ATMOSPHERIC AND OCEANIC SCIENCES

The Department of Atmospheric and Oceanic Sciences (ATOC) is an interdisciplinary program that provides an educational and research environment to examine the dynamical, physical and chemical processes in the atmosphere, ocean and land surface, and the manner in which they interact. A major theme is the establishment of a physical basis for understanding, observing and modeling climate and global change.

Graduate students admitted to ATOC are eligible to receive an advanced degree in atmospheric and oceanic sciences. Graduate students outside of ATOC can pursue the graduate certificate in atmospheric and oceanic sciences while earning a graduate degree from another department at CU Boulder, or while taking course work as a non-degree-seeking student through Continuing Education's ACCESS Program provided they have already earned a bachelor's degree and meet the course prerequisites. In addition, students inside and outside the department may pursue a graduate certificate in oceanography. For more information on graduate certificate programs, see the Graduate School/Interdisciplinary Programs section.

For more information about ATOC programs and application procedures, call the ATOC office at 303-492-6633 or visit the Atmospheric and Oceanic Sciences website (http://www.colorado.edu/atoc) website.

Course code for this program is ATOC.

Master's Degree
- Atmospheric and Oceanic Sciences - Master of Science (MS) (catalog.colorado.edu/graduate/colleges-schools/arts-sciences/programs-study/atmospheric-oceanic-sciences/atmospheric-oceanic-sciences-master-science-ms)

Doctoral Degree
- Atmospheric and Oceanic Sciences - Doctor of Philosophy (PhD) (catalog.colorado.edu/graduate/colleges-schools/arts-sciences/programs-study/atmospheric-oceanic-sciences/atmospheric-oceanic-sciences-doctor-philosophy-phd)

Certificates
- Atmospheric and Oceanic Sciences - Graduate Certificate (catalog.colorado.edu/graduate/colleges-schools/arts-sciences/programs-study/atmospheric-oceanic-sciences/atmospheric-oceanic-sciences-graduate-certificate)
- Oceanography - Graduate Certificate (catalog.colorado.edu/graduate/colleges-schools/arts-sciences/programs-study/atmospheric-oceanic-sciences/oceanography-graduate-certificate)

Faculty
While many faculty teach both undergraduate and graduate students, some instruct students at the undergraduate level only. For more information, contact the faculty member's home department.

Brown, Derek Philip (https://experts.colorado.edu/display/fisid_150027)  
Instructor; PhD, University of Colorado Boulder

Cassano, John J. (https://experts.colorado.edu/display/fisid_121781)  
Associate Professor, Associate Chair; PhD, University of Wyoming

Forrest, Betsy Carroll (https://experts.colorado.edu/display/fisid_101645)  
Lecturer; PhD, University of Colorado Boulder

Friedrich, Katja (https://experts.colorado.edu/display/fisid_133607)  
Associate Professor; PhD, Ludwig-Maximilians-Universität München

Giglio, Donata  
Assistant Professor; PhD, University of California, San Diego

Han, Weiqing (https://experts.colorado.edu/display/fisid_115493)  
Professor; PhD, Nova University

Hart, John E.  
Professor Emeritus

Jahn Hall, Alexandra (https://experts.colorado.edu/display/fisid_155096)  
Assistant Professor; PhD, McGill University

Karnauskas, Kristopher Benson (https://experts.colorado.edu/display/fisid_155094)  
Assistant Professor; PhD, University of Maryland, College Park

Kay, Jennifer E. (https://experts.colorado.edu/display/fisid_153815)  
Assistant Professor; PhD, University of Washington

Keen, Richard A.  
Instructor Emeritus

Lemone, Margaret Anne (https://experts.colorado.edu/display/fisid_115199)  
Professor Adjoint

Lenaerts, Jan (https://experts.colorado.edu/display/fisid_158530)  
Assistant Professor; PhD, Utrecht University

