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 foundation and breadth classes and specific track classes, students build skills in these areas. For ex-ample, 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 sta-tistics. 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 prob-lem 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, Law, Energy Resources 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, knowl-edge synthesis in the senior seminar, an optional upper division course on environmental problem solving, or an honors project. Students interested in Earth Systems should come to the program office for current information on our curriculum, alumni career paths, environ-mental 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

Subject and Catalog Number	*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 FOUNDATION AND BREADTH COURSES

Biology (any one course below):

BIOSCI 41. Genetics, Biochemistry, and Molecular Biology	5
or BIOSCI 43. Plant Biology, Evolution, and Ecology	5

Chemistry:

CHEM 31A. Chemical Principles I	4
CHEM 31B. Chemical Principles II	4
or CHEM 31X. Chemical Principles	4
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 1A. Elementary Microeconomics	5
ECON 1B. Elementary Macroeconomics	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
STATS 110. Statistical Methods in Engineering and Physical Sciences	4

Physics:

PHYSICS 41. Mechanics	4
PHYSICS 45. Light and Heat*	4
(Additional physics foundation course for Energy Track):	
PHYSICS 43. Electricity and Magnetism	3

* Students may take either PHYSICS 45 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 FOUNDATION AND BREADTH COURSES:

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	3
and GES 175. Science of Soils	3
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	4
or PETENG 101. Energy and the Environment	3
and one from the following list:	
EARTHSYS 113. Earthquakes and Volcanoes	3
EARTHSYS 180. Fundamentals of Sustainable Agriculture	3

Measuring and Observing the Earth (choose two):

GEOPHYS 140. Introduction to Remote Sensing	3
GEOPHYS 141. Remote Sensing of the Ocean	3
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	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	2-4
GES 175. Science of Soils	3

Conservation Biology (choose one):

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

Ecology (choose two):

BIOSCI 101. Ecology	4
BIOSCI 125. Ecosystems of California	3
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

ADDITIONAL FOUNDATION AND BREADTH COURSES:

ECON 50. Economic Analysis I

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 SYSTEMS

ADDITIONAL FOUNDATION AND BREADTH COURSES:

GES 144. Fundamentals of GIS	4
or GES 142. Remote Sensing of Land Cover and Land Use	4

Choose six courses, with at least one from each grouping:

Land Systems:

BIOSCI 125. Ecosystems of California	3
BIOSCI 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
GES 175. Science of Soils	4

Water Systems:

CEE 101B. Mechanics of Fluids	4
CEE 166A. Watersheds and Wetlands	3
CEE 171. Environmental Planning Methods	4
CEE 265D. Water and Sanitation in Developing Countries	3
EARTHSYS 104. The Water Course	3
GES 130. Environmental Earth Sciences I: Soil Physics and Hydrology	3

Urban Systems:

CASA 123. Eurocities and the Anthropology of Urban Spaces: Life in the City	5
CEE 176A. Energy Efficient Building Design	4
GES 138. Urbanization, Global Change, and Sustainability	3
URBANST 110. Introduction to Urban Studies	4
URBANST 163. Land Use Control	4
URBANST 165. Sustainable Urban and Regional Transportation Planning	4-5

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 101. Energy and the Environment	3
or EARTHSYS 103. Energy Resources	3
ENGR 30. Engineering Thermodynamics	3

OCEANS

GES 8. The Oceans: An Introduction to the Marine Environment	3

Physics of the Sea

CEE 164. Introduction to Physical Oceanography	4

Biological Oceanography

GEOPHYS 130. Biological Oceanography	4

Marine Chemistry

GES 159. Marine Chemistry	3

Remote Sensing of the Ocean

GEOPHYS 141. Remote Sensing of the Ocean	4

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

Only two electives are required for the Geosphere track.

BIOSCI 121. Biogeography	3
BIOSCI 216. Terrestrial Biogeochemistry	3
EARTHSYS 103. Energy Resources	3
GES 110. Structural Geology and Tectonics	5-6
GES 111A. Fundamentals of Structural Geology	4
GES 164. Stable Isotopes	3
GES 185. Volcanology	4
PETENG 260. Groundwater Pollution and Oil Slicks: Environmental Problems in the Petroleum Industry	3

BIOSPHERE TRACK

BIOHOPK 161H. Invertebrate Zoology	5
BIOHOPK 163H. Oceanic Biology	4
BIOHOPK 164H. Marine Botany	4
BIOSCI 125. Ecosystems of California	3
BIOSCI 139. Biology of Birds	3
BIOSCI 184. Principles of Biosystematics	4
BIOSCI 215. Biochemical Evolution	3
BIOSCI 216. Terrestrial Biogeochemistry	3

ANTHROSPHERE TRACK

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
HISTORY 254. Popular Culture and American Nature	5
MS&E 243. Energy and Environmental Policy Analysis	2-3
PUBLPOL 103A. Introduction to Political Philosophy	3
URBANST 163. Land Use Control	4

LAND SYSTEMS TRACK

Only two electives are required for the Land Systems track.

