Data Visualization – CSE 3020

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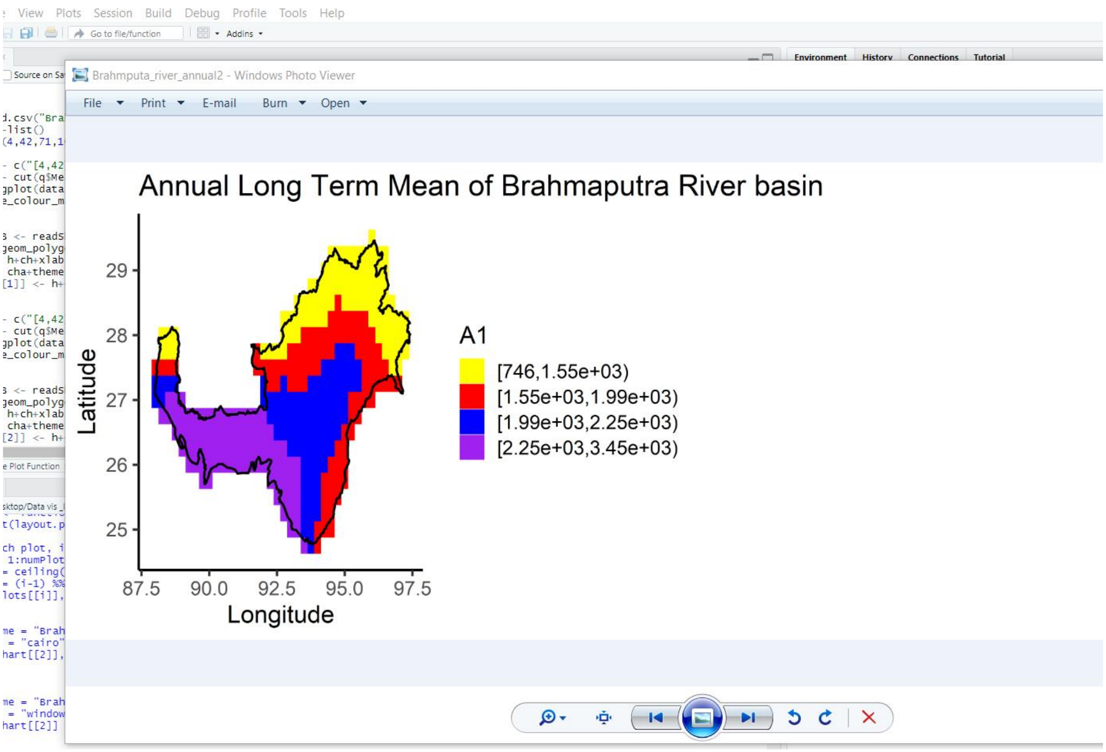
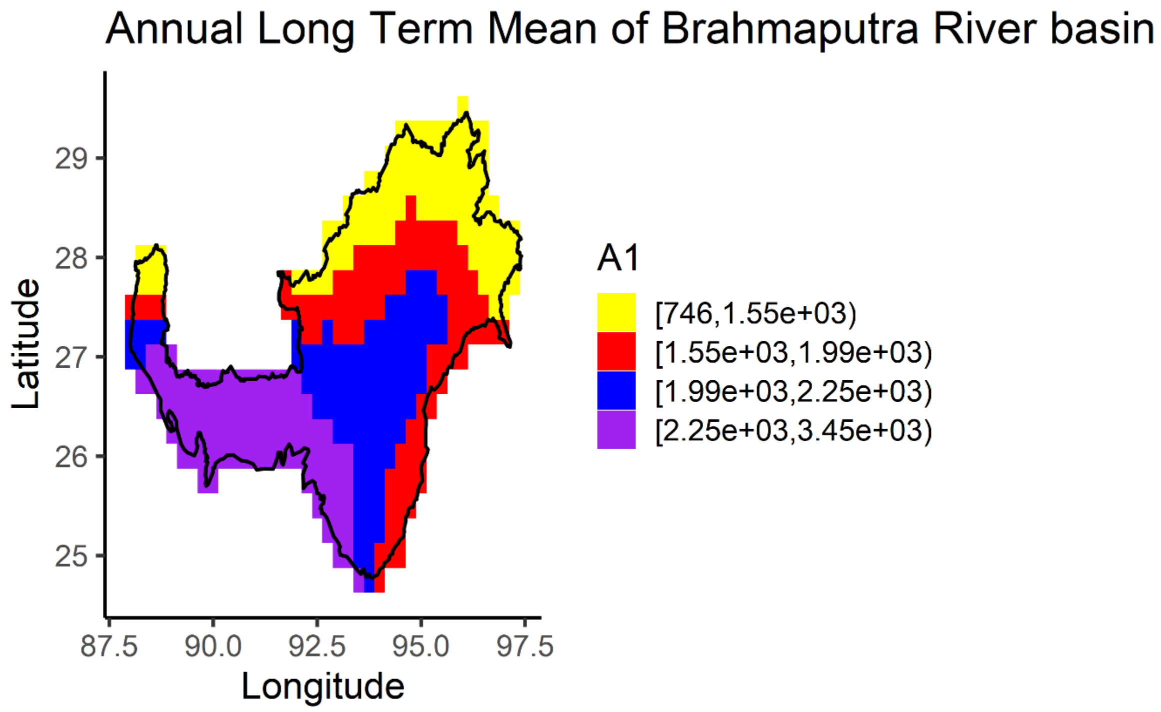
1. Brahmaputra River basin data

Q1. Calculate long term mean in each of grid. Map the derived result into geographical structure with suitable color palettes.

Geographical Structure for Long Term Annual Mean from 1901-2015:





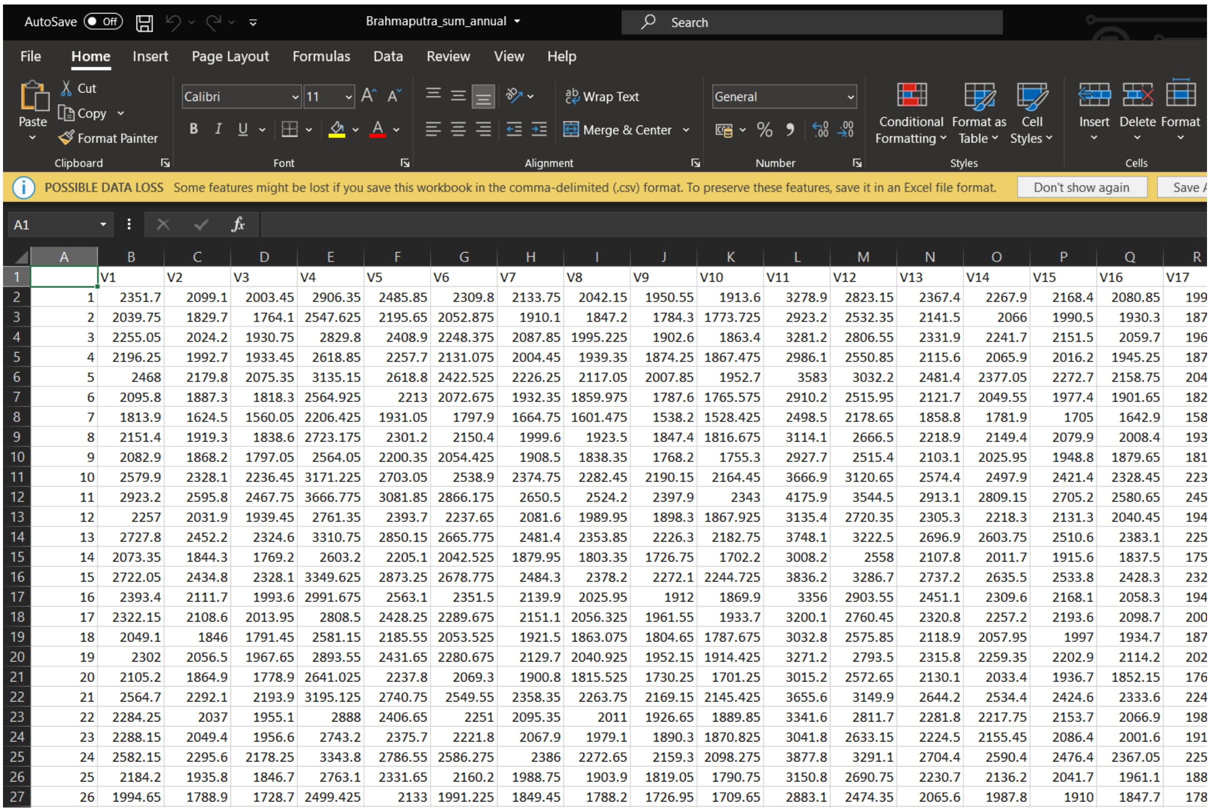
INFERENCES:

- From the plot and the associated data (screenshots provided below) we have visual representation of the Annual Long Term Mean of Rainfall in the Brahmaputra River basin from the year 1901 to 2015.
- The plot is filled by colours separated by a range of values from min to quartile 1 to median to quartile 3 and max value. We have 4 subsequent colour ranges.
- From the above plot we can infer that the northern part of the Brahmaputra River basin receives the least rainfall (between 746-1550).
- As we move south, the rainfall generally becomes sequentially heavier.
- The eastern border receives rainfall in the red range(1550 to1990)
- The southern-eastern region receives the highest average annual rainfall and it falls in the purple band (2250-3450)
- The interior region receives the 2nd highest rainfall In the blue band (1990 to 2250)
- From the data we have calculated, Min avg annual rainfall =746.12 ; Quartile 1= 1553 ; Median =1989.987 ; Quartile 3= 2247.146 Max value= 3349.344

- There is a general trend in average annual rainfall in which the further south the more rainfall in the Brahmaputra river basin.

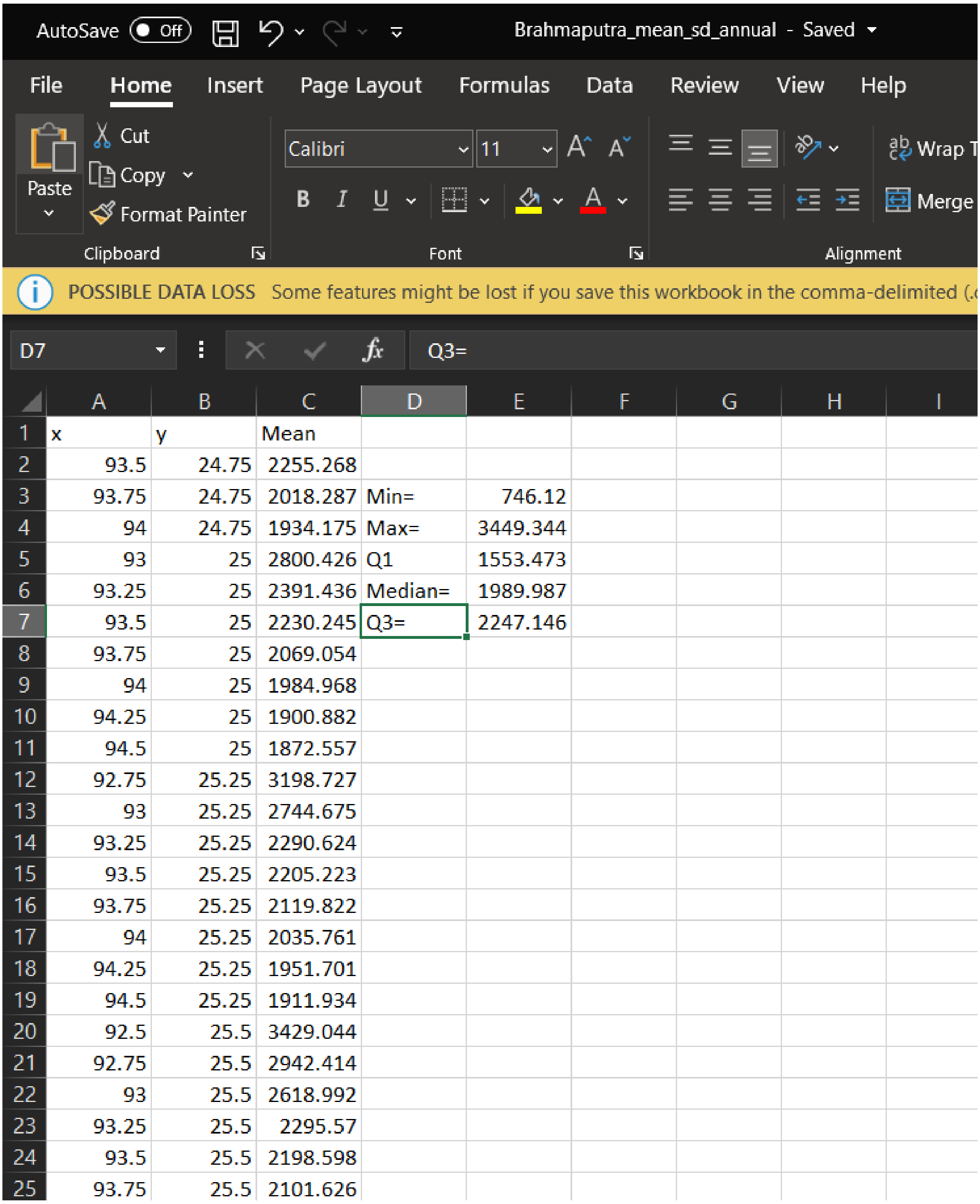
Data from CSV screenshots:

1. Sum of Annual Rainfall per year for each grid



	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	2351.7	2099.1	2003.45	2906.35	2485.85	2309.8	2133.75	2042.15	1950.55	1913.6	3278.9	2823.15	2367.4	2267.9	2168.4	2080.85	199
2	2039.75	1829.7	1764.1	2547.625	2195.65	2052.875	1910.1	1847.2	1784.3	1773.725	2923.2	2532.35	2141.5	2066	1990.5	1930.3	187
3	2255.05	2024.2	1930.75	2829.8	2408.9	2248.375	2087.85	1995.225	1902.6	1863.4	3281.2	2806.55	2331.9	2241.7	2151.5	2059.7	196
4	2196.25	1992.7	1933.45	2618.85	2257.7	2131.075	2004.45	1939.35	1874.25	1867.475	2986.1	2550.85	2115.6	2065.9	2016.2	1945.25	187
5	2468	2179.8	2075.35	3135.15	2618.8	2422.525	2226.25	2117.05	2007.85	1952.7	3583	3032.2	2481.4	2377.05	2272.7	2158.75	204
6	2095.8	1887.3	1818.3	2564.925	2213	2072.675	1932.35	1859.975	1787.6	1765.575	2910.2	2515.95	2121.7	2049.55	1977.4	1901.65	182
7	1813.9	1624.5	1560.05	2206.425	1931.05	1797.9	1664.75	1601.475	1538.2	1528.425	2498.5	2178.65	1858.8	1781.9	1705	1642.9	158
8	2151.4	1919.3	1838.6	2723.175	2301.2	2150.4	1999.6	1923.5	1847.4	1816.675	3114.1	2666.5	2218.9	2149.4	2079.9	2008.4	193
9	2082.9	1868.2	1797.05	2564.05	2200.35	2054.425	1908.5	1838.35	1768.2	1755.3	2927.7	2515.4	2103.1	2025.95	1948.8	1879.65	181
10	2579.9	2328.1	2236.45	3171.225	2703.05	2538.9	2374.75	2282.45	2190.15	2164.45	3666.9	3120.65	2574.4	2497.9	2421.4	2328.45	223
11	2923.2	2595.8	2467.75	3666.775	3081.85	2866.175	2650.5	2524.2	2397.9	2343	4175.9	3544.5	2913.1	2809.15	2705.2	2580.65	245
12	2257	2031.9	1939.45	2761.35	2393.7	2237.65	2081.6	1989.95	1898.3	1867.925	3135.4	2720.35	2305.3	2218.3	2131.3	2040.45	194
13	2727.8	2452.2	2324.6	3310.75	2850.15	2665.775	2481.4	2353.85	2226.3	2182.75	3748.1	3222.5	2696.9	2603.75	2510.6	2383.1	225
14	2073.35	1844.3	1769.2	2603.2	2205.1	2042.525	1879.95	1803.35	1726.75	1702.2	3008.2	2558	2107.8	2011.7	1915.6	1837.5	175
15	2722.05	2434.8	2328.1	3349.625	2873.25	2678.775	2484.3	2378.2	2272.1	2244.725	3836.2	3286.7	2737.2	2635.5	2533.8	2428.3	232
16	2393.4	2111.7	1993.6	2991.675	2563.1	2351.5	2139.9	2025.95	1912	1869.9	3356	2903.55	2451.1	2309.6	2168.1	2058.3	194
17	2322.15	2108.6	2013.95	2808.5	2428.25	2289.675	2151.1	2056.325	1961.55	1933.7	3200.1	2760.45	2320.8	2257.2	2193.6	2098.7	200
18	2049.1	1846	1791.45	2581.15	2185.55	2053.525	1921.5	1863.075	1804.65	1787.675	3032.8	2575.85	2118.9	2057.95	1997	1934.7	187
19	2302	2056.5	1967.65	2893.55	2431.65	2280.675	2129.7	2040.925	1952.15	1914.425	3271.2	2793.5	2315.8	2259.35	2202.9	2114.2	202
20	2105.2	1864.9	1778.9	2641.025	2237.8	2069.3	1900.8	1815.525	1730.25	1701.25	3015.2	2572.65	2130.1	2033.4	1936.7	1852.15	176
21	2564.7	2292.1	2193.9	3195.125	2740.75	2549.55	2358.35	2263.75	2169.15	2145.425	3655.6	3149.9	2644.2	2534.4	2424.6	2333.6	224
22	2284.25	2037	1955.1	2888	2406.65	2251	2095.35	2011	1926.65	1889.85	3341.6	2811.7	2281.8	2217.75	2153.7	2066.9	198
23	2288.15	2049.4	1956.6	2743.2	2375.7	2221.8	2067.9	1979.1	1890.3	1870.825	3041.8	2633.15	2224.5	2155.45	2086.4	2001.6	191
24	2582.15	2295.6	2178.25	3343.8	2786.55	2586.275	2386	2272.65	2159.3	2098.275	3877.8	3291.1	2704.4	2590.4	2476.4	2367.05	225
25	2184.2	1935.8	1846.7	2763.1	2331.65	2160.2	1988.75	1903.9	1819.05	1790.75	3150.8	2690.75	2230.7	2136.2	2041.7	1961.1	188
26	1994.65	1788.9	1728.7	2499.425	2133	1991.225	1849.45	1788.2	1726.95	1709.65	2883.1	2474.35	2065.6	1987.8	1910	1847.7	178