Lovenduski, Nicole Suzanne (https://experts.colorado.edu/display/fisid_147557)  
Assistant Professor; PhD, University of California, Los Angeles

Lundquist, Julie Kay (https://experts.colorado.edu/display/fisid_147838)  
Associate Professor; PhD, University of Colorado Boulder

Nigro, Melissa A. (https://experts.colorado.edu/display/fisid_152154)  
Instructor; PhD, University of Colorado Boulder

Pilewskie, Peter Andrew (https://experts.colorado.edu/display/fisid_134466)  
Professor; PhD, University of Arizona

Randall, Cora Einterz (https://experts.colorado.edu/display/fisid_102010)  
Professor, Chair; PhD, University of California, Santa Cruz

Subramanian, Aneesh  
Assistant Professor; PhD, University of California, San Diego

Toohy, Darin W. (https://experts.colorado.edu/display/fisid_110652)  
Professor; PhD, Harvard University

Toon, Owen Brian (https://experts.colorado.edu/display/fisid_110521)  
Professor; PhD, Cornell University

Wang, Zhien (https://experts.colorado.edu/display/fisid_164340)  
Professor; PhD, University of Utah
Weiss, Jeffrey B. (https://experts.colorado.edu/display/fisid_102145)
Professor; PhD, University of California, Berkeley

Courses

ATOC 5000 (3) Critical Issues in Climate and the Environment
Discusses current issues such as ozone depletion, global warming and air quality for graduate students in nonscientific fields. Provides the scientific background necessary to understand, follow scientific developments and critically evaluate these issues.
Equivalent - Duplicate Degree Credit Not Granted: ATOC 4800 and ENVS 5830
Requisites: Restricted to graduate students only.

ATOC 5050 (3) Atmospheric Thermodynamics and Dynamics
Covers atmospheric thermodynamics and dynamics and the underlying governing laws and mathematical and physical principles. Topics include atmospheric composition and thermodynamics, conservation laws and atmospheric governing equations, geostrophic balance and balanced flows, vorticity dynamics and boundary layers. ATOC graduate core course.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite one year of calculus-based physics and math through differential equations.

ATOC 5051 (3) Introduction to Physical Oceanography
Provides fundamental knowledge of observations, theory, dynamics and modeling in physical oceanography. Promotes critical thinking and the development of skills for data analysis and interpretation. ATOC graduate core course.
Requisites: Restricted to graduate students only.
Recommended: Prerequisites one year of calculus-based physics and math up through differential equations.

ATOC 5060 (3) Dynamics of the Atmosphere and Oceans
Examines large-scale motions in a stratified rotating atmosphere and ocean, and quasi-geostrophic flow, barotropic and baroclinic instabilities, cyclogenesis, global circulations and boundary layer processes. Ageostrophic motions, including Kelvin waves, internal gravity waves and the theory of frontogenesis are also considered. ATOC graduate core course.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite ATOC 5050, one year of calculus-based physics and math up through differential equations.

ATOC 5061 (3) Dynamics of Oceans
Explores theories of the large-scale ocean, including quasigeostrophic, planetary geostrophic and shallow water equations. Topics may vary to focus on ocean climate (e.g. thermocline, westward intensification), ocean waves (e.g. gravity, Rossby, and Kelvin) or ocean models (toy, analytic and numerical).
Repeateable: Repeatable for up to 9.00 total credit hours.
Requisites: Restricted to graduate students only.
Recommended: Prerequisites ATOC 5400 and ATOC 5051 or ATOC 5060.

ATOC 5151 (3) Atmospheric Chemistry
Reviews basic kinetics and photochemistry of atmospheric species and stratospheric chemistry with emphasis on processes controlling ozone abundance. Tropospheric chemistry focusing on photochemical smog, acid deposition, oxidation capacity of the atmosphere and global climate change. ATOC graduate core course.
Equivalent - Duplicate Degree Credit Not Granted: CHEM 5151
Requisites: Restricted to graduate students only.
Recommended: Prerequisite one semester of college-level chemistry.

