



SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY

Administration

Pacific Ocean Science and Technology 802
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General Information

The School of Ocean and Earth Science and Technology (SOEST) was established in 1988. It combines and integrates the Departments of Atmospheric Sciences, Geology and Geophysics, Ocean and Resources Engineering, and Oceanography, as well as the Hawai'i Institute of Geophysics and Planetology, Hawai'i Institute of Marine Biology, Hawai'i Natural Energy Institute, and Pacific Biosciences Research Center. 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.

Baccalaureate degree programs are offered in the Departments of Atmospheric Sciences, Geology and Geophysics, and Oceanography. Information on entrance and degree requirements for all SOEST graduate programs (MS and PhD) in atmospheric sciences, geology and geophysics, 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: BS in atmospheric sciences, BA in geology (environmental earth science track and earth science education track), BS in geology and geophysics, BS in global environmental science: environmental health sciences track, environmental planning track, sustainability science track, sustainability tourism track

Master's Degrees: MS in atmospheric sciences, MS in geology and geophysics, MS in marine biology, MS in ocean and resources engineering, MS in oceanography, MGEO in geoscience

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Doctoral Degrees: PhD in atmospheric sciences, PhD in geology and geophysics, PhD in marine biology, PhD in ocean and resources engineering, PhD in oceanography

Advising

Director: Leona M. Anthony
 SOEST Student Academic Services
 2525 Correa Road, HIG 135
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 Fax: (808) 956-9987
 Email: leonaa@hawaii.edu
 Web: www.soest.hawaii.edu/soest_web/soest.academics.htm

New Students. A multi-day orientation for new students is held each fall semester before classes begin. Incoming students should contact the Student Academic Services Office in HIG 135 to schedule an appointment for pre-advising prior to registering and for more information.

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 meet regularly 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.

Mandatory advising is required from semester of entry through graduation.

Undergraduate Programs

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

School Requirements

1. Successful completion of OEST 100 – The College Experience;
2. Completion of basic course work as specified by their degree programs;
3. Completion of requirements for the major;
4. Completion of 45 upper division credit hours (courses numbered 300 and above);
5. GPA of 2.0 (C average) for all UH Mānoa registered credits;
6. GPA of 2.0 (C average) for all courses applied to the major requirements;
7. Completion of a degree audit (Graduation Worksheet) to the Student Academic Services Office at least two semesters preceding the award of the degree;
8. Completion of an application for graduation to the Student Academic Services Office in the semester preceding the award of the degree; and
9. Completion of an exit interview by the Student Academic Services Office.

Multiple Majors/Degree

Students seeking a multiple major/degree must have a



minimum 3.0 cumulative GPA, submit an application, personal statement and academic plan, in addition to meeting with a SOEST academic advisor. Students desiring to add a SOEST major/degree as their secondary major/degree, must successfully complete the introductory course for the SOEST major with a C or better and started math course work. Course work used towards a major/minor/certificate in the first degree cannot be used to satisfy major/minor/certificate requirements in the second degree, unless specific courses are required in both.

Second Baccalaureate Degree

Second degree students must earn a minimum of 30 credits in courses taken at UH Mānoa after admission as a second baccalaureate degree candidate while continuously enrolled in the school. Course work used towards a major/minor/certificate in the first degree cannot be used to satisfy major requirements in the second degree, unless specific courses are required in both.

Bachelor of Arts and Bachelor of Science Degrees Requirements

1. Courses required by UH Mānoa Undergraduate General Education Requirements; and
 2. Support science requirements from mathematics, chemistry, biology, and physics vary with degree programs and all courses may have prerequisites.
- Note that introductory chemistry and mathematics courses have placement exams.

BA and BS degree candidates are required to 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 (includes moons,

comets, and asteroids), 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, geodetics, and petrology. The institute maintains various specialized facilities in support of its research endeavors such as a secondary ion mass spectrometry lab and advanced electron microscopy lab 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, UH Maui College, all six community colleges within the UH System, and the University of Guam. Some of the programs supported by HSGC include undergraduate fellowship and traineeship programs (approximately 10-20 students per semester are supported); related-Future Flight Hawai'i Programs 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. Significant goals of the program is to promote STEM education through cooperative and interdisciplinary programs to encourage research while recruiting and training the next diverse workforce. 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-Kanaloa*. 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 UH 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.

Pacific Biosciences Research Center

The Pacific Biosciences Research Center (PBRC) is an organized research unit that supports interdisciplinary biological/biomedical research and training in basic and applied areas with particular relevance to Hawai'i. Current research is focused on cellular, developmental and molecular biology, Hawaiian evolutionary biology and conservation, and neuro-behavioral biology; the unit has implemented plans for a more cohesive focus on biodiversity. PBRC maintains core research support facilities in molecular biology (supporting genomics and bioinformatics) and in confocal and electron microscopy that serve the entire UH Mānoa campus and the state. PBRC fosters undergraduate and graduate research training through the National Science Foundation Advanced Technological Education and Partnership for Advanced Marine and Environmental Science Training for Pacific Islanders (ATE), and through the Minority Access to Research Careers (MARC U*STAR) honors undergraduate program funded by the National Institutes of Health. PBRC administers the Békésy Laboratory of Neurobiology and the Center for Conservation and Research Training on the UH Mānoa campus and the Kewalo Marine Laboratory off-campus.

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 UH 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.

Atmospheric Sciences

HIG 350

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Email: metdept@hawaii.edu

Web: www.soest.hawaii.edu/MET

Faculty

- *S. Businger, PhD (Chair)—mesoscale and synoptic meteorology, satellite meteorology, storm structure and dynamics
- *T. Li, PhD (Graduate Chair)—climate dynamics and coupled atmosphere-ocean modeling
- *Y. L. Chen, PhD—mesoscale meteorology, heavy rainfall
- *P. S. Chu, PhD—climate variability and natural hazards, tropical cyclones, climate prediction
- *J. D. S. Griswold, PhD (Undergraduate Advisor)—satellite remote sensing of clouds and aerosol, cloud microphysics, aerosols and climate meteorology
- *F. F. Jin, PhD—atmospheric dynamics, climate dynamics
- *C. Karamperidou, PhD (Undergraduate Advisor)—climate dynamics and modeling, interannual and decadal climate variability; paleoclimate
- *A. D. Nugent, PhD (Undergraduate Advisor)—mountain meteorology, cloud physics, cloud microphysics
- G. Torri, PhD—atmospheric convection, cloud physics, storm dynamics, severe weather, mesoscale meteorology, land-atmosphere interactions
- *B. Wang, PhD—climate dynamics, geophysical fluid dynamics, and tropical meteorology
- *Y. Wang, PhD—atmospheric dynamics and physics, climate modeling, tropical meteorology
- *J. Zhao, PhD—atmospheric chemistry and aerosols

Affiliate Graduate Faculty

- G. M. Barnes, PhD—mesometeorology, hurricanes, and boundary, layer meteorology
- M. M. Bell, PhD—tropical cyclone, mesoscale, and radar meteorology
- J. Li, PhD—climatic dynamics and predictability, monsoon and air-sea interactions, ENSO

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

The Academic Program

Atmospheric Sciences (ATMO) is the study of phenomena in the Earth's atmosphere. These phenomena include both weather and climate. Students pursuing the BS receive preparation for professional employment in the atmospheric sciences and are qualified for employment in the federal meteorological agencies. The atmospheric sciences major must be well-grounded in the fundamentals of mathematics, chemistry, and physics. Thus BS graduates are qualified to pursue graduate studies both in atmospheric sciences and other applied sciences, such as oceanography or geography. Graduate degrees prepare students

to pursue research careers both with government and in academia.

The atmospheric sciences program at UH Mānoa is unique in its focus on tropical meteorology. The tropics exert critical controls on the entire global atmosphere. BS students receive comprehensive training in tropical weather analysis and forecasting. Graduate students often pursue their research in tropical meteorology; some of their study topics take advantage of Hawai'i's unique natural laboratory. Some students pursue graduate research with funding from the National Weather Service, whose Honolulu Weather Forecast Office is housed in the same building as the atmospheric sciences department. Atmospheric sciences 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*).
- ATMO 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
- 20 credit hours in atmospheric sciences courses numbered 300 and above, including ATMO 302, 303, 305, and 402; and ATMO 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 topical plant and soil science) including (but not limited to) ATMO 310, 405, 406, 412 or 416, 600, 610; CEE 424 and 626; GEOG 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 ATMO 320

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

Student Learning Outcomes (BS Atmospheric Sciences)

1. Know the horizontal and vertical variation of temperature, moisture, and wind in the atmosphere.
2. Recognize the various scales of motion from turbulence to planetary scales.
3. Evaluate the accuracy and precision of standard meteorological instrumentation.
4. Apply basic atmospheric thermodynamic principles such as potential temperature, equivalent potential temperature, vapor pressure, mixing ratio, and the first and second laws of thermodynamics to understand weather and climate issues.
5. Apply basic atmospheric dynamic principles, including equations with partial derivatives such as the equation of motion, various approximations of that equation, conservation of a quantity and key kinematic concepts such as divergence and vorticity to understand weather and climate problems.
6. Predict the weather by diagnosing observations and interpreting guidance products.
7. Design and execute basic computer programs to determine desired variables from raw data.
8. Communicate study results and forecasts in both written and oral forms.

