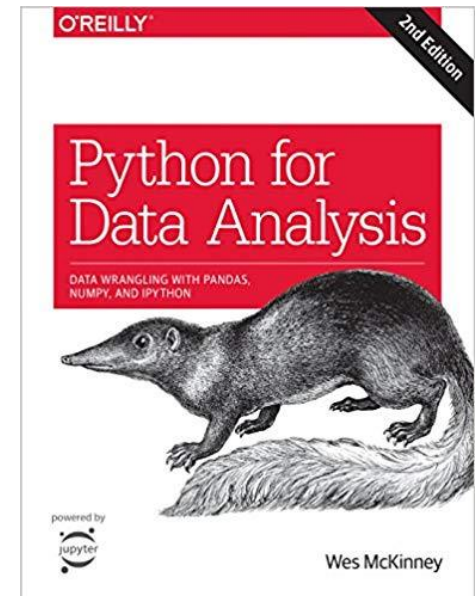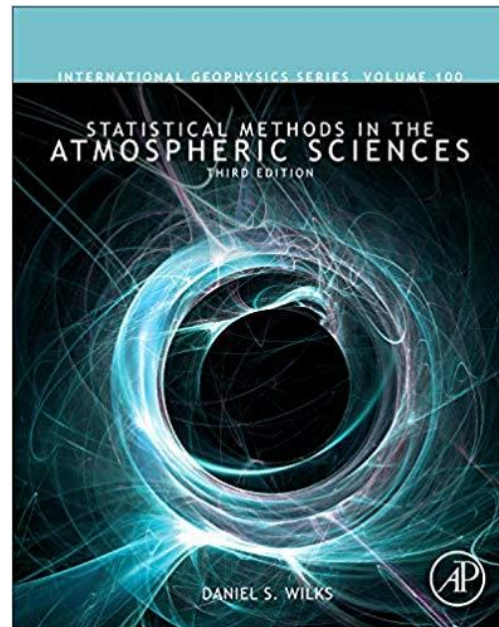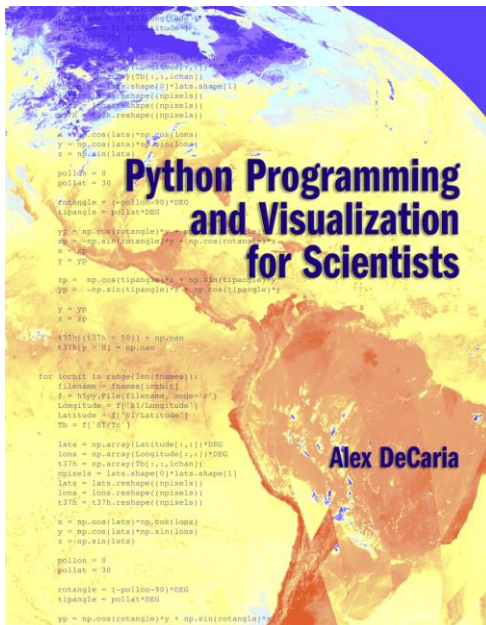# ATMOSPHERIC SCIENCES 5040/6040- Environmental Statistics

- Instructors: John Horel, TA Aaron Meyer

- Required text for everyone: Python Programming … A. deCaria

- Recommended text for graduate students: Statistical *Methods in the Atmospheric Sciences*

I'm taking this course because:

I don't want to but it is required.		0 %	✓
I'm required to take it and I suspect it might be useful in my future career.	9 respondents	64 %	
I expect it to be very useful for my future career.	7 respondents	50 %	
I have no clue why I am here.		0 %	

How confident are you with your level of understanding of basic Python commands?

I really know nothing about Python	1 respondents	7 %	
I took a CS course but don't remember a thing		0 %	
I might not know them well, but I know how to use the web to get more info on python	1 respondents	7 %	
I use python all the time and feel very comfortable with it		0 %	
I took ATMOS 5020, but still don't feel very confident about using python	6 respondents	43 %	
I took ATMOS 5020 and now feel confident using python	6 respondents	43 %	

How comfortable are you working with computers to solve problems?

It scares me a lot to even try		0 %	✓
I think I'll be ok if I understand what is being asked	10 respondents	71 %	
I just want to get the assignment over with and will look for the fastest way to do so.	2 respondents	14 %	
I enjoy the challenge of working through and solving tough problems	5 respondents	36 %	

What level of statistics have you been exposed to?

What's statistics?	3 respondents	**21**$^{\%}$	✓
I like to compute on base percentages before going to bed		0$^{\%}$	
I had a statistics class in high school	7 respondents	**50**$^{\%}$	✓
I have taken one or more statistics classes in college	4 respondents	29$^{\%}$	

My perception of statistics is:

something really boring, really really boring	1 respondents	7 %	✓
likely boring but so are most of the other classes I have to take	1 respondents	7 %	
going to be somewhat useful for my career	9 respondents	64 %	
going to be very useful for my career	5 respondents	36 %	

What level of exposure have you had to analyze environmental data?

Never, only canned text book stuff		0 %	✓
Some in a really cool class-ATMOS 5020	13 respondents	93 %	
Frequently as an undergrad	2 respondents	14 %	
Frequently as a grad student	1 respondents	7 %	

My perception of analyzing environmental data is

really really boring		0 %	✓
something I might have to do but I won't like it	1 respondents	7 %	
I expect I better learn how to do it	8 respondents	57 %	
I really want to learn so I can get a good job in my field	10 respondents	71 %	
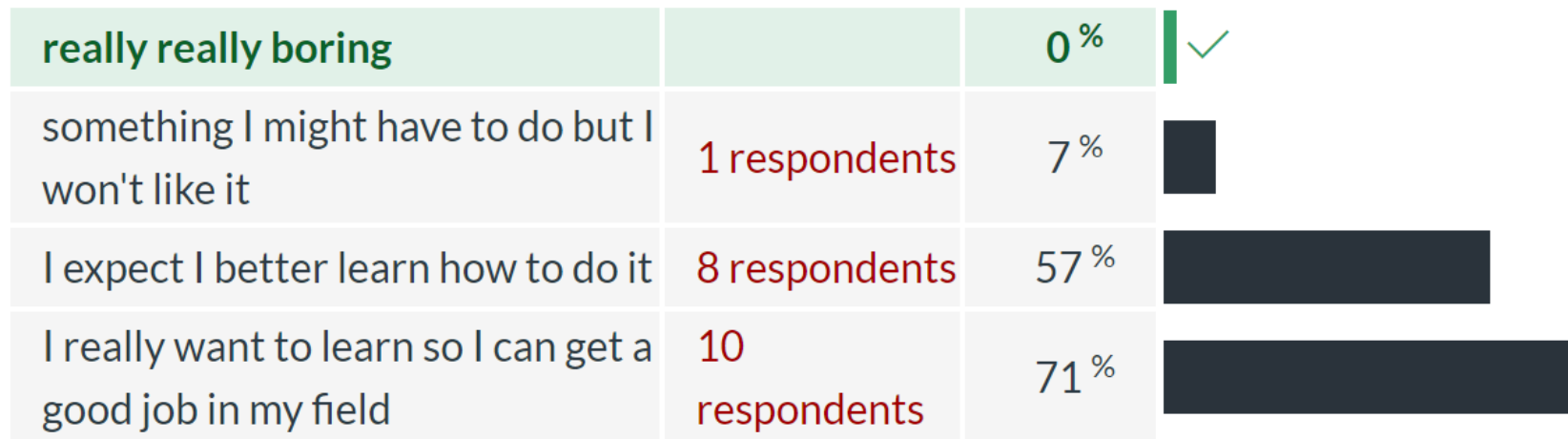
How do you perceive the use of statistics in society? For example, how much attention do you pay regarding statistical studies on health and diet?

Ignore all that stuff		0 %	✓
Read headlines but don't do much more than that	7 respondents	50 %	
Worry about it but don't change my behavior	4 respondents	29 %	
I take it very seriously and adjust my behavior	4 respondents	29 %	

How do you perceive the use of statistics in relation to the climate change "debate"?

what debate?	4 respondents	29 %	✓
there are two sides and everyone can make up their own mind	4 respondents	29 %	
statistics really doesn't play much of a role as far as I can tell- it's all about climate models	3 respondents	21 %	
people on both sides of the debate really abuse statistics	5 respondents	36 %	

Everyone is entitled to his own opinion, but not his own facts.