2. Annual Rainfall Avg per grid



	A	B	C	D	E	F	G	H	I
1	x	y	Mean						
2	93.5	24.75	2255.268						
3	93.75	24.75	2018.287	Min=	746.12				
4	94	24.75	1934.175	Max=	3449.344				
5	93	25	2800.426	Q1	1553.473				
6	93.25	25	2391.436	Median=	1989.987				
7	93.5	25	2230.245	Q3=	2247.146				
8	93.75	25	2069.054						
9	94	25	1984.968						
10	94.25	25	1900.882						
11	94.5	25	1872.557						
12	92.75	25.25	3198.727						
13	93	25.25	2744.675						
14	93.25	25.25	2290.624						
15	93.5	25.25	2205.223						
16	93.75	25.25	2119.822						
17	94	25.25	2035.761						
18	94.25	25.25	1951.701						
19	94.5	25.25	1911.934						
20	92.5	25.5	3429.044						
21	92.75	25.5	2942.414						
22	93	25.5	2618.992						
23	93.25	25.5	2295.57						
24	93.5	25.5	2198.598						
25	93.75	25.5	2101.626						

Code Screenshot:

```
setwd("C:/Users/mmouk/Desktop/Data vis _lab")
par(mar = c(10,10,10,10))
#par(mfrow=c(1,4))
library(ggplot2)
library(grid)
library(gridExtra)
library(extrafont)
library(ggmap)
library(maptools)
library(plyr)
library(maps)
counter=0;
summ=0;
ro=1;
i=0;
p <- read.csv("Brahmputra_basin_data.csv") ## Import the data
##mat<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
mat<-matrix(0, nrow = 115,ncol=335, byrow = FALSE)
for(i in 2:336)
{
  for(j in 1:1380)
  {
    counter=counter+1;
    summ=summ+p[j,i];
    if(counter==12)
    {
      mat[ro,i-1]=summ;
      summ=0;
      ro=ro+1;
      counter=0;

```

```
      ro=ro+1;
      counter=0;

    }

  }
  ro=1;
  counter=0;
  summ=0;


}
mat;
write.csv(mat,'Brahmaputra_sum_annual.csv')

avg<-read.csv("Brahmaputra_sum_annual.csv")

t=dim(avg)
mat2<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
for(i in 1:(t[2]-1))
{
  m = mean(avg[,i+1])    ##  mean
  mat2[i,1]<-m
  s<-sd(avg[,i+1])
  mat2[i,2]<-s         ##   standard deviation
}
write.csv(mat2,'Brahmaputra_mean_sd_annual.csv')

q<-read.csv("Brahmaputra_mean_sd_annual.csv")
chart<-list()
w <- c(746,1.55e+03,1.99e+03,0.225e+04,0.345e+04)

```

```r
}
write.csv(mat2,'Brahmaputra_mean_sd_annual.csv')

q<-read.csv("Brahmaputra_mean_sd_annual.csv")
chart<-list()
w <- c(746,1.55e+03,1.99e+03,0.225e+04,0.345e+04)

cols <- c("[746,1.55e+03)" = "yellow", "[1.55e+03,1.99e+03)" = "red", "[1.99e+03,0.225e+04)" = "blue", "[0.225e+04,0.345e+04)"
q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("11-9-2019-3772456")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Mean of Brahmaputra River basin")


 cols <- c("[746,1.55e+03)" = "yellow", "[1.55e+03,1.99e+03)" = "red", "[1.99e+03,2.25e+03)" = "blue", "[2.25e+03,3.45e+03)" =
 q$A2 <- cut(q$Mean,breaks = w,right = FALSE)
 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
```

Multiple Plot Function ÷ R Script

Jobs

```r

##### Multiple Plot Function #####

multiplot <- function(..., plotlist=NULL, cols) {
  require(grid)

  # Make a list from the ... arguments and plotlist
  plots <- c(list(...), plotlist)

  numPlots = length(plots)

  # Make the panel
  plotCols = cols                          # Number of columns of plots
  plotRows = ceiling(numPlots/plotCols)    # Number of rows needed, calculated from # of cols

  # Set up the page
  grid.newpage()
  pushViewport(viewport(layout = grid.layout(plotRows, plotCols)))
  vplayout <- function(x, y)
    viewport(layout.pos.row = x, layout.pos.col = y)

  # Make each plot, in the correct location
  for (i in 1:numPlots) {
    curRow = ceiling(i/plotCols)
    curCol = (i-1) %% plotCols + 1
    print(plots[[i]], vp = vplayout(curRow, curCol ))
  }
}
tiff(filename = "Brahmputa_river_annual2.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole =
multiplot(chart[[2]], cols = 2)
dev.off()
```

361:1 Multiple Plot Function ÷ R Script

Console Jobs

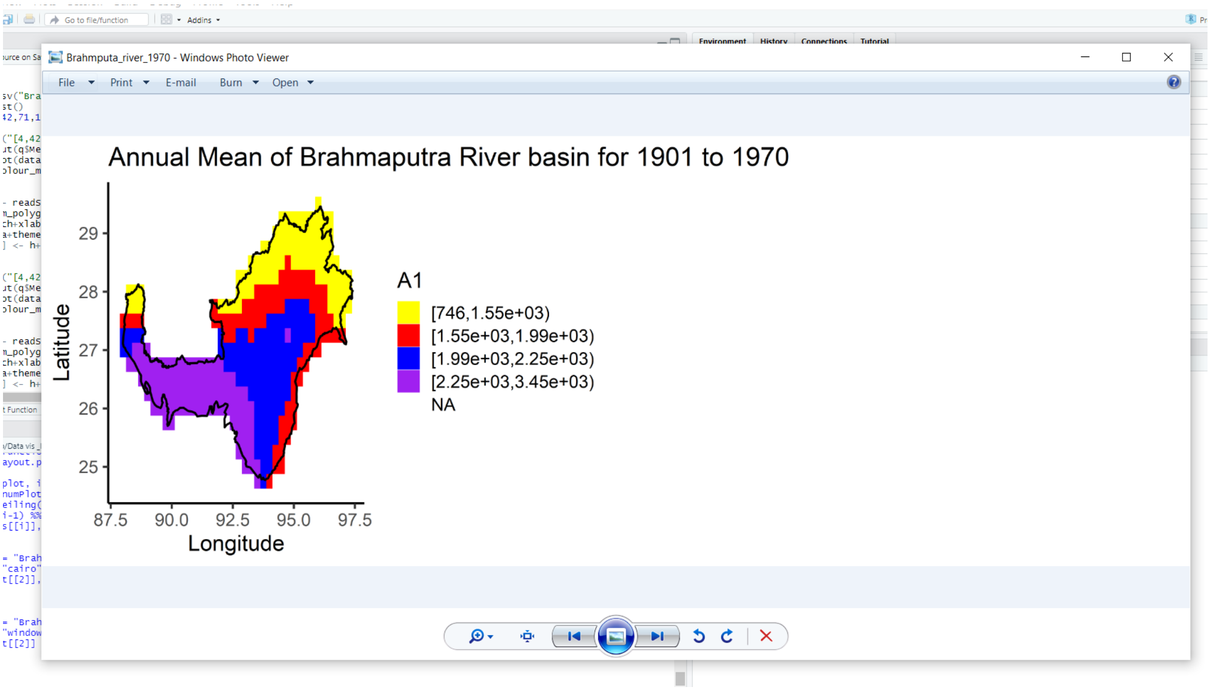
:/Users/mmouk/Desktop/Data vis _lab/

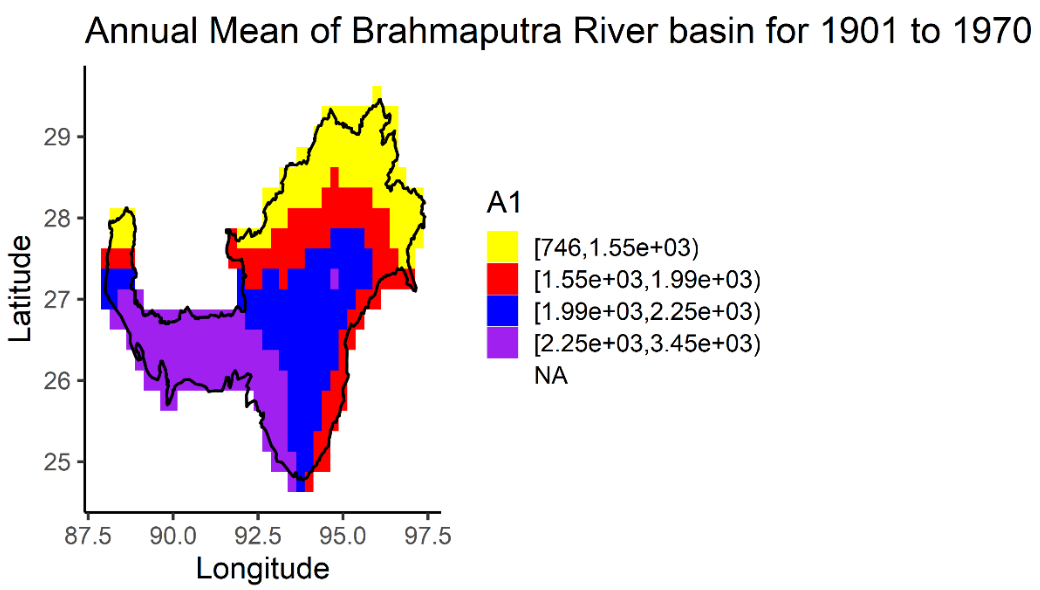
```r
    curCol = (i-1) %% plotCols + 1
    print(plots[[i]], vp = vplayout(curRow, curCol ))
  }
}
tiff(filename = "Brahmputa_river_annual2.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole =
multiplot(chart[[2]], cols = 2)
dev.off()
jpeg(filename = "Brahmaputa_river_annual2.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole =
multiplot(chart[[2]] ,cols = 2)
dev.off()
```

Q2. . Calculate the change in average annual rainfall with respect to global warming in each grid. Then plot the derived result.

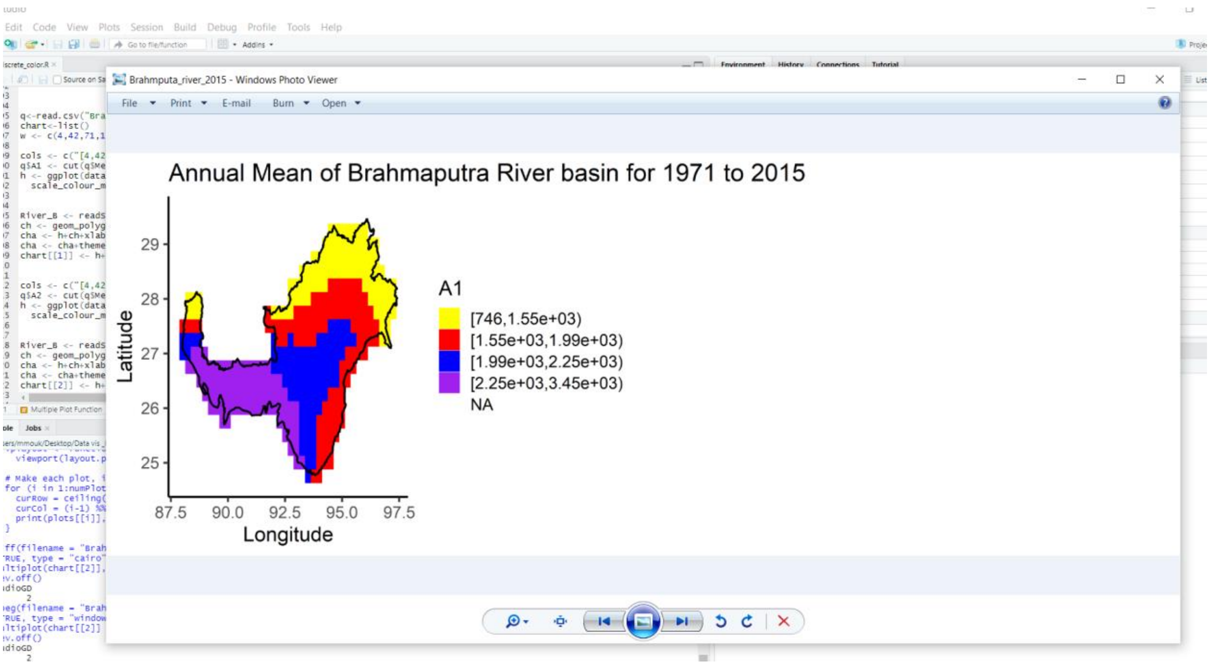
Plot:

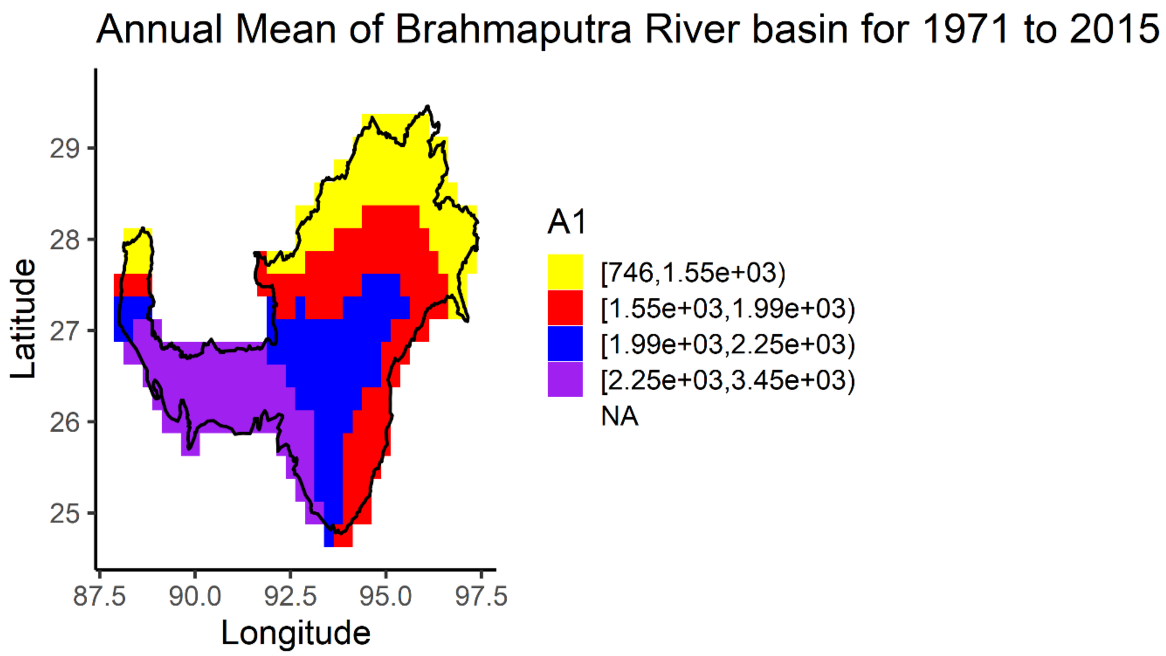
1. 1901-1970 Annual Average Rainfall





2.. 1971-2015 Annual Average Rainfall

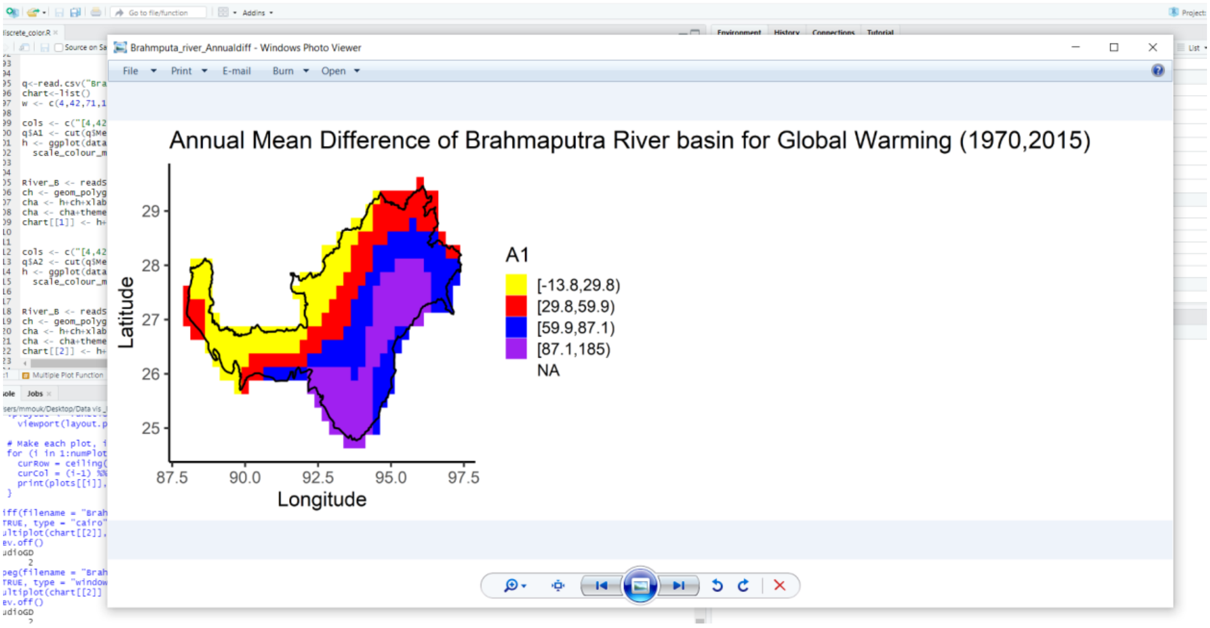


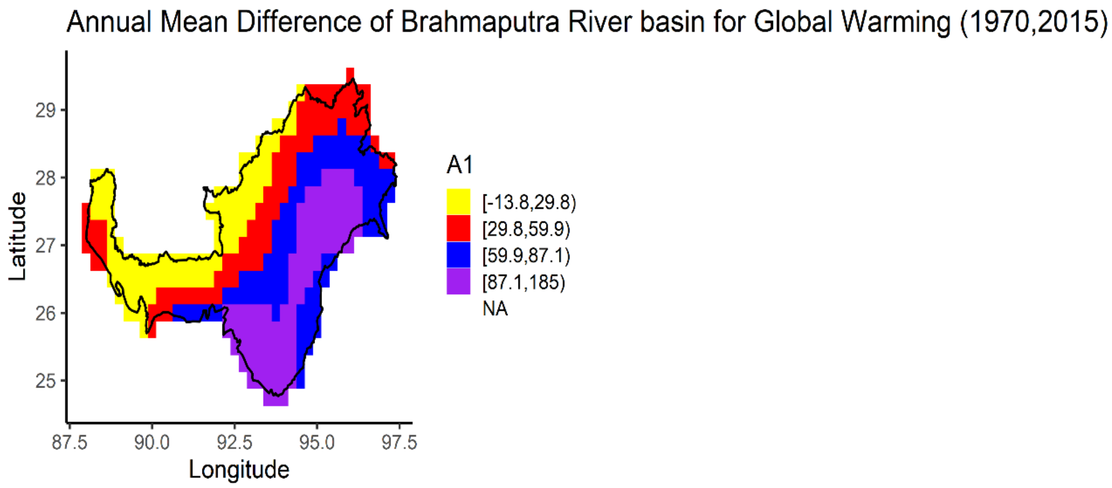


Inference from Plot 1 and Plot 2:

- Plot 1shows the average annual rainfall between 1901 to 1970 and Plot 2 shows the average annual rainfall between 1971 to 2015 in the Brahmaputra river Basin. The global warming delimiter for comparison is considered to be the end of 1970.
- We use the same range of min, quartile, median and max values as we do in the previous section as we are still comparing average annual rainfall data itself.
- From the outset, on studying these plots, both show similar tendencies to the average annual rainfall plot from the previous section with more rainfall in the southern part as compared to the northern portion.
- Interestingly, there is a small patch in Plot 1, which falls in the purple range (2250-3450).
- Both the plots show similar tendencies with respect to range of values with differences. However, a comparative plot is presented next (Plot 3 below) which highlights the difference in rainfall based on another scale.

3. Difference graph of rainfall between the two periods





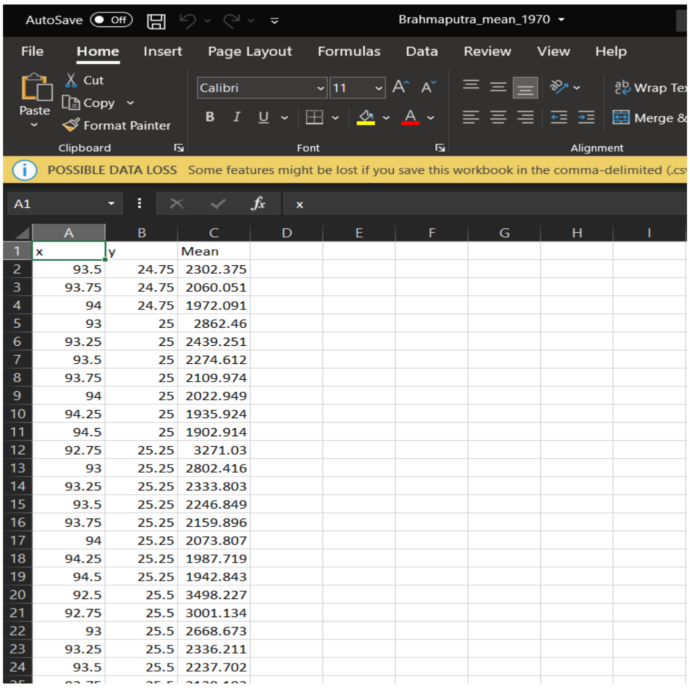
Inferences from Plot 3 (Difference Plot):

- Plot 3 shows the annual mean difference in rainfall for Brahmaputra river basin between the periods (1901-1970) and (1971-2015).
- In the above plot 2015 values are subtracted from the 1901 data that is, if column 1 contains 1901-1970 period data and column 2 contains 1971-2015 data, the difference value is column1-column2.
- This implies that purple colour band means that there was much more rainfall in that region before global warming as compared to after it.
- Min difference= -13.88 (negative value implies that region receives more rainfall after 1971 as compared to before 1971. Quartile 1= 29.835 ; Median = 59.98; Quartile 3= 87.19; Max difference is 184.77 (Refer to screenshot of CSV below).
- From the above plot, we can infer that there is a south-eastern cascading in the difference in rainfall. The western region receives more or about the same or sightly less rainfall post global warming as compared to before global warming.
- As we move east the plot transitions to red band which implies that the region receives less rainfall (29.8-59.9) post global warming as compared to before global warming. The northern tip too is red .
- Further east we encounter the blue band (range given in diagram) which receives even lesser rainfall post global warming .than pre-1970. This blue band wraps around the purple region covering the eastern border of the plot.

- In the east, there lies a purple region signifying that the region has the highest difference between pre global warming and post global warming rainfall. It even extends to the southern part of the plot. The region receives much less rainfall in the recent present as compared to the past.
- The range of difference between the pre and post global warming can also be seen in the plot.

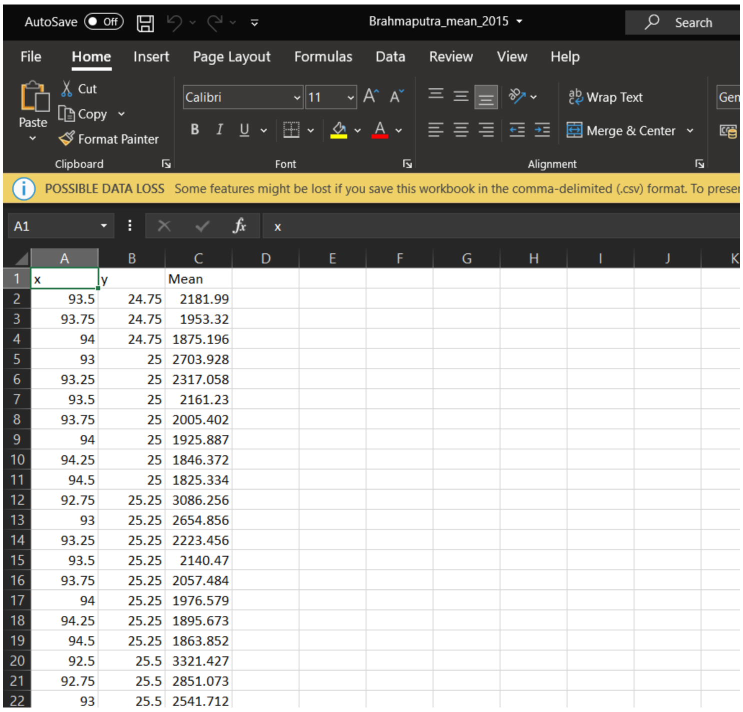
Data Screenshots in CSV:

1901-1970 Annual Rainfall Avg



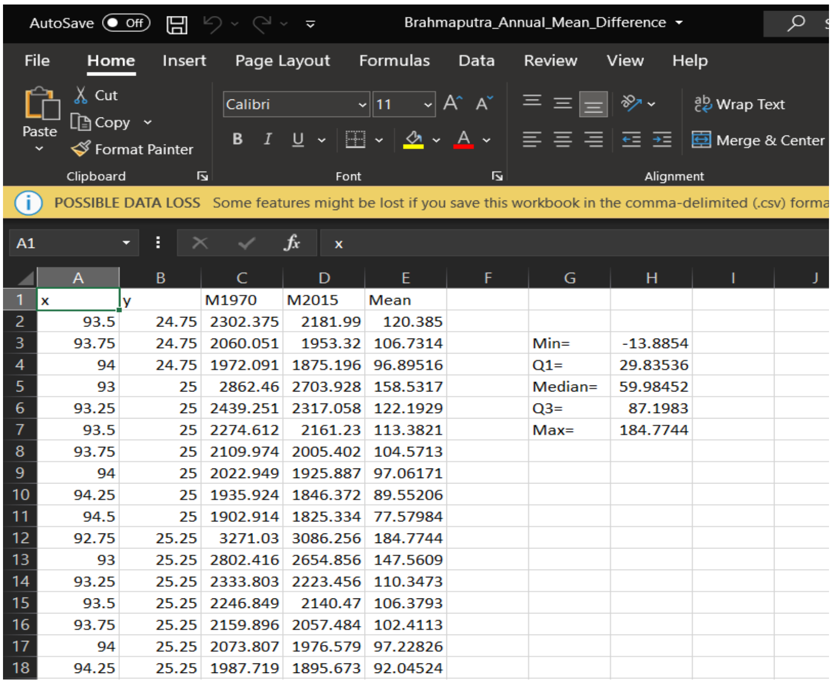
x	y	Mean
93.5	24.75	2302.375
93.75	24.75	2060.051
94	24.75	1972.091
93	25	2862.46
93.25	25	2439.251
93.5	25	2274.612
93.75	25	2109.974
94	25	2022.949
94.25	25	1935.924
94.5	25	1902.914
92.75	25.25	3271.03
93	25.25	2802.416
93.25	25.25	2333.803
93.5	25.25	2246.849
93.75	25.25	2159.896
94	25.25	2073.807
94.25	25.25	1987.719
94.5	25.25	1942.843
92.5	25.5	3498.227
92.75	25.5	3001.134
93	25.5	2668.673
93.25	25.5	2336.211
93.5	25.5	2237.702

1971- 2015 Annual Rainfall Avg



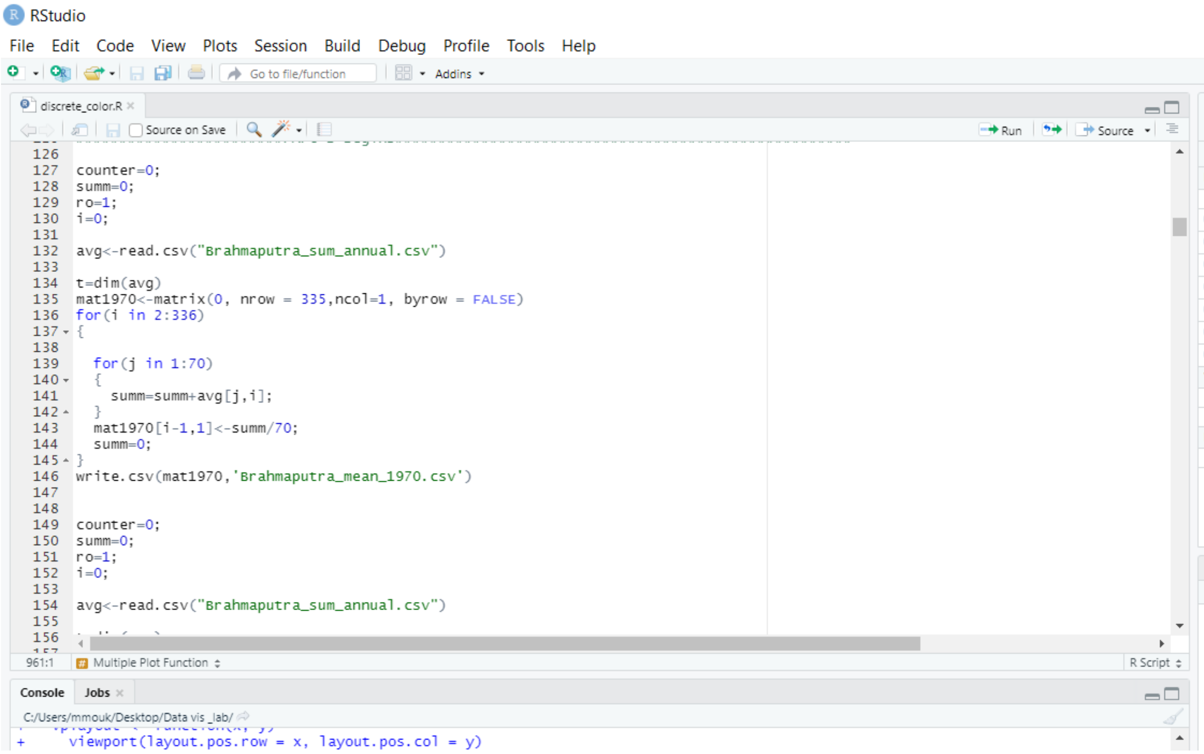
	A	B	C
1	x	y	Mean
2	93.5	24.75	2181.99
3	93.75	24.75	1953.32
4	94	24.75	1875.196
5	93	25	2703.928
6	93.25	25	2317.058
7	93.5	25	2161.23
8	93.75	25	2005.402
9	94	25	1925.887
10	94.25	25	1846.372
11	94.5	25	1825.334
12	92.75	25.25	3086.256
13	93	25.25	2654.856
14	93.25	25.25	2223.456
15	93.5	25.25	2140.47
16	93.75	25.25	2057.484
17	94	25.25	1976.579
18	94.25	25.25	1895.673
19	94.5	25.25	1863.852
20	92.5	25.5	3321.427
21	92.75	25.5	2851.073
22	93	25.5	2541.712

