The Department of Earth, Atmospheric, and Planetary Sciences offers the bachelor’s degree in earth, atmospheric, and planetary sciences, and master’s and doctoral degrees in atmospheric sciences, climate science, geology, geochemistry, geobiology, geophysics, and planetary sciences. The department participates in the MIT/WHOI Joint Program in Oceanography/Applied Ocean Science and Engineering (http://catalog.mit.edu/interdisciplinary/joint-program-woods-hole-oceanographic-institution) with doctoral degree programs in chemical oceanography, physical oceanography, biological oceanography, and marine geology and geophysics.

Departmental programs apply physics, chemistry, and mathematics to the study of the Earth and planets in order to understand the processes that are active in the Earth’s interior, oceans, and atmosphere, as well as the interiors and atmospheres of other planets. The department also uses the basic sciences to understand the past history of the Earth and planets. By combining the past history with models of present physical, biological, and chemical processes, faculty and students work to develop an understanding of the dynamics of systems as diverse as the global climate system, regional tectonics and deformation, petroleum and geothermal reservoirs, and the solar system.

Research in the department is fundamental in nature, but underpins many of the most pressing societal questions of our time: climate and environmental change; natural hazards; natural resources; the origins of life both on Earth and elsewhere. Much of the research is interdisciplinary, so faculty, researchers, and students commonly cross discipline boundaries. Modern problems in these fields are approached by field measurements, laboratory studies, simulations, and theory. Experimental facilities for training and research are available not only in departmental laboratories such as the Earth Resources Laboratory, but also in MIT’s interdepartmental laboratories such as the Center for Global Change Science, Kavli Institute for Astrophysics and Space Research, Lincoln Laboratory, Haystack Radio Observatory and Millstone Radar facility, and the Wallace Astrophysical and Geophysical Observatories (described in the section on Research and Study (http://catalog.mit.edu/mit/research)), and in cooperating institutions such as the Woods Hole Oceanographic Institution.

Undergraduate Study

Bachelor of Science in Earth, Atmospheric, and Planetary Sciences (Course 12)
The Earth, Atmospheric, and Planetary Sciences Department offers undergraduate preparation for professional careers in a wide range of fields in geoscience (which includes geology, geophysics, geobiology, and geochemistry), atmospheric science, climate science, environmental systems, and planetary science and planetary astronomy.

The curriculum for the Bachelor of Science in Earth, Atmospheric, and Planetary Sciences (http://catalog.mit.edu/degree-charts/earth-atmospheric-planetary-sciences-course-12) ensures a fundamental background through general departmental subjects and advanced study in a concentration area chosen by the student. The student and advisor plan an appropriate and relevant selection of electives. Students are also required to take field and/or laboratory subjects, and to complete an independent research project as part of the degree requirements.

Double Major
Studies in physics, chemistry, biology, applied mathematics, and electrical or civil engineering are directly relevant preparation for work in earth, atmospheric, and planetary sciences. Students from these departments can arrange a program of study in Course 12 leading to a second major with subjects that strengthen their undergraduate program.

Five-Year Program
Students with strong academic records from the departments of Earth, Atmospheric, and Planetary Sciences, Chemistry, Physics, Mathematics, Civil and Environmental Engineering, Electrical Engineering and Computer Science, or Chemical Engineering, should be able to complete a Master of Science in Earth and Planetary Sciences, in Atmospheric Sciences, or in Ocean Sciences in one year of additional study, particularly if programs are arranged for this purpose from the beginning of the fourth year.

Applications for graduate enrollment in the department are considered any time after the beginning of the fourth year. Students may receive the Bachelor of Science as soon as the requirements are completed, or may elect to defer the award for simultaneous presentation with the Master of Science.

Minor in Earth, Atmospheric, and Planetary Sciences
The Minor in Earth, Atmospheric, and Planetary Sciences provides an opportunity to complement or expand upon one’s major by exploring in depth the natural processes that govern the structure and evolution of the Earth and planets. Areas of study include planetary surfaces, interiors, atmospheres, oceans, and biospheres. The EAPS Minor requires a solid foundation in two core subjects plus electives that create expertise in a particular area. Opportunities for field work, laboratory work, and independent study are an essential component of the minor.

Core Subjects
Select two of the following: 24

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
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<tbody>
<tr>
<td>12.001</td>
<td>Introduction to Geology</td>
</tr>
<tr>
<td>12.002</td>
<td>Introduction to Geophysics and Planetary Science</td>
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</table>
Graduate Study

The Department of Earth, Atmospheric, and Planetary Sciences offers opportunities for graduate study and research in a wide range of fields:

- Atmospheric chemistry
- Atmospheric dynamics
- Biogeochemistry
- Climate chemistry
- Climate dynamics
- Paleoclimate
- Geology
- Geobiology
- Geochemistry
- Geophysics
- Planetary sciences

Study in chemical oceanography, physical oceanography, biological oceanography, and marine geology and geophysics is offered in cooperation with the Joint Program with Woods Hole Oceanographic Institution (http://mit.whoi.edu).

Coursework during the first two years is the usual prelude to a thesis demonstrating that the student is capable of independent and creative research. The Department offers the following degrees: a Master of Science, a Doctor of Philosophy, or a Doctor of Science in the field of specialization.

A graduate thesis may have either a theoretical, experimental, or observational focus. Modern laboratory facilities, computers, instrumentation, and extensive collections of specimens and data are available to students. Field study is an essential part of the graduate curriculum in geology, geophysics, and geochemistry, and special arrangements may be made for summer employment and field research on departmental projects and with industrial organizations and government agencies. In atmospheric science and climate studies graduate study includes a mixture of theoretical and experimental studies sharing a common appreciation of the dynamics of the underlying processes.

Inquiries
Additional information may be obtained from the department’s Education Office, Room 54-912, 617-253-3381.
MIT undergraduate curricula. If students are not fully prepared in certain of the fields or required subjects, they usually are asked to extend their studies in these areas while pursuing advanced work. The doctoral program can be entered without a Master of Science as a prerequisite.

Master of Science in Earth and Planetary Sciences, in Atmospheric Science, or in Climate Physics and Chemistry
The General Degree Requirements for the degree of Master of Science in Earth and Planetary Science, in Atmospheric Science, or in Climate Physics and Chemistry are described under Graduate Education (http://catalog.mit.edu/mit/graduate-education). An individual program of study and research is arranged to suit the special background, needs, and goals of each student. The program is worked out in detail by the student with his or her personal faculty advisor and a departmental committee. There are no foreign language requirements for the degree.

Doctor of Philosophy and Doctor of Science
A specialized program of study and research is tailored to each student's background, needs, and goals by the student in consultation with a faculty advisor and a departmental committee. A doctoral candidate's program should be broad and may include formal study in other departments in addition to the specialized subjects that prepare the candidate for thesis research. There is no foreign language requirement for the degree. Thesis research normally begins immediately after successful completion of the general examination by the end of the second year. The general examination is intended to test the candidate's aptitude and preparation for independent research.

Thesis research is closely supervised by one or more faculty members interested in and knowledgeable about the research topic, who are chosen by the student and may be members of other departments. The thesis is expected to meet high professional standards, and to be a significant original contribution to the scientific field.

Interdisciplinary Programs

Joint Program with the Woods Hole Oceanographic Institution
The Joint Program with the Woods Hole Oceanographic Institution (WHOI) (http://mit.whoi.edu) is intended for students whose primary career objective is oceanography or oceanographic engineering. Students divide their academic and research efforts between the campuses of MIT and WHOI. Joint Program students are assigned an MIT faculty member as academic advisor; thesis research may be supervised by MIT or WHOI faculty. While in residence at MIT, students follow a program similar to that of other students in their home department. The program is described in more detail under Interdisciplinary Graduate Programs (http://catalog.mit.edu/interdisciplinary/graduate-programs/joint-program-woods-hole-oceanographic-institution).

Financial Support
The department offers a considerable number of research and teaching assistantships each year. Research assistants work on one of the many research projects in the department, often related to the student's thesis research. Teaching assistants assist in laboratory instruction or in the preparation of teaching materials and the grading of papers.

The department also offers several fellowships beyond normal teaching and research assistantships. Selection of individuals is based on the excellence of the applicant's record.

Inquiries
Additional information regarding academic and current research programs in the department, admission requirements, assistantship appointments, and financial aid may be obtained by writing to the department's Education Office, Room 54-912, 617-253-3381.

Research Laboratories and Programs
The department's faculty, staff, and students are engaged in a wide variety of research projects in the laboratories of individual faculty members and in the departmental laboratories described below. Many also participate in the activities of interdisciplinary laboratories such as the Center for the Global Change Science and the Joint Program on the Science and Policy of Global Change, described in the section on Research and Study (http://catalog.mit.edu/mit/research).

Earth Resources Laboratory
The Earth Resources Laboratory (ERL) (http://erl.mit.edu) is MIT's primary home for research and education focused on sub-surface energy resources. Through integration across disciplines, departments, and school boundaries, and with support from federal agencies and a consortium of energy companies, ERL addresses questions concerning hydrocarbon exploration and production, geothermal energy, CO₂ sequestration, and near-surface environments.

ERL's faculty, research staff, and students work with a variety of methodologies (including geophysical imaging, rock physics and chemistry, multiphase flow, geomechanics, microseismics, and remote sensing) to obtain a holistic understanding of sub-surface reservoirs—their structure, the geological materials of which they are made, the fluids that flow through them, and changes that occur in response to production.

Building on a rich tradition, ERL aims to produce tomorrow's industry leaders through rigorous disciplinary education and broad exposure to the earth sciences, mathematics, and engineering.

Professor Bradford H. Hager is the current director of ERL. For further information, please visit ERL website (http://erl.mit.edu).
George R. Wallace, Jr., Astrophysical Observatory
The George R. Wallace, Jr., Astrophysical Observatory (http://web.mit.edu/wallace) is a versatile facility for research and teaching optical astronomy. The observatory located in Westford, MA, has several optical telescopes ranging from 24-in to 8-in diameters and modern instrumentation. The telescopes are used in formal instruction; faculty, staff, and student research projects; and as testbeds for instrumentation to be used with larger telescopes. Further information on the Wallace Observatory may be obtained by contacting Dr. Michael Person (mjperson@mit.edu), 54-418, 617-452-2304.

George R. Wallace, Jr., Geophysical Observatory
The George R. Wallace, Jr., Geophysical Observatory is a unique research facility designed to monitor ground motions and to aid in the development and testing of new seismic and other geophysical instrumentation. It is also a key component of MIT’s five-station seismic network in New England.

Located 35 miles north of Boston in Westford, MA, the observatory has a large, multi-room underground vault and a surface control room. The vault has a controlled temperature environment and instrument piers resting directly on the basement granite. The observatory contains sensitive seismometers and instruments for monitoring ground tilts and the earth’s tidal motions. The surface building houses a work area and control and recording instruments. Data from the observatory are telemetered directly to the Earth Resources Laboratory of the Department of Earth, Atmospheric, and Planetary Sciences. The data from the observatory and the New England Seismic Network are recorded, displayed, and analyzed by three dedicated COMPAQ computers, which are also connected to workstations to facilitate data sharing and transfers. Data from the observatory along with the numerous resources of the department provide a unique facility for undergraduates, graduate students, and staff to pursue research concerning the interior of the earth.

Further information may be obtained by contacting EAPS Headquarters, 54-918, 617-253-2127.

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Professor Emeritus of Geology

Charles C. Counselman III, PhD  
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Frederick August Frey, PhD  
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M. Nafi Toksöz, PhD  
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Carl Wunsch, PhD  
Cecil and Ida Green Professor Emeritus  
Professor Emeritus of Physical Oceanography

Undergraduate Subjects

Core and General Science Subjects

12.000 Solving Complex Problems
Prereq: None
U (Fall)
1-2-6 units

Provides an opportunity for entering freshmen to gain firsthand experience in integrating the work of small teams to develop effective solutions to complex problems in Earth system science and engineering. Each year’s class explores a different problem in detail through the study of complementary case histories and the development of creative solution strategies. Includes exercises in website development, written and oral communication, and team building. Subject required for students in the Terrascope freshman program, but participation in Terrascope is not required of all 12.000 students. Students who pass 12.000 are eligible to participate in the Terrascope field trip the following spring. Limited to freshmen.  
D. McGee, A. Epstein

12.001 Introduction to Geology
Prereq: None
U (Fall)
3-4-5 units. REST

Major minerals and rock types, rock-forming processes, and time scales. Temperatures, pressures, compositions, structure of the Earth, and measurement techniques. Geologic structures and relationships observable in the field. Sediment movement and landform development by moving water, wind, and ice. Crustal processes and planetary evolution in terms of global plate tectonics with an emphasis on ductile and brittle processes. Includes laboratory exercises on minerals, rocks, mapping, plate tectonics, rheology, glaciers. Two one-day field trips (optional).  
EAPS Staff

12.002 Introduction to Geophysics and Planetary Science
Prereq: Physics II (GIR), Calculus II (GIR)
U (Spring)
3-1-8 units. REST

Study of the structure, composition, and physical processes governing the terrestrial planets, including their formation and basic orbital properties. Topics include plate tectonics, earthquakes, seismic waves, rheology, impact cratering, gravity and magnetic fields, heat flux, thermal structure, mantle convection, deep interiors, planetary magnetism, and core dynamics. Suitable for majors and non-majors seeking general background in geophysics and planetary structure.  
L. H. Royden, B. Weiss
12.003 Introduction to Atmosphere, Ocean, and Climate Dynamics
Prereq: Calculus II (GIR), Physics I (GIR)
U (Fall)
3-1-8 units. REST

Introduces the dynamical processes that govern the atmosphere, oceans, and climate. Topics include Earth's radiation budget, convection and clouds, the circulation of the atmosphere and ocean, and climate change. Illustrates underlying mechanisms through laboratory demonstrations with a rotating table, and through analysis of atmospheric and oceanic data.
T. Cronin

12.005 Applications of Continuum Mechanics to Earth, Atmospheric, and Planetary Sciences
Prereq: Physics II (GIR), Calculus II (GIR); Coreq: 18.03
U (Spring)
3-2-7 units

Practical applications of the continuum concept for deformation of solids and fluids, emphasizing force balance. Stress tensor, infinitesimal and finite strain, and rotation tensors are developed. Constitutive relations applicable to geological materials, including elastic, viscous, brittle, and plastic deformation. Laboratory component provides specific examples of elastic and inelastic mechanical behavior of rocks and illustrates several methods of measurement in the laboratory.
B. Hager

12.006[J] Nonlinear Dynamics: Chaos
Same subject as 2.050[J], 18.353[J]
Prereq: 18.03 or 18.032; Physics II (GIR)
U (Fall)
3-0-9 units

