# Annual Precipitation Analysis and How it Might be used to Quantify the Effect on Calhoun Brake

**The Table below holds Annual Precipitation data from 1892 to 2009. Data from 1892 to 2009 were used in this analysis.**

**The values in each monthly cell are inches*100, the values in Annual and Summer cells are in inches.**

$\begin{pmatrix} out1 \\ out2 \\ out3 \\ out4 \\ out5 \end{pmatrix} :=$

| MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | Annual | Summer | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | |
| 643 | 1006 | 260 | 537 | 492 | 438 | 501 | 150 | 573 | 923 | 65.5 | 19.68 | | | |
| 234 | 722 | 689 | 782 | 213 | 328 | 28 | 31 | 478 | 254 | 43.21 | 13.51 | | | |
| 822 | 563 | 335 | 170 | 660 | 325 | 203 | 397 | 132 | 617 | 55.25 | 13.58 | | | |
| 407 | 186 | 494 | 1315 | 355 | 469 | 107 | 165 | 423 | 299 | 48.35 | 22.46 | | | |
| 464 | 247 | 153 | 78 | 28 | 307 | 371 | 516 | 561 | 33 | 37.26 | 7.84 | | | |
| 622 | 200 | 270 | 393 | 332 | 247 | 162 | 249 | 112 | 917 | 45.54 | 11.34 | | | |
| 403 | 462 | 137 | 861 | 381 | 226 | 462 | 528 | 718 | 191 | 53.59 | 19.3 | | | |
| 485 | 169 | 136 | 194 | 158 | 222 | 49 | 248 | 245 | 510 | 30.74 | 6.23 | | | |
| 433 | 1189 | 341 | 803 | 848 | 147 | 390 | 243 | 325 | 197 | 57.67 | 21.88 | | | |

$i := 1 .. 118$

$year_i := out1_i$

**Output the annual precipitation for each year:** $A\_P_i := out2_i \cdot in$

**Output January precipitation for each year :** $J\_P_i := \frac{out3_i}{100} \cdot in$

Output June precipitation for each year: $Ju\_P_i := \frac{out4_i}{100} \cdot in$

Output summer precipitation for each year: $summer\_P_i := out5_i \cdot in$

$mean(A\_P) = 51.036 \cdot in$ $median(A\_P) = 49.78 \cdot in$

**Note that the mean and median of the data set are very close together suggesting that the data may exhibit a symmetrical distribution about the mean.**

**Below I have plotted the data as solid bars and I have used a median smoothing algorithm with windows of 5, 10 and 15 years. The median smoothing algorithm replaces each point with the median of the n points centered on that value. The window width, n, is contracted near the ends of the vector.**

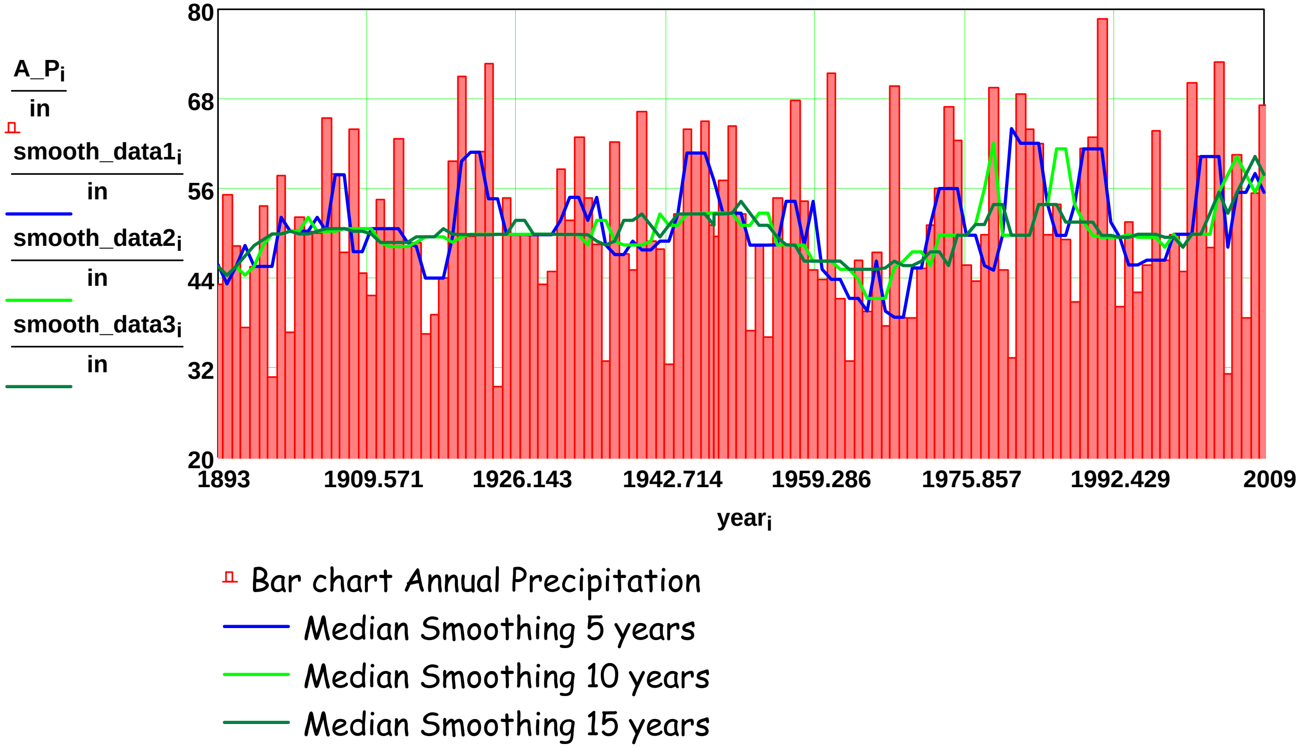
**Note that when a window of 31 is used the plot is nearly horizontal. This suggests no trends in the data extending over 30 years.**

