

# STAT\_V 547-P: Spatial Statistics

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## Course Introduction

This course covers foundational concepts and theories in spatial statistics, key methodologies widely used in applications, machine and deep learning approaches for complex spatial and spatio-temporal data, and cutting-edge applications of spatial statistics in climate science, environmental studies, and related fields.

Students are required to complete assignments involving the analysis of spatial data using the methods and software packages introduced in class. In addition, each student will give a paper presentation on a topic related to spatial statistics.

Through this course, students will learn the core principles of spatial statistics and develop practical coding skills for visualizing, modeling, and analyzing spatial data. Moreover, they are encouraged to connect the methodologies and theories introduced in this course with knowledge gained from other courses and with their own research interests.

## Topics

- **Topic 1: Course Introduction and Overview of Spatial Statistics**
  - Course orientation
  - Spatial statistics and its applications
  - Spatial data types
- **Topic 2: Stochastic Processes and Covariance Function**
  - Stochastic processes and random fields
  - Covariance and variogram functions
  - Stationarity, isotropy, mean square continuity and differentiability
- **Topic 3: Estimation of Covariance Functions and Kriging**
  - Modeling and estimation of covariance functions from data
  - Kriging and co-kriging

- Connection with kernel ridge regressions
- **Topic 4: Scalable Methods for Large Spatial Data**
  - Low-rank approximations
  - Gaussian Markov random fields and stochastic partial differential equations (SPDEs)
  - Composite likelihood methods
  - Covariance tapering
  - Distributed and high-performance computing
- **Topic 5: Spatio-Temporal Data Modeling**
  - Spatio-temporal covariances: separable and nonseparable
  - State-space and dynamic spatio-temporal modeling frameworks
- **Topic 6: Machine and Deep Learning Methods for Spatial and Spatio-Temporal Data**
  - Graph neural networks
  - Variational autoencoders
  - Diffusion models
  - Echo state networks
- **Topic 7: Additional Topics of Student Interest**