SYLLABUS

Fall 2018
ENVR 416: Aerosol Physics and Chemistry (4 credit hours)

Class Meets: Tuesdays & Thursdays 12:30-1:45 PM, 2304 McGavran-Greenberg
Instructor: Dr. Jason Surratt, *Professor* in Department of Environmental Sciences & Engineering. Atmospheric and Aerosol Chemist.
Office: 164 Rosenau Hall
Office Phone: (919)-966-0470
Email: surratt@unc.edu
Office Hours: By appointment; however, if door is open you are welcome to stop by.
Skype Name: jason_surratt
Surratt Website: http://sph.unc.edu/profiles/jason-surratt-phd/

Guest Lecturers:
Dr. Barbara Turpin, *Professor and Chair* in the Department of Environmental Sciences & Engineering. Website: http://sph.unc.edu/profiles/barbara-turpin/

Dr. Havala Pye, *Adjunct Associate Professor* and *Physical Scientist* at the National Exposure Research Laboratory within the U.S. Environmental Protection Agency (EPA). Website: http://havalapye.wordpress.com

Dr. Yue Zhang, *Postdoctoral Scholar* in the Department of Environmental Sciences & Engineering with the Surratt Research Group

Graduate Lab Teaching Assistant:
Yuzhi Chen, 4th Year Ph.D. Student in the Surratt Research Group

Course Description and Goals:

The physical and chemical properties of aerosols impact the world around us, explaining many natural phenomena (e.g., the color of the sky, presence of clouds, and blue haze commonly observed in the Smoky Mountains), as well as impacting global climate change, air quality, and human health. In order to understand how aerosols impact our environment (both indoors and outdoors), this course will consist of two major sections; aerosol physics and aerosol chemistry.

First, in the aerosol physics section we will discuss the physical principles underlying the behavior of particles suspended in air, which includes rectilinear and curvilinear motion of particles in a force field, diffusion, evaporation, condensation, coagulation and electrical properties. The principles learned from the aerosol physics section of the course will allow students to understand how to size, collect and remove aerosols.

Owing to the fact that the second section of this course is devoted to understanding the chemistry that leads to atmospheric aerosol formation, principles gained from the first section will be important to understanding sources and fates of atmospheric aerosols. Primary focus in this section will be given on the chemistry that leads to the formation, evolution, and aging of organic aerosols, especially since organic compounds contribute a large fraction (i.e., 20-90%) towards the total mass of atmospheric fine (i.e., 2.5 μm and smaller) aerosol. High concentrations of atmospheric fine aerosol are known to have adverse human health effects and play a role in the Earth's climate system. The impact of atmospheric fine aerosols on climate and health cannot be fully assessed without understanding their detailed chemical processes. In addition, students will learn how to chemically characterize aerosols using both off-line and on-line analytical techniques.

Although the aerosol physics and chemistry examined in this course is primarily related to atmospheric aerosols, which is critical to those graduate students pursuing careers in air pollution control, air quality and atmospheric chemistry, the physical and chemical principles learned during this course will also be invaluable to those students pursuing careers in industrial hygiene, nanotechnology, atmospheric science (or meteorology), chemical manufacturing, pharmaceuticals (e.g., drug delivery), public health, epidemiology, toxicology and material science.

Prerequisites:

This is an introductory graduate level course to aerosol physics and chemistry; however, this course is also open to advanced undergraduates, especially those students who have: (1) had at least one undergraduate course in chemistry (organic chemistry is strongly recommended); (2) had at least one undergraduate course in physics; (3) and at least two semesters of calculus.

Grading and Course Requirements:

In-class quizzes	20%
In-class midterm exam (aerosol physics only)	20%
In-class final exam (aerosol chemistry only)	20%
Problem sets (i.e., homework assignments)	0% (optional, but highly encouraged!)
Review & Presentation of Journal Articles	20%
Labs	20%
	100%

Final Grades Assigned to Graduate Students:
High pass (H) – students in top 10% of class will receive this grade
Pass (P) – most students receive this grade if course work completed adequately
Low Pass (L)
Fail (F) – given if failure to attend lectures or labs, turn in assignments, or adequately complete quizzes/exams

Final Grades Assigned to Undergraduate Students:

Percentage Score	Grade
93-100	A
90-92	A-
87-89	B+
83-86	B
80-82	B-
77-79	C+
73-76	C
70-72	C-
67-69	D+
60-66	D
<60	F

Instructor's Philosophy of Grading Scale: This is a graduate level course, and as a result, no letter grades are given (see Graduate School Handbook for details). The purpose of graduate school (in the opinion of the instructor) is for students to produce original research that advances the scientific knowledge in one's field of study. Thus, the lack of letter grades will hopefully stimulate an atmosphere of self-learning and thinking during this course that will be a useful skill to apply during one's graduate student career. Although the grading scheme is on a pass/fail system, please do not assume the instructor will not fail students in this course, especially if you do not attend class or do very poorly on quizzes/exams and other assignments. You are expected to participate in all lab sessions.

