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 B.

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 our students to be effective contributors to the solutions of 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 in these areas, students concentrate on advanced course work in one of seven focus areas: biology, energy, environmental economics and policy, geology, land management, education, or oceanography. Along with formal course requirements, all Earth Systems students complete a 9-unit (270-hour) internship. The internship provides a hands-on, rigorous 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 System 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, Introduction to Earth Systems, and three core courses, the Geosphere, the Biosphere, and the Anthrosphere.

   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 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 America Studies, Law, Petroleum Engineering, Political Science, Public Policy, and Urban Planning. The Earth Systems Program 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. Please note: 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 a strong 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.

REQUIRED CORE

Course No. and Subject	*Units*
EARTHSYS 10. Introduction to Earth Systems	4
EARTHSYS 110. Geosphere	3
EARTHSYS 111. Biosphere	3
EARTHSYS 112. Anthrosphere	5
EARTHSYS 210. Senior Seminar	4
EARTHSYS 260. Internship	
or EARTHSYS 250. Directed Research	9

REQUIRED COGNATE COURSES

Biology (any one course below):	
BIOSCI 41. Evolution, Genetics, Genomes, and Biochemistry	5
or BIOSCI 43. Physiology, Ecology, and Behavioral Biology	5
Chemistry:	
CHEM 31. Chemical Principles	3
CHEM 33. Organic Chemistry*	4
Computer Programming:	
CS 106. Programming Methodology	5
or CS 138. Matlab and Maple for Science and Engineering Applications	5
Economics:	
ECON 1. Elementary Economics	5
ECON 50. Economic Analysis I	5
Geological and Environmental Sciences:	
GES 1. Fundamentals of Geology	5
Mathematics:	
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
and MATH 51. Linear Equations and Differential Calculus 5	
Probability and Statistics (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
Physics:	
PHYSICS 53. Mechanics	4
PHYSICS 51. Light and Heat*	4
(Additional physics cognate for Energy Track only):	
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 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. Check with your adviser about recommendations beyond the requirements specified above.

TRACKS

GEOSPHERE

ADDITIONAL COGNATES:

GES 80. Earth Materials	5
GES 90. Introduction to Geochemistry	3
Earth's Surface & 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	3
and GES 175. Science of Soils	3
or GES 130. Environmental Earth Science I: Soil Physics & Hydrology	5
and GES 131. Environmental Earth Science II: Fluvial Systems & Landscape Evolution	5
Human Society in the Geosphere:	
CEE 173A. Energy Resources	4
or PETENG 101. Energy & the Environment	3
and one from the following list:	
EARTHSYS 113. Earthquakes & Volcanoes	3
EARTHSYS 169. Science and Politics of Radioactive Waste Management	3
EARTHSYS 180. Fundamentals of Sustainable Agriculture	3
Measuring & Observing the Earth (choose two):	
GEOPHYS 40. The Earth From Space: Introduction to Remote Sensing	3
GEOPHYS 135. Remote Sensing of the Ocean	3
GES 195. Integrating Remote Sensing and Geographic Information Systems	3
or choose one course from the previous list and one from the following:	
GES 112. Mapping the Geologic Environment	4
GES 197. Remote Sensing of Land Use and Land Cover Change	5
EARTHSYS 189. Field Studies in Earth Systems	5

BIOSPHERE

BIOSCI 41. Evolution, Genetics, Genomes, and Biochemistry	5
BIOSCI 42. Cell Biology, Developmental Biology, and Neurobiology	5
BIOSCI 43. Physiology, Ecology, and Behavioral Biology	5
Biogeochemistry (choose one)**:**	
BIOSCI 124. Ecosystem Physiology	4
BIOSCI 216. Biogeochemistry/Ecosystem Ecology	4
EARTHSYS 189. Field Studies in Earth Systems	5
GES 175. Science of Soils	3
Conservation Biology (choose one):	
BIOSCI 144. Conservation Biology	4
or BIOSCI 173H. Marine Conservation Biology	3
Ecology (choose two):	
BIOSCI 101. Ecology	4
BIOSCI 136. Evolutionary Paleobiology	4
BIOSCI 138. Ecology and Evolution of Plants	4
BIOSCI 145. Behavioral Ecology	4

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
ECON 160. Game Theory and Economic Application	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

GES 80. Earth Material	
The Natural Environment (choose one from each grouping):	
GES 102. Introduction to Field Geology	
or GES 175. Science of Soils	3
GES 112. Mapping the Geologic Environment	
or GES 195. Remote Sensing and GIS	4
HUMBIO 119. Conservation Biology	
or BIOSCI 125. Ecosystems of California	4
The Managed Environment (choose one):	
EARTHSYS 150. Sustainable Agriculture	
ECON 106. The World Food Economy	5

