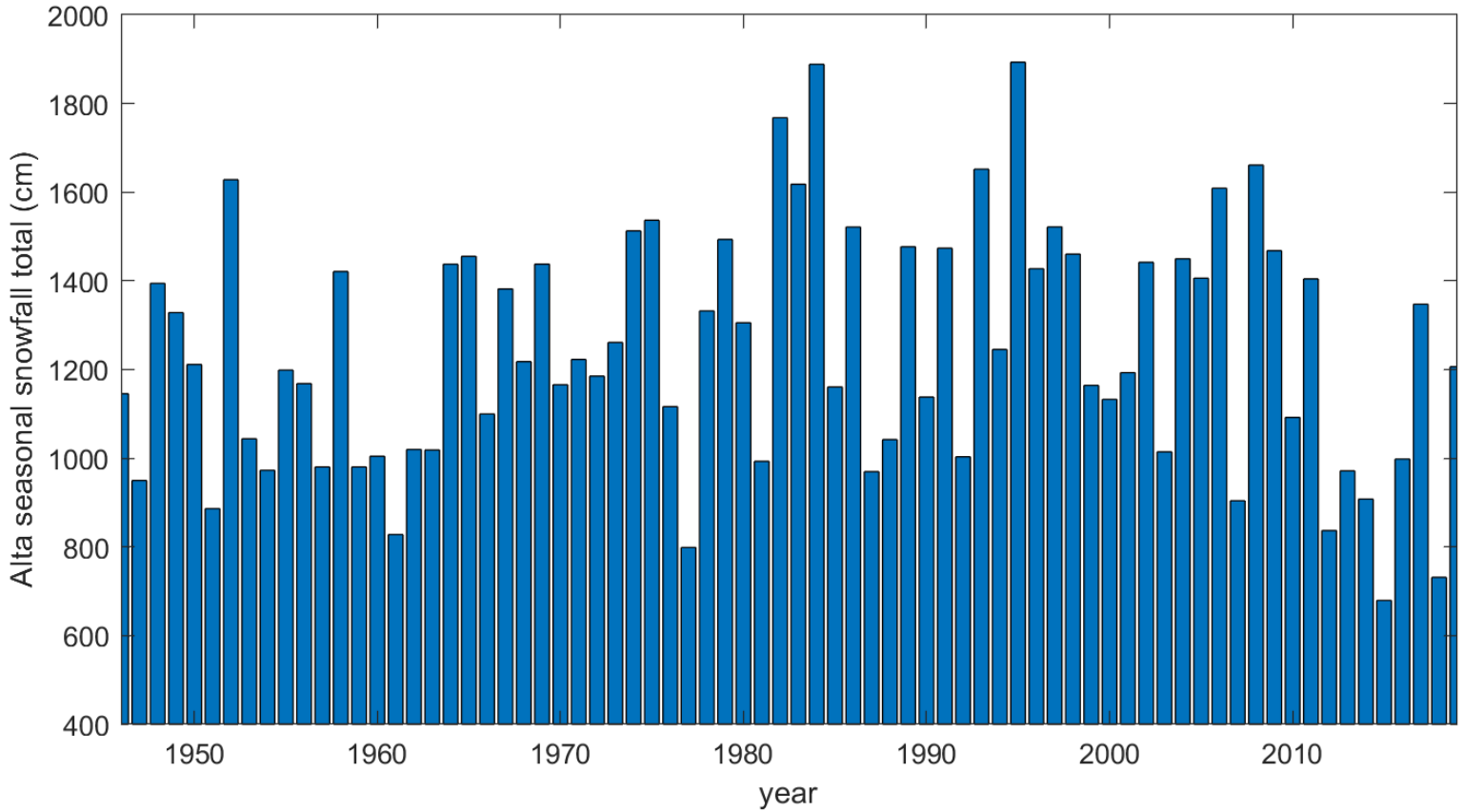
Alta Snowfall Seasonal Totals

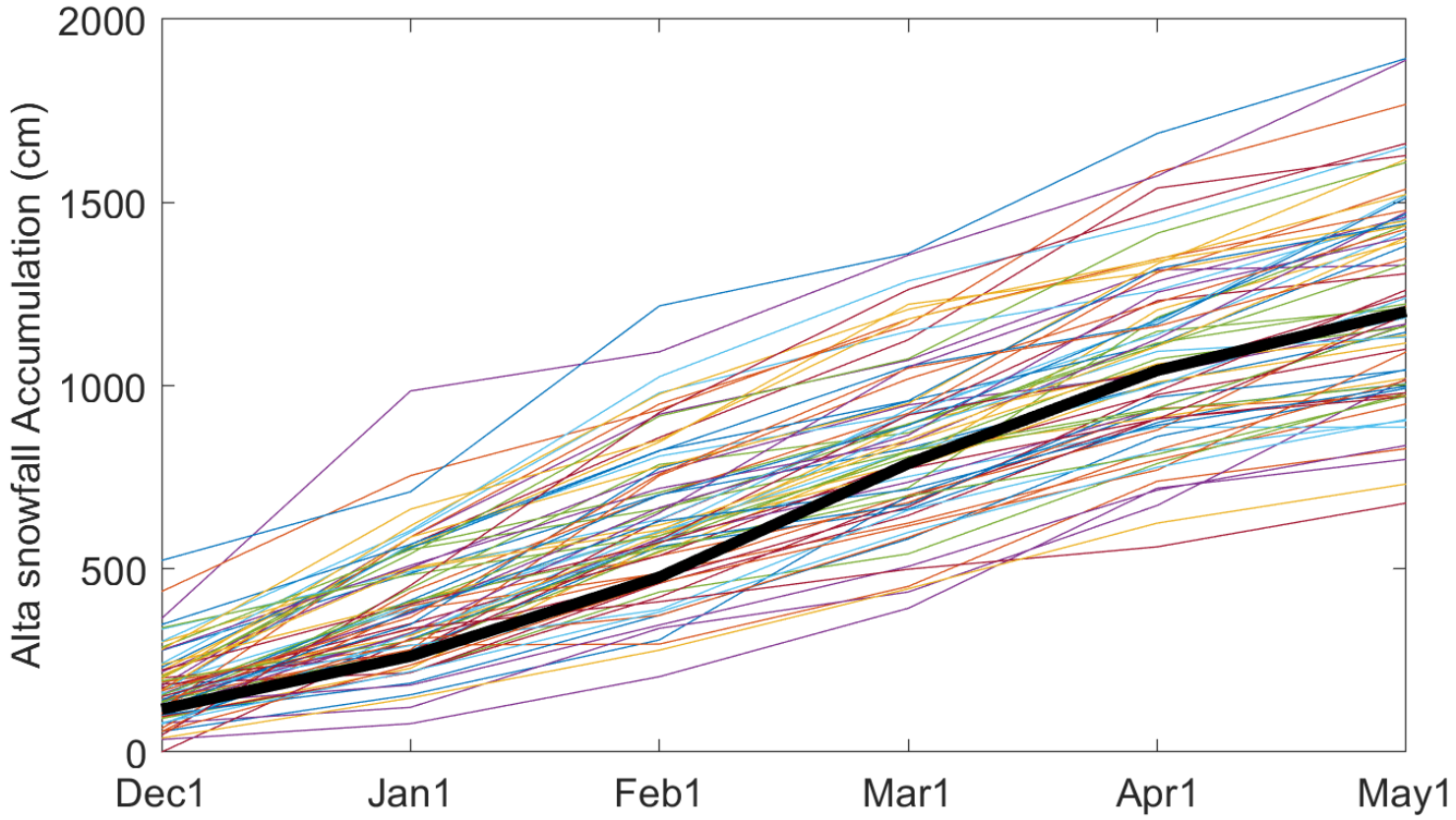


https://utahavalanchecenter.org/alta-monthly-snowfall

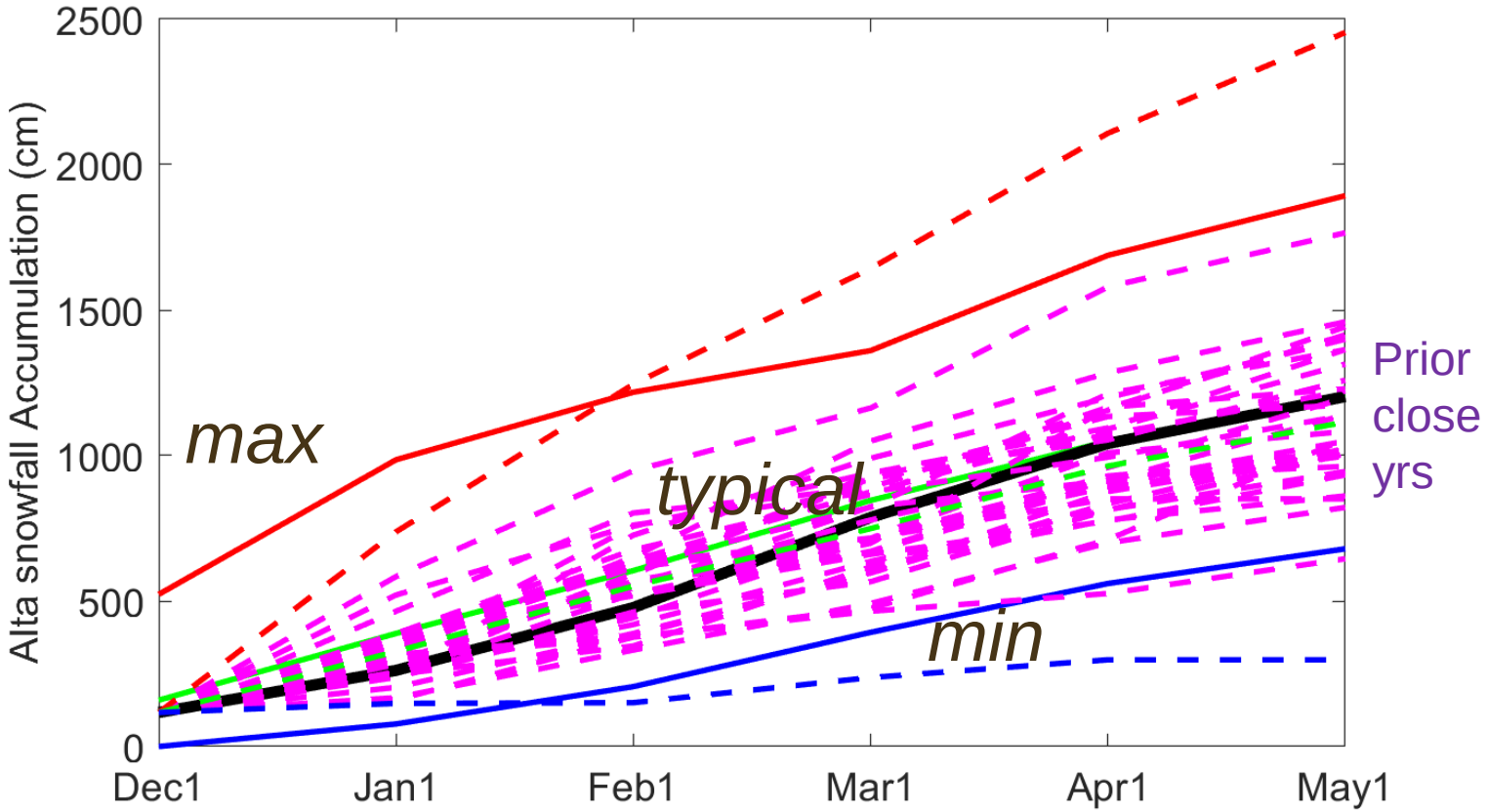
What can we say about estimating this winter’s snow total will be?

