

# GEOL351: Climate Systems

Julien Emile-Geay

Spring 2022

## General Information

*Where/When* Class meets Mon-Wed 10:00-11:25am in ZHS 200.  
Lab meets Thurs 12:00-1:50pm in ZHS 130.

### *Instructors*

Professor:	Julien Emile-Geay	ZHS 275	<a href="mailto:julieneg@usc.edu">julieneg@usc.edu</a>
Teaching Assistant:	Jordan Landers	ZHS 275	<a href="mailto:tbd@usc.edu">tbd@usc.edu</a>

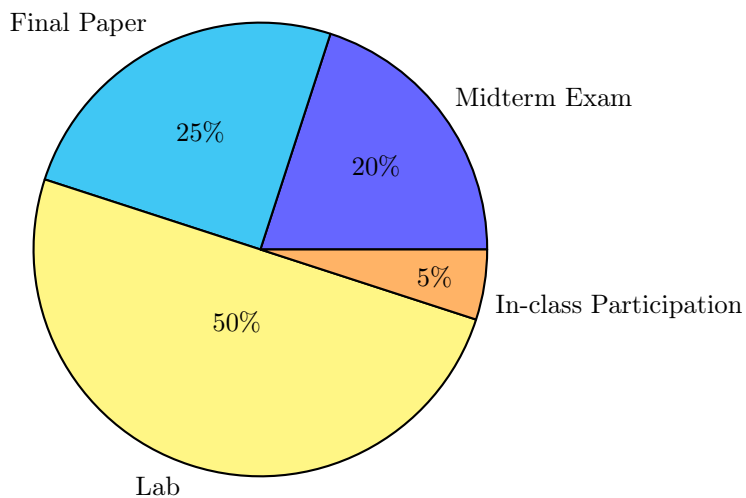
*Office Hours* Julien: Wed 2-5pm or by appointment (ZHS 275).

*Preparation* MATH 125

## 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. Yet, understanding and predicting their behavior has never been more important. This class will cover the basics of understanding environmental systems, using numerical experimentation as its principal teaching device. Python-based labs will present examples will be 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 (a basic competence in the Sustainability curriculum), including how to analyze, control and (to some extent) predict the behavior of nonlinear dynamical systems.

*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 showcases how you approach one environmental system of your choice, preferably connected to climate. This is worth about 1/4 of the grade and is usually underappreciated by students, who unexplainably prefer to freak out over the midterm exam. So let it be known: the midterm will be easy, and mostly a measure of much you've come to class. The real work is in the weekly labs and term paper. It's also really nice if you pipe up in class, whether in-person or Zoom!



*Rules* There aren't many rules for the course, but they're all important. First, read the assigned readings before you come to class. Second, turn everything in on time. Third, ask questions when you don't understand things; chances are you're not alone. Fourth, don't miss class or lab.

*Computing* This class will rely heavily on numerical experimentation. There are two reasons for that: (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. We will be using **Jupyter** as a computing/visualization framework. Prior exposure to Python, while helpful, is absolutely 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 1 point penalty for every late day will be assessed.

## Reading

### *Books*

#### **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](#).
- Rose, B., **The Climate Laboratory**, 2021, (free!).

## Schedule

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### I DYNAMICAL SYSTEMS: A TOOLBOX

#### **Week 1— January 10— Introduction**

**Mon:** Thinking in Systems.

**Wed:** Climate System: components and behavior.

#### **Week 2— January 17— Dynamical Systems I**

**Mon:** MLK day – NO CLASS

**Wed:** The Harmonic Oscillator

**Thur:** **Lab 1: Introduction to Jupyter and Python**

#### **Week 3— January 24— Dynamical Systems II**

**Mon:** Linear Stability Analysis

**Wed:** Bifurcation Theory

**Thur:** **Lab 2: Harmonic Oscillators**

## II THE CLIMATE SYSTEM

### **Week 4— January 31— Energy Balance**

**Mon:** Earth's Radiative Budget;

**Wed:** Forcings and Feedbacks.

**Thur:** Lab 3: Drawing Phase Portraits

### **Week 5— February 7—Climate Stability**

**Mon:** Icehouse vs Hothouse

**Wed:** A zero-dimensional climate model

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

### **Week 6— February 14— Atmospheric Circulation**

**Mon:** Atmospheric Motion

**Wed:** Lorenz and the butterfly effect

**Thur:** Lab 5: Climate Feedbacks in a 1D climate model

### **Week 7— February 21— Midterm**

**Mon:** President's Day – NO CLASS

**Wed:** Midterm

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

### **Week 8— February 28— Oceanic Circulation**

**Mon:** Oceanic Motion

**Wed:** The Meridional Overturning Circulation

**Thur:** Lab 7: MOC stability

### **Week 9— March 7— Sea ice**

**Mon:** Sea-ice dynamics

**Wed:** Energy Balance Models

**Thur:** Lab 8: Climate equilibria in an Energy Balance Model

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## **SPRING BREAK : Mar 13 – 20**

