
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 Geology and Geophysics, Meteorology, Ocean Engineering, and Oceanography, as well as the Hawai'i Institute of Geophysics and Planetology, the Hawai'i Institute of Marine Biology, and the Hawai'i Natural Energy Institute. The Sea Grant and Space Grant College Programs, the Hawai'i Undersea Research Laboratory, and the 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. In addition, SOEST includes the Marine Option Program.

Although the Department Ocean Engineering offers several undergraduate courses, baccalaureate degrees are not offered in this area. The Department of Oceanography offers the BS in global environmental science. Undergraduate students may also pursue ocean-related interests by means of the undergraduate certificate program

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administered by the Marine Option Program (see the "Certificate Programs" section). Baccalaureate degree programs are offered in the Department of Geology and Geophysics and the Department of Meteorology. Those with long-range plans for graduate work in oceanography or ocean engineering should prepare themselves with an undergraduate course of study that will satisfy the entry requirements for admission to these graduate programs. Information on entrance and degree or certificate requirements for all SOEST graduate programs (MS and PhD in geology and geophysics, meteorology, ocean engineering, and oceanography; and certificates in Graduate Maritime Archeology and History and Graduate Ocean Policy) is in this *Catalog*. Candidates for advanced degrees and the graduate certificate programs apply through the Graduate Division of the University. 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 the University of Hawai'i a leading center in ocean and earth science and technology. Scientists 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 the University of Hawai'i at Mānoa to preeminence in research and development in ocean and earth science and technology;
3. Build the strength of the University 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 and Certificates

Bachelor's Degrees: BA in geology, BS in geology and geophysics, BS in meteorology, BS in global environmental science

Master's Degrees: MS in geology and geophysics, MS in meteorology, MS in ocean engineering, MS in oceanography

Doctoral Degrees: PhD in geology and geophysics, PhD in meteorology, PhD in ocean engineering, PhD in oceanography

Certificate Programs: Marine Option Program Certificate, Maritime Archaeology and History Graduate Certificate, Graduate Ocean Policy Certificate

Advising

For general information about the school and its programs, contact the associate dean's office at Marine Science 212, 1000 Pope Road; tel. (808) 956-9109.

For information on specific degree programs, contact the appropriate departments. For information on certificate programs, contact the Marine Option Program (see the "Certificate Programs" section).

Undergraduate Programs

Candidates for the BA degree in geology, the BS degree in geology and geophysics, the BS degree in meteorology, and the BS degree in global environmental science, apply through the undergraduate Admissions Office.

School Requirements

To be entitled to a bachelor's degree offered by the school, students must fulfill these requirements.

1. Basic course work as specified by their degree programs.
2. Completion of requirements for the major, including presentation of goldenrod form to the Student Academic Services Office.
3. Completion of 60 credit hours in non-introductory level courses (i.e., courses numbered 300 and above) or 200-level courses that have an explicit college-level course prerequisite.
4. GPA of 2.0 (C average) for all University of Hawai'i at Mānoa registered credits.
5. GPA of 2.0 (C average) for all courses applied to the major requirements.
6. A degree audit at the Student Academic Services Office in the semester preceding the award of the degree.
7. Application for graduation at the Student Academic Services Office in the semester preceding the award of the degree.

Bachelor of Arts and Bachelor of Science Degrees

Basic Requirements

1. Courses in written communication and in world civilizations as required by the UH Mānoa General Education Core (see the "Mānoa General Education and Graduation Requirements" section of this *Catalog*).

2. Three semester courses chosen from the three humanities groups in the General Education Core (see the "Mānoa General Education and Graduation Requirements" section of this *Catalog*).
3. Three semester courses from three different departments in the social sciences group in the General Education Core (see the "Mānoa General Education and Graduation Requirements" section of this *Catalog*).
4. At least one course in biological sciences chosen from natural sciences group one in the General Education Core (see the "Mānoa General Education and Graduation Requirements" section of this *Catalog*).

Support science requirements from mathematics, chemistry, and physics vary with degree programs. The following are the minimum required courses (consult departmental adviser for further details).

Mathematics

MATH 205 (BA)

MATH 206 (BS, geology and geophysics)

MATH 232 (BS, meteorology)

Chemistry

CHEM 161/161L, 162/162L

CHEM 171/171L (mandatory for meteorology)

Physics

PHYS 151/151L and 152/152L (BA)

PHYS 170/170L and 272/272L (BS)

(BS majors may enroll in PHYS 151/151L, 152/152L with permission of departmental adviser)

Note that introductory chemistry and mathematics courses have placement tests.

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

Certificate Programs

Marine Option Program

The Marine Option Program (MOP) is a unique opportunity for undergraduates with an interest in the ocean. It is open to students in all fields and provides a clearinghouse for marine-oriented experiential education as well as a chance for students with common interests to meet. MOP sponsors a wide variety of marine activities, including field trips, workshops, seminars, symposia, and noncredit courses.

A certificate is awarded to undergraduates who successfully complete at least 12 credit hours of marine-related courses (including OCN 201, OE 202, ZOOL 200, or an equivalent survey course; one 3-credit interdisciplinary ocean course; and 6 credit hours of marine electives). In addition, they must complete a unique MOP skill project: design and conduct a personal marine or aquatic project related to their educational goals. Past projects have run from scientific research to endeavors in the arts. Unclassified graduate students are also eligible to enroll in MOP and earn a certificate.

Students interested in MOP or in marine careers and curricula should visit the Marine Option Program offices in Hawai'i Institute of Geophysics, room 215A; tel. (808) 956-8433; e-mail mop@hawaii.edu.

Maritime Archaeology and History

The field of maritime archaeology and history is relatively undeveloped in the Pacific, yet a great potential exists to explore, document, preserve, and interpret the rich heritage of ocean-related culture, history, anthropology, archaeology, science, and technology. The University of Hawai'i is exceptionally well-located, staffed, and equipped to conduct education, research, and service for Pacific Ocean maritime archaeology and history of Polynesians and other Pacific Islanders as well as the maritime peoples of Asia—with expertise spanning from coastal wetlands to the technologies required for deep water exploration. This graduate certificate is offered as a complement to classified graduate students pursuing advanced degrees or as a stand-alone credential. Cooperating faculty from several departments and programs in the UH system are complemented by faculty and professionals from throughout the Pacific and continental United States. Completion of the certificate requires a minimum of 20 credits, including OEST/HIST 489 (3) and ANTH 640F (3) or OEST/

ANTH 668 (6), plus a seminar and electives from courses in the following areas: history and social science, archaeology, techniques, and natural sciences and engineering. For further information contact the Marine Option Program, tel. (808) 956-8433; e-mail mop@hawaii.edu.

Ocean Policy

The wise use and careful stewardship of the ocean require people with multidisciplinary and interdisciplinary advanced education in the natural and social sciences. This program offered by the School of Ocean and Earth Science and Technology, in collaboration with several other colleges and schools, is designed for classified graduate students, law students, and community professional practitioners who wish to complement their existing degree or curriculum. An advisory committee assists each student in custom-designing a 21-credit (minimum) program that draws on marine-related courses in law, geography, agricultural and resource economics, oceanography, coastal management, civil and ocean engineering, geology and geophysics, meteorology, botany and zoology, and includes an interdisciplinary seminar and two practica (one each in natural science and social science). For further information and applications, contact the Marine Option Program, Marine Sciences 229, 1000 Pope Road; tel. (808) 956-8433; e-mail mop@hawaii.edu.

