

# EARTH SYSTEMS PROGRAM

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Courses given in Earth Systems Program have the subject code EARTHSYS. For complete list of subject codes, see Appendix.

The Earth Systems Program is an interdisciplinary environmental studies 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 seven focus areas: biology, energy, environmental economics and policy, geology, land management, education, 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. Training in the fundamentals comes 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. As students begin to question the role that humans play in affecting these systems, they find that many programs and departments at Stanford offer courses that approach this question from different directions. Students are encouraged to come to the Earth Systems office for course selection advice or 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 must be understood to achieve effective solutions to environmental problems.

Several Earth Systems courses introduce students to the dynamic and multiple interactions that characterize global change problems. They include the introductory course, EARTHSYS 10, Introduction to Earth Systems, and three core courses concerning, respectively, the geosphere, the biosphere and the anthrosphere: EARTHSYS 110. Geosphere, 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. More information on such classes is available in the program office.

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.

The test of an Earth Systems degree is the student's ability to recognize, describe, quantify, and help solve complex problems that face our society. Through required cognates and specific track classes, students build skills in these areas. For example, training in satellite remote sensing and geographic information systems is either required or highly recommended for all tracks. Quantification of environmental problems requires solid training in calculus, linear algebra, chemistry, physics, programming, and statistics. These courses are required of all majors. Specialized training, such as in laboratory or field methods, may be necessary and is highly recommended.

Having the ability to effectively communicate ideas and results is critical. Indeed, workable solutions to our environmental problems begin with common understanding of the issues. Writing intensive courses (WIM) help students to communicate complex concepts to expert and non-expert audiences alike. Stanford requires that each student complete one WIM course in his or her major. The WIM requirement is met through completion of the Senior Seminar. Several Earth Systems courses 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.

Many courses at Stanford focus on solutions. 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: Anthropological Sciences, Biological Sciences, Civil and Environmental Engineering, Earth Systems, Economics, Geological and Environmental Sciences, Geophysics, Human Biology, International Policy Studies, International Relations, Latin American Studies, Law, Petroleum Engineering, Political Science, Public Policy, and Urban Studies. Earth Systems emphasizes the importance of workable solutions in several

ways, including a required 9-unit internship, knowledge synthesis in the Senior Seminar, an optional upper division course on environmental problem solving, or an honors through the Goldman Environmental Honors Program. Potential honors students must complete the Geosphere, Biosphere, Anthrosphere sequence by the end of the junior year.

Students interested in Earth Systems should come to the program office for current information on our curriculum, alumni career paths, environmental jobs and internships, and undergraduate honors options. The Earth Systems Program provides an advising network that includes faculty, staff, and student peer advisers.

## UNDERGRADUATE PROGRAMS

### BACHELOR OF SCIENCE

The B.S. in Earth Systems (ESYS) 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 (WIM). *Note:* students interested in earning a California Teaching Credential for general high school science through the STEP Program should contact the program office for specific guidelines. The Education Track has State of California specific cognate requirements which vary from the other tracks.

#### REQUIRED CORE

Course No. and Subject	Units
EARTHSYS 10. Introduction to Earth Systems	4
EARTHSYS 110. Geosphere	3
EARTHSYS 111. Biology and Global Change	3
EARTHSYS 112. Environmental Economics and Policy	5
EARTHSYS 210. Senior Seminar	4
EARTHSYS 260. Internship or EARTHSYS 250. Directed Research	9

