandtl number) fluid. The results will be directly comparable to observations, leading to better understanding of the dynamics of the core.

- Magma Dynamics

The methods developed in the last 6 years for extraction of essential information from natural systems by coupling natural observations with high spatial and temporal resolution and quantitative physicochemical modeling that appropriately describes the phenomena will be further developed. Determination of controlling factors in magmatism, which is indispensable in modeling, particularly parameters related to material transport, will be made by high P-T experiments. On the basis of these approaches, a comprehensive understanding of the dynamics of material and thermal transportation in the upper mantle through magmatism will be built by clarifying coupling among deformation, P-T history, and melting-melt segregation.

- Global Tectonics

  Our main program in next 5~6 years is to carry out the Nankai Trough seismogenic zone experiments that will start in 2007. The purpose of this program is to reveal the physical-chemical processes of large earthquake in subduction zone by direct drilling into the seismogenic plate boundary, coring,, logging and long term in-situ borehole observation using new "riser" drilling technology. Such an integrated program will the first in the world. In addition to this program, experimental studies of rock mechanism and quantitative analysis of exhumed plate boundary rocks will be emphasized to clarify the plate boundary process at orogenic belts in convergent plate boundary zone.

- Dynamic geomorphology

  Our main targets are plate convergence zones (in particular subduction zones). Since the subduction zones of the earth are highly diverse in terms of strain buildup-and-release and geomorphic evolution, our principal goals are to systemize the diversity of subduction zones and to clarify what engenders the diversity. In the next five years, we will study the process of strain buildup and release in subduction zones on both geologic and geodetic time scales. As a result of the processes occurring at subduction zones, the topography of island arcs evolves with time; we will also study the topographic evolution of island arcs by using both geologic and geophysical methods including field observations and modeling.
- Earthquake Physics

  We will seek to explain and predict various phenomena related to earthquakes, constructing a comprehensive earthquake model that includes multi-scale processes from microscopic fractures within fault zones to tectonic stress accumulation due to plate motion. There will be three directions of research: 1) field observations, including deep bore-hole drilling and laboratory experiments to study the physics and chemistry of fault materials, 2) analysis of high-quality seismic data and related numerical experiments to study scaling and physical conditions during dynamic earthquake rupture, and 3) development of an unified numerical model of earthquake genesis due to physical interaction at plate boundary. We will emphasize collaboration between the teams working on these three research topics, and encourage interaction with related research areas such as rheology and geographical evolution.

(e) Geosphere and Biosphere Science group

All the faculty members of Geosphere and Biosphere Science Group had their offices in Science Building #5 at the southern end of the Hongo Campus and were geographically isolated from other four groups who stationed either in Science Buildings #1, #3 or #5. Besides, some of the laboratories are allocated to temporary prefab #B due to the shortage of the floor space. However, this situation has been improved dramatically after the completion of new Science Building #1 (Central Wing) beside the West Wing of the same building in January 2005. All the offices and laboratories, except few, moved to the new building and the interaction with other groups grew substantially. This effect is not yet obvious as published papers but will be so in near future. The overall research activity of our group is regarded excellent in spite of the interruption due to the organizational change of the University of Tokyo from national university to an agency and the relocation to the new place. The recommendation of previous External Review Committee to put more emphasis to researches on geosphere-biosphere interaction has been brought into life as is evident in various aspects. For example, published papers in the field of geo-microbiology that is emphasized to pursue within our group increased substantially. Besides, research collaborations with agricultural scientists, chemists, and biologists started since 2000 and topics cover various aspects including; bio-mineralization, interface processes between organic and inorganic compounds, biogenic methane hydrate, microbiological and chemical processes at deep-sea

hydrothermal vents, organic geochemistry, long-range mutual biological interactions and evolution, hard tissue research to construct bio-archive, and water-rock-air interaction. It should be noted that these researches contain various seeds of new research fields and, with our additional efforts to be made, some of them will flourish as a cutting-edge topics of the earth science. Currently, we are nominating two new faculty members (professor- and associate professor-levels) and the addition of them will accelerate the trend stated above. Our fundamental belief of the research group is the importance of primary data production on the basis of fieldwork, analyses on natural specimens, laboratory experiments, and measurements. We will pursue this direction both on our research and education.