- What physically is happening?
- Could we use last winter’s snow total to predict this winter’s?
  - Persistence from one year to next
- What about the amount of snow right now?
  - Persistence from one month to the next…

Atla Snowfall Accumulation Each Winter



How Much Snow Might Accumulate During this Season (19-20)at Alta?



Predict May 1 Snowfall from Dec 1 Snowfall

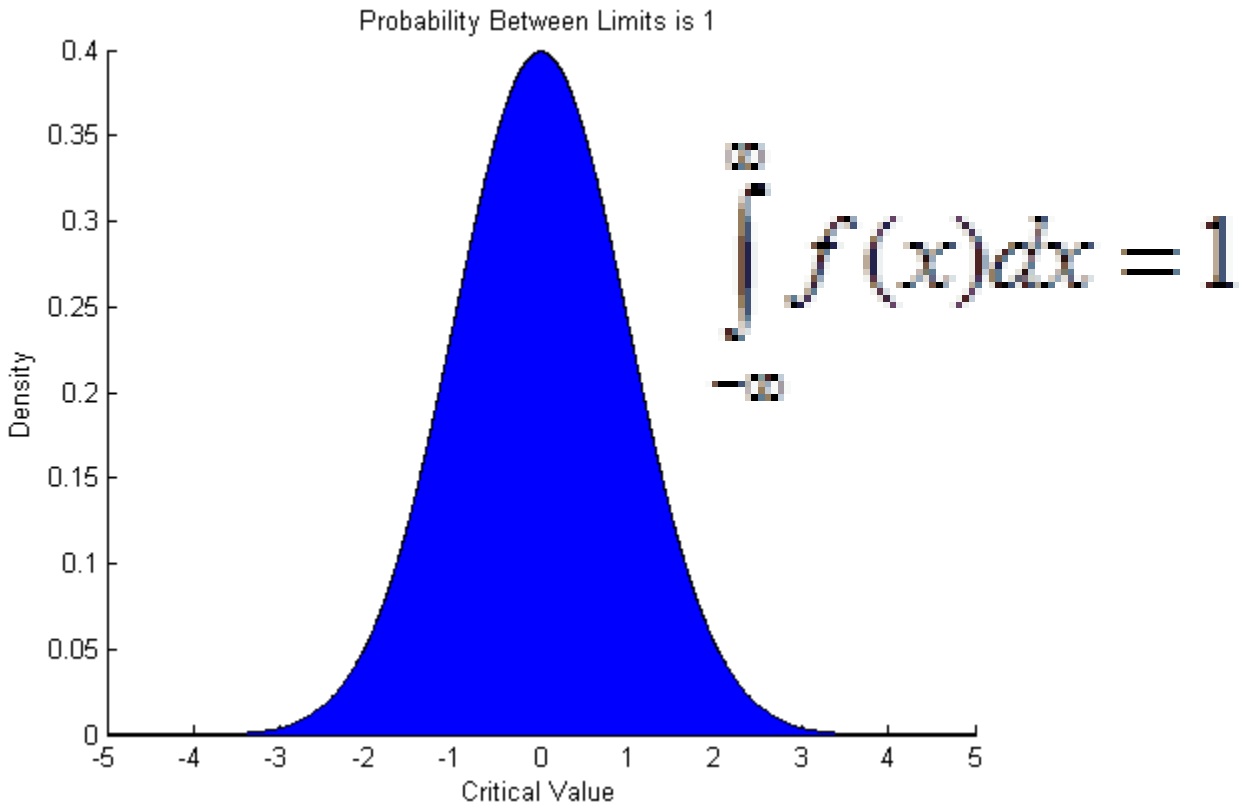
Below< 121 cm; Above> 193 cm

So far: ~35 cm

Case 1. Predictor: Dec1 total snowfall (cm)					
Predictand: May 1 Total snowfall at Alta (cm)		Below (E_1)	Near (E_2)	Above (E_3)	M Marginal Totals
	Below (M_1)	14	10	1	25
	Near (M_2)	7	7	10	24
	Above (M_3)	4	7	14	25
	E Marginal Totals	25	24	25	74

Empirical vs. Parametric Distributions

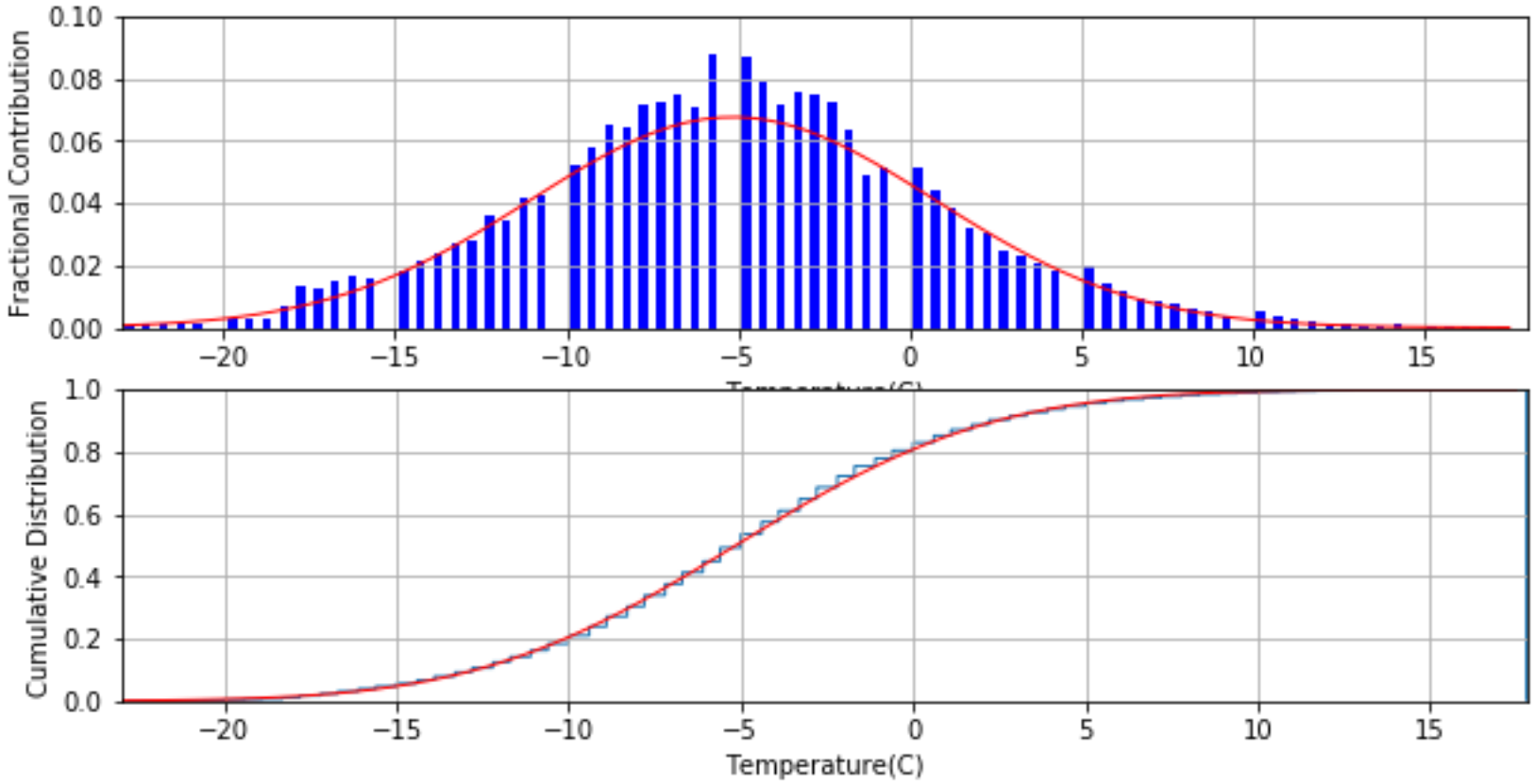
- Parameteric distributions:
  - Theoretical approach to define populations with known properties
  - Can be defined by a function with couple parameters and assumption that population composed of random events



