Washington University in St. Louis

Earth, Environmental, and Planetary Sciences

The Department of Earth, Environmental, and Planetary Sciences offers a PhD with a master's along the way. This department is one of the few departments in the country with an integrated program of graduate instruction and research that treats Earth as a planet and that makes direct use of knowledge gained by exploring the solar system. Our field is changing rapidly and becoming more interdisciplinary as links emerge among geology, geochemistry, geophysics, and geobiology. New opportunities are developing as research in natural hazards, energy sources, and the environment become more important to the global economy and as new space missions are developed to explore the solar system. The relatively small size of the department engenders a friendly and personal place that offers a lot of personal interaction with faculty and researchers. Our graduate students have the opportunity to use cutting-edge laboratory equipment, high-speed parallel computers, and the latest planetary mission data throughout the course of their research. They travel to field sites around the world and publish research in the leading scientific journals.

The PhD program is open to qualified students who have previously specialized in Earth sciences, physics, chemistry, biology, environmental science, soil science, mathematics, or engineering. Both students with traditional degrees in geoscience areas and students with diverse academic backgrounds regularly enroll in our program because of the inherently interdisciplinary nature of our field. Doctoral education has a strong research emphasis that begins immediately upon arrival and that emphasizes modern, quantitative approaches to studying Earth, planetary, and environmental systems. Graduate research may involve field and laboratory studies as well as theory and advanced computation. Students earn the AM degree during the first phase of the PhD program; the department generally does not admit students for terminal AM degrees. After degree completion, our graduates go on to careers in academia, research laboratories, government agencies, and the private sector, serving as leaders in the field of earth, environmental, and planetary sciences.

Website: https://eeps.wustl.edu/

Faculty

Chair

David A. Fike
Glassberg/Greensfelder Distinguished University Professor of Earth, Environmental, and Planetary Sciences
PhD, Massachusetts Institute of Technology

Director of Graduate Studies

Alexander S. Bradley
Associate Professor
PhD, Massachusetts Institute of Technology

Director of Undergraduate Studies

Philip A. Skemer
Associate Chair and Professor of Earth, Environmental, and Planetary Sciences
PhD, Yale University

Department Faculty

Paul Byrne
Associate Professor
PhD, Trinity College, Dublin

Jeffrey G. Catalano
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PhD, Standford University

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Bradley L. Jolliff
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Director of the McDonnell Center for the Space Sciences
PhD, South Dakota School of Mines and Technology

Bronwen L. Konecky
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Roger Michaelides
Assistant Professor
PhD, Stanford University

Rita Parai
Assistant Professor
PhD, Harvard University

William Hayden Smith
Professor
PhD, Princeton University

Viatcheslav S. Solomatov
Professor
PhD, Moscow Institute of Physics and Technology and the Schmidt Institute of Physics of the Earth

Kun Wang
Associate Professor
PhD, Washington University in St. Louis

Douglas A. Wiens
Professor
Robert S. Brookings Distinguished Professor
PhD, Northwestern University

Michael E. Wysession
Professor
PhD, Northwestern University

Degree Requirements

- Earth, Environmental, and Planetary Sciences, PhD

Courses

Visit online course listings to view semester offerings for L19 EEPS.

