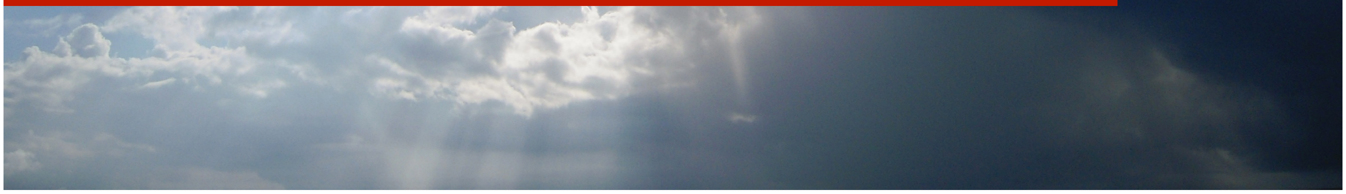
Spring 2020

Atmospheric Dynamics (MATH-GA 3004)



Tuesday 1:25 pm to 3:15 pm, Warren Weaver Hall 512

Instructor

Edwin Gerber
gerber@cims.nyu.edu (e-mail is the best way to reach me)
WWH 911, Office hours Tuesday 3:30-4:30 and Wednesday 2:30-3:30

Course Description

What effects the large scale circulation of the atmosphere? Like the antiquated heating system of a New York apartment, solar radiation unevenly warms the Earth, leading to gradients in energy in both altitude and latitude. But unlike the simple convection of air in your drafty home, the effects of rotation, stratification, and moisture lead to exotic variations in weather and climate, giving us something to chat about over morning coffee ... and occasionally bringing modern life to a standstill.

The goals of this course are to describe and understand the processes that govern atmospheric fluid flow, from the Hadley cells of the tropical troposphere to the polar night jet of the extratropical stratosphere, and to prepare you for research in the climate sciences. Building on the foundation in Geophysical Fluid Dynamics, we will explore how stratification and rotation regulate the atmosphere's response to gradients in heat and moisture. Much of our work will be to explain the zonal mean circulation of the atmosphere, but in order to accomplish this we'll need to learn a great deal about deviations from the zonal mean: eddies and waves. It turns out that eddies and waves, planetary, synoptic (weather system size) and smaller in scale, are the primary drivers of the zonal mean circulation.

There will also be a significant numerical modeling component to the course. You will learn how to run atmospheric models on NYU's High Performance Computing facility, and then design and conduct experiments to test the theory developed in class for a final course project. A new focus this year is to make our science reproducible, learning best practices for future research.

Expectations

I hope that students will have taken a course on Geophysical Fluid Dynamics, or the equivalent, and so are already familiar with the equations of fluid flow appropriate for the Earth's atmosphere. If you haven't taken a course on this subject, you will likely need to do a bit of catch up work — we will be using reduced equations (e.g. the quasi-geostrophic or primitive equations, as opposed to the full blown Naviers-Stokes equations in rotating frame), and I will assume that you're familiar with the assumptions behind their derivation, and their limitations. If you are concerned, please contact me individually and we can discuss your background.

In terms of the course itself, I look forward to seeing you in all the lectures! If you can't make it, please e-mail me in advance if at all possible. Do the homework; it will solidify the lectures. Work together; you'll learn more as a group. Ask questions, both of me and your fellow classmates!

Your grade will be based on a final project. You'll be expected to present them in a short, conference style talk. While solid results are certainly the most important requisite for a successful research career, as with most things in life, the packaging matters, so it's important to learn good communication and presentation skills!

Recommended Textbook

Vallis, Geoffrey K., 2017, *Atmospheric and Oceanic Fluid Dynamics: Fundamentals and Large-Scale Circulation* (Second Edition), Cambridge University Press, 946 pp.

(We can work with the 2006 version if you have already purchased it.)

Additional Resources (for background and context)

Lorenz, Edward 1967, *The Nature and Theory of the General Circulation of the Atmosphere*, World Meteorological Organization, 161 pp. (find it on course page)

Marshall, John and R. Alan Plumb 2008, *Atmosphere, Ocean, and Climate Dynamics: An Introductory Text*, Academic Press, 319 pp.

Walker, Gabrielle, 2007, *An Ocean of Air*, Houghton Mifflin Harcourt, 288 pp.

Topics for the Semester

Why is Earth Habitable? (And will it remain so?) *0-Dimensional Climate Models*
- Energy balance and global warming
- Devil in the details: why weather matters for climate

What sets the vertical structure of the atmosphere? *1-D atmospheric models*
- Dry and moist convection
- Finding the right variable(s): (Equivalent) potential temperature

What sets the latitudinal structure of our atmosphere? *The zonal mean circulation*
- Tropics: Axis-symmetric models of the Hadley Circulation
- Extratropics: Jets, Storm tracks, and the essential role of eddies

What can we say about the eddies, absent a computer? *Eddy-Mean Flow Interactions*
- The Transformed Eulerian Mean Equations
- Diffusive closures
- Revisiting the vertical structure of the atmosphere

Why is Madrid warmer than New York? *Longitudinal variations in the circulation*
- Stationary planetary waves
- The Stratospheric Circulation

Final Project

The goal is to design and conduct an experiment with an Atmospheric General Circulation Model to further explore material we've covered in the course, or illustrate another topic of the atmospheric circulation. In lieu of a written report, I ask you to (1) present the results of your study on the last day of class in a c. 15 minute oral presentation and (2) set up a python script (or set of scripts) that would allow me — or any other researcher — to exactly reproduce the figures in your presentation.

Part 2 is new for this semester. There is a growing movement in our field toward the open sharing of data and analysis methods. Suppose I wrote a paper and you wanted to build on my results. In the dark ages (i.e., the period I'm still inhabiting), you'd have to track me down to figure out what model code I was using, and then hope that you can get it to run on your own system. Assuming you got that far, then you would have to determine the integration parameters based on my paper and conduct the integrations. You made it that far? But alas, what about the figures in my paper. When you realize I never specified the details of the digital filter used in the process of developing Figure 3, you'd again have to hunt me down, at which time I'd start rummaging though my matlab directories to find the scripts, hoping that I could reproduce it myself.

Or, imagine if my paper had a citation to a repository which hosted both the model code a python scripts or two. Once you set up a minimal list of machine specific environmental parameters, the scripts would (i) set up and run the integrations in my paper and (ii) repeat the analysis that I did to make all of the figures.

That would be reproducible science.

I am not yet so enlightened, but aspire to this gold standard. Together, let's see how far we can get this semester…