College of Oceanic and Atmospheric Sciences

The College of Oceanic and Atmospheric Sciences has a three-fold mission: to increase the world's store of knowledge about the oceans and atmosphere through research that furthers national atmospheric and oceanic endeavors; to transmit this knowledge to future scientists by educating students for careers in oceanography, atmospheric science, geophysics, marine resource management and related fields; and to extend this information on the atmosphere, the marine environment and its natural resources to the people of the state, nation, and the world to aid in the wise development and management of the oceans and atmosphere.

Since its inception in 1959 as a department, oceanography at Oregon State University has grown to a college with a faculty of about 100 scientists, all leaders in their research areas. In 1992, the Department of Atmospheric Sciences was merged with the college to form the College of Oceanic and Atmospheric Sciences (COAS). The college is now Oregon's principal source of expert knowledge about the atmosphere and the ocean, especially the northeast Pacific, which has long been the focus of major research efforts by OSU oceanographers. It conducts the only comprehensive oceanographic and atmospheric research programs in Oregon. Today, research activities of the college extend throughout the world, and to all oceans. Its advanced degree graduates hold oceanographic positions in the United States and many other countries, as well as leadership positions in science and resource management, education, and the private sector.

COAS is a member of the Joint Oceanographic Institutions (JOI, Inc.), which represents the 10 major oceanography schools in the U.S. In fiscal year 2002–03, the college received more than $25 million in support from research grants and contracts. In 1991, NASA selected the college as a data analysis site for its Earth Observation System (EOS) project, part of the U.S. Global Change Research Program. In 1995, the National Research Council's research doctorate programs report ranked OSU's oceanography graduate program fifth in the U.S.

Students from around the United States and from other countries are enrolled in the four graduate programs of the college. By fall of 2003, 987 advanced degrees in oceanography, geophysics and atmospheric sciences been awarded through COAS at OSU.

FACULTY

Professors Abbott, Barnes, Barth, Bennett, Chelton, Coakley, Cowles, deSzoeke, Duncan, Egbert, Esbensen, Fisk, Freilich, Good, Holman, Klinkhammer, Levine, Mahrt, R. Miller, Mix, Moum, Nelson, Nielsen, Pisias, Prahl, Reimers, Samelson, Schultz, B. Sherr, E. Sherr, Strub, Trehu, Unsworth, Wheeler

Associate Professors Batchelder, Christie, Collier, Falkner, Goldfinger, Graham, Kosro, Letelier, Matano, Nabelek, Richman, Rushdi, Skyllingstad, Smyth, Torres, Vong, Wheatcroft

Assistant Professors Chase, Chin, D'Andrea, Hales, Keller, Maloney, McManus, Nash, Özkan-Haller, Pegau, Spitz, Strutton, Twohy, Wijesekera

Research Associates Boyd, Dale, Desiderio, Erofeev, Erofeeva, Gan, James, Kurapov, Newberger, Pierce, Springer, Vanhoff, Zolotov

ADJUNCT APPOINTMENTS

Auyong (OSU), Boehlert (HMSC), Chadwick (CIMRS), Charnov (OSU), Cramer (OSU), Daly (OSU), Fiedler (CIMRS), Gerrodette (CIMRS), Haller (OSU), Heppell (OSU), Hildreth (UO), Kimerling (OSU), Langdon (OSU), Law (OSU), Mate (OSU), Matzke (OSU), Morrissey (OSU), Rettig (OSU), Sampson (OSU), C. Smith (OSU), Sylvia (OSU), Thierstein (OSU), Webster (HMSC), Wright (OSU)

COURTESY APPOINTMENTS

Adamus (Adamus Resource), Allan (Ore. Dept. of Geol. and Min. Indus.), Boss (U. of Maine), Bottom (Ore. Dept. of Wildlife), Brodeur (National Marine Fisheries Ser.), Davis (Nat'l Marine Fisheries Ser.), Drake (OSU), Embley (NOAA), Fox (NOAA), Garono (Earth Design Con.), Ha (Univ. of Pusan, Korea), Hammond (NOAA), Heimowitz (U.S. Fish and Wildlife Ser.), Jay (Ore. Graduate Inst.), Lupton (NOAA), Markham (Arch Cape), Peterson, E. (OSU), Peterson, W. (NOAA), Priest (Ore. Dept. of Geol. and Min. Indus.), Reysenbach (Portland State U.), Rumrill (Nat'l Estuarine Res. Reserve), Rushdi (OSU), Sandgathe (ONR), Schirripa (Nat'l. Marine Fisheries), Sigleo (EPA), Wolfe (Cal. State U.), Young (EPA)

Undergraduate Minor

Oceanography

Graduate Majors

Atmospheric Sciences (MA, MS, PhD)

Graduate Areas of Concentration

Atmospheric Chemistry and Pollution
Atmospheric Radiation and Remote Sensing
Global Climate Dynamics
Large-Scale Dynamics and Planetary Atmospheres
Turbulence and Convection
Statistical and Applied Meteorology

Geophysics (MA, MS, PhD)

Marine Resource Management (MA, MS)

Oceanography (MA, MS, PhD)

Graduate Areas of Concentration

Biological Oceanography
Chemical Oceanography
Geological Oceanography
Physical Oceanography
Interdisciplinary Oceanography

Graduate Minors

Atmospheric Sciences
Geophysics
Marine Resource Management
Oceanography

TEACHING AND RESEARCH

The teaching and research programs within the college are highly interdisciplinary. They emphasize the interdepen-

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Oregon State University
Corvallis, OR 97331-5503
(541) 737-3504
FAX (541) 737-2064
http://www.coas.oregonstate.edu/
Students may contact the Student Programs Office, COAS Administration Building, (541) 737-5188.

ADMINISTRATION

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Robert Allan
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Marine Superintendent
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dence of biological, chemical, geological, geophysical, and physical processes within and under the sea, and their interactions with atmospheric processes. The faculty of the college comprises groups of scientists representing each of the basic disciplines involved in the study of the sea and atmosphere. The interdisciplinary and informal character of the college promotes the rapid exchange of ideas often necessary for the solution of research or management problems. Graduate students are essential participants in carrying out the research programs of the college.

UNDERGRADUATE OFFERINGS

Undergraduate offerings include courses at the 100, 200, 300, and 400 level. Although no oceanography, geophysics, marine resource management or atmospheric science undergraduate majors are available, there are sufficient offerings to provide interesting courses to motivated undergraduate students. Most employment in oceanography, atmospheric sciences, and geophysics requires a graduate degree. Students planning on graduate study in the college are advised to complete a baccalaureate degree in a basic natural science, mathematics, or engineering. The college provides undergraduates with the opportunity to become acquainted with the fields offered through undergraduate-level courses in oceanography and atmospheric sciences taught by leading scientists.

DEGREE PROGRAMS

Although the college provides some undergraduate courses, it offers graduate degrees only. Programs leading to the Master of Science (MS), Master of Arts (MA), and Doctor of Philosophy (PhD) degrees are available in atmospheric sciences, geophysics, and in biological, chemical, geological, physical, and interdisciplinary oceanography. In addition, the college offers a master's degree in marine resource management.

JOB OPPORTUNITIES

Graduate study in the college prepares students for research, teaching, and management positions in academic, industrial, and governmental organizations. Branches of the federal government employing atmospheric scientists, geophysicists, marine resource managers, and oceanographers include the Navy, Coast Guard, Department of the Interior, National Oceanic and Atmospheric Administration, National Science Foundation, National Aeronautics and Space Administration, Department of Energy, Army Corps of Engineers, and Environmental Protection Agency.

The main U.S. research effort in oceanography, atmospheric science, and geophysics is centered around federal agency programs or federally funded programs. Most of the university research in these fields is supported by federal grants and contracts. There are career opportunities in marine and atmospheric education and research in many colleges and universities, especially at those institutions in the coastal and Great Lakes states. Opportunities for oceanographic and atmospheric research careers are also found in private enterprise, especially in businesses involved with the use of marine and coastal resources and in which climate and weather are important influences. In addition, graduates have also gone on to successful careers in communications; creative, entrepreneurial enterprises; law and medical schools; and teaching kindergarten through grade 12.

PROGRAM RECOGNITION

The Western Interstate Commission for Higher Education (WICHE) has selected the biological, chemical, geological, physical, and interdisciplinary oceanography MA, MS and PhD programs, as well as the marine resource management master's program, as among unique or specialized graduate programs it coordinates in the Northwest. Residents of Alaska, Arizona, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, South Dakota, Utah, Washington, and Wyoming, who major in these programs, qualify to pay resident tuition rates at OSU.

RESEARCH VESSELS

The college's major research vessels, the *R/V Wecoma* and the *R/V Elakha*, are based at the Hatfield Marine Science Center in Newport, 50 miles (90 kilometers) from the Corvallis campus. The *Wecoma*, which came into service in early 1976, is 185 feet long (56.4 meters) and has space for 18 scientists. It is especially designed for oceanographic research and is used mainly for deep ocean work. The *Elakha*, which came into service during the summer of 2000, is 54 feet long and is used in navigable harbors and rivers along the coast.

