Handling big datasets for Analyzing long term weather over western India (CSN 1020)

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INTRODUCTION

Objective: Handling and analyzing various large datasets for long term weather analysis over western India specifically Jaipur

Duration of the Project: 3 Months

Tools Used: MATLAB, Panoply

DATASETS USED

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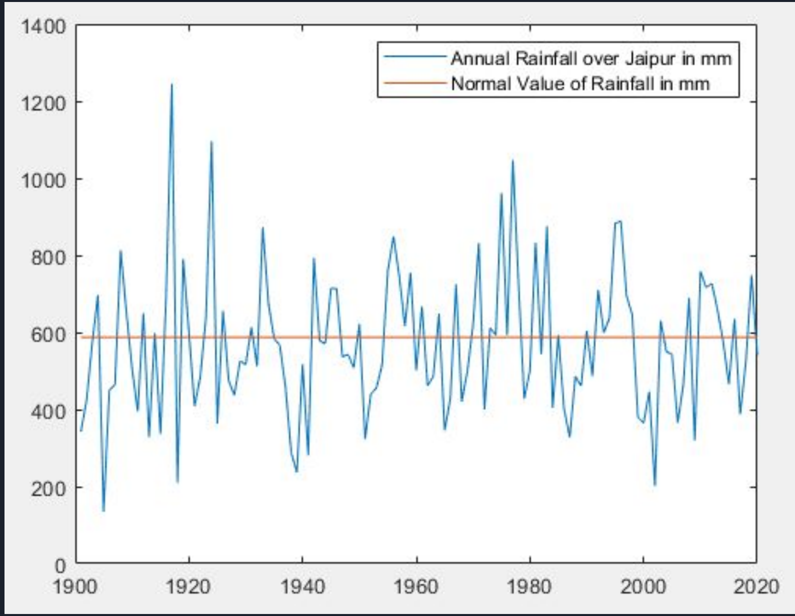
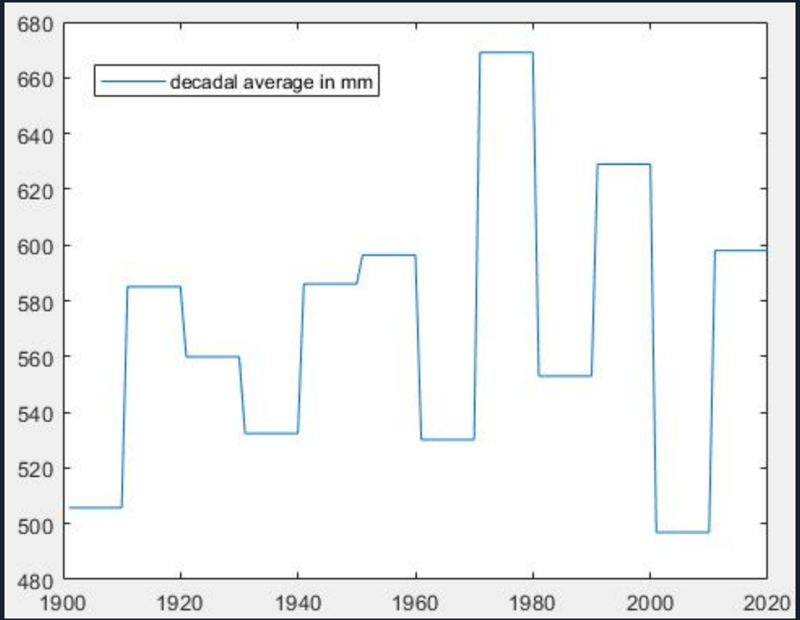
- WRIS annual ground based observation for rainfall
- ICRISAT data for irrigated land
- WRIS monthly ground based observation for rainfall
- Evapotranspiration data from FLDAS, Giovanni (Model Data)
- Soil Temperature data from MERRA-2, Giovanni (Model Data)
- Total Ground Precipitation monthly data from MERRA-2, Giovanni (Model Data)
- Total surface Precipitation monthly data from AIRS-SSMI, Giovanni (Satellite Data)
- Air Temperature time averaged data from MERRA-2, Giovanni (Model Data)
- Precipitation time averaged data from TRMM, Giovanni (Satellite Data)

OBSERVATIONS AND RESULTS

1. Rainfall Analysis Over Jaipur using WRIS data



Annual trend of rainfall in mm and its average



Converted it into decadal average for better analysis.

2. Rainfall And Irrigated Land

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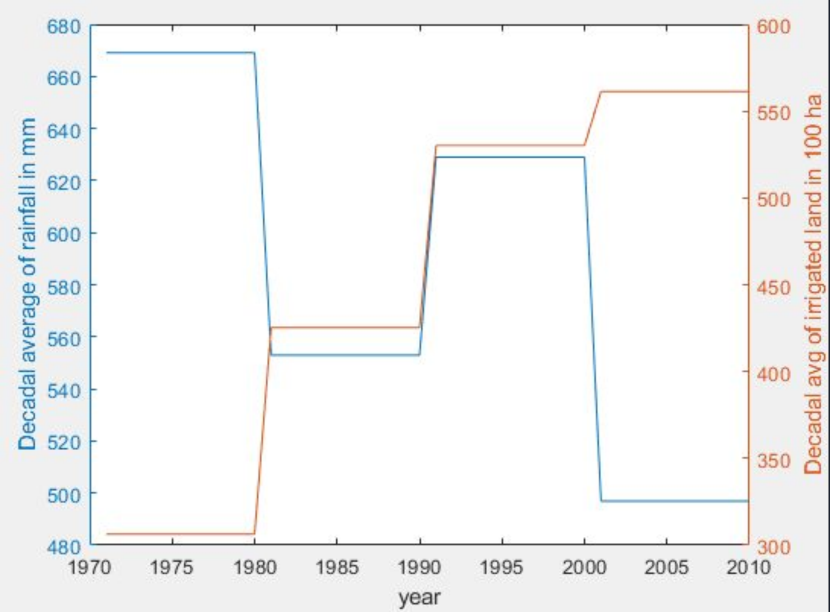
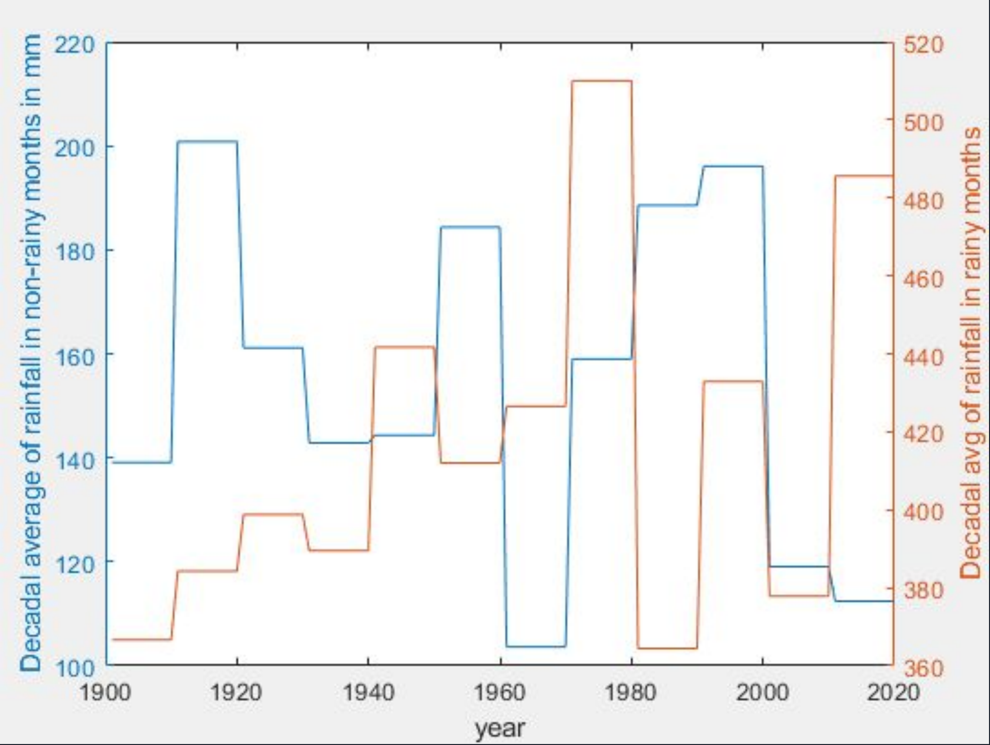