Minor

Requirements

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

- ATMO 200, 302, and 303
- 6 credits of electives from ATMO 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 for fall semester is due **March 1** for both U.S. and international applicants. The application deadline for spring semester is **October 1** for both international applicants and U.S. applicants. In special circumstances, late applications for either semester will be considered.

Master's Degree

Plan A: Thesis Option 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 consisting of:

1. At least 18 credits of regular course work (i.e., excluding ATMO 699, 700 and 765), with a minimum of 12 credits in courses numbered 600 and above.
2. 1 credit of ATMO 765
3. 6 credits of ATMO 700 Thesis Research and
4. 5 more credits either from regular courses or ATMO 699

Directed Research

Our core requirements include ATMO 600, 610, 620. Students must obtain a grade of B- or higher for each of the core courses. Incoming students who have taken a synoptic meteorology course elsewhere with a grade of B- or higher will be exempt from taking ATMO 412 or 416 in the ATMO department as determined by the ATMO department graduate chair.

Incoming students without synoptic meteorology course work will need to take a synoptic meteorology class and lab equivalent, either ATMO 412 or 416, and obtain a grade B- or higher. In these cases, the synoptic meteorology credits will be counted towards the students' MS degree.

Students must obtain a minimum of a combined GPA of 3.0 or higher for the courses ATMO 600, 610, 620, and 412 or 416 if taken at UH Mānoa. Students must also maintain a cumulative GPA of at least 3.0 for all courses in the MS program.

Plan B: Non-Thesis Option Requirements

Graduation requirements for a master's degree Plan B emphasize a greater number of graduate level courses, but no thesis.

A total of 30 official ATMO course credit hours must be earned, including the following:

1. At least 18 credits of regular course work (i.e., excluding ATMO 699, 700 and 765), in courses numbered 600 and above.
2. 1 credit of ATMO 765
3. 9 additional credits of regular ATMO course work in 400-level undergraduate courses and graduate courses (600- and 700-level). Regarding undergraduate courses, we expect that students without a U.S. major in atmospheric sciences may want to take the advanced dynamics course (ATMO 402) and one or both of the forecasting courses (ATMO 412, 416).
4. 2 credits of ATMO 699 Directed Research/Reading. These 2 credits with a written term paper, along with ATMO 765, Seminar in Atmospheric Sciences with an oral presentation, are the capstone project for the Plan B program.
5. Our core requirements include ATMO 600, 610, 620. Students must obtain a grade of B- or higher for each of these core courses. Incoming students who have taken a synoptic meteorology course elsewhere with a grade of B- or higher will be exempt from taking ATMO 412 or 416 in the ATMO department as determined by the ATMO department graduate chair. Incoming students without synoptic meteorology course work will need to take a synoptic meteorology class and lab equivalent, either ATMO 412 or 416, and obtain a grade B- or higher. In these cases, the synoptic meteorology credits will be counted towards the students' MS degree. Students must obtain a minimum of a combined GPA of 3.0 or higher for the courses ATMO 600, 610, 620, and 412 or 416 if taken at UH Mānoa.

MS Plan B candidates must be enrolled during the term in which they complete the requirements for the degree; regular course work or ATMO 600 (Master's Plan B Studies) may be used to meet this requirement. ATMO 600 is offered as a 1-credit course with a mandatory grading of S/NG but does not carry credit toward meeting degree requirements.

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 courses with 6 of those 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 the discretion of the graduate chair, a student must be awarded credit for up to 3 relevant graduate courses taken elsewhere, therefore a minimum of 5 courses must be completed at UH Mānoa. The courses taken either here or elsewhere need to cover ATMO 600, 610, 620, and 412 or 416 with a grade of B- or higher. Incoming students without synoptic meteorology course work will need to take a synoptic meteorology class and lab equivalent, either ATMO 412 or 416, and obtain a grade B- or higher.

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 atmospheric sciences 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 ATMO 765 during his or her PhD studies (ATMO 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 dissertation and successfully defend it in a public final oral defense.

Geology and Geophysics

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Faculty

- *K. H. Rubin, PhD (Chair)—geochemistry, environmental chemistry, volcanology
- *G. T. Apuzen-Ito, PhD—marine geophysics and geodynamics
- *H. Dulai, PhD—coastal hydrology and groundwater geochemistry
- *R. A. Dunn, PhD—marine geophysics and seismology
- D. Eason, PhD—igneous petrology, volcanology, marine geology
- *A. I. El-Kadi, PhD—groundwater and watershed hydrology
- *C. H. Fletcher, PhD—coastal geology
- *L. N. Frazer, PhD—modeling and Bayesian statistics
- *E. J. Gaidos, PhD—geobiology, planetary science
- *M. O. Garcia, PhD—igneous petrology, volcanology
- *C. R. Glenn, PhD—coastal groundwater, environmental geochemistry, marine sediments
- N. Grobbs, PhD—(hydro-)geophysics, seismic, electromagnetic,

volcanoes, groundwater, inverse problems

- *J. E. Hammer, PhD—physical volcanology and experimental petrology
- *E. W. Hellebrand, PhD—igneous petrology
- *B. F. Houghton, PhD—physical volcanology and volcanic hazards
- *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
- *G. F. Moore, PhD—exploration seismology, tectonics
- *B. N. Popp, PhD—isotopic biogeochemistry
- *G. E. Ravizza, PhD—paleoceanography and marine geochemistry
- *S. K. Rowland, PhD—volcanology, Hawaiian geology, remote sensing
- K. Rittenberg, PhD—biogeochemistry, marine geochemistry
- *T. Shea, PhD—physical volcanology
- *B. R. Smith-Konter, PhD—crustal deformation and planetary tectonics
- *S. M. Stanley, PhD—paleobiology, geobiology
- *B. Taylor, PhD—plate tectonics, geology of ocean margin basins
- *P. Wessel, PhD—plate tectonics, marine geophysics

Cooperating Graduate Faculty

- B. Bruno, PhD—planetary volcanology and geoscience education
- R. Butler, PhD—seismology
- B. Chen, PhD—mineral physics, mineralogy, petrology, and geochemistry
- E. H. De Carlo, PhD—marine geochemistry, marine resources
- P. Dera, PhD—mineral physics, mineralogy, petrology, crystallography
- M. H. Edwards, PhD—marine geology and geophysics
- P. Englert, PhD—nuclear chemistry, planetary geoscience, remote sensing
- S. A. Fagents, PhD—planetary volcanology
- L. Flynn, PhD—remote sensing of fires and volcanoes
- J. Foster, PhD—marine, volcano, tectonic geodesy, GPS meteorology
- P. B. Fryer, PhD—marine geology, petrology, tectonics
- M. A. Garcés, PhD—infrasound, wave propagation, volcanology
- J. Gillis-Davis, PhD—planetary geosciences, remote sensing
- E. Herrero-Bervera, PhD—paleomagnetism, geomagnetism
- R. N. Hey, PhD—marine geophysics and tectonics
- G. R. Huss, PhD—cosmochemistry, early solar system chronology
- H. Ishii, PhD—cosmochemistry, small solar system bodies, electron microscopy
- A. N. Krot, PhD—meteorites, planetary geosciences
- N. Lautze, PhD—water and geothermal resources; physical volcanology
- P. G. Lucey, PhD—planetary geosciences, remote sensing
- M. H. Manghnani, PhD—high-pressure geophysics, mineral physics
- F. Martinez, PhD—marine geophysics
- F. W. McCoy, PhD—marine geology, sedimentology
- A. Misra, PhD—LIBS and fluorescence, material science
- P. J. Mouginis-Mark, PhD—planetary science, remote sensing
- K. Nagashima, PhD—ion microprobe analysis, cosmochemistry
- N. Schörghofer, PhD—permafrost, planetary surfaces
- S. K. Sharma, PhD—Raman and IR spectroscopy in geochemistry
- G. J. Taylor, PhD—planetary geosciences
- D. Thomas, PhD—groundwater and hydrothermal systems
- R. Wright, PhD—volcanology

