

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

Mary-Louise Timmermans

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, Noah Planavsky, Peter Raymond, James Saiers, Mary-Louise Timmermans, John Wettlaufer

Associate Professors Bhart-Anjan Bhullar, Matthew Eisaman, Pincelli Hull

Assistant Professors Juan Lora, Alan Rooney, Lidya Tarhan, Jordan Wostbrock, Elizabeth Yankovsky

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. See Degree Requirements under Policies and Regulations. Additional requirements include a research essay or thesis and M.S. defense 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 510a, Introduction to Isotope Geochemistry Alan Rooney and Jordan Wostbrock
An overview of the fundamental principles of stable and radiogenic isotope geochemistry. Emphasis is placed on applications to specific geologic problems, including petrogenesis, geochronology, geothermometry, surface processes, hydrology, and biogeochemistry.

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 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 529a, Introduction to Geodynamics Jun Korenaga
This introductory course starts with the basics of continuum mechanics and covers a range of topics in geodynamics and relevant fields including the structure and dynamics of lithosphere, thermal convection and magmatism, Rayleigh-Taylor instability and plume dynamics, geoid and dynamic topography, and the thermal history of the core and geodynamo.

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

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, ultrahigh pressure and ultrahigh temperature metamorphism, spatial and temporal patterns of petrologic processes throughout geologic time, and pressure-temperature-time paths of metamorphic and igneous rocks.

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 620a or b, Essentials of Earth and Planetary Sciences Jun Korenaga

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 632b, Evolution of Lizards Jacques Gauthier

Review of the phylogeny, morphology, biogeography, behavior, fossil record, and evolution of lizards (aka *Squamata*). Undergraduates permitted with instructor's permission.

EPS 650a, Deformation of Earth Materials Shun-ichiro Karato

Microscopic physics of deformation of minerals and rocks and its applications to global geophysics.

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 659a, Data Analysis in Earth and Environmental Sciences Jeffrey Park

Introductory course in geoscience data analysis and time series methods, with emphasis on multiple-taper time series techniques. Examples drawn from seismological, paleoclimate, and historical climate data. Weekly computer assignments. Python proficiency helpful.

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, the origin of diffusion, transport theory, and reciprocity from the linear thermodynamics of irreversible processes. Topics of focus include Onsager reciprocal relations, the Fokker-Planck and Cahn-Hilliard equations, stability in the sense of Lyapunov, time invariance symmetry and maximum principles. We explore phenomena across a range of problems in science and engineering. Prerequisites for Yale College students: PHYS 301, PHYS 410, MATH 246 or similar and/or permission of instructor.

EPS 690a, Directed Research in Earth and Planetary Sciences Staff

By arrangement with faculty.

EPS 691a, Independent Research Staff

Faculty-supervised individual graduate student research. Prerequisite: approval of DGS and adviser.

EPS 703a or b / E&EB 930a or b, 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 Mary-Louise Timmermans and Maureen Long

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. o Course cr

EPS 720b, The Role of the Oceans in Climate Solutions: Physical, Environmental, Societal and Legal Constraints Matthew Eisaman

In this seminar, we explore the role that oceans can play in helping to address the climate crisis. We first review seawater carbonate chemistry and the role of oceans in the global carbon cycle. We then dive into the physical, environmental, societal, and legal constraints that may place limits on the degree to which oceans can contribute to climate solutions.

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 or b, 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 775a, Seminar on Lithosphere and Surface Processes Mark Brandon and Jordan Wostbrock

This semester, the LSP Seminar focuses on using stable isotopes to measure the topographic evolution of the continents. The format includes weekly discussions of assigned published papers and book chapters. The time, location, and format are flexible and are adjusted to accommodate the participants' interests and schedules. The seminar is open to undergraduate students, but permission from the instructors is required to enroll.

EPS 789a, Current Topics in Metamorphic Processes Jay Ague

This seminar is based mostly on readings from the literature and focuses on emerging issues in metamorphic petrology, including deep element cycling, non-lithostatic pressure, and ultrahigh-temperature and ultrahigh-pressure metamorphism.

EPS 790a or b, Colloquium in Earth and Planetary Sciences Staff

This course focuses on discussion of emerging research across the Earth and planetary sciences. ½ Course cr