GEOL351: Climate Systems

Julien Emile-Geay

Spring 2026

General Information

Where/When Class meets Mon-Wed 10:00-11:20 in ZHS 200.
Lab meets Fri 10:00-11:50 in ZHS 130

Instructors

Professor:	Julien Emile-Geay	ZHS 275	julieneg@usc.edu
Teaching Assistant:	Jordan Landers	ZHS 275	lplander@usc.edu

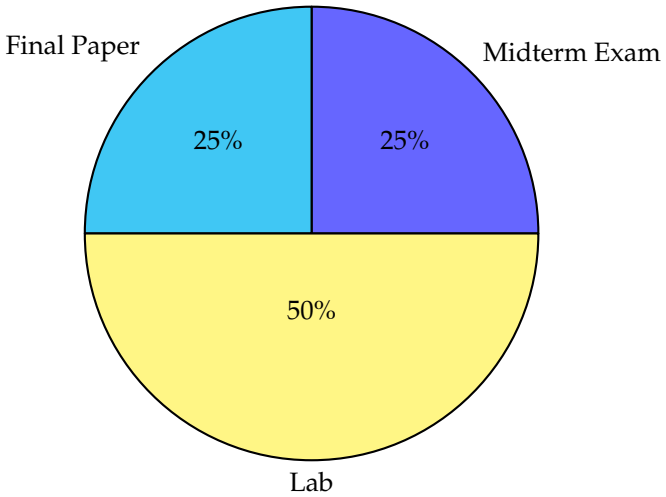
Office Hours Julien: Thursdays 12:30-16:00 (arrange first!)
Jordan: By appointment

Preparation Calculus and some basic matrix algebra (MATH 125 equivalent). Python programming experience beneficial but not required.

Course Description

Synopsis Earth's environments, both natural and managed, exhibit the hallmarks of complex adaptive systems: emergent behavior, tipping points, hysteresis, chaos, and other challenging features. Understanding and predicting their behavior has never been more important, so we must embrace this complexity – even at the undergraduate level. This class will cover the basics of complex systems science, with a light touch on math and using numerical experimentation as a principal teaching device. Python-based labs will present examples drawn from weather prediction, climate dynamics, oceanography, population dynamics, wildfire dynamics, and coupled human-environmental systems. Along the way, you will learn the basics of systems thinking, including how to analyze, control and (to some extent) predict the behavior of nonlinear dynamical systems so prevalent on our planet.

Grade The class will earn you 4 units, which means that it requires substantial work, every week. I do not believe in curving grades; if everybody gets an A, I'll pop some bubbly. Other than the laboratory practicums, the main assignment for this class is for you to write a paper that either takes a deep dive into a system seen in class, or draw parallels between these systems. The midterm will be mostly a measure of much you've come to class. Asking questions is the best way to get the answers you seek.



The numeric to letter grade conversion is shown in Table 1.

Table 1: Numeric to letter grade conversion (cutoffs)

< 60	60-62	63-66	67-69	70-72	73-76	77-79	80-82	83-86	87-89	90-94	95-100
F	D-	D	D+	C-	C	C+	B-	B	B+	A-	A

Lab grade Each lab is worth an equal fraction of lab grade. The lowest grade will be dropped automatically, which includes missing one due to illness of any kind. If you miss more than one, please justify your absence with the TA.

Computing This class will rely heavily on numerical experimentation, as (1) this lowers the level of mathematics required to get acquainted with dynamical systems and (2) we live in a digital age, and any exposure you get to information sciences will likely give you an edge in any conceivable job. Python will be our language of choice and we will be using Jupyter as a computing/visualization framework. Prior exposure to Python, while helpful, is not required. However, if you feel like a tutorial we recommend this bootcamp. You will be expected to install the (free) Miniconda software distribution to your personal computer so you can run these Jupyter notebooks and manage all the associated packages.

Late Work With assignments due virtually every week of the term, it's easy to fall behind. While it may seem desirable to take extra time to deepen your understanding of a subject, this will have a domino effect on subsequent assignments. As a result, lab assignments are due every Thursday, one week after each lab session. A late policy of 5% per day will be assessed, with a bound of not more than a week late without prior arrangement.

Reading

Required Meadows, D., Thinking in Systems, Chelsea Green Publishing, 2008, ISBN: 9781603580557.

Optional

- Strogatz, S. H. (2015). Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering (2nd ed.). CRC Press. DOI.
- Kaper, H., & Engler, H. (2013). Mathematics and climate. Society for Industrial and Applied Mathematics. DOI (PDFs available for free via USC libraries)
- Rose, B., The Climate Laboratory, 2021, (free JupyterBook).