Global Environmental Science

Marine Science 205C
1000 Pope Road
Honolulu, HI 96822
Tel: (808) 956-7932
Fax: (808) 956-9225
E-mail: ges@soest.hawaii.edu
Web: www.soest.hawaii.edu/oceanography/GES/

Faculty

*F. T. Mackenzie, PhD (Program Coordinator)—geochemistry, biogeochemical cycling, global environmental change
*R. Batiza, PhD—igneous petrology, marine geology, volcanology
*J. M. Becker, PhD—geophysical fluid dynamics, nonlinear waves and stability, coastal processes, general ocean circulation
*R. R. Bidigare, PhD—bio-optical oceanography, pigment biochemistry, plankton metabolism
*S. Businger, PhD—mesoscale and synoptic meteorology
*A. D. Clarke, PhD—physical and chemical properties of aerosol in remote troposphere, aircraft studies of aerosol in free troposphere

*J. P. Cowen, PhD—microbial geochemistry, particle aggregation dynamics, hydrothermal systems
*E. H. DeCarlo, PhD—aquatic chemistry; metals and their anthropogenic inputs, transformations, fate and transport
*S. Dollar, PhD—biogeochemistry, nearshore processes and effects of human activity on the coastal zone
*A. Eli-Kadi, PhD—hydrogeology, modeling groundwater systems
*R. C. Ertekin, PhD—hydrodynamics, computational methods, offshore and coastal engineering, oil-spill spreading, fishpond circulation
*P. J. Flament, PhD—surface ocean layer dynamics, mesoscale circulation structures of the ocean, remote sensing of the sea surface
*C. H. Fletcher, PhD—quaternary and coastal marine geology, sea-level history, coastal sedimentary processes
*P. Fryer, PhD—marine geology, petrology, tectonics
*M. O. Garcia, PhD—volcanology, igneous petrology, geochemistry
*C. R. Glenn, PhD—paleoceanography, marine geology, sedimentology, sediment diagenesis
*E. G. Grau, PhD—environmental physiology and comparative endocrinology of fish
*R. W. Grigg, PhD—ecology and paleoecology of coral reefs, precious corals
*B. J. Huebert, PhD—air pollution, climate change, atmospheric aerosols, global elemental cycles
D. E. Konon, PhD—international trade, microeconomics, computational economics
*M. R. Landry, PhD—zooplankton, population dynamics, marine ecosystem modeling
*E. A. Laws, PhD—phytoplankton ecology, aquatic pollution, aquaculture
*Y. H. Li, PhD—marine geochemistry, environmental pollution
*R. Lukas, PhD—physical oceanography, interannual and decadal climate variability
*J. J. Mahoney, PhD—isotope geochemistry of oceanic and continental crust and mantle
*A. Malahoff, PhD—submarine volcanic processes and the geophysical monitoring of submarine volcanoes, processes of formation of ocean floor minerals
*S. J. Martel, PhD—engineering and structural geology
*G. M. McMurtry, PhD—geochemistry, geology and geophysics
*C. Measures, PhD—trace element geochemistry, hydrothermal systems, elemental mass balances
*M. A. Merrifield, PhD—physical oceanography; coastal circulation; sea level variability; current flows and mixing in the vicinity of coral reefs, islands and seamounts
*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

*Graduate Faculty

*P. K. Muller, PhD—ocean circulation, waves and turbulence
*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
*R. L. Radtke, PhD—fisheries oceanography, migrations and history
J. Roumasset, PhD—environmental economics and sustainable growth
*K. Rubin, PhD—isotope geochemistry, chronology
*F. J. Sansone, PhD—suboxic/anoxic diagenesis in sediments, hydrothermal geochemistry, lava-seawater interactions, trace gas geochemistry
*T. Schroeder, PhD—mesometeorology, tropical meteorology
*S. Self, PhD—volcanology and volcanoclastic sedimentation
*S. K. Sharma, PhD—atmospheric instrumentation and remote sensing; Lidar, Raman, and infrared spectrometry and fiber-optic environmental sensors
*C. R. Smith, PhD—seafloor ecology, deep-ocean food webs, sediment geochemistry
*K. J. Spencer, PhD—isotope geochemistry, petrology, environmental geochemistry
M. E. Tiles, PhD—logic, history, and philosophy of mathematics, science, and technology
*J. S. Tribble, PhD—sedimentary geochemistry and diagenesis
*B. Wang, PhD—atmospheric and climate dynamics

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. It is a bold new academic program designed to educate leaders and citizenry to become wise stewards of our planet. Global environmental science focuses on the global reservoirs of hydrosphere (water, primarily oceans), biosphere (life and organic matter), atmosphere (air), lithosphere (land, sediments, and rocks), and cryosphere (ice); their interfaces; and the processes acting upon and within this interactive system, including human activities. In the course of their scientific studies, global environmental science students are able to investigate natural as well as economic, policy, and social systems and their response and interaction with the Earth system. Global environmental science has important ties to the more classical sciences of geology and geophysics,

meteorology and climatology, oceanography, and ecology as well as to the social sciences. Thus, the scope of global environmental science is extremely broad. This breadth is reflected in the interdisciplinary nature of the faculty, which is primarily drawn from numerous departments and research institutions within the School of Ocean and Earth Science and Technology.

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

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

The ultimate objective of the global environmental science program is to produce a student informed in the environmental sciences at a rigorous level who is able to go on to graduate or professional school; enter the work force in environmental science positions in industry, business, or government; enter or return to teaching with knowledge of how the Earth system works and the prerequisites for the National Science Teachers Certification; 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 205C; tel. (808) 956-7932, fax (808) 956-9225; e-mail: ges@soest.hawaii.edu

BS in Global Environmental Science Requirements

Aside from core University 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 in 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 required foundation courses in global environmental science and 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.

Core University Requirements (69 credit hours total; 56 credit hours exclusive of science and mathematics)

Maximum of 69 credit hours of core requirement course work minus 13 credit hours of mathematics and natural sciences equals 56 credit hours of work, up to 15 credit hours of which can also be in science provided that these hours (or others elsewhere in the curriculum) meet the writing intensive requirement. This leaves 68 to 83 hours of science and mathematics for a 4-year program.

Core Basic Sciences Requirement (39 hours)

MATH 241, 242/242L, 243 (or GG 312), 244 (or ECON 321)

PHYS 170/170L, 272/272L

CHEM 161/161L, 162/162L

BIOM 171/171L, 172/172L

Core Derivative Sciences Requirement (10 hours)

GG 101/101L

OCN 201

MET 200

The global environmental science core requirement represents 49 hours of work. This requirement plus the University

General Education Core requirement of 41 to 56 hours leaves 19 to 34 credit hours for other courses for a 4-year program. This is equivalent to six to eleven 3-credit courses that can be taken from the foundation and coupled systems courses and from senior research.

Foundation Course Requirements (17 hours)

OEST 310/310L Global Environmental Change

GEOG 411 Human Dimensions of Global Environmental Change

PHIL 315 (OCN 315) Modeling Natural Systems

OCN 363 Earth System Sciences Databases

OCN 401 Biogeochemical Systems

Coupled Systems Courses (Examples)

ASTR 140 Foundations of Astronomy

OCN 320 Aquatic Pollution

OCN 330 Mineral and Energy Resources of the Sea

OCN 331 Living Resources of the Sea

OCN 620 Physical Oceanography

OCN 621 Biological Oceanography

OCN 622 Geological Oceanography

OCN 623 Chemical Oceanography

BIOL 265 Ecology and Evolutionary Biology

BIOL 360 Island Ecosystems

BIOL 410 Human Role in Environmental Change

BIOC 241 Fundamentals of Biochemistry

GG 301 Mineralogy

GG 309 Sedimentology and Stratigraphy

GG 324 Low temperature & Environmental Geochemistry

GG 455 Hydrogeology

GG 466 Planetary Geology

MET 302 Atmospheric Physics

MET 303 Introduction to Atmospheric Dynamics

GEOG 300 Climatology

GEOG 402 Agricultural Climatology

GEOG 405 Water in the Environment

AREC 432 Natural Resource Economics

SOIL 304 Fundamentals of Soil Science

SOIL 430 Soil Chemistry

SOIL 461 Soil Erosion and Conservation

ECON 321 Introduction to Statistics

ECON 358 Environmental Economics

ECON 638 Environmental Resource Economics

PHIL 316 Science, Technology, and Society

SOC 412 Analysis in Population and Society

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

Global environmental science currently has no formal tracks (or combination of electives). However, majors may emphasize, for example, the marine environment, the climatic environment, or policy issues related to the environment. Majors should consult with their adviser as early as possible to devise a curriculum suited to their particular goals.

