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 five focus areas: biology, energy, environmental economics and policy, land management, or oceanography. Along with formal course requirements, Earth Systems students complete a 9-unit (270-hour) internship. The internship provides a hands-on academic experience working on a supervised field, laboratory, government, or private sector project of their choice.

The following is an outline of the sequential topics covered and skills developed in this major.

1. The fundamental components of the Earth Systems Program help students understand current environmental problems against the backdrop of natural change through introductory course work in geology, biology, and economics. Depending on the Earth Systems track chosen, training may also include introductions to the study of energy systems, microbiology, oceans, or soils. Students find that many programs and departments at Stanford offer courses that approach the role that humans play in affecting these systems. Students are encouraged to come to the Earth Systems office for course selection advice and to pick up a current list of environmental courses at Stanford.
2. Focus is on the fundamental interactions among the physical, biological, and human components of the Earth system: the dynamics of the interplay between natural variation and human-imposed influences is understood to achieve effective solutions to environmental problems.

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

   Competence in understanding system-level interactions is critical to development as an Earth Systems thinker, so additional classes that meet this objective are excellent choices as electives.
3. Development of skills to recognize, quantify, and report change in the environment: key analytical and computational tools and measurement systems are used for insight into global and regional environmental change, and in the development of solutions.

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

   Workable solutions to environmental problems require the ability to effectively communicate ideas and results. Writing intensive courses (WIM) help students to communicate complex concepts to expert and non-expert audiences. Stanford requires that each student complete one WIM course in the major. The WIM requirement is met through completion of the senior seminar. Other Earth Systems courses also focus on effective written and oral communication.
4. Work to design solutions to environmental problems that take into consideration natural processes as well as human needs: human needs must be met in sustainable ways that focus on ecosystem health, human prosperity, and long-term effectiveness.

A comprehensive list of environmental courses, and advice on those that focus on problem solving, is available in the program office. Students can also review the quarterly *Time Schedule* for solution-based courses. Among others, the following departments and programs may provide subject areas that are a useful guide: Anthropology, 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 through a required 9-unit internship, knowledge synthesis in the senior seminar, an optional upper division course on environmental problem solving, or an honors project. The Earth Systems Program provides an advising network that includes faculty, staff, and student peer advisers.

UNDERGRADUATE PROGRAMS

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 guidelines.

REQUIRED CORE

Subject and Catalog Number	*Units*
EARTHSYS 10. Introduction to Earth Systems	4
EARTHSYS 111. Biogeosphere	4
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
or BIOSCI 101. Ecology	3
or HUMBIO 2A,B. Genetics, Evolution and Ecology; Culture Evolution, and Society	10

Chemistry:

CHEM 31A. Chemical Principles I	4
CHEM 31B. Chemical Principles II	4
or CHEM 31X. Chemical Principles	4

Computer Programming:

CS 106. Programming Methodology	5

Economics:

ECON 1A. Elementary Microeconomics	5
ECON 50. Economic Analysis I	5

Geological and Environmental Sciences:

GES 1. Fundamentals of Geology	5

Mathematics:

MATH 19. Calculus	3
MATH 20. Calculus	3
MATH 21. Calculus	4
or MATH 41. Calculus	5
MATH 42. Calculus	5
and MATH 51. Linear Equations and Differential Calculus of Several Variables	5

Probability and Statistics (any one course below):

BIOHOPK 174H. Experimental Design and Probability	3
BIOSCI 141 (same as STATS 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
STATS 116. Theory of Probability	3-5
STATS 160. Introduction to Statistical Methods	5

Physics:

PHYSICS 41. Mechanics	4

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

TRACKS

BIOSPHERE

ADDITIONAL FOUNDATION AND BREADTH COURSES:

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

Biogeochemistry (choose one):

BIOSCI 216 (Same as GES 220). Terrestrial Biogeochemistry	4
EARTHSYS 189. Field Studies in Earth Systems	5
GEOPHYS 131. Marine Biogeochemistry	3-4
GES 175. Science of Soils	3

Conservation Biology (choose one):

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

Ecology (choose two):

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

Ecosystems and Society (choose one):

ANTHSCI 162. Indigenous Peoples and Environmental Problems	3-5
ANTHSCI 164. Ecological Anthropology	3-5
ANTHSCI 179. Environmental Change and Emerging Infectious Diseases	3-5

ANTHROSPHERE

ADDITIONAL FOUNDATION AND BREADTH COURSES:

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

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

Economics and Environmental Policy:

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

Social Entrepreneurship and the Environment:

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

Sustainable Development:

ANTHSCI 162. Indigenous Peoples and Environmental Problems	3-5
ANTHSCI 163. Human Behavioral Ecology	3-5
ANTHSCI 164. Ecological Anthropology	3-5
BIOSCI 102. Demography: Health, Development, Environment	3
CASA 185. Environmental Ethics	3-5
CASA 343. Culture as Commodity	5
CASA 349. Anthropology of Capitalism	4-5
CASA 364. The Anthropology of Development	5
CEE 124. Sustainable Development Studio	1-5
CEE 142A. Sustainable Development	3
EARTHSYS 180. Fundamentals of Sustainable Agriculture	3
ECON 52. Economic Analysis III	5
POLISCI 140. Political Economy of Development	5
POLISCI 143. Nongovernmental Organizations and Development in Poor Countries	5
POLISCI 441. Politics of Development	5
URBANST 163. Land Use Control	4

LAND SYSTEMS

ADDITIONAL FOUNDATION AND BREADTH COURSES:

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

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

Land:

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
HISTORY 254. Popular Culture and American Nature	5

Water:

CEE 101B. Mechanics of Fluids	4
CEE 166A. Watersheds and Wetlands	3
CEE 171. Environmental Planning Methods	3
CEE 265D. Water and Sanitation in Developing Countries	3

EARTHSYS 104. The Water Course 3
GES 130. Soil Physics and Hydrology 3

Urban:

CEE 176A. Energy Efficient Buildings 3
GES 138. Urbanization, Global Change, and Sustainability 3
HISTORY 252G. Environmental History of Urban America 5
HISTORY 267E. The Suburban West 5
HISTORY 267F. Cities in the North American West, 1840-1940 4-5
URBANST 110. Introduction to Urban Studies 4
URBANST 113. Introduction to Urban Design 5
URBANST 163. Land Use Control 4
URBANST 165. Sustainable Urban and Regional Transportation Planning 4-5

ENERGY SCIENCE AND TECHNOLOGY

CEE 176A. Energy Efficient Buildings 3-4
CEE 176B. Electric Power: Renewables and Efficiency 3-4
EARTHSYS 101. Energy and the Environment 3
or EARTHSYS 103. Energy Resources 4-5
ENGR 30. Engineering Thermodynamics 3
PHYSICS 43. Electricity and Magnetism 3

OCEANS

ADDITIONAL FOUNDATION AND BREADTH COURSES:

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

Physics of the Sea:

CEE 164. Introduction to Physical Oceanography 4

Biological Oceanography (choose one):

BIOHOPK 163H. Oceanic Biology 4
GEOPHYS 131. Marine Biogeochemistry 3-4

Remote Sensing of the Ocean (choose one):

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

Additional Requirement (choose one):

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

UPPER-DIVISION ELECTIVES

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

BIOSPHERE TRACK

BIOHOPK 161H. Invertebrate Zoology 5
BIOHOPK 163H. Oceanic Biology 4
BIOHOPK 164H. Marine Botany 4
BIOSCI 120. General Botany 3-5
BIOSCI 139. Biology of Birds 3
BIOSCI 184. Principles of Biosystematics 4
BIOSCI 215. Biochemical Evolution 3
BIOSCI 216. Terrestrial Biogeochemistry 3
EARTHSYS 180. Fundamentals of Sustainable Agriculture 3

ANTHROSPHERE TRACK

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

LAND SYSTEMS TRACK

Only two electives are required for the Land Systems track.

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

ENERGY SCIENCE AND TECHNOLOGY TRACK

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

OCEANS TRACK

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

SUMMARY OF COURSE REQUIREMENTS AND UNITS

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

Tracks:

Anthrosphere 24-30
Biosphere 23
Energy Science and Technology 24
Land Systems 23
Oceans 28
Upper-division electives 9-15
Senior research 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 Biogeosphere and Anthrosphere sequence by the end of the junior year. Qualified students apply in Spring Quarter of the junior year, or the fourth quarter before graduation, by submitting a detailed research proposal and a brief statement of support from a faculty research adviser. Students who elect to do an honors thesis should begin planning no later than Winter Quarter of the junior year.

A maximum of 9 units is awarded for thesis research through 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 Woods Institute for the Environment. More information on Goldman cmay be obtained by phoning (650) 723-5697.

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. Students may either (1) complete 180 units required for the B.S. degree and then complete the three quarters required for the M.S. degree, or (2) complete a total of 15 quarters during which the requirements of the degrees are fulfilled concurrently. The student has the option of receiving the B.S. degree after completing that degree's requirements or receiving two degrees concurrently at the end of the master's program.

