EARTH AND PLANETARY SCIENCES

Kline Geology Laboratory, 203.432.3124
http://earth.yale.edu
M.S., M.Phil., Ph.D.

Chair
Maureen Long

Director of Graduate Studies
Derek Briggs

Professors Jay Ague, David Bercovici, Ruth Blake, Mark Brandon, Derek Briggs, David Evans, Alexey Fedorov, Debra Fischer, Jacques Gauthier, Shun-ichiro Karato, Jun Korenaga, Maureen Long, Jeffrey Park, Peter Raymond, James Saiers, Mary-Louise Timmermans, John Wettlaufer

Associate Professor Noah Planavsky

Assistant Professors Bhart-Anjan Bhullar, Pincelli Hull, Juan Lora, Alan Rooney, Lidya Tarhan

FIELDS OF STUDY

Fields include geochemistry and petrology, geophysics, ice physics, mineral physics, seismology and geodynamics, structural geology and tectonics, paleontology and paleoecology, oceanography, meteorology, cryospheric dynamics, and climatology.

Students admitted in 2020 or earlier have the option of receiving a degree in either Geology and Geophysics or Earth and Planetary Sciences. Students admitted in 2021 and subsequent years will receive a degree in Earth and Planetary Sciences.

SPECIAL REQUIREMENTS FOR THE PH.D. DEGREE

There is no formal language requirement and no required curriculum. Students plan their course of study in consultation with their adviser to meet individual interests and needs and to lay the foundations for dissertation research. At the end of the first year the faculty reviews the standing of each student. A student recommended for continuation in the Ph.D. program will be so notified. Some students may be encouraged at that time to pursue only the M.S. degree. At the end of the second year the faculty reviews each student’s overall performance to determine whether the student is qualified to continue for the Ph.D. degree. In order to qualify, a student must have met the Graduate School Honors requirement and maintained a better than passing record in the areas of concentration. Also, a student must have satisfied the requirements of the Qualifying Exam by having completed two Research Discourses termed (according to their degree of development) the Minor and the Major Discourses. The Major Discourse will be presented at the Qualifying Presentation, followed by an extended question period wherein the student must successfully defend both Discourses. Remaining degree requirements include a dissertation review in the third year; the preparation and defense of the dissertation; and the submission of the dissertation to the Graduate School.
Teaching experience is regarded as an integral part of the graduate training program in Earth and Planetary Sciences. For this reason, all students are required to serve as teaching fellows for two terms during the course of their predoctoral training. Students who require additional support from the Graduate School must teach additional terms, if needed, after they have fulfilled the academic teaching requirement.

In addition to all other requirements, students must successfully complete EPS 710, Responsible and Ethical Conduct of Research, prior to the end of their first year of study.

**MASTER’S DEGREES**

**M.Phil.** See Degree Requirements under Policies and Regulations.

**M.S.** Awarded only to students who are not continuing for the Ph.D. Students are not admitted for this degree. Minimum requirements include satisfactory performance in a course of study (typically six or more courses with at least one Honors grade in a graduate-level class) that is approved by the director of graduate studies (DGS), and a research project with the approval of the DGS and the student's thesis committee.

Program materials are available at http://earth.yale.edu or upon request to the Director of Graduate Studies, Department of Earth and Planetary Sciences, Yale University, PO Box 208109, New Haven CT 06520-8109; email, dgs@eps.yale.edu.

**COURSES**

**EPS 512a, Structural Geology**  Mark Brandon
An introduction to the origin and structure of the lithosphere and continental and oceanic crust. Topics include what controls the solid versus fluid behavior of rocks during deformation, and what controls the character and motion of tectonic plates. Laboratory exercises and field trips.

**EPS 523b, Climate Dynamics**  Alexey Fedorov
A survey of fluid dynamics with application to circulation in the ocean and atmosphere, as well as mantle and core. Mathematical models are used to illustrate the fundamental dynamical principles of geophysical fluid phenomena such as convection, waves, boundary layers, flow stability, turbulence, and large-scale flows. The course aims to provide a general theoretical framework for understanding the structure and circulation of the ocean, atmosphere, and Earth’s interior.