COMPUTING RESOURCES

The Environmental Computing Center (ECC) was completed in 1993 to house the college's computing resources. For high performance computing the ECC provides several supercomputer-class machines including: two Connection Machines CM-5/CM-500 massively parallel supercomputers (32 and 256 processors), an integrated IBM SP-2/RS-6000 cluster (13 processors), a SGI Origin 3400 (10 processors), and a SGI Origin 3800 (8 processors). For file/application/print/e-mail services, the college maintains eight Sun 250- and 450-class systems. All systems are integrated within COAS' high-speed GB optical network, which also includes approximately 500 desktop workstations, PCs, Macs, a wide variety of input and output devices, and more than 10 terabytes of disk storage.

A digital media lab contains a variety of computers, including high-end UNIX workstations, Intel P4-based PCs, and Apple G4 Macintosh systems. High quality black-and-white and color printers, wide format HP plotters, Matrox digital editing suites, a CD-ROM and DVD mastering and etching station for production of CD-ROMs and DVDs are also located in the digital media lab. A visualization lab contains state-of-the-art computing and video equipment for producing data visualizations and complete video presentations of research projects.

An extensive network, connecting computing equipment within the college, is linked externally for electronic communications and remote computing. In the college's local network domain, 12 buildings are connected together via optical fiber cabling so that sharing of information and utilization of college computing resources is maximized. From this local network domain, the college is connected to the OSU campus network, which in turn is connected to the global network of the Internet, where vast computing resources (e.g., NCSA, NCAR, UCSD) can be accessed and over which worldwide electronic communication is possible.

COAS students have access to the one-of-a-kind computing system for their studies and research in addition to four labs dedicated to teaching and student research. These include GIS (geographic information system) teaching and research labs, both operated cooperatively with the Department of Geosciences. COAS graduates leave Oregon State University with a superb education in their chosen field and also are among the best-trained graduates in the world in advanced computing applications.

COURSES

Many of the courses in the college are offered every other year. Consult the *Schedule of Classes* or the college student programs office for current offerings.

ADMISSION REQUIREMENTS

Requirements for admission to the graduate programs in the college:

1. A bachelor's degree with a major (40 quarter credits or more) in a basic natural science (such as physics, mathematics, chemistry, biology, geology, atmospheric science, or computer science) or engineering. Marine resource

management applicants must also have a bachelor's degree, but the major may be in the social or political sciences, economics, business administration, the natural sciences, fisheries, or engineering.
2. A minimum cumulative grade-point average of 3.00 on a 4.00 scale for the last 90 quarter credits of undergraduate work.
3. One year each of undergraduate course work in physics, chemistry, and calculus. Qualified applicants deficient in these prerequisites may be admitted conditionally.
4. Graduate Record Examination (GRE) scores (general). Subject GRE recommended.
5. Three letters of recommendation.
6. A score of 550 or higher on the TOEFL for geophysics and oceanography applicants from countries where English is not the official language. Atmospheric science applicants must score at least 600 on the TOEFL. Marine resource management applicants must score at least 575 on the TOEFL.

Students may apply for admission any term. January 15 is the deadline to apply for fall admission. Early application is recommended.

PROGRAM REQUIREMENTS

Oceanography and marine resource management students are required to take a selection of prescribed core courses in the following fields: biological oceanography, chemical oceanography, geological oceanography, physical oceanography, and atmospheric science. Geophysics students are normally required to take one or more courses in physical and geological oceanography in addition to their geophysics courses. Atmospheric sciences students are required to take core courses in atmospheric radiation, dynamics and cloud physics, and two of the oceanography core courses of their choice.

Students in oceanography, atmospheric sciences, and geophysics usually minor in some other field of science, mathematics, statistics, or engineering. Marine resource management students have multidisciplinary programs and are not required to declare a minor.

MASTER'S PROGRAMS

All atmospheric science, geophysics, and oceanography students must satisfy the minimum program requirements (45 credits including 6 credits of thesis) established by the Graduate School. Some graduate credits earned at other institutions may be approved for inclusion in the program. Marine resource management graduate programs have 60 credits of course work and 6 credits of internship.

A two-hour, final oral examination is required for completion of the master's program.

MARINE RESOURCE MANAGEMENT PROGRAM

This master's degree program is designed to prepare students for direct entry into careers in resource management. The program typically consists of courses in oceanography, economics, fisheries, and business administration. Courses may also be taken in the Colleges of Engineering, Agricultural Sciences, Science, and Liberal Arts. Each program is adjusted to the needs of the individual. Students complete an internship, project report, or thesis. Applicants must meet the general admission requirements of the college.

DOCTOR OF PHILOSOPHY PROGRAM

In graduate programs in the college, the content of PhD programs, other than core requirements, is determined by individual students and their committees. Specific university requirements are formulated by the Graduate School. Approximately 80 credits of courses in the graduate major (including the core courses and 30 to 35 credits of thesis) are usually included in the major. A first and second minor or an integrated minor totaling about 40 credits are common. Graduate credits earned at other institutions may be accepted in the major and minor. There are no fixed requirements on the number of course credits to be taken; each program corresponds to the needs of the individual candidate. The dissertation is based on an original investigation in some area of the graduate major.

Courses taken as a part of the master's program at OSU are normally transferable into the PhD program.

OCEANOGRAPHY GRADUATE MINORS

Master's candidates who wish to minor in oceanography must take one course in physical oceanography and from 8 to 15 credits of other oceanography courses.

PhD candidates who wish to minor in oceanography must take the core oceanography courses. If oceanography is the first minor, the program should include a total of approximately 30 credits of oceanography.

OCEANOGRAPHY MINOR (27)

Undergraduates interested in the marine sciences can complete a minor in oceanography by following the curriculum below. This minor will add interdisciplinary breadth to undergraduate programs, broaden employment prospects, and enhance chances for gaining admission to graduate programs. The undergraduate Oceanography minor is suggested for students in any of the major programs of the College of Science, in fisheries or in engineering. The minor also provides a broad environmental science background for students planning to become high school teachers of earth or life sciences. The Oceanography minor is administered under the dean by the College of Oceanic and Atmospheric Sciences' Student Programs Office.

MRM 414. Ocean Resources Management (3)
  or MRM 415. Coastal Resources Management (4)
OC 331. Intro to Oceanography (3)
OC 332. Coastal Oceanography (3)
  or OC 333. Oceanic Research Frontiers (3)
OC 401. Research Projects (1–4)
  or OC 405. Reading and Conference (1–4)
  or OC 499. Special Topics in Oceanography (1–4)
OC 430. Principles of Physical Oceanography (4)
  or OC 433. Coastal and Estuarine Oceanography (3)
OC 440. Intro to Biological Oceanography (3)
OC 450. Chemical Oceanography (3)
OC 460. Geological Oceanography (3)
OC 464. Coastal Sedimentary Processes (3)

One of the following:

Additional course in oceanography or marine resource management (3)
  or ATS 210. Intro to the Atmospheric Sciences (3)
Z 351. Marine Ecology (3)
  or FW 431. Dynamics of Marine Biological Resources (4)
GPH 463. Geophysics and Tectonics (4)
  or other approved course (4)

ATMOSPHERIC SCIENCES (MA, MS, PhD)

Graduate Areas of Concentration

Atmospheric chemistry and pollution, atmospheric radiation and remote sensing, global climate dynamics, large-scale dynamics and planetary atmospheres, turbulence and convection, statistical and applied meteorology

The atmospheric sciences are concerned with dynamics, physics and processes, including the interactions of the atmosphere with soil physics, hydrology and oceanic circulation.

The atmospheric sciences graduate program in the College of Oceanic and Atmospheric Sciences prepares students for careers in teaching and research through advanced study and participation in research projects directed by faculty members. Master's and doctoral degrees are offered.

Applicants should have an undergraduate degree in physics, mathematics, engineering, chemistry or atmospheric

science, with strength in mathematics. All applicants should have completed one year each of chemistry and physics with calculus, and courses in vector calculus and in differential equations. Graduate Record Exam (GRE) scores are required of all applicants. International applicants must score at least 600 on the written TOEFL or an equivalent score on the computerized version of the test.

Students perform thesis research on a wide range of problems including the study of global climate change, clouds and the earth's radiation budget, the structure and dynamics of turbulent flows, air-sea interaction, planetary atmospheres, the optimal use and economic value of weather and climate forecasts, and the study of acid rain and its effects on terrestrial ecosystems. In addition to theoretical, numerical, and observational methods of analysis, approximately one-fourth of the research projects either use or are developing methods for obtaining meteorological information from satellites.

Opportunities exist for PhD candidates to conduct some of their thesis research in Europe or at the National Center for Atmospheric Research. Most research projects involve collaboration with other scientists, either on the Oregon State University campus or at major domestic or international research centers.

Requirements
All atmospheric science students must satisfy the minimum program requirements (45 credits including 6 credits of thesis) established by the Graduate School. Some graduate credits earned at other institutions may be approved for inclusion in the program. Marine resource management graduate programs have 60 credits of course work and 6 credits of internship.

A two-hour, final oral examination is required for completion of the master's program.

ATMOSPHERIC SCIENCES GRADUATE MINOR

For more details, see the college adviser.

