

Department of the Geophysical Sciences

Chair

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- Susan M. Kidwell
- Douglas R. MacAyeal
- Noboru Nakamura
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- David B. Rowley

Associate Professors

- Dorian Abbot
- Andrew Campbell
- Fred Ciesla
- Dion L. Heinz
- Elisabeth J. Moyer
- Mark Webster

Assistant Professors

- Maureen Coleman
- Malte Jansen
- Edwin Kite
- Tiffany Shaw
- Graham J. Slater
- Jacob Waldbauer

Emeritus Faculty

- Alfred T. Anderson, Jr.
- Victor Barcion
- Roscoe R. Braham, Jr.
- Robert N. Clayton
- John E. Frederick
- Lawrence Grossman
- Michael C. LaBarbera, Organismal Biology & Anatomy
- Paul B. Moore
- Robert C. Newton
- Raymond T. Pierrehumbert
- William H. Reid
- Frank M. Richter
- Ramesh C. Srivastava
- Alfred M. Ziegler

Program of Graduate Study

Overview and Philosophy

The department serves graduate students who seek the Ph.D. in Earth, planetary, geological and environmental sciences and the paleontological and paleobiological disciplines of biological and historical sciences broadly conceived.

The Ph.D. signifies the graduate's mastery of the problems, techniques and knowledge covering the full spectrum of intellectual pursuit in the many disciplines listed above. The degree additionally acknowledges the candidate's contribution

to specialized knowledge through original research conducted in experimental, observational and theoretical venues. The M.S. is also awarded to graduate students in the program, and is given in recognition of post-undergraduate scholarship. Students considering the program of graduate study should realize, however, that it is conceived primarily for study and research leading to the Ph.D.

The Department of the Geophysical Sciences was created in 1961 when the departments of geology and meteorology of the university were united to better embrace the multidisciplinary nature of research and scholarship applied to Earth, its place in the cosmos and its environmental and biological history. The precursor Department of Geology was founded in the 1890's and reflected the University of Chicago's distinctively modern philosophy toward education and research. What is today lauded as new, namely the approach to physical, chemical, biological and natural science of Earth that values connections and multidisciplinary ways of thinking, was the original organizing principle of the university's activities in Earth science at the time the university was first created. Faithful to its original conception, the department is exemplified today by the diverse, yet interactive, composition of the faculty, students and research activities.

Our program distinguishes itself from those at other institutions through our rigorous adherence to a principle that the path to knowledge in Earth sciences is best traveled when disciplinary ways of thinking are applied interactively. To follow this path, our students and faculty engage each other in a constant exchange of ideas that spans a variety of specialized interests and disciplines. Indeed, the range of specialized interests and disciplines encompassed by our single intimate community is, at typical universities elsewhere, housed in separate departments. The exchange of ideas our community offers is both literal (as when research techniques from one discipline are applied in another) and figurative (as when students of diverse background and interests attend a common seminar), and is marshaled through our philosophical view that intellectual power is drawn from many sources. The tension created by bringing together disparate disciplines with differing traditions leads to constructive discourse in our community.

Areas of Study

Research, classroom teaching and seminar activity in the program reflect the long tradition of esteem directed toward multidisciplinary knowledge. Graduate study and research today thus ranges from geochemical approaches to nucleosynthesis and planet forming cosmochemistry to geomorphology, from evolutionary paleobiology to microbial ecology, and from climate dynamics of Earth and other planets, biogeochemical cycles to early Earth geochemistry. Graduate students are exposed to the breadth of intellectual activity in the physical and natural science of the Earth through courses they take during their first two years of study and through weekly attendance of seminars where both faculty and visiting scientists present research lectures. Graduate students are expected to develop two skills. First is the ability to conduct scientific discourse across the full range of disciplines. Second is the ability to conduct original research leading to unique contributions in an area of specialization.

Research and teaching within the program is further amplified by associations with other groups within the university. The most notable programs allied with ours are: the committee on evolutionary biology (CEB, research on the evolution of life), the chemistry department (research on atmospheric and environmental chemistry), the department of astronomy and astrophysics (research on exoplanets), the Argonne National Lab (environmental chemistry, advanced computing, the Advanced Photon Source, CARS), the center for robust decision making on climate and energy policy (RDCEP), and the department of statistics.

Student Advising

A distinctive element in the everyday life of the department is the mentoring relationship the faculty of the department provide for students of the program. In our program, students are regarded as colleagues, not subordinates. Students are guided in their learning and research activities by mentorship engaging both the program faculty and fellow students. This mentorship oversees both the course work activity and the student's research, and is conceived as a means of establishing the student as a full partner in research and scholarship. Formal mentoring activities involve regular academic advisory committee meetings that include a combination of faculty covering the student's field of specialty and faculty covering allied fields where cross disciplinary exchange of ideas or techniques may prove helpful to the student's progress. In addition to formal activities, mentoring also proceeds along informal avenues: the department faculty prides itself in maintaining an open door atmosphere, where students seeking help or advice can readily find it down the hall.

Research

Dissertation research can address any aspect of physical, chemical, biological and natural sciences of the Earth, its life and environment, and the solar system environment from which the planets were formed. Typically, dissertation research begins in the second year of the student's residence after courses taken in preparation for the preliminary examination have been completed and an oral research prospectus has been defended.