Senior Research Paper (3–6 hours)

OCN 499 Undergraduate Thesis

Each student is required to complete a senior thesis based on research conducted with one or more chosen advisers.

Instructional and Research Facilities

Hawai'i Institute of Geophysics and Planetology

The Hawai'i Institute of Geophysics and Planetology (HIGP) conducts geological, geochemical, geophysical, and oceanographic and atmospheric laser and passive remote sensing research, as well as remote sensing research in earth, space, and marine sciences. Programs embrace research and advanced training in marine geology and geophysics, marine geochemistry, materials science and high-pressure geophysics, oceanic biology, evolution of the solar system, seismology and solid earth geophysics, planetary geology, volcanology, and petrology. The institute maintains various specialized facilities in support of its research endeavors. HIGP includes the Hawai'i Space Grant College, which runs a wide variety of education and fellowship programs at the K-12, undergraduate, and professional levels and also provides outreach to the Hawai'i community.

Hawai'i Institute of Marine Biology

The Hawai'i Institute of Marine Biology (HIMB) provides facilities and services for faculty members, graduate and undergraduate students, and visiting scholars for research and education in marine biology and related topics. Marine biology is concerned with 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, tropical aquaculture, fish endocrinology, behavior

of reef animals, pollution and management of marine ecosystems, coastal biogeochemical processes, and fisheries.

HIMB is unique in that it lies close to a well-equipped laboratory, to a major university campus, and to subtropical environments. The primary focus of HIMB activities is on Coconut Island in Kāne'ōhe Bay (on the east coast of O'ahu), which provides a unique setting for graduate-level topics courses and field-trip and demonstration opportunities for undergraduate and graduate students. The island is surrounded by a 64-acre coral reef dedicated to scientific research. Facilities at the marine laboratory include research vessels and skiffs; ponds, aquaria, and tanks; a flow-through seawater system; remote monitoring capabilities; reef microcosm systems; a wide array of computerized analytical equipment; and support services. HIMB also operates the Mariculture Research and Training Center, with both saltwater and freshwater capabilities for pond aquaculture and research activities.

Hawai'i Natural Energy Institute

The Hawai'i Natural Energy Institute (HNEI) was established by the state Legislature in 1974 as a research institute at the University to provide leadership, focus, and support for natural energy research, development, and demonstration. HNEI works closely with the federal, state, and county governments; private industry; the utilities, community and international organizations; and individuals to initiate and complete renewable energy and ocean resources activities. HNEI attracts government and industrial funds for basic research, demonstration projects, feasibility studies, and field evaluation programs.

As part of SOEST, the institute draws on the expertise of faculty and staff from throughout the campus to investigate technical, cultural, environmental, social, legal, and economic aspects of renewable energy and ocean resources.

Hawai'i Undersea Research Laboratory

Hawai'i Undersea Research Laboratory (HURL) was established in 1980 by a cooperative agreement between the National Oceanic and Atmospheric Administration (NOAA) and the University of Hawai'i. HURL is one of the national laboratories sponsored by NOAA's Office of Undersea Research. HURL operates the

Pisces V research submersible and the *RCV-150* remotely operated vehicle to support marine research to oceanic depths of 2,000 meters. These underwater vehicles are being integrated into the new mother ship, the 222-foot R/V *Ka'imikai-o-Kanaloa*. Archived data are available to researchers on deep-sea biology, geology, and chemistry of the central Pacific.

James K. K. Look Laboratory

The James K. K. Look Laboratory of Oceanographic Engineering, part of the Department of Ocean Engineering, conducts research on ocean engineering problems related to structures in and physical characteristics of the coastal zone and open ocean, and it provides service to researchers on problems related to ocean resources and the calibration of wind-measuring instruments. The Look Laboratory is also the site of the Marine Mining Technology Center, which deals with the subject of deep ocean minerals. Facilities at Look Laboratory include two- and three-dimensional hydraulic scale model spaces, an in-ocean test range, a wet chemistry and biology laboratory, and supporting electronics and machine shops.

Joint Institute for Marine and Atmospheric Research

The Joint Institute for Marine and Atmospheric Research (JIMAR) was formed in 1977 under a memorandum of understanding between the NOAA and the University of Hawai'i. The principal research interests of JIMAR are tsunamis, equatorial oceanography, climate, fisheries oceanography, and tropical meteorology.

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 and regional aspects of global environmental change in the Asia-Pacific sector.

Sea Grant College Program

The Sea Grant College Program develops and administers a multidisciplinary institutional research

and extension program dedicated to the wise use and management of the marine environment and its resources. The research is conducted by UH faculty and staff in 26 departments in 10 colleges and institutes at the Mānoa campus, the Hilo campus, and the Community Colleges; graduate and undergraduate education is supported through the research projects. Results of the research are disseminated to marine agencies, the marine industry, and the general public through the program's extension service and communications program. The program has strong linkages with the 29 Sea Grant programs across the nation and with the United States flag territories and freely associated states of the western Pacific.

Space Grant College Program

The Space Grant College Program 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 Leeward, Windward, and Maui Community Colleges, and new programs are being developed at the University of Guam and at UH Hilo. Some of the programs supported by Space Grant include an Undergraduate and Graduate Fellowship Program (approximately 15 students per semester are supported); the Future Flight Program for teachers, school students and their parents; an annual two-week Teachers' Workshop; undergraduate remote-sensing field trip to California; an undergraduate telescope facility; maintenance of several World Wide Web sites including the "Virtually Hawai'i" site; and outreach to state and federal agencies related to the use of satellite and aircraft remote-sensing data. A significant goal of the program is to encourage interdisciplinary studies and research and to train future generations of space scientists in the physical sciences. Students, teachers, and researchers in Hawai'i are encouraged to contact the Mānoa Space Grant office at (808) 956-3138 to learn more about the opportunities for financial support.

Geology and Geophysics

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1680 East-West Road
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Tel: (808) 956-7640
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Faculty

- *J. M. Sinton, PhD (Chair)—igneous petrology, marine geology
 - *R. Batiza, PhD—igneous petrology, marine geology
 - *J. M. Becker, PhD—geophysical fluid dynamics, nonlinear dynamics
 - *D. Bercovici, PhD—geodynamics
 - *P. Cooper, PhD—seismology
 - *F. K. Duennebieer, PhD—seismology, marine geophysical instrumentation
 - *A. I. El-Kadi, PhD—groundwater hydrology
 - *P. F. Fan, PhD—sedimentary and geothermal mineralogy, geology of Asia
 - *C. H. Fletcher, PhD—coastal processes
 - *L. N. Frazer, PhD—theoretical seismology
 - *M. O. Garcia, PhD—igneous petrology, volcanology
 - *C. R. Glenn, PhD—paleoceanography, sedimentology
 - *C. E. Helsley, PhD—paleomagnetism, seismology, marine geophysics
 - *G. T. Ito, PhD—marine geophysics, geodynamics
 - *J. L. Karsten, PhD—petrology
 - P. D. Lee, MS—paleontology
 - *J. J. Mahoney, PhD—geochemistry
 - *S. J. Martel, PhD—engineering geology, geomchanics
 - *R. Moberly, PhD—marine geology, sedimentology
 - *G. F. Moore, PhD—exploration seismology, tectonics
 - *J. K. Morgan, PhD—sediment mechanics, convergent margin processes, numerical modeling of granular materials
 - *B. N. Popp, PhD—isotopic biogeochemistry
 - *C. B. Raleigh, PhD—seismology, rock mechanics
 - *J. M. Resig, DrRerNat—micropaleontology
 - *K. H. Rubin, PhD—isotope geochemistry, age dating
 - *S. Self, PhD—volcanology, petrology
 - *K. J. Spencer, PhD—geochemistry, instrumentation
 - *B. Taylor, PhD—plate tectonics, geology of ocean margin basins
 - *C. S. Todd, PhD—metamorphic petrology
 - *P. Wessel, PhD—marine geophysics
- Cooperating Graduate Faculty**
- J. Anderson, PhD—volcanology
 - T. B. Applegate, PhD—marine geology and geophysics, seafloor mapping and plate tectonics
 - J. Bell, PhD—planetary geosciences