#### REQUIRED COGNATE COURSES

<b>Biology</b> (any one course below):	
BIOSCI 41. Genetics, Biochemistry, and Molecular Biology or BIOSCI 43. Plant Biology, Evolution, and Ecology	5
<b>Chemistry:</b>	
CHEM 31A. Chemical Principles I	4
CHEM 31B. Chemical Principles II or CHEM 31X. Chemical Principles	4
CHEM 33. Organic Chemistry*	4
<b>Computer Programming:</b>	
CS 106. Programming Methodology or CS 138. Matlab and Maple for Science and Engineering Applications	5
<b>Economics:</b>	
ECON 1. Elementary Economics	5
ECON 50. Economic Analysis I	5
<b>Geological and Environmental Sciences:</b>	
GES 1. Fundamentals of Geology	5
<b>Mathematics:</b>	
MATH 19. Calculus and Analytic Geometry	3
MATH 20. Calculus and Analytic Geometry	3
MATH 21. Calculus and Analytic Geometry or MATH 41. Calculus and Analytic Geometry	4
MATH 42. Calculus and Analytic Geometry and MATH 51. Linear Equations and Differential Calculus	5
<b>Probability and Statistics</b> (any one course below):	
BIOSCI 141. Biostatistics	4
ECON 102A. Introduction to Statistical Methods	5
GES 160. Statistical Methods for Earth and Environmental Sciences	4
GES 161. Geostatistics	4
STATS 110. Statistical Methods in Engineering and Physical Sciences	4
<b>Physics:</b>	
PHYSICS 53. Mechanics	4
PHYSICS 51. Light and Heat*	4
(Additional physics cognate for Energy Track):	
PHYSICS 55. Electricity and Magnetism	3

\* Students may take either PHYSICS 51 or CHEM 33; Biosphere students must take CHEM 33.

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

lutionary 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. Check with your adviser about recommendations beyond the requirements specified above.

#### TRACKS

##### GEOSPHERE

##### ADDITIONAL COGNATES:

GES 90. Introduction to Geochemistry	3
GES 102. Earth Materials	5

##### Earth's Surface and Fluid Envelopes:

Choose one from these three:	
GES 8. The Oceans: An Introduction to the Marine Environment	3
GES 159. Marine Chemistry	4
GEOPHYS 130. Biological Oceanography	

##### Plus one of the two following groups of courses:

GEOPHYS 104. The Water Course and GES 175. Science of Soils or GES 130. Environmental Earth Science I: Soil Physics and Hydrology	3
and GES 131. Environmental Earth Science II: Fluvial Systems & Landscape Evolution	3

##### Human Society in the Geosphere:

CEE 173A. Energy Resources or PETENG 101. Energy and the Environment and one from the following list:	4
EARTHSYS 113. Earthquakes and Volcanoes	3
EARTHSYS 169. Science and Politics of Radioactive Waste Management	3

##### EARTHSYS 180. Fundamentals of Sustainable Agriculture

EARTHSYS 180. Fundamentals of Sustainable Agriculture	3
Measuring and Observing the Earth (choose two):	

##### GEOPHYS 140. Introduction to Remote Sensing

GEOPHYS 140. Introduction to Remote Sensing	3
GEOPHYS 141. Remote Sensing of the Ocean	3

or choose one course from the previous list and one from the following:

GES 142. Remote Sensing of Land Use and Land Cover Change	5
EARTHSYS 189. Field Studies in Earth Systems	5

#### BIOSPHERE

##### BIOSCI 41. Genetics, Biochemistry, and Molecular Biology

BIOSCI 41. Genetics, Biochemistry, and Molecular Biology	5
BIOSCI 42. Cell Biology and Animal Physiology	5
BIOSCI 43. Plant Biology, Evolution, and Ecology	5

##### Biogeochemistry (choose one):

BIOSCI 124. Plant Physiological Ecology	4
BIOSCI 216. Terrestrial Biogeochemistry	4
EARTHSYS 189. Field Studies in Earth Systems	5

##### GES 159. Marine Chemistry

GES 159. Marine Chemistry	2-4
GES 175. Science of Soils	3

##### Conservation Biology (choose one):

HUMBIO 119. Conservation Biology or BIOSCI 125. Ecosystems of California	4
	3

##### Ecology (choose two):

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

##### Ecosystems and Society (choose one):

ANTHSCI 124. Perspectives on Sustainable Development in Latin America	5
ANTHSCI 160B. Conservation Anthropology	5
ANTHSCI 162. Indigenous Peoples and Environmental Problems	3-5
ANTHSCI 164A. Ethnoecology	5

