EPS 50: The Fluid Earth
Fall 2023

Instructor: Marianna Linz (mlinz@seas.harvard.edu)

Teaching Fellows: Ariana Castillo (arianacastillo@fas.harvard.edu)
Jacob Bushey (jbushey@g.harvard.edu)

1st meeting: Wednesday September 6.

Time: Mondays and Wednesdays, 10:30-11:45 + lab/section

Location: GeoMuseum 102 Classroom, (1st floor of the Geology Museum Building)

Lab/Section: Tuesday time TBD

Office Hours: Marianna, Monday 1:30-2:30 PM MCZ 433G, Thursday 8-9 PM on Zoom, or by appointment. Ariana and Jacob TBD.

Textbook: This course has no required textbook. Some chapters from *Meteorology Today* (C. Donald Ahrens, Robert Henson) and *Oceanography, An Invitation to Marine Science* (Tom Garrison, Robert Ellis) or other readings are listed in connection to each lecture, but these readings are not required. Copies of these books are on reserve at Cabot Library. Another option is to purchase used editions of the individual books online, purchase or rent e-textbook versions, or use the 1-hour digital loan available through Hollis. Other selected readings will be available for download from the course website, including a few chapters of the textbook *Earth's Climate, Past and Future* (William Ruddiman).

Overview: EPS 50 gives an overview of the mechanisms governing the oceans, atmosphere, and cryosphere and how they have combined to enable the study of climates past, present, and future. The course includes lectures with active learning components, hands-on laboratory activities, problem sets, mid-term exams, and a final writing assignment.

Course Learning Outcomes & Objectives

Knowledge:

- *Explain blackbody radiation and how it is related to the Earth's energy balance*
- *Predict where rainfall occurs, given information about temperature, circulation, and moisture content of the atmosphere*
- *Explain the large-scale circulation of the atmosphere and ocean*
- *Explain the interaction between the large-scale atmospheric circulation and extreme events*
- *Calculate the solubility of inorganic carbon in seawater, and the equilibrium between atmospheric carbon dioxide and that of seawater*
- *Recognize the orbitally driven climate cycles, and differentiate them from both longer and shorter-term climate variability*

- *Understand controls on the geologic carbon cycle, and use them to explain why anthropogenic greenhouse gas increases cannot be part of the natural variation of the carbon cycle*
- *Describe the long and short-term changes in global mean temperatures and their correspondence to greenhouse gas levels*
- *Define grounded vs. floating glaciers, and explain the importance of the grounding line for controlling glacial stability*
- *Explain why ice mass loss does not cause a uniform change in global sea level*

Skills:

- *Apply basic physics and chemistry equations to applied science problems*
- *Conduct laboratory experiments to represent geophysical fluid dynamics*
- *Read a scientific paper and understand its major points*
- *Synthesize a variety of perspectives to approach a complex topic*

Administrative

Requirements: The course consists of 2.5 hours per week of lecture, 2 hours per week of laboratory or 1 hour of section with associated lab write-ups or problem sets, 2 mid-term exams, each 1.25 hours long, and a final project. There is no 3-hr final exam. *Attendance at lectures and sections is required unless you have a valid reason*, and this should be discussed with the instructors as soon as possible. *During (on average) one of the two lectures each week, an introductory quiz will be given, and this will be graded primarily on completion and make up a substantial component of your participation grade.* All lectures will be on Zoom if you are ill and recorded and posted after class for re-review or for absent students, but this is not license to not attend lecture for students who are able to attend in person.

Prerequisites: This is an introductory course designed to be accessible to all students interested in the Earth Sciences. Background including introductory physics and chemistry at the high school or college level is helpful, but the relevant concepts will be covered in lectures and labs.

Grading: Based on participation (including weekly quizzes) (15%), problem sets and lab reports (30%), the exams (40%), and the final project (15%).

Late Work: If you realize you will have difficulty getting an assignment in on time, please discuss with the instructors as soon as possible in order to determine if it will constitute an excused extension. In addition, all students will receive 5 late days (unexcused delays, taken no more than 2 per assignment) without penalty. Unexcused late work beyond those days will result in a 10% penalty per day, and you are required to complete all assignments even if your grade on a given assignment would be 0%.

Collaboration policy: Discussion and the exchange of ideas are essential to doing academic work. For assignments in this course, you are encouraged to consult with your classmates as you work on problem sets, laboratories, and writing assignments. After discussions with peers, however, make sure that you can work through the problem yourself and ensure that any answers you submit for evaluation are the result of your own efforts.