- M. G. Bevis, PhD—crustal motion geodesy, GPS, geodynamics
- K. A. W. Crook, PhD—sedimentology, tectonics, geoscience policy
- E. H. DeCarlo, PhD—marine geochemistry, marine resources
- M. H. Edwards, PhD—marine geology and geophysics
- F. P. Fanale, PhD—planetary surfaces
- G. J. Fryer, PhD—seismology, computer modeling, marine geophysics
- P. B. Fryer, PhD—marine geology, petrology, tectonics
- M. D. Fuller, PhD—paleomagnetism, geomagnetism
- B. R. Hawke, PhD—planetary geosciences
- E. Herrero-Bervera, PhD—paleomagnetism, geomagnetism
- R. N. Hey, PhD—marine geophysics and tectonics
- B. H. Keating, PhD—paleomagnetism
- K. Keil, Dr rer nat—meteorites, planetary geosciences
- L. S. L. Kong, PhD—seismology
- L. W. Kroenke, PhD—marine geology and geophysics
- B. R. Lienert, PhD—geophysics
- P. G. Lucey, PhD—planetary geosciences
- F. Mackenzie, PhD—sedimentary geochemistry, sedimentology
- M. H. Manghnani, PhD—high-pressure geophysics, mineral physics
- F. Martinez, PhD—marine geophysics
- T. B. McCord, PhD—planetary surfaces, remote sensing
- F. W. McCoy, PhD—marine geology, sedimentology
- L. C. Ming, PhD—high-pressure mineralogy
- P. J. Mouginis-Mark, PhD—planetary science, remote sensing
- E. R. D. Scott, PhD—planetary geosciences
- S. K. Sharma, PhD—raman and IR spectroscopy in geochemistry
- G. J. Taylor, PhD—planetary geosciences
- D. M. Thomas, PhD—geothermal and volcanic geochemistry
- J. S. Tribble, PhD—marine geology and geochemistry
- R. Wilkens, PhD—rock and sediment properties, bore-hole research
- S. Zisk, PhD—planetary geosciences

Affiliate Graduate Faculty

- D. Clague, PhD—marine geology, volcanology
- A. L. Clark, PhD—economic geology, resources
- J. Gradie, PhD—planetary sciences
- C. J. Johnson, PhD—resource systems
- K. T. M. Johnson, PhD—marine geology and geophysics
- J. P. Kauahikaua, PhD—volcanology
- J. P. Lockwood, PhD—volcanology
- P. G. Okubo, PhD—geophysics
- G. H. Sutton, PhD—seismology, marine geophysics
- C. R. Thornber, PhD—geochemistry, volcanology
- G. W. Tribble, PhD—geochemistry, coral reef geology
- D. A. Walker, PhD—seismology
- C. G. Wheat, PhD—low-temperature geochemistry

Degrees Offered: BA in geology, BS in geology and geophysics, MS in geology and geophysics, PhD in geology and geophysics

The Academic Program

Geology and geophysics (GG) are important branches of the geosciences, which encompass the scientific study of Earth and other bodies in our solar system. Thus, the scope of the geosciences is extremely broad. Geology and geophysics tend to focus primarily on the solid, rocky portions of planets (including Earth) but have important ties to meteorology and oceanography. The Earth and other planets are highly dynamic; geoscientists study the internal and surface changes that occur to decipher the fundamental causes of these changes. In turn, these studies shed light on the origin and evolution of Earth, the other planets, and, indeed, the entire solar system. The range of interest in the Earth and planetary sciences is from submarine volcanism to monitoring the environment, from coastal erosion to past climate changes, from the origins of life to monitoring the earthquakes of active volcanoes, and from the composition of meteorites and Mars to the distribution of petroleum and water resources. The geosciences offer a richness in variety and unrivaled opportunity for multidisciplinary research on problems of great intellectual and practical importance.

Geology and geophysics have much to offer students curious about humankind's place in nature. Undergraduate majors can look forward to expanding opportunities in both the private and the public sectors (e.g., petroleum, mining, the environment, geological hazards, hydrogeology). Such jobs offer incredible variety, the opportunity to work outdoors, and many opportunities for distant travel. Prospective undergraduates are strongly encouraged to build a solid background of understanding in chemistry, physics, and mathematics as these disciplines are essential for solving the basic questions about how Earth and the other planets work. Students with graduate degrees (both MS and PhD) can look forward to interesting research careers in industry, government, or in colleges and universities. The intellectual rewards of basic geosciences research are comparable to such other exciting fields as biomedical research, particle physics, and cosmology. Geosciences have many exciting frontiers

and challenges for the future including learning to predict earthquakes and volcanic eruptions, discovering the history of Mars, and understanding the forces that move the surface plates of Earth.

At the University of Hawai'i at Mānoa, the department offers outstanding programs of study at the graduate and undergraduate levels. The faculty is large (about 30 teaching and research faculty and about 30 additional graduate faculty) and diverse, so there are strong programs in all major subdisciplines. The geographic location in the midst of the Pacific Ocean and the rich geologic setting provide a natural focus for research programs in seismology, volcanology, marine geology and geophysics, planetary science, sedimentology, hydrogeology, geochemistry, paleoceanography, meteorites, and many other fields. The quality of the school's research vessels, submersibles, and analytical and computing facilities reflects its commitment to excellence in field studies, as well as in theoretical and modeling studies. The quality of the faculty, research facilities, and opportunities is difficult to match.

Advising

Students contemplating a major or minor in geology and geophysics should visit the undergraduate adviser at the earliest opportunity. Inquire at the department's student services office, POST 701C. Since geology and geophysics students have a variety of backgrounds and interests, the undergraduate adviser coordinates a board of advisers for a proper match of student and adviser.

Undergraduate Study

BA in Geology

Requirements

Study of the BA includes 39 credits in the geology and geophysics curriculum including one introductory level geology course with a lab (GG 101 or 103, and GG 101L), four non-introductory GG courses (GG 201, 202, 203 and 305) and 20 credits of approved electives in geology and geophysics. With advice and consent of the undergraduate adviser, courses in other natural sciences, mathematics, or engineering may be substituted as electives. Required support mathematics and science courses include physics, chemistry, biological science, and one semester of college calculus.

