Master of Science in Sustainability Science

SUSC PS5010 Climate Science for Decision Makers: Modeling, Analysis, and Applications
Wednesday, 4:10-6:00 PM
3 Credits

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Office Hours: By appointment over zoom or phone

Response Policy: We are available for short chats and clarification after class, but longer discussion should be left for Office Hours. You can also email us with questions and issues, and we will respond within 2 business days (most likely much earlier than that).

Course Overview

Both human and natural systems are growing more vulnerable to climate variability (e.g., the anomalous weather induced by the El Niño-Southern Oscillation, or the increase in hurricanes that occurs when ocean currents warm the Atlantic) and human-induced climate change (which manifests itself primarily through increases in temperature, precipitation intensity, and sea level, but which can potentially affect all aspects of the global climate). Multiple impacts of climate anomalies to ecosystems, human health, and infrastructure have been widely documented as has been, in many cases, the rise of both hazards and vulnerability. Fortunately, growing risks is being matched by a growing mobilization of intellectual and financial resources to make human and natural systems resilient and adaptive to a changing climate. This course will prepare you to estimate climate hazards in your field thereby accelerating the design and implementation of climate-smart, sustainable practices.

Climate models are the primary tool for predicting global and regional climate variations, for assessing climate-related risks, and for guiding adaption to climate variability and change. Thus, a basic understanding of the strengths and limitations of such tools is necessary to decision makers and professionals in technical fields. This course will provide:

1. A foundation in the dynamics of the physical climate system that underpin climate models and a full survey of what aspects of the climate system are well observed and understood and where quantitative uncertainties remain.
2. A fundamental understanding of the modeling design choices and approximations that distinguish Intergovernmental Panel on Climate Change (IPCC)-class climate models from weather forecasting models and that create a diversity of state-of-the-art climate models and climate projections.
3. An overview of the ways in which climate model output and observations can be merged into statistical models to support applications such as seasonal and decadal projections of climate extremes, global and regional climate impacts, and decision making.
4. The skills to visualize, analyze, validate, and interpret climate model output, calculate impact-relevant indices such as duration of heat waves, severity of droughts, or probability of inundation, and the strategies to characterize strengths and uncertainties in projections of future climate change using ensembles of climate models and different emission scenarios.

Through lectures, discussions, and hands-on experience with climate model output, students will learn to independently assess the reliability of published impact projections and to build and customize their own. The students will apply the acquired knowledge of climate-prediction methods and predictability limits for specific phenomena, spatial scales, or time horizons in their professional commitment to design robust climate-smart sustainable practices for ecosystems, agriculture, water and energy use, human health, or infrastructure.

Some background in engineering or physical sciences, computer programming languages, and basic statistical analysis is desirable.

This course is approved to meet the Area 3 – Analysis and Modeling Environmental Conditions and Impacts – curriculum area requirement for the M.S. in Sustainability Science program.

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Learning Objectives

By the end of this course, students will be able to:

L1: Describe the main features of the mean state of the climate system and of the circulations of the atmosphere and ocean.

L2: Select the appropriate observational data sets to assess climatic trends and validate model output.

L3: Describe the modeling strategy underpinning weather forecasting models, global and regional climate models, and earth system models and identify the scope of use for each class of models.

L4: Appraise the theoretical, observational, and modeling evidence for anthropogenic climate change.

L5: Apply basic statistical techniques to analyze model output and construct a projection for regional climate change.

L6: Synthesize the knowledge of climate projections and of the strengths of different classes of climate models and apply it to formulate examples of climate adaptation strategies and climate-smart sustainability practices.

L7: Identify and effectively communicate the sources of uncertainty in projections for different aspects of the climate system and for different lead time of the projections.

Readings

Core Text: Neelin, J. David. *Climate change and climate modeling*. Cambridge; New York: Cambridge University Press, 2011. ISBN 9780521841573 (hbk.) 9780521602433 (pbk.) (https://clio.columbia.edu/catalog/10086710)

Other Readings:

1. IPCC 6th Assessment Report, Working Group I. *Climate Change 2021: The Physical Science Basis.* (http://www.ipcc.ch/report/ar6/wg1/)
2. Additional reading materials will be assigned for in-class discussion.

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: http://library.columbia.edu/.

SPS Academic Resources
The Office of Student Affairs provides students with academic counseling and support services such as online tutoring and career coaching: http://sps.columbia.edu/student-life-and-alumni-relations/academic-resources.

Course Requirements (Assignments)

Participation

Class participation hones your ability to talk about the role of climate and climate predictions in sustainability practices. Weekly readings will be assigned so please come to class having read the material and ready to participate in classroom discussions during lectures. Classroom participation makes up 10% of your final grade. Most importantly, it provides an indication of your interests and grasp of the material.

In-Class Discussion

We will have ~30-45 minutes of in-class discussion on selected topics in most of the classes. The papers that we will discuss are listed below on the Course Calendar. Each student will be responsible for leading (or co-leading, depending on the number of students) the discussion on one of the papers. This will involve providing a brief summary of the paper, and posing questions/topics for discussion. In-class discussion makes up 30% of your final grade. You will be graded on both the paper that you lead, and on your overall contributions to the discussion throughout the semester.