GEOPHYSICS (MA, MS, PhD)

Graduate Area of Concentration
Geophysics

Geophysics is concerned with physical processes within and on the earth, especially the internal physical constitution of the planet, and seismic, gravitational, geothermal, geoelectrical, geomagnetic phenomena and their relation to geological processes.

The geophysics program in the College of Oceanic and Atmospheric Sciences offers graduate work toward Master of Science, Master of Arts, and Doctor of Philosophy degrees in Geophysics. Candidates should have an undergraduate degree in physics, mathematics, engineering, geology, or geophysics. Mathematics through differential equations is required and mathematical physics is desirable. Graduate Record Exam scores are required of all applicants. Opportunities for research exist on a wide range of geophysical problems in marine and continental regimes, emphasizing experimental, applied, and theoretical aspects.

Requirements
All geophysics students must satisfy the minimum program requirements (45 credits including 6 credits of thesis) established by the Graduate School. Some graduate credits earned at other institutions may be approved for inclusion in the program.

A two-hour, final oral examination is required for completion of the master's program.

GEOPHYSICS GRADUATE MINOR

For more details, see the college adviser.

MARINE RESOURCE MANAGEMENT (MA, MS)

Area of Concentration
Marine Resource Management

Marine resource management is an interdisciplinary field integrating an understanding of the scientific aspects of marine environments with consideration of the social, economic, political, and legal processes that govern human use of marine and coastal resources. Effective management of marine and coastal ecosystems and their economic uses includes many aspects of planning, development, conservation, protection and utilization of the diverse range of commodity and non-commodity natural resources found in these systems.

The Marine Resource Management graduate program in the College of Oceanic and Atmospheric Sciences is designed to prepare students to meet demands for professionals to fill positions of responsibility in the management of marine and coastal resources in both the public and private sectors. Graduates deal with problems in allocation, utilization, and development of oceanic, coastal, and estuarine resources. This program accommodates prospective and practicing resource managers from diverse backgrounds through its flexible curriculum requirements. A core of basic oceanography courses is coupled with additional multidisciplinary course work selected on the basis of the resource management interests of each student. An internship or research project serves as capstone for the program, although a thesis option exists. Applicants should have an undergraduate major in a physical, natural or social science; or business administration, or engineering, and one year each of college-level chemistry, physics and calculus. A course in intermediate microeconomics is desirable. The Graduate Record Examination is required. International students must score at least 575 on the TOEFL.

Specialized Programs
The Western Interstate Commission for Higher Education (WICHE) has selected the biological, chemical, geological, and physical oceanography programs (MS and PhD), as well as the marine resource management (MS, MA) programs, as unique or specialized graduate programs it coordinates in the Northwest. Residents of Alaska, Arizona, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, South Dakota, Utah, Washington, and Wyoming, who major in one of these programs, pay resident tuition at OSU.

Requirements
This master's degree program is designed to prepare students for direct entry into careers in resource management. The program typically consists of courses in oceanography, economics, fisheries, and business administration. Courses may also be taken in the Colleges of Engineering, Agricultural Sciences, Science, and Liberal Arts. Each program is adjusted to the needs of the individual. Students complete an internship, project report, or thesis. Applicants must meet the general admission requirements of the college.

MARINE RESOURCE MANAGEMENT GRADUATE MINOR

For more details, see the college adviser.

OCEANOGRAPHY (MA, MS, PhD)

Graduate Areas of Concentration
Biological, chemical, geological, physical oceanography, interdisciplinary oceanography

Oceanography, the application of the sciences to the study of the oceans, is an interdisciplinary environmental science concerned with all processes in the ocean: biological, chemical, geological, and physical, as well as the interactions between the ocean and atmosphere. The oceanography graduate program of the College of Oceanic and Atmospheric Sciences offers Master of Arts, Master of Science, and Doctor of Philosophy degrees.

For all areas in oceanography, applicants should have a strong quantitative background and an undergraduate degree in a relevant field of science or engineering and one year each of chemistry, physics, and calculus. Prior background in oceanography is not

essential. Graduate Record Exam scores are required of all applicants.

Research in biological oceanography involves the interactions of oceanic plants and animals with each other and with chemical, physical and geological processes in the sea. The ecological aspects of marine biology in the open ocean, coastal zones, and estuaries are emphasized. Candidates should have an undergraduate major in biology or chemistry.

Chemical processes of the ocean and their relation to the biological, physical, and geological processes of sea, land, and air are the concern of chemical oceanography research efforts. Applicants must have an undergraduate major in chemistry. Graduate students in chemical oceanography may concentrate on natural or contaminant organic, nutrient, trace metal, or radionuclide materials in the oceans, assessing the oceanic effects of such materials and their exchanges with atmospheric and terrestrial reservoirs.

In geological oceanography (marine geology), a broad range of geological processes that influence the ocean is studied. Fields of interest include plate tectonics and the structure of the ocean basins, igneous petrology and geochemistry, sedimentation, paleoceanography and paleoclimatology, the chemistry of hydrothermal solutions and coastal sedimentary processes. The undergraduate degree of candidates for graduate study should show strength in one or more of these fields: earth science, chemistry, physics, biology or mathematics.

Physical oceanography research covers the physical processes in the sea, exchange of energy and momentum at the air-sea interface, and the transmission and absorption of energy in the sea (e.g., light, heat, and sound). Circulation, tides, waves, heat content, and density distributions are some of the other phenomena of particular interest. Candidates should have an undergraduate major in physics, mathematics, or engineering.

Interdisciplinary oceanography combines research in more than one discipline, allowing for an integrated approach to the quest for knowledge of the oceans.

Specialized Programs

The Western Interstate Commission for Higher Education (WICHE) has selected the biological, chemical, geological, and physical oceanography programs (MS and PhD), as well as the marine resource management (MS, MA) programs, as unique or specialized graduate programs it coordinates in the Northwest. Residents of Alaska, Arizona, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, South Dakota, Utah, Washington, and Wyoming, who major in one of these programs pay resident tuition at OSU.

OCEANOGRAPHY (MS)

Requirements

All oceanography students must satisfy the minimum program requirements (45 credits including 6 credits of thesis) established by the Graduate School. Some graduate credits earned at other institutions may be approved for inclusion in the program. Marine resource management graduate programs have 60 credits of course work and 6 credits of internship.

A two-hour, final oral examination is required for completion of the master's program.

DOCTOR OF PHILOSOPHY PROGRAM

In graduate programs in the college, the content of PhD programs, other than core requirements, is determined by individual students and their committees. Specific university requirements are formulated by the Graduate School. Approximately 80 credits of courses in the graduate major (including the core courses and 30 to 35 credits of thesis) are usually included in the major. A first and second minor or an integrated minor totaling about 40 credits are common. Graduate credits earned at other institutions may be accepted in the major and minor. There are no fixed requirements on the number of course credits to be taken; each program corresponds to the needs of the individual candidate. The dissertation is based on an original investigation in some area of the graduate major.

Courses taken as a part of the master's program at OSU are normally transferable into the PhD program.

OCEANOGRAPHY GRADUATE MINOR

For more details, see the college adviser.

ATMOSPHERIC SCIENCES COURSES

ATS 210. INTRODUCTION TO THE ATMOSPHERIC SCIENCES (3). Physical basis of atmospheric phenomena on small, medium and large scales; introduction to atmospheric dynamics and thermodynamics; examination of atmospheric circulation systems; introduction to atmospheric physics and chemistry. PREREQ: College algebra and elementary functions. Offered every term.

ATS 320. *MAN'S IMPACT ON CLIMATE (3). Survey the climate and the factors that influence the climate. Examine sources for changes in atmospheric composition, the expected consequences of these changes, problems predicting future changes, and what can be done about the changes. Offered annually. (Bacc Core Course)

ATS 401. RESEARCH (1-16).

ATS 403. THESIS (1-16).

ATS 405. READING AND CONFERENCE (1-16).

ATS 406. PROJECTS (1-16).

ATS 407. SEMINAR (1). One-credit sections, graded P/N.

ATS 411. THERMODYNAMICS AND CLOUD MICROPHYSICS (4). Thermodynamic processes in the atmosphere, and an introduction to cloud microphysics. PREREQ: MTH 254, PH 213. Offered annually.

ATS 412. ATMOSPHERIC RADIATION (3). Radiative transfer in the earth and planetary atmospheres, absorption and scattering of sunlight, absorption and emission of terrestrial radiation, absorption and scattering cross sections for molecules, cloud droplets and aerosols. Applications include enhancement of photochemical reaction rates in clouds, remote sensing, and the earth's radiation budget, radiative-convective equilibrium, radiative forcing due to changes in atmospheric composition and climate change. PREREQ: MTH 256, PH 213, MTH 254.

ATS 413. ATMOSPHERIC CHEMISTRY (3). Principles of atmospheric chemistry; chemical fundamentals, sampling principles, sources, reactions, scavenging, and deposition of sulfur, nitrogen, ozone, and carbon compounds. Atmospheric aerosol size distribution, mechanics, optics, and scavenging. PREREQ: MTH 254, PH 213 and CH 221. Offered annually.