This is a plot for decadal average of Rainfall(in mm) and Irrigated land(in 100ha) in Jaipur over the years.

Interestingly, this graph has a correlation coefficient(R)=-0.6611
This suggests that they are anti-correlated.

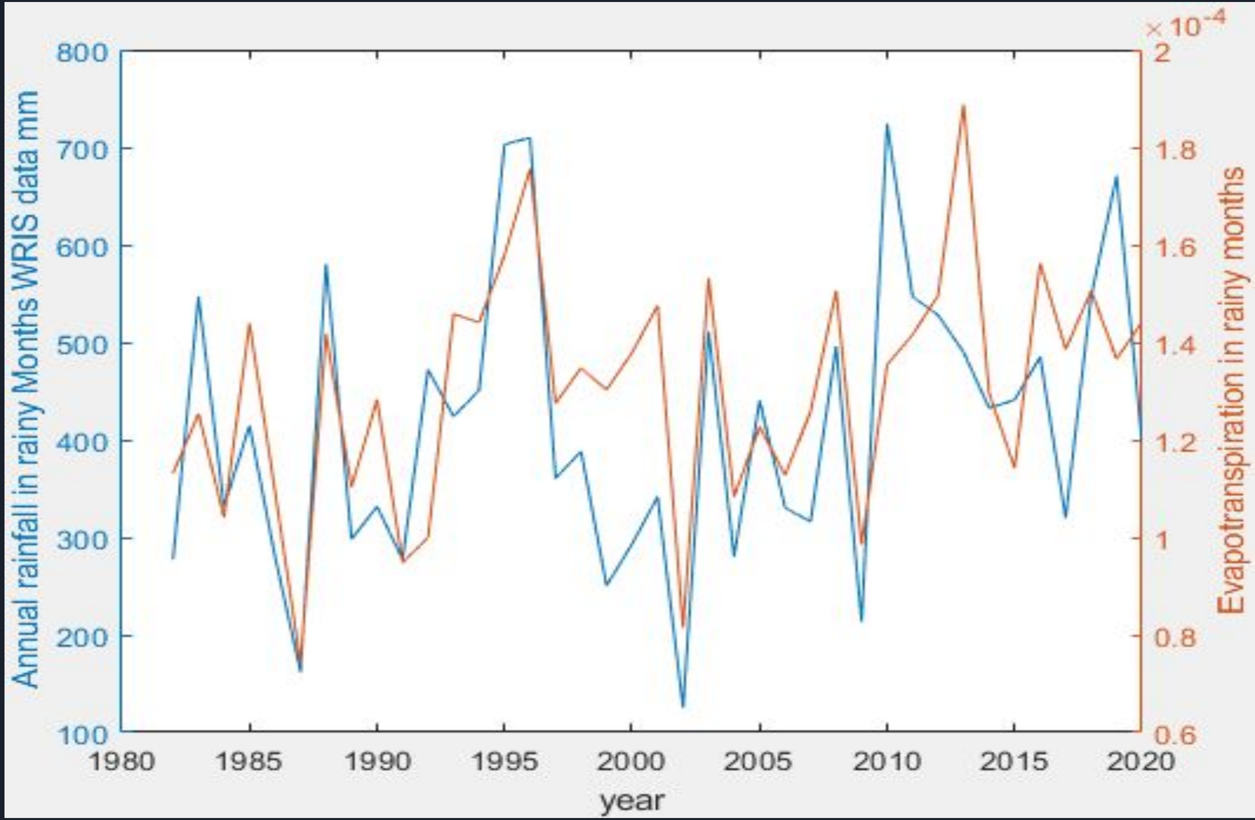
3. SEASONAL ANALYSIS OF RAINFALL IN JAIPUR



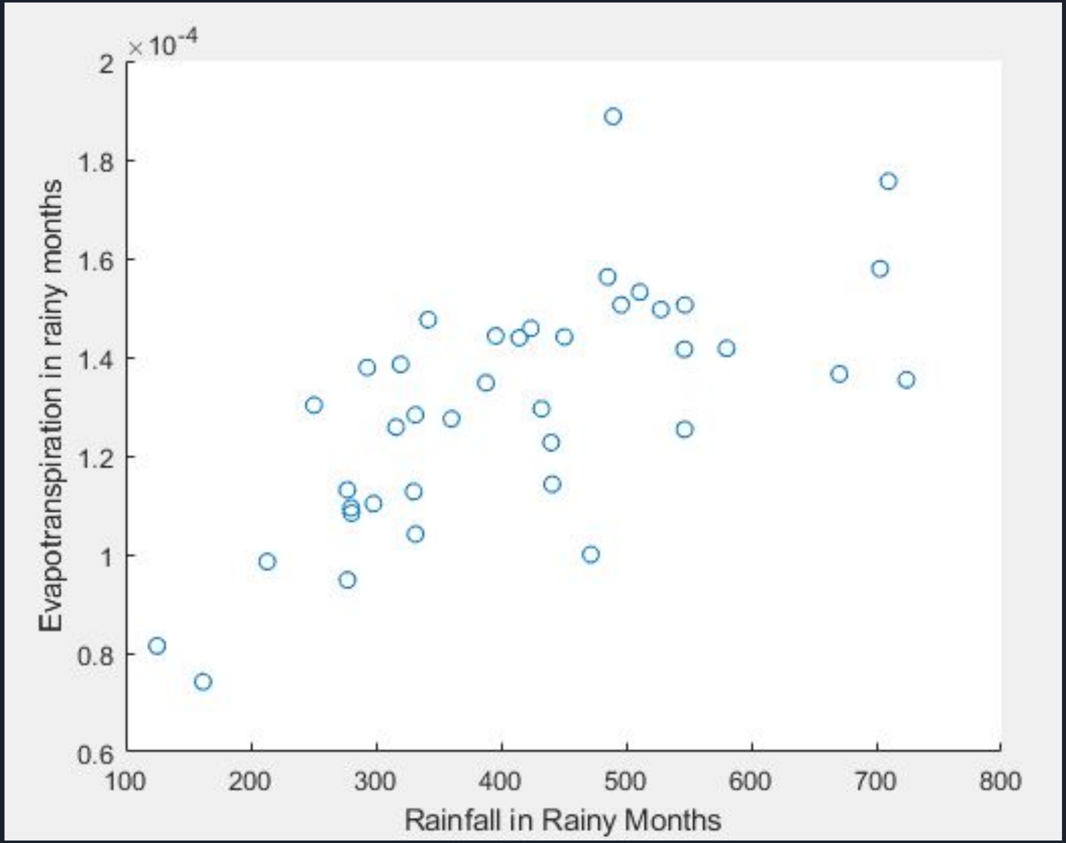
WRIS annual and monthly rainfall data (1900-2020), ICRISAT data for irrigated Land used