L19 EEPS 5004 Special Topics
The content of this course varies each time it is offered, as announced by the Department. With permission of the advisor, this course may be repeated for credit. Variable credit.
Same as L19 EEPS 400
Credit variable, maximum 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 5014 Earth Systems Science
This is a quantitative introduction to physical and chemical interactions among the atmosphere, oceans and solid earth. Topics covered include terrestrial atmospheric chemistry, geochemical cycles, inventories, and reservoirs of carbon, nitrogen, & sulfur, and bulk composition of the Earth. Prerequisite: EEPS 340.
Same as L19 EEPS 401
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 5074 Remote Sensing
Use of different parts of the electromagnetic spectrum (visible, ultraviolet, infrared, and radio wavelengths) for interpretation of physical and chemical characteristics of the surfaces of Earth and other planets. Digital image systems and data processing. Prerequisite: Phys 192.
Same as L19 EEPS 407
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 5084 Earth's Atmoshpere & Global Climate
Structure and dynamics of Earth's atmosphere. Basic factors controlling global climate of Earth. Quantitative aspects of remote sensing of atmosphere. Remote sensing instrumentation. Prerequisites: Math 232 and Phys 191.
Same as L19 EEPS 408
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 509 Surface Processes
How do landscapes evolve? This course focuses on the physical processes of erosion and deposition that shape Earth and planetary surfaces. Course aims (1) understanding emergent landscape patterns, (2) reconstructing past conditions using the sedimentary record, and (3) predicting landscape change under climate scenarios. Review of relevant climatic and tectonic processes, followed by detailed discussion of rivers and deltas, hillslopes, weathering, glaciers, and coasts. Prerequisites: EEPS 353 or Physics 191.
Same as L19 EEPS 409
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 5104 Earth Remote Sensing Methods and Instrumentation
Detection of electromagnetic radiation reflected,scattered, or emitted by components of the Earth system. Spectroscopy of remote sensing. Interpretation of received radiation via radiative transfer within a context of real measurements. Theory of instruments and detectors. Comparison of realized equipment to theoretical models.
Same as L19 EEPS 410
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 511 Minerals in Aqueous Environments
Systematic mineralogy and crystal chemistry of common low-temperature minerals, including clays, zeolites, carbonates, oxides of aluminum, iron, and manganese, and metal sulfides. Reactions between minerals and aqueous solutions, including growth and dissolution, surface complexation, and redox reactions. Role of these reactions in chemical weathering, contaminant fate, microbe-mineral interactions, and biomineralization. Focus will be on processes and mechanisms. Common analytical methods introduced.
Credit 3 units.

L19 EEPS 5134 Introduction To Soil Science
Physical, chemical, and biological processes that occur within soil systems. Types of soils and their formation. Major components of soil, including soil water, minerals, organic matter, and organisms. Soils in wetlands and arid regions. Mapping of soils and their spatial variability. Cycling of nutrients and contaminants in soils. Sustainable use of soils and their role in climate change. Prerequisites: EEPS 202 and EEPS 323 or CHEM 106 or CHEM 112.
Same as L19 EEPS 413
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 517 Soil Science
Physical, chemical, and biological processes that occur within soil systems. Types of soils and their formation. Major components of soil, including soil water, minerals, organic matter, and organisms. Soils in wetlands and arid regions. Mapping of soils and their spatial variability. Cycling of nutrients and contaminants in soils. Sustainable use of soils and their role in climate change. Prerequisites: EEPS 202 or EECE 210 or BIOL 2950.
Same as L19 EEPS 317
Credit 3 units. A&S IQ: NSM

L19 EEPS 5224 Sedimentary Geology
Survey introduction to sedimentary processes and materials, including description, formation, and interpretation. Sedimentary materials account for most of the Earth's crust, and much of our understanding of Earth history comes from their examination. Many of our economic resources, such as coal, oil, and natural gas, and many environmental problems, are related to or derive from sediments. Goals: understanding and identifying sediments and processes and

using them to interpret stratigraphic, paleoenvironmental, and tectonic information; obtaining the understanding of sedimentology that is relevant to environmental issues; increasing scientific literacy and critical thinking. Prerequisite: EEPS 202. Mandatory field trips.
Same as L19 EEPS 422
Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 5280 Hydrology
Survey of principles that govern the flow of water in river and groundwater systems in deep geologic environments. Basic equations of fluid flow, dynamics, and the characteristics of drainage basins, rivers, floods, and important aquifers. Exploitation of ground water systems. Prerequisite: EEPS 353 or Physics 191.
Same as L19 EEPS 428
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 5304 Environmental Mineralogy
Topics connected with environmental mineralogy, some selected by students. Topics may include: mineral dust such as asbestos, containment materials for nuclear waste disposal, environmental ramifications of the processing and use of phosphate fertilizers, lead in the environment, acid mine drainage, microbial mediation of sulfide oxidation, minerals in the human body, weathering of building materials, materials engineering, and engineering of materials for more effective recycling. Three class hours and one two-hour laboratory a week. Participation in discussions, term paper, two field trips required. Most readings from primary sources.
Same as L19 EEPS 430
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 5374 Igneous & Metamorphic Petrology
Classification, origin, mineralogy, and geological occurrence of major igneous and metamorphic rocks. Laboratory emphasis on identification of rocks and minerals in hand specimens and in thin sections. Three class hours and one two-hour laboratory a week.
Same as L19 EEPS 437
Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 542 Chemical Petrology
Application of chemical data to the petrogenesis of selected metamorphic, igneous, and sedimentary rock suites. Topics include: abundance and distribution of elements in crustal materials; crystal-chemical controls on elemental fractionations; elemental mobility and immobility in crustal metamorphic processes; uses and abuses of discriminant diagrams; secular trends in crustal composition. Two class hours and one two-hour discussion period a week.
Credit 3 units.