#### ANTHROSPHERE

##### Economics and Environmental Policy (choose three):

ECON 51. Economic Analysis II	5
ECON 102B. Introduction to Econometrics	5
ECON 106. The World Food Economy	5
ECON 118. Economics of Development	5
ECON 150. Economics and Public Policy	5

##### Legal and Political Institutions and the Environment (choose one):

ECON 154. Economics of Legal Rules and Policy	5
PUBLPOL 101. Politics and Public Policy	5

#### LAND MANAGEMENT

##### The Natural Environment (choose one from each grouping):

GES 175. Science of Soils or EARTHSYS 189. Field Studies in Earth Systems	4
	5

or GES 130. Environmental Earth Sciences I: Soil Physics & Hydrology	3	<b>DEVELOPMENT PSYCHOLOGY (CHOOSE ONE):</b>	3
or GES 131. Environmental Earth Sciences II: Fluvial Systems and Landscape Evolution	3	PSYCH 60. Introduction to Development Psychology	3-5
HUMBIO 119. Conservation Biology	3-4	PSYCH 146. Observation of Children	3-5
or BIOSCI 125. Ecosystems of California	3-4	PSYCH 147. Development in Early Childhood	3-5
GEOPHYS 140. Introduction to Remote Sensing	3	HUMBIO 126. Adolescent Development	4
or GES 142. Remote Sensing of Land Cover and Land Use	4	EDUC 239. Contemporary Social Issues in Child & Adolescent Dev't	4
or GES 144. Fundamentals of GIS	4		
<b>The Managed Environment</b> (choose one):		<b>TEACHING PRACTICUM COURSE:</b>	
EARTHYS 180. Sustainable Agriculture	3	EDUC 101X. Undergraduate Teaching Practicum	3-5
ECON 106. The World Food Economy	5	All students completing the Education track must:	
GEOPHYS 104. The Water Course	3	1. be jointly advised during the undergraduate degree by Julie Kennedy and a faculty adviser from the STEP Program.	
<b>The Built Environment</b> (choose one from each grouping):		2. enroll in the coterminal STEP Program in the School of Education upon completion of the undergraduate degree.	
URBANST 110. Introduction to Urban Studies	4	<i>Note:</i> Students who begin study in the Education Track and subsequently choose not to enroll in the STEP Program must complete the degree requirements for one of the remaining Earth Systems tracks. Degrees are not awarded for the Education Track without subsequent enrollment in STEP.	
or URBANST 113. Introduction to Urban Design	5		
or URBANST 163. Land Use Control	4		
CEE 176A. Energy Efficient Building Design	4		
or CEE 148. Design and Construction of Affordable Housing	4		
CEE 171. Environmental Planning Methods	4		
<b>ENERGY SCIENCE AND TECHNOLOGY</b>		<b>UPPER-DIVISION ELECTIVES</b>	
CEE 173B. The Coming Energy Revolution	3	Three intermediate to advanced courses, 100 level or above, minimum of 3 units, consistent with the primary track are required of all majors and must be approved. Eligible upper-division electives are listed below. Additional courses may be selected; see the program office for the most current list.	
CEE 176A. Energy Efficient Buildings	4		
CEE 176B. Electric Power: Generation and Conservation	4		
EARTHYS 103. Energy Resources	3		
or EARTHYS 101. Energy and the Environment	3		
ENGR 30. Engineering Thermodynamics	3		
<b>OCEANS</b>			
GES 8. The Oceans: An Introduction to the Marine Environment	3		
<b>Physics of the Sea</b>			
CEE 164. Introduction to Physical Oceanography	4		
<b>Biological Oceanography</b>			
GEOPHYS 130. Biological Oceanography	4		
<b>Marine Chemistry</b>			
GES 159. Marine Chemistry	3		
<b>Remote Sensing of the Ocean</b>			
GEOPHYS 141. Remote Sensing of the Ocean	4		
<b>EDUCATION</b>			
New track designed in concert with Stanford's STEP Program to meet the State of California's Commission on Teaching Credentialing requirement for general science.			
<b>COGNATES AND CORE:</b>			
EARTHYS 10. Introduction to Earth Systems	4		
EARTHYS 110. Geosphere	3		
EARTHYS 111. Biology and Global Change	3		
EARTHYS 112. Environmental Economics and Policy	5		
EARTHYS 210. Senior Seminar	4		
EARTHYS 260 Internship	9		
BIOSCI 41. Genetics, Biochemistry, and Molecular Biology	5		
BIOSCI 42. Cell Biology and Animal Physiology	5		
BIOSCI 43. Plant Biology, Evolution, and Ecology	5		
CEE 63. Weather and Storms	3		
CHEM 31A. Chemical Principles I	4		
CHEM 31B. Chemical Principles II	4		
or CHEM 31X. Chemical Principles	4		