Using parametric distributions

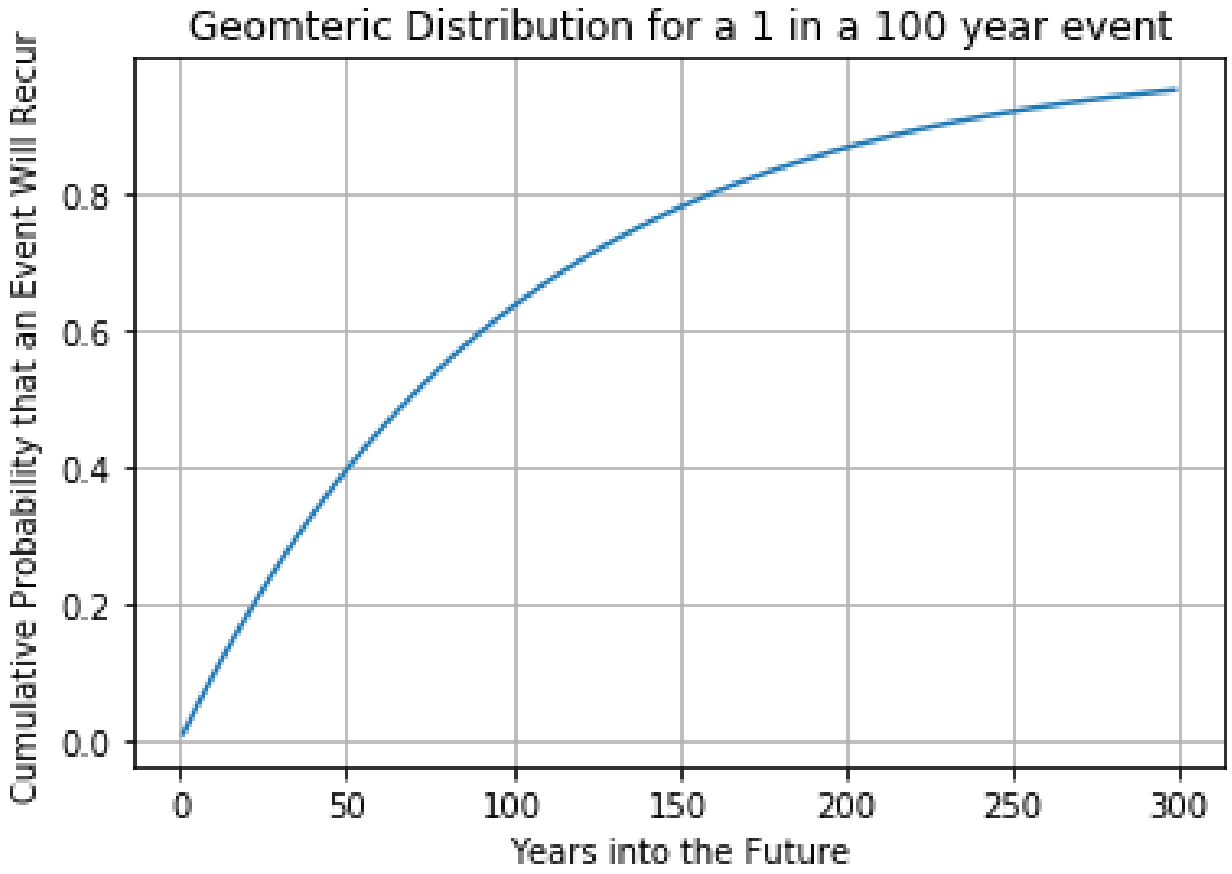
- Generate an empirical cumulative probability (CDF)
- See if there is a good match between the empirical CDF and a particular parametric distribution
- Use the parameters from that parametric distribution to estimate the probabilities of values above below a threshhold or extreme events

Alta Winter Temperatures with Gaussian fit using mean, σ



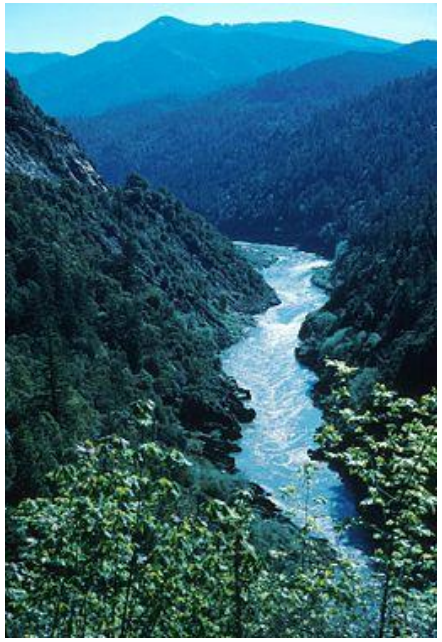
Geometric Distribution

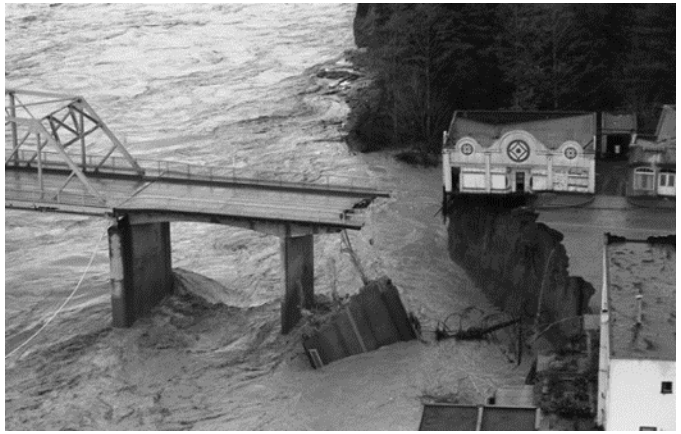
- Estimating how likely rare events can happen by chance
- Pr{0.01}- probability of a 1 in 100 year event
- probability for the next event to happen in 1, 10, 30, 100, 200, 300 years
- 63% chance in next 100 years
- 12% chance not until 200 years
- This is nothing “real”, just one of many assumptions you might choose



Klamath River, northern CA

http://water.weather.gov/ahps2/hydrograph.php?wfo=eka&gage=klmc1





Flood Categories (in feet)

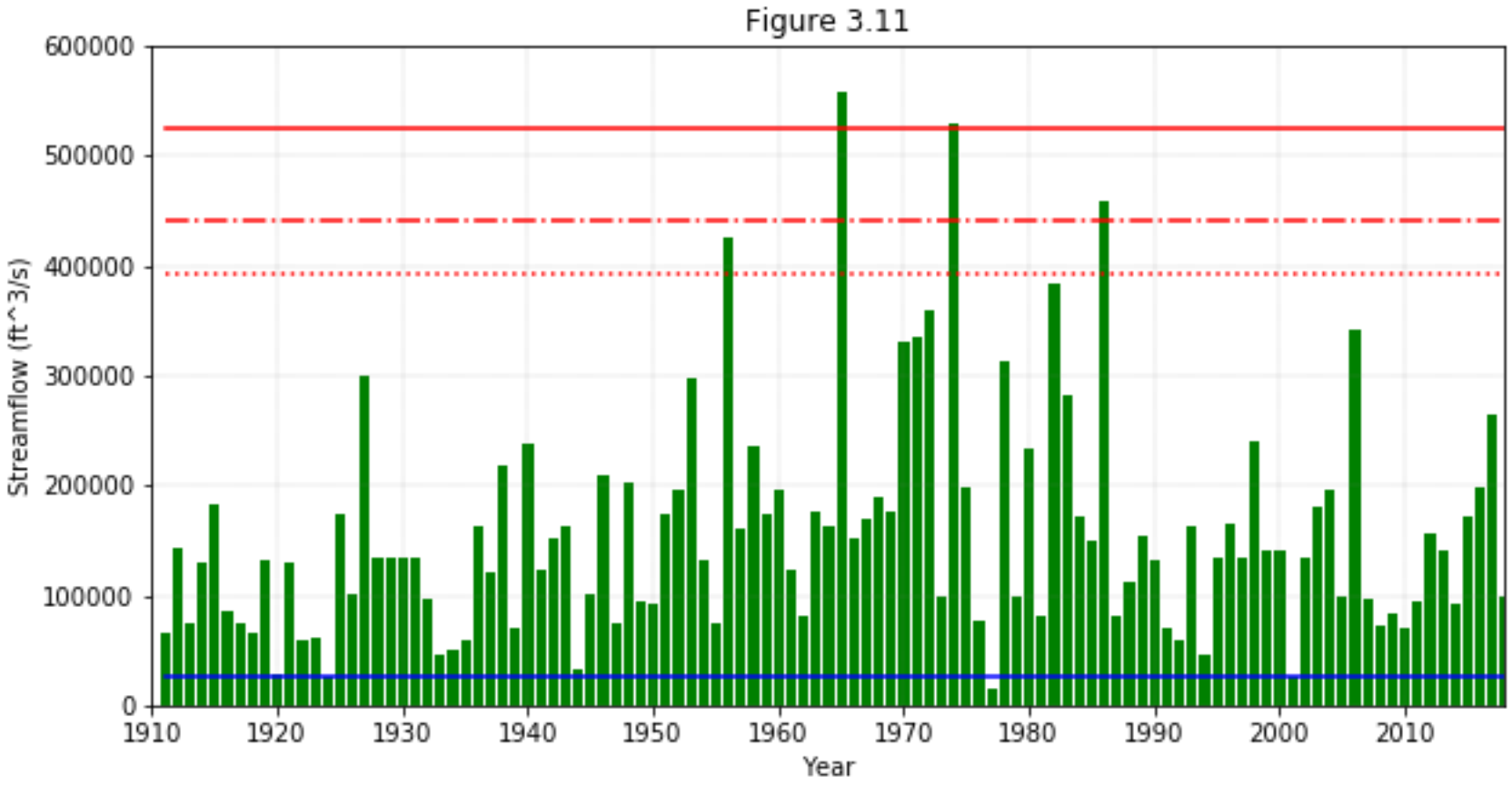
Major Flood Stage:	46
Moderate Flood Stage:	42
Flood Stage:	38
Action Stage:	30

Historic Crests
(1) 61.29 ft on 12/23/1964
(2) 47.12 ft on 12/31/2005
(3) 43.80 ft on 01/01/1997
(4) 41.64 ft on 02/10/2017 **(P)**
(5) 40.52 ft on 12/29/2005
Show More Historic Crests

(P): Preliminary values subject to further review.