H. Ronellenfitsch

12.007 Geobiology: History of Life on Earth
Prereq: None
U (Spring)
3-0-9 units

Surveys the interactive Earth system: biology in geologic, environmental and climate change throughout Earth's history. Introduces the concept of "life as a geological agent" and examines the interaction between biology and the Earth system during the roughly 4 billion years since life first appeared. Topics include the origin of the solar system and the early Earth atmosphere; the origin and evolution of life and its influence on climate up through and including the modern age and the problem of global warming; the global carbon cycle; and astrobiology.
T. Bosak, R. Summons

12.008 Classical Mechanics: A Computational Approach
Subject meets with 6.946[J], 8.351[J], 12.620[J]
Prereq: Physics I (GIR), 18.03, permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: U (Fall)
3-3-6 units

J. Wisdom, G. J. Sussman

12.009[J] Nonlinear Dynamics: The Natural Environment
Same subject as 18.352[J]
Prereq: Physics I (GIR), Calculus II (GIR); Coreq: 18.03
U (Spring)
3-0-9 units

Analyzes cooperative processes that shape the natural environment, now and in the geologic past. Emphasizes the development of theoretical models that relate the physical and biological worlds, the comparison of theory to observational data, and associated mathematical methods. Topics include carbon cycle dynamics; ecosystem structure, stability and complexity; mass extinctions; biosphere-geosphere coevolution; and climate change. Employs techniques such as stability analysis; scaling; null model construction; time series and network analysis.
D. H. Rothman
12.010 Computational Methods of Scientific Programming
Prereq: Calculus II (GIR), Physics I (GIR)
U (Fall)
4-0-8 units
Introduces programming languages and techniques used by physical scientists: FORTRAN, C, C++, MatLab, and Mathematica. Emphasis on program design, algorithm development and verification, and comparative advantages and disadvantages of different languages. Students first learn the basic usage of each language, common types of problems encountered, and techniques for solving a variety of problems encountered in contemporary research: examination of data with visualization techniques, numerical analysis, and methods of dissemination and verification. No prior programming experience is required.
T. Herring, C. Hill

12.011 Archaeological Science
Same subject as 3.985[J], 5.24[J]
Prereq: Chemistry (GIR) or Physics I (GIR)
U (Spring)
3-1-5 units. HASS-S
See description under subject 3.985[J].
H. N. Lechtman

12.012 MatLab, Statistics, Regression, Signal Processing
Subject meets with 12.444
Prereq: None. Coreq: 18.06
U (Fall)
3-0-9 units
Introduces the basic tools needed for data analysis and interpretation in the Geosciences, as well as other sciences. Composed of four modules, targeted at introducing students to the basic concepts and applications in each module. MatLab: Principles and practice in its uses, script and function modules, basic approaches to solving problems. Statistics: Correlation, means, dispersion, precision, accuracy, distributions, central limit theorem, skewness, probability, Chi-Square, Gaussian and other common distributions used in hypothesis testing. Regression: Random and grid search methods, basic least squares and algorithms applicable to regression, inversion and parameter estimation. Signal Processing: Analog and digital signals, Z-transform, Fourier series, fast Fourier transforms, spectral analysis leakage and bias, digital filtering. Students taking the graduate version complete different assignments.
F. D. Morgan, T. A. Herring, S. Ravela

12.021 Earth Science, Energy, and the Environment
Prereq: Physics I (GIR), Calculus I (GIR), Chemistry (GIR)
U (Fall)
3-1-8 units
Provides understanding of the Earth System most relevant to production of our planet’s natural energy resources, including the physics, chemistry, and biology of conventional and alternative energy sources. Includes a broad overview of traditional and alternative energy sources: hydrocarbons (conventional and unconventional), nuclear, geothermal, hydroelectric, and wind and tides, along with their potentials and limitations. Develops detailed knowledge of the formation, concentration, and production of fossil and nuclear fuels, as well as the waste products associated with their consumption. An examination of conventional and alternative energy sources includes the environmental issues associated with the exploitation of these resources, both regional and global.
B. H. Hager

Same subject as 1.018A[J], 7.30A[J]
Prereq: None
U (Fall; first half of term)
2-0-4 units
See description under subject 1.018A[J].
O. Cordero, M. Follows

Same subject as 1.018B[J], 7.30B[J]
Prereq: 1.018A[J]
U (Fall; second half of term)
2-0-4 units
See description under subject 1.018B[J].
O. Cordero, M. Follows
12.086 Modeling Environmental Complexity
Subject meets with 12.586
Prereq: 18.03
U (Fall)
3-0-9 units
Introduction to mathematical and physical models of environmental processes. Emphasis on the development of macroscopic continuum or statistical descriptions of complex microscopic dynamics. Problems of interest include: random walks and statistical geometry of landscapes; percolation theory and transport in disordered media; fractals, scaling, and universality; ecological dynamics and the structure of ecosystems, food webs, and other natural networks; kinetics of biogeochemical cycles. Appropriate for advanced undergraduates. Beginning graduate students are encouraged to register for 12.586. Students taking the graduate version complete different assignments.
D. H. Rothman

12.090 Current Topics in Earth, Atmospheric, and Planetary Sciences
Prereq: Permission of instructor
U (Fall)
Units arranged
Can be repeated for credit.
Laboratory or field work in earth, atmospheric, and planetary sciences. Consult with department Education Office.
EAPS Faculty

12.091 Current Topics in Earth, Atmospheric, and Planetary Sciences
Prereq: Permission of instructor
U (Fall)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.
Laboratory or field work in earth, atmospheric, and planetary sciences. Consult with department Education Office.
EAPS Faculty

12.092 Current Topics in Geology and Geochemistry
Prereq: None
U (Fall, IAP, Spring)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.
Laboratory or field work in geology and geochemistry. Consult with department Education Office.
Staff

12.093 Current Topics in Geology and Geochemistry
Prereq: Permission of instructor
U (Fall)
Units arranged [P/D/F]
Can be repeated for credit.
Laboratory or field work in geology and geochemistry. To be arranged with department faculty. Consult with department Education Office.
EAPS Faculty

12.094 Current Topics in Geophysics
Prereq: Permission of instructor
U (Fall, IAP, Spring)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.
Laboratory or field work in geophysics. Consult with department Education Office.
EAPS Faculty

12.095 Current Topics in Geophysics
Prereq: Permission of instructor
U (IAP)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.
Laboratory or field work in geophysics. To be arranged with department faculty. Consult with department Education Office.
EAPS Faculty

12.096 Current Topics in Atmospheric Science and Oceanography
Prereq: Permission of instructor
U (Fall, IAP, Spring)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.
Laboratory or field work in atmospheric science and oceanography. To be arranged with department faculty. Consult with department Education Office.
EAPS Faculty
12.097 Current Topics in Atmospheric Science and Oceanography
Prereq: Permission of instructor
U (Fall)
Units arranged [P/D/F]
Can be repeated for credit.
Laboratory or field work in atmospheric science and oceanography.
To be arranged with department faculty. Consult with department Education Office.
EAPS Faculty

12.098 Current Topics in Planetary Science
Prereq: Permission of instructor
U (Fall)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.
Laboratory or field work in planetary science. To be arranged with department faculty. Consult with department Education Office.
EAPS Staff

12.099 Current Topics in Planetary Science
Prereq: Permission of instructor
U (Fall)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.
Laboratory or field work in planetary science. To be arranged with department faculty. Consult with department Education Office.
EAPS Faculty

Geology and Geochemistry

12.102 Environmental Earth Science
Prereq: None
U (Fall)
Not offered regularly; consult department
3-0-9 units. REST
The geologic record demonstrates that our environment has changed over a variety of time scales from seconds to billions of years. Explores the many ways in which geologic processes control and modify the Earth's environment. Topics include chemical and physical interactions between the solid Earth, its oceans and atmosphere; the effect of catastrophic events such as volcanic eruptions and earthquakes on the environment; geologic hazards; and our role in modifying the environment through Earth resource development. Serves as an introduction to 12.120, which addresses field applications of these principles in the American Southwest.
S. A. Bowring

12.104 Geochemistry of the Earth and Planets
Prereq: Calculus II (GIR)
Acad Year 2017-2018: U (Fall)
Acad Year 2018-2019: Not offered
3-2-7 units
Focuses on low-temperature geochemistry and the Earth's biogeochemical cycles, including the biologic and inorganic chemical processes that create chemical variability and element partitioning among lithosphere, hydrosphere and atmosphere. Covers basic thermodynamics, aqueous chemistry, major and trace element geochemistry, and stable isotopic geochemistry.
S. Ono, D. McGee

12.108 Structure of Earth Materials
Prereq: Chemistry (GIR)
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: U (Fall)
3-4-5 units
Provides a comprehensive introduction to crystalline structure, crystal chemistry, and bonding in rock-forming minerals. Introduces the theory relating crystal structure and crystal symmetry to physical properties such as refractive index, elastic modulus, and seismic velocity. Surveys the distribution of silicate, oxide, and metallic minerals in the interiors and on the surfaces of planets, and discusses the processes that led to their formation.
T. L. Grove

12.109 Petrology
Prereq: 12.108
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: U (Spring)
3-6-6 units
Surveys the distribution, chemical composition, and mineral associations in rocks of the Earth's crust and upper mantle, and establishes its relation to tectonic environment. Emphasis is on the use of chemistry and physics to interpret rock forming processes. Topics include dynamics of crust and mantle melting as preserved in the chemical composition of igneous rocks and minerals, the long-term record of global climate change as preserved in the minerals of sedimentary rocks, and the time-temperature-depth record preserved in minerals of metamorphosed crustal rocks.
T. L. Grove
12.11 Nature's Sandbox: A Record of Great Moments in Earth History
Prereq: None
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: U (IAP)
2-0-0 units

Designed for students curious about Earth Systems. Covers how sediments and the sedimentary rock record preserve information about events in Earth History and ancient climates and oceans. Serves as an introduction to the subjects 12.110A Sedimentary Environments and 12.110B Sedimentology in the Field.

K. Bergmann

12.110A Sedimentary Environments
Subject meets with 12.465A
Prereq: 12.11 or 12.001
U (Spring; first half of term)
2-1-3 units. Partial Lab

Covers the basic concepts of sedimentation from the properties of individual grains to large-scale basin analysis. Lectures cover sediment textures and composition, fluid flow and sediment transport, and formation of sedimentary structures. Depositional models, for both modern and ancient environments are a major component and are studied in detail with an eye toward interpretation of depositional processes and reconstructing paleoenvironments from the rock record. Satisfies 6 units of Institute Laboratory credit. Students taking graduate version complete additional assignments.

K. Bergmann

12.110B Sedimentology in the Field
Subject meets with 12.465B
Prereq: 12.110A
U (Spring; second half of term)
2-2-5 units. Partial Lab
Can be repeated for credit.

Examines the fundamentals of sedimentary deposits and geological reasoning through first hand fieldwork. Students practice methods of modern geological field study off-campus during a required trip over spring break making field observations, measuring stratigraphic sections and making a sedimentological map. Relevant topics introduced are map and figure making in ArcGIS and Adobe Illustrator and sedimentary petrology. Culminates in an oral and written report built around data gathered in the field. Field sites and intervals of geologic time studied rotate annually and include Precambrian, Phanerozoic and Modern depositional environments. Satisfies 6 units of Institute Laboratory credit. May be taken multiple times for credit. Students taking graduate version complete additional assignments.

K. Bergmann

12.113 Structural Geology
Prereq: 12.001
U (Fall)
3-3-6 units

Introduces mechanics of rock deformation. Discusses recognition, interpretation, and mechanics of faults, folds, structural features of igneous and metamorphic rocks, and superposed deformations. Introduces regional structural geology and tectonics. Laboratory includes techniques of structural analysis, recognition and interpretation of structures on geologic maps, and construction of interpretive cross sections.

O. Jagoutz

12.115 Field Geology
Prereq: 12.113
Acad Year 2017-2018: U (IAP)
Acad Year 2018-2019: Not offered
0-9-0 units. Partial Lab

Introduction to the methods of modern geological field study off-campus during an intensive two-week experience. Exercises include geological and geomorphological mapping on topographic and photographic base maps of a wide variety of bedrock and surficial rocks. Where feasible, geochemical and geophysical field measurements are correlated with geology. Location is usually in the western US. Contact department regarding travel fee and resources for funding opportunities. Satisfies 9 units of Institute Laboratory credit.

O. Jagoutz

12.116 Analysis of Geologic Data
Prereq: 12.115
U (Spring)
0-2-4 units. Partial Lab

Includes in-depth laboratory analysis of samples, interpretation of geological data, and where possible, geophysical and geochemical data. Includes the preparation of reports based on the field studies conducted in 12.115 during January; report generally exceeds 30 pages in length and includes one major revision and rewrite. Instruction in writing techniques provided. Contact department regarding travel fee and resources for funding opportunities. Satisfies 3 units of Institute Laboratory credit.