Teaching, Outreach and Professional Skills Development

Young scientists are faced with an ever increasing demand for breadth in the scope of their professional skills: from teaching to proposal writing, and from website design to mountaineering. To help prepare our students for the varied challenges they will encounter in their post graduate career, we involve them to the maximum extent possible in teaching, research planning, public outreach and field activity. While there are no strict requirements for teaching activities, the majority of our students participate in at least some teaching as laboratory assistants for the large, undergraduate-level classes taught by our faculty. Typical demands on a graduate student's time might involve four to eight hours a week of student contact time, and four to six hours a week of preparation and grading. To emphasize the value the university places on graduate student participation in undergraduate teaching, a slightly larger stipend is provided to teaching assistants over research assistants. In addition to teaching, our graduate students typically become involved in the scientific funding

process through exposure to the efforts undertaken by faculty in the securing of research funds through the writing of proposals. Public outreach is also an important element of professional skills, and is emphasized through scientific web site development (required by funding agencies for grants funded in support of scientific research) and other activities (e.g., local science fairs and lectures at surrounding schools) which emphasize contact with the general public. Many of our graduate students include field work as part of their research projects--from scuba-based sampling in Central America to mapping in Tibet--and we offer formal courses and trips to help students develop their skills for this mode of scientific research. Class trips typically focus on (1) modern and ancient sedimentary environments, which explicitly integrates across geology and biology (every 2-3 years, usually in a tropical or subtropical marine setting); (2) sequence stratigraphy of siliciclastics, mostly Meso-Cenozoic; and (3) integrated structure, tectonics, sedimentation, and paleontology, with an eye to reconstructing paleogeography at regional scales (early Paleozoics of Great Basin and Death Valley; Cenozoic of southern California). Students also have opportunities to join faculty in some field campaigns, which include oceanographic cruises.

Curriculum

The diversity of intellectual pursuit encompassed by the program places students and faculty into a challenging position when confronted with the need to design a curriculum capable of preparing students of the program to become Ph.D. scientists. Our approach to this challenge is to focus on thinking tools that prepare students for research. Thinking tools embody knowledge of methodologies, awareness of fundamental scientific problems, understanding of current research areas and creative thought when encountering difficult questions. These tools are taught, in part, by a curriculum of courses that delve deeply into various subsets of knowledge covered by the department's scholarly interests. While a student may enter the program with the ultimate goal of writing a dissertation in one area of specialization, courses taken in closely allied areas of specialization are often, by virtue of practicality, all that our curriculum offers. While this may seem detrimental to progress toward specialized research, in practice, the specific subject material used to build the student's base of knowledge and rigorous understanding of thought and methodologies is not strongly correlated with the student's subsequent success. Our curriculum of courses thus focuses on teaching notions of understanding and methodologies that are universal in their application to a wide range of specialized phenomena.

Required Course Activities

This time period is divided into two parts, the pre-candidacy phase where the student focuses on course work and general scholarship, and the candidacy phase where the student focuses on specialized research directed to the completion of the dissertation. While flexibility is a distinct advantage of the department's small, intimate setting of graduate study compared to other, larger programs, graduate students are normally expected to progress through their study as follows. Classes are taken through the first two years of residence at the university, and a preliminary examination is taken normally in the spring of the second year. Classes are selected from the department's graduate courses, appropriate upper-level undergraduate courses and courses offered elsewhere in the university. Selection of courses is made through consultation with a faculty advisory committee, which meets regularly through the first two years of the student's residence.

The preliminary examination taken at the end of the second year of residence serves to promote students to candidacy for the Ph.D. The purpose of the examination is to ensure the student's progress in the two goals of graduate study: breadth of fundamental knowledge, and depth of knowledge in a particular area of specialization (chosen normally to be consistent with the student's anticipated dissertation topic).

The preliminary examination has two parts. The written part (taken either in one single sitting or as a series of written tests taken in conjunction with final exams of courses, depending on the particular situation) covers the aspects of knowledge addressed in courses and in the weekly seminars which students are expected to attend. The oral part requires the student to present a research prospectus to a committee of faculty advisors. The topic of this prospectus is normally expected to be the student's planned research activity directed toward the dissertation.

The Dissertation

The Ph.D. degree is awarded to the candidate who has completed a written dissertation, defended it orally to a body of scientists which includes members of the department's faculty (who have the responsibility to vote in favor or against acceptance of the dissertation), and who have submitted the dissertation to the university dissertation office in proper form.

Courses

Courses are modified from year to year. Students are expected to consult course schedules published by the University for information regarding courses offered on an infrequent basis. A student's course load is expected to be three to four classes per quarter during the first five quarters (not including Summer Quarter) of residence. Over this period, the student will take a mixture of high level (designated by numbers greater than 30000) and medium level (designated by numbers in the 20000s) classes listed under the department's offerings, and appropriate courses offered by other departments of the university.

Geophysical Sciences Courses

GEOS 30200. Introduction to Research in the Geophysical Sciences. 100 Units.

This course is mandatory for all incoming graduate students in the department. Its purpose is to introduce the faculty's current research themes/areas and to familiarize incoming graduate students with research areas they might contemplate for further specialization. Lectures are presented by individual faculty on either 1) a general survey of a research area, or 2) a specialized topic of interest. Student activity varies from year to year and is based on a combination of oral and written presentations.

Instructor(s): Staff Terms Offered: Autumn

GEOS 30500. Topics in the Geophysical Sciences. 100 Units.

This course is offered from time-to-time as a means of covering topics that are generally not covered by regularly offered courses in the curriculum. Students should consult with appropriate faculty regarding opportunities to take this course when the situation arises.

Instructor(s): Staff Terms Offered: Autumn. Not offered 2017-2018

Equivalent Course(s): GEOS 20500

GEOS 31005. Mineral Science. 100 Units.

This course examines the relationship between the structure of minerals, their chemistry, and their physical properties. Topics include crystallography, defect properties, phase transitions, and analytical tools, followed by detailed study of specific mineral groups.

Instructor(s): A. Campbell Terms Offered: Winter. not offered 2017-2018

Prerequisite(s): GEOS 21000 or consent of instructor.

Equivalent Course(s): GEOS 21005

GEOS 31200. Physics of the Earth. 100 Units.

This course considers geophysical evidence bearing on the internal makeup and dynamical behavior of the Earth, including seismology (i.e., properties of elastic waves and their interpretation, and internal structure of the Earth); mechanics of rock deformation (i.e., elastic properties, creep and flow of rocks, faulting, earthquakes); gravity (i.e., geoid, isostasy); geomagnetism (i.e., magnetic properties of rocks and history, origin of the magnetic field); heat flow (i.e., temperature within the Earth, sources of heat, thermal history of the Earth); and plate tectonics and the maintenance of plate motions. (L)

Instructor(s): D. Heinz Terms Offered: Spring

Prerequisite(s): Prior calculus and college-level physics courses, or consent of instructor.