ANTHSCI 162. Indigenous Peoples and Environmental Problems	3-5
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 131. Environmental Earth Sciences II: Fluvial Systems and Landscape Evolution	3
HISTORY 164. American Spaces	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

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 Slicks: Environmental Problems in Petroleum Engineering	3
PETENG 269. Geothermal Reservoir Engineering	3
POLISCI 140. The Political Economy of Development	3

OCEANS TRACK

BIOHOPK 161H. Invertebrate Zoology	5
BIOHOPK 163H. Principles of Oceanic Biology	4
BIOHOPK 164H. Marine Botany	4
GES 205. Advanced Oceanography	3
GES 225. Isotopes in Geological and Environmental Research	1-3

SUMMARY OF COURSE REQUIREMENTS AND UNITS

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

HONORS

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 Geosphere, Biosphere, 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 EARTHSYS 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 Center for Environmental Science and Policy (CESP) at the Freeman Spogli Institute for International Studies. More information on Goldman can be found at CESP in Encina Hall East, in the Earth Systems office, or at http://cesp.stanford.edu/docs/goldmanhonors/.

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 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, 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.

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. For University coterminal degree program rules and University application forms, see http://registrar.stanford.edu/shared/publications.htm#Coterm.

COURSES

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

UNDERGRADUATE

EARTHSYS 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, G)

EARTHSYS 45N. Powering the Rim: Energy Issues for the Pacific—(Same as GES 45N.) Stanford Introductory Seminar. Preference to freshman. Geologic, economic, and policy issues shaping energy use and development throughout the Pacific Rim. Topics include the resource potential of fossil fuels, the curse of oil, energy security, global climate change, how efficiency and conservation can reduce demand, alternative energy resources, trade vulnerabilities, the geopolitics of energy use, and energy flow among the countries of the Pacific. Game simulation. Students develop an energy profile for a specific country.

3 units, Win (Howell, D; Graham, S)

EARTHSYS 100. Exploring Interdisciplinary Problem Solving—Preference to Earth Systems sophomores and juniors. The relationship between the Earth Systems curriculum and environmental problem solving. Interdisciplinary problem solving processes from problem definition to solution development and evaluation. The rationale behind components of Earth Systems training and its relationship to applied interdisciplinary environmental analysis. Case studies and guest speakers.

3 units, not given this year

EARTHSYS 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; Gerritsen, M)

EARTHSYS 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-NatSci

3 units, Spr (Kovscek, A; Horne, R)

EARTHSYS 103. Energy Resources—(Same as CEE 173A/207A.) 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, 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 108/208. Coastal Wetlands—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)

EARTHSYS 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: EARTHSYS 10, GES 1. GER: DB-NatSci
3 units, Aut (Zoback, M; Tabazadeh, A)

EARTHSYS 111. Biology and Global Change—(Same as BIOSCI 117, GEOPHYS 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, 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, 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, Spr (Staff)

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 decisionmaking 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, not given this year

EARTHSYS 130/230. Biological Oceanography—(Same as GEOPHYS 130/231.) 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. Corequisite: GES 159/259.
2-4 units, Spr (Arrigo, K)

EARTHSYS 141/241. Remote Sensing of the Oceans—(Same as GEOPHYS 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, alternate years, not given this year

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, Win (Seto, K)

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, alternate years, not given this year

EARTHSYS 147/247. Controlling Climate Change in the 21st Century—(Same as BIOSCI 147/247, HUMBIO 116.) 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, Win (Schneider, S; Mastrandrea, M)

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 (Hench, J)

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, not given this year

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) GER:DB-SocSci
5 units, Spr (Irvine, D)

EARTHSYS 175/275. Law and Science of California Coastal Policy—(Same as CEE 175A/275A, LAW 514.) Interdisicplinary. 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 (Caldwell, M; Boehm, A; Sivas, D)

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, Spr (Naylor, R; Daily, G), alternate years, not given next year

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, Spr (Chiariello, N; Fendorf, S; Matson, P; Field, C; Dirzo, R), alternate years, not given next year

EARTHSYS 199. Honors Program in Earth Systems—Honors Program in Earth Systems
1-9 units, Aut, Win, Spr, Sum (Staff)

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 (Kennedy, J)

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 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 (Staff)

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, 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 (Kennedy, J)

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, EEES 300, ENERGY 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, P; Graham, S)

COGNATE COURSES

ANTHSCI 162/262. Indigenous Peoples and Environmental Problems
3-5 units, Aut (Durham, W)

BIOHOPK 163H/263H. Oceanic Biology
4 units, Win (Denny, M; Somero, G)

