

## Earth & Environmental Science (EES)

### Courses

#### **EES 002 (ES 002) Introduction to Environmental Science 3 Credits**

Focuses on natural and human-induced drivers and consequences of environmental change. Exploring options for mitigating and adapting to environmental change in ecosystems, physical and social systems, we will examine such topics as biogeochemical cycles, population pressure, ecosystem diversity, productivity and food security, energy, water resources, climate change, pollution, ozone, urban issues and sustainability. Stresses interactions and interrelationships, using a series of case studies. Intended for any student with an interest in the environment. May be combined with EES 022.

**Attribute/Distribution:** NS

#### **EES 004 The Science of Environmental Issues 1 Credit**

Analysis of current environmental issues from a scientific perspective. The focus on the course will be weekly discussions based on assigned readings.

**Prerequisites:** (EES 002 or ES 002 or EES 028 or GCP 002 or EES 011 or EES 012 or EES 014 or EES 015 or EES 016 or IR 016 or EES 021 or EES 024 or EES 025 or EES 026 or GCP 026 or EES 027 or GCP 027 or GCP 028 or EES 028 or EES 031 or EES 089 or EES 090 or EES 095 or EES 105 or ASTR 105 or PHY 105 or EES 022)

**Can be taken Concurrently:** EES 002, ES 002, EES 028, GCP 002, EES 011, EES 012, EES 014, EES 015, EES 016, IR 016, EES 021, EES 024, EES 025, EES 026, GCP 026, EES 027, GCP 027, GCP 028, EES 028, EES 031, EES 089, EES 090, EES 095, EES 105, ASTR 105, PHY 105, EES 022

**Attribute/Distribution:** NS

#### **EES 011 Environmental Geology 3 Credits**

Analysis of the dynamic interaction of geologic processes and human activities. Catastrophic geologic processes (earthquakes, volcanoes, landslides), pollution of geologic systems, and engineering case studies. May be combined with EES 022 or EES 004 for 4 credits.

**Attribute/Distribution:** NS

#### **EES 012 Glaciers and Glaciation 3-4 Credits**

An investigation of how cold climates and the associated processes of glaciation and periglacial activity have left their imprint on the Earth. May be combined with EES 022 or EES 004 for 4 credits.

**Attribute/Distribution:** NS

#### **EES 014 Lands of the Midnight Sun 3 Credits**

Investigations of polar exploration and science, the environment at high latitudes, and cultures of the Arctic, as well as discussion of issues related to understanding interactions among extreme environments, global change, pollution, and indigenous cultures. Lecture, discussion, classroom activities. May be combined with EES 022 or EES 004 for 4 credits.

**Attribute/Distribution:** NS

#### **EES 015 Volcanoes and the Ring of Fire 3 Credits**

Volcanoes are a tangible, often breathtaking, reminder of the inner workings of our restless planet. In this course, we consider the processes leading to volcanic eruptions, the significance of volcanism for long-term Earth evolution, and the hazards volcanoes create for humans, particularly those living in the circum-Pacific (the Ring of Fire). May be combined with EES 022 or EES 004 for 4 credits.

**Attribute/Distribution:** NS

#### **EES 016 Geology of War 3 Credits**

Introduction to Earth and Environmental Sciences through a study of the geologic underpinnings of human conflict, the geologic influences over the outcomes of great battles, and the long-term environmental impacts of war. Instructional format includes lectures, discussions, student projects, and a field trip to Gettysburg National Military Park. May be combined with EES 022 or EES 004 for 4 credits.

**Attribute/Distribution:** NS

#### **EES 021 Introduction to Planet Earth 3 Credits**

Processes within the Earth and dynamic interactions between the solid earth, the atmosphere, and the oceans. Lectures.

**Attribute/Distribution:** NS

#### **EES 022 Exploring Earth 1 Credit**

Laboratory course in methods, data acquisition, data analyses and scientific communication relevant to Earth and Environmental Sciences. Building on the framework of the "Earth Science Literacy Initiative" the course introduces students to the foundations of the scientific method, the basic concepts of the Earth systems, and the influence and interaction of the natural world in everyday life. Hazards, resources, anthropogenic forcing and impacts, biogeochemical cycles and sustainability are discussed and modeled among other timely topics.