Equivalent Course(s): GEOS 21200

GEOS 31205. Introduction to Seismology, Earthquakes, and Near-Surface Earth Seismicity. 100 Units.

This course introduces the mechanics and phenomenology of elastic waves in the Earth and in the fluids near the Earth's surface (e.g., S and P waves in the solid earth, acoustic waves in the ocean and atmosphere). Topics include stress and strain, constitutive equations, elasticity, seismic waves, acoustic waves, theory of refraction/reflection, surface waves, dispersion, and normal modes of the Earth. Phenomenology addressed includes exploration geophysics (refraction/reflection seismology), earthquakes and earthquake source characterization, seismograms as signals, seismometers and seismological networks, and digital seismogram analysis.

Instructor(s): D. Heinz Terms Offered: Winter

Equivalent Course(s): GEOS 21205

GEOS 31400. Thermodynamics and Phase Change. 100 Units.

This course develops the mathematical structure of thermodynamics with emphasis on relations between thermodynamic variables and equations of state. These concepts are then applied to homogeneous and heterogeneous phase equilibrium, culminating in the construction of representative binary and ternary phase diagrams of petrological significance.

Instructor(s): A. Campbell Terms Offered: Spring. This course is offered in alternate years.

Prerequisite(s): MATH 20000-20100-20200 and college-level chemistry and calculus, or consent of instructor.

Equivalent Course(s): GEOS 21400

GEOS 31500. Mineral Physics. 100 Units.

The application of physics at the microscopic level to geologic and geophysical problems. Topics: vibrational, electric and transport properties of minerals.

Instructor(s): D. Heinz

Prerequisite(s): 2 yrs. math beyond calculus; 1 year physical chemistry or 1 year of both physics and chemistry; general geology, general geophysics and mineralogy, petrology or equivalent

GEOS 32000. Origin and Evolution of the Solar System. 100 Units.

This course will explore the formation and evolution of the Solar System, from the collapse of the natal molecular cloud core to the orbital restructuring of the planets. Topics to be covered include: structure and evolution of the solar nebula, dust dynamics in the solar nebula and the formation of planetesimals, accretion of the terrestrial planets, giant planet formation and migration, and meteorites and the historical record of the Solar System they preserve. (L)

Instructor(s): F. Ciesla Terms Offered: Winter

Prerequisite(s): At least one year of physics or chemistry and an understanding of multivariate calculus.

Note(s): This course is offered in alternate years.

Equivalent Course(s): ASTR 21300, GEOS 22000

GEOS 32040. Formation of Planetary Systems in Our Galaxy: From Dust to Planetesimals. 100 Units.

This course examines the physical and chemical processes that operate during the earliest stages of planet formation when dust in a protoplanetary disk aggregates into bodies 1 to 10 km in size. Topics include the physical and chemical evolution of protoplanetary disks, radial transport of dust particles, transient heating events, and the formation of planetesimals. We discuss the evidence of these processes found in meteorites and observed in disks around young stars. Chemical and physical models of dust evolution are introduced, including an overview of basic numerical modeling techniques.

Instructor(s): F. Ciesla Terms Offered: Not offered 2017-2018

Prerequisite(s): One year of college-level calculus and physics or chemistry, or consent of instructor.

Note(s): This course is offered in alternate years.

Equivalent Course(s): GEOS 22040

GEOS 32050. Formation of Planetary Systems in our Galaxy: From Planetesimals to Planets. 100 Units.

This course explores the stage of planet formation during which 1 to 10 km planetesimals accrete to form planets. Topics include heating of planetesimals, models of giant planet formation, the delivery of water to terrestrial planets, and the impact that stellar mass and external environment have on planet formation. We also discuss what processes determine the properties (mass, composition, and orbital parameters) of a planet and its potential for habitability. Basic modeling techniques and current research papers in peer-reviewed journals are also discussed.

Instructor(s): F. Ciesla Terms Offered: Not offered 2017-2018

Prerequisite(s): Consent of instructor

Equivalent Course(s): GEOS 22050

GEOS 32060. What Makes a Planet Habitable? 100 Units.

This course explores the factors that determine how habitable planets form and evolve. We will discuss a range of topics, from the accretion and loss of atmospheres and oceans, to the long-term carbon cycle, climate dynamics, and the conditions that sustain liquid water on a planet's surface over timescales relevant to the origin and evolution of life. Students will be responsible for reading and discussing papers in peer-reviewed journals each meeting and for periodically preparing presentations and leading the discussion.

Instructor(s): E. Kite Terms Offered: Spring

Equivalent Course(s): ASTR 45900, GEOS 22060

GEOS 32200. Geochronology. 100 Units.

This course covers the duration of planetary differentiation and the age of the Earth (i.e., extinct and extant chronometers); timescales for building a habitable planet (i.e., the late heavy bombardment, the origin of the atmosphere, the emergence of life, and continent extraction); dating mountains (i.e., absolute ages, exposure ages, and thermochronology); the climate record (i.e., dating layers in sediments and ice cores); and dating recent artifacts (e.g., the Shroud of Turin). (L)

Instructor(s): N. Dauphas Terms Offered: Autumn

Prerequisite(s): Background in college-level geology, physics, and mathematics.

Equivalent Course(s): GEOS 22200

GEOS 32300. Cosmochemistry. 100 Units.

Chemical, mineralogical, and petrographic classifications of meteorites. Topics include: abundances of the elements, origin of the elements and stellar evolution, the interstellar medium and formation of the solar nebula, condensation of the solar system, chemical fractionations in meteorites and planets, age of the solar system, extinct radionuclides in meteorites, isotope anomalies.

Instructor(s): L. Grossman Terms Offered: Winter

Note(s): This course is offered in alternate years.

GEOS 32400. Nucleosynthesis and Its Record in the Solar System and Stars. 100 Units.

The course will cover the environments where the chemical elements are made (supernovae, red giant stars, the Big Bang) and the record of nucleosynthesis in meteorites, planets and other stars (both by remote observation and study of stardust in the laboratory). The course is open to graduate students and advanced undergraduates.

