General Information

The School of Ocean and Earth Science and Technology (SOEST) was established in 1988. It combines and integrates the Departments of Geology and Geophysics, Meteorology, Ocean and Resources Engineering, and Oceanography, as well as the Hawai‘i Institute of Geophysics and Planetology, Hawai‘i Institute of Marine Biology, and the Hawai‘i Natural Energy Institute. The Sea Grant and Space Grant College Programs, Hawai‘i Undersea Research Laboratory, and Joint Institute for Marine and Atmospheric Research, all jointly supported by state and federal funds, are also part of SOEST. In 1997, the International Pacific Research Center was established in SOEST under the U.S.-Japan Common Agenda. The center is jointly supported by the state, Japanese, and federal funds.

Although the Department of Ocean and Resources Engineering offers several undergraduate courses, baccalaureate degrees are not offered in this area. The Department of Oceanography offers the BS in global environmental science. Baccalaureate degree programs are offered in the Department of Geology and Geophysics and the Department of Meteorology. Those with long-range plans for graduate work in oceanography or ocean and resources engineering should prepare themselves with an undergraduate course of study that will satisfy the entry requirements for admission to these graduate programs. Information on entrance and degree requirements for all SOEST graduate programs (MS and PhD) in geology and geophysics, meteorology, ocean and resources engineering, and oceanography is in this Catalog. Candidates for advanced degrees and the graduate certificate program apply through the Graduate Division of UH Mānoa. The school has developed a number of interdisciplinary courses at both the undergraduate and the graduate levels, which are listed under OEST within the “Courses” section of the Catalog.

Mission

The mission of SOEST is to make UH Mānoa a leading center in ocean and earth science and technology. Scientists and engineers of SOEST intend to understand the subtle and complex interrelations of the seas, the atmosphere, and the Earth in order to learn how to preserve the quality of our lives and to bring to Hawai‘i an enrichment of intellect and culture along with technological advances well suited to the needs of these islands. To that end, the objectives of SOEST are as follows:

1. Enhance educational opportunities in ocean and earth science and technology for the people of Hawai‘i, the nation, and the Pacific Basin;
2. Accelerate the growth of UH Mānoa to preeminence in research and development in ocean and earth science and technology;
3. Build the strength of UH Mānoa for public service and outreach in the Pacific Basin; and
4. Provide a foundation for economic interaction and development of marine-related industries within the State of Hawai‘i.

Degrees

Bachelor’s Degrees: BA in geology, BS in geology and geophysics, BS in meteorology, BS in global environmental science
**Master’s Degrees**: MS in geology and geophysics, MS in marine biology, MS in meteorology, MS in ocean and resources engineering, MS in oceanography, M GEO in geoscience

**Doctoral Degrees**: PhD in geology and geophysics, PhD in marine biology, PhD in meteorology, PhD in ocean and resources engineering, PhD in oceanography

**Advising**

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All undergraduate majors in SOEST are assigned to an advisor in their major upon admission into the school. Mandatory advising for all majors takes place every semester prior to the next semester’s registration. All students are encouraged to regularly meet with their advisors throughout each semester to discuss their educational and personal goals and to formulate an academic plan to attain those goals.

Program goals: To create and develop a teaching-learning relationship between the advisor/advisee to implement the advisee’s educational plan toward his or her intended degree.

Advising mission: SOEST values and promotes collaborative relations between academic advisors, faculty advisors, and students to implement a personal education plan that is consistent with the student’s goal.

**Undergraduate Programs**

Application to the following programs are accepted by the Admissions Office: the BA in geology, the BS in geology and geophysics, the BS in global environmental science, and the BS in meteorology.

**School Requirements**

1. Completion of basic course work as specified by their degree programs;
2. Completion of requirements for the major;
3. Completion of 45 upper division credit hours (courses numbered 300 and above);
4. GPA of 2.0 (C average) for all UH Mānoa registered credits;
5. GPA of 2.0 (C average) for all courses applied to the major requirements;
6. Completion of a degree audit (Graduation Worksheet) to the Student Academic Services Office at least two semesters preceding the award of the degree;
7. Completion of an application for graduation to the Student Academic Services Office in the semester preceding the award of the degree; and
8. Completion of an exit interview by the Student Academic Services Office.

**Bachelor of Arts and Bachelor of Science Degrees Requirements**

1. Courses required by UH Mānoa Undergraduate General Education Requirements;
2. One year of a second language (101 and 102); and
3. Support science requirements from mathematics, chemistry, and physics vary with degree programs and all courses may have prerequisites. The following are the minimum required courses (consult program advisor for details).

**Mathematics**

- MATH 241 (BA)
- MATH 242 (BS, geology and geophysics)
- MATH 244 (BS, meteorology)
- MATH 243 and MATH 244 or OCN 312 and ECON 321 (BS, global environmental science)

**Chemistry**

- CHEM 161/161L, 162/162L

**Physics**

- PHYS 151/151L and 152/152L (BA)
- PHYS 170/170L and 272/272L (BS)

Note that introductory chemistry and mathematics courses have placement exams.

Students who have not completed a high school course equivalent to pre-calculus should take MATH 140 during the summer session prior to their first semester. All BA and BS degree candidates should consult with the departmental advisor before registering.

**Major Requirements**

See appropriate departments for specific major requirements leading to a bachelor of arts or a bachelor of science degree.

**Graduate Programs**

See appropriate departments for specific major requirements leading to MS and PhD degrees.

**Instructional and Research Facilities**

**Hawai‘i Institute of Geophysics and Planetology**

The Hawai‘i Institute of Geophysics and Planetology (HIGP) conducts geological, geochemical, geophysical, oceanographic, acoustic, and atmospheric research, as well as remote sensing research, in Earth, space, and marine sciences. Programs embrace research and advanced training in marine geology and geophysics, small satellite development and launch, infrasound, materials science and high-pressure mineral geophysics, evolution of the Solar System, seismology and solid Earth geophysics, planetary geology, meteoritics, volcanology, rock magnetism, geodesics, and petrology. The institute maintains various specialized facilities in support of its research endeavors and has a number of instrument development programs, including the Hawai‘i Mapping Research Group who build and operate advanced sonars for seafloor mapping. Other instrument development programs include hyperspectral imagers, Raman spectrometers, and small satellites. HIGP includes the Hawai‘i Space Grant Consortium, which runs a wide variety of education and fellowship programs at the K-12, undergraduate, and professional levels in the form of workforce development and also provides outreach to the Hawai‘i community. HIGP is also the home of the Pacific Regional Planetary Data Center, and maintains several websites for the community, including “Planetary Science Research Discoveries” and the “Hawai‘i MODVOLC Near Real-time Thermal Monitoring of Global Hot-spots.”

**Hawai‘i Institute of Marine Biology**

The Hawai‘i Institute of Marine Biology (HIMB) was established on the island of Moku O Lo‘e in 1965 when its name was changed from the Hawai‘i Marine Laboratory. The
institute is responsible for providing leadership and support for studies in the marine environment, particularly coral reefs. It provides facilities and services for faculty members, graduate and undergraduate students, and visiting scholars for research and education in marine biology and related topics. The core faculty, plus many from other UH departments, study the life processes of marine organisms including plants, animals, and microbes. Research at HIMB covers a broad range of topics including coral reef biology and ecology, the behavior, physiology and sensory systems of marine mammals, tropical aquaculture, the behavior of reef fish, shark ecology and sensory systems, fish endocrinology, pollution and management of marine ecosystems, coastal biogeochemical processes, fisheries, and bioengineering and genetics.

HIMB is unique in that it has modern molecular biology laboratories and immediate access to the reef, Kāne‘ohe Bay, and deep ocean waters. It is located on Moku O Lo‘e (Coconut Island) in Kāne‘ohe Bay (on the east coast of O‘ahu), providing a unique setting for graduate-level topics courses and field-trip demonstration opportunities. Kāne‘ohe Bay has many healthy coral reefs. The 28 acre island, located within a 30 minute drive distance from UH Mānoa campus, is surrounded by a 64 acre coral reef dedicated to scientific research. Facilities at the marine laboratory include research vessels and skiffs, protected harbors, a pelagic fish laboratory; Hawaiian fish ponds, aquaria and tanks; a flow-through seawater system; remote environmental monitoring capabilities; reef microcosm systems; a wide array of computerized analytical and acoustic equipment; a floating marine mammal research complex; a functional genomics facility; and the Barbara Pauley Pagen Library and classrooms.

Hawai‘i Natural Energy Institute

The Hawai‘i Natural Energy Institute (HNEI) was established by the Legislature in 1974 to develop renewable energy resources and technologies to reduce the state’s dependence on fossil fuels, was given a broader mandate by the Hawai‘i Legislature (ACT 253 in 2006) to also demonstrate and deploy efficient energy end-use technologies and to coordinate closely with the state’s energy resource coordinator. Today, with funding from state and federal agencies as well as industry, HNEI conducts basic and applied research on a wide range of topics to address society’s critical energy and environmental problems. Current research includes hydrogen fuel cells, ocean energy and resources, fuels and high value products derived from biomass, photovoltaics, and batteries and electric vehicles. The institute conducts studies and assessments to support policy development and conducts testing and evaluation of emerging energy generation, grid enabling, and energy efficiency technologies. Many of these activities are conducted under public/private partnerships managed by the institute, with the goal of supporting increased penetration of renewable technologies onto the electrical grid systems.

Hawai‘i Space Grant Consortium

The Hawai‘i Space Grant Consortium (HSGC) is a wide-ranging community educational program supported by the National Aeronautics and Space Administration (NASA) that promotes studies in scientific fields related to space. These fields include astronomy, geology, meteorology, oceanography, mathematics, physics, engineering, computer science, and life sciences. Affiliate campuses are UH-Hilo, all seven community colleges within the UH System, and the University of Guam. Some of the programs supported by Space Grant include undergraduate fellowship and traineeship programs (approximately 10-20 students per semester are supported); the Future Flight Program for teachers, school students, and their parents; teacher workshops; undergraduate remote-sensing classes; an undergraduate telescope classes facility; a CanSat project geared for community college students to create a satellite similar to UH Mānoa’s own CubeSat project; an undergraduate internship program awarded for students to participate in Science, Technology, Engineering, and Mathematics (STEM) related research at local businesses; and outreach to state and federal agencies related to the use of satellite and aircraft remote-sensing data. A significant goal of the program is to encourage interdisciplinary studies and research, and to train future generations of space scientists and engineers. Students, teachers, and researchers in Hawai‘i are encouraged to contact the UH Mānoa HSGC office at (808) 956-3138 to learn more about the opportunities.