The Geosphere and Biosphere Science Group will conduct research and education to elucidate the evolutionary processes and mechanisms of the geosphere-biosphere interaction though geologic time on the basis of field observation, instrumental analysis of geologic samples and laboratory experiments. Particularly, we aim to take the leadership in research and education of the geosphere and biosphere science in Japan, with mutual relationship of the present faculty members and newly employing geobiologist(s). Furthermore, in order to promote the research on the “humanosphere”, an important component of geosphere-biosphere research in this century, we will participate in big projects by mutual cooperation with other research groups in our department, the Ocean Research Institute, the Climate Research Center, and the University Museum of the University of Tokyo, JAMESTIC and the Geological Survey of Japan, and try to make an international contribution to this important research field.

8 List of Publications during 2000-2005

8.1 Atmospheric and Oceanic Science Group

2000

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H. Aiki and T. Yamagata: "Successive formation of planetary lenses in an intermediate layer," Geophys. Astrophys. Fluid Dyn., 92 (2000) 1-29.

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M. Nagasawa, Y. Niwa and T. Hibiya: "Spatial and temporal distribution of the wind-induced internal wave energy available for deep water mixing in the North Pacific", J. Geophys. Res., 105 (2000) 13933-13943.

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9 List of Theses

Name	Title
FY2000	
YONEMURA, Seiichiro	A Study on Exchange Processes of Carbon Monoxide and Hydrogen Molecule between the Atmosphere and the Biosphere
FUJIKAWA, Nobuko	Time-of-flight Neutral Mass and Velocity Spectrometer for Upper Atmospheric Reserch
CHUDA, Takashi	対流圏の鉛直微細構造に関する研究
KATSUMATA, Akio	A Revision of Magnitude Determination Methods for Regional Earthquakes In and Around Japan
KOTAKE, Yoshiko	Study on the Tectonics of Western Pacific Region Derived from GPS Data Analysis (in Japanese)
NAKANO, Hideyuki	Modeling global abyssal circulation by incorporating bottom boundary layer parameterization
TAKIGAWA, Masayuki	成層圏硫酸エアロゾルの気候変動に及ぼす影響について
ONIZAWA, Shin'ya	Magma Plumbing System of Izu-Oshima Volcano as Inferred from Seismic Velocity Structure Analysis
MIYAMOTO, Hideaki	Fluid-related Processes and Landforms on Terrestrial Planets
YAMASHIRO, Toru	Characteristics of variations in current axis and velocity of the Kuroshio around the Tokara Strait
KATAGIRI, Shuichiro	赤外射出法を用いた上層雲の長期衛星モニタリングに関する研究
LUO, Jingjia	A Study on Long-Term Climate Variations in the Pacific
ENOMOTO, Takeshi	The formation mechanism for equivalent-barotropic structure of the Bonin high
AOKI, Yosuke	The formation mechanism for equivalent-barotropic structure of the Bonin high.
AOYAMA, Hiroshi	Evolution Mechanism of an Earthquake Swarm under the Hida Mountains, Central Japan, in 1998
MUNEKANE, Hiroshi	Correction of the Galvanic Effect in Magnetotellurics and its Application to Regional Sounding of Southern Kyushu Area
OGAWA, Tsutomu	Study of coseismic electromagnetic signals due to the piezoelectricity of crustal rocks
NODA, Hirotomo	Spacecraft observation of interstellar pickup He+ by E/q type ion detectors