Affiliate Graduate Faculty

- C. Bina, PhD—mineralogy
- R. J. Carey, PhD—physical volcanology
- C. P. Conrad, PhD—geodynamics, marine geophysics
- S. Izuka, PhD—hydrology, groundwater
- C. Neal, MS—volcanology
- D. Oki, PhD—hydrology
- P. Okubo, PhD—seismology, geophysics
- T. Orr, PhD—volcanology
- K. Rotzoll, PhD—groundwater, hydrogeology
- D. A. Swanson, PhD—volcanology
- R. Whittier, MS—hydrologic modeling, ground water

Degrees Offered: BA in geology (environmental earth science or earth science education), BS in geology and geophysics, Master of Geoscience for Professionals (MGeo), MS in geology and geophysics, PhD in geology and geophysics

The Academic Program

The Department of Geology and Geophysics (GG) is dedicated to 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; and 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 produced in rock units by deformational processes such as mountain building, rifting, and earthquakes. *Engineering geologists* provide geotechnical recommendations affecting the design, construction, and operation of engineering projects based on Earth material properties, geological structures, and processes such as faulting, landslides, 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 to understand a very broad range of subjects 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 mitigation. *Geophysicists* use seismic waves, 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 to model Earth and planetary processes. *Planetary scientists* examine how the Earth and Solar System formed, study past and present 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, fieldwork, and shipboard exercises. 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 in Hawai'i and on Pacific islands, as well as the ways human civilization impacts the Earth and environment. Students are able to use skills in math, physics, chemistry, and biology as well as technical knowledge in computer applications, laboratory methods, and field techniques for solving real-world 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 very 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 development; 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 SOEST Director of Student Services in HIG 135 (808) 956-8763. The two undergraduate advisors can be contacted through the department office (808) 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 school. It is more flexible than the BS program and has two tracks: Environmental Earth Science and Earth Science Education. The BA degree requires completion of 120 credit hours of course work, the equivalent of four years of full-time study. A minimum grade of C (not C-) must be achieved in each class in the major and in all support classes.

BA in Geology, Environmental Earth Science Track

The Environmental Earth Science track is geared toward students who plan to enter the environmental and geotechnical fields upon graduation. It includes a combination of traditional geology topics such as field methods and sedimentology, as well as more applied topics such as hydrogeology, geospatial information, and environmental geochemistry.

This BA track requires 27 credits in the geology and geophysics curriculum. This includes one introductory level GG course with a lab, six non-introductory GG courses, a two-credit seminar, and at least 15 credits of approved electives in GG or other departments. With the advice and consent of an undergraduate advisor, courses in other natural sciences, mathematics, or engineering may be substituted as electives. Required support classes include physics, chemistry, biological sciences, and one semester of college calculus; these total 24-25 credits and should be taken as early as possible.

Geology and Geophysics and Other Courses

- Required Courses (27 credits)

- GG 101 Dynamic Earth (3), or GG 102 Quantifying Global and Environmental Change (3), or 103 Geology of the Hawaiian Islands (3), or GG 104 Volcanoes in the Sea (3), or GG 106 Humans and the Environment (3), or GG 130 Geologic Hazards, or GG 170 Physical Geology (4)
- GG 101L Dynamic Earth Laboratory (1) (unless GG 170 is taken)
- GG 200 Geological Inquiry (4)
- GG 305 Geological Field Methods (3)
- GG 309 Sedimentology and Stratigraphy (4)
- GG 325 Geochemistry (3), or GG 425 Environmental Geochemistry (3)
- GG 410 Undergraduate Seminar (2)
- GG 455 Hydrogeology (4)
- GG 461 Geospatial Information (3)
- Lower Division Science Electives
 - GG 250 Scientific Programming (3)
- Upper Division Science Electives (12 credits)
 - GG 300 Volcanology (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); GG 312 Advanced Mathematics for Scientists and Engineers I (3); GG 325 Geochemistry (3); GG 395 Undergraduate Internship (V); GG 399 Directed Reading (V); GG 402 Hawaiian Geology (3); GG 406 Natural Disasters (3); GG 407 Energy and Mineral Resources (3); GG 413 Introduction to Statistics and Data Analysis (3); GG 420 Beaches, Reefs, and 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 and Crustal Deformation (3); GG 454 Engineering Geology (3); GG 460 Geological Remote Sensing (4); GG 466 Planetary Geology (3); GG 499 Undergraduate Thesis (3); NREM 477 Geographic Information Systems for Resource Managers (4); OCN 320 Aquatic Pollution (3); TPSS 304 Fundamentals of Soil Science (4)
- Required Support Courses (24-25 credits)
 - General Chemistry (CHEM 161, 161L, 162, 162L)
 - Calculus I (MATH 215 or 241)
 - College Physics (PHYS 151, 151L, 152, 152L)
 - Biological Sciences (BIOL 171, BIOL 171L, or BOT 101, or ZOOL 101, or MICR 130)
- OEST 100

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

BA in Geology, Earth Science Education Track

The Earth Science Education track is for students who want to become excellent middle school and high school Science teachers. The curriculum includes required topical course work for Earth Sciences certification by the Hawai'i State Department of Education, including courses in geology and geophysics, meteorology, oceanography, astronomy, biology, chemistry, and physics. If students in the Earth Science Education track enroll in the College of Education's Post-Baccalaureate certificate program after they earn the BA, they will be certified as Earth Science teachers in Hawai'i.

This BA track requires 39 credits in the geology and geophysics, oceanography, and/atmospheric sciences curriculum, including introductory level GG and ATMO courses with labs, eight non-introductory GG, ATMO,

and OCN courses, a two-credit seminar, an upper-division teacher education course, and at least 5 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. Students are strongly encouraged to take a mainland summer field course as an elective. 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.

Geology and Geophysics and Other Courses

- Required Courses (39 credits)
 - GG 101 Dynamic Earth (3), or GG 102 Quantifying Global and Environmental Change (3), or 103 Geology of the Hawaiian Islands (3), or GG 104 Volcanoes in the Sea (3), GG 105 Voyage Through the Solar System (3), or GG 106 Humans and the Environment (3), or GG 130 Geologic Hazards, or GG 170 Physical Geology (4)
 - GG 101L Dynamic Earth Laboratory (1) (unless GG 170 is taken)
 - ATMO 101/101L Introduction to Meteorology/Lab (4)
 - GG 105 Voyage through the Solar System (3) or ASTR 110 Survey of Astronomy (3)
 - GG 200 Geological Inquiry (4)
 - ATMO 200 Atmospheric Processes and Phenomena (3)
 - OCN 201, 201L Science of the Sea (4)
 - GG 300 Volcanology (3)
 - GG 305 Geological Field Methods (3)
 - OCN 310 Global Environmental Change (3)
 - GG 406 Natural Disasters (3)
 - ITE 401 Engaging the Adolescent Learner (3)
 - GG 410 Undergraduate Seminar (2)
- Upper Division Science Electives (5 credits)
 - GG 301 Mineralogy (4); GG 302 Igneous and Metamorphic Petrology (3); GG 303 Structural Geology (3); GG 304 Physics of Earth and Planets (4); GG 312 Advanced Mathematics for Scientists and Engineers (3); GG 325 Geochemistry (3); GG 395 Undergraduate Internship (V); GG 399 Directed Reading (V); GG 402 Hawaiian Geology (3); GG 407 Energy and Mineral Resources (3); GG 413 Statistics and Data Analysis (3); GG 420 Beaches, Reefs, and 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 454 Engineering Geology (3); GG 455 Hydrogeology (4); GG 460 Geological Remote Sensing (4); GG 461 Geospatial Information (3); GG 466 Planetary Geology (3); GG 499 Undergraduate Thesis (3); GEOG 405 Water in the Environment (3); NREM 477 Geographic Information Systems for Resource Managers (4); OCN 320 Aquatic Pollution (3); OCN 331 Living Resources of the Sea (3); TPSS 304 Fundamentals of Soil Science (4)
- Required Support Courses (23-24 credits)
 - General Chemistry (CHEM 161, 161L, 162, 162L)
 - Calculus I (MATH 215 or 241)
 - College Physics (PHYS 151, 151L, 152, 152L)
 - Biological Sciences (BIOL 171, 171L)
 - The College Experience (OEST 100)

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.