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

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

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

The student must devise a program of study that shows a level of specialization appropriate to the master's level, as determined in consultation with the adviser. The program should demonstrate further specialization and focus within the student's undergraduate track.

With the adviser's approval, 9 units may be in the form of research. This may culminate in the preparation of a master's thesis; however, a thesis is not required for the degree. Master's students must take part in the Winter Quarter master's seminar (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. Energy Issues Confronting the World—(Same as GES 45N.) Stanford Introductory Seminar. Preference to freshman. Geologic, economic, and policy issues shaping energy use and contrasting human perceptions of energy security. Topics include discourse of resources, history and future of fossil fuels, curse of oil, global climate change, adaptation versus mitigation, relationship between wealth and energy, demand and strategies for efficiency and conservation, alternative energy prospects, geopolitics of energy trading, and energy flow among countries of the world. Game simulation, outside readings, class brainstorming, and student oral presentations on country energy profiles. GER:DB-NatSci

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

EARTHSYS 85. Troubled Waters—Adjunct to the public lecture series Troubled Waters which includes a primer on water, discussions about the state of water sources, pollution challenges, the dynamics of water in rivers and aqueducts, the effects of levees and dams, water risks in the form of floods and droughts, and the outlook for freshwater in the future. Corequisite: attendance at the lecture series.

1 unit, Win (Howell, D), offered once only

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; Gerritsen, M)

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, Spr (Knight, R)

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. GER:DB-NatSci

3 units, alternate years, not given this year

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

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

EARTHSYS 112. Environmental Economics and Policy—(Same as ECON 155.) Economic sources of environmental problems and alternative policies for dealing with them (technology standards, emissions taxes, and marketable pollution permits). Evaluation of policies addressing regional air pollution, global climate change, water allocation in the western U.S., and the use of renewable resources. Connections between population growth, economic output, environmental quality, and human welfare. Prerequisite: ECON 50. GER:DB-NatSci

5 units, Win (Goulder, L)

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, not given this year

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

3 units, Aut (Vitousek, P)

EARTHSYS 123. From Local to Global: Collaborations for International Environmental Education—(Same as EDUC 122X.) A collaboration with three universities in Africa. Discourse and debate using Internet and mobile technology interactions. Topics include the global environment, climate change, sustainable development, and food security.

2 units, Aut (Goldman, S)

EARTHSYS 124/224. Environmental Justice: Local, National, and International Dimensions—Focus is on whether minorities and low income citizens suffer disproportionate environmental and health impacts resulting from government and corporate decision making in contexts such as the siting of industrial facilities and waste dumps, toxic chemical use and distribution, and the enforcement of environmental mandates and policies. Implications of environmental justice issues at the international level, emphasizing climate change.

4 units, Aut (Burns, W)

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

3 units, Win (Arrigo, K)

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, not given this year

EARTHSYS 144. Fundamentals of Geographic Information Science (GIS)—(Same as GES 144.) Survey of geographic information including maps, satellite imagery, and census data, approaches to spatial data, and tools for integrating and examining spatially-explicit data. Emphasis is on fundamental concepts of geographic information science and associated technologies. Topics include geographic data structure, cartography, remotely sensed data, statistical analysis of geographic data, spatial analysis, map design, and geographic information system software. Computer lab assignments. GER:DB-NatSci

4 units, Spr (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, alternate years, not given this year

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, Spr (Hench, J)

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

4 units, Spr (Robinson, T)

EARTHSYS 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. GER:DB-SocSci

5 units, Spr (Irvine, D)

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: ANTHSCI 190 or consent of instructor. GER:DB-SocSci

5 units, Aut (Irvine, D)

EARTHSYS 175/275. The 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, 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, alternate years, not given this year

EARTHSYS 180B. Local Sustainable Agriculture—Field-based training in ecologically sound agricultural practices at the Stanford Community Farm; guest lectures from Bay Area farmers, agricultural educators, and food policy advocates; and a field trip to an educational farm. Weekly fieldwork led by an instructor with extensive organic farming experience. Topics include bed preparation, starting seedlings, composting, irrigation techniques, and harvesting methods. May be repeated for credit.

1 unit, Aut, Spr (Staff)

EARTHSYS 181/281. Concepts of Urban Agriculture—For advanced undergraduates and graduate students from all fields. Seminar. Current status of and potential for global urban agriculture. Topics include: environmental and economic dimensions of urban food production and sourcing; city policy and land-use planning; and an ecosystem services approach to urban agriculture. Developed and developing world contexts. Two field trips to nearby cities; guest lectures; case studies; group projects. Prerequisite: application.