**EPS 525a, Vertebrate Paleontology**  Jacques Gauthier
Phylogeny and evolution of the major clades of vertebrates from Cambrian to Recent, as inferred mainly from the fossilized remains of the musculoskeletal system (cranial, axial, and appendicular skeletons). Special attention given to the evolution of vertebrate feeding, locomotor, and sensory systems.

**EPS 526a, Introduction to Earth and Planetary Physics**  Shun-ichiro Karato
An introduction to the structure and dynamics of Earth and other planets in the context of cosmic evolution. Review of basic physical principles and their applications to geophysics and planetary physics. Star formation and nucleosynthesis; planetary accretion and the birth of the solar system; heat flow, plate tectonics, and mantle dynamics; seismology and geodesy; core dynamics, geomagnetism, and planetary magnetism. Prerequisites: PHYS 181 and MATH 120 or equivalents.
EPS 528a, Science of Complex Systems  Jun Korenaga
Introduction to the quantitative analysis of systems with many degrees of freedom. Fundamental components in the science of complex systems, including how to simulate complex systems, how to analyze model behaviors, and how to validate models using observations. Topics include cellular automata, bifurcation theory, deterministic chaos, self-organized criticality, renormalization, and inverse theory.

EPS 535a, Physical Oceanography  Alexey Fedorov
An introduction to ocean dynamics and physical processes controlling the large-scale ocean circulation, ocean stratification, the Gulf Stream, wind-driven waves, tides, tsunamis, coastal upwelling, and other oceanic phenomena. Equations of motion. Modern observational, theoretical, and numerous other techniques used to study the ocean. The ocean role in climate and global climate change.

EPS 538a / ASTR 520a, Computational Methods in Astrophysics and Geophysics  Paolo Coppi
The analytic and numerical/computational tools necessary for effective research in astronomy, geophysics, and related disciplines. Topics include numerical solutions to differential equations, spectral methods, and Monte Carlo simulations. Applications are made to common astrophysical and geophysical problems including fluids and N-body simulations.

EPS 555a, Rock Formation in Mountain Belts  Jay Ague
Examination of the fundamental principles governing the formation of metamorphic and igneous rocks during mountain building. Topics include processes of heat and mass transfer in orogenic belts, generation of igneous rocks in continental and subduction settings, ultra-high-pressure and ultra-high-temperature metamorphism, spatial and temporal patterns of petrologic processes throughout geologic time, and pressure-temperature-time paths of metamorphic and igneous rocks.

EPS 557a, Advanced Seismology  Jeffrey Park

EPS 562b / ARCG 762b, Observing Earth from Space  Xuhui Lee
A practical introduction to satellite image analysis of Earth’s surface. Topics include the spectrum of electromagnetic radiation, satellite-borne radiometers, data transmission and storage, computer image analysis, the merging of satellite imagery with GIS and applications to weather and climate, oceanography, surficial geology, ecology and epidemiology, forestry, agriculture, archaeology, and watershed management.

EPS 590a, Master’s Degree Research in Earth and Planetary Sciences  Staff
Independent research under the supervision of a EPS faculty member, toward completion of the simultaneous award of the bachelor’s and master’s degrees. Eligibility limited to previously accepted participants in that program. For more information, please consult either the DUS or DGS of Earth and Planetary Sciences.
EPS 620a or b, Essentials of Earth and Planetary Sciences  Staff
EPS faculty take turns to teach what they think everyone in the EPS department should know about their own field (geophysics, geology, geochemistry, atmospheric, ocean, climate dynamics, and paleontology).

EPS 625a, Oceanography  Pincelli Hull and Noah Planavsky
This course provides an introduction to the basics of oceanography. It is structured as an interdisciplinary overview, designed to ensure that graduate students working in the oceans (i.e., those from paleontology, geochemistry, and/or AOCD) have the ability to form interdisciplinary collaborations through shared vocabulary and concepts, and to answer such basic questions as: why are there currents? what makes sea water salty? where is most life in the ocean? Topics are treated in interactive lectures, flipped classroom discussions/activities, and labs and are rigorously tested in one-on-one oral exams.