ATS 415. ATMOSPHERIC DYNAMICS I (4). Derivation of equations governing atmospheric motions; shallow atmosphere approximation and the primitive equations. Simple balanced flows; vertical motion; circulation, vorticity and potential vorticity; Ekman layer dynamics; prototypical atmospheric waves; geostrophic adjustment; quasi-geostrophic motions; analysis of structure of synoptic-scale systems; baroclinic instability. PREREQ: MTH 256, PH 213. Offered alternate years.

ATS 416. ATMOSPHERIC DYNAMICS II (4). Review of basic equations; scale analysis and approximations. Turbulence and boundary layers. Dry and moist convection; convective storms. Frontogenesis; symmetric instability; internal gravity waves and mountain waves; differentially heated circulations including sea breezes. Slope flows and urban circulations. PREREQ: ATS 415/ATS 515 or equivalent. Offered alternate years.

ATS 420. PRINCIPLES OF ATMOSPHERIC SCIENCE (4). Essential principles and observations of the atmosphere. Atmospheric composition and structure; hydrostatics and thermodynamics. Radiative processes; energy transfer and energy balances in the atmosphere. Cloud and aerosol processes; atmospheric storm systems. Atmospheric dynamics and the general circulation of the atmosphere. PREREQ: One year of college physics and college calculus. Offered annually.

ATS 446. GEOPHYSICAL BOUNDARY LAYERS (3). Descriptive introduction to atmospheric and oceanic boundary layers, Reynolds averaging, approximate equations of motion, tensor budget equations for higher moments, turbulence energy equation, similarity theory of the surface layer and boundary layer, closure schemes, convective mixed layer, stable boundary layer; air-sea interaction and land surface processes. PREREQ: ATS 416/ATS 516 or equivalent. Offered alternate years.

ATS 475. PLANETARY ATMOSPHERES (3). Origin and evolution of planetary atmospheres; vertical structure of atmospheres; hazes and clouds; atmospheric motions and general circulation. Presentation of recent observations and current research issues, focusing on Venus, Earth, Mars, Jupiter, Saturn, and Titan. Emphasis on comparative aspects and simple models. PREREQ: MTH 254, PH 213.

ATS 499. SELECTED TOPICS (1-16).

ATS 501. RESEARCH (1-16).

ATS 503. THESIS (1-16).

ATS 505. READING AND CONFERENCE (1-16).

ATS 506. PROJECTS (1-16).

ATS 507. SEMINAR (1). One-credit sections, graded P/N.

ATS 511. THERMODYNAMICS AND CLOUD MICROPHYSICS (4). Thermodynamic processes in the atmosphere, and an introduction to cloud microphysics. PREREQ: MTH 254, PH 213. Offered annually.

ATS 512. ATMOSPHERIC RADIATION (3). Radiative transfer in the earth and planetary atmospheres, absorption and scattering of sunlight, radiation, absorption and emission of terrestrial absorption and scattering cross sections for molecules, cloud droplets and aerosols. Applications include enhancement of photochemical reaction rates in clouds, remote sensing, and the earth's radiation budget, radiative-convective equilibrium, radiative forcing due to changes in atmospheric composition and climate change. PREREQ: MTH 256, PH 213, MTH 254.

ATS 513. ATMOSPHERIC CHEMISTRY (3). Principles of atmospheric chemistry; chemical fundamentals, sampling principles, sources, reactions, scavenging, and deposition of sulfur, nitrogen, ozone, and carbon compounds. Atmospheric aerosol size distribution, mechanics, optics, and scavenging. PREREQ: MTH 254, PH 213 and CH 221. Offered annually.

ATS 515. ATMOSPHERIC DYNAMICS I (4). Derivation of equations governing atmospheric motions; shallow atmosphere approximation and the primitive equations. Simple balanced flows; vertical motion, circulation, vorticity and potential vorticity; Ekman layer dynamics; prototypical atmospheric waves; geostrophic adjustment; quasi-geostrophic motions; analysis of structure of synoptic-scale systems; baroclinic instability. PREREQ: MTH 256, PH 213. Offered alternate years.

ATS 516. ATMOSPHERIC DYNAMICS II (4). Review of basic equations; scale analysis and approximations. Turbulence and boundary layers. Dry and moist convection; convective storms. Frontogenesis; symmetric instability; internal gravity waves and mountain waves; differentially heated circulations including sea breezes. Slope flows and urban circulations. PREREQ: ATS 415/ATS 515 or equivalent. Offered alternate years.

ATS 520. PRINCIPLES OF ATMOSPHERIC SCIENCE (4). Essential principles and observations of the atmosphere. Atmospheric composition and structure; hydrostatics and thermodynamics. Radiative processes; energy transfer and energy balances in the atmosphere. Cloud and aerosol processes; atmospheric storm systems. Atmospheric dynamics and the general circulation of the atmosphere. PREREQ: One year of college physics and college calculus. Offered annually.

ATS 546. GEOPHYSICAL BOUNDARY LAYERS (3). Descriptive introduction to atmospheric and oceanic boundary layers, Reynolds averaging, approximate equations of motion, tensor budget equations for higher moments, turbulence energy equation, similarity theory of the surface layer and boundary layer, closure schemes, convective mixed layer, stable boundary layer; air-sea interaction and land surface processes. PREREQ: ATS 416/ATS 516 or equivalent. Offered alternate years.

ATS 564. INTERACTIONS OF VEGETATION AND ATMOSPHERE (3). Quantitative treatment of radiation, heat, mass, and momentum exchange between vegetation and atmosphere; forest, natural and agricultural ecosystem examples. Physical and biological controls of carbon dioxide and water vapor exchange; remote sensing of canopy processes; models of stand-scale evaporation, photosynthesis and respiration; landscape and regional scale exchanges; vegetation and planetary boundary layer coupling; vegetation in global climate models. PREREQ: PH 201, MTH 251, BI 201. CROSSLISTED as FS 564.

ATS 575. PLANETARY ATMOSPHERES (3). Origin and evolution of planetary atmospheres; vertical structure of atmospheres; hazes and clouds; atmospheric motions and general circulation. Presentation of recent observations and current research issues, focusing on Venus, Earth, Mars, Jupiter, Saturn, and Titan. Emphasis on comparative aspects and simple models. PREREQ: MTH 254, PH 213.

ATS 590. SELECTED TOPICS (1-4). Maximum of 12 credits may be used in a graduate program.

ATS 601. RESEARCH (1-16).

ATS 603. THESIS (1-16).

ATS 605. READING AND CONFERENCE (1-16).

ATS 606. PROJECTS (1-16).

ATS 607. SEMINAR (1). One-credit sections, graded P/N.

ATS 613. AEROSOL AND CLOUD PHYSICS (3). Formation, composition and Brownian coagulation of atmospheric aerosol. Nucleation, composition, growth and evaporation of cloud droplets and ice crystals; precipitation processes. Scavenging of aerosol by cloud droplets. PREREQ: ATS 511,513.

ATS 615. LARGE-SCALE INTERACTIONS OF THE OCEAN AND ATMOSPHERE (3). Ocean-atmosphere circulations in the time-mean and seasonal cycles, equatorial wave modes, El Niño-Southern Oscillation, Madden-Julian oscillation, teleconnections and atmospheric bridges, mid-latitude air-sea interactions, Pacific and Atlantic decadal variability, the North Atlantic oscillation/ Arctic oscillation. PREREQ: ATS 515 or OC 670 or instructor approval.

ATS 630. CLIMATE DYNAMICS (3). Physical basis of climate and climatic change; radiation budget, surface energy budget, atmosphere and ocean circulation; energy balance models and their application to problems in climate change. PREREQ: MTH 254, PH 213. Offered alternate years.

ATS 655. MESOSCALE NUMERICAL MODELING (3). Review and classification of governing equations, finite difference approaches, Galerkin methods, truncation error and accuracy of solutions. Analysis of numerical stability, boundary conditions, and gridding methods focusing on issues relevant to mesoscale modeling such as nesting and terrain-following coordinate systems. Discussion of elliptical systems and methods for pressure solution. Study of current models with emphasis on turbulence parameterization, microphysics and initialization. Development of simple models and application of existing model systems. PREREQ: ATS 515, ATS 516, or OC 671 or instructor approval.

ATS 683. DATA ANALYSIS IN THE FREQUENCY AND WAVE NUMBER DOMAINS (3). Theory of classical and modern techniques for analysis of data in the frequency and wave number domains with applications to real oceanographic and atmospheric data. Topics include sampling theory, one-dimensional autospectral analysis, multidimensional autospectral analysis, coherence and phase analysis, bi-spectral analysis, wavelet analysis, and confidence tests. PREREQ: MTH 341, MTH 342, MTH 418, ST 314, OC 608 and working knowledge of Matlab, IDL, or Fortran. Offered alternate years. CROSSLISTED as OC 683.

ATS 690. SELECTED TOPICS (1-16). Maximum of 12 credits may be used in a graduate program.

GEOPHYSICS COURSES

GPH 463/GPH 563. GEOPHYSICS AND TECTONICS (4). Geophysical observations as constraints on geologic interpretation. Field trip(s) required; transportation fee charged. Lec/lab. PREREQ: MTH 251, PH 202 or PH 212 or equivalent. CROSSLISTED as GEO 463/GEO 563.