Hawai‘i Undersea Research Laboratory

The Hawai‘i Undersea Research Laboratory (HURL) was established in 1980 by a cooperative agreement between the National Oceanic and Atmospheric Administration (NOAA) and the UH. HURL was one of six National Undersea Research Centers sponsored by NOAA’s National Undersea Research Program (NURP). HURL operates the *Pisces IV and Pisces V* research submersibles to conduct marine research to oceanic depths of 2,000 meters. These underwater vehicles are operated from HURL’s dedicated support ship, the 222-foot R/V *Ka‘imikai-o-Kanalou*. Extensive data archives are available to the scientific and academic community for biology, geology and marine chemistry research from submersible dives dating back to 1980. Principal research projects conducted are those aligned with the mission of NOAA.

International Pacific Research Center

The International Pacific Research Center was established in 1997 under the U.S.-Japan Common Agenda for Cooperation in Global Perspective. Its mission is to provide an international, state-of-the-art research environment to improve understanding of the nature and predictability of climate variability in the Asia-Pacific sector, including regional aspects of global environmental change.
Joint Institute for Marine and Atmospheric Research

The Joint Institute for Marine and Atmospheric Research (JIMAR) was created in 1977 through a Memorandum of Understanding between the National Oceanic and Atmospheric Administration (NOAA) and the University of Hawai‘i Mānoa to conduct research of mutual interest. The principal research interests of JIMAR are ecosystem forecasting, ecosystem monitoring, ecosystem-based management, protection and restoration of resources, equatorial oceanography, climate research and impacts, tropical meteorology, and tsunamis and other long-period ocean waves.

Sea Grant College Program

The University of Hawai‘i Sea Grant College Program (UH Sea Grant) supports an innovative program of research, education, and outreach services directed to the improved understanding and stewardship of marine and coastal resources of the state, region, and nation. UH Sea Grant is a partnership of the University of Hawai‘i Mānoa, the National Oceanic and Atmospheric Administration, and the State of Hawai‘i that is facilitated by strong linkages with 32 Sea Grant programs across the nation and affiliations throughout the Pacific.

UH Sea Grant research currently focuses on promoting coastal community sustainability, sustainable aquaculture, marine biotechnology, ecosystem-based use of nearshore resources and habitats, sustainable tourism, coastal water quality, and resilience to natural hazards. Knowledge is disseminated to policy makers, marine agencies, the marine industry, and the general public through UH Sea Grant’s extension faculty, outreach activities, and communications program. UH Sea Grant supports educational activities that include K-12 through graduate and postgraduate and professional training. Human resources are built in part through internships, traineeships, and fellowships. The overall goal is to develop knowledge and the will to build Hawai‘i’s economy and protect its habitats and resources through UH Mānoa’s excellence and our cultural heritage.

School of Ocean and Earth Science and Technology

Geology and Geophysics

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*J. M. Becker, PhD—geophysical fluid dynamics
*C. P. Conrad, PhD—geodynamics, marine geophysics
*H. Dulaiova, PhD—coastal hydrolgy and geochemistry
*R. A. Dunn, PhD—marine geophysics
*A. I. El-Kadi, PhD—groundwater and watershed hydrology
*C. H. Fletcher, PhD—coastal geology
*L. N. Frazer, PhD—geophysics
*E. J. Gaidos, PhD—geobiology, planetary science
*M. O. Garcia, PhD—igneous petrology, volcanology
*C. R. Glenn, PhD—coastal groundwater, environmental geochemistry, marine sediments
*J. E. Hamer, PhD—physical volcanology
*E. W. Hellebrand, PhD—igneous petrology
*B. F. Houghton, PhD—physical volcanology
*A. H. Jahren, PhD—geobiology, environmental science
*K. T. M. Johnson, PhD—geochemistry, petrology, marine geology
*J. G. Konter, PhD—solid earth geochemistry, volcano petrology
*S. J. Martel, PhD—engineering geology, structural geology, geomechanics
*C. Miller, PhD—igneous petrology
*G. F. Moore, PhD—exploration seismology, tectonics
*B. N. Popp, PhD—igneous petrology
*G. E. Ravizza, PhD—paleoceanography
*S. K. Rowland, PhD—volcanology, Hawaiian geology
*K. H. Rubin, PhD—geochemistry, environmental chemistry, volcanology
*K. Ruttenberg, PhD—biogeochemistry, geochemistry
*T. Shea, PhD—physical volcanology
*B. R. Smith-Konter, PhD—geophysics
*G. J. Taylor, PhD—planetary geosciences
*S. K. Sharma, PhD—Raman and IR spectroscopy in geochemistry
*R. J. Carey, PhD—physical volcanology
*K. Keil, DrRerNat.—meteorites, planetary geosciences
*R. N. Hey, PhD—marine geophysics and tectonics
*R. A. Lienert, PhD—geophysics
*P. G. Lucey, PhD—planetary geosciences
*M. H. Manghanu, PhD—high-pressure geophysics, mineral physics
*F. Martinez, PhD—marine geophysics
*F. W. McCoy, PhD—marine geology, sedimentology
*A. Misra, PhD—LIBS and Brucine, material science
*P. J. Mouginis-Mark, PhD—planetary science, remote sensing
*K. Ruttenberg, PhD—biochemistry
*J. E. Schoonmaker, PhD—marine geology and geochemistry
*N. Shröghofner, PhD—permafrost, planetary surfaces
*E. R. D. Scott, PhD—planetary geosciences
*S. K. Sharma, PhD—Raman and IR spectroscopy in geochemistry
*G. J. Taylor, PhD—planetary geosciences
*R. Wright, PhD—volcanology
*P. Zinin, PhD—geophysics, planetology

Affiliate Graduate Faculty

C. Blay, PhD—sedimentology, Hawaiian geology
B. A. Brooks, PhD—geodetic, GPS
R. J. Carey, PhD—physical volcanology
A. Greene, PhD—geochemistry
C. Gregg, PhD—volcanology
V. Keener, PhD—climate, hydrological systems
F. Mackenzie, PhD—sedimentary geochemistry, sedimentology
D. Oki, PhD—hydrolgy
M. Patrick, PhD—volcanology
A. Pietrusza, PhD—geochemistry
M. Reid, PhD—hydrogeology
D. Pyle, PhD—geochemistry, petrology
K. Rozzol, PhD—groundwater, hydrogeology
T. Sale, PhD—hydrology
B. Schmitz, PhD—geobiosphere, astronomy
The Academy Program

The Department of Geology and Geophysics (GG) is centered around the scientific study of the exterior and interior of the Earth and other planetary bodies. Sub-disciplines within GG are many, and offer rich opportunities for multidisciplinary study of problems of great intellectual and practical importance. Coastal geologists study processes such as sedimentation and beach erosion, reef growth and degradation, and sea level change. Hydrologists and Hydrogeochemists study the cycling of fresh water between the atmosphere, land, and ocean. Of particular emphasis is how climate change impacts this cycle; how fresh water supplies are impacted by human activities, including land-use practices and the introduction of contaminants into surface and groundwater; how climate, hydrologic, and terrestrial processes impact the ocean and its ecosystems by way of surface water and submarine groundwater discharge. Structural geologists study the physical features in rock units with respect to stress and deformation related to processes such as mountain building, rifting, and earthquakes. Engineering geologists provide geotechnical recommendations affecting the design, construction, and operation of engineering activities, based on geologic factors such as material properties, landslides and slope stability, erosion, and flooding. Mineralogists and petrologists examine the temperature, pressure, and environmental conditions that influence the formation of minerals and rocks. Geochemists specialize in the chemistry of earth materials for gaining knowledge about a huge range of aspects including the make-up of the deep earth, the formation of the seafloor, the origin of volcanoes, as well as past and present changes in Earth’s climate, ocean environment, and life. Volcanologists study how gas, fluid, and magma interact to create different types of volcanic eruptions, and address hazard remediation. Geophysicists use seismology, potential fields, sonar, radar, and GPS for studying earthquakes, Earth’s surface and internal structure, land deformation, and plate tectonics. They also use mathematics, continuum mechanics, and high performance computing for studying Earth and planetary processes. Planetary scientists examine how the Earth and Solar System formed, study active processes on planetary bodies, search for extrasolar planets, and explore planetary conditions needed for life.

Undergraduate and graduate students in GG are instructed and advised by world-class researchers in a variety of the above sub-disciplines. Students participate in a diverse course curriculum involving in-class instruction, laboratory activities, and field trips. They have access to state-of-the-art facilities including a number of different types of mass spectrometers, an electron microprobe, an X-ray fluorescence laboratory, and high-performance computing facilities. Field trips take students to volcanoes on Hawai‘i and other islands, as well as geologic settings on the U.S. mainland and around the world. Students also participate on research cruises onboard one of several research vessels that are operated by SOEST. GG students who are involved in research projects regularly present their findings in scientific conferences and journal publications. These varied activities allow students to take full advantage of Hawai‘i’s unique geographic location and its rich geologic and environmental setting.

Students graduate from the Department of Geology and Geophysics (GG) with an in-depth understanding of the relevance of the geosciences to society, especially Hawai‘i and Pacific islands, as well as the ways human civilization impacts the Earth and environment. Students are able to use basic skills in math, physics, chemistry, and biology as well as technical knowledge in computer applications, laboratory methods, and field techniques for solving real-work problems in the geosciences. Graduates know how to ethically apply the scientific method, and can use basic principles in geoscience for explaining natural phenomenon. GG graduates develop proficiency in communicating their knowledge in oral presentations and in writing professional documents. As a result, GG majors are widely successful in obtaining jobs in fields within or closely related to the geosciences. These fields include environmental assessment and remediation; engineering; geotechnical consulting; oil, natural gas and mineral resources; water resource management; science education; as well as applied and basic research.

Advising

Students contemplating a major or minor in geology and geophysics should contact the Director of Student Services for SOEST in HIG 135 (tel. 956-8763). There are two undergraduate advisors who may be contacted through the department office (956-7640, ggdept@soest.hawaii.edu). Graduate students are appointed a faculty advisor upon admittance into the program.

