

EARTH SYSTEMS

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Courses offered by the Earth Systems Program have the subject code EARTHSYS, and are listed in the "Earth Systems (EARTHSYS) Courses" section of this bulletin.

The Earth Systems Program is an interdisciplinary environmental science major. Students learn about and independently investigate complex environmental problems caused by human activities in interaction with natural changes in the Earth system. Earth Systems majors become skilled in those areas of science, economics, and policy needed to tackle the globe's most pressing environmental problems, becoming part of a generation of scientists, professionals, and citizens who approach and solve problems in a new way: a systematic, interdisciplinary way.

For students to be effective contributors to solutions for such problems, their training and understanding must be both broad and deep. To this end, Earth Systems students take courses in the fundamentals of biology, calculus, chemistry, geology, and physics, as well as in computer science, economics and policy, and statistics. After completing breadth training, they concentrate on advanced work in one of five focus areas: biology, energy, environmental economics and policy, land management, or oceanography. Along with formal course requirements, Earth Systems students complete a 9-unit (270-hour) internship. The internship provides a hands-on academic experience working on a supervised field, laboratory, government, or private sector project of their choice.

The following is an outline of the sequential topics covered and

skills developed in this major.

1. The fundamental components of the Earth Systems Program help students understand current environmental problems against the backdrop of natural change through introductory course work in geology, biology, and economics. Depending on the Earth Systems track chosen, training may also include introductions to the study of energy systems, microbiology, oceans, or soils. Students find that many programs and departments at Stanford offer courses that approach the role that humans play in affecting these systems. Students are encouraged to come to the Earth Systems office for course selection advice and to pick up a current list of environmental courses at Stanford.

2. Focus is on the fundamental interactions among the physical, biological, and human components of the Earth system: the dynamics of the interplay between natural variation and human-imposed influences is understood to achieve effective solutions to environmental problems.

Earth Systems courses that introduce students to the dynamic and multiple interactions that characterize global change problems include EARTHSYS 10, Introduction to Earth Systems, and two core courses concerning, respectively, the biogeosphere and the anthrosphere: EARTHSYS 111, Biology and Global Change, and EARTHSYS 112, Environmental Economics and Policy.

Competence in understanding system-level interactions is critical to development as an Earth Systems thinker, so additional classes that meet this objective are excellent choices as electives.

3. Development of skills to recognize, quantify, and report change in the environment: key analytical and computational tools and measurement systems are used for insight into global and regional environmental change, and in the development of solutions.

Required foundation and breadth classes and track classes: students build skills in the student's ability to recognize, describe, quantify, and help solve complex problems that face society. For example, training in satellite remote sensing and geographic information systems is either required or recommended for all tracks. Quantification of environmental problems requiring training in calculus, linear algebra, chemistry, physics, programming, and statistics are required of majors. Specialized training, such as in laboratory or field methods, is recommended.

Workable solutions to environmental problems require the ability to effectively communicate ideas and results. Writing intensive courses (WIM) help students to communicate complex concepts to expert and non-expert audiences. Stanford requires that each student complete one WIM course in the major. The WIM requirement is met through completion of EARTHSYS 195, Effectively Communicating Environmental Concepts. Other Earth Systems courses also focus on effective written and oral communication.

4. Work to design solutions to environmental problems that take into consideration natural processes as well as human needs: human needs must be met in sustainable ways that focus on ecosystem health, human prosperity, and long-term effectiveness.

A comprehensive list of environmental courses, and advice on those that focus on problem solving, is available in the program office. Students can also review the quarterly *Time Schedule* for solution-based courses. Among others, the following departments and programs may provide subject areas that are a useful guide: Anthropology, Biology, Civil and Environmental Engineering, Economics, Environmental Earth System Science, Geological and Environmental Sciences, Geophysics, Human Biology, International Policy Studies, International Relations, Law, Energy Resources Engineering, Political Science, Public Policy, and Urban Studies. Earth Systems emphasizes the importance of workable solutions through a required 9-unit internship, knowledge synthesis in the senior seminar, an optional upper division course on environmental

problem solving, or an honors project. The Earth Systems Program provides an advising network that includes faculty, staff, and student peer advisers.

UNDERGRADUATE PROGRAMS IN EARTH SYSTEMS

BACHELOR OF SCIENCE IN EARTH SYSTEMS

The B.S. in Earth Systems (EARTHSYS) requires the completion of at least 110 units that can be divided into three levels of courses. The student must complete a series of courses comprising a broad base of specialized study and must complete five required and three elective courses in that track. Finally, the student must carry out a senior-level research or internship project and participate in the senior seminar, as well as the writing in the major course. *Note:* students interested in earning a California Teaching Credential for general high school science through the STEP program should contact the program office for guidelines.

