Time Series Analysis

STA457 / STA2202 – Winter 2026

University of Toronto

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Land Acknowledgement: *We wish to acknowledge this land on which the University of Toronto operates. For thousands of years it has been the traditional land of the Huron-Wendat, the Seneca, and the Mississaugas of the Credit. Today, this meeting place is still the home to many Indigenous people from across Turtle Island and we are grateful to have the opportunity to work on this land.*

Course Description: Time series are data collected over time. The interesting structures in time series are, well, *temporal,* whether they be probabilistic or deterministic (independent observations over time do not make for interesting time series. In fact, that's called noise). This course will spend most of its time looking at probabilistic models for time series in which the observations are collected at regular intervals. We will look at some ways to deal with deterministic temporal structures, and how to use these models for forecasting purposes.

Learning Goals

By the end of the course, students should know:

1. Methods to estimate and eliminate trends and seasonal components
2. The concepts of stationarity, autocovariance, and autocorrelation
3. What linear filters are, and their properties
4. Relevant hypothesis tests and confidence intervals
5. Optimal linear forecasting for a variety of time series models
6. AR(p), MA(q), and ARMA(p,q) models
7. Estimation techniques for ARMA models
8. What power spectral densities are, and some simple methods for their estimation
9. The use of R for working with time series
10. The use of Quarto for rendering PDF reports with dynamic output
11. How to apply the course's techniques to real data, and interpret the results

Table of Contents

Quick Info

Class Meeting Schedule	Section 5101	Sections 0101 & 2001
(Check ACORN for locations)	17:00 - 20:00 (Mondays)	13:00 - 15:00 (Tuesdays) 18:00 - 19:00 (Thursdays)

Textbook Introduction to Time Series and Forecasting (third edition)
by Peter J. Brockwell and Richard A. Davis

Web Portal All materials will be posted on Quercus (https://q.utoronto.ca)

Office Hours Professor Griffith's office hours: Fridays, 13:00 - 15:00 (online)
On Jan 16th and Feb 27th, these office hours will be shifted to 15:00 - 17:00

See Quercus for TA office hour schedule and Zoom links

Course Email sta457@course.utoronto.ca

Grading Scheme

Component	Weight	Due Date
Classwork	10%	Best 80% of your submissions (see *Assessment*) Complete and submit during class · In case of absence, due Fridays at 23:59 · Submission window open until Sunday at 23:59
Homework Assigments	20%	Best 4 of 5 submissions, due at 23:59 on the following Fridays: Homework 1 · January 30 Homework 2 · February 13 Homework 3 · March 6 Homework 4 · March 20 Homework 5 · April 3
Midterm	30%	Sections 0101/2001: March 2nd, 17:00 - 19:00 Section 5101: March 3rd, 13:00 - 15:00 *If you miss the midterm due to illness or personal emergency, this weight may be shifted to the final exam. In this case, the midterm will be worth 0% of your final grade, and the final will be worth 70%.* *See* Missed Term Work *for more details.*
Final Exam	40%	To be scheduled by the Faculty of Arts & Science

Course Tools

Textbook	Introduction to Time Series and Forecasting (third edition) by Peter J. Brockwell and Richard A. Davis
Quercus	Course materials, announcements, grades, assignment links, Piazza forum Log in with your UTORid (e.g. griff421) at q.utoronto.ca
Piazza	Ask questions and discuss course content. Join via the tab on the left hand side of Quercus
Utoronto Zoom	Attend online office hours and emergency online classes if needed. Set up with your mail.utoronto.ca email address at https://utoronto.zoom.us/
Microsoft Forms	Submit your Coffee Date Convo ideas, amongst other forms for the class. Log in with your mail.utoronto.ca email address.
Crowdmark	Review midterm grades and feedback.

Software

Computing is critical to analysing time series, and will be a major component of the assignments. The required computing environment for this course is the R statistical environment, however, we will be extending this environment to use a variety of special tools throughout the course. All such software is **mandatory,** and also **free.**

Rstudio This program can be used online, and also runs on windows, mac and linux operating systems. It is an interface that allows you work with your R console, scripts, data, and plots all in the same place. You **must** access RStudio to do the computing in this course.