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### **Week 10— March 21— Climate Variability:ENSO**

**Mon:** El Niño-Southern Oscillation, part 1

**Wed:** El Niño-Southern Oscillation, part 2

**Thur:** Lab 9: ENSO in the recharge oscillator paradigm

### **Week 11— March 28— Climate Change**

**Mon:** Climate Models and Attribution

**Wed:** Climate Projections

**Thur:** Lab 10: A nonlinear perspective on climate change.

### III CLIMATE AND LIFE

#### **Week 12— April 4— Population Dynamics**

**Mon:** Population Dynamics: the logistic equation

**Wed:** Population Dynamics: Lotka-Volterra

**Thur:** Lab 11: Preys, Predators and climate

#### **Week 13— April 11— Homeostasis**

**Mon:** Term paper outlines (presentations)

**Wed:** Daisyworld

**Thur:** Lab 12: Daisyworld

#### **Week 14— April 18— Ecosystem Crisis**

**Mon:** Wildfire Dynamics

**Wed:** Fisheries Collapse

**Thur:** Lab 13: Wildfire Percolation

#### **Week 15— April 25— Human-Climate Interactions**

**Mon:** Climate Interventions. Control of Chaos.

**Wed:** Economics as the Science of Planet Earth

**Thur:** Lab 14: Human-Climate Collaborations

**May 11—Final Project Due**

## IV 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. Papers can be of two types:

**Literature review**, gathering information from the published literature and synthesizing it in an original way. Because this type of paper will not involve writing code, the expected quality of the writing will be correspondingly higher.

**Research**, modeling a system you identified as interesting, and commenting on the results in a way that shows you understood what you did. It is of course perfectly acceptable (in fact, encouraged) to repurpose existing code for your analysis, either by

### Components

Both paper types must:

- 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. )

### Timeline

You need to have identified a potential topic by week 13, as you will then present it to the class and get feedback on your plan.

The papers are **due by 23:59 PST on May 11**. 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 the principles of scientific writing, and I'll expect succinct, lucid commentary on whatever results you obtain. 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.

## V 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.

<https://studenthealth.usc.edu/counseling>

#### **National Suicide Prevention Lifeline** –1-800-273-8255 – 24/7 on call

Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

<http://www.suicidepreventionlifeline.org>

#### **Relationship & Sexual Violence Prevention Services (RSVP)** – (213) 740-9355(WELL), press “0” after hours – 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

<https://studenthealth.usc.edu/sexual-assault>

#### **Office of Equity and Diversity (OED)** (213) 740-5086. Title IX Office – (213) 821-8298

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. <https://equity.usc.edu/>, <https://titleix.usc.edu>

#### **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 of Equity and Diversity |Title IX for appropriate investigation, supportive measures, and response. [https://usc-advocate.symplicity.com/care\\_report](https://usc-advocate.symplicity.com/care_report)

#### **The Office of Disability Services and Programs** - (213) 740-0776

Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs. <https://dsp.usc.edu>

#### **USC Campus Support and Intervention** - (213) 821-4710

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student. <https://campussupport.usc.edu>

#### **Diversity at USC** - (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. <https://diversity.usc.edu/>

#### **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. <https://dps.usc.edu>, <https://emergency.usc.edu>

#### **USC Department of Public Safety** - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call. Non-emergency assistance or information. <https://dps.usc.edu>

#### **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. <https://ombuds.usc.edu>

## 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](#).

## 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 [sexual assault resource center webpage](#) describes reporting options and other resources.

## GradeBuddy

The following is a reminder from Academic Policies memo 11/25:

*Any student selling or distributing notes taken in a classroom is in violation of the University's Academic Integrity policy and is subject to university sanctions. This policy is clearly stated in Section 11.12 of the student handbook, [SCampus](#), which identifies the following as violations of community standards:*

- Acquisition of term papers or other assignments from any source and the subsequent presentation of those materials as the student's own work, or providing term papers or assignments that another student submits as his/her own work.*
- Distribution or use of notes or recordings based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes, but is not limited to, providing materials for distribution by services publishing class notes. This restriction on unauthorized use also applies to all information which had been distributed to students or in any way had been displayed for use in relationship to the class, whether obtained in class, via email, on the Internet or via any other media. (See Section C.1 Class Notes Policy.)*
- Recording a university class without the express permission of the instructor and announcement to the class. Recording can inhibit future free discussion and thus infringe on the academic freedom of other students as well as the instructor.*