Daniel Patrick Moynihan

BrainyQuote

Is consensus irrelevant?

[T]he work of science has nothing whatever to do with consensus. Consensus is the business of politics. Science, on the contrary, requires only one investigator who happens to be right, which means that he or she has results that are verifiable by reference to the real world. In science consensus is irrelevant. What is relevant is reproducible results.

—Michael Crichton, from "Aliens Cause Global Warming," a lecture given at California Institute of Technology, Pasadena, California, January 17, 2003

What do you want to get out of this course?

A good grade	10 respondents	71 %	✓
some understanding of statistical tools	12 respondents	86 %	
how to analyze environmental data	13 respondents	93 %	
determine statistically a cure for cancer	2 respondents	14 %	
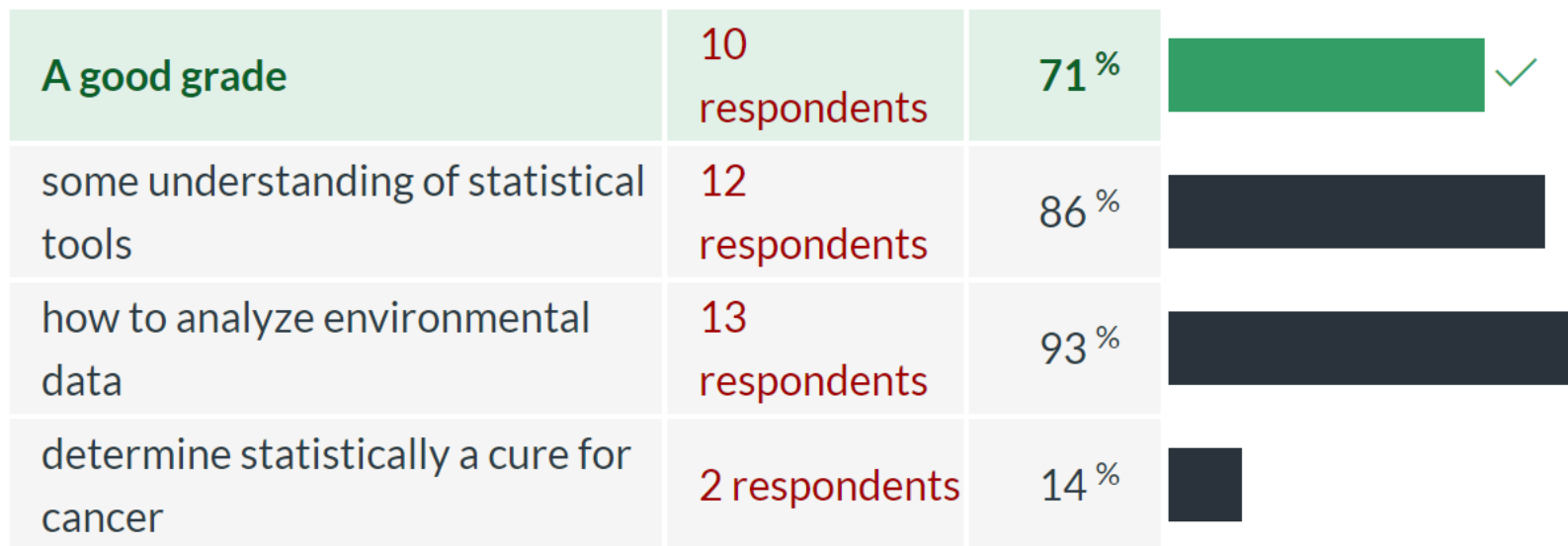
Drought Index from Tree Rings
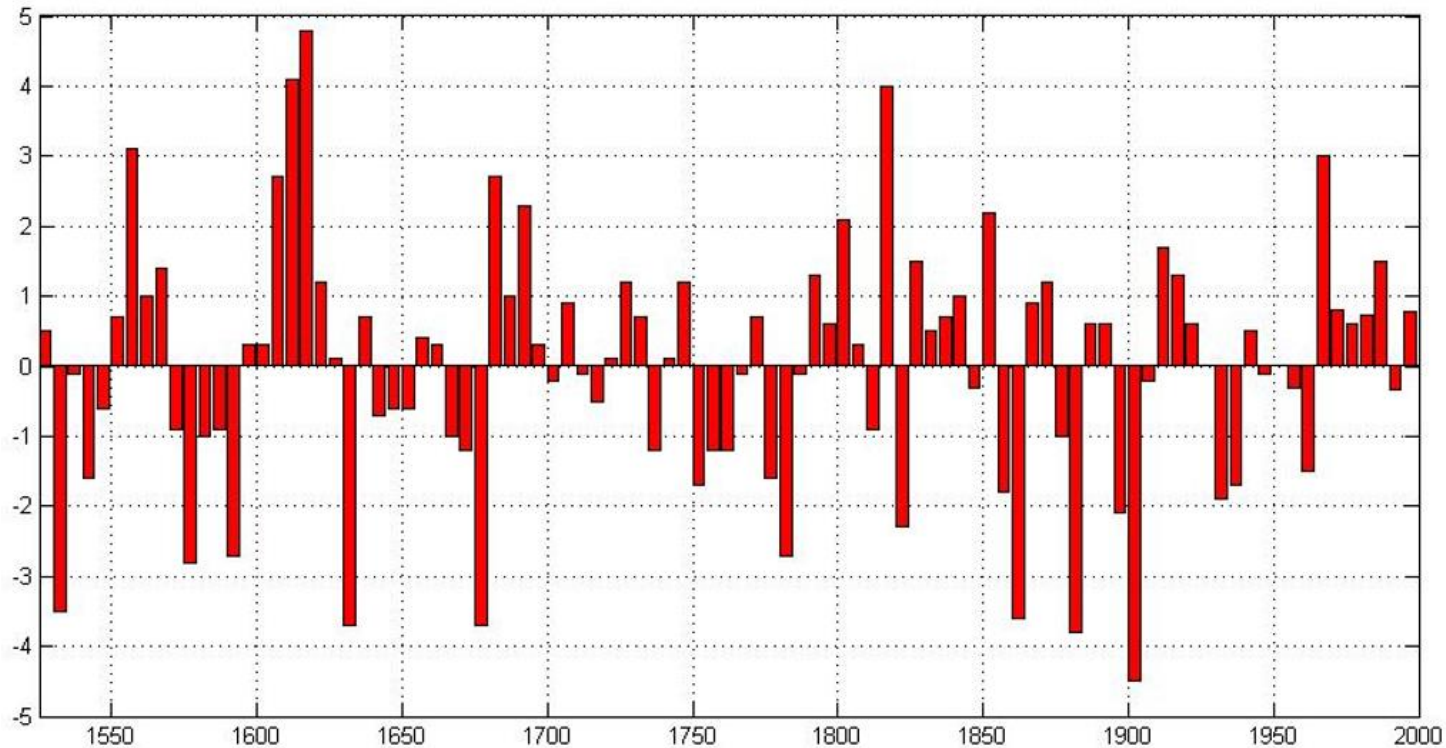
Figure 1.1. Utah drought index derived from an isotopic analysis of tree ring data near Alton Utah

Steps for Effective Research

- distill a general interest in a subject into a specific question/hypothesis that can be evaluated

- organize the data

- find relationship(s) among the data

- examine the significance of your results

- review thoroughly what you have done and document your analysis and results

- submit your results and study for independent evaluation

Causes of Uncertainty

- 1. we can never measure the environment with complete accuracy and precision

- 2. the environment is a chaotic system, which is a maddening combination of randomness and order arising from the characteristics of a complex nonlinear system,

- 3. our understanding of the environmental system is imperfect, so physical (and certainly statistical) models do not capture the complete behavior of the system.

