

Earth and Environmental Sciences

The Department of Earth and Environmental Sciences (EES) is Lehigh's home for teaching and research in the areas of ecology, environmental science, and geological sciences. Matters of environmental quality and natural resources will increasingly impact people and society in the years to come, and the EES department offers a range of undergraduate and graduate programs that provide students with an understanding of Earth's biosphere, atmosphere, lithosphere, and hydrosphere, with an emphasis on how these components function as an integrated Earth system. Training in Earth and Environmental Sciences can lead to technical and scientific careers in research, environmental consulting, conservation ecology, government agencies, and the energy sector. It can also serve as an excellent liberal arts degree that provides context, depth, and preparation for careers in law, policy, journalism, economics, and health and medicine.

Faculty in the EES department have a wide range of interests and strong reputations in the fields of geology, ecology, and environmental sciences. In instruction at all levels, the department emphasizes field experiences, laboratory techniques, and experiential learning, as well as the development of quantitative and communication skills. The EES department is committed to building diversity and inclusion at Lehigh and in the Earth and Environmental Sciences. As such, we maintain a welcoming, respectful, relaxed, and personal atmosphere where students interact with faculty in many ways, including seminars, special symposia on topics of the students' choice, field research, and departmental field trips.

EES is a core department in the Environmental Initiative Program (EI), which offers students access to interdisciplinary training in Environmental Science, Engineering, and Policy.

At the undergraduate level, students may choose from a B.A. or a B.S. degree in Earth and Environmental Sciences. The flexible B.A. program provides students an opportunity to acquire breadth, design a specialized program, or find room for a double major. A popular choice is a double major in Earth and Environmental Sciences and in Environmental Studies, a major offered through the Environmental Initiative (<http://www.ei.lehigh.edu>). The B.A. is well suited to students with career aspirations in areas such as engineering, environmental law, journalism, economics, government, and health and medicine. The B.S. degree, while still offering considerable flexibility, provides the more in-depth technical training required for graduate school and scientific careers, and is well suited for students seeking science graduate degrees or employment as professionals in the earth and environmental sciences.

An accessible minor program is available for students wishing to add Earth and Environmental Science insight into any number of other technical or non-technical degree programs, helping students distinguish themselves as they prepare to enter today's fast-evolving job markets and graduate programs.

For students with strong interests in areas such as hydrology, water and soil remediation, hazards and associated geotechnical strategies, EES, in conjunction with the Department of Civil and Environmental Engineering (CEE), offers a five-year program leading to dual B.S. degrees in EES and CEE (students having these interests may also want to see the description of the B.S. in Environmental Engineering in the catalog entry for the Department of Civil and Environmental Engineering).

EES offers graduate training leading to either M.S. or Ph.D. in Earth and Environmental Sciences. The EES graduate program is marked by close faculty-student collaboration. Graduate students can take advantage of strong externally funded faculty research programs and the extensive analytical and computing facilities available in the department; these facilities and specific EES research programs are described in some detail on the EES departmental web page at www.ees.lehigh.edu (<http://www.ees.lehigh.edu>).

FIELD WORK AND EXPERIENTIAL LEARNING

Field experiences are a hallmark of the EES undergraduate program. The goal of these experiences is to place students into learning environments that are distinct from the classroom or lab, where all

the complexities and subtleties of the field can be appreciated in their natural setting. The Department runs a nationally recognized ~5 week long (6 credit) summer field camp in the Rocky Mountains, which offers immersive field training in geology, geomorphology, and field methods including computer-based mapping. The Department has long offered opportunities for field research and courses in Costa Rica that focus on tropical ecology and natural history. Students can also participate in the department's longstanding research programs in hydrology, geochemistry, ecology, and geomorphology of the Lehigh River watershed. Supervised internships allow students at all levels to become engaged in projects involving cross-disciplinary research, assessment, and consulting work. Undergraduate students can also become involved in forefront research programs. In recent years, students have played a role in research in the Himalaya, Alaska, California, Idaho, Argentina, Mongolia, Italy, and the world's oceans in addition to more nearby sites in the mid-Atlantic states. We strongly encourage all EES majors to take advantage of the special field programs and opportunities made available by the department. Most EES courses also include field experiences in the form of one-day or weekend-long field trips, and several courses include weekly or bi-weekly field trips.