O. Jagoutz
12.119 Analytical Techniques for Studying Environmental and Geologic Samples  
Prereq: None  
U (Spring)  
2-6-4 units. Institute LAB  
Focuses on analytical facilities that are used to determine elemental and isotopic abundances in soils, rocks, minerals, and fluids. Emphasis is on isotopic ratios Sr, Nd, and Pb, whose isotopic ratios can be used for geochronology, and abundances of trace elements such as Rb, Sr, Cu, Cd, Hg, rare-earths, Pb, Th, and U. Analytical techniques include mass spectrometry, emission spectrometry, atomic absorption, neutron activation, and electron microprobe. A major lab project utilizes these techniques to address specific environmental and geologic problems.  
E. Boyle, T. Grove

12.120 Environmental Earth Science Field Course  
Prereq: Permission of instructor  
U (IAP)  
1-5-0 units  
Field study to foster understanding of natural hazards and human influence on the environment. Class conducted in the western United States, at locations such as Death Valley and the White Mountain Research Station in Bishop California. Topics include water use and availability, climate change, earthquakes and faulting, and landslides. Also examines volcanic hazards and geothermal power, effects of river diversion, and the geology of the Yucca Mountain facility for the storage of radioactive waste. Students partially responsible for travel expenses. Designed to follow 12.001 or 12.102; other students will be accepted when space is available.  
T. L. Grove

12.141 Electron Microprobe Analysis  
Prereq: None  
U (IAP)  
1-1-4 units  
Introduction to the theory of x-ray microanalysis through the electron microprobe including ZAF matrix corrections. Techniques to be discussed are wavelength and energy dispersive spectrometry, scanning backscattered electron, secondary electron, cathodoluminescence, and x-ray imaging. Lab sessions involve use of the electron microprobe.  
T. Grove, N. Chatterjee

12.158 Molecular Biogeochemistry  
Subject meets with 12.458  
Prereq: Permission of instructor  
Acad Year 2017-2018: Not offered  
Acad Year 2018-2019: U (Fall)  
2-4-3 units  
Covers all aspects of molecular biosignatures, such as their pathways of lipid biosynthesis, the distribution patterns of lipid biosynthetic pathways with regard to phylogeny and physiology, isotopic contents, occurrence in modern organisms and environments, diagenetic pathways, analytical techniques and the occurrence of molecular fossils through the geological record. Students analyze in depth the recent literature on chemical fossils. Lectures provide background on the subject matter. Basic knowledge of organic chemistry required. Students taking graduate version complete additional assignments.  
R. Summons

12.163 Geomorphology  
Subject meets with 12.463  
Prereq: 12.001, Physics I (GIR), Calculus I (GIR); or permission of instructor  
Acad Year 2017-2018: U (Fall)  
Acad Year 2018-2019: Not offered  
3-3-6 units  
Quantitative examination of processes that shape Earth's surface. Introduction to fluvial, hillslope, and glacial mechanics. Essentials of weathering, soil formation, runoff, erosion, slope stability, sediment transport, and river morphology. Landscape evolution in response to climatic and tectonic forcing. Application of terrestrial theory to planetary surfaces. Additional instruction in geographic information systems (GIS) and remote sensing analysis, field measurement techniques, and numerical modeling of surface processes. Students taking the graduate version complete different assignments.  
T. Perron
12.170 Essentials of Geology
Subject meets with 12.470
Prereq: Physics II (GIR), Calculus II (GIR); or permission of instructor
U (Fall)
Not offered regularly; consult department
4-0-8 units
Studies the geology of planetary interiors and surfaces, including
plate tectonics, as a unifying theory of terrestrial geology, surface
processes, and the Earth’s interior. Covers igneous, metamorphic,
and sedimentary processes associated with tectonic settings and
the typical rock suites created; mineral and rock identification;
and causes of compositional differences on many scales (mineral
grains, rocks, regions of the Earth, different planets). Also addresses
conditions required for melting and melting processes; rock
structure and field techniques; and Earth history. Treatment of
these topics includes discussions of the geochemical, petrologic,
geochronological, experimental, or field techniques used to
investigate them; the limitations of current geological techniques
and geological controversies; and major geological expeditions,
experiments, and studies from the past, along with their premises
and results. Students taking graduate version complete additional
assignments.
EAPS Staff

12.177 Astrobiology, Origins and Early Evolution of Life (New)
Subject meets with 12.477
Prereq: Chemistry (GIR), Biology (GIR), or permission of instructor
U (Spring)
3-0-9 units
Provides an understanding of major areas of research into
the problem of the origin of life on the early Earth from an
astrobiological perspective. Topics include the timing, setting
and conditions for the origin of life on the Hadean Earth; roles of
planetary and extra-planetary processes; defining life; prebiotic
chemistry; origins of nucleic acids and peptides; evolution of
cellularity, replication, metabolism, and translation; establishment
of the genetic code; biogenesis vs. ecogenesis; the nature of the
last common ancestor of life; conceptualizing the “tree of life;”
and the early evolution of the ancestors of bacteria, archael, and
eukaryal lineages. Students taking graduate version complete an
extra project.
G. Fournier

Geophysics

12.201 Essentials of Global Geophysics
Subject meets with 12.501
Prereq: Physics II (GIR), 18.03
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: U (Fall)
4-0-8 units
Overview of basic topics in solid-earth geophysics, such as the
Earth’s rotation, gravity and magnetic field, seismology, and thermal
structure. Formulation of physical principles presented in three
one-hour lectures per week. Current applications discussed in an
additional one-hour tutorial each week. Students taking graduate
version complete different assignments.
R. van der Hilst

12.207[J] Nonlinear Dynamics: Continuum Systems
Same subject as 1.062[J], 18.354[J]
Subject meets with 18.3541
Prereq: 18.03 or 18.032; Physics II (GIR)
U (Spring)
3-0-9 units
See description under subject 18.354[J].
L. Bourouiba
12.213 Alternate Energy Sources  
Prereq: None  
U (IAP)  
Not offered regularly; consult department  
1-4-1 units  
Can be repeated for credit.  
Explores a number of alternative energy sources such as geothermal energy (heat from the Earth's interior), wind, natural gas, and solar energy. Includes a field trip to visit sites where alternative energy is being harvested or generated. Content and focus of subject varies from year to year.  
F. D. Morgan

12.214 Essentials of Applied Geophysics  
Subject meets with 12.507  
Prereq: 18.03  
Acad Year 2017-2018: U (Fall)  
Acad Year 2018-2019: Not offered  
3-3-6 units  
Introduces the application of geophysical methods to all aspects of near-surface environmental and engineering geophysics, including the exploration for petroleum, water, and minerals. Topics include seismic, electrical, electromagnetic, ground penetrating radar, magnetics, gravity, rock physics and chemistry, borehole geophysics and the global positioning system (GPS). Uses a quantitative approach to emphasize basic principles and a physical/chemical understanding of each method. Discusses specific illustrative field examples. Lab work is mainly devoted to local field work and equipment preparation for the IAP Field Geophysics class. Students taking the graduate version complete additional assignments.  
F. D. Morgan, T. A. Herring, B. H. Hager

Atmospheres, Oceans, and Climate

12.300[J] Global Change Science  
Same subject as 1.071[J]  
Prereq: 18.03  
Acad Year 2017-2018: Not offered  
Acad Year 2018-2019: U (Fall)  
3-0-9 units  
See description under subject 1.071[J].  
E. A. B. Eltahir

12.301 Climate Science  
Subject meets with 12.842  
Prereq: Chemistry (GIR), 18.03, or permission of instructor  
U (Fall)  
4-0-8 units  
Introduction to climate studies, including beginnings of the solar system, time scales, and climate in human history; methods for detecting climate change, including proxies, ice cores, instrumental records, and time series analysis; physical and chemical processes in climate, including primordial atmosphere, ozone chemistry, carbon and oxygen cycles, and heat and water budgets; internal feedback mechanisms, including ice, aerosols, water vapor, clouds, and ocean circulation; climate forcing, including orbital variations, volcanism, plate tectonics, and solar variability; climate models and mechanisms of variability, including energy balance, coupled models, and global ocean and atmosphere models; and outstanding problems. Students taking the graduate version complete different assignments.  
K. Emanuel, E. Boyle, D. McGee

12.306 Atmospheric Physics and Chemistry  
Subject meets with 10.571[J], 12.806[J]  
Prereq: 5.60 or 5.61; 18.075; or permission of instructor  
U (Spring)  
3-0-9 units  
Introduction to the physics and chemistry of the atmosphere including experience with computer codes. Aerosols and theories of their formation, evolution, and removal. Gas and aerosol transport from urban to continental scales. Coupled models of radiation, transport, and chemistry. Solution of inverse problems to deduce emissions and removal rates. Emissions control technology and costs. Applications to air pollution and climate. Students taking the graduate version complete different assignments.  
R. G. Prinn
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Prerequisites</th>
<th>Credits</th>
<th>Schedule</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.307</td>
<td>Weather and Climate Laboratory</td>
<td>Prereq: Calculus II (GIR), Physics I (GIR)</td>
<td>1-4-7</td>
<td>U (Spring)</td>
<td>A laboratory subject intended to illustrate, by means of hands-on projects, the basic dynamical and physical principles which govern the general circulation of the atmosphere and the day-to-day sequence of weather events. Real-time meteorological observations are studied together with laboratory fluid experiments. Projects based on real-time observations stress the analysis and dynamical interpretation of the real phenomena, while complementary rotating tank experiments stress planning and testing of ideas in a more controlled laboratory environment. Written critical summaries of the results of each project and oral presentations are an integral part of the subject. Satisfies 12 units of Institute Laboratory credit.</td>
</tr>
<tr>
<td>12.310</td>
<td>An Introduction to Weather Forecasting</td>
<td>Prereq: Physics I (GIR), Calculus I (GIR)</td>
<td>1-1-4</td>
<td>U (IAP)</td>
<td>Basic principles of synoptic meteorology and weather forecasting. Analysis of hourly weather data and numerical weather prediction models. Regular preparation of weather forecasts.</td>
</tr>
<tr>
<td>12.315</td>
<td>Atmospheric Radiation and Convection (New)</td>
<td>Subject meets with 12.815</td>
<td>5-2-5</td>
<td>U (Spring)</td>
<td>Introduction to the physics of atmospheric radiation, remote sensing, and convection, including use of computer codes. Radiative transfer equation including emission and scattering, spectroscopy, Mie theory, and numerical solutions. Physics of dry and moist convection, including moist thermodynamics. Radiative-convective equilibrium. Solution of inverse problems in remote sensing of atmospheric temperature and composition. Students taking graduate version complete different assignments.</td>
</tr>
<tr>
<td>12.318</td>
<td>Introduction to Atmospheric Data and Large-scale Dynamics (New)</td>
<td>Prereq: None. Coreq: 12.390</td>
<td>3-3-6</td>
<td>U (Fall)</td>
<td>Provides a general introduction to meteorological data and analysis techniques, and their use in the MIT Synoptic Laboratory to study the phenomenology and dynamics of large-scale atmospheric flow. Illustrates balance concepts as applied to the dynamics of frontal and synoptic scales, using real-time upper-air and surface station data and gridded analyzed fields. Uses advanced meteorological software packages to access, manipulate, and graphically display the data. Students taking graduate version complete different assignments.</td>
</tr>
<tr>
<td>12.320B[J]</td>
<td>Introduction to Hydrology Modeling</td>
<td>Same subject as 1.070B[J]</td>
<td>2-0-4</td>
<td>U (Fall; second half of term)</td>
<td>See description under subject 1.070B[J].</td>
</tr>
</tbody>
</table>

* L. Illari, J. Marshall
* T. Cronin
* D. Entekhabi
12.333 Atmospheric Dynamics
Prereq: 12.003, 8.03, 18.03; or permission of instructor
U (Fall)
Not offered regularly; consult department
4-0-8 units

Discusses the dynamics of the atmosphere, with emphasis on the large scale. Topics include zonally symmetric circulations and the tropical Hadley circulation; internal gravity waves; balanced flows, potential vorticity conservation and Rossby waves; stability of zonal flows; baroclinic instability and extratropical storms; tropical waves, the Walker circulation, and El Niño and the Southern Oscillation; and the role of eddies in the general circulation. Students taking graduate version complete different assignments.

EAPS Staff

12.335 Experimental Atmospheric Chemistry
Subject meets with 12.835
Prereq: Chemistry (GIR)
U (Fall)
2-4-6 units. Institute LAB

Introduces the atmospheric chemistry involved in climate change, air pollution, and ozone depletion using a combination of interactive laboratory and field studies and simple computer models. Uses instruments for trace gas and aerosol measurements and methods for inferring fundamental information from these measurements. Provides instruction and practice in written and oral communication. Students taking the graduate version complete different assignments.

R. Prinn, S. Ono, K. Dryer

12.336[J] Air Pollution
Same subject as 1.085[J]
Prereq: 18.03
U (Fall)
3-0-9 units

See description under subject 1.085[J].

C. Heald

12.338 Aerosol and Cloud Microphysics and Chemistry
Subject meets with 1.842[J], 12.814[J]
Prereq: 12.335, 12.336[J], or permission of instructor
U (Spring)
3-0-9 units

Focuses on understanding how aerosol particles form droplets or ice crystals during several atmospheric processes: determining Earth’s radiative balance; heterogeneous chemistry and acid rain; understanding where, when and how much precipitation occurs. Provides tools for understanding the physics of aerosol and cloud element motion; the interaction of particles with water vapor, including phase changes and droplet and ice nucleation; the chemical composition of particles and the effect on cloud formation processes; and the effect of cloud processing on aerosol chemistry. Discusses relevant topics of contemporary interest, e.g., geoengineering and weather modification and volcanic effects. Students taking the graduate version complete different assignments.

D. Cziczo

12.340 Global Warming Science
Prereq: Calculus I (GIR), Physics I (GIR), or permission of instructor;
Coreq: 5.60
U (Spring)
Not offered regularly; consult department
3-0-9 units

Provides students with a scientific foundation of anthropogenic climate change and an introduction to climate models. Focuses on fundamental physical processes that shape climate (e.g. solar variability, orbital mechanics, greenhouse gases, atmospheric and oceanic circulation, and volcanic and soil aerosols) and on evidence for past and present climate change. Discusses material consequences of climate change, including sea level change, variations in precipitation, vegetation, storminess, and the incidence of disease. Examines the science behind mitigation and adaptation proposals.

EAPS Staff

12.346[J] Global Environmental Negotiations
Same subject as IDS.062[J]
Subject meets with 12.846[J], IDS.525[J]
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: U (Fall)
2-0-4 units

See description under subject IDS.062[J].

