Earth System Science

Courses offered by the Department of Earth System Science are listed under the subject code ESS on the (http://explorecourses.stanford.edu/CourseSearch/search?view=catalog&catalog=&page=0&q=EESS&filter-catalognumber-EESS=on) Stanford Bulletin's (http://explorecourses.stanford.edu/CourseSearch/search?view=catalog&catalog=&page=0&q=EESS&filter-catalognumber-EESS=on) ExploreCourses web site (http://explorecourses.stanford.edu/CourseSearch/search?view=catalog&catalog=&page=0&q=EESS&filter-catalognumber-EESS=on).

On April 16, 2015, the Senate of the Academic Council approved the change of name for the department to become the Department of Earth System Science. Prior to April 16, the department was named the Department of Environmental Earth System Science.

Earth System Science studies the planet's oceans, lands, and atmosphere as an integrated system, with an emphasis on changes occurring during the current period of overwhelming human influence, the Anthropocene. Faculty and students within the department use the principles of biology, chemistry, and physics to study problems involving processes occurring at the Earth's surface, such as climate change and global nutrient cycles, providing a foundation for problem solving related to environmental sustainability and global environmental change.

Graduate Programs in Earth System Science

The University's basic requirements for the M.S. and Ph.D. degrees are discussed in the "Graduate Degrees (http://www.stanford.edu/dept/registrar/bulletin/4901.htm)" section of this bulletin. The Department of Earth System Science does not offer coterminal admission to the master's in Earth System Science.

Learning Objectives (Graduate)

The objectives of the doctoral program in Earth System Science are to enable students to develop the skills needed to conduct original investigations in environmental and earth system sciences, to interpret the results, and to present the data and conclusions in a publishable manner. Graduates should develop strong communication skills with the ability to teach and communicate effectively with the public.

The objectives of the master's program in Earth System Science is to continue a student's training in one of the earth science disciplines and to prepare students for a professional career or doctoral studies.

On April 16, 2015, the Senate of the Academic Council approved the Master of Science in Earth System Science. Students who matriculated into the Master of Science in Environmental Earth System Science have the option of changing the name of their degree to Earth System Science. Degree requirements remain the same.

Master of Science in Earth System Science

The University's requirements for M.S. degrees are outlined in the "Graduate Degrees (http://www.stanford.edu/dept/registrar/bulletin/4901.htm)" section of this bulletin. Additional departmental requirements include the following:

Admission

For admission to graduate work in the department, the applicant must have taken the Aptitude Test (verbal, quantitative, and analytical writing assessment) of the Graduate Record Examination. In keeping with University policy, applicants whose first language is not English must submit TOEFL (Test of English as a Foreign Language) scores from a test taken within the last 18 months. Individuals who have completed a B.S. or two-year M.S. program in the U.S. or other English-speaking country are not required to submit TOEFL scores.

Course Work

		Units
Required Core Courses		
ESS 305	Climate Change: An Earth Systems Perspective	2
ESS 306	From Freshwater to Oceans to Land Systems: An Earth System Perspective to Global Challenges	2
ESS 307	Research Proposal Development and Delivery	2
Distribution Requirements		
Area A: Analysis of the Earth System (Select one course)		
ESS 211	Fundamentals of Modeling	3-5
ESS 260	Advanced Statistical Methods for Earth System Analysis	3
Area B: Measurement of the Earth System (Select one course)		
ESS 212	Measurements in Earth Systems	3-4
ESS 241	Remote Sensing of the Oceans	3-4
ESS 262	Remote Sensing of Land	4
Area C: Earth System Processes, Models, and Human-Environmental Interactions (Select one course)		
ESS 220	Physical Hydrogeology	4
ESS 221	Contaminant Hydrogeology and Reactive Transport	4
ESS 246A	Atmosphere, Ocean, and Climate Dynamics: The Atmospheric Circulation	3
ESS 246B	Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation	3
ESS 270	Analyzing land use in a globalized world	3
Seminar Requirements		
Each quarter during the first academic year:		
EARTH 300	Earth Sciences Seminar	1
Autumn Quarter of first academic year:		
ESS 301	Topics in Earth System Science	1

Unit Requirements

1. A minimum of 45 units of course work at the 100 level or above.
2. Half of the courses used to satisfy the 45-unit requirement must be intended primarily for graduate students, usually at the 200 level or above.
3. No more than 15 units of thesis research may be used to satisfy the 45-unit requirement.
4. Some students may be required to make up background deficiencies in addition to these basic requirements.
5. By the end of Winter Quarter of the first year in residence, a student must complete at least three courses taught by a minimum of two different department faculty members.

Teaching Assistantship

Each student must serve as a teaching assistant in at least two quarters during their graduate career.

Advising

The department's graduate coordinator, in coordination with the departmental faculty, appoints an academic adviser prior to registration with appropriate consideration of the student's background, interests, and professional goals. In consultation with the adviser, the student plans a program of course work for the first year. The faculty adviser is charged with designing the curriculum in consultation with the student specific to the research topic.

Thesis

Each student must complete a thesis describing his or her research. Thesis research should begin during the first year of study at Stanford and should be completed before the end of the second year of residence. Early during the thesis research period, and after consultation with the student, the thesis adviser appoints a second reader for the thesis who must be approved by the graduate coordinator; the thesis adviser is the first reader. The two readers jointly determine whether the thesis is acceptable for the M.S. degree in the department.

Master of Science, Course Work Only Option for ESS Ph.D. Students

The course-work-only M.S. for EESS Ph.D. students requires 45 unduplicated units of which all 45 must be course work (non-research, non-independent study, non-thesis units). All required units must be in courses at the 100-level or above, 50 percent of those units must be in graduate-level courses (generally, at the 200-level or above). No units are awarded for course work completed elsewhere (i.e., not eligible to transfer-in units). All 45 units can be applied to the 135 unit requirement for the Ph.D. The remaining 90 units can consist of all research units

On April 16, 2015, the Senate of the Academic Council approved the Doctor of Philosophy in Earth System Science. Students who matriculated into the Doctor of Philosophy in Environmental Earth System Science have the option of changing the name of their degree to Earth System Science. Degree requirements remain the same.

Doctor of Philosophy in Earth System Science

The University's requirements for the Ph.D. degree are outlined in the "Graduate Degrees (http://www.stanford.edu/dept/registrar/bulletin/4901.htm)" section of this bulletin. A summary of additional department requirements follows:

Admission

For admission to graduate work in the department, the applicant must have taken the Aptitude Test (verbal, quantitative, and analytical writing assessment) of the Graduate Record Examination. In keeping with University policy, applicants whose first language is not English must submit TOEFL (Test of English as a Foreign Language) scores from a test taken within the last 18 months. Individuals who have completed a B.S. or two-year M.S. program in the U.S. or other English-speaking country are not required to submit TOEFL scores.

Course Work

A minimum of 135 units of graduate study at Stanford must be satisfactorily completed. Required courses must be taken for a letter grade, if offered. Ph.D. students must complete the required courses in their individual program or in their specialized area of study with a grade point average (GPA) of 3.0 (B) or higher, or demonstrate that they have completed the equivalents elsewhere. Ph.D. students must complete a minimum of four graduate level, letter-grade courses of at least 3 units each from four different faculty members on the Academic Council in the University. By the end of Spring Quarter of their first year in residence, students must complete at least three graduate level courses taught by a minimum of two different ESS faculty members.