A total of 37 credits are required in the GG curriculum, including one introductory level geology course with a lab, nine 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 can also be taken as electives. Students are strongly encouraged to take a summer field course as an elective. An undergraduate thesis is also encouraged but not required. The required supporting science classes (28-30 credits) include physics, chemistry, biological science, and college calculus, and should be taken as early as possible. A minimum grade of C (not C-) must be achieved in each class of the major and in all support classes.

Geology and Geophysics Courses

- 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)
- Upper Division Science Electives (11 credits). See listing under the BA Environmental Track.

With advice and consent of an undergraduate advisor, courses in other natural sciences, mathematics, or engineering may be substituted as electives.

- Required Support Courses (29-30 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, 171L, or ZOOL 101, or MICR 130)
 - OEST 100

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 30 credits of the required support

courses (see below) plus in GG 170 (or 101 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 and the proposed faculty thesis advisor. Acceptance into the research track requires the approval of both the faculty advisor and the proposed thesis advisor.

The thesis must be carefully planned and meet departmental requirements. A thesis supervisor and topic should be identified when a student enters 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 170 Physical Geology (4) (or 101 Dynamic Earth (3), or 103 Geology of the Hawaiian Islands (3) and 101L Dynamic Earth Laboratory)
 - GG 200 Geological Inquiry (4)
 - GG 250 Scientific Programming (3)
 - GG 410 Undergraduate Seminar (2)
 - GG 413 Introduction to Statistics and Data Analysis (3)
 - GG 499 Undergraduate Thesis (6)
- Upper Division GG Electives (25 credits, see above)
- Required Support Courses (30 credits)
 - Chemistry: CHEM 161 (3), 161L (1), 162 (3), 162L (1)
 - Calculus I and II: MATH 241 (4) and 242 (4)
 - Physics: PHYS 170 (4), 170L (1), 272 (3), 272L (1)
 - Biology: BIOL 171 (3), 171L (1)
 - OEST 100

Minor in Geology and Geophysics

The minor requires GG 101 or 103 or 170, 101L (unless 170 is taken), 200, and 11 credits of non-introductory courses at the 300 level or higher. A 2.0 GPA is required in these courses. The minor is flexible and can provide either an introductory survey of geology or emphasize areas of particular interest to the student. A student interested in a minor in geology and geophysics should consult with an advisor from the department to tailor a plan best suited to the student's interest.

Graduate Study

Admission Requirements

All applicants must take the GRE General Test. All students are urged to have completed a course in a computer programming language before entrance. U.S. applications are due by **January 15** for admission in the fall semester or by **September 1** for the spring semester. International applications are due **January 1** and **August 15** for the fall and spring semesters, respectively.

Any undergraduate deficiencies will be determined from the student's transcripts and intended field of study, and a plan to address them will be devised at a preliminary conference. GG 611 is intended for students entering from a non-geoscience field to prepare them for graduate studies in the geosciences.

The department offers three master's degrees. The research MS (Plan A degree) emphasizes research and culminates in the public defense of a written thesis. The course work MS (Plan B) degree involves a research project but does not require a thesis.

The MGeo degree emphasizes an internship and a professional focus but does not require a thesis. Applicants who are unsure about which MS program to apply should consult with the department prior to applying.

Master of Geoscience for Professionals (MGeo)

The MGeo is a degree for individuals seeking advanced training for careers in geoscience-related industries or federal, state, and local agencies. Key courses are appropriately scheduled or administered for working professionals to obtain an MGeo in as little as two years of half-time study. Applicants must have a bachelor's degree in the natural sciences, mathematics, or engineering, and are normally expected to have completed at least one year each of college mathematics, geology, physics, and chemistry.

Requirements

The MGeo degree requires a minimum of 30 credit hours, including a total of 6 credits of MGeo Professional Project. At least 12 credits will be in GG graduate courses (GG 600-740), excluding GG 699; and 12 credits may be taken from a list of upper-division undergraduate courses that emphasize applied geoscience.

MGeo Seminar is a 1-credit course that must be taken each year, as many as three times. Students will participate in a professional work project as an employee, intern, or volunteer with a company or agency (gaining the credits in MGeo Professional Project). The outcome of the project is presented orally and in a written report.

Master's Degree

Candidates are accepted from undergraduate majors in the natural sciences, mathematics, and engineering. Incoming students normally are expected to have completed at least one year each of college mathematics, geology, physics, and chemistry. The 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 the suitability of a Plan A (thesis) or Plan B (non-thesis) pathway at a preliminary conference. Plan A requires a minimum of 30 credits, including 6 credits of GG 700 Thesis Research and at least 24 credits of course work (as many as 6 course work credits may be in GG 699). Plan B requires a minimum of 30 credit hours of course work and a final project.

Doctoral Degree

Requirements

PhD candidates are accepted with either a BS or MS degree. Students without an MS degree 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 the end of the fourth semester of residence (for students without an MS degree). The comprehensive exam includes oral and written parts that cover subjects in-depth within the student's field of interest as well as relevant general information from geology, geophysics, and other disciplines. A final defense of the dissertation is required.

Space and financial aid for the PhD program are limited, and each student's progress will be reviewed annually.

Areas of Interest

The areas of interest listed below are active fields of faculty and graduate 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 additional information on research opportunities and financial aid in each of the areas of interest. Many research efforts in the department involve participation in extensive fieldwork and oceanographic expeditions. Graduate students are encouraged to participate in these opportunities as a part of their career training.

Geophysics and Tectonics (GT). 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 in GT 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 convection and plume-plate interaction; 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) program is focused on the dynamic physical, biological, and chemical interactions that characterize Earth's 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 about global phenomena to pragmatic problem-solving of environmental problems, and including everything in-between. Faculty and students of the MEG group work throughout the Hawaiian Islands and travel to field sites all over the world to study processes and interactions between water, atmosphere, submarine groundwater discharge, sediments, and living organisms and their tissues. 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 system environments, 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 have important implications and benefits for the sustainability of fresh water resources and reserves, agriculture, coastal and marine ecosystems, fisheries, Hawai'i's beaches and economy, and other topics of immediate societal concern.

The MEG program is multidisciplinary with cooperating faculty and courses from several other departments including civil engineering, geography, oceanography, and soil sciences among others. 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, moreover, 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 research vessels based at UH Mānoa and other institutions, investigates 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, 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; and 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 relies heavily on GG graduate faculty based in the Hawai'i Institute of Geophysics and Planetology (HIGP), as well as faculty members based in GG. It studies the geology and composition of objects (planets, asteroids, moons, and meteorites) in the Solar System to understand their origin and evolution. Faculty members are on the science teams of multiple planetary missions (Lunar Reconnaissance Orbiter, Mars Odyssey, and Mars Reconnaissance Orbiter). The program 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; (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 more. 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 infrasonics 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, chemistry, physics, or engineering, accompanied by basic courses in chemistry, physics, and mathematics, provides a sufficient background 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 requirements in the Department of Geology and Geophysics.

Global Environmental Science

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

Faculty

- M. Guidry, PhD (Undergraduate Chair)—biogeochemical modeling, mineral precipitation/dissolution kinetics, K-12/university curriculum development
- R. Alegado, PhD—marine microbial ecology, influence of bacteria on animal evolution
- H. Annamalai, PhD—diagnostic and modeling aspects of the Asian Summer Monsoon system, prediction and predictability of the Asian Summer Monsoon system, dynamical and physical link between Monsoon-ENSO
- 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—evolution and structure of destructive atmospheric storms including: frontal cyclones, hurricanes, and severe thunderstorm
- B. C. Bruno, PhD—planetary geosciences, geoscience education
- G. S. Carter, PhD—physical oceanography, ocean mixing, tides, internal waves, underwater ocean gliders
- Q. Chen—environmental changes and use of multiple tools to address these issues
- A. D. Clarke—physical and chemical properties of aerosol in remote troposphere, aircraft studies of aerosol in free troposphere
- M. J. Cooney, PhD—high rate anaerobic digestion, bio-oil extraction from biomass, and the analytical characterization of chemical microenvironments surrounding immobilized enzymes
- E. H. De Carlo, PhD—aquatic chemistry, metals and their anthropogenic inputs, transformations, fate and transport, sedimentary geochemistry, marine minerals
- J. L. Deenik, PhD—soil fertility and soil quality, nitrogen and carbon cycling in agroecosystems, traditional agroecosystems, biochar and sustainable agriculture
- E. F. DeLong, PhD—application of contemporary genomic technologies to understand the ecology, evolution and biochemistry of complete microbial assemblages
- S. Dollar, PhD—biogeochemistry, nearshore processes and effects of human activity on the coastal zone
- J. C. Drazen, PhD—physiological ecology of marine fishes, energetics and trophodynamics, deep-sea biology, adaptations of fishes to the deep-sea
- K. Edwards—phytoplankton ecology, community ecology, ecological theory and statistics, benthic communities
- M. Edwards, PhD—marine geology and geophysics, remote sensing of the seafloor, Mid-Ocean Ridges, Arctic Basin
- 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. Flament, PhD—dynamics of surface ocean layer, mesoscale structures, remote sensing