Name	Title
YAMAZAKI, Atsushi	Observational study of inter- and circum-planetary space using EUV emissions
SHIOMI, Kei	Observation of the Moon with the NOZOMI Extreme Ultraviolet Scanner
NAGASHIMA, Tatsuya	The Roles of high latitude ozone deplation in the middle atmosphere (in Japanese)
NISHIDA, Kiwamu	Earth's background free oscillations
KUNUGI, Takashi	気圧・海洋荷重に対するサブサイスミック帯域における地殻ひずみ応答特性 ―長周期水平地震動の高精度観測に向けて―
HAYASHI, Yoshinari	群発地震を伴うダイク成長過程－伊豆東方沖群発地震の震源時空間分布からの推定
SEKO, Hiromu	Study of the shapes and maintenance mechanisms of meso-β scale line-shaped precipitation systems in the middle-latitudes (in Japanese)
KATSUMATA, Katsuro	Parameterization of tide-topography interaction at straits and application to water exchange between the Sea of Okhotsk and the North Pacific
HASHIMOTO, Chihiro	3-D Physical Modelling of Earthquake Generation Cycles and Evolution of Fault Constitutive Properties
ENDO, Takahiro	Numerical Simulation of the Transient Responses of the Kuroshio Leading to the Large Meander Formation South of Japan
YOSHIHARA, Arata	Numerical Simulation of the Transient Responses of the Kuroshio Leading to the Large Meander Formation South of Japan
HATAKEYAMA, Tadahiro	A model of time-averaged geomagnetic field and paleosecular variation for the last 5 million years
HARII, Saki	保育型造礁サンゴ幼生の分散・加入過程
HORI, Kazuaki	Evolution of coastal depositional systems of the Changjiang River in response to latest Pleistocene-Holocene sea-level changes
YAMAMOTO, Junji	Investigation of the subcontinental mantle based on noble gas isotopes, petrological and spectroscopic studies of Siberian mantle xenoliths
Hassan Mohamed Baioumy	Origin of Late Cretaceous Phosphorite in Egypt
HASHIMOTO, Yoshitaka	Fluid flow and its P-T condition along the subduction interface: example from the ancient underplated Shimanto Complex, SW Japan
YAMAGUCHI, Shigetaka	Phylogenetic history and morphological evolution of ostracodes inferred from 18S ribosomal DNA sequences

Name	Title
UJIIE, Yurika	Late Quaternary changes of surface waters in the Kuroshio source region, northwestern Pacific Ocean
GESHI, Nobuo	Development of a magma plumbring system of polygenetic volcanic inferred from the structural and petrologial evolution of the Otoge volcanic complex
KASAMA, Takeshi	The effects of microorganisms on the formation of iron minerals and the distribution of toxic metals
KANEDA, Kentaro	Fe-Ni metal bearing eucritic meteorite EET92023： possible relationship between mesosiderite and HED meteorite parent body
KOMATSUBARA, Junko	Sedimentary Environment of the Lower Miocene Nojima Group and the Development of Freshwater Sedimentary Basin at the beginning of the Opening of Japan Sea
Nemalikanti Purnachandra Rao	Active Tectonics of the Plate Margins and the Stable Continental Region of the Indian Plate
FY2001	
KIMURA, Toshiyoshi	A study of the Earth's radiation budget from satellite-received infrared spectral radiances (in Japanese)
TAKAGI, Masahiro	Thermal Tides and Topographic Waves in the Atmosphere of Venus
YAMAMURA, keiko	In situ measurements of seismic velocity and attenuation at Aburatsubo,central Japan
IWASA, Koji	A study on frictional sliding processes of faults from a micromechanical point of view -A laboratory experiment to monitor the contact state of a fault by transmission waves and a verification by computer simulation-
ASANO, Yoshihiro	Configuration of thin current sheet in substorms
MOROOKA, Michiko	On the current-voltage relationship in the upward field-aligned acceleration region at high latitudes
SUEYOSHI, Tetsuo	A study on the Response of the Permafrost Layar to Climate Change
SUZUKI, Yuki	Petrological study on magmatic process in felsic magma eruption -Especially on magma ascent deduced from degassing, vesiculation, and crystallization in the ejecta-
MICHIKAMI, Tatsuhiro	Evolution of Asteroid Regolith Layers by Cratering
TAKEMURA, Toshihiko	A study on Aerosol Distributions and Optical Properties with a Global Climate Model
Mohamad Hosein Mahmudy Gharaie	Sedimentology and geochemistry of Upper Devonian in Central Iran with special reference to environmental changes leading Frasnian-Famennian boundary event