$smooth\_data1 := medsmooth(A\_P, 5)$

$smooth\_data2 := medsmooth(A\_P, 11)$

$smooth\_data3 := medsmooth(A\_P, 15)$

## Annual Precipitation in inches, Monroe, La. 1892-2008




**The statements below are used to create the probability plots for Monroe Rainfall, shown below**

**mean(A_P) = 51.036·in**

**sorted_precip_data := sort(A_P)**　　**sorted_summer_data := sort(summer_P)**

**x := sorted_precip_data**　　**xx := sorted_summer_data**

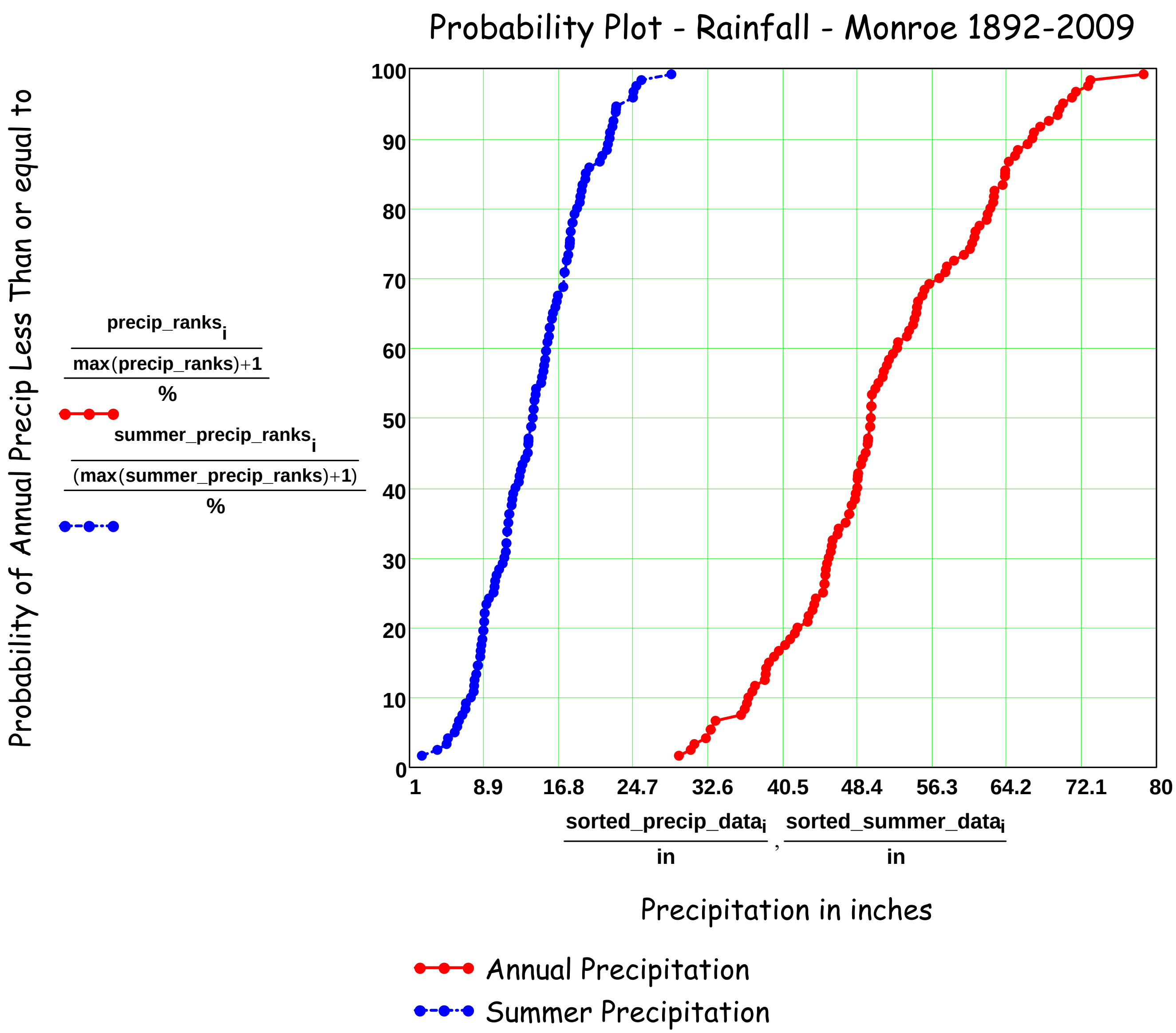
```
Rankdemo(x) := | sorted ← sort(x)
               | for  i ∈ 0 .. length(x) − 1
               |     | m ← match(x_i , sorted) + 1
               |     | rank_i ← mean(m)
               | rank
```

