Tuesday and Thursdays 3:30-4:45 pm, Warren Weaver Hall 517

Instructor

Edwin Gerber

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WWH 911, Office hours Friday 10:30-12:30 (or by appointment; just email me!)

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. 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.

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.

https://edwinpgerber.github.io/teaching/2026-spring-atmospheric-dynamics

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!

Textbooks (I will mix and match: do not buy them all!)

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

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

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

Wallace, John M, David S. Battisti, David W. J. Thompson, and Dennis L. Hartmann, 2023, *The Atmospheric General Circulation*, Cambridge University Press, 406 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
     Radiative Transfer
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. Given the size of the course this year, I suggest that we break into teams of about 3 students.

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.

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…