Instructor(s): Andrew Davis Terms Offered: Autumn

GEOS 32500. Topics in Planetary Science. 100 Units.

In this seminar we explore the latest research and results in planetary science. General topics to be discussed include planet formation, planetary evolution, spacecraft exploration, and astrobiology. The specific focus for each class offering will be determined by the interests of the faculty and students. Can be taken multiple times for credit since the specific topic will change each quarter.

Instructor(s): Staff Terms Offered: Winter

GEOS 32700. Analytical Techniques in Geochemistry. 100 Units.

Measurement of the isotopic and chemical compositions of solar system materials involves a wide variety of analytical techniques. In this course, we will review the major types of instrumentation used in modern laboratories. The goal is not to produce experts in the operation of each instrument, but rather that everyone gain an appreciation for how instruments work and what the capabilities and limitations are for each kind of instrument.

Instructor(s): A. Davis

GEOS 32705. Analytical Techniques. 100 Units.

Theory and practice of analytical techniques.

Instructor(s): I. Steele

GEOS 33205. Introductory Glaciology. 100 Units.

The fundamentals of glacier and ice-sheet dynamics and phenomenology will be covered in this introductory course (snow and sea ice will be excluded from this course, however may be taken up in the future). Emphasis will be placed on developing the foundation of continuum mechanics and viscous fluid flow as a means of developing the basic equations of glacier deformation, ice-sheet and -shelf flow, basal processes, glacier hydrology, and unstable modes of flow. This course is intended for advanced undergraduate students in physics, math, geophysical sciences, and related fields as well as graduate students considering research in glaciology and climate dynamics. This course is part of the College Course Cluster program, *Climate Change, Culture, and Society*. (L)

Instructor(s): D. MacAyeal Terms Offered: Winter

Prerequisite(s): Knowledge of vector calculus, linear algebra, and computer programming.

Equivalent Course(s): GEOS 23205

GEOS 33300. Advanced Topics in Climate Dynamics. 100 Units.

The course will go beyond radiative-convective equilibrium and explore spatial and temporal aspects of Earth's climate with a focus on the atmosphere. The goal is to gain a physical understanding of Earth's climate and its past and future changes.

We will discuss a range of topics from the surface and atmospheric energy balance, hydrological cycle, atmospheric general circulation and energy transport, climate variability, paleoclimate, natural & anthropogenic climate change. The course will combine lectures of the theory and observations underlying our understanding of Earth's climate with student presentations of peer-reviewed papers. The evaluation will be based on a data-analysis project.

Instructor(s): T. Shaw Terms Offered: Winter

Prerequisite(s): GEOS 24220 or equivalent

GEOS 33800. Global Biogeochemical Cycles. 100 Units.

This survey course covers the geochemistry of the surface of the Earth, focusing on biological and geological processes that shape the distributions of chemical species in the atmosphere, oceans, and terrestrial habitats. Budgets and cycles of carbon, nitrogen, oxygen, phosphorous, and sulfur are discussed, as well as chemical fundamentals of metabolism, weathering, acid-base and dissolution equilibria, and isotopic fractionation. The course examines the central role that life plays in maintaining the chemical disequilibria that characterize Earth's surface environments. The course also explores biogeochemical cycles change (or resist change) over time, as well as the relationships between geochemistry, biological (including human) activity, and Earth's climate.

Instructor(s): J. Waldbauer Terms Offered: Winter

Prerequisite(s): CHEM 11100-11200 or consent of instructor

Equivalent Course(s): ENSC 23800, GEOS 23800

GEOS 33805. Stable Isotope Biogeochemistry. 100 Units.

Stable isotopes of H, C, O, N, and S are valuable tools for understanding the biological and geochemical processes that have shaped the composition of Earth's atmosphere and oceans throughout our planet's history. This course examines basic thermodynamic and kinetic theory to describe the behavior of isotopes in chemical and biological systems. We then examine the stable isotope systematics of localized environmental processes, and see how local processes contribute to global isotopic signals that are preserved in ice, sediment, rock, and fossils. Special emphasis is placed on the global carbon cycle, the history of atmospheric oxygen levels, and paleoclimate.

Instructor(s): A. Colman Terms Offered: Winter. Not offered 2017-2018

Prerequisite(s): CHEM 11100-11200-11300 or equivalent; 13100-13200-13300 or consent of instructor

Equivalent Course(s): ENSC 23805, GEOS 23805

GEOS 33825. Topics in Microbial Biogeochemistry. 100 Units.

In this seminar we explore the role of microorganisms in biogeochemical cycles. Topics include microbial metabolism, physiology, ecology and evolution in natural habitats, responses to short- and long-term climate change, and coevolution of life and its environment over Earth history. Can be taken multiple times for credit since the specific topic will change each quarter.

Instructor(s): M. Coleman Terms Offered: Autumn, Winter

GEOS 33900. Environmental Chemistry. 100 Units.

The focus of this course is the fundamental science underlying issues of local and regional scale pollution. In particular, the lifetimes of important pollutants in the air, water, and soils are examined by considering the roles played by photochemistry, surface chemistry, biological processes, and dispersal into the surrounding environment. Specific topics include urban air quality, water quality, long-lived organic toxins, heavy metals, and indoor air pollution. Control measures are also considered. This course is part of the College Course Cluster program, *Climate Change, Culture, and Society*.

Instructor(s): D. Archer Terms Offered: Autumn

Prerequisite(s): CHEM 11101-11201 or equivalent, and prior calculus course

Equivalent Course(s): ENST 23900, ENSC 23900, GEOS 23900

GEOS 34100. Fundamentals of Fluid Mechanics. 100 Units.

This course provides an introduction to concepts and phenomenology of fluid mechanics of newtonian fluids. Classroom demonstrations are coupled with analytical treatment of equations of motion and their approximations. Topics include (1) pressure and stress, (2) Bernoulli's theorem, (3) vorticity and turbulence, (4) surface and internal waves, (5) effects of rotation and gravity on stability, (6) spin up. The lectures are supplemented by problem sets. Commands of vector calculus are highly desirable.