N. E. Selin
Same subject as 15.026[J]
Subject meets with 12.848[J], 15.023[J]
Prereq: Calculus II (GIR), 5.60, 14.01; or permission of instructor
U (Spring)
3-0-6 units
See description under subject 15.026[J].
R. G. Prinn

12.349 Mechanisms and Models of the Global Carbon Cycle
Subject meets with 12.849
Prereq: Calculus II (GIR), Physics I (GIR)
U (Spring)
3-0-9 units
Addresses changes in the ocean, terrestrial biosphere and rocks modulation of atmospheric carbon dioxide on timescales from months to millions of years. Includes feedbacks between carbon cycle and climate. Combines hands-on data analysis with the formulation of simple models rooted in basic physical, chemical and biological principles. Students create individual “toy” global carbon cycle models. Students taking graduate version complete different assignments.
M. Follows

12.372 Elements of Modern Oceanography (New)
Subject meets with 12.702
Prereq: Permission of instructor
U (Fall)
3-0-9 units
Examines a series of crosscutting topics that exemplify current directions in interdisciplinary oceanography. Focuses on current themes in oceanography, their interdisciplinary nature, and the role of ocean sciences in society. Introduces core concepts across the disciplines of biological, physical, and chemical oceanography as well as marine geology. Emphasizes the interdisciplinary aspects of these core concepts, the kinds of approaches and modes of thinking common to all of the disciplines, and the technological developments underpinning current advances. Students taking graduate version complete different assignments.
G. Lawson, A. Kirincich (WHOI)

12.377 The History of Earth’s Climate (New)
Subject meets with 12.707
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: U (Spring)
3-0-9 units
Studies the climate history of the Earth, from the formation of the early atmosphere and ocean to the present. Evaluates geochemical, sedimentological, and paleontological evidence for changes in ocean circulation, global temperatures, and atmospheric carbon dioxide levels. Covers theories and models of Phanerozoic climate change. Provides a long-term history of the global carbon cycle. Students taking graduate version complete different assignments.
D. McGee

12.385 Science, Politics, and Environmental Policy
Subject meets with 11.373[J], 12.885[J]
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: U (Fall)
3-0-6 units
Examines the role of science in US and international environmental policymaking. Surveys the methods by which scientists learn about the natural world; the treatment of science by experts, advocates, the media, and the public and the way science is used in legislative, administrative and judicial decision making. Through lectures, group discussions, and written essays, students develop a critical understanding of the role of science in environmental policy. Potential case studies include fisheries management, ozone depletion, global warming, smog, and endangered species. Students taking the graduate version complete different assignments.
S. Solomon, J. Knox-Hayes

12.386[J] Environment and History (New)
Same subject as 21H.185[J]
Prereq: None
U (Fall)
3-0-9 units. HASS-S; CI-H
See description under subject 21H.185[J]. Enrollment limited.
H. Ritvo, S. Solomon
12.387[J] People and the Planet: Environmental Governance and Science (New)
Same subject as 15.874[J], IDS.063[J]
Prereq: None
U (Fall)
3.0-6 units
Introduces governance and science aspects of complex environmental problems and approaches to solutions. Introduces quantitative analyses and methodological tools to analyze environmental issues that have human and natural components. Demonstrates concepts through a series of in-depth case studies of environmental governance and science problems. Students develop writing, quantitative modeling, and analytical skills in assessing environmental systems problems and developing solutions. Through experiential activities, such as modeling and policy exercises, students engage with the challenges and possibilities of governance in complex, interacting systems, including biogeophysical processes and societal and stakeholder interactions.
N. Selin, S. Solomon, J. Sterman

12.390 Fluid Dynamics of the Atmosphere and Ocean (New)
Subject meets with 12.800
Prereq: 12.003
U (Fall)
3.0-9 units
Introduction to fluid dynamics. Students acquire an understanding of some of the basic concepts of fluid dynamics that are needed as a foundation for advanced coursework in atmospheric science, physical oceanography, ocean engineering, climate science, etc. Emphasizes fluid fundamentals, with an atmosphere/ocean twist. Students taking graduate version complete additional assignments.
A. Mahadevan, C. Cenedese

Planetary Science and Astronomy

12.400 The Solar System
Prereq: Physics I (GIR)
U (Spring)
Not offered regularly; consult department
3.0-9 units. REST
Introduction to the study of the solar system with emphasis on the latest spacecraft results. Subject covers basic principles rather than detailed mathematical and physical models. Topics include an overview of the solar system, planetary orbits, rings, planetary formation, meteorites, asteroids, comets, planetary surfaces and cratering, planetary interiors, planetary atmospheres, and life in the solar system.
R. P. Binzel

12.402[J] Introduction to Astronomy
Same subject as 8.282[J]
Prereq: Physics I (GIR)
U (Spring)
3.0-6 units. REST
See description under subject 8.282[J].
Staff

12.409 Hands-On Astronomy: Observing Stars and Planets
Prereq: None
U (Spring)
0.4-2 units
Background for, and techniques of, visual observation and electronic imaging of the Moon, planets, satellites, stars, and brighter deep-space objects. Weekly outdoor observing sessions using 8-inch diameter telescopes when weather permits. Indoor sessions introduce skills necessary for observation. Introduction to contemporary observational astronomy including astronomical computing, image and data processing, and how astronomers work. Student must maintain a careful and complete written log which is graded. Consumes an entire evening each week; 100% attendance at observing sessions required to pass. Enrollment limited; priority to freshmen.
A. Bosh

12.410[J] Observational Techniques of Optical Astronomy
Same subject as 8.287[J]
Prereq: 8.282[J], 12.402[J], 12.409, or other introductory astronomy course; Coreq: 8.03
U (Fall)
3.4-8 units. Institute LAB
Fundamental physical and optical principles used for astronomical measurements at visible wavelengths and practical methods of astronomical observations. Topics: astronomical coordinates, time, optics, telescopes, photon counting, signal-to-noise ratios, data analysis (including least-squares model fitting), limitations imposed by the Earth’s atmosphere on optical observations, CCD detectors, photometry, spectroscopy, astrometry, and time variability. Project at Wallace Astrophysical Observatory. Written and oral project reports. Limited to 18; preference to Course 8 and Course 12 majors and minors.
R. Binzel, A. Bosh
**12.411 Astronomy Field Camp**  
Prereq: 12.410[J] or 8.287[J]  
U (IAP)  
0-6-3 units  
Can be repeated for credit.  

Individual research projects in planetary science and astrophysics, involving supervised work at Lowell Observatory in Flagstaff, AZ. Projects may include observations made using Lowell’s telescope facilities. Project topics and objectives vary from year to year. Written and oral reports required. Limited to 6.  
* A. Bosh  

**12.420 Physics and Chemistry of the Solar System**  
Subject meets with 12.601  
Prereq: 12.002 or permission of instructor  
Acad Year 2017-2018: U (Fall)  
Acad Year 2018-2019: Not offered  
3-0-9 units  

Advanced applications of physical and chemical principles to the study of the solar system. Topics include terrestrial and giant planets, meteorites, asteroids, comets, Kuiper belt objects, rings, impact craters, interiors, surfaces, atmospheres, geomagnetism, cosmochemistry, remote sensing, formation and evolution of the solar system.  
* B. P. Weiss  

**12.422 Planetary Atmospheres (New)**  
Subject meets with 12.622  
Prereq: 12.003 or permission of instructor  
U (Spring)  
3-0-9 units  

Provides a basic understanding of the physics and chemistry of planetary atmospheres. Explores the formation and evolution of atmospheres, their structure and dynamics, and what is known about their chemical composition. Pays particular attention to their energy balance. Also presents the current state of understanding of exoplanet atmospheres. Students taking graduate version complete an additional research project.  
* D. Cziczo  

Same subject as 8.290[J]  
Subject meets with 12.625  
Prereq: 8.03, 18.03  
U (Fall)  
2-1-9 units. REST  

Presents basic principles of planet atmospheres and interiors applied to the study of extrasolar planets. Focuses on fundamental physical processes related to observable extrasolar planet properties. Provides a quantitative overview of detection techniques. Introduction to the feasibility of the search for Earth-like planets, biosignatures and habitable conditions on extrasolar planets. Students taking graduate version complete additional assignments.  
* S. Seager  

**12.43[J] Space Systems Engineering**  
Same subject as 16.83[J]  
Prereq: Permission of instructor  
U (Fall)  
3-3-6 units  

See description under subject 16.83[J].  
* R. P. Binzel, D. W. Miller  

**12.431[J] Space Systems Development**  
Same subject as 16.831[J]  
Prereq: Permission of instructor  
Acad Year 2017-2018: U (Spring)  
Acad Year 2018-2019: Not offered  
2-10-6 units. Institute LAB  

See description under subject 16.831[J].  
* J. A. Hoffman, A. Saenz-Otero  

**Independent Research Subjects**  

**12.UR Undergraduate Research**  
Prereq: None  
U (Fall, IAP, Spring, Summer)  
Units arranged [P/D/F]  
Can be repeated for credit.  

Undergraduate research opportunities in Earth, Atmospheric, and Planetary Sciences.  
* Consult Department UROP Coordinator
12.URG Undergraduate Research
Prereq: None
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Undergraduate research opportunities in Earth, Atmospheric, and Planetary Sciences.
Consult Department UROP Coordinator

12.IND Independent Study
Prereq: 12.TIP
U (Fall, IAP, Spring, Summer)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

Independent reading, laboratory, or fieldwork in Earth, Atmospheric, and Planetary Sciences. To be arranged by student and an appropriate EAPS faculty member. A written report may be required at the discretion of the advisor. Units arranged should reflect the project requirements.
Consult EAPS Education Office

12.TIP Thesis Preparation
Prereq: None
U (Fall, Spring)
2-0-4 units

Definition of and early-stage work on the thesis project. Students develop a written research proposal and begin writing the supporting text of the thesis concurrent with conducting research for the thesis project. Supervision of the writing continues into the spring term which concludes with an oral presentation of the research results.
J. Connor

12.THU Undergraduate Thesis
Prereq: 12.TIP
U (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Program of research leading to the writing of a thesis; to be arranged by the student and an appropriate MIT faculty member.
EAPS Faculty

Graduate Subjects

12.44 Practical Work Experience (New)
Prereq: None
G (Fall, IAP, Spring, Summer)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.

For Course 12 students participating in off-campus work experiences related to their research. Before registering for this subject, students must have an employment offer from a company or organization, must identify an EAPS supervisor, and must receive prior approval from their advisor. Upon completion of the work, student must submit a letter from the employer describing the work accomplished, along with a substantive final report from the student approved by the EAPS supervisor. Consult departmental academic office.
EAPS Faculty

12.440, 12.441 Collaborative Seminar in Geology and Geophysics
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Focuses on problems of current interest in geology and geophysics; subject matter varies from term to term. Includes guest speakers from outside of EAPS. 12.441 is graded P/D/F.
Geology and Geophysics Staff

12.442, 12.443 Collaborative Seminar in Planetary Science
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Focuses on problems of current interest in planetary science; subject matter varies from term to term. Includes guest speakers from outside of EAPS. 12.443 is graded P/D/F.
Planetary Science Staff
**12.444 Matlab, Statistics, Regression, Signal Processing**
Subject meets with 12.012
Prereq: 18.06
G (Fall)
3-0-9 units
Introduces the basic tools needed for data analysis and interpretation in the Geosciences, as well as other sciences. Composed of four modules, targeted at introducing students to the basic concepts and applications in each module. Matlab: Principles and practice in its uses, script and function modules, basic approaches to solving problems. Statistics: Correlation, means, dispersion, precision, accuracy, distributions, central limit theorem, skewness, probability, Chi-Square, Gaussian and other common distributions used in hypothesis testing. Regression: Random and grid search methods, basic least squares and algorithms applicable to regression, inversion and parameter estimation. Signal Processing: Analog and digital signals, Z-transform, Fourier series, fast Fourier transforms, spectral analysis leakage and bias, digital filtering. Students taking the graduate version complete different assignments.
*F. D. Morgan, T. A. Herring, S. Ravela*

**12.445 Communication in the Earth, Atmospheric, and Planetary Sciences**
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-3 units
Concentrated instruction and practice in professional writing and presentation. Topics include review of various communication styles prevalent in the field; strategies for tailoring reports, technical papers, and presentations for specific audiences; and mechanics of organization and style. Weekly assignments in writing or speaking, with peer and instructor feedback. Limited to 6.
*F. D. Morgan*

**12.448, 12.449 Collaborative Seminar in Atmospheres, Oceans and Climate**
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
Units arranged
Can be repeated for credit.
Focuses on problems of current interest in atmospheres, oceans, and climate; subject matter varies from term to term. Includes guest speakers from outside of EAPS. 12.449 is graded P/D/F.
*PAOC Staff*

**12.THG Graduate Thesis**
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.
Program of research leading to the writing of an SM, PhD, or ScD thesis; to be arranged by the student and an appropriate MIT faculty member.
*Consult Department Headquarters*

**Geology and Geochemistry**

**12.450 Seminar in Geology and Geochemistry**
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
2-0-4 units
Can be repeated for credit.
Seminar on topics of current interest in geology and geochemistry. Required background preparation for students taking pre-doctoral general examinations in these subjects.
*Geology and Geochemistry Staff*

**12.451 Seminar in Regional Tectonics**
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
3-0-6 units
Can be repeated for credit.
Applies techniques of tectonic synthesis to study the roles of particular orogenic belts in global plate tectonics. Treats different applications in different terms, so that the subject may be taken repeatedly to learn the range of orogenic responses to temporal and spatial variations of activity at plate boundaries.
*B. C. Burchfiel, L. H. Royden*
12.453-12.454 Crosby Lectures in Geology
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
3-0-6 units
Can be repeated for credit.
A series of presentations on an advanced topic in the field of geology by the visiting William Otis Crosby lecturer. The Crosby lectureship is awarded to a distinguished international scientist each year to introduce new scientific perspectives to the MIT community. Subject content and structure vary from year to year.
Consult Department Education Office

12.456 Seminar in Rock Mechanics
Prereq: Permission of instructor
G (Spring)
2-0-4 units
Can be repeated for credit.
Discussion of current research or advanced topics in continental tectonics, rock mechanics, or experimental structural geology.
B. Evans

12.458 Molecular Biogeochemistry
Subject meets with 12.158
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
2-4-3 units
Covers all aspects of molecular biosignatures, such as their pathways of lipid biosynthesis, the distribution patterns of lipid biosynthetic pathways with regard to phylogeny and physiology, isotopic contents, occurrence in modern organisms and environments, diageneric pathways, analytical techniques and the occurrence of molecular fossils through the geological record. Students analyze in depth the recent literature on chemical fossils. Lectures provide background on the subject matter. Basic knowledge of organic chemistry required. Students taking graduate version complete additional assignments.
R. Summons

12.460-12.461 Current Research in Geology and Geochemistry
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.
Original investigations on problems in geology, petrology, mineralogy, geochemistry, or geobiology. 12.460 is letter-graded.
EAPS Staff

12.463 Geomorphology
Subject meets with 12.163
Prereq: 12.001, Physics I (GIR), Calculus I (GIR); or permission of instructor
Acad Year 2017-2018: G (Fall)
Acad Year 2018-2019: Not offered
3-3-6 units
Quantitative examination of processes that shape Earth’s surface. Introduction to fluvial, hillslope, and glacial mechanics. Essentials of weathering, soil formation, runoff, erosion, slope stability, sediment transport, and river morphology. Landscape evolution in response to climatic and tectonic forcing. Application of terrestrial theory to planetary surfaces. Additional instruction in geographic information systems (GIS) and remote sensing analysis, field measurement techniques, and numerical modeling of surface processes. Students taking the graduate version complete different assignments.
T. Perron

12.465A Sedimentary Environments
Subject meets with 12.110A
Prereq: Permission of instructor
G (Spring; first half of term)
2-1-3 units
Covers the basic concepts of sedimentation from the properties of individual grains to large-scale basin analysis. Lectures cover sediment textures and composition, fluid flow and sediment transport, and formation of sedimentary structures. Depositional models, for both modern and ancient environments are a major component and are studied in detail with an eye toward interpretation of depositional processes and reconstructing paleoenvironments from the rock record. Students taking graduate version complete additional assignments.
K. Bergmann
12.465B Sedimentology in the Field
Subject meets with 12.110B
Prereq: 12.456 or permission of instructor
G (Spring; second half of term)
2-2-5 units
Can be repeated for credit.

