EES1133H: Climate Change Science and Modeling

Class: 09:00 - 11:00 Wednesdays, Synchronous
Lab: Wednesdays, Asynchronous
Quercus Course Website

1 Instructor

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Preferred method of contact: Email is the best way to get in touch with me. Feel free to email me with any course-related questions.

2 Teaching Assistant

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3 Course Overview

Welcome to Climate Change Science and Modeling! Many of you are taking this course because you are passionate about Earth's climate and are concerned about how humans are altering climate - I am too. In this course we will explore how climate changes, how humans have contributed to climate change and how we can use climate models to help interpret past change and predict future change.

The questions that we will begin to answer in this course are: How does the current climate system work? How can we predict how it will change in the future? Our focus is on understanding the present day climate, the Holocene, and how it is projected to change in the near future due to anthropogenic activities. We will explore the underlying physics and dynamics responsible for regulating the Earth's climate system using theory and a hierarchy of idealized climate models. We will identify the natural and anthropogenic drivers of climate change, and gain a deeper understanding of the critical role of internal climate feedbacks. Finally, we will unpack the fundamental components of the current generation of global climate and earth system models and describe how they are used to make predictions about the future climate.

I strongly believe in "learning by doing", and as such, this course includes assignments, computer labs and interactive class activities to allow you to fully realize the scope and implications (and beauty!) of the theoretical concepts we discuss in class.

4 Learning Objectives

By the end of the course you will be able to:

- identify the components of the climate system
- explain how the Earth maintains energy balance
- evaluate scale of anthropogenic carbon emissions within the context of the global carbon cycle
- describe the natural and anthropogenic climate drivers responsible for controlling Earth's climate both in the recent past and in the future.

- determine how the climate system responds to climate drivers via climate feedbacks and what role each of the components (the atmosphere, the ocean and the cryosphere) plays.
- describe how global climate models (GCMs) work
- analyze, compare and interpret data from idealized GCM simulations in order to better understand how climate scientists use climate models to detect past and project future climate changes.
- examine the evidence for anthropogenic climate change, by applying physical principles and assessing the uncertainties associated with observational climate data and GCMs.
- critically interpret and evaluate peer-reviewed journal articles on climate change.

5 Expectations

We all come to this course with pre-conceived expectations about how the course will progress. To get us all on the same page, I have outlined those that I feel are most important in order to make this course a success.

As your instructor, I expect you will:

- take full responsibility for your own learning
- come on time and prepared for every class
- complete all work on time and with appropriate effort
- treat your fellow students, TA and instructor with respect
- ask questions when you don't understand or need clarification. Instructors love questions! Asking questions is a sign that you're engaged in the material
- contribute to building a positive learning community
- keep your microphone on mute unless asking a question or engaged in a break-out room

As students, you are entitled to expect that I will:

- foster a constructive environment for learning
- come prepared to every class
- plan each class to help you achieve the course learning objectives
- understand that the material is challenging and that extra time may be needed to work through certain topics
- provide clear instructions for assignments and lab exercises
- provide timely and constructive feedback

6 Text Books & Resources

Primary Textbook:

The textbook for this class is ***Climate Change*** by Edmund A. Mathez and Jason E. Smerdon, 2nd Edition, Publisher: Columbia University Press. Available as an e-book through the U of T Library system.

Secondary Resources:

Global Physical Climatology by Dennis L. Hartmann, 2nd Edition, Publisher: Elsevier. Available as an e-book through the U of T Library system.

The Warming Papers, edited by David Archer and Raymond Pierrehumbert, Publisher: Wiley-Blackwell. Available as an e-book through the U of T Library system.

Climate Science, Risk and Solutions (aka Climate Primer) by Kerry Emanuel.

Lecture slides, readings and other resources will be posted on the course webpage.

