Physics and Chemistry of the Atmosphere (II)

Tuesday & Thursday 9:30 am – 10:45 am, ATL 3426

Instructor:

Xin-Zhong Liang (xliang@umd.edu; 301-405-6300)

Office Hours: No formal set is posted; students may request appointments via email

Required Textbooks:

Atmospheric Science (*2nd Edition*), Academic Press, 2006
John M. Wallace and Peter V. Hobbs **[WH]**

Radiative Transfer in the Atmosphere and Ocean, Cambridge University Press, 2017
Knut Stamnes, Gary E. Thomas and Knut Stamnes **[STS]**

Recommended Textbooks:

Cloud Dynamics (2nd Edition), Academic Press, 2014
Robert A. Houze, Jr. **[RH]**

Theory of Atmospheric Radiative Transfer, Wiley-VCH, 2012
Manfred Wendisch and Ping Yang **[WY]**

Lecture Material:

The material in this course is based on the textbooks and my review of many other books and papers. My lectures will focus on the key principles of the topics listed. The lecture notes will be available after each class: http://www.atmos.umd.edu/~xliang/aosc621/.

Course Description:

This is a comprehensive course designed to help students in mastering the fundamental principles, quantitative analysis, and numerical modeling of atmospheric radiation, cloud physics, and chemistry. Topics include solar and terrestrial radiative transfer processes, specifically absorption, scattering and emission through interactions with atmospheric constituents (gases, aerosols, clouds), cloud microphysics, and the Earth's surface, as well as how radiation drives atmospheric chemistry and climate dynamics.

Prerequisites:

MATH 462 – Partial Differential Equations for Scientists and Engineers

AOSC 620 – Physics and Chemistry of the Atmosphere (I)

Grade:

Your final grade will be based on your performance on homework (30%), two in-class exams (20% each), and a final exam (30%). These evaluations will involve both physical process understanding and quantitative problem solving.

Course Topics:

Solar and terrestrial radiation spectroscopy, radiative transfer processes in the atmosphere (emission, scattering, absorption), basic radiation laws, radiative transfer equations, spectral properties of atmospheric constituents, radiative effects of gases, aerosols and clouds, solution of radiation problems, warm and cold cloud microphysical processes (nucleation, diffusion, collection), particle size distribution, fallspeed, collision, breakup, and sedimentation, warm and cold precipitation, Earth radiation budget, radiation effects on climate, photochemistry and photolysis rate, human perturbations and climate change, climate sensitivity, feedback processes, prediction uncertainty, radar meteorology.

Tentative Course Schedule

The schedule below gives a tentative overview of the topics this course will cover along with the homework assignment set and due dates. It may be subject to changes as appropriate. Please see my class website for update.

Class	Date	Topic Covered	Text Reading	Homework
1.	01/26	Atmospheric composition, radiative equilibrium, thermal structure	STS:1-22	
2.	01/28	Cloud formation: cloud type, droplet growth, condensation, collision-coalescence, Bergeron process, cloud condensation nuclei, cloud drop terminal velocity – an overview	WH:209-232	
3.	02/02	Warm cloud microphysics: homogeneous and heterogeneous nucleation, growth of droplets by condensation and diffusion	RH:47-50 Rodgers & Yau:99-119	HW1 set
4.	02/04	Warm rain: CCN population, raindrop growth by continuous and stochastic collection, turbulence and mixing, radiative broadening, giant CCN, and drop breakup	RH:51-54 Lamb & Verlinde:433-454	
5.	02/09	Cold cloud microphysics: ice nucleation – homogeneous, heterogeneous, deposition, and contact; ice nuclei and action modes; crystal growth – deposition, sublimation, aggregation riming; hail formation, melting, fallspeed	RH:54-65 Lamb & Verlinde:307-313 369-413 472-477	
6.	02/11	Cold rain: precipitation growth processes – cold cloud particle growth, glaciation, mass conversion, ice multiplication, stratiform and convective clouds	Lamb & Verlinde:457-471	HW1 due HW2 set
7.	02/16	Microphysics modeling (1): bin and bulk parameterizations, particle size distribution, spectral bin microphysics, microphysical method of moments, PSD observed and parameterized, cloud particle collision, bulk autoconversion, sedimentation	Khain et al. (2015) review Tao @ NASA Morrison @ NCAR	
8.	02/18	Microphysics modeling (2): bin and bulk prognostic schemes of warm and cold clouds	RH:65-76 Morrrison	
9.	02/23	**Review for First Exam**		HW2 due
10.	02/25	**First Exam**		
11.	03/02	Radiation quality and quantity: wavelength, frequency, polarization, density, radiance, irradiance, emittance, brightness, actinic flux	STS:37-50	HW3 set

12.	03/04	Radiative transfer principles: Planck law, Kirchhoff law, Stefan-Boltzmann law, Earth's surface emission, solar insolation	STS:97-102 148-151 167-168	
13.	03/09	Radiation extinction and scattering: Extinction law, Lorentz theory, differential RTE, single / Rayleigh / Mie scattering	STS:50-58 59-73 78-87	
14.	03/11	Radar Meteorology: basic principles, range equation, Doppler effect, dBZ, refraction		HW3 due
		Enjoy Spring Break (March 14 to 21)		
15.	03/23	Radiation absorption by atmospheric gases, photon-molecular interactions, absorption or emission lines and bands	STS:89-97 114-115	
16.	03/25	Greenhouse effect, spectroscopy, absorption line strengths, molecular energy transitions, line broadening, major absorption bands	STS:116-129 73-78	HW4 set
17.	03/30	Atmospheric photochemistry: photolysis frequency and rate, photochemistry of O_2 and O_3, chemical kinetics and lifetime	SP:114-151 75-93	
18.	04/01	Radiative transfer equation, transmission in slab geometry, solution including scattering and emission, radiative heating rate	STS:168-181 280-298	
19.	04/06	Formulation of radiative transfer problems: direct and diffuse radiation, phase function, azimuthal dependence, delta approximations	STS:186-214	HW4 due
20.	04/08	**Review for Second Exam**		
21.	04/13	**Second Exam**		
22.	04/15	Prototype radiative transfer problems: boundary conditions, single scattering approximation, successive orders of scattering	STS:215-221 227-234	
23.	04/20	Two-stream approximations for isotropic and anisotropic scattering, Eddington method	STS:234-268	HW5 set
24.	04/22	Optical properties of clouds	STS:422-426	
25.	04/27	Cloud-aerosol-radiation interactions	STS:322-335	
26.	04/29	Radiative forcing, climate response	AR4: 94-127	HW5 due
27.	05/04	Climate sensitivity, radiative-convective equilibrium	STS:22-26 302-322	
28.	05/06	Earth radiation budget, cloud radiative effect, climate feedbacks, climate change uncertainty		
29.	05/11	**Review for Final Exam**		
	05/14	**Final Exam,** 08:00 am-10:00 am		