Course Name and No. XXXX: Climate Mathematics

Quarter, Year, Date and Hours: XXX
Project preparation week and presentation: XXX
Classroom: XXX

Instructor: XXX
Office Location: XXX
Email: XXX
Course website: XXX

Office Hours: XXX
Tel: XXX-XXXX

Text: *Climate Mathematics: Theory and Applications* by Samuel S. P. Shen and Richard C. J. Somerville, Cambridge University Press, 2019.

Prerequisites: Calculus III and basic linear algebra

Topics covered in this course: This course is designed for advanced-level undergraduate students and entry-level graduate students in atmospheric or oceanic sciences. It will train them with sufficient mathematical, statistical and computing skills to do research. The course covers Chapters 2, 5, 8-11, plus selected topics from other chapters and appendices of the textbook. Specifically, the course will cover the following materials: R programming, computer visualization of climate data of different formats including netCDF and csv, singular value decomposition (SVD) of matrices, energy balance models for climate, Taylor's theorem, ideal gas law, hypsometric equation and its approximation, Planck's law of radiation and Stefan-Boltzmann's law of radiation, total derivative, conservation laws, basic equations for the geophysical fluid dynamics, geostrophic approximation, vorticity and its conservation, computer graphics for climate science, empirical orthogonal function (EOF) analysis and visualization of real climate model and observed datasets, R analysis for incomplete data, and trends of historical climate change.

Computing: R will be taught and used extensively in class. Bring your laptop to class.

Grading Policy: The final grades for this class will be determined as follows:

Homework assignments (4 times)	36%
Midterm (60 minutes)	14%
Final exam (120 minutes)	30%
Final research project	20%
Total-------------------------------------	**100%**

Table 1. Course chapters, lecture hours, schedules for four assignments, a midterm, a final, and a project.

Course No. XXX	**Climate Mathematics**		
Chapter	**Materials**	**Hrs**	**Cumulative Hrs**
2	R programming	2	2
	Assignment #1 assigned and due in two weeks		
3	Review of linear regression and multivariate regression with real data	2	4
4	Review of linear algebra: Singular value decomposition, EOFs, plot EOF maps and PC time series, plot patterns of El Niño and climate changes	2	6
5	Concepts of climate models and energy balance models	3	9
	Assignment #2 assigned and due in two weeks		
6 and 7	Climate science applications of calculus: Taylor's theorem, Fourier series, ideal gas law, hypsometric equation and its approximation, Planck's law of radiation and Stefan-Boltzmann's law of radiation, total derivative	4	13
	Assignment #3 assigned and due in two weeks		
	Midterm Exam (closed book for theory and open book for R coding): in class	1	14
8	Conservation laws in climate dynamics: cross product, Coriolis force, Eulerian and Lagrangian coordinates, total derivative, mass conservation, momentum conservation, geostrophic approximation, geostrophic wind, vorticity conservation	5	19
	Final research project assigned and due in three weeks		
	Preparation of the final research project: requirements, writing format, figure quality	1	20
9	Basics of R computer graphics for climate science	3	23
	Assignment #4 assigned and due in two weeks		
10	Advanced R computer graphics, visualization of EOFs and PCs	3	26
11	R analysis of incomplete climate data	2	28
	Final project presentation: time and day/date	2	30
	Final Exam (closed book for theory and open book for R coding): 2 hours, time and day/date		

Student learning outcomes:

Upon completion of this course, students should be confident in their ability to use methods of calculus, linear algebra, statistics, and computer programming to formulate and solve climate science problems and present the corresponding quantitative solutions. In particular, students will be able to:

- Develop climate model equations based on the balance of mass, energy, and momentum with specific assumptions for Earth and other planets;
- Develop computer codes to analyze commonly used climate datasets, such as, NCEP/NCAR Reanalysis, and NOAA Global Surface Temperature (NOAAGlobalTemp), in different formats, including Network Common Data Form (netCDF), and Comma-Separated Values (csv);
- Use the singular value decomposition approach and computer codes to compute and visualize empirical orthogonal functions (EOFs), and interpret their climate implications;
- Write computer codes to plot various kinds of 2D and 3D graphics for climate research, including line graphs, histograms, contours, filled-color contour maps, flow fields, and space-time Hovmöller diagrams;
- Write computer codes to make animations;
- Write computer codes to make simple and multivariate regression analyses of climate data and plot the relevant figures;
- Master sufficient knowledge of mathematics to take most graduate courses in atmospheric and oceanic sciences, such as physical oceanography, atmospheric thermodynamics, and marine chemistry;
- Use the mathematical, statistical, and computing skills and tools from this course to conduct research in climate science;
- Demonstrate mastery of the knowledge and skills by completing and presenting a research project based on real climate data.