		Units
Required Core Courses		
ESS 305	Climate Change: An Earth Systems Perspective	2
ESS 306	From Freshwater to Oceans to Land Systems: An Earth System Perspective to Global Challenges	2
ESS 307	Research Proposal Development and Delivery	2
Distribution Requirements		
Area A: Analysis of the Earth System (Select one course)		
ESS 211	Fundamentals of Modeling	3-5
ESS 260	Advanced Statistical Methods for Earth System Analysis	3
Area B: Measurement of the Earth System (Select one course)		
ESS 212	Measurements in Earth Systems	3-4
ESS 241	Remote Sensing of the Oceans	3-4
ESS 262	Remote Sensing of Land	4
Area C: Earth System Processes, Models, and Human-Environmental Interactions (Select one course)		
ESS 220	Physical Hydrogeology	4
ESS 221	Contaminant Hydrogeology and Reactive Transport	4
ESS 246A	Atmosphere, Ocean, and Climate Dynamics: The Atmospheric Circulation	3
ESS 246B	Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation	3
ESS 270	Analyzing land use in a globalized world	3
Seminar Requirements		
Each quarter during the first academic year:		
EARTH 300	Earth Sciences Seminar	1
Autumn Quarter of first academic year:		
ESS 301	Topics in Earth System Science	1

Teaching Assistantship

Each student must serve as a teaching assistant in at least two quarters during their graduate career.

Annual Review

During Spring Quarter of each year, students must undergo an annual review by their thesis committee to allow the committee to monitor the progress of the student and make recommendations, where necessary.

Candidacy and Qualification Exam

Qualify for candidacy for the Ph.D. by the end of the sixth quarter in residence, excluding summers. Department procedures require selection of a faculty thesis adviser, preparation of a written research proposal, approval of this proposal by the thesis adviser, selection of a committee for the Ph.D. qualifying examination, and approval of the membership by the graduate coordinator and chair of the department. The research examination consists of three parts: oral presentation of a research proposal; examination on the research proposal; and examination on subject matter relevant to the proposed research. The exam should take place prior to May 1 so that its outcome is known at the time of the annual spring evaluation of graduate students.

Upon qualifying for Ph.D. candidacy, the student and thesis adviser, who must be a department faculty member, choose a research committee that includes a minimum of two faculty members in the University in addition to the adviser. Annually, in the month of March or April, the candidate must organize a meeting of the full research committee to present a progress report covering the past year and provide expected goals for the coming year.

Doctoral Dissertation and Oral Defense

Under the supervision of the research advisory committee, the candidate must prepare a doctoral dissertation that is a contribution to knowledge and is the result of independent research; curriculum must also be developed with the supervision of the committee, which should be designed to provide a rigorous foundation for the research area. The format of the dissertation must meet University guidelines. The student is urged to prepare dissertation chapters that, in scientific content and format, are readily publishable.

The doctoral dissertation is defended in the University oral examination. The department appoints the research adviser and two other members of the research committee to be readers of the draft dissertation. The readers are charged to read the draft and to certify in writing to the department that it is adequate to serve as a basis for the University oral examination. Upon obtaining this written certification, the student is permitted to schedule the University oral examination.

Co-Chairs: Scott Fendorf, Eric Lambin

Professors: Kevin Arrigo, C. Page Chamberlain, Robert Dunbar, Scott Fendorf, Christopher Field[1], Steven Gorelick, , Robert Jackson[2,3], Julie Kennedy, Eric Lambin[3], Pamela Matson (Dean), Rosamond Naylor [3,4]

Associate Professors: Karen Casciotti, Noah Diffenbaugh[2], Christopher Francis, David Lobell[3,4]

Assistant Professors: Marshall Burke [4], Ann Dekas, Balakanapathy Rajaratnam[5], Leif Thomas, Paula Welander

Courtesy Professors: Gregory Asner, Ken Caldeira, Anna Michalak, Peter Vitousek

Visiting Professors: Andreas Mulch, Hans Nelson, Christopher Oze, Roger Summons

[1]Joint appointment with Biology

[2]Joint appointment with the Precourt Institute for Energy

3 Joint appointment with the Woods Institute for the Environment

[4]Joint appointment with the Freeman Spogli Institute for International Studies

5 Joint appointment with Statistics

Courses

ESS 10SC. In the Age of the Anthropocene: Coupled-Human Natural Systems of Southeast Alaska. 2 Units.
Southeast Alaska is often described as America's "last frontier," embodying a physical reality of the "pristine" that was once revered by the early romantics and founders of the modern conservation movement throughout Western North America. Although endowed with more designated Wilderness land than any other state, Alaska remains a working landscape: a mixed cash-subsistence economy where communities rely upon the harvest and export of natural resources. Here, ecosystem services remain tangible, and people living in communities that are unconnected by roads confront questions of sustainability on a daily basis. This field-based course introduces students to the global questions of land use change and sustainable resource management in the American West through the place-based exploration of Southeast Alaska. Focused on four key social-ecological challenges -- fisheries, forestry, tourism, and energy -- the coupled human-natural systems of Southeast Alaska provide a unique lens for students to interpret broader resource management and conservation issues. The curriculum balances field explorations and classroom lectures with community exploration in which students will engage with fishermen, hatchery workers, forest managers, loggers, mill owners, tour operators, tourists, city officials, citizens, and Native residents. Students will catch their own salmon, walk through old-growth and logged forests, kayak next to glacial moraines, and witness the impacts of human activities, both local and global, on the social-ecological systems around them. In the context of rapidly changing ecosystems, students will confront the historical, ecological, and economic complexities of environmental stewardship in this region. By embedding their experiences within frameworks of land change science, land-ocean interactions, ecosystem ecology, and natural resource management and economics, students will leave this course ready to apply what they have learned to the global challenges of sustainability and conservation that pervade systems far beyond Alaska. This course is co-sponsored by the School of Earth Sciences and takes place in Sitka, Alaska. Students arrange for their arrival in Seattle, WA on August 30; all subsequent travel is made possible by Sophomore College and the School of Earth Sciences.

ESS 12SC. Environmental and Geological Field Studies in the Rocky Mountains. 2 Units.
The Rocky Mountain area, ecologically and geologically diverse, is being strongly impacted by changing land-use patterns, global and regional environmental change, and societal demands for energy and natural resources. This three-week field program emphasizes coupled environmental and geological problems in the Rocky Mountains and will cover a broad range of topics including the geologic origin of the American West from three billion years ago to the recent; paleoclimatology and the glacial history of this mountainous region; the long- and short-term carbon cycle and global climate change; and environmental issues in the American West that are related to changing land-use patterns and increased demand for its abundant natural resources. These broad topics are integrated into a coherent field study by examining earth/environmental science-related questions in three different settings: 1) the three-billion-year-old rocks and the modern glaciers of the Wind River Mountains of Wyoming; 2) the sediments in the adjacent Wind River basin that host abundant gas and oil reserves and also contain the long-term climate history of this region; and 3) the volcanic center of Yellowstone National Park and mountainous region of Teton National Park, and the economic and environmental problems associated with gold mining and extraction of oil and gas in areas adjoining these national parks. Students will complete six assignments based upon field exercises, working in small groups to analyze data and prepare reports and maps. Lectures will be held in the field prior to and after fieldwork. Note: This course involves one week of backpacking in the Wind Rivers and hiking while staying in cabins near Jackson Hole, Wyoming, and horseback riding in the Dubois area of Wyoming. Students must arrive in Salt Lake City on Monday, Sept. 1. (Hotel lodging will be provided for the night of Sept. 1, and thereafter students will travel as a Sophomore College group.) We will return to campus on Sunday, Sept. 21. Sophomore College Course: Application required, due noon, April 7, 2015. Apply at http://soco.stanford.edu.
Same as: EARTHSYS 12SC, GS 12SC