REQUIRED CORE

<i>Subject and Catalog Number</i>	<i>Units</i>
EARTHSYS 10. Introduction to Earth Systems	4
EARTHSYS 111. Biogeosphere	4
EARTHSYS 112. Environmental Economics and Policy	5
EARTHSYS 195. Effectively Communicating Environmental Concepts (WIM)	4
EARTHSYS 210. Senior Seminar	3
EARTHSYS 260. Internship or EARTHSYS 250. Directed Research	9

REQUIRED FOUNDATION AND BREADTH COURSES

Biology (any one course below):	
BIO 41. Genetics, Biochemistry, and Molecular Biology or BIO 43. Plant Biology, Evolution, and Ecology or BIO 101. Ecology or HUMBIO 2A,B. Genetics, Evolution and Ecology; Culture Evolution, and Society	5 5 3 10
Chemistry:	
CHEM 31A. Chemical Principles I	4
CHEM 31B. Chemical Principles II or CHEM 31X. Chemical Principles	4 4
Computer Programming:	
CS 106A. Programming Methodology	5
Economics:	
ECON 1A. Elementary Microeconomics	5
ECON 50. Economic Analysis I	5
Geological and Environmental Sciences:	
GES 1. Fundamentals of Geology	4
Mathematics:	
MATH 19. Calculus	3
MATH 20. Calculus	3
MATH 21. Calculus or MATH 41. Calculus	4 5
MATH 42. Calculus and MATH 51. Linear Equations and Differential Calculus of Several Variables	5 5
Probability and Statistics (any one course below):	
BIOHOPK 174H. Experimental Design and Probability	3
BIO 141. Biostatistics (Same as STATS 141)	4
ECON 102A. Introduction to Statistical Methods for Social Scientists	5
EESS 160. Statistical Methods for Earth and Environmental Sciences	4
EESS 161. Geostatistics	4
STATS 110. Statistical Methods in Engineering and Physical Sciences	4
STATS 116. Theory of Probability	3-5
STATS 160. Introduction to Statistical Methods	5
Physics:	
PHYSICS 41. Mechanics	4

More extensive work in mathematics and physics may be expected for those planning graduate study. Graduate study in

ecology and evolutionary biology and in economics requires familiarity with differential equations, linear algebra, and stochastic processes. Graduate study in geology, oceanography, and geophysics may require more physics and chemistry. Students should consult their adviser for recommendations beyond the requirements specified above.

TRACKS

BIOSPHERE

ADDITIONAL FOUNDATION AND BREADTH COURSES:

BIO 41. Genetics, Biochemistry, and Molecular Biology	5
BIO 43. Plant Biology, Evolution, and Ecology	5
CHEM 33. Structure and Reactivity	4

Biogeochemistry (choose one):

BIO 216. Terrestrial Biogeochemistry	4
EARTHSYS 189. Field Studies in Earth Systems	5
EESS 143. Marine Biogeochemistry	3-4
EESS 155. Science of Soils	3

Conservation Biology (choose one):

HUMBIO 112. Conservation Biology	4
BIOHOPK 173H. Marine Conservation Biology	1-3

Ecology (choose two):

BIO 101. Ecology	3
BIO 125. Ecosystems of California	3
BIO 136. Evolutionary Paleobiology	4
BIO 145. Behavioral Ecology	4

Ecosystems and Society (choose one):

ANTHRO 160B. Conservation Anthropology	5
ANTHRO 162. Indigenous Peoples and Environmental Problems	3-5
ANTHRO 164A. Ethnoecology	3-5
ANTHRO 170A. Issues in Water, Health and Development	5
ANTHRO 179A. Ethical Debates in Environment and Health Policy	5

ANTHROSPHERE

ADDITIONAL FOUNDATION AND BREADTH COURSES:

CHEM 33. Structure and Reactivity	4
PHYSICS 45. Light and Heat	4

Choose one course in each of the three sub-categories, total six required. At least one of the six must be a skills class marked with an asterisk (*).

Economics and Environmental Policy:

ECON 51. Economic Analysis II	5
ECON 102B. Introduction to Econometrics*	5
ECON 150. Economic Policy Analysis	5
ECON 154. Economics of Legal Rules and Institutions	5
ECON 243. Economics of the Environment	2-5
EARTHSYS 147. Controlling Climate Change in the 21st Century	3
EARTHSYS 175. The California Coast: Science, Policy, and Law	3-4
MSE 243. Energy and Environmental Policy Analysis	3
MSE 248. Economics of Natural Resources	3-4

Social Entrepreneurship and the Environment:

MSE 245G. Finance 1 for Non-MBAs	4
MSE 280. Organizational Behavior: Evidence in Action	3-4
MSE 285. Negotiation	3
URBANST 132. Concepts and Analytical Skills for the Social Sector*	4
URBANST 133. Social Entrepreneurship Collaboratory	4

Sustainable Development:

ANTHRO 160B. Conservation Anthropology	5
ANTHRO 162. Indigenous Peoples and Environmental Problems	3-5
ANTHRO 164A. Ethnoecology	3-5
ANTHRO 361. Human Behavioral Ecology	3-5
BIO 102. Demography: Health, Development, Environment	3
CASA 185. Environmental Ethics	3-5
CASA 343. Culture as Commodity	5
CASA 349. Anthropology of Capitalism	4-5
CASA 364. The Anthropology of Development	5
CEE 124. Sustainable Development Studio	1-5
CEE 142A. Sustainable Development	3
EARTHSYS 180. Fundamentals of Sustainable Agriculture	3

ECON 52. Economic Analysis III	5
ECON 106. World Food Economy*	5
POLISCI 140. Political Economy of Development	5
POLISCI 143. Nongovernmental Organizations and Development in Poor Countries	5
URBANST 163. Land Use Control	4

LAND SYSTEMS

ADDITIONAL FOUNDATION AND BREADTH COURSES:

EARTHSYS 144. Fundamentals of GIS
Choose six courses, with at least one from each grouping:

Land:

BIO 125. Ecosystems of California	3
BIO 144. Conservation Biology	3-4
EARTHSYS 180. Fundamentals of Sustainable Agriculture	3
EARTHSYS 189. Field Studies in Earth Systems	5
ECON 106. World Food Economy	5
EESS 155. Science of Soils	4
HISTORY 254. Popular Culture and American Nature	5

Water:

ANTHRO 170A. Issues in Water, Health and Development	5
CEE 101B. Mechanics of Fluids	4
CEE 166A. Watersheds and Wetlands	3
CEE 171. Environmental Planning Methods	3
CEE 265D. Water and Sanitation in Developing Countries	3
EARTHSYS 104. The Water Course	3
GES 130. Soil Physics and Hydrology	3

Urban:

CEE 176A. Energy Efficient Buildings	3
HISTORY 252G. Environmental History of Urban America	5
HISTORY 267E. The Suburban West	5
HISTORY 267F. Cities in the North American West, 1840-1940	4-5
URBANST 110. Introduction to Urban Studies	4
URBANST 113. Introduction to Urban Design	5
URBANST 163. Land Use Control	4
URBANST 165. Sustainable Urban and Regional Transportation Planning	4-5

ENERGY SCIENCE AND TECHNOLOGY

ADDITIONAL FOUNDATION AND BREADTH COURSES:

PHYSICS 43. Electricity and Magnetism 3

Energy Resources and Technology: (Choose one of the below combinations):

CEE 176A. Energy Efficient Buildings	3-4
CEE 176B. Electric Power: Renewables and Efficiency and	3-4
EARTHSYS 101. Energy and the Environment	3
EARTHSYS 102. Renewable Energy Sources and Greener Energy Processes or EARTHSYS 103. Energy Resources	3
	4-5

Energy Fundamentals:

ENGR 30. Engineering Thermodynamics 3

OCEANS

ADDITIONAL FOUNDATION AND BREADTH COURSES:

GES 8. The Oceans: An Introduction to the Marine Environment 3
PHYSICS 45. Light and Heat 4

Physics of the Sea:

CEE 164. Introduction to Physical Oceanography 4

Biological Oceanography (choose one):

BIOHOPK 163H. Oceanic Biology 4
EESS 143. Marine Biogeochemistry 3-4

Remote Sensing of the Ocean (choose one):

EESS 141. Remote Sensing of the Ocean 4
EARTHSYS 144. Fundamentals of Geographic Information Science (GIS) 4

Additional Requirement (choose one):

One quarter Stanford at Sea (EARTHSYS 323)
One quarter abroad at the Stanford in Australia Program
One quarter at the Hopkins Marine Station

UPPER-DIVISION ELECTIVES

Three intermediate to advanced courses, 100 level or above, minimum of 3 units, consistent with the primary track are required of majors and must be approved. Eligible upper-division electives are listed below. Additional courses may be chosen; see the program office for the most current list.

BIOSPHERE TRACK

BIO 139. Biology of Birds	3
BIO 175. Tropical Ecology and Conservation	5
BIO 215. Biochemical Evolution	3
BIO 216. Terrestrial Biogeochemistry	3
BIOHOPK 161H. Invertebrate Zoology	5
BIOHOPK 163H. Oceanic Biology	4
BIOHOPK 164H. Marine Botany	4
EARTHSYS 180. Fundamentals of Sustainable Agriculture	3

ANTHROSPHERE TRACK

ANTHRO 160B. Conservation Anthropology	5
CEE 171. Environmental Planning Methods	4
CEE 266A. Watersheds and Wetlands	3
CEE 266B. Floods and Droughts, Dams and Aqueducts	3
CEE 266C. Water Resources and Water Hazards Field Trips	2
ECON 158. Antitrust and Regulation	5
ECON 165. International Economics	5
MS&E 241. Economic Analysis	3-4
PUBLPOL 103B. Ethics and Public Policy	5
GSBGEN 339. Environmental Entrepreneurship	4

LAND SYSTEMS TRACK

Only two electives are required for the Land Systems track.

CEE 166B. Floods and Droughts, Dams and Aqueducts	3
CEE 173A. Energy Resources	4-5
CEE 175A. California Coast: Science, Policy, and Law	3-4
GES 112. Mapping the Geological Environment	3
GES 131. Environmental Earth Sciences II: Fluvial Systems and Landscape Evolution	3
HISTORY 268S. American Wests: Studies in Culture and the Environment	4-5
INTNLREL 161A. Global Human Geography: Asia and Africa	5
INTNLREL 161B. Global Human Geography: Europe and Americas	5
URBANST 132. Concepts and Analytic Skills for the Social Sector	4

ENERGY SCIENCE AND TECHNOLOGY TRACK

CEE 156. Building Systems	4
EARTHSYS 102. Renewable Energy Sources and Greener Energy Processes	3
ECON 158. Antitrust and Regulation	5
EE 293A. Fundamentals of Energy Processes	3
EE 293B. Fundamentals of Energy Processes	3
ENERGY120. Fundamentals of Petroleum Engineering	3
ENERGY 260. Groundwater Pollution and Oil Slicks: Environmental Problems in Petroleum Engineering	3
ENERGY269. Geothermal Reservoir Engineering	3
GEOPHYS 200A. Oil and Water: Oil Peaks and Oil Panics	2-3
ME 131A. Heat Transfer	3

OCEANS TRACK

BIOHOPK 161H. Invertebrate Zoology	5
BIOHOPK 163H. Principles of Oceanic Biology	4
BIOHOPK 164H. Marine Botany	4
EARTHSYS 175. California Coast: Science, Policy, & Law	3-4

SUMMARY OF COURSE REQUIREMENTS AND UNITS

Earth Systems Introduction and Core 26
Required allied courses 49-62

TRACKS

Anthrosphere	24-30
Biosphere	23
Energy Science and Technology	24
Land Systems	23
Oceans	28
Upper-division electives	9-15
Effectively Communicating Environmental Concepts	4
Senior research or internship	9
Senior seminar	3
Total units (depending on track, electives)	105-136

HONORS PROGRAM

The honors program in Earth Systems provides students with an opportunity to pursue individual research within a specific area or between areas of Earth Systems, through a year-long mentored research project with an Earth Systems-affiliated faculty member that culminates in a written thesis.