This is the decadal average of rainfall (in mm) for rainy and non-rainy months.
Here months from June to September are referred to as rainy and the rest of the months as non-rainy.
This graph had a R=-0.2167

4. Rainfall and Evapotranspiration for Jaipur



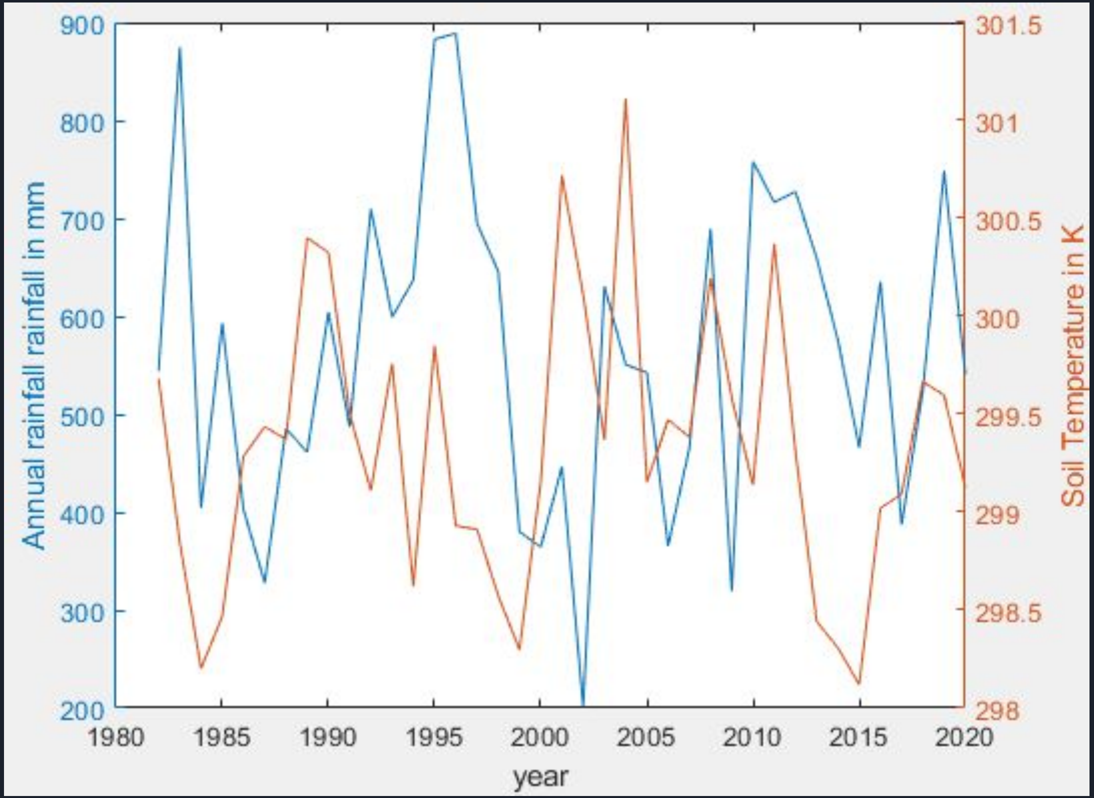
Evapotranspiration data from FLDAS model, Giovanni in Kg/m^2/s and WRIS data used for rainfall



R=0.6819

The R value and the Scatter plot suggest that their is a decent positive correlation between the Rainfall and Evapotranspiration.

5. Soil Temperature and Rainfall in Jaipur



The soil Temperature data has been obtained in K from MERRA-2 model at Giovanni and the WRIS data for rainfall has been used.