Recent Crests
(1) 41.64 ft on 02/10/2017 **(P)**
(2) 25.51 ft on 03/10/2014
(3) 30.83 ft on 12/02/2012
(4) 32.33 ft on 03/31/2012
(5) 25.82 ft on 12/29/2010

Klamath River Streamflow

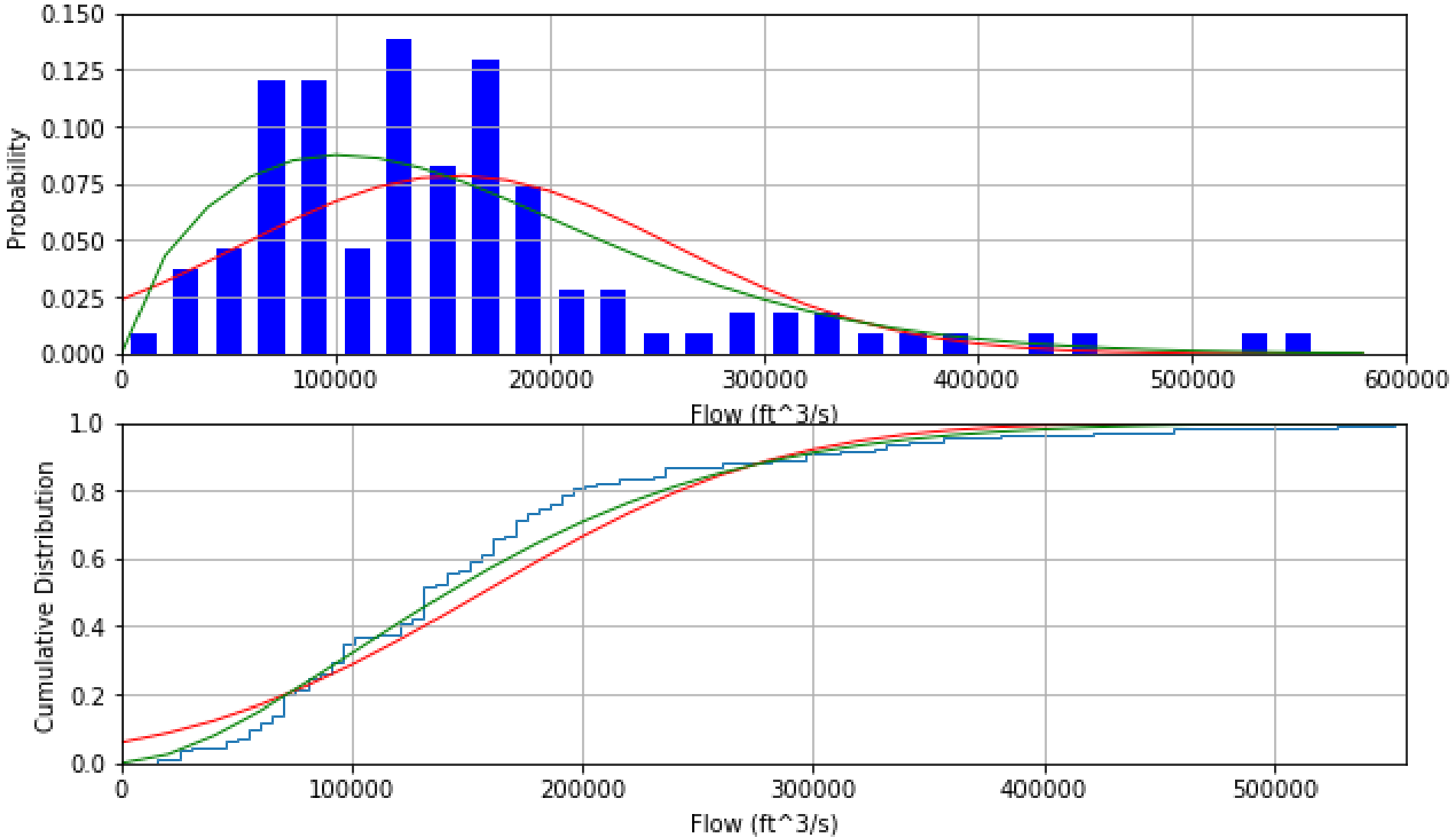


Empirical 99%

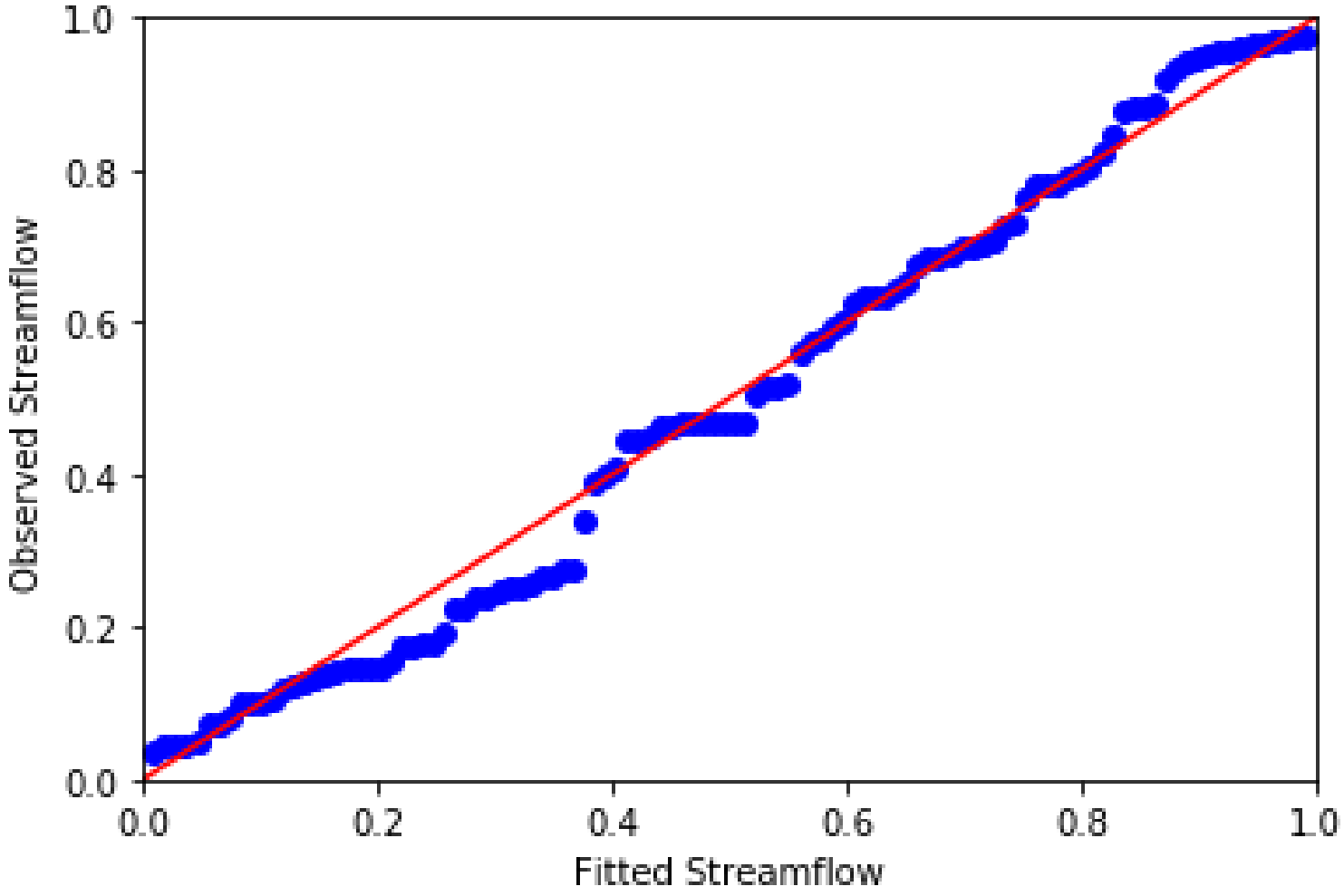
Gaussian 99%
Weibull 99%

Empirical 1%

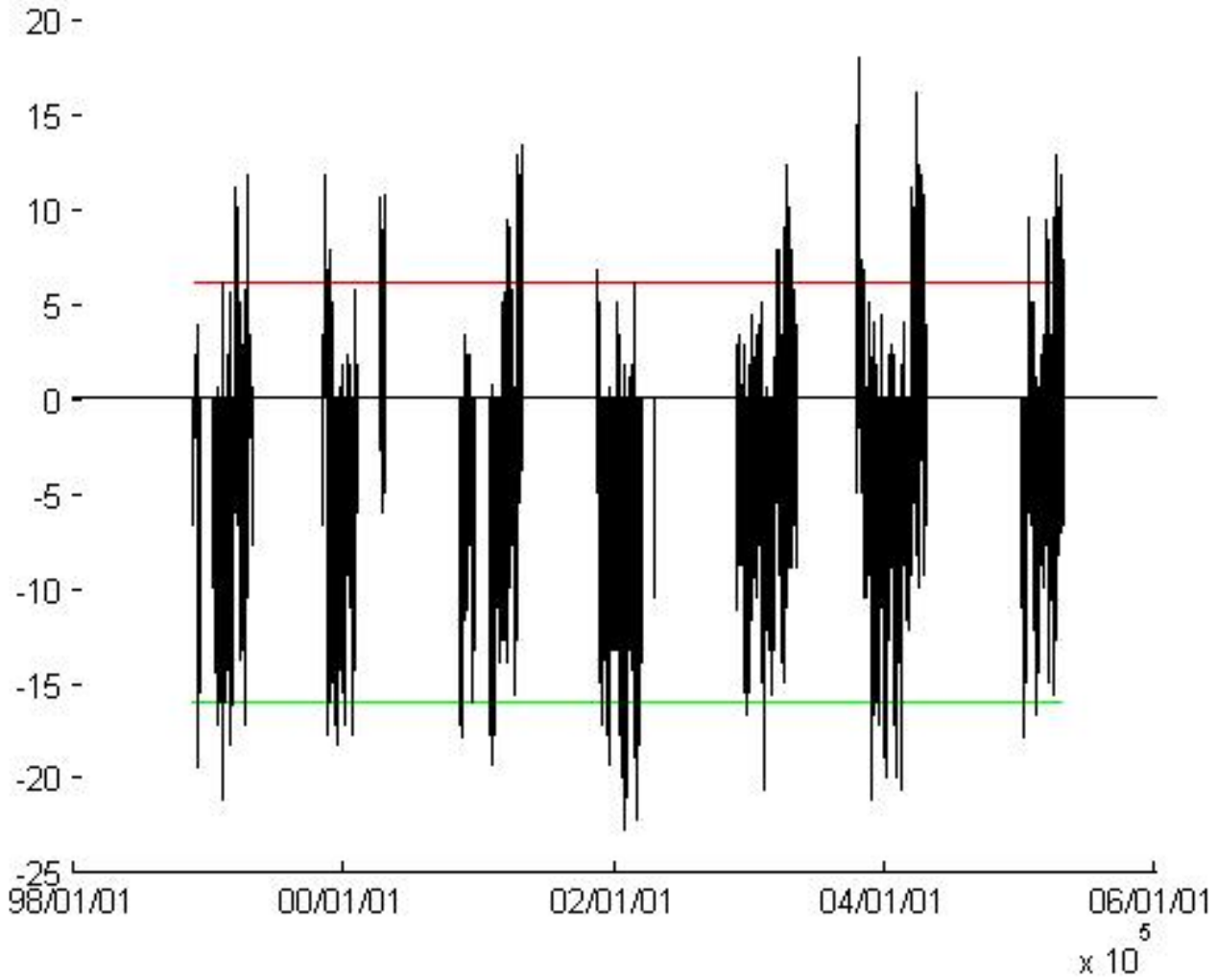
Klamath River Streamflow: Gaussian & Weibull parametric fits