GPH 464. SEISMIC REFLECTION INTERPRETATION (4). Use of seismic reflection data to interpret subsurface geology. For students with backgrounds in either geology or geophysics. Emphasis on the integration of reflection data with other types of geophysical and geological data to interpret the structure and stratigraphy of sedimentary basins and the gross structure of the earth's crust. Brief overview of wave propagation theory and acquisition and processing procedures. Laboratory exercises include computer modeling of reflection data and interpretation of profiles from a wide variety of tectonic settings. PREREQ: GEO 463/GEO 563, GPH 463/GPH 563.

GPH 501. RESEARCH (1-16). Original research work that will not be part of the data used in a thesis. Graded P/N.

GPH 503. THESIS (1-16). Thesis research and writing.

GPH 505. READING AND CONFERENCE (1-16). Independent reading and library research on specialized topics in geophysics, guided by discussions with supervising faculty. A written report may be required. PREREQ: Instructor and topic approval required before registration.

GPH 507. SEMINAR (1-16).

GPH 564. SEISMIC REFLECTION INTERPRETATION (4). Use of seismic reflection data to interpret subsurface geology. For students with backgrounds in either geology or geophysics. Emphasis on the integration of reflection data with other types of geophysical and geological data to interpret the structure and stratigraphy of sedimentary basins and the gross structure of the earth's crust. Brief overview of wave propagation theory and acquisition and processing procedures. Laboratory exercises include computer modeling of reflection data and interpretation of profiles from a wide variety of tectonic settings. PREREQ: GEO 463/GEO 563, GPH 463/GPH 563. CROSSLISTED as GEO 564.

GPH 601. RESEARCH (1-16). Original research work that will not be part of the data used in a thesis. Graded P/N.

GPH 603. THESIS (1-16). Thesis research and writing.

GPH 605. READING AND CONFERENCE (1-16). Independent reading and library research on specialized topics in geophysics guided by discussions with supervising faculty. A written report may be required. PREREQ: Instructor and topic approval required before registration.

GPH 607. SEMINAR (1-16).

GPH 620. PHYSICS OF THE EARTH (3). Effects of confining pressure, temperature, time, and solutions on properties of rocks; earth and moon in solar system; source materials and their reliabilities for determining nature and composition of the earth; composition of core, crust, and mantle; geodynamics; processes within the earth with special reference to their effect on earthquakes, isostasy, crustal structure, island arcs.

GPH 630. ELEMENTS OF SEISMOLOGY (4). Survey of basic concepts in global seismology: world seismicity; elastic structure of the earth; seismic wave paths in the earth; locating earthquakes; earthquake focal mechanisms, magnitudes, stress drop, energy; stress and strain, elasticity, wave equation, plane waves in homogeneous and layered media, surface waves, free oscillations; ray theory; seismometry; earthquake prediction. Laboratory exercises include interpretation and analysis of seismograms from global seismographic networks. PREREQ: Differential equations.

GPH 631. THEORETICAL SEISMOLOGY (3). Representation of seismic sources, moment tensors, wave radiation from point and finite sources; wave propagation in attenuating medium; reflection and refraction of spherical waves, Lamb's problem, Cagniard-De Hoop methods; surface waves in a vertically heterogeneous medium; free oscillations of the earth. PREREQ: GPH 630, differential equations, complex analysis.

GPH 632. CRUSTAL SEISMOLOGY (3). Structure of the earth's crust and upper mantle from seismic reflection and large offset (refraction, wide-angle reflection) data. Methods of data collection, data processing theory and practice, modeling and interpretation techniques, correlation of seismic results with laboratory measurements of rock properties, and regional case studies. PREREQ: GPH 630.

GPH 640. THE EARTH'S GRAVITY FIELD (4). Gravity field and gravity potential, earth ellipsoid; gravity measurements (sea, land, and space), reduction of gravity measurements; gravity anomalies, isostasy, deviations from isostatic equilibrium; internal constitution of the earth. PREREQ: Differential equations, two years of physics, one year of geology. Offered alternate years.

GPH 641. ELECTROMAGNETIC METHODS IN GEOPHYSICS (3). Survey of electromagnetic (EM) methods in geophysics. Review of electromagnetic theory, Maxwell's equations in the quasi-static limit, the diffusion of EM fields in a layered conductor, qualitative discussion of EM fields in 2- and 3-d conductors. EM techniques, including DC resistivity, magnetotellurics, controlled source EM, induced polarization, and long-period magnetometer array methods. Applications to exploration, to basic research on crustal structure and to studies of upper-mantel conductivity. PREREQ: Upper-division EM course.

GPH 642. EARTH MAGNETISM (3). Geomagnetism and magnetic potential: general morphology and secular change; internal and external sources; principles of paleomagnetism, including field and laboratory procedures; origin of remanent magnetism in rocks and the controlling physical and chemical processes; the origin of the Earth's magnetic field. PREREQ: Instructor approval required.

GPH 650. GEOPHYSICAL INVERSE THEORY (4). Survey of the theory and applications of inverse methods currently used in the geophysical sciences for the interpretation of inaccurate and inadequate data. Backus-Gilbert inverse theory, resolution, regularization methods (such as damped least squares) for linear and non-linear problems, stochastic inversion, and extremal models. Applications to seismic, gravity, magnetic and electromagnetic data. PREREQ: Linear algebra. Instructor approval required.

GPH 651. GEODYNAMICS I (3). Application of the techniques of continuum mechanics to geological problems. Thermal and subsidence history of the lithosphere; stress and strain in the earth; elasticity and flexure of the lithosphere; gravitational compensation. PREREQ: Instructor approval required. Offered alternate years.

GPH 652. GEODYNAMICS II (3). Application of the techniques of continuum mechanics to geological problems. Rheology of earth materials; fluid mechanics applied to the earth's mantle and to magma chambers; fluid flow in porous media. PREREQ: Instructor approval required. Offered alternate years.

GPH 665. GEOPHYSICAL FIELD TECHNIQUES (3). Instrumentation, field methods and interpretation of gravimetric, magnetic, electrical and seismic prospecting techniques. Students will be required to collect, reduce, analyze, and interpret data.

GPH 689. SPECIAL TOPICS IN GEOPHYSICS (1-4). Special topics of current interest in geophysics, not covered in detail in other courses. May be repeated on different topics for credit.

MARINE RESOURCE MANAGEMENT COURSES

MRM 414. OCEAN RESOURCES MANAGEMENT (3). Science, technology, economics, and management of specific resources and uses of the oceans. Domestic and international laws, regulations, programs, and management regimes related to living and non-living marine resource utilization and protection. Offshore petroleum; energy; metals; minerals; freshwater; waste disposal; marine mammals and fisheries; medicines; recreation; transportation; and international law of the sea. Relevant resource management concepts, strategies and tools.

MRM 415. COASTAL RESOURCES MANAGEMENT (4). Survey of coastal zone and nearshore ocean management institutions, policies, decision-making processes, and management tools, with a United States emphasis. Using the public policy process as an organizing framework, issues addressed include natural hazards, water quality, habitat protection, public access, and the management of coastal development. Management processes and tools include information technologies, planning, regulation, protected areas, restoration, and coordination. Offered alternate years.

MRM 501. RESEARCH AND SCHOLARSHIP (1-16). Graded P/N.

MRM 503. THESIS (1-16).

MRM 505. READING AND CONFERENCE (1-16).

MRM 506. PROJECTS (1-16).

MRM 507. SEMINAR (1-16).

MRM 508. WORKSHOP (1-16).

MRM 510. INTERNSHIP (1-9). Planned and supervised resource management experience with selected cooperating governmental agencies, private organizations, or business firms. Supplementary conferences, reports and evaluations. For marine resource management majors only.

MRM 514. OCEAN RESOURCES MANAGEMENT (3). Science, technology, economics, and management of specific resources and uses of the oceans. Domestic and international laws, regulations, programs, and management regimes related to living and non-living marine resource utilization and protection. Offshore petroleum; energy; metals; minerals; freshwater; waste disposal; marine mammals and fisheries; medicines; recreation; transportation; and international law of the sea. Relevant resource management concepts, strategies and tools.

MRM 515. COASTAL RESOURCES MANAGEMENT (4). Survey of coastal zone and nearshore ocean management institutions, policies, decision-making processes, and management tools, with a United States emphasis. Using the public policy process as an organizing framework, issues addressed include natural hazards, water quality, habitat protection, public access, and the management of coastal development. Management processes and tools include information technologies, planning, regulation, protected areas, restoration, and coordination. Offered annually.

MRM 525. SPECIAL TOPICS IN MARINE RESOURCE MANAGEMENT (1-4). Subjects of current interest in Marine Resource Management, not covered in depth in other courses. May be repeated on different topics for credit.

