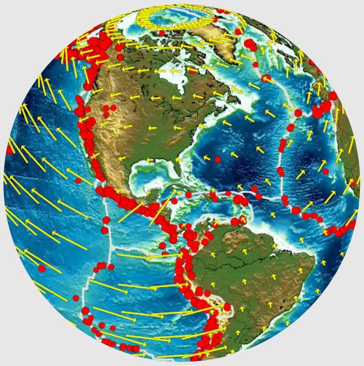

Earth System Modeling

EAS 4610

Fall 2025

Instructor Info —

Prof. Shi Joyce Sim

Office hrs on Wednesday 1-2pm (or by appointment)

Ford ES&T 3176 or virtual

jssim@eas.gatech.edu

Course Info

Prereq: CS 1301 or CS 1371 AND MATH 2551 AND MATH 2552

Lectures: Tue/Thu 9:30–10:45a

Skiles 256

Overview

Updated August 13, 2025

This course covers the fundamentals of numerical methods and their application to problems in Earth sciences. Course content includes how to solve (on a computer) differential equations (ordinary and partial), integrals, root-finding problems, and linear algebra. This course is targeted at undergraduate students in Earth Atmospheric Sciences, and is the undergraduate equivalent of EAS 6130.

Prerequisites

An undergraduate-level understanding of calculus and differential equations (i.e. MATH 1552, 1553, 2551, 2552). Some introductory ability with MATLAB or Python (i.e. CS 1370/1371): defining variables, performing matrix operations, making plots, using loops and logical operators. Please talk to Prof. Sim if you are concerned about coding.

Learning Objectives

At the end of this course, students should be able to use basic numerical methods to solve simple equations or model systems of equations. Students should also have more confidence with using MATLAB or Python to program simple numerical methods for solving fairly well-behaved problems in integration, differential equations, root-finding, and linear algebra.

Reading Material and Software

There is no required textbook, as course notes will cover all material required to complete assignments and assessments. Here are other useful textbooks to supplement lectures:

1. *G. Lindfield and J. Penny, Numerical Methods: Using MATLAB, Academic Press, 4th ed., 2018* (E-book available through GT library: https://ebookcentral.proquest.com/lib/gatech/detail.action?docID=953183).
2. *R. Slingerland and L. Kump, Mathematical Modeling of Earth's Dynamical Systems, Princeton U Press, Pbk edition, 2011* (E-book available through GTlibrary: https://ebookcentral.proquest.com/lib/gatech/detail.action?docID=664639)

Recommended Software

Matlab and/or *Python*

Grading

Problem sets every 2 weeks	50%
Midterm Individual Project	25%
Final Group Project	25%

Letter grade: A $\geq$ 90%; B = 80–89%; C = 70–79%; D = 60–69%; F $<$60%.

Satisfactory/Unsatisfactory: S $\geq$ 70%.

Evaluation

Problem sets are meant to challenge you. Figuring out an approach and solution to these problems may take some time. If you feel stuck or think the problem is incorrectly posed, please send me an e-mail or see me during office hours. Solution sheets will not be provided after grades are returned, but Prof. Sim can work through a problem in class or in office hours if students have questions.

Midterm projects will be completed individually. These projects should use ordinary differential equations to model an Earth system process. The topic may involve reproducing or modifying simple models from published papers. Two class sessions will be devoted to short (7 minute) lightning talks on the project, with 3 minutes of discussion afterward. To encourage participation and discussion of the lightning talks, students will be assigned to prepare questions during certain talks. A short (4-6 pages not including references) report will include details of the model equations, numerical methods used, and select results.

Final projects will be completed in groups of 2. These projects should use partial differential equations to model an Earth system process. The topic may involve reproducing or modifying models from published papers. The final project deliverable will be an interactive notebook (either MATLAB or Python-based) with step-by-step description of model equations, numerical methods used to solve the equations, and dynamically-generated plots. Project notebooks will be stored as repositories on Github (with a mid-semester tutorial showing students how to use Github).

Class Policies

Attendance and Participation

In-person attendance will not be taken or enforced in any way. All students are encouraged to attend all lectures whenever possible to maximize learning. The supplementary textbooks support these lectures, but they cannot replace the material covered in lecture. Lecture notes and tutorial code from class will be posted on Canvas.

