EES1132H: Climate Data Analysis

Class: 10:00 - 13:00 Tuesdays, BV469

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, or stop by in-person during office hours.

2 Teaching Assistant

Conor Anderson
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Office Hours: by appointment only

3 Course Overview

Welcome to Climate Data Analysis! One of the key questions that we have to address in climate science and climate change impact assessment is whether an observation arose due to anthropogenic climate change or whether it was simply a natural fluctuation - in other words, we are constantly assessing whether we are detecting a signal or whether all we have is noise. In order to do this we need statistics.

This course provides an overview of the statistical methods used to analyze and interpret data sets in climate science. This is a tools class: the objective is to provide a working knowledge of the data analysis tools most commonly used in the literature.

Many students find statistics challenging and intimidating - I certainly did when I was a student. That said, statistics is essential for assessing how robust our findings are in almost all fields of study. The ultimate goal of this course is to help you become independent data explorers. I want to empower you to know where and how to find reliable data, how to visualize data and how to apply statistical tools to analyze the data. My hope is that any intimidation you felt coming into the course will turn to confidence.

4 Learning Outcomes

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

- perform preliminary data discovery using descriptive statistics and visualization,
- assess probabilities associated with the standard normal distribution,
- break-down real science problems into testable hypotheses,
- apply analysis techniques to time series data, such as regression analysis and time-filtering
- test the statistical significance, i.e., the robustness, of your analysis,
- apply “sanity checks” to statistical results,
- wrangle multi-dimensional data and conceptualize the key elements of principal component analysis
• use programming software to perform statistical analysis
• review and assess the analysis techniques presented in the literature,
• present scientific results in a professional manner.

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

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
• provide timely and constructive feedback

6 Prerequisites

You are expected to be familiar with basic high-school and undergraduate-level mathematical concepts. Minimal time will be spent in lecture reviewing these topics:
• algebra (e.g. equations for lines, solving basic algebraic equations)
• basic calculus (e.g. how to take a derivative and an integral)
• basic matrix algebra (e.g. addition, subtraction, multiplication)
• sine and cosine functions

If you are concerned about your background in these areas, please speak with me. The UTSC Math and Stats Learning Centre has excellent resources to help students excel in their course work.

While the concepts, tools, and techniques explored in this course will be taught within the context of climate science, there are no climate science prerequisites.

7 Evaluation

Your course grade will be made up pre-class assessments (10%), assignments (60%) and a final project (30%).

The pre-class assessments will require you to read posted content and/or watch online videos before each class and answer questions about these materials and/or apply the concepts discussed in the materials to a specific problem. Pre-class assessments are expected to be completed independently.
All pre-class assessment materials and evaluation will be posted on the course website (see Section 10) and must be completed the night before class.

There will be four assignments throughout this course, each of varying length. Assignment instructions and templates will be provided on the course website. The assignments will be based on specific sections of the course material, while the final project will require you to integrate many of the tools and concepts used throughout the term. The final project will address a research question of your choice. Details of the final project will be posted on the course website.

Here is the evaluation breakdown:

1. Pre-class Assessments   10%
2. 4 Term Assignments   60% (15% each)
3. Final Project               30%

You are encouraged to interact with your classmates by sharing ideas and discussing the specifics of the course material and assignments. If you need help completing an assignment, first ask your classmates for assistance and request help from your TA and instructor second. You are, however, expected to hand-in your own assignment, and it should not be a direct copy of a classmate's.

Your assignments must be typed-up and clearly written. Figures should be of publication quality - no low-resolution figures. By doing this, you are not only being nice to the me and the TA, who have to grade your work, but you will gain practice in presenting your results clearly and professionally as required for your internships or research projects and your future careers.

In addition to being clear and neat, all figures should include a descriptive caption, legend (if applicable) and labeled axes with units. Having axes without labels or units will automatically deduct points from your assignment.

8 Text Books & Resources

There is no required textbook for this course. As such, the lecture slides are quite dense with material. Many of the materials, assignments, etc. in this course are adapted from the course materials of Prof. Elizabeth Barnes at Colorado State University and Prof. Dennis Hartmann at the University of Washington.

There is one required resource in this course - the internet. Google is amazing - use it. One of the most important things to learn in graduate school and in life is “how to look it up”.

9 Analysis and Plotting Software

In order to complete the pre-class assessments and the assignments, an analysis and plotting software package (often they are one in the same) is required. I will be using Python for the lectures, the pre-class assessments and the assignment templates and strongly encourage you to use it as well. However, you are free to use other software packages such as, MATLAB, IDL, or R, if desired.

