EARTH SYSTEM SCIENCE

Director: Elizabeth Safran
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Earth system science focuses on exchanges of energy and matter within and among key Earth components through physical, chemical, biological, and anthropogenic processes. These components, or "spheres," include Earth's slowly churning rocky substrate, the liquids circulating through and atop it, the patches of ice crowning its nether reaches, the thin envelope of air surrounding it, and the organisms that populate its surface—lithosphere, hydrosphere, cryosphere, atmosphere, and biosphere. Earth system science is distinctive for its broad scientific interdisciplinarity applied to understanding planetary functioning, its attention to interconnections among domains, and its emphasis on large spatial scales. Earth system science also acknowledges the role of humans as biophysical actors. It provides a framework for understanding large-scale transformations of Earth and the subsequent consequences, like changes in global land cover or atmospheric composition and related nutrient-loading, climate change, and biodiversity loss.

Earth system science minors at Lewis & Clark College learn foundational concepts in at least two areas of the natural sciences to better appreciate content taught in geoscience courses. The latter includes solid Earth processes, the climate system, terrestrial freshwater systems, and oceans. Students also have the opportunity to integrate quantitative analytic approaches into their ESS minor.

Earth system science helps us understand some of today's most pressing questions about our planet's functioning. The systems approach fits well within a liberal arts education, with its emphasis on integrating diverse scientific content and methodologies. Besides enhancing scientific literacy for the 21st century, training in ESS can augment research or professional opportunities in environmental monitoring and management or natural resource decision-making.

Minor Requirements

A minimum of 23 semester credits distributed as follows:

- Two courses chosen from the list of Earth system science courses below, of which at least 4 credits must be at the 200 level or above.
- Two courses chosen from the list of foundational natural science courses below. Courses must be taken from different departments.
- One or two courses chosen from either the list of electives or from the list of Earth system science courses below. More than one course may be necessary to satisfy the minimum of 23 credits required for the minor.

Earth System Science

ESS 150	Environmental Geology
ESS 170	Climate Science
ESS 270	Issues in Oceanography
ESS 280	The Fundamentals of Hydrology
ESS 290	Topics in Earth System Science
ESS 340	Spatial Problems in Earth System Science

Foundational Natural Science

BIO 201	Biological Core Concepts: Systems
CHEM 100	Perspectives in Environmental Chemistry
CHEM 110	General Chemistry I
PHYS 105	Astronomy
PHYS 141	Introductory General Physics I
PHYS 151	Physics I: Motion

Electives

BIO 317	Invertebrate Zoology
BIO 323	Plant Biology
BIO 335	Ecology
BIO 390	Evolution
CHEM 120	General Chemistry II
CHEM 315	Aquatic Chemistry
CS 230	Computational Mathematics
DSCI 140	Introduction to Data Science
ENVS 311	(Un)Natural Disasters
MATH 123	Calculus & Statistics for Modeling the Life Sciences
MATH 235	Differential Equations
MATH 255	Statistical Concepts and Methods
PHYS 142	Introductory General Physics II
or PHYS 251	Physics III: Electromagnetism
PHYS 201	Experimental Methods in the Physical Sciences

At least 12 semester credits must be exclusive to the minor (may not be used in any other set of major or minor requirements).

Faculty

Jessica M. Kleiss. Associate professor of environmental studies and program director. Oceanography, interface between the atmosphere and the ocean. PhD 2009 Scripps Institution of Oceanography, University of California at San Diego. BS 2000 Massachusetts Institute of Technology.

Elizabeth B. Safran. Associate professor of geological science, director of the Environmental Studies Program, coordinator of the Earth System Science Program. Geomorphology. PhD 1998 University of California at Santa Barbara. MSc 1993 University of Washington. BA 1989 Harvard University.

Courses

ESS 150 Environmental Geology
Content: Introduction to major geological processes that impact human activity. Emphasis on regional issues. Plate tectonics, loci of seismic and volcanic activity, distribution of mountain ranges, and sediment sources. Floods, landslides, mudflows, tsunamis. Assessment of anthropogenic shifts in landscape functioning. Chronic vs. catastrophic environmentally significant events. Lecture and laboratory. Weekly laboratory includes two required daylong field trips, held on weekends.
Prerequisites: QR 101.
Corequisites: ESS 150L.
Usually offered: Alternate Years, fall semester.
Semester credits: 5.

