

## Atmospheric and Environmental Sciences Ph.D.



### Contact Information

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### Faculty

Professors Davis, Detwiler, Duke, Fontaine, Fox, Kenner, Mott, Price, Stetler; Associate Professors Capehart, Kliche, Riley, Stone, Sundareshwar; Emeritus Professors Helsdon, Hjelmfelt, Orville, Smith; Adjunct Professors Mazur, Zimmerman.

### Program Description

The Atmospheric and Environmental Sciences program aims to unravel the complex interactions between all the earth's components, such as the biosphere, the atmosphere and oceans, as well as the influence of human activity on the global environment. These interactions occur across many spatio-temporal scales and can profoundly affect the living organisms, the atmosphere around them and the ecosystem. The atmosphere and biosphere are fundamentally coupled on a variety of time-scales and support a complex set of bi-directional interactions. Managing wildfire potential, for example, includes components of atmospheric dynamics, precipitation patterns, vegetation distribution and condition, topographic factors, and more. Similarly, in terrestrial ecosystems, rapid exchange of CO<sub>2</sub>, water and energy between the atmosphere and the land surface may dominate bi-directional interactions on short time-scales, whereas, on long time-

scales, the interactions involve changes in ecosystem structure and composition in response to changes in climate. The key to success lies in training scientists to form interdisciplinary teams that can simultaneously tackle the broad range of processes needed to achieve understanding and prediction of such complex phenomena.

Measuring, monitoring, and modeling earth and atmospheric systems increasingly demands an interdisciplinary approach, because problems in earth processes impacting society often cannot be solved by studying the atmosphere, hydrosphere, lithosphere, and/or biosphere in isolation.

The Atmospheric and Environmental Sciences program links expertise in atmospheric science, biogeochemistry, geology, hydrology, water quality and water resources to address regional and local issues that may also be nationally or globally significant. The fundamental objective lies in developing the predictive capability to address linkages between earth system components and land management practices in a way that benefits decision-making at regional and national levels. We use the Black Hills of South Dakota and the surrounding Great Plains as a natural laboratory for the development of methodologies to link fundamental observations of the environment across a range of temporal and spatial scales, and integrate them with state-of-the-art modeling, visualization, and analysis.

Key interrelated research themes drive the research and teaching program, building on ongoing research and disciplinary strengths already present at the School of Mines, including meteorology, biogeochemistry, ecology, geology, climatology, hydrology, remote sensing, and geographic information systems.

### **Specific examples include:**

- Physical meteorology and storm processes, including impacts on hydrology and fire issues.
- *In situ* atmospheric measurements of storms, aerosols, trace gas concentrations, and more using specially adapted storm-penetrating aircraft.

- Wildfire dynamics and associated issues related to fire prevention, suppression, and post-fire mitigation.
- Carbon cycling and the potential effects of local and regional climate change, including the frequency and severity of storms, drought cycles, and wildfire potential.
- Nutrient transformations in aquatic and terrestrial ecosystems, including Black Hills Forests and coastal salt marshes.
- Water quality and quantity as it impacts regional growth and environmental systems.
- A Geographic Information System (GIS) laboratory as well as IBM-compatible computers with modeling and remote sensing analysis software.
- The Museum of Geology, located on campus and housing over 300,000 specimens, serves as a resource for paleontological instruction.

Many School of Mines faculty members who are actively involved in the AES program have externally funded research projects. These projects provide research assistantship opportunities for AES students. In addition to graduate research assistantships, support is also possible through graduate teaching assistantships and various fellowships and scholarships. AES students are strongly encouraged to work with their advisors and faculty colleagues to apply for research funding or fellowships to support their studies.

### **Program Requirements**

Degree candidates in AES are expected to complete an approved multidisciplinary program of course work and also perform original research in a focused area. A minimum total of 80 credit hours beyond the bachelor's degree is required. Students entering the AES program with a previous M.S. degree in a relevant discipline are allowed to apply a maximum of 24 course credit hours in an appropriate field toward the course credit requirement and 6 thesis research credits

toward the research-credit requirement. There is no language requirement in the AES program. However, all AES students are expected to be proficient in speaking, understanding, and writing the English language. Graduate students who are enrolled full time in the AES program should be able to complete their degree requirements and graduate within three to four years starting with a master's degree, and four to five years starting from a bachelor's degree. The time required to complete the degree will vary depending on the transfer of previously earned credits, course work recommendations specified by the student's committee, and individual research requirements.

### **The following key learning outcomes will be developed in all students:**

- a. A core of basic and specialized scientific and technical knowledge;
- b. An understanding of the basic scientific tools of measuring, monitoring, and modeling;
- c. The ability to apply these tools to understand atmospheric and land-surface interactions;
- d. The professional skills crucial to research, including obtaining and reviewing research literature, proposing research problems, critically evaluating their own work and the work of others, and communicating in writing and orally with their colleagues;
- e. The understanding and application of professional methods and ethics in their work; and
- f. The ability to form interdisciplinary teams to solve complex problems.

Students entering the program will normally already possess a foundational degree (typically the M.S. degree) in atmospheric sciences, meteorology, geology, hydrology, or environmental sciences/engineering. Students will build on this foundation by pursuing elective courses that prepare them for advanced work in their chosen specialty. The student and his/her committee are charged to prepare a course of study that will help the student become proficient in a specific research area. Great emphasis is placed on the independent origination of a research problem that will yield a new, original scientific insight.