The Built Environment (choose one from each grouping):

ARTHIST 150. American Architecture and Urbanism *or* URBANST 110. Introduction to Urban Studies *or* URBANST 170. Introduction to Urban Design *or* URBANST 183. Land Use Control	4
CEE 176A. Energy Efficient Building Design *or* CEE 148. Design and Construction of Affordable Housing	*4*
URBANST 182. Urban Environmental Policy *or* CEE 171. Environmental Planning Methods	4

ENERGY SCIENCE AND TECHNOLOGY

CEE 173B. The Coming Energy Revolution	3
CEE 176A. Energy Efficient Buildings	4
CEE 176B. Electric Power: Generation and Conservation	4
EARTHSYS 103. Energy Resources	3
or EARTHSYS 101. Energy and the Environment	3
ENGR 30. Engineering Thermodynamics	3

OCEANS

GES 8. The Oceans: An Introduction to the Marine Environment

Physics of the Sea

CEE 164. Introduction to Physical Oceanography	4

Biological Oceanography (choose one):

BIOSCI 163H. Principles of Oceanic Biology	4
GEOPHYS 130. Biological Oceanography	4

Marine Chemistry

GES 159. Marine Chemistry	3

Remote Sensing of the Ocean (choose one):

GEOPHYS 135. Remote Sensing of the Ocean	4
GES 196. Introduction to GIS: Arc/Info and ARC-View	2

EDUCATION

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. Interested students should come by the Program office for more information.

UPPER-DIVISION ELECTIVES

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.

GEOSPHERE TRACK

Note: Only two electives are required for the Geosphere track.

BIOSCI 121. Biogeography	3
EARTHSYS 103. Energy Resources	3
GES 110. Structural Geology	5-6
GES 111. Structural Geology and Rock Mechanics	4
GES 112. Structural and Engineering Geology II	3
GES 164. Stable Isotopes	3
GES 185. Volcanology	4
GES 220. Terrestrial Biogeochemistry	3
GES 221. The Origins of Life in the Solar System	3
GES 254. Paleoceanography	3
GES 255. Introduction to Micropaleontology	5
GES 257. Climate Variability	3
PETENG 260. Groundwater Pollution and Oil Spills: Environmental Problems in the Petroleum Industry	3

BIOSPHERE TRACK

BIOSCI 125. Ecosystems of California	3-4
BIOSCI 139. Biology of Birds	3
BIOSCI 184. Principles of Biosystematics	4
BIOSCI 161H. Invertebrate Zoology	5
BIOSCI 163H. Principles of Oceanic Biology	4
BIOSCI 164H. Marine Botany	4
BIOSCI 215. Biochemical Evolution	3
BIOSCI 216. Ecosystem Ecology and Global Biogeochemistry	3
BIOSCI 217. Climate Theory, Modeling, Applications, and Implications	3
BIOSCI 283. Theoretical Population Genetics	3
GES 255. Introduction to Micropaleontology	5

ANTHROSPHERE TRACK

ANTHSCI 161. Conservation and Community Development in the Amazon	3-5
ANTHSCI 172. Indigenous Forest Management	5
CEE 171. Environmental Planning Methods	4
CEE 266. Environmental Policy Design and Implementation	4
ECON 158. Antitrust and Regulation	5
ECON 165. International Economics	5
ECON 243. Economics of the Environment	5
MS&E 194. The Role of Analysis in Environmental Policy Decisions	3-5
POLISCI 216M. Environmental Politics in the Asia/Pacific Region	5
PUBLPOL 103. Introduction to Political Philosophy	3
URBANST 183. Land Use Control	4

LAND MANAGEMENT TRACK

ANTHSCI 160. Development and Environment	5
ANTHSCI 162. Indigenous Peoples and Environmental Problems	3-5
HISTORY 152. American Spaces	5
HISTORY 254. Nature	5
LATINAM 161. Conservation and Community Development Issues	5

ENERGY SCIENCE AND TECHNOLOGY TRACK

ECON 158. Antitrust and Regulation	5
EE 293A. Fundamentals of Energy Processes	3
EE 293B. Fundamentals of Energy Processes	3
ME 130. Internal Combustion Engines	3
ME 131A. Heat Transfer	3
PETENG 120. Fundamentals of Petroleum Engineering	3
PETENG 260. Groundwater Pollution and Oil Spills	3
PETENG 269. Geothermal Reservoir Engineering	3
POLISCI 114. The Political Economy of Development	3
EARTHSYS 169. Science and Politics of Radioactive Waste Management	3