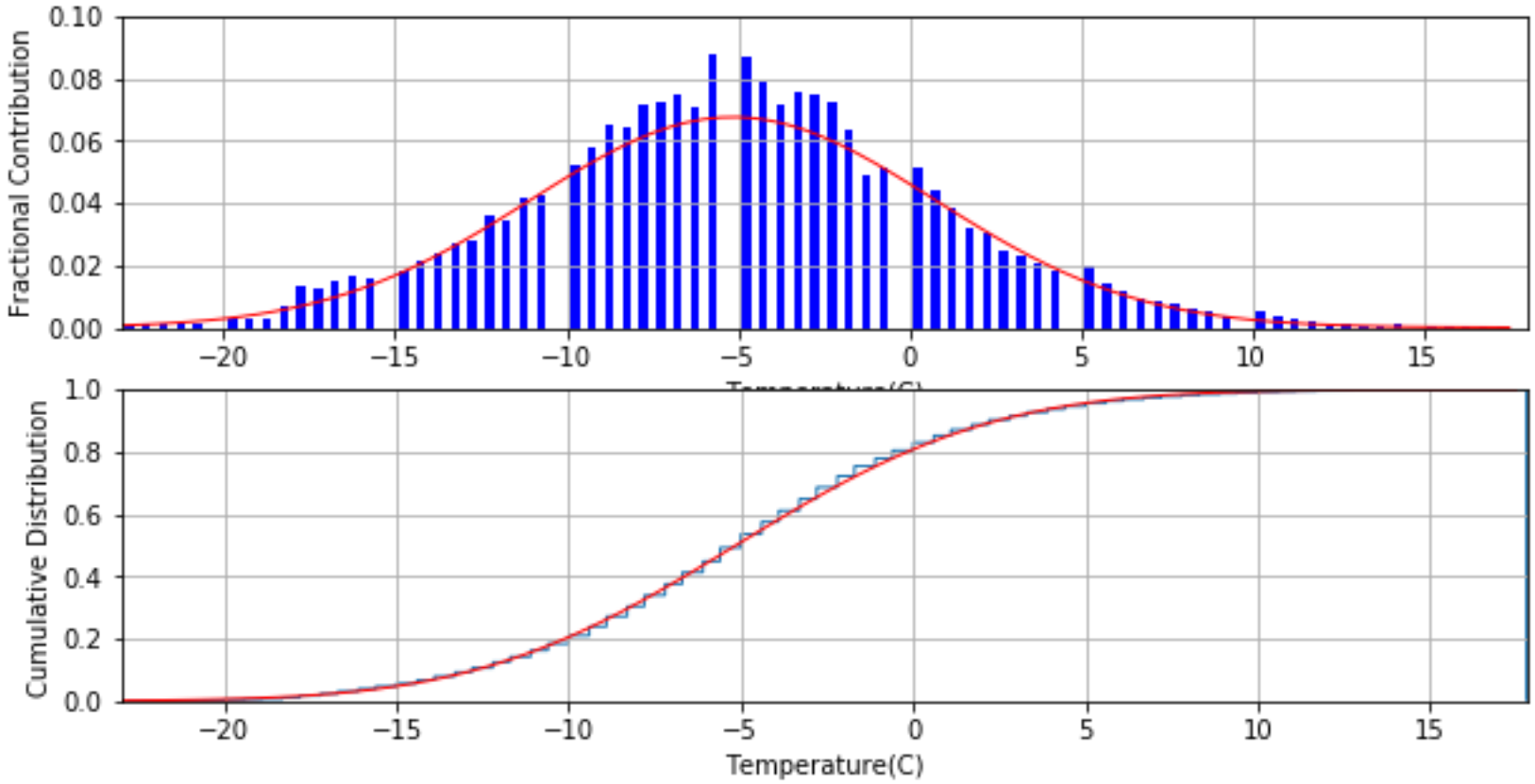
Klamath streamflow



Alta Collins Temperature

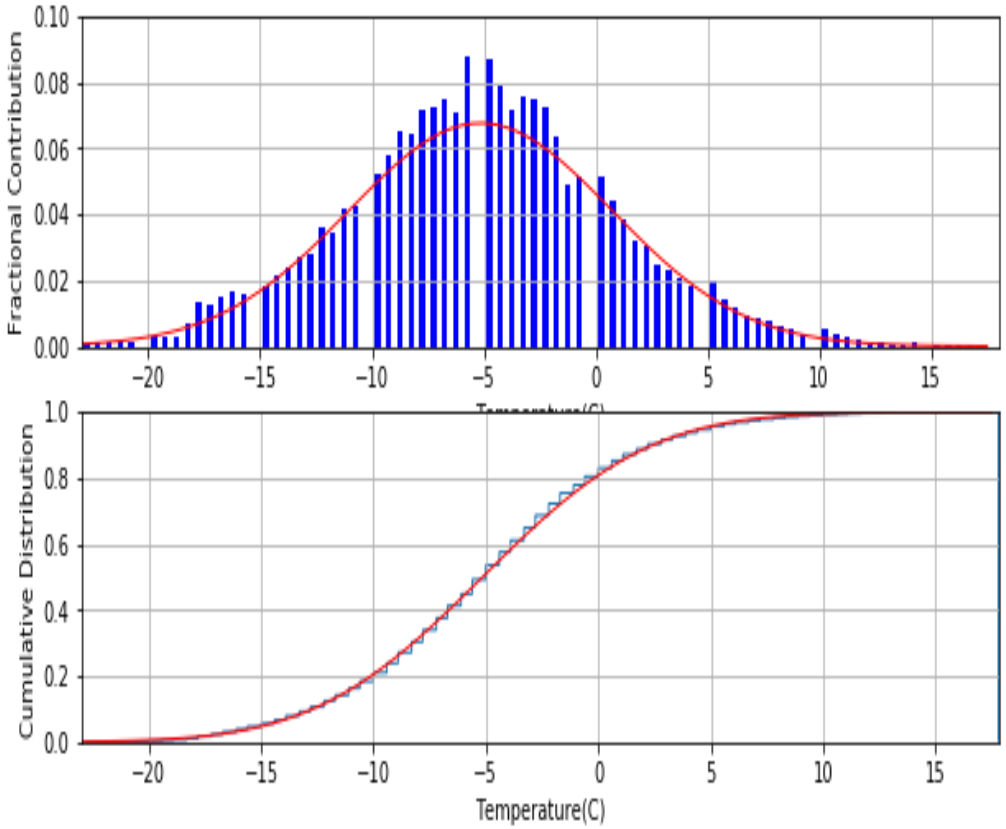


Alta Winter Temperatures with Gaussian fit using mean, σ



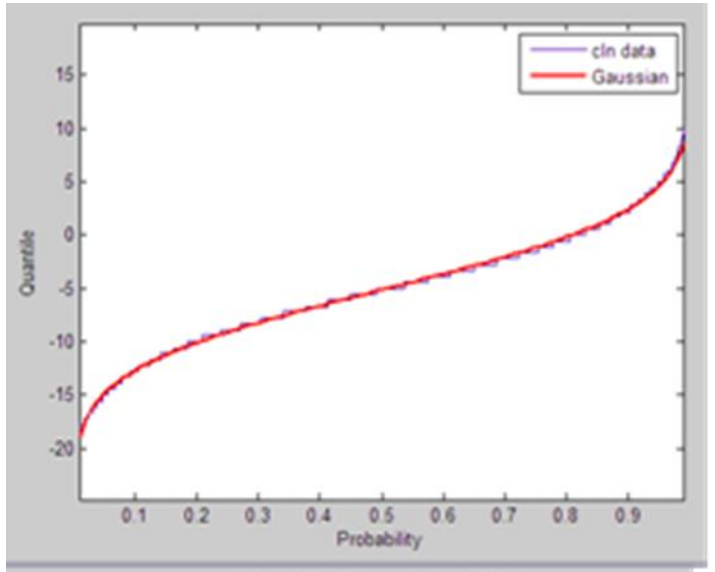
Hypothesis Testing

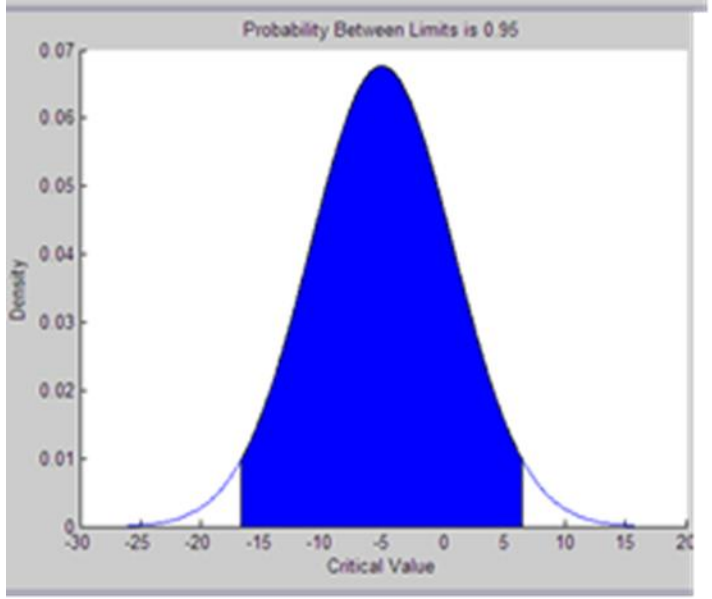
- Alta temperature:
- Empirically: probability of temperature less than -15C is low
- Empirical estimates:
  - Mean= -5.1C
  - Std dev = 5.9C
- What are chances of getting temp of -20C IF this was a population of random numbers with that mean and std dev?



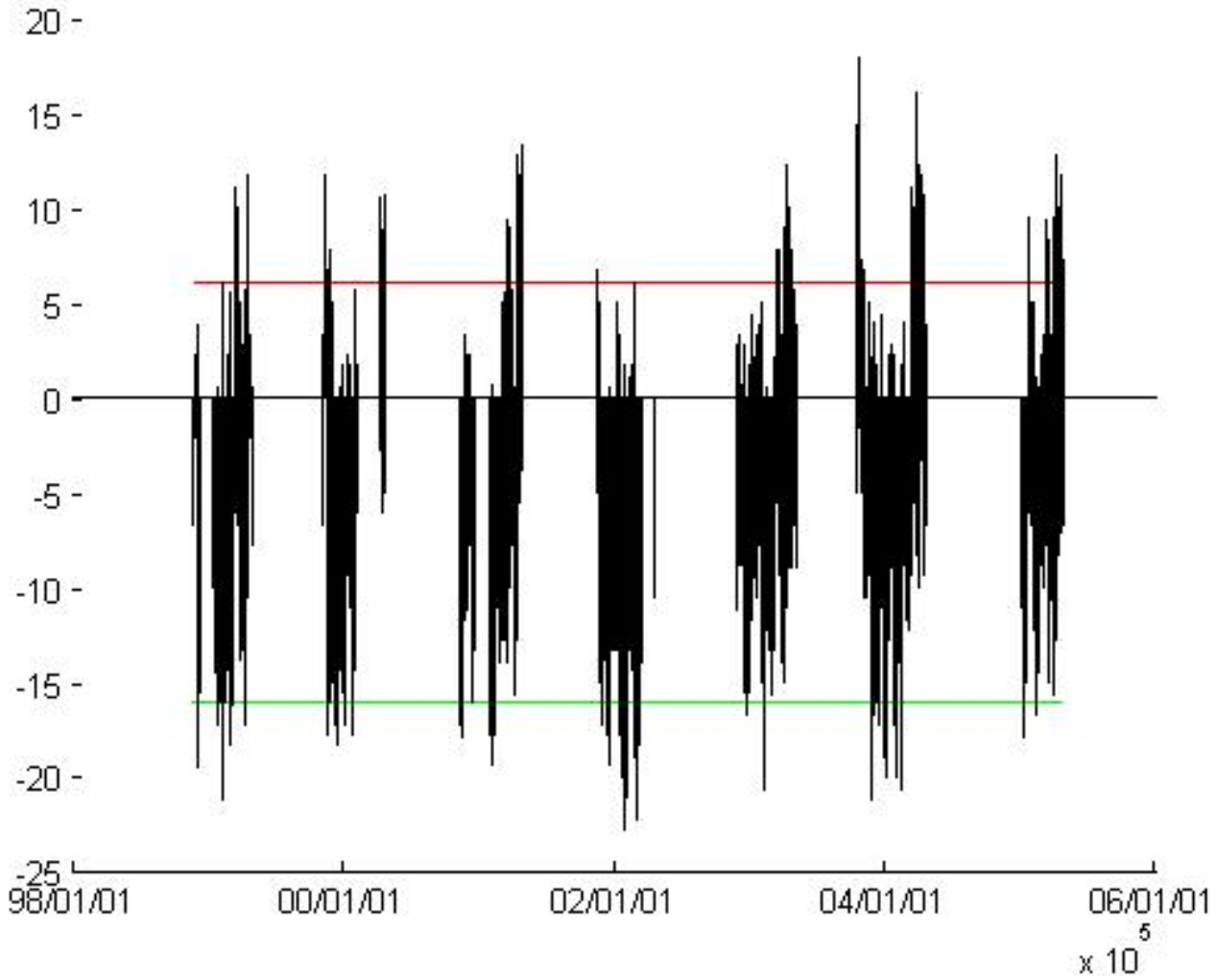