10 Course Web Page

The course web site is available through Quercus: https://q.utoronto.ca. The Quercus system is accessible using your UTORID which has been assigned to you as part of registration. All course information, resources, pre-class assessments, assignments, 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 a tutorial here and additional information at: [https://q.utoronto.ca/courses/46670/pages/student-quercus-guide](https://q.utoronto.ca/courses/46670/pages/student-quercus-guide). (Note that this is the first year that we are using Quercus. Please be patient as we work through any unforeseen issues).

11 Late Assignments

Assignments submitted late will not be accepted without an accompanying UTSC illness verification form. Late assignments without an illness verification form will be deducted 10% for each 24 hour period late (weekends included).

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](http://classrooms.utoronto.ca/course/academic-integrity).

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 (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.

14 Writing and English Language

As well as the faculty writing support, please see English Language and writing support at University of Toronto: [http://www.sgs.utoronto.ca/currentstudents/Pages/English-Language-and-Writing-Support.aspx](http://www.sgs.utoronto.ca/currentstudents/Pages/English-Language-and-Writing-Support.aspx). Students have commented that they found the latter address extremely helpful for writing term papers.

The following are also useful:


15 Emergency Planning

Students are advised to consult the university’s preparedness site ([http://www.preparedness.utoronto.ca](http://www.preparedness.utoronto.ca)) for information and regular updates regarding procedures relating to emergency planning.
16 Time Management and Stress

Graduate school can be a stressful time. In order to be successful in your courses, managing your time is key. If you are feeling overwhelmed there are many resources that can help you get back on track:

- Come and see 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: https://www.utsc.utoronto.ca/mslc/welcome-math-statistics-learning-centre (Note: graduate students are welcome!)
- Use the Writing Centre: https://www.utsc.utoronto.ca/twc/welcome
- Visit Health & Wellness: https://www.utsc.utoronto.ca/hwc/health-wellness-centre
- Visit AccessAbility Services: https://www.utsc.utoronto.ca/~ability/

17 Tentative Schedule

Some of the topics may have very technical sounding titles, but don't be intimidated. Our focus in this course is on applying these statistical tools, rather than deriving them from first principals.

All Assignments are due on Thursdays.

Sept. 11: 1. Probability & statistics
1.0. Introduction
1.1. Basic statistics, probability, Bayes Theorem

Sept. 18: 1. Probability & statistics cont’d
1.2. Statistical decision making; hypothesis testing
1.3. Monte Carlo techniques; bootstrap; jackknife

Sept. 25: 2. Regression & correlation
2.1. Linear regression

Sept. 27: Assignment 1 due

Oct. 2: 2. Regression & correlation cont’d
2.2. Theory of correlation
2.3. Compositing vs. regression

Oct. 9: 2. Regression & correlation cont’d
2.4. Autocorrelation/autoregressive methods; estimating the number of independent samples
2.5. Review of linear algebra; Multiple linear regression

Oct. 16: 3. Seeking Structure in Data
3.1. Review of linear algebra cont’d
3.2. Empirical orthogonal functions (EOF)

Oct. 18: Assignment 2 due

Oct. 23: 3. Seeking Structure in Data cont’d
3.2. Empirical orthogonal functions (EOF); singular value decomposition (SVD)
3.3. Application of EOFs to real data
Oct. 30: 3. Seeking Structure in Data cont’d
(Final Assignment topic finalized) 3.3. Application of EOFs to real data

Final Project Data Wrangling & Brainstorming Session

Nov. 6:
4. Time series analysis
   4.1. Filtering in the time domain; removing the seasonal cycle, running means

Nov. 8: Assignment 3 due

Nov. 13:
4. Time series analysis cont’d
   4.2. Harmonic analysis; power spectra; methods of computing power spectra
   4.3. Significance testing of spectral peaks

Nov. 20:
4. Time series analysis cont’d
   4.4. Convolution Theorem
   4.5. Filtering; Filter design; recursive/non-recursive filters; response functions

Nov. 22: Assignment 4 due

Nov. 27:
PRESENTATIONS w/ peer feedback

Dec. 11: Final Project due

**Final Words of Advice**

The CCIA MEnvSc program is training you to become a climate change specialist. At your future place of work, you may be *the one and only* climate change expert. That may seem a bit daunting, but keep in mind that this course and your other courses are designed to help you achieve that level of expertise. However, your course instructors need your help to get you 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.