

# EARTH & CLIMATE SCIENCES

## College of Science and Engineering

Dean: Dr. Carmen Domingo

### Department of Earth & Climate Sciences

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### Affiliations

The Department of Earth & Climate Sciences is a University Corporation for Atmospheric Research (UCAR) affiliate.

### Program Scope

The Department of Earth & Climate Sciences offers two undergraduate degree programs and a minor program spanning the Earth sciences, including geology, hydrology, oceanography, meteorology, and climate science, and a graduate program leading to a Master of Science in Geosciences. All programs aim to help students understand how planet Earth functions and to help them develop skills that enable them to critically evaluate and solve scientific problems related to Earth and environmental issues.

The Bachelor of Science in Earth Sciences provides students with a foundation in mathematics, physics, and chemistry; a broad background in the Earth sciences; an understanding of how Earth's systems are linked; depth of knowledge in one of three areas of Earth sciences; and strong quantitative, communication, and field skills. The B.S. degree is excellent preparation for professional employment and/or graduate study in one of the Earth sciences. Students in the B.S. take a common core of classes and choose one of three areas of emphasis, where they get in-depth training in an area of specialization: Geology, Hydrology, or Ocean, Weather, and Climate. The Geology emphasis provides fundamental skills and knowledge applied to understand processes in the solid Earth, and extensive experience conducting investigations in the field (that is, outdoors). The Hydrology emphasis draws from a broader range of Earth sciences to understand and solve environmental problems of water in Earth's systems and provides extensive hands-on lab and field work. In the Ocean, Weather, and Climate emphasis, students learn to describe the structure and behavior of the oceans and atmosphere and to apply concepts of mathematics, physics, and chemistry to understand and solve problems about how physical processes in the ocean and atmosphere create weather and climate and how climate can change.

The Bachelor of Arts in Earth Sciences program provides a flexible, integrated framework within which students can prepare to teach Earth Sciences in K-12 schools or for careers in museums, parks, governmental or private non-profit environmental or planning agencies, and other organizations where a broad knowledge of Earth sciences would be valued. The Minor in Earth Sciences provides a flexible opportunity to complement a wide variety of other majors.

The Master of Science in Geosciences provides advanced coursework in the geosciences, including an in-depth research investigation. Students

choose an area of specialization and a thesis topic that they work on in close collaboration with a faculty advisor.

### Career Outlook

Earth science investigations lead to better understanding of fundamental Earth processes and help solve problems arising from environmental contamination or mismanagement; natural hazards such as earthquakes, volcanic eruptions, severe storms, and global change; demand for new sources of useful Earth materials; and many others. Earth scientists use sophisticated instrumentation to collect and analyze data, and recent advances have provided new views of Earth, from the internal layers of the solid earth, from the ocean floor, and from both the lower and upper atmosphere, which are leading to improved understanding of our planet. Increasingly scarce energy, mineral, and water resources, and increasing environmental impacts of human activities (both global and local), present challenges that create demand for Earth science expertise. Because of increased demand and projected retirements, a shortage of geoscientists is projected in the near future.

Graduates in Earth Sciences may pursue a wide range of careers in the Earth sciences and related fields. For the next decade, geologists will find the greatest opportunities in the broad areas of environmental and engineering geology; for example, surface and groundwater hydrology studies aimed at characterizing water resources and remediating toxic sites, assessing earthquake and landslide hazards, developing restoration plans for river and coastal environments, and evaluating sites for urban planning or construction. There are also many positions available in the petroleum and mineral exploration industries. A shortage of certified high school and middle school science teachers has placed qualified teachers in high demand. Ocean, weather & climate students will find opportunities in air pollution assessment, global climate change research, and climate change risk assessment, adaptation, and mitigation, with government agencies that work on climate change and coastal management, or consulting firms specializing in coastal dynamics, ocean observations, and alternative energy. Recent job trends suggest that the strongest candidates, regardless of the area of specialization, will have a master's degree, several years of experience, and an interdisciplinary background with strong chemistry, physics, mathematics, computer science, and communication and collaboration skills. Earth scientists in the San Francisco Bay Area are employed by a relatively high concentration of government agencies, academic institutions, and private firms. In addition to preparing students for advanced work as professionals, the M.S. in Geosciences is excellent preparation for a community college or high school teaching career or entry into a doctoral program leading to a career in university teaching and/or research.

The increased emphasis on science in high schools and the new California mandate for earth science education in the elementary science curriculum provide many opportunities for teachers trained in the Earth sciences.

### Advising

The department requires that declared majors consult with an advisor every semester, and prospective majors should consult with an advisor as early as possible, particularly about selecting courses in the General Education program that best fit the major program. Students will also be advised about completing basic science requirements before taking upper-division courses in Earth Sciences, and about the order in which required courses should be taken. Students interested in preparing to teach high school or middle school earth sciences and integrated science should consult the department's teaching credential advisor.

Every course counted toward major requirements must be completed with a letter grade (CR/NC is not acceptable). No more than one course counted toward major requirements may be completed with a grade below a C-. Coursework used to satisfy major requirements must be completed with an overall GPA of 2.0 or better.

## Professor

PETRA DEKENS (2007), *Professor of Oceanography*; B.A.(1998), University of California, Santa Cruz; M.S. (2000), University of California, Santa Barbara; M.S. (2001), University of California, Santa Barbara; Ph.D. (2007), University of California, Santa Cruz.

MARY L. LEECH (2005), *Professor of Geology*; B.S. (1994), San Jose State University; Ph.D. (1999), Stanford University.

JOHN P. MONTEVERDI (1978), *Professor of Meteorology*; B.A. (1968), M.A. (1970), Ph.D. (1977), University of California, Berkeley.

DAVID A. MUSTART (1972), *Professor of Geology*; B.S. (1965), University of British Columbia; Ph.D. (1972), Stanford University.

## Associate Professor

JOHN CASKEY (1998), *Associate Professor of Geology*; B.A. (1987), Humboldt State University; M.S. (1991), Ph.D. (1996), University of Nevada.

