# ATS 655: Objective Analysis in Atmospheric Sciences
# Course Syllabus for Spring 2025

In-Person Lectures 08:45 - 10:00 Mon / Wed
Course Webpage: https://colostate.instructure.com/courses/196462

Objective analysis of geophysical data: basic statistics; matrix methods; filtering; time series analysis; basic machine learning methods. Emphasis on applications to real world data.

## 1 Instructors

**Professor Elizabeth A. Barnes**
email: eabarnes@colostate.edu
office hours: Wednesdays from 1000-1045; ATS 316 or by appointment

**TA – Nico Gordillo**
email: XXXX
office hours: XXXXX

## 2 Course Focus & Student Experiences

The course provides an overview of the methods used to interpret data sets in the atmospheric and oceanic sciences. This is a tools class: the objective is to provide a working knowledge of the statistical tools most commonly used in the field, as well as those that are up-and-coming. However, additional time will be spent on how to professionally present and objectively review scientific results and how the tools are appropriately and inappropriately used in the field.

Upon successful completion of this course student will be able to:
- become comfortable with basic statistical techniques
- learn to break-down real science problems into testable hypotheses
- learn to review and assess the analysis techniques presented in the literature
- practice writing-up scientific results in a professional manner.

Student learning experiences will include:
- In-class lectures and discussions
- Reading books/online tutorials/research papers on relevant topics
- Writing code to analyze data
- Development and implementation of homeworks and a final report
- Creation and presentation of final projects

## 3 Expectations

The following list presents the minimum requirements for passing this course:
- participate in live lectures
- keep up with the reading including course notes
- submit all assignments on time and at an acceptable level of quality
- satisfactorily complete all quizzes

## 4 Prerequisites

You are expected to be familiar with basic high-school and college-level mathematical concepts. Minimal time will be spent in lecture reviewing these topics:

- algebra (e.g. equations for lines, solving basic algebraic equations)
- basic calculus (e.g. how to take a derivative and an integral)
- basic matrix algebra (e.g. addition, subtraction, multiplication)
- sine and cosine functions

## 5 Webpage

The course web site will be used for posting resources and homework assignments. The course web site is through CSU Canvas and is listed at the top of this syllabus. All students enrolled in the course should have access to the Canvas material.

You will submit your assignments via Canvas by uploading a **pdf** file of your assignment by the due date. Canvas will also allow you to keep track of your grade/points in the course.

## 6 Grading

Your course grade will be determined by homeworks and graded reading quizzes. There will be approximately 8 homeworks (although this may change) of varying length. Late assignments will incur a 20% reduction in total points unless circumstances are discussed with the instructors.

If you need help in completing the assignment, first ask your peers for assistance and request help from your TA and instructor second. You are *encouraged* to interact with your classmates by sharing ideas and discussing the specifics of the material and homeworks. You are, however, expected to hand-in your own homework assignment, and it should not be a direct copy of your classmate's.

Your homework assignments must be typed-up and clearly written. Figures should be of publication quality - no low-resolution figures. I repeat, *no low-resolution figures*. By doing this, you are not just being nice to the me and the TA, who have to grade your work, but you will gain practice in presenting your results clearly and professionally as required for your careers as scientists.

In addition to being clear and neat, I expect all figures to include a descriptive caption, legend (if applicable) and *labeled axes with units*! Having axes without labels or units will automatically deduct points from your homework. (You may be surprised to learn that many papers sent out to review by scientists in the field do not satisfy these basic requirements.)

## 7 Textbooks & Resources

There is no required textbook for this course. Some of the materials, notes, homeworks, etc. in this course are borrowed from the course materials of Prof. Mike Wallace and Prof. Dennis Hartmann at the University of Washington and Prof. Dave Thompson at Colorado State University. We will make extensive use of the my own typed notes (you can also refer to those of Prof. Hartmann which I have linked to on the course webpage) and I advise you to save/print all chapters of these notes and store them somewhere easily accessible. You will likely use them long after this course is done.

There is one required resource in this course - **the internet**. Google is amazing - use it. In addition, the statistics pages on Wikipedia are very good, both the standard and advanced pages - you should use

them often. One of the most important things to learn in graduate school is ``how to look it up.'' In my own research, I use most of the techniques we will discuss, but I have very few of them memorized. By the end of this course, you should aim to be self-sufficient in finding the analysis techniques you need. You should not care whether you have a specific derivation or formula memorized, but whether you know how to find it.

Additional references you may find useful are listed on the course webpage.

## 8 Software

***Data Analysis***
This course will have a substantial coding component. While every student is welcome to use whatever software they desire, the instructors will be exclusively using Python 3.x. You are, however, welcome to use whatever software you wish to perform the assignments.

***LaTeX***
LaTeX[1] is a type-set program that takes macro code and formats it into a final (often pdf) document. For example, the course notes are written in LaTeX. The end result is a clean, consistently formatted document. Many scientists use LaTeX to write-up their research, and journals are increasingly preferring LaTeX files to Microsoft Word files for manuscript submission.

A main reason to use LaTeX is the ease with which mathematical symbols, equations, etc. are formatted. In addition, including figures is efficient: the user does not ``cut and paste'' the figure into the text, but rather places the actual document path of the figure in the LaTeX code. Thus, whenever the figure is changed, it is automatically updated in the manuscript file. LaTeX is free and can be used on all common operating systems (e.g. Linux, Mac, Windows). In addition, Overleaf.com is a fantastic (although expensive) for typesetting and collaborating with LaTeX in the cloud (i.e. does not require you install anything on your computer).