**Prerequisites:** EES 023 or EES 021 or EES 024 or EES 025 or EES 026 or EES 027 or EES 028 or EES 002 or ES 002 or EES 011 or EES 012 or EES 014 or EES 015 or EES 016 or EES 090 or IR 016 or GCP 026 or GCP 027 or EES 028 or EES 004

**Can be taken Concurrently:** EES 023, EES 021, EES 024, EES 025, EES 026, EES 027, EES 028, EES 002, ES 002, EES 011, EES 012, EES 014, EES 015, EES 016, EES 090, IR 016, GCP 026, GCP 027, EES 028, EES 004

**Attribute/Distribution:** NS

#### **EES 023 Weather and Climate: Past, Present, and Future 3 Credits**

Introduction to the basic principles of meteorology, as they pertain to past, present, and future climates. Earth's energy balance; cloud formation and precipitation; winds and atmospheric circulation; regional climatologies; past warm periods and ice ages in Earth's history; the latest ideas about future climate change and global warming. Students will maintain a weather notebook to enable them to relate theory to observations from real weather data. May be combined with EES 022 or EES 004 for 4 credits.

**Attribute/Distribution:** NS

#### **EES 024 Climate Change 3 Credits**

Examination and discussion of Earth's climate history and the multiple interactions among components of the climate system, including ice, water, air, land, and vegetation; review of the causes of climate change at various time scales. Assessment of historical and future climate change and the role of humans in causing climate change, including global warming. May be combined with EES 022 or EES 004 for 4 credits.

**Attribute/Distribution:** NS

#### **EES 025 The Environment and Living Systems 3 Credits**

The course will provide an introduction to the role of the environment in regulating living systems at a variety of scales and levels of organization. The role of the environment in regulating and shaping populations, communities, and ecosystems will be explored. In addition, the role of the environment will be discussed as it relates to the origin, evolution, and diversity of life on earth. Whenever possible, the role of anthropogenic environmental change will be discussed as it relates to the above topics. May be combined with EES 022 or EES 004 for 4 credits.

**Attribute/Distribution:** NS

#### **EES 026 Energy – Origins, Impacts, and Options 3 Credits**

Critical assessment of current and predicted energy resources used by humans, including their origins, distribution, environmental impacts, and feasibility. Lectures, discussion, field trips. May be combined with EES 022 or EES 004 for 4 credits.

**Attribute/Distribution:** NS

#### **EES 027 Natural Hazards: Impacts and Consequences 3 Credits**

Earthquakes, volcanoes, tsunamis, floods, and hurricanes are a natural part of the Earth and our environment. These events have violent consequences for our lives and significant economic implications. This course examines the causes, predictability, and risk mitigation for these events. We will also consider how natural disasters are represented by popular media and whether this helps or hurts public understanding of our dynamic planet and our relationship to it. May be combined with EES 022 or EES 004 for 4.

**Attribute/Distribution:** NS

**EES 028 Conservation and Biodiversity 3 Credits**

An introduction to the science of conservation biology. We examine the evolution of biodiversity on earth, spatial patterns of biodiversity, the impact of human activities on biodiversity, and assess strategies for the management and conservation of biodiversity. Students gain the scientific literacy necessary to make informed decisions about topics such as wilderness preservation, species conservation, and land use. May be combined with EES 022 or EES 004 for 4 credits.

**Attribute/Distribution:** NS

**EES 032 Oceanography 3 Credits**

An introduction to the structure, composition, and processes of the earth from a marine perspective. Topics include earth structure, plate tectonics, continental margins, coastal processes, seawater chemistry, ocean circulation, wave dynamics, primary productivity, plankton and plants, marine organisms and communities. May be combined with EES 022 or EES 004 for 4 credits.

**Attribute/Distribution:** NS

**EES 042 The Natural History of Costa Rica 3 Credits**

The interaction of ecology, geology, and climate shaping the natural history of Costa Rica. Population, community, and ecosystem ecology; evolution and natural selection; biodiversity and conservation biology. Offered during the winter inter-term through Lehigh Study Abroad, and involving lectures, electronic media, observations, and field experiences. Consent of instructor required. Limited enrollment. Requires payment of additional program fee and transportation to Costa Rica.