To be admitted to the honors program, applicants must maintain a minimum GPA of 3.3 in Earth Systems course work. Potential honors students should complete the Biogeosphere and Anthrosphere sequence by the end of the junior year. Qualified students apply in Spring Quarter of the junior year, or the fourth quarter before graduation, by submitting a detailed research proposal and a brief statement of support from a faculty research adviser. Students who elect to do an honors thesis should begin planning no later than Winter Quarter of the junior year.

A maximum of 9 units is awarded for thesis research through EARTHYSYS 199. Those 9 units may not substitute for any other required parts of the Earth Systems curriculum. All theses are evaluated for acceptance by the thesis faculty adviser and one additional member of the Earth Systems committee of the whole.

Honors students are encouraged to present their research through the School of Earth Sciences Annual Research Review, which highlights undergraduate and graduate research in the school during the annual visit of the School of Earth Sciences external advisory board. Faculty advisers are encouraged to sponsor presentation of student research results at professional society meetings.

Students interested in a group-oriented, interdisciplinary honors experience should investigate the Goldman Interschool Honors Program in Environmental Science, Technology, and Policy, a program of the Woods Institute for the Environment. More information on Goldman may be obtained by phoning (650) 723-5697.

COTERMINAL B.S. AND M.S. DEGREES IN EARTH SYSTEMS

The Stanford coterminal degree enables an undergraduate to embark on an integrated program of study leading to the master's degree before requirements for the bachelor's degree have been completed. An undergraduate majoring in Earth Systems may apply to work simultaneously toward B.S. and M.S. degrees. The M.S. degree in Earth Systems provides the student with enhanced tools to evaluate the primary literature of the discipline most closely associated with the student's track and allows an increased specialization through additional course work that may include 9 units of thesis research. Integration of earth systems concepts is furthered by participation in the master's seminar.

To apply, complete and return to the Earth Systems office an application that includes: a statement of purpose; a Stanford transcript; two letters of recommendation, one of which must be from the master's adviser; and a list of courses that fulfill degree requirements signed by the Associate Director, Academics, and the master's adviser. Applications must be submitted by the quarter preceding the anticipated quarter of graduation. A \$50 application fee is assessed by the Registrar's Office for coterminal applications. Students may either (1) complete 180 units required for the B.S. degree and then complete the three quarters required for the M.S. degree, or (2) complete a total of 15 quarters during which the requirements of the degrees are fulfilled concurrently. The student has the option of receiving the B.S. degree after completing that degree's requirements or receiving two degrees concurrently at the end of the master's program.

These requirements must be fulfilled to receive an M.S. degree:

1. All requirements for the B.S. degree.
2. Further course work (and/or thesis research), all of which should be at the 100-level or above, including 22 units at the 200-level or above, leading to further focus within the student's track.
3. Participation in the master's seminar.

The program consists of a minimum of 45 units of course work and/or thesis research, at least 22 of which must be at the 200-level or above.

The student must devise a program of study that shows a level of specialization appropriate to the master's level, as determined in

consultation with the adviser. The program should demonstrate further specialization and focus within the student's undergraduate track.

With the adviser's approval, 9 units may be in the form of research. This may culminate in the preparation of a master's thesis; however, a thesis is not required for the degree. Master's students must take part in the Winter Quarter master's seminar (EARTHYSYS 290) and have additional responsibilities appropriate to the master's level (thesis presentation, modeling problems, and so on), 2 units.

A more detailed description of the coterminal master's degree program may be obtained from the program office. For University coterminal degree program rules and University application forms, see <http://registrar.stanford.edu/shared/publications.htm#Coterm>.

EARTH SYSTEMS (EARTHYSYS) COURSES

For information on undergraduate programs in Earth Systems, see the "Earth Systems" section of this bulletin.

UNDERGRADUATE COURSES IN EARTH SYSTEMS

EARTHYSYS 10. Introduction to Earth Systems

For non-majors and prospective Earth Systems majors. Multidisciplinary approach using the principles of geology, biology, engineering, and economics to describe how the Earth operates as an interconnected, integrated system. Goal is to understand global change on all time scales. Focus is on sciences, technological principles, and sociopolitical approaches applied to solid earth, oceans, water, energy, and food and population. Case studies: environmental degradation, loss of biodiversity, and resource sustainability. GER:DB-NatSci

4 units, Aut (Ernst, G)

EARTHYSYS 45N. Energy Issues Confronting the World

Stanford Introductory Seminar. Preference to freshman. Geologic, economic, and policy issues shaping energy use and contrasting human perceptions of energy security. Topics include discourse of resources, history and future of fossil fuels, curse of oil, global climate change, adaptation versus mitigation, relationship between wealth and energy, demand and strategies for efficiency and conservation, alternative energy prospects, geopolitics of energy trading, and energy flow among countries of the world. Game simulation, outside readings, class brainstorming, and student oral presentations on country energy profiles. GER:DB-NatSci

