## Computational Earth Science
*EESC UN3400*
*Tuesdays and Thursdays 1:10 – 2:25 pm*
*Schermerhorn EXT 558*

### Instructor
Prof. Daniel M. Westervelt
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Office hours: On zoom, Monday evenings, time TBD
Github: dmw2166

*Unless it is an emergency, please expect email responses in 24-48 hours.*

### Course Description
Computer modeling is a critical tool for earth and environmental scientists. From topics such as projecting future climate change, to understanding groundwater flow, to simulating ocean currents, computer models are pervasive in this field, and have underpinned scientific understanding of Earth systems for decades. The goal of this course is to learn basic computer models to simulate earth and environmental processes. The material is designed to be accessible for Earth Science undergraduate students in any discipline, with prerequisites including basic physics and calculus. Coding experience is not required, as this course will begin with some basic instruction in Python.

This course is also intended to introduce students to modern computing software, programming tools and best practices that are broadly applicable to the analysis and visualization of Earth and Environmental data. This includes an introduction to Unix, version control (git and GitHub), and basic programming in the open-source Python language, specifically the scientific Python ecosystem, including Numpy, Scipy, Matplotlib, Pandas, and Xarray.

### Course Objectives
- Use Linux/Unix commands to work with files and directories
- Navigate the JupyterLab Environment effectively
- Construct complete, well-structured programs in Python
- Familiarity with several types of environmental models, including atmospheric models, groundwater models, ocean models, land surface models, etc
- Understand basic concepts of mass balance and how to apply it to problems
- Steady state modeling, pseudo-steady state approximation
- Familiarity with 0-D models (box models) as well as higher dimensional spatial models
- Familiarity with common processes across earth systems, such as diffusion, advection, convection, and other dynamical processes

### Course website
Courseworks: https://courseworks2.columbia.edu/courses/191326

### Method of Evaluation

| Activity | Weight | Due Date |
|---|---|---|
| Attendance and Participation | 10% | Each week |
| Assignments | 40% | Approx. every week |
| Final Project | 50% | End of semester |

### Course Format
Officially, this is a lecture-based course. However, slideshow presentation is not the most effective modality for learning to use modeling tools. The course will include some slideshow presentations and also will include real-time coding demonstrations. The best way to learn coding and modeling is hands-on, so students will have the most success if they are following along in real time. Therefore, be sure to bring your laptop to each class meeting. Tuesday meetings of class will consist of lectures and/or real-time coding demonstrations. **Thursday meetings will be more informal and will be used for either: finishing up some concepts from Tuesday, collaborative work time on assignments with classmates, and/or open office hours.**

**Textbook**
None

**Participation (10%)**
Students are expected to come to class prepared and to actively participate in discussion and activities. Participation grades will be assessed based on both the frequency and quality of students' engagement in class and/or on Slack. A good rule of thumb is asking at least one thoughtful question during a lecture-style class, and collaborating with at least one other student during work session-style class. Quality is not about being "correct" or "knowing all the answers", but about the extent to which students' comments reflect thoughtful engagement with the assigned materials and the comments of others.

**Assignments (40%)**
There will be approximately 10 assignments throughout the semester. Assignments are due by 11:59pm on Tuesdays. Assignments will be posted on courseworks and students will submit via courseworks.

We encourage assignments to be collaborative and will be setting aside dedicated time for collaborative work! However, it is important that every student submit their own homework assignment that accurately represents their own understanding of the topics of the assignment. Spot-checking code, asking for help from classmates if stuck, comparing answers, etc. are all encouraged. In your submission, please list your collaborators either in your code notebooks or other documents that you turn in. Copying one's code directly verbatim would be an example of an unacceptable level of group work. Please reach out to the professor or the TA if you would like any clarification.

**Final Project (50%)**
A final project will be submitted by each student. As with assignments, student collaboration is encouraged, as long as students submit an independent, unique project accurately representing their understanding. The project will synthesize many topics we cover over the course of the semester. Broadly, students will be asked to pick a dataset, and use this dataset to investigate a scientific question or hypothesis. They will use the coding skills to create figures (in a Jupyter notebook) that provides insight regarding the scientific question or hypothesis. There will also be a 5-minute presentation on the project. More details will be forthcoming later in the semester.