- C. H. Fletcher, PhD—quaternary and coastal marine geology, sea-level history, coastal sedimentary processes
- O. Francis—storm-generated ocean waves, meteorological and ocean processes on coastal infrastructure, water, and wastewater systems affected by climate change and water shortage
- K. Frank—identifying environmental drivers of microbial dynamics and to characterize the impact of the microorganisms on biogeochemical cycling in mineral-hosted ecosystems from mountain ridge to mid-ocean ridges
- 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
- S. Howell, PhD—environmental aerosol research, aerosol chemistry
- A. Jani—ecology of infectious diseases
- C. Karamperidou—ENSO dynamics and predictability, ENSO in past climate, response of mid-latitude atmospheric circulation to climate change and variability.
- D. Karl—microbiological oceanography, oceanic productivity, biogeochemical fluxes
- C. Kelley—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
- M. Kirs—environmental microbiology, Microbial source tracking, recreational water quality, quantitative PCR
- D. E. Konan, PhD—international trade, microeconomics, computational economics
- Y. H. Li—geochemical cycles from solar nebula to human brain
- 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—physical oceanography, interannual and decadal climate variability
- D. Luther—tide dynamics and energy flow, mixing in the abyssal ocean, circulation and energy fluxes in the North Atlantic
- F. T. Mackenzie—geochemistry, biogeochemical cycling, global environmental change.
- S. J. Martel, PhD—engineering and structural geology
- M. A. McManus, PhD—descriptive physical oceanography, coupled physical-biological numerical models; development of ocean observing systems
- G. M. McMurtry, PhD—geochemistry, geology and geophysics
- C. Measures, PhD—trace element geochemistry, elemental mass balances, hydrothermal systems
- 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
- A. Misra—material science, remote sensing, remote Raman, micro Raman, High T_c Superconductor, stress strain sensors
- T. Miura, PhD—remote sensing of terrestrial vegetation, GIS
- G. F. Moore, PhD—marine geophysics, structural geology
- M. J. Mottl, PhD—hydrothermal processes, geochemical cycles
- P. Mouginiis-Mark, PhD—volcanology from space, remote sensing of natural hazards
- P. K. Müller—ocean circulation, waves and turbulence
- C. E. Nelson, PhD—structure and function of natural bacterial communities in aquatic habitats such as coral reefs lakes, streams, and open ocean
- A. B. Neuheimer, PhD—quantitative ecology of fish and aquatic invertebrate populations, with applications to evolutionary biology, physiology, ecosystem dynamics, resource management, and climate issues
- A. Nugent—mountain meteorology and cloudy physics, orographic convection and precipitation, shallow cloud dynamics, cloud microphysics
- 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
- J. Potemra, PhD—general ocean circulation and its relationship to climate; oceanic processes in the western equatorial Pacific and eastern Indian Ocean and their connection
- B. S. Powell, PhD—numerical modeling, variational data assimilation, ocean predictability, ocean circulation, and ecosystem dynamics
- B. Qiu—large-scale ocean circulation, ocean atmosphere interaction, satellite observations, and numerical modeling of ocean circulation
- 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—observation 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
- O. Rouxel, PhD—co-evolution of life and Earth, sources and biogeochemical cycling of metals in the ocean, weathering processes, seafloor hydrothermal systems, marine mineral deposits, nontraditional stable isotope geochemistry
- K. Rubin, PhD—isotope geochemistry, chronology
- K. Ruttenger, 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—trace-gas geochemistry, hydrothermal geochemistry, suboxic/anoxic diagenesis in sediments, lava-seawater interaction
- N. Schneider, PhD—decadal climate variability, tropical air-sea interaction, coupled modeling
- J. Schoonmaker—sedimentary geochemistry and diagenesis; paleoenvironment and paleoclimate sedimentary records
- K. Selph—biological oceanography, microbial ecology, protistan grazer feeding dynamics, phytoplankton distributions, use of flow cytometry in ecological research

- 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
- B. Taylor—plate tectonics, geology of ocean margin basins
- R. Toonen—dispersal and recruitment of invertebrate larvae, population genetics, evolution and ecology of marine invertebrates
- B. Wang, PhD—atmospheric and climate dynamics
- J. C. Wiltshire, PhD—marine minerals, mine tailings and disposal, remediation and submersible engineering and operations
- R. Wright, PhD—hyperspectral imaging instrument development, remote sensing, infrared radiometry, volcanology
- 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 an environmentally focused senior research thesis in environmental study using one or more of these methodologies. Project 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, Ka Papa Lo'i O Kanewai, 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

requirements [Contemporary Ethical Issues (OCN 310), Oral Communications (OCN 490), and 4 Writing Intensive courses (BIOL 171L, OCN 310, 320, 399, 401, and 499)].

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 credits)

- 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 credits)

- GG 101/101L or GG 170
- ATMO 200
- OCN 201/201L

Foundation Course Requirements (18 credits)

- OCN 100 Global Environmental Science Seminar
- OCN 102 Introduction to Environmental Science and Sustainability
- 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)

- ANTH 328 Food Origins, Food Culture
- ANTH 415 Ecological Anthropology
- ANTH 459 Extinctions
- ANTH 482 Anthropology and the Environment: Culture, Power, and Politics
- ASTR 210 Foundations of Astronomy
- BIOC 241 Fundamentals of Biochemistry
- BIOL 265 Ecology and Evolutionary Biology
- BIOL 301 Marine Ecology and Evolution
- BIOL 310 Environmental Issues
- BIOL 340/CMB 351 Genetics, Evolutions and Society
- BIOL 360 Island Ecosystems

- BIOL 404 Advanced Topics in Marine Biology
- BIOL 410/GEOG 410 Human Role in Environmental Change
- BOT 350 Resource Management & Conservation in Hawai'i
- BOT 480 Algal Diversity and Evolution
- CHEM 272 Organic Chemistry I
- CHEM 273 Organic Chemistry II
- CHEM 445 Synthesis & Analysis of Organic Compounds
- ECON 321 Introduction to Statistics
- ECON 358 Environmental Economics
- ECON 458 Project Evaluation and Resource Management
- ECON 638 Environmental Resource Economics
- GEOG 300 Introduction to Climatology
- GEOG/PLAN 310 Introduction to Planning
- GEOG 322 Globalization and Environment
- GEOG/TIM 324 Geography of Global Tourism
- GEOG 330 Culture and Environment
- GEOG 388 Introduction to GIS
- GEOG 401 Climate Change
- GEOG 402 Agricultural Climatology
- GEOG 404 Atmospheric Pollution
- GEOG 405 Water in the Environment
- GEOG 412 Environmental Impact Assessment
- GEOG 413 Resource Management
- GEOG/PLAN 414 Environmental Hazards & Community Resilience
- GEOG/TIM 415 Nature-Based Tourism Management
- GG 301 Mineralogy
- GG 309 Sedimentology and Stratigraphy
- GG 325 Geochemistry
- GG 413 Introduction to Statistics and Data Analysis
- GG 420 Beaches, Reefs, and Climate Change
- GG 421 Geologic Record of Climate Change
- GG 425 Environmental Geochemistry
- GG 444/OCN 444 Plate Tectonics
- GG 450 Geophysical Methods
- GG 455 Hydrogeology
- GG 466 Planetary Geology
- ATMO 302 Atmospheric Physics
- ATMO 303 Introduction to Atmospheric Dynamics
- MICR 401 Marine Microbiology
- MBBE 412 Environmental Biochemistry
- 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 340 Ecology of Infectious Diseases
- OCN 403 Marine Functional Ecology and Biotechnology
- OCN 418 Advanced Environmental Monitoring Systems
- OCN 430 Introduction to Deep-Sea Biology
- OCN 435 Climate Change and Urbanization
- OCN 441 Principles of Sustainability Analysis
- OCN/PLAN 442/TIM 462 Principles of Environmental Management Systems
- OCN 457 Ridge to Reef: Coastal Ecosystem Ecology and Connectivity

- OCN 480 Dynamics of Marine Ecosystems: Biological-Physical Interactions in the Oceans
- OCN 481 Introduction to Ocean Ecosystem Modeling
- OCN 620 Physical Oceanography
- OCN 621 Biological Oceanography
- OCN 622 Geological Oceanography
- OCN 623 Chemical Oceanography
- OCN 633 Biogeochemical Methods in Oceanography
- OCN 638 Earth System Science and Global Change
- PEPS 310 Environment and Agriculture
- PEPS 451 Environmental Law
- PH 201 Introduction to Public Health
- PH 310 Introduction to Epidemiology
- PH 340 Public Health and the Environment
- PH 341 Public Health Biology and Pathophysiology
- PHIL 316 Science, Technology, and Society
- PLAN/GEOG 310 Introduction to Planning
- PLAN/GEOG 414 Environmental Hazards and Community Resilience
- POLS 315 Global Politics/International Relations
- POLS 316 International Relations
- POLS 380 Environmental Law and Politics
- SOC/GHPS 412 Analysis in Population and Society
- TIM 321 Sociocultural Issues in Tourism
- TIM/GEOG 324 Geography of Global Tourism
- TIM/GEOG 415 Nature-Based Tourism Management
- TIM 420 Sustainable Tourism Policies and Practices
- ZOOL 410 Corals and Coral Reefs
- ZOOL 466 Fisheries Science

The student may also wish to take additional courses in fundamental physics, chemistry, biology, or mathematics.