Undergraduate Study

BA in Geology

Requirements

The BA degree in geology is appropriate for students interested in Earth science but not necessarily intending to pursue graduate work or employment in traditional geological sciences. It is more flexible than the BS program and is suitable for students who are considering a double major or teaching.

The BA degree requires completion of 120 credit hours of coursework, the equivalent of four years of full-time study. The BA program requires 35 credits in the geology and geophysics curriculum. This includes one introductory level GG course with a lab, seven non-introductory GG courses, a two-credit research seminar, and at least five credits of approved upper division electives. With the advice and consent of an undergraduate advisor, courses in other natural sciences, mathematics, or engineering may be substituted as electives. A mainland summer field course is an elective that students are strongly encouraged to take. Required support classes include physics, chemistry, biological sciences, and one semester of college calculus; these total 23-24 credits and should be taken as early as possible. A minimum grade of C (not C-) must be achieved in all major and support classes.

Geology and Geophysics Courses

- Required Courses (30 credits)
- GG 101 Dynamic Earth (3), or 103 Geology of the Hawaiian Islands (3), or GG 170 Physical Geology (4)
GG 101L Dynamic Earth Laboratory (1) (unless GG 170 is taken)
- GG 200 Geological Inquiry (4)
- GG 250 Scientific Programming (3)
- GG 301 Mineralogy (4)
- GG 302 Igneous and Metamorphic Petrology (3)
- GG 303 Structural Geology (3)
- GG 305 Geological Field Methods (3)
- GG 309 Sedimentology and Stratigraphy (4)
- GG 410 Undergraduate Seminar (2)

Upper Division Science Electives (5 credits)
- GG 300 Volcanology (3)
- GG 304 Physics of Earth and Planets (4)
- GG 312 Geomathematics (3)
- GG 325 Geochemistry (3)
- GG 399 Directed Reading (V)
- GG 402 Hawaiian Geology (3)
- GG 407 Energy and Mineral Resources (3)
- GG 413 Geological Data Analysis I (3)
- GG 420 Coastal Geology (3)
- GG 421 Geologic Record of Climate Change (3)
- GG 423 Marine Geology (3)
- GG 425 Environmental Geochemistry (3)
- GG 444 Plate Tectonics (3)
- GG 450 Geophysical Methods (4)
- GG 451 Earthquakes (3)
- GG 455 Hydrogeology (4)
- GG 460 Geological Remote Sensing (3)
- GG 466 Planetary Geology (3)
- GG 499 Undergraduate Thesis (3)

Required Support Courses (23-24 credits)
- General Chemistry (CHEM 161, 161L, 162, 162L)
- Calculus I (MATH 241)
- College Physics (PHYS 151, 151L, 152, 152L)
- Biological Sciences (BIOL 171, or BOT 101, or ZOOL 101, or MICR 130)

For information on a Bachelor Degree Program Sheet, go to www.manoa.hawaii.edu/ovcaa/programsheets/.

BS in Geology and Geophysics

Requirements
This BS degree is designed for students interested in pursuing graduate work or employment in the geosciences. It provides essential grounding in computational, analytical, and observational skills needed in earth science. The program is interdisciplinary and emphasizes the integration of biology, chemistry, physics, and mathematics in the study of the Earth.

The BS in geology and geophysics (GG) requires completion of 120 credit hours of coursework, the equivalent of four years of full-time study. Of this, 48 credits are required in the GG curriculum, including one introductory level geology course with a lab, ten non-introductory level GG courses, a two-credit research seminar, and eleven credits of GG electives. With advice and consent of an undergraduate advisor, courses in other natural sciences, mathematics, or engineering may be substituted as electives.

Required Support Courses (28-29 credits)
- Chemistry (CHEM 161, 161L, 162, 162L)
- Calculus I and II (MATH 241 and 242)
- Physics (PHYS 170, 170L, 272, 272L)
- Biological Sciences (BIOL 171, or ZOOL 101, or MICR 130)

For information on a Bachelor Degree Program Sheet, go to www.manoa.hawaii.edu/ovcaa/programsheets/.

BS Track Emphasizing Basic Science and Research

This alternate BS track allows for a more flexible course work program that is tailored to the student’s individual goals. It requires the student to work with an advisor on a research thesis.

To apply for this track, the student must have a minimum combined GPA of 3.0 in 24 credits of the required support courses (see below) as well as in GG 170 (or 101 or 103 and 101L), 200, and 250. The application will consist of a one-page statement of the student’s objectives and research interests, presented to a GG departmental undergraduate advisor.

The thesis must be carefully planned and meet departmental requirements. A thesis advisor and topic should be identified in the student’s second-to-last year in the program. The thesis work requires at least 6 (but not more than 9) credit hours of GG 499 Undergraduate Thesis. The thesis research is presented in writing, following the style of a scientific article, and orally in a public seminar. The thesis is evaluated by both the research supervisor and a departmental undergraduate advisor.

Course Requirements
- Required GG Courses (22 credits)
  - GG 101 Dynamic Earth (3), or 103 Geology of the Hawaiian Islands (3), or GG 170 Physical Geology (4)
  - GG 101L Dynamic Earth Laboratory (1) (unless GG 170 is taken)
  - GG 200 Geological Inquiry (4)
  - GG 250 Scientific Programming (3)
  - GG 301 Mineralogy (4)
  - GG 302 Igneous and Metamorphic Petrology (3)
  - GG 303 Structural Geology (3)
  - GG 304 Physics of Earth and Planets (4) OR 450 Geophysical Methods (4)
  - GG 305 Geological Field Methods (3)
  - GG 309 Sedimentology and Stratigraphy (4)
  - GG 325 Geochemistry (3)
  - GG 410 Undergraduate Seminar (2)

  Upper Division GG Electives (11 credits)

  See the Upper Division Science Electives listing under the BA program. With advice and consent of an undergraduate advisor, courses in other natural sciences, mathematics, or engineering may be substituted as electives.

Required GG Courses (37 credits)
- GG 101 Dynamic Earth (3), or 103 Geology of the Hawaiian Islands (3), or GG 170 Physical Geology (4)
- GG 101L Dynamic Earth Laboratory (1) (unless GG 170 is taken)
- GG 200 Geological Inquiry (4)
- GG 250 Scientific Programming (3)
- GG 301 Mineralogy (4)
- GG 302 Igneous and Metamorphic Petrology (3)
- GG 303 Structural Geology (3)
- GG 304 Physics of Earth and Planets (4) OR 450 Geophysical Methods (4)
- GG 305 Geological Field Methods (3)
- GG 309 Sedimentology and Stratigraphy (4)
- GG 325 Geochemistry (3)
- GG 410 Undergraduate Seminar (2)
and they normally would be expected to have completed at least one year each of college mathematics, geology, physics, and chemistry. Adequacy of each applicant’s additional preparation will depend on the particular branch of geology and geophysics being pursued. At the time of application the student should state the field in which he or she intends to study.

Requirements

For MS students, the graduate studies committee of the department will determine suitability of Plan A (thesis) or Plan B (non-thesis) at the preliminary conference. Virtually all students are required to follow Plan A. Plan A requires a minimum of 30 credits, including 6 credits of GG 700 Thesis Research and at least 24 credits of course work (up to 6 course work credits may be in GG 699). Plan B requires a minimum of 30 credit hours of course work and a final exam.

Doctoral Degree

Requirements

PhD candidates are accepted with either a BS or MS degree. Students without an MS must pass a qualifying examination given at the beginning of their second semester in residence. All PhD candidates must pass a comprehensive examination no later than at the end of the fourth semester of residence for students without an MS degree or at the end of the second semester of residence for students with an MS degree. The comprehensive exam includes oral and written parts that cover in-depth subjects in the student’s field of interest and also relevant general information from this and other departments. A final examination in defense of the dissertation is required. Space and financial aid for the program are limited, so each student’s progress will be reviewed annually.

Areas of Interest

The areas of interest listed below are active fields of research in the department. For each, a brief description and the required undergraduate preparation are listed. Students with backgrounds other than these may be accepted in a field if their records and recommendations are strong, but advancement to candidacy may be delayed. A complete statement of the courses and other work in each field necessary for the MS or to prepare for the PhD comprehensive examination will be given to the entering student.

The department can provide further information on research opportunities and financial aid in each of the areas of interest.

Geophysics and Tectonics. Studies in geophysics and tectonics at UH Mānoa are interdisciplinary and include experimental and theoretical developments, field-based observations, and computer simulations. Together, they provide students with a background that combines both geology and geophysics for technical and professional work at industrial, governmental, and academic institutions. Subtopics include: (a) Plate Tectonics—rift propagation and plate break-up; initiation and evolution of continental margins and back-arc basins; relative and absolute motion of plates; thermo-mechanical properties of oceanic lithosphere; mantle convection and the driving forces of plate tectonics; and hot spot and intraplate volcanism; (b) Seismology—theory and analysis of seismic waves from active and passive sources; ocean-bottom geophysical instrumentation; multichannel seismic imaging of subduction zones, accretionary prisms, and submarine volcano flanks; (c) Geophysical Fluid Dynamics—mantle flow and plume-plate interaction;
plate generation and rheology from mantle flow; ocean/shore dynamics and nonlinear waves; (d) Rock Fracture Mechanics—field, theoretical, and laboratory analyses of the mechanics of fault growth, rock fracture, dike propagation, landslides, and crustal deformation; these topics are relevant to plate tectonics, structural geology, and engineering geology.

Entrance may be through majors in geophysics, geology, mathematics, physics, or engineering. Students need a background in geology (which can be obtained in graduate school) together with supporting mathematics and physics.

Marine and Environmental Geology (MEG). The Marine and Environmental Geology (MEG). The Marine and Environmental Geology program is focused on the dynamic physical, biological, and chemical interactions that characterize Earth surface terrestrial and marine environments and also the history of these interactions over the course of geologic time. Researchers work on problems ranging from those of pure scientific curiosity of global phenomena to pragmatic problem-solving of environmental problems, and including everything in-between. Faculty and students of the MEG group travel to field sites all over the world to study processes and interactions between water, atmosphere, sediments, and living tissues, and their travel also includes several large-scale projects located within the Hawaiian Islands. Research also extends backward through deep time, integrating the biological and physical aspects of earth history through the study of rocks and fossils. Instruction is designed to provide students with hands-on exposure to the most exciting, contemporary issues in environmental science, particularly on topics where the fields of geology and oceanography overlap with other environmental sciences. Laboratories use the newest biogeochemical technologies and instrumentation in order to assess the health and integrity of coastal systems, to reconstruct past climates and life forms, to characterize the movement of precious water resources, and to understand the chemical cycling of both organic and inorganic components of the ocean. MEG research topics carry important implications and benefits for the sustainability of fresh water resources and reserves, agriculture, coastal and marine ecosystems, fisheries, Hawaii’s beaches and economy, and other topics of immediate societal concern.