OCEANS TRACK

BIOSCI 161H. Invertebrate Zoology	5
BIOSCI 163H. Principles of Oceanic Biology	4
BIOSCI 164H. Marine Botany	4
EARTHSYS 167. Ocean Policy: Marine Stewardship and the Law	4
GES 119. Introduction to Paleoceanography	3
GES 163. Introduction to Isotope Geology	3
GES 205. Advanced Oceanography	3
GES 225. Isotopes in Geological and Environmental Research	3
GES 254. Paleoceanography	3

SUMMARY OF COURSE REQUIREMENTS AND UNITS

Earth Systems Introduction and Core	18
Required allied courses	47-50
Tracks:	
Anthrosphere	20
Biosphere	20
Geosphere	26
Energy Science and Technology	23
Land Management	23
Oceans	18
Education	32
Upper-division electives	9-15
Senior project or internship	9
Senior seminar	4
Total units (depending on track, electives)	110-130

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 a faculty member of the program; and a list of courses that fulfill degree requirements signed by the master's adviser. Students may be admitted as early as their eighth quarter at Stanford, or after earning 105 units, but no later than their eleventh quarter. 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 by 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 (EARTHSYS 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.

COURSES

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

UNDERGRADUATE

EARTHSYS 10. Introduction to Earth Systems—For non-majors and prospective Earth Systems majors. Multidisciplinary approach to how the Earth works as a system, utilizing the tools of geology, biology, and economics to understand global change on all time scales. Topics: origin of the solar system and earth, paleoclimate and climate modeling, ocean-atmosphere circulation, extinction and speciation, energy and mineral resources, economic attitudes and the environment. Case studies: acid rain, hunger and food, policy and the environment. GER:2a

4-5 units, Win (Ernst)

EARTHSYS 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:2b

3 units, Spr (Gerritsen, Durlofsky)

EARTHSYS 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, economies, 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:2b

4-5 units (Woodward) not given 2002-03

EARTHSYS 104. The Water Course—(Same as GEOPHYS 104.) Current issues associated with the use and abuse of surface and ground water supplies. The ways the geological environment controls the quantity and quality of water; illustrated with a taste test of water from around the world. An understanding of current concerns regarding water supplies is used as a basis for considering the past and future impact of the availability of water on natural ecosystems and human settlement. Lab. GER:2a

3 units, Win (Knight)

EARTHSYS 110. Geosphere—(Same as GEOPHYS 102.) The changing planet presents society with myriad problems. How do global climate systems work and how do natural and anthropogenic sources of climate change affect people? Is society running out of energy? What are the consequences of energy use? How do plate tectonics affect daily life, and what is the nature of earthquake hazards in California and the Bay Area? Large-scale system approach to the earth, oceans, and atmosphere. GER:2a

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. Prerequisites: Biological Sciences or Human Biology core or graduate standing in any department. (WIM)

3 units, Win (Matson, Vitousek, Mooney)

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.

5 units, Aut (Goulder)

EARTHSYS 113. Earthquakes and Volcanoes—(Same as GEOPHYS 3.) 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.

3 units, Aut (Beroza, Segall)

EARTHSYS 130/230. Biological Oceanography—(Same as GEOPHYS 130/231; graduate students register for 230.) Required for Earth Systems students in the Oceans track. Interdisciplinary look at 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.

4 units, Spr (Arrigo)

EARTHSYS 135/235. Remote Sensing of the Oceans—(Same as GEOPHYS 135/235; graduate students register for 235.) 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 units (Arrigo) alternate years, given 2003-04

EARTHSYS 147/247. Controlling Climate Change in the 21st Century—(Same as BIOSCI 147/247; graduate students register for 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. Enrollment limited to 12 seniors.
3 units, Spr (Schneider, Rosencranz)

EARTHSYS 159/259. Marine Chemistry—(Same as GES 159/259; graduate students register for 259.) For upper-division undergraduates and graduate students in the earth, biology, and environmental sciences. The oceans are in interactive contact with the atmosphere, biosphere, and lithosphere, and virtually all elements pass through the ocean at some point in their cycles. The first-order processes take place within the sea, which affects its chemistry. What controls the distribution of chemical species in water and sediments? How long do different elements spend, on average, in the ocean? How do marine chemical processes interact with the biological, geological, and physical processes in the oceans? Prerequisite: GES 8 or consent of the instructor.
2-4 units, Spr (Paytan)