In addition to students being able to choose their own coupled systems courses to customize their degree per their interests and goals, the global environmental science program also has four tracks (with defined coupled system courses) in the cross-disciplinary environmental science areas of (1) environmental planning, (2) environmental health, (3) sustainable tourism, and (4) sustainability science. For each of these tracks, the collaborating department and their faculty have agreed to support the major required research thesis project so that global environmental science students are able to focus both their curricular and research experience in track's subject material.

1. Environmental Planning (cross-disciplinary with Department of Urban and Regional Planning): Global environmental problems like human-induced climate change challenge local strategies to manage natural resources, protect sensitive species' habitats, and ensure the long-term health of ecosystems. With over fifty-percent of the world's population now living in urban areas and consuming most of the earth's resources, the way we plan, design, and regulate our cities exacerbates local conditions. At the same time, urban areas are also important locations for solutions. Environmental planners adopt solutions-oriented approaches to address environmental problems, such as supporting local food production, building disaster risk reduction, deploying clean sources of energy, conserving biodiversity and natural habitats, managing urban waste, adapting to sea-level rise, and preserving freshwater resources. Planning as a discipline has a long tradition in problem solving across different

scales from neighborhoods to entire regions with extensive community involvement. Graduates will be uniquely positioned for careers as environmental planners, specialists, and consultants employed by government agencies or private firms required to review planning permits, develop master plans, prepare environmental impact studies, or develop mitigation strategies to minimize development impacts.

- 2. Environmental Health Sciences (cross-disciplinary with Office of Public Health Studies):** This track enables a student in the Global Environmental Sciences Program to concentrate his/her academic studies in areas of significant importance in the relationship between environmental issues and public health. The inter-relationship between the environment and its impact on human health is vast and constantly changing. Issues such as food security, emerging zoonotic diseases, water scarcity, air and water pollution, over population, waste disposal, pesticide use, depletion of resources on land and in the sea are just a few of the pressing environmental issues that affect the health and well-being of millions of people worldwide. In this track students will gain the basic scientific knowledge necessary to understand the underlying science of the environment while simultaneously being exposed to public health principles that are essential for establishing cause and effect relationships between environmental conditions and human health, as well as understanding the compromises that sometimes must be made to accommodate economic, health, and environmental preservation goals. Graduates of this track will be uniquely positioned for careers in the environmental health field ranging from laboratory workers to regulatory policy and enforcement officers with environmental agencies.
- 3. Sustainable Tourism (cross-disciplinary with the School of Travel Industry Management):** The relationship between tourism and the natural environment is intimate and complex. The desire for contact with nature drives enormous volumes of tourism, yielding not only tourist spending and associated jobs and tax revenues, but also pollution, waste, and overdevelopment resulting from the transportation of masses of people and the construction and operation of tourism-related facilities. Indeed, such pollution, waste, and overdevelopment diminish the quality of the very environments that impel nature-based tourism to begin with. In addition, issues such as food security, water scarcity, overpopulation, urban sprawl, pesticide use, global warming, rising sea levels, and depletion of resources on land and in the sea are just a few of the pressing environmental issues that affect the attractiveness, competitiveness, and sustainability of destinations throughout the world. Graduates will be uniquely positioned for careers as planners, specialists, and consultants employed by government agencies required to prepare environmental impact studies and/or tourism plans, consulting firms that prepare such studies and/or plans for government agencies, and nonprofit organizations that operate tourism "ecocertification" programs that provide tourism-related businesses with credentials of their "greenness."
- 4. Sustainability Science:** Sustainability Science probes interactions between global, social, and human systems, the complex mechanisms that lead to degradation of these systems, and concomitant risks to human well-being. As Sustainability Science has emerged in the 21st century as a new academic discipline, it brings together scholarship and

practice, global and local perspectives, and disciplines across the natural and social sciences, engineering, and medicine—facilitating the design, implementation, and evaluation of practical interventions that promote sustainability in particular places and contexts. The GES graduate from the sustainability track is prepared for opportunities in all fields that would hire environmental scientists, and to be especially competitive for those opportunities that target the design, analysis, implementation, maintenance, and/or monitoring of processes or systems that target increased sustainability.

Directed Reading

■ OCN 399 Directed Reading

Course offering with an individual faculty member to do a one-on-one study on a topic of particular interest to you.

This could be used to explore a topic before deciding on a senior thesis, or because you are interested in an area in which there isn't a formal course offering. It can be taken for CR/NC or for a grade and you can register for 1-3 credits. This is not considered a CS class.

Senior Research Thesis (5-8 hours)

- OCN 490 Communication of Research Results
- OCN 499 Undergraduate Thesis

Each student is required to complete a written senior thesis based on research conducted with one or more chosen advisors, and to make a public presentation of their research results.

Marine Biology

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

Ocean and Resources Engineering

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Tel: (808) 956-7572
Fax: (808) 956-3498
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Web: www.ore.hawaii.edu

Faculty

- *E. Nosal, PhD (Chair)—passive acoustic monitoring methods, ocean ambient noise, sediment acoustics, bioacoustics
- *J. C. Wiltshire, PhD (Associate Chair)—submersibles, ROV, marine minerals, marine mining technology
- *K. F. Cheung, PhD (Graduate Chair)—coastal and offshore engineering, marine hydrodynamics, computational methods, water wave mechanics, coastal flood hazards
- *B. M. Howe, PhD—acoustical and physical oceanography, tomography, sensors and network infrastructure
- *Z. Huang, PhD—coastal and ocean engineering, wave-structure interactions, wave energy conversion, natural hazards-tsunamis, coastal sediment transport, coral reef hydrodynamics
- *G. C. Nihous, PhD—ocean thermal energy conversion, marine renewable energy

Cooperating Graduate Faculty

- J. M. Becker, PhD—general ocean circulation
- M. Chyba, PhD—control theory
- O. P. Francis, PhD—coastal engineering
- R. Ghorbani, PhD—dynamics, controls, design, alternative energy
- B. Glazer, PhD—instrumentation
- S. M. Masutani, PhD—ocean resources engineering
- G. McMurtry, PhD—oceanographic engineering
- M. A. Merrifield, PhD—coastal and near-shore processes
- H. R. Riggs, PhD—structural engineering
- J. R. Smith, PhD—marine survey
- J. Yu, PhD—marine bioproducts engineering

Affiliate Faculty

- B. D. Greeson, PhD—offshore engineering, hydrodynamics, ROV/submersible operations
- E. Pawlak, PhD—coastal mixing processes, fluid dynamics, sediment transport
- D. Rezachek, PhD—ocean energy and engineering design
- D. A. Smith, PhD—near-shore processes and coastal engineering
- L. J. Van Uffenlen, PhD—acoustical oceanography, oceanographic instrumentation
- D. Vithanage, PhD—coastal engineering, nearshore circulation

Degrees Offered: MS in ocean and resources engineering, PhD in ocean and resources engineering

The Academic Program

Ocean and Resources Engineering (ORE) is the application of ocean science and engineering design to the challenging conditions found in the ocean environment and to the synthesis of novel products from marine systems. Waves and currents, turbulence, dynamic loads, mobile sediment, high pressure and temperature variations, ocean acoustics, marine instrumentation, as well as chemical and biological processes, are among the considerations that set ocean and resources engineering apart from conventional land-based engineering.