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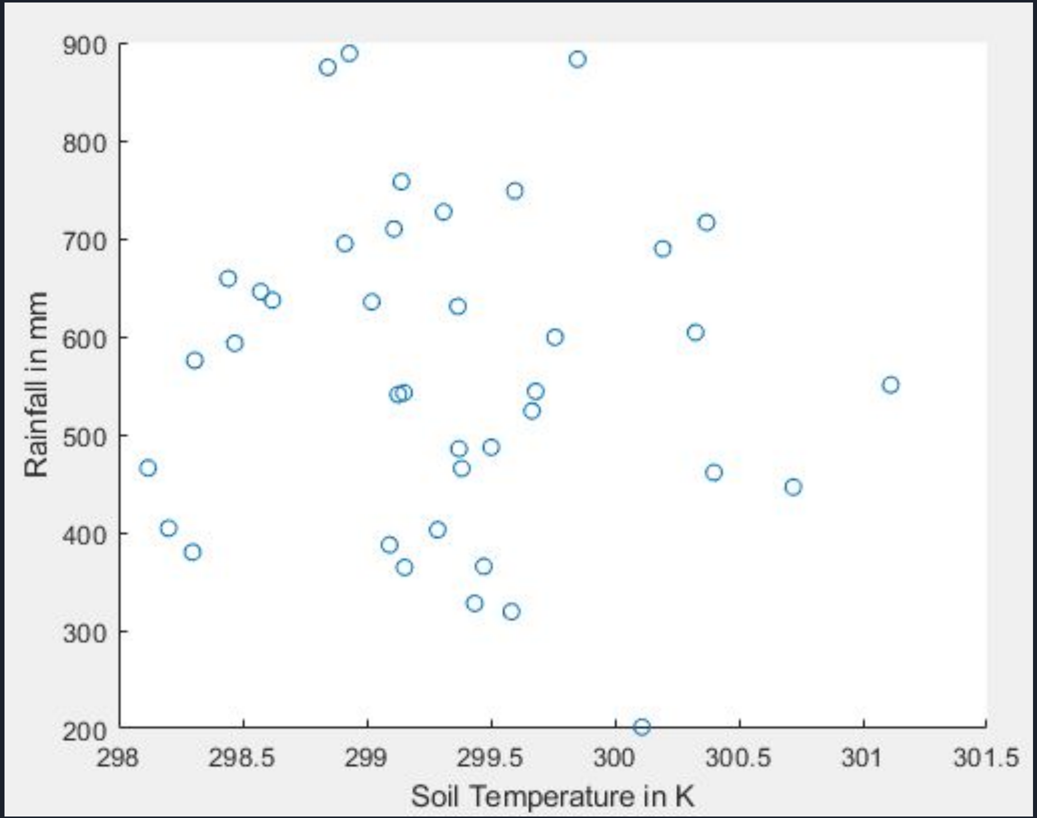
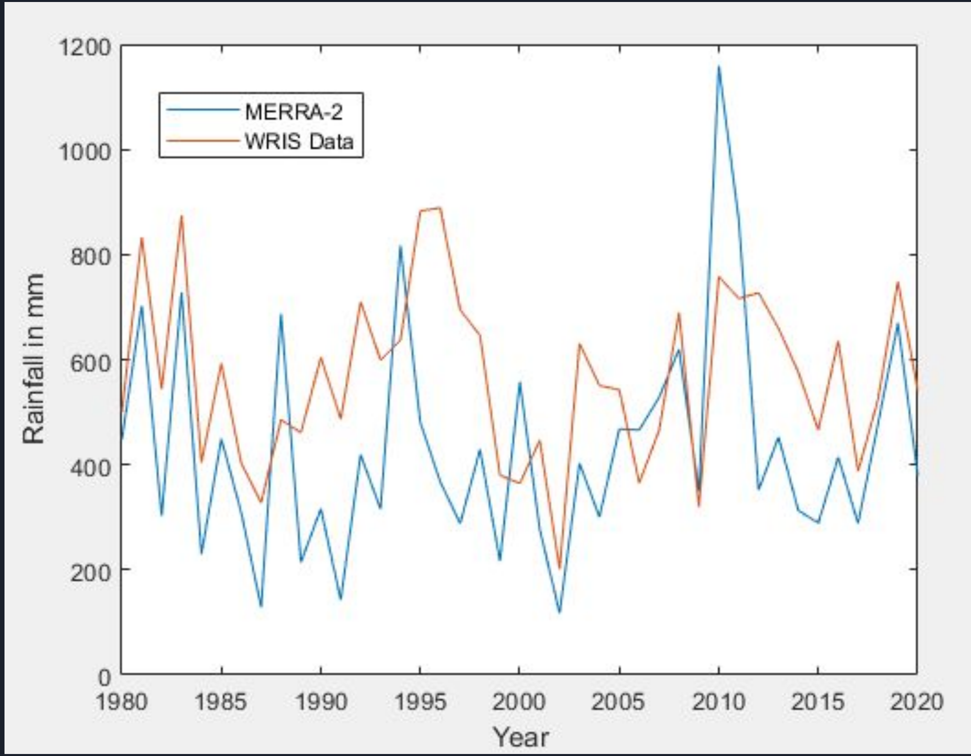


R Value= -0.06

Here, the negative correlation suggests that rainfall decreased with an increase in temperature but the dependence is very weak.

6. Model Analysis of Rainfall Data

(WRIS data vs MERRA-2 data)

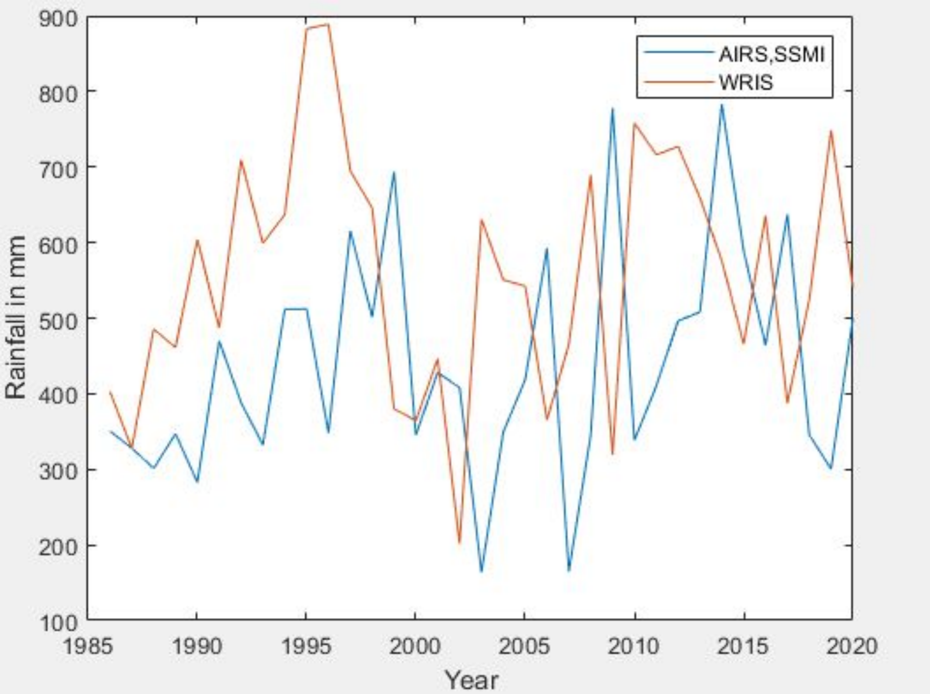


R= 0.5367

The positive correlation coefficient implies that MERRA-2 is satisfactorily consistent with the ground observation of WRIS data.

7. Satellite Data vs Ground Rainfall Data

(AIRS SSMI observation vs WRIS data)



R Value: 0.678

Again here we observe a decent positive correlation between AIRS, SSMI observations and the WRIS data.

8. Standardized Precipitation Index(SPI) and Droughts

SPI = (X – Xm)/ σ

Where X is precipitation for the station, Xm is mean precipitation and is standardized deviation.

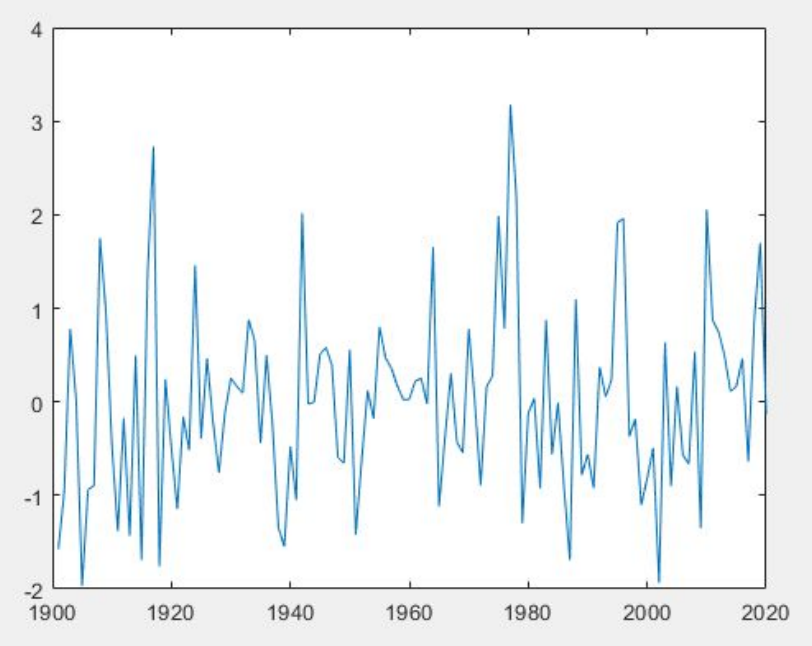
SPI can be a very useful tool to analyse drought frequency in a particular region.

