Geology 331 Climate Dynamics

Prof. Nick Holschuh

M/W/F 10:00-10:50, M 1:00-4:00

At the planetary scale, Earth's climate is simple. Earth's surface absorbs light energy from the sun, it radiates energy through the atmosphere back into space, and the balance of inputs and outputs sets our surface temperature. Thus, changes in solar radiation, atmospheric chemistry, and Earth's orbital configuration can explain the large-scale climate changes throughout Earth's history. But the details that matter to individual countries, cities, and communities are much more complicated. The atmosphere and ocean, engines driven by energy from the sun, work to distribute heat around the globe and drive regional variation. To understand the operation of the climate system, scientists use two complementary approaches: climate models, which rely on foundational principles of physics and modern observations to explain how energy flows through the Earth system; and the paleoclimate record, physical and chemical proxies, preserved in geologic materials, that tell the story of Earth's past.

In this class we will explore the processes that control both planetary and regional climate, identify the tools we use to understand climate change through time, and contextualize modern change using data sets derived from the geologic record. We will use our lab period to build skill with data analysis and visualization in Python, allowing hands-on experience working with the climate models and climate data policymakers use for our projections of future climate change. No prior Python experience is expected.

[Given the unpredictability of the semester, aspects of the syllabus are subject to change]

Course Textbooks (available for free, digitally):

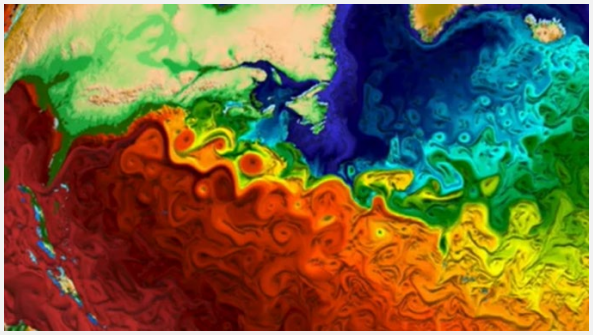
Randal, D. (2012). ***Atmosphere, Clouds, and Climate***. Princeton University Press (Library e-Book)
Vallis, R. (2012). ***Climate and the Oceans.*** Princeton University Press. (Library e-Book)
Bender, M. (2013). ***Paleoclimate.*** Princeton University Press. (Library e-Book)

Office Hours:

Monday (4:00-5:00 pm), Thursday (4:00-5:00 pm), or by appointment. Held in Beneski 311.

Classroom culture:

We continuously strive to be inclusive. Members of this class must recognize that we can all contribute in making our shared spaces welcoming, accessible, and affirming, and will not discriminate against others based on their identities or social and cultural backgrounds. We will do this by listening deeply, and by staying engaged and curious in other's perspectives, even during challenging conversations. If you feel like this community standard is not met, please feel free to reach out to me, the geology department chair (ammartini@amherst.edu), or the center for restorative practices.



*You probably each have a working definition of climate, but what is the climate **system**? What does it do, and how does that lead to the climates we experience? Do modern climate processes translate to all past climates?*

To answer these questions, we need to think about mass flow, energy flow, and the records of climate dynamics left behind in Earth materials.

Learning Objectives:

- Develop a working understanding of the organization of the climate system at different spatial (planetary, continental, local) and temporal scales.
- Build context for modern climate change using archives of past climate, to understand the difference in processes that governed past changes, those that govern modern changes, and those that will act to reshape the climate into the future.
- Make the math embedded in Earth science more approachable.
- Enable your independent visualization and interpretation of geospatial and time-series data.

Deliverable Overview:

- ***Readings and Pre-Labs:*** Weekly readings will be assigned, with the expectation that they are completed by Monday. Most weeks, this will include simple coding and reading comprehension questions for you to answer and submit via gradescope. This is meant to be a low stakes component of the class, mostly graded on completion.
- ***Labs:*** Labs are primarily focused on engaging with data through computational methods. These represent the bulk of your grade, and will be due weekly on Fridays. These, like your prelabs, will be mostly submitted through gradescope.
- ***Exams:*** There will be two exams ending the two major units. They are, designed to help you synthesize and apply your knowledge and will be administered in-person during the lab period.
- ***Final Project:*** You will be asked to provide a written report and video summary of expected climate change at a location of your choosing. This will include independent climate model interpretation using skills from the first half of the class (e.g., describing the changes in radiation balance, changes in precipitation, changes in wind speed and direction, and other relevant variables of interest). The deliverables include a 5 page paper + figures, and a 5 minute video summary, due at the time of our scheduled final.

