Instructor: Brian Spencer
319 Math Bldg
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Lectures: Tue/Thu 8:00-9:20 in Math 150
Office Hours: Tue/Thu 9:30-10:30am in Math 319
or by appointment (send email request with three possible times)

Course Description: the study of problems in climate science using methods of applied mathematics. The course focuses on conceptual models that capture important aspects of Earth’s climate system as well as mathematical and statistical techniques for analyzing these models. Topics from climate science include the Earth’s energy balance, temperature distribution, ocean circulation patterns, ice caps and glaciation periods. Mathematical and statistical techniques used may include dynamical systems and bifurcation theory, Fourier analysis, conservation laws, regression analysis, extreme value theory.

Prerequisites:
- This is a Master’s level class in applied mathematics which can be taken by advanced undergraduates.
- Students must have taken MTH 141, 142, 241, 306, 309 with grade of "B" or above, or equivalent background in calculus, differential equations and linear algebra.
- Students should have had some experience with mathematical models of scientific phenomena (for example science/engineering courses or MTH 443 Fundamentals of Applied Mathematics).
- It is recommended for students to have had some experience with introductory statistics (eg MTH 412), partial differential equations (eg MTH 418), and computational mathematics (eg MTH 337).

Learning Outcomes:
1. Knowledge and comprehension of the fundamental processes affecting the climate of Earth.
2. Experience and expertise in application of mathematical modeling methods to climate science.
3. Ability to analyze climate models using appropriate mathematical, statistical and numerical methods and evaluate the results.
4. Proficiency in communication of scientific and mathematical results and ideas.

Course Materials

- digital download (moderate quality page scans) from Google Play (rent $29, buy $51, free preview of p. 1-47)
- free preview of entire book but with a lot of pages missing on google books
- paperback from UB Bookstore ($64) or SIAM ($64/$44 for SIAM members) or amazon.com ($62)

UBLearns: contains lecture schedule, homework assignments, announcements, example codes

Handouts: I use handouts in class quite a bit for things like: long mathematical derivations that are too tedious to be writing out in class, notes that are mainly definitions, figures/pictures, printouts of example computer codes and results, etc.

Matlab: for numerical-based analysis, graphical representation of data, and homework (Python is also ok). Matlab is available on campus computers, from off-campus using “My Virtual Computing Lab”, or by downloading onto your personal computer, all of which are detailed here: https://www.buffalo.edu/ubit/service-guides/software/by-title/matlab.html
I do not expect you to be a proficient coder in matlab. I will go through example codes line-by-line in class. Any homework involving matlab would require minor modification to existing code examples and not completely new code.
Coursework

Assignments: homework assignments and occasional in-class activities.

Project: an open-topic assignment matching the specific interests of the student, expected to take about 25 hours of work to complete over the second half of the semester. A brief outline of the project requirements is below, full details will be provided later:

1. in consultation with the instructor, choose (a) and/or (b):
   (a) find a paper from the literature that goes beyond what is discussed in the text and summarize the paper in relation to the model(s) from the text.
   (b) create a modification to one of the mathematical models from the text and use analytical and/or numerical methods to analyze the behavior and evaluate the results.

2. Develop a written report on your project based on the following milestones (due dates to be announced)
   a) preliminary project proposal (1 page, discuss with instructor) [10% of project grade]
   b) final proposal (< 3 pages, instructor review) [20%]
   c) progress report (< 5 pages, discuss with instructor) [20%]
   d) first draft of paper (< 10 pages, peer review) [20%]
   e) second draft of paper (< 10 pages, discuss with instructor) [20%]
   f) final draft of paper (< 10 pages, instructor review) due during finals week [10%]

Participation: I take attendance and base the participation grade on attendance.

Grades

Course Grades are determined by averaging the grades with the following weightings:

Assignments 65%
Project 30%
Participation 5%

Grading Rubric: Points for homework and exam questions are allocated using the following guidelines (assuming 5 point question):

5/5 - Correct method, clearly presented, correct answer. No significant mistakes (grade A work).

4/5 - Correctly captures the essential method or idea in the solution of the problem, is clearly presented, but has one or more minor errors (grade B work).

3/5 - Displays some understanding of the underlying concepts and ideas but the solution contains significant errors in execution of the details (grade C work).

2/5 - Questionable understanding of the underlying concepts and ideas and/or major errors (grade D work).

1/5 - Minimal progress, but some parts of the solution are not totally incorrect (grade F work).

