Curriculum

2021-05-18

This is an introduction to the courses and outline of the Department of Earth and Planetary Science.

Basic Courses are offered every year, but **Advanced Courses are offered every year or every other year, etc., depending on the subject.**

Basic Courses□□Common Courses with Undergraduate Program□

Course	Course Objectives/ Overview
Time Series Analysis	For Earth Science, Fourier Transform (especially Discrete Fourier Transform; DFT) is a fundamental method to analyze various kinds of observed data of time series. We will give explanations about such method from its basics. Some fundamental topics on time-series analysis, such as frequency spectrum and correlation function, response of linear systems, errors in spectrum estimation, and numerical filters, will be discussed. Application of time series analysis in Geophysics is also introduced.

Course	Course Objectives/ Overview
Geophysical Data Analysis	In the field of earth and planetary physics, data analysis methods are frequently used for estimating unknown physical quantities and information related to physical principles behind the data. This course will focus on understanding the basics and application of standard geophysical analysis methods. Starting with a review of statistics, it will cover various methods with and without models, including linear regression analysis, time series analysis, principal component analysis, and inversion analysis methods.
Mathematical Methods in Geophysics	Fundamental mathematics needed for descriptions of various phenomena and processes in earth science is explained. This lecture is intended for graduate students who had few chances to take lectures for geophysical mathematics in undergraduate days.
Numeral Analysis in Geophysics	The technique and background theories for solving numerically partial differential equations are given in the context of earth and planetary physics. Especially the basics and applications of the finite difference methods are explained in detail.

Course	Course Objectives/ Overview
□Mechanics of Elastic Body	The continuum mechanics is a study field dealing with mechanical behavior of material in a macroscopic scale, which is an important base of earth sciences. In this class, we learn the continuum mechanics of elastic material, (the mechanics of elastic body), focusing on fundamental concepts and derivation of basic equations.
□Solid Earth Mechanics	Fundamentals of geodetic approaches to study geometric shape, deformation, gravity field, rotation and internal structures of the Earth and planets.
□Geophysical Fluid Dynamics I	In order to consider problems in geosciences, the treatment of fluid dynamics is often necessary. In this course, we learn fundamental fluid dynamics which governs various phenomena in nature. We start from deriving the basic equations which describe fluid motions, show the way to treat the governing equations and explain several features of complicated fluid motions. Students will proceed smoothly to the Geophysical Fluid Dynamics II course in the winter term.

Course	Course Objectives/ Overview
Geophysical Fluid Dynamics II	Geophysical fluids such as atmosphere, oceans and liquid core of the earth and other planets are strongly affected by the effects of density stratification and rotation of the planet, so that they not only exhibit motions much different from those we experience in ordinary life but also possess a variety of motions including waves, vortices and instabilities. In this lecture, basic mechanisms of motions of geophysical fluids such as the atmosphere and oceans on the earth and other planets and the theoretical methods that are used for studying the mechanisms are introduced.
Material Science of the Earth and Planetary Interiors	The essence of high-pressure mineral physics, such as the structure and properties of the Earth and planetary materials under extremely high pressure and temperature conditions, is explained with the basics of thermodynamics, quantum chemistry, and statistical physics. By comparing mineral-physics data with geophysical observations, it will be clarified that the structure, dynamics, and evolution of the Earth and planetary interiors are controlled by the properties of their constituent materials.

Course	Course Objectives/ Overview
□Planetary Aeronomy	The main purpose of this planetary aeronomy lecture is to understand common physical and/or chemical processes occurring in the solar-planetary environment (atmosphere, ionosphere, magnetosphere, and inter-planetary space) of terrestrial planets based on fundamental equations. Application to the exoplanets as well as basics of observation methods using rockets, satellites, and radars are also described.
□Elementary Comparative Planetology	Recent space explorations and theoretical studies have advanced greatly our understanding on planets, satellites, and small bodies both inside and outside our Solar System. Their origin and evolution are covered in this course.
□Elementary Earth and Planetary System Science	This lecture provides a basis for a unified understanding of the Earth and planets as a complex system. For the typical example, focusing on the issues associated with the formation and evolution of aquatic planets and the maintenance of the surface environments, we will explain the concepts and roles of feedback, branching, multiple solutions, time constants, etc. that are important for understanding the Earth and planetary systems.
□History of the Earth	Objective of this course is to outline the Earth history, from its birth to present.