Name	Title
TAKEDA, Tetsuya	Deep crustal imaging based on an improved mapping method - Application to wide-angle reflection data (in Japanese)
SENSHU, Hiroki	Early Thermal History, Core Formation, and Tectonics of Mars
Dimalanta Carla B.	A STUDY OF THE TECTONIC EVOLUTION OF OCEANIC ISLAND ARC SYSTEMS
AOIKE, Kan	Geology of the Tanzawa, Miska, Koma Districts Central Japan -Tectonic Evolution of the Izu Collision Zone-
MATSUBARA, Makoto	Three-dimensional P- and S- wave velocity structure in the Backbone Range of Tohoku, northeast Japan, by a travel time inversion method with spatial correlation of velocities
NAKAJIMA, Takashi	Development of a comprehensive analysis system for satellite measurement of the cloud microphysical properties
SATO, Kimiyasu	Inorganic/Organic Interfacial Interactions in Biomineralization Processes
TAKEGAWA, Nobuyuki	Effects of Biomass Burning on Atmospheric Chemistry over Australia
SAITO, Fuyuki	Development of a three dimensional ice sheet model for numerical studies of Antarctic and Greenland ice sheet
OGURA, Tomoo	The mechanisms which control the sea ice distribution：Influence of sea ice dynamics
YAMAMOTO, Yukio	MUSES-C 搭載用蛍光X線分光計の機上ソフトウェア開発
MIZUTANI, Hiromitsu	Accurate and efficient methods for calculating synthetic seismograms when elastic discontinuities do not coincide with the numerical grid
IKUSHIMA-NISHIYAMA, Norimasa	パイロライトの下部マントルにおける相関係の精密決定－マントル上昇流のダイナミクスへの応用－
KAMIMURA, Aya	A study of the seismic velocity structure at the Izu-Bonin subduction zone
SEKINE, Shutaro	Tomographic inversion of ground motion amplitudes f or the 3-D attenuation structure beneath the Japanese islands
ITO, Minpei	The origin and the age dependent distributions of flat-pebble conglomerates
KOYAMA, Takao	A study on the electrical conductivity of the mantle by voltage measurements of submarine cables (in Japanese)
TAKAYA, Kotaro	Amplification mechanisms and variations of the Siberian High：Interaction of stationary Ross by waves with surface baroclinicity
YONEZAWA, Chinatsu	Analysis and Modeling of Satellite Radar Interferometry in Urban Area