CHEM 33. Structure and Reactivity	4		
ECON 1. Elementary Economics	5		
ECON 50. Economics Analysis I	5		
GES 1. Fundamentals of Geology	5		
GES 8. The Oceans: An Introduction to the Marine Environment	3		
GES 160. Statistical Methods for Earth and Environmental Sciences	5		
or GES 161. Geostatistics	4		
MATH 19. Calculus and Analytic Geometry	3		
MATH 20. Calculus and Analytic Geometry	3		
MATH 21. Calculus and Analytic Geometry	4		
or MATH 41. Calculus and Analytic Geometry	5		
MATH 42. Calculus and Analytic Geometry	5		
MATH 51. Linear Equations and Differential Calculus	5		
PHYSICS 15. The Nature of the Universe	3		
PHYSICS 51. Light and Heat	4		
PHYSICS 53. Mechanics	4		
PHYSICS 55. Electricity and Magnetism	4		
Science Education Track Courses:			
EARTHYS 195. Directed Reading on California Geology	1		
EARTHYS 189. Field Studies in Earth Systems	5		
EDUC 180. Directed Reading in Education	1-15		
STS 101. Science, Technology, and Contemporary Society	4-5		
<b>DEVELOPMENT PSYCHOLOGY (CHOOSE ONE):</b>			
PSYCH 60. Introduction to Development Psychology			
PSYCH 146. Observation of Children			
PSYCH 147. Development in Early Childhood			
HUMBIO 126. Adolescent Development			
EDUC 239. Contemporary Social Issues in Child & Adolescent Dev't			
<b>TEACHING PRACTICUM COURSE:</b>			
EDUC 101X. Undergraduate Teaching Practicum			
All students completing the Education track must:			
1. be jointly advised during the undergraduate degree by Julie Kennedy and a faculty adviser from the STEP Program.			
2. enroll in the coterminal STEP Program in the School of Education upon completion of the undergraduate degree.			
<i>Note:</i> Students who begin study in the Education Track and subsequently choose not to enroll in the STEP Program must complete the degree requirements for one of the remaining Earth Systems tracks. Degrees are not awarded for the Education Track without subsequent enrollment in STEP.			
<b>UPPER-DIVISION ELECTIVES</b>			
Three intermediate to advanced courses, 100 level or above, minimum of 3 units, consistent with the primary track are required of all majors and must be approved. Eligible upper-division electives are listed below. Additional courses may be selected; see the program office for the most current list.			
<b>GEOSPHERE TRACK</b>			
<i>Note:</i> Only two electives are required for the Geosphere track.			
BIOSCI 121. Biogeography	4		
BIOSCI 216. Terrestrial Biogeochemistry	3		
EARTHYS 103. Energy Resources	3		
GES 110. Structural Geology	5		
GES 111. Structural Geology and Rock Mechanics	4		
GES 164. Stable Isotopes	3		
GES 185. Volcanology	4		
PETENG 260. Groundwater Pollution and Oil Spills: Environmental Problems in the Petroleum Industry	3		
<b>BIOSPHERE TRACK</b>			
BIOHOPK 161H. Invertebrate Zoology	5		
BIOHOPK 163H. Oceanic Biology	4		
BIOHOPK 164H. Marine Botany	4		
BIOSCI 125. Ecosystems of California	3-4		
BIOSCI 139. Biology of Birds	3		
BIOSCI 184. Principles of Biosystematics	4		
BIOSCI 215. Biochemical Evolution	3		
BIOSCI 216. Ecosystem Ecology and Global Biogeochemistry	3		
BIOSCI 283. Theoretical Population Genetics	3		
<b>ANTHROSPHERE TRACK</b>			
ANTHSCI 25. Human Ecology of the Amazon	5		
ANTHSCI 172. Indigenous Forest Management	5		
CEE 171. Environmental Planning Methods	4		
ECON 158. Antitrust and Regulation	5		
ECON 165. International Economics	5		
ECON 243. Economics of the Environment	5		
MS&E 243. Energy and Environmental Policy Analysis	2-3		
PUBLPOL 103A. Introduction to Political Philosophy	3		
URBANST 163. Land Use Control	4		
<b>LAND MANAGEMENT TRACK</b>			
ANTHSCI 162. Indigenous Peoples and Environmental Problems	3-5		
HISTORY 164. American Spaces	5		
HISTORY 254. Nature	5		
<b>ENERGY SCIENCE AND TECHNOLOGY TRACK</b>			
ECON 158. Antitrust and Regulation	5		
EE 293A. Fundamentals of Energy Processes	3		
EE 293B. Fundamentals of Energy Processes	3		
ME. 150 Internal Combustion Engines	3		
ME 131A. Heat Transfer	3		
PETENG 102 Renewable Energy Sources and Greener Energy Processes	3		
PETENG 120. Fundamentals of Petroleum Engineering	3		
PETENG 260. Groundwater Pollution and Oil Spills	3		
PETENG 269. Geothermal Reservoir Engineering	3		