Extensions and Late Assignments

Late assignments will only be accepted without penalty if you have asked for permission (with GT-approved excused or for other extenuating circumstances) at least 24 hours before the assignment is due with a proposed date of submission. Otherwise, late assignments, up to 24 hours, will automatically have 20% credit deducted. Assignments will not be accepted more than 24 hours late (i.e. you will receive no credit for the assignment) unless you have received prior permission.

Use of Mobile Devices in the Classroom

You are allowed to use whatever tool (laptop, tablet, etc.) you need in class to take notes and generally be successful. However, unless you have asked me ahead of time to be able to use your phone during class (to take notes or for emergency purposes), using your phone in class is not permitted. If an emergency comes up unexpectedly in class that requires you to use your phone, please let me know.

Diversity, Inclusivity, and Student-Faculty Expectations

As a member of the Georgia Tech community, I am committed to creating a learning environment in which all of my students feel safe and included. I welcome and encourage your constructive feedback and/or suggestions for improvement. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class. Please see http://catalog.gatech.edu/rules/22/ for some basic expectations that we should have of each other.

Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at 404-894-2563 or online at http://disabilityservices.gatech.edu, as soon as possible, to make an appointment to discuss your needs and to obtain an accommodation letter. Please also schedule a meeting with me to discuss your learning needs.

Academic Integrity

It is expected that all students are aware of their individual responsibilities under the Georgia Tech Academic Honor Code (https://osi.gatech.edu/students/honor-code), which will be strictly adhered to and is central to the tenets of this course.

Collaboration & Group Work

You may find it useful to discuss assignments with your fellow students. The course policy is that discussion is acceptable if the goal is to determine an approach to a possible solution. However, sharing/comparing complete solutions is not allowed, including code, derivations or plots from your final write-up. If you discuss an assignment with someone else, please put their name on the first page of your submitted solutions. If it is clear that any part of a solution or code is the exact same as a classmate's (beyond likely coincidence), then both of you will receive a zero for the entire assignment.

AI/GPT Policy

AI assistants (like internet forums and friends) can be a helpful aid for understanding material, and figuring out how to write certain kinds of code. However, when used in an attempt to do entire problems, they hinder learning and will often provide incorrect answers. Therefore, if you use GPT or another AI as an aid, please cite it in your code and indicate which part of your code was helped by the AI assistant. If it is clear that an entire solution is direct output from GPT, then you will receive a zero for the entire assignment.

Plagiarism is strictly forbidden. Plagiarism is the submission of material that is wholly or substantially identical to that created or published by another person or persons, without adequate credit notations indicating authorship (as defined by the Georgia Tech Academic Honor Code).

Course Schedule

The schedule below serves as a reference point and will likely change as the semester progresses.

MODULE 1: ODEs

Aug 19	Preliminaries: course logistics, why we need numerical methods
Aug 21	MATLAB/Python refresher
Aug 26	ODE review, box models (+coupled ODEs)
Aug 28	ODE solvers: forward Euler method, backward Euler method
Sep 2	ODE box model examples: carbon cycle, ocean overturning
Sep 4	Stability and convergence of numerical methods
Sep 9	Higher-order ODE methods: Runge-Kutta, predictor-corrector, Euler-Richardson
Sep 11	Higher-order ODE example: Volcanic bomb
Sep 16	Numerical integration and sea level example
Sep 18	in-class office hours for midterm project

MODULE 2: Root-finding

Sep 23	Lightning talks for midterm project
Sep 25	Lightning talks for midterm project
Sep 30	Root-finding methods
Oct 2	planetary orbits example
Oct 7	FALL BREAK
Oct 9	Review of linear algebra
Oct 14	Inverse problems, matrix inversion, matrix decomposition
Oct 16	Example: Gravity Inversion. Github tutorial

MODULE 3: PDEs

Oct 21	Review of partial differential equations
Oct 23	Boundary Value Problems. Finite difference method. Diffusion BVP Example: Geothermal heat flux
Oct 28	Time-dependent diffusion equation and Crank-Nicolson Scheme

Oct 30	NO CLASS
Nov 4	Advection and advection-diffusion equations
Nov 6	Upwind Scheme. Examples: Hillslope erosion
Nov 11	Wave Equation
Nov 13	Example: Seismic Waves
Nov 18	in-class office hour for final project
Nov 20	Complex Earth System Models I
Nov 25	Complex Earth System Models II
Nov 27	THANKSGIVING BREAK
Dec 2	In-class office hours for final project