JASON J. GURDAK (2009), *Associate Professor of Geology*; B.S. (1998) Bates College; M.S. (1999), Ph.D. (2006), Colorado School of Mines.

ALEXANDER STINE (2013), *Associate Professor of Oceanography*; Sc.B. (1996), Brown University; Sc.M. (2002), Massachusetts Institute of Technology; Ph.D. (2010), University of California, Berkeley.

## Assistant Professor

ERIN BRAY (2019), *Assistant Professor of Earth and Climate Sciences*; B.S. (2003), Cornell University; M.A. (2005), Brown University; Ph.D. (2013), University of California, Santa Barbara.

YADIRA IBARRA (2016), *Assistant Professor of Earth and Climate Sciences*; B.A. (2009), Brown University; Ph.D. (2014), University of Southern California.

PIERO MAZZINI (2017), *Assistant Professor of Earth and Climate Sciences*; B.S. (2006), Universidade do Vale do Itajai; M.S. (2009), University of Sao Paulo; Ph.D. (2014), Oregon State University.

## Adjunct Professor

STUART W. SIEGEL (2016), *Adjunct Professor of Estuarine Science*; B.A., B.S. (1986), M.A. (1993), Ph.D. (2002), University of California, Berkeley.

LEONARD SKLAR (2003), *Adjunct Professor of Geology*; B.S. (1989), New York University; B.E.(1989), Cooper Union; M.S. (1990), Ph.D.(2003), University of California, Berkeley.

LISA D. WHITE (1990), *Adjunct Professor of Geology*; B.A. (1984), San Francisco State University; Ph.D. (1989), University of California, Santa Cruz.

## Majors

- Bachelor of Arts in Earth Sciences (<http://bulletin.sfsu.edu/colleges/science-engineering/earth-climate-science/ba-earth-sciences/>)

- Bachelor of Science in Earth Sciences (<http://bulletin.sfsu.edu/colleges/science-engineering/earth-climate-science/bs-earth-sciences/>)

## Minor

- Minor in Earth Sciences (<http://bulletin.sfsu.edu/colleges/science-engineering/earth-climate-science/minor-earth-sciences/>)

## Certificate

- Certificate in Weather Study (<http://bulletin.sfsu.edu/colleges/science-engineering/earth-climate-science/certificate-weather-study/>)

## Masters

- Master of Science in Geosciences (<http://bulletin.sfsu.edu/colleges/science-engineering/earth-climate-science/ms-geosciences/>)

### ERTH 110 Our Dynamic Earth (Units: 3)

Prerequisite: Not open to students who have completed ERTH 112.

Investigating the geologic processes that are continually shaping our planet, emphasizing the connections between humans and nature and the process of scientific discovery. Designed for non-science majors. [Formerly GEOL 100]

#### Course Attributes:

- B1: Physical Science
- Environmental Sustainability

### ERTH 111 Our Dynamic Earth Lab (Unit: 1)

Prerequisite: ERTH 110 (may be taken concurrently); not open to students who have completed ERTH 112.

Investigating the geologic processes that are continually shaping our planet, emphasizing the connections between humans and nature and the process of scientific discovery. Hands-on activities to explore Earth processes. Extra fee required. [Formerly GEOL 101]

#### Course Attributes:

- B3: Lab Science

### ERTH 112 Our Dynamic Earth Lecture and Lab (Units: 4)

Prerequisite: Not open to students who have completed ERTH 110 or ERTH 111.

Investigate the geologic processes that are continually shaping our planet with an emphasis on the connections between humans and nature and the process of scientific discovery. Designed for non-science majors. Lecture, 3 units; laboratory, 1 unit. Extra fee required. [Formerly GEOL 104]

#### Course Attributes:

- B1: Physical Science
- B3: Lab Science
- Environmental Sustainability

### ERTH 115 History of Life (Units: 3)

Origin and early development of life; evolution of life through geologic time; extinction and replacement of organisms. [Formerly GEOL 105]

#### Course Attributes:

- B2: Life Science
- Environmental Sustainability

**ERTH 160 Our Dynamic Weather (Units: 3)**

Prerequisite: Not open to students who have completed EARTH 162.

The nature of weather, including winds, storms, clouds, and precipitation. How and why weather changes, emphasizing the process of scientific discovery. Weather map interpretation and weather forecasting. Designed for non-science majors. [Formerly METR 100]

**Course Attributes:**

- B1: Physical Science
- Global Perspectives

**ERTH 162 Our Dynamic Weather Lecture and Lab (Units: 3)**

Prerequisite: Not open to students who have completed EARTH 160.

The nature of weather, including winds, storms, clouds, and precipitation. How and why weather changes, emphasizing the process of scientific discovery. Weather map interpretation and weather forecasting. Designed for non-science majors. Lecture, 2 units; laboratory, 1 unit. Extra fee required. [Formerly METR 104]

**Course Attributes:**

- B1: Physical Science
- B3: Lab Science

**ERTH 170 Our Dynamic Ocean (Units: 3)**

Prerequisite: Not open to students who have completed EARTH 172.

Investigating components and operating principles of the ocean system, including ocean basin features, currents, nutrient cycling, and climatic influences, emphasizing the process of scientific discovery. Designed for non-science majors. [Formerly OCN 100]

**Course Attributes:**

- B1: Physical Science
- Environmental Sustainability

**ERTH 171 Our Dynamic Ocean Lab (Unit: 1)**

Prerequisite: EARTH 170 (may be taken concurrently); not open to students who have completed EARTH 172.

Investigating ocean processes that play a dominant role in regulating our climate and environment. Emphasizes nature human connections and the process of scientific discovery through hands-on activities. Extra fee required. [Formerly OCN 101]

**Course Attributes:**

- B3: Lab Science

**ERTH 172 Our Dynamic Ocean Lecture and Lab (Units: 4)**

Prerequisite: Not open to students who have completed EARTH 170 or EARTH 171.