PROGRAMS IN EARTH AND ENVIRONMENTAL SCIENCES

The descriptions of the following programs in the Department of Earth and Environmental Sciences are organized as follows:

- Minor in Earth and Environmental Sciences
- Bachelor of Arts Degree in Earth and Environmental Sciences
- Bachelor of Sciences Degree in Earth and Environmental Sciences
- Department Honors in Earth and Environmental Sciences
- Civil and Environmental Engineering and Earth and Environmental Sciences
- Graduate Studies

REQUIREMENTS FOR A MINOR IN EARTH AND ENVIRONMENTAL SCIENCES

A minor is designed for students wishing to explore an area of Earth or Environmental Sciences in conjunction with a major program in another field for personal development or career enhancement.

Select one of	4
EES 080 Introduction to the Earth System ¹	
EES 022 Exploring Earth & ONE ADDITIONAL EES COURSE	
EES Courses	3
EES Courses at 100 level or above	8
Total Credits	15

1

Students are recommended to take EES080 to satisfy upper division prerequisites. Careful planning is required if a student selects EES022 + a course instead.

Natural science (NS) designated EES College seminars (EES 090) may be used to meet minor requirements.

DEGREE REQUIREMENTS FOR A BACHELOR OF ARTS DEGREE IN EARTH AND ENVIRONMENTAL SCIENCES

The B.A. degree is designed with flexibility in mind and is recommended for students interested in a sound liberal arts degree that will permit them to bring a scientific perspective to a wide variety of careers. The degree also permits students to take a double major, or design a specialized program tailored to specific topics in the earth and environmental sciences. Students who choose the B.A. but are interested in attending graduate school should talk to their faculty advisor and consult the B.S. program descriptions to see the type of requirements that may be required for graduate admission.

College Requirements	25
College Seminar	3

English Composition (2 courses)	6
Distribution Requirements: at least 2 Humanities courses	8
Distribution Requirements: at least 2 Social Science courses	8

Junior Writing RequirementEES 200 Earth History ¹**MATH and Collateral Science Requirements** ² 4

Select one course from Chemistry (CHM 030 or above), Physics (PHY 010 or above), Mathematics (MATH 012 or above), or Computer Science and Engineering (CSE 001 or above).

Core Sequence in EES Major 9

EES 080 Introduction to the Earth System

EES 200 Earth History ¹

EES 380 The Practice of Science

Major Electives 24

Select six courses from EES or cross-listed offerings at the 100 level or above. ^{3,4}

Free Electives

Courses chosen from anywhere in the University's curriculum, sufficient to bring the total to a minimum of 120 credits.

1

Writing intensive

2

Students interested in scientific careers or pursuing graduate education in the sciences are recommended to take at least two additional math and collateral science courses chosen in consultation with an advisor.

3

Up to 8 credits of EES internship (EES 293) and EES research (EES 393) may be used as major electives (no more than 4 of which can be EES 293).

4

Four credits of EES 341 may be applied to major electives; all 6 credits for this course apply to the graduation requirement of 120 total credits.

DEGREE REQUIREMENTS FOR BACHELOR OF SCIENCES DEGREE IN EARTH AND ENVIRONMENTAL SCIENCES**College Requirements** 25

College Seminar	3
English Composition (2 courses)	6
Distribution Requirements: at least 2 Humanities courses	8
Distribution Requirements: at least 2 Social Science courses	8

Junior Writing RequirementEES 200 Earth History ¹**Mathematics and Collateral Science Requirements** 22-25