Instructor(s): N. Nakamura

Prerequisite(s): Classical mechanics and vector calculus

GEOS 34105. Dynamics of Viscous Fluids. 100 Units.

This course is offered on an occasional basis, and deals with the thermomechanical properties and behavior of ideal viscous fluids, with applications in special areas of geophysical fluid dynamics, particularly glaciology and mantle isostasy. Topics to be covered include: constitutive descriptions of ideal and non ideal fluids, compressible and incompressible fluids, Coulomb failure laws, plastic approximations, kinematics of flow fields, strain and strain rate tensors, equations governing the balance of momentum and energy, stress tensor, Navier Stokes equations, Stokesian flows, non Newtonian constitutive laws and laminar/turbulent transitions. Special cases of fluid flow will be examined, including irrotational and incompressible flow, Bernoulli's theorem for inviscid fluids, jets, wakes and flow past rigid boundaries. Special boundary conditions will be examined, including both dynamic and kinematic. Geophysical applications in 2005 ranged across the basics of glaciological flow systems, including classical Nye/Vialov icesheet flow, ice shelf flow and basal sliding. Readings will include chapters from G.K. Batchelor's *An Introduction to Fluid Dynamics* and occasional classical journal articles in glaciology.

Instructor(s): D. MacAyeal

GEOS 34220. Climate Foundations. 100 Units.

This course introduces the basic physics governing the climate of planets, the Earth in particular but with some consideration of other planets. Topics include atmospheric thermodynamics of wet and dry atmospheres, the hydrological cycle, blackbody radiation, molecular absorption in the atmosphere, the basic principles of radiation balance, and diurnal and seasonal cycles. Students solve problems of increasing complexity, moving from pencil-and-paper problems to programming exercises, to determine surface and atmospheric temperatures and how they evolve. An introduction to scientific programming is provided, but the fluid dynamics of planetary flows is not covered. (L)

Instructor(s): E. Moyer Terms Offered: Autumn

Prerequisite(s): Prior physics course (preferably PHYS 13300 and 14300) and knowledge of calculus required; prior geophysical sciences course not required.

Note(s): Prior programming experience helpful but not required.

Equivalent Course(s): GEOS 24220

GEOS 34230. Geophysical Fluid Dynamics: Foundations. 100 Units.

This course is for incoming graduate students in physical sciences intending to take further courses in geophysical fluid dynamics, fluid dynamics, condensed matter physics, and other areas requiring this fundamental skill set. It sets the stage for follow-on courses that present the detail of the behavior of fluids and continuums in geophysical, physical, chemical, and other settings. The material may be a student's first contact with continuum mechanics or a remedial or review for students who have previously taken similar courses. Topics include description of material properties in a continuum, including displacement, velocity, and strain rate; scalar, vector, and tensor properties of continuums, strain, strain rate, and stress; derivations and understanding of mass, momentum, and energy conservation principles in a continuum; applications of conservation principles to simple rheological idealizations, including ideal fluids and potential flow, viscous fluids and Navier-Stokes flow, elasticity and deformation; introductory asymptotic analysis, Reynolds number; heat transfer by conduction and convection, convective instability, Rayleigh number; fluids in gravitational fields, stratification, buoyancy; elliptic, parabolic, and hyperbolic partial differential equations, typical properties of each.

Instructor(s): D. MacAyeal Terms Offered: Autumn

Prerequisite(s): Vector calculus, linear algebra, advanced classical mechanics, basic knowledge of computing. Undergrads who take this course should intend to complete a second fluid-dynamics course in Geophysical Sciences.

Equivalent Course(s): GEOS 24230

GEOS 34240. Geophysical Fluid Dynamics: Rotation and Stratification. 100 Units.

This course is an introduction to geophysical fluid dynamics for upper-level undergraduates and starting graduate students. The topics covered will be the equations of motion, the effects of rotation and stratification, shallow water systems and isentropic coordinates, vorticity and potential vorticity, and simplified equations for the ocean and atmosphere.

Instructor(s): T. Shaw Terms Offered: Winter

Prerequisite(s): PQ: GEOS 24230 or equivalent; Knowledge of mechanics (PHYS 13100 or equivalent), thermodynamics (PHYS 19700 or equivalent), vector calculus and linear algebra (MATH 20000-20100-20200 or equivalent)

Equivalent Course(s): GEOS 24240

GEOS 34250. Geophysical Fluid Dynamics: Understanding the Motions of the Atmosphere and Oceans. 100 Units.

This course is part of the atmospheres and oceans sequence (GEOS 24220, 24230, 24240, 24250) and is expected to follow Geophysical Fluid Dynamics: Rotation and Stratification (GEOS 24240). The course demonstrates how the fundamental principles of geophysical fluid dynamics are manifested in the large-scale circulation of the atmosphere and oceans and their laboratory analogs. Topics include: balance of forces and the observed structure of the atmospheric and oceanic circulations, statistical description of the spatially and temporally varying circulation, theory of Hadley circulation, waves in the atmosphere and oceans, baroclinic instability, wind-driven ocean circulation.

Instructor(s): N. Nakamura Terms Offered: Spring

Prerequisite(s): GEOS 24230 and 24240, or consent of the instructor. Knowledge of vector calculus, linear algebra, and ordinary differential equations is assumed.

Equivalent Course(s): GEOS 24250

GEOS 34400. Topics in Geophysical Fluid Dynamics. 100 Units.

This course teaches science and art of numerical modeling at an elementary level. Classroom discussions on mathematical principles will be supplemented by a series of actual coding assignments. (Command of a programming language is assumed; this is not a course on programming.) It is our goal that at the end of the course each student will have coded a working copy of shallow water model on a rotating sphere (and do science with it). Prereq: Calculus, working knowledge of Fourier Transform and of a programming language (C, Fortran, IDL, etc.), access to a computer with a compiler and runtime environment. No previous experience in fluid dynamics is necessary, although this course alone does not fully prepare one to become a fluid dynamicist.