Course	Course Objectives/ Overview
Solid Earth Science	This course aims understanding the internal structure (state, composition, temperature, pressure), dynamics (mantle convection and plate movement, core convection and geomagnetism, heat transport), and relevant surface processes (plate tectonics, earthquake, crustal movement, topography, volcanics, continental growth, mountain building) of the Earth. The evolution of solid Earth is also discussed.
Cosmo-and Geo-chemistry	Learning chemical fundamentals that control the evolution of Earth and planets, such as chemical reactions, elemental partitioning, isotope fractionation and radioactive decay.
Diffraction Crystallography	In order to understand and investigate atomic structures of crystalline materials, this lecture teaches the basic concept of crystallography including symmetry of crystals, diffraction phenomena and practical methods.
Instrumental Analyses of solids	This lecture explains fundamentals and applications of several analytical techniques which are important to investigate solid materials in geosciences. Demonstrations of the instruments in laboratories are also included. The techniques and/or instruments explained are 1) scanning electron microscopy (SEM), 2) Infrared (IR) and Raman spectroscopy, 3) X-ray absorption spectroscopy, 4) X-ray microanalysis of composition, and inductive coupling plasma mass spectrometry (ICP-MS).

Advanced Courses (Atmospheric and Oceanic Science)

Course	Course Objectives/ Overview
Atmospheric Physics	Since the Earth’s surface climate system is a heat engine driven by solar radiation energy received from the Sun and Earth radiation energy ejected into space, it is important to understand the mechanisms of these energy transfer and their interaction with the Earth’s surface system in order to understand the mechanisms of climate formation and change. Cloud physics, which is concerned with the generation and maintenance of clouds and precipitation that deeply affect the Earth’s energy balance, is also an important field in atmospheric science. In this lecture, we will learn the basic understanding of radiative transfer processes and cloud physics processes, which have such importance, as well as the role of radiation budget in climate formation and its application to climate modeling and satellite observations.

Course	Course Objectives/ Overview
Atmospheric Physics II	For the foundation to understand the various large-scale aspects of tropical and subtropical cloud and precipitation systems, basics of various types of instability, meso-scale characteristics of the precipitation systems, and large-scale tropical waves will be lectured. In addition, the multi-scale interaction among precipitation systems, large-scale atmospheric waves, and atmospheric general circulation, as well as the role of cloud and precipitation systems in climate will be discussed, along with introductions of recent scientific findings.
Atmospheric Physics III	The first half of this course overviews fundamental theories of atmospheric dynamics such as atmospheric waves, instabilities and turbulence which is necessary to understand and investigate the mechanism of flows in the atmosphere from the global circulation to small-scale disturbances. The second half of the lecture is devoted to the science of the middle atmosphere (stratosphere, mesosphere, and lower thermosphere), including dynamical characteristics of waves that are important for the momentum budget of the middle atmosphere, how waves drive Lagrangian circulations and equatorial large-scale oscillations, and the formation mechanism of the ozone hole.

Course	Course Objectives/ Overview
Physical Oceanography□	Accurately parameterizing turbulent mixing processes in the ocean and incorporating them into ocean general circulation models and coupled atmosphere-ocean models is an essential issue for improving the prediction accuracy of mid- to long-term climate change. In fact, deep-ocean turbulence is regarded as an important physical process that controls the intensity and pattern of the deep ocean general circulation, and surface turbulence has an important influence on air-sea interaction as one of the determinants of sea surface temperature. In this lecture, I will introduce the physical mechanisms that excite turbulent mixing and attempts to quantify the turbulence intensity based on these physical mechanisms. I would like to clarify the new direction that physical oceanography should take in the future by considering how microphysical processes, such as turbulent mixing, are intertwined with ocean general circulation and air-sea interactions.
Physical Oceanography□	Students will learn about the structure and variability of the oceanic wind circulation, represented by the Kuroshio and Oyashio currents, and its mechanisms. Students will also learn about the temperature and salinity structure of the ocean, especially the distribution and variability of water masses in the surface and middle layers. The latest oceanographic observations will also be introduced.