Select one of the following: 4

MATH 021 Calculus I

MATH 031 Honors Calculus I

MATH 051 Survey of Calculus I

MATH 075 Calculus I, Part A
& MATH 076 and Calculus I, Part B

One additional Mathematics course (MATH 012 and above). 3-4

Select one of the following: 4

CHM 030 Introduction to Chemical Principles

CHM 040 Honors General Chemistry I

Select one of the following: 5

PHY 010 General Physics I
& PHY 012 and Introductory Physics Laboratory IPHY 011 Introductory Physics I
& PHY 012 and Introductory Physics Laboratory I

Complete 6-8 credits (at least two additional courses) in Biology (BIOS 041 or above), Chemistry (CHM 031 or above), Mathematics (MATH 012 or above), Computer Science and Engineering (CSE 001 or above), or Physics (PHY 013 or above). 6-8

Core Sequence in EES Major 21

EES 080 Introduction to the Earth System

EES 115 Surficial Processes

EES 131 Introduction to Rocks and Minerals

EES 152 Ecology

EES 200 Earth History ¹

EES 380 The Practice of Science

Major Electives 28

Select three courses from EES or cross-listed offerings at the 100 level or above. ^{2,3} 12

Select four courses from EES or cross-listed offerings at the 300 level or above. ^{2,3} 16

Free Electives

Courses chosen from anywhere in the University's curriculum, sufficient to bring the total to a minimum of 120 credits.

Field Requirement ⁴

Select one of the following:

Internships or work experience, approved by your advisor: the experience must include substantial work in the field involving research and/or technical work.

EES 341 Field Camp in Earth and Environmental Sciences ²

Complete 5 of the following 7 courses

EES 089

EES 115 Surficial Processes

EES 152 Ecology

EES 201 Seismology: The Earth and Environment

EES 250 Terrestrial Ecosystems

EES 223 Structural Geology and Tectonics

EES 316 Hydrogeology

1

Writing intensive

2

Four credits of EES 341 may be applied to major electives; all 6 credits for this course apply to the graduation requirement of 120 total credits.

3

Up to 8 credits of EES internship (EES 293) and EES research (EES 393) may be used as major electives (no more than 4 of which can be EES 293).

4

Courses used to satisfy the field requirement may be used to satisfy EES degree requirements.

DEPARTMENT HONORS IN EARTH AND ENVIRONMENTAL SCIENCES

Students in either the B.A. or B.S. degree programs may undertake a program that leads to graduation with department honors. To participate, the student must (1) have a minimum major GPA of 3.4 and an overall cumulative GPA of 3.0 expected at graduation, (2) complete at least four credits of EES 393 (Supervised Research in Earth and Environmental Sciences), and (3) prepare a written honors thesis on the EES 393 research project. To graduate with honors students should (1) file a written request with the EES undergraduate instruction coordinator no later than the beginning of the senior year (preferably during the junior year), (2) constitute an advisory committee of two EES faculty plus the student's research supervisor to guide the research, (3) prepare a research proposal for committee's approval, and (4) give an oral presentation of research results and conclusions at a department seminar on or before the last day of

classes in the second semester of the senior year. The committee should approve the research proposal and the honors thesis by signing the required form and cover sheet, which will be filed with the Department.

CIVIL AND ENVIRONMENTAL ENGINEERING AND EARTH AND ENVIRONMENTAL SCIENCES

This program is designed for students interested in combining programs in two departments: Civil & Environmental Engineering and Earth & Environmental Sciences, leading to two bachelor of science degrees, a civil and environmental engineering B.S. degree and a B.S. degree in earth and environmental sciences. Both degrees would be awarded at the end of the fifth year. This program is one of the dual degree programs mentioned in the Five-Year Programs section. The student will have a primary advisor in the P.C. Rossin College of Engineering and Applied Sciences and a secondary advisor in the College of Arts and Sciences. The program provides alternatives for students who may decide not to complete the dual-degree program. Students who make this decision prior to the beginning of the fourth year may qualify at the end of that year for the bachelor of science in civil or environmental engineering, as well as a minor in earth and environmental sciences. Also, if a student decides after two years to pursue only a B.S. degree in the EES department, it is possible to complete the requirements in four years. If the decision to work toward this degree is made during the fourth year, at least one additional semester is required to qualify for either B.S. degree. Interested students should consult with the respective departmental advisors to create a schedule of courses to resolve conflicts or if a specified course is not offered that semester. Required courses and major electives for the EES B.S. degree are listed in the catalog entry for EES. Crosslisted EES/CEE courses used to satisfy Civil Engineering Approved Electives can reduce the individual semester and total program credits when chosen to satisfy EES program requirements. The dual degree, and a suggested schedule of courses, is described more fully elsewhere in the catalog (<http://catalog.lehigh.edu/coursesprogramsandcurricula/engineeringandappliedscience/civilandenvironmentalengineeringandearthandenvironmentalsciences/#undergraduatetext>). Additional useful information can be found on the web sites (www.lehigh.edu/~incee/ (<http://www.lehigh.edu/~incee/>) and www.ees.lehigh.edu (<http://www.ees.lehigh.edu>)).