precip_ranks := Rankdemo(x)

```
Rankdemo(xx) := | sorted ← sort(xx)
                | for  i ∈ 0 .. length(xx) − 1
                |     | m ← match(x_i , sorted) + 1
                |     | rank_i ← mean(m)
                | rank
```

summer_precip_ranks := Rankdemo(xx)

**Probability plots for annual precipitation data as well as summertime precipitation data are shown on the next page**




**These curves give the relationship between precipitation and the probability of that or a lesser amount falling in a subsequent year. For example there is a 50 % chance of an annual precipitation amount of 49.8 inches OR LESS falling in any subsequent year. There is a 27% (about 1 in 4) chance of getting a summer rain total greater than the 2010 summer rain total of 17.46 inches (curve on the left)**

**The median summer precipitation amount is 14.03 in. The summer 2010 amount was 17.41 in.**

## How to use the probability plot above to assess the effect on the break

**The mean annual precipitation based on the data used here is 50.9 inches. Thus, there is a 50% chance that in any subsequent year either more or less than this amount will occur. Lets assume that in any year where less than the mean annual precipitation occurs there is opportunity for Cypress germination. Now, the annual plant cooling water discharge is equivalent to 6 inches over the break. So, we can construct an equivalent scenario in terms of total depth on the break if, in a year when $50.9 \cdot in - 6 \cdot in = 44.9 \cdot in$ falls, the probability of this amount of precipitation or less occurring is approximately 26%. Thus, given the assumptions made, the plant's discharge causes the break to dry up 1 out of every 4 years instead of 1 in every 2 years.**

# Histogram of Annual Precipitation Amounts

**The purpose of this analysis is to see if the annual precipitation values appear to follow any known statistical distribution**

**The algorithm below constructs a 20 bin histogram of the annual precipitation data**

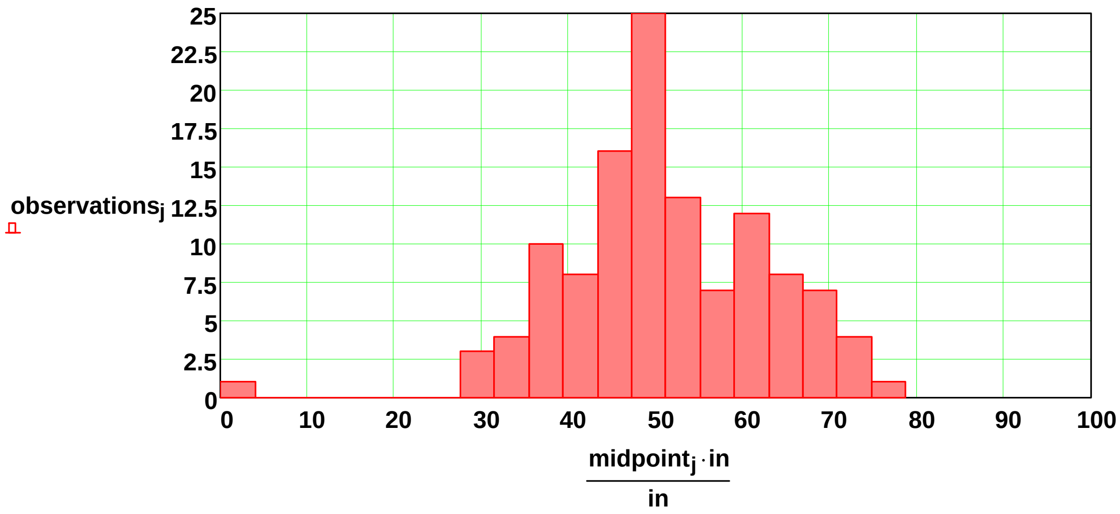
$$\mathbf{Annual\_Precip\_histogram} := \mathbf{histogram}\left(20, \frac{A\_P}{in}\right) =$$

| | 0 | 1 |
|---|---|---|
| 0 | 1.966 | 1 |
| 1 | 5.898 | 0 |
| 2 | 9.83 | 0 |
| 3 | 13.762 | 0 |
| 4 | 17.694 | 0 |
| 5 | 21.626 | 0 |
| 6 | 25.558 | 0 |
| 7 | 29.49 | 3 |
| 8 | 33.422 | 4 |
| 9 | 37.354 | 10 |
| 10 | 41.286 | 8 |
| 11 | 45.218 | 16 |
| 12 | 49.15 | 25 |
| 13 | 53.082 | 13 |
| 14 | 57.014 | 7 |
| 15 | 60.946 | ... |

$$j := 0 .. 19$$

$$observations_j := Annual\_Precip\_histogram_{j,1} \qquad midpoint_j := Annual\_Precip\_histogram_{j,0}$$

