AT 655: Objective Analysis in the Atmospheric Sciences
Course Syllabus

Class: 10:00AM - 10:50AM MWF, ATS 101
`http://barnes.atmos.colostate.edu/COURSES/AT655_S15/index.html`

Objective analysis of geophysical data: basic statistics; matrix methods; filtering; time series analysis; pattern identification. Emphasis on applications to real world data and evaluating techniques in the literature.

1 Instructor

Dr. Elizabeth A. Barnes

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Office Hours:	T Th 2:00 - 3:00, and other times by appointment

2 Teaching Assistant

Chris Slocum

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Office Hours:	W 1:00-3:00, and other times by appointment

Alex Goodman will be serving as the Department Programming TA over the semester and he will be available to assist with coding questions. Please speak with Alex for specific office hours (goodman@atmos.colostate.edu).

3 Course Focus

The course provides an overview of the statistical 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 literature. However, additional time will be spent on how to professionally and objectively present and review scientific results and how the tools are appropriately and inappropriately used in the field. During this course you will:

- 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.

4 Course Expectations

The following list presents the minimum requirements for passing this course:

- show-up to class and ask questions,
- keep up with the reading (when applicable),
- submit all assignments on time and at an acceptable level of quality (it is expected that you will spend *at least* 2 hours of effort outside of class for each hour of class time),
- satisfactorily complete all quizzes.

5 Course 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

If you are concerned about your background in these areas, please speak with me. While the concepts, tools, and techniques explored in this course will be taught within the context of atmospheric science, there are no atmospheric science prerequisites.

You will be expected to write and implement computer code throughout this course. I do not care what software you use, but note, I will not spend office hours debugging your code for you.

6 Course Web Page

The course web site will be used for posting notes and homework assignments. The course web site is available through the instructors webpage and is listed at the top of this syllabus.

7 Grading

7.1 Grade Break-down

The overall course grade will be made up of two different components: homeworks and quizzes, with quizzes taking up approximately 20% of your grade and homeworks covering the other 80%.

7.2 Homework

There will be approximately 6 homeworks throughout this course (although I maintain the right to increase or decrease this number), each of varying length. You will be *at least* one week to complete each assignment.

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 clear and legible. I recommend typing them up to ensure that your steps can be followed. Figures should be of publication quality - no low-resolution figures. By doing this, you are not just being nice to the TA and instructor 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.)

7.3 Quizzes

There will be in-class quizzes throughout the semester (approximately 6 total, although I once again maintain the right to increase or decrease this number). Quizzes will always be announced at least one class-day prior to the quiz - no "pop" quizzes. The quizzes will cover lectures, assigned reading, and previous homework problems. Quizzes will be **open notes**, but not open internet. The quizzes will be designed to test your basic knowledge of the topic, not to stretch your thinking (this is what the homeworks are for). If you come to lecture, read the material, do the homeworks, and ask questions, the quizzes should not be hard. I repeat, *you should not have to study for the quizzes if you keep-up with the expectations for this course.*

7.4 Midterm & Final Exams

There will not be a midterm or a final exam in this course.

8 Text Books & Resources

There is no required textbook for this course. Many 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 typed notes of Prof. Hartmann, and these notes are available on the course webpage. 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 (for this reason, all quizzes will be open notes).

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

9 Software

9.1 Analysis & Plotting Software

You are required to have an analysis and plotting software package (often they are one in the same) with which you can do the homeworks. I do not care what you use, but keep in mind you will want it to have basic statistical algorithms including (e.g. correlation, fast fourier transform "fft", singular value decomposition "svd")[1]. Keep in mind that I used *MATLAB* for all of my analysis (the TA will use the Python-based ecosystem SciPy), so I won't be able to answer specific coding questions for other software. If you are interested in using *MATLAB*, it is free to students for their home and personal computers through the College of Engineering. For Python, the Anaconda Scientific Python Distribution is free and easy to setup.

9.2 *Optional: LaTeX*

LaTeX[2] is a type-set program that takes macro code and formats it into a final (often pdf) document. For example, this syllabus was written with *LaTeX*. The end result is a clean, consistently formatted document. More and more scientists are using *LaTeX* to write-up their research, and journals are increasingly preferring *LaTeX* files to Mircrosoft 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).

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*[3].

As an incentive for you to use *LaTeX*, I may provide extra credit points for those that write-up their homework in *LaTeX*.

[1] often, if your software package is widely available, the code will exist somewhere on the internet.
[2] pronounced "LAY-tek" or "LAH-tek".
[3] *LaTeX*'s bibliography manager.