Annual Difference wrt Global Warming



	A	B	C	D	E	F	G	H
1	x	y	M1970	M2015	Mean			
2	93.5	24.75	2302.375	2181.99	120.385			
3	93.75	24.75	2060.051	1953.32	106.7314		Min=	-13.8854
4	94	24.75	1972.091	1875.196	96.89516		Q1=	29.83536
5	93	25	2862.46	2703.928	158.5317		Median=	59.98452
6	93.25	25	2439.251	2317.058	122.1929		Q3=	87.1983
7	93.5	25	2274.612	2161.23	113.3821		Max=	184.7744
8	93.75	25	2109.974	2005.402	104.5713			
9	94	25	2022.949	1925.887	97.06171			
10	94.25	25	1935.924	1846.372	89.55206			
11	94.5	25	1902.914	1825.334	77.57984			
12	92.75	25.25	3271.03	3086.256	184.7744			
13	93	25.25	2802.416	2654.856	147.5609			
14	93.25	25.25	2333.803	2223.456	110.3473			
15	93.5	25.25	2246.849	2140.47	106.3793			
16	93.75	25.25	2159.896	2057.484	102.4113			
17	94	25.25	2073.807	1976.579	97.22826			
18	94.25	25.25	1987.719	1895.673	92.04524			

CODE Screenshots:



discrete_color.R

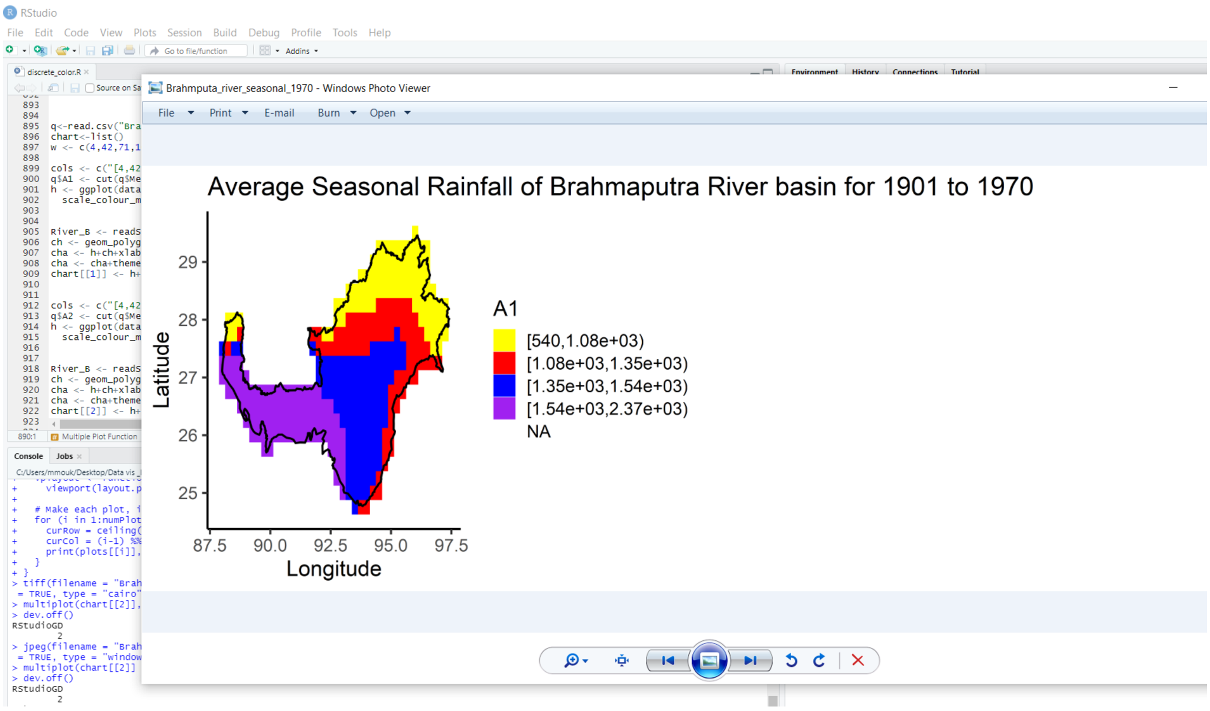
```r

cols <- c("[746,1.55e+03)" = "yellow", "[1.55e+03,1.99e+03)" = "red", "[1.99e+03,0.225e+04)" = "blue", "[0.225e+04,0.345e+04)"
q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("11-9-2019-3772456")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Mean of Brahmaputra River basin")


cols <- c("[746,1.55e+03)" = "yellow", "[1.55e+03,1.99e+03)" = "red", "[1.99e+03,2.25e+03)" = "blue", "[2.25e+03,3.45e+03)" = "
q$A2 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("11-9-2019-3772456")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[2]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Annual Mean of Brahmaputra River basin for 1971 to 2015 ")



##### Multiple Plot Function #####

multiplot <- function(..., plotlist=NULL, cols) {
```

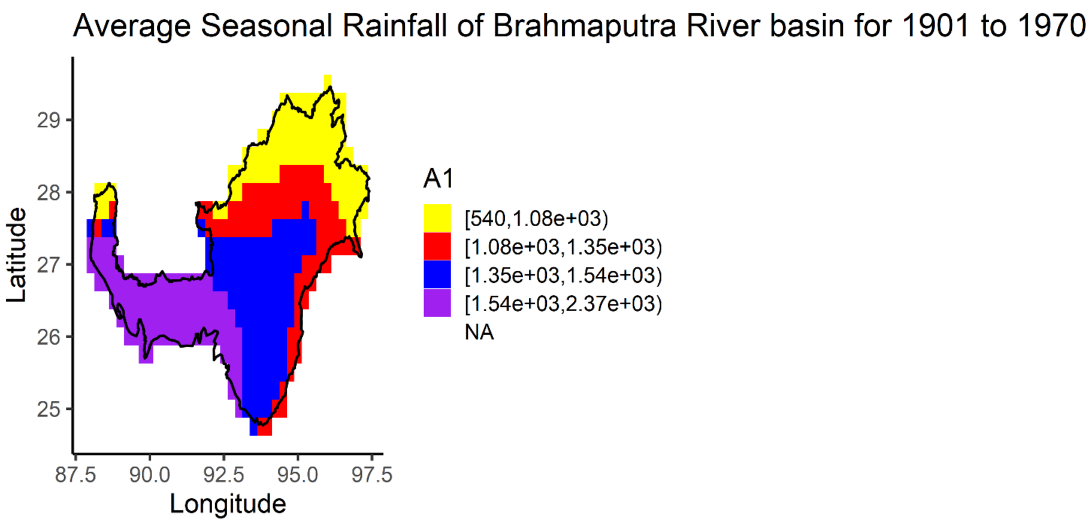
```r
  # Make a list from the ... arguments and plotlist
  plots <- c(list(...), plotlist)

  numPlots = length(plots)

  # Make the panel
  plotCols = cols                          # Number of columns of plots
  plotRows = ceiling(numPlots/plotCols)    # Number of rows needed, calculated from # of cols

  # Set up the page
  grid.newpage()
  pushViewport(viewport(layout = grid.layout(plotRows, plotCols)))
  vplayout <- function(x, y)
    viewport(layout.pos.row = x, layout.pos.col = y)

  # Make each plot, in the correct location
  for (i in 1:numPlots) {
    curRow = ceiling(i/plotCols)
    curCol = (i-1) %% plotCols + 1
    print(plots[[i]], vp = vplayout(curRow, curCol ))
  }
}
tiff(filename = "Brahmputa_river_2015.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole = TRU
multiplot(chart[[2]], cols = 2)
dev.off()
jpeg(filename = "Brahmaputa_river_2015.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TR
multiplot(chart[[2]] ,cols = 2)
dev.off()
```

Q3. Calculate the change in seasonal average rainfall with respect to global warming in each of grids. Plot the derived results.

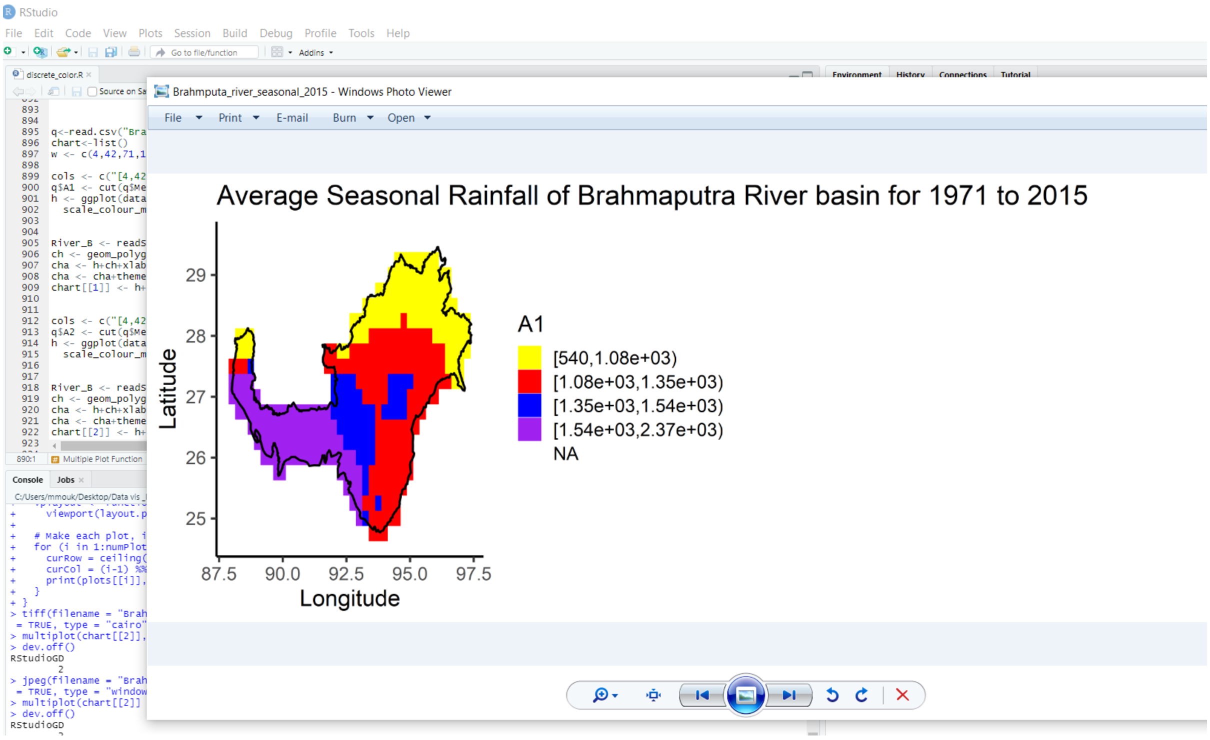
Plot:

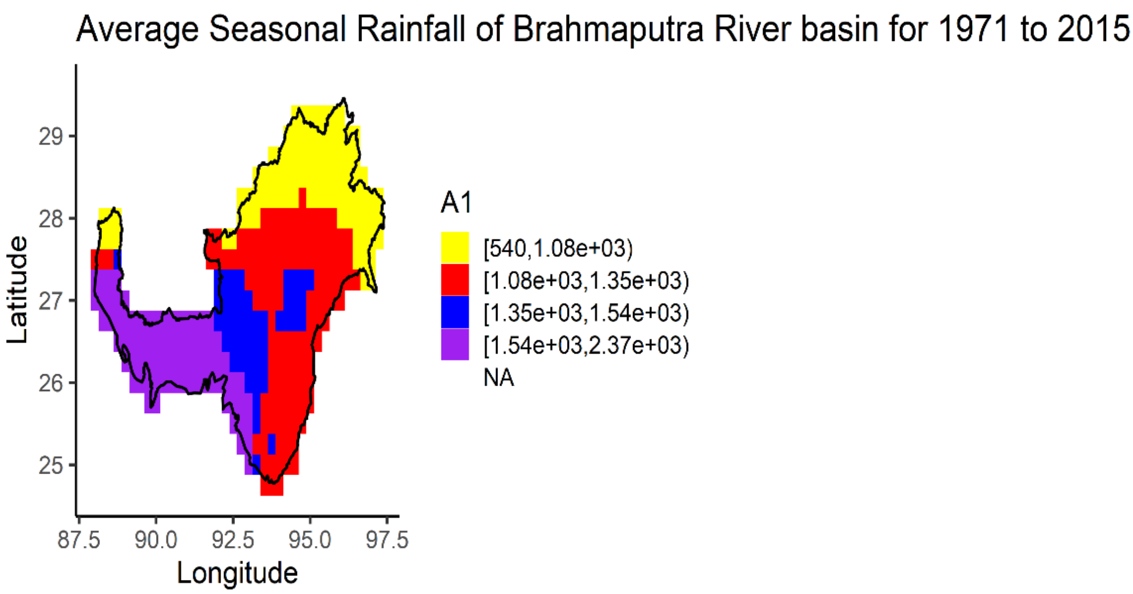
1. 1901 – 1970 seasonal rainfall average (June to Sept)





2. 1971-2015 seasonal rainfall average(June to Sept)

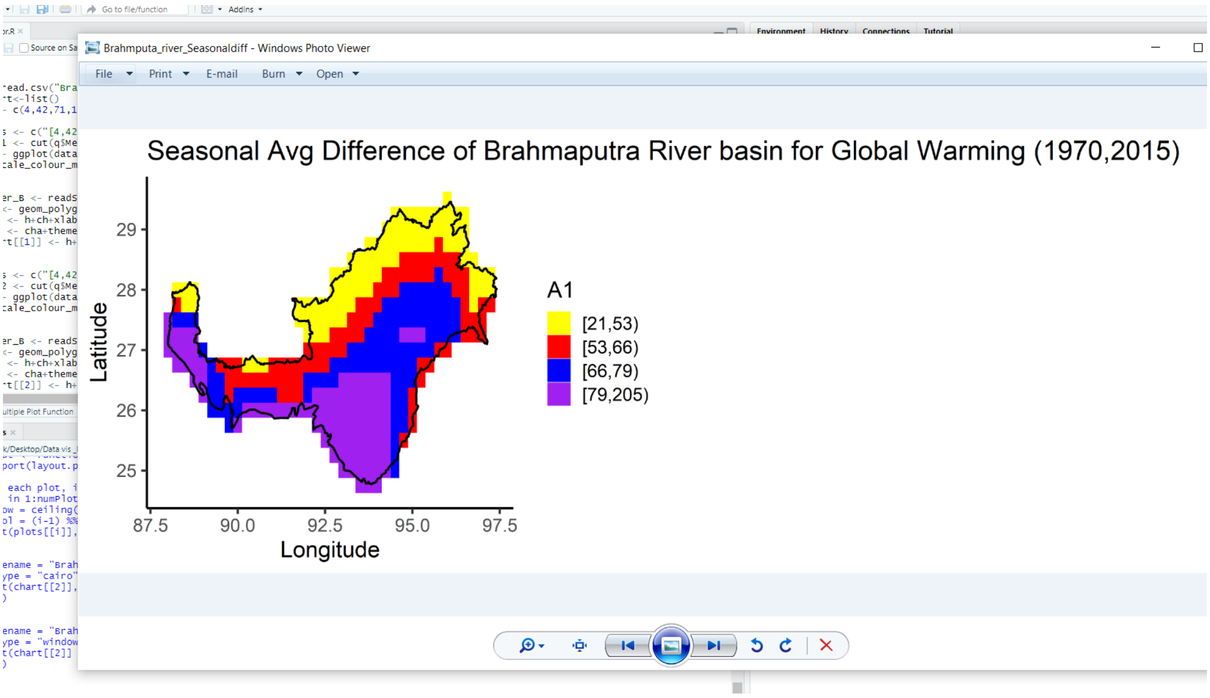


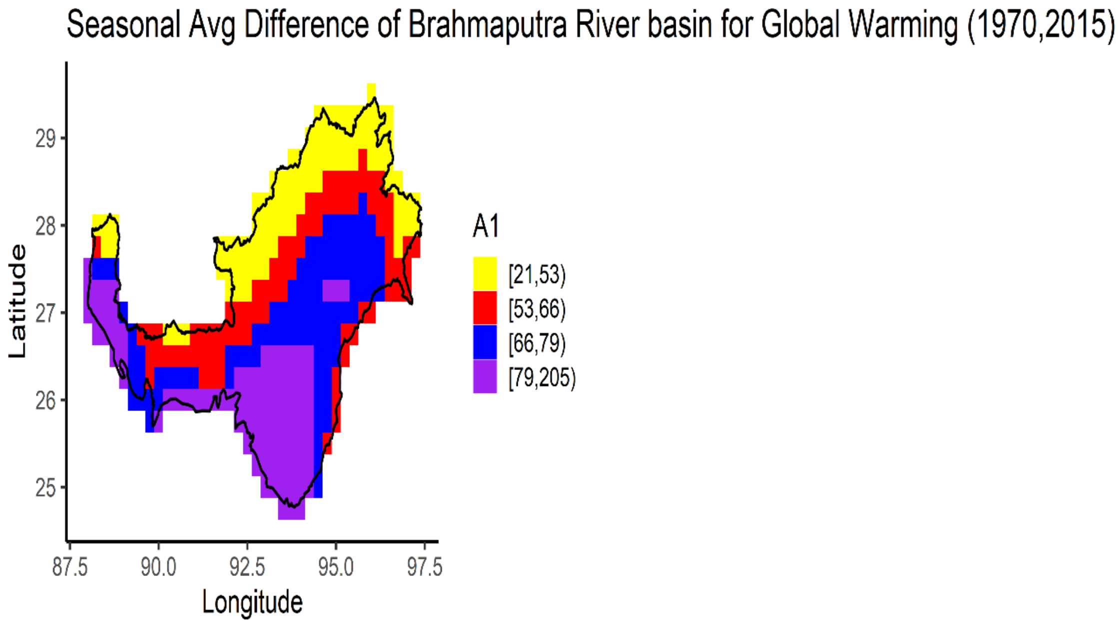


Inferences from Plot 1 and Plot 2:

- Plot 1 shows the average seasonal rainfall for each grid which is the sum of the rainfall from months (June to September) averaged out over a period of 70 years for each grid from 1901 to 1970 (referred to as pre global warming).
- Plot 2 shows the average seasonal rainfall for each grid which is the sum of the rainfall from months (June to September) averaged out over a period of 45 years for each grid from 1971 to 2015 (referred to as post global warming).
- Both the plots utilize the same range for min, quartile, median, max values
- Min=543.07 ; Q1=1078.8 Median=1349.05 ; Q3=1539.7 ; Max = 2367.59
- In the western region for both plots, we can see the same trend of them both being in the purple band (receiving the highest range of seasonal rainfall).
- The main difference in both the plots is that Pre Global warming plot(Plot 1) is more the blue range (more rainfall) in the eastern half as compared to Post Global warming plot (Plot 2). In the other regions we see a similar range of rainfall received.
- Difference between the two is studied in the next plot (Plot 3).

3. Seasonal difference between the two periods





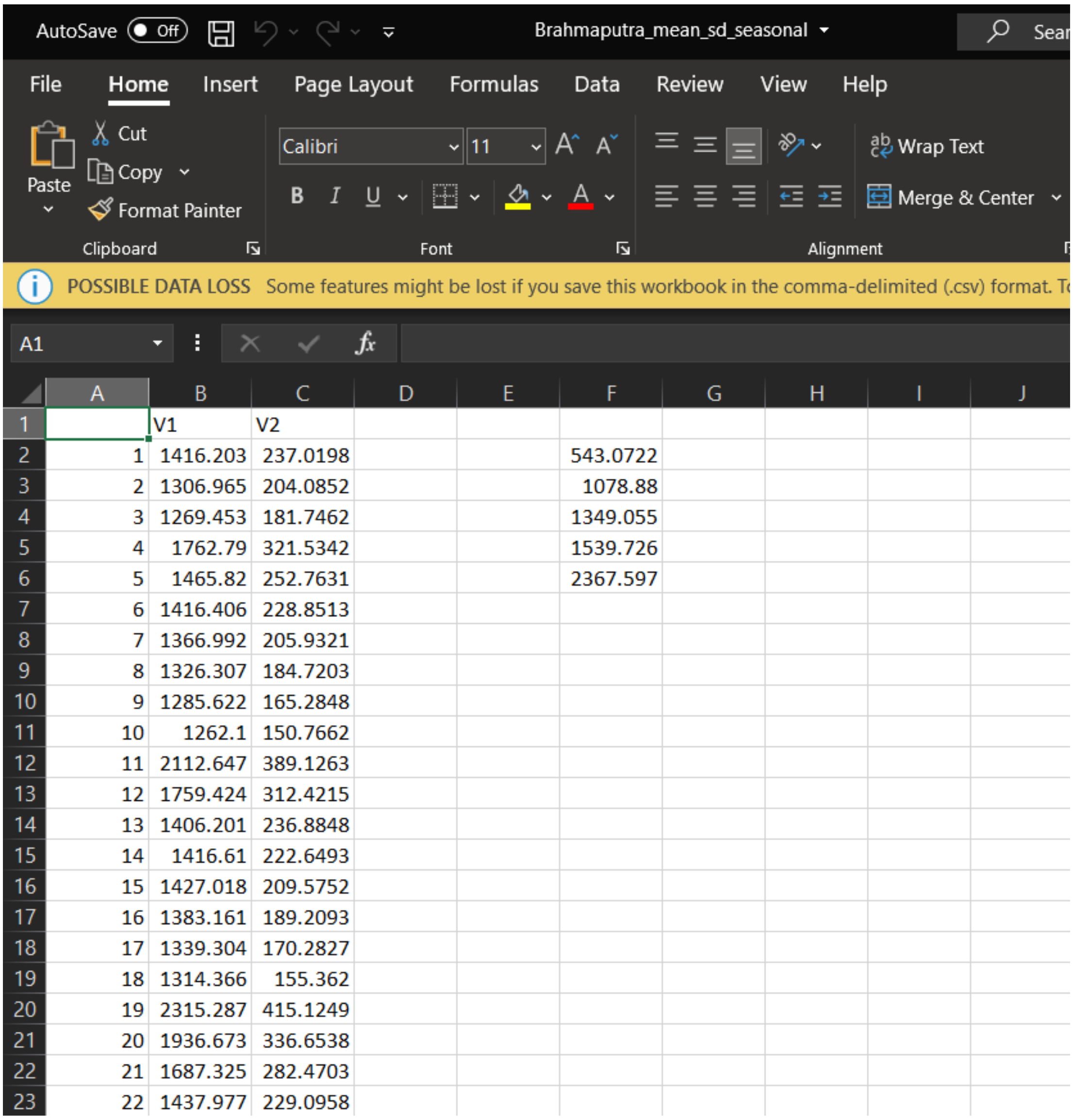
Inference from Plot 3:

- Plot 3 shows the average seasonal (June to September) difference in rainfall for Brahmaputra river basin between the periods (1901-1970) and (1971-2015).
- In the above plot 2015 values are subtracted from the 1901 data that is, if column 1 contains 1901-1970 period data and column 2 contains 1971-2015 data, the difference value is column1-column2.
- This implies that purple colour band means that there was much more rainfall in that region before global warming as compared to after it.
- Min difference= 21.8 Quartile 1=53.3; Median = 66.7; Quartile 3= 79; Max difference is 202.1 (Refer to screenshot of CSV (4th screenshot) below).
- From the difference plot we can infer that since all the ranges are greater than 0, the entire region has received less rainfall from 1971 to 2015 as compared to 1901-1970.
- The difference in rainfall is the smallest in the northern region (yellow fill) and it gradually becomes greater as we move south. It changes from yellow to red and then from red to blue and blue to purple further south.
- The north western tip changes directly from yellow to blue.

- The western border and the southern region have the largest difference in seasonal rainfall. They have the most difference between pre global warming and post global warming periods.
- There is also a tiny region of purple in the west among the blue which also receives much less rainfall post global warming.

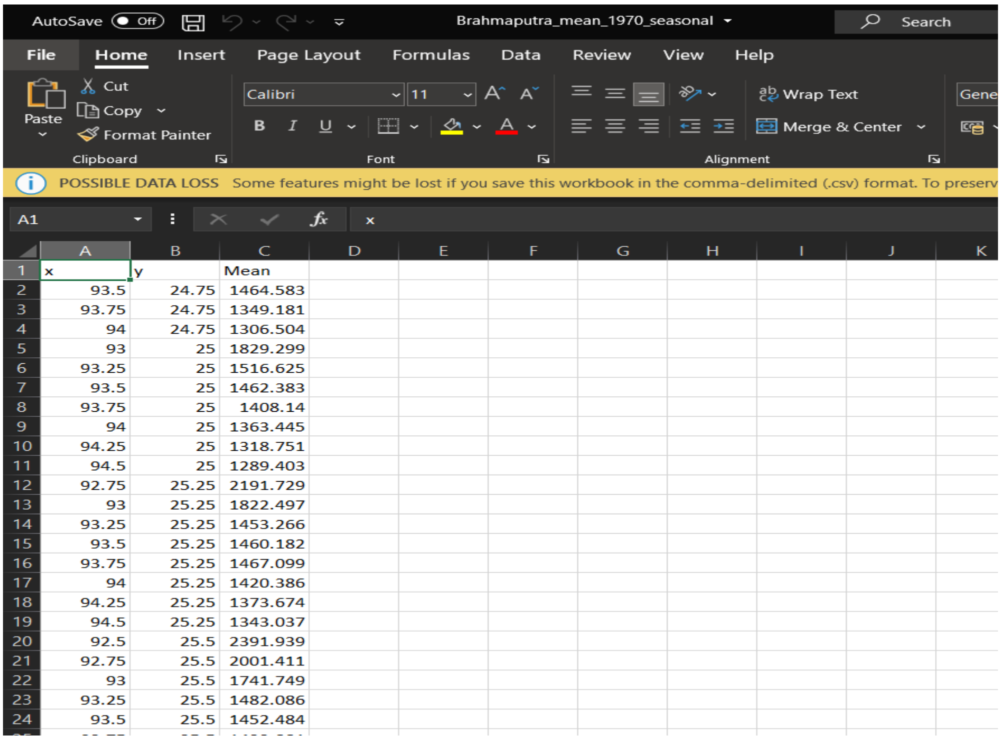
Data Screenshots in CSV:

1. Average Seasonal Rainfall between 1901-2015



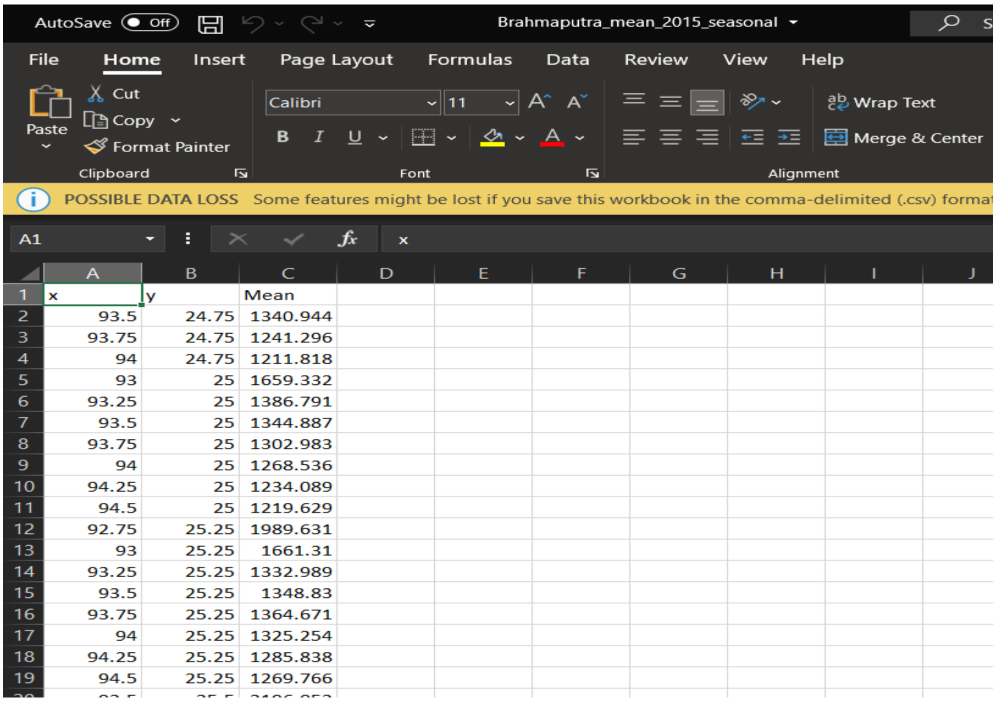
	A	B	C	D	E	F
1		V1	V2			
2	1	1416.203	237.0198			543.0722
3	2	1306.965	204.0852			1078.88
4	3	1269.453	181.7462			1349.055
5	4	1762.79	321.5342			1539.726
6	5	1465.82	252.7631			2367.597
7	6	1416.406	228.8513			
8	7	1366.992	205.9321			
9	8	1326.307	184.7203			
10	9	1285.622	165.2848			
11	10	1262.1	150.7662			
12	11	2112.647	389.1263			
13	12	1759.424	312.4215			
14	13	1406.201	236.8848			
15	14	1416.61	222.6493			
16	15	1427.018	209.5752			
17	16	1383.161	189.2093			
18	17	1339.304	170.2827			
19	18	1314.366	155.362			
20	19	2315.287	415.1249			
21	20	1936.673	336.6538			
22	21	1687.325	282.4703			
23	22	1437.977	229.0958			

3. 1901 – 1970 Seasonal Average Rainfall



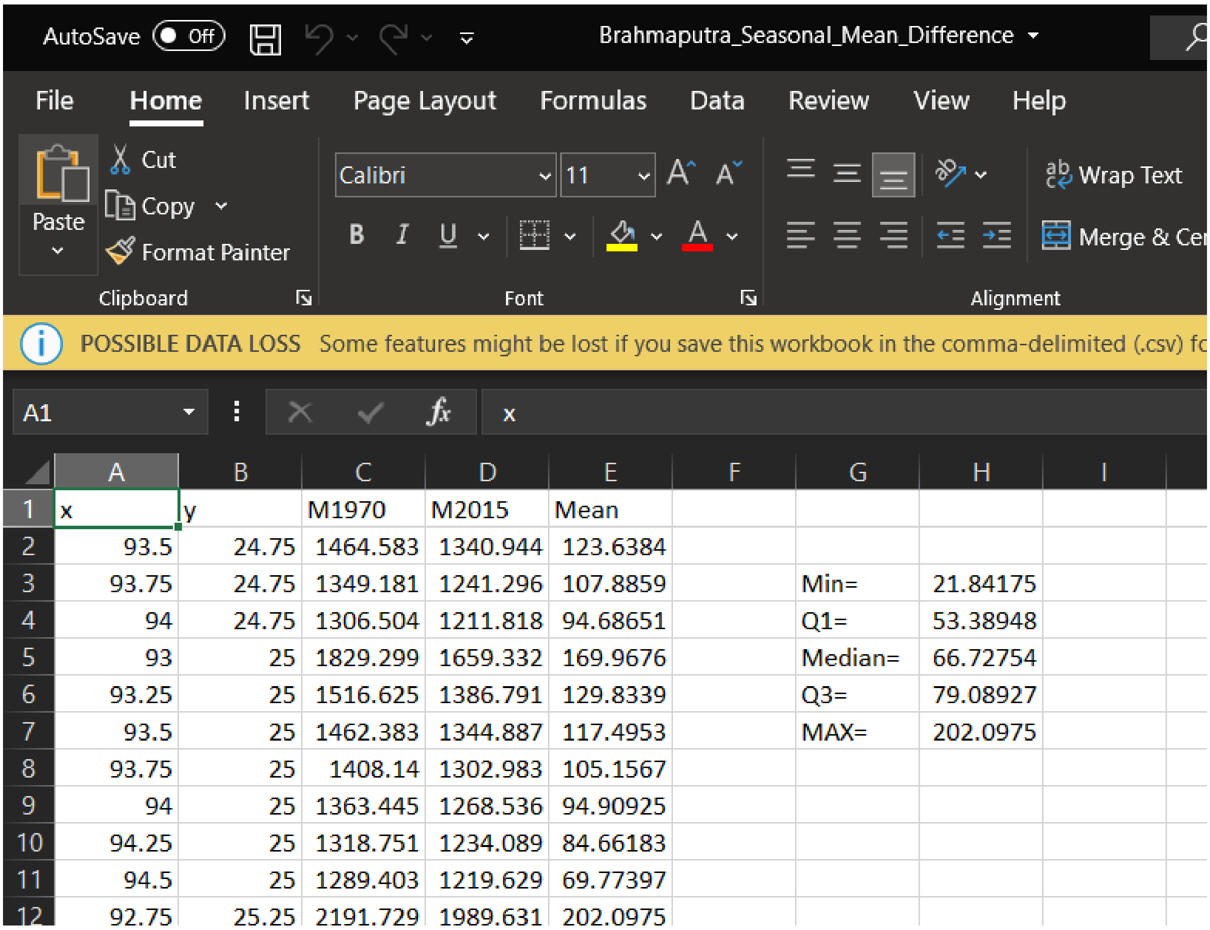
x	y	Mean
93.5	24.75	1464.583
93.75	24.75	1349.181
94	24.75	1306.504
93	25	1829.299
93.25	25	1516.625
93.5	25	1462.383
93.75	25	1408.14
94	25	1363.445
94.25	25	1318.751
94.5	25	1289.403
92.75	25.25	2191.729
93	25.25	1822.497
93.25	25.25	1453.266
93.5	25.25	1460.182
93.75	25.25	1467.099
94	25.25	1420.386
94.25	25.25	1373.674
94.5	25.25	1343.037
92.5	25.5	2391.939
92.75	25.5	2001.411
93	25.5	1741.749
93.25	25.5	1482.086
93.5	25.5	1452.484