<b>Ph.D. in Atmospheric and Environmental Studies</b>	<b>Credit Hours</b>
M.S. academic core (24 cr) and research (6 cr)	30
Required academic courses	10
Elective academic courses	13
Research credits	27
<b>Total required for the degree</b>	<b>80</b>

**The required academic courses include:**

**AES 790 Seminar**

This course builds professional communication skills, including writing and oral presentation, while exposing students to examples of disciplinary and interdisciplinary research. (1credit)

**AES 792 Topics (Interdisciplinary Problems)**

This innovative course brings together faculty and students to create a working group that selects a research problem, studies the literature, and develops a research plan that integrates the multiple disciplines of all the participants. Students participate in this course for 1 credit in their first year, and repeat the course in the second year for two credits, taking a correspondingly greater role in the work of the group. This course is modeled after traditional disciplinary research working groups, but is intended to facilitate the emergence of cohesive interdisciplinary teams, and to provide an incubator for new research plans and funding proposals. (3credits)

**AES 808 Fundamental Problems in Engineering and Science**

This course trains students to identify and tackle fundamental research problems; it combines literature review, proposal development, critical thinking, and professional ethics, and leads to an actual proposal in the student's specialty for submission to a funding agency. (3 credits)

**Department Elective in Measuring/Modeling of Earth Systems**

Students must complete at least one course in measuring and/or modeling techniques, to be selected by the student's committee. An array

of courses are offered at the School of Mines to fulfill this 3 credit elective course requirement. These courses are offered by the Departments of Civil and Environmental Engineering, Geology and Geological Engineering, Atmospheric Sciences, Chemistry, and Chemical and Biological Engineering, and Mathematics and Computer Sciences, and by other departments on campus as well. Listed below are examples of courses that might be included as electives in an AES program of study. These lists are intended as examples and are not intended to limit a student and committee as they construct an individual program.

**Potential elective courses for AES:**

- ATM 501 Atmospheric Physics
- ATM 502 The Global Environmental Change
- ATM 503 Biogeochemistry
- ATM 505 Air Quality
- ATM 510 Introduction to Environmental Remote Sensing
- ATM 515 Earth Systems Modeling
- ATM 519 Computing Methods in Atmospheric Sciences
- ATM 520 Remote Sensing for Research
- ATM 530 Radar Meteorology
- ATM 540 Atmospheric Electricity
- ATM 555 Synoptic Meteorology II
- ATM 560 Atmospheric Dynamics
- ATM 603 Biosphere-Atmosphere Interactions
- ATM 612 Atmospheric Chemistry
- ATM 625 Scaling in Geosciences
- ATM 642 Physics and Dynamics of Clouds
- ATM 643 Precipitation Physics and Cloud Modification
- ATM 644 Numerical Dynamics and Prediction
- ATM 660 Atmospheric Dynamics II
- ATM 670 Boundary Layer Processes
- ATM 673 Mesometeorology
- CEE 634 Surface Water Hydrology
- CEE 521 Environmental Systems Analysis
- CEE 526/526L Environmental Engineering Physical/Chemical Process Design
- CEE 527/527L Environmental Engineering Biological Process Design
- CEE 528 Advanced Treatment Plant Design
- CEE 533 Open Channel Flow
- CEE 628 Environmental Engineering

Measurements  
 CEE/GEOE 692 Environmental Remediation Processes  
 CEE 723 Environmental Contaminant Fate and Transport  
 CEE 721 Principles of Environmental Engineering  
 CEE 733 Techniques of Surface Water Resource and Water Quality Investigations I  
 CEE 784 Modeling and Computation in Civil Engineering  
 CEE 785 Applications of Finite Element Methods in Civil Engineering  
 GEOL 516/517/519 GIS I/II/III  
 GEOL 633 Sedimentation  
 GEOE 663 Ground-water Geochemistry  
 GEOE 682 Fluvial Processes

Student progress and mastery will be measured using the usual instruments in a doctoral program. A written or oral qualifying exam is used to assess the student's mastery of the M.S. course work. A comprehensive examination is given to evaluate the student's ability to formulate a research problem based on substantive literature review, and to test the student's knowledge in the area of specialty. It is given in two parts: 1) a written examination consisting of a review paper in the student's field of study and a research proposal, and 2) an oral examination to evaluate the research proposal and verify the student's understanding of the basic sciences and specialized field of study. The dissertation forms the final test of the student's ability to perform and communicate research. The student must prepare a doctoral dissertation and successfully complete a public defense covering the scientific validity of the work, as well as the student's basic and specialized knowledge in the field of study.

### **Management of the AES Program**

The AES program is managed by the Graduate Office. A program committee composed of 3-5 faculty representing different disciplines oversees the program, including setting policies and reviewing the curriculum. The program committee will also take measures to facilitate interaction by all faculty and students

participating in the program. A program coordinator heads the program committee, and provides oversight of student affairs, including meeting with new and existing students, tracking student progress, and conducting orientations for new students.

The preceding committee is distinct from the graduate student advisory committees that provide guidance to individual AES students during the course of their academic studies. The graduate student's major professor serves as the head of this advisory committee.