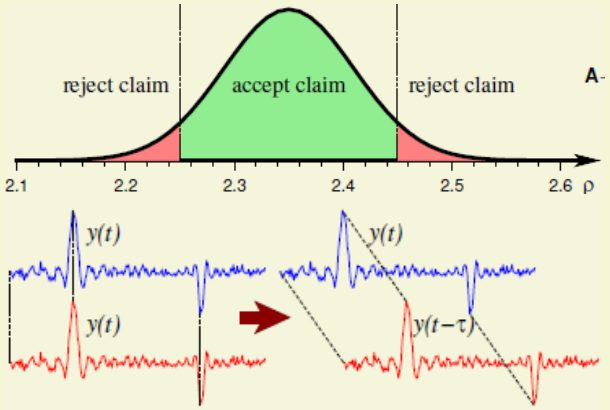
ERTH413/613: Introduction to Statistics and Data Analysis



- **Exploratory Data Analysis**
- **Error Propagation**
- **Probability Theory and Statistics**
- **Statistical Tests**
- **Curve Fitting and Regression**
- **Sequence Analysis**
- **Spectral Analysis**
- **Analysis of Directional Data**

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Prerequisites: Math242 (2nd semester calculus), ERTH250 (scientific programming using Matlab), or instructor consent

Textbook: Paul Wessels Lecture Notes. Recommended (optional) text: John C. Davis, Statistics and Data Analysis in Geology, 3rd Edition

OVERVIEW AND OBJECTIVES:

In this course students gain foundational understanding of the basic theory behind statistics, probability, and quantitative data analysis, as well as practical experience in working with real data sets using computer software (Matlab). The course emphasizes solving problems and independent learning and inquiry. Students...

- Learn how to apply exploratory data analysis techniques to characterize their data or discover patterns within it
- Understand how to propagate errors in calculations of derived quantities
- Learn and apply concepts of samples, population, probability distributions, and the central limit theorem
- Doing formal hypothesis testing in interpreting data
- Gain an introduction to matrices, linear algebra, and least squares formalism for curve fitting and regression
- Explore various ways to examine sequential data
- Practice spectral analysis and apply concepts of aliasing and leakage
- Analyze directional data

Applications will emphasize geosciences but the course is *relevant to all fields of science*.

FORMAT AND WORKLOAD

Lectures are to be viewed outside of class on YouTube (links provided below). Class time is an interactive learning environment and largely dedicated to working problem sets. Problem sets will be assigned approximately weekly and will involve using computer software to apply and practice using the techniques covered. There will be a mid-term and a final exam.

STUDENTS TAKING ERTH613 will analyze a data set of their choice—ideally something related to their thesis/dissertation research—and gain professional practice presenting this work in writing and orally.

GRADING

Data analysis is a very hands-on activity and there will be weekly problem sets that require a mix of mathematical and computational manipulations. Homework must be handed in at the beginning of class on the due date, unless you have made prior arrangements with me. Otherwise, unexcused late homework will receive 10% less credit for each day it is late. If you anticipate a conflict for exams, you must re-schedule the exam *prior* to the scheduled date. The final grade for **ERTH413** will be a weighted average of grades for homework (70%), mid term (15%), and final exam (15%). For **ERTH 613** the grade is a weighted average of grades for homework (55%), midterm (15%), final exam (15%), and the project report (15%).

EARTH SCIENCES PROGRAMMATIC STUDENT LEARNING OBJECTIVES

This course emphasizes three *student learning objectives* for undergraduate and graduate students:

- "Students can apply technical knowledge of computer applications and mathematics and physics to solving real-world problems in earth sciences
- "Students use the scientific method to define, critically analyze, and solve a problem in earth science
- "Students can communicate scientific knowledge in both oral presentations and in writing

WORKING COURSE SYLLABUS

1. Basic Statistical Concepts

Week 1: (Reading: *Swan and Sandilands* Handout and *Wessel* 1.1-1.3)

1.1 Classification of data (see video #1 on Data Types and Precision vs. accuracy)
1.2 Exploratory data analysis (see EDA_Lecture files)
1.3 Error Analysis
video #2, Reporting uncertainties, significant figures, & errors of sums & differences
video #3, Computing errors of products & quotients
video #4 Computing errors of products & quotients for Gaussian distributions
Examples 1 and 2
Homework #1 and required datasets

Week 2: (HW #1 due Tuesday)

1.4 Probability Basics
Lecture Videos
#1: 1.4.1 Permutations
#2: 1.4.2 Combinations
#3: The Binomial probability distribution
#4: The Hypergeometric distribution, 1.4.3 Probability, 1.4.4 Some Rules of Probability
#5: 1.4.6 Additional rules, 1.4.7 Conditional Probability
#6: 1.4.7 Conditional Probability and Bayes Theorem
Examples: Binomial & Hypergeometric PDs (& Matlab scripts for examples 1 & 2), and Conditional Probability
Homework #2: Probability

Week 3: (HW #2 due)