Gauging Uncertainty

- Accuracy- difference in response between a standard and instrument in varying environmental conditions a measure of how close a measurement is to the "true" value

- Precision- how well repeated measurements of some quantity agree with each other. A precise instrument can be inaccurate
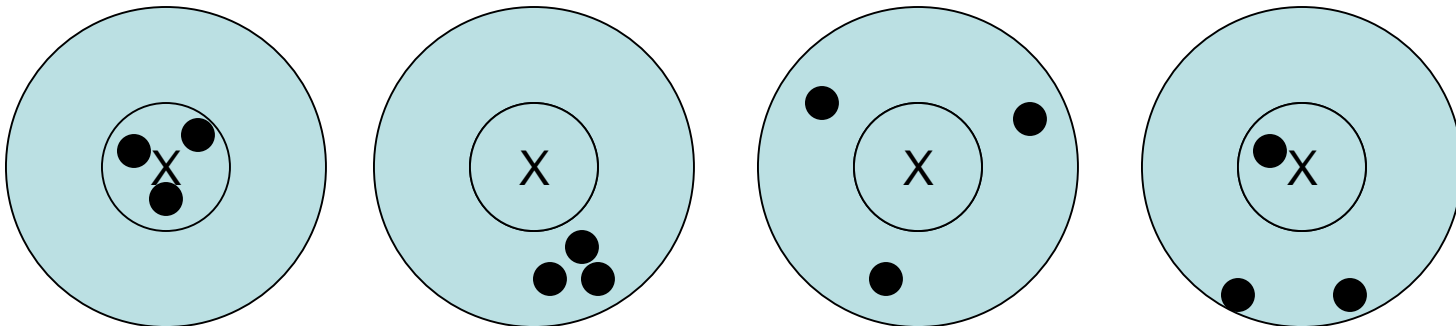
Systematic vs. Random Errors

- Random- that which is not precisely predictable or determinable
- Systematic- errors arising from a consistent response of a measuring device to environmental conditions or faulty characteristics of instrumentation that occurs frequently

Truth vs. single and large sample of observations
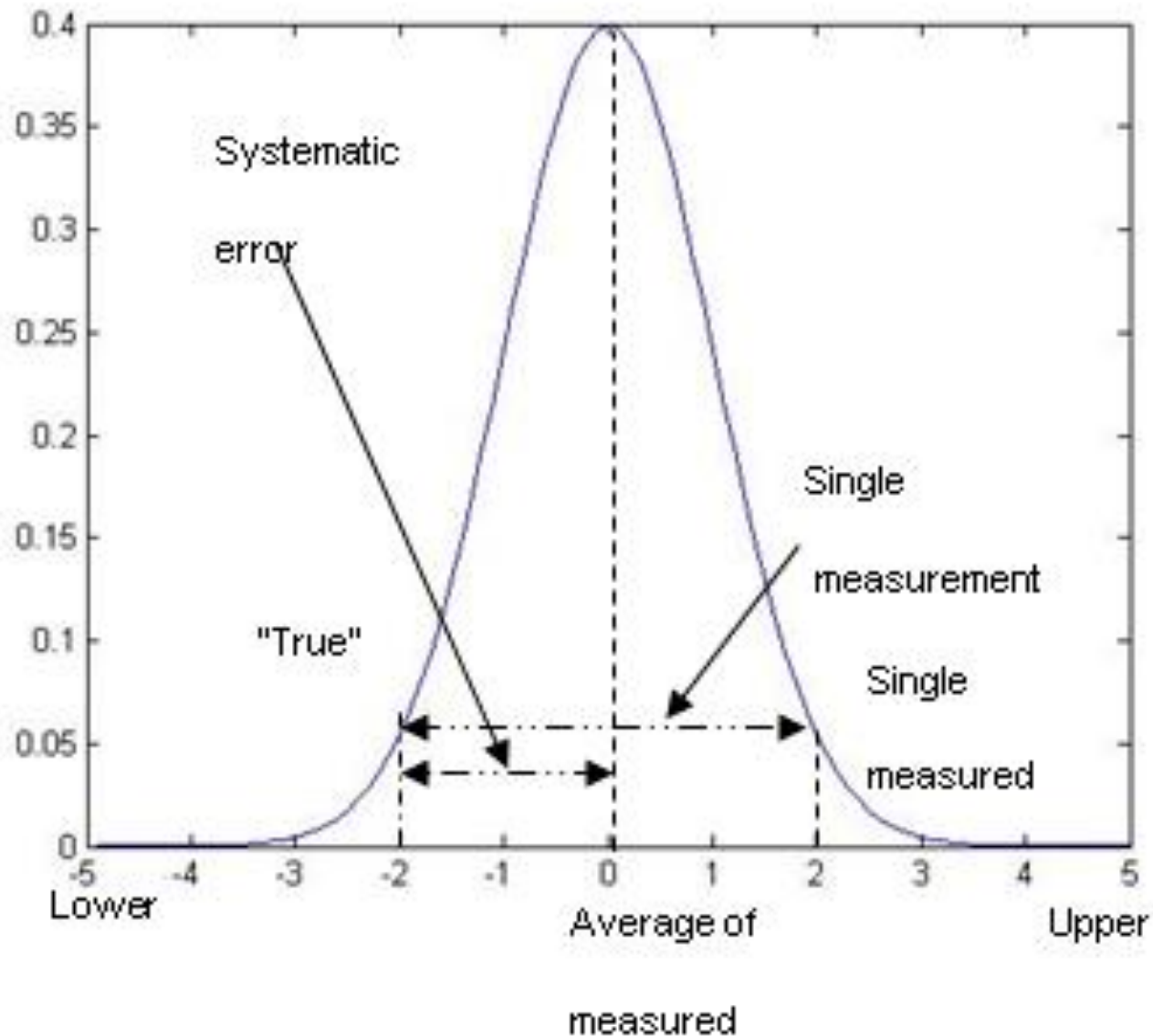
Population vs. Sample

- we never know the entire population of true values as the environmental conditions change in time or space.
- We hope that we choose a sample of observations for analysis such that each element in the population has an equal chance to be selected.
- Sampling issues
  - Trends
  - serial dependence of environmental data
  - model sample tend to be less variable than observed samples

Selecting a Sample

- Selecting the sample for analysis is a critical aspect of organizing the data and depends on the question to be addressed by the study
- rule of thumb: sample should be large enough to capture the phenomenon of interest many times
- "Degrees of freedom": number of independent elements in the sample;
  - usually much smaller than the total number of members in the sample in environmental data sets
- Keeping your powder dry- saving data for an independent sample to evaluate and confirm your results.
- Tendency to assume sample is drawn randomly from the population, when sample grossly underestimates the variability inherent in the population

Selfies

"It's not surprising that men who post a lot of selfies and spend more time editing them are more narcissistic, but this is the first time it has actually been confirmed in a study,"

Study Links Selfies To Narcissism And Psychopathy

The sample included 800 men from age 18 to 40 who completed an online survey asking about their photo posting behavior on social media. The participants also completed standard questionnaires for anti-social behaviors and for self-objectification. (This study doesn't include women because the dataset, which Fox received from a magazine, did not have comparable data for women.):

Facebook updates may stave off loneliness, even if no one 'likes' you, study finds

- Compared with other students, those who had been urged to go on a status-writing blitz felt less lonely
- happiness and depression levels unchanged, "suggesting that the effect is specific to experienced loneliness," Simply thinking about their friends can have a "social snacking" effect.
- "Similar to snack temporarily reducing hunger until next meal, social snacking may help tolerate lack of 'real' social interaction for a certain amount of time"

- Scientists have found clues to what compels people to constantly update their Facebook status. College students who posted more status updates than they normally did felt less lonely over course of a week, even if no one "liked" or commented on their posts
- researchers at Free University Berlin recruited 100 undergraduates at University of Arizona; paper published last month in Social Psychological and Personality Science.
- Participants filled out surveys to measure their levels of loneliness, happiness and depression, and gave researchers access to their Facebook
- students were sent an analysis of their average weekly status updates; some were told to post more updates than usual over next seven days. During that week, all completed a short online questionnaire at the end of each day about their mood and level of social connection.

