**EES1133H: Climate Change Science and Modeling**

Class: 13:00 - 15:00 Mondays, AA205  
Lab: 15:00 - 16:00 Mondays, BV469

1 **Instructor**

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3 **Course**

We know that climate has natural variability, has changed dramatically in the past, and will change in the future. We also know that humans are rapidly altering the environment, particularly through a disruption of the carbon cycle. The questions that we will begin to answer in this class are: How does the current climate system work? How can we predict how it will change in the future? This course provides an introduction to the fundamental physical processes responsible for regulating the Earth’s climate system. Our focus in this course 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 that establish the temperature structure of the planet 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 global climate and earth system models and describe how they are used to make predictions about the future climate.

4 **Course Expectations**

By the end of the course students will be able to identify the primary processes responsible for the structure of the Earth's climate both in the recent past and in the future. Students will be able to explain, in simple terms, what controls the climate system and what role each of the components, the
atmosphere, the ocean and the cryosphere, plays. Students will also have a general understanding of how climate models work and be able to evaluate the importance of uncertainties in climate prediction. Finally, students will be able to critically read and interpret popular science articles on climate change.

5 Course Web Page

The course web site is available through Blackboard: https://portal.utoronto.ca. The Blackboard system is accessible using your UTORID which has been assigned to you as part of registration. All course information, resources, assignments and communications will be posted on Blackboard. It is your responsibility to check the information frequently. You must also ensure that you use your University of Toronto email address on Blackboard. If you are unfamiliar with Blackboard you can find a tutorial here and additional information at: http://www.utsc.utoronto.ca/technology/blackboard-portal

6 Evaluation

Your course grade will be made up of weekly tickets, four assignments, a midterm exam and a final project. All deadlines are listed below in “Section 12: Tentative Schedule”.

Tickets are quasi-weekly questions relating to the past lecture and are worth 5% of your final mark. They must be submitted at the beginning of class in order to get credit. There will be a total of 5 tickets. Tickets will be posted on the course website.

There will be four assignments relating to the content of the course, worth 30% of your final mark. If you need help in completing an assignment, please visit the TA and/or instructor’s office hours. The assignments are expected to be completed independently. Assignments will be posted on the course website.

In addition, there will be an in-class midterm exam covering topics discussed in the first half of the course. The midterm exam is worth 25% of your final mark.

The final project will consist of students evaluating two related peer-reviewed journal articles, one observational study and one modeling study, about a climate change topic of the student’s choice. The project components include a brief 5-page memo summarizing the articles and a 10-minute presentation to the class at the end of term. The final project is worth 40% of your final mark. Further details about the final project will be posted on the course website.

1. Tickets 5%
2. Assignments 30%
3. Midterm Exam 25%
4. Final Project 40%

7 Text Books & Resources

Suggested, but not required: Some of the key original papers on climate science and climate change are compiled with commentary in “The Warming Papers”, edited by David Archer and Raymond Pierrehumbert. I will post some of these papers on the course webpage throughout the course.

A break from math and models: For those interested in the history of climate change science, “The Discovery of Global Warming” by Spencer Weart, is an excellent and short read.

Other readings and resources will be posted on the course webpage.

8 Analysis and Plotting Software

We will likely be running and analyzing output from idealized climate models written in Python in lectures and as part of your assignments. Note that in order to do these assignment questions, you will be required to use Python. We will work through many examples together in class and clear instructions will be given in the assignments.

9 Late Assignments

Assignments submitted late will not be accepted without an accompanying UTSC illness verification form (http://www.illnessverification.utoronto.ca/document/Verification%20of%20Student%20Illness%20(VOI)%20-%20Oct%202016.pdf). Late assignments without an illness verification form will be deducted 10% for each 24 hour period late (weekends included).

10 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.

11 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 (located in Rm SW302, Science Wing) are available by appointment to assess specific needs, provide referrals and arrange appropriate accommodations 416-287-7560 or email ability@utsc.utoronto.ca. The sooner you let us know your needs, the quicker we can assist you in achieving your learning goals in this course.

12 Tentative Outline

Sept. 11:  
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. 18: 2. Global Energy Balance
(Ticket 1 due) 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. 25: 2. Global Energy Balance cont’d
(Assignment 1 due) 2.5. Zonal mean energy fluxes + transport
2.6. Surface energy balance
2.7. Hydrological cycle

Oct. 2: 3. Drivers of Climate Change
(Ticket 2 due) 3.1. Drivers of past climate change
3.2. Drivers of 20th-century climate change

Oct. 9: THANKSGIVING

Oct. 16: 4. Climate Regulators and Feedbacks
(Assignment 2 due) 4.1. The carbon cycle
4.2. Climate feedbacks
4.3. Midterm review

Oct. 23: MIDTERM

Oct. 30: 5. Introduction to Climate Modeling:
(Ticket 3 due) Guest lecture: Steve Easterbrook (http://www.cs.toronto.edu/~sme/)
5.1. History of climate model development
5.2. Introduction to energy balance models (EBMs) with Climlab
   (https://github.com/brian-rose/climlab)

Nov. 6: 5. Introduction to Climate Modeling, cont’d:
(Ticket 4 due) 5.3. EBM with heat transport (Climlab)
5.4. EBM with albedo feedback (Climlab)

(Assignment 3 due) 6.1. Basic components and governing equations
6.2. Parameterizations

Nov. 20: 7. Climate Change Prediction
(Ticket 5 due) 7.1. Climate model projections (with EzGCM; ezgcm.com)
7.2. Climate sensitivity, climate change projection uncertainty

Nov. 27: 8. Detection and Attribution
(Assignment 4 due) 8.1. Observed climate change + climate variability
8.2. Lessons from the past
8.3. Mitigation + Geoengineering

Dec. 4: STUDENT PRESENTATIONS