OCEANOGRAPHY COURSES

OC 103. *EXPLORING THE DEEP: GEOGRAPHY OF THE WORLD'S OCEANS (4). Introduces non-science students to the oceans, including marine geology and chemistry, ocean currents, coastal and biological processes. Lec/lab. CROSSLISTED as GEO 103. (Bacc Core Course)

OC 103H. *EXPLORING THE DEEP: GEOGRAPHY OF THE WORLD'S OCEANS (4). Introduces non-science students to the oceans, including mar geology and chemistry, ocean currents, coastal and biological processes. Lec/lab. CROSSLISTED as GEO 103. (Bacc Core Course) PREREQ: Honors College approval required.

OC 199. SPECIAL TOPICS IN OCEANOGRAPHY (1-4). Introduction to topics of current interest in oceanography for lower-division undergraduates. May be repeated on different topics for credit.

OC 331. INTRODUCTION TO OCEANOGRAPHY (3). Comprehensive survey of oceanography as an interdisciplinary marine science. Geological features, plate tectonics, dynamics of ocean basins; chemistry of sea water, sediments; heat, motion, climate, air-sea interactions; surface, deep ocean circulation; biological processes in the sea. PREREQ: One year each of algebra, chemistry, and physics. Offered every quarter.

OC 332. COASTAL OCEANOGRAPHY (3). Physics, geology, biology and hydrology of coastal oceans. How coastal waters respond to forcing by heating, cooling, winds, tides, waves, rain, evaporation, river runoff and freezing. Geography and geology of coastlines: erosion and deposition processes, beach dynamics. Coastal equilibrium cells as sources and sinks of sediment. Rocky shore, beach, mudflat, estuarine, and coastal biotic communities; animal migrations. Law of the Sea rights and responsibilities of coastal states. Fisheries and mariculture in coastal seas. Pollution and coastal ocean resources. Using a matrix to define environmental problems; pathways that pollutants take through the coastal ecosystem. Offered annually.

OC 333. OCEANIC RESEARCH FRONTIERS (3). An introduction to oceanographic research today. Current and developing concepts, techniques, and questions in geological, physical, chemical, and biological oceanography, presented by researchers. Topics include formation of the planet, the ocean, and the ocean basins; sea floor geologic and geochemical processes; oceanic interaction with global climate; satellite observations; microbial and large scale biological processes. Brief overview introduces each lecture. Video format, with classroom, live broadcast, and tape-delayed viewing options. PREREQ: OC 331 recommended.

OC 401. RESEARCH PROJECTS (1-4). Field and laboratory research in oceanography for undergraduates, resulting in a written report. PREREQ: Instructor and topic approval required before registration.

OC 405. READING AND CONFERENCE (1-4). Independent library research and reading in specialized topics in oceanography for undergraduates, guided by discussions in conferences with faculty. A written report may be required. PREREQ: Instructor and topic approval required before registration.

OC 407. SEMINAR (1-3). Undergraduate seminar on current developments in the oceanographic research literature, with student presentations and group discussions. A written report may be required.

OC 407H. HONORS SEMINAR (1-3).

OC 430. PRINCIPLES OF PHYSICAL OCEANOGRAPHY (4). Fundamental principles of physical oceanography; conservation of mass, heat, momentum and vorticity; equations governing motion in the ocean; geostrophy; planetary boundary layers; wind-driven and thermohaline circulation. Descriptive oceanography; application of the fundamental principles to the ocean; examination of the major current systems; water mass analysis. PREREQ: One year each of college physics and college calculus. Offered annually.

OC 433. COASTAL AND ESTUARINE OCEANOGRAPHY (3). Circulation of the coastal ocean including continental shelf circulation, upwelling, coastal jets, undercurrents, coastal-

trapped waves. Fundamentals of surface waves and tides; tsunamis, wind generation, breaking waves. Estuary classification and circulation patterns; shallow-water processes and beach morphology. PREREQ: One year of college physics, one year of calculus. Offered alternate years.

OC 440. INTRODUCTION TO BIOLOGICAL OCEANOGRAPHY (3). Introduction to the ocean as an ecosystem, with emphasis on the processes affecting productivity and structure of oceanic communities. Interactions of biological processes with chemical, physical, and geological processes in the ocean. Effects of light and nutrients on phytoplankton, grazing by zooplankton, microbial activity and recycling, distributional patterns of zooplankton and nekton, ecology of benthic animals, marine fisheries, and pollution problems. Offered annually.

OC 441. MARINE ZOOPLANKTON (4). Small animal life in the sea: population biology, biogeography, migrations, life cycles, physiology. Role of zooplankton in pelagic ecosystem dynamics is examined through modeling. PREREQ: An ecology course, invertebrate zoology, or OC 440/OC 540. Offered alternate years.

OC 450. CHEMICAL OCEANOGRAPHY (3). Chemical properties and processes in the oceans. Composition, origin and evolution of sea water; thermodynamic and kinetic predictions for reactions in sea water; major and minor element reservoirs and fluxes; vertical and horizontal transport of materials; isotopic clocks and tracers; nutrients; chemical processes and fluxes across major marine interfaces, including estuaries, atmosphere, sediments, suspended particles and hydrothermal systems. PREREQ: One year of college-level general chemistry. Offered annually.

OC 460. GEOLOGICAL OCEANOGRAPHY (3). Structure of ocean basins, plate tectonics and sea floor spreading, marine sedimentation, history of ocean basins, and analysis of geological and geophysical data. PREREQ: One year each of physics and chemistry or science background. Offered annually.

OC 461. MARINE GEOLOGY CASE STUDIES (1-4). Modular course providing laboratory experience in current marine geological research areas. Modules are self-contained projects, based on current faculty research or recently published literature. Modules include field trips to examine marine sedimentary and submarine volcanic rocks and to observe coastal processes, including beach morphology and sedimentary processes. Examination of deep sea sediment cores including chemical and paleontologic analysis to extract paleoclimate or paleoenvironmental information. Experimental igneous petrology. Relationships of submarine basalt chemistry to topographic and tectonic features. Plate tectonic reconstructions. PREREQ: OC 460/OC 560 or equivalent, one year each physics, calculus and geology, and instructor approval required on modules. Offered annually.

OC 464. COASTAL SEDIMENTARY PROCESSES (3). Nearshore ocean processes including tides, sea-level variations, waves, currents, sediment transport, and the resulting beach morphology; coastal erosion problems and management issues.

OC 499. SPECIAL TOPICS IN OCEANOGRAPHY (1-4). Subjects of current interest in oceanography, not covered in depth in other courses. For upper-division undergraduates. May be repeated on different topics for credit. PREREQ: Varies with current topic. Graded P/N.

OC 499H. SPECIAL TOPICS IN OCEANOGRAPHY (1-4). Subjects of current interest in oceanography, not covered in depth in other courses. For upper-division undergraduates. May be repeated on different topics for credit. PREREQ: Varies with current topic; Honors College approval required. Graded P/N.

OC 501. RESEARCH (1-16). Original research work that will not be part of the data used in a thesis. PREREQ: Instructor approval required. Graded P/N.

OC 503. THESIS (1-16). Thesis research and writing.

OC 505. READING AND CONFERENCE (1-16). Independent reading and library research on specialized topics in oceanography, guided by discussions with supervising faculty. A written report may be required. PREREQ: Instructor and topic approval required before registration.

OC 506. PROJECTS (1-16).

OC 507. SEMINAR (1-3). Student presentations and discussions of current research literature or personal research results. Original research presentations by visiting scientists, OSU faculty and graduate students presenting final thesis results. Other sections and specific topics by arrangement.

OC 508. WORKSHOP (1-16).

OC 528. MICROPROBE ANALYSIS (3). Theory and application of electron microprobe analysis to problems in geology, engineering, chemistry, physics, and biology.

OC 530. INTRODUCTION TO PHYSICAL OCEANOGRAPHY (4). Fundamental principles of physical oceanography; conservation of mass, heat, momentum and vorticity; equations governing motion in the ocean; geostrophy; planetary boundary layers; wind-driven and thermohaline circulation. Descriptive oceanography application of the fundamental principles to the ocean; examination of the major current systems; water mass analysis. PREREQ: One year each of college physics and college calculus. Offered annually.

OC 533. COASTAL AND ESTUARINE OCEANOGRAPHY (3). Circulation of the coastal ocean including continental shelf circulation, upwelling, coastal jets, undercurrents, coastal-trapped waves. Fundamentals of surface waves and tides; tsunamis, wind generation, breaking waves; shallow-water processes and beach morphology. PREREQ: One year of college physics, one year of calculus. Offered alternate years.

OC 540. BIOLOGICAL OCEANOGRAPHY (3). The ocean as an ecosystem, with emphasis on the processes affecting productivity and structure of oceanic communities. Interactions of biological processes with chemical, physical and geological processes in the ocean. Effects of light and nutrients on phytoplankton, grazing by zooplankton, microbial activity and recycling, distributional patterns of zooplankton and nekton, ecology of benthic animals, marine fisheries and pollution problems. Offered annually.

OC 541. MARINE ZOOPLANKTON (4). Small animal life in the sea; population biology, biogeography, migrations, life cycles, physiology. Role of zooplankton in pelagic ecosystem dynamics is examined through modeling. PREREQ: An ecology course, invertebrate zoology, or OC 440/OC 540. Offered alternate years.