Investigate components and operating principles of the ocean system, including ocean basin features, currents, nutrient cycling, and climatic influences, emphasizing the process of scientific discovery. Designed for non-science majors. Lecture, 3 units; laboratory and fieldwork, 1 unit. Extra fee required. [Formerly OCN 104]

**Course Attributes:**

- B1: Physical Science
- B3: Lab Science
- Environmental Sustainability

**ERTH 205 Techniques in Earth Sciences (Units: 2)**

Prerequisite: An introductory course in one of the earth sciences (geology, meteorology, oceanography) or EARTH 400.

Introduction to field and laboratory techniques in the earth sciences, including scientific writing and library research. Laboratory and fieldwork, 2 units. (Plus-Minus letter grading only)

**ERTH 210 Physical Geology (Units: 4)**

Composition, structure, and evolution of the earth; earth materials; tectonic and hydrologic systems; landform development; relation of geologic systems to the human environment. Lecture, 3 units; laboratory and fieldwork, 1 unit. Extra fee required. (Plus-minus letter grade only) [Formerly GEOL 110]

**Course Attributes:**

- B1: Physical Science
- B3: Lab Science
- Environmental Sustainability

**ERTH 230 Environmental Geology (Units: 3)**

Human interaction with the geologic environment. Social and political implications, resource and energy exploitation, land use planning, waste disposal, and human modification of nature. Lecture, 2 units; laboratory and fieldwork, 1 unit. Designed for non-science majors. [Formerly GEOL 270]

**Course Attributes:**

- B1: Physical Science
- B3: Lab Science
- Environmental Sustainability

**ERTH 240 Environmental Water Resources (Units: 3)**

Apply concepts from hydrology, the science of water, to investigate the distribution, flow, and properties (physical, chemical, and biological) of water resources. Characterize the environmental state of freshwater and related food, energy, and ecological resources. Problem-solving related to pollution and prevention, natural disasters, such as droughts and floods, water scarcity, urbanization and stormwater, sustainable groundwater management, engineering solutions, seawater intrusion, and climate variability, with a focus on CA and San Francisco. Experience with hydrologic measurements, testing, data collection, and analysis in the field and using computer models. Lecture, 2 units; laboratory, 1 unit. (Plus-minus letter grade only)

**Course Attributes:**

- B1: Physical Science
- B3: Lab Science
- Environmental Sustainability

**ERTH 260 Physical Processes in the Atmosphere (Units: 4)**

Prerequisite: MATH 199 or equivalent or satisfactory score on calculus pretest.

Observed behaviors of the atmosphere and the processes and principles that explain and predict them. Algebra-based problem solving. Lecture, 3 units; laboratory, 1 unit. Extra fee required. [Formerly METR 201]

**Course Attributes:**

- B1: Physical Science
- B3: Lab Science
- Environmental Sustainability
- Global Perspectives

**ERTH 270 Physical Processes in the Ocean (Units: 3)**

Prerequisite: MATH 199 or equivalent.

Observed behaviors of the ocean and the underlying processes and principles that explain and predict them. Algebra-based problem solving. Lecture, 2 units; laboratory, 1 unit.

**ERTH 310 The Violent Earth (Units: 3)**

Prerequisites: GE Areas A1\*, A2\*, A3\*, and B4\* all with grades of C- or better or consent of the instructor.

The catastrophic geological agents that modify the environment. The significance of processes such as earthquakes and volcanic eruptions in the development of our planet. The concept of time in evaluating the magnitude of these violent events. Designed for non-science majors. [Formerly GEOL 302]

**Course Attributes:**

- UD-B: Physical Life Science
- Environmental Sustainability

**ERTH 325 Geology of the National Parks (Units: 3)**

Prerequisites: GE Areas A1\*, A2\*, A3\*, and B4\* or consent of the instructor.

Applying geologic principles to natural environments of North America, focusing on the geologic history and landscape evolution of the National Parks. The uniqueness of natural regions and questions of preservation. Lecture, 2 units; laboratory, 1 unit. Designed for non-science majors. (Plus-minus letter grade only) [Formerly GEOL 350]

**Course Attributes:**

- UD-B: Physical Life Science
- Environmental Sustainability

**ERTH 330 California Water (Units: 3)**

Prerequisites: GE Areas A1\*, A2\*, A3\*, and B4\* all with grades of C- or better or consent of the instructor. Intended for non-science majors.

Human interaction with the hydrologic environment; science and politics of water issues facing California; hydrologic cycle, floods, droughts, groundwater, contamination; water needs of cities, farms, ecosystems; effects of climate change on water resources. (Plus-minus letter grade only) [Formerly GEOL 370]

**Course Attributes:**

- UD-B: Physical Life Science
- Environmental Sustainability

**ERTH 335 Global Warming (Units: 3)**

Prerequisites: GE Areas A1\*, A2\*, A3\*, and B4\* all with grades of C- or better or consent of the instructor.

Scientific understanding of global warming. Greenhouse gases, records of past climate change, warming of the recent past, human impact on climate, projections of future climate, and the impact on society. Critical evaluation of popular media coverage of climate change. [Formerly GEOL 375]

**Course Attributes:**

- UD-B: Physical Life Science
- Environmental Sustainability
- Global Perspectives

**ERTH 360 California Weather Events (Units: 3)**

Prerequisites: GE Areas A1\*, A2\*, A3\*, and B4\* all with grades of C- or better or consent of the instructor.

Investigation of the basic meteorology of normal and abnormal weather events in California. [Formerly METR 356]

**Course Attributes:**

- UD-B: Physical Life Science
- Environmental Sustainability
- Global Perspectives

**ERTH 365 Extreme Weather in a Warming World (Units: 3)**

Prerequisites: GE Areas A1\*, A2\*, A3\*, and B4\* all with grades of C- or better or consent of the instructor.

Atmosphere and ocean as agents of catastrophic change. Fluctuations in atmospheric and oceanic circulations and their environmental impacts. Implications of human modification of the ocean-atmosphere system. Weather variability as evidenced by recent floods, droughts, and severe weather. Designed for non-science majors. [Formerly METR 302]

**Course Attributes:**

- UD-B: Physical Life Science
- Environmental Sustainability
- Global Perspectives

**ERTH 400 Earth Systems I (Units: 3)**

Prerequisites: At least 9 units of coursework in geoscience, earth sciences, chemistry, or physics.