7 Analysis and Plotting Software

We will be running and analyzing output from idealized climate models written in **Python** in lectures and as part of your labs and assignments. Note that in order to do the lab and assignment questions, you will be required to use Python. Python is open-source (that means it's free!). Python is installed on all the computer lab computers and instructions on how to download and install Python on your own computer can be found on the course website. Clear instructions will be given in the labs and assignments.

Graduate Professional Skills Python Workshop

Knowledge of Python is not a prerequisites for this course. Although I will guide you through the Python activities, I have created a two-part Python workshop through the Graduate Professional Skills (GPS) program that you are ***strongly*** encouraged to register for. ***Your participation in this workshop will count towards your class participation grade (see below).***

The workshop is asynchronous online. You have until Friday, September 17th, 2021 to complete it. ***In order to get both GPS credit and credit towards your class participation in this course, you need to complete the reflection at the end of the workshop within the one week time period.***

8 Course Web Page

The course web site is available through Quercus. The Quercus system is accessible using your UTORID which has been assigned to you as part of registration. ***All course information, resources, readings, assignments, lab exercises and communications will be posted on Quercus.***

It is your responsibility to check the course website frequently. You must also ensure that you use your University of Toronto email address on Quercus. To familiarize yourself with Quercus, you can find additional information here.

9 Evaluation

Your course grade will be made up of class and discussion board participation, three assignments, ten lab exercises, a midterm exam and a final project. All deadlines are listed below in "Section 19: Tentative Schedule".

9.1 Class + Discussion Board Participation

Participation in activities and discussion during the synchronous lecture time and in Discussion Boards is an important component of the course and is worth 10% of your final grade.

Synchronous Lecture Time (5%): During the synchronous lecture time, there will be opportunities to engage with your fellow classmates in break-out room discussions and activities.

Discussion Boards (5%): Each week, one or two discussion questions related to the readings will be posted on a new discussion board. The discussion boards will provide an opportunity for 1) active and constructive discourse with your fellow classmates and 2) a deeper exploration of climate science concepts.

9.2 Assignments

There will be two assignments relating to the content of the course, worth 15% of your final mark (7.5% each). If you need help in completing an assignment, please contact the TA and/or visit the instructor during office hours. The assignments are expected to be completed independently. Assignment instructions and resources will be posted on the course website. See Section 16 for assignment deadlines.

9.3 Lab Exercises

Lab exercises will involve using Python-based simple climate models (see Section 7). Lab exercises will be asynchronous, but a short video introductions will be provided. There are 10 lab exercises worth a total of 25% of the final mark. See Section 16 for lab sessions and deadlines.

9.4 Midterm

In addition, there will be a take-home midterm exam from October 20-22, 2021 covering topics discussed in the first half of the course. The midterm exam is worth 20% of your final mark.

9.5 Final Project

For the final project you will be evaluating two related peer-reviewed journal articles, one observational study and one modeling study, about a climate change topic of your choice. The project components include a peer-feedback reflection, a brief 5-page memo summarizing the articles, and a 10-minute presentation shared with the class at the end of term. The final project is worth 30% of your final mark. Further details about the final project will be posted on the course website.

1. Class + Discussion Board Participation 10%
2. Assignments 15%
3. Lab Exercises 25%
4. Midterm Exam 20%
5. Final Project 30%

10 Verification of Illness

A ***Verification of Illness*** (also known as a "doctor's note") is temporarily not required. Students who are absent from academic participation for any reason (e.g., COVID, cold, flu and other illness or injury, family situation) and who require consideration for missed academic work should report their absence through the online absence declaration. The declaration is available on ACORN under the Profile and Settings menu. Students should also advise their instructor of their absence.
Visit COVID-19 Information for University of Toronto Students or UTSC COVID-19 Absence Declaration in ACORN for more information.

11 Late Assignments

I understand that sometimes "life happens" and an assignment might be submitted late due to illness or injury, a death in the family, or other sudden and unanticipated event. However, assignments submitted late will not be accepted without accompanying documentation (online absence declaration, see above). Late assignments without documentation will be deducted 10% for each 24 hour period late (weekends included).

