Climate Systems – GEOL 351

SYLLABUS as of Jul 8, 2017

This course provides a modular set of lectures and problem sets/labs aimed at teaching system-level behavior in the Earth's outer fluid envelopes. Our emphasis is on climate dynamics and climate-related geosystems as a point of entry to understand complex (including human) systems. . The course is team-taught as a set of 3 modules, covering an introduction to (geo) system behavior (phase space analysis, non-linear dynamics, deterministic chaos), climate system components (planetary energy balance thermohaline circulation; short and long-term carbon cycle) and non-linear climate dynamics (multiple climate equilibria in energy balance and ocean circulation models; dynamics and predictability of the El Niño-Southern Oscillation). The final lectures will present civilization viewed as a geosystem. This is an upper level Earth Science class, developed not only for Earth Science majors, but also with the new Climate Resiliency & Stewardship Minor target audience in mind—the Economics/IR/PoliSci/Psych majors interested in the relationship between climate systems and their field, which also exhibits complex system behavior.

Lectures: Mon, Wed 9-10:25 am, Location: ZHS 118

Laboratory: Fri, 9-11am (flexible), location: ZHS 130

Instructors: Julien Emile-Geay (julieneg@usc.edu); office hours: TBD

Tom Jordan (tjordan@usc.edu); office hours: TBD

Lowell Stott (stott@usc.edu); office hours: TBD

TA: TBD will be responsible for labs and will help with project development, Office Hours TBD

Required Reading: *Various book chapters and articles will be assigned per week/module. PDF's will be posted on Blackboard*

Optional Texts:

Essentials of the Earth's Climate System, Barry & Hall-McKim, Cambridge University Press, ISBN: 9781107620490

Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering, Steven H Strogatz. Westview Press Classroom Classics

The Global Carbon Cycle. D. Archer, Princeton University Press

The Art of Modeling Dynamic Systems; Forecasting for Chaos, randomness and determinism. F. Morrison, Dover Pubs.

Atmosphere, Ocean, and Climate Dynamics. An Introductory Text. Marshall, J., Plumb, R. A. Academic Press

Basis of Grade:

40%	Lab Exercises
10%	Homework (weekly readings)
5%	Class participation
45%	Final Project papers (30%)/presentations (15%)

Synopsis

Students will learn the mathematics and informatics of complex system behavior as applied to geosystems, particularly climate and climate-related systems. Examples of complex system behavior will be demonstrated, and their application to non-scientific topics will be discussed. Laboratories and discussion sessions will involve working with 'toy' models, the exploration of parametric sensitivity, regime changes, and inference from simple models. A research project on a complex climate-related geosystem will enforce a student's ability to generate and synthesize data, prepare and deliver presentations and write a short research paper.

Additional Information:

Prerequisites: Math 125 Required and/or Exposure to AP or College Physics Recommended

Final Project: Under the supervision of one or more of the instructors each student will choose a climate-related geosystem to investigate. The intent of this project is to give you an opportunity to formulate a question or hypothesis about a geosystem and then use a geosystem model to answer your question or evaluate your hypothesis. You may either conduct a model simulation or access previously published model results for your investigation. An analysis of the model results, together with any relevant observational data, will be used to answer your question or evaluate your hypothesis. Your research findings and interpretations are to be written into a formal paper. The paper itself must follow the guidelines and formatting instructions of a professional scientific journal. Students are required to give regular updates about their research to the instructors and to other students in the class.

The project will be evaluated in two ways:

1. Students will formally present their work on Nov 29. This presentation will represent 15% of the final grade. These will be 15 minute talks.
2. A 10-20 page (double-spaced) paper will be due during finals week (Dec. 8). Not including figures, an approximate breakdown would be 2-3 pages for the introduction (motivation, exposition of the hypothesis or problems & questions), 3-5 pages for the analysis and results, and 2-3 pages for the discussion/conclusion. The paper will represent 30% of the final grade and will be evaluated by 2 or more instructors. Remember: QUALITY OVER QUANTITY! If you can say it all in 9 pages, that is better than 19.

Components of the paper:

- An introduction describing the **behavior** of the system you are trying to understand, explaining why it is interesting, and outlining one or more key question(s) that you have about this system (e.g. "How will this change as greenhouse gas concentrations increase?").
- An exposition of one (or more) model(s) that mathematically represent(s) the geosystem behavior. This can be a model that you have run or can be

published model results. If no model results can be obtained, you must state the reasons why. In this case you should describe the analysis of observational data that was used to quantify the geosystem behavior.