Examines the fundamentals of sedimentary deposits and geological reasoning through first hand fieldwork. Students practice methods of modern geological field study off-campus during a required trip over spring break making field observations, measuring stratigraphic sections and making a sedimentological map. Relevant topics introduced are map and figure making in ArcGIS and Adobe Illustrator and sedimentary petrology. Culminates in an oral and written report built around data gathered in the field. Field sites and intervals of geologic time studied rotate annually and include Precambrian, Phanerozoic and Modern depositional environments. May be taken multiple times for credit. Students taking graduate version complete additional assignments.
K. Bergmann

12.467 Seminar in Geomorphology
Prereq: Permission of instructor
G (Spring)
2-0-4 units
Can be repeated for credit.

Discussion of current research or advanced topics in landscape evolution, surface hydrology, mechanics of sediment transport, basin analysis, or experimental geomorphology. Advanced instruction in process geomorphology.
EAPS Staff

12.470 Essentials of Geology
Subject meets with 12.170
Prereq: Physics II (GIR), Calculus II (GIR); or permission of instructor
G (Fall)
Not offered regularly; consult department
4-0-8 units

Geology of planetary interiors and surfaces, including plate tectonics, as a unifying theory of terrestrial geology, surface processes, and the Earth’s interior. Igneous, metamorphic, and sedimentary processes associated with tectonic settings and the typical rock suites created. Mineral and rock identification. Causes of compositional differences on many scales: mineral grains, rocks, regions of the Earth, different planets. Conditions required for melting and melting processes. Rock structure and field techniques. Earth history. Treatment of these topics includes discussions of the geochemical, petrologic, geochronological, experimental, or field techniques used to investigate them; the limitations of current geological techniques and geological controversies; and great geological expeditions, experiments, and studies from the past, their premises, and their results. Students taking graduate version complete additional assignments.
EAPS Staff

12.471 Essentials of Geobiology
Prereq: None
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
3-4-5 units

Introduces basic concepts of microbial structure, growth, energetics, molecular biology, and biochemistry. Presents examples of microbial interactions with environments throughout Earth’s history as well as current topics in astrobiology. Includes lectures, discussions of literature, and a field trip. Lab focuses on student-designed projects that involve cultivation, modeling, or sample analyses. Intended for students whose background is not in biology, but who want to learn more about the contribution of microbes to geochemistry and planetary evolution.
T. Bosak
12.473 Paleomagnetism and Planetary Magnetism
Prereq: 12.002, 18.03; or permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
2-0-4 units
Introduces the study of natural remanent magnetization and the generation of planetary magnetic fields. Topics include paleomagnetism, rock magnetism, geomagnetism, magnetostratigraphy, paleomagnetic measurement techniques, polar wander and continental drift, biomagnetism, dynamo theory, and the history and evolution of magnetic fields on the Earth and planets.
B. P. Weiss

12.474 Origin and Evolution of the Earth's Crust
Prereq: Permission of instructor
Acad Year 2017-2018: G (Spring)
Acad Year 2018-2019: Not offered
3-0-6 units
Broad overview of the origin and evolution of Earth's crust and mantle with emphasis on the study of the Precambrian rock record. Topics include: processes of crustal growth, stabilization, and reactivation; evaluation of secular change; and use of radiogenic isotopes in geochronology and as tracers of crust forming processes.
O. Jagoutz

12.475 Plate Tectonics and Continental Deformation
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Spring)
3-0-6 units
First half covers basic elements of plate tectonics, including sea floor spreading, magnetic anomalies, and subduction zone. Second half covers implications of plate tectonics for continental processes, including continental rifting, continental collision, and mountain building. Emphasis will be on correlating plate tectonic and continental processes using specific examples from around the world.
L. H. Royden

12.476 Radiogenic Isotope Geology
Prereq: Permission of instructor
G (Spring)
Not offered regularly; consult department
3-3-6 units
Applications of the variations in the relative abundance of radiogenic isotopes to problems of petrology, geochemistry, and tectonics. Topics: geochronology; isotopic evolution of Earth's crust and mantle; petrogenesis; and analytical techniques.
S. Bowring

12.477 Astrobiology, Origins and Early Evolution of Life (New)
Subject meets with 12.177
Prereq: Permission of instructor
G (Spring)
3-0-9 units
Provides an understanding of major areas of research into the problem of the origin of life on the early Earth from an astrobiological perspective. Topics include the timing, setting and conditions for the origin of life on the Hadean Earth; roles of planetary and extra-planetary processes; defining life; prebiotic chemistry; origins of nucleic acids and peptides; evolution of cellularity, replication, metabolism, and translation; establishment of the genetic code; biogenesis vs. ecogenesis; the nature of the last common ancestor of life; conceptualizing the “tree of life;” and the early evolution of the ancestors of bacteria, archaeal, and eukaryal lineages. Students taking graduate version complete an extra project.
G. Fournier

12.480 Thermodynamics for Geoscientists
Prereq: 5.60 or 3.046
Acad Year 2017-2018: G (Spring)
Acad Year 2018-2019: Not offered
3-3-6 units
Principles of thermodynamics are used to infer the physical conditions of formation and modification of igneous and metamorphic rocks. Includes phase equilibria of homogeneous and heterogeneous systems and thermodynamic modelling of non-ideal crystalline solutions. Surveys the processes that lead to the formation of metamorphic and igneous rocks in the major tectonic environments in the Earth's crust and mantle.
T. L. Grove
12.481 Advanced Field Geology I  
Prereq: 12.113, 12.114  
Acad Year 2017-2018: Not offered  
Acad Year 2018-2019: G (Fall)  
2-2-2 units  
Can be repeated for credit.

Introduction to the problems to be investigated in 12.482, as well as the regional setting and local geology of the field area. Various special techniques may be introduced and preparatory investigations may be conducted that are specific to the area to be studied in 12.482.

B. C. Burchfiel, O. Jagoutz

12.482 Advanced Field Geology II  
Prereq: 12.481  
Acad Year 2017-2018: G (IAP, Spring)  
Acad Year 2018-2019: Not offered  
Units arranged  
Can be repeated for credit.

In January, a geological and geomorphological study of a selected field area is conducted during a two-week excursion. The following term includes: preparation of maps and report based on field study conducted in January; and laboratory analysis of samples. Meets with 12.115 when offered concurrently.

O. E. Jagoutz

12.484 Directed Field Studies  
Prereq: Permission of instructor  
G (IAP)  
Not offered regularly; consult department  
0-6-0 units  
Can be repeated for credit.

Intensive training in field geological methods. Includes specific exercises selected to complement the backgrounds of the students enrolled and provides supervised experience in applying field analytical techniques to geological problems. Cannot be taken as a substitute for 12.115. Preference will be given to students associated with Course 12. Enrollment limited; students should apply early.

B. C. Burchfiel

12.485 Advanced Directed Field Studies  
Prereq: 12.484  
G (IAP)  
Not offered regularly; consult department  
0-6-0 units  
Can be repeated for credit.

Continuation of 12.484. Designed to provide more advanced training in specific field geological methods. Can be taken during the same IAP period as 12.484. Preference will be given to students associated with Course 12. Enrollment limited; students should apply early.

Staff

12.486 Advanced Igneous Petrology  
Prereq: Permission of instructor  
Acad Year 2017-2018: G (Fall)  
Acad Year 2018-2019: Not offered  
3-2-7 units  
Can be repeated for credit.

Comprehensive overview of igneous rocks from the Earth, Moon, and meteorite parent bodies. Discusses the compositional diversity of igneous rocks and how it can be used to elucidate rock forming processes in the major tectonic provinces on modern Earth, including mid-ocean ridges, subduction zones, ocean islands, and inter-continental rifting environments. Also covers magma generation processes in the terrestrial planets prior to 2.6 billion years ago. Laboratory exercises on selected suites of igneous rocks reinforce readings and classroom discussions. Uses evidence from related geo-science disciplines to develop an integrative approach to understanding processes that lead to the chemical differentiation of planetary bodies through time. Subject matter may be modified to reflect the interests of the group.

T. L. Grove

12.492 Fundamentals of Stable Isotope Fractionation  
Prereq: None  
Acad Year 2017-2018: Not offered  
Acad Year 2018-2019: G (Fall)  
2-4-6 units  
Designed for bio-geo-chemists to gain a first order understanding of the origin of stable isotope effects and their application in understanding important geochemical processes on earth and planets. Includes an introduction of relevant physical chemistry, simple numerical integration methods of time-forward modeling to solve isotope systematics of complex systems, and discussion of the latest as well as classic papers of the topic.

S. Ono
12.493[J] Microbial Genetics and Evolution
Same subject as 1.87[J], 7.493[J], 20.446[J]
Prereq: 7.03, 7.05, or permission of instructor
G (Fall)
4-0-8 units
See description under subject 7.493[J].
A. D. Grossman, E. Alm

Geophysics

12.501 Essentials of Global Geophysics
Subject meets with 12.201
Prereq: Physics II (GIR), 18.03
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
4-0-8 units
Overview of basic topics in solid-earth geophysics, such as the
Earth’s rotation, gravity and magnetic field, seismology, and thermal
structure. Formulation of physical principles presented in three
one-hour lectures per week. Current applications discussed in an
additional one-hour tutorial each week. Students taking graduate
version complete different assignments.
R. van der Hilst

12.507 Essentials of Applied Geophysics
Subject meets with 12.214
Prereq: 18.03
Acad Year 2017-2018: G (Fall)
Acad Year 2018-2019: Not offered
3-3-6 units
Introduces the application of geophysical methods to all aspects
of near-surface environmental and engineering geophysics, including
the exploration for petroleum, water, and minerals. Topics include
seismic, electrical, electromagnetic, ground penetrating radar, magnetics, gravity, rock physics and chemistry, borehole geophysics and the global positioning system (GPS). Uses a quantitative approach to emphasize basic principles and a physical / chemical understanding of each method. Discusses specific illustrative field examples. Lab work is mainly devoted to local field work and equipment preparation for the IAP Field Geophysics class. Students taking graduate version complete additional assignments.
F. D. Morgan, T. A. Herring, B. H. Hager

12.510 Introduction to Seismology
Prereq: 18.075 or 18.085
G (Spring)
3-1-8 units
A basic study in seismology and the utilization of seismic waves
for the study of Earth’s interior. Introduces techniques necessary
for understanding of elastic wave propagation in stratified media
and for calculation of synthetic seismograms (WKBJ and mode
summation). Ray theory; interpretation of travel times (e.g.,
tomography); surface wave dispersion in layered media; Earth’s
free oscillations; and seismicity, (earthquake locations, magnitude,
moment, and source properties).
G. Prieto

12.511 Field Geophysics
Prereq: None
Acad Year 2017-2018: G (IAP)
Acad Year 2018-2019: Not offered
1-4-1 units
Covers practical methods of modern geophysics, including the
global positioning system (GPS), gravity, and magnetics. Field
work is conducted in western US and includes intensive 10-day
field exercise. Focuses on measurement techniques and their
interpretation. Introduces the science of gravity, magnetics,
and the GPS. Measures crustal structure, fault motions, tectonic
deformations, and the local gravity and magnetic fields. Students
perform high-precision measurements and participate in data
analysis. Emphasizes principles of geophysical data collection and the relevance of these data for tectonic faulting, crustal structure, and the dynamics of the earthquake cycle. Students taking graduate
version complete additional assignments.
T. A. Herring, B. H. Hager, F. D. Morgan

12.512 Field Geophysics Analysis
Prereq: 12.511
Acad Year 2017-2018: G (Spring)
Acad Year 2018-2019: Not offered
2-0-4 units
Focuses on in-depth data analysis and development of skills
needed to report results both in writing and orally. Students use
data collected in 12.511 to develop written and oral reports of the
results, with each student focusing on a different area. For example,
students can develop the geophysical modeling or synthesis of
the results into other studies in the area. The final written and oral
reports are combined into a comprehensive report and presentation
of the field camp and its results. Students taking graduate version
complete additional assignments.
T. A. Herring, B. H. Hager, F. D. Morgan
### 12.515 Data and Models

**Prereq:** 18.075 or 18.085  
**Acad Year 2017-2018:** Not offered  
**Acad Year 2018-2019:** G (Fall)  
3-0-9 units

Surveys a number of methods of inverting data to obtain model parameter estimates. Topics include review of matrix theory and statistics, random and grid-search methods, linear and non-linear least squares, maximum-likelihood estimation, ridge regression, stochastic inversion, sequential estimation, singular value decomposition, solution of large systems, genetic and simulated annealing inversion, regularization, parameter error estimates, and solution uniqueness and resolution. Computer laboratory and algorithm development.  
*F. D. Morgan*

### 12.520 Geodynamics

**Prereq:** 18.075 or 18.085  
**G (Spring)**  
3-0-9 units

Mechanics of deformation of the crust and mantle, with emphasis on the importance of different rheological descriptions: brittle, elastic, linear and nonlinear fluids, and viscoelastic.  
*B. H. Hager*

### 12.521 Computational Geophysical Modeling

**Prereq:** Permission of instructor  
**Acad Year 2017-2018:** Not offered  
**Acad Year 2018-2019:** G (Fall)  
3-0-9 units

Introduces theory, design, and practical methods of computational modeling in geodynamics and geophysical fluid dynamics. Covers the most effective and widely used numerical modeling approaches (e.g., boundary element, finite difference, finite element) and emphasizes problem-solving skills through illustrative examples of heat and mass transfer in the mantle and the ocean. Students acquire experience with various numerical methods through regularly assigned computational exercises and a term-long modeling project of each student’s choice.  
*J. Lin, O. Marchal, M. Behn*

### 12.522 Geological Fluid Mechanics

**Prereq:** 8.03; 18.075 or 18.085  
**G (Fall)**  
Not offered regularly; consult department  
3-0-9 units

Treats heat transfer and fluid mechanics in the Earth, low Reynolds number flows, convection instability, double diffusion, Non-Newtonian flows, flow in porous media, and the interaction of flows with accreting and deforming boundaries. Applications include: the flow under plates, postglacial rebound, diapirism, magma dynamics, and the mantle convection problem.  
*J. A. Whitehead (WHOI)*

### 12.524 Mechanical Properties of Rocks

**Prereq:** 8.03, 18.03  
**Acad Year 2017-2018:** Not offered  
**Acad Year 2018-2019:** G (Fall)  
3-0-9 units

A survey of the mechanical behavior of rocks in natural geologic situations. Topics: brief survey of field evidence of rock deformation, physics of plastic deformation in minerals, brittle fracture and sliding, and pressure-solution processes. Results of field petrologic and structural studies compared to data from experimental structural geology.  
*B. Evans*

### 12.525 Mechanisms of Faulting and Earthquakes

**Prereq:** Permission of instructor  
**Acad Year 2017-2018:** Not offered  
**Acad Year 2018-2019:** G (Fall)  
3-0-9 units

