ATMOSPHERIC RADIATIVE TRANSFER – Fall 2009

EAS 8803

Instructor: Prof. Irina N. Sokolik

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Meeting Time: Tuesdays/Thursday: 1:35-2:55 PM

Meeting place: L1175

Office hours: by appointment

What this course is about

The atmospheric radiative transfer is central to understanding the workings of the Earth's climate system. This course covers the physical principles, quantitative analysis, and numerical modeling of atmospheric radiation and its interaction with atmospheric constituents (gases, aerosol, and clouds) and the land and ocean surfaces. The topics to be covered include the radiative balance at the surface, radiative forcing at the top of the atmosphere, radiative heating/cooling rates and their role in the atmospheric dynamics and thermodynamics, actinic fluxes, PAR, methods for solving the one- and three-dimensional radiative transfer, radiation codes in regional and global atmospheric dynamical models, among others.

Prerequisites: EAS Remote Sensing classes or prior experience in radiative transfer are required. This is an advanced graduate level course.

How this course is organized:

- **Lectures:**

Lectures are developed to provide the most critical material and to complement a class textbook. Lecture notes will be posted (in PDF format) at the course website: http://irina.eas.gatech.edu/irina/EAS8803_Fall2009/

!!!! Please review lecture materials before coming to the class.

- **Homework assignments**

will include problem solutions, radiative transfer numerical modeling, radiation data analysis, and literature review.

- **Class research project**

The goal will be to perform the radiative transfer modeling and interpretation of the results in a well-defined problem. This will involve learning how to run a radiative transfer code selected for the project. Class project presentation is required at the end of the term.

- **Exams:**

Two midterm exams, but no final exam.

- **Grading:**

Mid-term exams (2)	30%
Homeworks/Numerical RT modeling	40%
Research Project	30%

Required Text:

K.N. Liou *An Introduction to Atmospheric Radiation*, 2002 (Second Edition).

Additional Text:

Radiation and cloud processes in the atmosphere. K.N. Liou, 1992

Atmospheric Radiation: *Theoretical basis.* R.M. Goody and Y. L. Yung, 1989

Radiative Transfer in the Atmosphere and Ocean. G. E. Thomas and K. Stamnes, 1999.

Absorption and Scattering of Light by Small Particles. C. Bohren and D. Huffman, 1983.

Atmospheric transmission, Emission, and Scattering. Kyle, 1991.

COURSE OUTLINE

1. The role of atmospheric radiation in the Earth's energy budget, atmospheric dynamics and thermodynamics, and photochemistry.
2. The nature of solar and thermal IR atmospheric radiation. Concepts of scattering, absorption, and emission.
3. Basic radiometric quantities. Main radiation laws. Blackbody radiation.
4. Sun as an energy source. Solar spectrum and solar constant.
5. Gaseous absorption and emission. Concepts of a spectral line and a band. Band models. Absorption by atmospheric gases in IR, visible, and UV regions.
6. Interaction of electromagnetic radiation with aerosol and cloud particles. Single-scattering by spherical and non-spherical particles. The nature of light absorption by particulate matter. Lorenz-Mie theory.
7. Fundamentals of the thermal IR radiative transfer. Line-by-line approach. Correlated K-distribution approximation.
8. Principles of multiple scattering. Methods for solving the radiative transfer equation with multiple scattering and absorption (Two-stream and Eddington's approximations, Discrete-ordinates method, Adding method, Monte Carlo). Radiative transfer with polarization.
9. Earth's energy balance. Direct and indirect radiative forcings. Radiation budget at the surface. Radiative feedbacks.
10. Radiative heating and cooling rates and their role in the atmospheric dynamics and thermodynamics.
11. Actinic fluxes. Basics of photochemistry.
12. Photosynthetic active radiation (PAR) and its role in the climate system.
13. Radiation codes in regional and global atmospheric dynamical models.