Observations

- Observations are not perfect…
  - Gross errors
  - Local siting errors
  - Instrument errors
  - Representativeness errors

Representative errors to be expected in mountains
## Alta Ski Area
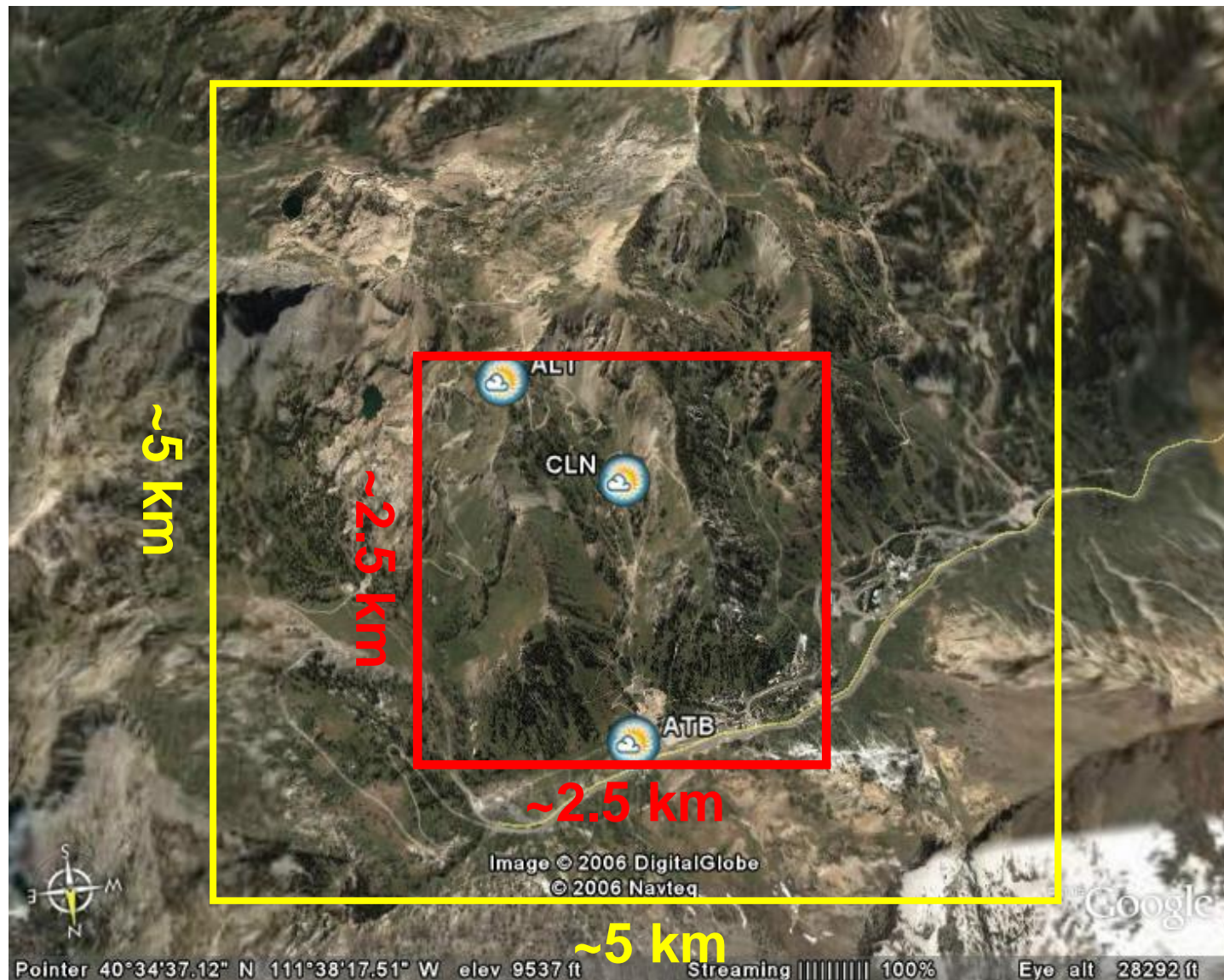
# Common Goal is to Synthesize and Reduce Dimensionality

- Statistical analysis of environmental data typically involves reducing the dimensionality of the data to a manageable size.

- Which variable(s) do we need to consider?

- Can we consider one variable (univariate analysis) or must we consider multiple variables (multivariate analysis)?

- What time scales are we interested in? Hours, days, months, years? And, what region (local, regional, globally) or level in the vertical (surface, subsurface, upper air)?

- Are the data available on a spatial grid or at specific points?

Large Dimensionality of Geophysical Data Sets
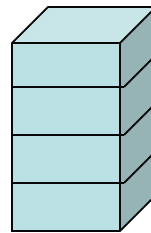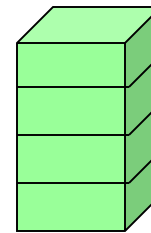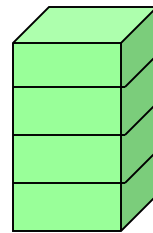
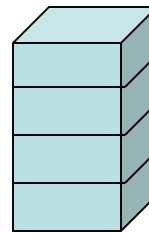- Space: x, y, z

z
y
x
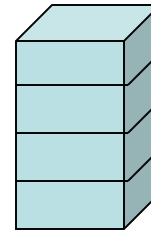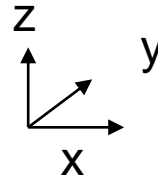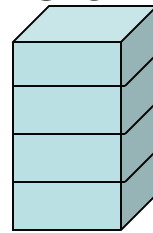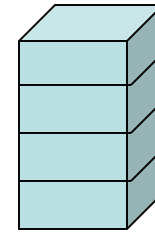
t $t+1$

- Time: time (t) and forecast time (t_f)

- Parameter & Source (temperature, winds, different models, measuring systems, perturbations)

t $t+1$
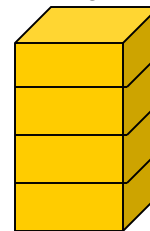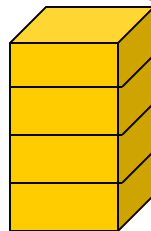
Why use statistics to describe the environment?

- Environment controlled by innumerable factors, which we hope to segregate into a few critical factors from the rest that, for the most part, simply contribute to background noise

- the characteristics of the system include linearly unstable processes such as baroclinic waves that cause growth of small features into larger ones

- the characteristics of the system (dynamics, thermodynamics) are nonlinear and include discrete step functions (i.e., rain/no rain) that can lead to the amplification of small errors into large ones

- the system is dissipative, which guarantees "stationarity", i.e., the climate system will remain stable and not run away from the current state