ATOC 5152 (3) Advanced Atmospheric Chemistry
Follows Graduate Atmospheric Chemistry (ATOC 5151) and explores advanced topics in atmospheric chemistry, such as secondary aerosol formation, oxidant formation, the chemistry of global climate change and/or design of advanced laboratory experiments.
Equivalent - Duplicate Degree Credit Not Granted: CHEM 5152
Recommended: Prerequisite CHEM 5151 or ATOC 5151.
Grading Basis: Letter Grade

ATOC 5200 (3) Biogeochemical Oceanography
Provides a large-scale synthesis of the processes impacting ocean biogeochemistry. Transforms theoretical understanding into real-world applications using oceanographic data and models. Topics include: chemical composition, biological nutrient utilization and productivity, air-sea gas exchange, carbonate chemistry, ocean acidification, ocean deoxygenation, iron fertilization, biogeochemical climate feedbacks and more.
Equivalent - Duplicate Degree Credit Not Granted: ATOC 4200
Requisites: Restricted to graduate students only.

ATOC 5215 (3) Descriptive Physical Oceanography
Introduces descriptive and dynamical physical oceanography, focusing on the nature and dynamics of ocean currents and their role in the distribution of heat and other aspects of ocean physics related to the Earth’s climate. Dynamical material limited to mathematical descriptions of oceanic physical systems.
Equivalent - Duplicate Degree Credit Not Granted: ASEN 5215
Requisites: Restricted to graduate students only.

ATOC 5235 (3) Introduction to Atmospheric Radiative Transfer and Remote Sensing
Examines fundamentals of radiative transfer and remote sensing with primary emphasis on the Earth’s atmosphere; emission, absorption and scattering by molecules and particles; multiple scattering; polarization; radiometry and photometry; principles of inversion theory; extinction- and emission-based passive remote sensing; principles of active remote sensing; lidar and radar; additional applications such as the greenhouse effect and Earth’s radiative energy budget. ATOC graduate core course. Department enforced prerequisite: one year of calculus-based physics, and math up through differential equations.
Equivalent - Duplicate Degree Credit Not Granted: ASEN 5235
Requisites: Restricted to graduate students only.

ATOC 5300 (3) The Global Carbon Cycle
Covers the role of the ocean, terrestrial biosphere, and atmosphere in the global carbon cycle. Specific topics include marine carbonate chemistry, biological production, terrestrial fluxes, anthropogenic emissions, and the evolution of the global carbon cycle in a changing climate.
Requisites: Restricted to graduate students only.

ATOC 5400 (3) Introduction to Fluid Dynamics
Covers equations of fluid motion relevant to planetary atmospheres and oceans and stellar atmospheres; effects of rotation and viscosity; and vorticity dynamics, boundary layers and wave motions. Introduces instability theory, nonlinear equilibration and computational methods in fluid dynamics. Department enforced prerequisite: partial differential equations or equivalent.
Equivalent - Duplicate Degree Credit Not Granted: ASTR 5400
Requisites: Restricted to graduate students only.
ATOC 5410 (3) Fluid Instabilities, Waves, and Turbulence
Nonlinear waves and instabilities; wave-mean and wave-wave interactions, resonant triads; secondary instability and transition to turbulence; diagnosis, modeling, and parameterization of turbulent flows in geophysics and astrophysics. Department enforced prerequisite: ASTR 5120 or ATOC 5060 or ATOC 5400.
Equivalent - Duplicate Degree Credit Not Granted: ASTR 5410
Requisites: Restricted to graduate students only.

ATOC 5540 (3) Mathematical Methods
Applied mathematics course; provides necessary analytical background for courses in plasma physics, fluid dynamics, electromagnetism, and radiative transfer. Covers integration techniques, linear and nonlinear differential equations, WKB and Fourier transform methods, adiabatic invariants, partial differential equations, integral equations, and integrodifferential equations.
Equivalent - Duplicate Degree Credit Not Granted: ASTR 5540
Requisites: Restricted to graduate students only.