Course	Course Objectives/ Overview
Physical Oceanography III	We learn about the ocean general circulation, especially focusing on the ocean deep circulation. The numerical simulation using the ocean general circulation model is also introduced, and we discuss its application for investigating the mechanism of the ocean deep circulation and its role on the climate.
Climate Dynamics □	Natural variability of climate in which the ocean plays an important role, especially the coupled atmosphere-ocean phenomena in the tropics, will be discussed in terms of their dynamical properties and mechanisms. Interpretation of the mechanisms, including theoretical considerations, based on observational data and numerical models will be discussed.
Climate Dynamics II	Understanding a variety of natural climate variations in terms of their|structure, timescale, and mechanisms. Specific phenomena taken as examples|are: extratropical decadal variability associated with the North Atlantic Oscillation or the Pacific/North America teleconnection, roles of storm tracks in interannual and decadal climate variations, and ENSO remote influence.

Course	Course Objectives/ Overview
Ocean-Atmosphere Material Circulation Physics	Atmospheric materials, depending on their physicochemical properties, have a great impact on the Earth system as a player in the Earth’s radiation budget, air quality, and material cycle. In this lecture, we will first review the roles of these atmospheric materials and learn the basics of chemical reactions, transport processes, and radiative processes in the atmosphere. Then, ozone, which is the center of atmospheric chemistry in the stratosphere and troposphere, and various related radical components will be outlined. In the second half of the class, we will review the formation and disappearance processes of aerosols (fine particles) in the atmosphere, which play an important role in recent climate change, radiation processes, and their effects on clouds and precipitation. Cloud microphysics will also be briefly reviewed. Methods of observation of atmospheric materials are also discussed, and the latest findings on atmospheric environmental change research and climate effects of atmospheric materials are outlined.

Course	Course Objectives/ Overview
Ocean-Atmosphere Material Circulation Physics II	This course gives a lecture on the physical and biogeochemical processes related with ocean water-mass distribution, formation and transformation which are the key to understand ocean circulations and their long-term variability, with particular emphasis on ocean mixing processes and their impact on ocean biogeochemical circulation and climate. Ocean mixing and its impacts, fundamental turbulence theory, turbulence measurements, water-mass analysis, mixing distribution and North Pacific deep, North Pacific Intermediate Water circulation and biogeochemical cycles, long-term ocean, climate ecosystem variability and 18.6-yer period tidal cycles.
Special Lecture of Oceanic and Atmospheric Science □-□	Invite researchers from inside and outside the university as lecturers, and introduce the latest topics and research results related to atmospheric and oceanic sciences in intensive lectures.

Advanced Courses (Space and Planetary Science)

Course	Course Objectives/ Overview
Space Plasma Physics □	Universal physical processes in space and astronomical plasmas will be discussed. Collisionless shock waves, magnetic reconnection, and various instabilities and plasma wave phenomena will be reviewed, with particular attention to the acceleration process of high-energy particles.

Course	Course Objectives/ Overview
Space Plasma Physics II	The magnetohydrodynamics (MHD) of the solar (and astrophysical) plasmas are lectured basically from the theoretical point of view, aiming to show that the various solar and astrophysical phenomena can be understood by the framework of MHD. The topics will be: 1. Magnetic reconnection 2. Convection and large-scale flows of stellar interior 3. Magnetic buoyancy 4. Dynamo 5. MHD waves in stellar atmosphere 6. MHD turbulence in solar winds 7. radiative MHD in the solar atmosphere.
Physics of Magnetosphere □	The magnetosphere is the force field formed in space around a planet by the interaction of the solar wind (supersonic plasma flow from the Sun) with the planet’s intrinsic magnetic field and atmosphere. Depending on the combination of the planet’s intrinsic conditions and physical mechanisms, the planetary magnetosphere shows various aspects. In this lecture, the basic properties of planetary magnetospheres including the Earth will be explained, and the current status and issues of research on the diversity and universality of magnetospheres, which are being revealed by flying object exploration, will be discussed. Students will be expected to present and lead a discussion on one of the selected papers on current topics during the lecture, including applications to space weather and space climate research.