EARTHSYS 164. Introduction to Physical Oceanography—(Same as CEE 164.) Introduction to the dynamic basis of physical oceanography. Topics: a general description of the physical environment of the ocean; conservation equations for salt, heat, and momentum; geostrophic flows; wind-driven flows; the Gulf Stream; equatorial dynamics and ENSO; the thermohaline circulation of the deep oceans; and tides. Prerequisite: PHYSICS 53.
4 units, Win (Monismith)

EARTHSYS 167/267. Ocean Policy: Marine Stewardship and the Law—(Graduate students register for 267; same as ANTHSCI 166C.) Introduction to the formulation and implementation of ocean policy with regard to a variety of issues across a range of spatial scales: U.S., foreign, and international efforts to regulate ocean uses such as fishing, mineral extraction, and pollution. Emphasis is on problem solving, using case studies to encourage creative thinking about new tools to improve ocean use management, including economic and regulatory options. Multidisciplinary approach to ocean policy, with readings in science, economics, anthropology, and law.
4 units, Aut (Eagle)

EARTHSYS 169/269. Science and Politics of Radioactive Waste Management—(Graduate students register for 269.) The safe storage and disposal of radioactive waste, an environmental legacy of nuclear weapons production and nuclear power generation, is a scientific, engineering, political, and societal issue. Focus is on scientific, engineering, and economic issues, leading to formulation of answers to political questions, particularly the balance between risk and reward to society. Field trips to waste sites. Recommended: working knowledge of first-year physics, chemistry, and geology/hydrology.
3 units, Spr (McWilliams)

EARTHSYS 180/280. Fundamentals of Sustainable Agriculture—(Graduate students register for 280.) Ecological, economic, and social dimensions of sustainable agriculture in the context of a growing world population. Focus is on both management and technological approaches and on 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 (Falcon, Naylor, Matson, Kennedy)

EARTHSYS 189. Field Studies in Earth Systems—(Same as BIOSCI 206, GES 189.) For advanced upper-division undergraduates and graduate students in Earth Systems, Biological Sciences, or Geological and Environmental Sciences. 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.
5 units, Spr (Chiariello, Fendorf, Ackerly, Matson, E. Miller)

EARTHSYS 197/297. Remote Sensing of Land Use and Land Cover Change—(Same as GES 197/297; graduate students register for 297.) Explores the use of satellite remote sensing and digital image processing techniques to monitor terrestrial land cover and land use change. Data from a range of sensors is used to explore a variety of applications: deforestation, urbanization, and wildfires. Labs include a case study of a local land use issue. Prerequisite: 195, GEOPHYS 40, or consent of instructor.
5 units, Spr (Seto)

EARTHSYS 210. Senior Seminar—Focus is on communication skills, oral and written. Each student presents results of the Earth Systems internship in an oral presentation and leads a follow-up round table discussion subsequent to talk. Group project analyzing local environmental problems requires an Earth Systems approach. Peer reviews of internship papers as required. (WIM)
4 units, Aut, Spr (J. Kennedy)

EARTHSYS 250. Directed Research—Independent research into an aspect of Earth Systems related to the 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, or can see adviser for research ideas. 10-15 page thesis required.
1-9 units, quarter by arrangement (Staff)

EARTHSYS 260. Internship—Supervised field, lab, private sector, or advocacy project, normally through an internship sponsored by government agencies, research institutions or other organizations, or independently developed by the student with the prior written approval of the Associate Director of Academics. Provides hands-on experience within the student's primary track. 10-15 page report required.
1-9 units, quarter by arrangement (J. Kennedy)

EARTHSYS 290. Master's Seminar—Open to Earth Systems master's students only. Focus is on critical examination and discussion of topics in Earth Systems. Requires 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 298. Advanced Topics in Earth Systems—Open to Earth Systems master's students only. Continuation of 290.
2 units (J. Kennedy) not given 2002-03

EARTHSYS 299. M.S. Thesis—Research for the master's paper.
1-9 units, any quarter (Staff)

EARTHSYS 323. Stanford at SEA—(Same as GES 323, BIOHOPK 323H.) Five weeks of marine science including oceanography, marine physiology, policy, conservation, and nautical science at Hopkins Marine Station, followed by five weeks at sea aboard a sailing research vessel in the Pacific Ocean. The shore component is comprised of three multidisciplinary courses, each of which meets daily and continues through the shipboard experience. Students develop an independent research project plan while ashore, and carry out the research at sea. The class at Stanford is offered in collaboration with the Sea Education Association of Woods Hole, MA. The Hopkins and shipboard experience and its emphasis on student research projects create a focused and unique learning experience.
18 units, Spr (Dunbar, Block, Gilly) alternate years, not given 2003-04