L19 EEPS 5425 Aqueous Geochemistry
Introduction to the geochemistry of natural waters and the processes that alter their composition. Key principles of aqueous geochemistry are introduced and then used to describe the main controls of the chemistry of pristine and polluted soil, surface, and ground water environments. Topics covered include mineral solubility, complexation, acids and bases, carbonate chemistry, rock weathering and clay formation, adsorption and ion exchange, redox reactions, microbial energetics and redox zonations, the geochemistry of iron, sulfur, trace elements, and radionuclides, and geochemical kinetics. Geochemical modeling will be introduced. Prerequisites: EEPS 323 or Chem 105 or Chem 111A.
Same as L19 EEPS 442
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 5441 Introduction to Geochemistry
Application of the principles of nuclear and physical chemistry to problems of the composition and differentiation of the Earth. Introduction to nucleosynthesis of the elements, stellar evolution, the periodic properties of the elements, chemical bonding and ionic substitution, geochronology and stable isotope geochemistry, and the age and composition of the Earth, Moon and meteorites. Prerequisites: EEPS 202 and Chem 106 or Chem 112.
Same as L19 EEPS 441
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 545 Radiogenic Isotope Geochemistry
Applications of variations in abundance of daughter isotopes of major natural radionuclides. Topics include the use of isotopes such as 87Sr, 143Nd, 206-207-208Pb, 40Ar, 4He, etc. as isotopic tracers in petrogenetic studies, and as sources of constraints on the evolution of the Earth's mantle, crust, and atmosphere.
Credit 3 units.

L19 EEPS 5454 Organic Geochemistry
Introduction to the composition and analysis of organic material in the environment and geological record. Molecular to global-level perspective of organic matter cycling, reactivity, and fluxes; formation and classification of organic matter, its preservation potential, diagenesis, catagenesis, and kerogen formation; coal, petroleum, and gas formation and accumulation; biomarkers in Earth history; genetics and phylogeny of biomarker compounds; overview of analytical techniques including both structural and isotopic aspects; oceanographic and paleoenvironmental applications of organic biomarkers; contaminants and residue analysis. Prerequisites: EEPS 202 and Chem 106 or Chem 112.
Same as L19 EEPS 445
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 5460 Stable Isotope Geochemistry
Applications of equilibrium and kinetic isotope fractionation and material balance principles to the distribution of oxygen and hydrogen isotopes in natural systems. Geothermometry and paleotemperatures, mass spectrometry, isotope hydrology and ice cores, fluid-rock interaction, igneous rocks and meteorites. Prerequisites: EEPS 441 and MATH 233.
Same as L19 EEPS 446
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 5524 Introduction to Seismology
Introduction to earthquake and exploration seismology. Seismic wave propagation, data analysis and processing, earthquake mechanisms, seismic contraints on the structure of the Earth, relationship of seismicity to plate tectonics. Prerequisites: EEPS 353 and Math 217.
Same as L19 EEPS 452
Credit 3 units. A&S IQ: NSM Art: NSM

L19 EEPS 553 Geophysical Data Analysis
Survey of geophysical data analysis techniques with applications to seismology, geodynamics, and remote sensing. Time series analysis techniques, including Fourier transforms, convolution and deconvolution, and filters. Linear and non-linear geophysical inverse problems, including discussion of solution uncertainty and uniqueness.
Credit 3 units.