Course	Course Objectives/ Overview
Physics of Magnetosphere II	Interaction between the solar wind and a solar system object varies largely according to the object’s properties, such as the existence of a global intrinsic magnetic field and/or thick atmosphere. Recent knowledge on the structure/dynamics of the magnetized planets’ magnetosphere and plasma environment around non-magnetized bodies based on the plasma data obtained by spacecraft and /or sounding rockets as well as the instrumentation for plasma measurements are the main topics of this lecture.
Planetary Exploration Science I	We review the evolution of surfaces and atmospheres, and variety of related phenomena/structures of planets. We also illustrate previous planetary explorations with special emphases on instrumentation. The goal is to understand the history of explorations and touch spirits of exploration projects.
Planetary Exploration Science□	To understand the formation of the space around the earth and planets, and to learn the basics of observation techniques using flying objects. This course introduces and explains the principles and techniques of astronomical observations using flying objects and the methods of analyzing the physical data obtained, using actual examples and focusing on basic physics. In addition, the latest research results, technical issues, and future plans for near-landing exploration of planets and comets will be explained.

Course	Course Objectives/ Overview
Comparative Planetology□	The purpose of this course is to understand the origin and evolution of the various planets revealed by solar system exploration.
Comparative Planetology II	Recent space missions successfully explore Mars, Venus, the Moon, asteroids, comets and other objects in the solar system. In this course, we will focus on observational data of these bodies obtained in-situ by spacecraft. There are many ongoing missions today, which means we are acquiring large amount of data even at this moment. Thus, comprehensive views will not be necessary presented at the lecture. Instead, I would prefer to share the most recent data the truly cutting-edge knowledge from the space missions.
Cosmic and Planetary Material Science □	Lectures on the origin and early evolution of the Solar System through analysis of pristine extraterrestrial materials, laboratory experiments, and Solar System exploration and on basic physical chemistry and material science.
Cosmic and Planetary Material Science II	Lectures on the origin and early evolution of the Solar System through analysis of pristine extraterrestrial materials, laboratory experiments, and Solar System exploration and on basic physical chemistry and material science.
Special Lecture of Space and Planetary ScienceI-□	Invite researchers from inside and outside the university as lecturers, and introduce the latest topics and research results related to space and planetary science in intensive lectures.

Advanced Courses (Earth and Planetary System Science)

Course	Course Objectives/ Overview
Earth and Planetary System Science	This course is an extension of the basic theory of Earth and Planetary Systems. Focusing on the study of glacial-period climate change, the course also includes the carbon dioxide cycle, planetary climate stability, and examples of ecosystems, with the aim of learning useful ways of thinking and methods for understanding the complex behavior and phenomena of the Earth and planets from a systems perspective, and to acquire applied skills. In particular, the concept and application of time constants. Elementary concepts of feedback, stability/instability, bifurcation, and oscillation, which are important for understanding and predicting continuous and discontinuous changes and variations in Earth and planetary systems.

Course	Course Objectives/ Overview
Theory of Planetary System Formation	There are eight planets in the solar system: the inner four (Mercury, Venus, Earth, and Mars) are light rocky planets, the middle two (Jupiter and Saturn) are very heavy gas planets, and the outer two (Uranus and Neptune) are relatively heavy ice planets. The basic structure of the solar system can be explained, at least qualitatively, within the framework of the standard model of solar system formation called the Kyoto Model. Quantitatively, however, several important issues remain unresolved. In addition, thousands of planets have been detected around stars other than the Sun to date. These planets are called extrasolar planets or exoplanets. Exoplanets and exoplanetary systems show great diversity in, for example, planetary mass, orbital characteristics, and bulk density. Such diversity has forced us to re-examine the current picture of solar system formation. What is it that gives rise to the diversity of planets and planetary systems? What processes are overlooked by the Kyoto model? What features are common to planetary systems and what features are unique to the solar system? This lecture aims to provide a basic understanding of the ever-evolving theory of planetary system formation.

Course	Course Objectives/ Overview
Exoplanets, Advanced Course	Since their first detection in 1995, exoplanets have been one of the hottest topics in astronomy, and both observational and theoretical studies have progressed rapidly. More than 5,000 exoplanets, including candidates, have been discovered, and we are now reaching the stage where we can study the properties of individual planets, such as atmosphere detection by spectroscopic observations. In this class, we will review the current status of exoplanet research, explain the theories and observations that form the basis of exoplanet research, and aim to acquire these basic knowledge.
Exoplanets, Advanced Course -V	Since their discovery in 1995, extrasolar planets have become one of the hottest topics in astronomy. In this lecture, both observational and theoretical aspects of extrasolar planets will be discussed in detail, including the latest results.