BIOHOPK 164H/264H. Marine Botany
5 units, Win (Connor, J), alternate years, not given next year

BIOSCI 41. Genetics, Biochemistry, and Molecular Biology
5 units, Aut (Simoni, R; Bergmann, D)

BIOSCI 42. Cell Biology and Animal Physiology
5 units, Win (Sapolsky, R; Jones, P; Cyert, M; Luo, L; Heller, C)

BIOSCI 43. Plant Biology, Evolution, and Ecology
5 units, Spr (Gordon, D; Petrov, D)

BIOSCI 101. Ecology
3 units, Aut (Vitousek, P; Dirzo, R)

BIOSCI 125. Ecosystems of California
3 units, Spr (Mooney, H)

BIOSCI 139. Biology of Birds
3 units, Spr (Root, T)

BIOSCI 141. Biostatistics—(Same as STATS 141.)
4-5 units, Aut (Rogosa, D), Win (Feldman, M)

BIOSCI 145/245. Behavioral Ecology
4 units, Spr (Gordon, D)

BIOSCI 184/284. Principles and Practice of Biosystematics
4 units, not given this year

BIOSCI 215. Biochemical Evolution
3 units, Win (Watt, W)

BIOSCI 216. Terrestrial Biogeochemistry
3 units, Spr (Vitousek, P)

CEE 63/263C. Weather and Storms
3 units, Aut (Jacobson, M)

CEE 101B. Mechanics of Fluids
4 units, Spr (Koseff, J)

CEE 166A/266A. Watersheds and Wetlands
3 units, Aut (Freyberg, D)

CEE 166B/266B. Floods and Droughts, Dams and Aqueducts
3 units, Win (Staff)

CEE 171. Environmental Planning Methods
3 units, Win (Ortolano, L)

CEE 176A. Energy Efficient Buildings
3-4 units, Win (Masters, G)

CEE 176B. Electric Power: Renewables and Efficiency
3-4 units, Spr (Masters, G)

CEE 265D. Water and Sanitation in Developing Countries
3 units, Aut (Davis, J)

CHEM 31A,B. Chemical Principles I/II
4 units, A: Aut (Chidsey, C), B: Win (Andersen, H)

CHEM 31X. Chemical Principles
4 units, Aut (Waymouth, R; Fayer, M), Sum (Staff)

CHEM 33. Structure and Reactivity
4 units, Win (Stack, T; Kohler, J), Spr (Wender, P), Sum (Staff)

CS 106A. Programming Methodology—(Same as ENGR 70A.)
3-5 units, Aut (Young, P), Win (Roberts, E), Spr (Young, P), Sum (Staff)

ECON 1A. Introductory Economics A
5 units, Aut (Clerici-Arias, M), Win (Wright, G)

ECON 1B. Introductory Economics B
5 units, Win, Spr (Staff)

ECON 50. Economic Analysis I
5 units, Aut (Abramitzky, R), Spr (Tendall, M)

ECON 51. Economic Analysis II
5 units, Win, Sum (Staff)

ECON 102A. Introduction to Statistical Methods (Postcalculus) for Social Scientists
5 units, Aut (Tendall, M), Win (Staff)

ECON 102B. Introduction to Econometrics
5 units, Win (Mahajan, A), Spr (Staff)

ECON 106. World Food Economy
5 units, Win (Staff)

ECON 118. Development Economics
5 units, Aut (Jayachandran, S)

ECON 154. Economics of Legal Rules and Institutions—(Same as PUBLPOL 106.)
5 units, Win (Owen, B)

ECON 158. Antitrust and Regulation
5 units, Win (Rosston, G)

ECON 165. International Economics
5 units, Aut (Fitzgerald, D), Win (Staiger, R), Sum (Desmet, K)

ECON 243. Economics of Environment
2-5 units, Spr (Goulder, L)

EE 293B. Fundamentals of Energy Processes
3-4 units, Win (da Rosa, A)

ENERGY 120. Fundamentals of Petroleum Engineering—(Same as ENGR 120.)
3 units, Aut (Horne, R)

ENERGY 161. Statistical Methods for the Earth and Environmental Sciences: Geostatistics—(Same as GES 161.)
3-4 units, Win (Caers, J)

GEOPHYS 140. Introduction to Remote Sensing
3 units, Aut (Zebker, H)

GES 1. Dynamic Earth: Fundamentals of Earth Science
5 units, Aut (Egger, A), Spr (Hilley, G)

GES 8. The Oceans: An Introduction to the Marine Environment
3 units, Spr, Sum (Ingle, J)

GES 90. Introduction to Geochemistry
3-4 units, Win (Stebbins, J)

GES 102. Earth Materials
5 units, Aut (Brown, G)