Name	Title
HAMABE, Yoshimi	Study of time-of-flight mass spectrometry for in-situ analysis of dust particles in space
YAGI, Yuji	日向灘と三陸沖における地震時滑りと非地震性滑りの相補関係
KATO, Aitaro	Experimental study of the shear failure process of rock in seimogenic environments： Formulation of shear failure law
NAGASAWA, Maki	Spatial distribution of the internal wave energy available for deep water mixing in the North Pacific
TAKADA, Yoichiro	Theoretical Studies on Crustal Deformation in the India-Eurasia Collision Zone
NAMIKI-SUMIDA, Atsuko	Dynamics of the D'‘ layer： experimental approaches
OGAWA, Yoshiko	Evaluation of melting process of the permafrost on Mars： its implication for surface features
MORIYA, Kazuyoshi	Mode of life and habitat of Late Cretaceous ammonoids inferred from oxygen isotopic records
IGUCHI, Hiroki	Experimental Research on Vegetation Changes due to Climate Warming at a High Mountain, Central Japan
MOAMEN Mahmoud Ibrahim El-Masry	Sedimentation and physical property variability of hemipelagic mudstone in response to the Pleistocene glacial and interglacial cycles - Records from the Choshi area, Chiba Prefecture, Japan-
TAKIZAWA, Yoshiyuki	Development of a new generation EUV imaging spectrometer for space plasma observation
FY2002	
KADOKURA, Akira	Detailed analysis of auroral substorm evolution observed at ground and by the AKEBONO satellite UV imager
YOKOTA, Yasuhiro	Photometric Properties of Lunar Surface in Visible - Near Infrared Wavelength （in Japanese)
NAKAGAWA, Takashi	Numerical Modeling of Mantle Convection with a Complex Heterogeneity：Towards an Integrated Physical and Chemical Theory
AKIYAMA, Hiroaki	Effects of rock coating on reflectance spectra of rock samples
SHIMOKAWA, Shin'ya	Thermodynamics of the oceanic general circulation：entropy increase rate of a fluid system
IIZUKA, Satoshi	A numerical study of air-sea interaction in the Indian Ocean
TAKASHIMA, Jun'ya	Synthesis and crystal structure of Al-P-O materials with zeolite-type framework

Name	Title
MATSUTA, Nobuhisa	Structure and behavior of the Itoigawa-Shizuoka Tectonic Line, central Japan, in Quaternary tim：Partitioning of slip on an oblique-slip fault zone
KAZAMA, Yoichi	Remote Sensing of Magnetospheric Structure with Particle Measurements
Siakeu Jean	Spatial and Temporal Variability of Suspended Sediment Concentration in River Water of Central Japan
MORIMOTO, Maki	A high time-resolution calibration of coral oxygen isotope records and mid-Holocene climate in the Northwestern Pacific from corals
SATO, Naoki	Dynamical processes in the large-scale fields related to interannual variations of midsummer weather in Japan (in Japanese)
OHARA, Yasuhiko	Tecotonics and lithospheric composition of Philippine Sea backarc basins
AFNIMAR	Joint Inversion of Refraction and Gravity Data for 3-D Basin Structures
Wahyu Srigutomo	Resistivity structure of Unzen Volcano from time domain electromagnetic (TDEM) data and its implication to volatile-groundwater interaction process
KAIDEN, Hiroshi	Microstructure and High-Temperature Properties of Al_2O_3-based Oxide Eutectics
SIMANO, Taketo	Eruption style and degassing process in terms of water content and vesicularity
ISHIBASHI, Yukihiro	小惑星の光度曲線：観測とモデルの構築
TAKAHASHI-KOMATSU, Mutsumi	Mineralogical Study of Amoeboid Olivine Aggregates in CV3 chondrites：Implications for Their Origin and Relation to Chondrules
IKEDA, Takashi	Reconstruction of global carbon cycle during the Quaternary using a vertical one-dimensional marine carbon cycle model
AIKI, Hidenori	A Numerical Study on Oceanic Lens Formation with Application to Meddies
TSUSHIMA, Yoko	Cloud and total influences of radiative feedback processes on the annual variation of global mean surface temperature
NAKAMURA, Hiromitsu	広帯域震源インバージョンに基づく高周波地震動励起過程の研究
HATA, Hiroshi	Community production and carbon dynamics in the coral reef ecosystem
TOMIKAWA, Yoshihiro	Small-scale waves trapped in the edge region of stratospheric polar vortices
MIYAZAKI, Yuzo	A Study on Chemistry and Transport of Tropospheric Ozone and Reactive Nitrogen over the Western Pacific in Spring