Instructor(s): N. Nakamura

GEOS 34505. Dynamics of the Stratosphere. 100 Units.

Focus on the vertical structure of the Earth's atmosphere due to compressibility and radiative heating, and its consequences on the dynamics, particularly of the stratosphere. Emphasis is placed more on the underlying physics than on the mere phenomenology of the stratosphere.

Instructor(s): N. Nakamura

Prerequisite(s): GEOS 34200 or equivalent

GEOS 34510. Topics in Atmospheric Science. 100 Units.

Topics of current interest in atmospheric science, with a particular emphasis on issues arising in recent publications. Topics covered have included: tropical circulations, cloud climate feedbacks, and dynamics of the stratosphere.

Instructor(s): Staff

Prerequisite(s): consent of instructor

GEOS 34530. Turbulence & Transport Processes in the Atmosphere & Oceans. 100 Units.

The atmosphere and oceans exhibit non-linear turbulent motions on a wide range of scales. Yet introductory classes in atmosphere and ocean dynamics focus almost exclusively on linear theories. While there is undoubtedly much to learn from linear theory, statistical descriptions of turbulent flows provide a valuable perspective from a different angle. In this advanced graduate course we will discuss the theory of 3-dimensional, 2-dimensional and quasi-geostrophic turbulence, as well as the role of turbulent motions for the transport of properties in the atmosphere and ocean. We will also discuss the wave-turbulence crossover, and eddy-mean-flow interactions, thus connecting back to linear theories. The format of the course will be a mixture of lectures and student-led paper discussions.

Instructor(s): M. Jansen Terms Offered: Autumn

Prerequisite(s): GEOS 24230 and GEOS 24240 or equivalent; Knowledge of mechanics (PHYS 13100 or equivalent), vector calculus and linear algebra (MATH 20000-20100-20200 or equivalent). Knowledge of the basics of statistics/stochastics is also expected.

GEOS 34705. Energy: Science, Technology, and Human Usage. 100 Units.

This course covers the technologies by which humans appropriate energy for industrial and societal use, from steam turbines to internal combustion engines to photovoltaics. We also discuss the physics and economics of the resulting human energy system: fuel sources and relationship to energy flows in the Earth system; and modeling and simulation of energy production and use. Our goal is to provide a technical foundation for students interested in careers in the energy industry or in energy policy. Field trips required to major energy converters (e.g., coal-fired and nuclear power plants, oil refinery, biogas digester) and users (e.g., steel, fertilizer production).

Instructor(s): E. Moyer Terms Offered: Spring

Prerequisite(s): Knowledge of physics or consent of instructor

Equivalent Course(s): GEOS 24705, ENST 24705, ENSC 21100

GEOS 34800. Radiation Transfer Theory. 100 Units.

Develops the theory of radiation emission, absorption, and scattering by planetary atmospheres. Emphasis on the derivation and solution of the radiative transfer equation for plane parallel, horizontally homogeneous atmospheres.

Instructor(s): J. Frederick, R. Pierrehumbert

Prerequisite(s): Advanced undergraduate level knowledge of electromagnetic theory, atomic structure, and differential equations.

GEOS 35100. Data Analysis for the Geophysical Sciences. 100 Units.

A graduate-level introduction to probability, modeling, and data analysis. Though some emphasis is given to paleontological problems, the goal is to keep approaches sufficiently general that they should be relevant to students across the geophysical sciences as well as evolutionary biology. Required work includes coding exercises and a term project based on original research.

Instructor(s): M. Foote Terms Offered: Spring

GEOS 35400. Introduction to Numerical Techniques for the Geophysical Sciences. 100 Units.

This class provides an introduction to different types of numerical techniques used in developing models used in geophysical science research. Topics will include how to interpolate and extrapolate functions, develop functional fits to data, integrate a function, or solve partial differential equations. Students are expected to have some familiarity with computers and programming—programming methods will not be discussed in detail. While techniques will be the focus of the class, we will also discuss the planning needed in developing a model as well as the limitations inherent in such models.

Instructor(s): F. Ciesla Terms Offered: Winter

Prerequisite(s): Familiarity with a computer programming language such as C, Fortran, or IDL, or a mathematical computing environment like Mathematica or Matlab. Spreadsheets such as Excel or Numbers can also be used for many problems.

Equivalent Course(s): GEOS 25400

GEOS 35500. Mathematical Methods for the Earth Sciences. 100 Units.

This course is intended to be a brief introduction to mathematical methods that may be of use in the Earth Sciences. The focus will be on building physical intuition and practical problem solving. Students may solve problems analytically, or write numerical codes to solve them.

Instructor(s): D. Abbot Terms Offered: Spring

GEOS 36000. Morphometrics. 100 Units.

This graduate-level course serves as an introduction to the field of morphometrics (the analysis of organismal shape).

Quantitative exploratory and confirmatory techniques involving both traditional (length-based) and geometric (landmark-based) summaries of organismal shape are introduced in a series of lectures and practical exercises. Emphasis is placed on the application of morphometric methods to issues such as (but not restricted to) quantification of intraspecific variability, interspecific differences, disparity, ontogenetic growth patterns (allometry), and phylogenetic changes in morphology.

Relevant statistical and algebraic operations are explained assuming no prior background. Students are required to bring personal laptop computers, and are expected to acquire and analyze their own data sets during the course.

Instructor(s): M. Webster

Equivalent Course(s): EVOL 36700

GEOS 36050. Models of Morphological Evolution. 100 Units.

Over the past 30 years the study of morphological evolution, from inference of evolutionary process to understanding correlated trait changes, has increasingly relied on phylogenetic approaches. This is due to the realization that species may exhibit similar traits due to shared evolutionary history as much as due to similar adaptive responses to other factors. The field of phylogenetic comparative methods is rapidly expanding. This graduate course will cover basic and advanced models of morphological character evolution that underlie comparative methods, as well as the statistical models themselves. Topics covered in this class will span: Brownian motion as a model of quantitative trait evolution; Independent contrasts and evolutionary regressions; Measuring phylogenetic signal; Alternative models of quantitative trait evolution - early bursts, Ornstein-Uhlenbeck processes, and multivariate data; Discrete traits, Markov processes and the threshold model; Phylogenetic analogues of traditional comparative methods (e.g., ANOVA, PCA). Lectures will cover theory behind concepts but students will also be expected to bring laptops to class so as to write code to simulate data and fit statistical models. All coding will be done in the R statistical language.