ESS 170 Climate Science
Content: Introduction to the earth's climate from a physical, earth-systems perspective. Prehistoric and historic fluctuations in the earth's climate, the current climate system, and projections for future climate and climate impacts. Topics will include the radiative balance of the earth's atmosphere, the greenhouse effect, albedo, aerosols, clouds, climate feedbacks, ocean circulation, climate variability including El Niño and the Pacific decadal oscillation, the carbon cycle, paleoclimate proxy records, ocean acidification, and climate models. We will examine some responses to climate change, including geoengineering, adaptation, and mitigation. Weekly laboratory exercises with climate data observations and models (computer-based) and physical mechanisms (lab- and field-based). Lecture and lab.
Prerequisites: QR 101.
Corequisites: ESS 170L.
Usually offered: Annually, fall semester.
Semester credits: 5.

ESS 270 Issues in Oceanography
Content: A quantitatively rigorous investigation of the geological, biological, chemical, and physical dynamics of the global oceans, including implications of ocean policy. Topics include geology of the seafloor, coastal erosion, waves, tides, storm surge, sea-level rise, ocean circulation, composition of seawater, biogeochemical cycles, and ocean acidity. Compelling issues in oceanography, which may include deep-ocean mining, coastal development, tsunami hazards, ocean pollution, or others. Weekly laboratory includes two required daylong field trips, held on weekends.
Prerequisites: QR 101. Freshman-level natural sciences or math course recommended.
Corequisites: ESS 270L.
Restrictions: Sophomore standing required.
Usually offered: Alternate Years, spring semester.
Semester credits: 5.

ESS 280 The Fundamentals of Hydrology
Content: The behavior and movement of water in natural and modified environments. Major components of the hydrologic cycle, including precipitation, interception, evaporation, evapotranspiration, runoff, groundwater. Introduction to river channel behavior, flood hazard calculation, water supply issues. Quantification, through measurements and calculations, of water fluxes through various pathways, with allusion to planning applications. Students should be comfortable with quantitative work and spreadsheet use. Lecture, laboratory, and one daylong field trip.
Prerequisites: QR 101.
Restrictions: Sophomore standing required.
Usually offered: Alternate Years, fall semester.
Semester credits: 5.

ESS 290 Topics in Earth System Science
Content: Investigation of a subfield of Earth system science. Topic varies by year; for example: glaciology, biogeochemistry, paleoclimatology, volcanology, atmospheric science, or meteorology. Each topic necessarily encompasses the biological, physical, chemical, and geological interactions of the Earth system. Course may be taken two times for credit with change of topic. However, registration for subsequent sections must be done via the registrar's office.
Prerequisites: ESS 150 or ESS 170 recommended.
Usually offered: Every fourth year.
Semester credits: 4.

ESS 299 Independent Study
Content: Independent study topic to be arranged with instructor.
Prerequisites: None.
Restrictions: Sophomore standing and consent required.
Usually offered: Annually, fall and spring semester.
Semester credits: 1-4.

ESS 340 Spatial Problems in Earth System Science
Content: Recognition and interpretation of spatial patterns in Earth system science. Firsthand analysis of current research questions with a strong spatial component. Familiarization with the background of the research questions and their broader contexts. Hypothesis development about Earth processes from remote data (e.g., topographic data, satellite imagery), articulation of appropriate field tests for hypotheses. Development of analytical skills and use of spatial analysis tools, including geographic information systems (GIS) software. Lecture and laboratory.
Prerequisites: Any ESS course or ENVS 220.
Restrictions: Sophomore standing required.
Usually offered: Alternate Years, spring semester.
Semester credits: 5.

ESS 499 Independent Study
Content: Opportunities for well-prepared students to design and pursue an advanced, substantive course of independent learning. Details determined by the student and the supervising instructor.
Prerequisites: None.
Restrictions: Junior standing required.
Usually offered: Annually, fall and spring semester.
Semester credits: 1-4.