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SUDO, Kengo	Changing process of global tropospheric ozone distribution and related chemistry：a study with a coupled chemistry GCM
YOSHIDA, Masaki	Numerical Studies on the Dynamics of the Earth's Mantle Convection with Moving Plates
UENO, Hiromichi	Distribution and formation of the mesothermal structure (temperature inversions) in the North Pacific subarctic region
TERADA, Asahiko	画像解析による噴煙温度と水放出量の推定　-三宅島火山噴煙への応用-
OKA, Akira	Role of freshwater forcing and salt transport in the formation of the Atlantic deep circulation
NODA, Akira	A Numerical Study on Tornadogenesis in a Supercell Thunderstorm (in Japanese)
Yusuf Surachmann Djajadihardja	TECTONIC EVOLUTION OF THE CELEBES SEA, EASTERN INDONESIA－SUBDUCTION PROCESSES ALONG THE SULAWESI TRENCH AND SEISMIC STRATIGRAPHY OF THE CELEBES BASIN
IGA, Shin'ichi	球面浅水系でのシア不安定
OKAMOTO, Atsushi	QUANTITATIVE ANALYSES OF AMPHIBOLE SOLID SOLUTION AND EXHUMATION PROCESS OF THE SANBAGAWA METAMORPHIC BELT
OKI, Atsushi	西部北太平洋域における大気エアロソルの化学的特徴
SASAKAWA, Motoki	北部北太平洋における海霧の化学的特徴と発生・除去機構
SATA, Nagayoshi	High pressure studies on Fe_xO：Quasi-isothermal compression experiments and applications to the Earth's core
MATSUDA, Shigehiko N.	Carbonate sedimentation cycle and origin of dolomite in the Lower Pennsylvanian intracratonic Amazon Basin, Northern Brazil

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Wahyu Triyoso	Shallow crustal earthquake hazard in the Japanese Islands
TANAKA, Yoshiyuki	Effect of Physical Environmental Factors on Community Structure of Tropical Seagrass Meadows
SHIMURA, Rayko	Mechanism of thermal and chemical evolution of a sheet-like magma body： constraints from the Nosappu-misaki intrusion, Nothern Japan
FUJINE, Kazuho	Fluctuation of the alkenone SST in the Japan Sea during the last 160 kys
ITO, Sachihiko	Behavior and dynamics of Kuroshio Warm-Core Rings

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TAKAFUJI, Naoto	Chemical reaction and wetting behavior between molten iron and silicate perovskite
TANAKA, Tasuku	A Solution Of Chandrasekhar's Integral Equation For Radiative Transfer In Plane-Parallel Atmospheres With Very Thin Opitical Thickness
KUZE, Akihiko	Space-borne atomsphere measuring UV spectrometer development and study on retrieval algorithm
FUJII, Kazuko	Syntheses of layered inorganic/organic hybrids by using organotrialkoxysilanes
KIKUCHI, Kazuyoshi	A study of propagation characteristics of the Madden-Julian oscillation based on data analyses (in Japanese)
TATEBE, Hiroaki	Numerical studies on the Oyashio southward intrusion and associated cross-gyre transport
JIN, Hidekatsu	IMF penetration into the ionospheres of Venus and Mars
TANAKA, Hiroki	Fine Structures of Field-Aligned Electron Acceleration in the Dayside Cusp Region
TAKEMI-YASUTOMI, Natsuko	Detection and dynamics of principal modes of Asian summer monsoon variability
YOKOTA, Shoichiro	Development of an ion energy mass spectrometer onboard a lunar orbiter
NAKAGAWA, Shigeki	Imaging of the crust by aftershocks of the 2000 Western Tottori prefecture earthquake
TAJIKARA, Masayoshi	Vertical crustal movements of northeast Japan arc in late Quaternary time
SEKIGUCHI, Miho	ガス吸収大気中における放射フラックスの算定とその計算最適化に関する研究
YOKOYAMA, Tadashi	Mechanisms and kinetics of water-rock interactions -Weathering of Kozushima rhyolites-
WATANABE, Atsushi	Process of Seawater CO_2 System Formation and Biological Community Metabolism in Coral Reefs and Brackish Estuaries
NOGUCHI, Katsuyuki	Climatology and origin of small-scale vertical structures in stratospheric ozone
YOSHIMURA, Reiko	Contribution of gravity waves to ionization layers in the lower E region -Rocket-ground-based observations of the lower thermosphere/ionosphere-
NAGANO, Akira	Characteristics of the generation and propagation of small meanders of the Kuroshio clarified by sea-level analysis

