GEOG 696F Advanced Methods and Techniques
Python for Spatial and Temporal Data Science
Autumn 2024

This course is designed as a graduate level class with an interactive lecture and tutorial format to give students theoretical background and practical experience in using a range of statistical methods to analyze data with spatial and/or temporal dimensions. Topics include large data handling and exploratory data analysis, correlation and regression, Monte Carlo techniques, time series and spectral analysis, empirical orthogonal functions, kriging and interpolation, probability theory and applications, and Bayesian methods. The course encompasses instruction and training in Python and in the use and manipulation of space-time datasets.

Students participating in the class will be expected to actively engage with tutorials and lectures and half of the course grade will reflect this. The major outcome for the class for each student will be a new and independent analysis of a substantial dataset, a formal manuscript describing the motivation, methods, and results of this analysis, and a professional oral presentation. Students are encouraged to bring with them or seek out data relevant to their research to use for their final project. Ideally, students' final projects will provide the material for a thesis chapter and/or peer-reviewed article.

This syllabus and course schedule are subject to change.
Please check regularly for updated information on D2L

Locations and Times

Monday and Wednesday, 12:30PM to 1:45PM
ENR2, Room S223
Course materials online via D2L (`http://d2l.arizona.edu`)

Instructor Information

Kevin Anchukaitis
Professor, School of Geography, Development, and Environment
Laboratory of Tree Ring Research
Room S514, Environment and Natural Resources Building 2 (ENR2)
Room 419, Bannister Tree Ring Lab Building
Email: kanchukaitis@arizona.edu

Office Hours
Office Hours: By appointment (Monday, Tuesday, or Wednesday)

Course Information

Prerequisites
Continuing graduate student status in a degree program and in good standing at the University of Arizona or with permission from instructor. Undergraduates as welcome with permission from instructor. Some prior mathematics or statistical courses are encouraged but not required. Prior programming experience encouraged but not required.

Course Objectives
This course has the following objectives:

- Factual: You will acquire fundamental knowledge of statistical methods for the analysis of data with a spatial and/or temporal dimension. You will become familiar with the terminology used to described

the characteristics and format of these data and the statistical procedures and outcomes applied in them. You will be able to locate and acquire appropriate data.

- Conceptual: You will develop an understanding of the available statistical tools and when to best or appropriately apply them to exploratory data analysis and hypothesis testing. You will cultivate a first-order understanding of the motivations, advantages, and disadvantages for different statistical procedures and how uncertainties in the underlying data and violations of the assumptions for methods potentially propagate through your analyses.

- Procedural: You will learn how to apply specific methodologies to the analysis of data with a spatial and/or temporal, including the practical, hands-on procedures for managing data and implementing these methods and approaches in a high level programming language (Python). You will be able to differentiate between the relative magnitudes and significance of effects or processes and recognize and remove errors associated with data or the implementation of your procedures ('debugging').

- Metacognitive: You will recognize the potential and limitation of statistical methods with respect to data and phenomena you wish analyze and interpret. You will be able to identify reasonable (and unreasonable) inferences or conclusions from your analyses in light of those limitations. You will develop an enhanced recognition of how potential biases – including both methodological as well as cognitive – enter into statistical analyses. You will practice deploying both quantitative analyses using your methodological skills and systems-based knowledge.

Learning Outcomes

By the end of the semester, students will be able to design and conduct a complete statistical analysis of a dataset with a spatial and/or temporal dimension appropriate to their research area. The students will be able to build and test their own analytical programs using a high-level computer language (Pytthon) and apply their code to the quantitative analysis of their dataset. Students will be able to make abductive inferences about the system they are studying by applying their analysis, their understanding of the magnitude and sources of uncertainty, and their knowledge of the theory and processes that underpin the systems they are studying. Students will be able to describe, support, and defend their inferences in a public presentation to the class.

Required Texts or Readings

There is no required textbook for this course.

Assignments and Methods of Assessment

Active Participation: [50%] The course requires consistent regular attendance and active participation from all students. Half of the semester grade will come from the combined self-assessment and instructor grade for each class period. These assessments will be based on (1) attendance in class, (2) participation in the tutorial or lecture, and (3) thoughtful and meaningful engagement with the topic of the day. Each student is permitted 2 absences without penalty.