L19 EEPS 5535 Interior of the Earth
Composition and temperature of Earth's mantle and core, determined by geophysical methods. Inferences about mantle and core dynamics, especially interactions. Current understanding and history of interior in fields of seismology, geomagnetism, mineral physics, geodynamics.
Prerequisite: EEPS 353
Same as L19 EEPS 453
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 5544 Exploration and Environmental Geophysics
Basic geophysical techniques used in exploration and environmental geophysics, emphasizing seismic and electromagnetic methods. Basic theory, field procedures, and interpretation of data. Use of geophysical instruments on field trips, followed by reduction and analysis of acquired data. Two class hours and one two-hour laboratory a week, and approximately four one-day field trips during the semester.
Prerequisites: EEPS 353 and Phys 191 and Math 132.
Same as L19 EEPS 454
Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 555 Mathmatical Methods in Earth, Environmental, and Planetary Sciences
This course introduces a variety of mathematical approaches commonly used in Earth, environmental, and planetary sciences. The course is structured to progress in difficulty throughout the semester, starting with dimensional analysis, order-of-magnitude estimates, and basic analytical methods, then advancing to numerical solutions of differential equations. Throughout the course, students will gain programming experience with MATLAB. Examples of problems that can be considered include population growth, radioactive decay, landscape evolution, carbon cycle, thermal and chemical diffusion, wave phenomena, groundwater flow, glacier dynamics, magma transport, thermal convection, and secular cooling of Earth and planets. The specific methods and problems may vary from year to year, tailored to students' interests and needs. A key element of the course is developing the ability to effectively communicate quantitative concepts. This includes presenting the material in a clear and concise manner, both orally and in writing, as well as creating compelling visualizations of quantitative information.
Credit 3 units.

L19 EEPS 5594 Geodynamics
Fundamental physical processes necessary to understand plate tectonics and a variety of geological phenomena. Heat flow, gravity, elasticity and flexure, rheology of Earth materials. Prerequisites: EEPS 353 and Math 217.
Same as L19 EEPS 459
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 5604 Introduction to Structural Geology
The landforms that surround us are being modified constantly by tectonic forces. Structural geology provides a framekwork for investigating, describing, and quantifying these changes. This course provides an introduction to the structures that form at all scales, from millimeter-sized fractures to plate-boundary-scale rifts. Topics include descriptive analysis of microscopic and macroscopic structures, field methods, the physical basis for rock deformation, and global tectonics. Three hours of lecture and one two-hour laboratory a week.
Prerequisites: EEPS 340 and EEPS 353.
Same as L19 EEPS 460
Credit 4 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 561 Advanced Seismology
Advanced treatment of seismology theory and computational methods, including: ray theory, plane waves, cylindrical waves, attenuation, anisotropy, seismic waves in laterally heterogeneous media, surface waves, free oscillations of the earth. Calculation of synthetic seismograms using several methods.
Credit 3 units.

L19 EEPS 564 Multidisciplinary Study of Subduction Zones
Earth is a dynamic planet, and the most geologically hazardous areas on Earth are subduction zones. Activity in subduction zones may be sudden and violent, often with dramatic societal consequences. In addition, subduction zones are crucial for understanding Earth as a planet as they control the circulation of material from the surface back into the mantle. This course is a graduate-level survey intended for students concerned with Earth processes at subduction zones. The course integrates principles of geology, geophysics, geochemistry, experimental petrology, mineral physics, geodynamics, and seismology. It will review the current state of scientific knowledge for subduction on Earth. Topics range from the physics and chemistry of downgoing slabs from the surface to the deep mantle, mantle flow and structure in the wedge, earthquakes and deformation, melting and volcanism at arcs, and the geology of subduction initiation.
Credit 3 units.

L19 EEPS 565 Mantle Geochemistry
This is a graduate-level seminar-style course on fundamentals of mantle geochemistry. The course will use important papers in the scientific literature to introduce key topics in this field, including ocean island basalt and mid-ocean ridge basalt geochemical systematics, crust-mantle chemical exchange, and early Earth processes. The course will provide a foundation for high-temperature geochemical studies of the Earth's interior and a basis for understanding geochemical ties to adjacent disciplines such as geodynamics and seismology. Some introductory lectures will supplement discussions of readings. A substantial portion of the course will involve student-led discussions and development of scientific communication skills.
Credit 3 units.

L19 EEPS 566 Advances in Stable Isotope Geochemistry
The development of non-traditional isotope geochemistry in the past decade has greatly expanded our understanding of many facets of Earth and planetary sciences. Over 1000 papers have been published using non-traditional isotopes to study the origin of the solar system, the formation of planetary bodies, the differentiation of mantle and core, the evolution of the crust, the changes of paleo-climate, the global geochemical cycle of elements, and the genesis of natural resources. This course will survey these new isotope systems in either high-temperature igneous differentiation or low-temperature environments. It aims to help students understand the wide applications of these new isotopes in tracing chemical, biological and physical processes. The course is divided into three parts. Part I will first introduce the principles and theories of non-traditional isotopic fractionation and then it will review analytical methods that are primarily used for non-traditional isotopes such as MC-ICP-MS, TIMS and SIMS. Part II will dive into individual isotopic systems (Li, Mg, Si, Cl, Ca, Fe, Ni, Cu, Zn, Ge, Se, Mo, Hg, Tl and U stable isotopes) and it will focus on one or two of their main applications. Part III will be carried out in the instructor's lab for the last three weeks of the class. The instructor and the students will decide together on the one topic of the final project carried out all class members. The scope of the final project will depend on the students' own research interests and the instructor's role is to help the students to identify useful non-traditional isotope tools to advance the students' main research goals.
Credit 3 units. Arch: NSM Art: NSM