3. 1971- 2015 Seasonal Average Rainfall



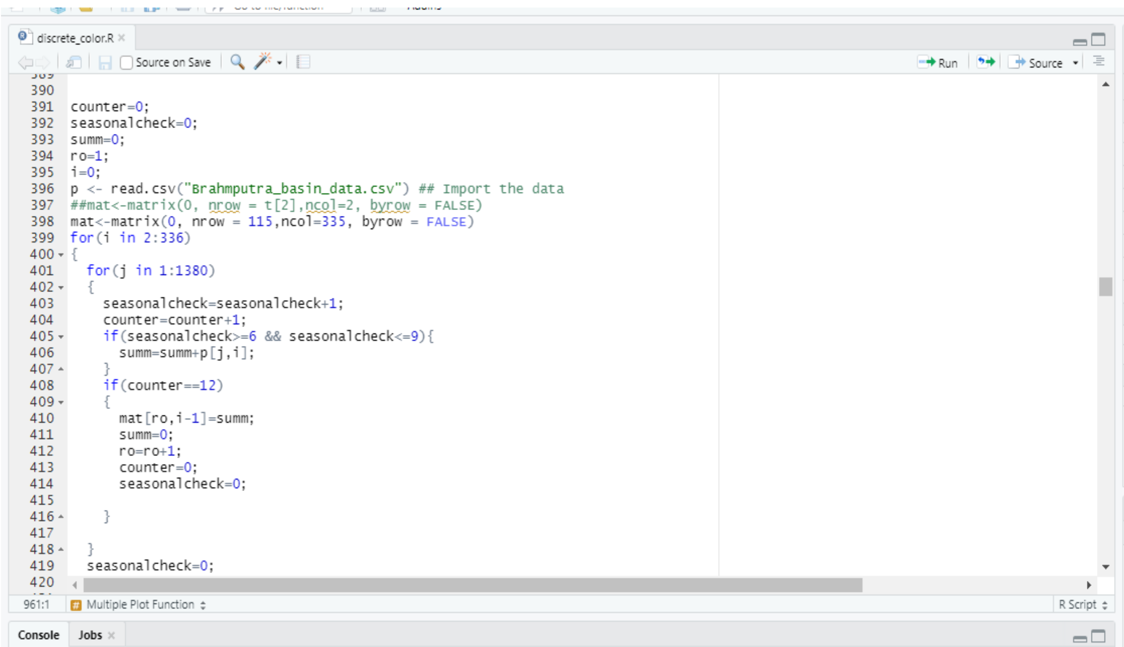
x	y	Mean
93.5	24.75	1340.944
93.75	24.75	1241.296
94	24.75	1211.818
93	25	1659.332
93.25	25	1386.791
93.5	25	1344.887
93.75	25	1302.983
94	25	1268.536
94.25	25	1234.089
94.5	25	1219.629
92.75	25.25	1989.631
93	25.25	1661.31
93.25	25.25	1332.989
93.5	25.25	1348.83
93.75	25.25	1364.671
94	25.25	1325.254
94.25	25.25	1285.838
94.5	25.25	1269.766

4. Difference wrt Global warming between the two periods

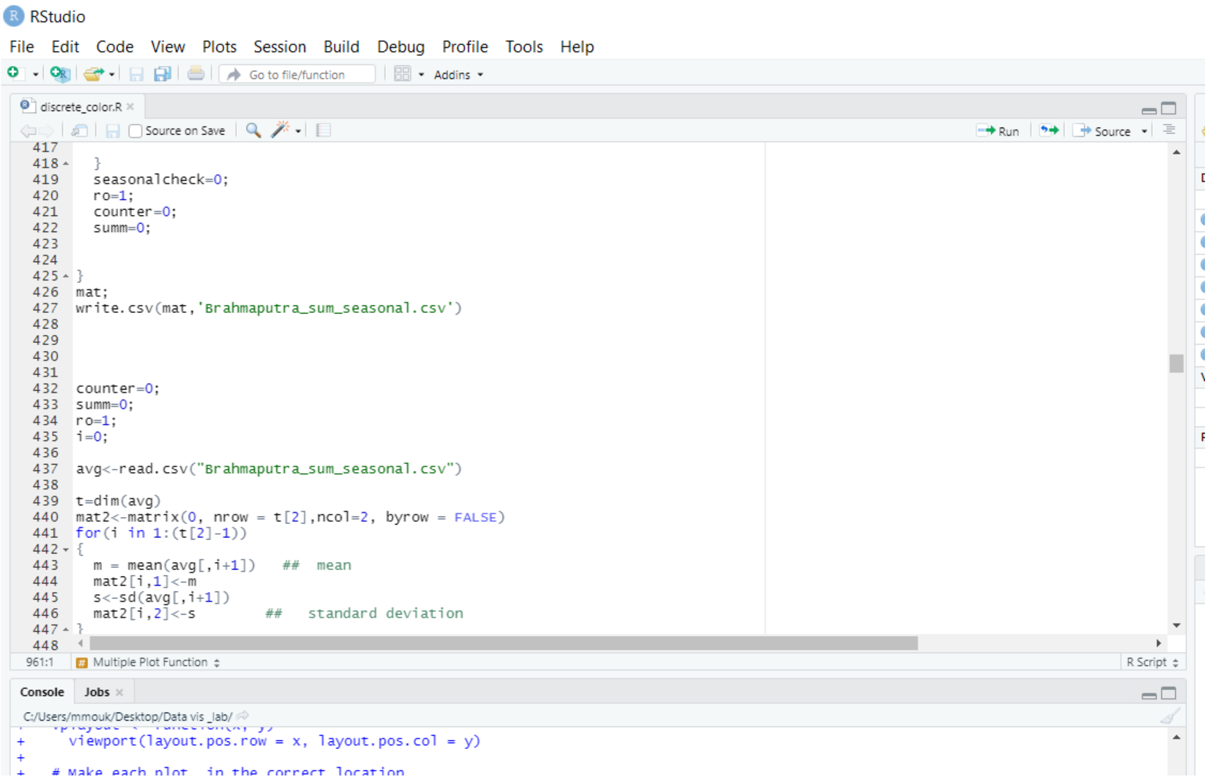


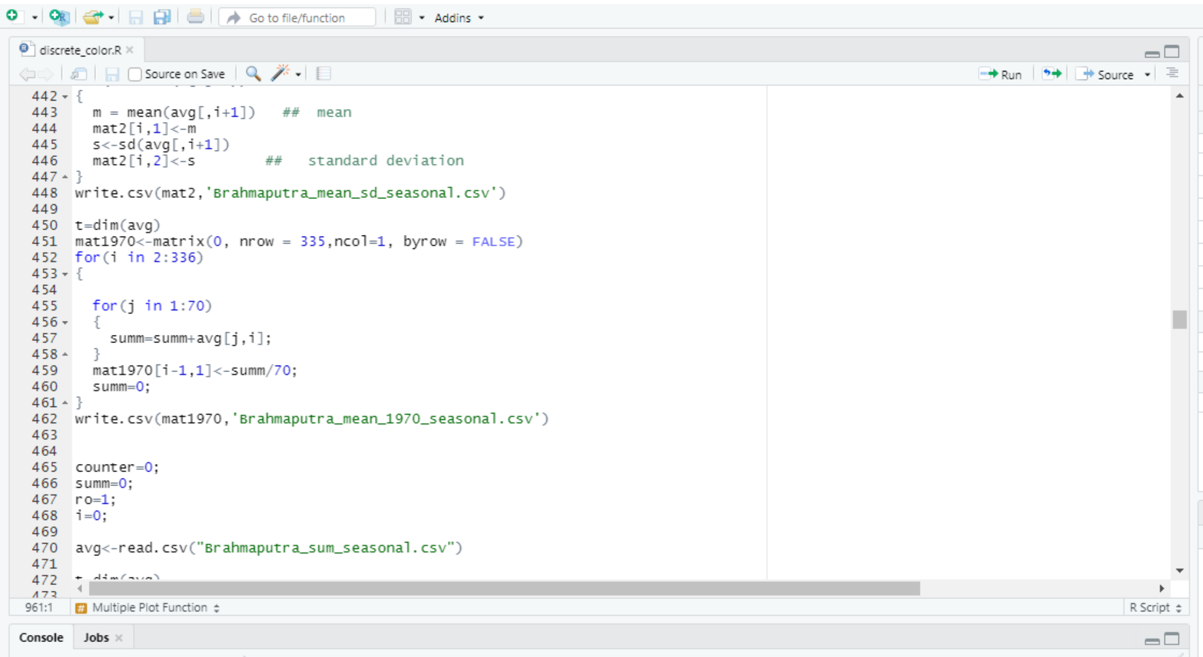
	A	B	C	D	E	F	G	H
1	x	y	M1970	M2015	Mean			
2	93.5	24.75	1464.583	1340.944	123.6384			
3	93.75	24.75	1349.181	1241.296	107.8859		Min=	21.84175
4	94	24.75	1306.504	1211.818	94.68651		Q1=	53.38948
5	93	25	1829.299	1659.332	169.9676		Median=	66.72754
6	93.25	25	1516.625	1386.791	129.8339		Q3=	79.08927
7	93.5	25	1462.383	1344.887	117.4953		MAX=	202.0975
8	93.75	25	1408.14	1302.983	105.1567			
9	94	25	1363.445	1268.536	94.90925			
10	94.25	25	1318.751	1234.089	84.66183			
11	94.5	25	1289.403	1219.629	69.77397			
12	92.75	25.25	2191.729	1989.631	202.0975			

CODE Screenshots:



```
counter=0;
seasonalcheck=0;
summ=0;
ro=1;
i=0;
p <- read.csv("Brahmaputra_basin_data.csv") ## Import the data
##mat<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
mat<-matrix(0, nrow = 115,ncol=335, byrow = FALSE)
for(i in 2:336)
{
  for(j in 1:1380)
  {
    seasonalcheck=seasonalcheck+1;
    counter=counter+1;
    if(seasonalcheck>=6 && seasonalcheck<=9){
      summ=summ+p[j,i];
    }
    if(counter==12)
    {
      mat[ro,i-1]=summ;
      summ=0;
      ro=ro+1;
      counter=0;
      seasonalcheck=0;

    }

  }
  seasonalcheck=0;
```


RStudio
File Edit Code View Plots Session Build Debug Profile Tools Help
Go to file/function
Addins
discrete_color.R
Source on Save
Run
Source
  }
  seasonalcheck=0;
  ro=1;
  counter=0;
  summ=0;
}
mat;
write.csv(mat,'Brahmaputra_sum_seasonal.csv')
counter=0;
summ=0;
ro=1;
i=0;
avg<-read.csv("Brahmaputra_sum_seasonal.csv")
t=dim(avg)
mat2<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
for(i in 1:(t[2]-1))
{
  m = mean(avg[,i+1])   ## mean
  mat2[i,1]<-m
  s<-sd(avg[,i+1])
  mat2[i,2]<-s   ##   standard deviation
}
961:1
Multiple Plot Function
R Script
Console
Jobs
C:/Users/mmouk/Desktop/Data vis _lab/
+   viewport(layout.pos.row = x, layout.pos.col = y)
+
+   # Make each plot, in the correct location


Go to file/function
Addins
discrete_color.R
Source on Save
Run
Source
{
  m = mean(avg[,i+1])   ## mean
  mat2[i,1]<-m
  s<-sd(avg[,i+1])
  mat2[i,2]<-s   ##   standard deviation
}
write.csv(mat2,'Brahmaputra_mean_sd_seasonal.csv')
t=dim(avg)
mat1970<-matrix(0, nrow = 335,ncol=1, byrow = FALSE)
for(i in 2:336)
{
  for(j in 1:70)
  {
    summ=summ+avg[j,i];
  }
  mat1970[i-1,1]<-summ/70;
  summ=0;
}
write.csv(mat1970,'Brahmaputra_mean_1970_seasonal.csv')
counter=0;
summ=0;
ro=1;
i=0;
avg<-read.csv("Brahmaputra_sum_seasonal.csv")
961:1
Multiple Plot Function
R Script
Console
Jobs

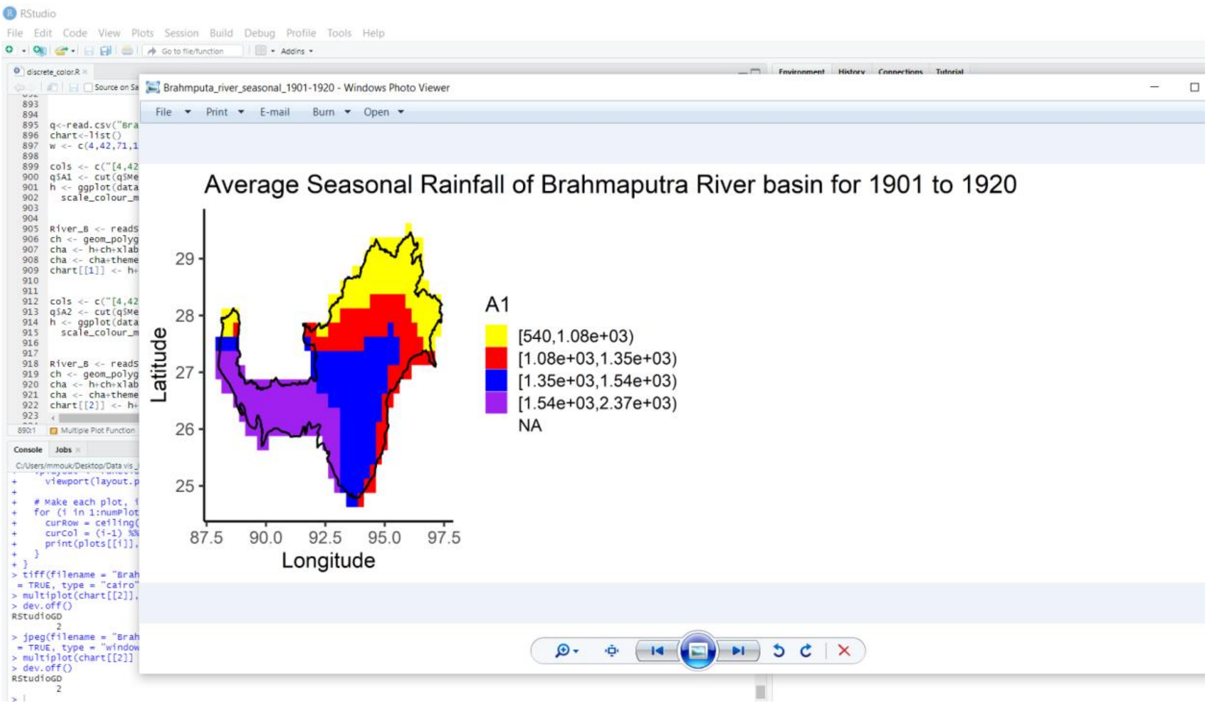
```r
t=dim(avg)
mat2015<-matrix(0, nrow = 335,ncol=1, byrow = FALSE)
for(i in 2:336)
{

  for(j in 71:115)
  {
    summ=summ+avg[j,i];
  }
  mat2015[i-1,1]<-summ/45;
  summ=0;
}
write.csv(mat2015,'Brahmaputra_mean_2015_seasonal.csv')


q<-read.csv("Brahmaputra_mean_2015_seasonal.csv")
chart<-list()
w <- c(540,1.08e+03,1.35e+03,1.54e+03,2.37e+03)

cols <- c("[540,1.08e+03)" = "yellow", "[1.08e+03,1.35e+03)" = "red", "[1.35e+03,1.54e+03)" = "blue", "[1.54e+03,2.37e+03)" = "
q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("11-9-2019-3772456")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average Seasonal Rainfall of Brahmaputra River basin for 19
```

