EARTH / CLIMATE 323: Earth System Analysis

Winter 2019

Instructor: Ashley Payne (aepayne@umich.edu)
Office Hours: MW 12:15 - 1:15 pm, CSRB 2215b (or by appointment)
Grader: Adam Werkema (adwerk@umich.edu)

Lectures: MW 10:30 - 12:00 pm, CSRB 2246
Lab: F 10:30 - 12:30 pm, CSRB 2230 (CAEN Lab)
Course webpage: Canvas
Textbook: Kreyszig, Advanced Engineering Mathematics, 9th ed. (helpful but not required, on reserve at library)

Suggested Prerequisites:
Introductory integral and differential calculus
Introductory linear algebra and vector spaces
Programming basics (review of MATLAB will be included in first lab)

Course Description

EARTH / CLIMATE 323 is an introduction to the analysis of Earth and Space Science Systems. The mathematical topics that will be covered include:

- Linear systems
- Harmonic analysis
- Discrete mathematics
- Sampling theory
- Statistical error analysis

The course is designed to emphasize a conceptual understanding of the underlying mathematical concepts in lecture and their applications to the analysis of scientific measurements in a programming environment. Current topics in the atmospheric and space sciences are addressed in each of the labs as a means of demonstrating the relevance of the mathematical tools to problems in Earth Systems.

The labs are also intended to expose students to the MATLAB programming environment at a level beyond that covered in a typical freshman introductory course. Each lab requires students to write or to substantially modify a considerable amount of MATLAB source code. In addition to coding that is directly related to the topics covered in the lectures, a number of other MATLAB procedures that are often useful for analysis of measurements and model outputs. These include:

- Reading archival environmental data records
- Automated searching and filtering of data records
- Statistical analysis of raw data and of processed data products
- Plotting data in various ways

These additional programming tools are often useful for analysis of measurements and model outputs. One objective of the course is for a student, upon completion, to be able to download environmental data records from the web, import them into MATLAB, perform various spectral analysis and linear filter operations on them, and display the results both graphically and with summary statistics.

Course Goals

By the end of the semester, all students should have an understanding of the mathematical concepts underlying common data analysis techniques on time series data (often the case in the Earth sciences).

Students will be able to load data stored in a variety of formats into MATLAB and be able to extract information from the data. Students will learn best practices for exploratory data analysis and effective communication through meaningful figures and scientific writing.

Course Policies

Late Work: Late assignments will not be accepted without prior approval from an instructor. Absence from exams will not be accepted or made up except under extraordinary conditions that are properly certified. Please review deadlines them carefully and email the instructor if you anticipate any scheduling conflicts well in advance.

Homework: Homework will be assigned weekly, with the exception of exam weeks. Paper copies of homework solutions should be handed in at the beginning of class (10:30 am) the following week. Homework solutions will be posted to the course webpage the week after the homework is assigned.

You may discuss this homework assignment with your fellow students, and complete the work with other students in the class, including working in a group around a common table and discussing problems as you work on them. However, you must submit individual work that is not a verbatim copy of any other student's work. Do not forget that even when you work in a group, you are individually responsible for the learning that should accompany homework completion. Exams will be based entirely on material covered in lecture and in all homework sets.

Lab: Labs will be assigned weekly on Fridays, with the exception of exam weeks. Electronic copies (.doc or .docx) should be posted on to the course website by the end of lab (12:30 pm, Fridays). You do not need to print out and hand in a paper copy.

You are encouraged to discuss the labs with other students and to collaborate on the development of algorithms and the debugging of software. However, you are individually responsible for producing their own technical report for each lab that is not a verbatim copy of any other student's work (this includes figures, code, etc). In particular, students should individually compose the discussions, comments and responses to questions in the lab reports.

Exams: There will be two exams, each covering approximately 1/2 of the material of the course. The first exam will be during the regular class time and the second will be a take home exam. For the in-class exam, students are allowed to prepare and bring in one sheet of paper (8.5" x 11") with helpful information / concepts (both sides of paper allowed).