- Required GG Courses
 - GG 101 Dynamic Earth, or 103 Geology of the Hawaiian Islands, and GG 101L Dynamic Earth Lab (3/1)
 - GG 201 Earth Materials (4)
 - GG 202 Earth History (4)
 - GG 203 Earth Structure and Dynamics (4)
 - GG 305 Geological Field Methods (3)
- Required Support Courses
 - CHEM 161/161L and 162/162L General Chemistry I and II/Lab
 - CHEM 171/171L Principles of Chemistry
 - MATH 205 Calculus I
 - PHYS 151/151L, 152/152L College Physics
 - Biological Sciences (a 3-credit class listed under the natural sciences section of the University's General Education and Core requirements)

BS in Geology and Geophysics Requirements

Study of the BS includes 39 credits in the geology and geophysics curriculum including one introductory level geology course with a lab (GG 101 or 103, and GG 101L) and four non-introductory GG courses (GG 201, 202, 203 and 305) and 20 credits of approved electives in geology and geophysics. With advice and consent of the undergraduate adviser, courses in other natural sciences, mathematics, or engineering may be substituted as electives. Required support mathematics and science courses include physics, chemistry, biological science, and two semesters of college calculus.

- Required GG Courses
 - GG 101 Dynamic Earth or 103 Geology of the Hawaiian Islands, and GG 101L Dynamic Earth Lab (3/1)
 - GG 201 Earth Materials (4)
 - GG 202 Earth History (4)
 - GG 203 Earth Structure and Dynamics (4)
 - GG 305 Geological Field Methods (3)
- Required Support Courses
 - General Chemistry (CHEM 161/161L and 162/162L) or Principles of Chemistry (CHEM 171/171L)
 - Calculus I and II (MATH 205 and 206)
 - General Physics I and II (PHYS 170/170L and 272/272L) or College Physics (PHYS 151/151L, 152/152L) with permission from departmental adviser.
 - Biological Sciences (a 3-credit class listed under the natural sciences

- section of the University's General Education and Core requirements)
- Approved GG Electives
 - GG 300 Volcanology (3)
 - GG 301 Mineralogy (4)
 - GG 302 Igneous & Metamorphic Petrology (3)
 - GG 303 Earth & Environmental Mechanics (3)
 - GG 309 Sedimentology & Stratigraphy (3)
 - GG 312 Geomathematics (3)
 - GG 313 Geological Data Analysis I (3)
 - GG 324 Low-Temperature & Environmental Geochemistry (3)
 - GG 325 High-Temperature Geochemistry (3)
 - GG 399 Directed Reading (V)
 - GG 401 Introduction to Mineral Physics (3)
 - GG 407 Energy and Mineral Resources (2)
 - GG 420 Quaternary Geology (3)
 - GG 423 Marine Geology (3)
 - GG 426 Sedimentary Isotope Geochemistry (3)
 - GG 430 Geology and Mineral Resources of Asia (3)
 - GG 440 Physics of Earth & Planets (3)
 - GG 444 Plate Tectonics (3)
 - GG 450 Geophysical Methods (3)
 - GG 451 Earthquakes (3)
 - GG 454 Engineering Geology (3)
 - GG 455 Hydrogeology (4)
 - GG 466 Planetary Geology (3)
 - GG 491 Teaching Geology (6)
 - GG 499 Undergraduate Thesis (3)

The Department of Geology and Geophysics lists five different tracks (or combinations of electives) within its undergraduate program: general geology; volcanology, geochemistry and petrology; environmental geoscience; Earth dynamics and mechanics; and Earth and space science teaching. These tracks are intended to serve as guidelines only. Majors should consult with their adviser as early as possible in order to devise a curriculum suited to their particular goals.

Minor Requirements

In each of the following fields of concentration, 15 credit hours in non-introductory courses (i.e., 200-level or higher), in addition to GG 101 (or 103) and 101L, are required with a grade of C or better. Possible options include the following:

- Geophysics: GG 203, 303, 440 and 450, and 2 remaining credits;
- Geochemistry: GG 201, 324, and 325, and 5 remaining credits;
- Environmental geology: GG 303, 454, and 455, and 5 remaining credits;
- General geology: GG 201, 202 and 203, and 3 remaining credits (this program is recommended for prospective teachers of science in Hawai'i); and
- Individual programs designed in consultation with GG undergraduate advisers.

National Science Teachers Certification

The Department of Geology and Geophysics offers a geology curriculum to provide the necessary science course work required of science majors in order for them to apply for certification in intermediate or high school science teaching from the National Science Teachers Association. No other science department in the UH system is currently in a position to offer a curriculum that can lead to National Science Teacher Certification.

Students who complete the new curriculum for the bachelor of arts of geology will meet course distribution requirements necessary for certification in one or more of four of the NSTA's seven fields. The curriculum also fulfills the pre-education core requirements and science distribution requirements of the current UH College of Education's post-baccalaureate secondary teaching certification program.

To gain NSTA certification, a student completes the BA in geology, gains teaching credentials (in any state), and applies after having taught for three years in the field(s) for which he or she wished certification.

Graduate Study

Admission Requirements

All applicants must take the GRE General Test. The subject test is recommended for PhD candidates and may be in geology or the student's major. All students are urged to have completed a course in C or similar computer programming language before entrance. Domestic 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 1**, respectively.

Undergraduate deficiencies will be listed on the basis of the student's transcripts and intended field of study. Courses may be added to the list or removed from it as a result of questioning during the preliminary conference and the general examination. Course GG 611 is intended for students entering from a non-geoscience field to prepare them for graduate studies in geosciences.

Master's Degree

Intended candidates will be accepted from undergraduate majors in the natural sciences, mathematics, and engineering, and they normally would be expected to have completed at least one year each of college mathematics, geology, physics, and chemistry. Adequacy of each applicant's additional preparation will depend on the particular branch of geology and geophysics being pursued. At the time of application the student should state the field in which he or she intends to study.

Requirements

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

Doctoral Degree

Students wishing to bypass the MS degree and advance directly into PhD candidacy must pass a qualifying examination during the second semester in residence.

Requirements

PhD candidates are accepted with either a BS or MS degree. Students without an MS must pass a qualifying examination given at the beginning of their second semester of residence. All PhD candidates must pass a comprehensive examination no later than at the end of the fourth semester of residence for students without an MS degree or at the end of the second semester of residence for students with an MS degree. The comprehensive examination includes oral and written parts that cover in-depth those subjects in the student's field of interest and also the breadth of several areas in this and other departments that bear on the field. A final examination in defense of the dissertation

is required. Space and aid for the program are limited, so each student's progress will be reviewed annually.

Areas of Interest

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

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

Seismology and solid earth

geophysics. Seismologists collect extensive digital seismic reflection and refraction data at sea aboard the research vessel *Moana Wave* and develop new methods for processing and interpreting these data. Active research areas include seismic wave propagation, dispersion, and attenuation; seismicity; anisotropy; downhole seismometry; and ocean bottom seismometry, inversion, and migration.

Other active research areas are crustal deformation studies using laser distance measurements, satellite gravimetry and altimetry, geodetic reference systems, standardization of geodetic data, integration of surface and satellite data, morphology of the geomagnetic field, earth density models, seaborne and land gravimetry, heat flow, geomagnetism, and geoelectricity. 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 geology and geophysics.

This field combines geological studies with geophysical studies to focus on investigations of ocean basins and margins. Current research involving graduate students includes acoustic imaging, seismic profiles, and tectonic interpretation of mid-ocean ridges, trenches and fore-arcs, and back-arc basins; geodynamics; sea-floor monitoring; near-shore processes; and isotopic, micropaleontological, and geochemical investigations of paleoceanography.

Typically, an undergraduate major in geology or one of the other natural sciences along with basic courses in physics,

chemistry, and mathematics would be sufficient for entrance. The student should be prepared to commence or continue course work in (1) structural or tectonic geology, (2) exploration geophysics, and (3) any one or more of sedimentology, paleontology, geochemistry, and petrology, as applied to marine research.

