STA465/STA2016/ENV1112
Spatial Data Analysis

Term:	Fall 2025
Time:	Fridays 10 am - 1 pm
Location:	VC 115
Instructor:	Meredith Franklin
Contact	meredith.franklin@utoronto.ca
Office:	700 University Ave #9087
Office Hours:	By Appointment
TA:	Yovna Junglee
	yovna.junglee@mail.utoronto.ca

Course Description

Spatial data arise in almost every field of study. Examples include environmental measurements, demographics, and tracking the spread of disease incidence. This course is intended as an introduction to analysis techniques for spatial data and aims to provide students with the background necessary to investigate geographically/spatially represented data. There are numerous research questions involving spatial data, but in this course, focus will be placed on methods that are relevant in the fields of environment, public health, and social science. Lectures will cover the three main areas of spatial statistics: geostatistical data, lattice (areal) data, and point patterns. We will also cover machine learning methods that are commonly used in for spatial and spatio-temporal data, including density-based scanning, tree-based methods (spatial random forest, gradient boosting machines, and hybrid methods).

Learning Objectives

The learning objectives of this course are that upon completion, the student should be able to:

- Distinguish different types of spatial data (geostatistical, areal, point process).
- Understand how spatial dependence/autocorrelation plays a role in analysis and modeling.
- Use methods introduced in lectures to investigate spatial patterns in both example datasets provided as exercises and in the class project dataset of your choosing.
- Read and discuss spatial methods in the literature based on an understanding of the basic spatial analytical approaches, principles and main assumptions.

Undergraduate Prerequisite(s): STA302H1/STAC67H3/STA302H5, STA303H1

Course Notes

Lecture notes presented in class will be posted on Quercus.

Readings

Lecture notes and handouts will be the primary source of information for this course. Several textbooks on spatial data analysis will prove to be useful, but lectures will be primarily based on material presented in the following (Note these are NOT REQUIRED):

1) Edzer J. Pebesma and Roger S. Bivand *Spatial Data Science* (2025) https://r-spatial.org/book/ (Applied and Methods)
2) Thierry Warin *Geospatial Data Science with R and Python* (2025) https://warin.ca/geospatial/ (Applied)
3) Sergio Rey, Dani Arribas-Bel, Levi J. Wolf *Geographic Data Science with Python 1st edition* https://geographicdata.science/book/intro.html (Applied)
4) Chris Brunsdon and Lex Comber *An Introduction to R for Spatial Analysis & Mapping 2nd edition* (2022), Sage Publishing (Applied)
5) S. Banerjee, B. Carlin, and A. Gelfand. *Bayesian and Hierarchical Modeling of Spatial Data, 2nd edition* (2014), Chapman and Hall. (Methods)

Technological Proficiency and Hardware/Software Required

Computation using R (downloaded from http://cran.r-project.org) and reports in RMarkdown (https://rmarkdown.rstudio.com/) will be used throughout the semester. Option to use Python, and we will see some computation in Python. Students without computing experience may be allowed to take the course but should be aware that they will need to become familiar with R or Python coding on their own.

There will not be a separate computer lab, but some lecture time will be set aside to go through code and procedures to familiarize students with the implementation of various spatial methods. Students should bring their laptop to class and may use JupyterHub https://live-datatools.pantheonsite.io/ or install the tools on their laptops.

Description and Assessment of Assignments

Assignments (bi-weekly): There will be 5 assignments given throughout the semester. Students may discuss the problems with one another; however, individual solutions must be submitted, and copying will not be tolerated. Late assignments will be penalized by 10% per day past the due date (except when there is a verifiable illness).

Assignments for ENV and STA students will differ slightly (more statistics focused questions for the STA students and applied questions for ENV students).

Midterm:

For STA students the midterm will consist of two parts: 1) a methodological component requiring explanation of a specific statistical approach and application to a dataset that will be provided, and 2) a brief report that describes the topic and dataset you have chosen for your final project including exploratory data analysis and a description for what spatial methods you will use.