3 units, Win (Howell, D)

EARTHYSYS 101. Energy and the Environment

(Same as ENERGY 101.) Energy use in modern society and the consequences of current and future energy use patterns. Case studies illustrate resource estimation, engineering analysis of energy systems, and options for managing carbon emissions. Focus is on energy definitions, use patterns, resource estimation, pollution. Recommended: MATH 21 or 42, ENGR 30. GER:DB-EngrAppSci

3 units, Win (Kovscek, A; Durlofsky, L)

EARTHYSYS 102. Renewable Energy Sources and Greener Energy Processes

(Same as ENERGY 102.) The energy sources that power society are rooted in fossil energy although energy from the core of the Earth and the sun is almost inexhaustible; but the rate at which energy can be drawn from them with today's technology is limited. The renewable energy resource base, its conversion to useful forms, and practical methods of energy storage. Geothermal, wind, solar, biomass, and tidal energies; resource extraction and its consequences. Recommended: 101, MATH 21 or 42. GER:DB-EngrAppSci

3 units, Spr (Kovscek, A; Gerritsen, M)

EARTHSYS 103. Energy Resources

(Same as CEE 173A, CEE 207A.) Fossil and renewable energy resources: oil, natural gas, coal, nuclear, hydropower, solar, geothermal, biomass, wind, ocean energy, and energy efficiency. Topics for each resource: resource abundance, location, recovery, conversion, consumption, end-uses, environmental impacts, economics, policy, and technology. Buildings, transportation, the electricity industry, and energy in the developing world. Required field trips to local energy facilities. Optional discussion section for extra unit. GER:DB-EngrAppSci

4-5 units, Aut (Woodward, J)

EARTHSYS 104. The Water Course

(Same as GEOPHYS 104.) The pathway that water takes from rainfall to the tap using student home towns as an example. How the geological environment controls the quantity and quality of water; taste tests of water from around the world. Current U.S. and world water supply issues. GER:DB-NatSci

3 units, not given this year

EARTHSYS 108. Coastal Wetlands

(Same as EARTHSYS 208.) Ecological structure and function of wetlands emphasizing local, coastal wetlands. Topics include: wetland distribution, classification, and history; and interactions between biotic and abiotic components of wetland ecosystems. Labs and local field trips for exposure to landscape patterns, and common sampling equipment and methods. Recommended: 104 or CEE 166A. GER:DB-NatSci

3 units, Aut (Myers, L), alternate years, not given next year

EARTHSYS 111. Biology and Global Change

(Same as BIO 117, EESS 111.) 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. GER:DB-NatSci

4 units, Win (Vitousek, P; Arrigo, K)

EARTHSYS 112. Environmental Economics and Policy

(Same as ECON 155.) Economic sources of environmental problems and alternative policies for dealing with them (technology standards, emissions taxes, and marketable pollution permits). Evaluation of policies addressing regional air pollution, global climate change, water allocation in the western U.S., and the use of renewable resources. Connections between population growth, economic output, environmental quality, and human welfare. Prerequisite: ECON 50. GER:DB-NatSci

5 units, Win (Staff)

EARTHSYS 113. Earthquakes and Volcanoes

(Same as GEOPHYS 113.) Earthquake location, magnitude and intensity scales, seismic waves, styles of eruptions and volcanic hazards, tsunami waves, types and global distribution of volcanoes, volcano forecasting. Plate tectonics as a framework for understanding earthquake and volcanic processes. Forecasting; earthquake resistant design; building codes; and probabilistic hazard assessment. For non-majors and potential earth scientists. GER:DB-EngrAppSci

3 units, Spr (Beroza, G; Segall, P)

EARTHSYS 114. Field Course on Tropical Biogeochemistry: Amazon as Case Study

(Same as BIO 114.) Post-field seminar for students who went on the two-week field trip to the Amazon in September with Brazilian students under Professor Martinelli of the University of São Paulo and Stanford Latin American Studies. Land use changes over the last 30 years including the conversion of natural forest for cattle ranching and soy beans in the Amazon, the largest continuous area of tropical forests on Earth with the greatest number of plant and animal species. In English.

3 units, not given this year

EARTHSYS 123. From Local to Global: Collaborations for International Environmental Education

(Same as EDUC 122X.) A collaboration with three universities in Africa. Discourse and debate using Internet and mobile technology interactions. Topics include the global environment, climate change, sustainable development, and food security.

2 units, not given this year

EARTHSYS 124. Environmental Justice: Local, National, and International Dimensions

(Same as EARTHSYS 224.) Focus is on whether minorities and low income citizens suffer disproportionate environmental and health impacts resulting from government and corporate decision making in contexts such as the siting of industrial facilities and waste dumps, toxic chemical use and distribution, and the enforcement of environmental mandates and policies. Implications of environmental justice issues at the international level, emphasizing climate change.

4 units, alternate years, not given this year

EARTHSYS 132. Energy Cooperation in the Western Hemisphere

(Same as EARTHSYS 232, IPS 263.) Current political dynamics in major western hemisphere fossil fuel producers in N. America, the Andean region, the Southern Cone of S. America, and Trinidad and Tobago. The potential for developing sustainable alternative energy resources in the western hemisphere for export particularly biofuels, and its impact on agricultural policy, environmental protection, and food prices. The feasibility of creating regional energy security rings such as the proposed N. American Energy Security and Prosperity Partnership.