ESS 38N. The Worst Journey in the World: The Science, Literature, and History of Polar Exploration. 3 Units.
This course examines the motivations and experiences of polar explorers under the harshest conditions on Earth, as well as the chronicles of their explorations and hardships, dating to the 1500s for the Arctic and the 1700s for the Antarctic. Materials include The Worst Journey in the World by Aspley Cherry-Garrard who in 1911 participated in a midwinter Antarctic sledging trip to recover emperor penguin eggs. Optional field trip into the high Sierra in March.
Same as: EARTHSYS 38N, GS 38N

ESS 42. The Global Warming Paradox II. 1 Unit.
Further discussion of the complex climate challenges posed by the substantial benefits of energy consumption, including the critical tension between the enormous global demand for increased human well-being and the negative climate consequences of large-scale emissions of carbon dioxide. Discussions of topics of student interest, including peer-reviewed scientific papers, current research results, and portrayal of scientific findings by the mass media and social networks. Focus is on student engagement in on-campus and off-campus activities. Prerequisite: EESS 41N or EARTHSYS 41N or consent of instructor.
Same as: EARTHSYS 42

ESS 43. The Global Warming Paradox III. 1 Unit.
Further discussion of the complex climate challenges posed by the substantial benefits of energy consumption, including the critical tension between the enormous global demand for increased human well-being and the negative climate consequences of large-scale emissions of carbon dioxide. Discussions explore topics of student interest, including peer-reviewed scientific papers, current research results, and portrayal of scientific findings by the mass media and social networks. Focus is on student engagement in on-campus and off-campus activities.May be repeat for credit.

ESS 46N. Exploring the Critical Interface between the Land and Monterey Bay: Elkhorn Slough. 3 Units.
Preference to freshmen. Field trips to sites in the Elkhorn Slough, a small agriculturally impacted estuary that opens into Monterey Bay, a model ecosystem for understanding the complexity of estuaries, and one of California's last remaining coastal wetlands. Readings include Jane Caffrey's *Changes in a California Estuary: A Profile of Elkhorn Slough*. Basics of biogeochemistry, microbiology, oceanography, ecology, pollution, and environmental management.
Same as: EARTHSYS 46N

ESS 49N. Multi-Disciplinary Perspectives on a Large Urban Estuary: San Francisco Bay. 3 Units.
This course will be focused around San Francisco Bay, the largest estuary on the Pacific coasts of both North and South America as a model ecosystem for understanding the critical importance and complexity of estuaries. Despite its uniquely urban and industrial character, the Bay is of immense ecological value and encompasses over 90% of California's remaining coastal wetlands. Students will be exposed to the basics of estuarine biogeochemistry, microbiology, ecology, hydrodynamics, pollution, and ecosystem management/restoration issues through lectures, interactive discussions, and field trips. Knowledge of introductory biology and chemistry is recommended.
Same as: CEE 50N, EARTHSYS 49N

ESS 56Q. Changes in the Coastal Ocean: The View From Monterey and San Francisco Bays. 3 Units.
Preference to sophomores. Recent changes in the California current, using Monterey Bay as an example. Current literature introduces principles of oceanography. Visits from researchers from MBARI, Hopkins, and UCSC. Optional field trip to MBARI and Monterey Bay.
Same as: EARTHSYS 56Q

ESS 57Q. Climate Change from the Past to the Future. 3 Units.
Preference to sophomores. Numeric models to predict how climate responds to increase of greenhouse gases. Paleoclimate during times in Earth's history when greenhouse gas concentrations were elevated with respect to current concentrations. Predicted scenarios of climate models and how these models compare to known hyperthermal events in Earth history. Interactions and feedbacks among biosphere, hydrosphere, atmosphere, and lithosphere. Topics include long- and short-term carbon cycle, coupled biogeochemical cycles affected by and controlling climate change, and how the biosphere responds to climate change. Possible remediation strategies.
Same as: EARTHSYS 57Q

ESS 60. Food, Water and War: Life on the Mekong. 1 Unit.
Preparatory course for Bing Overseas Studies summer course in Cambodia. Prerequisite. Requires instructor consent.

ESS 61Q. Food and security. 3 Units.
The course will provide a broad overview of key policy issues concerning agricultural development and food security, and will assess how global governance is addressing the problem of food security. At the same time the course will provide an overview of the field of international security, and examine how governments and international institutions are beginning to include food in discussions of security.
Same as: EARTHSYS 61Q, INTNLREL 61Q

ESS 101. Environmental and Geological Field Studies in the Rocky Mountains. 3 Units.
Three-week, field-based program in the Greater Yellowstone/Teton and Wind River Mountains of Wyoming. Field-based exercises covering topics including: basics of structural geology and petrology; glacial geology; western cordillera geology; paleoclimatology; chemical weathering; aqueous geochemistry; and environmental issues such as acid mine drainage and changing land-use patterns.
Same as: EARTHSYS 100, GS 101

ESS 105. Food and Community: New Visions for a Sustainable Future. 3 Units.
Through this course students will learn about the community and outreach component of the urban gardening movement. Over the quarter students will learn about urban farming, about projects that work to increase access of the most underserved to fresh and local food, and about the challenges surrounding these efforts. The theme of the course will be stories- stories of food and community, of innovation, and of service. Students will learn through engaging in conversation with different leaders in the local food movement. Additionally, through hands-on learning and participation, students will become familiar with different types of community food projects in the Bay Area, including urban farms, free food giveaways, food banks, and gleaning projects. Service Learning Course (certified by Haas Center). Limited enrollment. May be repeated for credit.
Same as: EARTHSYS 105

ESS 106. World Food Economy. 5 Units.
The economics of food production, consumption, and trade. The micro- and macro- determinants of food supply and demand, including the interrelationship among food, income, population, and public-sector decision making. Emphasis on the role of agriculture in poverty alleviation, economic development, and environmental outcomes. (graduate students enroll in 206).
Same as: EARTHSYS 106, EARTHSYS 206, ECON 106, ECON 206, ESS 206

ESS 107. Control of Nature. 3 Units.
Think controlling the earthiquest;s climate is science fiction? It is when you watch Snowpiercer or Dune, but scientists are already devising geoengineering schemes to slow climate change. Will we ever resurrect the woolly mammoth or even a T. Rex (think Jurassic Park)? Based on current research, that day will come in your lifetime. Who gets to decide what species to save? And more generally, what scientific and ethical principles should guide our decisions to control nature? In this course, we will examine the science behind ways that people alter and engineer the earth, critically examining the positive and negative consequences. Weiquest;ll explore these issues first through popular movies and books and then, more substantively, in scientific research.
Same as: EARTHSYS 107

ESS 111. Biology and Global Change. 4 Units.
The biological causes and consequences of anthropogenic and natural changes in the atmosphere, oceans, and terrestrial and freshwater ecosystems. Topics: glacial cycles and marine circulation, greenhouse gases and climate change, tropical deforestation and species extinctions, and human population growth and resource use. Prerequisite: Biology or Human Biology core or graduate standing.
Same as: BIO 117, EARTHSYS 111

ESS 112. Human Society and Environmental Change. 4 Units.
Interdisciplinary approaches to understanding human-environment interactions with a focus on economics, policy, culture, history, and the role of the state. Prerequisite: ECON 1.
Same as: EARTHSYS 112, HISTORY 103D