OC 550. CHEMICAL OCEANOGRAPHY (3). Chemical properties and processes in the oceans. Composition, origin and evolution of sea water; thermodynamic and kinetic predictions for reactions in the sea water; major and minor element reservoirs and fluxes; vertical and horizontal transport of materials; isotopic clocks and tracers; nutrients; chemical processes and fluxes across major marine interfaces, including estuaries, atmosphere, sediments, suspended particles and hydrothermal systems. PREREQ: One year of college-level general chemistry. Offered annually.

OC 560. GEOLOGICAL OCEANOGRAPHY (3). Structure of ocean basins, plate tectonics and sea floor spreading, marine sedimentation, history of ocean basins, and analysis of geological and geophysical data. PREREQ: One year each of physics and chemistry or science background. Offered annually.

OC 561. MARINE GEOLOGY CASE STUDIES (1-4). Modular course providing laboratory experience in current marine geological research areas. Modules are self-contained projects, based on current faculty research or recently published literature. Modules include field trips to examine marine sedimentary and submarine volcanic rocks and to observe coastal processes, including beach morphology and sedimentary processes. Examination of deep sea sediment cores including chemical and paleontologic analysis to extract paleoclimate or paleoenvironmental information. Experimental igneous petrology. Relationships of submarine basalt chemistry to topographic and tectonic features. Plate tectonic reconstructions. PREREQ: OC 460/OC 560 or equivalent, one year each physics, calculus and geology, and instructor approval required on modules. Offered annually.

OC 564. COASTAL SEDIMENTARY PROCESSES (3). Nearshore ocean processes including tides, sea-level variations, waves, currents, sediment transport, and the resulting beach morphology; coastal erosion problems and management issues.

OC 599. SPECIAL TOPICS IN OCEANOGRAPHY (1-4). Subjects of current interest in oceanography, not covered in depth in other courses. May be repeated on different topics for credit. PREREQ: Varies with current topic. Graded P/N.

OC 601. RESEARCH (1-16). Original research work that will not be part of the data used in a thesis. PREREQ: Instructor approval required. Graded P/N.

OC 603. THESIS (1-16). Thesis research and writing.

OC 605. READING AND CONFERENCE (1-16). Independent reading and library research on specialized topics in oceanography, guided by discussions with supervising faculty. A written report may be required. PREREQ: Instructor and topic approval required before registration.

OC 606. PROJECTS (1-16).

OC 607. SEMINAR (1-3). Student presentations and discussions of current research literature or personal research results. Original research presentations by visiting scientists, OSU faculty and graduate students presenting final thesis results. Other sections and specific topics by arrangement.

OC 608. WORKSHOP (1-16).

OC 633. GEOCHRONOLOGY AND ISOTOPE GEOLOGY (3). Measurements of cosmic and geologic time by radioactive decay. Use of radiogenic and stable isotopic tracers in geology. PREREQ: Graduate standing in geology or related fields. Offered alternate years. CROSSLISTED as GEO 633.

OC 641. BIOLOGICAL OCEANOGRAPHY LABORATORY (3). Laboratory and field experience with techniques for the determination of standing stocks of planktonic organisms, rate measurements, and analyses of physiological adaptations to oceanic environmental variables. PREREQ: OC 440/OC 540 or instructor approval required.

OC 642. MARINE NEKTON (3). Ecology, behavior, and special adaptations of swimming marine animals, including fish, invertebrate nekton, and marine mammals. Topics include locomotion, respiration, feeding, reproduction, sensory biology, schooling, seasonal migration and navigation, diel vertical migration, patterns of distribution and abundance, population dynamics, and community organization. PREREQ: OC 440/OC 540 or equivalent.

OC 644. MARINE PHYTOPLANKTON ECOLOGY (4). Ecology of photosynthetic plankton in the oceans; autotrophic, heterotrophic, and mixotrophic nutrition; limitation of growth and photosynthesis by light, nutrients and trace elements; grazing and other removal processes; primary productivity and its control in major ocean provinces and the global ocean; role of the marine phytoplankton in the global carbon balance on time scales ranging from seasonal to glacial/interglacial. PREREQ: OC 440/ OC 540 or two years of biology. Offered alternate years.

OC 645. MARINE PHYTOPLANKTON PHYSIOLOGY (4). Life processes of plankton algae: energy-capturing processes, mineral nutrition, flotation mechanisms, cell division. Evaluation of experimental procedures; problems of existence in the open ocean; artificial production of maximum yields. PREREQ: OC 644. Offered alternate years.

OC 646. PHYSICAL/BIOLOGICAL INTERACTIONS IN THE UPPER OCEAN (4). Variability in physical oceanic processes in the upper ocean and relationship to spatial and temporal variations in biomass, growth rates, and other biological patterns in the organisms of ocean surface waters. The relationship between variability in ocean physical phenomena and ecosystem dynamics, including the requirements of sampling design for upper ocean ecological studies. Time and space scales of physical and biological phenomena in the upper ocean. PREREQ: OC 430/OC 530 and OC 440/OC 540 or instructor approval required. Offered alternate years.

OC 647. MARINE MICROBIAL PROCESSES (4). Roles of procaryotic and eukaryotic microbes in the biological and chemical processes of the sea, with emphasis on pelagic ecosystems. Functional and taxonomic types and distribution of marine micro-organisms. Biochemical and physiological processes of major groups of microbes as these relate to geochemical cycles of biologically active elements in the sea. Heterotrophic and mixotrophic protists in pelagic foodwebs. Discussion of current experimental approaches to determining aspects of microbial activity and production. PREREQ: Two years of biology, OC 440/OC 550, or instructor approval required. Offered alternate years.

OC 648. MARINE BENTHIC ECOLOGY (4). Differences between benthic and water-column biological oceanography. Historical, observational approaches including sedimentology, fluid mechanics and geochemistry. PREREQ: Two years of biology, OC 440/OC 540, or instructor approval required.

OC 649. SPECIAL TOPICS IN BIOLOGICAL OCEANOGRAPHY (1-4). Special topics of current interest in biological oceanography not covered in detail in other courses. May be repeated on different topics for credit.

OC 651. ADVANCED CHEMICAL OCEANOGRAPHY (3). Advanced topics in chemical oceanography emphasizing problems and issues of contemporary interest. Descriptive studies of chemical properties and processes in sea water and the oceans; interactions of oceanic circulation and chemical distributions; sea water chemistry in specialized environments; geochemical and biochemical cycles; sea water-sediment interactions; analytical chemical advances. PREREQ: OC 450/OC 550.

OC 652. CHEMICAL OCEANOGRAPHY LABORATORY (3). Chemical analytical techniques for seawater and marine sediments. Topics include: salinity; dissolved oxygen; nutrients; the CO_2 system; dissolved and particulate organic materials; trace metals; radionuclides; analytical barriers and recent advances. PREREQ: OC 450/ OC 550 or instructor approval required.

OC 653. MARINE RADIOCHEMISTRY (3). Basic principles of radioactive decay and growth; marine biogeochemistry of uranium and thorium series radionuclides; release of artificial radionuclides into marine environments; applications of radioisotopic techniques to oceanic circulation and mixing, paleoceanography, sediment geochronology, archeometry, and marine pollution. PREREQ: One year of college-level general chemistry. OC 450/OC 550 desirable.

OC 654. MARINE POLLUTION (3). Identification of sources for organic and inorganic pollutants in estuarine, coastal and oceanic environments; mechanisms of introduction and dispersal; chemical and biological behavior and removal processes; regional and global scale effects; case studies and future research strategies; monitoring programs for pollution assessment. PREREQ: OC 450/OC 550. Offered alternate years.

OC 655. ADVANCED AQUATIC CHEMISTRY (4). Low temperature thermodynamic, selective kinetic treatments of natural waters' inorganic chemistry; organic ligands, surface active groups; prediction techniques, comparisons, observations; computer laboratory. PREREQ: Physical chemistry or chemical thermodynamics.

OC 656. MARINE ORGANIC GEOCHEMISTRY (3). Models for the formation and decomposition of simple and macromolecular organic matter in waters and sediments of the marine environment. Chemotaxonomic methods to distinguish sources of sedimentary organic matter and to identify the processes that influence the transfer and preservation of organic matter in the geological record. PREREQ: CH 332 or CH 336 and OC 450/ OC 550.

OC 659. SPECIAL TOPICS IN CHEMICAL OCEANOGRAPHY (1-4). Special topics of current interest in chemical oceanography not covered in detail by other courses. May be repeated on different topics for credit.

OC 660. PALEOCEANOGRAPHY (3). Large-scale changes in the oceanic and atmospheric system, as recorded in marine sediments, and their implications for understanding global environment changes. Chemical, physical, and biological proxies for oceanic and atmospheric processes in the geologic record period. Evidence for changing global climate at time scales longer than the historical record; the oceanic history of the Late-Cenozoic ice ages, long term evolution of climate change patterns, catastrophic global environmental events, and application of quantitative models to the past. Current research topics in paleoceanography. PREREQ: OC 560 or OC 662, or instructor approval required. Offered alternate years.