4 units, Spr (O'Keefe, T)

EARTHSYS 141. Remote Sensing of the Oceans

(Same as EESS 141, EESS 241, EARTHSYS 241.) 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. GER:DB-NatSci

3-4 units, alternate years, not given this year

EARTHSYS 142. Remote Sensing of Land Use and Land Cover

(Same as EESS 162, EARTHSYS 242.) 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.

4 units, not given this year

EARTHSYS 144. Fundamentals of Geographic Information Science (GIS)

(Same as EESS 164.) 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. GER:DB-NatSci

4 units, Aut (Reilly, M)

EARTHSYS 147. Controlling Climate Change in the 21st Century

(Same as BIO 147, BIO 247, EARTHSYS 247, HUMBIO 116.) Global climate change science, impacts, and response strategies. Topics: scientific understanding of the climate system; modeling future climate change; global and regional climate impacts and vulnerability; mitigation and adaptation approaches; the international climate policy challenge; and decarbonization of energy and transportation systems. GER:DB-NatSci

3 units, Win (Schneider, S; Mastrandrea, M), alternate years, not given next year

EARTHSYS 152. Pathways Out of Rural Poverty

(Same as EARTHSYS 252, ECON 155B, IPS 261.) Determinants of rural poverty and historical pathways that have led the rural poor out of it. Policy perspectives: the macro level concerning overall economic growth and structural transformation; the sectoral level focusing on the role of agriculture in poverty reduction; and the household level focusing on individual characteristics and asset holdings, including human capital. The impact of globalization on pathways out of poverty and on agriculture and structural transformation in developing countries. Prerequisite: ECON 106 or 118 or EARTHSYS 180.

5 units, Spr (Timmer, C)

EARTHSYS 164. Introduction to Physical Oceanography

(Same as CEE 164, CEE 262D.) 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). GER:DB-NatSci

4 units, Win (Fong, D)

EARTHSYS 165. Promoting Behavior Change

(Same as HUMBIO 165.) How to apply principles of behavioral change to a real world public health problem: climate change and environmental sustainability. Sources include theory, research, and practice from perspectives such as social and cognitive psychology, media and communication, education, behavioral medicine, social marketing, and consumer behavior. Student groups create an intervention to help elementary school students reduce their environmental footprint. Research performed in local high schools to develop optimally feasible, acceptable, and effective interventions. Prerequisite: Human Biology core or equivalent, or consent of instructor.

4 units, Spr (Robinson, T)

EARTHSYS 175. Law and Science of California Coastal Policy

(Same as CEE 175A, CEE 275A, EARTHSYS 275.) Interdisciplinary. The legal, science, and policy dimensions of managing California's coastal resources. Coastal land use and marine resource decision making. The physics, chemistry, and biology of the coastal zone, tools for exploring data from the coastal ocean, and the institutional framework that shapes public and private decision making. Field work: how experts from different disciplines work to resolve coastal policy questions.

3-4 units, Win (Boehm, A; Sivas, D; Caldwell, M)

EARTHSYS 180. Fundamentals of Sustainable Agriculture

(Same as BIO 180, BIO 280, EARTHSYS 280.) Ecological, economic, and social dimensions of sustainable agriculture in the context of a growing world population. Focus is on management and technological approaches, and historical content of agricultural growth and change, organic agriculture, soil and water resource management, nutrient and pest management, biotechnology, ecosystem services, and climate change. GER:DB-NatSci

3 units, Spr (Naylor, R), alternate years, not given next year

EARTHSYS 180B. Local Sustainable Agriculture

Field-based training in ecologically sound agricultural practices at the Stanford Community Farm; guest lectures from Bay Area farmers, agricultural educators, and food policy advocates; and a field trip to an educational farm. Weekly fieldwork led by an instructor with extensive organic farming experience. Topics include bed preparation, starting seedlings, composting, irrigation techniques, and harvesting methods. May be repeated for credit.

1 unit, Aut (Staff), Spr (Staff)

EARTHSYS 181. Concepts of Urban Agriculture

(Same as EARTHSYS 281.) For advanced undergraduates and graduate students from all fields. Seminar. Current status of and potential for global urban agriculture. Topics include: environmental and economic dimensions of urban food production and sourcing; city policy and land-use planning; and an ecosystem services approach to urban agriculture. Developed and developing world contexts. Two field trips to nearby cities; guest lectures; case studies; group projects. Prerequisite: application.

2 units, Win (Matson, P)

EARTHSYS 184. Climate and Agriculture

(Same as EARTHSYS 284.) The effects of climate change on global food and agricultural systems. Climate assessment and socioeconomic modeling approaches to quantify the impacts of climate on agro-ecosystems and society. Enrollment limited to 25; priority to graduate students, seniors, and juniors. Prerequisites: ECON 106/206, and consent of instructor.

3 units, Spr (Naylor, R; Lobell, D)

EARTHSYS 188. The Political Economy of Energy in India

(Same as EARTHSYS 288.) Seminar. How central, state, and local governments in India balance the competing goals of alleviating poverty, protecting the environment, and assuring the financial viability of India's energy companies. Case studies. Two-week field trip to India in June 2007 to visit industrial sites and meet with stakeholders in industry, government, and consumer advocacy. Prerequisite: application.