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KAWATANI, Yoshio	Gravity Wave Activities in an AGCM Simulation: Analysis of their Global distribution, sources and 3D propagation (in Japanese)
YANASE, Wataru	A Numerical Study on the Structure and Dynamics of Polar Lows
MIURA, Hiroaki	Development of a mixed finite-difference/finite-volume scheme for the shallow water model on a spherical geodesic grid
KITAMURA, Yuji	Numerical study on energy cascades in stratified turbulence with the application to the atmospheric mesoscales
KURIHARA, Jun'ichi	Energetics and structure of the lower thermosphere observed by sounding rocket experiment
UMEZAWA, Yu	Nutrient Dynamics in Tropical and Subtropical Coastal Ecosystems Assessed byδ^{15} N in Macroalgae
WADA, Koji	Numerical Simulation of Impact into Granular Material by Distinct Element Method
IMANAKA, Hiroshi	Laboratory Simulations of Titan's Organic Haze and Condensation Clouds
TOMARU, Hitoshi	Geological and Geochemical Studies on the Occurrence and Stability of Natural Gas Hydrates in Nankai Trough, Hydrate Ridge and Mackenzie Delta
WU Changjiang	Estimation of fault geometry and slip-weakening parameters from waveform inversion and application to dynamic ruptures of earthquakes on a bending fault
JIN Honglin	Estimation of fault slip using a new inversion method based on spectral decomposition of Green's function
TOZUKA, Tomoki	Basin-wide seasonal air-sea interaction in the tropical Pacific：Annual ENSO
UMEZU, Isao	The Influence of Bottom Topography on Seasonal Variation of the Western Boundary Current －Energetics of JEBAR－
SUSUKI, Rieko	Relationship between ocean-atmosphere coupled phenomena and seasonal changes in the Indian Ocean
HIKIDA, Hajime	Lunar Crustal Structure from Topography and Gravity data
KOBAYASHI, Tomokatsu	Analysis of low frequency seismic events observed during the 2000 Miyake-jima volcano activities involving magma intrusion and summit eruptions
NAKAMURA, Takasumi	Evolution of the Surface Environment of Mars： Numerical Studies on the Climate System

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GOTO, Kazuhisa	A study of Cretaceous/Tertiary boundary proximal deep-sea tsunami deposits and their generation mechanism
MONKAWA, Akira	Formation process of magmatic inclusion in martian meteorites : Implication for water in parent magma
MACHIDA, Shiki	Backarc volcanism along the en echelon seamounts in the northern Izu-Ogasawara Arc (in Japanese)
GENDA, Hidenori	Effects of Giant Impacts on the Atmosphere Formation of Terrestrial Planets
CHIKIRA, Minoru	A numerical study on the green Sahara during the mid-Holocene : an impact of convection originating above boundary layer
MATSUMOTO, Yosuke	Turbulent Mixing and Transport of Collision-less Plasmas across a Stratified Velocity Shear Layer
NOGUCHI, Takashi	Formation, Growth and Structure of Multi-layered Convection due to Double-diffusive Instability
IENAGA, Masanori	The early stages of formation and evolution of the Nankai accretionary prism inferred from quantitative analysis of logging-while-drilling and core data, ODP Leg 196
KAMIYAMA, Hiroyuki	Petrology of the Tottabetsu plutonic complex, north Japan : a sub-vertical section of the time-integrated magma chamber
SUGI, Masato	Studies on Climate Prediction using NWP Model
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SASAKI, Tomoyuki	Subduction tectonics in the northern Japan Trench based on seafloor swath mapping bathymetry (in Japanese)
IHARA, Akifumi	Global Structure of Magnetic Flux Ropes Based on Energetic Particle Measurements onboard NOZOMI
KIGUCHI, Masashi	Seasonal march from the dry season to rainy season over the Indochina Peninsula
MORI, Atsushi	Dynamics of non-linear horizontal convections with and without rotation
KAMEDA, Jun	Mechanochemical process of H_2 generation by wet grinding of silicate minerals -Experimental approach and Implications to natural fault zone-
IWAKUNI, Makiko	Tectonics in east Asia as seen from GPS data
OSADA, Yukihito	Development of a GPS/Acoustic seafloor positioning system on a towed buoy and its trial observation on the deep seafloor (in Japanese)
TAKASHIMA, Shin'ichiro	Experimental Study on the Dynamics of the Partially Molten System