Many research efforts in this program involve participation in oceanographic expeditions. Graduate students are encouraged to participate in these voyages as a part of their career training. The program is multidisciplinary with cooperating faculty and courses from several other departments including civil engineering, geography, oceanography, and soil sciences. The diverse research and teaching interests of the faculty make it possible to tailor graduate degree work to fit the needs and desires of the student. Requirements for admission typically include an undergraduate major in geology or one of the other natural sciences, along with basic courses in physics, chemistry, and mathematics. Students often study a combination of geology, geophysics, oceanography, biology, civil engineering, and/or geochemistry, as appropriate for his or her optimum intellectual development.

Volcanology, Geochemistry, and Petrology (VGP). UH Mānoa is uniquely situated to study all major aspects of volcanic systems. Active Hawaiian volcanoes are natural laboratories of intraplate volcanism and hydrothermal activity; eroded fossil volcanic systems on other islands provide windows into deeper volcanic structures; and Hawai’i is at the center of the Pacific “Ring of Fire.” Collectively, the VGP group has active field programs that are global in scope. The group studies submarine volcanoes with UH Mānoa and other research vessels, and on terrestrial volcanoes around the world, and participates in remote monitoring of volcanoes on Earth and other planets using ground-based and space-borne observatories. Faculty of the VGP group operate a wide range of modern, well-equipped, state-of-the-art analytical laboratories that provide data on the chemical composition and physical properties of rocks and minerals. In addition, VGP covers basic courses in Hawaiian geology, geologic hazards, geochemistry, optical mineralogy, petrology, structural geology, volcanology, geological field methods, remote sensing and GIS techniques.

Specialized topics that members of the group study include (a) geometry and dynamics of mantle flow, melt generation and magma chamber processes at submarine volcanoes from petrologic, geochemical, and isotopic variations at mid-ocean ridges and back-arc basin spreading centers; active volcanism at submarine volcanoes; geochronology of submarine volcanism, and volcano interactions with the submarine environment; (b) physical processes at volcanoes giving rise to degassing, and fragmentation of magma in conduits; transport and deposition from volcanic plumes and pyroclastic density currents; flood basalts and the eruption and emplacement of lavas; caldera volcanoes and ignimbrites; volatile degassing and retention in magma chambers; environmental impact and social consequences of eruptions; and volcanic processes on extraterrestrial bodies. (c) geochemical and isotopic tracing of mantle composition and evolution; geochemical cycling; geosphere–hydrosphere exchanges; (d) petrologic, geochemical, isotopic, and geologic evolution of Hawaiian and other oceanic islands and seamounts; petrologic, seismic, and geodetic monitoring of magmatic systems at active Hawaiian volcanoes; satellite monitoring of volcanic hazards and eruption clouds; remote-sensing observation of extraterrestrial volcanoes.

Entrance through majors in geology or chemistry is most typical. Students need a background in geology (which can be obtained in graduate school) together with supporting mathematics and physics.

Planetary Geoscience and Remote Sensing. This program, centered in the Hawaiian Institute of Geophysics and Planetology (HIGP), studies the geology and composition of objects (planets, asteroids, moons, and meteorites) in the Solar System to understand their origin and evolution. It involves research in planetary and terrestrial geology, cosmochemistry, volcanology, planetary astronomy, and scientific instrumentation. Current research areas include: (a) research on extraterrestrial materials from asteroids, the Moon, and Mars as records of processes in the solar nebula; alteration processes; the effects of shock; igneous processes; and planetary crustal compositions and evolution; (b) remote sensing and petrology of the moon, Mars, and Mercury to understand planetary formation, differentiation, and weathering of planetary crusts, volcanic processes, and the mode of formation of impact craters. Faculty are science team members on multiple planetary missions (MESSENGER, Lunar Reconnaissance Orbiter, Mars Odyssey, and Mars Reconnaissance Orbiter); (c) terrestrial remote sensing using spacecraft (Landsat 7, EO-1, Terra, Aqua, GOES), aircraft, and ground observations to study the flux of magma through volcanic systems, eruption precursors, forest fires worldwide and the like. Data from the GOES geostationary satellite are made available on the HIGP website (goes.higp.hawaii.edu) and MODIS thermal alerts for the entire world are made available at modis.higp.
hawaii.edu. Imaging radar remote sensing is also conducted within HIGP. This includes interferometric studies of volcano deformation using ENVISAT and ALOS data for understanding magma emplacement and volcano tectonics. HIGP is a major partner (with the College of Engineering) in the Hawai‘i Space Flight Laboratory, which includes preparation for future UH-led space missions involving small satellites; (d) developing instruments for use in studying global and regional problems in Earth and planetary science, such as hyperspectral thermal infrared imagers for use in lithologic mapping, the analysis of temperature anomalies, the flux of sulfur dioxide from volcanoes, an infrasound array for a global monitoring system for the detection of atmospheric disturbances, and lidar systems for the measurement of atmospheric aerosols and rock compositions.

Typically, an undergraduate major in geology, astronomy, physics, or engineering, along with basic courses in chemistry, physics, and mathematics, would be sufficient for entrance. The student should be prepared to commence or continue course work in whatever combination of geology, geophysics, geochemistry, planetary science, spectroscopy, radar science, or remote sensing is appropriate for optimum development in the field and to satisfy minimum requirements in the Geology and Geophysics department.

**Global Environmental Science**

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1000 Pope Road
Honolulu, HI 96822
Tel: (808) 956-2910
Fax: (808) 956-9225
Email: ges@soest.hawaii.edu
Web: www.soest.hawaii.edu/oceanography/GES/

**Faculty**

J. E. Schoonmaker, PhD (Undergraduate Chair)—sedimentary geochemistry and diagenesis; interpretation of paleoenvironment and paleoclimate sedimentary records
J. M. Becker, PhD—geophysical fluid dynamics, nonlinear waves and stability, coastal processes, general ocean circulation
D. Beilman, PhD—long-term terrestrial ecology, paleoscience approaches to global change science, carbon cycling
R. R. Bidigare, PhD—bio-optical oceanography, pigment biochemistry, plankton metabolism
S. Businger, PhD—mesoscale and synoptic meteorology
B. C. Bruno, PhD—planetary geosciences, geoscience education
G. S. Carter, PhD—physical oceanography, ocean mixing, tides, internal waves
M. J. Church, PhD—microbial oceanography, aquatic nitrogen cycling, and microbial physiology
A. D. Clarke, PhD—physical and chemical properties of aerosol in remote troposphere, aircraft studies of aerosol in free troposphere
M. J. Cooney, PhD—anaerobic digestion of high strength wastewaters, development of next generation biofilm carriers for use in packed bed anaerobic digesters, solvent based bio-oil extraction from biomass
E. H. DeCarlo, PhD—aquatic chemistry; metals and their anthropogenic inputs, transformations, fate and transport
J. L. Deenik, PhD—soil fertility and soil quality, nitrogen and carbon cycling in agroecosystems, traditional agroecosystems, biochar and sustainable agriculture
S. Dollar, PhD—biogeochemistry, nearshore processes and effects of human activity on the coastal zone
J. C. Drazen, PhD—deep-sea ecology and fisheries, energetics and trophodynamics, physiological ecology of marine fishes
A. El-Kadi, PhD—hydrogeology, modeling groundwater systems
R. C. Ertekin, PhD—hydrodynamics, computational methods, offshore and coastal engineering, oil-spill spreading, fishpond circulation, ocean renewable energy
E. Firing, PhD—ocean circulation and currents on all scales, with emphasis on observations and dynamics
P. J. Flamant, PhD—dynamics of surface ocean layer, mesoscale structures, remote sensing, water-types formation subduction and thermocline ventilation, mixing process
C. H. Fletcher, PhD—quaternary and coastal marine geology, sea-level history, coastal sedimentary processes
P. Fryer, PhD—marine geology, petrology, tectonics
E. Gaidos, PhD—molecular evolution; microbiology of extreme environments; biosphere-climate feedbacks; critical intervals in Earth history; exobiology; biological networks
M. O. Garcia, PhD—volcanology, igneous petrology, geochemistry
T. W. Giambelluca, PhD—interactions between the atmosphere and the land surface, including influences of land use and land cover change on climate and surface hydrology and effects of global climate change on hydrologic processes and terrestrial ecology
B. T. Glazer, PhD—biogeochemical processes in marine environments; use of molecular methods to characterize and understand synergy of geomicrobiology
C. R. Glenn, PhD—paleoceanography, marine geology, sedimentology, sediment diagenesis
E. Goetze, PhD—marine zooplankton ecology; dispersal and gene flow in marine plankton populations; evolution, behavioral ecology and systematics of marine calanoid copepods
E. G. Grau, PhD—environmental physiology and comparative endocrinology of fish
M. P. Hamnet, PhD—coastal zone management; fisheries economics; disaster preparedness and mitigation
D. T. Ho, PhD—air-water gas exchange, tracer oceanography, carbon cycle, and environmental geochemistry
P. Kemp, PhD—growth, activity and diversity of marine microbes; biosensor applications in microbial oceanography; molecular ecology of marine bacteria
D. E. Konan, PhD—international trade, microeconomics, computational economics
K. Lowry, PhD—design, planning and evaluation of ocean and coastal management programs; experience in Hawai‘i, Indonesia, Sri Lanka, Philippines and Thailand
R. Lukas, PhD—physical oceanography, interannual and decadal climate variability
F. T. Mackenzie, PhD—geochemistry, biogeochemical cycling, global environmental change, Program Coordinator for GES
S. J. Martel, PhD—engineering and structural geology
M. A. McManus, PhD—coast circulation, mesoscale processes, physical-biological interactions in the ocean
G. M. McMurtry, PhD—geochemistry, geology and geophysics
C. Measures, PhD—trace element geochemistry, shipboard analytical methods, atmospheric deposition to the oceans, elemental mass balances
M. Merlin, PhD—biogeography, natural history of the Pacific
M. A. Merrifield, PhD—physical oceanography; coastal circulation; sea level variability; current flows and mixing in the vicinity of coral reefs, islands and seamounts
T. Miura, PhD—remote sensing of terrestrial vegetation, GIS
G. F. Moore, PhD—marine geophysics, structural geology
M. J. Mortl, PhD—hydrothermal processes, geochemical cycles