GRADUATE STUDIES

The Department of Earth & Environmental Sciences offers graduate programs leading to the M.S. and Ph.D. in Earth and Environmental Sciences. These degrees emphasize what we feel is an important and growing trend in ecology, environmental science, and geology, namely the blending of expertise and perspectives from many disciplines. Research is an integral component of all EES graduate programs and leads to an M.S. thesis or Ph.D. dissertation prepared under a research supervisory committee and chaired by a departmental faculty research advisor. An advising commitment by one or more faculty members is required for graduate admission.

The University has outlined the general academic requirements for M.S. and Ph.D. students in its Graduate Student Handbook, and EES has additional Departmental requirements that must also be fulfilled. It is the student's responsibility to insure that all graduation requirements are met. All graduate students work with an advisor who chairs the student's research supervisory committee. Graduate students make annual presentations of their research to the Department. All graduate students are required to take one of the Department's graduate core courses (EES 411, EES 426) and five additional courses (15 credits) at the 400-level. M.S. students complete 30 credits of coursework and thesis research and orally defend a written thesis that encompasses the findings and conclusions of their research. Candidates for the Ph.D. must first pass the qualification evaluation in the first year, then defend their dissertation proposal in the General Exam, and finally, orally defend a dissertation. For more details beyond this brief summary, please see the graduate handbook online at: <http://www.ees.lehigh.edu/content/overview-ees-graduate-program> (<http://www.ees.lehigh.edu/content/overview-ees-graduate-program/>)

Research Facilities

Our Department is well equipped for a broad range of field and laboratory investigations in the Environmental, Ecological, and Geological Sciences. Our laboratories and equipment include:

- Petrographic microscopy facilities, rock-crusher, ball mill, rock saws, and cathodoluminescence and camera lucida digitizing capabilities;
- Laboratory for Ar-Ar, U-Th/He, and fission-track geochronology including dual UV and CO₂ lasers, VG 3600 noble-gas mass spectrometer, Balzers quadrupole mass spectrometer, dedicated He and Ar extraction lines with low-blank furnaces, all under full LabVIEW automation;
- A stable isotope geochemistry laboratory equipped with a Finnigan MAT model 252 mass spectrometer (with dual-inlet and carrier gas capabilities), on-line peripherals, and off-line vacuum extraction lines, for O, H, C, and N isotope analyses of silicate minerals and rocks, carbonates, fluid inclusions, and organic matter;
- Equipment for sampling groundwater wells as well as automated samplers for surficial water systems;
- A microbial ecology laboratory (fluorescence and phase contrast microscopy, bioreactors, UV phototron, walk-in controlled environment chambers);
- Field instruments to characterize solar radiation (UV bands, PAR, broadband, and high resolution spectral irradiance with automated shadowband options for diffuse and direct spectral irradiance), water quality & optical properties (Biospherical PUV profilers, YSI datasondes, SCUFA CDOM fluorometers), weather parameters, and hydrology (precise water level, precipitation, wind, humidity, atmospheric pressure, water temperature thermistor chains) plus automated ISCO rain-triggered samplers for applications in aquatic and terrestrial ecosystem studies;
- Aquatic ecology laboratory instruments to characterize water quality and optical properties (pH, specific conductance, dissolved oxygen, UV-VIS spectrophotometers, scanning fluorometer, Turner CDOM/Chlorophyll fluorometer, N & P nutrient analyzer, automated Shimadzu TOC/TN analyzer, CHN analyzer, scintillation counter, photobleaching laboratory, low-carbon water purification system);
- An aqueous geochemistry laboratory with a ThermoElectron X-Series inductively-coupled plasma mass spectrometer with collision cell, and hydride generation apparatus that can be coupled to an HPLC system for species analysis, a Dionex ion chromatograph for simultaneous analysis of anions and cations, a Mercury analyzer for analysis of gaseous and liquid samples, and a Class 100 clean room for ultra trace sample preparation; additional instruments including a Waters computer-assisted ion chromatograph, an ARL 34000 inductively-coupled plasma atomic emission spectrometer, a Netzsch DTA/TGA instrument, and a high-pressure core-holder/column reactor for flow-through experiments;
- A sedimentation and soils analysis laboratory including equipment for particle size analysis;
- A paleomagnetism laboratory with a magnetically shielded room, a 2G superconducting magnetometer and built-in af demagnetizer, Molspin spinner magnetometer, a Schonstedt AF demagnetizer modified to apply pARMs, and an ASC thermal demagnetizer, and a KLY-3S Kappabridge magnetic susceptibility system, and an ASC impulse magnetizer;
- A reflection seismology laboratory has equipment including broadband seismometer linked to global networks; computer workstations for seismic processing, Bison DIFP multi-channel seismograph, various seismic energy sources, and ground-penetrating radar;
- Field geophysical equipment includes a Worden Master gravimeter, and a Geometrics portable proton precession magnetometer;
- Geomorphology lab including a Topcon total station, flow gages, LASCI digitizer, complete airphoto analysis facility, and a flume facility in the CEE hydraulics lab. We also maintain several PC

and UNIX computer labs devoted to GIS (ArcGIS) and large spatial digital topographic databases;

- Paleoecological laboratories with facilities for the analysis and photo documentation of tree rings, pollen, macrofossils, and other biological and physical parameters of environmental archives, including lake and peatland sediments.
- A sediment core laboratory with facilities for initial core preparation and core storage, including a walk-in cold room, a GeoTek MultiSensor Core Logger, a VirTis AdVantage Freezer Dryer and various corers (Livingstone, Mackereth, Glew Gravity, Russian peat Corers);
- A remote sensing laboratory with image processing software, extensive spatial data collections, as well as equipment for measuring field characteristics of important remotely sensed parameters.

Courses

EES 002 (EVST 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, the course examines 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 using case studies. Intended for any student with an interest in the environment. May be combined with EES 022 or EES 004 for 4 credits.

Attribute/Distribution: NS

EES 004 (EVST 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. May be combined with other EES 3 credit courses for 4 credits.

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 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 resource and environmental change causes of human conflict. Earth and Environmental Science basis for permanent and contingent operating factors during 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. May be combined with EES 022 or EES 004.

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. Topics include Hazards, resources, anthropogenic forcing and impacts, biogeochemical cycles and sustainability. May be combined with other EES Courses for 4 credits.

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 029 Human Health and the Environment 3 Credits

An introductory course that explores the connections between the environment and human health. Topics related to human health include climate change, energy production, genome-environment interactions, zoonotic disease, and drinking water chemistry. Introduction to the disciplines of geochemistry, ecology, geospatial data analysis, environmental epidemiology, toxicology, risk assessment, and exposure science. Course format includes a combination of lectures on fundamentals and seminar style topical readings. May be combined with EES 022 or EES 004 for 4 credits.

Attribute/Distribution: NS

EES 032 (BIOS 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 033 Life from Stardust 3 Credits

An examination of the history of planet Earth and the development of life. Includes the formation of Earth and the evidence for changing conditions in the inter-connected geosphere, hydrosphere, atmosphere, and biosphere over the past 4.5 billion years, and theories for the origin and early evolution of life. Discuss the tools used for the search for life on other planetary bodies, both in our solar system and around other stars. May be combined with EES022 or EES004 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 072 Topics in Earth and Environmental Science 1-4 Credits

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

Repeat Status: Course may be repeated.