Course Breakdown:

	Lecture Topics	*Lab*
Week 1	How might we think about climate (change) as a physicist?	"Visualizing" Code
Week 2	Energy from the sun	"Implementing" Code
Week 3	Clouds, Evaporation, and Precipitation	Turbulent Energy Flux
Week 4	Atmospheric Heat Transport	Geostrophic Balance
Week 5	Oceanic Heat Transport	Oceans + Sea Ice
Week 6	The Carbon Cycle	Atlantic Synthesis
	Spring Break	
Week 7	The Cryosphere + Feedbacks	Polar Amplification
Week 8	Atmosphere and Ocean Variability	Exam #1
Week 9	How might we think about climate (records) as a chemist?	Isotopes
Week 10	What happened when the sun was weaker?	Final Project Intro
Week 11*	What happened when ice took over?	-- *No Lab* --
Week 12	What happened when volcanoes ramped up CO2?	UMass Visit
Week 13	What happened when the orbit wobbled?	Ice Cores
Week 14*	What happens if we burn it all?	Exam #2

Grade Breakdown:

Reading + Pre Labs		Exam 1		Final Project
15%	40%	15%	15%	15%
	Labs		Exam 2	

Course Policies and Campus Resources:
Below are documented resources and policies that you can refer back to over the course of the semester. These are in place to standardize our practice, to make sure you all get equitable and fair treatment from me, and to make sure my expectations are as clear as possible. Don't hesitate to reach out if you have questions!

Late Homework Policy:
Please let me know in advance if there are circumstances that interfere with getting your labs turned in – I tend to be very flexible if you submit a request more than 48 hours ahead of the deadline. To request a late submission without penalty, please use this form. Otherwise, everyone has 2 automatic late passes, good for an extension until Monday, no questions asked. Work that is turned in late without talking to me and without using a pass will lose 10% for every calendar day it is late.

To ensure that late homework is received and your grade is updated, I require that you submit late assignments using this form. It can be very difficult to keep track of late assignments, so I do this to standardize the process, and to ensure that you get the credit you deserve for the work you submit.

Attendance Policy:
I want you to have a rich experience in this class, which is best done by having all of us show up and actively engage during the lecture period. To incentivize this, occasional in class activities will contribute to your participation grade. These cannot be made up after the fact, but can be waived for excused absences discussed with me in advance by email.

Disability Accommodation:
The office of Accessibility Services at Amherst College works hard to ensure equitable treatment for students by standardizing our accommodation practices. This process is designed to protect you, so that you are not forced to share personal or private information with your faculty in order to get the resources you need for success. To maintain that standard of care, please identify yourself to Accessibility Services if you need accommodation in this class, and I will make sure it is provided once communicated to me.

Code Development, Plagiarism, and Intellectual Responsibility:
This class is unique in the department -- it has a core focus on data analysis and visualization through scientific programming. I am the first to say that coding skills, for us, are a means to an end, and I support your use of online resources (stackoverflow, stackexchange, and even ChatGPT) to help you find solutions to coding problems. But what I don't support is *submitting solutions that you do not personally understand.* When using internet resources for code development, don't just copy and paste until something runs; ask yourselves, ask others, or ask me to help make sense of code before moving on.

In general, my role as a professor is to emphasize the expectations for scholarly work, and to set you up for success in the rest of your time here at Amherst and beyond. Much of your life's work will require creation – writing, calculating, presenting your own ideas. When you skip that act of creation here, you cheapen your own experience, and you leave me in a position where I can't tell what you've mastered yourself. You are encouraged to work together and share thoughts on assignments, but ultimately, *understanding* is something you each have to develop and demonstrate on your own. If you submit words or ideas that are either uncited or not your own, I cannot give you a grade for the associated assignment, and it will default to a zero.

Anyone can quote the internet -- leaving Amherst I want you to be critical of what you read, make connections and find consistency across multiple sources, and be able to distill your own insights about climate. Push yourself to do more, I know that you can!