Null hypothesis

- Null hypothesis: Temp of -20C does not differ significantly from mean of -5.1C
- 95% of time, random value would be within -16 and 6C
- So 5% of time, random value would be outside this range
- REJECT the null hypothesis accepting a 5% risk that we are rejecting the null hypothesis incorrectly
- If null hypothesis: Temp of -15C does not differ significantly from mean of -5.1C
- CANNOT reject the null hypothesis since 95% of the time the value could be within -16 and 6C





Collins: Confidence Intervals



Warning

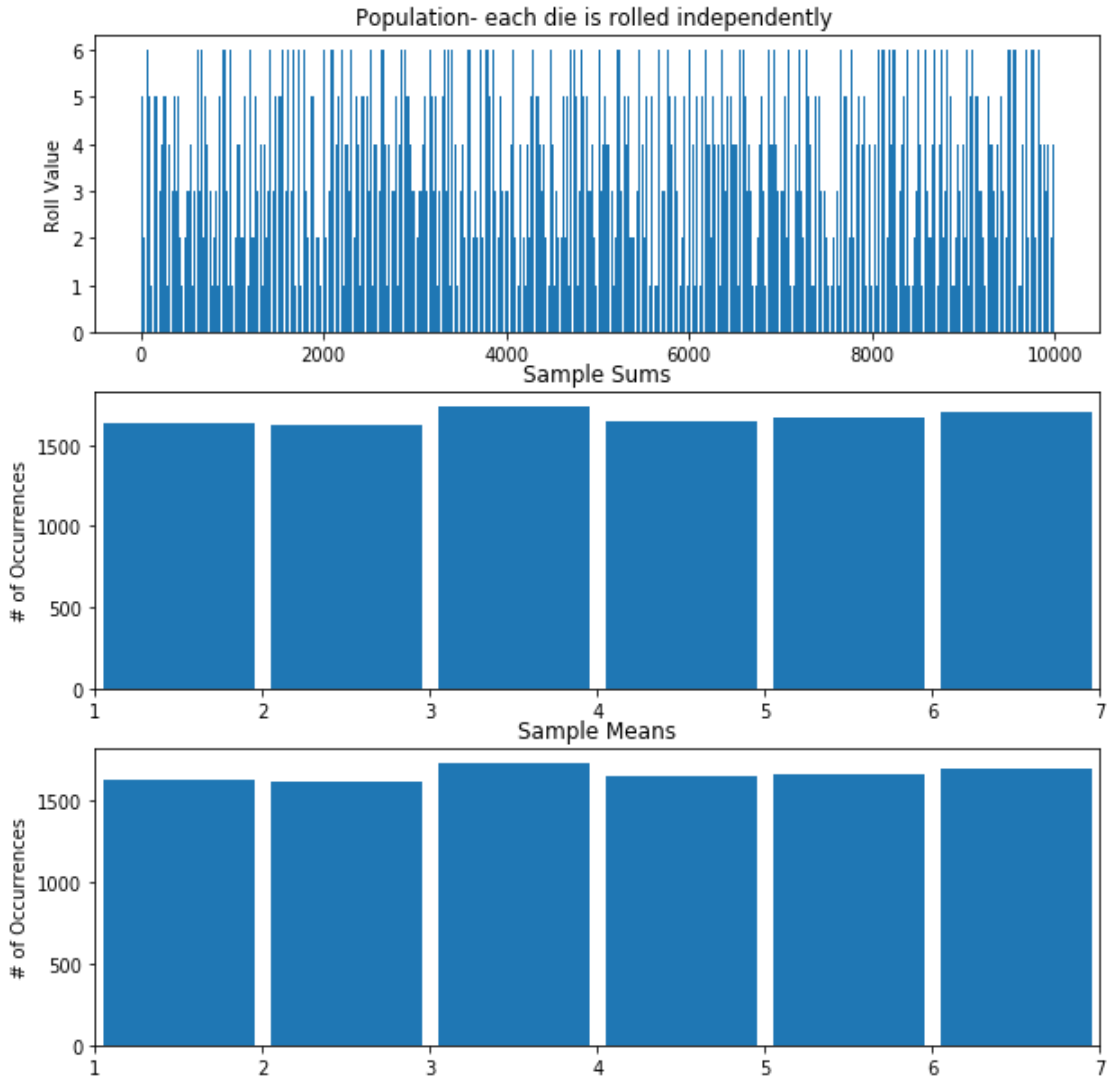
Don’t use language such as:

- the results are significant at the 5% level

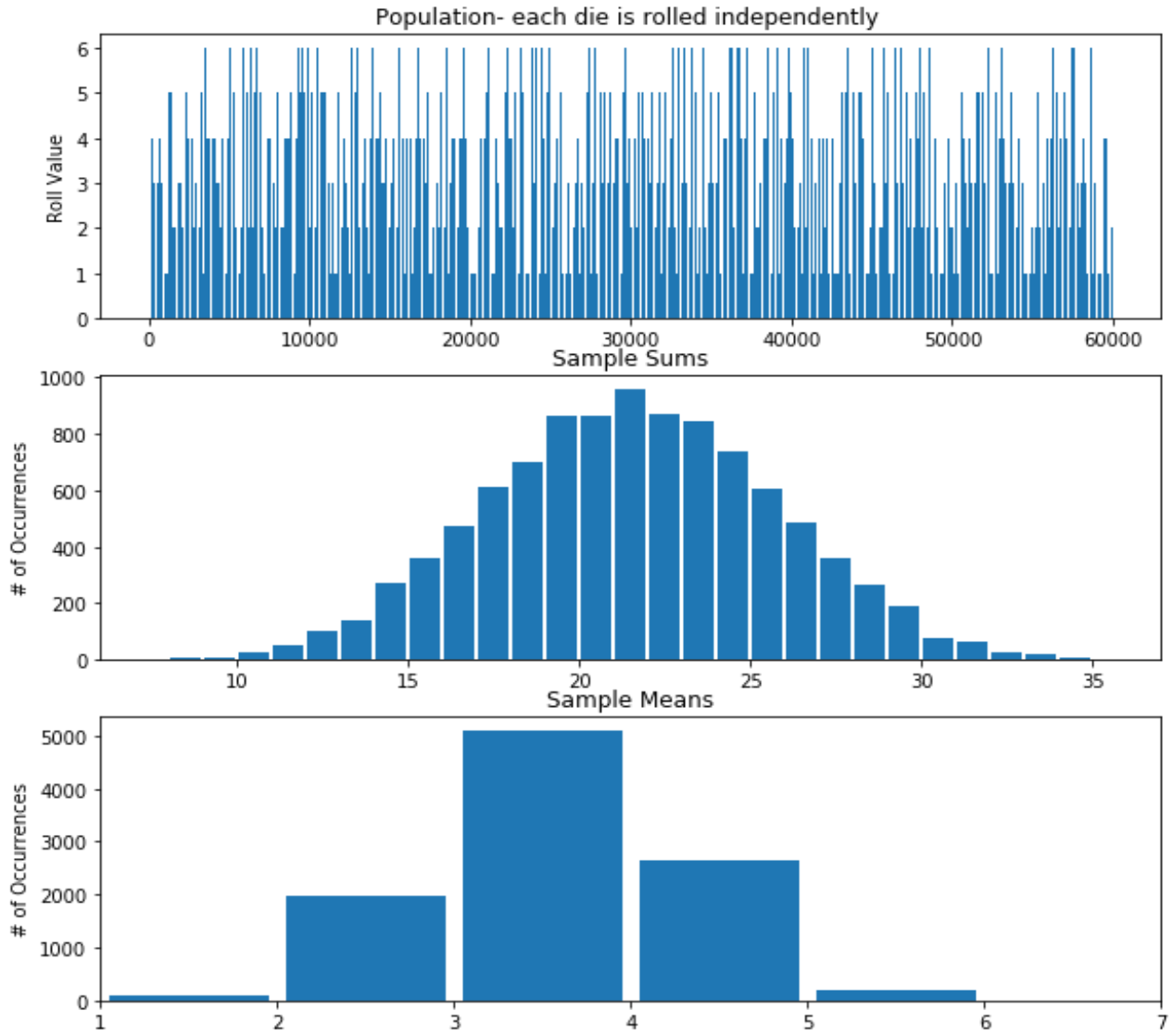
You can only state:

- Null hypothesis is rejected as too unlikely to be true with a risk of 5% that the null hypothesis is incorrectly being rejected

Roll 1 6 sided die 10000 times



Roll 6 6-sided dice 10000 times



Central Limit Theorem

sum (or mean) of a sample (6 dice) will have a Gaussian distribution even if the original distribution (one die) does not have a Gaussian distribution, especially as the sample size increases.

$$\sigma_{\bar{x}} = \sigma / \sqrt{n}$$

$\sigma_{\bar{x}}$ standard deviation of the sample means

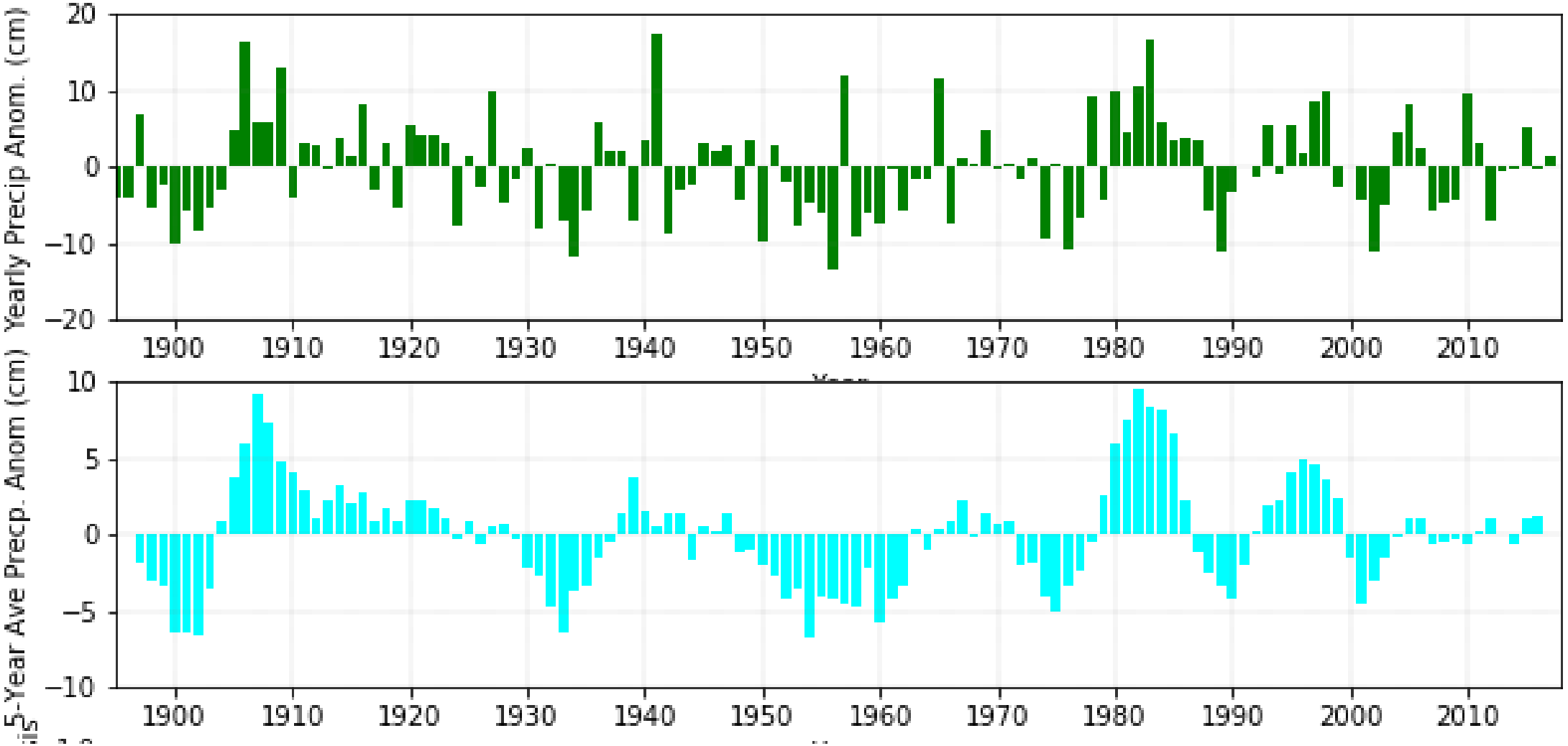
σ standard deviation of the original population

n sample size

$$s_x = \sqrt{\frac{n-1}{n}}\sigma \qquad \sigma_{\bar{x}} = s_x / \sqrt{n-1}$$

degrees of freedom: n-1, since sample can be described by the mean (1 value) plus n-1 others

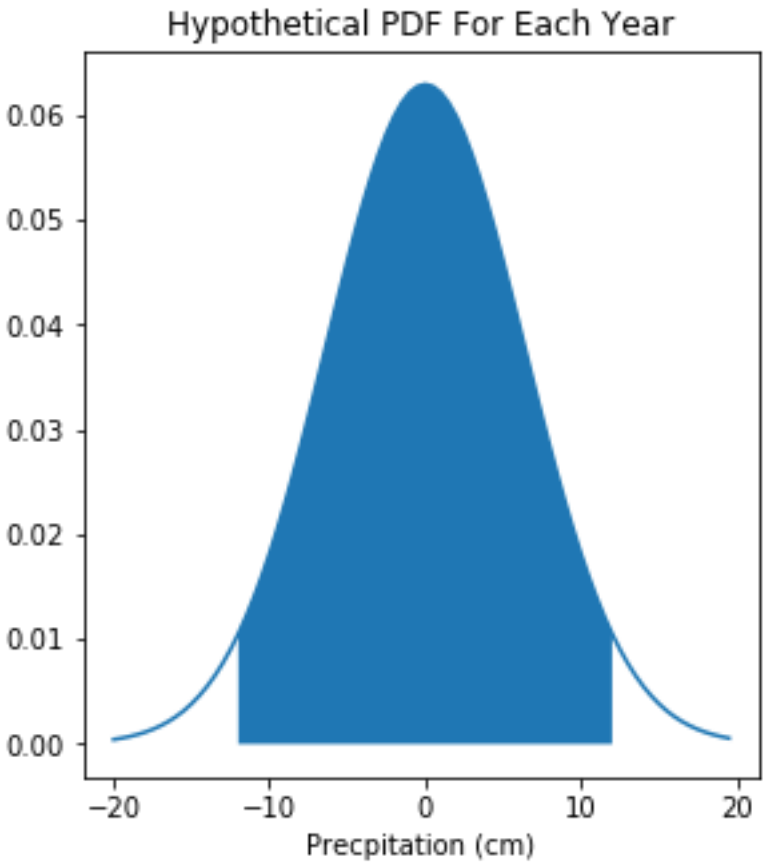
Which 5-yr samples would be considered a drought for Utah?