Attribute/Distribution: NS

EES 080 Introduction to the Earth System 0,4 Credits

Study of the earth system, including the atmosphere, biosphere, geosphere, and hydrosphere and their interactions (e.g., plate tectonics, biogeochemical cycling, climate, anthropogenic impacts). The course is designed to prepare students for a major in EES and includes a lab that develops important skills including data analysis, modeling, use of maps and geospatial data, and field work. Lectures and lab. Open to declared EES majors and minors. Also open to intended majors and others by departmental permission.

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 102 Environmental Science and Sustainability 0,4 Credits

An examination of how the Earth and environment work and sustain human health and well-being, how our actions support and conserve or disrupt and deplete the natural systems and resources we depend on, and how environmental impacts are distributed globally and socioeconomically. Focus on scientific inquiry, cultivating curiosity, a critical approach to challenges and opportunities related to environmental issues, and evidence based decision making. Active learning and case studies. Required for registration: at least 1 credit of any EES course.

Attribute/Distribution: NS

EES 115 Surficial Processes 0,4 Credits

An introduction to process geomorphology and sedimentology that emphasizes the dynamic interactions of climate, tectonics, and watershed hydrology on the erosional, transportation, 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 0,4 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 0,4 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 0,4 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 0,4 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 0,4 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

EES 250 Terrestrial Ecosystems 0,4 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

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 0-4 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 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),) or ES 319

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 122 or CEE 316 or EES 316 or ME 231 or CHE 044

EES 325 Remote Sensing of Terrestrial and Aquatic Environments 0-4 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 and (EES 115 or EES 152 or EES 131),) or ES 319

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 122 or ME 231 or CHE 044) and CEE 222

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

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.

Prerequisites: EES 152

Attribute/Distribution: NS

EES 363 Volcanology 0-4 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 372 Topics in Earth & Environmental Science 0-4 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, and seminar/laboratory.

Prerequisites: EES 080 and EES 115

Can be taken Concurrently: EES 080

Attribute/Distribution: NS

EES 379 (CEE 379) Environmental Case Studies 3 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 375 or CHE 375

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. Students will explore a variety of career paths and further develop professional skills. 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 EES Major and senior standing.

Attribute/Distribution: NS

EES 386 Wetland Ecology 0-4 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 (EVST 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.

EES 403 Earth System Modeling 3 Credits

This course will introduce the concepts behind computer modeling, including deterministic vs stochastic, stocks and fluxes, finite differencing, initial and boundary conditions, sensitivity, feedbacks, calibration, validation, and uncertainty. We will apply these ideas to projects of interest to students in the course, and may include any of the components of the earth system. Students will learn both agent-based and systems dynamics modeling using NetLogo, Stella, and Excel, simple programming with C++, and research-oriented models as their independent research projects allow.

Repeat Status: Course may be repeated.

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 446 Human-Climate Interactions 3 Credits

This course explores climatic impacts of human activity, along with feedbacks between climate change and the land/sea surface, hydrology, productivity, etc., in the context of assessing both the causes and societal consequences of climate change. Such consequences include storm frequency, SSTs, floods/droughts, sea level rise, etc. Emphasis is placed on understanding the processes controlling climate response greenhouse gases, land cover, and land-atmosphere / ocean-atmosphere mass and energy exchanges.

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 477 Chemical and Geological Oceanography 3 Credits

This course will investigate the pathways that chemical species follow on their transit through the world's oceans, and related geologic processes. Fundamental principles will be combined with quantitative approaches to construct mass balance models across boundaries including the atmosphere, rivers, groundwater, and hydrothermal systems. Chemistry topics, including seawater composition, isotope tracers, ocean circulation, carbonate chemistry and biogeochemical cycling, will be linked with geology topics, including sedimentation and the formation of basaltic crust of the seafloor via igneous petrogenesis and volcanism.

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.