P\_\text{rogram \ of \ Graduate \ Study}

The Department of the Geophysical Sciences trains graduate students who seek the PhD in Earth, planetary, historical, biological, and environmental sciences. The Department was created in 1961 when the departments of geology and meteorology merged to better embrace the multidisciplinary nature of research and training spanned by these related disciplines.

PhD students design and conduct original research using experimental, observational, and theoretical approaches, thus developing scientific independence from the very start of their studies. The Department has no formal MS program, but many PhD students earn a master’s degree along the way.

The Department maintains close ties with other programs on campus, including Astronomy and Astrophysics, Chemistry, Evolutionary Biology, Microbiology, Physics, and Statistics, among many others. The University is not saddled with barriers between units, a feature that facilitates interdisciplinary collaboration. The Department also benefits from formal connections with people and resources at Argonne National Laboratory,
The Department of the Geophysical Sciences encompasses the Fermi National Accelerator Laboratory, the Field Museum of Natural History, and the Marine Biological Laboratory at Woods Hole.

The Department and the University also provide training in pedagogy—for example, through teaching assistantships in undergraduate courses, workshops at the Chicago Center for Teaching and Learning, and outreach activities at local schools and museums.

Regarding classes, each student plans a program of study with their advisory committee that best suits their needs. Students are expected to recruit a permanent advisor by the end of their first year of study, and to assemble an advisory committee and pass qualifying exams by the end of their second year. These exams include a defense of a dissertation research proposal and demonstration of background knowledge relevant to the proposed research.

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

GEOS 31000. Mineralogy. 100 Units.
This course covers structure, chemical composition, stability, and occurrence of major rock-forming minerals. Labs concentrate on mineral specimen identification and optical microscopy. (L)

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

Prerequisite(s): CHEM 10100 & 10200 or equivalent

Equivalent Course(s): GEOS 21000

GEOS 31005. Mineral Science. 100 Units.
This course examines the physics and chemistry of minerals, and their relationship with mineral structure. Topics may include mineral thermodynamics, crystallography, defect properties, phase transitions, analytical tools, and detailed study of specific mineral groups.

Instructor(s): A. Campbell Terms Offered: Winter. Offered every other year. The undergraduate section of this course (GEOS 21005) will not be offered in AY 2023-24.

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 plastic 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 31210. Global Seismology. 100 Units.
This course covers theories of seismic wave propagation and fundamental concepts of global seismology. Topics include stress/strain, wave equation, ray theory, surface waves, earthquake source, etc.

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

Prerequisite(s): Multivariable calculus (e.g., MATH 15300) and mechanics (e.g., PHYS 13100). If not, permission of instructor.

Equivalent Course(s): GEOS 21210

GEOS 31250. Topics in Seismology. 100 Units.
In this seminar, we discuss seismological and multidisciplinary topics. Topics include, but are not limited to: seismic imaging techniques, planetary seismology, environmental seismology, deep earthquakes and other emerging subjects in seismology. 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): S. Park Terms Offered: Spring

Prerequisite(s): GEOS 21205/31205 or permission of instructor
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 formation of planets around stars and the delivery of water, to the formation of atmospheres, climate dynamics, and the conditions that allow for the development of life and the evolution of complex life. Students will be responsible for periodically preparing presentations based on papers in peer-reviewed journals and leading the discussion.
Instructor(s): E. Kite Terms Offered: Winter
Equivalent Course(s): ASTR 22060, ASTR 32060, 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): A. Davis Terms Offered: Autumn. This course is offered in alternate years.
Equivalent Course(s): GEOS 22300

GEOS 32600. Topics in Earth Science: The Accretion of Extraterrestrial Matter Throughout Earth’s History. 100 Units.
This course will provide a discussion of the nature and variability of extraterrestrial (ET) matter accreted throughout Earth’s history that is preserved in the geological record. This record is a rich archive of ET matter whose study not only provides unique insight into the origin and evolution of different Solar System objects but also enables a better understanding of delivery mechanisms. The course will highlight periods of dramatically increased accretion rates and important impact events. This includes events such as the recent Chelyabinsk and Tunguska air blasts, the “global killer” Chicxulub impact 66 Ma ago, the Ordovician meteorite showers, all the way to cataclysmic events that occurred on early Earth. The course will also provide an introduction to related key techniques such as classification with material from the meteorite collection, the identification of impact craters, and the use of tracers of ET material in the geological record.
Instructor(s): P. Heck Terms Offered: Autumn
Prerequisite(s): Background in college-level geology and mineralogy or consent of instructor
Equivalent Course(s): GEOS 22600

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: Spring
Prerequisite(s): CHEM 11100-11200 or consent of instructor
Equivalent Course(s): GEOS 23800, ENSC 23800

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; J. Waldbauer Terms Offered: Spring

GEOS 33850. Low Temperature Geochemistry. 100 Units.
This course covers topics related to the geochemistry of Earth’s surface, including all its fluid and solid components. Specific emphasis will be placed on stable isotopic tools for understanding modern Earth system processes and the ancient geological record. Seminar format will allow students to choose topics of interest to them and shape the reading and discussion content of the course.
Instructor(s): Clara Blättler Terms Offered: Autumn
Equivalent Course(s): ENSC 33850
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
Equivalent Course(s): GEOS 23900, ENST 23900, ENSC 23900