ESS 117. Earth Sciences of the Hawaiian Islands. 4 Units.
Progression from volcanic processes through rock weathering and soil-ecosystem development to landscape evolution. The course starts with an investigation of volcanic processes, including the volcano structure, origin of magmas, physical-chemical factors of eruptions. Factors controlling rock weathering and soil development, including depth and nutrient levels impacting plant ecosystems, are explored next. Geomorphic processes of landscape evolution including erosion rates, tectonic/volcanic activity, and hillslope stability conclude the course. Methods for monitoring and predicting eruptions, defining spatial changes in landform, landform stability, soil production rates, and measuring biogeochemical processes are covered throughout the course. This course is restricted to students accepted into the Earth Systems of Hawaii Program.
Same as: EARTH 117, EARTHSYS 117

ESS 118. Understanding Natural Hazards, Quantifying Risk, Increasing Resilience in Highly Urbanized Regions. 3 Units.
Integrating the science of natural hazards, methods for quantitatively estimating the risks that these hazards pose to populations and property, engineering solutions that might best ameliorate these risks and increase resilience to future events, and policy and economic decision-making studies that may increase long-term resilience to future events. Panel discussions by outside experts exploring the science, engineering, policy, and economics that underly the hazards, risks, and strategies for increasing resilience. Group assignments to evaluate the way in which natural hazards, and human population and developing interact in megacities to produce risk, and what strategies might be adopted in each area to reduce risks posted by the specific hazards faced by these urban areas.
Same as: ESS 218, GEOPHYS 118, GEOPHYS 218, GS 118, GS 218

ESS 122. GIS for good: Applications of GIS for International Development and Humanitarian Assistance. 3-4 Units.
This service-learning course exposes students to geographic information systems (GIS) as a tool for exploring alternative solutions to complex environmental and humanitarian issues in the international arena. The project-based, interdisciplinary structure of this class gives primary emphasis to the use of GIS for field data collection, mapping, analysis and visualization that allows for multi-criteria assessment of community development. Those with no prior GIS experience will be required to take an introductory GIS workshop hosted by the Geospatial Center in Branner Library during the first two weeks of class.
Same as: EARTHSYS 127, ESS 222

ESS 141. Remote Sensing of the Oceans. 3-4 Units.
How to observe and interpret physical and biological changes in the oceans using satellite technologies. Topics: principles of satellite remote sensing, classes of satellite remote sensors, converting radiometric data into biological and physical quantities, sensor calibration and validation, interpreting large-scale oceanographic features.
Same as: EARTHSYS 141, EARTHSYS 241, ESS 241, GEOPHYS 141

ESS 146A. Atmosphere, Ocean, and Climate Dynamics: The Atmospheric Circulation. 3 Units.
Introduction to the physics governing the circulation of the atmosphere and ocean and their control on climate with emphasis on the atmospheric circulation. Topics include the global energy balance, the greenhouse effect, the vertical and meridional structure of the atmosphere, dry and moist convection, the equations of motion for the atmosphere and ocean, including the effects of rotation, and the poleward transport of heat by the large-scale atmospheric circulation and storm systems. Prerequisites: MATH 51 or CME100 and PHYSICS 41.
Same as: EARTHSYS 146A, EARTHSYS 246A, ESS 246A, GEOPHYS 146A, GEOPHYS 246A

ESS 146B. Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation. 3 Units.
Introduction to the physics governing the circulation of the atmosphere and ocean and their control on climate with emphasis on the large-scale ocean circulation. This course will give an overview of the structure and dynamics of the major ocean current systems that contribute to the meridional overturning circulation, the transport of heat, salt, and biogeochemical tracers, and the regulation of climate. Topics include the tropical ocean circulation, the wind-driven gyres and western boundary currents, the thermohaline circulation, the Antarctic Circumpolar Current, water mass formation, atmosphere-ocean coupling, and climate variability. Prerequisites: EESS 146A or EESS 246A, or CEE 164 or CEE 262D, or consent of instructor.
Same as: EARTHSYS 146B, EARTHSYS 246B, ESS 246B, GEOPHYS 146B, GEOPHYS 246B

ESS 148. Introduction to Physical Oceanography. 4 Units.
The dynamic basis of oceanography. Topics: physical environment; conservation equations for salt, heat, and momentum; geostrophic flows; wind-driven flows; the Gulf Stream; equatorial dynamics and ENSO; thermohaline circulation of the deep oceans; and tides. Prerequisite: PHYSICS 41 (formerly 53).
Same as: CEE 164, CEE 262D, EARTHSYS 164

ESS 151. Biological Oceanography. 3-4 Units.
Required for Earth Systems students in the oceans track. Interdisciplinary look at how oceanic environments control the form and function of marine life. Topics include distributions of planktonic production and abundance, nutrient cycling, the role of ocean biology in the climate system, expected effects of climate changes on ocean biology. Local weekend field trips. Designed to be taken concurrently with Marine Chemistry (EESS/EARTHSYS 152/252). Prerequisites: BIO 43 and EESS 8 or equivalent.
Same as: EARTHSYS 151, EARTHSYS 251, ESS 251

ESS 152. Marine Chemistry. 3-4 Units.
Introduction to the interdisciplinary knowledge and skills required to critically evaluate problems in marine chemistry and related disciplines. Physical, chemical, and biological processes that determine the chemical composition of seawater. Air-sea gas exchange, carbonate chemistry, and chemical equilibria, nutrient and trace element cycling, particle reactivity, sediment chemistry, and diagenesis. Examination of chemical tracers of mixing and circulation and feedbacks of ocean processes on atmospheric chemistry and climate. Designed to be taken concurrently with Biological Oceanography (EESS/EARTHSYS 151/251).
Same as: EARTHSYS 152, EARTHSYS 252, ESS 252

ESS 155. Science of Soils. 3-4 Units.
Physical, chemical, and biological processes within soil systems. Emphasis is on factors governing nutrient availability, plant growth and production, land-resource management, and pollution within soils. How to classify soils and assess nutrient cycling and contaminant fate. Recommended: introductory chemistry and biology.
Same as: EARTHSYS 155

ESS 156. Soil and Water Chemistry. 1-4 Unit.
(Graduate students register for 256.) Practical and quantitative treatment of soil processes affecting chemical reactivity, transformation, retention, and bioavailability. Principles of primary areas of soil chemistry: inorganic and organic soil components, complex equilibria in soil solutions, and adsorption phenomena at the solid-water interface. Processes and remediation of acid, saline, and wetland soils. Recommended: soil science and introductory chemistry and microbiology.
Same as: EARTHSYS 156, EARTHSYS 256, ESS 256

ESS 158. Geomicrobiology. 3 Units.
How microorganisms shape the geochemistry of the Earth's crust including oceans, lakes, estuaries, subsurface environments, sediments, soils, mineral deposits, and rocks. Topics include mineral formation and dissolution; biogeochemical cycling of elements (carbon, nitrogen, sulfur, and metals); geochemical and mineralogical controls on microbial activity, diversity, and evolution; life in extreme environments; and the application of new techniques to geomicrobial systems. Recommended: introductory chemistry and microbiology such as CEE 274A.
Same as: EARTHSYS 158, EARTHSYS 258, ESS 258

ESS 162. Remote Sensing of Land. 4 Units.
The use of satellite remote sensing to monitor land use and land cover, with emphasis on terrestrial changes. Topics include pre-processing data, biophysical properties of vegetation observable by satellite, accuracy assessment of maps derived from remote sensing, and methodologies to detect changes such as urbanization, deforestation, vegetation health, and wildfires.
Same as: EARTHSYS 142, EARTHSYS 242, ESS 262