POLISCI 140. The Political Economy of Development  
EARTHYS 169. Science and Politics of Radioactive  
Waste Management

#### OCEANS TRACK

BIOHOPK 161H. Invertebrate Zoology  
BIOHOPK 163H. Principles of Oceanic Biology  
BIOHOPK 164H. Marine Botany  
GES 205. Advanced Oceanography  
GES 225. Isotopes in Geological and Environmental Research

#### SUMMARY OF COURSE REQUIREMENTS AND UNITS

Earth Systems Introduction and Core	18-22
Required allied courses	47-50
<b>Tracks:</b>	
Anthrosphere	20
Biosphere	20
Geosphere	26
Energy Science and Technology	23
Land Management	23
Oceans	18
Education	42
Upper-division electives	9-15
Senior project or internship	9
Senior seminar	4
Total units (depending on track, electives).....	110-140

#### COTERMINAL B.S. AND M.S. DEGREES

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 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, effective Autumn Quarter 2004-05. 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. Note: students interested in enrolling in the STEP Program during their fifth year and gaining a California Teaching Credential for high school general science should come to the program office.

Three levels of 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. At least 22 units must be at the 200-level or above. 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 (EARTHYS 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/publications/#Coterm>.

#### COURSES

WIM indicates that the course satisfies Writing in the Major requirements.

#### UNDERGRADUATE

**EARTHYS 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, Win (Ernst)*

**EARTHYS 101. Energy and the Environment**—(Same as PETENG 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 (Gerritsen, Durlofsky, Kovscek)*

**EARTHYS 102. Renewable Energy Sources and Greener Energy Processes**—(Same as PETENG 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, and tidal energies; resource extraction and its consequences. Recommended: 101, MATH 21 or 42. GER:DB-EngrAppSci

*3 units, Spr (Horne, Kovscek)*

**EARTHYS 103. Energy Resources**—(Same as CEE 173A/207A.) Overview of oil, natural gas, coal, nuclear, hydro, solar, geothermal, biomass, wind, and ocean energy resources in terms of supply, distribution, recovery and conversion, environmental impacts, economics, policy, and technology. The opportunities for energy efficiency, electric power basics, the changing role of electric utilities, transportation basics, and energy use in developing countries. Field trips. Recommended: CEE 70. GER:DB-EngrAppSci