Table 1. SPI drought classes

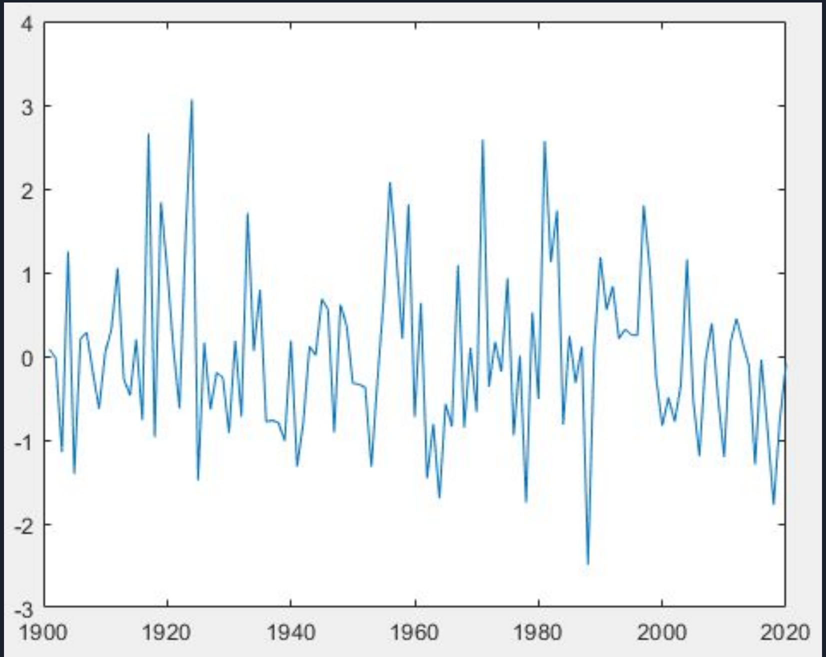
S. No	Criteria of SPI values	Type of drought
1.	0.00 to -0.99	Mild drought
2	-1.0 to - 1.49	Moderate drought
3.	-1.5 to -1.99	Severe drought
4.	-2 and less	Extreme drought
5.	More than 0	Above normal drought