For ENV students the midterm will be focused on the selection of a topic and dataset for the final project along with a detailed literature review that will form the basis of the introduction of your final report. Also include a description of the data with exploratory

data analysis and visualizations as well as a brief outline of your analytic plan for the final report.
For both STA and ENV, all work must be done individually.

Final Project: The final project is a formal analysis of a spatial dataset that is written up like a scientific paper (Introduction, Methods, Results, Discussion). It should include tables and figures summarizing your data and modeling results. Work must be done individually, and originality will be assessed. A short, 5-minute recorded presentation will be submitted as well.
For STA students, your project will be evaluated for technical details and description of methods, as well as clarity and presentation.
For ENV students, your project will be evaluated for the description of your research (introduction/background about the data), methods used, and overall clarity and presentation of your results. Less emphasis will be placed on detailed descriptions of the statistical methods than STA students.

In-Class Discussion: Participation and engagement in class and office hours will be noticed and will be considered in evaluating your final project.

Grading Breakdown

Assignment	**% of Grade**
Homework (5)	50%
Midterm	20%
Final Project	30%

Weekly Breakdown

	Topics/Daily Activities	**Deliverable/ Due Dates**
Week 1 September 5	Overview of different types of spatial data, introduction to tools needed for spatial analysis, quick review of non-spatial regression	
Week 2 September 12	Data visualization, mapping, geocoding	**HW0**
Week 3 September 19	Geostatistics: variograms and covariance functions	
Week 4 September 26	Geostatistics: fitting variogram functions	**HW 1 Due**
Week 5 October 3	Geostatistics: kriging	
Week 6 October 10	Areal data: neighborhoods, testing for spatial association	**HW2 Due**
Week 7 October 17	Areal data: global and local tests of association	

Week 8 October 24	Areal data: CAR and SAR models, inference	**HW3 Due**
Week 9 October 31	Fall Break – no class	
Week 10 November 7	Point process data: types of spatial patterns, spatial randomness	**Midterm**
Week 11 November 14	Point process data: spatial clustering and testing for clustering	**HW4 Due**
Week 12 November 21	Spatial data computation and machine learning	
Week 13 November 28	Spatiotemporal data and machine learning	**HW5 Due**
Finals Period	Final Project Due	**Final Paper, Short Recorded Presentation**

Statements on Academic Conduct and Support Systems

Academic Conduct

All suspected cases of academic dishonesty will be investigated following procedures outlined in the *Code of Behavior on Academic Matters*. If you have questions or concerns about what constitutes appropriate academic behavior or appropriate research and citation methods, please reach out to me. Note that you are expected to seek out additional information on academic integrity from me or from other institutional resources (for example, the University of Toronto website on Academic Integrity).

Accommodations

The University provides academic accommodations for students with disabilities in accordance with the terms of the Ontario Human Rights Code. This occurs through a collaborative process that acknowledges a collective obligation to develop an accessible learning environment that both meets the needs of students and preserves the essential academic requirements of the University's courses and programs.

Students with diverse learning styles and needs are welcome in this course. If you have a disability that may require accommodations, please feel free to approach me and/or the Accessibility Services* office. Accessibility Services on the St. George campus

Religious Observances

The University provides reasonable accommodation of the needs of students who observe religious holy days other than those already accommodated by ordinary scheduling and statutory holidays. Students have a responsibility to alert members of the teaching staff in a timely fashion to upcoming religious observances and anticipated absences and instructors will make every reasonable effort to avoid scheduling tests, examinations or other compulsory activities at these times. Please reach out to me as early as possible to communicate any anticipated absences related to religious observances, and to discuss any possible related implications for course work.

Family Care Responsibilities

The University of Toronto strives to provide a family-friendly environment. You may wish to inform me if you are a student with family responsibilities. If you are a student parent or have family responsibilities, you also may wish to visit the Family Care Office website at familycare.utoronto.ca.

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.

Land Acknowledgement

A land acknowledgement is a way of honoring the Indigenous people who have lived and worked here for thousands of years, and whose land was colonized. It is also an invitation to reflect on the history of this land and we encourage you to consider the history of the land wherever you are now. https://native-land.ca/