In-Class Quizzes (20% of grade): Except for the first week of class, in-class quizzes will be given at the beginning of each Tuesday class period. These quizzes will be closed book and closed notes and should only last you 10 minutes (unless otherwise specified by the instructor). The purpose of the in-class quizzes is to motivate each student to review their lecture notes from the prior week as well as any required readings from the prior week so they stay up-to-speed on the course material. It is possible we may not have a quiz every Tuesday; however, you should be prepared each Tuesday for a quiz. ***I will discard your lowest quiz grade before determining your final grade for the course. If you miss a Tuesday class when a quiz is given, you will receive a grade of zero for that quiz but that grade will be the one I discard***. You will also receive a grade of zero for each additional quiz missed after the first. We will likely have up to 10-12 quizzes throughout the semester, and as a result, do not worry if you miss one or do poorly on a couple of quizzes. This is graduate school, so if you must miss a Tuesday class for training on an instrument, a necessary scientific workshop or conference, or some understandable personal reason, then an alternative quiz (or solution) will be worked out between the student and the instructor.

In-Class Midterm Exam (20% of grade): The date of the **in-class midterm exam is Tuesday, October 30, 2018.** This midterm exam will focus only on the aerosol physics material presented through Thursday, October 11, 2018. This exam will be closed notes and closed book. All

necessary equations will be provided to you, but no description of what the symbols or meaning of these equations will be provided.

In-Class Final Exam (20% of grade): The date of the **in-class final exam is Friday, December 7, 2018 from 12:00 until 3:00 PM**, in accordance with the UNC exam schedule for classes that meet TH at 12:30 PM. Like the midterm exam, the in-class final exam be 75 minutes long and will also be closed notes and closed book. The exam will **only** focus on atmospheric aerosol chemistry. Note we will use 2nd half of exam period to present your aerosol chemistry journal articles (see below). Our Final Exam is in the same class room as we use during the semester.

Problem Sets (0% of grade): Periodically (i.e., 4-6 times) during the semester, I will handout take home problem sets for you to work through. You are encouraged to work together with your classmates on all problem sets. If you have difficulty with any of these assignments, please feel free to schedule a time to meet with me. **Problem sets will NOT BE GRADED, but answer keys will be posted**. The amount you learn in this course will directly relate to your ability to work problems of this level. In addition to doing the reading assignments and reviewing your lecture notes, understanding the problem sets should help prepare you for any in-class quizzes and exams.

Review of Journal Article (20% of grade): Fundamental to a research career is reading, comprehending, and critiquing published or under-review research articles, as well as presenting to your colleagues complicated research findings in a clear and concise manner. Due to the importance of these skills, you will practice in this course selecting two peer-reviewed journal articles; one article will be relevant to the aerosol physics portion of the course and the other will be relevant to the aerosol chemistry portion of the course. Your grade for this portion of the course will be based on how much you improve upon your first presentation and written report. You will have to make two presentations and provide two written reports in total.

Details of this assignment will be provided in a separate document. Briefly, you will pick any research article (**not a review article**) from any peer-review journal of your choice, but with the requirement that this article be related to the aerosol physics and aerosol chemistry. The two articles you select and have approved by the instructor represent what an Associate Editor from a high-impact peer-review journal requested you to review (evaluate) that were recently submitted by the authors for potential publication. In selecting your article, it is preferred by the instructor that you have not read it before and that it might be helpful to your own research project (or thesis or dissertation work). **The instructor should approve the journal article at least 2 weeks before the presentations are conducted.** In providing your evaluation to the Associate Editor (which is the instructor in this case), you should formally write-up your response addressing the 3 principal criteria (scientific significance, scientific quality, and presentation quality); details of these criteria will be provided in separate documentation. This assignment will be graded based on how you seriously take this assignment and how thoroughly you address the 3 principal criteria. In writing a formal response, generally a reviewer of a submitted manuscript has 3 components: overall comments section (which summarizes the purpose, design, and major findings of the study and also includes recommendation of either reject, accept with minor revisions, or accept with major revisions), specific comments section (which is where you directly address the 3 principal criteria of scientific significance, scientific quality, and presentation quality) and finally a technical or minor comments section. Your role as a reviewer should be to guide the Associate Editor easily

and clearly through your reasoning for recommending that the article be rejected, accepted with minor revisions, or accepted with major revisions for publication. Finally, I would like for you to conclude your response to this assignment by describing to me how this article directly relates to material covered in this course.