**Late Assignment Policy**
All assignments should be submitted via CourseWorks by the due date and time. That said, we understand when illnesses, burnout, research travel, job interviews, or other things get in the way of work and school. Each student will have up to 5 total days of "no questions asked" extensions that they may use on any assignment. This is 5 cumulative days, meaning students could use a 1-day (24 hour) extension 5 times, or a 5-day extension one time, or anything in between. Note that weekends don't count towards the 5-day tally. For example, a 24-hour extension of an assignment due Friday afternoon would extend to Monday afternoon. Extensions are given in 1-day increments, so submitting a homework 1 minute late uses up 1 day of your extension. You do not need to ask or wait for permission or give a reason in order to use the extension days. However, when you have turned in the late assignment, you must email both the instructor and the TA with the words "Late Assignment Submission" in the subject line to inform them of your submission. Of course, extensions will always be given for medical or family emergencies and extended professional obligations, outside of these 5-day extensions. For this, please communicate with the instructor and the TA as soon as reasonably possible.

**A Note on Late Work and Plagiarism**
Plagiarism often happens not by desire but in desperation. Since Columbia has strict zero-tolerance policies regarding plagiarism, even one incident can have long-standing effects on your academic career. If you are struggling to understand the concepts to the point of being unable to do the assignments, or if you are submitting work late because the assignments are taking you significantly longer than the allotted time, then we want to hear about it, and we will take your feedback as we grow our teaching in the future. Often students wait until the last few weeks of the semester to reach out – there is not much we can do then! We hope to create a supportive and inclusive environment, so please reach out and **communicate proactively** so that we can help! Please also refer to the

Academic Integrity statement towards the end of this document.

## Grades: Definitions and Scale
Final grades are assigned to course average scores based on the following scale:
A+      Rare performance. Reserved for highly exceptional achievement.
A       Excellent. Outstanding achievement.
A-      Excellent work, close to outstanding.
B+      Very good. Solid achievement expected of most graduate students.
B        Good. Acceptable achievement.
B-      Acceptable achievement, but below what is generally expected of graduate students.
C+      Fair achievement, above minimally acceptable level.
C        Fair achievement, but only minimally acceptable.
C-       Very low performance.
F        Failure. Course usually may not be repeated unless it is a required course.

## Course Schedule

| Date | Topics Covered | Description | Items Due on Tuesday 11:59pm |
|------|----------------|-------------|------------------------------|
| Week 1, Sep 3 and 5 | Intro | Intro to computer modeling in environmental and earth science | N/A |
| Week 2, Sep 10 and 12 | Git, github | Version control | Assignment 1 |
| Week 3, Sep 17 and 19 | Unix, JupyterLab | Terminal, command-line, shell scripting, interactive computing environment | Assignment 2 |
| Week 4, Sep 24 and 26 | Python fundamentals | Numpy, scipy, pandas, etc | Assignment 3 |
| Week 5, Oct 1 and 3 | Making figures in python | Matplotlib | None |
| Week 6, Oct 8 and 10 | Types of models | Lagrangian vs eulerian models, stochastic vs deterministic, etc | Assignment 4 |
| Week 7, Oct 15 and 17 | Numerical methods | Runge-Kutta, Euler's method | Assignment 5 |
| Week 8, Oct 22 and 24 | Mass balance and box models | Reservoirs, airsheds as examples | Assignment 6 |
| Week 9, Oct 29 and 31 | Least squares estimation | Using global warming data | Assignment 7 |
| Week 10, Nov 5 and 7 | Election day | *No class Nov 5* | None |
| Week 11, Nov 12 and 14 | Simplified global warming model | | Assignment 8 |
| Week 12, Nov 19 and 21 | Fourier series, Fast Fourier Transform | Examples using environmental datasets | Assignment 9 |
| Week 13, Nov 26 and 28 | Thanksgiving | *No class* | None |

| Date | Topics Covered | Description | Items Due on Tuesday 11:59pm |
|---|---|---|---|
| Week 14, Dec 3 and 5 | Linear regression and curve fitting | | Assignment 10 |
| Week 15, Final | Final projects due | | Final project |

