[STAT 412] Bayesian Statistics

Fall 2025

Section:	STAT 412	**Professor:**	Becky Tang (she/her)
Class hours:	MW 9:45-11:00AM	**Office:**	Warner 214
Room:	Warner 011	**E-mail:**	btang@middlebury.edu
Coreqs:	STAT 311	**Office Hours:**	M 3-4, T 3:30-4:30, F 11-12

Course Description

Bayesian methods are increasingly important in both industry and academia. In this course, students will be introduced to the Bayesian paradigm of statistics, in which one's inferences about parameters or hypotheses are updated as evidence accumulates. Students will learn the essential distinctions between classical and Bayesian methods and become familiar with the origins of Bayesian inference, which are rooted in Bayes' rule. Students will learn how to apply Bayes' rule to relate prior distributions with observed data to obtain a posterior distribution. The course will have three core components: Bayesian foundation, computing, and modeling. The course uses the programming language R extensively for simulations an analyses. All students must have the theoretical background covered in the prerequisites in order to enroll in this course.

Key Learning Outcomes

- ❏ Understand the basic concepts of Bayesian inference, that is, be able to define likelihood functions, prior distributions, posterior distributions, prior predictive distributions and posterior predictive distributions.
- ❏ Derive posterior distributions, prior predictive distributions and posterior predictive distributions, for common likelihood-prior combinations of distributions.
- ❏ Assess the adequacy of Bayesian models to any given set of data.
- ❏ Apply Bayesian inference approaches to solve scientific research problems and real-world problems.
- ❏ Use JAGS or other software to implement Markov chain Monte Carlo samplers.
- ❏ Gain familiarity and confidence in statistical modeling.
- ❏ Learn to effectively communicate results through written assignments and presentations.

Textbooks and Course Materials

- **Required**: *A First Course in Bayesian Statistical Methods* by Hoff, Peter: https://www.amazon.com/Bayesian-Statistical-Methods-Springer-Statistics/dp/0387922997. **The Middlebury College library provides an online version.**
- **R**: We will learn and frequently use the R programming language. We will program using the RStudio interface. Students should ensure they have access to both R and RStudio, preferably updated to the lastest versions, either by downloading the software onto their own computers, or by using a campus computer.

Course Structure

While theory will feature throughout the entire semester, the use of R will increase as the semester progresses. I will frequently live-code and present results during class. Therefore, I encourage you to always bring your laptop or tablet to class to follow along if that is helpful to you. Additionally, the textbook has lots of R code. I encourage you to read the code and test it out yourself if you do not understand what a certain line is doing.

A prepared student will attend the 75-minute class, and spend roughly three-five hours per day of class on work outside the classroom (attending office hours, watching videos, doing homework, coding, practicing presentations, etc.). As this course meets two days a week, this represents a 8.5-12.5 hour weekly commitment.

Class Expectations and Code of Conduct

- **You are expected to physically show up to class, actively participate, and make space for everyone to contribute**. You are an integral part of the class community! Exceptions include previously-communicated illness or planned absence.
- **Please arrive on time.** I expect everyone, myself included, to arrive on time and dedicate full attention during the class. Class will begin promptly at the scheduled time. In turn, I will do my best to always end class on time.
- **Technology.** You are encouraged to bring a laptop and/or tablet to class each day for note-taking, referencing the textbook, and live coding.
- **Cell phones should be turned to silent**. I don't mind cell phones in class, but please silence them so as to not disrupt the class.
- **Please ask questions!**
- **Positively contribute to your group problem-solving**, which includes asking questions, throwing out ideas, and voicing confusions. There are many ways to solve the problems we will encounter in this class.
- I expect all members of the class to make participation a harassment-free experience for everyone, regardless of race, creed, color, place of birth, ancestry, ethnicity, national origin, religion, sex, sexual orientation, gender identity or expression, age, marital status, service in the armed forces of the United States, positive HIV-related blood test results, genetic information, or against qualified individuals with disabilities on the basis of disability and/or any other status or characteristic as defined and to the extent protected by applicable law. We will not tolerate the use of violence against any individual.