ATOC 5550 (3) Mountain Meteorology
Investigating main processes that control weather and climate in the western United States and other mountain ranges around the world is the emphasis of this course. Provides an advanced survey of synoptic, mesoscale, and microscale meteorology in complex terrain including orographically modified cyclone evolution, front-mountain interactions, terrain and thermally driven flows, mountain waves, downslope winds, and orographic precipitation.
Equivalent - Duplicate Degree Credit Not Granted: ATOC 4550
Requisites: Restricted to graduate students only.

ATOC 5560 (3) Radiative Processes in Planetary Atmospheres
Application of radiative transfer theory to problems in planetary atmospheres, with primary emphasis on the Earth's atmosphere; principles of atomic and molecular spectroscopy; infrared band representation; absorption and emission of atmospheric gases; radiation flux and flux divergence computations; radiative transfer and fluid motions; additional applications such as the greenhouse effect, inversion methods and climate models. Department enforced prerequisite: ATOC 5235.
Equivalent - Duplicate Degree Credit Not Granted: ASTR 5560
Requisites: Restricted to graduate students only.

ATOC 5570 (3) Wind Energy Meteorology
Explores the complex interactions of the atmosphere and wind energy generation. Surveys wind turbine designs. Explores planetary boundary layer dynamics, traditional and novel wind measurement methods, forecasting methods, wind turbine and wind farm wakes, wind farm optimization, sound propagation from wind plants, climate change impacts on wind resources and the impacts of wind plants on local environments.
Equivalent - Duplicate Degree Credit Not Granted: ATOC 4770

ATOC 5600 (3) Physics and Chemistry of Clouds and Aerosols
Examines the physics and chemistry of clouds and aerosols in the planetary atmospheres, where they impact climate, atmospheric chemistry, remote sensing and weather. Applies basic microphysical, radiative and chemical processes affecting particles to issues in current literature. ATOC graduate core course.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite one semester of college-level chemistry and calculus-based physics and math up through differential equations.

ATOC 5730 (3) Physical Oceanography and Climate
Introduces the field of physical oceanography, with emphasis on the ocean's interaction with the global atmosphere. Analysis of the ocean's heat, salt, and momentum budgets, wind-driven and thermohaline circulations, climate cycles including El Nino, and the ocean's role in climate change. Theory complemented by state-of-the-art observations and models. Department recommended prerequisites: ATOC 1060 or ATOC 3070 or ATOC 3600 and one semester of calculus.
Equivalent - Duplicate Degree Credit Not Granted: ATOC 4730

ATOC 5750 (3) Desert Meteorology and Climate
Introduces students to the dynamic causes of deserts in the context of atmospheric processes and land-surface physics. Discusses desert severe weather, desert microclimates, human impacts and desertification, inter-annual variability in aridity (drought), the effects of deserts on global climate and the impact of desert climate on humans.
Equivalent - Duplicate Degree Credit Not Granted: ATOC 4750
Requisites: Restricted to graduate students only.

ATOC 5770 (3) Wind Energy Meteorology
Explores the complex interactions of the atmosphere and wind energy generation. Surveys wind turbine designs. Explores planetary boundary layer dynamics, traditional and novel wind measurement methods, forecasting methods, wind turbine and wind farm wakes, wind farm optimization, sound propagation from wind plants, climate change impacts on wind resources and the impacts of wind plants on local environments.
Equivalent - Duplicate Degree Credit Not Granted: ATOC 4770

ATOC 5810 (3) Planetary Atmospheres
Covers the structure, composition, and dynamics of planetary atmospheres. Also includes origin of planetary atmospheres, chemistry and cloud physics, greenhouse effects, climate, and the evolution of planetary atmospheres past and future.
Equivalent - Duplicate Degree Credit Not Granted: ASTR 5810 and GEOL 5810
Requisites: Restricted to graduate students only.