0/5 - The solution has no redeeming features (no credit).

Point scores are scaled proportionally for problems of 10 points, 15 points, etc.
5-point grading scale: For keeping track of course grades on exams and homework a 5-point scale is used:

- **A+ = 4.66-5.00**
- **A = 4.33-4.66**
- **A- = 4.00-4.33**
- **B+ = 3.66-4.00**
- **B = 3.33-3.66**
- **B- = 3.00-3.33**
- **C+ = 2.66-3.00**
- **C = 2.33-2.66**
- **C- = 2.00-2.33**
- **D+ = 1.66-2.00**
- **D = 1.33-1.66**
- **D- = 1.00-1.33**
- **F = 0 - 1.00**

+/- grades will be used in assigning course grades. Note the university does not permit final course grades of A+ or D- for undergraduates or A+, D+, D- for graduate students.

Late assignment policy: assignments are due at the end of class on the due date. Late assignments are accepted up to one day after the due date with the following penalties:
- turned in by 5pm on due date: -5%
- turned in by 5pm day after due date: -10%
- two days late: -20% and -20% per day for each school day after.

Attendance: I expect you to attend every class. I take attendance and base the participation grade on attendance. If you miss a class you are responsible for getting the homework, lecture notes and any other in-class information or materials from a classmate. Missing an in-class assignment results in zero credit.

Academic Honesty: Students must obey the university policy on academic honesty. Homework assignments are to be completed without help from other students unless stated otherwise in the assignment. Cheating, plagiarism, or misrepresentation of your work will result in formal charges. For more information see https://academicintegrity.buffalo.edu/policies.php

Incompletes: Incompletes will be given only under extraordinary circumstances (like surgery during the last week of class).

Other

Important Dates:
- Tue Sep 3 - Last day to drop the course - no record appears on transcript.
- Fri Nov 8 - Last day to resign from the course - an 'R' appears on transcript.

Students with disabilities:
If you have a diagnosed disability (physical, learning, or psychological) which will make it difficult for you to carry out the course work as outlined, or requires accommodations such as recruiting note takers, readers, or extended time on exams and/or assignments, please advise me during the first two weeks of the course so that we may review possible arrangements for reasonable accommodations.
Course Outline

**course introduction** (syllabus, etc);  **ch 1 climate and mathematics** – general intro to climate models, statistics and data (1 lecture)

**ch 2 Earth’s energy budget** – black body radiation, EBM, greenhouse effect, multiple equilibrium, Budyko’s model, snowball earth, bifurcation (1 lec)

**ch 3 oceans and climate** - ocean circulation, thermohaline circulation, conveyor belt, density, temperature, salinity, ocean layers: mixing, thermocline, abyssal zone, box model for ocean circulation, T-mode, S-mode (2 lec)

**ch 6 Stommel’s box model** - 2-box model, formulation as a dynamical system, stability and bifurcation analysis, historical importance (2 lec)

**ch 7 Lorenz equations and chaos** – Lorenz model, symmetries and trapping set, equilibrium solutions and stability, numerical solutions (1 lec)

**ch 8 climate and statistics** – challenges of large data, heterogeneous data, processed data, incomplete data; proxy data, reanalysis, model skill; **ch 9 regression analysis** – statistical modeling and examples, linear regression, regression diagnostics (1 lec)

**ch 10 Mauna Loa CO₂ data** – Keeling data, analysis of Keeling data: trend, periodic component and residuals (1 lec)

**ch 11 Fourier transforms and Milankovitch glacial cycle theory** – Fourier analysis, discrete Fourier transforms, FFT, power spectrum, correlation and autocorrelation, Fourier integrals, application to glacial data, Milankovitch glacial cycle theory (3 lec)

**ch 12 zonal energy budget** – zonal energy balance model, analysis using Legendre polynomials and spectral solution to zonal EBM, equilibrium temperature profile of earth vs latitude (4 lec).

**ch 17 cryosphere and climate** – components of the cryosphere, glaciers, sea ice, melt ponds, scaling analysis of melt ponds using image processing (4 lec)

**ch 19 extreme events** – climate and weather extremes, exceedances, tail probabilities and return periods, order statistics and extreme value distribution (4 lec)

**topic to be determined from class input** (4 lec)
   a. **ch 13 atmosphere models**; **ch 16 El Nino southern oscillation**
   b. **ch 18 carbon cycle NPZ model for ocean plankton and algal blooms**
   c. **ch 20 data assimilation and prediction**

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