Exploring the components of Earth's systems: atmosphere, hydrosphere, lithosphere, biosphere, and anthroposphere, with focus on the physical and biogeochemical processes through which the components interact. Lecture, 2 units; laboratory, 1 unit. [Formerly GEOL 401]

**ERTH 410 Volcanology (Units: 3)**

Prerequisite: EARTH 210 or consent of the instructor.

Volcanic processes, landforms, structures, and rocks; origin and differentiation of magma and relation to plate boundaries; case studies of volcanic events on earth and other planets; applications to archaeology and other disciplines. Lecture, 2 units; laboratory and fieldwork, 1 unit. Extra fee required. [Formerly GEOL 410]

**ERTH 420 Mineralogy and Petrology I (Units: 4)**

Prerequisites: EARTH 210 and CHEM 115 or consent of the instructor.

Minerals: physical properties, crystal chemistry, reactions and stability, and identification of common types, including optical mineralogy. Lecture, 2 units; laboratory and fieldwork, 2 units. [Formerly GEOL 420]

**ERTH 425 Geomorphology (Units: 4)**

Prerequisites for EARTH 825: Graduate or senior standing; EARTH 210, EARTH 505 or MATH 226, and PHYS 111 and PHYS 112 or PHYS 220 and PHYS 222; or consent of the instructor.

Prerequisites for EARTH 425: Upper-division standing; EARTH 210, EARTH 505 or MATH 226, and PHYS 111 and PHYS 112 or PHYS 220 and PHYS 222; or consent of the instructor.

Landscapes, their geologic evolution, and the processes which create and modify them. Lecture, 3 units; laboratory, 1 unit.

(ERTH 825/ERTH 425 [Formerly GEOL 450/GEOL 750] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 430 Fluid Dynamics in Earth Systems (Units: 3)**

Prerequisites: MATH 227 and PHYS 111 or (recommended) PHYS 220, or consent of the instructor.

Introduction to the basic principles of fluid dynamics as applied to the ocean and atmosphere; and related fields in earth sciences, such as surface water flow and groundwater dynamics. Lecture, 2 units; laboratory, 1 unit. [Formerly OCN 320/METR 320]

**ERTH 434 Coastal Processes (Units: 3)**

Prerequisites for EARTH 834: Graduate or senior standing; MATH 226 and PHYS 111 or PHYS 220; GPA of 3.0 or higher; or consent of the instructor. Prerequisites for EARTH 434: Upper-division standing; MATH 226 and PHYS 111 or PHYS 220; GPA of 3.0 or higher; or consent of the instructor.

Dynamics of the nearshore ocean and interactions with the coast and beaches. Topics include tides, coastal waves and currents, sediment transport and beaches, inner shelf processes, and estuarine dynamics. Lecture, 2 units; laboratory, 1 unit.

(ERTH 834/ERTH 434 [Formerly OCN 410/OCN 710] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 442 Surface Water Hydrology (Units: 4)**

Prerequisites: MATH 226 and EARTH 210 or EARTH 505 are recommended; or consent of the instructor.

Introduction to surface water hydrology; exploration of hydrologic processes; how precipitation and snowmelt become streamflow, evapotranspiration, and groundwater; watershed hydrology, streamflow processes, and water quality. Lecture, 3 units; activity, 1 unit. (Plus-minus letter grade only)

(This course is offered as EARTH 442 [Formerly GEOL 473] and GEOG 342. Students may not repeat the course under an alternate prefix.)

**ERTH 444 Hydrogeology (Units: 4)**

Prerequisites for EARTH 744: Graduate or senior standing; EARTH 210, EARTH 505 or MATH 226, and PHYS 111 and PHYS 112 or PHYS 220 and PHYS 222 or an upper-division Engineering course; or consent of the instructor.

Prerequisites for EARTH 444: Upper-division standing; EARTH 210, EARTH 505 or MATH 226, and PHYS 111 and PHYS 112 or PHYS 220 and PHYS 222; GPA of 3.0 or higher; or consent of the instructor.

Physical and geologic factors controlling the occurrence and dynamics of groundwater. Chemical parameters and distribution. Aquifer testing and analysis. Lecture, 3 units; laboratory, 1 unit.

(ERTH 744/ERTH 444 [Formerly GEOL 475/GEOL 775] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 446 Quaternary Geology and Soils (Units: 3)**

Prerequisites for EARTH 846: Graduate standing; EARTH 210; or consent of the instructor.

Prerequisites for EARTH 446: Senior standing; EARTH 210; GPA of 3.0 or higher; or consent of the instructor.

Pleistocene and Holocene environments, and their geomorphic and stratigraphic record. Emphasis on landform evolution, soil genesis, soil genesis, climatic history, sea-level changes, neotectonics, and environmental impact. Lecture, 2 units; laboratory, 1 unit.

(ERTH 846/ERTH 446 [Formerly GEOL 454/GEOL 754] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 456 Use of Computers in the Earth Sciences (Units: 2)**

Prerequisite: A college course in one of the earth sciences (geology, meteorology, oceanography) or EARTH 400.

Use of computers to access, display, and analyze earth science data. [Formerly METR/OCN 460]

**ERTH 461 Weather Chart Analysis and Discussion (Unit: 1)**

Prerequisite for EARTH 861: Graduate standing or consent of the instructor.

Prerequisite for EARTH 461: Upper-division standing; EARTH 260 (may be taken concurrently); GPA of 3.0 or higher; or consent of the instructor.

Weather chart analysis techniques. Weather briefing and discussion. Laboratory. (Plus-minus letter grade only)  
(ERTH 861/ERTH 461 [Formerly METR 301/METR 801] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 465 Weather Analysis and Forecasting I (Units: 4)**

Prerequisites: EARTH 260, EARTH 461, MATH 227, PHYS 111 or (recommended) PHYS 220.

Weather analysis and forecasting as an application of the principles of atmospheric physics and dynamics. Weather satellite analysis techniques. Operational forecasting. Lecture, 2 units; laboratory, 2 units. (Plus-minus letter grade only) [Formerly METR 430GW]

**ERTH 470 Physical Oceanography (Units: 4)**

Prerequisites for EARTH 870: Graduate or senior standing; EARTH 170 or EARTH 172 or EARTH 270 and PHYS 220; or consent of the instructor.