Online Rstudio Application	https://datatools.utoronto.ca/
Download RGui / RStudio	https://posit.co/download/rstudio-desktop/
R Code to install ITSMR:	install.packages(itsmr)
R Code to install TinyTex:	install.packages('tinytex'); tinytex::install_tinytex()

Quarto This program allows you to produce PDF documents from within the RStudio environment. You will submit fully rendered Quarto documents for all assignments in this course.

LaTeX Math notation included in your final project must be typed using LaTeX. We will cover the basics of this skill, and will use it during the coding workshops.

Back to Top ♥

Class Meetings

Lectures

See *Quick Info* (page 2) for your section's class meeting schedule.

"Blank" lecture slides will be uploaded to Quercus before the start of each class. These slides feature labelled blank boxes that are to be filled with items from the lesson, including definitions, derivations, and diagrams. Monday lectures will include 2 breaks, and Tuesday lectures will include 1 break.

If you have a tablet that you can write on: Bring it to class, download the blank slides from Quercus, and annotate the pdf as you follow along with the lesson.

If you do not have a tablet to write on: Write lesson items in a notebook, labelling each so that you know which box it corresponds to on the slide.

Attendance & Cancellations

The better your attendance, the more you will get out of this course. Considering the classwork component of your grade, attendance is strongly encouraged, but it is not officially required or graded. However, **if you are feeling unwell, please do not come to campus.** Lecture recordings will be available, and you can attend office hours to clarify any points of confusion.

Class meetings will be in person unless extenuating circumstances arise. If I'm unable to come to campus or access the classroom, class meetings may instead be delivered on Zoom. If this occurs, you will be notified via a Quercus announcement prior to the normal class meeting time – it is your responsibility to check Quercus regularly.

Annotations & Recordings

Annotated class slides will NOT be posted on Quercus, by default. If you need to refer to the written lesson items, you can navigate the lecture recording to retrieve the annotations from class. You can also come to office hours, where I (and/or the TAs) can walk you through the lesson items that you need help with.

Lecture recordings will be provided whenever possible, but are not guaranteed. These videos will be available on Quercus via the OCCS Student App. If a recording is missing for a particular lecture (e.g. due to technical issues), I will either: record a make-up lecture and post it to Quercus, or post the annotated slides to Quercus.

Please allow 24 hours for any of these resources to appear on Quercus for a given lecture.

Workshops

Some class meetings (or portions of class meetings) will take the form of interactive coding workshops. You must **bring your laptop for these workshops, with RStudio installed.** Tentative workshop dates are posted to the class calendar on Quercus, but subject to change. Regardless, I will let you know ahead of time if we are running a class meeting as a workshop, via Quercus announcement.

Workshop Files

Prior each workshop, a Quarto Markdown Document (.qmd) file will appear on Quercus, in a folder called **Workshop Files**. You will edit this file in RStudio, filling in the missing code as we work through the lesson. Sometimes, there will also be a .csv file containing data for the workshop. **Download all workshop files before coming to workshop.**

Assessment

Classwork

This portion of your grade will be calculated as min(m/0.8M, 100), where M is the total value of points for work assigned, and m is your grade. In other words, you will get full marks if you submit at least 80% of tasks in this category, which include Class Worksheets and Coffee Date Convo submissions.

Classwork items are due each Friday at 23:59, with a weekend grace-period (submission window closes on Sundays at 23:59). Before submitting this material, you should attend classes on Tuesday and Thursday's classes, or if that is not possible for you, watch the recording afterwards and review the course notes.

These activities are meant to be fun, low-stakes opportunities for you to engage with the lectures, build understanding, and exercise your statistical communication skills. They will always be graded on a simple 0 - 2 scale.

Roughly speaking,

0 = submission is missing / incorrect / irrelevant
1 = submission is incomplete / contains *major* errors / in the case of coffee dates, uses way too much jargon
2 = submission is *mostly* correct and a decent effort was made

Class Worksheets

Each week, I will designate one of the lecture slides as a "worksheet." You will submit a copy of the worksheet slide once it has been annotated with your own notes from class. You will only be graded on whatever appears in the labelled boxes. You may carefully paraphrase text (e.g. definitions) as long as what you write correctly equates to the lecture content. *Your notes do not have to be pretty!*

Tip: *If the worksheet slide appears in the first half of the class meeting, just submit it during the break so you don't forget! Otherwise, I recommend submitting it right at the end of class.*

Coffee Date Conversations

The end of each lesson will feature a roleplay exercise to summarize the material. You will pretend that you are on a coffee date with a friend who has not taken math or stats since highschool. Your task: come up with a way to describe each lesson in simple enough terms for your friend to understand the "big picture" of what you've learned.

