GEOL 515: Elements of Atmospheric Science

Julien Emile-Geay

Fall 2020

General Information

Where/When Class meets Tues/Thurs, 10:00–11:20pm on Zoom.

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

Office Hours Zoom, by appointment.

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

Connectivity The course will employ a flipped classroom model, with students expected to have read all course materials before lectures.

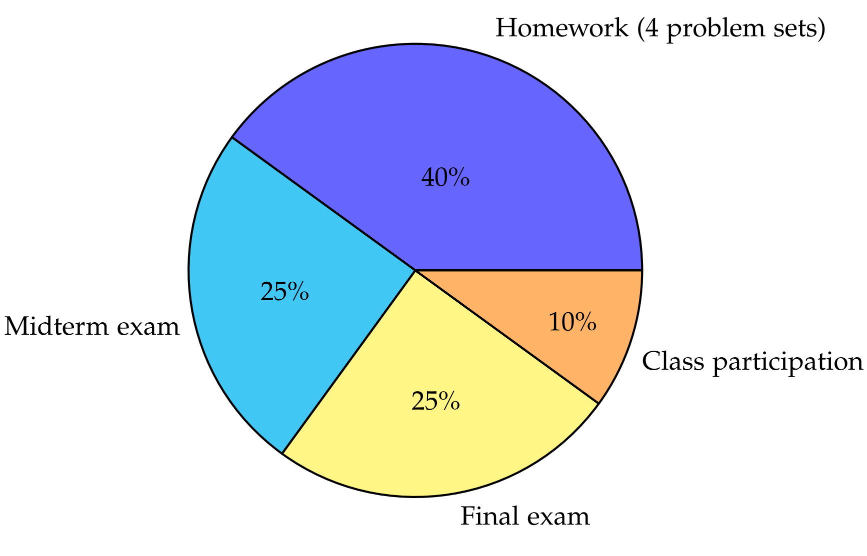
Blackboard: announcements, assignments, course materials, link to lectures.
Access at `https://blackboard.usc.edu`.

Zoom: live lectures, recorded and posted within the day. link.

Slack: there is an (optional) Slack channel in the USC Dornsife workspace. This may be used for asynchronous discussions with everyone in the class, at your discretion. You may find it a useful way to keep in touch with classmates or work through problem sets together.

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

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
Wallace & Hobbs, Atmospheric Science, Second Edition: An Introductory Survey , Academic Press, 1997. URL. *Ultimate classic, appropriate for undergraduates but actually rather complete.*

Relevant books

– Andrews, D.G., An Introduction to Atmospheric Physics, Cambridge University Press, 2010. URL. *Nice and compact book with fundamentals of physics and dynamics. More arduous than W&H, and fewer exercises.*

– 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

– Gill, A.E. Atmosphere-Ocean Dynamics, (International Geophysics Series, Volume 30), 1982, URL. *A classic on tropical dynamics, mostly written from a linear waves perspective*.

– 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 17— Scales, Mass, Pressure

Tuesday: Atmospheric length and time scales, chemical composition, thermal structure and nomenclature. Gravity and Geopotential.

Thursday: Mass distribution of planetary atmospheres. Pressure. Ideal gas law. Hydrostatic equilibrium. Hypsometry. Vertical coordinates

Read: W&H chap 1,2. Sections 3.1 to 3.2

Week 2 — August 24— First Law and consequences

Tuesday: First principle of thermodynamics, Enthalpy. Lapse rate. Potential temperature. Dry Static Energy.

Thursday: Static Stability. Brunt-Väisälä frequency. Dry convection.

Read: W&H sec 3.3, 3.4, 3.6

Week 3 — August 31— Entropy & Phase changes

Tuesday: Second principle of thermodynamics, Carnot Cycle. Entropy.

Thursday: Phase changes. Clausius-Clapeyron relation. Virtual temperature.

Read: W&H chap 3.7

Week 4 — September 7—Moist thermodynamics

Tuesday: Moist Static Energy. Equivalent potential temperature. Conditional static instability.

Thursday: Moist convection. Review.

Read: W&H chap 3.5 and 3.6.

II Atmospheric Radiation

Week 5 — September 14—Radiation Basics

Tuesday: Nature of electromagnetic radiation, blackbody radiation. Planck's law. Wien's displacement law. Stefan-Boltzman Law.

Thursday: Molecular Absorption. Beer-Lambert's Law. Absorption bands and windows.

Read: W&H, Chap 4.1 - 4.4. Problem set 1 due

Week 6 — September 21— 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 — September 28— Energy Balance

Tuesday: Top-of-the-atmosphere Energy Balance. Greenhouse Effect. Radiative equilibrium.

Thursday: Surface energy balance. Surface Heat Fluxes. Radiative-Convective Equilibrium.

Read: W&H, Chap 4.6. Problem set 2 due

III Cloud Microphysics

Week 8 — October 5— Cloud Microphysics I

Tuesday: MIDTERM EXAM

Thursday: Cloud structural types. Condensation of water vapor & homogenous nucleation.

Week 9 — October 12— Cloud Microphysics II

Tuesday: Warm Cloud Processes: Heterogeneous nucleation. Collisional & Coalescence.

Thursday: Cold Cloud Processes: Ice phase microphysics.

Read: W&H, sec 6.1 – 6.5

IV Atmospheric Dynamics

Week 10 — October 19— Clouds & Dynamics

Tuesday: Cumulus dynamics. Cloud feedbacks.

Thursday: Elementary fluid dynamics. Eulerian vs Lagragian Descriptions. Kinematics. Vorticity and divergence

Read: W&H, Chap 6.3, 7.1.

Week 11 — October 26— Fundamental Laws of motion

Tuesday: Elementary fluid dynamics. Eulerian vs Lagragian Descriptions. Kinematics. Vorticity and divergence

Thursday: Conservation laws: Continuity Equation; Navier Stokes Equation, Heat equation.

Read: W&H, Chap 7.1, 7.2 ; Problem set 3 due

Week 12 — November 2— Rotation

Tuesday: Rotating reference frames. Coriolis acceleration. Rossby number.

Thursday: Prevailing balances. Scale analysis. Geostrophy.

Read: W&H, 7.2 7.3.

Week 13 — November 9— Midlatitude Circulation

Tuesday: Gradient and Thermal Wind Balances. Jet streams.

Thursday: Baroclinic Instability. Eddy-driven circulation

Read: W&H, 7.3 9.1

Week 14 — November 16— General Circulation

Tuesday: Angular momentum conserving solution. Hadley circulation.

Read: W&H, 7.3 9.1 .

Problem set 4 due.

Final on Nov 23, 10:00–11:20 as per https://classes.usc.edu/term-20203/finals/.