Prerequisites for EARTH 470: Upper-division standing; EARTH 170 or EARTH 172 or EARTH 270 and PHYS 220; GPA of 3.0 or higher; or consent of the instructor.

The dynamic character of the ocean environment with an emphasis on the properties of seawater, surface heat transfer, Coriolis force, surface and deep ocean circulation, deep and shallow wave phenomena, and underwater sound and optics. Designed for both the physical scientist and marine biologist. Lecture, 3 units; laboratory, 1 unit.

(ERTH 870/ERTH 470 [Formerly OCN 420/OCN 720] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 490 Public Weather Forecasting (Units: 1-3)**

Prerequisites: EARTH 160 or EARTH 162 or EARTH 260, and declared Earth Sciences major or participant in the Broadcast Meteorology Certificate program.

Weather forecasting tailored for public use. Forecasting and nowcasting in the media. Weather briefing duties of intern forecaster. May be repeated for a total of 3 units. (Plus-minus letter grade only) [Formerly METR 698]

**ERTH 500 Earth Systems II (Units: 3)**

Prerequisite: EARTH 400.

Exploration of how physical and biochemical processes in Earth's systems led to the origin and evolution of the continents, oceans, atmosphere, and life through geologic time. Lecture, 2 units; laboratory and fieldwork, 1 unit.

**ERTH 505 Quantitative Methods in Earth Sciences (Units: 3)**

Prerequisites: EARTH 400, MATH 199, or sufficient score on calculus pretest.

Quantitative reasoning and techniques, including statistics, applied to problems in earth science. Lecture, 2 units; laboratory and fieldwork, 1 unit. Weekend field trip required. (Plus-minus letter grade only) [Formerly GEOL 125]

**ERTH 510 Structural Geology (Units: 4)**

Prerequisites: EARTH 500, EARTH 420, and any one of the following: MATH 199, satisfactory score on online precalculus test, EARTH 505.

Mechanical aspects of rock deformation. Description, classification, and genesis of folds, faults, and other structures of the earth's crust. Evolution of regional structures. Lecture, 2 units; laboratory and fieldwork, 2 units. [Formerly GEOL 430]

**ERTH 515 Sedimentology and Stratigraphy (Units: 4)**

Prerequisites: EARTH 205, EARTH 420, and EARTH 500.

Sedimentary particles and processes, depositional environments, principles of stratigraphic correlation, and basin analysis. Lecture, 2 units; laboratory and fieldwork, 2 units. (Plus-minus letter grade only) [Formerly GEOL 460GW]

**ERTH 520 Mineralogy and Petrology II (Units: 4)**

Prerequisite for EARTH 820: Graduate standing or consent of the instructor.

Prerequisites for EARTH 520: Upper-division standing; EARTH 420; GPA of 3.0 or higher; or consent of the instructor.

Advanced mineralogy and igneous and metamorphic petrology with a focus on physical and chemical processes in the earth. Lecture, 2 units; laboratory, 2 units. Extra fee required.

(ERTH 820/ERTH 520 [Formerly GEOL 426/GEOL 726] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 522 Geochemistry (Units: 4)**

Prerequisite for EARTH 822: Graduate or senior standing or consent of the instructor.

Prerequisites for EARTH 522: Upper-division standing; EARTH 420 and EARTH 505 or MATH 226; GPA of 3.0 or higher; or consent of the instructor.

Chemistry of the earth including cosmochemistry, crystal chemistry, thermodynamics, aqueous geochemistry, stable and radiogenic isotope geochemistry, major and trace element geochemistry, and analytical techniques. Lecture, 3 units; laboratory, 1 unit.

(ERTH 822/ERTH 522 [Formerly GEOL 480/GEOL 780] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 526 Ore Deposits (Units: 4)**

Prerequisite for EARTH 826: Graduate standing; EARTH 420; or consent of the instructor.

Prerequisites for EARTH 526: Upper-division standing; EARTH 420; GPA of 3.0 or higher; or consent of the instructor.

The origin of ore deposits emphasizing the mineralogic, petrologic, and plate tectonic environments of major deposits from around the world. Chemical and physical controls on ore transport and deposition. Techniques of mineral exploration and mining. Lecture, 3 units; laboratory, 1 unit.

(ERTH 826/ERTH 526 [Formerly GEOL 485/GEOL 785] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 535 Planetary Climate Change (Units: 4)**

Prerequisites: At least 9 units of physical sciences coursework.

Interdisciplinary investigation of physical processes, principles, and tools contributing to our understanding of climate and climate change. Lecture, 3 units; laboratory, 1 unit. [Formerly GEOL/METR/OCN 405]

**ERTH 544 Groundwater Contamination (Units: 3)**

Prerequisites for EARTH 844: Graduate or senior standing; EARTH 744.

Prerequisites for EARTH 544: Upper-division standing; EARTH 444; CHEM 115 recommended; GPA of 3.0 or higher; or consent of the instructor.

Application of hydrogeologic principles to the solution of groundwater contamination problems. Seminar, 2 units; laboratory, 1 unit. (ERTH 844/ERTH 544 [Formerly GEOL 476/GEOL 776] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 556 Computer Programming with Applications in the Earth Sciences (Units: 3)**

Prerequisites: An introductory course in one of the earth sciences (geology, meteorology, oceanography) or EARTH 400, EARTH 456 recommended.

Principles of computer programming, illustrated with applications in the earth sciences. [Formerly METR/OCN 465]

**ERTH 560 Atmospheric Dynamics I (Units: 4)**

Prerequisites: MATH 228 and PHYS 220; MATH 245 and EARTH 556 recommended; or consent of the instructor.

Basic dynamical equations governing atmospheric motions, particularly on large scales. Lecture, 3 units; laboratory, 1 unit. Extra fee required. [Formerly METR 420]

**ERTH 565 Weather Analysis and Forecasting II (Units: 3)**

Prerequisites for EARTH 865: Graduate standing; EARTH 430 and EARTH 465; or consent of the instructor.