L19 EEPS 567 Planetary Materials
In-depth look at suites of materials from the Moon, Mars, Vesta, and selected other achondrite meteorite groups. Mineralogy, geochemistry, petrography, and petrology of samples and their geologic settings. Relationships between samples and orbital mineralogical and geochemical data. Comparative planetology and origins.
Credit 3 units.

L19 EEPS 568 Scientific Exploration of the Moon
Detailed look at scientific exploration of the Moon, focusing on surface and orbital experiments and results: landers, astronauts, and rover activities, photogeology, surface processes, what has been learned from Apollo exploration and samples, geophysical experiments, petrology and origin of lunar rock suites, impact craters and basins, lunar meteorites, results from recent missions, and plans for future missions. Origin and geologic history of the Moon, potential resources, and the role of the Moon for understanding planetary and solar system processes and history.
Credit 3 units.

L19 EEPS 5680 Geospatial Field Methods
This course is an introduction to field geospatial surveying using high-precision GNSS systems and UVA's (drones) outfitted with a variety of sensors such as cameras, multispectral sensors, and lidar. Coursework will cover basic principles as well as provide hands on experience. Most of the course is project based, and students will complete a series of exercises designed to familiarize them with the effective use of field equipment. Students will design data collection strategies, collect data, and become familiar with data processing pipelines and visualization techniques. After completing the course, students will be prepared to safely and effectively conduct independent GNSS and drone surveys, and use the data for studies in Earth, environmental, and planetary science, archaeology, environmental science, ecology, landscape architecture, urban design, agriculture and a variety of other field-based disciplines. Prerequisites: Previous 300+ level coursework in Earth sciences, archaeology, ecology, or other coursework for which these methods are relevant.
Same as L19 EEPS 468
Credit 3 units. A&S IQ: NSM Art: NSM

L19 EEPS 569 Thermodynamics & Phase Equilibria
Basic equilibrium thermodynamics relevant to geological systems, including derivation of reaction log K as f(T,P) and activity-composition models for various minerals and co-existing gas/fluid phase. These principles are applied to calculation of phase diagrams for simple systems and interpretations of phase relations for more complex systems determined by experiment and topological constraints.
Credit 3 units.

L19 EEPS 570 Planetary Geophysics & Dynamics
Relationships between solar system dynamics and planetary evolution, with emphasis on orbital mechanics, gravity fields of planets and satellites, heat transfer in planetary interiors, and tidal interactions. Topics include resonant orbits and rotation rates, effects of large-body impact, volcanism on Io, and the origin of the Moon.
Credit 3 units.

L19 EEPS 5730 Planetary Geology
Discussion of the evolution of the terrestrial planets and the outer-planet satellites as evidenced by the geologic records left on the surfaces of these bodies. Focus on major processes affecting planetary surfaces:impact cratering, volcanism, tectonism, and erosion and sedimentation by wind and water. Prerequisite: EEPS 353
Same as L19 EEPS 473
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 5744 Planetary Geochemistry
A survey of the geochemistry of the planets and their satellites using data from Earth-based, Earth-orbital, and spacecraft observations.
Same as L19 EEPS 474
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM

L19 EEPS 576 Advanced Planetary Geology: Ice Worlds
Discussion of icy bodies and terrains in the solar system. Water and other ices as geologic materials, including remote sensing of ices, impacts into ice, cryovolcanism, and ice tectonics. Focus on major satellites of Jupiter and Saturn (Europa, Ganymede, Callisto, and Titan), midsized icy satellites, and the martian polar caps.
Credit 3 units.