2 units, Win (Matson, P)

EARTHSYS 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. Standard field techniques, experimental design, data analysisa, and written and oral presentation. Small team projects test the original questions in the functioning of natural ecosystems. Admission by application. Prerequisites: BIOSCI 141 or GES 160, or equivalent. GER:DB-NatSci

5 units, alternate years, not given this year

EARTHSYS 199. Honors Program in Earth Systems

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

EARTHSYS 205. Political Economy of Energy Policy—Theoretical frameworks used by political scientists, sociologists, economists, and other intellectuals to understand how societies make and implement public policies related to energy and how the energy industry responds. Topics include theories of the state, monopoly and regulation, public choice, organizational behavior, international agreements, and innovation. Applications of those theories to energy policy issues, such as ethanol, climate change, energy security, the role of national oil companies in the world oil market, the functioning of OPEC, and the California electricity crisis. Prerequisite: application.

4 units, Spr (Victor, D)

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

4-5 units, Spr (Staff)

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 EEES 300, GES 300, GEOPHYS 300, IPER 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)

EARTHSYS 323. Stanford at Sea—(Same as 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. Only 6 units may count towards the BioSci major. GER:DB-NatSci

16 units, alternate years, not given this year

COGNATE COURSES

ANTHSCI 160B. Conservation Anthropology

5 units, not given this year

ANTHSCI 162/262. Indigenous Peoples and Environmental Problems

3-5 units, not given this year

ANTHSCI 163/263. Human Behavioral Ecology—(Same as HUMBIO 117.)

3-5 units, Aut (Bird, R)

ANTHSCI 164. Ecological Anthropology

3-5 units, not given this year

ANTHSCI 179/279. Environmental Change and Emerging Infectious Diseases—(Same as HUMBIO 114.)
3-5 units, Aut (Durham, W; Jones, J)

BIOHOPK 163H. Oceanic Biology
4 units, not given this year

BIOHOPK 164H/264H. Marine Botany
5 units, not given this year

BIOHOPK 174H/274H. Experimental Design and Probability
3 units, Spr (Watanabe, J)

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

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

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

BIOSCI 102. Demography: Health, Development, Environment—(Same as HUMBIO 119)
3 units, not given this year

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

BIOSCI 136. Evolutionary Paleobiology
4 units, not given this year

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

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

BIOSCI 145. Behavioral Ecology—(Same as BIOSCI 245.)
4 units, Spr (Gordon, D)

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

BIOSCI 216. Terrestrial Biogeochemistry
3 units, Spr (Vitousek, P), alternate years, not given next year

CASA 343. Culture as Commodity
5 units, Aut (Ebron, P)

CASA 349. Anthropology of Capitalism
4-5 units, Aut (Yanagisako, S)

CASA 364. The Anthropology of Development
5 units, not given this year

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

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

CEE 124. Sustainable Development Studio
1-5 units, Aut (Staff), Win (Staff), Spr (Staff)

CEE 142A/242A. Creating Sustainable Development
3 units, Win (Christensen, S)

CEE 151/251. Negotiation—(Same as ME 207, MS&E 285.)
3 units, Spr (Christensen, S)

CEE 156/256. Building Systems
4 units, Spr (Daly, A)

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

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

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, Win (Davis, J)

CEE 266C. Advanced Topics in Hydrology and Water Resources
3 units, not given this year

CHEM 31A. Chemical Principles I
4 units, Aut (Chidsey, C)

CHEM 31B. Chemical Principles II
4 units, 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; Du Bois, J), Spr (Wender, P), Sum (Staff)

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

ECON 1A. Introductory Economics A
5 units, Aut (Clerici-Arias, M), Win (Makler, C), Sum (Lampe, R)

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

ECON 51. Economic Analysis II
5 units, Aut (Tendall, M), Win (Einav, L), Sum (Nicholson, S)

ECON 52. Economic Analysis III
5 units, Win (Jaimovich, N), Spr (Klenow, P), Sum (Desmet, K)

ECON 102A. Introduction to Statistical Methods (Postcalculus) for Social Scientists
5 units, Aut, Win (Steiner, F)

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

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

ECON 154. Economics of Legal Rules and Institutions—(Same as PUBLPOL 106.)
5 units, Aut (Staff)

ECON 158. Antitrust and Regulation
5 units, Spr (Steiner, F)

ECON 165. International Trade and Finance
5 units, Aut (Fitzgerald, D), Win (Staiger, R; Sykes, A), Sum (Desmet, K)