*4-5 units, Aut (Woodward)*

**EARTHYS 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, Win (Knight)*

**EARTHYS 106. Antarctic Marine Geology**—(Enroll in GES 206.) *3 units (Dunbar, Cooper) alternate years, given 2006-07*

**EARTHYS 110. Geosphere**—(Same as GEOPHYS 102.) Large-scale natural systems of the solid earth, oceans, and atmosphere, their variation through space and time, and the implications of how these systems impact and are being impacted by humankind. Topics include plate tectonics and its relationship to natural hazards and climate, large-scale ocean and atmospheric systems, energy systems, and the linkages among these topics. Prerequisites: EARTHYS 10, GES 1. GER:DB-NatSci

*3 units, Aut (Zoback, Arrigo)*

**EARTHSYS 111. Biology and Global Change**—(Same as BIOSCI 117.) 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: Biological Sciences or Human Biology core or graduate standing. GER:DB-NatSci

3 units, Win (Vitousek)

**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, Spr (Goulder)

**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, Win (Beroza, Segall)

**EARTHSYS 120. Planetary and Early Biological Evolution Seminar**—(Enroll in GES 120/220.)

2-3 units, Spr (Lowe)

**EARTHSYS 124/224. Environmental Justice**—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. The political economy of decision making. Case studies.

4 units, Aut (Burns)

**EARTHSYS 130/230. Biological Oceanography**—(Same as GEO-PHYS 130/231.) Required for Earth Systems students in the oceans track. Interdisciplinary. How oceanic environments control the form and function of marine life. Topics: 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. Possible local field trips on weekends. Prerequisites: BIOSCI 43 and GES 8 or equivalent. Corequisite: GES 159/259.

2-4 units, Spr (Arrigo)

**EARTHSYS 138. Urbanization, Global Change, and Sustainability**—(Enroll in GES 138.)

3 units (Seto) not given 2005-06

**EARTHSYS 140. Introduction to Remote Sensing**—(Enroll in GEOPHYS 140.)

3 units, Aut (Zebker)

**EARTHSYS 141/241. Remote Sensing of the Oceans**—(Same as GEO-PHYS 141/241.) 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

4 units, Win (Arrigo)

**EARTHSYS 142/242. Remote Sensing of Land Use and Land Cover**—(Same as GES 142.) 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 (Seto) not given 2005-06

**EARTHSYS 144. Fundamentals of Geographic Information Science (GIS)**—(Enroll in GES 144.)

4 units, Spr (Seto)

**EARTHSYS 145/245. Energy Flow and Policy: The Pacific Rim**—(Same as GES 145/245.) Factors shaping energy use and development throughout the Pacific Rim. Topics include fossil and alternative energy resources, supply and trade vulnerabilities, the geopolitics of energy use, and the environmental and social impacts of waste streams. Class develops a game simulation based on critical energy issues, student-initiated energy projections, and assessment of the principal stakeholders.

3 units, Win (Howell)

**EARTHSYS 147/247. Controlling Climate Change in the 21st Century**—(Same as BIOSCI 147/247.) The science, economics, and environmental diplomacy of global climate change. Topics: the science of climate change, climate change and global environmental law; global economic approaches to carbon abatement, taxes, and tradable permits; joint implementation, consensus, and division in the EU; gaining the support of China, other developing countries, and U.S. corporations; alternative energy and energy efficiencies for less carbon-intensive electric power and transport. GER:DB-NatSci

3 units (Schneider, Rosencranz) alternate years, given 2006-07

**EARTHSYS 159. Marine Chemistry**—(Enroll in GES 159/259.)

2-4 units, Spr (Paytan)

**EARTHSYS 164. Introduction to Physical Oceanography**—(Same as CEE 164/262D.) 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)