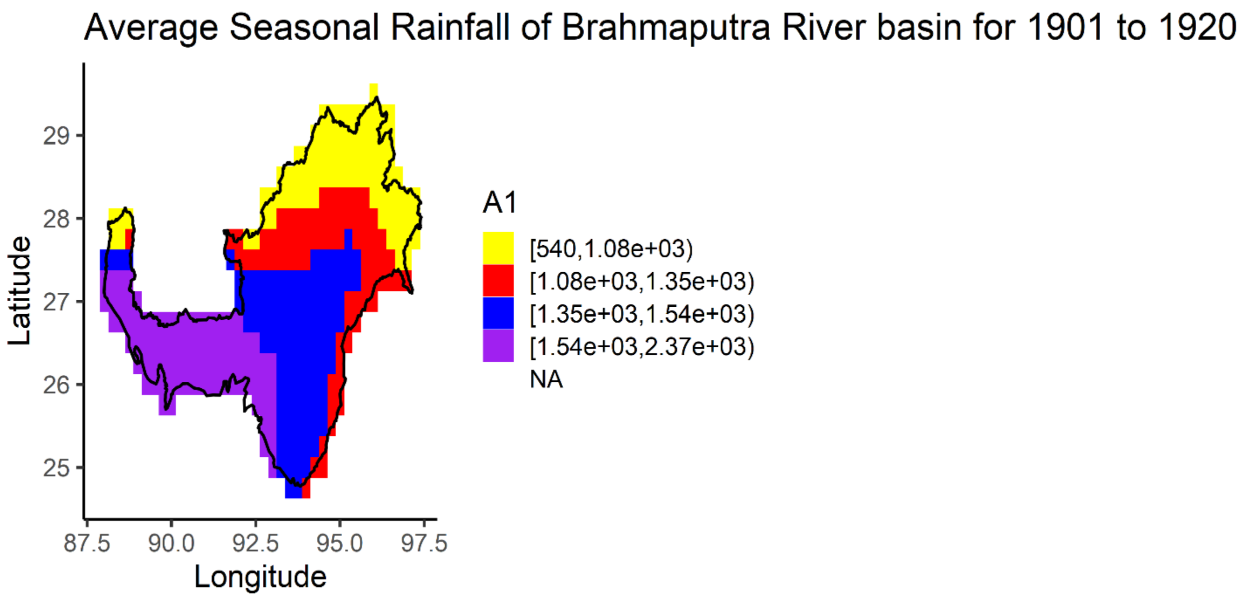
```r
  # Make a list from the ... arguments and plotlist
  plots <- c(list(...), plotlist)

  numPlots = length(plots)

  # Make the panel
  plotCols = cols                          # Number of columns of plots
  plotRows = ceiling(numPlots/plotCols)    # Number of rows needed, calculated from # of cols

  # Set up the page
  grid.newpage()
  pushViewport(viewport(layout = grid.layout(plotRows, plotCols)))
  vplayout <- function(x, y)
    viewport(layout.pos.row = x, layout.pos.col = y)

  # Make each plot, in the correct location
  for (i in 1:numPlots) {
    curRow = ceiling(i/plotCols)
    curCol = (i-1) %% plotCols + 1
    print(plots[[i]], vp = vplayout(curRow, curCol ))
  }
}
tiff(filename = "Brahmputa_river_Seasonaldiff.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConso
multiplot(chart[[2]], cols = 2)
dev.off()
jpeg(filename = "Brahmaputa_river_Seasonaldiff.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreCons
multiplot(chart[[2]] ,cols = 2)
dev.off()
```

Q4. Calculate the average seasonal (June-Sept) rainfall in each grid for the period 1901-1920. Similarly calculate the average seasonal (June-Sept) rainfall in each grid for the period 1990-last year. Calculate the change in average seasonal and plot them.

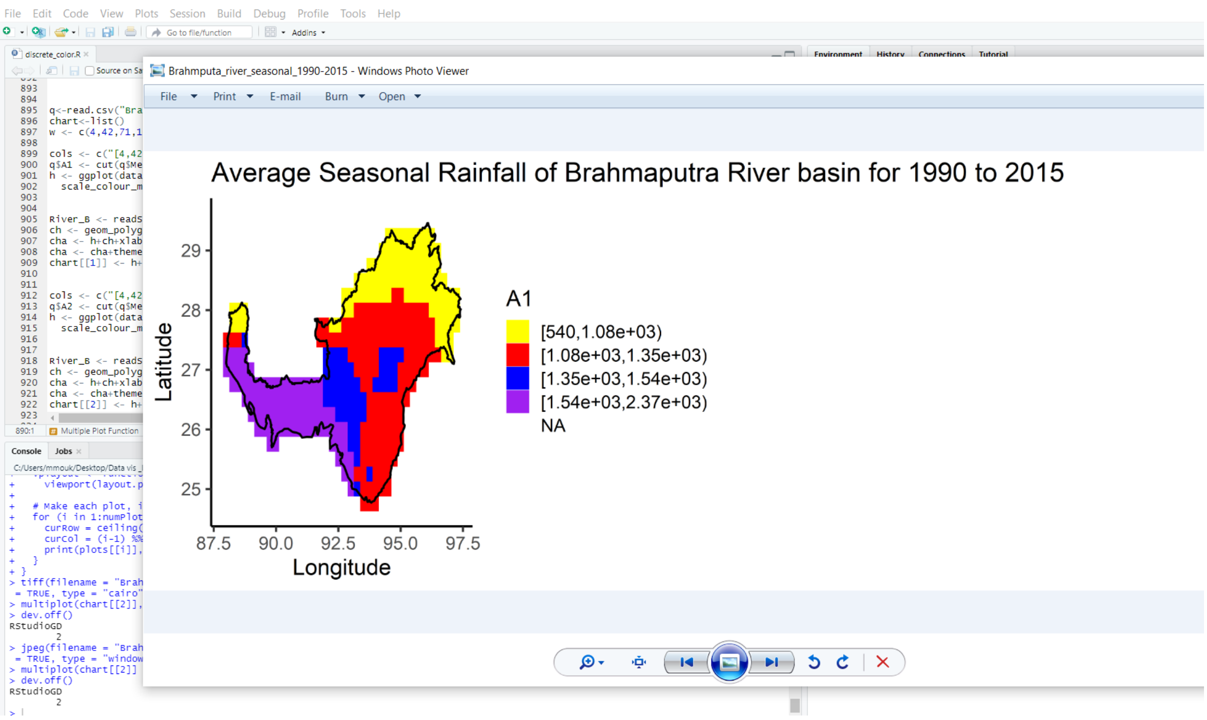
Plot:

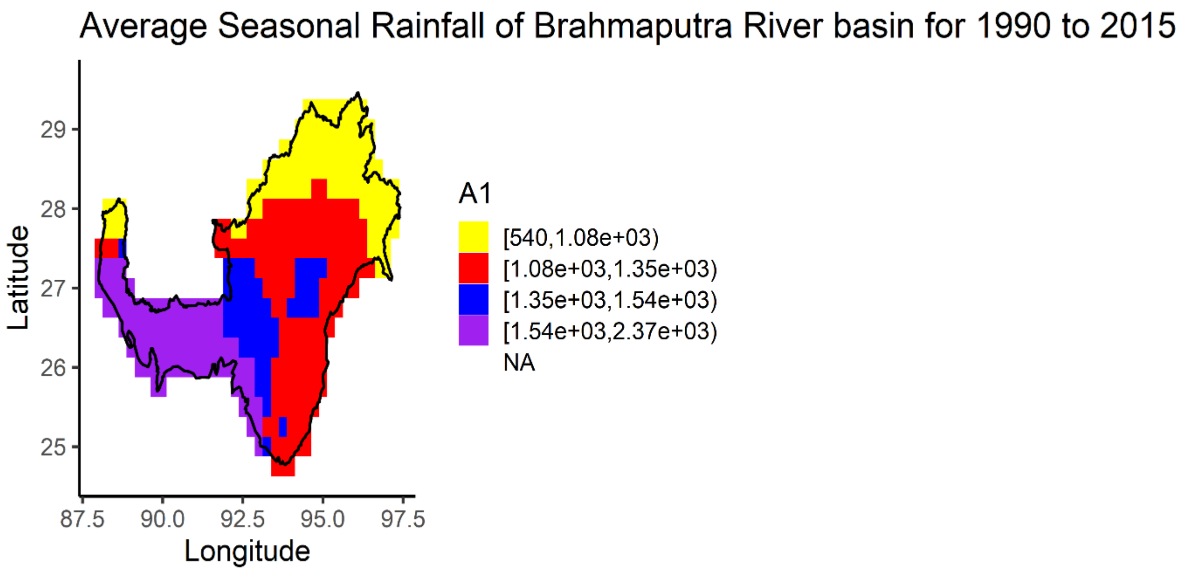
1. Average Seasonal (June to Sept) Rainfall between 1901-1920





2. Average Seasonal (June to Sept) Rainfall between 1990-2015

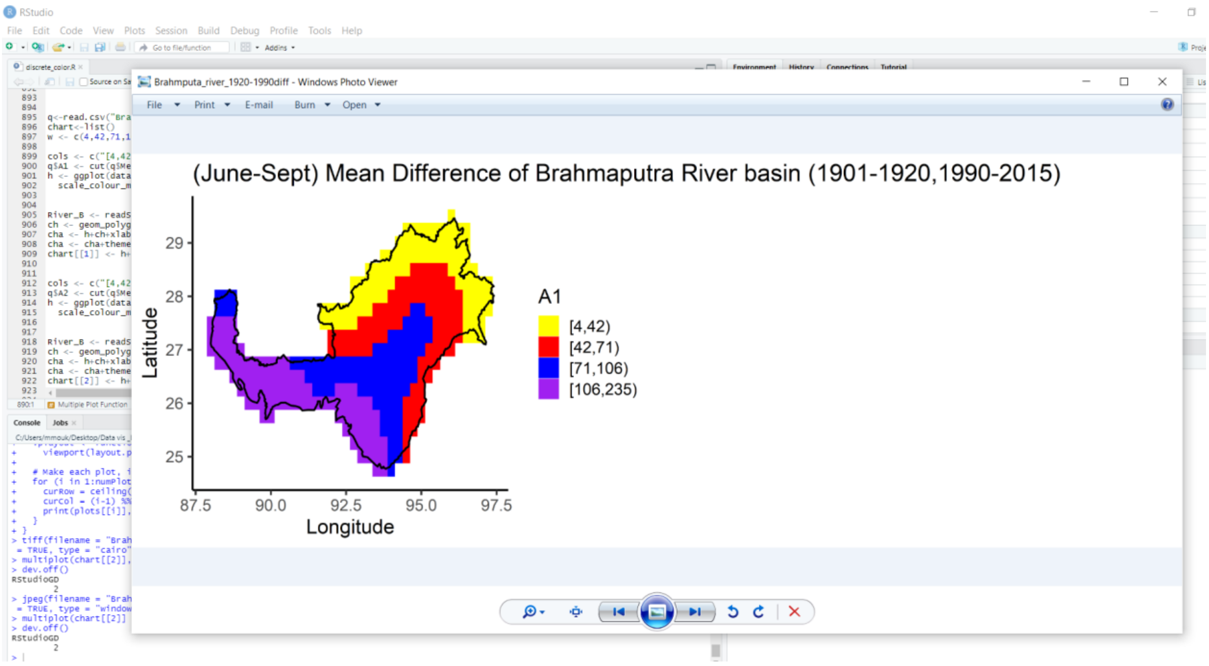


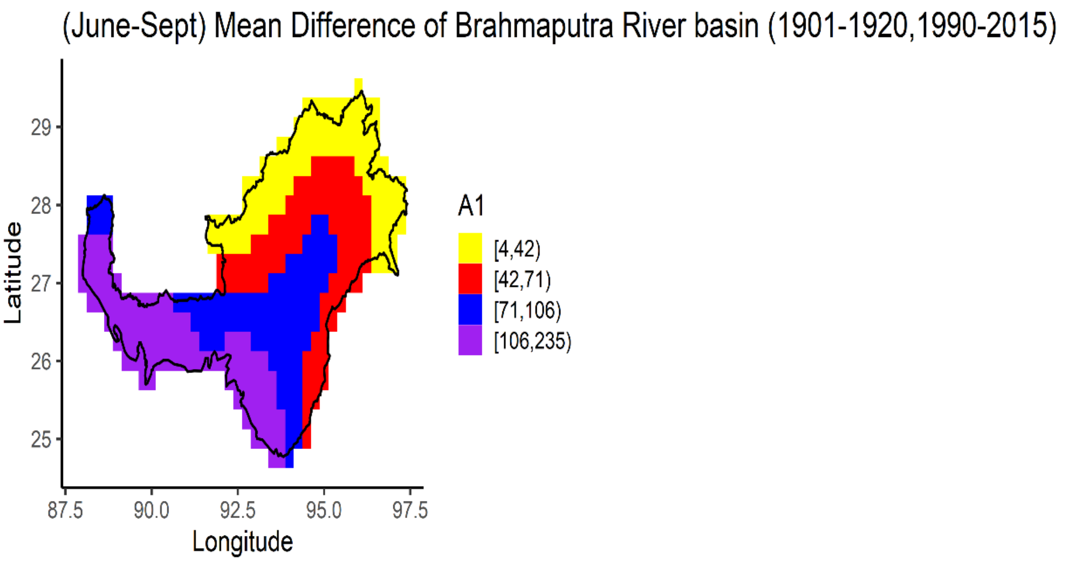


Inferences from Plot 1 and Plot 2:

- Plot 1 shows the average seasonal rainfall for each grid which is the sum of the rainfall from months (June to September) averaged out over a period of 20 years for each grid from 1901 to 1920 (referred to as Period 1).
- Plot 2 shows the average seasonal rainfall for each grid which is the sum of the rainfall from months (June to September) averaged out over a period of 26 years for each grid from 1990 to 2015 (referred to as Period 2).
- Both the plots utilize the same range for min, quartile, median, max values as the previous section as they both plot seasonal averages.
- Min=543.07 ; Q1=1078.8 Median=1349.05 ; Q3=1539.7 ; Max = 2367.59
- In the western region for both plots, we can see the same trend of them both being in the purple band (receiving the highest range of seasonal rainfall).
- The main difference in both the plots is that Period 1 plot (Plot 1) is more the blue range (more rainfall) in the eastern half as compared to Period 2 (Plot 2). In the other regions we see a similar range of rainfall received.
- Difference between the two is studied in the next plot (Plot 3).