Homework Assignments

There will be 5 computer-based homework (HW) assignments aimed at developing the necessary programming skills to work with climate data. Each HW assignment will be distributed in class and will be due the following class.

HW 1 will be focused on calculating global-mean time series from gridded climate data. You will be asked to perform simple operations on these time series such as linear regression to estimate long-term trends.

HW 2 will be focused on zero- and one-dimensional climate models. You will be asked to derive an empirical estimate of climate sensitivity using observational data, and to compare this estimate with simulations from a one-dimensional radiative-convective model.

HW 3 will be focused on plotting gridded climate data in two dimensions (e.g., latitude-longitude or latitude-height). You will be asked to make plots on climatological fields and the long-term trends.

HW 4 will be focused on three-dimensional general circulation models. You will be asked to calculate trends in climatic variables as simulated by these models. You will compare historical simulated trends to observations and you will identify the range of possible projected trends in light of natural variability, model choice, and emissions scenario.

HW 5 will synthesize the programming skills that you develop in previous HWs in order to analyze the future projections in an ensemble of IPCC AR5 climate models.

Final Project & Presentation

You will choose a topic for your final project according to your own interest and in consultation with the course instructors. A mandatory project proposal will need to be written and submitted. The proposal will not be graded; it is meant to ensure an appropriate topic and it is a pre-requisite for the acceptance of the final project. For the proposal we request the submission of a document of less than one page describing the project and how you plan to approach your paper. Failing to turn in the proposal in a timely manner will forfeit the submission of the final project or will result in points removal from the final written project. Final project topics might aim, for example, to outline a climate-smart sustainability practice. This involves identifying the correct climate variable(s) that affects your system of interest, estimating possible changes in the relevant climate hazards, and assessing the range of risk. For instance, you might outline a risk assessment of the following: public transportation disruptions due to climate change; modulations of extreme heat waves and flooding in NYC; or water shortage due to climate variability (e.g., droughts) and climate change in California. Work on the final project will be of the same kind as that done in the labs and homework assignments, but you will have to determine the correct tools to address your problem. You will be responsible for reading primary source material on the topic, customizing a climate projection to assess changes in climate hazards, and evaluating the scientific certainty/uncertainty behind the issue. You will also be responsible for making the appropriate links and associations with the relevant theoretical material covered during the course. You will present your results to the class in a short (approximately 15 minute) slide presentation and through a written project report that describes your work. The project report should include background and motivation, methods, results, and conclusions, along with proper citation of scientific literature. The length of the project report is limited to 5 pages, not including references.

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Evaluation/Grading

Participation (10%)

Participation will be graded on a scale of 0-100. Participation includes class attendance and active discussions during lectures. The students are expected to show critical thinking, respectful interactions with classmates and a positive attitude towards learning and freely discussing the class materials.

In-Class Discussion (30%)

In-class discussion will be graded on a scale of 0-100. In-class discussion will be graded based on critical thinking, discussion within each group and report/discussion in the entire class.

Homework Assignments (30%)

HWs 1-5 will each be graded on a scale of 0-100. HW assignments will be graded based on the correctness and completeness of the programming code, and thoughtful interpretation of the results.

Final Project (30%)

Both the written final project report (60% of the final project grade) and the class presentation (40% of the final project grade) will be graded on a scale of 0-100. The written report will be graded based on completeness (i.e., including background and motivation, methods, results, conclusions and references) and correct interpretation of the results. The class presentation will be graded based on clarity, quality of the slides, finishing in a timely manner, and responses to audience questions.

The final grade will be calculated as described below:

FINAL GRADING SCALE

Grade	Percentage
A+	98–100 %
A	93–97.9 %
A-	90–92.9 %
B+	87–89.9 %
B	83–86.9 %
B-	80–82.9 %
C+	77–79.9 %
C	73–76.9 %
C-	70–72.9 %
D	60–69.9 %
F	59.9% and below

ASSIGNMENT	% Weight
Participation	10
In-Class Discussion	30
Homework Assignments	30
Final Project	30

Course Policies

Participation and Attendance

We expect you to come to class on time and thoroughly prepared. We will keep track of attendance and look forward to an interesting, lively and confidential discussion. If you miss an experience in class, you miss an important learning moment and the class misses your contribution. More than one absence will affect your grade.

Late work

Work that is not submitted on the due date noted in the course syllabus without advance notice and permission from the instructors will be graded down 1/3 of a grade for every day it is late (e.g., from a B+ to a B).

Submission of assignments

All assignments should be submitted via CourseWorks.

School Policies

Copyright Policy

Please note—Due to copyright restrictions, online access to this material is limited to instructors and students currently registered for this course. Please be advised that by clicking the link to the electronic materials in this course, you have read and accept the following:

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted materials. Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction is not to be "used for any purpose other than private study, scholarship, or research." If a user makes a request for, or later uses, a photocopy or reproduction for purposes in excess of "fair use," that user may be liable for copyright infringement.

