SIOC 290: Climate Mathematics

MTWR 09:00-10:50am, F 9:00-9:50am, July 31 (M)-September 8 (F), 2017
Project preparation week: September 11-15/M-F, 2017
Classroom: Nierenberg Hall 101

Instructor: Samuel Shen Office: NH430 Tel: 858-246-0205
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Course website: http://scrippsscholars.ucsd.edu/s4shen/pages/teaching

Office Hours: 11:00-12:00pm MTWRF or by appointment

Text: *Climate Mathematics*, Lecture Notes by Samuel Shen and Richard Somerville, plus online materials

Prerequisites: Basic science background and pre-calculus.

Topics covered in this course: The course is designed for the students in the Masters of Advanced Studies program in Climate Sciences and Policy. These students will need to understand, explain and present the results from climate models and observations. They will use SIOC 290 to prepare themselves to take SIOC 210 (Physical Oceanography), SIOC 217A (Atmospheric Thermodynamics), SIOG 260 (Marine Chemistry). They will learn probability, statistics, mathematics, and plotting skills to present and describe climate data from both observations and models.

The course covers the following materials dimensional analysis, calculus review, basic R programming, linear algebra, EOFs using SVD, climate data visualization, mass balance equation for chemical reactions, basic probability and statistics, linear approximation, Newton's method for solving equations, energy balance model for climate, dot and cross products, internal energy, enthalpy, entropy, exact differentials, Planck's law of radiation, spherical coordinates, total derivative, conservation laws, geostrophic approximation, geostrophic wind, Rossby waves, oceanic gyres, and coastal currents.

PhD students who need additional mathematics and statistics skills or who would like to learn modern tools and unconventional approaches to climate data analysis can also take this course.

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 (3 times)	39%
Final exam (120 minutes)	41%
Final project	20%
Total-------------------------------------	**100%**

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

SIOC 290	**Climate Mathematics**		
Chapter	**Materials**	**Hrs**	**Cumulative Hrs**
1	Assessment test (60 minutes, 3% bonus points, July 31/Mon) Dimensional analysis	3	3
2	R programming	2	5
3	Concepts of probability and statistics, mean, standard deviation, normal distribution, linear regression, t-test	3	8
Hwk #1	**Assignment #1 (due 8/9 Wed, submit all files on BB)**		
4	Calculus review: derivatives, integrals, partial derivatives, exact differentials, trigonometric function, spherical coordinates, double and triple integrals, and line integrals	6	14
5	Linear algebra: Climate data matrices, EOFs, plot EOF maps and PC time series, plot patterns of El Nino and climate changes, mass balance equation for chemical reactions	3	17
Hwk #2	**Assignment #2 (due 8/23 Wed, submit all files on BB)**		
6	Concept of climate models and energy balance models	2	19
7	Climate science topics of derivative applications: Stefan-Boltzmann radiation equation and Budyko's approximation, linear approximation, Newton's method, higher order derivatives, and Taylor series	3	22
8	Climate science topics of integral applications: geopotential, exponential decrease of air pressure, work by air mass expansion, internal energy, enthalpy, entropy, Planck's law of radiation	11	33
Hwk #3	**Assignment #3 (due 8/30 Wed, submit all files on BB)**		
9	Conservation laws in climate dynamics: cross product, Coriolis force, Eulerian and Lagrangian coordinates, total derivative, mass conservation, momentum conservation, geostrophic approximation, geostrophic wind, ocean boundary layer, vorticity conservation, oceanic gyres	9	42
10	Special topic: Monte Carlo simulations	1	43
11	Special topic: Extreme value distribution	1	44
12	Special topic: Concept of the probabilistic weather forecast	1	**45 Hrs**
Final	**September 8/Friday: 2 hours, 10:00am-12:00pm**	Close book	
	Final project research and writing: September 11-15		
	Final project presentation: September 20/Wednesday		

About the Final Project: The final project is a two-student-a-team research on given climate datasets. The project report requires 20 double-space pages, including cover, references, figures, and tables and is due online by September 15/Friday, 2017, 11:59pm on BB). The project presentation is on September 20/Wednesday: 9am-12noon. The project must also satisfy all the requirements of the SIOC291S @Climate final project.

Learning outcome:

The course is designed for the students in the Masters of Advanced Studies program in Climate Sciences and Policy. These students will need to understand, explain and present the results from climate models and observations. They will use SIOC 290 to prepare themselves to take SIO 210 (Physical Oceanography), SIO 217A (Atmospheric Thermodynamics) and SIO 260 (Marine Chemistry). They will learn probability, statistics, mathematics, and plotting skills to present and describe climate data from both observations and models, particularly about climate extremes and uncertainties. Every mathematics formula and theory included in this book is presented with at least one climate application example.

The students may have different mathematics background, ranging from three semesters of calculus, linear algebra, differential equations, complex variables and basic statistics, to only Calculus I and basic statistics. Even the students who have taken many mathematics courses before may find that the mathematics and statistics in climate science are used in a different format. Thus, SIOC 290 will adopt an innovative instruction of mathematics and statistics to present the minimum amount of mathematics needed to make effective climate data interpretation and presentation. The course starts from basic concept of calculus without limit, and goes to linear approximation and geostrophic approximation, from basic concept of probability and statistics to advanced theory of sampling error estimation, from basic R programming to more advanced climate data plotting and visualization skills, and from dimensional analysis to Rossby waves and coastal currents.

PhD students who need additional mathematics and statistics skills or who would like to learn modern tools and unconventional approaches to climate data analysis and models can also take this course.