**Attribute/Distribution:** NS

**EES 080 Introduction to the Earth System 4 Credits**

Study of the integrated earth system, including the atmosphere, biosphere, geosphere, and hydrosphere and interactions between these components (e.g., plate tectonics, biogeochemical cycling, climate, anthropogenic impacts). The course is designed to prepare students for a major in earth and environmental sciences and includes a lab that develops skills relevant to this broad field including data analysis, modeling, use of maps and geospatial data, and field work. Lectures and lab.

**Attribute/Distribution:** NS

**EES 089 Geographic Analysis of our Changing World 3 Credits**

This course will introduce students to maps, spatial data, and electronic tools for geographic analysis. Fundamental geographic and database concepts will include map types, spatial referencing systems, map projection systems, map scale, and database characteristics. Tools including ArcGIS Desktop software and Global Positioning System receivers will be used to acquire and analyze spatially referenced data sets drawn from diverse sources and disciplines relating to the environment. Students will use their new skills in geographic analysis to develop an electronic portfolio.

**Attribute/Distribution:** NS

**EES 093 Freshman Supervised Internship in Earth and Environmental Sciences 1-2 Credits**

Experiential learning opportunities supervised by EES faculty, including fieldwork, data collection or analysis, literature review, and information management. A maximum of two credits is allowed. Consent of supervising faculty required.

**Repeat Status:** Course may be repeated.

**Attribute/Distribution:** ND

**EES 115 Surficial Processes 4 Credits**

An introduction to process geomorphology and sedimentology that emphasizes the dynamic interactions of climate, tectonics, and watershed hydrology on the erosional, transportational, depositional, and biological processes that shape landscapes. Includes a field and computer-intensive lab.

**Prerequisites:** EES 080

**Can be taken Concurrently:** EES 080

**Attribute/Distribution:** NS

**EES 131 Introduction to Rocks and Minerals 4 Credits**

Hand-specimen identification of the major mineral groups and rock types. Atomic structure of minerals; relationship of mineral structure to chemical and physical properties. Placement of igneous, sedimentary, and metamorphic rocks into a plate tectonics context. Introduction to optical mineralogy and x-ray diffraction techniques. Lectures, laboratories, field trips.

**Prerequisites:** EES 080 or (EES 021 and EES 022)

**Can be taken Concurrently:** EES 080

**Attribute/Distribution:** NS

**EES 152 Ecology 4 Credits**

The study of relationships among organisms and their physical environment. Ecology of individual organisms, populations, communities, ecosystems, landscapes, and the biosphere. Topics include organism adaptations and natural selection, life histories, population growth and dynamics, species interactions, energy flow, nutrient cycling, and ecological impacts of human activities. Field-based laboratories focus on the quantitative study of biological populations and communities. Lectures, field-based laboratories, and applied activities.

**Prerequisites:** EES 025 or EES 028 or EES 080

**Can be taken Concurrently:** EES 025, EES 028, EES 080

**Attribute/Distribution:** NS

**EES 172 Topics in Earth & Environmental Science 1-4 Credits**

Study of topics in earth and environmental science not covered in other 100-level courses. Primarily used for transfer credit. Consent of instructor required.

**Repeat Status:** Course may be repeated.

**Attribute/Distribution:** NS

**EES 200 Earth History 4 Credits**

Review of the coevolution of Earth, life, climate, and the environment, and introduction to the records used to constrain this history. The course addresses environmental changes at both geologic and human time spans. Includes laboratory exercises and field trips.

**Prerequisites:** EES 080

**Attribute/Distribution:** NS

**EES 201 Seismology: The Earth and Environment 4 Credits**

An examination of how earthquakes and active source seismology are used to understand the Earth beneath our feet. Fundamentals of seismic wave propagation in the Earth. Study of earthquakes, and reflection and refraction techniques at a variety of scales: near-surface, crustal, lithospheric, and whole Earth. Practical applications to both earth and environmental science, experiment design, data collection, processing, analysis and interpretation. Field and laboratory projects.

**Prerequisites:** EES 080 and EES 115 and EES 131

**Can be taken Concurrently:** EES 115

**Attribute/Distribution:** NS

**EES 223 Structural Geology and Tectonics 4 Credits**

Material behavior of rocks and the architecture of the Earth's crust. Plate tectonic processes and plate margin deformation. Introduction to geologic maps and field techniques. Lectures, laboratories, and one or two weekend fieldtrips.