Prerequisites for EARTH 565: Upper-division standing; EARTH 430 and EARTH 465; GPA of 3.0 or higher; or consent of the instructor.

Quasi-geostrophic theory in the understanding of mid-latitude synoptic systems. Evolution and motion of mid and upper tropospheric waves. Fronts and jet streaks. Mesoscale and severe weather meteorology. Lecture, 2 units; laboratory, 1 unit. (ERTH 865/ERTH 565 [Formerly METR 500/METR 800] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 600GW Earth's Climate History - GEAR (Units: 3)**

Prerequisites: GE Area A2; CHEM 115 and EARTH 500 (may be taken concurrently).

Examination of Earth's climate history over the last 50 million years; analysis of different mechanisms of climate forcing including tectonic changes, greenhouse gas forcing on long and short time scales, orbital forcing, and internal climate feedback. Lecture, 2 units; laboratory, 1 unit. (ABC/NC grading only) [Formerly GEOL 458GW]

**Course Attributes:**

- Graduation Writing Assessment

**ERTH 610 Neotectonics (Units: 3)**

Prerequisites for EARTH 810: Graduate or senior standing; EARTH 510; or consent of the instructor.

Prerequisites for EARTH 610: Senior standing; EARTH 510; GPA of 3.0 or higher; or consent of the instructor.

Principles of earthquake geology including plate tectonics, fault mechanics, basic seismology, geodesy, tectonic geomorphology, seismic hazard analysis, and case studies of large historical earthquakes. Lecture, 2 units; laboratory, 1 unit. (Plus-minus letter grade only) (ERTH 810/ERTH 610 [Formerly GEOL 470/GEOL 770] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 620 Field Methods in Geology (Units: 2)**

Prerequisites: EARTH 210, EARTH 510, EARTH 515, satisfactory standing in the major, or consent of the instructor.

Field methods: plotting features on topographic maps and aerial photographs, use of field instruments, mapping, and preparation of geologic reports. Laboratory and fieldwork. [Formerly GEOL 695]

**ERTH 642 Watershed Assessment and Restoration (Units: 4)**

Prerequisites: GEOG 101 or EARTH 210, GEOG 603, and MATH 199 or a sufficient score on calculus pretest.

Assessing and restoring watersheds and streams. Exploration of hydrologic and watershed processes, variables influencing runoff and erosion, and hillslope and stream restoration techniques. Lecture, 3 units; activity, 1 unit. [CSL may be available] (This course is offered as GEOG 642 and EARTH 642. Students may not repeat the course under an alternate prefix.)

**ERTH 643 Biogeomorphology of Sierra Nevada Streams and Meadows (Units: 2)**

Prerequisite: GEOG 101 or EARTH 110.

Understanding the complex interactions of hydrologic and biogeomorphic systems on streams and meadows in the northern Sierra Nevada, and learning field methods for assessing stream function as they respond to long-term impacts related to glacial history and short-term human impacts of timber extraction, road construction, and grazing. Activity. (This course is offered as GEOG 643 and EARTH 643. Students may not repeat the course under an alternate prefix.)

**ERTH 652 Geoscience Partners in K-12 Education (Units: 4)**

Prerequisite: Completion of at least one upper division course in your major field of study.

Introduction to geoscience K-12 teaching and learning; examine understanding of geoscience, discuss science education literature, and analyze science lessons and student learning. Lecture, 2 units; fieldwork, 2 units. [Formerly GEOL/OCN/METR 652]

**ERTH 660 Atmospheric Dynamics II (Units: 2)**

Prerequisites: EARTH 560, MATH 245, PHYS 240 recommended.

Development of the vorticity equation and the quasi-geostrophic approximation to the full dynamical equations governing atmospheric behavior. Lecture, 1 unit; laboratory, 1 unit. [Formerly METR 520]

**ERTH 690 Earth Sciences Capstone Presentation (Unit: 1)**

Prerequisites: Restricted to Earth Sciences seniors (BS/BA), EARTH 695 or EARTH 698 (may be taken concurrently).

Principles and best practices of presenting scientific information orally and by poster. Practice presenting senior project or senior thesis research. Presentation of senior project at a poster session or oral thesis defense open to the public. (Plus-minus letter grade only)

**ERTH 693 Cooperative Education Program (Units: 6-12)**

Prerequisites: ENG 114, COMM 150, consent of the instructor. Intended for Earth Sciences majors.

Objectives are career development, occupational experience, and educational subsidy. Units do not count toward the degree. (CR/NC grading only) [Formerly GEOL 693]

**ERTH 694 Cooperative Education in Earth Sciences (Units: 1-3)**

Prerequisite: Intended for Earth Sciences majors.

Objectives are career development, occupational experience, and educational subsidy. Units do not count toward degree. [Formerly GEOL 694]

**ERTH 695 Senior Project (Units: 1-3)**

Prerequisites: Senior standing in Earth Sciences, 3.0 GPA in major course work, and consent of Earth Sciences faculty adviser.

Directed, original research on an Earth Sciences-related problem. [Formerly GEOL 697, METR 697, and OCN 697]

**ERTH 697 Undergraduate Research (Units: 2)**

Prerequisites: Senior standing, consent of the instructor.

Research activities, including literature review, project design, data collection, and analysis. (Plus-minus letter grade only) [Formerly GEOL 697]

**ERTH 698 Senior Thesis (Units: 2)**

Prerequisite: EARTH 697 (may be taken concurrently).

Undergraduate research, to include a written report and oral presentation approved by the thesis committee. (Plus-minus letter grade only) [Formerly GEOL 698]

**ERTH 699 Independent Study (Units: 1-3)**

Prerequisite: Consent of the instructor.

Independent study in the laboratory, field, or library under the direction of a faculty member. The student must present a written report of the work accomplished to the faculty. [Formerly GEOL/METR/OCN 699]

**ERTH 700 Graduate Seminar in Geosciences (Units: 2)**

Prerequisite: Graduate standing.

