

# EARTH SYSTEM SCIENCE

Courses offered by the Department of Earth System Science are listed under the subject code ESS on the Stanford Bulletin's ExploreCourses web site.

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.

#### 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
<b>Seminar Requirements</b>		
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.

### Units 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<sup>1</sup>, Steven Gorelick, Robert Jackson<sup>2,3</sup>, Julie Kennedy, Eric Lambin<sup>3</sup>, Pamela Matson (Dean), Rosamond Naylor<sup>3,4</sup>

*Associate Professors:* Karen Casciotti, Noah Diffenbaugh<sup>2</sup>, Christopher Francis, David Lobell<sup>3,4</sup>

*Assistant Professors:* Marshall Burke<sup>4</sup>, Ann Dekas, Balakanapathy Rajaratnam<sup>5</sup>, Leif Thomas, Paula Welander

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

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

<sup>1</sup>Joint appointment with Biology

<sup>2</sup>Joint appointment with the Precourt Institute for Energy

<sup>3</sup>Joint appointment with the Woods Institute for the Environment

<sup>4</sup>Joint appointment with the Freeman Spogli Institute for International Studies

<sup>5</sup>Joint appointment with Statistics