Final Project: An individual project will take the place of a final exam. By the beginning of March, each student should identify a dataset of interest and develop a research project using one or more tools from the course. Students will submit a project proposal (500 words max) March 18th. You will report the results of your work in an oral presentation of your analysis (12 min) and with a written report (6 to 8 pages) at the end of the semester. Your total project grade will be a weighted combination of your grades on the project proposal, and the written and oral reports. Additional details, sample topics and a grading rubric will be posted to the course website closer to the first deadline for the final project.

Grading Policy:
Grades will be assigned according to the following weighted average of scores:

8 Homework sets	10 – 30%
7 Lab Reports	20 – 40%
Two Midterms	10 – 20% each
Final Project	10 – 30% and greater than the weight of one midterm

Each student may select values for weights in each grading category within the specified ranges (the total must add up to 100%). Please email me with this information the week after the first exam is returned (around Mar 11). If you do not select individualized weights, then the following default weights will be used:

8 Homework sets	20%
7 Lab Reports	30%

Two Midterms	15% each
Final Project	20%

Course Outline

We will begin the course with a review of linear algebra and basics of MATLAB programming. Each week, material in the lectures will be applied in Friday's lab. The lectures include in-class discussions and review of problems similar to those found in homework sets and exams.

Lecture / Lab Schedule
1/9 (W): Logistics; Linear algebra; **HW 1 assigned**
1/11 (F*): Linear algebra (**NOTE: lecture in regular classroom, 10:30 - 12:00**)
1/14 (M): Linear algebra
1/16 (W): Linear algebra **HW 1 due**
1/18 (F): Lab 1 (Introduction to MATLAB, Absolute and Relative Humidity)

1/21 (M): HOLIDAY - MLK day

1/23 (W): Exploratory data analysis
1/25 (F): Lab 2 (Covariance in the Planetary Boundary Layer), **Lab 1 due**
1/28 (M): Statistics and probability; **HW 2 assigned**

1/30 (W): Classes cancelled

2/1 (F): Lab 3 (El Niño / Southern Oscillation), **Lab 2 due**
2/4 (M): Probability; **~~HW 3 assigned~~, HW 2 due**
2/6 (W): Significance tests and introduction to time series
2/8 (F): Lab 4 (Time Harmonic Precipitation), **Lab 3 due**
2/11 (M): Fourier Series; **HW 4 assigned, ~~HW 3 due~~**
2/13 (W): Fourier Series
2/15 (F): Lab 5 (Cloud Drop Sizes and Doppler Spectra), **Lab 4 due**
2/18 (M): Fourier Transform; **HW 5 assigned, HW 4 due**
2/20 (W): Review of MATLAB concepts and final project
2/22 (F): No lab (workspace for final project), **Lab 5 due**
2/25 (M): In-class review and CRLT evaluation; **HW 5 due**
2/27 (W): **IN-CLASS EXAM #1**
3/1 (F): **Open lab session for individual projects**

3/4 - 3/8: HOLIDAY - Spring Break

3/11 (M): Review exam; Fourier Transform
3/13 (W): Convolution
3/15 (F): Lab 6 (Time Dependent Periodicity of Sunspots)
3/18 (M): Convolution; Filters **Project description due**
3/20 (W): Filters; Wavelets
3/22 (F): Lab 7 (Wave Propagation in Dispersive Media), **Lab 6 due**
3/25 (M): Regression; **HW 6+7 assigned**

3/27 (W): Class cancelled

3/29 (F*): Regression; EOFs (**NOTE: lecture in regular classroom, 10:30 - 12:00**), **Lab 7 due**
4/1 (M): EOFs; Statistical significance; **HW 8 assigned, HW 6+7 due**
4/3 (W): Classification
4/5 (F*): Classification (**NOTE: lecture in regular classroom, 10:30 - 12:00**)
4/8 (M): Virtual review of material; **HW 8 due**; **TAKE-HOME EXAM #2 released at 12:30 pm**

4/10 (W): Class cancelled

4/12 (F): **Open lab session for individual projects, Ashley available remotely for questions**
4/15 (M): **TAKE-HOME EXAM #2 due at 10:30 am**; **Open lab session for individual projects**
4/17 (W): **Student presentations**
4/19 (F*): **Student presentations** (**NOTE: lecture in regular classroom, 10:30 - 12:00**)

4/22 (M): **Student presentations**
5/1 (W): **Project reports due at 4:00 pm**