ESS 164. Fundamentals of Geographic Information Science (GIS). 3-4 Units.
Survey of geographic information including maps, satellite imagery, and census data, approaches to spatial data, and tools for integrating and examining spatially-explicit data. Emphasis is on fundamental concepts of geographic information science and associated technologies. Topics include geographic data structure, cartography, remotely sensed data, statistical analysis of geographic data, spatial analysis, map design, and geographic information system software. Computer lab assignments. All students are required to attend a weekly lab on Tuesdays or Thursdays from 6 pm to 9 pm.
Same as: EARTHSYS 144

ESS 173. Aquaculture and the Environment: Science, History, and Policy. 3 Units.
Can aquaculture feed billions of people without degrading aquatic ecosystems or adversely impacting local communities? Interdisciplinary focus on aquaculture science and management, international seafood markets, historical case studies (salmon farming in Chile, tuna ranching in the Mediterranean, shrimp farming in Vietnam), current federal/state legislation. Field trip to aquaculture farm and guest lectures. By application only - instructor consent required. Contact gerhart@stanford.edu or dhklinger@stanford.edu prior to first day of class.
Same as: EARTHSYS 173, EARTHSYS 273, ESS 273

ESS 179S. Seminar: Issues in Environmental Science, Technology and Sustainability. 1-2 Unit.
Invited faculty, researchers and professionals share their insights and perspectives on a broad range of environmental and sustainability issues. Students critique seminar presentations and associated readings.
Same as: CEE 179S, CEE 279S, EARTHSYS 179S

ESS 181. Urban Agriculture in the Developing World. 3-4 Units.
In this advanced undergraduate course, students will learn about some of the key social and environmental challenges faced by cities in the developing world, and the current and potential role that urban agriculture plays in meeting (or exacerbating) those challenges. This is a service-learning course, and student teams will have the opportunity to partner with real partner organizations in a major developing world city to define and execute a project focused on urban development, and the current or potential role of urban agriculture. Service-learning projects will employ primarily the student's analytical skills such as synthesis of existing research findings, interdisciplinary experimental design, quantitative data analysis and visualization, GIS, and qualitative data collection through interviews and textual analysis. Previous coursework in the aforementioned analytical skills is preferred, but not required. Admission is by application.
Same as: EARTHSYS 181, EARTHSYS 281, ESS 281, URBANST 181

ESS 183. Food Matters: Agriculture in Film. 1 Unit.
Film series presenting historical and contemporary issues dealing with food and agriculture across the globe. Students discuss reactions and thoughts in a round table format. May be repeated for credit.
Same as: EARTHSYS 183, EARTHSYS 283, ESS 283

ESS 184. Climate and Agriculture. 3-4 Units.
The effects of climate change on global agriculture and food security, and the effects of agriculture on climate change. An overview of different lines of evidence used to measure impacts and adaptations, and to quantify future impacts, risks, and adaptation needs for agro-ecosystems and society. Enrollment limited to 25; priority to juniors, seniors, and graduate students. Prerequisites: ECON 106/206 or permission of instructor.
Same as: EARTHSYS 184, EARTHSYS 284, ESS 284

ESS 206. World Food Economy. 5 Units.
The economics of food production, consumption, and trade. The micro- and macro- determinants of food supply and demand, including the interrelationship among food, income, population, and public-sector decision making. Emphasis on the role of agriculture in poverty alleviation, economic development, and environmental outcomes. (graduate students enroll in 206).
Same as: EARTHSYS 106, EARTHSYS 206, ECON 106, ECON 206, ESS 106

ESS 208. Topics in Geobiology. 1 Unit.
Reading and discussion of classic and recent papers in the field of Geobiology. Co-evolution of Earth and life; critical intervals of environmental and biological change; geomicrobiology; paleobiology; global biogeochemical cycles; scaling of geobiological processes in space and time.
Same as: GS 208

ESS 211. Fundamentals of Modeling. 3-5 Units.
Simulation models are a powerful tool for environmental research, if used properly. The major concepts and techniques for building and evaluating models. Topics include model calibration, model selection, uncertainty and sensitivity analysis, and Monte Carlo and bootstrap methods. Emphasis is on gaining hands-on experience using the R programming language. Prerequisite: Basic knowledge of statistics.
Same as: EARTHSYS 211

ESS 212. Measurements in Earth Systems. 3-4 Units.
Restricted to EESS first-year, graduate students. Techniques to track biological, chemical, and physical processes operating across the San Francisquito Creek watershed, encompassing upland, aquatic, estuarine, and marine environments. Topics include gas and water flux measurement, assessment of microbiological communities, determination of biological productivity, isotopic analysis, soil and water chemistry determination, and identification of rock strata and weathering processes.

ESS 214. Introduction to geostatistics and modeling of spatial uncertainty. 3-4 Units.
Introduction of fundamental geostatistical tools for modeling spatial variability and uncertainty, and mapping of environmental attributes. Additional topics include sampling design and incorporation of different types of information (continuous, categorical) in prediction. Assignments consist of small problems to familiarize students with theoretical concepts, and applications dealing with the analysis and interpretation of various data sets (soil, water pollution, atmospheric constituents, remote sensing) primarily using Matlab. No prior programming experience is required. Open to graduates. Open to undergraduates with consent from the instructor. 3-credit option includes midterm/final or student-developed project. 4-credit option requires both. Prerequisite: College-level introductory statistics.

ESS 215. Earth System Dynamics. 2 Units.
This is a graduate level course that examines the dynamics of the Earth System from an integrated perspective. Lectures introduce the physical, biogeochemical, ecological, and human dimensions of the Earth System, with emphasis on feedbacks, thresholds and tipping points. Human interactions with climate and land systems are emphasized in order to enable in-depth exploration of Earth System dynamics. Lab projects focus on a region of the globe for which rich coordinated data sources exist and complex Earth System dynamics dominate the environment.

ESS 216. Terrestrial Biogeochemistry. 3 Units.
Nutrient cycling and the regulation of primary and secondary production in terrestrial, freshwater, and marine ecosystems; land-water and biosphere-atmosphere interactions; global element cycles and their regulation; human effects on biogeochemical cycles. Prerequisite: graduate standing in science or engineering; consent of instructor for undergraduates or coterminal students.
Same as: BIO 216

ESS 217. Climate of the Cenozoic. 3 Units.
For upper-division undergraduate and graduate students. The paleoclimate of the Cenozoic and how climate changes in the past link to the carbon cycle. Topics include long- and short-term records of climate on continents and oceans, evidence for and causes of hyperthermal events, how the Earth's climate has responded in increased carbon dioxide in the atmosphere. Guest speakers, student presentations.

ESS 218. Understanding Natural Hazards, Quantifying Risk, Increasing Resilience in Highly Urbanized Regions. 3 Units.
Integrating the science of natural hazards, methods for quantitatively estimating the risks that these hazards pose to populations and property, engineering solutions that might best ameliorate these risks and increase resilience to future events, and policy and economic decision-making studies that may increase long-term resilience to future events. Panel discussions by outside experts exploring the science, engineering, policy, and economics that underly the hazards, risks, and strategies for increasing resilience. Group assignments to evaluate the way in which natural hazards, and human population and developing interact in megacities to produce risk, and what strategies might be adopted in each area to reduce risks posted by the specific hazards faced by these urban areas.
Same as: ESS 118, GEOPHYS 118, GEOPHYS 218, GS 118, GS 218

ESS 219. Climate Variability during the Holocene: Understanding what is Natural Climate Change. 3 Units.
Many elements of the debate about attribution of modern climate change to man-made influences hinge on understanding the past history of climate as well as forcing functions such as solar output, volcanism, and "natural" trace gas variability. Interest in Holocene reconstructions of past climate and forcing functions has surged in the last 20 years providing a robust literature set for discussion and analysis. The goal of this class is to provide graduate students with a view of the archives available for Holocene paleoenvironmental analysis, the tracers that are used, and the results thus far. We will also explore the world of data-model comparisons and examine the role that paleorecords play in the IPCC reports. The class will consist of some lectures as well as many class discussions based on assigned readings.