Introduction to the graduate program; discussion of interdisciplinary geoscience topics; format to include speakers and assigned readings. (Plus-minus letter grade only) [Formerly GEOL/METR/OCN 700]

**ERTH 701 Research Methods in Geosciences (Units: 3)**

Prerequisite: EARTH 700 or consent of the instructor.

Application of research methods: problem formulation, literature searches, proposal writing, scientific report writing, and oral presentation. Preparation of proposal for master's thesis. (Plus-minus letter grade only) [Formerly GEOL/METR/OCN 701]

**ERTH 702 Quantitative Methods in Geosciences (Units: 3)**

Prerequisites: Courses in basic statistics, calculus, and computer applications, or consent of the instructor.

Quantitative methods and computer techniques necessary for geoscience problem-solving. Lecture, 2 units; laboratory and fieldwork, 1 unit. (Plus-minus letter grade only) [Formerly GEOL/METR/OCN 702]

**ERTH 730 Paleoclimate (Units: 2)**

Prerequisite: Graduate standing or consent of the instructor.

Reading and discussion of primary cutting edge literature on climate science. (Plus-minus letter grading only) [Formerly GEOL 794]

**ERTH 741 Electron Microscopy (Units: 4)**

Prerequisite: Graduate or senior standing and consent of the instructor.

Introduction to electron microscopy with a focus on instrumentation, image formation and interpretation, x-ray microanalysis, sample preparation, artifacts, and related techniques. Laboratory work includes operation of the electron microscope, x-ray microanalysis, and the preparation of biological and inorganic specimens for scanning and transmission electron microscopy. Seminar, 2 units; laboratory, 2 units. Extra fee required. (Plus-minus letter grade only) (This course is offered as BIOL 741, CHEM 741, and EARTH 741. Students may not repeat the course under an alternate prefix.)

**ERTH 744 Hydrogeology (Units: 4)**

Prerequisites for EARTH 744: Graduate or senior standing; EARTH 210, EARTH 505 or MATH 226, and PHYS 111 and PHYS 112 or PHYS 220 and PHYS 222 or an upper-division Engineering course; or consent of the instructor.

Prerequisites for EARTH 444: Upper-division standing; EARTH 210, EARTH 505 or MATH 226, and PHYS 111 and PHYS 112 or PHYS 220 and PHYS 222; GPA of 3.0 or higher; or consent of the instructor.

Physical and geologic factors controlling the occurrence and dynamics of groundwater. Chemical parameters and distribution. Aquifer testing and analysis. Lecture, 3 units; laboratory, 1 unit.

(ERTH 744/ERTH 444 [Formerly GEOL 475/GEOL 775] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 750 Our Dynamic Classroom (Unit: 1)**

Prerequisite: Graduate standing or consent of the instructor.

Teaching and Learning Community. Exploration of innovative pedagogical techniques and integrating laboratory and lecture components for introductory geosciences courses. (Plus-minus letter grade only) [Formerly GEOL/METR/OCN 792]

**ERTH 790 Advanced Public Weather Forecasting (Units: 1-3)**

Prerequisite: EARTH 490 [formerly METR 698] and/or consent of instructor.

Direction of a forecast office. Students assume lead forecaster responsibilities in administration of the SF State Public Weather Forecast Center. (Plus-minus letter grade only) [Formerly METR 798]

**ERTH 795 Selected Topics in the Geosciences (Units: 3)**

Prerequisite: Graduate standing or consent of the instructor.

Topics to be specified in the Class Schedule. May be repeated for a maximum of 12 units when topics vary. (Plus-minus letter grade only) [Formerly GEOL 795]

**ERTH 810 Neotectonics (Units: 3)**

Prerequisites for EARTH 810: Graduate or senior standing; EARTH 510; or consent of the instructor.

Prerequisites for EARTH 610: Senior standing; EARTH 510; GPA of 3.0 or higher; or consent of the instructor.

Principles of earthquake geology including plate tectonics, fault mechanics, basic seismology, geodesy, tectonic geomorphology, seismic hazard analysis, and case studies of large historical earthquakes. Lecture, 2 units; laboratory, 1 unit. (Plus-minus letter grade only) (ERTH 810/ERTH 610 [Formerly GEOL 470/GEOL 770] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 820 Mineralogy and Petrology II (Units: 4)**

Prerequisite for EARTH 820: Graduate standing or consent of the instructor.

Prerequisites for EARTH 520: Upper-division standing; EARTH 420; GPA of 3.0 or higher; or consent of the instructor.

Advanced mineralogy and igneous and metamorphic petrology with a focus on physical and chemical processes in the earth. Lecture, 2 units; laboratory, 2 units. Extra fee required.

(ERTH 820/ERTH 520 [Formerly GEOL 426/GEOL 726] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 822 Geochemistry (Units: 4)**

Prerequisite for EARTH 822: Graduate or senior standing or consent of the instructor.

Prerequisites for EARTH 522: Upper-division standing; EARTH 420 and EARTH 505 or MATH 226; GPA of 3.0 or higher; or consent of the instructor.

Chemistry of the earth including cosmochemistry, crystal chemistry, thermodynamics, aqueous geochemistry, stable and radiogenic isotope geochemistry, major and trace element geochemistry, and analytical techniques. Lecture, 3 units; laboratory, 1 unit.

(ERTH 822/ERTH 522 [Formerly GEOL 480/GEOL 780] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 825 Geomorphology (Units: 4)**

Prerequisites for EARTH 825: Graduate or senior standing; EARTH 210, EARTH 505 or MATH 226, and PHYS 111 and PHYS 112 or PHYS 220 and PHYS 222; or consent of the instructor.

Prerequisites for EARTH 425: Upper-division standing; EARTH 210, EARTH 505 or MATH 226, and PHYS 111 and PHYS 112 or PHYS 220 and PHYS 222; or consent of the instructor.

Landscapes, their geologic evolution, and the processes which create and modify them. Lecture, 3 units; laboratory, 1 unit.

(ERTH 825/ERTH 425 [Formerly GEOL 450/GEOL 750] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 826 Ore Deposits (Units: 4)**

Prerequisite for EARTH 826: Graduate standing; EARTH 420; or consent of the instructor.