SCHEDULE

I DYNAMICAL SYSTEMS: A TOOLBOX

Week 1— January 12— Introduction

Mon: Thinking in Systems.

Wed: Climate System: components and behavior.

Fri: Bootcamp on Differential Equations. Intro to Python/Jupyter

Read: Meadows, Intro and Chapter 1. K&E, Chapter 1.

Week 2— January 19— Dynamical Systems I

Mon: MLK day – NO CLASS

Wed: The Harmonic Oscillator

Fri: Lab 1: Harmonic Oscillators

Week 3— January 26— Dynamical Systems II

Mon: Linear Stability Analysis

Wed: Bifurcation Theory

Fri: Lab 2: Drawing Phase Portraits

Read: Strogatz, Chapter 2, 3. K&E, Chapter 5.

II THE CLIMATE SYSTEM

Week 4— February 2— Energy Balance

Mon: Earth's Radiative Budget;

Wed: Forcings and Feedbacks.

Fri: Lab 3: Box Models

Read: Meadows, Chapter 2. K&E, Chapter 5.

Week 5— February 9—Climate Stability

Mon: Icehouse vs Hothouse: observations

Wed: Icehouse vs Hothouse: insights from a 0D model

Fri: Lab 4: Multiple Climate Equilibria in a 0D climate model

Read: K&E, Chapter 2.

Week 6— February 16— Atmospheric Motion

Mon: President's Day – NO CLASS

Wed: Atmospheric Motion

Fri: Lab 5: Climate Feedbacks in a 1D climate model

Read: K&E, Chapter 13. Strogatz, Chapter 9

Week 7— February 23— Chaos

Mon: Lorenz and the butterfly effect

Wed: Oceanic Motion

Fri: Lab 6: Chaos, Hysteresis and Tipping Points in the Lorenz System

Week 8— March 2— Midterm

Mon: Midterm

Wed: The Meridional Overturning Circulation

Fri: Lab 7: MOC stability

Read: K&E, Chapter 3.

Week 9— March 9— Sea ice

Mon: Sea-ice dynamics

Wed: Energy Balance Models

Fri: Lab 8: Climate equilibria in an Energy Balance Model

Read: Wagner & Eisenman (2015). K&E, Chapter 17.

SPRING BREAK : Mar 15 – 22

Week 10— March 23— Climate Variability:ENSO

Mon: El Niño-Southern Oscillation, part 1

Wed: El Niño-Southern Oscillation, part 2

Fri: Lab 9: ENSO in the recharge oscillator paradigm

Read: K&E, Chapter 16.

Week 11— March 30— Climate Change

Mon: Climate Models and Attribution

Wed: Climate Projections

Fri: Lab 10: A nonlinear perspective on climate change.

Read: K&E, Chapter 15.

III Climate and Life

Week 12— April 6— Population Dynamics

Mon: Population Dynamics: the logistic equation

Wed: Population Dynamics: Lotka-Volterra

Fri: Lab 11: Preys, Predators and climate

Read: Strogatz, sections 2.3, 6.4. Meadows, Chap 3.

Week 13— April 13— Carbon

Mon: Term paper outlines (presentations)

Wed: The Carbon Cycle

Fri: Final paper clinic

Read: Meadows, Chap 4.

Week 14— April 20— Homeostasis

Mon: Wildfire Dynamics

Wed: Homeostasis

Fri: Final paper clinic

Read: Meadows, Chap 5-6.

Week 15— April 27— Human-Climate Interactions

Mon: Dynamics of Human-Natural Systems

Wed: Economics as Ecology

Read: Meadows, Chap 7.

May 8—Final Project Due

Term Project

An important component of this course is an individual research project where you will apply some of the concepts/methods learned over the semester to investigate one climate-related system.

Before embarking on the paper, please follow this tutorial to get some background on good research practices. A menu of models and general lines of investigation will be provided as a way to seed ideas.

Components Papers should hit all these high notes:

- State the problem and why it is important/interesting.
- Describe what is currently known about the system
- Explain how you will approach the system
- Do your magic
- Provide an overall conclusion.
- Include references in a standard format (e.g. AGU, AMS, APA)

Timeline You need to have identified a potential topic by week 12, as you will then present it to the class and get feedback on your plan in week 13. I will set up 20min sessions with each student to go over potential topics in weeks 11-12.

The papers are **due by 23:59 PST on May 8**. Please do yourself a favor and do not wait until the last possible minute to get started. Writing always takes more time than you would think/hope.