**EARTHSYS 165. Ethnoecology**—(Enroll in ANTHSCI 164A/264A.)

5 units (Irvine) not given 2005-06

**EARTHSYS 167/267. Social Policy for Sustainable Resource Use**—(Same as ANTHSCI 167/267.) The development of social policies that foster a positive human role in the ecosystem. Goal is to develop group skills in a team setting while researching case studies of forest peoples impacted by integration into the global economy. The case of voluntary forest product certification under the Forest Stewardship Council system. Local participation in policy development, the effectiveness of certification, tenure and institutional aspects of sustainability, indigenous rights and forest conservation, and the role of local communities and workers in sustaining forests over the long term. Prerequisite: consent of instructor. (HEF II, IV, V; DA-A) GER:DB-SocSci

5 units, Spr (Irvine)

**EARTHSYS 167C/267C. Managing the Commons: Evolving Theories for Sustainable Resource Use**—(Same as ANTHSCI 167C/267C.) Development of common property theory since Hardin's article on the tragedy of the commons. Interdisciplinary theorizing about sustainable management of common-pool resources such as grazing, forest, or marine resources; debates about sustainability of commons management within heterogeneous state and global systems; and new commons such as atmosphere or the information commons. Links among theory, methods, and policy. Prerequisite: 190 or consent of instructor. (HEF II, III, IV)

5 units (Irvine) not given 2005-06

**EARTHSYS 175/275. California Coast: Science, Policy, and Law**—(Same as CEE 175A/275A, LAW 514.) 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, Aut (Caldwell, Boehm, Sivas)

**EARTHSYS 180/280. Fundamentals of Sustainable Agriculture**—(Same as BIOSCI 180/280.) 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 (Naylor, Daily) alternate years, given 2006-07

**EARTHSYS 189. Field Studies in Earth Systems**—(Same as BIOSCI 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 *Time Schedule*. Prerequisites: BIOSCI 141 or GES 160, or equivalent. GER:DB-NatSci

5 units (Chiariello, Fendorf, Matson, Miller)  
alternate years, given 2006-07

**EARTHSYS 195. Directed Reading on California Geology**—For Earth Systems education track. Teacher preparation in California geology with focus on regional variability. Preparation of field trip exercises appropriate for K-12 age groups.

1 unit, Aut, Win, Spr (J. Kennedy)

**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. Peer reviews of internship papers. WIM

4 units, Aut, Spr (J. Kennedy)

**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, Win, Spr, Sum (Staff)

**EARTHSYS 259. Marine Chemistry**—(Enroll in GES 159/259.)

2-4 units, Spr (Paytan)

**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, Win, Spr, Sum (J. Kennedy)

**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 (J. Kennedy)

**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, Win, Spr, 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, Spr (J. Kennedy)

**EARTHSYS 299. M.S. Thesis**

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

**EARTHSYS 300. Earth Sciences Seminar**—(Same as GES 300, GEOPHYS 300, IPER 300, PETENG 300.) 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 (Matson, Graham)

**EARTHSYS 323. Stanford at Sea**—(Same as GES 323, BIOHOPK 182H/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. GER:DB-NatSci

16 units (Block, Dunbar, Michel) alternate years, given 2006-07

## OVERSEAS STUDIES

Courses approved for the Earth Systems major and taught overseas can be found in the "Overseas Studies" section of this bulletin, or in the Overseas Studies office, 126 Sweet Hall.

### AUSTRALIA

**EARTHSYS 120X. Coral Reef Ecosystems**—(Same as BIOSCI 109Z, HUMBIO 61X.)

3 units, Win (Arrigo, Dove, Hoegh-Guldberg)

**EARTHSYS 121X. Coastal Resource Management**—(Same as BIOSCI 110Z, HUMBIO 62X.)

3 units, Win (Johnstone)

**EARTHSYS 122X. Coastal Forest Ecosystems**—(Same as BIOSCI 111Z, HUMBIO 63X.)

3 units, Win (Duke, Pole)

### BEIJING

**EARTHSYS 105X. Environmental Challenges in China's Development**

4 units, Aut (Li)

### SANTIAGO

**EARTHSYS 110X. Living Chile: A Land of Extremes**—(Same as LATINAM 58X.)

5 units, Aut (Poblete, Ginocchio)