*Graduate Faculty*
P. Mougini-Mark, PhD—volcanology from space, remote sensing of natural hazards
P. K. Muller, PhD—ocean circulation, waves and turbulence
A. B. Neuhäuser, PhD—quantitative ecology of fish and aquatic invertebrate populations, with applications to evolutionary biology, physiology, ecosystem dynamics, resource management, and climate issues
B. N. Popp, PhD—isotope biogeochemistry, organic geochemistry
J. N. Porter, PhD—atmospheric science, use of satellites to study aerosol and cloud forcing, ship measurements of aerosol and cloud optical properties
B. S. Powell, PhD—numerical modeling, variational data assimilation, ocean predictability, ocean dynamical modes, and ocean ecosystem dynamics
M. S. Rappe, PhD—ecology of marine microorganisms; genomics; coral-associated microorganisms; ecology of microorganisms in the deep subsurface
G. Ravizza, PhD—paleoceanography and environmental chemistry; geologic history of chemical weathering; geochemistry of recent and ancient metalliferous sediments; anthropogenic influences on the geochemical cycles of the platinum group elements; chemical signatures of extraterrestrial matter in marine sediments; biogeochemistry of molybdenum in the marine environment
K. J. Richards, PhD—observations and modeling of ocean processes, ocean dynamics, ocean atmosphere interaction, ecosystem dynamics
M. A. Ridgley, PhD—resource management and human-environment system analysis
J. Roumasset, PhD—environmental economics and sustainable growth
K. Rubin, PhD—isotope geochemistry, chronology
K. Ruttenberg, PhD—biogeochemistry of phosphorus and phosphorus cycling in the ocean, rivers, and lakes; nutrient limitation of aquatic primary productivity; effects of redox chemistry on nutrient cycling; early diagenesis in marine sediments with focus on authigenic mineral formation and organic matter mineralization
F. J. Sansone, PhD—biogeochemistry of permeable (sandy) sediments, coastal processes, trace-gas biogeochemistry, hydrothermal geochemistry
N. Schneider, PhD—decadal climate variability, tropical air-sea interaction, coupled modeling
S. K. Sharma, PhD—atmospheric instrumentation and remote sensing; Lidar, Raman, and infrared spectrometry and fiber-optic environmental sensors
C. R. Smith, PhD—benthic and ecology, deep-sea biology, sediment geochemistry, climate-change effects on Antarctic ecosystems, marine conservation
G. F. Steward, PhD—aquatic microbial ecology, molecular ecology and diversity of viruses and bacteria
A. Timmermann, PhD—tropical climate variability, large-scale ocean circulation, Paleoceanography, Earth-system modeling
B. Wang, PhD—atmospheric and climate dynamics
J. C. Wiltshire, PhD—marine minerals, mine tailings and disposal, remediation and submersible engineering and operations
R. E. Zeebe, PhD—global biogeochemical cycles, carbon dioxide system in seawater and interrelations with marine plankton, paleoceanography, stable isotope geochemistry

Degree Offered: BS in global environmental science

The Academic Program

Global environmental science is a holistic, scientific approach to the study of the Earth system and its physical, chemical, biological, and human processes. This academic program is designed to educate leaders and citizenry to become wise stewards of our planet. Global environmental science focuses on the global reservoirs of hydrosphere (water, primarily oceans), biosphere (life and organic matter), atmosphere (air), lithosphere (land, sediments, and rocks), and cryosphere (ice); their interfaces; and the processes acting upon and within this interactive system, including human activities. In the course of their scientific studies, global environmental science students are able to investigate natural as well as economic, policy, and social systems and their response and interaction with the Earth system. Global environmental science has important ties to the more classical sciences of geology and geophysics, meteorology and climatology, oceanography, and ecology as well as to the social sciences. Thus, the scope of global environmental science is extremely broad. This breadth is reflected in the interdisciplinary nature of the faculty, which is primarily drawn from numerous departments and research institutions within the School of Ocean and Earth Science and Technology.

Global environmental science has much to offer the student who is interested in the environment and the effect of humans on the environment. The skills developed in global environmental science can be brought to bear on local, regional, and global environmental issues. Many of the critical environmental problems confronting humankind involve large-scale processes and interactions among the atmosphere, oceans, biosphere, cryosphere, shallow lithosphere, and people. Some of the problems derive from natural causes; others are a result of human activities. Some of the issues that global environmental science students deal with are: climatic changes from anthropogenic inputs to the atmosphere of CO₂ and other greenhouse gases; human interventions and disruptions in the biogeochemical cycles of carbon, nitrogen, phosphorus, sulfur, trace metals, and other substances; emissions of nitrogen and sulfur oxide gases and volatile organic compounds to the atmosphere and the issues of acid deposition and photochemical smog; depletion of the stratospheric ozone layer and associated increase in the flux of ultraviolet radiation to Earth’s surface; increasing rates of tropical deforestation and other large-scale destruction of habitat, with potential effects on climate and the hydrologic cycle; disappearance of biotic diversity through explosive rates of species extinction; global consequences of the distribution and application of potentially toxic chemicals in the environment and biotechnology; interannual and interdecadal climate variability, e.g., El Niño/Southern Oscillation; eutrophication; water and air quality; exploitation of natural resources with consequent problems of waste disposal; earthquakes, tsunamis, and other natural hazards and prediction; and waste disposal: municipal, toxic chemical, and radioactive. In all cases, the student is encouraged to understand and appreciate the social, economic, and ultimately the policy decisions associated with these and other environmental issues.

Specifically with respect to learning objectives, the students develop competency in understanding how the physical, biological, and chemical worlds are interconnected in the Earth system. They obtain skills in basic mathematics, chemistry, physics, and biology that enable them to deal with courses in the derivative geological, oceanographic, and atmospheric sciences at a level higher than that of qualitative description. In turn, these skills enable the students to learn the subject matter of global environmental science within a rigorous context. The students develop an awareness of the complexity of the Earth system and how it has changed during geologic time and how human activities have modified the system and led to a number of local, regional, and global environmental issues. They become competent in using computers and dealing with environmental databases and with more standard sources of information in the field. They are exposed to experimental,
observational, and theoretical methodologies of research and complete a senior research thesis in environmental studies using one or more of these methodologies. Field work is encouraged for the senior thesis and, depending on the topic chosen by the student, can be carried out at the Hawai‘i Institute of Marine Biology’s Coconut Island facility, E. W. Pauley Laboratory, associated He‘eia ahupua‘a, or elsewhere.

The ultimate objective of the global environmental science program is to produce a student informed in the environmental sciences at a rigorous level who is able to go on to graduate or professional school; enter the work force in environmental science positions in industry, business, or government; enter or return to teaching with knowledge of how the Earth system works; or enter the work force in another field as an educated person with the knowledge required to become a wise environmental steward of the planet.

Advising
Students contemplating a major in global environmental science should visit the program coordinator at the earliest opportunity. Inquire at the global environmental science office, Marine Science Building 205; tel. (808) 956-2910, fax (808) 956-9225; email: ges@soest.hawaii.edu.

BS in Global Environmental Science

University Core and Graduation Requirements
Of the 31 credits of General Education Core Requirements, 10 are in math and science and are fulfilled through the GES degree. Graduation Requirements include 8 Focus courses, 7 of which can currently be taken through the GES program [Contemporary Ethical Issues (OCN 310), Oral Communications (OCN 490), and 4 Writing Intensive courses (BIOL 171L, 172L, OCN 320, 401, and 499)]. GES majors are required to complete one year of Hawaiian/Second Language.

Global Environmental Science Requirements
Aside from General Education Core and Graduation requirements, the global environmental science program has core requirements of two basic types: basic sciences and derivative sciences. The former provides the foundation to understand and appreciate the latter in the context of basic skills and mathematics, biology, chemistry, and physics. Both global environmental science core requirements provide the necessary cognitive skills to deal with the higher academic level courses within the global environmental science curriculum. These include 7 required foundation courses in global environmental science and a minimum of 4 coupled systems courses. It is within this latter category of course work that the formal course program will be tailored to the individual student’s needs. For example, we anticipate that most students will follow closely a natural science track of study, perhaps concentrating on the terrestrial, marine, or atmospheric environment. However, because of the human dimensions issues involved in the subject matter of environmental change, some students may wish to expand their academic program into the social sciences that bear on the issues of global change.

A minimum grade of C must be obtained in all GES required courses.

Core Basic Sciences Requirement (38 hours)
- BIOL 171/171L, 172/172L
- CHEM 161/161L, 162/162L
- MATH 241, 242
- MATH 243, 244 or OCN/GG 312, ECON 321
- PHYS 170/170L, 272/272L

Core Derivative Sciences Requirement (11 hours)
- GG 101/101L or GG 170
- MET 200
- OCN 201/201L

Foundation Course Requirements (18 hours)
- GEOG 411 Past Global Change and the Human Era or GEOG 410 Human Role in Environmental Change
- OCN 100 Global Environmental Science Seminar
- OCN 310/310L Global Environmental Change/Lab
- OCN 320 Aquatic Pollution
- OCN 363 Earth System Science Databases
- OCN 401 Biogeochemical Systems

Coupled Systems Courses (4 minimum–Examples)
- ASTR 240 Foundations of Astronomy
- BIOC 241 Fundamentals of Biochemistry
- BIOL 265 Ecology and Evolutionary Biology
- BIOL 301 Marine Ecology and Evolution
- BIOL 404 Advanced Topics in Marine Biology
- BOT 350 Resource Management & Conservation in Hawai‘i
- BOT 480 Algal Diversity and Evolution
- ECON 358 Environmental Economics
- ECON 458 Project Evaluation and Resource Management
- ECON 496 Contemporary Economic Issues
- ECON 638 Environmental Resource Economics
- GEOG 300 Introduction to Climatology
- GEOG 388 Introduction to GIS
- GEOG 401 Climate Change
- GEOG 402 Agricultural Climatology
- GEOG 404 Atmospheric Pollution
- GEOG 405 Water in the Environment
- GG 301 Mineralogy
- GG 309 Sedimentology and Stratigraphy
- GG 420 Coastal Geology
- GG 421 Geologic Record of Climate Change
- GG 425 Environmental Geochemistry
- GG 444/OCN 444 Plate Tectonics
- GG 455 Hydrogeology
- GG 466 Planetary Geology
- MET 302 Atmospheric Physics
- MET 303 Introduction to Atmospheric Dynamics
- MICR 401 Marine Microbiology
- NREM 301/301L Natural Resources Management/Lab
- NREM 302 Natural Resource and Environmental Policy
- NREM 304 Fundamentals of Soil Science
- NREM 461 Soil and Water Conservation
- OCN 330 Mineral and Energy Resources of the Sea
- OCN 331 Living Resources of the Sea
- OCN 403 Marine Functional Ecology and Biotechnology
- OCN 435 Climate Change and Urbanization
- OCN 480 Dynamics of Marine Ecosystems: Biological-Physical Interactions in the Oceans
- OCN 620 Physical Oceanography
- OCN 621 Biological Oceanography
Marine Biology

See the "Interdisciplinary Programs" section of the Catalog for more information on the Marine Biology Graduate Program.