The lecture slides will include a QR code where you can submit your ideas (a few sentences per topic). Sometimes, as you submit your ideas, I will host a discussion on the wordcloud produced in real-time by your responses.

To submit your ideas, you will have to log in with your utoronto email. Your responses will remain anonymous to your classmates. Participation will go towards the "Classwork" portion of your grade for the course. Your ideas don't have to be amazing, but they should be accurate to the lesson.

You should submit your ideas in class. If you are unable to attend class, your submission will be due that Friday at 23:59 with a weekend grace-period (submission window closes on Sundays at 23:59).

Homework Assignments

In each homework assignment, you'll be asked to complete a set of problems. These include theoretical written problems, computational written problems, and data-driven problems to be completed using R-coding. Solutions will not be posted, but you are encouraged to come to office hours to work through problems one-on-one with either myself or a TA.

Only your top 4 of 5 homework assignments will count towards your final homework score. Because of this, no declaration of illness is required to be excused for your first missed homework assignment of course, as this calculation will be applied automatically. Further accommodations for missed homework can be requested as outlined in the *Missed Term Work* section of this syllabus. You are encouraged to submit your assignments (even if they are incomplete) in case circumstances later in the term make it difficult for you to complete homework at that point.

Formatting Expectations

All assignment submissions must be PDF documents rendered using Quarto. You will also hand in the .qmd files which produce each PDF.

Quarto is included with RStudio. We will cover how to use it in class, in case you have not used it before. This is a transferable skill that will allow you to produce professional quality reports within the RStudio environment. Moreover, all plots and computations rendered in these documents are produced by your true code *(dynamic output).*

On the homework assignments, all coding and discussion of the material must be typed. However, theoretical proofs may be written by hand and embedded in the final document using Markdown, unless otherwise indicated.

Midterm & Final Exam

There will be two written exams during the course: a 2 hour midterm exam (20%) that will take place on March 2nd and 3rd, and a final exam (40%) that will take place during the final exam period. Additional details on the nature of the exams will be provided on Quercus when they are available, later in the term.

Graduate Students

Each assignment will have an additional **Graduate Problem** (I'll make clear which one this is). Undergraduate students may attempt a Graduate Problem in place of one regular problem per assignment, if they choose to. The midterm and final exam will both include some graduate-level questions – these are only mandatory for graduate students to complete.

Back to Top ♥

Course Policies

Missed Term Work

Homework

Due to the "best 4 of 5" policy for Homework assignments, no declaration of illness is required to be excused for your first missed homework assignment of the course, as this calculation will be applied automatically. If you are unable to complete one of the remaining 4 homework assignments, then you will need to request academic consideration via one of the following recognized forms of documentation:

- Absence Declaration via ACORN
- U of T Verification of Illness or Injury Form (VOI)
- College Registrar's letter
- Letter of Academic Accommodation from Accessibility Services

Note that you may only use the Absence Declaration once per academic term for a maximum period of 7 consecutive calendar days. For more information, please visit https://www.artsci.utoronto.ca/current/academics/delayed-arrivals-absences.

Classwork

Due to the 20% buffer policy (See *Classwork*), no declaration of illness is required to be excused for the first 20% of missed Classwork for the course. If you are unable to complete more than 20% of the course Classwork, you may submit a request for academic consideration via the same documentation applicable to missed Homework assignments.

Midterm

If you miss the midterm for a valid reason, you may ask for an accommodation via the "Declaration of Illness or Personal Emergency" form linked on the midterm page on Quercus within one week of the missed midterm (the earlier the better). If approved, the weight of your midterm will be shifted to your final exam – in this case, the final exam will be worth 70% of your final grade. Since the midterm is scheduled in the usual tutorial time, there should not be conflicts with assessments from other courses - midterms scheduled during class/tutorial time take priority over midterms outside of the regular schedule.

Final Exam

If you are sick or have a personal emergency that prevents you from writing the final exam, you will need to submit a petition to defer your exam. This process is managed by the Faculty of Arts and Science, so course instructors cannot make any accommodations beyond this for missing the final exam.

