EES1132H/EESD21H3: Geophysical & Climate Data Analysis

Class: 10:00 - 13:00 Tuesdays, Synchronous
Quercus Course Website

1 Instructor

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3 Course Overview

Welcome to Geophysical & Climate Data Analysis! One of the key questions we ask 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 the climate and geophysical sciences. More specifically, this is a tools course: the objective is to provide a working knowledge of the data analysis tools most commonly used in the field.

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: you will 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 become confidence.

4 Learning Outcomes

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

- perform preliminary data exploration using descriptive statistics and visualization,
- assess probabilities associated with the standard normal distribution,
- diagnose and break-down real science problems into testable hypotheses,
- apply analysis techniques to time series data, such as regression and spectral analysis
- evaluate the robustness of your analysis using statistical significance tests,
- verify statistical results using “sanity checks”,
- wrangle multi-dimensional data and conceptualize the key elements of principal component analysis

- employ programming software to perform statistical analysis
- review and assess the analysis techniques presented in the literature,
- develop and generate independent scientific data analysis
- present scientific data analysis 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
- keep your microphone on mute unless asking a question or engaged in a break-out room discussion

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 also 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 Course Resources

There is no required textbook for this course. All of the course notes are available through a dedicated online courseware. 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. My course notes also draw from the following textbooks:

- Wilks, D. S, Statistical Methods in the Atmospheric Sciences (Academic Press, 1995).
- von Storch, H. and F. W. Zwiers, Statistical Analysis in Climate Research (Cambridge University Press, 1999)

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"***.

8 Course Format

This course will meet synchronously online from 10am-1pm on Tuesdays. However, I will not be lecturing during that time in the typical way. This course uses the "flipped classroom" model, which means that you will be reviewing most of the content at home and we will use the synchronous time to engage in practice exercises and Q&A, review quizzes and work on assignments. The flipped class room model has been shown to be a very effective pedagogical approach, specifically with respect to enhancing student engagement and ownership over their own learning.

The course content is available through a dedicated online courseware. You will be assigned sections of this courseware each week to work through on your own.

9 Course Web Page

The official 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, weekly courseware sections, 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 additional information here.

10 Analysis and Plotting Software

In order to complete the course assessments, an analysis and plotting software package (often they are one and the same) is required. I will be using **Python** for the lectures, the pre-class assessments and the assignment templates. Python is open-source (that means it's free!). You can download and install Python on your own computer, acmes Python using the UofT JupyterHub or through the UTSC computer labs. Instructions on how to download and install Python on your own computer can be found in the courseware.

Graduate Professional Skills Python Workshop

Notice that experience with Python or using any analysis software, in general, are not listed as prerequisites for this course. Thus, this course will also act as an introductory to coding for many of you. In order to help accelerate your knowledge of coding in Python, I have created a two-part Python workshop through the Graduate Professional Skills (GPS) program. ***You are strongly encouraged to participate in this workshop*** and your participation will count towards your class-participation grade.

The workshop is asynchronous online. Once you are registered you will have access to the online materials starting on Friday, September 11th, 2020 and you will have one week to complete it. Please register via the GPS website: https://forms.office.com/Pages/ResponsePage.aspx?

id=JsKqeAMvTUuQN7RtVsVSEIZQAA72eoRIrn3oKL5We-RUM0xMV01WMk9WWk5BMjNCSzJERkNUMFQ3VC4u

11 Evaluation

Your course grade will be made up class participation (5%), pre-class assessments (10%), assignments (55%) and a final project (30%). See the "Tentative Schedule" in Section 21 for deadlines.

11.1 Class Participation (5%)

The best way to learn statistics is to ***do*** statistics. The "flipped classroom" model means that you are expected to join the online, synchronous sessions regularly and participate in weekly exercises, activities and discussions. Data sets and Python files and data files will be provided for each synchronous exercise.

11.2 Pre-Class Assessments (10%)

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 apply the concepts discussed in the materials to a specific problem. This course has a lot of material, so the pre-class assessments are designed to help you keep on top of the material presented in the last week and to prepare you for the next week. Pre-class assessments are expected to be completed independently.

All pre-class assessment materials and evaluation will be posted on the course website after class on Tuesdays (see Section 9 for course website) and must be completed by the Monday night before the next class. If you do not complete the pre-class assessment by Monday night, you will get a zero (see Sections 12 and 13 for more information on verification of illness and late work) .

11.3 Assignments (55%)

There will be ***four assignments*** corresponding to the four main topics in the course, each of varying length. Assignment instructions and and Python file templates will be provided on the course website. The assignments will take you through the analysis of provided climate data sets using techniques from specific sections of the course material. See Section 21 for the assignment deadlines.

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.

Note for EES1132: each assignment will include an advanced question for the graduate students.

11.4 Final Project (30%)

The final project will address a research question of your choice and will require you to integrate many of the tools and concepts used throughout the semester. We will be required to formulate your own

research question, find the data to address the question, analyze the data using techniques covered in the course, and write-up your results in the style of a short scientific journal article. The evaluation of the final project includes a break-out room poster presentation on the final day of class. Specific details of the final project will be posted on the course website in September.

Here is the evaluation breakdown:

1.	Class Participation	5%
2.	Pre-class Assessments	10%
3.	4 Assignments	55%
4.	Final Project	30%

12 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.

13 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.

14 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.

15 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.

16 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.

17 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.

18 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)

19 Emergency Planning

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

20 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

21 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

Date	Topic
Sept. 14	1. Introduction to Statistics in Climate and Geophysical Sciences 1.1. Introduction 1.2. Descriptive Statistics
Sept. 21	2. Probability & Hypothesis Testing 2.1. Probability 2.2. Statistical decision making; hypothesis testing 2.3. Monte Carlo techniques; bootstrap; jackknife
Sept. 28	3. Regression & correlation 3.1. Linear regression
Sept. 30	**Assignment 1 is due**
Oct. 5	3. Regression & correlation cont'd 3.2. Theory of correlation 3.3. Compositing vs. regression
Oct. 12	3. Regression & correlation cont'd 3.4. Autocorrelation/autoregressive methods; estimating the number of independent samples 3.5. Multiple linear regression
Oct. 19	4. Time series analysis 4.1. Filtering in the time domain; removing the seasonal cycle, running means
Oct. 21	**Assignment 2 is due**
Oct. 26	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. 2	4. Time series analysis cont'd 4.4. Convolution Theorem 4.5. Filtering; response functions *Final Project Data Wrangling and Brainstorming Session* **Final Project Proposal and Goal-setting due**
Nov. 9	5. Seeking Structure in Multivariate Data 5.1. Intro to Empirical orthogonal functions (EOF) 5.2. Review of linear algebra
Nov. 11	**Assignment 3 is due**

Nov. 16	5. Seeking Structure in Multivariate Data cont'd 5.3. Eigen analysis & Empirical orthogonal functions (EOF) 5.4. Application of EOFs to real data
Nov. 23	5. Seeking Structure in Multivariate Data cont'd 5.3. Application of EOFs to real data
Nov. 25	**Assignment 4 is due**
Nov. 30	Final Project poster presentations w/ peer feedback
Dec. 16	***Final Project due***

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. 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 your 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.