Baroclininc Wave Growth

- Physical processes in atmosphere can be unstable at times but environmental system overall is "stationary"
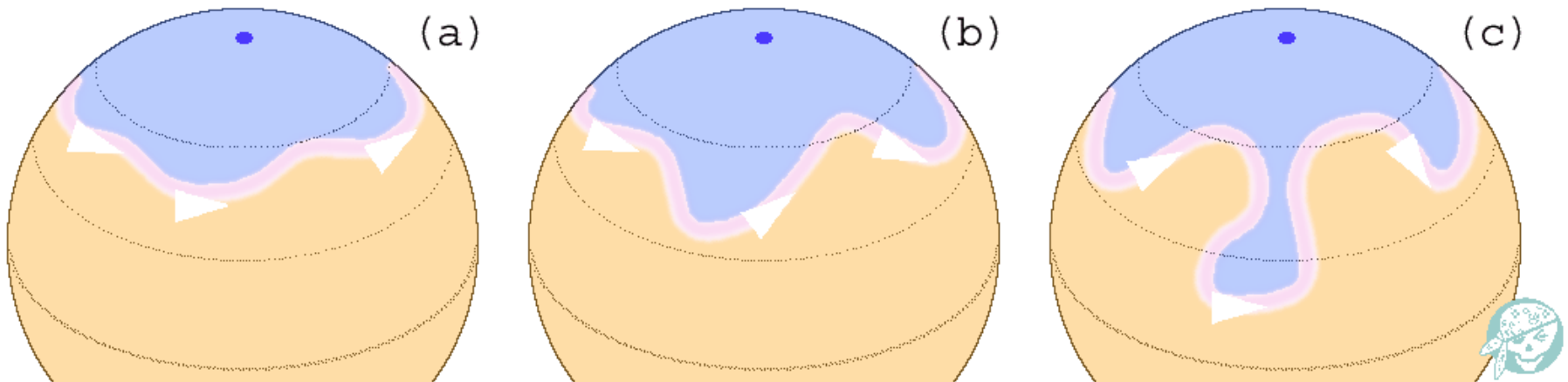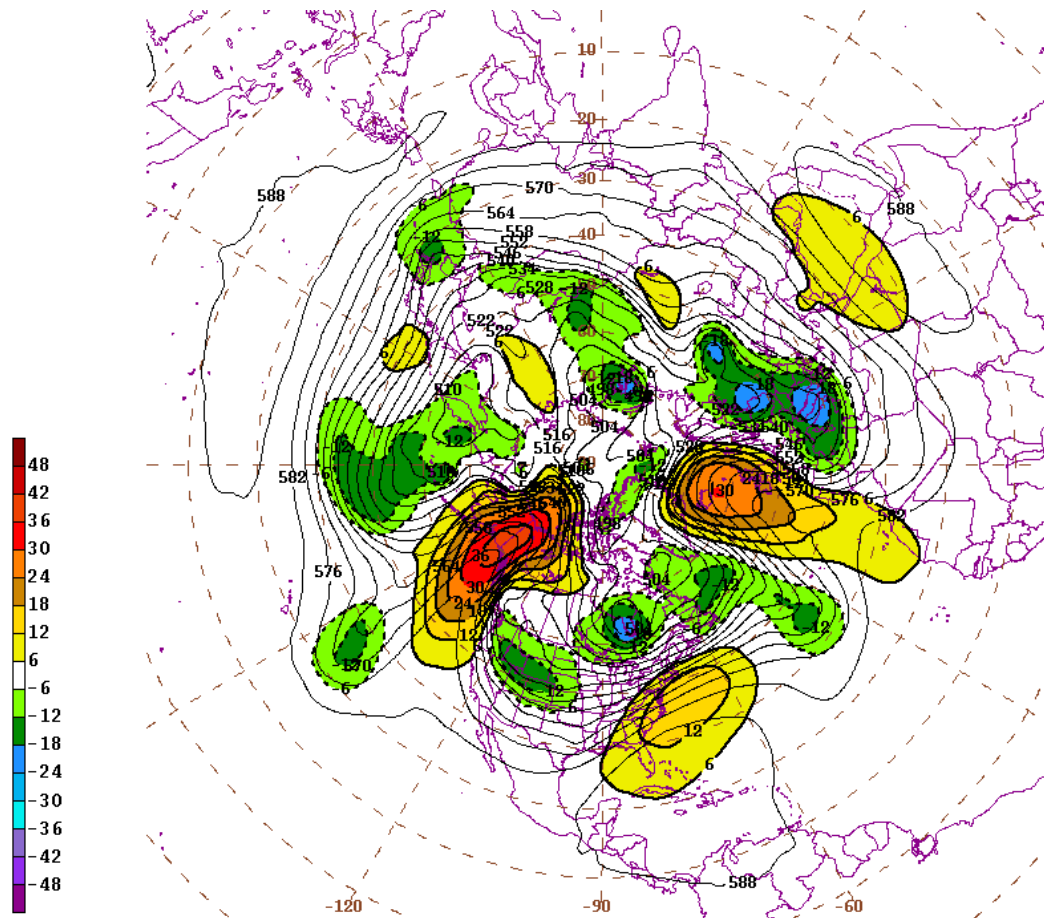
141229/0000F000 500 hPa Height and Height Anomaly (dam), from GFS

Degrees of Freedom

- A sample should be large enough to capture the phenomenon of interest many times.

- "Degrees of freedom" refers to the number of independent elements in the sample

- the number of degrees of freedom is usually much smaller than the total number of members in the sample in environmental data sets

Atmospheric CO_2 at Mauna Loa Observatory

https://www.esrl.noaa.gov/gmd/ccgg/trends/full.html
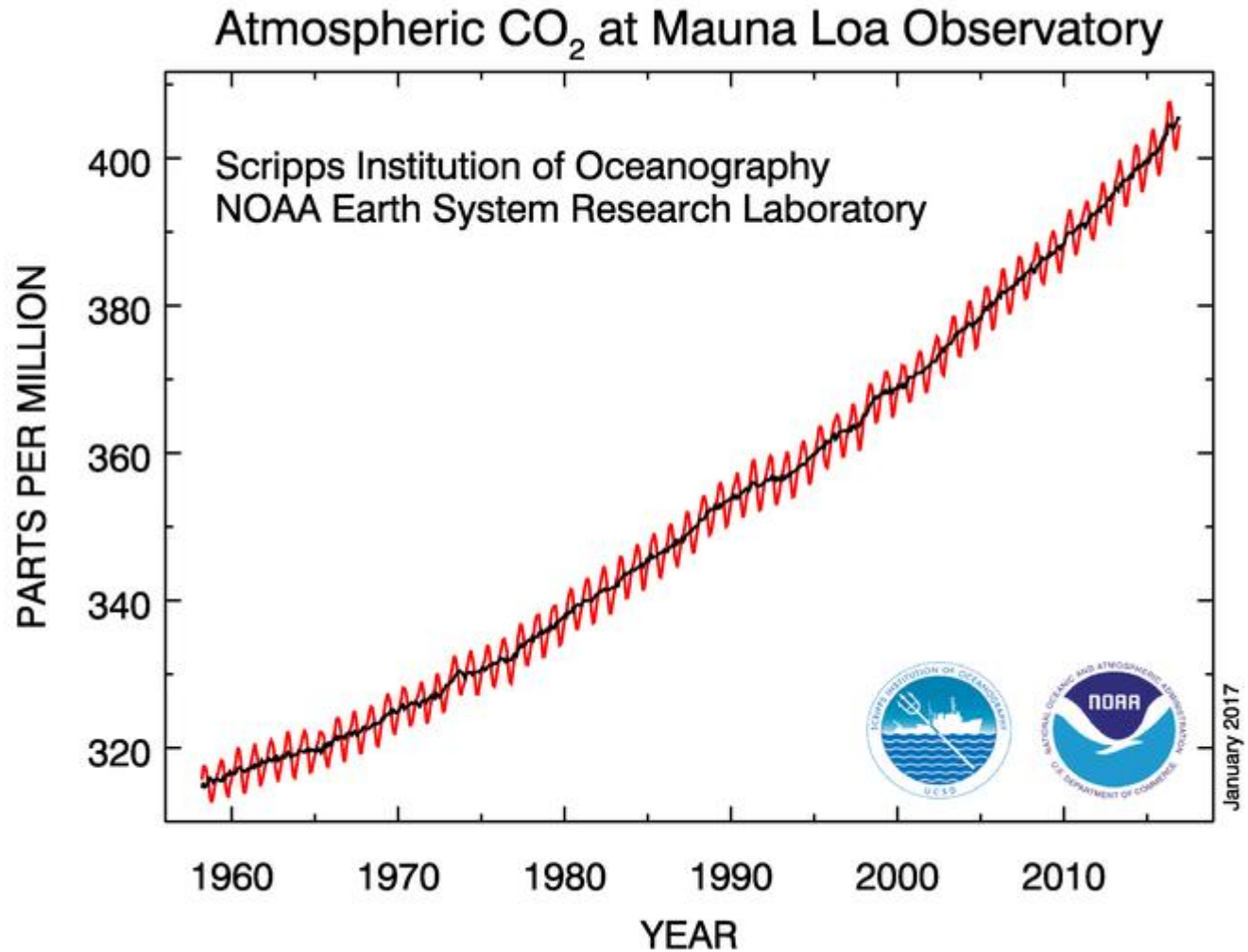
One year of CO_2 daily and weekly means at Mauna Loa
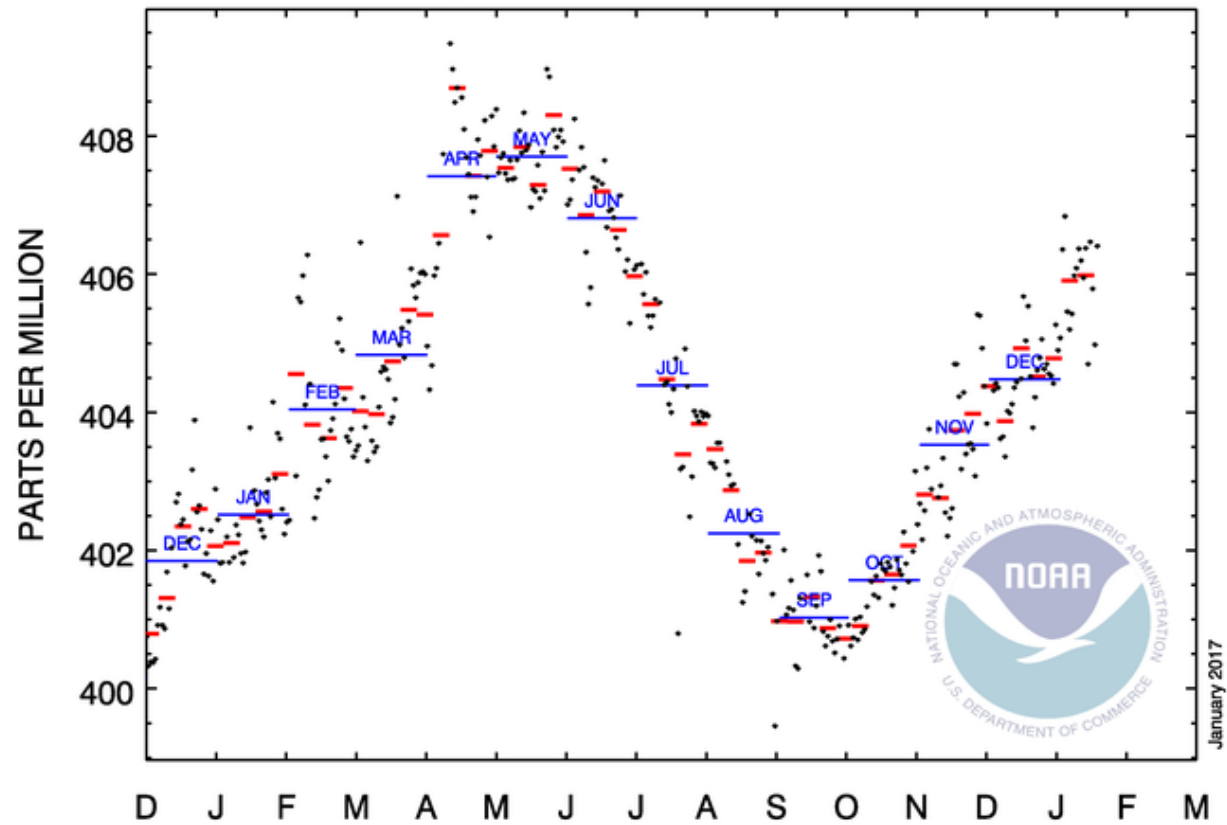
Global Land and Ocean