Instructor(s): G. Slater Terms Offered: Winter. Not offered 2017-2018

GEOS 36100. Phylogenetics and the Fossil Record. 100 Units.

Phylogenies are branching diagrams that reflect evolutionary relationships. In addition to providing information on the history of life, phylogenies are fundamental to modern methods for studying macroevolutionary and macroecological pattern and process. In the biological sciences, phylogenies are most often inferred from genetic data. In paleobiology, phylogenies can only be inferred from the fossilized remains of morphological structures, and collecting and analyzing morphological data present a different set of challenges. In this course, students will study both traditional and state-of-the-art approaches to inferring phylogenies in the fossil record, from data collection to interpretation. Lectures will explore the statistical underpinnings of phylogenetic methods, as well as their practical implementation in commonly used software. Topics will include: identifying and coding morphological characters, models of morphological evolution, parsimony, maximum likelihood, and bayesian methods, supertree approaches, and integrating time into phylogenetic inference. Fifty percent of the final assessment will come from a research paper due at the end of the quarter.

Instructor(s): G. Slater Terms Offered: Autumn. Not offered 2017-2018

Prerequisite(s): BIOS 20197 or equivalent.

Equivalent Course(s): GEOS 26100

GEOS 36200. Evolution and the Fossil Record. 100 Units.

This course serves as an introduction to the practical and theoretical issues involved in obtaining primary systematic data from the fossil record, and demonstrates the criticality of such data to the rigorous documentation and interpretation of evolutionary patterns. Precise topics of the seminar discussions will vary from year to year depending on relevance to student research projects and interest, but are likely to focus on issues such as (but not restricted to) practical techniques in specimen-based paleontology (including fossil preparation and photography), species delimitation (including species concepts, variability, and ecophenotypy), stratigraphic/geographic range determination (including biostratigraphic correlation), phylogeny reconstruction (including the relevance of stratigraphic data), and the importance of these topics to broader macroevolutionary issues such as diversity/disparity dynamics and the determination of evolutionary trends, rates and processes.

Instructor(s): M. Webster

Equivalent Course(s): EVOL 46200

GEOS 36300. Invertebrate Paleobiology and Evolution. 100 Units.

This course provides a detailed overview of the morphology, paleobiology, evolutionary history, and practical uses of the invertebrate and microfossil groups commonly found in the fossil record. Emphasis is placed on understanding key anatomical and ecological innovations within each group and interactions among groups responsible for producing the observed changes in diversity, dominance, and ecological community structure through evolutionary time. Labs supplement lecture material with specimen-based and practical application sections. An optional field trip offers experience in the collection of specimens and raw paleontological data. Several "Hot Topics" lectures introduce important, exciting, and often controversial aspects of current paleontological research linked to particular invertebrate groups. (L)

Instructor(s): M. Webster Terms Offered: Autumn

Prerequisite(s): GEOS 13100 and 13200, or equivalent. For BIOS students: Three quarters of a Biological Sciences Fundamentals sequence.

Equivalent Course(s): BIOS 23261, EVOL 32400, GEOS 26300

GEOS 36600. Geobiology. 100 Units.

Geobiology seeks to elucidate the interactions between life and its environments that have shaped the coevolution of the Earth and the biosphere. The course will explore the ways in which biological processes affect the environment and how the evolutionary trajectories of organisms have in turn been influenced by environmental change. In order to reconstruct the history of these processes, we will examine the imprints they leave on both the rock record and on the genomic makeup of living organisms. The metabolism and evolution of microorganisms, and the biogeochemistry they drive, will be a major emphasis.

Instructor(s): M. Coleman, J. Waldbauer Terms Offered: Spring. Not offered 2017-2018

Prerequisite(s): GEOS 13100-13200-13300 or college-level cell & molecular biology

Equivalent Course(s): ENSC 24000, GEOS 26600

GEOS 36700. Taphonomy. 100 Units.

Lecture and research course on patterns and processes of fossilization, including rates and controls of soft tissue decomposition, post mortem behavior of skeletal hard parts, concentration and burial of remains, scales of time averaging, and the net spatial and compositional fidelity of (paleo)biologic information, including trends across environments and evolutionary time. Offered alternate years.

Instructor(s): S. Kidwell

Equivalent Course(s): EVOL 31800

GEOS 36800. Macroevolution. 100 Units.

Patterns and processes of evolution above the species level, in both recent and fossil organism. A survey of the current literature, along with case studies.

Instructor(s): D. Jablonski Terms Offered: Spring

Equivalent Course(s): EVOL 31700

GEOS 36900. Topics in Paleobiology. 100 Units.

In this seminar we investigate paleobiological or multidisciplinary topics of current interest to students and faculty. Previous subjects include the origin of phyla, historical and macro-ecology, the stratigraphic record and evolutionary patterns, and climate and evolution.

Instructor(s): D. Jablonski, S. Kidwell, T. Price Terms Offered: Autumn

Equivalent Course(s): EVOL 31900, ECEV 36900

GEOS 36905. Topics in Conservation Paleobiology. 100 Units.

Paleobiological data from very young sedimentary records, including 'death assemblages' of shells and bones that are accumulating on modern-day seabeds and land surfaces, provide unique information on the status of present-day populations, communities, and ecosystems and their responses to natural and anthropogenic stress. This course on the emerging discipline of 'conservation paleobiology' uses a mix of lectures, seminars, and individual research projects to introduce how basic geologic methods, applied to modern samples, can address critical issues in the conservation and restoration of biodiversity and natural environments, including the identification of shifted baselines and disentangling human and natural drivers of ecological change. The course is designed to accommodate biologists with little background in paleontology and geology, focusing on methods of age-dating, paleo-environmental reconstruction, and geohistorical inference relevant to analysis of the last few thousands of years of human expansion and cultural/industrial development. The 2017 version will include hands-on experience with already-collected marine benthic samples. Enrollment limited.