ATOC 5820 (3) Scientific Programming, Data Analysis and Visualization Laboratory
Teaches programming in python, as well as analysis skills for accessing, analyzing and visualizing data that are commonly used in the atmospheric and oceanic sciences. Basic data analysis includes curve fitting and re-gridding/aggregation of satellite observations or meteorological data for global climatologies. The course content is primarily conveyed through hands-on code development. A final project, involving the independent analysis and visualization of a scientific data set, integrates skills acquired throughout the course.

ATOC 5850 (3) Origin and Evolution of Planetary Systems
Reviews protoplanetary disks, condensation in the solar nebula, composition of meteorites, planetary accretion, comets and asteroids, planetary rings and extrasolar planets. Applies celestial mechanics to the orbital evolution of solar system bodies.
Equivalent - Duplicate Degree Credit Not Granted: ASTR 5820 and GEOL 5820
Requisites: Restricted to graduate students only.
**ATOC 5830 (3) Topics in Planetary Science**
Examines current topics in planetary science, based on recent discoveries, spacecraft observations and other developments. Focuses on a specific topic each time the course is offered, such as Mars, Venus, Galilean satellites, exobiology, comets or extrasolar planets. **Equivalent - Duplicate Degree Credit Not Granted:** ASTR 5830 and GEOL 5830  
**Repeatable:** Repeatable for up to 6.00 total credit hours.  
**Requisites:** Restricted to graduate students only.

**ATOC 5835 (1) Seminar in Planetary Science**
Studies current research on a topic in planetary science. Students and faculty give presentations. Subjects may vary each semester. **Equivalent - Duplicate Degree Credit Not Granted:** ASTR 5835 and GEOL 5835  
**Repeatable:** Repeatable for up to 4.00 total credit hours.  
**Requisites:** Restricted to graduate students only.

**ATOC 5900 (1-6) Independent Study**
Students may register for more than one section of this course in the same semester.  
**Repeatable:** Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.  
**Requisites:** Restricted to graduate students only.

**ATOC 6020 (1) Seminar in Atmospheric and Oceanic Sciences**
Studies an area of current research in the atmospheric and oceanic sciences. Students read selected papers from the literature. Students and faculty give presentations and participate in discussions. May be repeated for a total of 6 credit hours within the degree. May be repeated for a total of 3 credit hours within a semester.  
**Repeatable:** Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.  
**Requisites:** Restricted to graduate students only.  
**Recommended:** Prerequisite ATOC 5050 or calculus.

**ATOC 6700 (1) Weather Forecasting and Discussion**
Explores the techniques used to make short-term weather forecasts in the mid-latitudes using real-time weather observations, numerical forecast model output and conceptual models of mid-latitude weather phenomena. Students will be required to develop and defend conceptual models of the short-term evolution of the weather and will conduct detailed post-forecast analysis of successful and unsuccessful forecasts.  
**Repeatable:** Repeatable for up to 3.00 total credit hours.  
**Requisites:** Restricted to graduate students only.  
**Recommended:** Prerequisite ATOC 5050.

**ATOC 6950 (1-6) Master's Thesis**
**Requisites:** Restricted to graduate students only.

**ATOC 7500 (1-3) Special Topics in Atmospheric and Oceanic Sciences**
Acquaints students with current research in atmospheres, oceans, and climate. Topics may vary each semester. Students may register for more than one section of this course in the same semester.  
**Repeatable:** Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.  
**Requisites:** Restricted to graduate students only.

**ATOC 8990 (1-10) Doctoral Dissertation**
All doctoral students must register for not fewer than 30 hours of dissertation credit as part of the requirements for the degree. For a detailed discussion of doctoral dissertation credit, refer to the Graduate School section.  
**Requisites:** Restricted to graduate students only.