Educational and research emphasis in ORE is placed on coastal, offshore, ocean resources, and oceanographic engineering. Coastal engineering deals with coastal and harbor problems, sediment transport, near-shore environmental engineering, and coastal flood hazards. Offshore engineering is concerned with structures and systems used in the deeper parts of the ocean and includes hydrodynamics of fluid-body interaction, sea-keeping and dynamic responses of ships and platforms, and hydro-elasticity of floating structures. Ocean resources engineering considers the engineering systems needed to develop the ocean's energy, mineral, and living resources, the potential use of the ocean for waste disposal, and the environmental and economic aspects of such activities. Oceanographic engineering involves the design, operation, and maintenance of the mechanical, electrical, and computing technology and instrumentation that supports oceanographic and marine operations. Students can also pursue interdisciplinary studies that cater to the rapidly evolving aspects of ocean engineering, and that bridge ocean engineering with other marine disciplines.

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 (ADV) 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, downslope 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; and 9% decided to pursue non-engineering positions. 62% of the graduates stayed in Hawai'i.

Graduate Study

Educational Objectives

ORE 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. Candidates for the MS program usually have a bachelor's degree in an engineering discipline that provides an adequate background in mathematics, and mechanics. Students seeking admission to the PhD program should have an MS in engineering or equivalent qualification. 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 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 or IELTS 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.soest.hawaii.edu/ore/program/admission/:

- supplemental information form
- statement of objectives
- letter of recommendation form
- graduate assistantship application

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

Master's Degree

The MS degree is accredited by the Accreditation Board for Engineering and Technology (ABET) and has the following requirements: Pre-program; MS General Exam; Core, option-area, and elective courses, and; MS thesis (Plan A) or independent project (Plan B).

The pre-program (which includes a general education component, one year of college-level mathematics and science, and one and one-half years of engineering topics) provides students with a broad educational background that covers the technical and non-technical issues commonly encountered by engineers in professional practice. Students with an undergraduate engineering degree from an ABET accredited program satisfy the pre-program requirements a priori. Not all students in the program have an undergraduate degree in engineering. The department requires these students to make up any deficiencies by completing required pre-program courses.

Students who satisfy the pre-program requirements must take the general examination during the first semester of their full-time enrollment. This test is used to gauge incoming student's knowledge of mathematics, science, and basic engineering principles, as well as their preparation for graduate-level course work. Students requiring pre-program work must take the general examination in the first semester following the completion of their pre-program, and prior to their semester of graduation. The general examination may be repeated once. Passing this exam advances the student to master's candidacy. Students who have passed the Fundamentals of Engineering (FE) examination within the three years prior to their admission to ORE are exempted from taking the general examination.

The core courses (ORE 411, 601, 603, and 607) provide students with a broad understanding of the topics of interest to ocean and resources engineering discipline. This includes hydrostatics, oceanography, water wave mechanics, underwater acoustics, and a laboratory course that connects material covered in the classroom with observations made and data collected in the ocean. Option-area courses prepare students for specialization in coastal, offshore, ocean resources, and oceanographic engineering, or an interdisciplinary field of study. A required capstone design project is typically team-taught by faculty members and practicing professional engineers. Its objective is to familiarize students with the planning and design of an engineering project in a consulting firm setting. All MS students are required to attend 15 seminars which cover the latest in developments and research—as well as contemporary issues—related to ocean and resources engineering. Elective courses are chosen to meet the 30 credit degree requirement and to form a coherent plan of study.

Students complete their study with a thesis (Plan A) or independent project (Plan B). The thesis is research oriented and carries six academic credits. The independent project focuses on engineering application and design and carries three academic credits. Both require a proposal outlining the subject area, objectives, proposed methodology, sources

of data, and anticipated results, and must be approved by a committee of at least three graduate faculty members. The thesis/project provides students with an opportunity to explore and contribute to the development of the latest technology in an ocean and resources engineering discipline. This work results in a thesis (Plan A) or a report (Plan B) that should demonstrate both mastery of the subject matter and an aptitude for clear and effective communication. The student must present and defend their work at a final examination which may be repeated once.

PhD Degree

Students pursuing a PhD are required to achieve a broad understanding of the principal areas of ocean and resources engineering, as well as a thorough understanding of their research area. Students are expected to have knowledge related to fundamental engineering courses (i.e., MS basic engineering pre-program requirements) as well as the core courses of the ORE MS degree. Doctoral students are also encouraged to take courses relevant to their research interests.

The ORE program at the PhD level has the following requirements: PhD qualifying exam; An advanced mathematics course at the graduate level and ORE 792 Seminar; PhD comprehensive exam, and; PhD dissertation and defense.

All intended PhD candidates are expected to take a qualifying examination, preferably before or during the third semester of full-time enrollment. In addition to covering basic undergraduate mathematics and engineering fundamentals, the examination tests the students' understanding of the core courses of the ORE MS degree. The examination is conducted by ORE's PhD qualifying exam committee and the outcome is determined by a vote of the departmental faculty. The qualifying examination may be repeated only once.

After passing the qualifying examination and advancing to candidacy, the student forms a dissertation committee and begins preparing their dissertation proposal. Upon completion of their dissertation proposal, the student must take a comprehensive examination which is conducted by the dissertation committee. This is meant to measure the student's preparation and ability to conduct original research in the area of their proposed dissertation topic. The examination consists of a presentation of the student's proposed research followed by an oral component in which the student must defend the novelty of their proposed research, address any issues raised by the committee, and demonstrate his/her ability to successfully conduct the proposed research. The comprehensive examination may be repeated only once.

PhD students are expected to publish their research in refereed journals. This provides feedback from the research community while developing a publication track record prior to graduation. The student must present and defend their dissertation at a final examination, which is conducted by the dissertation committee. This examination may not be repeated except with approval from the graduate faculty involved and the Dean of Graduate Division, which has additional rules pertaining to the defense.

Advising

Upon admission, the ORE department chair meets with each incoming student at a preliminary conference to discuss the program requirements. The ORE graduate chair will reconfirm any pre-program deficiencies for students from non-ABET accredited undergraduate programs through evaluation of

transcripts and course descriptions.

The ORE graduate chair serves as the advisor to students who do not meet the pre-program requirements. Once pre-program requirements are met, the ORE department chair appoints an academic advisor from the pool of ORE departmental faculty. The academic advisor helps student navigate the program requirements and ensures that all university and department guidelines are met. At the onset of their research, students must select a research advisor to guide their research and serve as their committee chair.

Oceanography

Marine Science 205
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Fax: (808) 956-9225
Email: ocean@soest.hawaii.edu
Web: www.soest.hawaii.edu/oceanography