Prerequisites for EARTH 526: Upper-division standing; EARTH 420; GPA of 3.0 or higher; or consent of the instructor.

The origin of ore deposits emphasizing the mineralogic, petrologic, and plate tectonic environments of major deposits from around the world. Chemical and physical controls on ore transport and deposition. Techniques of mineral exploration and mining. Lecture, 3 units; laboratory, 1 unit.

(ERTH 826/ERTH 526 [Formerly GEOL 485/GEOL 785] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 834 Coastal Processes (Units: 3)**

Prerequisites for EARTH 834: Graduate or senior standing; MATH 226 and PHYS 111 or PHYS 220; GPA of 3.0 or higher; or consent of the instructor.

Prerequisites for EARTH 434: Upper-division standing; MATH 226 and PHYS 111 or PHYS 220; GPA of 3.0 or higher; or consent of the instructor.

Dynamics of the nearshore ocean and interactions with the coast and beaches. Topics include tides, coastal waves and currents, sediment transport and beaches, inner shelf processes, and estuarine dynamics. Lecture, 2 units; laboratory, 1 unit.

(ERTH 834/ERTH 434 [Formerly OCN 410/OCN 710] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 844 Groundwater Contamination (Units: 3)**

Prerequisites for EARTH 844: Graduate or senior standing; EARTH 744.

Prerequisites for EARTH 544: Upper-division standing; EARTH 444; CHEM 115 recommended; GPA of 3.0 or higher; or consent of the instructor.

Application of hydrogeologic principles to the solution of groundwater contamination problems. Seminar, 2 units; laboratory, 1 unit. (ERTH 844/ERTH 544 [Formerly GEOL 476/GEOL 776] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 846 Quaternary Geology and Soils (Units: 3)**

Prerequisites for EARTH 846: Graduate standing; EARTH 210; or consent of the instructor.

Prerequisites for EARTH 446: Senior standing; EARTH 210; GPA of 3.0 or higher; or consent of the instructor.

Pleistocene and Holocene environments, and their geomorphic and stratigraphic record. Emphasis on landform evolution, soil genesis, soil genesis, climatic history, sea-level changes, neotectonics, and environmental impact. Lecture, 2 units; laboratory, 1 unit. (ERTH 846/ERTH 446 [Formerly GEOL 454/GEOL 754] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 861 Weather Chart Analysis and Discussion (Unit: 1)**

Prerequisite for EARTH 861: Graduate standing or consent of the instructor.

Prerequisite for EARTH 461: Upper-division standing; EARTH 260 (may be taken concurrently); GPA of 3.0 or higher; or consent of the instructor.

Weather chart analysis techniques. Weather briefing and discussion. Laboratory. (Plus-minus letter grade only) (ERTH 861/ERTH 461 [Formerly METR 301/METR 801] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 865 Weather Analysis and Forecasting II (Units: 3)**

Prerequisites for EARTH 865: Graduate standing; EARTH 430 and EARTH 465; or consent of the instructor.

Prerequisites for EARTH 565: Upper-division standing; EARTH 430 and EARTH 465; GPA of 3.0 or higher; or consent of the instructor.

Quasi-geostrophic theory in the understanding of mid-latitude synoptic systems. Evolution and motion of mid and upper tropospheric waves. Fronts and jet streaks. Mesoscale and severe weather meteorology. Lecture, 2 units; laboratory, 1 unit. (ERTH 865/ERTH 565 [Formerly METR 500/METR 800] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 870 Physical Oceanography (Units: 4)**

Prerequisites for EARTH 870: Graduate or senior standing; EARTH 170 or EARTH 172 or EARTH 270 and PHYS 220; or consent of the instructor.

Prerequisites for EARTH 470: Upper-division standing; EARTH 170 or EARTH 172 or EARTH 270 and PHYS 220; GPA of 3.0 or higher; or consent of the instructor.

The dynamic character of the ocean environment with an emphasis on the properties of seawater, surface heat transfer, Coriolis force, surface and deep ocean circulation, deep and shallow wave phenomena, and underwater sound and optics. Designed for both the physical scientist and marine biologist. Lecture, 3 units; laboratory, 1 unit.

(ERTH 870/ERTH 470 [Formerly OCN 420/OCN 720] is a paired course offering. Students who complete the course at one level may not repeat the course at the other level.)

**ERTH 896 Directed Reading in the Geosciences (Units: 3)**

Prerequisite: Graduate status or consent of adviser.

Supervised literature research in a specific area chosen on the basis of individual student need. Readings, tutorial discussion, and research report or creative projects. May be repeated for a total of 6 units. (Plus-minus letter grade, RP grading only) [Formerly GEOL 896]

**ERTH 897 Research Project (Units: 1-3)**

Prerequisites: Graduate standing, EARTH 700 [formerly GEOL 700/METR 700/OCN 700], EARTH 701 [formerly GEOL 701/METR 701/OCN 701].

Thesis research incorporates all aspects of investigative studies from data collection to data analysis. May be repeated for a total of 6 units. (Plus-minus letter grade, RP grading only) [Formerly GEOL 897]

**ERTH 898 Master's Thesis (Units: 3)**

Prerequisites: Graduate standing, EARTH 700 [formerly GEOL 700/METR 700/OCN 700], EARTH 701 [formerly GEOL 701/METR 701/OCN 701], EARTH 702 [formerly GEOL 702/METR 702/OCN 702], consent of instructor and approval of Advancement to Candidacy (ATC) and Culminating Experience (CE) forms by Graduate Studies.

Advancement to Candidacy (ATC) and Proposal for Culminating Experience Requirement forms must be approved by the Graduate Division before registration. (Plus-minus letter grade, RP grading only) [Formerly GEOL/METR/OCN 898]

**ERTH 899 Independent Study (Units: 1-3)**

Prerequisites: Graduate standing and consent of the adviser.

Independent study in the laboratory or field under the direction of a faculty member. A detailed written report of the work accomplished must be submitted to the department. May be repeated for a total of 6 units. (Plus-minus AB/NC grading only) [Formerly GEOL 899]