# Histogram of Annual Precipitation Values




**<u>The histogram looks reasonably symmetrical about the mean suggesting that annual precipitation can be described by a normal distribution</u>**

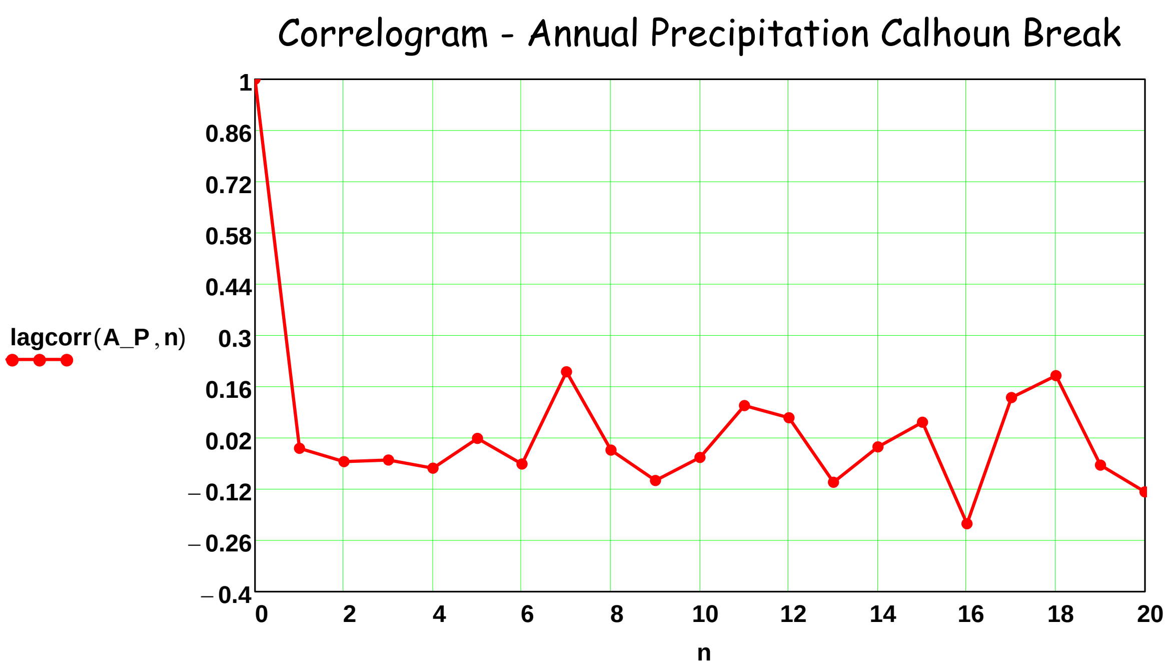
**Next, I examine the data to see if it is "autocorrelated", that is "does the precipitation amount in a given year imply anything about values to be expected in future years.**

## <u>Autocorrelation Analysis</u>

**An autocorrelation analysis tests for correlation between successive values of annual precipitation in time, that is does the fact that you have a low value for precip in one year imply that you will have a low (or high) value the next year.**

$$n := 0 .. 20$$

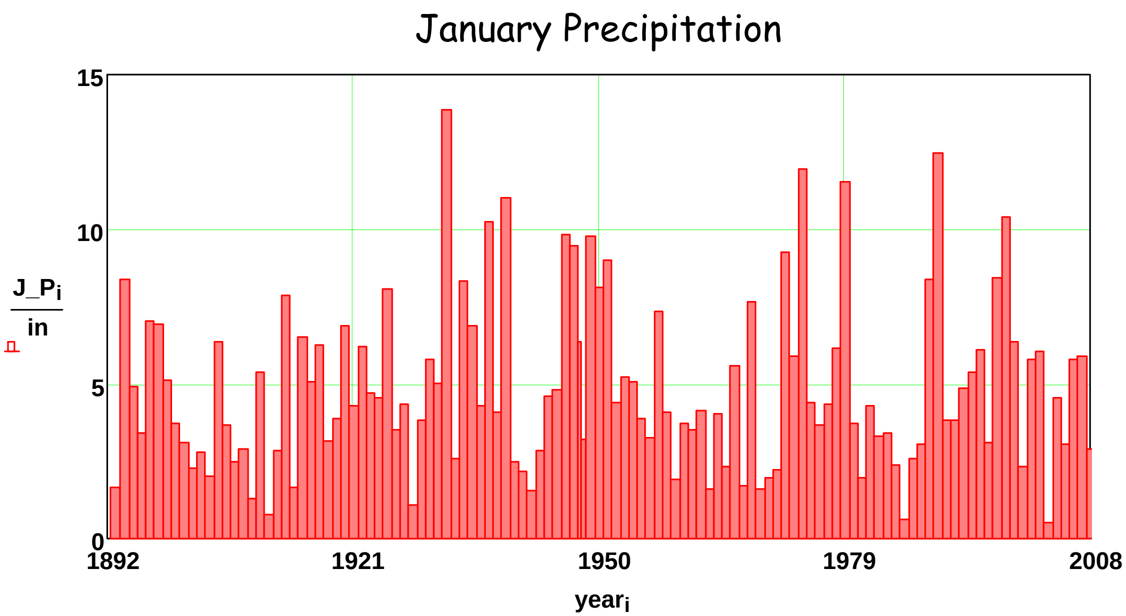
$$lagcorr(A\_P, n) := \frac{1}{length(A\_P) \cdot stdev(A\_P)^2} \cdot \sum_{i = n}^{last(A\_P)} \left[ \left( A\_P_i - mean(A\_P) \right) \cdot \left( A\_P_{i-n} - mean(A\_P) \right) \right]$$