The second part of this assignment will require a formal presentation of each written report. Students will be given 12 minutes for their presentation, with an additional 3 minutes for questions/discussion. Details of the expectations for the presentation will be provided in separate handout. **Written reports are due 1 week prior to the presentations. Oral presentations (in either pdf or powerpoint format) are due by 5 PM the day before the presentations. Both written reports and oral presentations should be emailed directly to the instructor**.

Labs (20% of grade): Three major lab sessions are included in this course and are required by all students to attend. The lab sessions will be spread out through the semester and will cover topics relevant to both aerosol physics and chemistry. In each lab session you will work together with a partner (or partners depending on the class size) to do the experiment planned. For both of the major labs planned, we will use two sessions **(Monday and Wednesday 10AM – 2PM or 10AM – 2PM) for each lab** outside our normal lecture times. The first session will allow for the Lab TA and instructor to brief you on the planned experiment. The second session scheduled (i.e., Wednesday) for each lab will allow all students an opportunity to tie up any loose ends on their labs. It should be noted that the 4-hr lab sessions outside of the scheduled lecture periods are needed due to the time required to complete the planned experiment. We understand that the extra meetings may cause conflict for some students, and as a result, we will work with you to find a time that minimizes any such problems. This course carries four hours of credit rather than three; the additional hour of credit is due to the additional effort involved with the laboratory assignments. **After completion of the lab sessions, you will then be asked to prepare a brief report of your findings. These will be due one week after the lab periods are completed.**

Honor Code: The University of North Carolina at Chapel Hill has had a student-administered honor system and judicial system for over 100 years. The system is the responsibility of students and is regulated and governed by them, but faculty shares the responsibility. If you have questions about your responsibility under the honor code, please bring them to your instructor or consult with the office of the Dean of Students or the Instrument of Student Judicial Governance. This document, adopted by the Chancellor, the Faculty Council, and the Student Congress, contains all policies and procedures pertaining to the student honor system. Your full participation and observance of the honor code is expected.

Students have four general responsibilities under the Honor Code:

1. Obey and support the enforcement of the Honor Code;
2. Refrain from lying, cheating, or stealing;
3. Conduct themselves so as not to impair significantly the welfare or the educational opportunities of others in the University community; and
4. Refrain from conduct that impairs or may impair the capacity of University and associated personnel to perform their duties, manage resources, protect the safety and welfare of members of the University community, and maintain the integrity of the University.

Textbooks and Other Readings:

Required Textbooks:

William C. Hinds, Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles, 2nd Edition, 1999.

Additional Required Readings: Research articles or photocopies of chapters from other textbooks may be handed out in class from time to time to supplement any of the material that is not adequately covered in the required textbook. Students will be required to read these in order to be better prepared for lectures, quizzes and exams.

Recommended Textbooks:

John H. Seinfeld and Spyros Pandis, Atmospheric Chemistry and Physics: From Air pollution to Climate Change, 2nd Edition, 2006, Wiley.

Barbara J. Finlayson-Pitts and James N. Pitts, Jr., Chemistry of the Upper and Lower Atmosphere, 1999, Academic Press.

Pramod Kulkarni, Paul A. Baron, and Klaus Willeke. Aerosol Measurement: Principles, Techniques, and Applications, 3rd Edition, 2011, Wiley.

Class Schedule (subject to updates; T = Tuesdays; H = Thursdays):

Day	Day of Month	Month	Topic	Readings	Instructor
T	21	Aug	Course introduction, objectives, policies, and schedule	H: 1-15	Surratt
H	23	Aug	Particle size distributions: number, surface area, volume and mass	H: 1-15, 75-89 SP: 350-360	Surratt
T	28	Aug	Particle size distributions: log-normal distributions and ambient size distributions	H: 90-107 SP: 362-381	Surratt
H	30	Aug	Properties of gases	H: 15-23; 27-31 SP: 396-400	Surratt
T	***4***	***Sep***	***NO CLASS – Jason and his research group @ AAAR Conference in St. Louis, MO***		
H	***6***	***Sep***	***NO CLASS – Jason and his research group @ AAAR Conference in St. Louis, MO***		
T	11	Sep	Uniform particle motion: Newton's resistance law, Stoke's law, and slip correction	H: 42-55 SP: 403-407; 426-431	Surratt