**Prerequisites:** EES 115 or EES 131

**Can be taken Concurrently:** EES 131

**Attribute/Distribution:** NS

**EES 250 Terrestrial Ecosystems 4 Credits**

Ecosystem ecology in the context of the Earth system; discussion of mechanisms by which terrestrial ecosystems function, including the flow of water and energy and the cycling of carbon and nutrients; characterization of temporal and spatial patterns in ecosystem processes and their sensitivity to environmental and biotic changes; integration of global scale effects of these processes. Includes lectures, field trips and laboratories.

**Prerequisites:** EES 115 or EES 152

**Attribute/Distribution:** NS

**EES 293 Supervised Internship in Earth and Environmental Sciences 1-4 Credits**

Experiential learning opportunities supervised by EES faculty, including data collection or analysis, literature review, and/or information management most likely as part of a longterm, continued project. The student should submit a work plan that describes activities involved and credits requested. A maximum of four credits of EES 293 and no more than eight credits combined from EES 093, EES 293 and 393 may be applied to EES B.A. and B.S. degrees (additional credits apply to free electives). Consent of supervising faculty required.

**Repeat Status:** Course may be repeated.

**Attribute/Distribution:** NS

**EES 300 Apprentice Teaching 3 Credits****EES 306 Geologic Records of Environmental Change 3-4 Credits**

This course provides an overview of high-resolution geologic records of environmental and global change, how they are analyzed, and how they can be used in a variety of disciplines. Time series analysis, age control, completeness of sequences, and correlation of records will be covered. A class project will use acquisition and analysis of environmental magnetic data to demonstrate how records of global and environmental change are constructed.

**Prerequisites:** EES 080 and EES 115

**Attribute/Distribution:** NS

**EES 316 (CEE 316) Hydrogeology 3-4 Credits**

Water plays a critical role in the physical, chemical, and biological processes that occur at the Earth's surface. This course is an introduction to surface and groundwater hydrology in natural systems, providing fundamental concepts and a process-level understanding using the hydrologic cycle as a framework. Geochemistry will be integrated to address natural variations and the human impact on the environment. Topics covered include: watershed hydrology, regional and local groundwater flow, water chemistry, and management of water resources. Lectures and recitation/laboratory.

**Prerequisites:** (EES 080 and EES 115 or EES 131 or EES 152) or (CEE 170)

**Can be taken Concurrently:** EES 115, EES 131, EES 152

**Attribute/Distribution:** NS

**EES 318 Geographic Analysis in EES 3-4 Credits**

Techniques for acquisition, manipulation and integration of data in Geographic Information System (GIS) environment, with emphasis on statistical and spatial analysis. Traditional and digital maps, spatial data collection and integration, geodesy concepts and time series analysis will be applied to case studies and projects relevant to Earth sciences, environmental sciences, and other disciplines according to the diversity of the audience. Different OS platforms and software will be used throughout the course. Includes lectures and laboratory exercises.

**Prerequisites:** EES 080 and (EES 115 or EES 152)

**Attribute/Distribution:** NS

**EES 320 (CEE 320) Engineering Hydrology 3 Credits**

Rainfall-runoff analysis, overland flow, hydrograph theories, modeling. Frequency analysis of extreme events. Flood routing. Design storms. Floodplain hydraulics, floodplain delineation.

**Prerequisites:** (CEE 222)

**Attribute/Distribution:** NS

**EES 323 (CEE 323) Environmental Groundwater Hydrology 3 Credits**

The study of subsurface water, its environment, distribution, and movement. Included are flow patterns, well hydraulics, and an introduction to the movement of contaminants. Design problems are included to simulate flow with analytical and numerical models, and contaminant migration using analytical models.

**Prerequisites:** CEE 121 or CEE 316 or EES 316

**Attribute/Distribution:** NS

**EES 325 Remote Sensing of Terrestrial and Aquatic Environments 3,4 Credits**

Techniques of observing the Earth from air- and space-borne instruments, including issues of geometry and scale associated with making measurements, electromagnetic properties of Earth surface materials, the range of instruments used to observe the Earth, image interpretation, and applications of satellite remote sensing to geological, ecological, and environmental questions. Lecture and lab.

**Prerequisites:** EES 080

**Attribute/Distribution:** NS

**EES 327 (CEE 327) Surface Water Quality Modeling 3 Credits**

Fundamentals of modeling water quality parameters in receiving water bodies, including rivers, lakes, and estuaries. Modeling of dissolved oxygen, nutrients, temperature, and toxic substances. Emphasis on water quality control decisions as well as mechanics and model building.