Meteorology

HIG 350
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Tel: (808) 956-8775
Fax: (808) 956-2877
Email: metdept@hawaii.edu
Web: www.soest.hawaii.edu/MET

Faculty

*G. M. Barnes, PhD (Chair)—mesometeorology, hurricanes, and boundary layer meteorology
*M. M. Bell, PhD—radar meteorology, tropical cyclones, and mesoscale meteorology
*S. Businger, PhD—atmospheric chemistry and aerosols
*J. Zhao, PhD—atmospheric chemistry and aerosols
*F. F. Jin, PhD—atmospheric dynamics
*T. Li, PhD—climate dynamics and coupled atmosphere-ocean modeling
*D. E. Stevens, PhD—tropical meteorology
*B. Wang, PhD—cloud hydrology
*Y. Wang, PhD—cloud microphysics, aerosols and climate meteorology
*K. P. Hamilton, PhD—mesoscale dynamics
*P. S. Chu, PhD—climate variability and natural hazards, tropical cyclones, climate prediction
*J. D. Griswold, PhD—satellite remote sensing of clouds and aerosol, cloud microphysics, aerosols and climate meteorology
*P. S. Chu, PhD—cloud microphysics, aerosols and climate meteorology
*K. P. Hamilton, PhD—mesoscale dynamics
*T. Li, PhD—climate dynamics and coupled atmosphere-ocean modeling
*D. E. Stevens, PhD—tropical meteorology
*B. Wang, PhD—cloud hydrology
*Y. Wang, PhD—cloud microphysics, aerosols and climate meteorology
*S. P. Xie, PhD—large scale ocean-atmosphere interaction, climate dynamics
*J. Zhao, PhD—cloud microphysics, aerosols and climate meteorology

Cooperating Graduate Faculty

A. D. Clarke, PhD—marine aerosols, biogeochemical cycles, optical properties
J. Porter, PhD—satellite and ground-based optical sensing of atmospheric aerosols

Degrees Offered: BS (including minor) in meteorology, MS in meteorology, PhD in meteorology

The Academic Program

Meteorology (MET) is the study of phenomena in the Earth’s atmosphere. These phenomena include the daily weather and climate. Students pursuing the BS in meteorology receive preparation for professional employment in meteorology and are qualified for employment in the federal meteorological agencies. The meteorology major must be well-grounded in the fundamentals of mathematics and physics. Thus BS graduates are qualified to pursue graduate studies both in meteorology and other applied sciences, such as oceanography or computer sciences. Graduate degrees prepare students to pursue research careers both with government and in academia.
The meteorology program at UH Mānoa is unique in its focus on tropical meteorology. The tropics exert critical controls on the global atmosphere. BS students receive comprehensive training in tropical weather analysis and forecasting. Graduate students often pursue thesis research in tropical meteorology; some study topics that take advantage of Hawai‘i’s unique natural laboratory. Some students pursue graduate thesis research with funding from the National Weather Service, whose Honolulu Weather Forecast Office is housed in the same building as the meteorology department. Meteorology faculty cooperate actively with physical oceanography faculty through the Joint Institute for Marine and Atmospheric Research and the International Pacific Research Center in the study of air-sea interaction and climate variability. Students also have access to both research databases and cooperative employment opportunities at the Joint Typhoon Warning Center, Pearl Harbor.

**Affiliations**

UH Mānoa is an active member of the University Corporation for Atmospheric Research.

**Advising**

Inquire about the major by contacting the department office (808) 956-8775. Graduate students are assigned individual faculty advisors by the graduate chair after their preliminary conference.

**Undergraduate Study**

**Bachelor’s Degree**

**Requirements**

Students must complete 120 credit hours, including:

- General Education Core (see the “Undergraduate General Education Requirements” section of this Catalog).
- MET 101L and 200
- MATH 241, 242, 243, and 244 (Students planning careers with federal meteorological agencies should take MATH 405.)
- PHYS 170/170L and 272/272L
- 21 credit hours in meteorology courses numbered 300 and above, including MET 302, 303, 305, and 402; and MET 412 or 416 (Students planning careers with federal meteorological agencies should take at least two courses from 405, 412 and 416.)
- 15 additional credit hours from physical and mathematical sciences (e.g., engineering, geography, geology and geophysics, information and computer sciences, mathematics, oceanography, physics, and soil science) including (but not limited to) MET 310, 405, 406, and 600; MET 412 or 416; CEE 424 and 626; GEGO 300, 303, 402, and 412; GG 455; ICS 211, 311, and 442; MATH 311, 371, 373, 402, 403, and 405; OCN 620; PHYS 274/274L and 400
- CHEM 161/161L and 162
- ICS 111 or MET 320

For information on a Bachelor Degree Program Sheet, go to www.manoa.hawaii.edu/ovcaa/programsheets/.

**Student Learning Outcomes (BS Meteorology)**

1. Apply physical principles to explain the thermal structure of the atmosphere.
2. Describe atmospheric circulation systems.
3. Develop and explain a forecast in the short-to-medium time range.
4. Know the design and use of instrumentation, computer software, and data interpretation methods in atmospheric studies.
5. Be able to explain ideas and results through written, numerical, graphical, oral, and computer-based forms of communication.
6. Be adaptable to new avenues of scientific inquiry, which offer interdisciplinary and practical applications to commercial and public needs for atmospheric studies.

**Minor**

**Requirements**

Students must complete 15 credit hours of non-introductory courses, including:

- MET 200, 302, and 303
- 6 credits of electives from MET 305, 310, 405, 406, 412 and 416

**Graduate Study**

The department offers MS and PhD degrees. Through courses in dynamic, synoptic, and physical meteorology, students develop a strong foundation in tropical meteorology, the department’s special field, and are prepared to do research in the atmospheric sciences.

Candidates should have a thorough preparation in physics (with calculus), chemistry, and mathematics through differential equations. Undergraduate courses in physical, dynamic, and synoptic meteorology are expected, but they can be taken in the first year. The application deadline for fall semester is **January 15** for both U.S. and international applicants. The application deadline for spring semester is **August 15** for international applicants, and **September 1** for U.S. applicants.

**Master’s Degree**

**Requirements**

Graduation with a master’s degree requires completion of an acceptable thesis and a successful defense of the thesis in an oral examination.

A total of 30 official course credit hours must also be earned. This will be made up of:

1. At least 18 credits of regular course work (i.e., excluding MET 699, 700 and 765), with a minimum of 12 credits in courses numbered 600 and above.
2. 1 credit of MET 765
3. 6 credits of MET 700 Thesis Research and
d4. 5 more credits either from regular courses or MET 699

**Directed Research**

Our core requirements include MET 600, 610, 620 and one term of synoptic meteorology (MET 412 or 416), unless a student has completed an equivalent synoptic meteorology course elsewhere with at least a B-.

Students must obtain a minimum GPA of 3.0 for the courses counted as our core (MET 600, 610, and 620, plus one of MET 412 or 416, if that is taken by the student).

As well, students must maintain a GPA of at least 3.0 for the courses they take in the MS program.
Doctoral Degree
The PhD student exhibits a higher level of independence and originality of thought than that required of the MS student.

Requirements
Students must satisfy several requirements in order to graduate with a PhD degree. Each student is required to pass at least 8 graduate level courses numbered 600 and above with a grade of B- or higher. These courses will be in dynamic, synoptic, physical, tropical meteorology, oceanography, or other closely related fields. At least five of these courses must be completed at the UH Mānoa campus. At the discretion of the graduate chair, a student must be awarded credit for up to three relevant graduate courses taken elsewhere. The courses taken either here or elsewhere need to cover the core requirements MET 600, 610, 620 and one of 412 or 416. A student must pass each of these core courses with a grade of at least B-. A student must obtain a minimum 3.0 GPA in the core courses taken at UH Mānoa. A student must also maintain a GPA of at least 3.0 for all the courses taken in the PhD program at UH Mānoa.

After these 8 courses are successfully completed, but no later than the 24th month in the PhD program, each student must pass a two-part comprehensive examination. The purpose of this exam is to ascertain the student’s comprehension of the broad field of meteorology and so to insure that the student is well prepared for PhD research. The first part of the comprehensive examination is a set of written exercises completed on a single day. Within 3 to 7 days after the written exam, the student sits for the oral portion with his or her committee. No later than 12 months after successful completion of the comprehensive examination, each student is required to submit a written research prospectus for approval to his or her dissertation committee.

A PhD student must also successfully complete two semesters of MET 765 during his or her PhD studies (MET 765 taken before the student was admitted to the PhD program cannot be counted towards satisfying this requirement).

Finally, the student must complete an acceptable PhD thesis and successfully defend it in a public final oral defense.
Educational and research emphasis is placed on coastal engineering, offshore engineering, and ocean resources engineering. Coastal engineering deals with coastal and harbor problems, sediment transport, nearshore environmental engineering, and coastal flood hazards due to storm surge and tsunamis. Offshore engineering is concerned with structures and systems used in the deeper parts of the ocean, including the continental shelf. It also includes hydrodynamics of fluid-body interaction, seakeeping and dynamic responses of marine vehicles and platforms, and hydroelasticity of very large floating structures. Ocean resources engineering is concerned with the engineering systems to develop the energy, minerals and living resources of the oceans, the use of the ocean for waste disposal, and the environmental and economic aspects of these activities. The MS program in ocean and resources engineering is accredited by the Accreditation Board for Engineering and Technology (ABET), which provides accreditation services to the first degree offered by engineering programs.

