General Information

Where/When Class meet Tues/Thurs, 11:00–12:20pm in ZHS 200.

Instructors Professor: Julien Emile-Geay ZHS 275. email: julieneg@usc.edu

Office Hours Mon - Thurs 2 - 3 pm or by appointment in ZHS 275.

Preparation Multivariate calculus, ordinary differential equations. Basic thermodynamics and mechanics.

Overview

Objectives 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 thermodynamics, radiation, absorption and scattering, greenhouse effect, large-scale dynamical balances. Distribution of mass, enthalpy, entropy and momentum will be explained in an internally consistent framework. We will 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, anthropogenic global warming, and the Ozone hole.

Grade

The class will earn you 3 units. I do not believe in curving grades; if everybody gets an A, I’ll pop some bubbly.
Rules
There are few rules for this course, but all are important. First, read the assigned readings before you come to class. Second, turn everything in on time. Third, ask questions when you don’t understand things; chances are you’re not alone. Fourth, don’t miss class.

Late Work
With assignments due virtually every week of the term, it’s easy to fall behind. While it may seem desirable to take extra time to deepen your understanding of a subject, this will have a domino effect on subsequent assignments. As a result, homework assignments are due on time. A 5 points penalty for every late day will be assessed.

Reading

Class notes
The notes are a work in progress, and will highly benefit from your careful reading. Submitting comments, pointing out typos, asking questions about them (whether in class or via real or electronic interaction) will all count for class participation. The notes and other relevant material will be posted each week on BlackBoard.

Books
The notes being necessarily partial, many of you will want to explore some subjects more deeply, so here is a short (non-exhaustive) list of useful books.

Recommended Book

Relevant books
- Cushman-Roisin, B. & Beckers, J.M., Introduction to Geophysical Fluid Dynamics, Academic Press, 2011, URL. The previous edition was a classic that introduced GFD notions in an intuitive and luminous way. This one is more complete, but I have not read it in depth.
- Salby, M.L., Physics of the Atmosphere and Climate, Cambridge University Press, 2012. URL. Expanded edition of an earlier – excellent – text, after Dr Salby lost his marbles and became a climate denialist. The fundamental atmospheric physics are treated very well, but the climate part is fanciful at best, misleading at worst.

Advanced Books
- Vallis, G.K. Atmospheric and Oceanic Fluid Dynamics, Cambridge University Press, 2006, URL. The new bible on the dynamics of atmospheres and oceans, treating both in a very cohesive framework.
SCHEDULE

I  Atmospheric Thermodynamics

Week 1 — August 20— Scales, Mass, Pressure
Tuesday: Atmospheric length and time scales, chemical composition, thermal structure and nomenclature. Gravity and Geopotential.
Read: W&H chap 1,2. Sections 3.1 to 3.2

Week 2 — August 27— First Law and consequences
Tuesday: First principle of thermodynamics, Enthalpy. Lapse rate.
Read: W&H sec 3.3, 3.4, 3.6

Week 3 — September 3— Stability and Entropy
Read: W&H chap 3.7

Week 4 — September 10—Moist thermodynamics
Tuesday: Phase changes. Clausius-Clapeyron relation. Virtual temperature.
Read: W&H chap 3.5 and 3.6.

II  Atmospheric Radiation

Week 5 — September 17—Radiation Basics
Read: W&H, Chap 4.1 - 4.4. Problem set 1 due
Week 6 — September 24— Radiation Continued
Tuesday: Pressure and Lorentz broadening of spectral lines. Rayleigh and Mie scattering
Thursday: Radiative transfer in planetary atmospheres. Schwartzchild’s Equation.
Read: W&H, Chap 4.4 - 4.5

Week 7 — October 1— Energy Balance
Read: W&H, Chap 4.6. Problem set 2 due

III Cloud Microphysics
Week 8 — October 8— Cloud Microphysics I
Tuesday: MIDTERM EXAM
Read: W&H, sec 6.1

Week 9 — October 15— Cloud Microphysics II
Thursday: Cold Cloud Processes: Ice phase microphysics.
Read: W&H, sec 6.2, 6.4, 6.5

IV Atmospheric Dynamics
Week 10 — October 22— Dynamics I
Tuesday: Cumulus dynamics. Cloud feedbacks.
Thursday: Elementary fluid dynamics. Eulerian vs Lagragian Descriptions. Kinematics. Vorticity and divergence

Week 11 — October 29— Fundamental Laws
Tuesday: Conservation laws: Continuity Equation; Navier Stokes Equation, Heat equation.
Read: W&H, 7.2 7.3. Problem set 3 due
Week 12 — November 5— Dynamical Balances & Approximations
Read: W&H, 7.3 9.1

Week 13 — November 12— Global Heat Transport
Tuesday: Angular momentum conserving solution. Hadley circulation.
Thursday: Baroclinic Instability. Eady solution. Eddy-driven circulation (Ferrel Cell)
Read: W&H, 7.3 9.1

THANKSGIVING BREAK : November 21 – 25

Applications

Week 14 — November 19— Applications I
Tuesday: Numerical weather prediction. Climate Modeling.
Thursday: Ozone photochemistry. Stratospheric & tropospheric Ozone.
Read: W&H Sec 7.5 & 5.7. Problem set 4 due.

Week 15 — November 26— Applications II
Tuesday: Atmospheric energetics
Thursday: Review
Read: everything
FINA L (Dec 11, 8-10am as per http://classes.usc.edu/term-20183/finals/)