H	13	Sep	Uniform particle motion: terminal settling velocity @ low and high Re numbers	H: 42-67 SP: 403-411; 426-431	Surratt
T	18	Sep	Shape correction to terminal settling, instruments that rely on settling, particle acceleration, and stopping distance	H: 55-67; 111-119	Surratt
H	20	Sep	Curvilinear motion and Stokes number	H: 119-136 SP: 422-426	Surratt
F	***21***	***Sep***	***Lab Session 1: Aerosol Generation and Sizing Measurement – (10AM - 2PM in MHRC 0016)***	***H: 428-445***	***Surratt & Chen***
T	25	Sep	Curvilinear motion - impactors	H: 119-136 SP: 422-426	Surratt
H	27	Sep	Electric Forces, motion in an electric field	H: 316-323 SP: 411-412	Surratt
T	2	Oct	Electric Forces, motion in an electric field	H: 316-323 SP: 411-412	Surratt
H	4	Oct	Electric Forces, motion in an electric field	H: 316-323 SP: 411-412	Surratt
T	9	Oct	Electric Forces, motion in an electric field	H: 316-323 SP: 411-412	Surratt
H	11	Oct	Particle charging, charge limits, and differential mobility analysis	H: 323-345 H: 278-301	Surratt
T	16	Oct	Kelvin effect, droplet equilibrium, condensation, nucleation, evaporation Brownian motion, and diffusion	H: 150-165 SP: 412-421 H: 278-301	Surratt
H	18	Oct	***NO CLASS – Fall Break***		
T	23	Oct	Coagulation	H: 260-275	Surratt
H	***25***	***Oct***	***Aerosol Physics Relevant Journal Article Presentations***		Surratt
T	***30***	***Oct***	***IN-CLASS MIDTERM EXAM - Aerosol Physics Section***		Surratt
H	1	Nov	Introduction to atmospheric aerosol chemistry – atmospheric structure, sources, compositions,	H: 304-314 SP: 27-47 SP: 381-388	Surratt

			and quick review of important organic classes	SP: 628-647	
F	***2***	***Nov***	***Lab Session 2: Real-Time Characterization of Inorganic Aerosol and Aerosol Acidity (10AM – 2PM in MHRC 0016)***	***Sorooshian et al. (2006, AS&T) Jang et al. (2002,***	***Surratt & Chen***
T	6	Nov	Secondary Organic Aerosol (SOA): General mechanism and SOA Yields	SP: 647-666 Kroll & Seinfeld (2008, Atmos. Environ.)	Surratt
H	8	Nov	Key Gas-Phase Oxidation Reactions – Importance for Secondary Organic Aerosol (SOA) Formation	SP: 647-666 Kroll & Seinfeld (2008, Atmos. Environ.)	Surratt
F	***9***	***Nov***	***Lab Session 2: Real-Time Characterization of Inorganic Aerosol and Aerosol Acidity (Finish Up) (10AM – 2 PM in MHRC 0016***	***Sorooshian et al. (2006, AS&T) Jang et al. (2002, Science)***	***Surratt & Chen***
T	13	Nov	SOA: Gas-phase oxidation chemistry of isoprene	Teng et al. (2018, JACS) and Carlton et al. (2010, ACP)	Surratt
H	15	Nov	SOA: Role of heterogeneous (or multiphase) chemistry in isoprene SOA formation – need for chemical measurements in both gas and aerosol phases – Part 1	SP: 666-670 Gaston et al. (2014, ES&T) Riedel et al. (2016, ACP) Budisulistiorini et al. (2017, ES&T)	Surratt
F	***16***	***Nov***	***LAB Session 3: Isoprene SOA Generation in Indoor Smog Chamber (10 AM - 2 PM in MHRC 0016)***	***Lin et al. (2012, ES&T***	***Surratt & Chen***
T	20	Nov	Modeling of atmospheric organic aerosols	Kroll & Seinfeld (2008, Atmos. Environ.) Pye et al. (2015, ES&T)	Pye

H	***22***	***Nov***	***NO CLASS – Thanksgiving Holiday***		
T	27	Nov	SOA: Role of heterogeneous (or multiphase) chemistry in isoprene SOA formation – need for chemical measurements in both gas and aerosol phases – Part 2	SP: 666-670 Gaston et al. (2014, ES&T) Riedel et al. (2016, ACP) Budisulistiorini et al. (2017, ES&T)	Surratt
H	29	Nov	SOA: Role of viscosity and diffusion	Koop et al. (2010, PNAS)	Zhang
F	***30***	***Nov***	***Lab Session 3: SOA Chemical Characterization of Indoor Chamber-Generated Isoprene SOA Sample (10 AM – 2 PM in MHRC 0016)***	***Lin et al. (2012, ES&T***	***Surratt and Chen***
T	4	Dec	SOA: Importance of Cloud Water Chemistry	TBA	Turpin
F	7	Dec	***IN-CLASS FINAL EXAM - Aerosol Chemistry Section & Aerosol Chemistry Relevant Journal Article Presentations (Group 1)***		Surratt

Footnotes: SP = Seinfeld and Pandis textbook; H= Hinds textbook; TBA = to be announced.

Note about Class Schedule: The professor reserves the right to make changes to the syllabus, indicating project due dates and test dates, when unforeseen circumstances occur or we take longer than expected on certain subject matter. These changes will be announced as early as possible so that students can adjust their schedules.