Faculty

- *N. Schneider, PhD (Chair)—decadal climate variability, tropical air-sea interaction, coupled modeling
- *M. Guidry, PhD (Global Environmental Sciences Chair)—biogeochemical modeling, mineral precipitation/dissolution kinetics, K-12/university curriculum development, undergraduate research, and academic program management
- *R. Alegado, PhD—marine microbial ecology, influence of bacteria on animal evolution
- *H. Annamali, PhD—diagnostic and modeling aspects of the Asian Summer Monsoon system, prediction and predictability of the Asian Summer Monsoon system, dynamical and physical link between Monsoon-ENSO
- *G. S. Carter, PhD—physical oceanography, ocean mixing, tides, internal waves
- *E. H. De Carlo, PhD—aquatic chemistry, metals and their anthropogenic inputs, transformations, fate and transport, sedimentary geochemistry, marine minerals
- *E. F. DeLong, PhD—application of contemporary genomic technologies to understand the ecology, evolution and biochemistry of complete microbial assemblages
- *J. Drazen, PhD—physiological ecology of marine fishes, energetics and trophodynamics, deep-sea biology, adaptations of fishes to the deep-sea
- *K. F. Edwards, PhD—ecology of phytoplankton and other marine organisms; population and community ecology; theoretical ecology
- *E. Firing, PhD—ocean circulation and currents on all scales, with emphasis on observation and dynamics
- *P. J. Flament, PhD—dynamics of the surface layer, mesoscale structures, remote sensing
- *B. T. Glazer, PhD—biogeochemical processes in marine environments; use of molecular methods to characterize and understand synergy of geomicrobiology
- *E. Goetze, 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
- *S. Howell, PhD—environmental aerosol research, aerosol chemistry
- *A. Jani, PhD—ecology of microbial symbioses of marine and freshwater animals; assembly and regulation of microbial communities; ecology of infectious diseases
- *D. M. Karl, PhD—microbiological oceanography, oceanic productivity, biogeochemical fluxes
- *C. Kelley, PhD—deepwater habitats, ecology and fisheries, seafloor mapping and GIS
- *R. C. Kloosterziel, PhD—geophysical fluid dynamics, hydrodynamic, hydromagnetic stability, wave dynamics
- *D. S. Luther, PhD—tide dynamics and energy flow, mixing in the abyssal ocean, circulation and energy fluxes in the North Atlantic
- *M. McManus, PhD—descriptive physical oceanography, coupled physical-biological numerical models; development of ocean observing systems
- *G. McMurtry, PhD—geochemistry, geology, geophysics
- *C. Measures, PhD—trace element geochemistry, shipboard analytical methods, atmospheric deposition to the oceans, elemental mass balances
- *M. A. Merrifield, PhD—physical oceanography, coastal circulation, sea level variability, current flows and mixing in the vicinity of coral reefs, island and seamounts
- *M. J. Mottl, PhD—hydrothermal processes, geochemical cycles
- *C. E. Nelson, PhD—structure and function of natural bacterial communities in aquatic habitats such as coral reefs lakes, streams, and open ocean
- *A. Neuheimer, PhD—quantitative ecology of fish and aquatic invertebrate populations, with applications to evolutionary biology, physiology, ecosystem dynamics, resource management, and climate issues
- *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—observations and modeling of ocean processes, ocean dynamics, ocean atmosphere interaction, ecosystem dynamics
- *O. Rouxel, PhD—co-evolution of life and Earth, sources and biogeochemical cycling of metals in the ocean, weathering processes, seafloor hydrothermal systems, marine mineral deposits, nontraditional stable isotope geochemistry
- *K. Ruttenger, 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—trace-gas geochemistry, hydrothermal geochemistry, suboxic/anoxic diagenesis in sediments, lava-seawater interaction
- *K. Selph, PhD—biological oceanography, microbial ecology, protistan grazer 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—aquatic microbial ecology, molecular ecology and diversity of viruses and bacteria
- *A. Timmermann, PhD—ENSO dynamics, abrupt climate change, dynamics of thermohaline circulation, decadal climate predictability, dynamical systems' theory, glacial dynamic, reconstructing climate change in Hawai'i
- *R. E. Zeebe, PhD—global biogeochemical cycles, carbon dioxide system in seawater and interrelations with marine plankton, paleoceanography, stable isotope geochemistry

Cooperating Graduate Faculty

- J. M. Becker, PhD—geophysical fluid dynamics, coastal processes, general ocean circulation, waves and stability
- B. C. Bruno, PhD—planetary geosciences, geoscience education
- M. Cooney, PhD—high rate anaerobic digestion, bio-oil extraction from biomass, and the analytical characterization of chemical microenvironments surrounding immobilized enzymes

- K. Frank—identifying environmental drivers of microbial dynamics and to characterize the impact of the microorganisms on biogeochemical cycling in mineral-hosted ecosystems from mountain ridge to mid-ocean ridges
- E. Gaidos, PhD—molecular evolution; microbiology of extreme environments; biosphere-climate feedbacks; critical intervals in Earth history; exobiology; biological networks
- R. D. Gates, PhD—regulation and de-stabilization of coral/dinoflagellate symbioses, evolution and development of animal sensory systems
- P. H. Lenz, PhD—sensory capabilities underlie the behavior of any organism
- B. Popp, PhD—stable isotope biogeochemistry, marine organic geochemistry, isotopic biogeochemistry of individual biomarkers and gases
- J. Potemra, PhD—general ocean circulation and its relationship to climate; processes in the western equatorial Pacific and eastern Indian Ocean and their connection
- M. Rappe, PhD—ecology of marine microorganisms; genomics; coral-associated microorganisms; ecology of microorganisms in the deep subsurface
- F. Thomas, PhD—coral reef and coastal ecology, reproductive biology, hydrodynamics and biomechanics
- R. Toonen, PhD—dispersal and recruitment of invertebrate larvae, population genetics, evolution and ecology of marine invertebrates
- J. C. Wiltshire, PhD—geology and geochemistry of marine mineral deposits, marine mining and processing, minerals policy issues, research-submersible technology

Affiliate Graduate Faculty

- A. Andrews, PhD—fishes from all marine environments, geochemical techniques to validate age growth
- F. Ascani, PhD—ocean dynamics, marine ecosystem dynamics, climate, nonlinear science
- J. Auean—waves, tides and sea-level, observations of interactions between physical and biological processes in the surface ocean
- R. Brainard, PhD—tropical reef-ecosystem integration, with a particular emphasis on the role of ocean variability on ecosystem health
- P. Falkowski, PhD—phytoplankton evolution and ecology, photosynthesis, coral biology, and biogeochemical cycles
- W. Grossman, PhD—environmental research, systems sciences, information society and innovation, higher education
- M. Hatta, PhD—trace elements, biogeochemical cycling of trace elements and dust deposition
- C. M. Jones, PhD—stable isotopes, microbial N and C Cycling
- D. W. Moore, PhD—geophysical fluid dynamics, equatorial oceanography
- E. Laws
- T. Oliver, PhD—coral reef evolutionary ecologist; uses spatial and genomic tools to document ecological responses to environmental change, especially warming and acidification
- J. Polovina, PhD—research in biological oceanography in the Central and Western Pacific with focus on population dynamics of high trophic animals
- J. Ruzicka, PhD—biochemistry, environmental: agricultural assays, biotechnology, oceanography, clinical chemistry
- J. R. Sibert
- K. Weng, PhD—behavior migration and habitat use of sharks and fishes, oceanography of key habitats of pelagic nekton, fishery management and conservation

Emeriti Graduate Faculty

- *P. Bienfang, PhD—phytoplankton ecology, ciguatera, aquatic pollution, aquaculture
- A. Clarke, PhD—physical and chemical properties of aerosol in remote troposphere, aircraft studies of aerosol in free troposphere
- B. J. Huebert, PhD—air pollution, climate change, atmospheric

- aerosols, global elemental cycles, air-sea gas exchange
- Y. H. Li, PhD—geochemical cycles from solar nebula to human brain
- R. Lukas, PhD—physical oceanography, interannual and decadal climate variability
- L. Magaard, Dr. rer. nat.—ocean waves, oceanic turbulence, oceanography of Hawaiian waters, climate and society
- F. T. Mackenzie—geochemistry, biogeochemical cycling, global environmental change
- A. Malahoff, PhD, DSc—geological and geophysical oceanography, submarine hydrothermal system, mineral formation processes, underwater volcanism
- *J. P. McCreary, Jr., PhD—equatorial ocean dynamics, coupled ocean-atmospheric modeling, general ocean circulation, coastal ocean dynamics, ecosystem modeling
- P. Muller, PhD—ocean circulation, waves and turbulence
- *J. E. Schoonmaker, PhD—sedimentary geochemistry and diagenesis, interpretation of paleoenvironment and paleoclimate sedimentary records
- S. Smith, PhD—C-N-P mass balance in marine systems, CO₂ biogeochemistry, coastal ecology
- R. Young, PhD—ecology and systematics of cephalopod mollusks

Degrees Offered: MS in oceanography, PhD in oceanography

The Academic Program

Oceanography (OCN) is the study of the physics, chemistry, and geology of the ocean and the ecology of organisms that live within the sea. Physical oceanography is concerned with ocean circulation, waves, tides, upwelling, air-sea interactions, and the effect of the oceans on climate. Chemical oceanographers study the distribution of dissolved and suspended substances in the ocean and the mechanisms, both natural and anthropogenic, that control their form and abundance. Geological oceanography includes the study of sea-floor spreading, submarine volcanism, beach formation, deep-seabed mineral resources, sediments, and paleoceanography. 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. The oceanography facilities at UH Mānoa 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 several hundred computers and servers. Precision instruments include mass spectrometers, gas and liquid chromatographs, a CHN analyzer, a flow cytometer, carbon analyzers, nutrient analyzers, 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 Departments of Defense, Commerce, and Interior. 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 his or her committee and a copy is 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, and 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 atmospheric science, botany, chemistry, engineering, geology, mathematics, physics, and zoology.

Admission Requirements

Applicants must have a 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-prepared 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, 700, 800, 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 (PhD) students are required to write a thesis (dissertation) based on original research. For MS students, to ensure a minimum effort spent learning the proper conduct of research, a requirement of six credits of both OCN 699 and OCN 700 has been established, but usually more credits will be required to complete the thesis (about 12 more credits of OCN 699). No minimum requirement for OCN 699 or OCN 800 is set for PhD students due to the much larger effort that is always required to produce a PhD dissertation. All students must pass a final oral examination in defense of their thesis/dissertation.

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, advanced geochemistry 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.