MEA 493 M: Introduction to Atmospheric Chemistry
MEA 593 I: Introduction to Atmospheric Chemistry
Department of Marine, Earth and Atmospheric Sciences, Spring 2005

Class Time:	Tuesday/Thursday, 1:05-2:20 pm	**Instructor**:	Dr. Yang Zhang
Class Location:	Room 1109 Jordan Hall	**Office**:	Room 5151 Jordan Hall
TA:	Ping Liu (513-4438)	**Phone**:	919-515-9688
Office Hours:	9:30-11:30 pm Tuesdays	**Fax**:	919-515-7802
	(or by appointment with Ping)	**Email**:	yang_zhang@ncsu.edu
	Room 5146 Jordan Hall		pliu4@ncsu.edu (TA)

Objectives

This course is designed for graduate and upper-level (junior/senior) undergraduate students who are interested in learning about air quality/atmospheric chemistry. It will introduce the fundamentals of atmospheric chemistry/air quality and serve as a step-stone to more advanced courses on air quality such as MEA 593J/793J: Air Quality Modeling and Forecasting and MEA 779: Advanced Air Quality. Upon completion of this course, the students should have a knowledge of major urban-to-global scale air pollution issues that we are facing today and a good understanding of important atmospheric chemical processes underlying these issues. Students who are interested in pursuing an environmental/air quality position upon graduation or summer internships in MEAS or other organizations are highly recommended to take this course to acquire chemistry background required for such positions.

Textbook

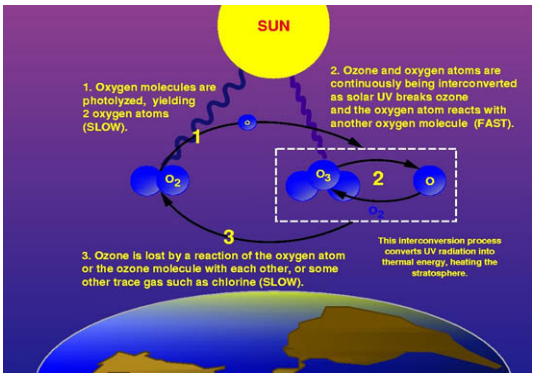
Atmospheric Pollution: History, Sciences and Regulation, M.Z. Jacobson, Cambridge University Press, New York, 2002, 399 pp.

Course Description

The course provides a comprehensive introduction to fundamentals of atmospheric composition, their sources, properties, and chemistry in the atmosphere, and their effects on human health and the environment. It first covers the history of discovery of chemicals, the evolution of the earth's atmosphere, and the structure and composition of the present-day atmosphere. It then covers science of major air pollution issues on urban through global-scale including urban outdoor air pollution, indoor air pollution, acid deposition, stratospheric ozone depletion, air pollution transport across political boundaries, and global climate change.

Specific course topics will include:

- **History of discovery of atmospheric chemicals**
- **Regulations and management of air pollution**
- **Atmospheric structure and composition**
- **Atmospheric photochemistry/chemical kinetics**
- **Chemistry of urban outdoor/indoor pollution**
- **Chemistry of troposphere**
- **Chemistry of stratosphere**
- **Chemistry of precipitation**
- **Acid deposition**
- **Global stratospheric ozone reduction**
- **The greenhouse effect and global warming**
- **Effect of meteorology on air pollution**



Prerequisites: CH 101, CH102, MEA 320, or consent of instructor.

Grading

Letter grades, on the +/- scale, determined by:

MEA493M:		**MEA593I:**	
Mid exam:	30%	Mid exam:	20%
Final exam:	40%	Final exam:	30%
Homework:	30%	Homework:	25%
		Term Project:	25%

Grade will be upgraded based on bonus points gained (see below for details)

Homework

(1) It must be neat and easily understood in terms of writing and presentation. It will be graded as a final report to the client and returned without grading if it does not follow this requirement.

(2) Homework will be handed out and collected on specific dates at the beginning of the class. Missed assignments and exams cannot be made up without an official university excuse. From 2:20 p.m. on the due date until noon one day after the due date there will be an automatic deduction of 25% of the total points from the grade. For the next 24-hour period (noon-to-noon) 50% will be deducted. This process will continue. Once a graded homework set has been returned, late homework will not be accepted. If you are sick or some special conditions arise, please contact me.