Course	Course Objectives/ Overview
Theory of Geochemical Cycle	Methods for studying the chemical evolution and material cycle of the Earth from the elemental and isotopic compositions of igneous rocks are described. The basic principles of secondary ion mass spectrometry and its characteristics as an analytical method are outlined, and the uranium-lead dating of zircon, apatite, and monazite, as well as the geochemistry of trace elements, especially rare earth elements, are lectured. In addition, meteorites, the oldest rocks and minerals on earth, and the first life on earth will be discussed as examples of their applications.
Introduction to Ocean-Atmosphere Circulation	This course offers a descriptive, introductory overview of typical thermal and circulation structures of the atmosphere (mainly the troposphere) and ocean, providing fundamental knowledge that is necessary for understanding the mechanisms. In addition, the role of atmospheric and oceanic processes in the formation and variability of our climate system is discussed. If necessary, equations are used, but emphasis is placed on their physical interpretation rather than on their derivation.
Geographical Information Science	This intensive lecture course in English introduces the basic of GIS (Geographical Information Systems) including cartography and examples of GIS applications in earth and environmental sciences.

Course	Course Objectives/ Overview
□Climate Dynamics	The goal is to study the climate system which forms the earth environment and understand the working mechanism and the physical processes. Through learning the climate data analysis and climate models, the climate change from the past to future is understood.
□Paleoclimatology/ Paleooceanography	This lecture explains the possible driving forces and mechanisms of global environmental changes in various timescales mainly during the Quaternary, from the viewpoint of the Earth system science.
Paleo-environmental Science	We study fundamental principles and applications of proxies for paleoenvironmental reconstructions, dating methods, and paleoclimate modeling. The lectures are given from a view point of paleoenvironmental science for the understanding and future prediction of global environmental changes. Examples primarily from the Quaternary period are presented.
Environmental Biology	Reviews articles on a new narrative for the oceans, the Anthropocene, and the economics of a sustainable ocean economy with respect to the global environment and human and ecological responses.

Course	Course Objectives/ Overview
Theory of Earth and Planetary Environmental Evolution	From the viewpoint of material circulation and energy balance in the Earth and planetary systems, the following issues are discussed: long-term stability of the Earth’s planetary environment, evolution of atmospheric and oceanic systems, coevolution of the Earth’s environment and biosphere, global environmental change in Earth history, comparative planetary environmental evolution, and habitable planets.
Special Lecture of Earth and Planetary System Science □-□	Aiming to understand basics of astrochemistry and the current issues. Formation of planetary system is one of the most fundamental structure-formation processes in the Universe. It’s physical processes have widely been investigated as one of the major targets of observational astronomy and astrophysics during the last few decades. Meanwhile, it is inevitably accompanied with the evolution of interstellar matter, which would ultimately be related to an origin of rich substances in the Solar System. This course introduces basics of astrochemistry, which characterized by extremely low density and low temperature condition, and current problems/challenges toward understanding the origin of the rich chemical substances.

Advanced Courses (Solid Earth Science)

Course	Course Objectives/ Overview
Seismic Wave Theory I	Introductory course on seismic wave propagation in the Earth
Seismic Wave Theory II	We will study characteristics of seismic wave propagation in heterogeneous subsurface structure and the developing process of strong ground motion to cause earthquake disasters based on the indication of observed seismic waveform data and computer simulations. In addition, we will learn several key methods to image crustal structures from propagation of seismic waves and basic properties of seismicity, and understand a linkage between heterogeneous crustal structure and earthquake generation.
Theory of Earth's Internal Structure	A course of introduction to the Earth's internal structure based on petrologic, seismic, and geoelectromagnetic studies.
Dynamics of Earth's Interior	We learn dynamic processes of the Earth's interior (including plate motion, earthquake/volcanism, crustal deformation, mantle convection, core convection) and the physical-chemical theory and elemental processes behind them. Through quantitatively analyzing the mechanisms and processes in time and space, we aim to understand the individual geologic phenomena accurately, based on which on-going processes on the planet Earth, as well as their history and future, will be overviewed.