ESS 220. Physical Hydrogeology. 4 Units.
(Formerly GES 230.) Theory of underground water occurrence and flow, analysis of field data and aquifer tests, geologic groundwater environments, solution of field problems, and groundwater modeling. Introduction to groundwater contaminant transport and unsaturated flow. Lab. Prerequisite: elementary calculus.
Same as: CEE 260A

ESS 221. Contaminant Hydrogeology and Reactive Transport. 4 Units.
For earth scientists and engineers. Environmental, geologic, and water resource problems involving migration of contaminated groundwater through porous media and associated biogeochemical and fluid-rock reactions. Conceptual and quantitative treatment of advective-dispersive transport with reacting solutes. Predictive models of contaminant behavior controlled by local equilibrium and kinetics. Modern methods of contaminant transport simulation and reactive transport modeling using geochemical transport software. Some Matlab programming / program modification required. Prerequisite: Physical Hydrogeology EESS 220 / CEE 260A (Gorelick) or equivalent. Recommended: course work in environmental chemistry or geochemistry (e.g., one or more of the following: EESS 155, EESS 156/256 GES 90, GES 170/279, GES 171, CEE 177 or CEE 270).
Same as: CEE 260C, GS 225

ESS 222. GIS for good: Applications of GIS for International Development and Humanitarian Assistance. 3-4 Units.
This service-learning course exposes students to geographic information systems (GIS) as a tool for exploring alternative solutions to complex environmental and humanitarian issues in the international arena. The project-based, interdisciplinary structure of this class gives primary emphasis to the use of GIS for field data collection, mapping, analysis and visualization that allows for multi-criteria assessment of community development. Those with no prior GIS experience will be required to take an introductory GIS workshop hosted by the Geospatial Center in Branner Library during the first two weeks of class.
Same as: EARTHSYS 127, ESS 122

ESS 240. Advanced Oceanography. 3 Units.
For upper-division undergraduates and graduate students in the earth, biologic, and environmental sciences. Topical issues in marine science/oceanography. Topics vary each year following or anticipating research trends in oceanographic research. Focus is on links between the circulation and physics of the ocean with climate in the N. Pacific region, and marine ecologic responses. Participation by marine scientists from research groups and organizations including the Monterey Bay Aquarium Research Institute.

ESS 241. Remote Sensing of the Oceans. 3-4 Units.
How to observe and interpret physical and biological changes in the oceans using satellite technologies. Topics: principles of satellite remote sensing, classes of satellite remote sensors, converting radiometric data into biological and physical quantities, sensor calibration and validation, interpreting large-scale oceanographic features.
Same as: EARTHSYS 141, EARTHSYS 241, ESS 141, GEOPHYS 141

ESS 242. Antarctic Marine Geology. 3 Units.
For upper-division undergraduates and graduate students. Intermediate and advanced topics in marine geology and geophysics, focusing on examples from the Antarctic continental margin and adjacent Southern Ocean. Topics: glaciers, icebergs, and sea ice as geologic agents (glacial and glacial marine sedimentology, Southern Ocean current systems and deep ocean sedimentation), Antarctic biostratigraphy and chronostratigraphy (continental margin evolution). Students interpret seismic lines and sediment core/well log data. Examples from a recent scientific drilling expedition to Prydz Bay, Antarctica. Up to two students may have an opportunity to study at sea in Antarctica during Winter Quarter.
Same as: EARTHSYS 272

ESS 244. Marine Ecosystem Modeling. 3 Units.
This course will provide the practical background necessary to construct and implement a 2-dimensional (space and time) numerical model of a simple marine ecosystem. Instruction on computer programming, model design and parameterization, and model evaluation will be provided. Throughout the 10-week course, each student will develop and refine their own multi-component marine ecosystem model. Instructor consent required.

ESS 245. Advanced Biological Oceanography. 3-4 Units.
For upper-division undergraduates and graduate students. Themes vary annually but include topics such as marine bio-optics, marine ecological modeling, and phytoplankton primary production. May be repeated for credit. Enrollment by instructor consent only.

ESS 246A. Atmosphere, Ocean, and Climate Dynamics: The Atmospheric Circulation. 3 Units.
Introduction to the physics governing the circulation of the atmosphere and ocean and their control on climate with emphasis on the atmospheric circulation. Topics include the global energy balance, the greenhouse effect, the vertical and meridional structure of the atmosphere, dry and moist convection, the equations of motion for the atmosphere and ocean, including the effects of rotation, and the poleward transport of heat by the large-scale atmospheric circulation and storm systems. Prerequisites: MATH 51 or CME100 and PHYSICS 41.
Same as: EARTHSYS 146A, EARTHSYS 246A, ESS 146A, GEOPHYS 146A, GEOPHYS 246A

ESS 246B. Atmosphere, Ocean, and Climate Dynamics: the Ocean Circulation. 3 Units.
Introduction to the physics governing the circulation of the atmosphere and ocean and their control on climate with emphasis on the large-scale ocean circulation. This course will give an overview of the structure and dynamics of the major ocean current systems that contribute to the meridional overturning circulation, the transport of heat, salt, and biogeochemical tracers, and the regulation of climate. Topics include the tropical ocean circulation, the wind-driven gyres and western boundary currents, the thermohaline circulation, the Antarctic Circumpolar Current, water mass formation, atmosphere-ocean coupling, and climate variability. Prerequisites: EESS 146A or EESS 246A, or CEE 164 or CEE 262D, or consent of instructor.
Same as: EARTHSYS 146B, EARTHSYS 246B, ESS 146B, GEOPHYS 146B, GEOPHYS 246B

ESS 249. Marine Stable Isotopes. 3 Units.
This course will provide an introduction to stable isotopes biogeochemistry with emphasis on applications in marine science. We will cover fundamental concepts of nuclear structure and origin of elements and isotopes, and stable isotopic fractionation. We will discuss mass spectrometry techniques, mass independent fractionation, clumped isotopes, mass balance and box models. Applications of these concepts to studies of ocean circulation, marine carbon and nitrogen cycles, primary productivity, and particle scavenging will also be discussed.

ESS 250. Elkhorn Slough Microbiology. 3 Units.
(Formerly GES 270.) The microbial ecology and biogeochemistry of Elkhorn Slough, an agriculturally-impacted coastal estuary draining into Monterey Bay. The diversity of microbial lifestyles associated with estuarine physical/chemical gradients, and the influence of microbial activity on the geochemistry of the Slough, including the cycling of carbon, nitrogen, sulfur, and metals. Labs and field work. Location: Hopkins Marine Station.