GEOS 34220. Climate Foundations. 100 Units.
This course introduces the basic physics governing the climate of 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. This course is part of the College Course Cluster program: Climate Change, Culture and Society.
Instructor(s): E. Moyer Terms Offered: Autumn
Prerequisite(s): Prior physics course (preferably PHYS 13300 and 14300) and knowledge of calculus required.
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. 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.
Instructor(s): N. Nakamura 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): M. Jansen 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 34300. Paleoecology. 100 Units.
This class will cover the theory and reconstruction of the evolution of Earth’s climate through geologic time. After reviewing fundamental principles that control Earth’s climate, the class will consider aspects of the climate reconstructions that need to be explained theoretically, such as the faint young sun paradox, snowball Earth episodes, Pleistocene glacial / interglacial cycles, and long-term Cenozoic cooling. Then we will switch to a temporal point of view, the history of Earth’s climate as driven by plate tectonics and biological evolution, and punctuated by mass extinctions. This will allow us to place the theoretical ideas from the first part of the class into the context of time and biological progressive evolution.
Instructor(s): D. Archer Terms Offered: Winter
Prerequisite(s): One quarter of chemistry
Equivalent Course(s): GEOS 24300
GEOS 34600. Introduction to Atmosphere, Ocean, and Climate Modeling. 100 Units.
This hands-on course will discuss how we model atmosphere- ocean- and climate-dynamics using numerical models of varying complexity. We will discuss both the relevant physics as well as numerical techniques, including finite-difference methods for ordinary and partial differential equations, as well as spectral methods. The primary focus of the course will be on relatively simple models, including 1D energy balance models, radiative-convective columns, and quasi-geostrophic models for atmosphere and ocean dynamics, which can be fully understood and applied in the context of a quarter-long course. We will end with an overview of the physics and numerics used in more complex general circulation and coupled climate models. The course will be structured using a combination of lectures, in-class exercises, and discussion of homework exercises. Homework will include programming exercises as well as simulations and analysis using existing model code.
Instructor(s): M. Jansen Terms Offered: Autumn
Prerequisite(s): Prerequisites: GEOS 24220/34220 “Climate foundations”; knowledge of vector calculus, linear algebra, and partial differential equations; basic knowledge of python (could potentially be replaced by significant programming experience in other languages). Recommended: Geophysical fluid dynamics 24220/34220 and 24240/34240.
Equivalent Course(s): GEOS 24600

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). This course is part of the College Course Cluster program: Climate Change, Culture and Society.
Instructor(s): E. Moyer Terms Offered: Spring
Prerequisite(s): Knowledge of physics or consent of instructor
Equivalent Course(s): ENST 24705, ENSC 21100, GEOS 24705, CEGU 24705

GEOS 35400. Intro to Numerical Techniques for 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): Ciesla, F. Terms Offered: Winter
Equivalent Course(s): GEOS 25400

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

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; completion of the general education requirement in the Biological Sciences, or consent of instructor.
Equivalent Course(s): BIOS 23261, EVOL 32400, GEOS 26300

GEOS 36650. Environmental Microbiology. 100 Units.
The objective of this course is to understand how microorganisms alter the geochemistry of their environment. The course will cover fundamental principles of microbial growth, metabolism, genetics, diversity, and ecology, as well as methods used to study microbial communities and activities. It will emphasize microbial roles in elemental cycling, bioremediation, climate, and ecosystem health in a variety of environments including aquatic, soil, sediment, and engineered systems.
Instructor(s): M. Coleman Terms Offered: Autumn
Prerequisite(s): CHEM 11100-11200 and BIOS 20186, BIOS 20197, or BIOS 20198
Equivalent Course(s): GEOS 26650, ENSC 24500

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.
Instructor(s): S. Kidwell Terms Offered: Offered in alternate years.
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; G. Slater
Equivalent Course(s): ECEV 36900, EVOL 31900

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. (L)
Instructor(s): D. Rowley Terms Offered: Winter. This course is offered in alternate years.
Prerequisite(s): GEOS 13100
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: Autumn Winter. This course is offered in alternate years.
Prerequisite(s): GEOS 13100 or consent of instructor
Equivalent Course(s): GEOS 28100

GEOS 38300. Time in Stratigraphy. 100 Units.
This course explores 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: Autumn Winter. This course is offered in alternate years.
Prerequisite(s): GEOS 13100 or consent of instructor
Equivalent Course(s): GEOS 28100
Instructor(s): S. Kidwell
Terms Offered: Autumn. This course is offered in alternate years.
Prerequisite(s): GEOS 13100-13200 or equivalent required; GEOS 23500 and/or 28200 recommended
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
Terms Offered: Spring
Equivalent Course(s): EVOL 41500

GEOS 39700. Reading and Research in the Geophysical Sciences. 300.00 Units.
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 Spring Summer Winter
Prerequisite(s): Admission to graduate status

GEOS 39715. Advanced Research: Seismology. 300.00 Units.
TBD

GEOS 39727. Research: Geochemistry. 300.00 Units.
TBD

GEOS 39733. Research: Paleoclimatology. 300.00 Units.
TBD

GEOS 39737. Research: Paleoceanography. 300.00 Units.
TBD

GEOS 39749. Research: Cloud Physics. 300.00 Units.
TBD

GEOS 39800. Reading and Research in the Geophysical Sciences for the Master’s. 300.00 Units.
An essay or formal thesis will be required.
Instructor(s): Staff
Terms Offered: Autumn Spring Summer Winter
Prerequisite(s): admission to grad status