**Prerequisites:** CEE 121 and (CEE 122 or CEE 222) and (CEE 170 or CEE 270)

**Attribute/Distribution:** NS

**EES 334 Geosphere Structure and Evolution 3-4 Credits**

Synthesis of the state of knowledge of Earth structure and long-term evolution, with emphasis on the crust and mantle, and integrating petrologic, geophysical, and geochemical perspectives. Mass and energy transfer through time among the crust, mantle, hydrosphere, biosphere, and atmosphere. Petrographic study of selected rock suites, and introduction to geophysical observations of the deep structure of the solid Earth. Lectures, discussion, laboratories, field trip.

**Prerequisites:** EES 080 and EES 115 and EES 131

**Attribute/Distribution:** NS

**EES 341 Field Camp in Earth and Environmental Sciences 6 Credits**

Integrated, capstone field experience for Earth and Environmental scientists using the diverse natural settings of the Rocky Mountains as the classroom. Projects challenge students to synthesize field data in solving real science problems. Projects include but not limited to classic and computer-based geologic mapping, section measuring, structural analysis, stream hydrology, sediment transport. Five weeks in the field; summer session. Students must apply through the Lehigh Field Camp Program, consent of Field Camp director required. Must have declared major in EES.

**Prerequisites:** EES 131 and EES 115 and EES 223 and EES 316

**Attribute/Distribution:** NS

**EES 342 Atmospheric Science 3,4 Credits**

An intermediate course on the basic principles of meteorology. The course considers atmospheric structure and composition, earth's energy balance and radiation laws, cloud formation and precipitation, atmospheric motion and circulation, including jet streams and planetary waves, atmospheric stability, frontal systems and air masses, regional climatologies, weather and climate modeling, and the latest ideas about future climate change and global warming. Students will view daily atmospheric charts to enable them to relate theory to observations from real weather data.

**Prerequisites:** EES 080 and EES 200 and MATH 021 and MATH 022

**Attribute/Distribution:** NS

**EES 352 Limnology 3,4 Credits**

Study of inland waters, incorporating physical, chemical, and biological aspects of the environment. The origin and morphology of lakes; light, heat, carbon, salinity, nutrients (N+P), dissolved gases, primary production, and secondary production. Emphasis is on lakes, but watersheds, streams and wetlands are also considered. Relies heavily on laboratory exercises and data analysis to underscore critical principles in limnology.

**Attribute/Distribution:** NS

**EES 357 Paleoecology and Landscape History 3-4 Credits**

Principles and methodologies of paleoecology, with emphasis on palynology. Applications of paleo-records in tracing flora, vegetation, climate and landscape history. Long-term ecological interactions and ecosystem responses to past environmental change. Field and laboratory experiences in collecting and characterizing sediments and in processing and interpreting fossil pollen and other proxy data. Students will explore regional vegetation, climate and landscape history by coring and analyzing sediments from lakes and wetlands. requires one or more weekend day-long field trips.

**Prerequisites:** EES 080 or EES 115 or EES 152 or EES 250

**Attribute/Distribution:** NS

**EES 358 Microbial Ecology 3-4 Credits**

The role of microorganisms in the environment. Topics include: Survey of microbial classification, structure, and metabolism; study of microbes at population, community, and ecosystem levels of organization; the role of microbes in biogeochemical cycles; application of microbes to bioremediation and resource recovery problems. Fall (alternate (even) years).

**Prerequisites:** EES 152

**Attribute/Distribution:** NS

**EES 363 Volcanology 3,4 Credits**

Volcanic eruptions can result in devastating effects on both a regional and a global scale. This course will examine physical dynamics that control eruptive processes at active volcanoes. Topics will include the role of volatiles, magma decompression, magma chamber and conduit dynamics, magma rheology, crystallization, fragmentation criteria, and transitions from explosive to effusive behavior. We will examine specifically how geochemical/textural analyses of volcanic rocks and minerals can provide quantifiable information on eruption processes.

**Prerequisites:** EES 131 and EES 115

**Attribute/Distribution:** NS

**EES 364 Glacial and Periglacial Processes 4 Credits**

The mineral ice. The formation, deformation and flow of glaciers. Erosion and deposition by glaciers and glacial meltwater. Subglacial processes. Distribution and age of Quaternary glacial deposits. Quaternary dating techniques and periglacial processes. A three day required field trip, recitations, readings from the primary literature and student presentations augment instructor lectures.