**The analysis above suggests that annual precipitation values are independent in time over time frames from one to twenty years. Simply stated "the value of annual precipitation in a given year implies nothing about the value to be expected in subsequent years". Lack of autocorrelation is also a prerequisite for using equations based on known statistical distributions.**

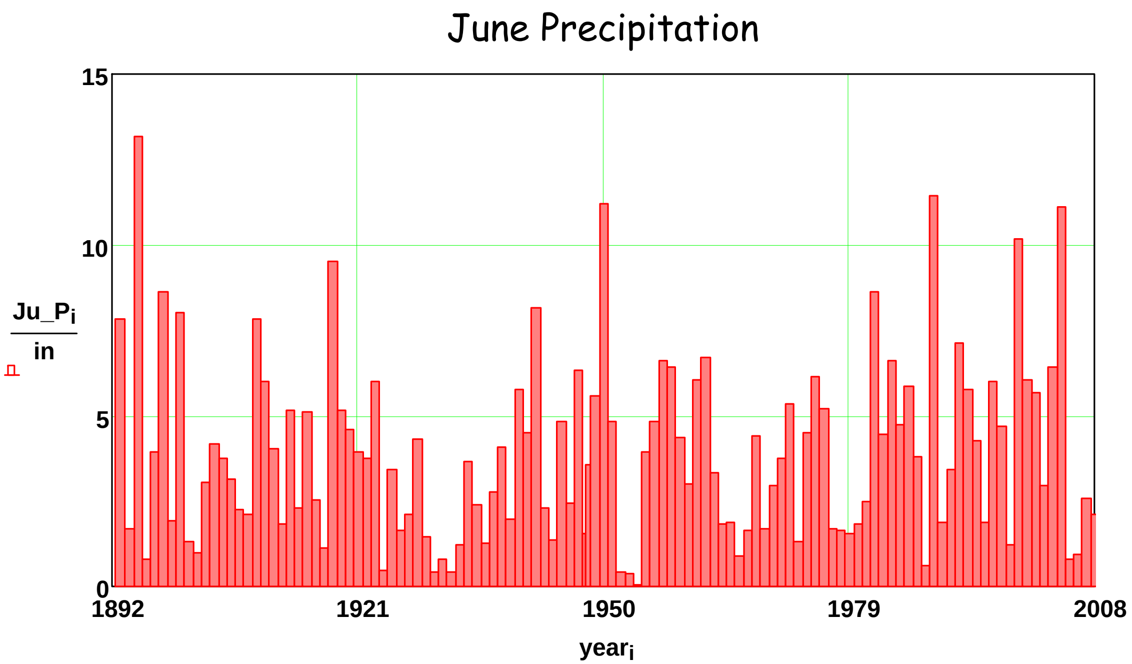
**In reality, I don't think anyone knows what level of precipitation will cause the Brake to "dry up" nor have we even defined "dry up". Further, (and this is a legal question) does the fact that cypress seeds need to germinate on soil that is not inundated and the fact that the plant's discharge may affect the availability of such conditions constitute any real, meaningful, damage in this case, or is this simply a straw man ? Does drying up 1 in 4 years instead of 1 in 2 years have any meaningful effect on the Brake's ability to produce Cypress trees ?**

**In the statements and plots below I examine the January and July precipitation amounts. In both months no trends are evident and the mean and median of the data are close together suggesting the distribution of both January and July precipitation amounts is symmetrical.**