January–December Temperature Anomalies
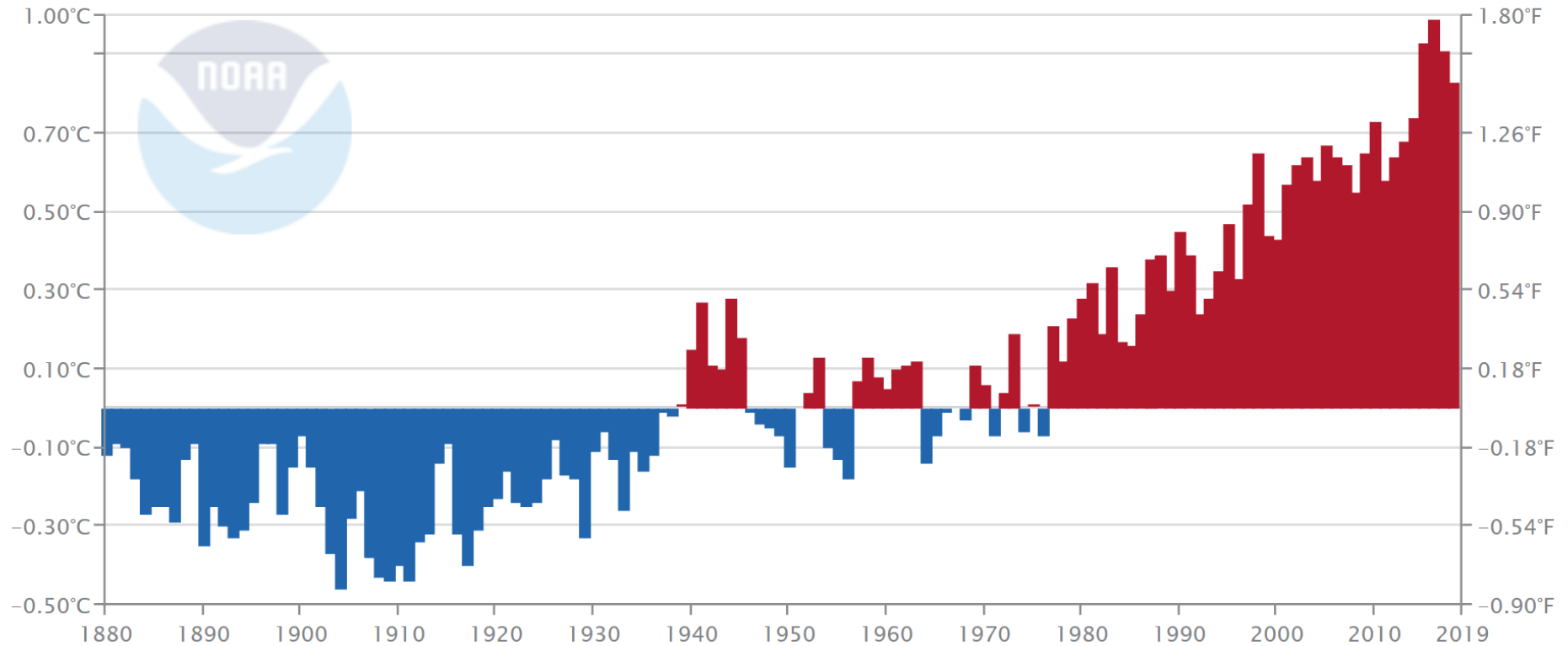
https://www.ncdc.noaa.gov/cag/global/time-series/globe/land_ocean/ytd/12/1880-2019

