ATMO 631 -- Statistical Meteorology   Syllabus Fall 2017

Fall 2017
MWF 10:30-11:20, HIG 309

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Textbook

Statistical Methods in the Atmospheric Sciences, D. Wilks, 3rd edition, Academic Press, 2011

Other reading material

Relevant journal articles will be provided.

Course Description

In ATMO 631, both the principles of statistical theories and their applications in climate and weather will be emphasized. We will cover the first five chapters of the book by Dan Wilks (2011). We will first present a brief review of the basic elements of probability and Bayes' Theorem. This is followed by exploratory data analysis which draws heavily on a variety of graphical methods to aid in the comprehension of the large batches of numbers that may confront analyst. We will then introduce various parametric probability distributions to represent variations in the underlying data. Also included are the extreme-value distributions which may represent statistics of extreme meteorological events such as very heavy rainfall or summer heat waves. Parameter fitting using the method of maximum likelihood, including the Expectation-Maximization algorithm, and statistical simulation of random numbers will be covered. Statistical inference in the formal testing of statistical hypotheses, also known as significance testing, will be the subject of the last chapter. Focus will be placed on the parametric and nonparametric hypothesis tests, including Monte Carlo tests. Multiplicity and field significance tests when the results of multiple statistical tests must be evaluated simultaneously will be covered.

Major Topics to be covered:

Review of Probability

Events, Venn diagram, Axioms of probability, domain, complements, unions, conditional probability, law of total probability, Bayes' theorem

Empirical Distributions and Exploratory Data Analysis

Quantiles, numerical summary measures (location, spread, symmetry), graphical summary techniques (boxplots, schematic plots, histograms, kernel density smoothing, cumulative frequency distributions), power transformations, standardized anomalies, Pearson correlation, rank correlation, autocorrelation function, scatterplot matrix

Parametric Probability Distributions (discrete, continuous)

Binomial, Geometric, Negative binomial, Poisson, statistical expectations, Gaussian and standard Gaussian, evaluating Gaussian probabilities, lognormal, bivariate normal, Gamma, evaluating Gamma distribution probabilities, standardized precipitation index, log-Pearson III, Beta, extreme-value distributions (Generalized extreme value, Gumbel, Weibull) and return periods, mixture distributions, goodness of fit (pdf and data histogram, QQ plots), maximum likelihood methods (Newton-Raphson, expectation maximization algorithm), statistical simulation (uniform random-number generators, nonuniform random-number generation by inversion, nonuniform random-number generation by rejection, simulating from mixture distributions and kernel density estimates)

Hypothesis Testing (Frequentist statistical inference)

Background (elements of hypothesis test, test levels and *p* values, error types, one-sided vs two-sided test, confidence intervals), **parametric tests**: one-sample t, two-sample t), tests for differences of mean under serial dependence, goodness-of-fit tests (chi-square, Kolmogorov-Smirnov), Filliben Q-Q correlation test for Gaussian distribution, likelihood ratio tests, **nonparametric tests**: Wilcoxon-Mann-Whitney rank-sum, Wilcoxon signed-rank, Mann-Kendall trend, **resampling test:** bootstrap confidence intervals, permutation, field significance and multiplicity, false discovery rate and field significance

Grading: Quasi-biweekly problem sets (75%) and a term project with a short paper (~ 5 pages) and class presentation (25%).

Term project

A project involving downloading, processing, computing, and graphical displays of atmospheric data from one of the topics covered will be performed and presented in class. The interpretation of major results is also required.

Student learning outcomes: Upon the completion of the course, students will be able to

1. Understand basic properties of probability
2. Compute and interpret summary measures of statistical data distributions
3. Use graphical summary devices and tools for presenting empirical data
4. Understand various discrete and continuous parametric probability distributions and maximum likelihood estimates
5. Evaluate the goodness of fit of underlying data to certain parametric distributions
6. Have a good understanding about statistical simulation
7. Understand elements of hypothesis test, test levels, *p*-values, confidence intervals

8. Conduct parametric and/or nonparametric tests and draw conclusions about the hypothesis test using real world atmospheric data
9. Understand the resampling tests and their applications in weather and climate research
10. Grasp the concept of multiplicity and field significance tests

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