(3) Reading assignments should be completed within the assigned schedule. Some test problems will be based on reading assignments.

(4) "Bonus" problems will be given for some topics, they are optional homework for students who are willing to spend more time on this course. For students signed up for 493M, your grade will be upgraded if you work on those additional problems and accumulate sufficient points. For students signed up for 593I, some of the bonus problems may be obligatory, your grade will be upgraded if you work on remaining bonus problems and accumulate sufficient points. Some optional quizzes may also be provided for you to gain bonus points. The following table illustrates how you can earn bonus points and how it will help upgrade your base grade.

Base grade*	**Homework Bonus pts, (total 200 pts; counted as 15 pts in final grade)**	**Homework Bonus pts in final bonus pts**	**Mid-term Bonus pts, (total 30 pts counted as 5 pts in final grade)**	**Mid-term Bonus pts in final bonus pts**	**Total bonus pts (full bonus pts = 15+5= 20)**	**Final grade (bonus pts are added)**
75 (B)	80	6	20	3.33	9.33	84.33 (B+)
83 (B+)	80	6	20	3.33	9.33	92.33 (A-)
89 (A-)	80	6	20	3.33	9.33	98.33 (A)
95 (A)	80	6	20	3.33	9.33	104.33 (A+)

* The scores shown in the above table do not necessarily correspond to the actual grades to be used for this class.

Tests

One midterm (Thursday, March 3) and one final exam (Thursday, May 5) are planned.

Project (for MEA 593 I only)

The term project accounts for 25% of your grade. Each team member/individual should spend at least 20 hours on the project. The term project will be assigned on March 1 and the report should be handed in by 10 a.m. Monday, May 2. You can pick up a suggested topic or choose your own upon my approval. The final report should be prepared as a report to a client. It should be typed with a font size clear and readily legible (12-point, 1 ½ line spacing). The written report should

be 8-10 pages in length including Figures, Tables and references. Every table and figure must have a title and caption adequately describing the table or figure. Also, every table or figure must be referred to in the text. In addition, each student is required to give a 10-minute oral presentation (including questions) on the course project (April 19 and 21). Your presentations will be evaluated by students and invited MEAS faculty members and/or external professionals in terms of technical quality, clarity and organization. **Project is not required for students in MEA 493 M, but they are required to attend all presentation sessions.**

Project Grading (for 593 I students only)

The project, itself, will be graded according to the following criteria:

Written Report of work (80%):	
Organization	10%
Clarity	10%
Comprehensiveness	10%
Technical quality	20%
Up-to-date of the survey	10%
Following specific instruction	10%
Inclusion of references cited	10%
Oral presentation of work	10%
Effort in overall project	10%
Total	100%

Class Absences

If you miss (or plan to miss) a class, contact me as soon as possible to identify the materials to be covered during your absence. You are expected to make up the materials by reading the appropriate sections(s) in the textbook, doing the home assignments and meeting with me as necessary to discuss the materials. See the university attendance regulation at http://www.ncsu.edu/policies/academic_affairs/pols_regs/REG205.00.4.php)

Academic Integrity:

The university provides a detailed policy on academic integrity (see http://www.ncsu.edu/policies/student_services/student_discipline/POL11.35.1.php
It is understood that when you sign and submit your homework, term project report and exams, you are implicitly agreeing to the university honor pledge: "I have neither given nor received unauthorized aid on this test, assignment and report."

Students with Disabilities:

Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with Disability Services for Students at 1900 Student Health Center, Campus Box 7509, 515-7653. See http://www.ncsu.edu/provost/offices/affirm_action/dss/.

Additional Reading Materials (reserved in Natural Resources Library):

1. Jacob, D.J., "Introduction to Atmospheric Chemistry," Princeton Univ. Pr., 1999.
2. Finlayson-Pitts, B.J. and J.N. Pitts, Jr., "Atmospheric Chemistry," Wiley-Interscience, 2000.
3. P. Warneck, "Chemistry of the Natural Atmosphere (Second Edition)," Academic Press, 1999.
4. Jacobson, M.Z., "Fundamentals of Atmospheric Modeling," Cambridge University Press, ISBN 0521637171, 1999, **please use the reprinted 2000 version only**.
5. Seinfeld, J.H. and S.N. Pandis, "Atmospheric Chemistry and Physics: from air pollution to climate change", John Wiley & Sons, Inc., ISBN 0471-178152.
6. McElroy, M.B., "The Atmospheric Environment: Effects of Human Activity", Princeton University Press, ISBN 0-691-00691-1, 2002.