$\text{mean}(J\_P) = 4.839 \cdot in$ $\text{median}(J\_P) = 4.3 \cdot in$

**The mean of the precipitation amount falling in January is 4.8 inches while the median is 4.3 inches**

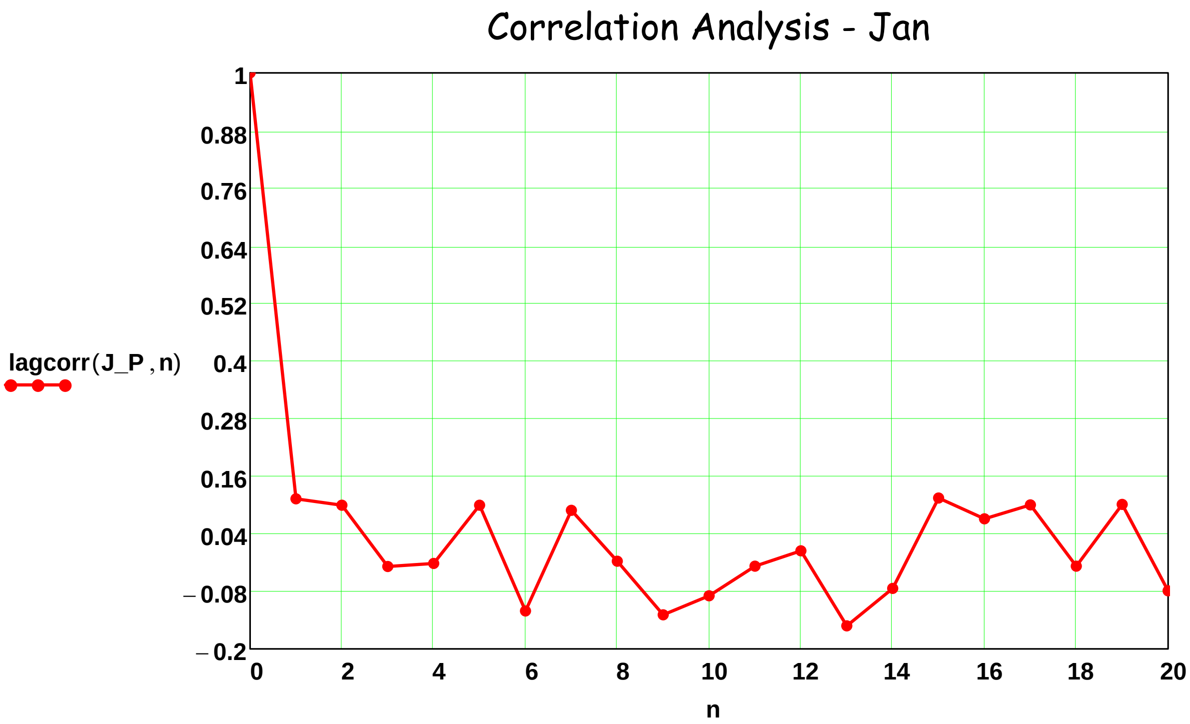



**mean(Ju_P) = 3.858·in** **median(Ju_P) = 3.57·in**

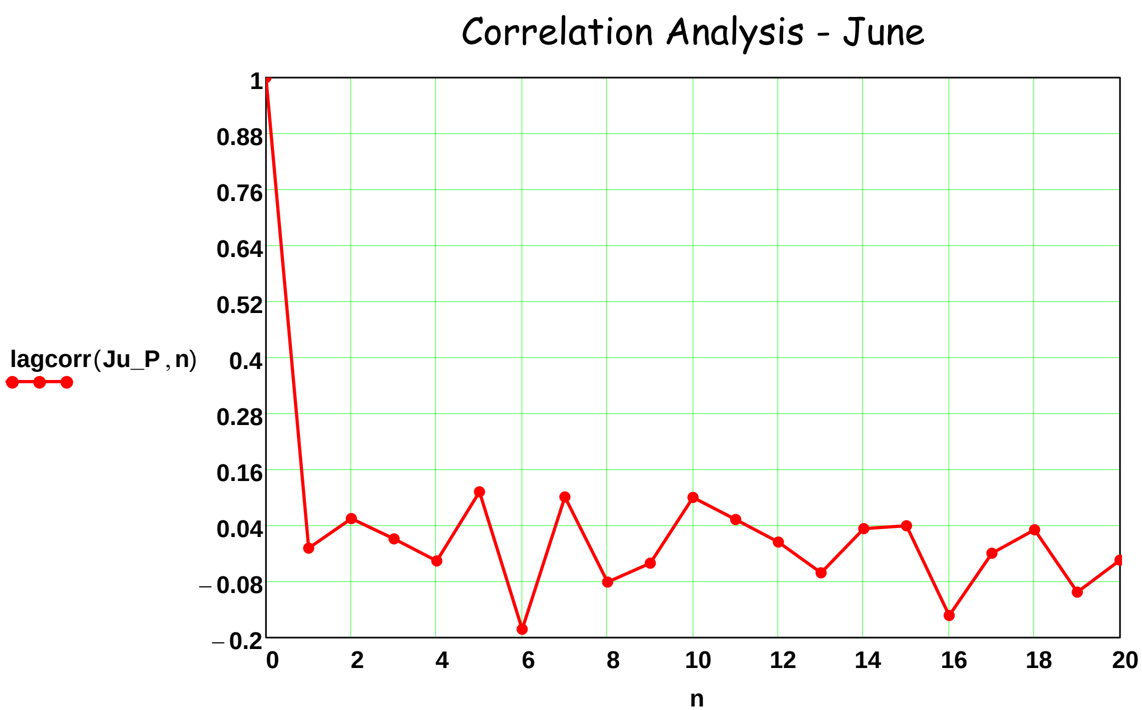
**The mean of the precipitation amount falling in July is 3.9 inches while the median is 3.6 inches**