Note that if you do not have appropriate documentation (as outlined above), pre-class assessments must be completed on time or you will receive a grade of zero for that pre-class assessment.

That said, I am happy to grant extensions on submitted work within reason; however, I appreciate at least 24 hours notification of a request for an extension.

12 Academic Integrity

Academic integrity is fundamental to learning and achieving our course goals. The assignments in this course are designed to give you an opportunity to learn important skills and concepts by making honest attempts through your own thinking, writing, and hard work.

I am strongly committed to assigning grades based on my students' honest efforts to demonstrate learning in this course. Academic dishonesty in any form will not be tolerated in my classes. All academic work in this course must adhere to the Code of Behavior on Academic Matters.

13 Accessibility

Students with diverse learning styles and needs are welcome in this course. In particular, if you have a disability/health consideration that may require accommodations, please feel free to approach me and/or the AccessAbility Services as soon as possible.

AccessAbility Services staff are available to assess specific needs, provide referrals and arrange appropriate accommodations. To register with AccessAbility Services, begin the registration process here. The sooner you let us know your needs, the quicker we can assist you in achieving your learning goals in this course.

14 Equity at the University of Toronto

The University of Toronto is committed to equity, human rights, and respect for diversity. All members of the learning environment in this course should strive to create an atmosphere of mutual respect where all members of our community can express themselves, engage with each other, and respect one another's differences. U of T does not condone discrimination or harassment against any persons or communities.

15 Online Courses and Recording

Notice of video recording and sharing: download permissible; re-use prohibited

This course, including your participation, will be recorded on video and will be available to students in the course for viewing remotely and after each session. Course videos and materials belong to your instructor, the University, and/or other sources depending on the specific facts of each situation and are protected by copyright. In this course, you are permitted to download session videos and materials for your own academic use, but you should not copy, share or use them for any other purpose without the explicit permission of the instructor.

16 Writing and English Language

As well as the faculty writing support, please see English Language and writing support at University of Toronto. Students have commented that they found the latter address extremely helpful for writing term papers.

The following are also useful:

- Sylvan Barnett, A Short Guide to Writing About Art. 5-7th edition (New York: Harper-Collins, 1997)
- William Strunk Jr., E.B. White. The Elements of Style (New York: MacMillan Publishing)

17 Emergency Planning

Students are advised to consult the university's preparedness site for information and regular updates regarding procedures relating to emergency planning.

18 Time and Stress Management

Graduate school can be a stressful time, and even more so during a global pandemic! In order to be successful in your courses, managing your time and stress is key. If you are feeling overwhelmed there are many resources that can help you get back on track:

- Talk to me. I may not always be able to help but I'll try my best to direct you to resources that can
- Use the Math & Stats Learning Centre (Note: graduate students are welcome!)
- Use the Writing Centre
- Visit Health & Wellness
- Visit AccessAbility Services

19 Tentative Schedule

Lectures:

****All Assignments are due before the beginning of lecture.****

Date	Topic
Sept. 15	1. Introduction to the Climate System 1.1. What is Climate? 1.2. Basic radiation, emission temperature 1.3. Simple slab model of greenhouse effect
Sept. 22	2. Atmospheric Radiation 2.1. Energy balance of Earth 2.2. Atmospheric constituents and clouds 2.3. Leaky greenhouse 2.4. Radiative equilibrium vs. radiative-convective equilibrium
Sept. 29 (Assignment 1 due)	3. Global Energy, Water and Carbon Cycles 3.1. Zonal mean energy fluxes + transport 3.2. Hydrological cycle 3.3. Carbon cycle
Oct. 6	4. Drivers of Climate Change 4.1. Drivers of past climate change 4.2. Drivers of 20th-century climate change
Oct. 13 (Assignment 2 due)	5. Climate Feedbacks
Oct. 20-22	**TAKE-HOME MIDTERM**
Oct. 27	6. Introduction to Climate Modeling 6.1. History of climate model development
Nov. 3	6. Introduction to Climate Modeling Cont'd: 6.2. Chaos theory and IC vs BC problems 6.3. Basic components and governing equations 6.4. Parameterizations
Nov. 10 (Assignment 3 due)	7. Detection and Attribution 7.1. Observed climate change + climate variability 7.2. Climate model projections (IPCC AR5)
Nov. 17	8. Uncertainty in Climate Change Projection 8.1. Sources of uncertainty 8.2. Climate sensitivity *Synchronous peer feedback activity*
Nov. 24	9. The Past is Prologue? 9.1. Lessons from the past (paleoclimate analogs) 9.2. Mitigation + Geoengineering
Dec. 1	STUDENT PRESENTATIONS
Dec. 19	***Final Project due***

