ATMO 632: Advanced Statistical Methods in Geosciences
Syllabus Fall 2024

Course Times: MWF 10:30-11:20 am, Class Location: HIG 309
Instructor: Pao-Shin Chu, chu@hawaii.edu, Office: 808-956-2567

Text: Wilks, **Statistical methods in the atmospheric sciences**, 4th Ed., Elsevier, 2019

Other reading materials: Relevant journal articles

Prerequisites: ATMO 303, 631, Math 242, or consent of the instructor

Course Description

In ATMO 632, both the principles of statistical theories and their applications in climate and weather will be emphasized. We will cover the statistical forecasting methods, forecast verification techniques, time series analysis, eigenvalues and eigenvectors of a square matrix, principal component analysis and cluster analysis in ATMO 632. Various kinds of statistical forecast methods, both linear or nonlinear, will be introduced. This course will also introduce predictor selection, ensemble forecasting, ensemble postprocessing and graphical display of ensemble forecast information. For characterizing and analyzing the time variations of meteorological data series, the ordering of the data in time is important. There are two fundamental approaches to time-series analysis: time-domain analysis and frequency-domain analysis. We will describe different time-domain methods with discrete data (i.e., a Markov chain) and continuous data (time-series models). Frequency-domain analyses represent data series in terms of contributions occurring at different frequencies. Harmonic analysis and spectral analysis are two major tools used in the frequency-domain approach. We will briefly review matrix algebra, including eigenvalues and eigenvectors and singular value decomposition. It is followed by the principal component analysis, canonical correlation analysis and cluster analysis

I. Statistical Forecasting: Linear regression, the analysis of variance table, goodness-of-fit measures, examining residuals, prediction intervals, multiple linear regression, predictor selection, screening predictors, stopping rules, cross validation, nonlinear regression (logistic regression, Poisson regression), nonparametric regression (Local polynomial regression, Thail-Sen regression, quantile regression), machine learning (Binary regression trees and random forests, artificial neural networks, support vector regression), model output statistics (*MOS)*

II. Ensemble Forecasting: Uncertainty of dynamical forecasts, ensemble forecasting, ensemble averaging and ensemble dispersion, ensemble postprocessing (nonhomogeneous Gaussian regression, logistic regression, Bayesian model averaging), graphical display of ensemble forecasts, *ensemble MOS*.

III Forecast Verification: Background, nonprobabilistic forecasts for discrete predictands, nonprobabilistic forecasts for continuous predictands, probability forecasts for discrete predictands (Brier score, reliability diagram, discrimination diagram, ROC diagram, ignorance score), probability forecasts for multiple-category events, probability distribution forecasts for continuous predictands (continuous ranked probability score), nonprobabilistic forecasts for fields (anomaly correlation, Taylor diagram

IV. Time Series Analysis: **Markov chains – discrete data** (two-state, first-order Markov chains, multiple-state Markov chains, higher-order Markov chains)**, time series models – continuous data** (first-order autoregression, higher-older autoregression, order selection criteria, autoregressive-moving average models, simulation and forecasting), **Harmonic analysis, Spectral analysis** (periodogram, theoretical spectra of AR models).

V. Multivariate Statistics: Matrix algebra, Euclidean distance, Mahalanobis (statistical) distance, eigenvalue solution, square roots of a symmetric matrix, singular-value decomposition.

VI. Principal Component Analysis: Basics, application of PCA to geophysical fields, truncation of the principal component analysis**,** sampling properties of the eigenvalues and eigenvectors, rotation of the eigenvectors, principal component regression.

VII. Multivariate Analysis of Vector Pairs: Basic, applications, and computational considerations of the canonical correlation analysis, maximum covariance analysis.

VIII. Cluster Analysis: Background, hierarchical clustering, nonhierarchical clustering such as the K-Means method and self-organizing maps.

Homework problems sets will be given on a regular basis. 5 points are taken off everyday after due date.