ECON 243. Economics of Environment
2-5 units, Spr (Staff), not given next year

EE 140. The Earth From Space: Introduction to Remote Sensing
3 units, Win (Zebker, H)

EE 293A. Fundamentals of Energy Processes
3 units, Aut (da Rosa, A)

EE 293B. Fundamentals of Energy Processes
3 units, Win (da Rosa, A; Parker, M)

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

ENERGY 269. Geothermal Reservoir Engineering
3 units, alternate years, not given this year

ENGR 30. Engineering Thermodynamics
3 units, Aut (Edwards, C), Win (Mitchell, R)

FINANCE 221. Finance for Non-MBAs—(Same as ECON 135, MS&E 245G.)
4 units, not given this year

GEOPHYS 136/236. Aerosols, Clouds, and Climate Change—(Same as CEE 161T/261T.)
3 units, Win (Tabazadeh, A)

GEOPHYS 161/261. Atmosphere and Global Environmental Change—(Same as CEE 161S/261S.)
3 units, Aut (Tabazadeh, A)

GEOPHYS 263. Atmospheric Heterogeneous Processes—(Same as CEE 261U.)
3 units, Spr (Tabazadeh, A)

GES 1. Dynamic Earth: Fundamentals of Earth Science
4 units, Aut, Spr (Scherer, H)

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 112. Mapping the Geological Environment
3 units, Win (Pollard, D)

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

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

GES 138. Urbanization, Global Change, and Sustainability
3 units, Spr (Seto, K)

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

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

GES 206. Antarctic Marine Geology
3 units, alternate years, not given this year

IPER 339. Environmental Entrepreneurship
4 units, Aut (Plambeck, E)

HISTORY 254. Popular Culture and American Nature
5 units, Spr (White, R)

HUMBIO 2A. Genetics, Evolution, and Ecology
5 units, Aut (Boggs, C; Durham, W; Francke, U)

HUMBIO 2B. Culture, Evolution, and Society
5 units, Aut (Klein, R; Brown, M)

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

HUMBIO 118. Ecological Anthropology—(Same as ANTHSCI 164/264.)
3-5 units, not given this year

HUMBIO 174. Foundations of Bioethics
3 units, Win (Magnus, D)

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, Win (Butscher, A)

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

MS&E 241. Economic Analysis
3-4 units, Win (Weber, T)

MS&E 248. Economics of Natural Resources
3-4 units, Aut (Sweeney, J)

MS&E 280. Organizational Behavior: Evidence in Action
3-4 units, Win (Sutton, R), Spr (Siino, R)

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

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

PHYSICS 45. Light and Heat
4 units, Aut (Gratta, G), Sum (Staff)

POLISCI 140. Political Economy of Development
5 units, Win (Díaz-Cayeros, A)

POLISCI 143. Nongovernmental Organizations and Development in Poor Countries—(Same as INTNLREL 143.)
5 units, Win (Abernethy, D)

POLISCI 441. Politics of Development
5 units, Win (Díaz-Cayeros, A)

PSYCH 10. Introduction to Statistical Methods: Precalculus—(Same as STATS 60/160.)
5 units, Aut (Thomas, E), Win (Walther, G), Spr, Sum (Staff)

PUBLPOL 101. Politics and Public Policy—(Same as POLISCI 123.)
5 units, not given this year

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

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

STATS 116. Theory of Probability
3-5 units, Aut (Donoho, D), Spr (Wong, W), Sum (Staff)

STS 110. Ethics and Public Policy—(Same as MS&E 197, PUBLPOL 103B.)
5 units, Win (McGinn, R)

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

URBANST 113. Introduction to Urban Design: Contemporary Urban Design in Theory and Practice
5 units, Win (Gast, G)

URBANST 132. Concepts and Analytic Skills for the Social Sector
4 units, Win (Kieschnick, M)

URBANST 133. Social Entrepreneurship Collaboratory
4 units, Aut (Edwards, M), Spr (Scher, L)

URBANST 163. Land Use Control
4 units, not given this year

URBANST 165. Sustainable Urban and Regional Transportation Planning
4-5 units, Spr (Kott, J)

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

OSPAUSTL 10. Coral Reef Ecosystems
3 units, Aut (Hoegh-Guldberg, O; Ward, S; Arrigo, K; Anthony, K)

OSPAUSTL 20. Coastal Resource Management
3 units, Aut (Johnstone, R; Chiffings, T)

OSPAUSTL 30. Coastal Forest Ecosystems
3 units, Aut (Hall, J; Duke, N)

SANTIAGO

OSPSANTG 58. Living Chile: A Land of Extremes
5 units, Aut, Spr (Staff)