L19 EEPS 579 Planetary Stratigraphy and Sedimentation
Geomorphic and geologic mapping approaches for moons and terrestrial planets. Basic methodologies, use of remote sensing and geographic information system technologies for map generation and display. Selected case studies for the Moon, Venus, and Mars that focus on surface processes such as impact, volcanism, and sedimentation.
Credit 3 units.

L19 EEPS 580 Deformation of Planetary Materials
Theoretical bases for brittle and plastic processes, covering all significant planetary materials. Stress and strain, thermodynamics, elasticity, crystalline defects, plastic deformation, microstructures, brittle fracture, rock friction. Applications to geology, geodynamics, seismology, and planetary sciences.
Credit 3 units.

L19 EEPS 585 Earth History
Introduction to the concept of "deep time" and the parallel biological evolutionary and environmental changes that have occurred throughout Earth history. Topics include early evolution of life, rise of atmospheric oxygen, global glaciation, mass extinctions. Prerequisite: EEPS 202
Same as L19 EEPS 385
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 586 The Earth's Climate System
This course introduces an integrative view of the Earth's climate system and its coupled components - the atmosphere, the oceans, the cryosphere, the biosphere, and the geosphere - and how they interact with each other. The goal is to provide the physical scientific background that is needed to understand climate variability and climate change, both natural and anthropogenic. Topics include energy balance; general circulation of the atmosphere and the oceans; the greenhouse effect; modes of variability such as El Nino; geologic-scale climate change in the geologic past; climate models; climate change detection and attribution; projection of future climates; and societal impacts. In addition to lectures, students will gain hands-on experience analyzing and interpreting real datasets through inquiry-based "practicum" exercises and in-class discussions.
Credit 3 units. Arch: NSM Art: NSM BU: SCI

L19 EEPS 5864 Paleoclimatology
The history of Earth's changing climates and environments on timescales from decades to millions of years. Key concepts in paleoclimatology include: external factors affecting the climate system (e.g., orbital cycles, volcanic eruptions, greenhouse gases); internal feedbacks, such as with monsoons and the El Nino- Southern

Oscillation; abrupt versus gradual change; interactions with the biosphere (including hominins/humans); and comparison to present-day climate change. Current controversies in paleoclimate. Prerequisite EEPS 386
Same as L19 EEPS 486
Credit 3 units. A&S IQ: NSM Arch: NSM Art: NSM BU: SCI

L19 EEPS 587 Geospatial Science
This course introduces students to the interdisciplinary field of geospatial science, which bridges the fields of geographic information systems (GIS), remote sensing, data science, and spatiotemporal analysis. This course will provide an overview of the fundamental concepts of geospatial science, including: visualizing and analyzing raster and vector datasets within a GIS database; coordinate systems, reference frames, and projections; the Geoid and geodetic techniques; remote sensing methods; image acquisition and interpretation; spatiotemporal analysis of geospatial data; sampling, interpolation, and time series analysis; uncertainty, error, accuracy, and precision. This course will be available at both the upper-level undergraduate and the graduate levels. Material will be covered through lectures, assignments, and computer exercises that will give students hands-on experience analyzing and interpreting real geospatial datasets. Exercises for students enrolled in the 587 option will be more in-depth and will require some basic programming experience and familiarity with quantitative techniques. These exercises will provide students with a sampling of geospatial science applications, such as environmental studies, cryospheric science, wildlife management, contagious disease monitoring, demography, and human geography. Students will complete a final project of their choosing that synthesizes the concepts and themes learned in this course; students enrolled in the 587 option are encouraged to develop a project proposal that aligns with their own research interests. Students particularly interested in GIS and remote sensing are further encouraged to also consider EnSt 380 and EEPS 407, respectively.
Same as L19 EEPS 387
Credit 4 units. A&S IQ: NSM, AN

L19 EEPS 590 Independent Study
Independent study for graduate students, supervised by a faculty member. Prerequisite: graduate standing and permission of instructor.
Credit variable, maximum 12 units.

L19 EEPS 592 Research
Individual research work under the direct supervision of a faculty member. Open only to graduate students. May be repeated for credit.
Credit variable, maximum 12 units.

L19 EEPS 595 Seminar
Weekly discussions to orient first-year students to graduate school. Topics to be covered include an introduction to the Department, program requirements, time management, working with a supervisor, ethics, the scientific literature, written and oral communication skills, scientific publishing, grant writing, and professional development. Required for all first-year graduate students in EEPS.
Credit variable, maximum 1 units.