2-3 units, not given this year

EARTHSYS 189. Field Studies in Earth Systems

(Same as BIO 206.) For advanced upper-division undergraduates and graduate students. Field-based, focusing on the components and processes by which terrestrial ecosystems function. Topics from biology, chemistry, ecology, geology, and soil science. Lecture, field, and lab studies emphasize standard field techniques, experimental design, analysis of data, and written and oral presentation. Small team projects test the original questions in the functioning of natural ecosystems. Admission by application; see Axxess. Prerequisites: BIO 141 or EESS 160 (formerly GES 160), or equivalent. GER:DB-NatSci

5 units, Spr (Chiariello, N; Dirzo, R; Field, C; Fendorf, S;

Freyberg, D; Matson, P), alternate years, not given next year

EARTHSYS 195. Effectively Communicating Environmental Concepts

For seniors in the Earth Systems major only. How to communicate earth systems issues to non-experts. Audience-specific writing assignments. Peer editing. WIM

4 units, Win (Staff)

EARTHSYS 199. Honors Program in Earth Systems

1-9 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

EARTHSYS 205. Political Economy of Energy Policy

Theoretical frameworks used by political scientists, sociologists, economists, and other intellectuals to understand how societies make and implement public policies related to energy and how the energy industry responds. Topics include theories of the state, monopoly and regulation, public choice, organizational behavior, international agreements, and innovation. Applications of those theories to energy policy issues, such as ethanol, climate change, energy security, the role of national oil companies in the world oil market, the functioning of OPEC, and the California electricity crisis. Prerequisite: application.

4 units, Win (Victor, D)

EARTHSYS 215. Free Trade, NAFTA, and the Environment

New forms of environmental governance stipulated within NAFTA policy. Topics include: theories of free trade, economic liberalization, and transnational environmental governance; green technology transfers; agricultural and industrial economies and implications for workers; transboundary conservation, water, and air quality issues in the N. American west.

4-5 units, Spr (Simon, G)

GRADUATE COURSES IN EARTH SYSTEMS

Primarily for graduate students; undergraduates may enroll with consent of instructor.

EARTHSYS 323. Stanford at Sea

(Same as BIOHOPK 182H, BIOHOPK 323H, EESS 323. Graduate students register for 323H.) Five weeks of marine science including oceanography, marine physiology, policy, maritime studies, conservation, and nautical science at Hopkins Marine Station, followed by five weeks at sea aboard a sailing research vessel in the Pacific Ocean. Shore component comprised of three multidisciplinary courses meeting daily and continuing aboard ship. Students develop an independent research project plan while ashore, and carry out the research at sea. In collaboration with the Sea Education Association of Woods Hole, MA. Only 6 units may count toward the Biology major.

16 units, Spr (Block, B; Dunbar, R; Micheli, F), alternate years, not given next year

EARTHSYS 208. Coastal Wetlands

(Same as EARTHSYS 108.) Ecological structure and function of wetlands emphasizing local, coastal wetlands. Topics include: wetland distribution, classification, and history; and interactions between biotic and abiotic components of wetland ecosystems. Labs and local field trips for exposure to landscape patterns, and common sampling equipment and methods. Recommended: 104 or CEE 166A.

3 units, Aut (Myers, L), alternate years, not given next year

EARTHSYS 210. Senior Seminar

Oral and written communication skills. Each student presents results of the Earth Systems internship and leads discussion. Group project analyzing local environmental problems with Earth Systems approach.

3 units, Win (Kennedy, J)

EARTHSYS 224. Environmental Justice: Local, National, and International Dimensions

(Same as EARTHSYS 124.) Focus is on whether minorities and low income citizens suffer disproportionate environmental and health impacts resulting from government and corporate decision making in contexts such as the siting of industrial facilities and waste dumps, toxic chemical use and distribution, and the enforcement of environmental mandates and policies. Implications of environmental justice issues at the international level, emphasizing climate change.

4 units, alternate years, not given this year

EARTHSYS 232. Energy Cooperation in the Western Hemisphere

(Same as EARTHSYS 132, IPS 263.) Current political dynamics in major western hemisphere fossil fuel producers in N. America, the Andean region, the Southern Cone of S. America, and Trinidad and Tobago. The potential for developing sustainable alternative energy resources in the western hemisphere for export particularly biofuels, and its impact on agricultural policy, environmental protection, and food prices. The feasibility of creating regional energy security rings such as the proposed N. American Energy Security and Prosperity Partnership.

4 units, Spr (O'Keefe, T)

EARTHSYS 241. Remote Sensing of the Oceans

(Same as EESS 141, EESS 241, EARTHSYS 141.) 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.

3-4 units, alternate years, not given this year

EARTHSYS 242. Remote Sensing of Land Use and Land Cover

(Same as EESS 162, EARTHSYS 142.) The use of satellite remote sensing to monitor land use and land cover, with emphasis on terrestrial changes. 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.

4 units, not given this year

EARTHSYS 247. Controlling Climate Change, 21st Century

(Same as BIO 147, BIO 247, EARTHSYS 147, HUMBIO 116.) Global climate change science, impacts, and response strategies. Topics: scientific understanding of the climate system; modeling future climate change; global and regional climate impacts and vulnerability; mitigation and adaptation approaches; the international climate policy challenge; and decarbonization of energy and transportation systems.