Explores the fundamental mechanics of faulting and earthquakes from four related perspectives: seismology, geodesy, geodynamics, and rheology. Topics to be covered include: (1) the physical processes that control the rheology of faults, including friction and fracture, (2) how these rheological processes are manifest in faulting and earthquakes in the earth from a geodynamics perspective, and (3) how the mechanics of faulting and earthquakes are constrained by seismological and geodetic observations. Both continental and oceanic examples of faulting and earthquakes will be featured.  
*J. Lin, J. McGuire, Y. Liu*
**12.533 Rock Physics**  
Prereq: Permission of instructor  
G (Spring)  
3-3-6 units  
Fundamentals of experimental and theoretical rock physics taught at an advanced level. Rocks viewed as complex composite media with behavior dependent both on the physical and chemical properties of the constituent phases, and on their geometries. Electrical, fluid transport, and seismic properties covered in detail. Other topics such as magnetic, mechanical, and thermal responses briefly discussed. Weekly laboratory.  
*F. D. Morgan*

**12.540 Principles of Global Positioning System**  
Prereq: Physics I (GIR), Calculus II (GIR), 18.06  
Acad Year 2017-2018: Not offered  
Acad Year 2018-2019: G (Spring)  
3-1-8 units  
The principles and applications of the Global Positioning System (GPS) and other space geodetic systems, including very-long-baseline interferometry (VLBI) and satellite laser ranging (SLR). The nature and uses of the course acquisition (CA), the precise positioning (P) codes, and the differential carrier phase observable. Techniques for estimating geodetic and geophysical quantities from these data. Other topics include: atmospheric refraction modeling, effects of Selective Availability (SA), estimation techniques (including Kalman filtering). Statistical and spectral analysis of data.  
*T. A. Herring*

**12.552 Advanced Seismology: Theory and Applications of Seismic Imaging**  
Prereq: 12.510  
Acad Year 2017-2018: Not offered  
Acad Year 2018-2019: G (Spring)  
3-0-9 units  
Introduces fundamental principles of seismic imaging used in both exploration and solid earth applications. Topics include ray theoretical approaches, scattering theory, and seismic waveform modeling. Through lectures, projects and student-led discussions of journal articles, the class covers the whole process of seismic imaging, from data preprocessing to model generation and geological interpretation of the results.  
*EAPS Faculty*

**12.560-12.561 Advanced Seminar in Exploration Geophysics**  
Prereq: Permission of instructor  
G (Fall, IAP, Spring)  
Not offered regularly; consult department  
2-0-4 units  
Can be repeated for credit.  
Advanced seminar focusing on areas of current interest in exploration geophysics and seismology. 12.560 is letter-graded.  
*Geophysics Staff*

**12.570 Topical Issues in Global Geophysics**  
Prereq: Permission of instructor  
Acad Year 2017-2018: Not offered  
Acad Year 2018-2019: G (Spring)  
Units arranged  
Can be repeated for credit.  
Series of formal lectures and seminars with the specific content varying by term to reflect current issues in research. Meets jointly with relevant Harvard course.  
*R. D. van der Hilst*

**12.571 Seminar in Geophysics**  
Prereq: Permission of instructor  
G (Fall)  
Not offered regularly; consult department  
Units arranged [P/D/F]  
Can be repeated for credit.  
Problems of current interest in geophysics; subject matter varying from term to term.  
*Geophysics Staff*

**12.580-12.581 Current Research in Geophysics**  
Prereq: Permission of instructor  
G (Fall, Spring, Summer)  
Units arranged [P/D/F]  
Can be repeated for credit.  
Original investigations, laboratory work, or fieldwork in geophysics. 12.580 is letter-graded.  
*Geophysics Staff*
12.586 Modeling Environmental Complexity  
Subject meets with 12.086  
Prereq: 18.03 or permission of the instructor  
G (Fall)  
3-0-9 units

Introduction to mathematical and physical models of environmental processes. Emphasis on the development of macroscopic continuum or statistical descriptions of complex microscopic dynamics. Problems of interest include: random walks and statistical geometry of landscapes; percolation theory and transport in disordered media; fractals, scaling, and universality; ecological dynamics and the structure of ecosystems, food webs, and other natural networks; kinetics of biogeochemical cycles. Appropriate for advanced undergraduates. Beginning graduate students are encouraged to register for 12.586. Students taking the graduate version complete different assignments.  
D. H. Rothman

Planetary Science

12.601 Essentials of Planetary Science  
Subject meets with 12.420  
Prereq: 8.03, 18.03  
Acad Year 2017-2018: G (Fall)  
Acad Year 2018-2019: Not offered  
3-0-9 units

Reviews fundamental physical concepts pertaining to the study of the solar system, and highlights recent spacecraft results. Topics include: meteorites, orbital dynamics, asteroids, impact craters, surfaces, atmospheres, atmospheric dynamics, interiors, magnetospheres, rings, comets, formation of the solar system.  
B. P. Weiss

12.602 Asteroids and Small Bodies  
Prereq: Physics II (GIR), 18.03  
Acad Year 2017-2018: Not offered  
Acad Year 2018-2019: G (Fall)  
3-0-9 units

Introduction to the study of asteroids and the ground-based and space-based techniques used to explore them. Topics include asteroid orbital properties, surface structure, physical properties, classifications, as well as their origin, thermal and collisional evolution, and interrelationships with meteorites and comets. Also covers the near-Earth asteroids, the probabilities and consequences of terrestrial collisions, and the possible utilization of asteroids as space resources.  
R. P. Binzel

12.603 Solar System Dynamics  
Prereq: Permission of instructor  
Acad Year 2017-2018: G (Spring)  
Acad Year 2018-2019: Not offered  
3-0-9 units

Studies the dynamics of the solar system and its major subsystems, and the dynamics of exoplanets, with a modern emphasis on the qualitative structure of phase space. Topics may include rotational dynamics, spin-orbit coupling, Cassini states, and orbital dynamics, resonances, and Kozai oscillations, tidal evolution and tidal heating.  
J. Wisdom

12.611 Advanced Planetary Observations  
Prereq: Permission of instructor  
G (IAP)  
0-6-3 units  
Can be repeated for credit.

Individual research projects in planetary science and astrophysics involving supervised work at Lowell Observatory in Flagstaff, AZ. Projects may include observations made using Lowell’s telescope facilities. Project topics and objectives vary from year to year. Written and oral reports required. Enrollment limited.  
A. Bosh

Same subject as 6.946[J], 8.351[J]  
Subject meets with 12.008  
Prereq: Physics I (GIR), 18.03, permission of instructor  
Acad Year 2017-2018: Not offered  
Acad Year 2018-2019: G (Fall)  
3-3-6 units

J. Wisdom, G. J. Sussman
12.622 Planetary Atmospheres (New)
Subject meets with 12.422
Prereq: Permission of instructor
G (Spring)
3-0-9 units
Provides a basic understanding of the physics and chemistry of planetary atmospheres. Explores the formation and evolution of atmospheres, their structure and dynamics, and what is known about their chemical composition. Pays particular attention to their energy balance. Also presents the current state of understanding of exoplanet atmospheres. Students taking graduate version complete an additional research project.
*D. Cziczo*

12.625 Extrasolar Planets: Physics and Detection Techniques
Subject meets with 8.290[J], 12.425[J]
Prereq: 8.03, 18.03
G (Fall)
3-0-9 units
In-depth study of current topics in exoplanets, such as exoplanet transits, radial velocity curves, current survey missions, the mass-radius relation, and super Earths. Class activities consist of reading the current literature, problem sets, and a term project. Students taking graduate version complete additional assignments.
*S. Seager*

12.650 Current Topics in Planetary Science
Prereq: Permission of instructor
Acad Year 2017-2018: G (Fall)
Acad Year 2018-2019: Not offered
3-0-9 units
Can be repeated for credit.
In-depth discussion of current and classic literature on selected topics in planetary science. Topics vary from year to year.
*J. Wisdom*

12.652 Current Topics in Planetary Science
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
3-0-9 units
Can be repeated for credit.
In-depth discussion of current and classic literature on selected topics in the specialty areas of asteroids and the Pluto-Charon system. Topics vary from year to year.
*R. P. Binzel*

12.690-12.691 Current Research in Planetary Science
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.
Original investigations, laboratory work, or fieldwork in planetary science. 12.690 is letter-graded.
*Planetary Science Staff*

12.701 Classic Papers in Physical Oceanography
Prereq: None
G (Spring)
3-0-3 units
Provides a historical perspective on fundamental topics in oceanography by considering individual works which, when pieced together, contribute to the more cohesive description of how the ocean works. In class discussions, students consider various aspects of the work in question, including motivation, approach, and implications for the broader context. They also synthesize information and make oral presentations. Develops basic analytical and critical skills in paper reading and writing.
*Y. Kwon (WHOI)*

12.702 Elements of Modern Oceanography
Prereq: None
G (Fall)
3-0-9 units
Examines a series of crosscutting topics that exemplify current directions in interdisciplinary oceanography. Focuses on current themes in oceanography, their interdisciplinary nature, and the role of ocean sciences in society. Introduces core concepts across the disciplines of biological, physical, and chemical oceanography as well as marine geology. Emphasizes the interdisciplinary aspects of these core concepts, the kinds of approaches and modes of thinking common to all of the disciplines, and the technological developments underpinning current advances. Students taking graduate version complete different assignments.
*G. Lawson, A. Kirincich (WHOI)*
12.703 Presenting Scientific Research
Prereq: None
G (Fall)
3-0-3 units

Presenting scientific research geared toward a scientific audience. Each student gives one 30-minute talk, one AGU-style 15-minute talk, and one poster presentation. Students present their ongoing research and use the class as a forum to practice for upcoming talks in more formal settings. Abstracts are prepared for each presentation and discussed in class. Students provide comments, questions, encouragement, critiques, etc. on their peers' presentations.
S. Nielsen, V. Le Roux (WHOI)

12.707 The History of Earth's Climate
Subject meets with 12.377
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Spring)
3-0-9 units

Studies the climate history of the Earth, from the formation of the early atmosphere and ocean to the present. Evaluates geochemical, sedimentological, and paleontological evidence for changes in ocean circulation, global temperatures, and atmospheric carbon dioxide levels. Covers theories and models of Phanerozoic climate change. Provides a long-term history of the global carbon cycle. Students taking graduate version complete different assignments.
D. McGee

12.708 Seminar in Paleoclimatology
Prereq: Permission of instructor
G (Fall)
Units arranged [P/D/F]
Can be repeated for credit.

Advanced seminar focusing on areas of current interest in paleoceanography and paleoclimatology. Includes discussion of current and classic literature. Topics vary from year to year.
D. Oppo, O. Marchal (WHOI)

12.710 Geological Oceanography
Prereq: Permission of instructor
G (Fall)
3-0-9 units

Provides a high level survey of a broad range of active science topics in Geological Oceanography. Presents background material that graduate students are expected to know in the disciplines of solid-earth geophysics, geochemistry, sedimentology and stratigraphy, coastal processes, and climate, including a representative set of canonical science papers, and builds on this material to give a sense of the current state of the science in these fields. Broad topics include the formation of the earth, petrogenesis, volcanism, plate tectonics, geodynamics, sedimentation in the oceans, coastal morphodynamics, paleo-oceanography, and climate. The interconnectedness of and feedbacks between processes discussed under these various topics is emphasized.
WHOI Staff

12.712 Advanced Marine Seismology
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
3-0-6 units
Can be repeated for credit.

Focuses on synthetic seismograms, ocean bottom refraction seismology, and multi-channel reflection seismology as applied to studies of the ocean sediments, crust, and lithosphere. Topics include: the wave equations for elastic/anelastic, isotropic/anisotropic, homogeneous/heterogeneous and fluid/solid media; ray theory and WKBJ approximations; the Sommerfeld/Weyl integrals, asymptotic analysis, and Lamb's problem for a fluid/solid interface; reflectivity and related methods; finite difference and finite element methods; and special topics of interest to the class. Extensive readings of geophysical and seismological literature.
R. Stephen (WHOI)

12.714 Computational Data Analysis
Prereq: 18.03
Acad Year 2017-2018: G (Spring)
Acad Year 2018-2019: Not offered
3-0-9 units

An introduction to the theory and practice of analyzing discrete data such as are normally encountered in geophysics and geology. Emphasizes statistical aspects of data interpretation and the nonparametric discrete-time approach to spectral analysis. Topics include: elements of probability and statistics, statistical inference, robust and nonparametric statistics, the method of least squares, univariate and multivariate spectral analysis, digital filters, and aspects of multidimensional data analysis.
A. D. Chave, T. A. Herring
12.716 Essentials of Oceanic Petrology
Prereq: 12.710 or permission of instructor
G (Fall)
3-2-4 units
Can be repeated for credit.
Qualitative interpretation and quantitative analysis of melting, melt transport, melt-rock reactions, igneous crustal accretion, metamorphism and hydrothermalism at oceanic spreading centers and subduction-related arcs applied to understanding the variations in the composition of the Earth’s (oceanic) mantle and crust and accretional processes at mid-ocean ridges. Combines theoretical methods with field, petrographic, geochemical, and computational techniques. Topics vary from year to year.
H. Dick, F. Klein, V. Le Roux (WHOI)

12.717 Coastal Geomorphology
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Spring)
3-0-9 units
Explores mechanisms behind the formation and reshaping of coastal environments. Focuses on a process-based understanding of both the fluid dynamic and sediment transport aspects of coastal landforms, and, especially, the importance of feedbacks between the two. Investigates coastal evolution at various scales - from ripples to coastline formation - with an emphasis on the behavior of coastal environments over integrated timescales of days and years to centuries and millennia. Students investigate the effect of storms, sea-level rise, and interactions with biological and anthropogenic influences. Covers a broad array of coastal environments, including beaches, barrier islands, spits, inlets, tidal flats, deltas, rocky coasts, arctic shores, and carbonate atolls.
A. Ashton

12.718 Kinetics and Mass Transport
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
3-0-6 units
Offers a broad overview of various kinetic and transport processes in geology, including volume and grain boundary solid-state diffusion, defects in minerals, rates of mineral reaction and transformation, crystal nucleation and growth, advective transport in porous media and partially molten aggregates, and percolation theory. Emphasis on processes in crystalline rocks. Covers theoretical, phenomenological, and experimental constraints, with a consistent application to “real-world” settings and actual case histories.
M. Behn and G. Gaetani (WHOI)

12.721 Current Research in Marine Geology and Geophysics at Woods Hole
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.
Original investigations, laboratory work, or fieldwork in marine geology and geophysics.
WHOI Staff

12.722 Current Research in Chemical Oceanography at Woods Hole
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.
Original investigations, laboratory work, or fieldwork in chemical oceanography.
WHOI Staff

12.723 Current Research in Biological Oceanography at Woods Hole (New)
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.
Original investigations, laboratory work, or field work in biological oceanography.
WHOI Staff

12.724 Current Research in Marine Geology and Geophysics at Woods Hole (New)
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.
Original investigations, laboratory work, or fieldwork in marine geology and geophysics.
WHOI Staff

12.725 Current Research in Chemical Oceanography (New)
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.
Original investigations, laboratory work, or field work in chemical oceanography.
WHOI Staff
12.726 Current Research in Biological Oceanography at Woods Hole (New)
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Original investigations, laboratory work, or field work in biological oceanography.
WHOI Staff

12.730-12.731 Current Research in Marine Geology and Geophysics at MIT
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

Original investigations, laboratory work, or fieldwork in marine geology and geophysics under the supervision of a faculty member in residence at MIT. For students in the MIT/WHOI Joint Program. 12.730 is letter-graded.
Marine Geology and Geophysics Staff

12.732 Current Research in Biological Oceanography at MIT (New)
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged
Can be repeated for credit.