Reference from paper by: MUNDETIA N. and SHARMA D. , 2014

SPI Analysis for Jaipur using WRIS data

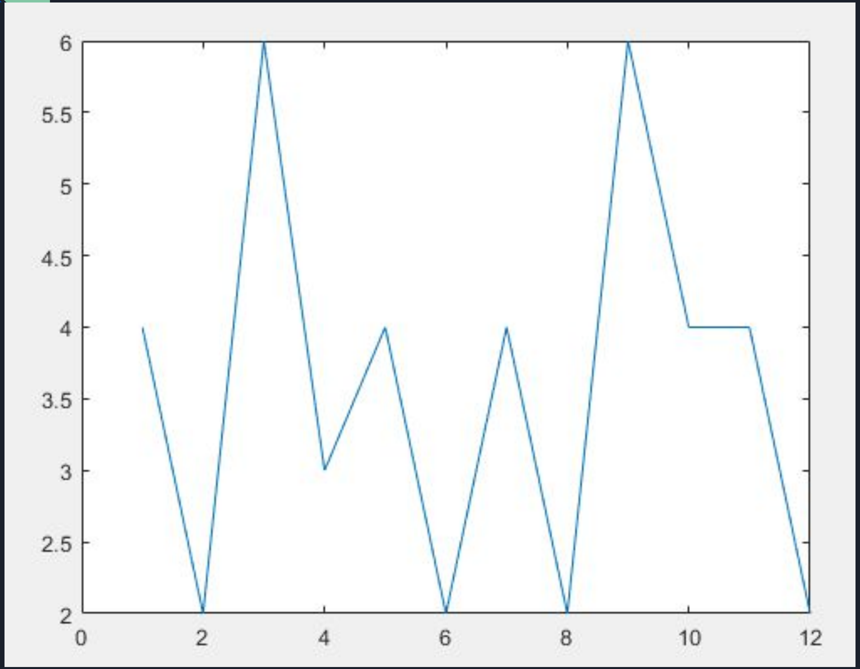


Annual SPI for Rainy Months

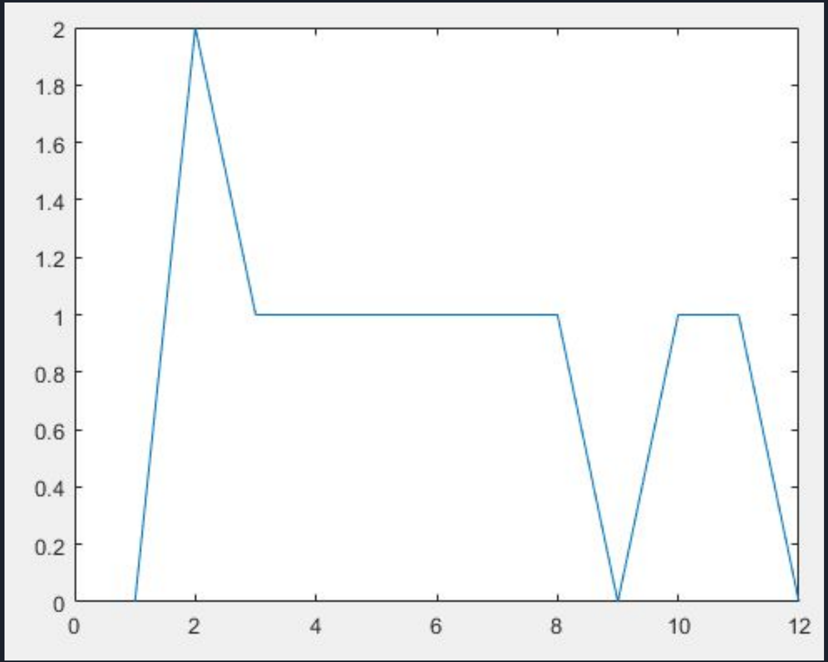


Annual SPI for non-rainy Months

Drought Analysis using SPI for Jaipur

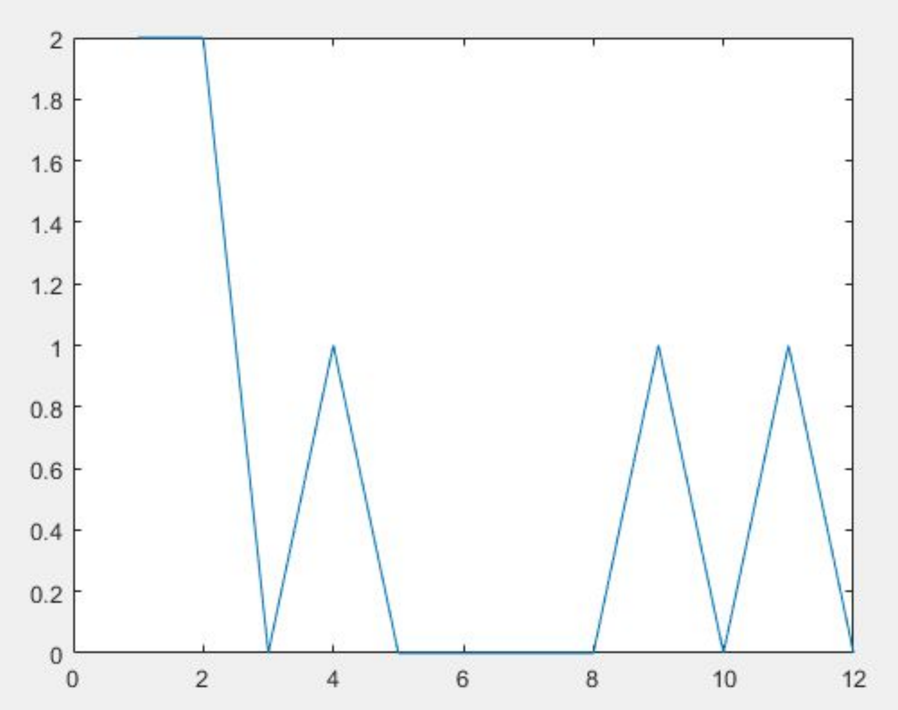


No. of mild droughts in each decade



No. of moderate droughts in each decade

Drought Analysis using SPI for Jaipur



No. of Severe droughts in each decade

Total Number of Mild Droughts: 43

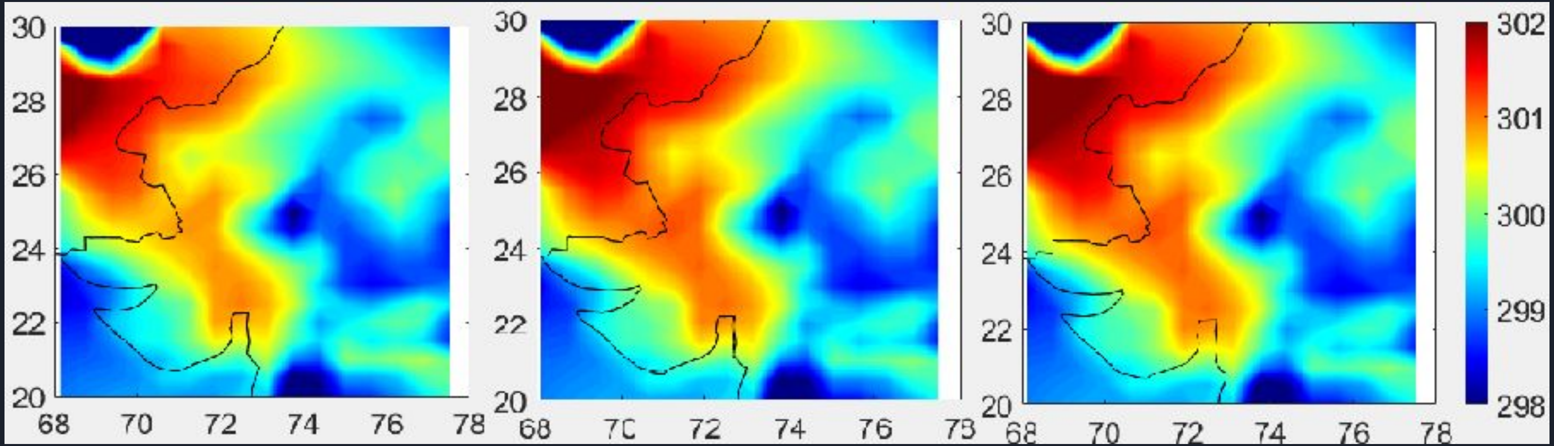
Total number of Moderate Droughts: 10

Total number of Severe Droughts:7

Total number of Extreme and above Normal Droughts: 0

9. Decadal Contour plots over Western India

A. <u>Air Temperature Trend (in K) from MERRA-2 model:</u>

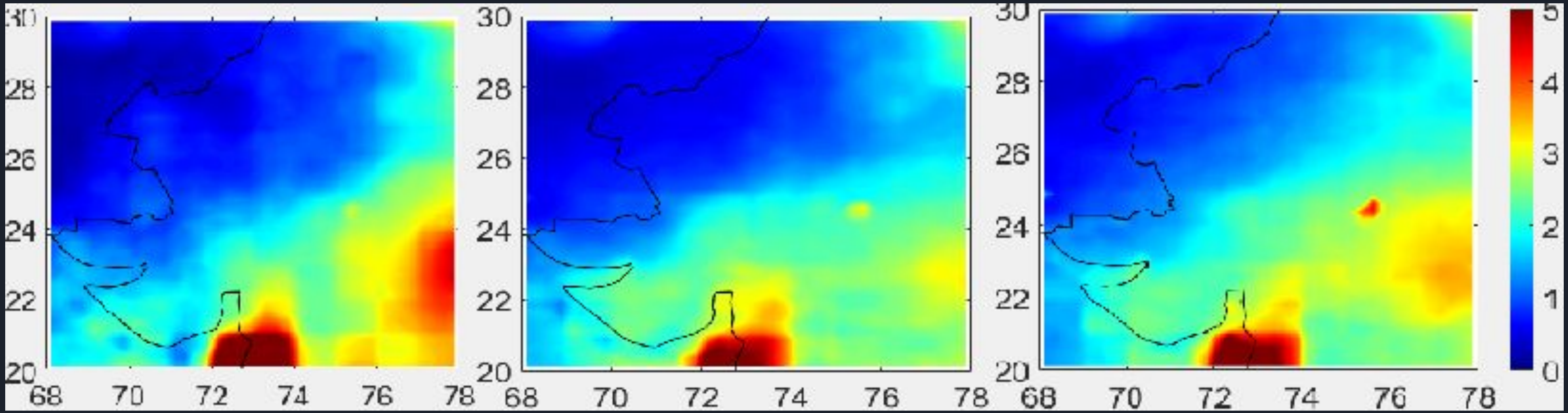


1980-1990 1990-2000 2000-2010

Here, we can clearly see that the Air Temperature is increasing over most of the parts of Western India with time.

9. Decadal Contour plots over Western India

B. Precipitation Over Western India (in mm/day) from TRMM data:



1990-2000 2000-2010 2010-2020

Here we observed something interesting, i.e. Rainfall first decreased from (1990-2000 decade) to (2000-2010) and then again increased in (2010-2020) decade.

Mathematical Analysis

There are two mathematical tests which we will perform to determine the significance of trends which we observed.