Volcanology, petrology, and

geochemistry. These fields focus on problems of magma generation, storage, and movement to Earth's surface; petrological and geochemical evolution of magmas, mantle and crust mechanisms of explosion, characteristics of explosive and effusive eruptions and their products; genesis of large igneous provinces, oceanic island volcanoes, and seamounts; processes that operate on mid-oceanic and back-arc-basin spreading centers and on circum-Pacific and Hawaiian volcanoes; and volcanic hazards.

In addition to basic courses in chemistry, physics, and mathematics, the well-prepared student would have had training in mineralogy, optical mineralogy, petrology, structural geology, and, in some cases, geological field methods and remote sensing techniques.

Planetary science. This field studies the composition and structure of the surfaces of planets, satellites, and asteroids; Earth as a planet; interaction of surfaces and interiors with atmospheres; surface state as an expression of interior evolution; surface alteration processes, such as impacts and chemical and space weatherings; spacecraft, telescope, and field observations and laboratory simulations; computer image and spectrum processing; instrument development; and remote sensing techniques as applied to Earth and other planets.

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

High-pressure geophysics and

geochemistry. This field, also referred to as mineral physics, is concerned with understanding the nature of Earth's crust and its deep interior through measurement of physical, chemical, and mechanical properties of pertinent earth materials (e.g., rock-forming minerals or their

analogs, rocks, and silicate glasses and melts) under high-pressure and high-temperature conditions.

Incoming students are expected to show a strong background in mathematics and physics as well as physical chemistry and some geology. The latter may, however, be acquired during the course of graduate studies.

Hydrogeology and engineering geology. This field involves the applications of geologic, hydrologic, mechanical, and chemical principles to a broad spectrum of processes relevant to human activities. Hydrogeology encompasses all aspects of the hydrologic cycle, including surface-water, soil-water, and ground-water occurrence, movement, development, and quality. Attention is also given to the special hydrological problems associated with islands. Engineering geology blends aspects of soil mechanics, rock mechanics, hydrogeology, and field geology to address topics such as slope stability, fracture phenomena, and neotectonics.

A normal undergraduate background should include basic courses in geology, chemistry, physics, and mathematics and a major in geology, another physical science, or engineering. The student should be prepared for additional work in whatever combination of geology, geophysics, civil engineering, and geochemistry is appropriate for his or her optimum development.

Meteorology

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E-mail: met-info@soest.hawaii.edu
Web: lumahai.soest.hawaii.edu

Faculty

- *G. M. Barnes, PhD (Chair)—convection, hurricanes, and boundary-layer meteorology
- *S. Businger, PhD—mesoscale and synoptic meteorology, satellite meteorology, storm structure and dynamics
- *Y. L. Chen, PhD—mesometeorology
- *P. S. Chu, PhD—tropical climate and circulation, statistical applications
- *P. A. Daniels, PhD—physical meteorology, atmospheric pollution, instrumentation
- *F. F. Jin, PhD—atmospheric and oceanic dynamics
- *T. A. Schroeder, PhD—mesometeorology, tropical meteorology
- *D. E. Stevens, PhD—atmospheric dynamics

*B. Wang, PhD—geophysical fluid dynamics, climate dynamics

*J. Zhao, PhD—atmospheric chemistry and aerosols

Cooperating Graduate Faculty

A. D. Clarke, PhD—marine aerosols, biogeochemical cycles, optical properties

B. J. Huebert, PhD—atmospheric chemistry

Affiliate Graduate Faculty

Y. H. (Bill) Kuo, PhD—mesometeorology

W. C. Lee, PhD—radar and mesoscale meteorology

T. Takahashi, PhD—cloud physics

Degrees Offered: BS in meteorology, MS in meteorology, PhD in meteorology

The Academic Program

Meteorology (MET) is the study of phenomena in the Earth's atmosphere. These phenomena include the daily weather and climate. Students pursuing the BS in meteorology receive preparation for professional employment in meteorology and are qualified for employment in the federal meteorological agencies. The meteorology major must be well-grounded in the fundamentals of mathematics and physics. Thus BS graduates are qualified to pursue graduate studies both in meteorology and other applied sciences, such as oceanography or computer sciences. Graduate degrees prepare students to pursue research careers both with government and in academia.

The meteorology program at the University of Hawai'i at Mānoa is unique in its focus on tropical meteorology. The tropics comprise 50 percent of Earth's surface and exert critical controls on the global atmosphere. BS students receive comprehensive training in tropical weather analysis and forecasting. Graduate students often pursue thesis research in tropical meteorology, some study topics that take advantage of Hawai'i's unique natural laboratory. Some students pursue graduate thesis research with funding from the National Weather Service, whose Honolulu Weather Forecast Office is housed in the same building as the meteorology department. Meteorology faculty cooperate actively with physical oceanography faculty through the Joint Institute for Marine and Atmospheric Research in the study of air-sea interaction and climate variability.

Affiliations

The University of Hawai'i is an active member of the University Corporation for Atmospheric Research.

Advising

The department has one undergraduate adviser, who may be contacted through the department office (808) 956-8775. Graduate students are assigned individual faculty advisers by the graduate chair after their preliminary conference.

Undergraduate Study

Bachelor's Degree

Requirements

Students must complete 124 credit hours, including:

- General Education Core (see the "Mānoa General Education and Graduation Requirements" section of this *Catalog*).
- MET 101L and 200
- 21 credit hours in meteorology courses numbered 300 and above, including MET 302, 303, 305, and 402; and MET 412 or 416 (Students planning careers with federal meteorological agencies should take both 412 and 416.)
- 15 additional credit hours from physical and mathematical sciences (e.g., engineering, geography, geology and geophysics, information and computer sciences, mathematics, oceanography, physics, and soil science) including (but not limited to) MET 405, 406, and 600; MET 412 or 416; AGRN 661; CE 424 and 626; GEOG 300, 302, 402, and 412; GG 412 and 455; ICS 211, 311, and 442; MATH 311, 371, 373, 402, 403, 404, and 405; OCN 620; OEST 310; PHYS 274/274L and 400; and SCI 394 or 395
- CHEM 171/171L
- ICS 111/111L
- MATH 231 and 232 (Students planning careers with federal meteorological agencies should take MATH 405.)
- PHYS 170/170L and 272/272L

Minor

Requirements

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

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

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 dynamic and synoptic meteorology are expected, but they can be taken in the first year.

All students in the program must complete two seminar courses of MET 765 (Alpha) involving active participation as speaker and listener.

Master's Degree

Requirements

At the master's level, only Plan A (thesis) is available, requiring a minimum of 24 credit hours of course work and 6 credit hours of thesis. A minimum of 18 credit hours, exclusive of research methods must be earned for the MS degree. All students must complete MET 600, 610, 620, and a synoptic analysis course (MET 412 or MET 416) with a minimum GPA of 3.0 for those courses. A thesis examination is required.

Doctoral Degree

The PhD student exhibits a higher level of independence and originality of thought than that required of the MS student.

Requirements

In the PhD program the student is required to pass a departmental qualifying examination. The examination is intended to evaluate the student's general meteorological knowledge at the master's level and to identify possible academic weaknesses. Passing the examination qualifies the student for PhD candidacy. If exam performance is inadequate, the faculty shall determine that either (a) the student should take the exam a second time within one year, or (b) the student should not pursue a PhD. The exam is to be taken by all students who wish to pursue a PhD and must be taken prior to the third semester in residence in the PhD program.

No later than the second semester after passing the qualifying exam, the student is required to submit a written research proposal to a dissertation committee. If the committee approves the proposal, the student will sit for an oral comprehensive examination. The purpose of the oral comprehensive examination is to ascertain the student's comprehension of the chosen field of study so that he or she is well prepared for the proposed research. Upon

successful completion of the comprehensive examination within six months, the student will proceed with his or her dissertation. In addition to meteorology courses listed in this *Catalog*, students may take courses in related disciplines such as engineering, information and computer sciences, geography, mathematics, oceanography, and physics, with the concurrence of the academic adviser.