Original investigations, laboratory work, or field work in biological oceanography.
MIT Staff

12.733 Current Research in Biological Oceanography at MIT (New)
Prereq: Permission of instructor
G (Fall, IAP, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

Original investigations, laboratory work, or field work in biological oceanography.
MIT Staff

12.735-12.736 Current Research in Chemical Oceanography at MIT
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

Original investigations, laboratory work, or fieldwork in chemical oceanography under the supervision of a faculty member in residence at MIT. For students in the MIT/WHOI Joint Program. 12.735 is letter-graded.
Chemical Oceanography Staff

12.739 Marine Microbiology and Biogeochemistry
Prereq: None
Acad Year 2017-2018: G (Fall)
Acad Year 2018-2019: Not offered
3-0-9 units

Integrates the fields of microbiology and biogeochemistry, and is centered on elucidating the linkages between microorganisms and geochemical processes in the oceans. Divided into modules that first lay the theoretical framework to familiarize students of diverse backgrounds (biologists, chemists, physical oceanographers). Next, introduces specific and general linkages between the topics and the major tools and techniques that have advanced their integrated study. Concludes with a synthesis module examining the role of microorganisms in the biogeochemical cycles of diverse ocean biomes
A. Apprill, S. Sievert (WHOI)

12.740 Paleoceanography
Prereq: Permission of instructor
Acad Year 2017-2018: G (Spring)
Acad Year 2018-2019: Not offered
3-0-9 units

Studies the basic principles of techniques for reconstructing the history of ocean climate from marine sediment cores, corals, ice cores, and other paleoclimate archives. Examines this data in the light of proposed climate change mechanisms. Micropaleontological, isotopic, geochemical, and mineralogical changes are used to infer changes in seawater composition, atmospheric chemistry, and climate. Observations are interpreted as consequences of changes in ocean temperature, circulation, and chemistry, and are used to evaluate theories proposed to account for glacial/interglacial cycles. Focuses on the past two million years, but major processes and events from the past 100 million years are also included.
E. A. Boyle
12.741 Marine Bioinorganic Chemistry  
Prereq: Permission of instructor  
Acad Year 2017-2018: G (Spring)  
Acad Year 2018-2019: Not offered  
2-0-7 units  
Provides an overview of trace element biogeochemistry and marine bioinorganic chemistry. Topics include controls on oceanic trace metal distributions; co-evolution of biological metal requirements and metal availability during early Earth history; chemical speciation and its influence on microbial bioavailability; applications of metal isotopes; roles of metalloenzymes and metal proteins in biogeochemical cycles; and biogeochemical applications of metagenomics, metaproteomics, and bioinformatics.  
M. Saito

12.742 Marine Chemistry  
Prereq: Permission of instructor  
G (Fall)  
3-0-9 units  
An introduction to chemical oceanography. Reservoir models and residence time. Major ion composition of seawater. Inputs to and outputs from the ocean via rivers, the atmosphere, and the seafloor. Biogeochemical cycling within the oceanic water column and sediments, emphasizing the roles played by the formation, transport, and alteration of oceanic particles and the effects that these processes have on seawater composition. Cycles of carbon, nitrogen, phosphorus, oxygen, and sulfur. Uptake of anthropogenic carbon dioxide by the ocean. Material presented through lectures and student-led presentation and discussion of recent papers.  
B. Van Mooy, S. Doney (WHOI)

12.743 Geochemistry of Marine Sediments  
Prereq: Chemistry (GIR), 5.60  
Acad Year 2017-2018: G (Spring)  
Acad Year 2018-2019: Not offered  
3-0-9 units  
Focuses on processes that control the composition of sediments in coastal, shelf, and deep-sea environments and processes that define their roles in biogeochemical cycles. Topics include calculating chemical fluxes across the sediment-water interface; evaluating the sources and reactivity of carbonate, silicic, and detrital sediments; using pore water gradients to calculate diffusion, reaction, and flux rates; sediment dating; estimating accumulation rates; and using stable isotopes and natural-series radioisotopes. Covers evaluation of the links between sedimentary and water column processes; the effects of anthropogenic disturbances (e.g., eutrophication, acidification, warming) on sedimentary processes; and the role of sediments in global biogeochemical cycles. Introduces sampling techniques and mathematical modeling of sedimentary processes.  
D. McCorkle, W. Martin, A. Spivak (WHOI)

12.744 Marine Isotope Chemistry  
Prereq: Permission of the instructor  
Acad Year 2017-2018: Not offered  
Acad Year 2018-2019: G (Fall)  
3-0-9 units  
Fundamentals of using isotopes to study processes and timescales for marine chemistry and geochemistry. Provides basic introduction to the nature, origins, and reasons for the distributions of isotopes in nature, then develops theory and approaches for radioactive dating methods. These are used to constrain the timing and nature of the geochemical evolution of the elements, solar system, earth, ocean, and atmosphere. Covers cosmogenic isotopes and their applications. Briefly discusses basics of mass spectrometry, followed by a closer inspection of the principles and applications of isotope fractionation. Introduces mass independent fractionation and clumped isotope methods. Explores applications of isotope methods to a number of water column processes, including particle scavenging, sedimentation, long term element budgets, redox processes, and air-sea exchange. Emphasizes quantitative methods and problem-solving. Includes problem sessions with development of problem solutions.  
WHOI Staff
12.746 Marine Organic Geochemistry
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
3-0-6 units
Provides an understanding of the distribution of organic carbon (OC) in marine sediments from a global and molecular-level perspective. Surveys the mineralization and preservation of OC in the water column and within anoxic and oxic marine sediments. Topics include: OC composition, reactivity and budgets within, and fluxes through, major reservoirs; microbial recycling pathways for OC; models for OC degradation and preservation; role of anoxia in OC burial; relationships between dissolved and particulate (sinking and suspended) OC; methods for characterization of sedimentary organic matter; application of biological markers as tools in oceanography. Both structural and isotopic aspects are covered.
D. Repeta, T. I. Eglinton (WHOI)

12.747 Modeling, Data Analysis, and Numerical Techniques for Geochemistry
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
3-0-9 units
Emphasizes the basic skills needed for handling and assimilating data as well as the basic tool-set for numerical modeling. Uses MATLAB as its computation engine; begins with an introduction to MATLAB to ensure familiarity with software. Topics include: probability distributions, error propagation, least squares and regression techniques, principle component and factor analysis, objective mapping, Fourier and spectral analysis, numerical solutions to ODEs and PDEs, finite difference techniques, inverse models, and scientific visualization.
D. Glover, W. Jenkins, S. Doney (WHOI)

12.749 Solid Earth Geochemistry
Prereq: Permission of instructor
Acad Year 2017-2018: G (Spring)
Acad Year 2018-2019: Not offered
3-0-9 units
Integrates methods in mineralogy, petrology (both igneous and metamorphic), and trace element and isotope geochemistry to address scientific issues of the solid earth. Covers processes in the solar nebula, accretion, and early differentiation of the earth. Discusses topics in three representative geodynamic environments - mid-ocean ridges, subduction zones, and mantle plumes - with respect to physical framework and petrological/geochemical aspects.
N. Shimizu, S. Nielsen (WHOI)

12.751-12.759 Seminar in Oceanography at Woods Hole
Prereq: Permission of instructor
G (Spring)
Units arranged [P/D/F]
Can be repeated for credit.
Topics in marine geology and geophysics, physical, dynamical, and chemical oceanography. Content varies from term to term. 12.754, 12.755, and 12.756 are letter-graded.
WHOI Staff

12.760-12.761 Seminar in Marine Geology and Geophysics at MIT
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.
Topics in marine geology and geophysics taught at MIT. Content varies from term to term. 12.760 is letter-graded.
Marine Geology and Geophysics Staff

12.770-12.771 Seminar in Chemical Oceanography at MIT
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.
Topics in chemical oceanography taught at MIT. Content varies from term to term. 12.770 is letter-graded.
Chemical Oceanography Staff

12.777 Field Oceanography (New)
Prereq: Permission of instructor
G (Spring)
3-4-5 units
Provides an introduction to the biogeochemistry of the ocean, and the field techniques and methods used in its study. Emphasizes biogeochemistry and the interrelated nature of elemental cycling, but also examines physical transport and air-sea gas exchange. Covers multiple aspects related to field instrumentation and measurements, including nutrients, oxygen, the carbon system, temperature, and salinity. Presents microbial analyses, such as metagenomics. Includes an optional spring break field trip aboard a research vessel. Students work in groups to propose a project over the week-long voyage that utilizes the field time to collect samples. During the second half of the term, students analyze and synthesize the data, and present it in a publication-quality manuscript.
A. R. Babbin
**Atmospheres, Oceans, and Climate**

**12.800 Fluid Dynamics of the Atmosphere and Ocean**
Subject meets with 12.390  
Prereq: 8.03, 18.04  
G (Fall)  
3-0-9 units  
Introduction to fluid dynamics. Students acquire an understanding of some of the basic concepts of fluid dynamics that are needed as a foundation for advanced coursework in atmospheric science, physical oceanography, ocean engineering, climate science, etc. Emphasizes fluid fundamentals, with an atmosphere/ocean twist. Students taking graduate version complete additional assignments.  
* A. Mahadevan, C. Cenedese

**12.801 Large-scale Ocean Dynamics**
Prereq: 12.800  
G (Spring)  
3-0-9 units  
Applies fundamental principles of geophysical fluid dynamics to understand the general patterns of the ocean circulation and stratification. Includes the mid-latitude wind-driven circulation, the Southern Ocean circulation, and the global overturning circulation. Uses a combination of theory, numerical simulations, and observations to illustrate the concepts.  
* R. Ferrari

**12.802 Waves, Instability and Turbulence at Small Scales**
Prereq: 12.800 or permission of instructor  
G (Spring)  
3-0-9 units  
Covers basic concepts of wave motion, flow instability, and turbulence in rotating and stratified fluids with emphasis on small scales. Presents wave properties, including the dispersion relation, phase and group velocities, and wave kinematics, and uses these concepts to study the dynamics of surface and internal gravity waves, Poincare waves, Kelvin waves, and topographic waves. Includes flow instability. Explores general concepts of linear instability in small-scale stratified shear flows (Rayleigh and Kelvin-Helmholtz instabilities); examines non-rotating stratified turbulence resulting from these instabilities. Also discusses wave-mean flow interaction, hydraulic control, the entrainment assumption, and the interpretation of microstructure observations.  
* K. Helfrich (WHOI)

**12.803 Advanced Geophysical Fluid Dynamics**
Prereq: 12.843  
G (Spring)  
2-0-7 units  
Further development of topics covered in 12.843, with a more mathematical treatment. Covers current topics of interest in rotating stratified flows of oceans and atmospheres.  
* G. Flierl

**12.805 Data Analysis in Physical Oceanography**
Prereq: 12.808  
G (Spring)  
3-0-6 units  
Directed at making scientifically-sensible inferences from physical oceanography data (both observations and models). Introduces linear inverse methods, including regression, singular value decomposition, objective mapping, and data assimilation. Connects these methods to time series analysis, including Fourier methods, spectra, coherence, and filtering. Focuses on working with data in a computer laboratory setting. Emphasizes how statistical information can be used to improve experimental design. Gives some attention to the instruments and algorithms used to acquire the data.  
* G. Gebbie

**12.806[J] Atmospheric Physics and Chemistry**
Same subject as 10.571[J]  
Subject meets with 12.306  
Prereq: 5.60 or 5.61; 18.075; or permission of instructor  
G (Spring)  
3-0-9 units  
Introduction to the physics and chemistry of the atmosphere including experience with computer codes. Aerosols and theories of their formation, evolution, and removal. Gas and aerosol transport from urban to continental scales. Coupled models of radiation, transport, and chemistry. Solution of inverse problems to deduce emissions and removal rates. Emissions control technology and costs. Applications to air pollution and climate.  
* R. G. Prinn

**12.807[J] Atmospheric Chemistry**
Same subject as 1.84[J], 10.817[J]  
Prereq: 5.60  
G (Fall)  
3-0-9 units  
See description under subject 1.84[J].  
* J. H. Kroll
12.808 Introduction to Observational Physical Oceanography
Prereq: Permission of instructor
Acad Year 2017-2018: G (Fall)
Acad Year 2018-2019: Not offered
3-0-9 units

Results and techniques of observations of the ocean in the context of its physical properties and dynamical constraints. Emphasis on large-scale steady circulation and the time-dependent processes that contribute to it. Includes the physical setting of the ocean, atmospheric forcing, application of conservation laws, description of wind-driven and thermohaline circulation, eddy processes, and interpretive techniques.

M. Andres, G. Gebbie (WHOI)

12.809 Hydraulic Phenomena in Geophysical Fluid Flows
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
3-0-6 units

Examination of the hydraulics of nonrotating flows (Long's experiments, hydraulic control, upstream influence, nonlinear wave steepening, hydraulic jump and bores, application to severe downslope winds). Other topics may include: nonrotating stratified flows (two-layer hydraulics, virtual and approach controls, maximal and submaximal flow, application to the Strait of Gibraltar and the Bab al Mandab); and deep ocean straits and sills (steady theories for rotating channel flow, nonlinear Kelvin and frontal waves, rotating hydraulic jumps, geostrophic adjustment in a rotating channel, and applications to the Denmark Strait and other deep passages).

L. Pratt, K. Helfrich (WHOI)

12.810 Dynamics of the Atmosphere
Prereq: 12.800
G (Spring)
3-0-9 units

 Discusses the dynamics of the atmosphere, with emphasis on the large scale. Topics include internal gravity waves in the atmosphere; potential vorticity conservation and Rossby waves; baroclinic instability and extratropical storms; the tropical Hadley and Walker circulations and equatorial waves; and the general circulation, annular modes, and the response to climate change.

P. O’Gorman

12.811 Tropical Meteorology
Prereq: 12.810 or Coreq: 12.843
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Spring)
3-0-9 units

A description of the large-scale circulation systems of the tropical atmosphere and analysis of the dynamics of such systems. Topics include: Radiative-convective equilibrium; the Hadley and walker circulation; monsoons; tropical boundary layers; theory of the response of the tropical atmosphere to localized sea-surface temperature anomalies; intraseasonal oscillations; equatorial waves; El Niño/Southern Oscillation; easterly waves; and tropical cyclones.