1) Mann- Kendall's Test
2) Sen's Slope Test

In this project I have performed both the tests for Annual Rainfall trend for Jaipur

Resources:

Sen's Slope Estimation,

Mann Kendall's test

Mann Kendall's Test

The purpose of the Mann-Kendall (MK) test is to statistically assess if there is a monotonic upward or downward trend of the variable of interest over time. A monotonic upward (downward) trend means that the variable consistently increases (decreases) through time, but the trend may or may not be linear. The MK test can be used in place of a parametric linear regression analysis

$$S = \sum_{k-1}^{n-1} \sum_{j-k+1}^{n} \operatorname{sgn}(x_j - x_k) \quad (1)$$

$$\mathrm{VAR}(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p-1}^{g} t_p(t_p-1)(2t_p+5)\right] \quad (2)$$

Mann- Kendall's test (contd.)

$$Z_{MK} = \frac{S-1}{\sqrt{VAR(S)}} \text{ if } S > 0$$

$$= 0 \text{ if } S = 0$$

$$= \frac{S+1}{\sqrt{VAR(S)}} \text{ if } S < 0 \qquad (3)$$

A positive (negative) value of Z_{MK} indicates that the data tend to increase (decrease) with time.

Significance of a trend

Normal Distribution table

Z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.50000	.50399	.50798	.51197	.51595	.51994	.52392	.52790	.53188	.53586
0.1	.53983	.54380	.54776	.55172	.55567	.55962	.56356	.56749	.57142	.57535
0.2	.57926	.58317	.58706	.59095	.59483	.59871	.60257	.60642	.61026	.61409
0.3	.61791	.62172	.62552	.62930	.63307	.63683	.64058	.64431	.64803	.65173
0.4	.65542	.65910	.66276	.66640	.67003	.67364	.67724	.68082	.68439	.68793
0.5	.69146	.69497	.69847	.70194	.70540	.70884	.71226	.71566	.71904	.72240
0.6	.72575	.72907	.73237	.73565	.73891	.74215	.74537	.74857	.75175	.75490
0.7	.75804	.76115	.76424	.76730	.77035	.77337	.77637	.77935	.78230	.78524
0.8	.78814	.79103	.79389	.79673	.79955	.80234	.80511	.80785	.81057	.81327
0.9	.81594	.81859	.82121	.82381	.82639	.82894	.83147	.83398	.83646	.83891
1.0	.84134	.84375	.84614	.84849	.85083	.85314	.85543	.85769	.85993	.86214
1.1	.86433	.86650	.86864	.87076	.87286	.87493	.87698	.87900	.88100	.88298
1.2	.88493	.88686	.88877	.89065	.89251	.89435	.89617	.89796	.89973	.90147
1.3	.90320	.90490	.90658	.90824	.90988	.91149	.91309	.91466	.91621	.91774
1.4	.91924	.92073	.92220	.92364	.92507	.92647	.92785	.92922	.93056	.93189
1.5	.93319	.93448	.93574	.93699	.93822	.93943	.94062	.94179	.94295	.94408
1.6	.94520	.94630	.94738	.94845	.94950	.95053	.95154	.95254	.95352	.95449
1.7	.95543	.95637	.95728	.95818	.95907	.95994	.96080	.96164	.96246	.96327
1.8	.96407	.96485	.96562	.96638	.96712	.96784	.96856	.96926	.96995	.97062
1.9	.97128	.97193	.97257	.97320	.97381	.97441	.97500	.97558	.97615	.97670
2.0	.97725	.97778	.97831	.97882	.97932	.97982	.98030	.98077	.98124	.98169
2.1	.98214	.98257	.98300	.98341	.98382	.98422	.98461	.98500	.98537	.98574
2.2	.98610	.98645	.98679	.98713	.98745	.98778	.98809	.98840	.98870	.98899
2.3	.98928	.98956	.98983	.99010	.99036	.99061	.99086	.99111	.99134	.99158
2.4	.99180	.99202	.99224	.99245	.99266	.99286	.99305	.99324	.99343	.99361
2.5	.99379	.99396	.99413	.99430	.99446	.99461	.99477	.99492	.99506	.99520
2.6	.99534	.99547	.99560	.99573	.99585	.99598	.99609	.99621	.99632	.99643
2.7	.99653	.99664	.99674	.99683	.99693	.99702	.99711	.99720	.99728	.99736
2.8	.99744	.99752	.99760	.99767	.99774	.99781	.99788	.99795	.99801	.99807
2.9	.99813	.99819	.99825	.99831	.99836	.99841	.99846	.99851	.99856	.99861
3.0	.99865	.99869	.99874	.99878	.99882	.99886	.99889	.99893	.99896	.99900
3.1	.99903	.99906	.99910	.99913	.99916	.99918	.99921	.99924	.99926	.99929
3.2	.99931	.99934	.99936	.99938	.99940	.99942	.99944	.99946	.99948	.99950
3.3	.99952	.99953	.99955	.99957	.99958	.99960	.99961	.99962	.99964	.99965
3.4	.99966	.99968	.99969	.99970	.99971	.99972	.99973	.99974	.99975	.99976
3.5	.99977	.99978	.99978	.99979	.99980	.99981	.99981	.99982	.99983	.99983
3.6	.99984	.99985	.99985	.99986	.99986	.99987	.99987	.99988	.99988	.99989
3.7	.99989	.99990	.99990	.99990	.99991	.99991	.99992	.99992	.99992	.99992
3.8	.99993	.99993	.99993	.99994	.99994	.99994	.99994	.99995	.99995	.99995
3.9	.99995	.99995	.99996	.99996	.99996	.99996	.99996	.99996	.99997	.99997

Mann Kendall test for rainfall data

A) **Mann Kendall's test for annual Rainfall Data(n=120 years):**

For complete 120 years: S= 414

Number of tied groups=0

Therefore, Zmk= 0.9368

For confidence interval, let α= 0.05 (95% confidence interval)

Here α represents the level of significance

This corresponds to Z value of 1.65

Since Z>Zmk: for the 120 year interval, trend isn't significant.

Mann Kendall test for rainfall data

B) For last 40 year interval (1980-2020):

S=6

Zmk= 0.0583

Z>Zmk: Trend is not Significant

C) For last 20 year interval (2000-2020):

S= 52

Zmk= 1.6546

Zmk>Z: Therefore we can say with 95% confidence that there is an increasing trend.

2) Sen's Slope Test

A measurement is obtained at *n* points in time; $t1,t2,...,tn$

at a specified location.

Compute the $N=n(n-1)/2$ slope estimates

$$Q=(yj-yk) / (tj-tk)$$

The non-parametric slope for the curve would be the median of these values.

Nonparametric Intercept, $\hat{\beta}_o$, of the Linear Trend

$$\hat{\beta}_o = y_{MED} - \hat{\beta}_1 \times t_{MED} \quad (9)$$

where

y_{MED} = median of the n measurements $y_1, y_2, \ldots, y_n$

t_{MED} = median of the n times $t_1, t_2, \ldots, t_n$

and

$\hat{\beta}_1$ = nonparametric slope estimate.