Course	Course Objectives/ Overview
Geo-Electromagnetics	Fundamentals of geomagnetism and geo-electromagnetic methods are lectured. Emphasis is on understanding that that electromagnetic properties of the Earth (and planets) are strongly related with dynamic processes of the Earth’s interior and evolution of Earth.
Magma Science	This course aims at understanding roles of magma in the formation and evolution of the Earth and other planets of our sola system by studying basic aspects of all the related physical and chemical processes, such as generation, separation from solid residue, transportation, solidification, fractionation, assimilation, mixing, and eruption.
Elementary Volcanology	In order to understand volcano phenomena, various types of knowledge such as geology, petrology, theory, modeling, geophysical observations, and lab-experiments. The target of this course is to understand these knowledge and deepening our understanding of volcanic phenomena through observational and analytic examples.
Plate-Boundary Zone Tectonics	Tectonic belt is located along the plate boundary on the earth. Multi-scale tectonics of plate-margins based on geophysics and modern short-term processes of the tectonic belts based on geology and geomorphology are learned in this series of lectures.

Course	Course Objectives/ Overview
Earth’s Rheology	Rheological properties of rocks play important roles at various time scales ranging from mantle convection to seismic wave propagation. We first learn the atomic-scale mechanism controlling rock rheology, which enables us to understand how temperature, rock microstructure, chemical composition, and/or presence of fluids affect the rheological properties. We learn methodology to observe mineral/rock microstructures. We also learn the relationship between rock rheology and geodynamics.
Ocean Floor Dynamics	The oceans cover the majority of our planet’s surface. The Earth’s lithosphere is separated into plates, and most plate boundaries, where active volcanism and tectonic movements occur, are located beneath the sea. The class ‘Ocean FLoor Dynamics’ aimes to give a broad overview of earth’s structure beneath the sea, ongoing geological/geophysical/geochemical process on the seafloor, and the pale environment recorded on the the seafloor. The recent marine survey techniques and state-of-art instruments are also introduced.

Course	Course Objectives/ Overview
Theory of Geomorphic Evolution	Geomorphology in large-scale orogenic belts at plate boundaries has been developed by the interaction between endogenetic and exogenetic processes. Its overview and each component will be explained in this lecture. We especially discuss the roles of inland active faults and crustal deformation in subduction zones from the point of views in geodetic measurements, tectonic geomorphology and numerical modeling.
□Earthquake Physics	Earthquakes are elastic wave radiation from frictional slip with fracture in an elastic medium. For a basic understanding of the physical process of earthquakes, this course addresses how to express earthquake sources in the theory of elasticity and how to recognize earthquake rupture based on the rock mechanics of friction and fracture.
Physics of Earthquake Generation	(The first half)Earthquake source process: basic understanding of fracture mechanics and its application to earthquake modeling .(The second half) Understanding and modeling of faulting processes on the basis of rock fracture and friction observed in laboratory.
Methodology of Solid Earth Observation	The progress of the Earth science depends on improvement of observations and new discovery. In this course, the principle and methodology of the observations and analyses in Earth science are introduced.
Special Lecture of Solid Earth Science □-IV	Invite researchers from inside and outside the university as lecturers, and introduce the latest topics and research results related to solid earth science in intensive lectures.

Advanced Courses (Geosphere and Biosphere Science)

Course	Course Objectives/ Overview
Evolution of Geosphere Environment	This lecture provides basic sedimentology and geochemistry of carbonate rock that has recorded biological evolution and surface environments. Specific cases of limestone caves and hot-springs are given to show how we can study environments, paleoclimates, and material circulation. The lecture also extends to recent topics on carbonate rock.
Theory of Biospheric Environmental Evolution	The lecture overview the 4.8 billion years history of Earth's surface since Precambrian to Quartanary period.
Analysis of Biosphere Materials	The lecture overview the methods to observe/analyze fine structure of terrestrial and planetary materials using electron microbeam.
Biomineralization	Biominerals, or inorganic substances formed by organisms as their hard tissues, are important materials related to fossil records and circulation of elements around the terrestrial surface. Their structures are generally well controlled for the activity of life, compared to abiotic or geological minerals. This lecture introduces variety of biominerals, their structural characteristics, organic macromolecules involved to the formation of biominerals, biological/environmental information recorded in biominerals, etc.