**The statements and plots below show that the precipitations for January and July are not autocorrelated. This equations based on known statistical distributions can be used make predictions about future precipitation values in these months.**

$$\text{lagcorr}(J\_P, n) := \frac{1}{\text{length}(J\_P)\cdot \text{stdev}(J\_P)^2}\cdot \sum_{i=n}^{\text{last}(J\_P)} \left[\left(J\_P_i - \text{mean}(J\_P)\right)\cdot\left(J\_P_{i-n} - \text{mean}(J\_P)\right)\right]$$



$$\text{lagcorr}(Ju\_P, n) := \frac{1}{\text{length}(Ju\_P)\cdot \text{stdev}(Ju\_P)^2}\cdot \sum_{i=n}^{\text{last}(Ju\_P)} \left[\left(Ju\_P_i - \text{mean}(Ju\_P)\right)\cdot\left(Ju\_P_{i-n} - \text{mean}(Ju\_P)\right)\right]$$



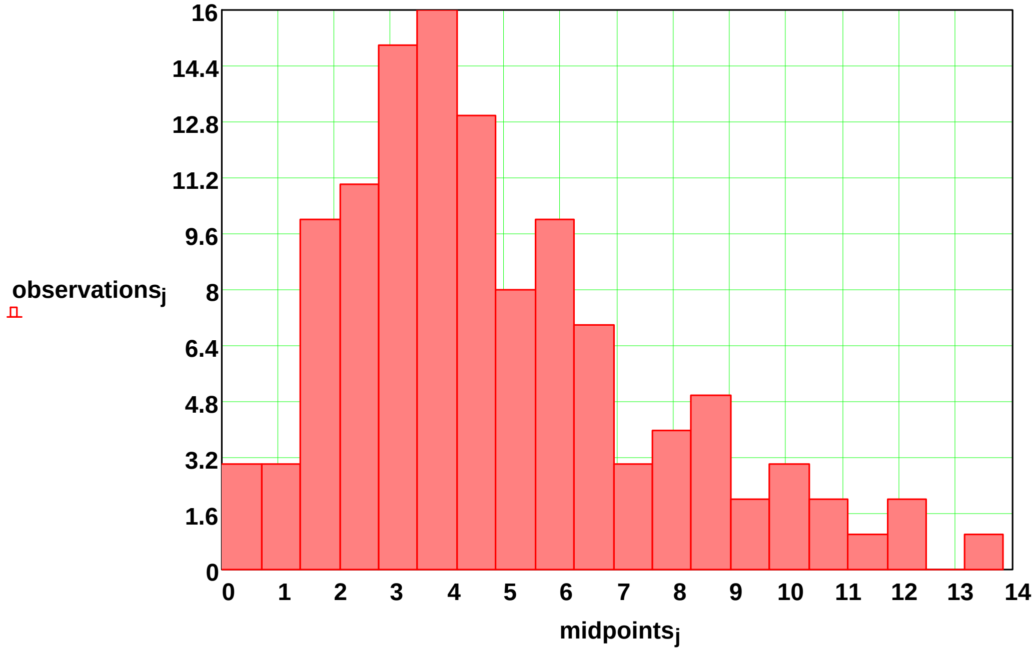
**The statements and plots below are used to produce histograms of the precipitation amounts in January and July**

$$\mathbf{Annual\_Precip\_histogram} := \mathbf{histogram}\left(20, \frac{J\_P}{in}\right) =$$

| | 0 | 1 |
|---|---|---|
| 0 | 0.346 | 3 |
| 1 | 1.039 | 3 |
| 2 | 1.731 | 10 |
| 3 | 2.424 | 11 |
| 4 | 3.116 | 15 |
| 5 | 3.809 | 16 |
| 6 | 4.501 | 13 |
| 7 | 5.194 | 8 |
| 8 | 5.886 | 10 |
| 9 | 6.579 | 7 |
| 10 | 7.271 | 3 |
| 11 | 7.964 | 4 |
| 12 | 8.656 | 5 |
| 13 | 9.349 | 2 |
| 14 | 10.041 | 3 |
| 15 | 10.734 | ... |

$$\mathbf{observations}_j := \mathbf{histogram}\left(20, \frac{J\_P}{in}\right)_{j,1} \qquad \mathbf{midpoints}_j := \mathbf{histogram}\left(20, \frac{J\_P}{in}\right)_{j,0}$$

