ESCI 796-05/896-05 – **Global Atmospheric Chemistry**

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Course Description:

Provides an introduction to the principles of atmospheric chemistry and their relationship to biogeochemical cycles, climate, and global change. The focus is on understanding the physical and chemical processes that influence the distribution of trace constituents in the global atmosphere. An introduction to atmospheric vertical structure and global circulation dynamics provides the foundation. Examines chemical cycles of important carbon, sulfur, and nitrogen species, including perturbations by human activities. Explores basic photochemical processes, particularly with respect to reactive nitrogen, hydrocarbons, and the production/destruction of ozone. Prereq: one year college chemistry. 3 cr.

Mastery Objectives: By the end of this course, students will…

- Know the major consistuents of Earth's atmosphere and how they are measured.
- Be able to identify, convert, and compare measures of atmospheric chemistry.
- Understand how the vertical structure and coordinate systems used in atmospheric science inform the study of trace gas photochemistry and transport.
- Know how atmospheric transport processes control the distribution of trace consituents.
- Identify the role that atmospheric chemistry plays in the biogeochemical cycling of carbon, oxygen, nitrogen, chlorine, and sulfur.
- Understand the impact of solar radiation, terrestrial radiaton, greenhouse gases, and aerosols on Earth's radiation balance.
- Be able to describe the photochemical mechanisms involved in photochemical smog (ozone), acid rain (sulfur chemistry), and stratospheric ozone (including the Antarctic ozone hole).
- Become familiar with several types of atmospheric models, where atmospheric chemistry fits into these models, and how to to access these tools.
- Know how to apply the laws of thermodynamics to atmospheric chemical reactions.
- Understand the processes that control the oxidizing capacity of the troposphere.
- Be proficient at working with first order reactions, bimolecular reactions, pressure-dependent reactions, and "lumped" reactions in atmospheric chemical mechanisms.
- Know how to represent aqueous and heterogenous reactions in chemical mechanisms and models. Understand the role of aerosols in the photochemistry and transport of atmospheric pollutants.

UNH Policies and Procedures and Support Services for Students *(click for link)*

Text Books

Main textbook: **Atmospheric Chemistry & Physics: From Air Pollution to Climate Change** – John Seinfeld and Spiros Pandis. 2006 or 2016 edition preferable (will be available in Dimond library).

Introduction to Atmospheric Chemistry – Daniel Jacob -- online textbook (no cost) http://acmg.seas.harvard.edu/people/faculty/djj/book/

Another excellent book (optional): **Chemistry of the Upper and Lower Atmosphere** –Barbara J. Finlayson-Pitts and James N. Pitts, Jr.

Activities and Assessments

Assignments	15%
In-class midterm exams (2)	30%
Take-home final exam	30%
In-class discussions, problems, participation	10%
Journal/blog entries	15%

Notes:

- *Lowest Assignment score dropped*
- *Midterm exams: 20% highest score, 10% lowest score*
- *Take-home Final Exam: extra problems for graduate students*
- *Journal/blog - different undergraduate & graduate expectations/rubrics*

Assignments: Biweekly (every two weeks) problem sets will provide an opportunity to practice and apply skills and content presented in class and the textbooks. Start early, work together, and ask questions. No plagiarism. The lowest score will be dropped.

Midterm Exams (3/7 & 4/18): Two in-class, hour-long exams will assess mastery of learning objectives. A couple questions on each exam will be modified directly from problem sets. Students can bring a 4x6 notecard and calculator to exams (extra calculators will be available, as cell phones are not allowed during exams).

Take-Home Final Exam: The final exam will be handed out ~10 days before the due date (currently due Friday, May 11th -- the date of the offically scheduled final exam).

In-class discussions, problems, participation: Students are expected to attend class and participate in class discussions and in-class problem solving.

Journals/blogs: Students are asked to keep an online journal/blog during the semester, with entries assigned approximately every two weeks. The content will relate concepts learned in class to 1) recent scientific journal articles, 2) university seminars, 3) your own research, 4) material being studied in your other classes, or 5) events in the news. (Undergraduates are only required to submit 2 entries.)

Late and Absence Policy

- Extensions will only be considered if requested 24 hours before the due date accompanied by a reasonable excuse.
- Extensions for take-home exam will not be granted once the exam begins.
- Late assignments will be deducted 10% per day. No late assignments will be accepted after solutions have been posted.
- If you are absent from class, please email me that day.
- Any in-class exams missed (with a valid excuse) will need to be scheduled and completed within one week.

Accommodations: Any accommodations for exams (including extended time) should be requested with appropriate paperwork and emails well in advance.