Grading Policy:

Homework assignments	80%
Class project (presentation, discussion, and term paper)	20%

Letter grade: 100: A+, 93-99:A, 90-92:A-, 87-89:B+, 83-86:B, 80-82:B-, 77-79:C+, 73-76:C, 70-72: C-, 67-69:D+, 63-66:D, 60-62:D-, <59:F

Office hour: MWF 11:30-12:00 am, or other times

Student learning outcomes: Upon the completion of the semester, students are expected to be able to

1. Understand statistical methods used in forecasting, the concept of ensemble forecasting and some methods used in ensemble postprocessing
2. Understand various forecast verification methods used in operational and research settings
3. Understand the Markov model, time-series models, harmonic and spectral analysis
4. Use some statistical software to display ANOVA table and explain the meaning of this table
5. Know how to compute eigenvalues and eigenvectors and understand EOF analysis as well as truncation criteria and the North's rule of thumb
6. Know the properties and application of canonical correlation analysis and maximum covariance analysis
7. Understand the distance measures and the distance matrix, agglomerative methods, dendrogram, the K-Means method and self-organizing maps

Title IX Statement:

The University of Hawai'i is committed to providing a learning, working and living environment that promotes personal integrity, civility, and mutual respect and is free of all forms of sex discrimination and gender-based violence, including sexual assault, sexual harassment, gender-based harassment, domestic violence, dating violence, and stalking. If you or someone you know is experiencing any of these, the University has staff and resources on your campus to support and assist you. Staff can also direct you to resources that are in the community. Here are some of your options:

As members of the University faculty, your instructors are required to immediately report any incident of potential sex discrimination or gender-based violence to the campus Title IX Coordinator. Although the Title IX Coordinator and your instructors cannot guarantee confidentiality, you will still have options about how your case will be handled. Our goal is to make sure you are aware of the range of options available to you and have access to the resources and support you need.

If you wish to remain ANONYMOUS, speak with someone CONFIDENTIALLY, or would like to receive information and support in a CONFIDENTIAL setting, use the **confidential resources available here**:

http://www.manoa.hawaii.edu/titleix/resources.html#confidential

If you wish to directly REPORT an incident of sex discrimination or gender-based violence including sexual assault, sexual harassment, gender-based harassment, domestic violence, dating violence or stalking as well as receive information and support,

Contact: Dee Uwono Title IX Coordinator (808) 956-2299, t9uhm@hawaii.edu.

Course Information, Policies and Resources

a. Focus designation and hallmarks *(if relevant)*

b. **Attendance policy:** *(Text to Be Used) Students who are enrolled in this course, but never attend will be flagged by the course instructor for non-participation before the last day to add/drop (for 100% tuition refund) deadline. Flagged students will be administratively dropped by the Office of the Registrar. Any changes to a student's enrollment status may affect financial aid eligibility and can result in the return of some of all of federal student financial aid. (specify for your course; may also be covered under Grading section)*

c. Use of Internet, mobile devices, and social media *(specify for your course, if allowed)*

d. **Statement on Disability: KOKUA Program** *(text to be used)* If you have a disability and related access needs, please contact the KOKUA Program (Office for Students with Disabilities) at 956-7511, KOKUA@hawaii.edu, or go to Room 013 in the Queen Lili'uokalani Center for Student Services. Please know that I will work with you and KOKUA to meet your access needs based on disability documentation. Kokua's services are confidential and offered free of charge.

e. **Academic Integrity and Ethical Behavior: Office of Student Conduct** (recommended text) Cheating, plagiarism, or other forms of academic dishonesty are not permitted within this course and are prohibited within the System-wide Student Conduct Code (EP 7.208). Examples include: fabrication, falsification, cheating, plagiarism, and use of improper materials. Any incident of suspected academic dishonesty will be reported to the Office of Student Conduct for review and possible adjudication. Additionally, the instructor may take action in regards to the grade for the deliverable or course as they see fit.

f. **Office of Title IX**: (808) 956-2299 / t9uhm@hawaii.edu / https://manoa.hawaii.edu/titleix/

g. **Department of Public Safety**: (808)956-6911 (Emergency) / (808)956-8211 (Non-Emergency) http://manoa.hawaii.edu/dps/

h. **UH System Basic Needs** *(text to be used)* include food and housing, childcare, mental health, financial resources and transportation, among others. Student basic

needs security is critical for ensuring strong academic performance, persistence and graduation and overall student well being. If you or someone you know are experiencing basic needs insecurity, please see the following resources: UH System Basic Needs

i. **Student Success Resources:** The Division of Student Success (DSS) houses student support services to build success inside and outside the classroom. If you want learning assistance, academic advising, career resources and guidance, counseling, family and relationship support, identity-based support, services for underrepresented groups, health and wellness services, opportunities for leadership growth, and community engagement, you will find this and more in DSS, (808) 956-3290, https://manoa.hawaii.edu/studentsuccess/departments/