**Prerequisites:** EES 131 and EES 115

**Attribute/Distribution:** NS

**EES 371 Methods in Water Quality Analysis 3-4 Credits**

Survey of methods used in water quality analysis. The course will include: (1) theory and application of standard techniques and instrumentation, (2) quantitative analysis or modeling of existing or acquired data sets, and (3) data presentation and scientific report writing. Fulfills college writing intensive course requirements. Includes both lectures and laboratories.

**Prerequisites:** CHM 025

**Attribute/Distribution:** NS

**EES 372 Topics in Earth & Environmental Science 1-4 Credits**

Study of topics in earth and environmental science not covered in other 300-level courses. Primarily used for transfer credit. Consent of instructor required.

**Repeat Status:** Course may be repeated.

**Attribute/Distribution:** NS

**EES 376 Geochemistry of Natural Waters 3,4 Credits**

Introduction to aqueous geochemistry. Applications of thermodynamics, mass balance, systems science, and kinetics to understanding mineral-water interactions in natural aquatic systems on a variety of spatial and temporal scales. Laboratories emphasize analytical and computer methods. Lectures, discussion, student presentations, and recitation/laboratory.

**Prerequisites:** EES 080 and EES 115

**Can be taken Concurrently:** EES 080

**Attribute/Distribution:** NS

**EES 379 (CEE 379) Environmental Case Studies 3-4 Credits**

Case studies will be used to explore the impact of politics, economics, society, technology, and ethics on environmental projects and preferences. Environmental issues in both affluent and developing countries. Multidisciplinary student teams investigate site characterization; environmental remediation design; environmental policy; and political, financial, social, and ethical implications of environmental projects.

**Prerequisites:** (EES 022 or CEE 276 or CHE 276)

**Attribute/Distribution:** NS

**EES 380 The Practice of Science 1 Credit**

The knowledge, skills, and discipline of mind developed in the Earth and Environmental Sciences major present students with a number of opportunities and career paths. This senior seminar provides students with the opportunity to synthesize their knowledge and expertise in EES in the context of the broader field and the opportunities and challenges facing society. The seminar also helps students explore a variety of career paths (industry, business, education, government, non-profits, etc.) and further develops professional skills. Students will build a portfolio of existing previous work and prepare a reflective narrative integrating their educational experiences into a greater whole. The seminar explores strategies for applying to graduate school or for a job, professional ethics and responsibility, and the methods and process of effective communication. Must have senior standing and EES major.

**Prerequisites:** EES 200

**Attribute/Distribution:** NS

**EES 386 Wetland Ecology 3,4 Credits**

Ecology of wetlands and factors controlling wetland structure and function. Responses and feedbacks of wetlands to natural and human-induced environmental variability. Topics include wetland classification and delineation, origin and development of wetlands, biotic adaptations to the wetland environment, wetland hydrology, wetland biogeochemistry and microbial communities, wetland vegetation dynamics, and wetland restoration. Lectures, laboratories, applied activities, and field trips.

**Prerequisites:** EES 152

**Attribute/Distribution:** NS

**EES 393 Supervised Research in Earth and Environmental Sciences 1-4 Credits**

Research opportunities supervised by EES faculty to carry out a well-defined project, including exposure to problem definition, selection of research approach, and communication of results. The student should prepare a proposal and, if taking 3 or more credits, should present the results at Undergraduate Research Symposium and write a research thesis. Both proposal and thesis are filed with EES Department. No more than eight credits may be applied to EES B.A. and B.S. degrees (additional credits apply to free electives). Consent of instructor required.

**Repeat Status:** Course may be repeated.

**Attribute/Distribution:** NS

**EES 402 (ES 402) Scientific Foundations for Environmental Policy Design 3 Credits**

This course explores the science behind the environmental issues that bear on policy process at local, national and global scales. The course delves into the science of selected environmental issues that have either arisen from anthropogenic activities, that impact social systems, or that help policy-makers understand the consequence of different policy options. The course consists of readings and discussions of timely topics and one major project.