Tentative Schedule for Fall 2009

Date			Required Reading
18-Aug	Lecture 1	Introduction&Logistics. Basics radiometric quantities.	L02: 1.1
20-Aug	Lecture 2	The Beer-Bouguer-Lambert law. Concepts of scattering, absorption, and emission. The "simple" radiative transfer equation.	L02: 1.1, 1.4
25-Aug	Lecture 3	Blackbody radiation. Main laws. Sun as an energy source. Solar spectrum and solar constant.	L02: 1.2, 1.4.3, 2 Appendix A
27-Aug	Lecture 4	Composition and structure of the atmosphere. Basic properties of radiatively active species.	L02: 3.1, 5.1 pp.169-176
1-Sep	Lecture 5	Gaseous absorption/emission: Concepts of a spectral line and a band. Line shapes. Absorption coefficient and transmittance.	L02: 1.3
3-Sep	Lecture 6	Absorption by atmospheric gases in the IR, visible and UV. HITRAN spectroscopic database.	L02: 4.2.1, 3.2
8-Sep	Lecture 7	Terrestrial infrared radiative transfer. Part 1: Fundamentals of thermal IR radiative transfer. Line-by-line method.	L02: 4.2.1-4.2.3
10-Sep	Lecture 8	Terrestrial infrared radiative transfer. Part 2: K-distribution approximations.	L02: 4.3
15-Sep	Lecture 9	IR radiative transfer modeling.	
17-Sep	Lecture 10	Terrestrial infrared radiative transfer. Part 3: Gaseous absorption/emission: Band models. Curtis-Godson Approximation.	L02: 4.4
22-Sep	Lecture 11	Terrestrial infrared radiative transfer. Part 4: IR radiative cooling rates.	L02: 4.2.2,4.5-4.7
24-Sep	Lecture 12	IR radiative transfer modeling.	
29-Sep	Lecture 13	Review for Exam 1: IR radiative transfer	
1-Oct		Mid-term Exam 1	
6-Oct		Fall Break	
8-Oct	Lecture 14	Scattering. Part 1: Main concepts. Stokes matrix. Polarization. Scattering by gases.	L02: 1.1.4, 3.3.1
13-Oct	Lecture 15	Scattering. Part 2: Scattering and absorption by an ensemble of spherical particles.	L02: 5.2, 3.3.2

15-Oct	Lecture 16	Scattering. Part 3: Scattering and absorption by nonspherical particles.	L02: 5.3, 5.5
20-Oct	Lecture 17	Optical modeling.	
22-Oct	Lecture 18	Principles of multiple scattering in the atmosphere. Radiative transfer equation with multiple scattering in a plane-parallel atmosphere.	L02: 3.4, 6.1
27-Oct	Lecture 19	Methods for solving the radiative transfer equation with multiple scattering. Part 1. Streams approximations.	L02: 6.3.1, 6.5
29-Oct	Lecture 20	Methods for solving the radiative transfer equation with multiple scattering. Part 2. Inclusion of surface reflection and emissivity.	L02: 6.3.5
3-Nov	Lecture 21	Methods for solving the radiative transfer equation with multiple scattering. Part 3. "Exact" methods (Discrete-ordinate, Adding and Monte Carlo methods).	L02: 6.2. 6.3.1-6.3.4, 6.4, 6.7
5-Nov	Lecture 22	Net (total) radiative heating/cooling rates.	L02: 3.5, 4.5.2, 4.6.1, 4.6.2, 4.7, 8.2.4
10-Nov	Lecture 23	RT modeling with multiple scattering.	
12-Nov	Lecture 24	Radiation and climate. Part 1. Radiative transfer codes in GCMs and NWPs.	L02: 8.1,8.3, 8.5, 8.6
17-Nov	Lecture 25	Radiation and climate. Part 2. Direct and indirect radiative forcing.	L02: 8.4, 8.6.3
19-Nov	Lecture 26	Class project presentation	
24-Nov	Lecture 27	Class project presentation	
26-Nov		NO CLASS: Thanksgiving	
1-Dec	Lecture 28	Review for Exam 2.	
3-Dec		Mid-term Exam 2	

Reading:
L02: Liou, An introduction to atmospheric radiation, 2002 (Second Edition).