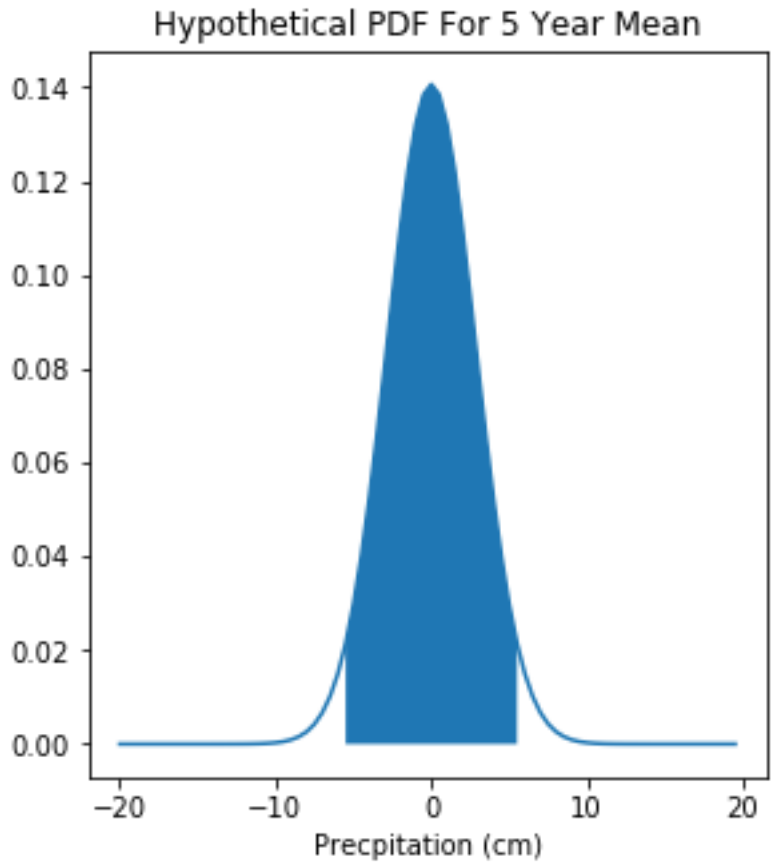
Steps of Hypothesis Testing

- Identify a test statistic that is appropriate to the data and question at hand
  - Computed from sample data values. 5 yr sample means
- Define a null hypothesis, H_0 to be rejected
  - 5 yr sample mean 0
- Define an alternative hypothesis, H_A
  - 5 yr sample mean < 0
- Estimate the null distribution
  - Sampling distribution of the test statistic IF the null hypothesis were true
  - Making assumptions about which parametric distribution to use (Gaussian, Weibull, etc.)
  - Use sample mean of 0 and 124 yr sd of 6.3 cm
- Compare the observed test statistics (5-yr means) to the null distribution. Either
  - Null hypothesis is rejected as too unlikely to have been true IF the test statistic fall in an improbable region of the null distribution
    - Possibility that the test statistics has that particular value in the null distribution is small
    - OR
    - The null hypothesis is not rejected since the test statistic falls within the values that are relatively common to the null distribution

Each Year individually: sample standard deviation = 6.3 cm
5 Year sample: sample standard deviation = 2.7cm



95% chance that individual year within 12.4 cm



95% chance that 5-yr mean anomaly within 5.4 cm

Conclusion:
Less likely to have a 5-yr drought (really large 5-yr mean) than to have a single really dry year

Caution!

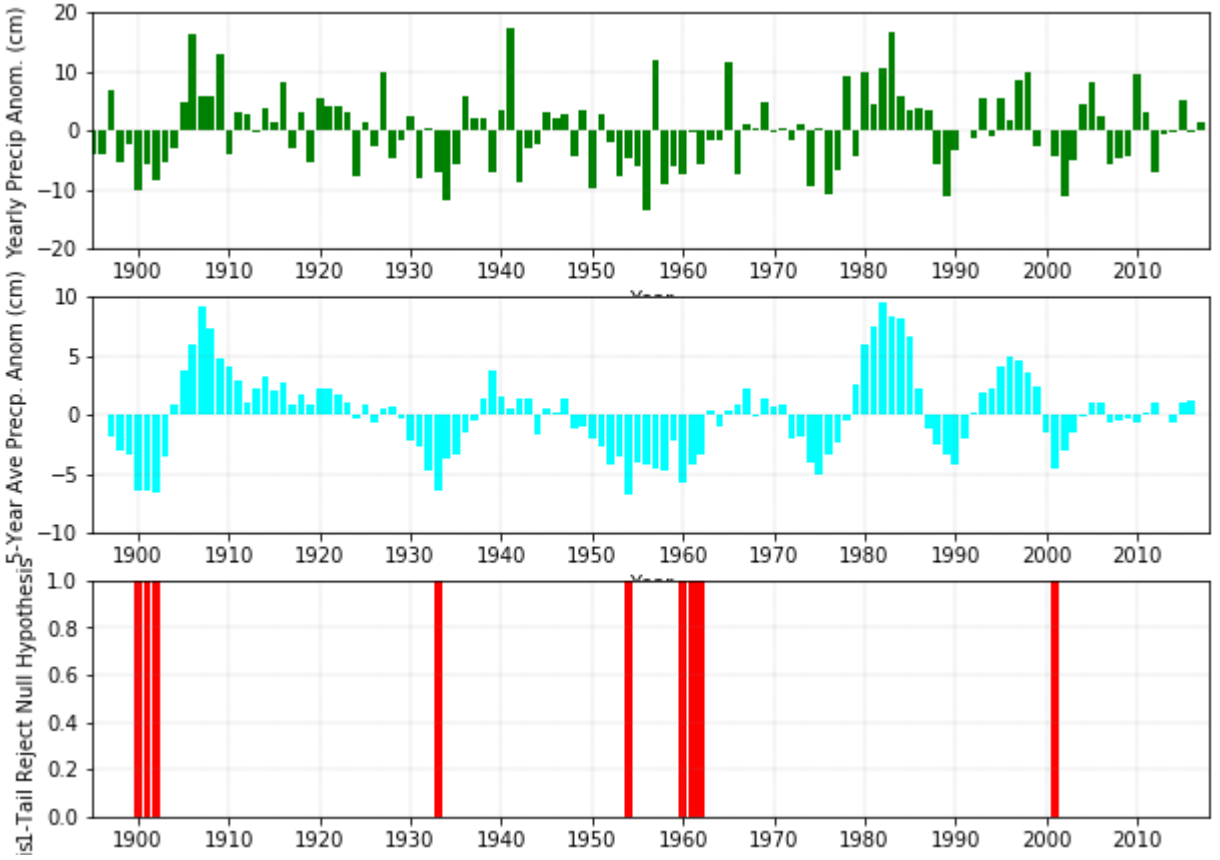
- NOT rejecting the null hypothesis is not the same as saying the null hypothesis is true
  - There is insufficient evidence to reject H_0
- H_0 is rejected if the probability p of the observed test statistic is ≤ α significance or rejection level
- If odds of test statistic occurring in the null distribution less than 1 or 5%, then we may choose to reject the null hypothesis
- Rejecting the null hypothesis MAY be same as accepting alternative hypothesis BUT there may be many other possible alternative hypotheses
- You must define ahead of time the α significance or rejection level
  - 1% or 5%, 1 in 100 or 5 in 100 chance that you accept the risk of rejecting the null hypothesis incorrectly
  - Type 1 category error of a false rejection of the null hypothesis

Students' t test

- $\sigma_{\overline{X}} = \frac{s_x}{\sqrt{n-1}}$
- Estimate of population variance from sample
- T value:
- Numerator: signal
- Denominator: noise
- At t gets larger, confidence in rejecting the null hypothesis (sample mean differs from population mean) gets higher
- T large IF:
  - Spread between sample and population means large
  - Degrees of freedom is large
  - Variability in sample is small

$$t = (\bar{x} - \mu)\sqrt{n-1} / s_x$$

Which 5-yr samples would be considered a drought?



Left, Right, 2 Sided (both)

- Left- alternative hypothesis is drought
- Right- alternative hypothesis is flood
- 2 Sided- either drought or flood
- 2 sided tests should be generally avoided as you are now just arguing something is “different” from the mean
- Sample value must be further from 0 (smaller p value) since α is smaller by 2 (2.5% in each tail)

Two Sided Test: Flood or Drought

One-sided test for drought

Two-sided test for drought or flood

Summary

- Research involves defining a testable hypothesis and demonstrating that any statistical test of that hypothesis meets basic standards
- Typical failings of many studies include:
  - (1) ignoring serial correlation in environmental time series that reduces the estimates of the number of degrees of freedom and
  - (2) ignoring spatial correlation in environmental fields that increases the number of trials that are being determined simultaneously.
    - Inflates the opportunities for the null hypothesis to be rejected falsely.
- Use common sense
- Be very conservative in estimating the degrees of freedom temporally and spatially
- Avoid attributing confidence to a desired result when similar relationships are showing up far removed from your area of interest for no obvious reason
- The best methods for testing a hypothesis rely heavily on independent evaluation using additional data not used in the original statitiscal analysis

What should you be doing?

- Read Chapter 4 notes
- Online final released after Thanksgiving will cover material from throughout the course with emphasis on Chapter 3 and 4