I will not require that you use LaTeX for your homeworks, however, I highly encourage you to do so, and a handout will be provided at the beginning of the semester. While the initial learning curve is rather steep, I think that the payoff is worth it. Equation type-setting is easy and always neat, figures will be easily updated, and references are straight-forward to handle with BibTeX[2]. As an incentive for you to try LaTeX, I will provide extra credit points for those that write-up at least one of their homeworks in LaTeX.

## 9 CSU Honor Pledge

This course will adhere to the CSU Academic Integrity Policy as found in the General Catalog and the Student Conduct Code. At a minimum, violations will result in a grading penalty in this course and a report to the Office of Conflict Resolution and Student Conduct Services."

[1] pronounced ``LAY-tek'' or ``LAH-tek''
[2] LaTeX's bibliography manager

## 10 Tentative Outline

The following is a tentative outline for the class. Reality will almost surely deviate from this.

1. **Basic Probability & Monte Carlo Methods**
    - Basic Probabilities and Discrete Bayes' Theorem
    - Distributions, Random Variables, and Sample Means
    - Monte Carlo and other resampling techniques
    - Bayesian Estimation
    - Hypothesis Testing
    - Tests for Quantities Beyond the Mean

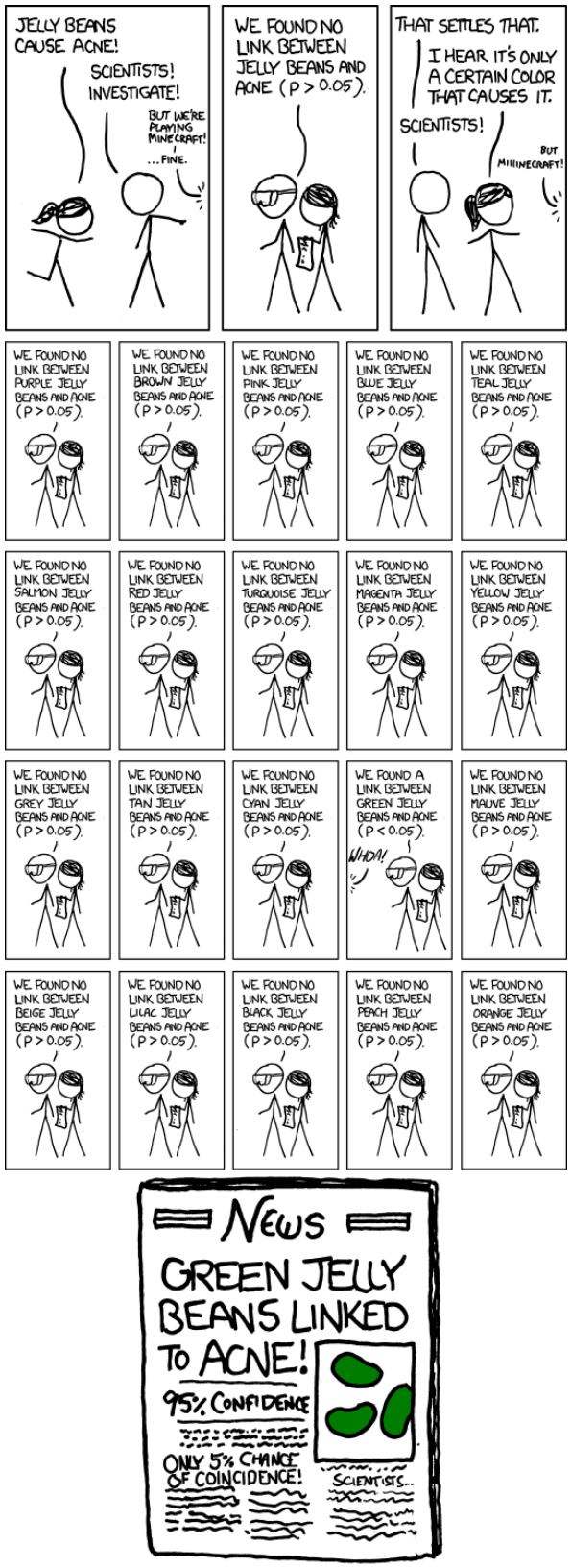
2. **Regression, Correlation & AR1 Processes**
    - Linear regression
    - Theory of correlation
    - Autocorrelation/autoregressive methods; estimating the number of independent samples
    - Multiple regression
    - Granger Causality

3. **Spectral Analysis**
    - Harmonic analysis; power spectra; methods of computing power spectra
    - Significance testing of spectral peaks
    - Data windows
    - Filtering; filter design; recursive/non recursive filters; response functions
    - Cross spectrum analysis
    - Mixed Space-Time Analysis

4. **Seeking Structure in Data with Principal Components**
    - Review of linear algebra
    - Empirical orthogonal functions (EOF)
    - Application of EOFs to real data

5. **Machine Learning Basics**
    - Loss functions and optimization
    - Training, testing, and validation data sets
    - Cluster Analysis (e.g., k-means, self-organizing maps)
    - Decision trees; Random forests
    - Neural networks; gradient descent; backpropagation
    - Convolutional neural networks
    - Overview of neural network visualization

6. **Effective Figures**




CAPTION: https://xkcd.com/882/