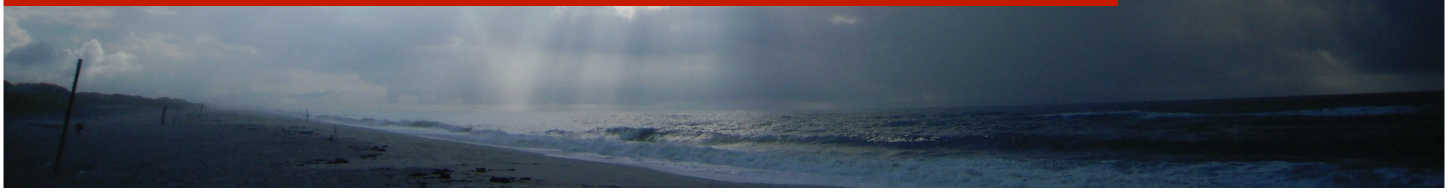
Spring 2021 **Climate Change (MATH-GA 3011)**



Thursday 9 to 10:50 am Eastern Time (New York) on Zoom

Instructor

Edwin Gerber
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Course Description

According to NASA, 2020 tied with 2016 as the warmest year ever recorded; NOAA had it losing out to 2016 by 0.02 degrees C. The last 7 years (2014-2020) are the 7 warmest years in recorded history. It is likely the hottest the Earth has ever been since the last interglacial period 125,000 years ago.

The first predictions of human induced global warming were made over a century ago, but the topic remains controversial despite the fact that the world has warmed 1 degree Celsius over the intervening years. In this course, we will investigate observational evidence as well as the physical and mathematical foundations upon which forecasts of future climate are based. What are the key uncertainties in the predictions, and what steps are required to reduce them? We will find that it is not the science of global warming that is controversial, but rather, what to do about it.

By reading through a mixture of historic and current studies, investigating key processes that affect the sensitivity of our planet to greenhouse gases, and exploring a hierarchy of climate models, this course will get you up to speed on the science of climate change. Grades will be based on a course project using a climate model to predict the impact of anthropogenic forcing on the Earth's climate. Particularly attention will be paid to establishing reproducible science and quantifying the uncertainty in your prediction.

Class Expectations

It is useful if you have some experience in atmospheric or climate science, but it is not required; the course will be self contained and allow flexibility in choosing a problem that is most interesting to you.

In terms of the course itself, I look forward to seeing you (virtually) in all the lectures. Please keep your camera on, so we can all see each other. If you can't make it, please e-mail me in advance if at all possible.

We'll be reading a lot of papers and I'll expect each of you to present parts of the work in turn throughout the course.

Your grade will be based on a final project. You'll be expected to present them in a short, conference style talk and turn in a Jupyter notebook (or something similar) that would allow others to reproduce your results.

Resources and Logistics

We'll be mostly reading papers and working with publicly available codes, all of which will be posted on our NYU Classes Page. Classes will also host our Zoom meetings.

For discussion, I had a good experience with Campuswire last year. It's basically a Slack/Microsoft Teams like forum, geared towards an academic class. I hope that we can use it to communicate and help each other out with the class projects.

You will need a NYU HPC account. Details to follow.

Course Plans

A tentative plan for the course is mapped out at the end of this syllabus. It revolves around three projects. We'll work together (or at least in parallel) on the first two. The final project will be your chance to pursue something that interest you.

Project I is to construct a relative simple 1-dimensional (in latitude) climate model, assuming a planet in radiative equilibrium. The goal is to see how the transport of heat by the atmosphere and ocean impact the global mean temperature, how ice-albedo feedback amplifies greenhouse gas perturbations, and explore the possibility of multiple equilibria.

Project 2 is another 1-dimensional climate model, but this time, in the vertical coordinate. This is is none as a "single column model of radiative equilibrium" in the field, and we'll use it to get a better understanding of how greenhouse gas increase causes global warming.

Project 3 is to run your own climate model projections. You get to pick the focus (climate sensitivity, precipitation changes, etc.) and the model(s). We'll use the publicly available Isca modeling framework, which offers you a suite of the different climate models to chose from.

Final Project

The goal is to design and conduct a climate change experiment with an Atmospheric General Circulation Model (AGCM) to further explore material we've covered in the course, or illustrate another topic of interest. 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 Jupyter notebook (and possibly a collection of other python scripts) that would ideally allow me — or any other researcher — to exactly reproduce model simulations and 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. Wow, you just reproduced my integrations?!? 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…

Tentative Course Schedule

Week	Topics
Jan 28	Introductions, goals, and a first (zero dimensional) climate model
Feb 4	History: Fourier (1827), Tyndall (1861), and Arrhenius (1896)
Feb 11	Project I: Energy balance models in one dimensional (latitude) and multiple equilibrium. Budyko (1969) and Sellers (1969)
Feb 17	**No class (a virtual winter break)**
Feb 25	Radiative Equilibrium: Manabe and Wetherald 1967
Mar 4	Radiation basics: Pierrehumbert, Chapter 3
Mar 11	More advanced radiative transfer: Pierrehumbert, Chapter 4
Mar 18	Project II: A single column climate model
Mar 25	Water vapor feedback (why would relative humidity stay constant?) Plus, an introduction to the Isca modeling framework.
Apr 1	Clouds and Aerosols (why climate modeling is hard)
April 8	CMIPs and AMIPs: Coupled/Atmospheric Model Intercomparison Projects
April 15	What to do about it: decarbonizing our world! Pacala and Socolow (2004)
April 22	How to do it? Collective action, not personal responsibility! Paris, and other agreements
April 29	The State of the Art: IPCC Assessment Report 6, WG1 Summary for Policy Makers, if available, and/or other CMIP6 results)
May 6	**Final Presentations (Project III)**