Readings:

Week of	Topic
Sept 15	• Prologue, *Mathez and Smerdon, Climate Change*
Sept. 22	• Chapter 5, *Mathez and Smerdon, Climate Change*
Sept. 29	• Chapter 5, *Mathez and Smerdon, Climate Change* • Chapter 14, *Archer and Pierrehumbert, The Warming Papers* • Chapter 2, *Weart, The Discovery of Global Warming (optional)*
Oct. 6	• Chapter 6, *Mathez and Smerdon, Climate Change* • Chapter 18, *Archer and Pierrehumber, The Warming Papers (Barnola et al. only)*
Oct. 13	• Chapter 6, *Mathez and Smerdon, Climate Change* • Chapter 10, *Hartmann, Global Physical Climatology*
Oct. 20	NO READINGS
Oct. 27	**VIDEO:** Ted Talk: Gavin Schmidt: The Emergent Patterns of Climate Change (https://www.youtube.com/watch?v=JrJJxn-gCdo)
Nov. 3	• Chapter 11, *Mathez and Smerdon, Climate Change* • IPCC AR5 Summary for Policy Makers, Sections D-E (http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf
Nov. 10	• Chapter 9, *Archer and Pierrehumber, The Warming Papers*
Nov. 17	• Chapter 7, *Emanuel, Climate Primer* + listen to the embedded "TIL Climate" podcast • Chapter 6, *Archer and Pierrehumber, The Warming Papers (optional; Hansen et al. only)*
Nov. 24	• Chapter 12, *Mathez and Smerdon, Climate Change* • Chapter 10, *Emanuel, Climate Primer*
Dec. 2	NO READINGS

Labs:

****All labs are due on the Friday following the lab posting.****

Date	Topic
Sept. 15	**Lab Exercise1**: Introduction to energy balance models (EBMs)
Sept. 22	**Lab Exercise 2**: Grey gas RE and RCE models
Sept. 29	**Lab Exercise 3**: The other CO_2 problem: Ocean acidification
Oct. 6	**Lab Exercise 4**: What is the most important GHG? Water vapour and the water vapour feedback
Oct. 13	**Lab Exercise 5**: Snowball Earth: Exploring the albedo feedback
Oct. 20	NO LAB
Oct. 27	**Lab Exercise 6**: Weather in a tank: An alternative GCM
Nov. 3	**Lab Exercise 7**: Confronting models with observations: GCM validation
Nov. 10	**Lab Exercise 8**: Detection and attribution: Natural vs. anthropogenic climate drivers
Nov. 17	**Lab Exercise 9**: Climate sensitivity: Doubling CO_2 in GCM integrations
Nov. 24	**Lab Exercise 10**: Geoengineering: Options for the future
Dec. 1	NO LAB

Words of Advice

"The expert at anything was once a beginner" - Helen Hayes

The CCIA MEnvSc program is fun, interesting and tough. It is training you to become a climate change specialist. This course and your other courses are designed to help your achieve that level of expertise. However, your course instructors need your help to get your there - you need to play an active role. Ask questions of me, your fellow students and most of all yourself. Mastery of course material requires you to fully engage in the learning process.