Final Project (Paper): [40%] This assignment will be a manuscript, appropriately formatted for a significant peer-reviewed journal in the student's field of interest. Specific length and content (figures and tables) depend both on the analysis, the data, the hypothesis and research question, and the standard of the target journal and scientific field, but should reflect a substantial body of work, reflect the standards of the field and journal, be free of errors, and be of appropriate quality and significance that the manuscript could reasonably be finalized for actual submission. This is an individual assignment and students must prepare and submit to D2L an individual (non-collaborative) manuscript. This assignment will be graded by the instructor. A rubric will be provided no later than Friday, November 22nd. The assignment is **due on D2L no later than Friday, December 13th at 5:00pm Arizona time**. Students planning to attend AGU that week are encouraged to turn their assignment in early.

Final Project (Presentation): [10%] This assignment is a 15 minute (12 minute talk, 3 minutes for questions) professional talk describing the motivations and findings of the students' paper and manuscript. The

presentation schedule will be determined and a rubric made available no later than Friday, November 17th. Students are expected to prepare and give a talk reflecting the standards and practices of their field and to run within the given time window (15 minutes). This is an individual assignment. This assignment will be graded by the instructor with input from the student's peers. ***Attendance is required for all students for the student presentation days***.

Grade polices and Letter Grade Distribution:
University policies regarding grades and grading systems are available at:
`https://catalog.arizona.edu/policy/grades-and-grading-system`

Grade distribution for this course:
A: 90% and above
B: 80% to 89%
C: 70% to 79%
D: 65% to 69%
E: below 65%

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at `https://catalog.arizona.edu/policy/grades-and-grading-system#incomplete` and `https://catalog.arizona.edu/policy/grades-and-grading-system#Withdrawal` respectively. Please be aware of deadlines for requesting these grades. Requests for reconsideration of a grade received on a paper, project, or exam must be made to the instructor no later than 1 week after the assignment is made available to be returned to the student.

There is no final exam for this course.

Late work Assignments that are not completed or handed in on time, without advance prior arrangement with the instructor, will receive 0% of the available points.

Course Communications All communications concerning class are via official UA email addresses. It is the student's responsibility to regularly check for email communications concerning class information and policies, and to contact the instructor from the student's official UA email address.

University Resources and Policies

Absence and Class Participation Policy
The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at `https://catalog.arizona.edu/policy/class-attendance-and-participation`. The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable: `http://policy.arizona.edu/human-resources/religious-accommodation-policy`. Absences pre-approved by the UA Dean of Students (or the dean's designee) will be honored.

Active participation in the course is vital to the learning process. In this course, attendance and active participation form a substantial part of the grade.

Life challenges If you are experiencing unexpected barriers to your success in your courses, please note the Dean of Students Office is a central support resource for all students and may be helpful. The Dean of Students Office can be reached at (520) 621-7057 or DOS-deanofstudents@email.arizona.edu.

Physical and mental-health challenges If you are facing physical or mental health challenges this semester, please note that Campus Health provides quality medical and mental health care. For medical appointments, call (520) 621-9202. For After Hours care, call (520) 570-7898. For the Counseling & Psych Services (CAPS) 24/7 hotline, call (520) 621-3334.

Assignment and Grading Policy for Students Who Register Late
Students who register late for the course will be required to complete all assignments. Due dates for assignments given prior to the student adding the course will be agreed upon my both student and the instructor.

Classroom Behavior Policy
To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading a newspaper, making phone calls, web surfing, etc.). Students observed engaging in disruptive activity will be asked to cease this behavior. Those who continue to disrupt the class will be asked to leave lecture or discussion and may be reported to the Dean of Students.

Threatening Behavior Policy
The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See `http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students`.

Accessibility and Accommodations
Our goal in this classroom is that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, please let me know immediately so that we can discuss options. You are also welcome to contact the Disability Resource Center (520-621-3268) to establish reasonable accommodations. For additional information on the Disability Resource Center and reasonable accommodations, please visit `http://drc.arizona.edu`. If you have reasonable accommodations, please plan to meet with me by appointment or during office hours to discuss accommodations and how my course requirements and activities may impact your ability to fully participate.