Ocean Engineering

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Web: www.oe.eng.hawaii.edu

Faculty

- *A. Malahoff, PhD (Chair)—ocean resources engineering, ship submersible-ROV integration
- *K. F. Cheung, PhD—coastal and offshore engineering, hydrodynamics, computational methods, water wave mechanics
- *H. J. Krock, PhD—environmental engineering, mixing and transport, water quality, ocean thermal energy conversion, hydrogen
- J. C. Radway, PhD—marine resources, photobioreactors and bioremediation
- *L. H. Seidl, PhD—offshore engineering, naval architecture, SWATH ships, mooring systems and ship hydrodynamics

Graduate Faculty

- K. A. W. Crook, PhD—sedimentology, tectonics, geoscience policy
- M. J. Cruickshank, PhD—deep-ocean mining
- B. D. Greeson, PhD—offshore engineering
- S. H. Masutani, PhD—ocean resources engineering
- C. L. Morgan, PhD—marine mining
- J. R. Smith, PhD—marine survey
- J. C. Wiltshire, PhD—marine minerals

Cooperating Graduate Faculty

- J. M. Becker, PhD—nonlinear hydrodynamic stability, general ocean circulation
- R. C. Ertekin, PhD—naval architecture, offshore engineering, hydrodynamics, computational methods
- R. H. Knapp, PhD—structural engineering
- M. A. Merrifield, PhD—coastal and near-shore processes, internal waves and mixing, oceanography
- H. R. Riggs, PhD—structural engineering

Affiliate Graduate Faculty

- G. Nihous, PhD—ocean resources engineering
- E. Noda, PhD—coastal and ocean engineering
- J. van Ryzin, PhD—mechanical and ocean engineering

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

The Academic Program

Ocean engineering (OE) is the application of ocean science and engineering design to the challenging conditions found in the ocean environment. Wave and current motion and forces, high pressure, and temperature variations, as well as chemical and biological effects, are among the considerations that set ocean engineering apart from conventional land-based engineering. Ocean engineering in the tropical, mid-ocean location of Hawai'i has the advantage of year-round access to explore research subjects related to oceanic island coastal processes, ocean energy development, deep-ocean mining, ocean instrumentation, ocean transportation, large floating platforms, and ocean bioproducts.

Ocean engineering, as an integral part of the School of Ocean and Earth Science and Technology, allows the complete coverage of questions involving ocean processes. Not only can the problem be defined scientifically, but engineering solutions can be devised.

Career opportunities for graduates in ocean engineering exist in various areas. Depending on the student's individual interest, employment may be sought with industry, government, or universities. Government positions are usually with the U.S. Army Corps of Engineers, the U.S. Naval Facilities Command, or with state, city, or county public works departments. Jobs in private industry are with large oil companies, shipyards, consulting and contracting firms, environmental services firms or laboratories, offshore mining companies, and large systems design companies. Graduates with the PhD degree in ocean engineering have found jobs in research-oriented positions in higher education, government, and the private sector.

Accreditation

The master's program in ocean engineering is accredited by the Accreditation Board of Engineering and Technology (ABET). Although the PhD degree is not specifically accredited (ABET only accredits the first degree), the ABET evaluation covers the PhD program.

* Graduate Faculty

Preliminary Conference

Upon entering the ocean engineering program, students are assigned a faculty adviser generally according to the option or area of interest selected by the student. Initial conference participants review the academic background of the student and advise the student on which courses are required and what, if any, deficiencies must be made up.

Graduate Study

The graduate program in ocean engineering is intended to channel the student's previous engineering or scientific experience to ocean-related work. Students may pursue their studies in coastal engineering, offshore engineering, or ocean-resources engineering.

Departmental interests in the coastal area include design of coastal and harbor structures, beach and surf parameters, near-shore and estuary hydrodynamics, hydraulic and numerical modeling, and tsunami wave studies.

In the offshore engineering area, analysis and design of fixed and floating structures, submersible and semi-submersible platforms, offshore ports, mooring systems, ship and platform motions in waves, and stability in waves are addressed.

In the ocean-resources engineering area, ocean thermal energy conversion (OTEC), ocean mining, wave energy extraction, ocean living resources, waste disposal in the ocean, and environmental response are addressed.

Master's Degree

The MS program in ocean engineering is aimed at training professional engineers.

Admission Requirements

An intended candidate for the master's program is expected to have a bachelor's degree in engineering, applied mathematics, physics, or applied sciences.

In order to satisfy ABET requirements, candidates with degrees other than in engineering will be required to make up deficiencies in engineering. All students must satisfy minimum undergraduate engineering requirements, consisting of 16 credit hours in natural sciences, 16 credit hours in mathematics, 32 credit hours in engineering science, and 16 credit hours in engineering design. Official scores in the GRE General Test must be submitted.

Generally the student's first semester is devoted to basic courses in the field of ocean engineering; then, the student specializes in coastal, offshore, or ocean-resources engineering.

Degree Requirements

The MS degree in ocean engineering may be earned under either Plan A (thesis) or Plan B (non-thesis).

Both degree plans require a balance between engineering science and advanced design. At least 24 credit hours must be earned in advanced courses numbered 600 and above. No more than 5 credit hours of 400-level courses can be counted toward the MS degree requirements.

Ten credits of core courses are required of all students in ocean engineering, and a minimum of 12 credit hours must come from the list of courses identified as basic courses for the option area chosen by the student. As part of the course work requirements, the students must be competent in at least one scientific programming language.

One credit of seminar is required. Students may attend 15 seminars of their choice in ocean-engineering-related areas. They register before the semester in which they plan to fulfill this requirement. The remaining credits are to be chosen so as to form a coherent plan of study.

During the first semester of full-time enrollment, the student must take an examination (general exam) to qualify for admission to candidacy. During the last semester of residence, an oral examination (final exam) is given. This consists of a presentation of the thesis or Plan B paper and provides the faculty with an opportunity to test the student's understanding of the chosen field and ability to integrate theory and design at the master's level. The general and final examinations may be repeated once. The general exam must be taken earlier than the semester in which the final exam is taken.

Plan A (Thesis) Requirements

The thesis option requires a minimum of 30 credit hours, including 6 credit hours of thesis and a minimum of 24 credit hours of course work, including at least 3 credit hours of advanced design or engineering science. No more than 2 credit hours of directed reading (699) may be used to fulfill the minimum requirements. The thesis can be scientifically and/or technologically oriented and requires independent work by the student. A verbal presenta-

tion and defense of the thesis are part of the final exam. The subject of the thesis must receive prior faculty approval.

Plan B (Non-thesis) Requirements

The non-thesis option requires a minimum of 30 credit hours, including at least 12 credit hours of engineering science and 12 credit hours of advanced design. Students are required to write and submit a paper on a technical subject prepared under faculty guidance. An oral presentation of the paper is part of the final exam. The subject of the paper must receive prior faculty approval.

Doctoral Degree

A student pursuing the doctoral program is required to achieve a broad understanding of the principal areas of ocean engineering, as well as a thorough understanding of a specific area. The student may give proof of mastering the subject matter in a selected area by passing a number of related courses offered in the department, as specified by the graduate faculty, or by examination of the material contained in these various courses.

Admission Requirements

Students seeking admission to the doctoral program should normally have an MS degree in engineering, applied mathematics, physics, or applied sciences. Exceptionally well-qualified students with a BS degree in these disciplines may petition to be admitted to the PhD program directly. Applicants must submit the GRE General Test score. Submission of the relevant subject test score is recommended.