Intercept and Slope Values

i) **For 120 years:**

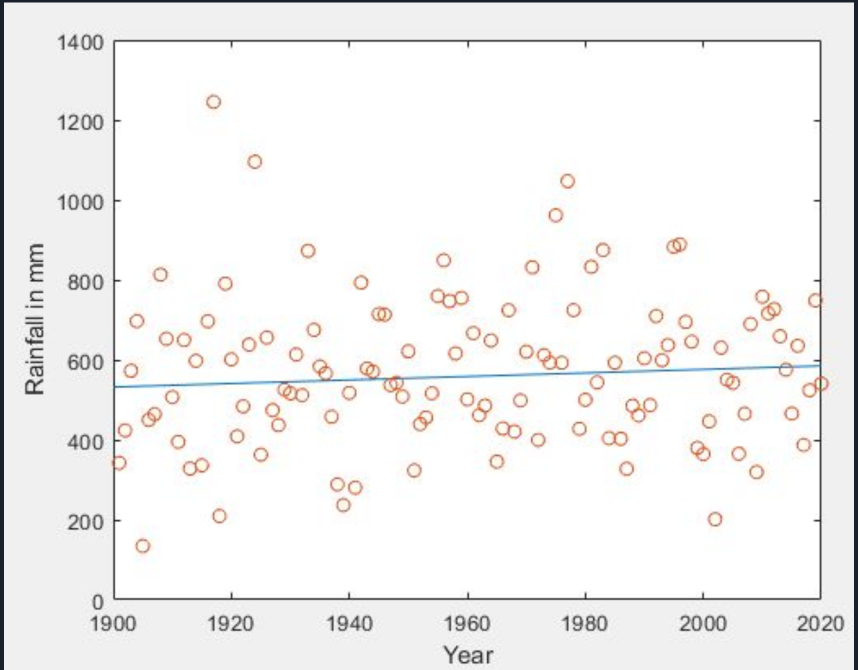
Non parametric slope= 0.4402

Ymed= 558.57

Tmed= 60

Therefore, the intercept= 532.158

```
Q=[];
count=1;
for i=1:119
    for j=i+1:120
        Q(count)= (ACTUALmm(j)-ACTUALmm(i))/(j-i);
        count=count+1;
    end
end
m= median(Q);
disp(m);
```



Intercept and Slope Values

ii) For last 40 years:

Years 1980-2020:

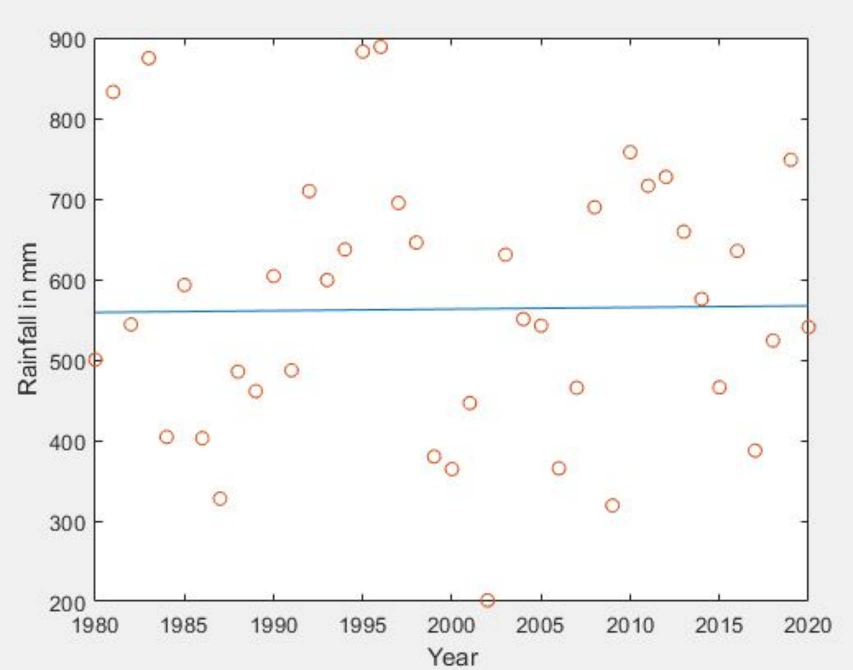
Non parametric slope= 0.2069

Ymed= 563.13

Tmed= 100

Therefore, the intercept= 542.44

```
Q=[];
count=1;
for i=81:119
    for j=i+1:120
        Q(count)= (ACTUALmm(j)-ACTUALmm(i))/(j-i);
        count=count+1;
    end
end
m= median(Q);
disp(m);
```



Intercept and Slope Values

iii) Last 20 years:

Years 1980-2020:

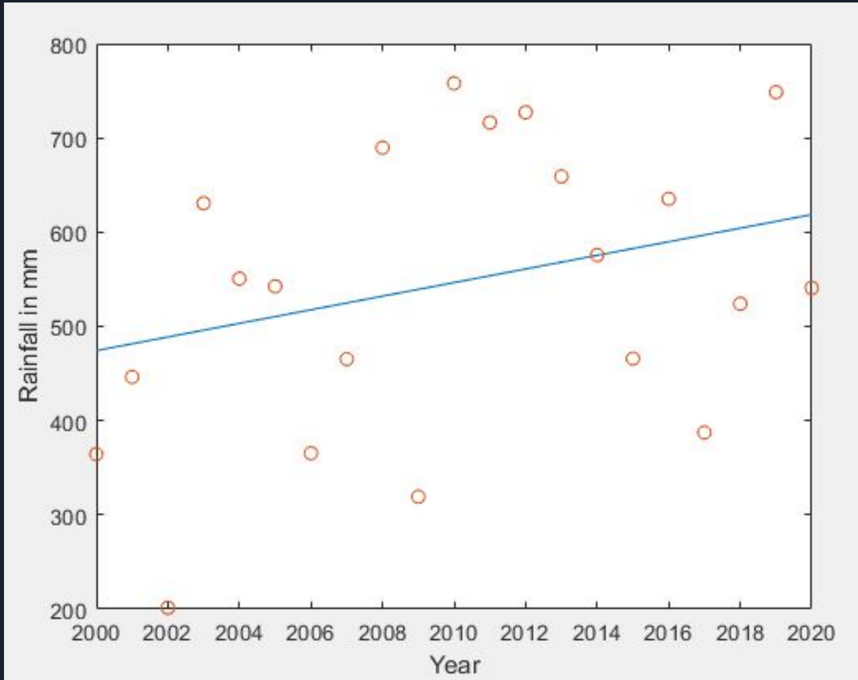
Non parametric slope= 7.2169

Ymed= 546.5700

Tmed= 110

Therefore, the intercept= 483.13

```
Q=[];
count=1;
for i=101:119
    for j=i+1:120
        Q(count)= (ACTUALmm(j)-ACTUALmm(i))/(j-i);
        count=count+1;
    end
end
m= median(Q);
disp(m);
```



CONCLUSION

This project made us handle a variety of datasets using matlab,panoply and many other tools. We applied a number of data analysis techniques and obtained a number of different types of plots. We handled various types of datasets(eg ground data, satellite data, model data etc.), gathered data from various file formats(csv,netcdf etc.) and made use of tools like MATLAB and Panoply.

RESOURCES

- https://indiawris.gov.in/wris/#/rainfall
- http://data.icrisat.org/dld/src/visualization.html
- https://giovanni.gsfc.nasa.gov/giovanni
- https://www.downtoearth.org.in/news/climate-change/irrigation-does-more-than-deplete-groundwater-it-changes-climate-too-68858
- https://journal.gnest.org/sites/default/files/Submissions/gnest_01379/gnest_01379_published.pdf


THANK
YOU