Resources

- ❑ **Office hours**. This time is meant for you! Please come by to ask questions, chat with me, or work on homework. You should never worry about disturbing me during this time.
- ❑ **One-on-one meetings**. If you would like to meet with me one-on-one, please send me an e-mail or approach me after class so we can schedule a time.
- ❑ **Your peers**. Unless otherwise noted, I encourage students to work together and discuss material! However, unless the assignment explicitly states that it is to be completed as group work, the submitted material must be your own.

Tips on how to succeed

- Come to every class.
- Attend office hours.
- Attempt the homework problems individually before working with others. A lot of this class is about developing intuition, and that comes with individual practice and struggle!
- The assigned readings convey a lot of information, both in the theory and the examples.
  - Read through the material at least twice. Be sure to read through the Examples and interpret the figures.
  - There are some errors in the textbook. If there is something that doesn't look quite right, please consult the errata: http://www2.stat.duke.edu/~pdh10/FCBS/Misc/errata.txt
- Ask questions (someone should ask me a question now!)
- Do not try to find answers on the internet or ChatGPT. Struggling through problems is how you learn!

College policies and resources

Academic Integrity

As an academic community devoted to the life of the mind, Middlebury requires every student to reflect complete intellectual honesty in the preparation and submission of all academic work. Details of our Academic Honesty, Honor Code, and Related Disciplinary Policies are available in Middlebury's handbook.

Using AI tools (e.g., ChatGPT, Bard, Co-Pilot) is generally forbidden in this class. You may not use them to assist in any part of your homework, case studies, or final project, with the exception of helping generating code to create plots in R. If you do use AI tools to assist with creating plots, you must somewhere in the assignment specify which lines of code were generated with the assistance of AI. Any other use of generative AI tools will be treated as a violation of Middlebury's Honor Code.

Honor Code Pledge

The Honor Code pledge reads as follows: "I have neither given nor received unauthorized aid on this assignment." It is the responsibility of the student to write out in full, adhere to, and sign the Honor Code pledge on all examinations, research papers, and laboratory reports. Faculty members reserve the right to require the signed Honor Code pledge on other kinds of academic work.

Disability Access and Accommodation

Students who have Letters of Accommodation in this class are encouraged to contact me as early in the semester as possible to ensure that such accommodations are implemented in a timely fashion. For those without Letters of Accommodation, assistance is available to eligible students through the Disability Resource Center (DRC). Please contact ADA Coordinators Jodi Litchfield, Peter Ploegman, and Deirdre Kelly of the DRC at ada@middlebury.edu for more information. All discussions will remain confidential.

Center for Teaching, Learning, and Research (CTLR)

The CTLR provides academic support for students in many specific content areas and in writing across the curriculum through both professional and peer tutors. The Center is also the place where students can find assistance in time management and study skills. These services are free to all students. go.middlebury.edu/connect

Types of assignments

- **Homework**. Assigned weekly and turned in individually (though you can work with your peers). In the homework, you will apply what you have learned during lecture to dive deeper into the material and explore more interesting problems and data. The homework will almost always include a coding component in R. Unless otherwise noted, homework assignments are due in-person on Wednesdays at the beginning of class.