EPS 655a, Extraordinary Glimpses of Past Life  Derek Briggs
Study of exceptionally well preserved fossil deposits (lagerstaetten) that contain nonmineralized animal skeletons and casts of the soft parts of organisms. Examples such as the Burgess Shale and Solnhofen limestones; what they can reveal about the history and evolution of life, ancient lifestyles and environments, and preservational processes.

EPS 666a / AMTH 666a / ASTR 666a / MATH 666a, Classical Statistical Thermodynamics  John Wettlaufer
Classical thermodynamics is derived from statistical thermodynamics. Using the multi-particle nature of physical systems, we derive ergodicity, the central limit theorem, and the elemental description of the second law of thermodynamics. We then develop kinetics, transport theory, and reciprocity from the linear thermodynamics of irreversible processes. Topics of focus include Onsager reciprocal relations, the Fokker-Planck equation, stability in the sense of Lyapunov, and time invariance symmetry. We explore phenomena that are of direct relevance to astrophysical and geophysical settings. No quantum mechanics is necessary as a prerequisite.

EPS 703a / E&EB 930a, Seminar in Systematics  Jacques Gauthier
Topics and class time are chosen by the participants, and have included reading books and/or a series of papers on particular topics (e.g., homology; morphological phylogenetics; evolution of egg colors and exposed nesting in dinosaurs/birds; origin of snake ecology; conflicts between morphology and molecules; role of fossils in phylogenetic inference).

EPS 710a, Ethical Conduct and Scientific Research  Staff
This seminar is required of all graduate students and must be completed within the first year. Postdoctoral associates supported by NSF funding are also required to take this course. Topics include: how to do science; how to treat data correctly (data management); mistakes and negligence; research misconduct; responding to suspected violation of standards; sharing of research results; the peer-review process; collaboration; authorship and the allocation of credit; conflict of interest; cultivating a respectful, inclusive, harassment-free scientific workplace; and science and society. This course is in addition to the online ethics module, The Yale Guide to Professional Ethics, that must be completed by all GSAS students within the first term of study, regardless of source of financial support.
EPS 721a, Topics in Geobiology  Lidya Tarhan
In this course, students explore recent papers and discuss emerging ideas concerning life-environment interactions through Earth's history, with a particular focus on integrating paleontological, sedimentological, and geochemical records.

EPS 742a, Polar Processes and Climate  Mary-Louise Timmermans
This seminar is for graduate students interested in understanding the climate of the Polar Regions. Atmosphere, ice, and ocean processes and interactions at high latitudes are studied in the context of global climate. Each week, one or two scientific papers will set the theme of tutorials and discussions. Small student groups present the papers weekly.

EPS 744a, Seminar in Mantle and Core Processes  Staff
The seminar covers advanced topics concerning physical and chemical processes in the mantle and core of the Earth and planets. Specific topic and hour are arranged in consultation with enrolled graduate students.

EPS 750a, Seminar on Planetary Atmospheric Dynamics  Juan Lora
This seminar focuses on the physical processes, governing mechanisms, and general circulation that result in and control the climates of various planetary bodies. The course is structured around reading and discussing a selection of papers related to the dynamics of planetary atmospheres.

EPS 775b, The Evolution of the Global Silica Cycle  Lidya Tarhan and Mark Brandon
This seminar focuses on the evolution of the global silica cycle. Discussion will cover a range of topics, such as the rise of the biogenic and terrestrial silica cycles; water-column, seafloor and soil silica cycling; geochemical, lithologic and fossil-based proxy systems; and feedbacks between weathering, silica cycling and climate. This course meets for one-and-a-half to two hours once a week, and meetings are organized around readings from the primary research literature.

EPS 790a, Colloquium in Earth and Planetary Sciences  Staff
This course focuses on discussion of emerging research across the Earth and planetary sciences. ½ Course cr