All students must satisfy minimum undergraduate engineering requirements, consisting of 16 credit hours in natural sciences, 16 credit hours in mathematics, 32 credit hours in engineering science, and 16 credit hours in engineering design. The student must also satisfy the minimum course work requirements or equivalence of an MS degree in ocean engineering, which consists of 10 credits of core courses and 12 credits of basic courses in the major area chosen by the student. As part of the course work requirements, the student must be competent in at least one scientific programming language.

All intended candidates for the PhD degree must take a qualifying examination. This examination is given during the student's first semester.

Requirements

After being advanced to candidacy, all students must take a comprehensive examination, which will cover the student's general preparation in the area of specialty and pertinent minor fields. An approved minor subject with at least 9 credits must be completed prior to the comprehensive examination. The results of the examination will determine whether the candidate will be allowed to pursue the dissertation.

The dissertation topic must be approved by the doctoral committee. After the dissertation is completed, it will be reviewed by the committee and a final oral examination will follow. The oral examination includes an oral presentation, announced University-wide, of the dissertation by the candidate.

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

Oceanography

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Faculty

- *M. J. Mottl, PhD (chair)—submarine hydrothermal processes, geochemical cycles, sea-water-sea-floor chemical interaction
- *R. Bidigare, PhD—bio-optical oceanography, pigment biochemistry, biogeochemical cycling
- *A. D. Clarke, PhD—marine aerosols, biogeochemical cycles, precipitation chemistry
- *J. P. Cowen, PhD—deep-sea hydrothermal vent biogeochemistry, microbial geochemistry, particle aggregation
- *E. H. DeCarlo, PhD—geochemistry of marine mineral deposits, fundamental chemistry of scavenging processes at the aqueous particle interface, hydrothermal processes
- *E. Firing, PhD—equatorial circulation, ocean currents and current profiling methods
- *P. J. Flament, PhD—dynamics of the surface layer, mesoscale structures, remote sensing
- *R. Grigg, PhD—coral reef ecology, paleoceanography, fisheries management
- *J. Hirota, PhD—plankton, fisheries, oceanic productivity
- *B. J. Huebert, PhD—atmospheric chemistry

- *D. M. Karl, PhD—microbiological oceanography, oceanic productivity, biogeochemical fluxes
- *M. R. Landry, PhD—zooplankton ecology, population dynamics, marine ecosystem modeling
- *E. A. Laws, PhD—phytoplankton ecology, aquatic pollution, aquaculture
- *Y. H. Li, PhD—marine geochemistry, marine pollution studies
- *R. Lukas, PhD—equatorial circulation, air-sea interaction and climate
- *D. S. Luther, PhD—observational physical oceanography
- *F. Mackenzie, PhD—geochemistry, sedimentology, greenhouse effect, biogeochemical cycles and global environmental change
- *L. Magaard, DrRerNat—physical oceanography, oceanic waves and turbulence
- *A. Malahoff, PhD—geological and geophysical oceanography, submarine volcanism, hydrothermal and mineral formation processes
- *G. McMurtry, PhD—marine sediment geochemistry, marine mineral formation and resources, submarine hydrothermal processes, radiochemistry
- *C. Measures, PhD—trace element geochemistry, elemental mass balance, geochemical effects of dust deposition
- M. A. Merrifield, PhD—coastal and near-shore processes, internal waves and mixing
- *P. Muller, DrRerNat—theoretical physical oceanography, analysis and interpretation of geophysical data
- *B. Qiu, PhD—numerical modeling
- *F. J. Sansone, PhD—gas geochemistry, reef and sediment diagenesis, hydrothermal geochemistry and lava-seawater interactions
- *C. R. Smith, PhD—benthic biological oceanography, bioturbation, deep-sea carbon flux
- *S. V. Smith, PhD—mass balance in ecosystems, dynamics of calcification and community metabolism
- *J. S. Tribble, PhD—sedimentary geochemistry and diagenesis, sedimentation and diagenesis at accretionary plate margins
- *R. E. Young, PhD—ecology of midwater animals, especially cephalopod mollusca

Cooperating Graduate Faculty

- M. J. Atkinson, PhD—coral reef biogeochemistry, solid-state sensor technology
- S. Atkinson, PhD—ecophysiology of marine mammals, conservation biology
- T. A. Clarke, PhD—marine fish ecology
- K. A. W. Crook, PhD—sedimentology, tectonics, geoscience policy
- W. C. Dudley, PhD—marine geology
- *P. Fryer, PhD—marine geology, petrology, tectonics
- L. Herman, PhD—behavior and ecology of marine mammals, animal cognition
- R. N. Hey, PhD—plate tectonics
- R. C. Kloosterziel, PhD—geophysical fluid dynamics
- *B. Popp, PhD—isotope biogeochemistry

- R. L. Radtke, PhD—population dynamics, fish biology, calcification
- J. R. Sibert, PhD—population dynamics, fisheries, modeling
- L. M. Tupas, PhD—marine microbial ecology, isotope geochemistry of dissolved particulate organics
- J. C. Wiltshire, PhD—geology and geochemistry of marine mineral deposits, marine mining and processing, minerals policy issues, research-submersible technology
- C. D. Winn, PhD—marine microbiology, organic chemistry, biogeochemistry

Affiliate Graduate Faculty

- W. L. Au, PhD—marine bioacoustics and echolocation
- P. K. Bienfang, PhD—phytoplankton ecology
- L. Campbell, PhD—microbial and phytoplankton ecology, population dynamics, immunochemistry and flow cytometry
- F. C. Dobbs, PhD—microbial ecology, symbiosis, benthic biogeochemistry
- G. T. Mitchum, PhD—tropical ocean dynamics
- *D. W. Moore, PhD—geophysical fluid dynamics, equatorial oceanography
- W. C. Patzert, PhD—ocean remote sensing
- J. J. Polovina, PhD—larval recruitment, dynamics of exploited populations, fisheries, satellite remote sensing
- L. M. Rothstein, PhD—physical oceanography, analytical modeling of equatorial ocean dynamics
- E. W. Vetter, PhD—benthic ecosystem and community ecology

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 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 the University. At Mānoa, the oceanography facilities are among the best in the United States 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 Kāne'ohe Bay. Computing facilities are based on a growing network of nearly 300 Sun workstations, Macintosh, and personal computers. Graphic peripherals include black/white and color laser printers, a 36-inch inkjet printer, film printers, and pen plotters. Precision instruments include mass spectrometers, gas and liquid chromatographs, liquid scintillation counters, a CHN analyzer, a flow cytometer, and a series of atomic spectroscopy-based instruments. The world-class faculty is actively involved in both teaching and research. The University ranks third 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 the Mānoa campus an ideal place to study oceanography.

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

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

Advising

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

Graduate Study

The department offers master's and doctoral programs with areas of specializations in biological, chemical, geological, and physical oceanography.

Oceanography courses listed in this *Catalog* may be taken for credit in the degree program. Additional courses may be selected from the fields of botany, chemistry, engineering, geology, mathematics, meteorology, physics, and zoology.

Admission Requirements

Applicants must have intensive, rigorous training in one of the basic sciences or engineering. Regardless of major, an applicant must have completed mathematical training, including calculus through first-order ordinary differential equations (equivalent to Calculus IV at the University). 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 write

to the department chair for a brochure and further information. For U.S. applicants, the deadline for application for admission is **February 1** 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. 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 and 12 credit hours of thesis or dissertation research. The 24 semester hours of course work must be in courses numbered 600 or above (excluding OCN 699 and 700 and seminar courses). At least 12 of those semester hours must consist of courses taken from three of the following groups: biological oceanography, geological oceanography, chemical oceanography, physical oceanography, mathematical methods and statistics, and meteorology. 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 and qualify in one foreign language. All students must pass a final oral examination in defense of their thesis/dissertation.