Grading Concerns

Any request to have an assessment remarked must be submitted to the correct MS form on Quercus within one week of the grades being posted. Your request will be reviewed by the course instructors and head teaching assistant. In this form, you will be asked to provide your full name and student number and a detailed written justification referring to your answer and the relevant course material (if applicable). It will NOT be enough to simply say you believe your answer deserves higher credit, rather you must support your request with specific reference to relevant course material. You'll find the forms on Quercus on the relevant page on Quercus (e.g. Tutorials, Midterm, Project). If an insufficient request is submitted (i.e., there is no detailed written justification for the remark request), the request will be denied by default. Please note that we reserve the right to review the grading of all questions or parts when you re-submit an assessment for reconsideration (i.e., your grade could go down)!

Accessibility

The University of Toronto is committed to accessibility. If you require accommodations for a disability, or have any accessibility concerns about the course, the classroom, or course materials, please contact Accessibility Services as soon as possible via email at accessibility.services@utoronto.ca or visit their website at https://studentlife.utoronto.ca/department/accessibility-services/

Accomodations If you have an accommodation letter from your accessibility advisor that is relevant to this course, please do the following:

1. Email your letter to sta457@course.utoronto.ca with "Accommodation Letter" as part of the email subject, CC your advisor, and let us know anything else you wish us to know/any questions you have. Please do this as soon as possible after you enroll in the course/receive this syllabus.

2. Confirm any accommodations for each specific assessment at least 1 week before the assessment. (i.e. if you receive extra time for timed assessments, confirm this one week prior to the midterm assessment and final assessment, even if we have already discussed this at the beginning of the semester.)

Religious Accommodation

At the University of Toronto, we are part of a diverse community of students, staff and faculty from a wide range of cultural and religious traditions. For this course, we have sought to avoid scheduling compulsory activities in ways that will clash with religious holy days (not captured by statutory holidays). Further to University Policy, if you anticipate missing a course activity due to a religious observance, please let us know as early in the course as possible. With sufficient notice (in general, at least three weeks) we can work together to make alternate arrangements.

Academic Integrity

You are responsible for knowing the content contained in the
University of Toronto's Code of Behaviour on Academic Matters.

As a general rule, we encourage you to discuss course material with each other and ask others for advice. However, it is not permitted to share answers or to directly share R code or written answers for anything that is to be handed in (e.g., weekly problems and assessment). For example: "For question 2.1 what R function did you use?" is a fair question when discussing course material with others in the class. "Please show me your R code for question 2.1" is not an appropriate question.

If writing or code is discovered to match another student's submission or outside source, this will be reported as an academic offence. When asked to hand in code and a problem set or project document, the code you submit must have been used to generate the document. If it does not (i.e., the submitted code does not match the submitted output), this is also considered an academic offense. Academic offenses will be taken very seriously and dealt with accordingly. If you have any questions about what is or is not permitted in this course, please do not hesitate to ask your instructor and/or send an email to sta130@course.utoronto.ca.

Plagiarism

You may be at risk of plagiarising if you do not understand the rules and your responsibilities. You must not present the work of others as your own. This includes, but is certainly not limited to, copying text and including it in your writing without a citation and quotation marks. There are many resources to help you learn more. To get started:

- https://guides.library.utoronto.ca/plagiarism
- https://www.academicintegrity.utoronto.ca/smart-strategies/

Private Tutoring Companies

You may have been contacted by private tutoring companies trying to sell their services to you for statistics courses. Please be extremely careful with these services as some forms of tutoring can pose an academic offence risk. A good tutor helps you understand the subject area and supports your learning.

Be cautious giving money to companies whose motivation is profit. They may tell you they have insider information. They don't. They may even offer you the opportunity to commit academic offences. Please do not put your University of Toronto education at risk by participating in these kinds of unacceptable behaviours. If you have any questions or concerns about what is okay and what is not in your course, please ask us.

Remember, your teaching team (me and the TAs) know our course best and are here to help you! Please reach out to ask for course help and advice on how to learn the material.

Intellectual Property Statement

Course material that has been created by your instructor (i.e. lecture slides, term test questions/solutions and any other course material and resources made available to you on Quercus) is the intellectual property of your instructors and is made available to you for your personal use in this course. Sharing, posting, selling or using this material outside of your personal use in this course is not permitted under any circumstances and is considered an infringement of intellectual property rights.