GES 110. Structural Geology and Tectonics
5 units, Spr (Miller, E)

GES 111A,B. Fundamentals of Structural Geology—(Same as CEE 195A,B.)
3 units, **A:** *Aut,* **B:** *Win (Pollard, D)*

GES 120/220. Planetary and Early Biological Evolution Seminar
2-3 units, Spr (Lowe, D)

GES 130. Soil Physics and Hydrology
3 units, Aut (Loague, K)

GES 131. Fluvial Systems and Landscape Evolution
3 units, Win (Staff)

GES 144. Fundamentals of Geographic Information Science (GIS)
4 units, Win (Seto, K)

GES 160. Statistical Methods for Earth and Environmental Sciences: General Introduction
3 units, Spr (Switzer, P)

GES 164/264. Stable Isotopes
3 units, Spr (Chamberlain, P)

GES 175. Science of Soils
4 units, Spr (Fendorf, S)

GES 185. Volcanology
4 units, Spr (Mahood, G), alternate years, not given next year

GES 206. Antarctic Marine Geology
3 units, Win (Dunbar, R)

HISTORY 153. American Environmental History From Pre-Columbian America to Today's World
5 units, Aut (Brock, E)

HISTORY 252G/352G. Environmental History of Urban America
5 units, Aut (Rawson, M)

HISTORY 269H. Burgers, Fries, and Fruit Pies: How the West Fed America
4-5 units, Spr (Wadewitz, L)

HUMBIO 112. Conservation Biology—(Same as BIOSCI 144.)
3-4 units, Win (Boggs, C; Launer, A)

INTNLREL 161A. Global Human Geography: Asia and Africa—(Same as HISTORY 106A.)
5 units, Aut (Lewis, M)

INTNLREL 161B. Global Human Geography: Europe and Americas—(Same as HISTORY 106B.)
5 units, Win (Lewis, M)

MATH 19. Calculus
3 units, Aut (Lee, B), Win, Sum (Staff)

MATH 20. Calculus
3 units, Win (Lee, B), Spr (Staff)

MATH 21. Calculus
4 units, Spr (Lee, B)

MATH 41. Calculus
5 units, Aut (Lucianovic, M)

MATH 42. Calculus
5 units, Aut (Thiem, F), Win (Lucianovic, M)

MATH 51. Linear Algebra and Differential Calculus of Several Variables
5 units, Aut (Levy, D), Win (Oprea, D), Spr (Lucianovic, M), Sum (Staff)

PHYSICS 41. Mechanics
4 units, Win (Susskind, L)

PHYSICS 43. Electricity and Magnetism
4 units, Spr (Osheroff, D)

PHYSICS 44. Electricity and Magnetism Lab
1 unit, Spr (Osheroff, D)

PHYSICS 45. Light and Heat
4 units, Aut (Michelson, P), Sum (Staff)

POLISCI 123. Politics and Public Policy
5 units, Spr (Sprague, M)

PUBLPOL 101. Politics and Public Policy
5 units, Win (Brady, D)

PUBLPOL 104. Economic Policy Analysis—(Same as ECON 150.)
5 units, Spr (Kessler, D)

STATS 110. Statistical Methods in Engineering and the Physical Sciences
4-5 units, Aut, Sum (Staff)

STS 101/201. Science, Technology, and Contemporary Society—(Same as ENGR 130.)
4-5 units, Aut (McGinn, R)

URBANST 110. Introduction to Urban Studies
4 units, Aut, Win (Stout, F), Spr (Kahan, M)

URBANST 113. Introduction to Urban Design
5 units, Win (Staff)

URBANST 163. Land Use Control
4 units, Spr (Hall, R)

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, CEE 168X, HUMBIO 111X) GER:DB-EngrAppSci
3 units, Aut (Ward, S; Fine, M; Anthony, K)

EARTHSYS 121X. Coastal Resource Management—(Same as BIOSCI 110Z, CEE 168Y, HUMBIO 112X) GER:DB-EngrAppSci
3 units, Aut (Johnstone, R; Chiffings, T)

EARTHSYS 122X. Coastal Forest Ecosystems—(Same as BIOSCI 111Z, CEE 168Z, HUMBIO 113X) GER:DB-EngrAppSci
3 units, Aut (Pole, M; Duke, N)

BEIJING

EARTHSYS 137X. China's Environment and Prospects for Sustainability—(Same as GES 135, URBANST 159V)
4 units, Spr (Seto, K)

EARTHSYS 139X. Urbanization and Land-Use Change in China—(Same as GES 136, URBANST 158V)
4 units, Spr (Seto, K)

SANTIAGO

EARTHSYS 110X. Living Chile: A Land of Extremes—(Same as LATINAM 58X) GER:DB-EngrAppSci
5 units, Aut (Poblete, V; Ginocchio, R), Spr (Poblete, V)