K. A. Emanuel

12.812 The General Circulation of the Atmosphere and Climate Change
Prereq: 12.843 or permission of instructor
G (Fall)
Not offered regularly; consult department
3-0-9 units

Explains the main features of the general circulation of the Earth's atmosphere. Final part of the course explores possible changes in the general circulation associated with climate change.

P. O’Gorman

Same subject as 1.842[J]
Subject meets with 12.338
Prereq: Permission of instructor
G (Spring)
3-0-9 units

Focuses on understanding how aerosol particles form droplets or ice crystals during several atmospheric processes: determining Earth’s radiative balance; heterogeneous chemistry and acid rain; understanding where, when and how much precipitation occurs. Provides tools for understanding the physics of aerosol and cloud element motion; the interaction of particles with water vapor, including phase changes and droplet and ice nucleation; the chemical composition of particles and the effect on cloud formation processes; and the effect of cloud processing on aerosol chemistry. Discusses relevant topics of contemporary interest, e.g., geoengineering and weather modification and volcanic effects. Students taking the graduate version complete different assignments.

D. Cziczo
12.815 Atmospheric Radiation and Convection
Subject meets with 12.315
Prereq: 12.800 or permission of instructor
G (Spring)
5-2-5 units
Introduction to the physics of atmospheric radiation, remote sensing, and convection, including use of computer codes. Radiative transfer equation including emission and scattering, spectroscopy, Mie theory, and numerical solutions. Physics of dry and moist convection, including moist thermodynamics. Radiative-convective equilibrium. Solution of inverse problems in remote sensing of atmospheric temperature and composition. Students taking graduate version complete additional assignments.
T. Cronin

12.817[J] Atmospheric Composition in the Changing Earth System
Same subject as 1.841[J]
Prereq: 1.841[J]
Acad Year 2017-2018: G (Spring)
Acad Year 2018-2019: Not offered
3-0-9 units
See description under subject 1.841[J].
C. Heald

12.818 Introduction to Atmospheric Data and Large-scale Dynamics
Subject meets with 12.318
Prereq: None. Coreq: 12.800
G (Fall)
3-3-6 units
Provides a general introduction to meteorological data and analysis techniques, and their use in the MIT Synoptic Laboratory to study the phenomenology and dynamics of large-scale atmospheric flow. Illustrates balance concepts as applied to the dynamics of frontal and synoptic scales, using real-time upper-air and surface station data and gridded analyzed fields. Uses advanced meteorological software packages to access, manipulate, and graphically display the data. Students taking graduate version complete different assignments.
L. Illari

12.820 Turbulence in the Ocean and Atmosphere
Prereq: 12.843
Acad Year 2017-2018: G (Spring)
Acad Year 2018-2019: Not offered
3-0-9 units
Covers phenomena, theory and modeling of turbulence in the Earth’s oceans and atmosphere. The scope will range from centimeter- to planetary-scale motions. Includes homogeneous isotropic three- and two-dimensional turbulence, convection, stratified turbulence, quasi-geostrophic turbulence, baroclinic turbulence, and macroturbulence in the ocean and atmosphere.
R. Ferrari, G. Flierl

12.823 Modeling the Biology and Physics of the Ocean
Prereq: 18.075 or 18.085
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Spring)
3-0-6 units
G. Flierl, D. McGillicuddy

12.824 Stability Theory for Oceanic & Atmospheric Flows
Prereq: 12.802 or permission of instructor
Acad Year 2017-2018: G (Fall)
Acad Year 2018-2019: Not offered
3-0-9 units
Basic theory of hydrodynamic instability with special application to flows of interest in oceanography and meteorology. Topics covered include general formulation of stability theory; concept of normal modes and linearization; fundamental stability theorems; baroclinic instability: Charney model, Eady model and the Phillips two-layer model; energy transformations; initial value theory and non-modal instability; barotropic instability for jets and shear layers; radiating instabilities; initial value problems applied to the concepts of convective, absolute and spatial instabilities; finite amplitude theory; stability of non-parallel flows.
G. Flierl
12.830 Topics in Waves and Instability
Prereq: 12.843
G (Fall)
Not offered regularly; consult department
3-0-9 units
A detailed presentation of selected advanced topics in waves and instability in the atmosphere. The precise selection varies from year to year. Topics have included wave-mean flow interaction, the quasi-biennial oscillation, sudden warmings, critical-level behavior, wave overreflection, nonlinear equilibration, wave breaking, tropical waves, and stationary waves.
EAPS Staff

12.835 Experimental Atmospheric Chemistry
Subject meets with 12.335
Prereq: Permission of instructor
G (Fall)
2-4-6 units
Introduces the atmospheric chemistry involved in climate change, air pollution, and ozone depletion using a combination of interactive laboratory and field studies and simple computer models. Uses instruments for trace gas and aerosol measurements and methods for inferring fundamental information from these measurements. Students taking the graduate version complete different assignments.
R. Prinn, S. Ono, K. Dryer

12.842 Climate Science
Subject meets with 12.301
Prereq: Chemistry (GIR), 18.03, or permission of instructor
G (Fall)
4-0-8 units
Introduction to climate studies, including beginnings of the solar system, time scales, and climate in human history; methods for detecting climate change, including proxies, ice cores, instrumental records, and time series analysis; physical and chemical processes in climate, including primordial atmosphere, ozone chemistry, carbon and oxygen cycles, and heat and water budgets; internal feedback mechanisms, including ice, aerosols, water vapor, clouds, and ocean circulation; climate forcing, including orbital variations, volcanism, plate tectonics, and solar variability; climate models and mechanisms of variability, including energy balance, coupled models, and global ocean and atmosphere models; and outstanding problems. Students taking the graduate version complete different assignments.
K. Emanuel, E. Boyle, D. McGee

12.843 Large-scale Atmosphere and Ocean Dynamics
Prereq: 12.801, 12.810, or permission of instructor
G (Fall)
2-4-9 units
Project-based with lectures covering the relevant theory. Students work in groups on four projects. Each of these comprises a numerical part, to illuminate and illustrate the theory, and a data part (drawn from laboratory tank experiments, atmospheric, or ocean observations), to illustrate the phenomena. Topics include: barotropic vorticity dynamics including inversion and evolution, geostrophic and higher order balance, baroclinic dynamics and the evolution of balanced flows, and stability with emphasis on the mutual interaction of disturbances. Projects include a verbal presentation and writeup covering both the numerical and geophysical parts plus additional derivations as needed.
G. Flierl, L. Illari

12.844[J] Modeling and Assessment for Policy
Same subject as IDS.410[J]
Prereq: None
G (Spring)
3-0-6 units
See description under subject IDS.410[J].
N. E. Selin

12.845[J] Sustainability Science and Engineering
Same subject as IDS.526[J]
Prereq: None
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
3-0-6 units
See description under subject IDS.526[J].
N. E. Selin

12.846[J] Global Environmental Negotiations
Same subject as IDS.525[J]
Subject meets with 12.346[J], IDS.062[J]
Prereq: None
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
2-0-4 units
See description under subject IDS.525[J].
N. Selin
Same subject as 15.023[J]
Subject meets with 12.348[J], 15.026[J]
Prereq: Calculus II (GIR); 5.60; 14.01 or 15.010; or permission of instructor
G (Spring)
3-0-6 units
See description under subject 15.023[J].
R. G. Prinn

12.849 Mechanisms and Models of the Global Carbon Cycle
Subject meets with 12.349
Prereq: Permission of instructor
G (Spring)
3-0-9 units
Addresses changes in the ocean, terrestrial biosphere and rocks modulation of atmospheric carbon dioxide on timescales from months to millions of years. Includes feedbacks between carbon cycle and climate. Combines hands-on data analysis with the formulation of simple models rooted in basic physical, chemical and biological principles. Students create individual "toy" global carbon cycle models. Students taking graduate version complete different assignments.
M. Follows

12.850 Computational Ocean Modeling
Prereq: None
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
3-0-9 units
Numerical modeling in oceanography and environmental fluid mechanics. Focuses on the building of computational models that describe processes such as transport (advection, diffusion), reaction (ecosystems), and boundary forcing, of relevance in the ocean. Models are developed in a hierarchical manner, starting from the simple (zero-dimensional in space), and incrementally advancing toward more complex, time-evolving systems in one-, two- (shallow water) and three-dimensions (Primitive equations). Students build their own models using the finite volume approach with an appreciation and understanding of the working of general circulation models.
A. Mahadevan (WHOI)

12.853 Advanced geophysical fluid dynamics
Prereq: 12.843 or permission of instructor
G (Fall)
2-0-7 units
Follow-on to 12.843, with a more mathematical treatment and extension of material to current topics of interest involving rotating, stratified flows of oceans and atmospheres.
G. Flierl

12.860 Climate Variability and Diagnostics
Prereq: Permission of instructor
G (Fall)
3-0-9 units
Explores climate variability and change, focusing on the atmosphere and ocean, while building experience applying diagnostic analyses to a range of modern observations and models. Provides practical insight, from regional to global scale, with applications to past and future climates. Emphasizes salient features of the mean climate system and modes of natural variability, as well as observed and projected manifestations of anthropogenic climate change. Students gain experience accessing, analyzing, and visualizing a wide range of gridded observational-based datasets, as well as output from global climate model simulations. Develops the tools necessary to apply climate diagnostic analysis to one's own research, as well as the interdisciplinary edge to critically assess and interpret the observational and model results underpinning the Fifth Assessment Reports of the Intergovernmental Panel on Climate Change.
C. Uhmmenhofer

12.862 Coastal Physical Oceanography
Prereq: 12.800
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
3-0-9 units
Introduction to the dynamics of flow over the continental shelf, nearshore, and estuaries, emphasizing both theory and observations. Content varies somewhat according to student and staff interests. Possible topics include fronts, buoyant plumes, surface and bottom boundary layers, wind-driven upwelling, coastal-trapped waves, internal waves, quasi-steady flows, high-latitude shelf processes, tides, and shelf-open ocean interactions.
R. Todd, D. Ralston (WHOI)
12.863 Advanced Topics in Coastal Physical Oceanography
Prereq: 12.862 or permission of instructor
Acad Year 2017-2018: G (Spring)
Acad Year 2018-2019: Not offered
3-0-6 units

More specialized topics in the dynamics of flow over the continental shelf, including coastal-trapped waves, wind-driving, and mean flows. Emphasis on the relationship between theory and observations. Instrumentation and the application of statistical techniques also covered.

Woods Hole Staff

12.866 Theory of the General Circulation of the Ocean
Prereq: 12.800, 12.801, 12.802
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
3-0-9 units


R. X. Huang (WHOI)

12.870 Air-Sea Interaction: Boundary Layers
Prereq: Graduate-level fluid mechanics and a subject on waves, or permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
3-0-9 units

Addresses the interaction of the atmosphere and ocean on temporal scales from seconds to days and spatial scales from centimeters to kilometers. Topics include the generation, propagation, and decay of surface waves; the processes by which mass, heat, momentum, and energy are transported vertically within the coupled atmospheric and oceanic boundary layers and across the air-sea interface; and the statistical tools, mathematical models, and observational methods that are used to quantify these processes.

J. Trowbridge, E. Terray (WHOI)

12.885(J) Science, Politics, and Environmental Policy
Same subject as 11.373(J)
Subject meets with 12.385
Prereq: Permission of instructor
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Fall)
3-0-6 units

Examines the role of science in US and international environmental policymaking. Surveys the methods by which scientists learn about the natural world; the treatment of science by experts, advocates, the media, and the public and the way science is used in legislative, administrative and judicial decision making. Through lectures, group discussions, and written essays, students develop a critical understanding of the role of science in environmental policy. Potential case studies include fisheries management, ozone depletion, global warming, smog, and endangered species. Students taking the graduate version complete different assignments.

S. Solomon, J. Knox-Hayes

12.910 Communicating Ocean Science
Prereq: None
Acad Year 2017-2018: Not offered
Acad Year 2018-2019: G (Spring)
3-0-6 units

For students interested in improving their ability to teach science, the focus is on inquiry-based instructional methods and application to various audiences. Includes an opportunity to teach in a course at a local state university and in a supervised elementary school classroom. Class meets twice a week for 11 sessions, and episodically thereafter. The undergraduate lesson is arranged in consultation with Bridgewater State University faculty. Outreach in local school classrooms involves one session observing and three sessions teaching.

L. Mullineaux (WHOI) and A. Michel (WHOI)

12.950, 12.951 Seminar in Physical Oceanography at MIT
Prereq: Permission of instructor
G (Fall, Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Topics in physical and dynamical oceanography. Content varying from term to term. 12.950 is letter-graded.

Physical Oceanography Staff
12.960, 12.961 Current Research in Physical Oceanography at MIT
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

Original investigations, laboratory work, or fieldwork in oceanography. 12.960 is letter-graded.
*Physical Oceanography Staff*

12.970, 12.971 Current Research in Physical Oceanography at Woods Hole
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

Original investigations, laboratory work, or field work on oceanographic problems. 12.970 is letter-graded.
*Woods Hole Staff*

12.980, 12.981 Current Research in Atmospheric Science
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

Original investigations on problems in atmospheric science. 12.980 is letter-graded.
*EAPS Staff*

12.982, 12.983 Current Research in Climate Physics and Chemistry
Prereq: Permission of instructor
G (Fall, Spring, Summer)
Units arranged [P/D/F]
Can be repeated for credit.

Original investigations, laboratory work, or fieldwork in problems related to climate. 12.982 is letter-graded
*PAOC faculty*

12.590, 12.591 Special Seminar in Geophysics
Prereq: Permission of instructor
Acad Year 2017-2018: G (IAP)
Acad Year 2018-2019: Not offered
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of geophysics not normally covered in regularly scheduled subjects. 12.590 is letter-graded.
*Consult EAPS Education Office*

12.592, 12.593 Special Seminar in Earth, Atmospheric and Planetary Sciences
Prereq: Permission of instructor
G (Fall)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of the earth sciences, planetary sciences, or astronomy not normally covered in regularly scheduled subjects. 12.592 is letter-graded.
*EAPS Staff*
Prereq: Permission of instructor
G (Fall, IAP, Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of planetary
science not normally covered in regularly scheduled subjects.
12.S680 is letter-graded.
Planetary Science Staff

12.S990, 12.S991 Special Subject in Atmospheric Science
Prereq: Permission of instructor
G (Fall, IAP, Spring)
Not offered regularly; consult department
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of atmospheric
science not normally covered in regularly scheduled subjects.
12.S990 is letter-graded.
PAOC Staff

12.S992, 12.S993 Special Subject in Climate Science
Prereq: Permission of instructor
G (Fall)
Units arranged [P/D/F]
Can be repeated for credit.

Organized lecture or laboratory subject on an aspect of climate not
normally covered in the regularly scheduled subjects. 12.S992 is
letter-graded.
PAOC Staff