**Attribute/Distribution:** NS

**EES 403 Earth System Modeling 3 Credits**

The concepts behind computer modeling, including stocks and fluxes, finite differencing, initial boundary conditions, feedbacks calibration, validation, data visualization, Monte Carlo, and sensitivity. We will apply these ideas to radiative energy balance, atmosphere and ocean dynamics, hydrological cycling, terrestrial carbon and nitrogen dynamics, and vegetation biogeography. Students will learn both agent-based and systems dynamics modeling using NetLogo and Stella, simple box modeling in Excel, and research-oriented models such as the NCAR Community Climate System Model using C++, Fortran and IDL.

**EES 405 Paleo- and Environmental Magnetism 3 Credits**

Topics in paleomagnetism and environmental magnetism. Class will design and conduct a research project, read the relevant literature and write a research paper. Consent of instructor required.

**EES 407 Seismology 3 Credits**

Seminar on advanced topics in seismology, review of classic and current literature. Topics include but are not limited to: wave propagation in ideal media and earth materials, seismic imaging of complex structures, tomography, modeling, and high-resolution seismic imaging. Must have completed an introductory geophysics course.

**EES 411 Physical and Chemical Processes at the Earth's Surface 3 Credits**

An advanced treatment of physical and chemical processes and their interaction in the critical zone. Quantitative methods, modeling, and process-oriented approaches are presented in a systems context from the meter, to watershed, to continental scale. Topics include weathering and soils, chemical and physical fluxes from watersheds, and global hydrology and erosion.

**EES 412 Advanced Fluvial and Tectonic Geomorphology 3 Credits**

Lecture, seminar, lab, and field-based investigation of the classic and contemporary geomorphologic literature using the processes and evolution of a watershed and its dynamic interaction with tectonics as a integrative common theme. Topics change according to student interest but typically include active tectonics, fluvial processes, landscape response to climate, and biogeomorphology. Include ArcGIS training, field trips, flume analogue modeling, and class projects with the goal of a published paper.

**EES 414 Glacial and Quaternary Geology 3 Credits**

Study of the origin, distribution, and movement of present and past glaciers. Special emphasis on glacial land forms and deposits, Quaternary stratigraphy and dating techniques, periglacial phenomena, and Pleistocene environments. Lectures and required field trips. Consent of instructor required.

**EES 415 Paleoclimatology 3 Credits**

Overview of climate system, including energy budget, feedbacks, atmospheric and ocean circulations, and their interactions. Earth's climate history and mechanisms of past climate variations at various time scales, with emphasis on late Quaternary. Lectures, presentations and discussion of recent literature, especially on approaches to studying climate change and paleo-perspectives on ongoing climate change. Must have graduate standing in EES, or consent of course instructor.

**Repeat Status:** Course may be repeated.

**EES 426 Tectonic Processes 3 Credits**

Current models of tectonic processes in intraplate settings and at plate boundaries. Critical evaluations by the class of the geological, geochemical and geophysical data sets which gave rise to these models. Must have graduate standing in EES, or consent of department chairperson.

**EES 427 Orogenic Belts 3 Credits**

Geometry, kinematics, and mechanics of orogenic belts. will explore current paradigms of depositional, deformational, and metamorphic processes in the Earth's crust. Lectures, seminars, and field trips. Topically variable Consent of instructor required.

**Repeat Status:** Course may be repeated.

**EES 429 Methods and Applications of Geochronology 3 Credits**

Examination of isotopic techniques used to measure geologic time, and their applications. Lectures, laboratories, research projects, field trips. Must have graduate standing in EES.

**Repeat Status:** Course may be repeated.

**EES 438 Petrogenetic Processes 3 Credits**

Metamorphism, melting, and magmatism in the Earth's crust and mantle. Tectonic evolution, crust-mantle heat and mass transfer, fluid-rock interactions, and rate processes. Varying combinations of lecture and seminar formats. May be repeated for credit when topics differ. May include laboratory and field experience and computational exercises. Consent of instructor required.

**Repeat Status:** Course may be repeated.

**EES 453 Advanced Microbial Ecology 3 Credits**

Lectures and seminars will focus on topics of current interest in the microbial ecology of pelagic (freshwater and marine), sediment, and/or soil environments. Emphasis will be placed on the role of microbes in ecosystems level processes such as energy transformations and elemental cycling. May include laboratory and field exercises. Must have graduate standing or consent of course instructor.