Electronic Device Etiquette (phones, tablets, laptops, etc.)
Electronic devices are allowed during lectures but not during in-class exams.

- *Please be respectful of your peers and instructor* and do not engage in activities that are unrelated to the class.
- Sit in the back of the room if your laptop might distract others.
- Remove earbuds.
- Silence cell phones.

Course Content (time devoted to each topic depends on class background and interest):

1. *Planetary Atmospheres* -- What is unique about Earth's atmosphere. The basic evolution and current composition of Earth's atmosphere. How the composition of Earth's atmosphere compares to other planetary atmospheres. Events that might dramatically change Earth's atmosphere

2. *Measures of Atmospheric Chemistry.* Common (and uncommon) units of atmospheric chemistry. Why particular units are used, basic methods for converting units, and online tools that make it easier. Review of how to develop new equations and empirical parameterizations using dimensional analysis. Atmospheric pressure. Vertical structure of the atmosphere -- temperature, pressure, scale height. When it is beneficial to view the atmospheric in terms of pressure, temperature, density, or scale height. Examples of vertical profiles of chemical constituents.

3. *Atmospheric Transport of Chemical Tracers*. Atmospheric forces. General circulation. Large-scale atmospheric thermodynamics. Thermal instability and vertical transport. Potential temperature and isentropic vertical coordinates to study chemical constituents. Impact of synoptic and mesoscale weather systems on the transport of pollutants. Stratosphere-troposphere exchange. Turbulence and dispersion. Atmospheric boundary layer and atmospheric surface layer. Wet and dry deposition. Where chemistry fits in to the equations of motion used in atmospheric dynamics.

4. *Atmospheric Models.* Box models and chamber experiments. Examples of when box models are used. Basic chemical kinetics and chemical lifetimes. Puff models and polluted plumes (smokestacks and fires). 2D (latitude and vertical models). 3D chemical

transport models -- urban, regional, and global (esp., EPA, NCAR, NASA, university, and European models). Data assimilation. Where to find and get access to various models and which offer training and computer time to PhD students.

5. *Solar Radiation and The Greenhouse Effect* – Solar radiation flux and atmospheric absorption. Terrestrial radiation flux and atmospheric absorption. Radiative equilibrium and radiative forcing. Impact of water vapor, clouds, and aerosols and remaining unknowns. Anthropogenic influence and climate change.

6. Global Geochemical Cycles, Emissions, and Atmospheric Lifetimes. Atmospheric residence times. Global cycles of Nitrogen, Oxygen, Carbon, and Chlorine. Particulates (aerosols). NAAQS and Clean Air Act. Emission inventories. How these cycles are representated in global earth system models.

7. *Photochemistry, Chemical Kinetics, and Thermodynamics.* First order reactions and radioactive decay. Bimolecular reactions. Pressure dependent reactions. Reversible reactions and chemical equilibria. Photochemistry. Laws of thermodynamics, Gibbs free energy and enthalpy of reaction. Chemical mechanisms for modeling, including “lumped" mechanisms and other short-cuts. We will use and expand on these basic skills throughout the course.

8. *Stratospheric Chemistry.* By the end of this course everyone should be able to explain stratospheric O_3 depletion and the Antarctic Ozone Hole. Chapman mechanism and catalytic cycles. Dynamics and chemistry of the Antarctic Ozone Hole, CFCs and HCFCs. History and Montreal Protocol. Where are we now?

9. *Tropospheric Chemistry.* Oxidizing Power of the Troposphere. The hydroxyl radical. Tropospheric ozone. Photochemical smog. Non-methane hydrocarbons. Isoprene and organic VOCs. Nightime photochemistry and NO_3. Isopleth diagrams. Policies, Clean Air Act Ammendments, U.S. success stories. Global megacities and O_3 pollution.

10. *Clouds and Aqueous Chemistry*. Cloud types and liquid water content. Henry’s Law. Aqueous-phase chemical equilibria. Aqueous-phase reactions rates. Sulfur chemistry and acid rain.

11. *Aerosols and Heteorgenous Chemistry.* Aerosol size distributions. Aerosols chemical composition. Source and sinks of aerosols. Troposphere - particulate pollution. Stratosphere - sulfate aerosols and volcanoes. Optical properties and radiative effects. Microphysical processes. Heterogeneous reactions. Deposition and atmospheric residence times. Aerosol models. Climate uncertainties associated with aerosols.

12. *Other topics.* The upper atmosphere and ion chemistry. Mercury and other heavy metals. Indoor air pollution.