GEOL515: Introduction to Atmospheric Science

Department of Earth Sciences, University of Southern California

Introduction

This graduate-level course will introduce students to the basic workings of the atmospheric environment. After introducing the relevant space and time scales, the class will introduce the basic thermodynamics, radiation theory, cloud microphysics and fluid dynamics to enable a description and understanding of the elementary structure and circulation of the atmosphere, and its central role in Earth's surface systems.

Instructor: Prof. Julien Emile-Geay (julieneg@usc.edu). 213 740 2945

Dates: Fall semester, 2010.

Class meeting times: *Mon - Wed* 1:30pm – 3 pm (lecture)

Location ZHS 200

Recommended Preparation Multivariate calculus, ordinary differential equations. Basic thermodyamics and mechanics.

Units 3

Objectives and approach

The objective of this graduate class is to provide students with the tools to understand basic atmospheric phenomena like weather systems, clouds, turbulence, greenhouse effect, the Hadley circulation, planetary waves, and tropical cyclones. The class is aimed at entry-level graduate students in science and engineering with prior exposure to basic thermodynamics, mechanics and differential calculus. It will serve as a building block for every student in the climate science program, paving the way for more advanced topics in atmospheric and climate dynamics. With instructor permission, the class is also open to undergraduate students who demonstrate prior knowledge of recommended preparation materials. Learning outcomes include: fundamentals of atmospheric radiation (absorption and scattering), planetary energy balance, greenhouse effect, large-scale dynamical balances, solving linear wave and instability problems. The approach is to lay out the fundamental physical principles underpinning our understanding of the atmosphere, work out traditional approximations, and end with some applications to real-world problems like meteorological forecasting, the physics of global warming, and the Ozone hole.

Course Requirements and Grades

Required reading:

Wallace, J.M. and Hobbs, P.V. *Atmospheric Science : An Introductory Survey* (2nd ed) Academic Press, 2006

Grading: Mid term exam 25% Final Exam 25%
Homework (4 problem sets) 40%;
Class Participation: 10%

Expectations of participation include: involvement in class discussions, solving in-class problems on the blackboard.

Syllabus (Fall 2010)

Introduction

Week 1 (Aug 23 - Aug 27)
Atmospheric length and time scales, chemical composition, thermal structure and nomenclature. Ideal gas law, first principle of thermodynamics, hydrostatic equilibrium. Scale height. Pressure coordinates.
Reading: Salby, chap 1.

Thermodynamics I

Week 2 (Aug 30 - Sep 3)
Second principle of thermodynamics, potential temperature. Static Stability. Brunt-Väisälä frequency. Thermodynamics of moist air. Phase changes. Clausius-Clapeyron relation.
Reading: Salby, Chap 2

Thermodynamics II

Week 3 (Sep 6 - Sep 10)
Equivalent potential temperature. Virtual temperature. Conditional static instability. Moist and dry convection.
Reading: Salby, Chap 2 (no class Sept 6, labor day)

Radiation I

Week 4 (Sep 13 - Sep 17)
Nature of electromagnetic radiation, blackbody radiation, Planck's law. Wien's displacement law. Stefan-Boltzman Law. Molecular Absorption.
Reading: Salby, Chap 3

Radiation II

Week 5 (Sep 20 - Sept 24)
Pressure and Lorentz broadening of spectral lines. Rayleigh and Mie scattering, Radiative transfer. Greenhouse Effect.
Reading: Salby, Chap 3

Radiation III

Week 6 (Sept 27 - Oct 1st)
Radiative-Convective Equilibrium. Albedo. Basic climate feedbacks (water-vapor feedback, ice-albedo feedback).
Global Energy Balance. Requirement for lateral heat transport.
Reading: Salby, Chap 4

Midterm

Week 7 (Oct 4 8)
Monday : review. Wednesday : Exam.

Cloud Physics

Week 8 (Oct 11- 15)
Collisional growth of droplets. Precipitation. Ice phase microphysics. Cloud structural types, cumulus dynamics. Cloud feedbacks.
Reading: Salby, Chap 9

Dynamics I	Week 9 (Oct 18- 22) Elementary fluid dynamics. Conservation laws: Continuity Equation; Navier Stokes Equation, Heat equation. *Reading*: Salby, Chap 5
Dynamics II	Week 10 (Oct 25-29) Rotating reference frames. Coriolis acceleration. Scale analysis. Rossby number. Gradient wind relation. Geostrophic/cyclostrophic equilibrium. *Reading*: Salby, Chap 5
Dynamics III	Week 11 (Nov 1- 5) Thermal Wind Balance. Jet streams. Buys-Ballot relation. Friction and dissipation. Notion of turbulence. Elementary Boundary Layer theory. Angular momentum conserving solution. Hadley circulation. *Reading*: Salby, Chap 6
Dynamics IV	Week 12 (Nov 8- 12) Waves in the atmosphere; gravity and Rossby waves. Equatorial Waves. *Reading*: Salby, Chap 8
Applications I	Week 13 (Nov 15 19) Instability theory : Baroclinic and Barotropic Instability . Macroturbulence. Ferrel Circulation. Global Heat Transport. *Reading*: Salby, Chap 12
Applications II	Week 14 (Nov 22) Tropical Cyclones. Carnot Cycle. Radial coordinates. No class Nov 24. *Reading*: Kerry Emanuel notes, chapter 7
Applications III	Week 15 (Nov 29 Dec 3) Ozone photochemistry. Stratospheric Ozone, Ozone Hole (notions) Numerical weather prediction. Climate Modeling. *Reading*: Salby, Chap 10
Final	Week 16 (Dec 10 15) Review. Final Exam

Statement for Students with Disabilities

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

Statement on Academic Integrity

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. *Scampus,* the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: http://www.usc.edu/dept/publications/SCAMPUS/gov/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/.

Synopsis

(25 words for USC Catalogue): Elementary physical principles underlying the behavior of Earth's atmosphere. Dry and moist thermodynamics, radiative transfer, conservation laws, fundamental dynamical balances, instability theory, cloud physics.