Course	**Course Objectives/ Overview**
Evolutionary Paleobiology	The lecture provides basic theory of paleontology and evolutionary biology to understand pattern and process of biological evolution. Especially, methods to analyze phylogenetic relationship and biological evolution are focused.
Evolution of the Biosphere	To gain knowledge of theories and methodologies of biogeosciences,|including and with special emphasis on geochemical and molecular|biological aspects.
Evolutionary History of Life on Earth	This course will provide a comprehensive introduction to theories and methods in paleontology. Students will be introduced to patterns and mechanisms of biological evolution. Topics covered will include a wide range of the biologial aspect of paleontology, with latest findings. The focus will extend beyond mere knowledge, and be put on concepts and theories in evolutionary biology.

Course	Course Objectives/ Overview
□Evolutionary Biology	Throughout the Earth's history, microbial life has tremendously influenced the evolution of the surface environment and elemental cycles. The diversity with respect to molecular phylogeney, physiology and habitability of microorganisms and the tight coupling of microbial activity and Earth's geochemical processes will be lectured in this course. The principle and application of organic geochemistry are also lectured. The objective of the latter half is to reconsider what is life, which characterizes the planet Earth. The key words are DNA, evolution, and 'forms'. Mention will be given to principles of and some important findings in chemical evolution, paleo-genomics, evolutionary developmental biology, morphology and molecular phylogenetics.
□Earth's Environmental Chemistry	The aim of this lecture is to learn physical chemistry and thermodynamics that control behaviors of elements at earth surface, in particular to understand chemical reactions in aqueous phase with lots of examples observed in natural systems.

Course	Course Objectives/ Overview
Geomicrobiology	Throughout the Earth’s history, microbial life has tremendously influenced the evolution of the surface environment and elemental cycles. The diversity with respect to molecular phylogeny, physiology and habitability of prokaryotes and the intimate relation between microbial activity and Earth’s geochemical processes will be studied in this course. Based on lessons from the ecology and metabolism of extremophiles, the origin of life and the possibility of extraterrestrial life will be discussed in the course.
□Resource Geology	To understand the physical, chemical, biological and geological processes to concentrate elements in association with mineral and energy resources
Special Lecture of Geosphere-Biosphere Science □-□	Invited lecture from inside or outside the department. The lecture introduce the latest topics and research outcome related to geosphere and biosphere sciences.

Advanced Courses (Common for all Groups) 1: Frontier Science

Course	Course Objectives/ Overview
Climate Prediction □	Students will learn about the fundamentals involved in short- and long-term weather forecasting and global warming prediction, and discuss problems and issues.

Course	Course Objectives/ Overview
Special Lectures on Earth-Space Frontier Science□-□	We will introduce recent interdisciplinary research on a wide variety of scientific topics, in particular the origin and evolution of the universe and life. The rink to industrial applications will be also discussed.

Advanced Courses (Common for all Groups) 2: Field Work and Practical Skills

Course	Course Objectives/ Overview
Field Work in Earth Science	Hands-on training in basic field research methods in earth science, how to read the distribution of rocks, geological structure, topography, and production of rocks and fossils, and how to observe, describe, observe, measure, and distribute the earth’s environment in the field.
Laboratory Experiments for Geophysical Observation	A course to learn geophysical observation of the solid Earth based on the filed trip. The principle and method of the geophysical observation are introduced in this course.
Laboratory Experiments for Instrumental Analysis□-□	The purpose of this exercise is to understand the principles of several physical and chemical analytical techniques for the earth and planetary materials, and give practical experiences of the analyses to the participants.
English for Scientific Researchers	Students will learn English language skills necessary for scientific researchers.