ESS 251. Biological Oceanography. 3-4 Units.
Required for Earth Systems students in the oceans track. Interdisciplinary look at how oceanic environments control the form and function of marine life. Topics include distributions of planktonic production and abundance, nutrient cycling, the role of ocean biology in the climate system, expected effects of climate changes on ocean biology. Local weekend field trips. Designed to be taken concurrently with Marine Chemistry (EESS/EARTHSYS 152/252). Prerequisites: BIO 43 and EESS 8 or equivalent.
Same as: EARTHSYS 151, EARTHSYS 251, ESS 151

ESS 252. Marine Chemistry. 3-4 Units.
Introduction to the interdisciplinary knowledge and skills required to critically evaluate problems in marine chemistry and related disciplines. Physical, chemical, and biological processes that determine the chemical composition of seawater. Air-sea gas exchange, carbonate chemistry, and chemical equilibria, nutrient and trace element cycling, particle reactivity, sediment chemistry, and diagenesis. Examination of chemical tracers of mixing and circulation and feedbacks of ocean processes on atmospheric chemistry and climate. Designed to be taken concurrently with Biological Oceanography (EESS/EARTHSYS 151/251).
Same as: EARTHSYS 152, EARTHSYS 252, ESS 152

ESS 253S. Hopkins Microbiology Course. 3-12 Units.
(Formerly GES 274S.) Four-week, intensive. The interplay between molecular, physiological, ecological, evolutionary, and geochemical processes that constitute, cause, and maintain microbial diversity. How to isolate key microorganisms driving marine biological and geochemical diversity, interpret culture-independent molecular characterization of microbial species, and predict causes and consequences. Laboratory component: what constitutes physiological and metabolic microbial diversity; how evolutionary and ecological processes diversify individual cells into physiologically heterogeneous populations; and the principles of interactions between individuals, their population, and other biological entities in a dynamically changing microbial ecosystem. Prerequisites: CEE 274A and CEE 274B, or equivalents.
Same as: BIO 274S, BIOHOPK 274, CEE 274S

ESS 255. Microbial Physiology. 3 Units.
Introduction to the physiology of microbes including cellular structure, transcription and translation, growth and metabolism, mechanisms for stress resistance and the formation of microbial communities. These topics will be covered in relation to the evolution of early life on Earth, ancient ecosystems, and the interpretation of the rock record. Recommended: introductory biology and chemistry.
Same as: BIO 180, EARTHSYS 255, GS 233A

ESS 256. Soil and Water Chemistry. 1-4 Unit.
(Graduate students register for 256.) Practical and quantitative treatment of soil processes affecting chemical reactivity, transformation, retention, and bioavailability. Principles of primary areas of soil chemistry: inorganic and organic soil components, complex equilibria in soil solutions, and adsorption phenomena at the solid-water interface. Processes and remediation of acid, saline, and wetland soils. Recommended: soil science and introductory chemistry and microbiology.
Same as: EARTHSYS 156, EARTHSYS 256, ESS 156

ESS 258. Geomicrobiology. 3 Units.
How microorganisms shape the geochemistry of the Earth's crust including oceans, lakes, estuaries, subsurface environments, sediments, soils, mineral deposits, and rocks. Topics include mineral formation and dissolution; biogeochemical cycling of elements (carbon, nitrogen, sulfur, and metals); geochemical and mineralogical controls on microbial activity, diversity, and evolution; life in extreme environments; and the application of new techniques to geomicrobial systems. Recommended: introductory chemistry and microbiology such as CEE 274A.
Same as: EARTHSYS 158, EARTHSYS 258, ESS 158

ESS 259. Environmental Microbial Genomics. 1-3 Unit.
The application of molecular and environmental genomic approaches to the study of biogeochemically-important microorganisms in the environment without the need for cultivation. Emphasis is on genomic analysis of microorganisms by direct extraction and cloning of DNA from natural microbial assemblages. Topics include microbial energy generation and nutrient cycling, genome structure, gene function, physiology, phylogenetic and functional diversity, evolution, and population dynamics of uncultured communities.

ESS 260. Advanced Statistical Methods for Earth System Analysis. 3 Units.
Introduction for graduate students to important issues in data analysis relevant to earth system studies. Emphasis on methodology, concepts and implementation (in R), rather than formal proofs. Likely topics include the bootstrap, non-parametric methods, regression in the presence of spatial and temporal correlation, extreme value analysis, time-series analysis, high-dimensional regressions and change-point models. Topics subject to change each year. Prerequisites: STATS 110 or equivalent.
Same as: STATS 360

ESS 261. Molecular Microbial Biosignatures. 1-3 Unit.
Critical reading and discussion of literature on molecular biosignatures as indicators of microbial life and metabolisms in modern and ancient environments. Focus will be primarily on recalcitrant lipids that form chemical fossils and topics covered will include biosynthetic pathways of these lipids, their phylogenetic origins, their physiological roles in modern organisms, and their occurrence throughout the geological record. Recommended: microbiology and organic chemistry.
Same as: GS 234A

ESS 262. Remote Sensing of Land. 4 Units.
The use of satellite remote sensing to monitor land use and land cover, with emphasis on terrestrial changes. Topics include pre-processing data, biophysical properties of vegetation observable by satellite, accuracy assessment of maps derived from remote sensing, and methodologies to detect changes such as urbanization, deforestation, vegetation health, and wildfires.
Same as: EARTHSYS 142, EARTHSYS 242, ESS 162

ESS 263. Topics in Advanced Geostatistics. 3-4 Units.
Conditional expectation theory and projections in Hilbert spaces; parametric versus non-parametric geostatistics; Boolean, Gaussian, fractal, indicator, and annealing approaches to stochastic imaging; multiple point statistics inference and reproduction; neural net geostatistics; Bayesian methods for data integration; techniques for upscaling hydrodynamic properties. May be repeated for credit. Prerequisites: 240, advanced calculus, C++/Fortran.
Same as: ENERGY 242

ESS 270. Analyzing land use in a globalized world. 3 Units.
This is a graduate level course that examines the dynamics of land use in relation to the multiple dimensions of globalization. The objective is to understand and analyze how the expansion of global trade, the emergence of new global actors, and public and private regulations affect land use changes. Beyond getting a better understanding of the dynamics of land use change, the course will enable students to better understand how to effectively influence land use change, from different vantage points: government, NGO, information broker, corporate actor. The main emphasis is on tropical regions. Lectures introduce various topics related to theories, practical cases, and evaluation tools to better understand and analyze contemporary land use dynamics. Data analyses will be conducted in the lab section, based on case studies.

ESS 273. Aquaculture and the Environment: Science, History, and Policy. 3 Units.
Can aquaculture feed billions of people without degrading aquatic ecosystems or adversely impacting local communities? Interdisciplinary focus on aquaculture science and management, international seafood markets, historical case studies (salmon farming in Chile, tuna ranching in the Mediterranean, shrimp farming in Vietnam), current federal/state legislation. Field trip to aquaculture farm and guest lectures. By application only - instructor consent required. Contact gerhart@stanford.edu or dhklinger@stanford.edu prior to first day of class.
Same as: EARTHSYS 173, EARTHSYS 273, ESS 173

ESS 280B. Principles and Practices of Sustainable Agriculture. 3-4 Units.
Field-based training in ecologically sound agricultural practices at the Stanford Community Farm. Weekly lessons, field work, and group projects. Field trips to educational farms in the area. Topics include: soils, composting, irrigation techniques, IPM, basic plant anatomy and physiology, weeds, greenhouse management, and marketing.
Same as: EARTHSYS 180B

ESS 281. Urban Agriculture in the Developing World. 3-4 Units.
In this advanced undergraduate course, students will learn about some of the key social and environmental challenges faced by cities in the developing world, and the current and potential role that urban agriculture plays in meeting (or exacerbating) those challenges. This is a service-learning course, and student teams will have the opportunity to partner with real partner organizations in a major developing world city to define and execute a project focused on urban development, and the current or potential role of urban agriculture. Service-learning projects will employ primarily the student's analytical skills such as synthesis of existing research findings, interdisciplinary experimental design, quantitative data analysis and visualization, GIS, and qualitative data collection through interviews and textual analysis. Previous coursework in the aforementioned analytical skills is preferred, but not required. Admission is by application.
Same as: EARTHSYS 181, EARTHSYS 281, ESS 181, URBANST 181