Code of Academic Integrity
Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See `https://deanofstudents.arizona.edu/student-rights-responsibilities/academic-integrity`.

The University Libraries have some excellent tips for avoiding plagiarism, available at:
`https://lib.arizona.edu/research/citing/plagiarism`.

Selling class notes, lectures, assignments, or other course materials to other students or to a third party for resale is not permitted without the instructor's express written consent. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA e-mail to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student e-mail addresses. This conduct may also constitute copyright infringement.

UA Nondiscrimination and Anti-harassment Policy
The University is committed to creating and maintaining an environment free of discrimination; see `http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy`. Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination of others.

Additional Resources for Students
UA Academic policies and procedures are available at:
`http://catalog.arizona.edu/policies`.

Student Assistance and Advocacy information is available at:

https://deanofstudents.arizona.edu/support/student-assistance

Confidentiality of Student Records
Please see the University's policy on the confidentiality of student records here: https://www.registrar.arizona.edu/privacy-ferpa/about-ferpa

Subject to Change Statement
Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.

Tentative Course Schedule

Date	Content and Assignments
Monday, August 26	Course introduction and overview Philosophy, statistics, inference, programming, and Python Setting up your system for Python Jupyter notebooks
Wednesday, August 28	Introduction to Python Data handling, data formats, data sources, and dealing with large datasets
Monday, September 2	*Labor Day, No class*
Wednesday, September 4	Intermediate Python Object-oriented programming vs. functional programming Writing your own classes and functions in Python
Monday, September 9	Correlation in time and space I Python skills: functions (`def`), `Pandas`, `SciPy`
Wednesday, September 11	Correlation in time and space II Python skills: `xarray`, `matplotlib`, `cartopy`
Monday, September 16	Monte Carlo and stochastic simulation methods I Python skills: `Numpy`, loops (`for`, `while`), `random`
Wednesday, September 18	Monte Carlo and stochastic simulation methods II Python skills: `Numpy`, `random`, `itertools`, functions for bootstrap and jacknife
Monday, September 23	Regression in time and space, calibration and model validation I Python skills: `scikit-learn`, `statsmodels`
Wednesday, September 25	Regression in time and space, calibration and model validation II Python skills: `scikit-learn`, `statsmodels`
Monday, September 30	Time series analysis I Python skills: `Pandas`, `statsmodels`
Wednesday, October 2	Time series analysis II Python skills: `statsmodels`, `pmdarima`
Monday, October 7	Spectral Analysis I Python skills: `SciPy`, `multitaper`
Wednesday, October 9	Spectral Analysis II Python skills: `SciPy`, `multitaper`
Monday, October 14	Empirical Orthogonal Functions and reduced space methods I Python skills: `Numpy.linalg`, `xeof`, `xarray`
Wednesday, October 16	Beyond EOF: reduced space methods II Python skills: `xeof`, `xarray`

Date	Content and Assignments
Monday, October 21	Interpolation and Gaussian Process Regression I Python skills: `Pandas`, `SciPy`, `missingno`, `scikit-learn`
Wednesday, October 23	Interpolation and Gaussian Process Regression II Python skills: `SciPy`, `george`
Monday, October 28	Introduction to Bayesian statistics I Python skills: `Numpy`, `pyMC`
Wednesday, October 30	Introduction to Bayesian statistics II Python skills: `PyStan`
Monday, November 4	Summary and final project discussion
Wednesday, November 6	Student project work
Monday, November 11	Veterans Day, *No class*
Wednesday, November 13	Student project work
Monday, November 18	Student project work
Wednesday, November 20	Student project work
Monday, November 25	*No class, Thanksgiving Break.*
Wednesday, November 27	*No class, Thanksgiving Break.*
Monday, December 2	Student Presentations
Wednesday, December 4	Student Presentations
Monday, December 9	Student Presentations
Friday, December 13	Final Paper Due

Final Paper
The final paper will be due no later than Friday, December 13th by 5pm. Students attending the AGU are encouraged to turn their papers in before the beginning of the meeting!