Global Land and Ocean
January–December Temperature Anomalies
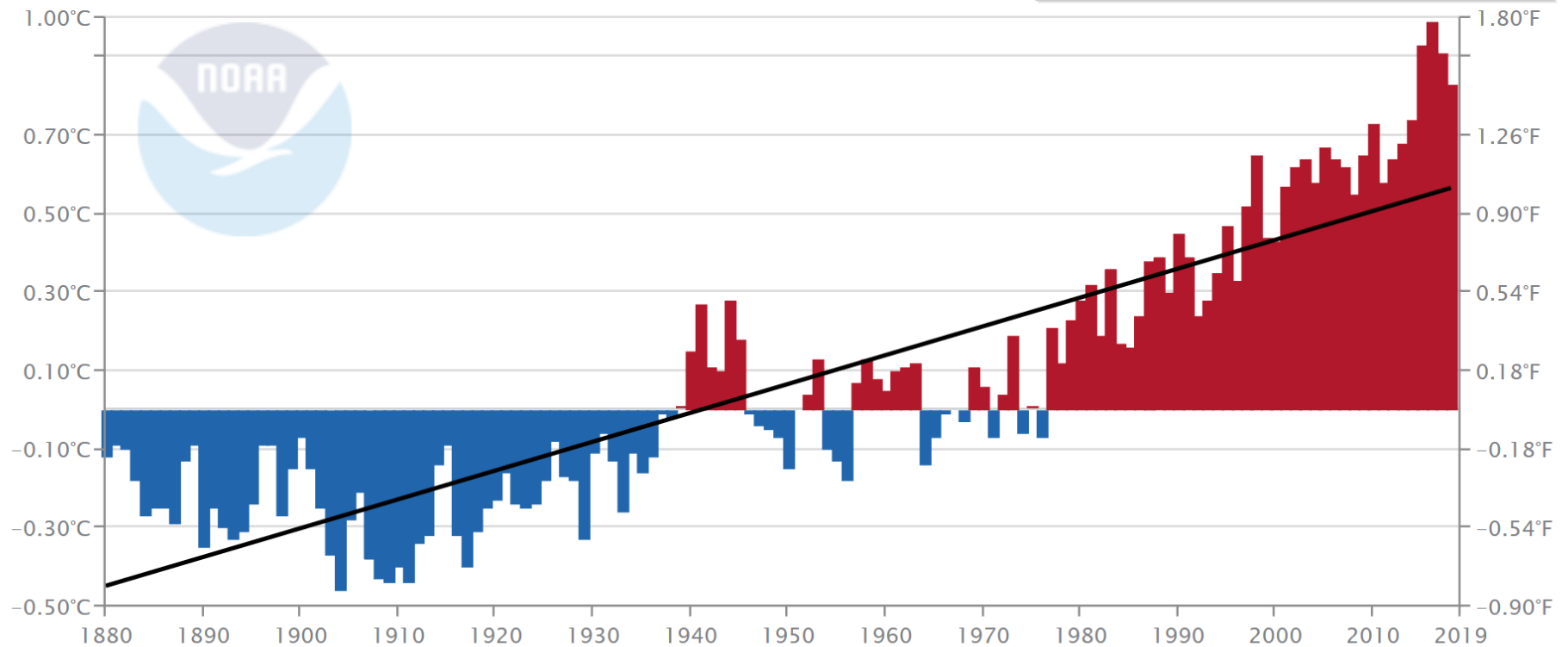
Causality vs. Simultaneity?
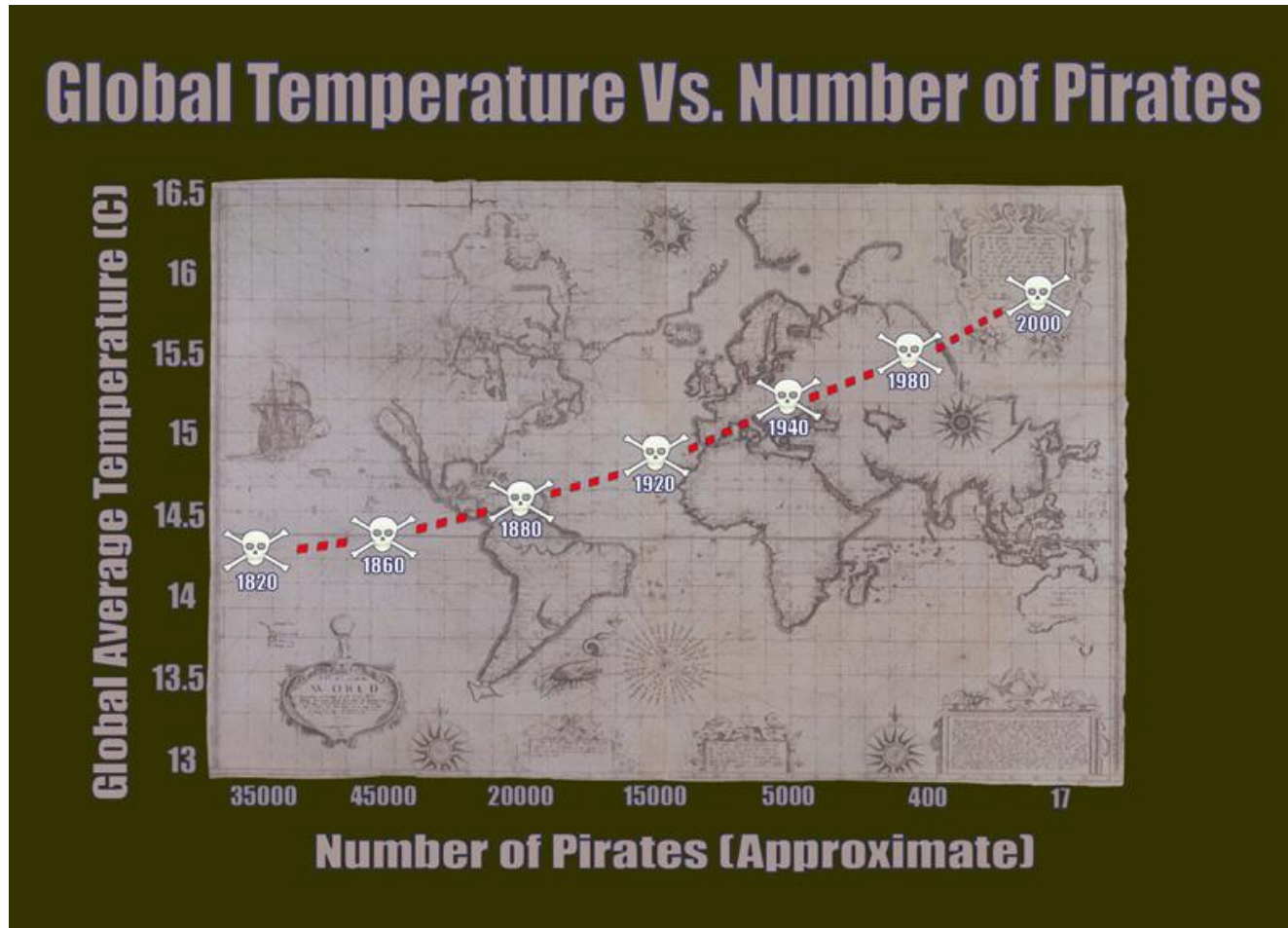
Reproducibility

- The extent to which measurements or observations agree when performed by different individuals defines this important tenet of the scientific method.

CrossMark
click for updates

Editorials

Irreproducible Experimental Results

Causes, (Mis)interpretations, and Consequences

Joseph Loscalzo, MD, PhD

+ Author Affiliations

[Reproducible-Science-Curriculum](#)

Irreproducible Examples

tnabtaf edited this page on Dec 11, 2014 · 18 revisions

Notes on examples of irreproducible research that has caused significant issues. Some of these will become case studies during the course. Initially, these are all from RetractionWatch.

Papers

- Editorial Expression of Concern: Non-adaptive origins of interactome complexity
- Retraction Watch Univ.: No misconduct, but "poor research practice" in mgt prof's work now subject to 7 retractions
  - "The investigation was severely hindered by the near total unavailability of raw data files and statistical output files for the seven papers under study."
- Retraction Watch Data questions prompt retraction of PLOS ONE cardiovascular paper
  - The authors have indicated that the raw data for Figures 3, 5 and 6 are not

Reproducibility vs. Replicability

- Replicability is assessed by performing an experiment under exactly the same conditions at different times
- reproducibility is assessed by performing similar, but not identical, experiments at different times, in different locations, and under somewhat different experimental conditions.
- replicability reflects the technical stringency or precision of a specific experiment
- reproducibility reflects the fundamental accuracy of an experimental observation
- a precisely conducted experiment can be inaccurate, and an accurate experiment may be performed imprecisely— especially in biomedicine where many factors can account for irreproducible results

Statistics and Irreproducibility

- errors in design, data analysis, and data interpretation.
- Bias clearly plays an important role in promoting false-positive results.
- Reasons for bias:
  - lack of experimental balance leading to an impassioned belief in one particular experimental outcome clouding objectivity;
  - perceived pressure to publish for academic advancement or to enhance the likelihood of competing successfully for grant funding[7]; and the lack of appeal of negative (or neutral) studies in most high-impact journals.
- study illustrating the inverse relationship between the scientific hierarchy (physical sciences at the top, social sciences at the bottom, and biological sciences in between) and the publication frequency of "positive" results
- Random and systematic errors contribute as well

Impact of Rarity on Irreproducibility

Black swan (Taleb)