ESS 282. Ecological Farm Management. 1 Unit.
A project-based course emphasizing `ways of doingiquest; in sustainable agricultural systems based at the new Stanford Educational Farm. Students will work individually and in small groups on farm projects of their choice facilitated and guided by the Educational Farm Director. Potential projects include: orchards, compost systems, pastured poultry, beekeeping, medicinal herbs, mushroom cultivation, native plants, etc.
Same as: EARTHSYS 182

ESS 283. Food Matters: Agriculture in Film. 1 Unit.
Film series presenting historical and contemporary issues dealing with food and agriculture across the globe. Students discuss reactions and thoughts in a round table format. May be repeated for credit.
Same as: EARTHSYS 183, EARTHSYS 283, ESS 183

ESS 284. Climate and Agriculture. 3-4 Units.
The effects of climate change on global agriculture and food security, and the effects of agriculture on climate change. An overview of different lines of evidence used to measure impacts and adaptations, and to quantify future impacts, risks, and adaptation needs for agro-ecosystems and society. Enrollment limited to 25; priority to juniors, seniors, and graduate students. Prerequisites: ECON 106/206 or permission of instructor.
Same as: EARTHSYS 184, EARTHSYS 284, ESS 184

ESS 292. Directed Individual Study in Environmental Earth System Science. 1-10 Unit.
Under supervision of an Environmental Earth System Science faculty member on a subject of mutual interest.

ESS 300. Climate studies of terrestrial environments. 3 Units.
This course will consist of a weekly seminar covering topics of interest in Cenozoic climate. The course examines the interactions between the biosphere, atmosphere and geosphere and how these interactions influence climate. The course will cover classic and seminal papers on the controls of the oxygen, hydrogen, and carbon isotopes of the hydrosphere, atmosphere and biosphere and how they are expressed in paleoclimate proxies. Seminar will consist of reading and discussion of these papers. Students will be responsible for presenting papers. Grades will be determined by class participation. (Chamberlain).

ESS 301. Topics in Earth System Science. 1 Unit.
Current topics, issues, and research related to interactions that link the oceans, atmosphere, land surfaces and freshwater systems. May be repeated for credit.

ESS 305. Climate Change: An Earth Systems Perspective. 2 Units.
A graduate-level, seminar-style class on climate nchange structured around the IPCCiquest;s AR5. Significant reading load and nweekly talks by a rotating roster of contributing and lead authors from nthe IPCC. The focus will be on the physical science basis, adaptation nand impacts (working groups 1 and 2), with some material drawn from nmitigation (working group 3).

ESS 306. From Freshwater to Oceans to Land Systems: An Earth System Perspective to Global Challenges. 2 Units.
Within this class we will have cover Earth System processes ranging from nutrient cycles to ocean circulation. We will also address global environmental challenges of the twenty-first century that include maintaining freshwater resources, land degradation, health of our oceans, and the balance between food production and environmental degradation. Weekly readings and problem sets on specific topics will be followed by presentations of EESS faculty and an in-depth class discussion. EESS first year students have priority enrollment.

ESS 307. Research Proposal Development and Delivery. 2 Units.
In this class students will learn how to write rigorous, high yield, multidisciplinary proposals targeting major funding agencies. The skills gained in this class are essential to any professional career, particularly in research science. Students will write a National Science Foundation style proposal involving testable hypotheses, pilot data or calculations, and broader impact. Restricted to EESS first-year, graduate students.

ESS 310. Climate and Energy Seminar. 3 Units.
This course examines the links between climate change policy and other regulation of the energy sector in the U.S. context. In the electricity sector, these policies are likely to be closely interconnected, yet they are often considered in isolation. We will evaluate the impacts of energy, air pollution, and water pollution regulations on US greenhouse gas emissions from the energy sector. We will also examine how state regulatory activities aimed at reducing greenhouse gas emissions in the electricity sector are likely to have co-benefits for air and water pollution.

ESS 311. Seminar in Advanced Applications of Remote Sensing. 1 Unit.
In this seminar course, we will invite the pioneering scientists from academia and leading experts from the industry to share their applications of remote sensing technology, with a focus on terrestrial use (e.g. agriculture and forestry). In each independent seminar, speakers will present the basic technology and focus on applications with case studies.nnStudents will gain insight into a variety of remote sensing applications in both academia and industry. No prior remote sensing knowledge is required, and each seminar is independent. Attendance is required to receive credit.

ESS 318. Global Land Use Change to 2050. 2-3 Units.
An exploration of the fundamental drivers behind long term shifts in the demand for, and supply of, land for agriculture, forestry and environmental uses over the next four decades. Topics include trends in food and bioenergy demand, crop productivity on existing and potential croplands, water and climate constraints, non-extractive uses such as carbon sequestration, and the role of global trade and public policies. Students will lead discussions of weekly readings and perform simple numerical experiments to explore the role of individual drivers of long run global land use.

ESS 322A. Seminar in Hydrogeology. 1 Unit.
Current topics. May be repeated for credit. Autumn Quarter has open enrollment, For Winter Quarter, consent of instructor is required.

ESS 322B. Seminar in Hydrogeology. 1 Unit.
Current topics. May be repeated for credit. Prerequisite: consent of instructor.

ESS 330. Advanced Topics in Hydrogeology. 1-2 Unit.
Topics: questioning classic explanations of physical processes; coupled physical, chemical, and biological processes affecting heat and solute transport. May be repeated for credit.

ESS 342. Geostatistics. 1-2 Unit.
Classic results and current research. Topics based on interest and timeliness. May be repeated for credit.

ESS 342B. Geostatistics. 1-2 Unit.
Classic results and current research. Topics based on interest and timeliness. May be repeated for credit.

ESS 342C. Geostatistics. 1-2 Unit.
Classic results and current research. Topics based on interest and timeliness. May be repeated for credit.

ESS 363F. Oceanic Fluid Dynamics. 3 Units.
Dynamics of rotating stratified fluids with application to oceanic flows. Topics include: inertia-gravity waves; geostrophic and cyclogeostrophic balance; vorticity and potential vorticity dynamics; quasi-geostrophic motions; planetary and topographic Rossby waves; inertial, symmetric, barotropic and baroclinic instability; Ekman layers; and the frictional spin-down of geostrophic flows. Prerequisite: CEE 262A or a graduate class in fluid mechanics.
Same as: CEE 363F

ESS 364F. Advanced Topics in Geophysical Fluid Dynamics. 2-3 Units.
A seminar-style class covering the classic papers on the theory of the large-scale ocean circulation. Topics include: wind-driven gyres, mesoscale eddies and geostrophic turbulence, eddy-driven recirculation gyres, homogenization of potential vorticity, the ventilated thermocline, subduction, and the abyssal circulation. Prerequisite: EESS 363F or CEE 363F. Recommended: EESS 246B.
Same as: CEE 364F

ESS 385. Practical Experience in the Geosciences. 1 Unit.
On-the-job training, that may include summer internship, in applied aspects of the geosciences, and technical, organizational, and communication dimensions. Meets USCIS requirements for F-1 curricular practical training. May be repeated for credit.

ESS 398. Current Topics in Ecosystem Modeling. 1-2 Unit.
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ESS 400. Graduate Research. 1-15 Unit.
May be repeated for credit. Prerequisite: consent of instructor.

ESS 401. Curricular Practical Training. 1-3 Unit.
CPT course required for international students completing degree. Prerequisite: Earth System Science Ph.D. candidate.

ESS 801. TGR Project. 0 Units.
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ESS 802. TGR Dissertation. 0 Units.
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