Lecture Topics and Schedule:

Class, Date	Topic	Lecture content	Reading*
1, 01-11	Intro.	Introduction, overview of current status, air quality standards	LN
2, 01-13	History	Discovery of atmospheric chemicals	MZJ 1.1-1.2, LN
3, 01-18	History	Evolution of Earth's atmosphere **(HWK#1 assigned)**	MZJ 2, LN
4, 01-20	Structure and Composition of Air	Structure/composition of the present atmosphere	MZJ 3.1-3.5, LN
5, 01-25	Structure, sources and reactions	Air pollutants, sources, and impacts **(HWK#1 due, HWK#2 assigned)**	MZJ 3.6-3.7, 1.3, LN
6, 01-27	Chem	Photochemistry and chemical kinetics	MZJ 1.4-1.6, LN
7, 02-01	Chem	Free-Tropospheric chemistry: oxidants	MZJ 4.2, LN
8, 02-03	Chem	Free-Tropospheric chemistry: sulfur and nighttime chemistry **(HWK#2 due, HWK#3 assigned)**	LN
9, 02-08	Chem	Urban air pollution – history and precursors	MZJ 4.1, LN
10, 02-10	Chem	Urban air pollution –Organic chemistry	MZJ 4.3-4.5, LN
11, 02-15	Chem	Stratospheric chemistry **(HWK#3 due, HWK#4 assigned)**	MZJ 11.1-11.4, LN
12, 02-17	Chem	Stratospheric/Antarctic ozone reduction	MZJ 11.5-11.11, LN
13, 02-22	Aerosols	Atmospheric PM: effect, composition, size	MZJ 5.1-5.2, 5.6, LN
14, 02-24	Aerosols	Atmospheric PM: controlling processes **(HWK#4 due, HWK#5 assigned)**	MZJ 5.3-5.5, 5.7, LN
15, 03-01	Meteorology	Air pollution meteorology **(Project topics assigned)**	MZJ 6, LN
03-03	**Mid-term**	**Test of topics covered from lectures 1-14**	
16, 03-15	Effect of Pollution	Effect of smog on radiation	MZJ 7.1, LN
17, 03-17	Effect of Pollution	Effect of smog on visibility and optics	MZJ 7.2-7.4, LN
18, 03-22	Regulation	History of air pollution regulation	MZJ 8, LN
19, 03-29	Indoor air quality	Indoor air pollution **(HWK#5 due, HWK#6 assigned)**	MZJ 9, LN
20, 03-31	Acid deposition	Acid deposition	MZJ 10, LN
21, 04-05	Greenhouse Effect	Greenhouse effect/global warming	MZJ 12.1-12.3, LN
22, 04-07	Whitehouse effect	Chemistry, aerosol and climate	MZJ 12.4-12.7, LN
23, 04-12	Advance	Modeling atmospheric gas-phase chemistry **(HWK#6 due)**	LN
24, 04-14	Advance	Aqueous-phase and heterogeneous chemistry	LN
04-19	**Course project**	**Class Presentations**	
04-21	**Course project**	**Class Presentations**	
25, 04-26**	Advance	Chlorine chemistry (guest lecturer)	LN
26, 04-28**	Advance	Atmospheric chemical mechanisms (guest lecturer) **(Project report due at 10 am, May 2)**	LN
05-05	**Final Exam**	**1-4 pm, Test of all of the above topics**	

* MZJ- Readings are from Jacobson, 2002; LN-lecture notes prepared by the instructor and guest lecturers.
** Zhang will be out of town for a conference. Substitute instructor/guest lecturer will be in the class.

