ATMO 632: Advanced Statistical Methods in Geosciences
Syllabus Spring 2020

Course Times: Monday/Wednesday 10:30-11:45, Class Location: HIG 309
Instructor: Pao-Shin Chu, chu@hawaii.edu, Office: 808-956-2567

Text: Wilks, **Statistical methods in the atmospheric sciences**, 3rd ed., Academic Press, 2011

Other reading materials: Relevant journal articles

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, time series analysis, eigenvalues and eigenvectors of a square matrix, principal component analysis and others 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, and graphical display of ensemble forecast information. Forecast verification is the process of assessing the quality of forecasts, and such a process is used frequently in research and operational agencies such as the NOAA's National Weather Service and the Climate Prediction Center. Attributes of forecast performance, skill scores, the reliability diagram, the ROC diagram, the Taylor diagram, and verification of ensemble forecasts will be discussed. For characterizing and analyzing the time variations of 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.

I. Statistical Forecasting: Linear regression, the analysis of variance table, goodness-of-fit measures, examining residuals, prediction intervals, multiple linear regression, nonlinear regression (logistic regression, Poisson regression), predictor selection, screening predictors, stopping rules, cross validation, *MOS*, *operational MOS forecasts*, ensemble forecasting, ensemble averaging and ensemble dispersion, graphical display of ensemble forecasts, *ensemble MOS*.

II. Forecast Verification: **Nonprobabilistic forecasts of discrete predictands** (2x2 contingency table, skill scores for contingency table, conversion of probabilistic to nonprobabilistic forecasts, extensions to multicategory discrete predictands),

Nonprobabilistic forecasts of continuous predictands (conditional quantile plots, scalar accuracy measures, skill scores), **Probability forecasts of discrete predictands (**joint distribution for dichotomous events, Brier score, algebraic decomposition of the Brier score, the reliability diagram, the discrimination diagram, the ROC diagram, probability forecasts for multi-category events, ranked probability score), **Probabilistic forecasts for continuous predictands** (Continuous ranked probability score), **Nonprobabilistic forecasts of fields** (mean squared error, Taylor diagram, anomaly correlation), **Verification of ensemble forecasts** (verification rank histogram).

III. 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).

IV. Multivariate Analysis: Matrix algebra, eigenvalue solution, singular-value decomposition, empirical orthogonal function analysis, truncation criteria, rotation of the eigenvectors, principal component regression.

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

Grading:

Homework assignments	70%
Class project (presentation, discussion, and term paper)	30%

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 verification techniques for both probabilistic and nonprobabilistic forecasts
2. Understand the Markov model, time-series models, harmonic and spectral analysis
3. Use some statistical software to display ANOVA table and explain the meaning of this table
4. Perform regression based forecasting, and compute various measures of scalar attributes and forecast skill scores
5. Draw the reliability diagram and ROC curve, calculate the RPS and ignorance score
6. Know how to compute eigenvalues and eigenvectors and understand EOF analysis as well as principal component regression analysis

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.