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TANAKA, Yasushi	Geomorphometrical study on erosion processes in a mountain drainage basin using high-resolution digital spatial data
SUZUKI, Kentaro	A study of cloud microphysical modeling scheme for calculating the particle growth process
KOUKETSU, Shin'ya	Frontal waves and salinity minimum formation along the Kuroshio Extension
Jose Alexis Palmero Rodriguez	Martian hydrogeologic processes related to the evolution and formation of Eastern Circum Chryse chaotic terrains and outflow channelsystems
KOMURO, Yoshiki	Role of the Arctic freshwater pathways in controlling t he Atlantic meridional overturning circulation
KIMURA, Jun	Tectonic History of the Icy Satellites：Discussions on the Internal Evolution and its Surface Manifestation
LIN Zhou	Geomorphological analysis of longitudinal/transverse profiles of watersheds and stream-net structure based on high-resolution DEMs
KIMURA, Haruo	Active tectonics of oblique collision zone between island arcs：a case study of the Izu peninsula in central Japan
NAOI, Takahiro	Near-infrared extinction law in the ρOphiuchi, Chamaeleon, and Coalsack dark clouds
NISHIZAWA, Manabu	Geochemistry of Archean surface environment
KURODA, Jun'icniro	Anatomy of Cretaceous black shales：paleoceaography of Oceanic Anoxic Event-2 based on the lamina-scale geochemical analyses
ANDO, Ryosuke	Development of Efficient Spatio-temporal Boundary Integral Equitation Method and Theoretical Study on Dynamics of Fault Zone Formation and Earthquake Ruotures (in Japanese)
NOMAKI, Hidetaka	The fate and degradation processes of phytodetritus by benthic communities： *in situ*^{13} C-tracer experiments
NAKAMURA, Tokuhiro	A Study on the Atmospheric Particulate Matter Transported from the East Asia to the Western North Pacific
NAGASHIMA, Kana	Reconstruction of millennial-scale variation in eolian dust transport path to the Japan Sea based on grain size and ESR analyses
TACHIBANA, Yurika	Isotopic study of noble gas and structure analysis on olivines from kimberlite
USHIKUBO, Takayuki	Isotopic and REE studies of refractory incusions in carbonaceous chondrites：formation of their precursors and rims

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ONO, Sosuke	An experimental study of chemical reactions in impact vapor clouds
YAMAMOTO, Mare	Volcanic fluid system inferred from broadband seismic signals
KITAZAWA, Mitsuko	High resolution vector magnetic anomalies acquired on a deep-sea submersible：methodology, geomagnetic variations and seafloor dating
SUGANUMA, Yusuke	Paleomagnetism of the Marble Bar Chert Member, Western Australia：implications for geomagnetic field behavior and an apparent polar wander path for Pilbara craton during Archean
MATSUZAWA, Takanori	Numerical simulations of the interaction between seismic slip and frictional melting
NAKAI, Munenori	Crystallographic studies on the melt growth YAG/corundum eutectic composite
NAKAHIGASHI, Kazuo	A study on the structures of the mantle wedge beneath an eastern part of the Japan Sea revealed by long-term broadband seafloor seismic observations