- A (brief) review of peer-reviewed studies that have attempted to quantify the geosystem behavior with models and/or observational data.
- A synthesis of what was learned from the models, and what remains to be learned. What answer can you give to your motivating question or hypothesis? And state what types of research could or should be pursued in the effort to better understand the geosystem behavior.

Logistics: papers should be submitted via BlackBoard by Dec 9, 11:59pm.

Class Participation: As part of your class participation grade you will be asked to give regular updates in class about the progress you are making towards the completion of your project. Note also that you will be expected to give a brief description of the overall project results on Oct. 18, prior to your formal presentation on Nov. 29th.

Lab exercises: Labs will include: demonstrations in which a complex system is 'built' and data must be collected and modeled; exercises in which models are used and manipulated; labs include discussion and group problem-solving.

Weekly homework will consist of a summary of the weekly reading.

Academic Integrity: University policies on academic dishonesty are printed in SCAMPUS and SJACS, , see http://www.usc.edu/student-affairs/SJACS. Because cheating negatively affects everyone in the class, we will follow USC guidelines and report all academic misconduct. USC policies on cheating are strict and the minimum punishment is a "0" on the assignment. Don't do it – it's not worth it. The instructor and TA's are always available for extra help and advice. If the Prof. thinks you are at risk of failing the course, he will let you know via email and will encourage you to get extra help.

Disability Services: Students requesting academic accommodations based on a disability are required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP when adequate documentation is filed; *please be sure the letter is delivered to the professor as early in the semester as possible, and at least 2 weeks prior to the first midterm*. DSP is open Monday-Friday, 8:30-5:00. The office is in Student Union 301 and the phone number is (213) 740-0776.

GEOL 351--Schedule of Lectures/Labs—2017

Week	Theme	Instructor
		T. Jordan
1	Mon Aug. 21—Introduction: geosystems as dynamical systems Wed Aug. 23— Intro to climate system behavior *Lab: none*	
2	Mon. Aug 29— Linear and non-linear behavior Wed. Aug 31— Non-linear dynamical systems *Lab 1: Explore your own system—Conceptualize a geosystem*	
		L. Stott
3	Mon. Sep 4 — Labor Day – no class Wed. Sep 6— The Earth's Atmosphere, Structure and Composition *Lab 2: Harmonic Oscillator*	
4	Mon. Sep 11— Electromagnetic radiation, energy balance Wed. Sep 13— General Atmospheric Overturning Circulation, maintaining heat and mass balances *Lab 3: Box modeling radiative balance*	
5	Mon. Sep 18 — Behavior of Carbon species in the ocean/atmosphere Wed. Sep 20 — The Carbon cycle, the Long and the Short of it *Lab 4: Carbon Cycle Box Modeling*	
6	Mon. Sep 25— Biogeochemical models of the Carbon cycle Wed. Sep 27— Biogeochemical models, carbon cycle feedbacks *Lab 5: cGENIE Earth System Modeling*	
7	Mon. Oct. 2 — Climate Sensitivity Wed. Oct. 4 —Model Simulations of Climate Sensitivity *Lab 6: IPCC Model Simulations*	
		T. Jordan
8	Mon. Oct. 9 — Stability, bifurcations ? Wed. Oct. 11 — Deterministic Chaos ? *Lab 7: The Lorenz Attractor*	
		J. Emile-Geay
9	Mon. Oct. 16 — What are models teaching us about Nature? Wed. Oct. 18 — Project Review/Update Talks by Students (5 min presentations, 3 slides max) *Lab 8: Write outline of term project*	
10	Mon. Oct. 23 — A zero-dimensional climate model Wed. Oct. 25 — Icehouse vs Hothouse *Lab 9: Multiple climate equilibria in a 0D model*	

11 Mon. Oct 30 — The thermohaline circulation: theory and models
Wed. Nov 1 — Thermohaline instabilities and abrupt climate change
Lab 10: Thermohaline Loops

12 Mon. Nov. 6 — El Niño: phenomenology and dynamics
Wed. Nov. 8 — El Niño: chaos and predictability
Lab 11: Toy models of El Niño

13 Mon. Nov. 13— Climate models; endogenous vs exogenous variability
Wed. Nov. 15— The climate attractor and the greenhouse magnet
Lab 12: A nonlinear dynamical perspective on climate change

T. Jordan

14 Mon. Nov. 20 — Civilization as a Geosystem
Nov, 22 – 26 — Thanksgiving
No Lab

15 Mon. Nov 27— Civilization as a Geosystem
Wed. Nov 29— Project Presentations (lab + lecture time)
15 min presentations (10 slides max).

Dec. 8—Project Papers Due