Writing Just because this is a science class, does not mean that you can get away with poor writing. We shall assume familiarity with English grammar and principles of composition. If you present original results, I'll expect a commentary on whatever results you obtain even (especially) if they are counter-intuitive. We're on the same side here: I don't want to read a long paper any more than you want to write one, so make every word count. Exact length is unimportant, but in general I expect about 5-10 pages of *double-spaced* text, not including figures: 1-2 pages for the introduction, 1-2 pages for the methods, 2-3 pages for the results, and 1-2 pages for the discussion/conclusion.

For typesetting, LaTeX is preferred, but Word/Pages will be tolerated, if submitted as PDF files. Work turned in using any other format will not be looked at.

Note that I highly welcome conversations about these papers at any point. Please feel free to share results/thoughts before the paper's submission deadline to get informal feedback and help you do your best work.

Poll Everywhere

We will use Poll Everywhere to gather live, in-class feedback. This will not be graded, so it remains a safe haven for learning, where you can be as candid as you wish without fear of judgment. However, your participation will be tracked to make sure you engage in the course. It is recommend to participate using a Web browser as some questions will require a fair amount of typing. PollEverywhere is free for you to use.

IV Resources and Reminders

Support Systems

Counseling and Mental Health – (213) 740-9355 — 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

988 Suicide and Crisis Lifeline – 988 for both calls and text messages – 24/7 on call
The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

Relationship and Sexual Violence Prevention Services (RSVP) – (213) 740-9355(WELL) — 24/7 on call. Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) – (213) 740-5086
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment – (213) 740-5086 or (213) 821-8298
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS) - (213) 740-0776
OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

USC Campus Support and Intervention – (213) 740-0411
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion – (213) 740-2101
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency – UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety – UPC: (213) 740-6000, HSC: (323) 442-1200 – 24/7 on call
Non-emergency assistance or information.

Office of the Ombuds – (213) 821-9556 (UPC) / (323-442-0382 (HSC)
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

Occupational Therapy Faculty Practice – (323) 442-2850 or otfp@med.usc.edu
Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.

Academic Integrity

The University of Southern California is foremost a learning community committed to fostering successful scholars and researchers dedicated to the pursuit of knowledge and the transmission of ideas. Academic misconduct is in contrast to the university's mission to educate students through a broad array of first-rank academic, professional, and extracurricular programs and includes any act of dishonesty in the submission of academic work (either in draft or final form).

This course will follow the expectations for academic integrity as stated in the USC Student Handbook. All students are expected to submit assignments that are original work and prepared specifically for the course/section in this academic term. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s). Students suspected of engaging in academic misconduct will be reported to the Office of Academic Integrity.

Other violations of academic misconduct include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Plagiarism Presenting someone else's ideas as your own, either verbatim or recast in your own words, is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Section 11, Behavior Violating University Standards. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct. These comments apply as well to text generated by artificial intelligence.

AI In a few short months, generative A.I. tools like ChatGPT have taken academia by storm and rocked the very foundations of the college experience. Mindfully used, large language models (LLMs) can be incredible tools to boost productivity and get your creative juices flowing; mindlessly used, they will stifle your creativity, dull your critical thinking, and stunt your intellectual growth. In an age where AI's capabilities are rapidly catching up with humankind's, your only competitive edge going forward is to use your limitless creativity to do what machines can never do: imagine, dream, intuit, critically evaluate and create. If you surrender to them now, there is no future for you.

In this class, instructors will assume that, if you are using LLMs, you are doing so mindfully and ethically. That means:

- critically evaluating their output
- keeping a record of the conversation you had with the chat bot, and documenting your prompts (e.g. in an appendix)
- appropriately crediting the LLM in your written assignments

Specifically, LLMs are acceptable for conducting literature searches, identifying unsolved problems in your field of study, and troubleshooting coding challenges. However, you may not use LLMs to write any portion of your labs or term paper – the writing must be entirely your own work. In your paper's acknowledgments or methods section, you must disclose which LLM(s) you used and describe specifically how you used them (e.g., "I used Claude to identify relevant papers on ENSO dynamics" or "I used ChatGPT to debug Python code"). Failure to disclose LLM use, or using LLMs to write paper content, will be considered a violation of academic integrity policies.

Discrimination

Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the Office of Equity and Diversity or to the Department of Public Safety . This is important for the safety whole USC community. Another member of the university community – such as a friend, classmate, advisor, or faculty member – can help initiate the report, or can initiate the report on behalf of another person. The Center for Women and Men provides 24/7 confidential support, and the Relationship and Sexual Violence Prevention and Services webpage describes reporting options and other resources.

Accommodations do not relieve you of the responsibility for completion of any part of the coursework you miss as the result of a religious observance. If you have questions or concerns about your request, you may contact EEO-TIX.

Students and Disability Accommodations

USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at `https://osas.usc.edu/`. You may contact OSAS at (213) 740-0776 or via email at `osasfrontdesk@usc.edu`.