# Histogram - January Precipitation

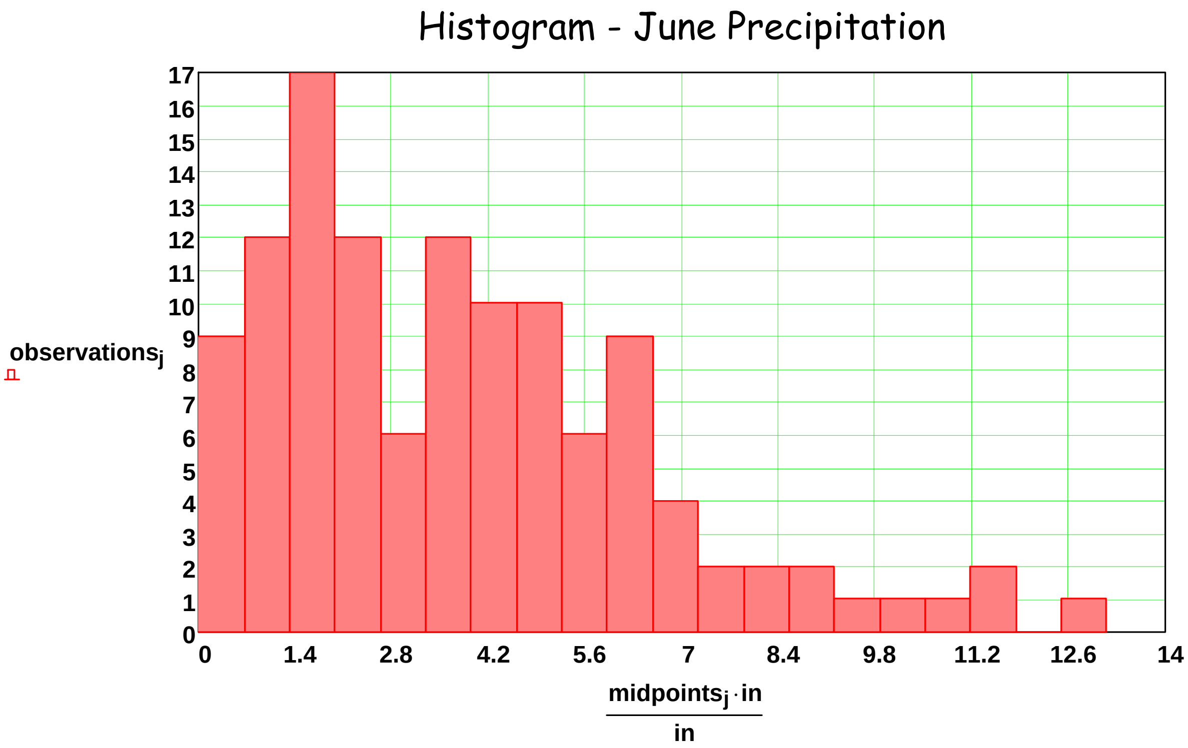


$$\mathbf{Annual\_Precip\_histogram} := \mathbf{histogram}\left(\mathbf{20}, \frac{\mathbf{Ju\_P}}{\mathbf{in}}\right) =$$

| | 0 | 1 |
|---|---|---|
| 0 | 0.329 | 9 |
| 1 | 0.986 | 12 |
| 2 | 1.644 | 17 |
| 3 | 2.301 | 12 |
| 4 | 2.959 | 6 |
| 5 | 3.616 | 12 |
| 6 | 4.274 | 10 |
| 7 | 4.931 | 10 |
| 8 | 5.589 | 6 |
| 9 | 6.246 | 9 |
| 10 | 6.904 | 4 |
| 11 | 7.561 | 2 |
| 12 | 8.219 | 2 |
| 13 | 8.876 | 2 |
| 14 | 9.534 | 1 |
| 15 | 10.191 | ... |

$$\mathbf{observations}_{\mathbf{j}} := \mathbf{histogram}\left(\mathbf{20}, \frac{\mathbf{Ju\_P}}{\mathbf{in}}\right)_{\mathbf{j},\mathbf{1}}$$

$$\mathbf{midpoints}_{\mathbf{j}} := \mathbf{histogram}\left(\mathbf{20}, \frac{\mathbf{Ju\_P}}{\mathbf{in}}\right)_{\mathbf{j},\mathbf{0}}$$




**Both histograms are skewed to the right, meaning that more "higher" values of precipitation are to be expected than would be if the data followed a normal distribution.**

## Summary

**I am not sure if it is possible (at least for me) to make explanatory statements understandable to folks without some background in probability and statistics, sorry.**

**1. The mean and the median of the annual precipitation amounts are very close to each other, this suggests the distribution of annual precipitation amounts is symmetrical.**

**2. Plots of annual precipitation amounts do not show long term trends**

**3. Probability plots of annual precipitation amounts and summer precipitation amounts are shown in the figure labeled "Probability Plot - Rainfall - Monroe 1892 -2009". Using these plots it is possible to determine the probabilty of future rainfall amounts. Examples are given adjacent to the plot.**

**4. The plot labeled "Histogram of Annual Precipitation Values" shows that annual precipitation values can be described by a normal distribution**

**5. The correlation analysis shows that the annual precipitation amounts are not "autocorrelated", that is the precipitation value in the current year does not imply anything about the value to be expected in subsequent years.**

**6. Items 4 and 5 above imply that equations developed for the "Normal Distribution" can be used to predict the probability of future annual precipitation values.**

**7. Based on the analyses above the following statements can be made:**

> **The most likely value of annual precipitation in any future year is 51 inches**
>
> **There is a 50% chance that in any future year the annual precipitation amount will be less than 50 inches**
>
> **Approximately 95% of future annual precipitation values will fall within 2 standard deviations of the mean of the data, approximately 99 % of future annual precipitation values will fall within 3 standard deviations of the mean of the data.**