The educational and research programs in the department have a good balance between numerical and laboratory modeling as well as field observation. Computing facilities include 5 Linux systems and a network of Pentium-based PCs. The cluster Kiwi comprises a 44 TB RAID and 22 processing nodes each containing 2 Intel Quad Core X5460 processes with 24 GB RAM. The department also maintains a number of software packages that are available to the students for course work and research.

The department’s Environmental Fluid Dynamics Laboratory (EFDL) focuses on the study of coastal marine processes including turbulent dispersal of pollutants and nutrients, wave dynamics, and sediment transport as well as fundamental fluid processes such as vortex breakdown and boundary layer turbulence. In addition, the laboratory is home to the Environmental Fluid Dynamics Education Laboratory, which serves as a center for teaching of fluids phenomena. Laboratory instrumentation includes acoustic Doppler velocimeters (ADVs) which obtain high frequency, single point, 3-component velocity measurements, and a laser-based digital particle imaging velocimetry (DPIV) system that obtains two-dimensional fluid velocity via laser imaging techniques. A pulsed Nd:YAG laser and UV light system with digital still and video cameras are used for flow visualization and measurement. The EFDL houses multiple experiment tanks, which are used for both research and teaching demonstrations. These include a 10-meter long, 30 x 10 cm wave channel, and a small rotating table. The tanks allow demonstration of a range of fluid flow phenomena including wave breaking, downscale currents, internal waves in stratified fluids along with rotational effects such as spin-up, Ekman flow and geostrophy.

The department maintains facilities at Kewalo Basin and Snug Harbor in Honolulu for fieldwork and in-ocean experiments. The department operates the Kilo Nalu Observatory offshore of Kakaako, which provides cabled power and Ethernet for in-ocean experimentation at 10 and 20m depths. Kilo Nalu provides comprehensive, real-time observations of ocean currents, waves and water properties, and hosts multiple ongoing research projects focused on coastal ocean processes and instrument development. Field observational equipment includes a REMUS autonomous underwater vehicle (AUV), an LBV 150 remotely operated vehicle (ROV), an array of wave gauges, acoustic current profilers, and current meters. In addition, the department has access to a 25-ft twin-outboard motorboat, two ocean-going vessels operated by SOEST, two 2000m depth submersibles operated by the Hawai‘i Undersea Research Lab and a new 6000m ROV which services the ALOHA Cable Observatory (ACO). ACO is the deepest operating node (power and internet) on the planet. ACO provides real time acoustic monitoring and communication.

In ocean acoustics, gliders are being used as gateways communicating between underwater mobile and fixed nodes and pilots on shore. Hydrophones on gliders monitor for ambient sound including marine mammals, wind and rain, and shipping. Research on detection, classification, and tracking of marine mammals and divers is underway. Tomographic remote sensing work is being developed for use on small scales in local waters as well as on regional and basin scales.

The graduate program in ocean and resources engineering channels the students’ previous engineering or scientific experience to ocean-related careers. Approximately 38% of the students graduating between Fall 2007–Fall 2013 found immediate employment in private industry including oil companies, engineering firms, environmental service firms and construction companies in the U.S. About 13% joined or continued their employment with federal or state agencies. 28% continued studies either by pursuing a higher degree or a post-doctoral position. 6% were employed by UH in engineering research positions. 4% returned to their countries of origin pursuing engineering. 2% received a tenure-track faculty position. 9% decided to pursue non-engineering positions. 62% of the graduates stayed in Hawai‘i.

**Graduate Study**

**Educational Objectives**

The Department of Ocean and Resources Engineering offers a graduate program leading to the Master of Science (MS) and Doctor of Philosophy (PhD) degrees. The goal of the program is to prepare students for the engineering profession and to conduct research in the support of the educational program. The objectives of the program at the MS level are to produce graduates who, during the first few years following graduation:

1. Are effective and creative engineers applying knowledge of mathematics and science to the solution of practical engineering problems;
2. Have general understanding of and ability to work in the ocean and resources engineering disciplines;
3. Are proficient in one or more of the ocean and resources engineering disciplines;
4. Are aware of professional, managerial, legal, ethical, and other non-technical issues commonly encountered in engineering practice;
5. Can communicate and work effectively with peers, clients, and the general public in promoting new ideas, products, or designs; and
6. Can adapt to the changing needs and technology of the ocean and resources industry.

The program at the PhD level shares these objectives with the additional emphasis to produce graduates who:

7. Are productive researchers conducting original research and developing new technology in ocean and resources engineering; and
8. Have the experience to publish in refereed journals.
This additional emphasis prepares the PhD graduate to pursue research careers in the industry or academia.

**Admission Requirements**

Students are admitted for graduate study on the basis of their scholastic records. Degree candidates for the MS program usually have a bachelor’s degree in an engineering discipline that provides an adequate background in mathematics, physics, chemistry, and mechanics. Students seeking admission to the PhD program should have an MS in engineering or equivalent qualification. However, exceptionally well qualified students with a BS in engineering, who do not have a master’s degree, may petition to be admitted to the PhD program directly. Students with mathematics, physics, or other science backgrounds may be admitted to the program, but are required to take specific undergraduate engineering courses to satisfy the pre-program requirements.

Deadlines to submit applications for admission to the graduate programs are **January 15** for fall semester admission and **August 15** for spring semester admission. The ORE application checklist (available on the ORE website) lists all the forms and supporting documents that need to be submitted; some forms and documents are submitted to the Graduate Division while others are submitted directly to the ORE department.

Detailed Graduate Division requirements and forms are available at manoa.hawaii.edu/graduate/content/prospective-students. Official scores in the GRE General Test are required from all applicants. Official TOEFL scores are required from all non-native English speaking students.

Forms required by the department can be downloaded from the ORE admissions webpage at www.ore.hawaii.edu/OE/ore_admission.htm:
- supplemental information form
- statement of objectives
- letter of recommendation form
- graduate assistantship application

Once an application is complete, the Graduate Division performs an initial screening to assure that admission requirements are satisfied. The Admission Committee and department chair then evaluate the application and determine the admissibility of the applicant to the ORE department.

**Master’s Degree**

The MS degree in ocean and resources engineering may be earned under either Plan A (thesis) or Plan B (non-thesis). The program requires a minimum of 30 credit hours. At least 24 credit hours must be earned in advanced courses numbered 600 or above. Up to 2 credit hours of directed reading and 6 transferred credits can be counted toward the MS requirements. Students are required to take the general examination during the first semester of their full-time enrollment to test their knowledge in mathematics, science, and basic engineering. Passing the examination advances the student to master’s candidacy.

Students generally devote their first semester to the basic disciplines in ocean and resources engineering and then specialize in coastal, ocean resources, or offshore engineering by taking the required courses in the area. The core courses ORE 411, 601, 603, 607, and 609 cover the basic disciplines that include hydrostatics, hydrodynamics, oceanography, water waves, underwater acoustics, and field and laboratory work. One credit of seminars, ORE 792, is also included in the core requirements. The required courses are ORE 661, 664, and 783B in coastal engineering; ORE 612, 630, and 783C in offshore engineering; and ORE 677, 678, and 783D in ocean resources engineering. The ORE 783 Capstone Design Project is team-taught by faculty members and practicing professional engineers to prepare students for the engineering profession. The core and required courses amount to 25 credit hours and the remaining credits are to be chosen to form a coherent plan of study.

Students complete their study with a Plan A thesis or a Plan B independent project. The thesis option is research oriented and students receive 6 academic credits for the work. The project option focuses on engineering application or design and carries 3 academic credits. Both require a proposal outlining the subject area, objectives, proposed methodology, sources of data, and anticipated results that must be approved by a committee of at least three graduate faculty members. The work results in a thesis or a report that demonstrates both mastery of the subject matter and a high level of communication skills. Students must present and defend the work at a final examination, which provides the faculty an opportunity to test the students’ understanding and ability to integrate their work at the MS level.

The general and final examination may be repeated once. The general examination must be taken earlier than the semester in which the final examination is taken.

**PhD Degree**

Students pursuing the PhD degree are required to achieve a broad understanding of the principal areas of ocean and resources engineering, as well as a thorough understanding of a specific area. Students must, at a minimum, possess the knowledge covered by the core courses of the MS degree in ocean and resources engineering.

All intended candidates for the PhD degree will take a written qualifying examination before or during the third semester of full-time enrollment. In addition to covering the basic undergraduate fundamentals, the examination tests the students’ understanding of the course work at the MS level. After passing the examination and being advanced to candidacy, students must take a comprehensive examination, which tests their ability to carry out original research and preparation for the selected dissertation topic.

The dissertation topic must be approved by a committee consisting of a minimum of five graduate faculty members with at least one outside member. Students are encouraged to publish the research work in refereed journals in order to obtain feedback from the research community and to develop a publication track record prior to graduation. They must present and defend the novelty of the dissertation at a final examination.

The qualifying and comprehensive examinations may each be repeated only once. The final examination may not be repeated, except with approval of the graduate faculty involved and the dean of the Graduate Division.

**Advising**

Upon admission, the department chair meets with each incoming student at a preliminary conference to discuss the program requirements and determine any pre-program deficiencies.

The graduate chair serves as the advisor to students without an undergraduate engineering degree until they satisfy the
pre-program requirements. Once pre-program requirements are met, the department chair appoints an academic advisor from the pool of ORE departmental faculty. The academic advisor is tasked with helping students navigate through the requirements of the program and ensuring that the guidelines are met. At the start of the research phase, students select a research advisor to guide their research and serve as their committee chair.