1.5 The M&M's of Statistics (Davis pages on Central Limit Theorem)
Lecture Videos:
#1: 1.5.1 Population and Samples, 1.5.2 Measure of central location (mean, median, mode)

#2: 1.5.3 Measure of variation
#2.5: 1.5.6 Covariance and Correlation
#3: 1.5.4 Robust Estimation (MAD)
#4: 1.5.5 Inference about the mean and Central Limits Theorem
#5: 1.5.8-1.5.10 Probability Distributions, Binomial and Normal Distributions
#6: 1.5.10 The Normal (Gaussian) Probability Density Function
#7: 1.5.10-1.5.11 Applications of the Normal Distribution & the Poisson's Distribution
See example script for plotting the binomial and normal distributions.
HW3: Statistics and Probability Distributions and (data for problems 2 & 3)

3. Hypothesis Testing

Week 4: (HW #3 due)

Read the following sections:
1.5. Inferences about means of populations, Videos #1, #2, #3
2.1 Null Hypothesis, Videos #4
2.2. Parametric Tests (Students *t*, Chi-squared, *F* tests),
#5: one and two-sample test of means
#6: two-sample t-test of means
#7: estimating the variance of a population
#8: one-sample, chi-square test of variance
#9: two sample test of F-test of variance
Tables: normal distribution, t-distribution, chi-squared, F-distribution
Hw4: Hypothesis Testing with Parametric Statistics

Week 5: (HW #4 due)

2.2 Parametric Tests, videos...
#1: general aspects of Chi-squared
#2: Chi-squared test of a pdf
#3: Chi-squared test of a pdf, example
#4: test of linear correlation
2.3 Non-Parametric Tests, see video
#5 on Parametric vs. Non-Parametric tests
#6: Sign test of central value
Hw5: Hypothesis Testing II: datasets: "quakedays.txt", and "rho.txt"

Week 6: (HW #5 due)

2.3 Non Parametric Tests
2.3.2 videos #1 and #2: Mann-Whitney 2-sample U test of median
2.3.3 #3: Kolmogorov-Smirnov goodness of fit test (1 or 2 sample) to a pdf
2.3.4 #4: Non Parametric test for correlation
Tables: Mann-Whitney, K-S (1-sample), K-S (2-sample)
Hw6: Hypothesis Testing III, see Matlab script kolsmir.m

3. Linear (Matrix) Algebra and Least Squares Inversion for Model Fitting

Week 7: B (HW #6 due)

3.1-3.2 #1 Matrices: General concepts and definitions
3.3-3.5 #2 Matrix Addition, Dot Product, and Matrix Multiplication

3.6 #3 Determinant of a Matrix
3.8 #4Matrix Division: the Inverse Matrix
3.10 #5 Simple Regression and #6 RMS Misfit
3.11 General Least Squares Regression: #8 Part I and #9 Part II
Hw7: Least Squares Regression: see dataset hf.txt

Week 8:
Review for Mid-term
>>MIDTERM (Covering material through HW #6) <<<<

Week 9: (Hw #7 due)
3.12 Video #1: Weighted Least Squares
#2: Line Fitting Revisited: Confidence Intervals on True Slope, Intercept, and Regression Line
#3: Derivation of Variances of True Slope, Intercept, and Regression Line
Hw8: Lease Square Regression II: see hawaii.txt, faultstep.txt, and heaviside.m

4. Analysis of Variance (ANOVA)
Week 10: (HW #8 due)
Video #1: Analysis of Variance (ANOVA) of Linear Regression
4.4 #2 One-way ANOVA
4.5 #3 Two-way ANOVA
See also Draper & Smith excerpt
Hw9: ANOVA, see Hw9_hf.txt, Hw9_Prob2_Chromium.txt, and Hw9_StudentPorosityMeasurements.txt

5. Sequences and Time Series Analysis
Week 11: (HW #9 due)
5.1 Markov Chains: videos #1 and #2
See detailed explanation of Example 5-1
Hw10: Markov Chains

Week 12: (HW #10 due)
5.5 Autocorrelation, Video #1
5.6 Cross-correlation, Video #2
Matlab script shown in videos, with data for auto- and cross-correlation
HW11: Autocorrelation and Cross-Correlation, data files: TEMPER.TXT, Chesapeake_salinity.txt

5.8 Spectral Analysis
Week 13: (HW #11 due)
#1: Introduction to spectral analysis
#2: Orthogonality of periodic functions
#3: Discrete Fourier series
5.9 The Periodogram or Discrete Power Spectrum, Video #4
Hw 12: Spectral Analysis. See data file honolulu_resampled.txt

Week 14:
6.0 Analysis of Directional Data

#1: Polar histogram, computing means and variance
#2: Confidence intervals, One-sample tests of means
#3: Two-sample F test of means
Read Davis Hand out

Hw13: Analysis of Directional Data
See data files Iceland_West.txt and Iceland_East.txt, as well as Matlab script polarhist.m

Week 15: (HW #12)
6.0 Analysis of Directional Data

Week 16:
Review for Final Exam

Title IX:

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 UwonoTitle IX Coordinator (808) 956-2299 t9uhm@hawaii.edu.