Academic Integrity

Columbia University expects its students to act with honesty and propriety at all times and to respect the rights of others. It is fundamental University policy that academic dishonesty in any guise or personal conduct of any sort that disrupts the life of the University or denigrates or endangers members of the University community is unacceptable and will be dealt with severely. 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.

SPS holds each member of its community responsible for understanding and abiding by the SPS Academic Integrity and Community Standards posted at http://sps.columbia.edu/student-life-and-alumni-relations/academic-integrity-and-community-standards. You are required to read these standards within the first few days of class. Ignorance of the School's policy concerning academic dishonesty shall not be a defense in any disciplinary proceedings.

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.

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Course Schedule/Course Calendar

Date	Topics and Activities	Readings (due on this day)	Assignments (due on this date)
Class 1 9/6	Introduction to the Climate System: Atmosphere, Ocean, Cryosphere, and Land	Neelin, Ch. 1.5-1.6, 2.1-2.8, 4.1-4.3	
Class 2 9/13	Observations of the Climate System	<u>In-Class Discussion:</u> Goddard and Gershunov (2021), "Impact of El Niño on Weather and Climate Extremes" <u>Other:</u> IPCC AR6 WG1, Ch. 2.3-2.5	HW1 assigned (due 9/27)
Class 3 9/20	Radiative Forcing and Climate Sensitivity	<u>In-Class Discussion:</u> Vecchi et al. (2021), "Changes in Atlantic major hurricane frequency since the late-19th century" <u>Other:</u> Neelin, Ch. 6.3-6.7 IPCC AR6 WG1, Ch. 2.2, 7.1-7.5	
Class 4 9/27	Modeling the Climate System: Model Types, Historical Development, and Assessing Model Skill	<u>In-Class Discussion:</u> Carvalho et al. (2022), "How well have CMIP3, CMIP5 and CMIP6 future climate projections portrayed the recently observed warming" <u>Other:</u> Neelin, Ch. 5	HW2 assigned (due 10/11)
Class 5 10/4	Detection and Attribution of Anthropogenic Climate Change	<u>In-Class Discussion:</u> Kirchmeier-Young and Zhang (2020), "Human influence has intensified extreme precipitation in North America" <u>Other:</u> IPCC AR6 WG1, Ch. 3	
Class 6 10/11	Future Climate Projections: Emission Scenarios, Projections and Uncertainties, Part I	<u>In-Class Discussion:</u> Fischer et al. (2021), "Increasing probability of record-shattering climate extremes" <u>Other:</u> IPCC AR6 WG1, Ch. 4	HW3 assigned (due 10/25)

Class 7 10/18	Future Climate Projections: Emission Scenarios, Projections and Uncertainties, Part II	In-Class Discussion: Deser et al. (2012), "Communication of the role of natural variability in future North American climate" Other: IPCC AR6 WG1, Ch. 4	
Class 8 10/25	Regional Climate Projections: Dynamical and Statistical Downscaling, Part I	In-Class Discussion: Roberts et al. (2020), "Projected future changes in tropical cyclones using the CMIP6 HighResMIP multimodel ensemble" Other: IPCC AR6 WG1, Ch. 10.1-10.3	HW4 assigned (due 11/8) Proposal for Final Project due on 11/8
Class 9 11/1	Regional Climate Projections: Dynamical and Statistical Downscaling, Part II	In-Class Discussion: Navarro-Racines et al. (2020), "High-resolution and bias-corrected CMIP5 projections for climate change impact assessments" Other: IPCC AR6 WG1, Ch. 10.1-10.3	
Class 10 11/8	Global Warming of 1.5ºC	In-Class Discussion: Diffenbaugh and Barnes (2022), "Data-driven predictions of the time remaining until critical global warming thresholds are reached" Other: Global Warming of 1.5ºC. An IPCC Special Report on the impacts of global warming of 1.5ºC above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty	HW5 assigned (due 11/22)
Class 11 11/15	Applications in Decision Making and Sustainability Management	In-Class Discussion: Goss et al. (2020), "Climate change is increasing the likelihood of extreme autumn wildfire conditions across California" Other: "Managing California's Water: From Conflict to Reconciliation" (2011) (https://www.ppic.org/wp-	

		content/uploads/content/pubs/report/R_211EHR.pdf	
No class 11/22			
Class 12 11/29	Superstorm Sandy and Decision Making	In-Class Discussion: Barnes et al. (2013), "Model projections of atmospheric steering of Sandy-like superstorms" Other: NYC Panel on Climate Change 2019 Report (https://nyaspubs.onlinelibrary.wiley.com/toc/17496632/2019/1439/1) Storm Surge: Hurricane Sandy, Our Warming Planet, and the Extreme Weather of the Past and Future, by Adam Sobel, Harper Wave, 2014	
Class 13 12/6	Geoengineering	In-Class Discussion: Robock (2020), "Benefits and Risks of Stratospheric Solar Radiation Management for Climate Intervention (Geoengineering)"	
12/13	Final Project Presentations		
12/20	Final Project Presentations		Final Project Report due on 12/20