**Oceanography**

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Fax: (808) 956-9225  
Email: ocean@soest.hawaii.edu  
Web: www.soest.hawaii.edu/oceanography

**Faculty**

*M. J. Mortl, PhD (Chair)—submarine hydrothermal processes, geochemical cycles, sea-water-sea-floor chemical interaction  
*R. Alegado, PhD—marine microbial ecology and evolution, symbioses, microbial predator-prey interactions, chemoafflagellate-bacterial interactions  
*P. Bienfang, PhD—phytoplankton ecology, cuguetera, aquatic pollution, aquaculture  
*B. C. Bruno, PhD—planetary geosciences, geoscience education  
*G. S. Carter, PhD—physical oceanography, ocean mixing, tides, internal waves  
*M. J. Church, PhD—microbial oceanography, biogeochemistry, plankton biomass and production, ocean ecosystem dynamics  
*A. D. Clarke, PhD—sea-salt and marine aerosols, global pollution, atmospheric optics, aerosol-cloud studies, biogeochemical cycles  
*J. P. Cowen, PhD—marine microbial geochemistry, biogeochemistry, deep subsurface biosphere, deep-sea hydrothermal processes, water quality issues particle dynamics  
*E. H. DeCarlo, PhD—aquatic geochemistry, environmental geochemistry, ocean observation systems, land/ocean/atmosphere interactions, CO2/carbonate mineral geochemistry in the coastal ocean and tropical coral reefs, trace element geochemistry  
*J. Drazen, PhD—deep-sea ecology and fisheries, energetics and trophodynamics, physiological ecology of marine fishes  
*K. F. Edwards, PhD—ecology of phytoplankton and other marine organisms; population and community ecology; theoretical ecology  
*E. Firing, PhD—equatorial circulation, general circulation, physical oceanographic technology  
*P. J. Flament, PhD—dynamics of the surface layer, mesoscale structures, remote sensing, water-types formation, subduction and thermocline ventilation, mixing processes  
*B. T. Glazer, PhD—biogeochemical cycling, redox transition zone geomicrobiology, in situ electrochemical techniques  
*E. Goetz, PhD—marine zooplankton ecology; dispersal and gene flow in marine plankton populations; evolution, behavioral ecology and systematics of marine calanoid copepods  
*D. T. Ho, PhD—air-water gas exchange, tracer oceanography, carbon cycle, and environmental geochemistry  
*D. M. Karl, PhD—microbiological oceanography, oceanic productivity, biogeochemical fluxes  
*C. Kelley, PhD—deepwater habitats, ecology and fisheries, seafloor mapping and GIS  
*P. Kemp, PhD—growth, activity and diversity of marine microbes; biosensor applications in microbial oceanography; molecular ecology of marine bacteria  
*R. C. Kloosterziel, PhD—geophysical fluid dynamics, hydrodynamic, hydromagnetic stability  
*D. S. Luther, PhD—oceanic waves from infragravity to Rossby, mesoscale variability, eddy-mean flow interaction, topography-catalyzed mixing, instrumentation, ocean observatories initiative  
*J. P. McCready, Jr., PhD—equatorial ocean dynamics, coupled ocean-atmospheric modeling, general ocean circulation, coastal ocean dynamics, ecosystem modeling  
*M. McManus, PhD—coastal circulation, mesoscale processes, physical-biological interactions in the ocean  
*G. McMurtry, PhD—geochemistry of marine deposits, seafloor venting processes, chemical volcanology, stable and radiotopic geochemistry, geochronology, in situ instrumentation development  
*C. Measures, PhD—trace element geochemistry, shipboard analytical methods, atmospheric deposition to the oceans, elemental mass balances  
*M. A. Merrifield, PhD—physical oceanography, waves, currents, sea level variability  
*P. Muller, Dr. rer. nat.—theoretical physical oceanography, foundations of complex system theories  
*C. E. Nelson, PhD—microbial ecology and ecosystem science in oceans, coral reefs, and freshwater habitats  
*A. Neuheimeer, PhD—quantitative marine ecology of fish and invertebrates  
*B. S. Powell, PhD—numerical modeling, variational data assimilation, ocean predictability, ocean dynamical modes, and ocean ecosystem dynamics  
*B. Qiu, PhD—large-scale ocean circulation, ocean atmosphere interaction, satellite observations, and numerical modeling of ocean circulation  
*K. Richards, PhD—ocean mixing processes, circulation and dynamics, ocean-atmosphere interaction, ecosystem modeling  
*K. Rutenberg, PhD—biogeochemistry of phosphorus and associated bioactive elements in freshwater and marine aqueous and sedimentary systems, sediment diagenesis, organic matter reactivity and mineral authigenesis, effect of redox chemistry on element cycling, global biogeochemical cycles  
*F. J. Sansone, PhD—biogeochemistry of permeable (sandy) sediments, coastal processes, trace-gas biogeochemistry, hydrothermal geochemistry  
*N. Schneider, PhD—decadal climate variability, tropical air-sea interaction, coupled modeling  
*J. E. Schoonmaker, PhD—sedimentary geochemistry and diagenesis, interpretation of paleoenvironment and paleoclimate sedimentary records  
*K. Selph, PhD—biological oceanography, microbial ecology, protistan grazier feeding dynamics, phytoplankton distributions, use of flow cytometry in ecological research  
*C. R. Smith, PhD—benthic ecology, deep-sea biology, sediment biogeochemistry, climate-change effects on Antarctic ecosystems, marine conservation  
*G. F. Steward, PhD—marine bacteria and viruses, microbial genomics, molecular ecology and biogeochemical cycles  
*A. Timmermann, PhD—tropical climate variability, large-scale ocean circulation, Paleoceanography, Earth-system modeling  
*K. Weng, PhD—behavior, migration and habitat use of sharks and fishes, oceanography of key habitats of pelagic nektan, fishery management and conservation  
*R. E. Zeebe, PhD—global biogeochemical cycles, carbon dioxide system in seawater and interrelations with marine plankton, pale-oceanography, stable isotope geochemistry

**Cooperating Graduate Faculty**

W. L. Au, PhD—bioacoustics and ecological acoustics of the marine environment  
J. M. Becker, PhD—geophysical fluid dynamics, coastal processes, general ocean circulation

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* Graduate Faculty
The study of sea-floor spreading, submarine volcanism, beaches and coasts are just a few areas of interest for oceanographers. Geological oceanography includes the mechanisms, both natural and anthropogenic, that control the distribution of dissolved substances in the ocean and ocean circulation, waves, tides, upwelling, air-sea interactions, and the effect of the oceans on climate. Biological oceanographers study the interactions of marine organisms with one another and the environment; topics include coral reef ecology, marine fisheries, hydrothermal-vent communities, plankton ecology, and near-shore and deep-sea benthic communities.

Because Hawai’i is located near the middle of the largest ocean on Earth, oceanography has a special significance for the state and UH Mānoa. At UH Mānoa, the oceanography facilities are among the best in the U.S. and include three ocean-going research vessels and two research submarines. Biological studies are facilitated by the presence of the Hawai’i Institute of Marine Biology on Coconut Island in Kane‘ohe Bay. Computing facilities are based on a growing network of nearly 300 Sun workstations, Macintosh, and personal computers. Precision instruments include mass spectrometers, gas and liquid chromatographs, liquid scintillation counters, a CHN analyzer, a flow cytometer, and a series of atomic spectroscopy-based instruments. The world-class faculty is actively involved in both teaching and research. UH Mānoa ranks fifth among universities in the nation in terms of National Science Foundation research funding for oceanographic research. The location, the facilities, and the faculty all make UH Mānoa an ideal place to study oceanography.

About 40 percent of marine scientists are employed by the U.S. government, especially by the defense, commerce, and interior departments. Another 40 percent teach and do research at academic institutions. About 20 percent are employed by industry.

The MS and PhD in oceanography are recognized WICHE regional graduate programs. Residents of Alaska, Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, Utah, Washington, and Wyoming are eligible, upon admission, to enroll at Hawai‘i-resident tuition rates.

**Advising**

Each student admitted to the oceanography department is assigned an advisory committee by the department chair. The committee initially consists of three graduate faculty members from at least two of the subdisciplines of oceanography. When formed, the student’s MS or PhD committee becomes the student’s advisory committee. A student must meet with his or her advisory committee at least twice per year. A written report summarizing each meeting must be signed by the student and the student’s advisory committee. A student must meet with his or her advisory committee at least twice per year. A written report summarizing each meeting must be signed by the student and her advisory committee at least twice per year. A written report summarizing each meeting must be signed by the student and the student’s advisory committee. A student must meet with his or her advisory committee at least twice per year. A written report summarizing each meeting must be signed by the student and her committee. A student must meet with his or her committee and a copy placed in the student’s file.

**Graduate Study**

The department offers master’s and doctoral programs with areas of specializations in biological and physical oceanography, marine geology, and geochemistry. Oceanography courses listed in this Catalog may be taken for credit in the degree program. Additional courses may be selected from such fields as botany, chemistry, engineering, geology, mathematics, meteorology, physics, and zoology.

**Admission Requirements**

Applicants must have intensive, rigorous training in one of the basic sciences or engineering. Regardless of major, an applicant must have completed mathematical training, including calculus through first-order ordinary differential equations (equivalent to Calculus IV at UH Mānoa). An applicant must also have a year each of physics and chemistry. The well-pre-
pared student will also have covered classical thermodynamics and applied differential equations and will have had a semester each of biology and geology. GRE test scores (General Test only) are required. Interested students should contact the department chair for further information. For U.S. applicants, the deadline for application for admission is **January 15** for the fall semester and **September 1** for the spring semester. For foreign applicants, the corresponding deadlines are **January 15** and **August 1**.

**Major Requirements**

All students pursuing a degree program must take OCN 620, 622, and 623. For non-biological students, the sequence is completed by taking OCN 621. Biological students complete the sequence by taking OCN 626, 627, and 628. Marine geology and geochemistry students must take CHEM 351 (if they have not already successfully completed a college-level course in physical chemistry). Students may be admitted to the MS program upon successful completion of the appropriate sequence. To be admitted to the PhD program, a student must receive a positive recommendation from a PhD-qualifying committee.

**Degree Requirements**

Both the MS and PhD programs require a minimum of 36 credit hours, including 24 credit hours of course work. The 24 semester hours of course work must be in courses numbered 600 or above (excluding OCN 699 and 700 and seminar courses). At least 12 of those semester hours must consist of courses taken from three of the following groups: biological oceanography, geological oceanography, chemical oceanography, physical oceanography, mathematical methods and statistics, and meteorology. MS students are required to take six credits of OCN 699 (Directed Research) and six credits of OCN 700 (Thesis Research).

Prior to completion of their graduate degree, biological oceanography students must have satisfactorily completed either an undergraduate or graduate course in statistics. Students specializing in marine geology and geochemistry must take at least one, and preferably more, advanced biogeochemistry course. All students must complete a seminar requirement, demonstrate computer competency, and accumulate at least 30 days of field experience. PhD candidates must also pass a comprehensive examination. All students must pass a final oral examination in defense of their thesis/dissertation.