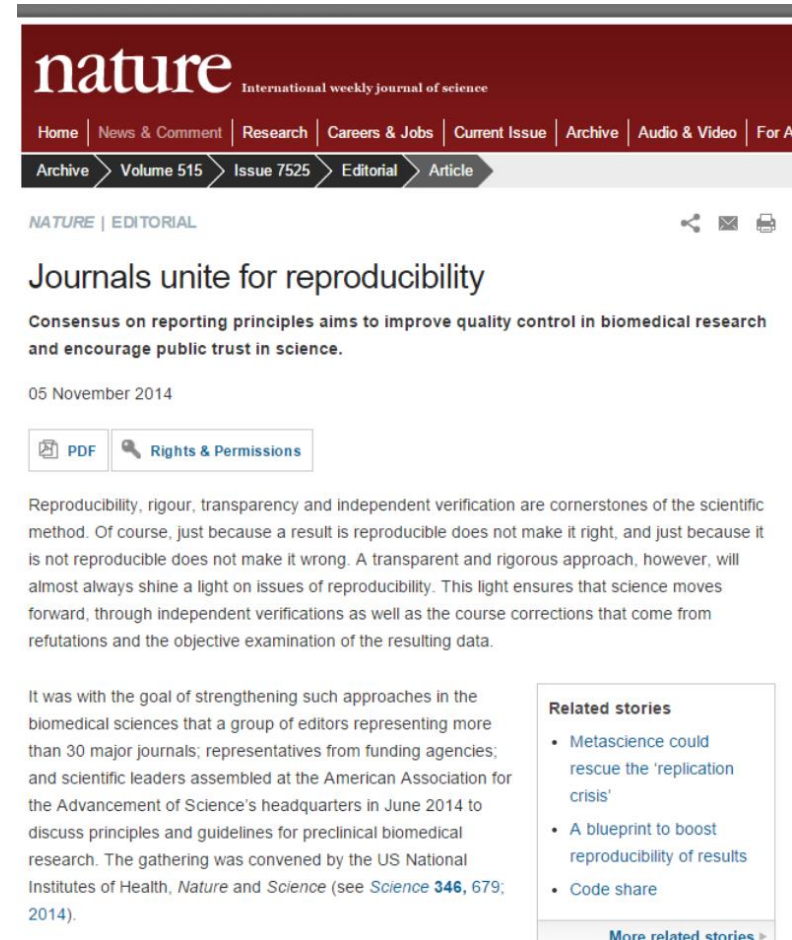- outcome is theoretically reproducible, but so rare that a sufficient number of experiments needed to determine its frequency exceeds feasibility

- Owing to its inherent rarity, it is effectively impossible to explain away an irreproducible result on the basis of a rare, singular event for which no supportive evidence can be marshaled

- Examples of irreproducible events in environmental fields?

What a mess we're in…

- Over the past decade, the number of journal articles worldwide doubled from 1.1 to 1.9 million.
- Of these, 0.5 million articles are published in the field of biomedicine, for an output of 1400 articles per day.
- Given this volume alone, is it any wonder that an increasing number of articles are being published that contain irreproducible results?
- Furthermore, with the growth in search technologies, a greater number of articles is being retracted over time: ~40/year in the late 1990s, ~300 in 2010, and ~400 in 2011.
- The reasons for these retractions include plagiarism, data manipulation (especially in figures), and proven data falsification;
- however, irreproducibility resulting from innocent causes may also be included in this pool of retracted publications without being recognized as such.
- With as many as 50% of all articles listed in PubMed never cited at all, one can conclude either that the work is of minimal significance and not worthy of further pursuit or that it has been pursued and could not be reproduced.
- The extent to which these two explanations account for this statistic has not been (nor cannot easily be) determined.

Taking Steps

- [Nature](#)
- Reproducibility, rigour, transparency and independent verification are cornerstones of the scientific method. Of course, just because a result is reproducible does not make it right, and just because it is not reproducible does not make it wrong.
- The guidelines recommend that journals include in their information for authors their policies for statistical analysis and how they review the statistical accuracy of work under consideration.

Journals unite for reproducibility

Consensus on reporting principles aims to improve quality control in biomedical research and encourage public trust in science.

05 November 2014

PDF | Rights & Permissions

Reproducibility, rigour, transparency and independent verification are cornerstones of the scientific method. Of course, just because a result is reproducible does not make it right, and just because it is not reproducible does not make it wrong. A transparent and rigorous approach, however, will almost always shine a light on issues of reproducibility. This light ensures that science moves forward, through independent verifications as well as the course corrections that come from refutations and the objective examination of the resulting data.

It was with the goal of strengthening such approaches in the biomedical sciences that a group of editors representing more than 30 major journals; representatives from funding agencies; and scientific leaders assembled at the American Association for the Advancement of Science's headquarters in June 2014 to discuss principles and guidelines for preclinical biomedical research. The gathering was convened by the US National Institutes of Health, *Nature* and *Science* (see *Science* **346,** 679; 2014).

Related stories
- Metascience could rescue the 'replication crisis'
- A blueprint to boost reproducibility of results
- Code share

More related stories ▶

The zen of programming

- Understand what you are expected to do
- Don't start from scratch- use example codes or search for examples
- Read text, look online for techniques and tricks
- There is never only one way to do something- build on what you are comfortable with but seek simpler ways

Debugging

- Programming is iterative
- Start from what works.
  - Get example code working first
- What did you change?
- Have you looked at the underlying data file?
- Have you looked at the workspace variables?
- Did you display some intermediate values?
- Don't assume that if your code runs that it is correct. Does the output make sense?
- Don't expect others to debug your code for you
  - Programming can be like solving a puzzle- it appears hard while you're doing it, but you get some great "ah ha" moments once you've figured it out for yourself
- Being able to work independently and solve problems is critical

- https://scipy-lectures.org/packages/statistics/index.html
- https://www.tutorialspoint.com/python_pandas/python_pandas_descriptive_statistics.htm
- https://www.tutorialspoint.com/python_pandas/python_pandas_statistical_functions.htm

Viewing Monthly Snowfall at Alta

- https://utahavalanchecenter.org/alta-monthly-snowfall

- https://github.com/johnhorel/atmos_5040_2019/blob/master/chapter%202/oct17_2019_inclass.ipynb

Alta water year snow total (cm) John Horel 1/13/2019
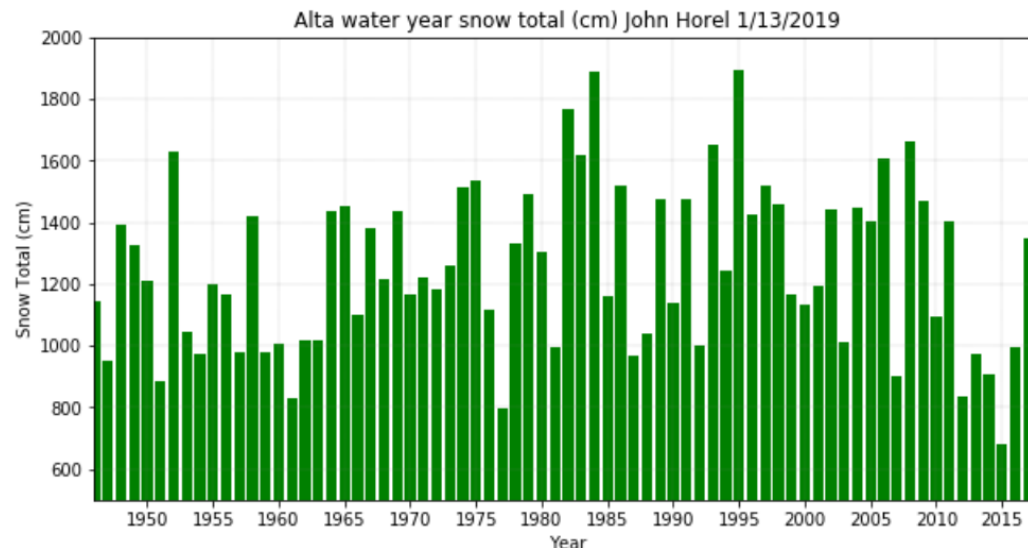
What you should be doing

- Assignment 1- Survey- Due Friday
- Read Chapter 1 & 2a-2b Notes
- Refamiliarize with using Mac lab and Python
- Today's in class assignment. Not due until next Tuesday. Send figure to Teams
- Assignment 2 due next week

Great Salt Lake
October 15, 2019

Great Salt Lake
Octrober 8, 2000

Great Salt Lake

- http://ut.water.usgs.gov/greatsaltlake/elevations/