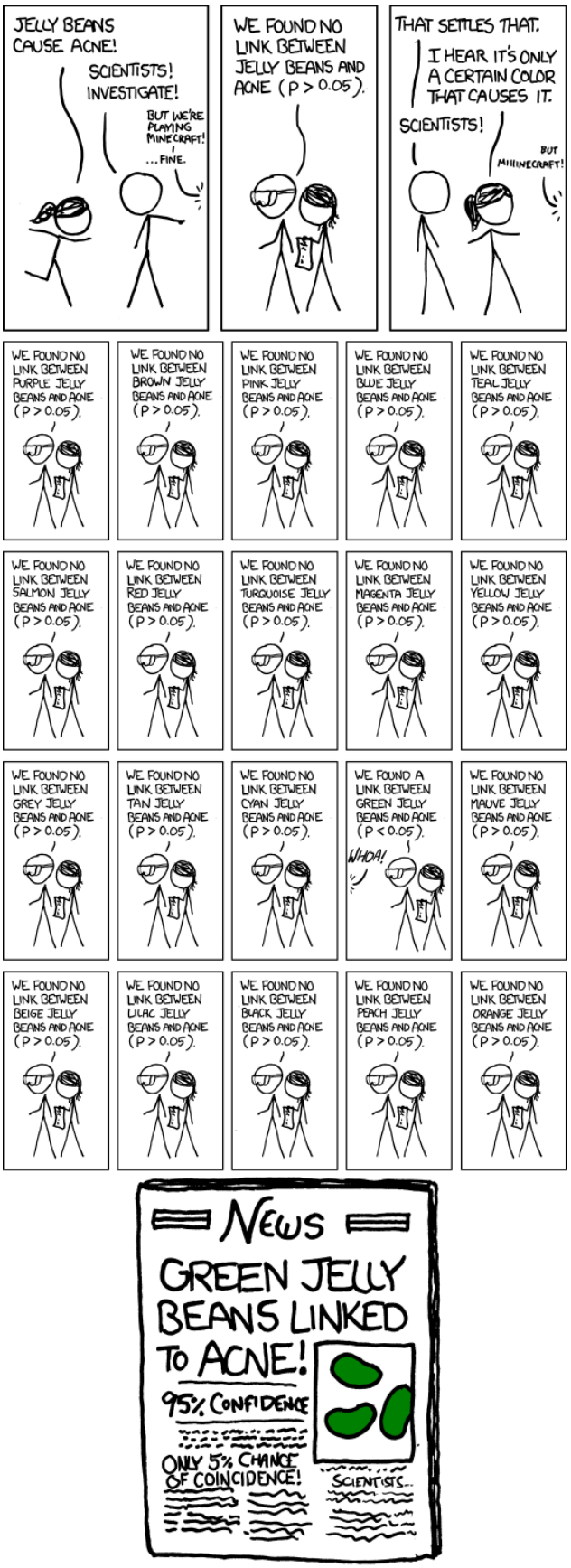
10 CSU Honor Pledge

This course will adhere to the CSU Academic Integrity Policy as found in the General Catalog (`http://www.catalog.colostate.edu/FrontPDF/1.6POLICIES1112f.pdf`) and the Student Conduct Code (`http://www.conflictresolution.colostate.edu/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."

11 Tentative Outline

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

1. **Probability & statistics**
   - 1.1. Basic statistics, probability distributions, Bayes Theorem
   - 1.2. Statistical decision making; hypothesis testing
   - 1.3. Basic nonparametric statistics
   - 1.4. Monte Carlo techniques; bootstrap; jackknife; field significance
   - 1.5. Compositing
2. **Regression & correlation**
   - 2.1. Linear regression
   - 2.2. Theory of correlation
   - 2.3. Autocorrelation/autoregressive methods; estimating the number of independent samples
   - 2.4. Multiple regression
3. **Matrix methods**
   - 3.1. Review of linear algebra
   - 3.2. Empirical orthogonal functions (EOF); singular value decomposition (SVD)
   - 3.3. Application of EOFs to real data
   - 3.4. Maximum covariance analysis (MCA); canonical correlation analysis (CCA)
4. **Time series analysis**
   - 4.1. Harmonic analysis; power spectra; methods of computing power spectra
   - 4.2. Significance testing of spectral peaks
   - 4.3. Data windows
   - 4.4. Filtering; filter design; recursive/nonrecursive filters; response functions
   - 4.5. Cross spectrum analysis
   - 4.6. Mixed Space-Time Analysis
5. **Effective figures**


JELLY BEANS CAUSE ACNE!
SCIENTISTS! INVESTIGATE!
BUT WE'RE PLAYING MINECRAFT!
...FINE.
WE FOUND NO LINK BETWEEN JELLY BEANS AND ACNE (P > 0.05).
THAT SETTLES THAT.
I HEAR IT'S ONLY A CERTAIN COLOR THAT CAUSES IT.
SCIENTISTS!
BUT MIIIINECRAFT!
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WE FOUND NO LINK BETWEEN BROWN JELLY BEANS AND ACNE (P > 0.05).
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WE FOUND A LINK BETWEEN GREEN JELLY BEANS AND ACNE (P < 0.05).
WHOA!
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WE FOUND NO LINK BETWEEN PEACH JELLY BEANS AND ACNE (P > 0.05).
WE FOUND NO LINK BETWEEN ORANGE JELLY BEANS AND ACNE (P > 0.05).
NEWS
GREEN JELLY BEANS LINKED TO ACNE!
95% CONFIDENCE
ONLY 5% CHANCE OF COINCIDENCE!
SCIENTISTS...