## COMMITMENT TO DIVERSITY, EQUITY, INCLUSION, AND ANTIRACISM

Diversity, equity, inclusion, and antiracism are critical values in education, but they must be supported by a commitment to action. The instructors are committed to creating an inclusive classroom environment. They expect students to work collaboratively to create an equitable classroom environment that actively engages all students in meaningful and relevant learning, values the contributions of students' diverse backgrounds, and acknowledges systemic and institutional challenges.

### *Names/Pronouns*

You deserve to be addressed in a manner that reflects your identity. Please see https://universitylife.columbia.edu/pronouns for more information on university policies and services.

### *Religious Observance*

It is the policy of the Columbia to respect its members' observance of their major religious holidays. Students should notify instructors at the beginning of the semester about their wishes to observe holidays on days when class sessions are scheduled. Where academic scheduling conflicts prove unavoidable, no student will be penalized for absence due to religious reasons, and alternative means will be sought for satisfying any course requirements.

### *Student Wellness*

Mental and physical health is important while undergoing graduate studies. While maintaining good health is a priority, occasional stress is an unavoidable part of a graduate education. Please know that there are resources on campus to help you cope with the pressures of student life. These include support groups and workshops on managing stress, healthy eating and life management. For resources for coping with stress, anxiety, and other specific health related concerns, please visit Columbia Health at https://www.health.columbia.edu/.

### *Accessibility*

Columbia is committed to providing equal access to qualified students with documented disabilities. A student's disability status and reasonable accommodations are individually determined based upon disability documentation and related information gathered through the intake process. For more information regarding this service, please visit the University's Health Services website: http://health.columbia.edu/services/ods/support.

In order to receive disability-related academic accommodations, students must first be registered with the Office of Disability Services (ODS). More information on the ODS registration process is available online at www.health.columbia.edu/ods. Please allow for at least two weeks to complete the ODS registration process. Students are encouraged to contact ODS at the start of the semester. Students who have, or think they may have, a disability are invited to contact ODS for a confidential discussion at 212.854.2388 (V) 212.854.2378 (TTY), or by email at disability@columbia.edu.

## COLUMBIA UNIVERSITY POLICIES
**https://www.gsas.columbia.edu/content/university-policies**

### *Academic Integrity*

Students should be aware that academic dishonesty (for example, plagiarism, cheating on an examination, or dishonesty in dealing with a faculty member or other university official) or the threat of violence or harassment are particularly serious offenses and will be dealt with severely under Dean's Discipline. Graduate students are expected to exhibit the high level of personal and academic integrity

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and honesty required of all members of an academic community as they engage in scholarly discourse and research. It is essential to the academic integrity and vitality of this community that individuals do their own work and properly acknowledge the circumstances, ideas, sources, and assistance upon which that work is based. Academic honesty in class assignments and exams is expected of all students at all times.

Students in this course should review and abide by the standards adopted by the Graduate School of Arts and Sciences: https://gsas.columbia.edu/content/academic-integrity-and-responsible-conduct-research. You should read these standards within the first few days of class. Ignorance of policies and standards concerning academic dishonesty shall not be a defense in any disciplinary proceedings.

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## ADDITIONAL RESOURCES

### *Columbia University Library*
Columbia's extensive library system ranks in the top five academic libraries in the nation, with many of its services and resources available online: https://library.columbia.edu/.

### *Columbia Writing Center*
The Columbia Writing Center aids undergraduate and graduate students with writing consultations for specific writing projects, writing productivity sessions, and workshops. The Writing Center offers these services for free to current Columbia students. Read more about their services on their website. You can also contact the center at writingcenter@columbia.edu with questions.