  Note that some days, homework will also include reading from textbook or watching videos.
- **Midterm**. One midterm exam is designed as an opportunity to assess the knowledge you've learned in the first half of the course. The date for the midterm is Friday, 10/17 at 2:30pm.
  Except in the cases of extreme illness or family emergency, students must take the midterm on the scheduled date and time.
- **Case studies**. Three case studies of real data will be assigned during the second half of the semester. For the case studies assignments, everyone will be given the same dataset and scientific question of interest. You will be asked to complete a Bayesian analysis of the data and write a report summarizing your findings. You are required to use an R Markdown or Quarto Markdown to type up your lab reports. You will also briefly present your work to the course. The case study assignments will be completed in partners/small groups. Case study write-ups and presentations will typically be due one week after being assigned, but specific due dates will be announced as the case studies are introduced and are subject to change.
- **Final project**. Instead of a final exam, we will have a final project. The purpose of the project is to apply what you have learned throughout the semester to analyze an interesting data-based research question of your choosing using Bayesian methods. The final projects are individual. The final project will include a written and coding report, as well as an in-person class presentation that includes slides. The presentations are scheduled to take place on our college-assigned final exam date 12/12. The written portion will be due to Canvas on 12/17 (tentative). You must present the final project to pass the course, but you do not need to be on campus to submit the written report.
- **Participation**: I expect you to be present and active learners in this course! Throughout the semester, there will be various small assignments/activities that will count towards participation (e.g. providing feedback on peer presentations, discussing assigned readings). Because this class is small, everyone will notice if you are absent and we will miss your presence! If you must miss class for whatever reason, please let Prof. Tang know in advance of class. Typically, you may miss up to two classes without penalty. More than two absences may affect your Participation grade. However, prolonged or recurring illness, as well as other emergencies, may require individual adjustment, in which case you should contact me to make appropriate arrangements.

GRADING

- Unless otherwise noted, homework assignments should be submitted in-person as physical copies. If a homework assignment has an associated R component, be sure to knit to PDF and print out the PDF for submission.
- Late work will always be considered within one week of the original due date. Unless otherwise stated, the late policy is as follows: for every 24-hour period the assignment is late, 10% from the maximum possible grade will be deducted.
- I will do my best to return assignments within one week of submission.
- Regrade requests: I do allow regrade requests, which must be submitted in-person within one week of when the assignment is returned. Keep in mind that regrade requests do not guarantee points back.
- **You must sit for the midterm and present the final project in order to pass the course.**

Component	Percentage
Homework	15%
Midterm	20%
Case Study 1	10%
Case Study 2	12.5%
Case Study 3	15%
Final Project	25%
Participation	2.5%

- Letter grades will be assigned based on the following course percentages, with the upper 3% and lower 3% of each category corresponding to + and −, respectively:
  - A: 90-100%
  - B: 80-89%
  - C: 70-79%
  - D: 60-69%
  - F: <60%

  These percentages reflect lower bound guarantees. For example, if you earn a 90% in the course, you are guaranteed an A-. Grades will typically not be rounded up in the case of decimal points, although I can adjust upwards if I have reason based on my assessment of student learning.

Tentative Course Content

(Last updated: 09/01/25)
NOTE: The following dates and content may be modified due to the requirements of the class may be moved backward or forward depending on class progress and my conference travel. **The date of the midterm is set**.

Week	Date	Topic
1	9/08	M - Welcome! Course logistics, Probability review, Likelihood W - Belief functions, Bayes' rule, Bayes modeling, Recap of `R` - Homework 00 due
2	9/15	M - Bayesian inference for proportion, discrete prior - Homework 0.5 due W - Bayesian inference for proportion, continuous prior
3	9/22	M - Conjugacy, confidence regions W - Bayesian updating - Homework 01 due
4	9/29	M - Poisson-Gamma model, Posterior predictive distribution W - Monte Carlo approximation, Posterior predictive model checking - Homework 02 due
5	10/06	M - MSE and Risk W - Inference for Normal (known variance) - Homework 03 due
6	10/13	M - Joint inference for Normal W - Flex day/Review - Homework 04 due F - Midterm at 2:30pm
7	10/20	M - Gibbs sampler W - Gibbs sampler (cont.), coding activity
8	10/27	M - MCMC diagnostics, Bayes SLR W - Compare to Freq., Introduce Case Study I - Homework 05 due F - Last day to drop classes
9	11/03	M - Metropolis W - Metropolis (cont.), Case Study I presentations - Homework 06 due
10	11/10	M - Introduction to JAGS W - JAGS (cont.), Introduce Case Study II

		- Homework 07 due
11	11/17	M - Case Study II presentations, Bayesian hierarchical modeling W - Hierarchical modeling (cont.), Introduce Case Study III - Homework 08 due
	11/24	Thanksgiving Break
12	12/1	M - Project or Case Study work day W - Case Study III presentations, CRFs
	12/12 12/17	F - Final project presentations W - Final project report due