Instructor(s): S. Kidwell Terms Offered: Winter

Prerequisite(s): Prerequisites for undergraduates: completion of GEOS 13100-13200-13300 or equivalent or completion of a 20000-level course in paleontology.

Equivalent Course(s): GEOS 26905, EVOL 36905

GEOS 38000. Introduction to Structural Geology. 100 Units.

This course explores the deformation of the Earth materials primarily as observed in the crust. We emphasize stress and strain and their relationship to incremental and finite deformation in crustal rocks, as well as techniques for inferring paleostress and strain in deformed crustal rocks. We also look at mesoscale to macroscale structures and basic techniques of field geology in deformed regions.

Instructor(s): D. Rowley Terms Offered: Winter

Prerequisite(s): GEOS 13100

Note(s): This course is offered in alternate years.

Equivalent Course(s): GEOS 28000

GEOS 38100. Global Tectonics. 100 Units.

This course reviews the spatial and temporal development of tectonic and plate tectonic activity of the globe. We focus on the style of activity at compressive, extensional, and shear margins, as well as on the types of basin evolution associated with each. (L)

Instructor(s): D. Rowley Terms Offered: Winter

Prerequisite(s): GEOS 13100 or consent of instructor

Note(s): This course is offered in alternate years.

Equivalent Course(s): GEOS 28100

GEOS 38300. Principles of Stratigraphy. 100 Units.

This course introduces principles and methods of stratigraphy. Topics include facies analysis, physical and biostratigraphic correlation, and development and calibration of the geologic time scale. We also discuss controversies concerning the completeness of the stratigraphic record; origin of sedimentary cycles; and interactions between global sea level, tectonics, and sediment supply. (L)

Instructor(s): S. Kidwell Terms Offered: Autumn. Not offered in 2017-2018

Prerequisite(s): GEOS 13100-13200 or equivalent required; GEOS 23500 and/or 28200 recommended

Note(s): This course is offered in alternate years.

Equivalent Course(s): GEOS 28300

GEOS 38400. Topics in Stratigraphy and Biosedimentology. 100 Units.

Seminar course using the primary literature and/or a field problem. Topic selected from the rapidly evolving fields of sequence stratigraphy, basin analysis, and animal sediment relationships.

Instructor(s): S. Kidwell

Prerequisite(s): GEOS 26400 and GEOS 28300 or equivalent

Equivalent Course(s): EVOL 41500

GEOS 38500. Stratigraphic Analysis. 100 Units.

Historical review of basic concepts and methods, leading to current frontiers and controversies in basin and global scale analysis of the sedimentary rock record.

Instructor(s): S. Kidwell

Prerequisite(s): GEOS 28300 or equivalent

GEOS 39002. Field Course in Modern and Ancient Environments. 100 Units.

This course uses weekly seminars during Winter Quarter to prepare for a one-week field trip over spring break, where students acquire experience with sedimentary rocks and the modern processes responsible for them. Destinations vary; past trips have examined tropical carbonate systems of Jamaica and the Bahamas and subtropical coastal Gulf of California. We usually consider biological, as well as physical, processes of sediment production, dispersal, accumulation, and post-depositional modification.

Instructor(s): S. Kidwell, Staff Terms Offered: Winter

Note(s): Organizational meeting and deposit usually required in Autumn Quarter; interested students should contact an instructor in advance.

Equivalent Course(s): ENSC 29002, GEOS 29002

GEOS 39700. Reading and Research in the Geophysical Sciences. Variable Units.

GEOS 39700-39799. Topics available include, but are not limited to: Mineralogy, Petrology, Geophysics, High Pressure Geophysics, Geodynamics, Volcanology, Cosmochemistry, Geochemistry, Atmospheric Dynamics, Paleoclimatology, Physical Oceanography, Chemical Oceanography, Paleoceanography, Atmospheric Chemistry, Fluid Dynamics, Glaciology, Climatology, Radiative Transfer, Cloud Physics, Morphometrics, Phylogeny, Analytical Paleontology, Evolution, Taphonomy, Macroevolution, Paleobiology, Aktuopaleontology, Paleobotany, Biomechanics, Paleoecology, Tectonics, Stratigraphy.

Instructor(s): Staff Terms Offered: Autumn, Winter, Spring, Summer

Prerequisite(s): Admission to graduate status

GEOS 39800. Reading and Research in the Geophysical Sciences for the Master's Degree. Variable Units.

An essay or formal thesis will be required.

Instructor(s): Staff Terms Offered: Autumn, Winter, Spring, Summer

Prerequisite(s): admission to grad status

GEOS 49700. Advanced Reading and Research in the Geophysical Sciences. Variable Units.

GEOS 49700-49799. Topics available include, but are not limited to: Mineralogy, Petrology, Geophysics, High Pressure Geophysics, Geodynamics, Volcanology, Cosmochemistry, Geochemistry, Atmospheric Dynamics, Paleoclimatology, Physical Oceanography, Chemical Oceanography, Paleoceanography, Atmospheric Chemistry, Fluid Dynamics, Glaciology, Climatology, Radiative Transfer, Cloud Physics, Morphometrics, Phylogeny, Analytical Paleontology, Evolution, Taphonomy, Macroevolution, Paleobiology, Aktuopaleontology, Paleobotany, Biomechanics, Paleoecology, Tectonics, Stratigraphy.

Instructor(s): Staff Terms Offered: Autumn, Winter, Spring, Summer

Prerequisite(s): admission to Ph.D. candidacy

GEOS 49900. Post Ph.D. Research. Variable Units.

No description available.

Instructor(s): Staff Terms Offered: Autumn, Winter, Spring, Summer



Font Notice

This document should contain certain fonts with restrictive licenses. For this draft, substitutions were made using less legally restrictive fonts. Specifically:

Times was used instead of Trajan.

Times was used instead of Palatino.

The editor may contact Leepfrog for a draft with the correct fonts in place.