This course, including your participation, may be recorded on video and will be available to students in the course for viewing remotely and after each session. These are intended only for students registered in the course. Course videos and materials belong to your instructor, the University, and/or other source 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.

Generative AI

Students may use artificial intelligence tools, including generative AI, as *learning aids*. However, students are ultimately accountable for the work they submit.

Homework Assignments

In this course, homework assignments are each accompanied by a set of *learning goals*. You are expected not to use AI when demonstrating your understanding of the learning goals, however, you may use AI to enhance other aspects of your assignments.

Example: Suppose an assignment asks you to model a polynomial trend using the *trend* function from the *ITSMR* package, as shown in class, and then to plot the results.

- If you submit the work of an LLM (e.g. ChatGPT) which used some other function to model the trend, then you will likely lose marks, because you did not demonstrate an understanding of the methods discussed in class.
- If you use an LLM to add a fancy legend to your plot, then your mark won't be penalized as long as the legend is accurate and relevant (in fact, if you make a good argument for *why you wanted to include a legend in the first place,* it might even make a good impression on some TAs.) Be sure to cite any LLM use (see below).

Appendices: If you do use an artificial intelligence tool on an assignment, you must include, as an appendix, any content produced by an artificial intelligence tool and the prompt(s) used to generate the content. Any content produced by an artificial intelligence tool must be cited appropriately. Many organizations that publish standard citation formats are now providing information on citing generative AI (for MLA format, you can use: https://style.mla.org/citing-generative-ai/)

Invigilated Tests

Students may not use generative artificial intelligence tools (e.g. ChatGPT and other AI writing and coding assistants) for the completion of, or to support the completion of invigilated, closed book assessments, including the midterm and final exam.

Classwork

This part is supposed to be fun! Please don't use AI for this component of the course. I want to see what YOU personally are gaining from each lesson, and I don't expect your responses to be perfect. Consider the Coffee Dates a low-stakes opportunity to exercise "big picture" thinking; the ability to summarize a lesson is as valuable as the summary itself. The more effort you put in, the more these activities will build your ability to communicate with your colleagues (as well as those in other disciplines) on these topics.

General Notes

If you are unsure if a particular usage of a generative AI tool is appropriate, please ask me for guidance. Note that policies for the use of these tools may be different across courses, **and even for different assignments within a course.**

Finally, it is almost always best to try completing an assignment without generative AI before turning to it, both from the perspective of mastering the material of the course, as well as from the perspective of querying generative AI effectively when you are at a point where it could be helpful.

Back to Top ♥

TLDR ♥

Time Series	Data collected over time. We'll learn to model patterns and predict the future!
Tools	*Please install RStudio on your computer before coming to Workshop 1 (week 2)* Code to install necessary R packages is on page 3.
Lectures	Slideshows, fill-in-the-blank style. I'll provide the slides beforehand. If you have a tablet to write on, bring it to class so you can directly annotate the slides. Otherwise, take notes by labelling lesson items as indicated in the slides (I will show you what I mean by this in the first lecture).
Workshops	Live coding tutorials. *Bring your laptop to these.* Schedule on Quercus. Workshop files will be uploaded to Quercus prior to each workshop.
Assessment Items	**Classwork | Worksheets:** You'll hand in 1 page of your lecture notes per week. It can be an annotated class slide, or a picture of your notebook with labelled lesson items. I will indicate which slide for you to hand in. **Classwork | Coffee Date Convos:** At the end of each lesson, you'll come up with an "explain like I'm 5" style summary of what you learned. I'll provide links to submit these. **Homework:** 5 assignments, each with a mix of coding and theory based problems. *All submissions MUST include a Quarto file (.qmd) and corresponding document (.pdf)* **Midterm & Final Exam:** Closed book. Midterm is in week 9. Exam TBD by A&S.
Course Policies	Fill out the supplied forms if you need to miss the midterm due to an emergency, or think there may have been a grading error on the midterm. You can use AI as a study tool, or to embellish your homework (e.g. making pretty plots). You're expected not to use AI for the Classwork components of the course, as these activities are meant to be low-stakes, engaging exercises to build youor understanding and communication skills.

Back to Top ♥