Citation and Attribution policy: Written work you submit must be the result of your own research and written by you, reflecting your own approach to the topic. You must formally cite any books, articles, websites, lectures, or other material that you have used in your submitted work. ***Finally, when you use generative AI on an assignment, you must state which tool you used and how you used it. Screenshots of prompts and outputs are strongly encouraged. (Think of this like showing your work in a math problem.)***

Integrity Policy: Course materials are the property of the instructional staff, Harvard University, or other copyright holders, and are provided for your personal use. You may not distribute them or post them on websites. Do not upload course materials to generative AI tools. Your work is your responsibility, and you will be held responsible for plagiarism, including self-plagiarism.

Schedule

1. Intro & History of Earth's Climate [1 wk]

6-Sep	W	Course introduction and overview: History of Earth's atmosphere; what is a greenhouse gas?		
11-Sep	M	When it was cold…and when it was warm: Understanding climate on multiple timescales.		

2. Atmosphere [2 wk]

13-Sep	W	Heating the Earth: Radiative balance and consequences of imbalance	PS1 hand out	
18-Sep	M	What is the Jet Stream? Pressure, winds, and Hadley circulation.		Lab1: The Jet Stream
20-Sep	W	Why does it rain, and what causes a desert? Clouds, climate, and feedbacks.		
25-Sep	M	Special weather: Tornadoes, monsoons, and hurricanes. Heat transport.	Add/drop without fees	

3. Ocean [2 wk]

27-Sep	W	Introduction to Ocean Dynamics *i*: Coriolis force and geostrophic balance.	PS1 due; PS2 hand out	
2-Oct	M	Introduction to Ocean Dynamics ii: Ekman layers, gyre circulations, and ocean currents.		Lab2: Stability
4-Oct	W	The Timescale of Ocean Transport: Anthropogenic tracers, radiocarbon, ocean-atmosphere mixing		
9-Oct	M	Indigenous People's Day (University Holiday)		
10-Oct	Tu	Deadline to Add/Drop or Change Grading		

11-Oct	W	Production and Nutrients: What is a nutrient and how is it distributed? Redfield Ratio; limits on fertilization.		
16-Oct	M	IN CLASS REVIEW FOR MIDTERM 1		

18-Oct W **Midterm 1 (in class)**

4. Carbon Cycle and Climate Forcing [2 wk]

23-Oct	M	Introduction to Marine Geology: Plate tectonics, ocean basins, rock cycle; types and age of sediments.	Ps2 due; PS3 hand out	
25-Oct	W	The Stable Geologic Carbon Cycle: Urey feedback; carbonate chemistry; the ocean carbon system.		Lab3: Ocean acidification from CO2
30-Oct	M	Hot and cold Earth: How do we know the past? Paleotemperatures, ice cores, and other proxy records		
1-Nov	W	Present and Future Carbon Cycle: Stable or Unstable? Feedbacks and imbalances.		

5. Climate Variability [2 wk]

6-Nov	M	The Unstable Ice Age Cycle: Milankovitch cycles	PS3 due; PS4 hand out	
8-Nov	W	Hot Summers and Cold Winters: Heat transport in the midlatitudes (eddies)		
13-Nov	M	What is El Niño? (part I) climate variability on a range of timescales		Lab4: Eddies and Waves
15-Nov	W	MIDTERM 2 IN CLASS REVIEW		

20-Nov M **Midterm 2 (in class)**

6. Cryosphere [1.5 wk]

27-Nov	M	What is a glacier? Properties of grounded and floating ice	PS4 due; PS5 hand out	Lab5: Ice Sheet Stability
29-Nov	W	Greenland and Antarctica: Maintenance and causes of change		
4-Dec	M	Sea Level: Past and future oceans; how soon will Florida be underwater?	PS5 due	

Final assignment: Due Thursday December 14 at 11:59 PM

Choose Lab 2, Lab 3, or Lab 4 to write a mini literature review (up to 5 pages) on the related topic and a more detailed explanation of the corresponding demo and how it could be modified to understand a subtopic related to the lab. You may want to repeat the experiment and perform additional measurements, but this is not required. You will be given 3 relevant papers and asked to find at least 2 more to develop your literature review.

- *Lab 2: Melting ice cubes in salt and fresh water + thermohaline circulation changes with global warming*
- *Lab 3: CO_2 dissolution in water + ocean acidification or carbon storage?*
- *Lab 4: Ice bucket with fast rotation rate + jet stream and extreme weather changes with global warming.*