3 units. Win (Schneider, S; Mastrandrea, M), alternate years, not given next year

EARTHSYS 250. Directed Research

Independent research related to student's primary track, carried out after the junior year, during the summer, and/or during the senior year. Student develops own project with faculty supervision. 10-15 page thesis. May be repeated for credit.

1-9 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

EARTHSYS 252. Pathways Out of Rural Poverty

(Same as EARTHSYS 152, ECON 155B, IPS 261.) Determinants of rural poverty and historical pathways that have led the rural poor out of it. Policy perspectives: the macro level concerning overall economic growth and structural transformation; the sectoral level focusing on the role of agriculture in poverty reduction; and the household level focusing on individual characteristics and asset holdings, including human capital. The impact of globalization on pathways out of poverty and on agriculture and structural transformation in developing countries. Prerequisite: ECON 106 or 118 or EARTHSYS 180.

5 units, Spr (Timmer, C)

EARTHSYS 260. Internship

Supervised field, lab, private sector, or advocacy project, normally through an internship sponsored by government agencies or research institutions, or independently developed by the student with the written approval of the Associate Director of Academics. 10-15 page report.

1-9 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

EARTHSYS 275. Law and Science of California Coastal Policy

(Same as CEE 175A, CEE 275A, EARTHSYS 175.) Interdisciplinary. The legal, science, and policy dimensions of managing California's coastal resources. Coastal land use and marine resource decision making. The physics, chemistry, and biology of the coastal zone, tools for exploring data from the coastal ocean, and the institutional framework that shapes public and private decision making. Field work: how experts from different disciplines work to resolve coastal policy questions.

3-4 units, Win (Boehm, A; Sivas, D; Caldwell, M)

EARTHSYS 280. Fundamentals of Sustainable Agriculture

(Same as BIO 180, BIO 280, EARTHSYS 180.) Ecological, economic, and social dimensions of sustainable agriculture in the context of a growing world population. Focus is on management and technological approaches, and historical content of agricultural growth and change, organic agriculture, soil and water resource management, nutrient and pest management, biotechnology, ecosystem services, and climate change.

3 units, Spr (Naylor, R), alternate years, not given next year

EARTHSYS 281. Concepts of Urban Agriculture

(Same as EARTHSYS 181.) For advanced undergraduates and graduate students from all fields. Seminar. Current status of and potential for global urban agriculture. Topics include: environmental and economic dimensions of urban food production and sourcing; city policy and land-use planning; and an ecosystem services approach to urban agriculture. Developed and developing world contexts. Two field trips to nearby cities; guest lectures; case studies; group projects. Prerequisite: application.

2 units, Win (Matson, P)

EARTHSYS 284. Climate and Agriculture

(Same as EARTHSYS 184.) The effects of climate change on global food and agricultural systems. Climate assessment and socioeconomic modeling approaches to quantify the impacts of climate on agro-ecosystems and society. Enrollment limited to 25; priority to graduate students, seniors, and juniors. Prerequisites: ECON 106/206, and consent of instructor.

3 units, Spr (Naylor, R; Lobell, D)

EARTHSYS 288. The Political Economy of Energy in India

(Same as EARTHSYS 188.) Seminar. How central, state, and local governments in India balance the competing goals of alleviating poverty, protecting the environment, and assuring the financial viability of India's energy companies. Case studies. Two-week field trip to India in June 2007 to visit industrial sites and meet with stakeholders in industry, government, and consumer advocacy. Prerequisite: application.

2-3 units, not given this year

EARTHSYS 290. Master's Seminar

Open to Earth Systems master's students only. Independent research, oral presentation of results, and preparation of an original proposal for innovative Earth Systems science/policy research.

2 units, Win (Kennedy, J)

EARTHSYS 297. Directed Individual Study in Earth Systems

Under supervision of an Earth Systems faculty member on a subject of mutual interest.

1-9 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

EARTHSYS 298. Advanced Topics in Earth Systems

For Earth Systems master's students only. Continuation of EARTHSYS 290. May be repeated for credit.

2 units, not given this year

EARTHSYS 299. M.S. Thesis

1-9 units, Aut (Staff), Win (Staff), Spr (Staff), Sum (Staff)

EARTHSYS 300. Earth Sciences Seminar

(Crosslisted in each department in the School of Earth Sciences.) Required for incoming graduate students except coterms. Research questions, tools, and approaches of faculty members from all departments in the School of Earth Sciences. Goals are: to inform new graduate students about the school's range of scientific interests and expertise; and introduce them to each other across departments and research groups. Two faculty members present work at each meeting. May be repeated for credit.

1 unit, Aut (Harris, J)

OVERSEAS STUDIES COURSES IN EARTH SYSTEMS

For course descriptions and additional offerings, see the respective "Overseas Studies" courses section of this bulletin or <http://bosp.stanford.edu>. Students should consult their program's student services office for applicability of Overseas Studies courses to a major or minor program.

AUSTRALIA EARTH SYSTEMS COURSES

OSPAUSTL 10. Coral Reef Ecosystems

3 units, Aut (Hoegh-Guldberg, O; Ward, S; Arrigo, K)

OSPAUSTL 20. Coastal Resource Management

3 units, Aut (Johnstone, R)

OSPAUSTL 30. Coastal Forest Ecosystems

3 units, Aut (Hall, J)

SANTIAGO EARTH SYSTEMS COURSES

OSPSANTG 58. Living Chile: A Land of Extremes

5 units, Aut (Reid, S), Win (Reid, S)