**EES 457 Advanced Remote Sensing of the Environment 3 Credits**

Seminars and hands-on, quantitative analysis of specialized satellite and aircraft data, including microwave and hyperspectral sources, will be used to investigate significant environmental questions. Students will refine visual and technical skills for image interpretation, digital image processing, change detection of environmental systems, and presentation of spatial data. Required research project. Must have graduate standing in EES or consent of the instructor.

**EES 459 Reconstructing Environmental Change 3 Credits**

Lectures, seminars, and in-depth discussion on current issues and selected topics in Quaternary paleoecology and paleoclimatology. Survey of techniques in studying and reconstructing environmental changes and biological responses. Use of multiple proxy data from paleo-archives (e.g., ice cores, lake sediments) to address nature of past climate variability. Quantitative analyses of paleo-records to test paleoecological hypothesis (e.g., multivariate analysis) and to infer possible causes and forcing mechanisms of past climate change (e.g., time series analysis). May include field and laboratory exercises.

**EES 471 Stable Isotope Chemistry - Theory, Techniques, and Applications in Earth and Environmental Sciences 3 Credits**

Distributions of stable isotopes (primarily of O, H, C, S, and N) in the lithosphere, hydrosphere, biosphere, and atmosphere. Topics include mechanisms of fractionation and mixing, advancements in techniques for extractions and mass spectrometry, and recent applications of stable isotopes in the earth and environmental sciences. Lectures, seminars, laboratory sessions. Consent of instructor required.

**EES 473 Aqueous Geochemistry 3 Credits**

Advanced study of the equilibria and kinetics of chemical reactions occurring at the earth's surface. A review of concepts in geochemistry including activity, solubility, thermodynamics, kinetics, and oxidation-reduction reactions is followed by readings from the literature. Topics covered depend on student interest, and have included chemical weathering, chemical evolution of surface and groundwater, acid mine drainage, trace element chemistry, biogeochemical cycles, and ocean chemistry. Must have graduate standing in EES or consent of instructor.

**Repeat Status:** Course may be repeated.

**EES 476 Environmental Engineering Microbiology 3 Credits**

Fundamentals of microbiology and biochemistry applied to environmental systems and water quality control. Systems ecology, energetics and kinetics of microbial growth, nutrition and toxicology, use of microorganisms for pollution monitoring and control. Pathogenicity and disease transmission, water quality using biological indices.

**Prerequisites:** CEE 375 or CHE 375

**EES 484 Ecosystem Processes 3 Credits**

Theoretical and experimental approaches to investigate ecosystem processes at local, regional, and global scales. Emphasis on interactions among physical, chemical, and biotic components of ecosystems. Must have graduate standing in EES.

**EES 485 Advanced Topics in Geophysics 1-6 Credits**

Intensive study of topics in geophysics not covered in more general courses.

**Repeat Status:** Course may be repeated.

**EES 490 Thesis Research 1-6 Credits**

Masters' thesis research directed by research committee. 3-6 credits required for EES M.S. programs. Consent of research advisor required.

**Repeat Status:** Course may be repeated.

**EES 491 Investigations in Earth and Environmental Sciences 1-3 Credits**

Research on a special problem; field, laboratory, or library study; report required. Credit above three hours granted only when a different problem is undertaken.

**EES 492 Advanced Topics in Modern and Quaternary Processes 3 Credits**

Intensive study of topics in modern and Quaternary geology not covered in more general courses.

**Repeat Status:** Course may be repeated.

**EES 493 Advanced Topics in Tectonics 1-6 Credits**

Intensive study of tectonic processes and products not covered in more general courses.

**Repeat Status:** Course may be repeated.

**EES 494 Advanced Topics in Ecosystem Ecology 1-6 Credits**

Intensive study of ecosystem processes not covered in more general courses.

**Repeat Status:** Course may be repeated.

**EES 496 Advanced Topics in Geochemistry 1-4 Credits**

Intensive study of geochemical processes not covered in more general courses.

**Repeat Status:** Course may be repeated.

**EES 497 Advanced Topics in Paleocology and Paleoclimatology 3 Credits**

Intensive study of paleocology and paleoclimatology not covered in more general courses.

**Repeat Status:** Course may be repeated.

**EES 499 Dissertation Research 1-15 Credits**

Ph.D. dissertation research directed by research committee. Consent of research advisor required.

**Repeat Status:** Course may be repeated.