Course outline

1. Introduction
    a. Course requirements
    b. Importance of atmospheric chemistry
    c. Air quality standards
    d. Current status of ambient air quality
2. Basics and History of Discovery of Atmospheric Chemicals
    a. Basic definitions
    b. History of Discovery of Atmospheric Chemicals
3. Evolution of Earth's Atmosphere
    a. The Sun and its origin
    b. Spectra of the radiation of the Sun and the Earth
    c. Primordial evolution of the Earth and its atmosphere
4. Structure and Composition of the Present Atmosphere
    a. Air pressure and density structure
    b. Temperature structure and processes affecting temperature
    c. Equation of state
    d. Composition of the Present Atmosphere
5. Air Pollutants and Their Sources and Impacts
    a. Atmospheric gases and aerosols
    b. Chemical structure and reactivity
    c. Health impact of air pollutants
6. Photochemistry and chemical kinetics
    a. Chemical reactions and photoprocesses
    b. Atmospheric chemical kinetics
    c. Lifetimes of chemicals
7. Free-tropospheric chemistry-I
    a. Photostationary-state relationship
    b. NO_x and NO_y cycles
    c. CO oxidation cycle
    d. Reactions of hydroxyl and hydroperoxy radicals
    e. CH_4 Oxidation cycles
8. Free-tropospheric chemistry- II
    a. Sulfur photochemistry
    b. nighttime nitrogen chemistry
9. Urban Photochemistry – I
    a. History and early regulation of urban air pollution
    b. Precursors of urban photochemical smog
    c. Atmospheric hydrocarbons and their structures
10. Urban Photochemistry – II
    a. Chemistry of oxidants and radicals
    b. Chemistry of anthropogenic hydrocarbons
    c. Chemistry of biogenic hydrocarbons
    d. Role of VOCs/NO_x in O_3 formation
11. Stratospheric chemistry-I
    a. Structure of the present-day ozone layer
    b. Relationship between the ozone layer and UV radiation
    c. Recent changes to the ozone layer
    d. Background stratospheric photochemistry
12. Stratospheric chemistry-II
    a. Effect of chlorine and bromine on global ozone reduction
    b. O_3 regeneration rates and Antarctic O_3 depletion
    c. Antarctic ozone depletion
    d. Heterogeneous stratospheric chemistry
    e. Regulation of CFCs
13. Aerosol component, effect, size and properties
    a. Health effects, classification and sources
    b. Size distributions: observations and modeling approaches

    c. Chemical compositions
    d. Single particle dynamics
14. Controlling processes of Aerosols
    a. Thermodynamics
    b. Nucleation
    c. Coagulation
    d. Condensation
    e. Removal
15. Air pollution meteorology
    a. Structure of troposphere
    b. General circulation of the atmosphere
    c. Boundary-layer meteorology
    d. Effect of important meteorological parameters on air pollution
16. Effects of Pollution on Atmosphere - I
    a. Gas absorption
    b. Gas scattering
    c. Aerosol and hydrometeor particle absorption and scattering
    d. Particle scattering and absorption extinction coefficients
17. Effects of Pollution on Atmosphere - II
    a. Visibility
    b. Colors in the atmospheric
18. History of Air Pollution Regulation
    a. Regulation in the United States
    b. Pollution trends and regulations outside the United States
19. Indoor Air Pollution
    a. Pollutants in indoor air and their sources
    b. Regulation of indoor air pollution
20. Acid Deposition
    a. Historic aspects of acid deposition
    b. Causes of acidity
    c. Effects of acid deposition
    d. Regulatory control of acid deposition
21. Greenhouse effect/global warming-I
    a. Temperature in the absence of a greenhouse effect
    b. The greenhouse effect and global warming
    c. Recent and historic temperature trends
22. Greenhouse effect/global warming-II
    a. Whitehouse effect
    b. Aerosol, chemistry and climate
    c. Regulatory control of global warming
23. Modeling gas-phase chemistry – I
    a. Characteristics of chemical ODEs
    b. Analytical and numerical solutions to ODEs
    c. Gas-phase chemical mechanisms used in air quality models
24. Aqueous-phase chemistry
    a. Aqueous-phase chemical equilibria and Henry's Law
    b. Aqueous-phase kinetic reactions of sulfur compounds
    c. Aqueous-phase kinetics of other compounds
    d. Coupled gas and aqueous-phase modeling system
25. Chlorine chemistry
    a. Importance of Chlorine chemistry
    b. Chlorine compounds and their sources and reactions
    c. Simulating Chlorine chemistry
26. Atmospheric chemical mechanisms
    a. Major chemical mechanisms used in air quality models
    b. Simulating atmospheric chemistry
    c. Intercomparison of atmospheric chemical mechanisms