OC 661. PLATE TECTONICS AND STRUCTURE OF OCEAN BASINS (3). Evidence and predictions of plate tectonic model; structure and evolution of divergent and convergent plate margins; petrology of oceanic crust and upper mantle; lithosphere-mantle interaction; evolution of oceanic lithosphere; models for development of continental margins. PREREQ: One year each of physics, calculus, and geology. Offered alternate years.

OC 662. PHYSICAL, CHEMICAL AND BIOLOGICAL SEDIMENTATION IN THE OCEAN (3). Fundamentals of transport, chemical reactions, and biological processes in sediment formation; including fluid flow and drag, threshold and sedimentary bed forms, sources, facies and budgets of sediments, early diagenetic reactions, marine microfossil stratigraphy and paleoceanographic interpretations. Offered alternate years.

OC 663. GEOCHEMISTRY OF DEEP-SEA SEDIMENT RECORD (3). Nature and distribution of deep-sea deposits; factors controlling the distribution of terrigenous, volcanic, biogenic, and authigenic components; diagenesis and redistribution at the ocean floor.

OC 664. LITTORAL PROCESSES AND SEDIMENTATION (3). Nearshore environmental processes including an examination of real waves (wave theories and their application, refraction, diffraction, reflection, and breaking); generation of longshore and rip currents, mechanics of sediment transport on beaches, and features of recent sediments. PREREQ: General physics; integral and differential calculus. Offered alternate years.

OC 665. ANALYSIS OF GEOLOGIC DATA BASES (4). Spatial and stratigraphic characteristics of geologic data; geologic data bases; application of matrix theory to the solution of geologic problems; descriptive models, predictive models, spatial models, and stratigraphic and time-series models. PREREQ: One year of statistics and one year of computer science. Offered alternate years.

OC 666. ISOTOPIC MARINE GEOCHEMISTRY (3). Radiogenic and light stable isotopes and application to composition and evolution of the suboceanic mantle, petrogenesis of the oceanic crust, sediment provenance and sedimentary processes, geochronology, seawater chemical dynamics and paleoclimatology. Offered alternate years.

OC 667. IGNEOUS PROCESSES IN THE OCEAN BASINS (3). Origin and evolution of oceanic crust including the origin and nature of chemical heterogeneity and igneous rocks in the ocean basins; interaction of mantle and lithosphere as reflected in the topography of ocean basins; hydrothermal processes and the alteration of oceanic crust; geothermometry and geobarometry of oceanic magmas; elementary fractionation patterns and modeling of partial melting; fractional crystallization in oceanic magmas. Offered alternate years.

OC 668. THEORETICAL PETROLOGY (3). Theoretical aspects of igneous petrology in marine petrochemical processes. Igneous and metamorphic geology; hydrothermal solutions. Principles of energy, enthalpy, entropy. Equilibrium processes of melting, crystallization, mineral chemistry, geothermometers, geobarometers. PREREQ: Petrology. Offered alternate years.

OC 669. SPECIAL TOPICS IN GEOLOGICAL OCEANOGRAPHY (1-4). Subjects of current interest in geological oceanography, not covered in depth in other courses. May be repeated on different topics for credit.

OC 670. FLUID DYNAMICS (4). Fundamentals of fluid dynamics: conservation laws of mass, momentum, and energy; inviscid and viscous flows; boundary layers; vorticity dynamics; irrotational and potential flow. PREREQ: One year of college physics; mathematics through differential equations and vector calculus. Offered annually.

OC 671. GEOPHYSICAL FLUID DYNAMICS (4). Dynamics of rotating and stratified fluids, potential vorticity, geostrophic motion; inviscid shallow-water theory, Poincare, Kelvin, and Rossby waves; geostrophic adjustment, quasigeostrophic approximation, Ekman layers, two-layer and continuously stratified models. PREREQ: OC 670. Offered annually.

OC 672. THEORY OF OCEAN CIRCULATION (4). Theory of steady and time-dependent large-scale circulation in ocean basins. Effects of earth's curvature: the beta-plane approximation. The wind-driven Sverdrup circulation, western boundary currents, eastern boundary upwelling; the effects of friction. Linear theory and nonlinear theory; inertial gyres. Effects of buoyancy forcing; heating, cooling, evaporation, precipitation; density stratification. Wind- and buoyancy-forced circulation in the thermocline; ventilation. Potential vorticity conservation and homogenization. PREREQ: OC 670 and OC 671. Offered annually.

OC 673. DESCRIPTIVE PHYSICAL OCEANOGRAPHY (4). Fundamental mass, force, and energy balances of the ocean; geostrophy; planetary boundary layers; wind-driven and thermohaline circulation; vorticity; air-sea fluxes of heat, salt, moisture and momentum. Application of these balances through descriptive examination of the ocean-global heat budget; surface current systems; abyssal circulation. Study of variability on a variety of time and space scales. Instrumentation and platforms used for observing the ocean. PREREQ: OC 430/OC 530 or OC 670, or ATS 415/ ATS 515. Offered annually.

OC 674. TURBULENCE (4). Governing equations, turbulent kinetic energy, vorticity dynamics; turbulent transports of mass and momentum; statistical description of turbulent flows, spectral dynamics; turbulent boundary layers, planetary boundary layers in the atmosphere and ocean, convective mixed layers, stable boundary layers; deep ocean turbulence. PREREQ: OC 670. Offered alternate years.

OC 675. NUMERICAL MODELING IN OCEAN CIRCULATION (4). Review of theoretical models of ocean circulation, including shallow water, barotropic, quasigeostrophic, and primitive equation models; adjustment times, internal length and time scales; the role of advection, bathymetry, and coastlines; global models, basin models, regional models and models of jets, eddies and boundary currents. Review of numerical techniques and problems specific to ocean modeling. Local facilities are used to develop models on remote supercomputers. PREREQ: OC 670, MTH 625, MTH 626 or equivalent, and a working knowledge of FORTRAN.

OC 676. INVERSE MODELING AND DATA ASSIMILATION (4). Survey of methods for combining oceanographic observations and observing systems with numerical models of ocean circulation. Topics include: finite-dimensional least squares theory with inequality constraints; optimal interpolation; the representation theory of smoothing; the Kalman smoother and filter; gradient descent methods for minimization; spatial and temporal regularity of filters and smoothers; linear theory of array design; nonlinear optimization, practical assimilation methods. PREREQ: Strong background in linear algebra and advanced calculus, geophysical fluid dynamics, numerical modeling of ocean circulation.

OC 678. SATELLITE OCEANOGRAPHY (3). Theory and applications of satellite remote sensing observations of the ocean with emphasis on strengths and limitations in the measurements. Topics include review of electricity and magnetism, absorption and scattering in the atmosphere (radiative transfer), satellite orbital mechanics, measurements of ocean color, infrared remote sensing, microwave radiometry, scatterometry, and satellite altimetry. PREREQ: MTH 252, PH 212 or equivalent. Offered alternate years.

OC 679. SPECIAL TOPICS IN PHYSICAL OCEANOGRAPHY (1-4). Subjects of current interest in physical oceanography, not covered in depth in other courses. May be repeated on different topics for credit.

OC 680. STABILITY OF GEOPHYSICAL FLUID FLOWS (4). Baroclinic instability—linear and nonlinear stability problems; models of Eady and Charney. Instability of parallel shear flow—linear inviscid theory; Rayleigh's theorem; nonlinear contour dynamics; effects of stratification; Taylor-Goldstein equation. Thermal instability—the linear Rayleigh-Bernard problem; nonlinear models; the Lorenz equations, chaos and strange attractors. Geostrophic turbulence—resonant Rossby wave interactions; energy and entropy. Instability of nonparallel flow—Arnold's criteria. PREREQ: OC 670.

OC 681. GEOPHYSICAL WAVES (4). Fundamentals of wave dynamics applied to geophysical fluids. Hyperbolic waves—linear and nonlinear; characteristics; shock waves. Dispersive waves—linear waves, dispersion relations, group velocity; isotropic and anisotropic dispersion; nonlinear solitary waves. Application to geophysical waves—surface gravity, capillary, internal gravity, Kelvin, planetary, coastal. PREREQ; OC 670. Offered alternate years.

OC 682. DATA ANALYSIS IN THE TIME AND SPACE DOMAINS (3). Theory of classical and modern techniques for analysis of data in the time and space domains with applications to real oceanographic and atmospheric data. Topics include correlation analysis, regression analysis, EOF analysis, objective mapping, interpolation, filtering, sampling errors, and confidence tests. PREREQ: MTH 341, MTH 342, MTH 418, ST 314, OC 608 and working knowledge of Matlab, IDL, or Fortran. Offered alternate years.

OC 683. DATA ANALYSIS IN THE FREQUENCY AND WAVE NUMBER DOMAINS (3). Theory of classical and modern techniques for analysis of data in the frequency and wavenumber domains with applications to real oceanographic and atmospheric data. Topics include sampling theory, one-dimensional autospectral analysis, multidimensional autospectral analysis, coherence and phase analysis, bi-spectral analysis, wavelet analysis, and confidence tests. PREREQ: MTH 341, MTH 342, MTH 418, ST 314, OC 608 and working knowledge of Matlab, IDL, or Fortran. Offered alternate years. CROSSLISTED as ATS 683.