Course	Course Objectives/ Overview
Field Work in Earth and Planetary Science	In order to learn how to investigate geology and sedimentology in the field, we will visit strata and rocks exposed in Japan for three days and two nights.
□Earth and Planetary Environmental Science International Short Course □	Joint course work with students at the Australian National University. If Covid-19 situation improve, we will visit Australia to learn Australian physical and cultural landscapes. Otherwise, online virtual joint course will be conducted.
□Earth and Planetary Environmental Science International Short Course □	Joint course work with students at the Australian National University. If Covid-19 situation improve, we will host students from the Australian National University to study various topics including Geohazards, AI, Science communications, Philosophy and Science and others. Otherwise, online virtual joint course will be conducted.
Exercises in Earth-Space Frontier ScienceI-□	Several students working on different disciplines will make a team and develop a new interdisciplinary research project.

Advanced Courses (Common for all Groups) 3: Seminars, Colloquia and Theses

Course	Course Objectives/ Overview
Basic Ocean Sciences	The ocean contains about 97% of the terrestrial water and regulates Earth's climate. Photosynthesis at the surface of the ocean supports not only fertile ecosystem but also influences the global geochemical cycle within the water column. Plate tectonics controls the dynamics beneath the seafloor including volcanism, hydrothermal activity, and other processes. Altogether, interaction among individual portions of the ocean constructs the major part of the Earth system. In other words, no one can understand the Earth without subtle knowledge of the ocean. In this class, general introduction to the related scientific aspects will be presented as collaborative effort of Departments of Earth and Planetary Science and Biological Sciences.

Compulsory Courses

Course	Course Objectives/ Overview
Seminar of Current Scientific Literature I	Through critical reviews of research papers and discussions, students will achieve deep/essential understanding on various subjects in the Earth and Planetary Sciences.
Seminar of Current Scientific Literature II	Through critical reviews of research papers and discussions, students will achieve deep essential understanding on various subjects in the Earth and Planetary Sciences.

Course	Course Objectives/ Overview
Earth and Planetary Science Colloquium I	Students will clarify the purposes of researches and acquire capabilities for the approach/management of the subjects, problem-resolving, production and presentation, through presentations and intensive discussions regarding research results by themselves on various subjects in the Earth and Planetary Sciences.
Earth and Planetary Science Colloquium II	Students will clarify the purposes of researches and acquire capabilities for the approach/management of the subjects, problem-resolving, production and presentation, through presentations and intensive discussions regarding research results by themselves on various subjects in the Earth and Planetary Sciences.
Research in Earth and Planetary Science I	Students will acquire systematic scientific knowledge and research capabilities on their professional subjects in the Earth and Planetary Sciences through the focused studies and presentations/publications of their results as master thesis works.
Research in Earth and Planetary Science II	Students will acquire systematic scientific knowledge and research capabilities on their professional subjects in the Earth and Planetary Sciences through the focused studies and presentations/publications of their results as doctor thesis works.

Common Lecture of the Graduate School of Science

Course	Course Objectives/ Overview
Theory of Science Communication	Why is science communication necessary? Using the history of science in postwar Japan, science and technology policy, the psychology of society, and science journalism as keywords, students will understand what science communication skills are necessary for science researchers with specialized knowledge.
Practice in Science Communication	The lecture will take the form of a practical training session on how to deal with trans-scientific and ethical issues and how to communicate the contents of research, assuming that this is a situation that science researchers encounter.
Scientific Writing, Publication, and Communication	Among the essential scientific communication skills for scientists, learn how to make effective presentations in English and how to write and submit papers to major scientific journals.
Science Writing	Invite editors, authors, and editing experts from prominent journals to develop essential writing skills for scientists through scientific manuscripts and essays.
Science Cluster Lecture	By introducing different views and approaches to a common object in nature, it provides an entry point to the creation of an interdisciplinary frontier that transcends existing disciplines.

Course	Course Objectives/ Overview
Introduction to Modern History of Science	The essence of science lies in how we perceive the universe, matter, life, and the earth. In this lecture, we will focus on the formation process of important concepts in each field of science. In this lecture, we will focus on the formation process of important concepts in each specialized field, and explain them in an easy-to-understand omnibus format from the standpoint of the history of science.

Interdisciplininary Education Program on Ocean Science and Policy

Course	Course Objectives/ Overview
Seminar in Marine Affairs□	“Use of sites”, “Use of resources”, and “Safe use” will be the three main themes of the lectures. S-semester will be provided with lectures by specialists including the ones from outside of UTokyo. A-semester will be more on practical exercises.