3. Difference in Seasonal Rainfall between the two periods



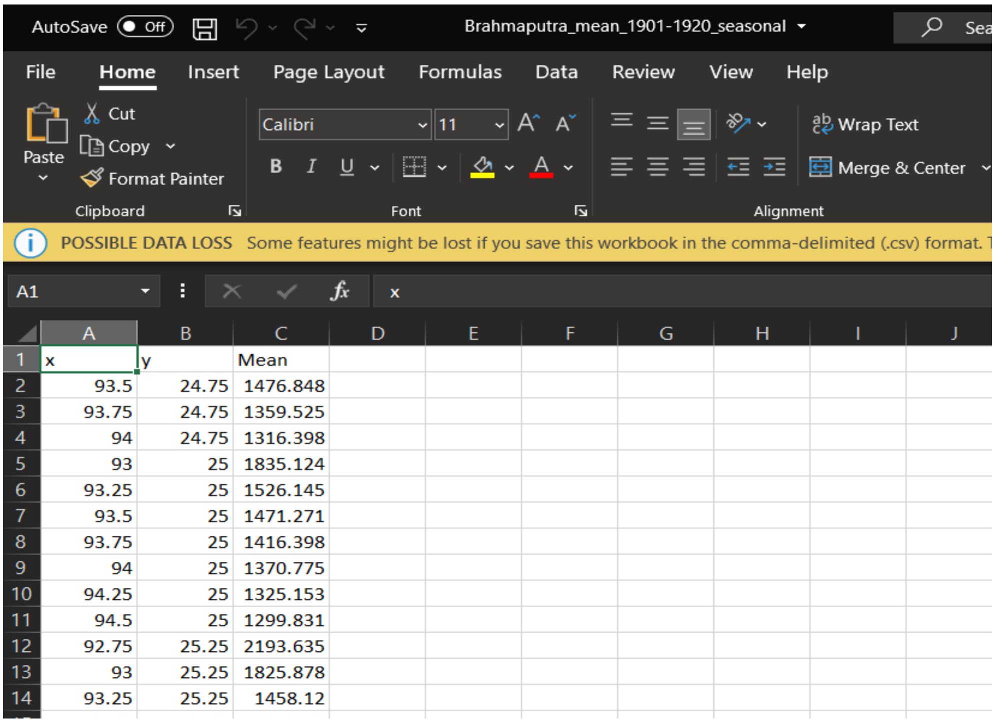


Inferences from Plot 3:

- Plot 3 shows the average seasonal (June to September) difference in rainfall for Brahmaputra river basin between the periods (1901-1920) and (1990-2015).
- In the above plot (1990-2015) values are subtracted from the (1901-1920) data that is, if column 1 contains 1901-1920 period data and column 2 contains 1990-2015 data, the difference value is column1-column2.
- This implies that purple colour band means that there was much more rainfall in that region in Period 1 as compared to Period 2.
- Min=4.29; Q1=42.3 Median=71.7; Q3=106.5; Max = 232.8(Refer to screenshots of csv below)
- From the difference plot we can infer that since all the ranges have values greater than 0, the entire region has received less rainfall from 1990 to 2015 as compared to 1901-1920.
- The plot follows a cascade from yellow to purple from north east to south west.
- The north eastern and northern tip is yellow which shows a minimal drop in rainfall between period 1 and period 2.
- As we move south and south west, the colour band changes from yellow to red which signifies a greater drop in rainfall. The red band also covers the eastern border.
- Further south and west the red changes to blue for further difference. The north western tip is also blue.
- The east and south eastern region of the river basin have the largest drop in rainfall from Period 1 to Period 2 as they lie in the purple range.

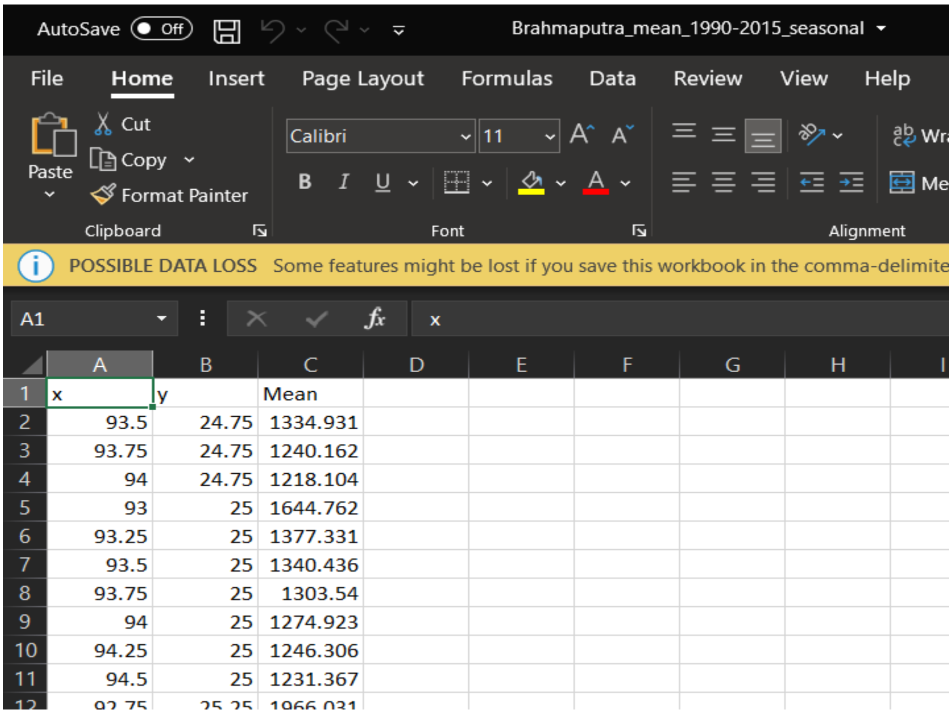
Data Screenshots from csv:

1. 1901-1920 Seasonal Average Rainfall



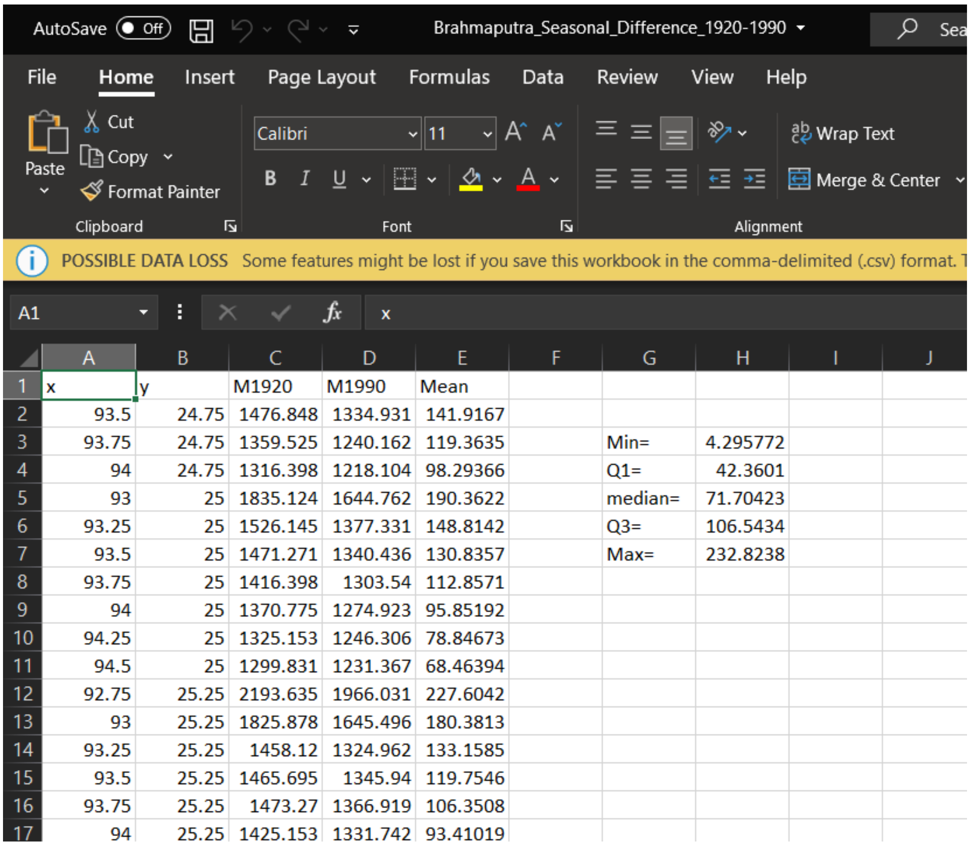
x	y	Mean
93.5	24.75	1476.848
93.75	24.75	1359.525
94	24.75	1316.398
93	25	1835.124
93.25	25	1526.145
93.5	25	1471.271
93.75	25	1416.398
94	25	1370.775
94.25	25	1325.153
94.5	25	1299.831
92.75	25.25	2193.635
93	25.25	1825.878
93.25	25.25	1458.12

2. 1990-2015 Seasonal Average Rainfall



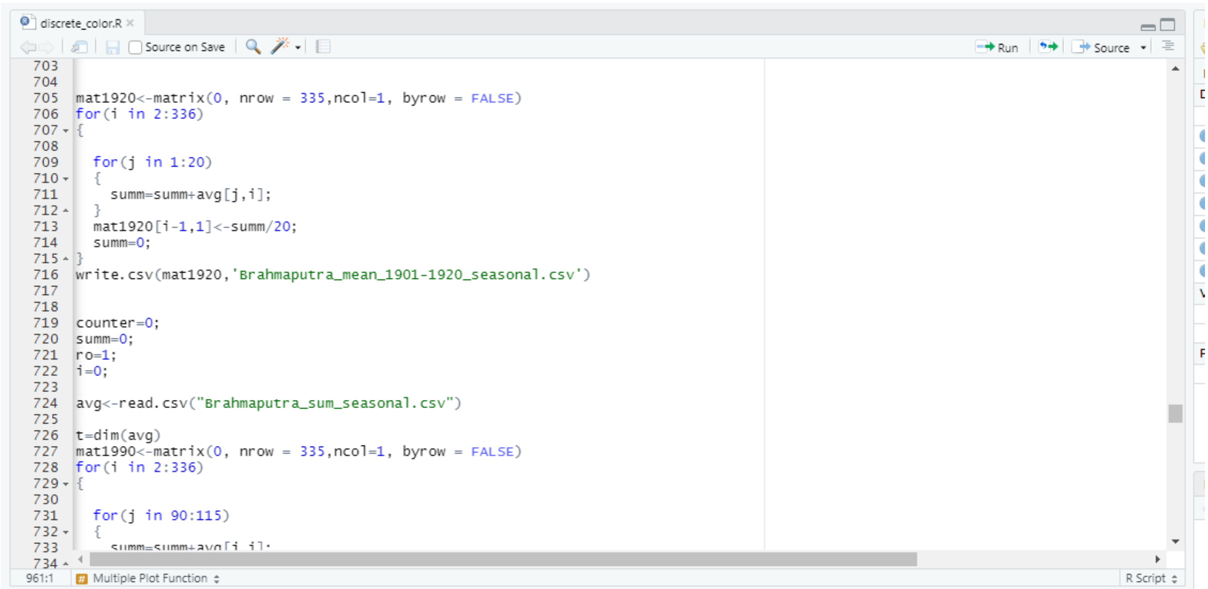
x	y	Mean
93.5	24.75	1334.931
93.75	24.75	1240.162
94	24.75	1218.104
93	25	1644.762
93.25	25	1377.331
93.5	25	1340.436
93.75	25	1303.54
94	25	1274.923
94.25	25	1246.306
94.5	25	1231.367

3. Difference in seasonal rainfall between the two periods



x	y	M1920	M1990	Mean			
93.5	24.75	1476.848	1334.931	141.9167			
93.75	24.75	1359.525	1240.162	119.3635		Min=	4.295772
94	24.75	1316.398	1218.104	98.29366		Q1=	42.3601
93	25	1835.124	1644.762	190.3622		median=	71.70423
93.25	25	1526.145	1377.331	148.8142		Q3=	106.5434
93.5	25	1471.271	1340.436	130.8357		Max=	232.8238
93.75	25	1416.398	1303.54	112.8571			
94	25	1370.775	1274.923	95.85192			
94.25	25	1325.153	1246.306	78.84673			
94.5	25	1299.831	1231.367	68.46394			
92.75	25.25	2193.635	1966.031	227.6042			
93	25.25	1825.878	1645.496	180.3813			
93.25	25.25	1458.12	1324.962	133.1585			
93.5	25.25	1465.695	1345.94	119.7546			
93.75	25.25	1473.27	1366.919	106.3508			
94	25.25	1425.153	1331.742	93.41019			

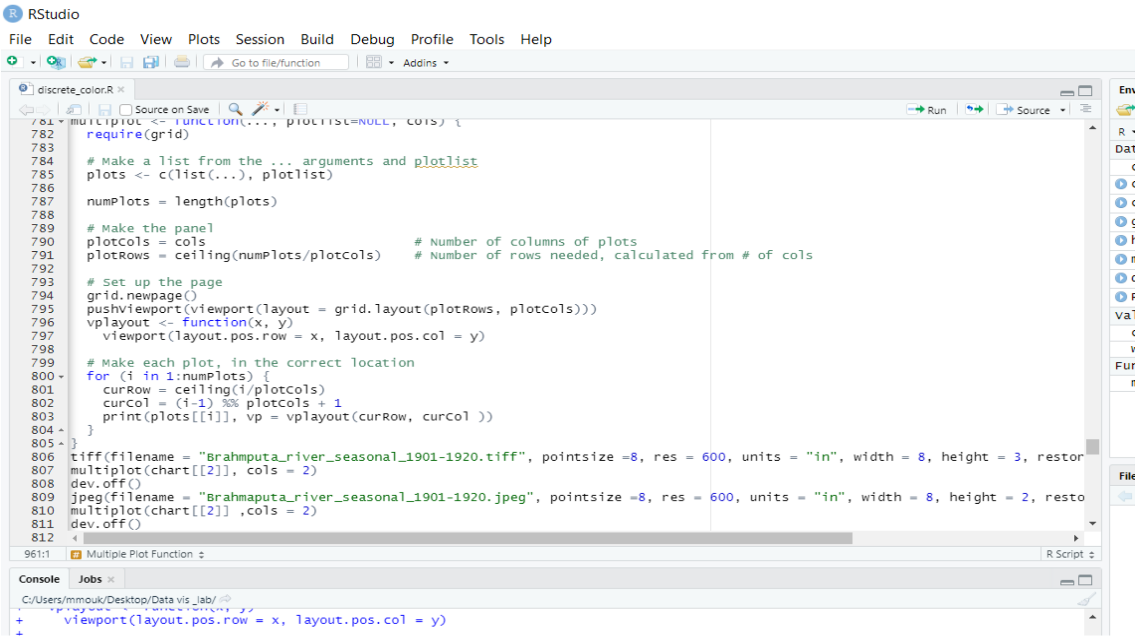
CODE Screenshots:



```
mat1920<-matrix(0, nrow = 335,ncol=1, byrow = FALSE)
for(i in 2:336)
{

  for(j in 1:20)
  {
    summ=summ+avg[j,i];
  }
  mat1920[i-1,1]<-summ/20;
  summ=0;
}
write.csv(mat1920,'Brahmaputra_mean_1901-1920_seasonal.csv')


counter=0;
summ=0;
ro=1;
i=0;

avg<-read.csv("Brahmaputra_sum_seasonal.csv")

t=dim(avg)
mat1990<-matrix(0, nrow = 335,ncol=1, byrow = FALSE)
for(i in 2:336)
{

  for(j in 90:115)
  {
    summ=summ+avg[j,i];
```

```r
counter=0;
summ=0;
ro=1;
i=0;

avg<-read.csv("Brahmaputra_sum_seasonal.csv")

t=dim(avg)
mat1990<-matrix(0, nrow = 335,ncol=1, byrow = FALSE)
for(i in 2:336)
{

  for(j in 90:115)
  {
    summ=summ+avg[j,i];
  }
  mat1990[i-1,1]<-summ/26;
  summ=0;
}
write.csv(mat1990,'Brahmaputra_mean_1990-2015_seasonal.csv')
```

```r
q<-read.csv("Brahmaputra_mean_1901-1920_seasonal.csv")
chart<-list()
w <- c(540,1.08e+03,1.35e+03,1.54e+03,2.37e+03)

cols <- c("[540,1.08e+03)" = "yellow", "[1.08e+03,1.35e+03)" = "red", "[1.35e+03,1.54e+03)" = "blue", "[1.54e+03,2.37e+03)" = "
q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("11-9-2019-3772456")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average Seasonal Rainfall of Brahmaputra River basin for 19


cols <- c("[540,1.08e+03)" = "yellow", "[1.08e+03,1.35e+03)" = "red", "[1.35e+03,1.54e+03)" = "blue", "[1.54e+03,2.37e+03)" = "
q$A2 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("11-9-2019-3772456")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[2]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average Seasonal Rainfall of Brahmaputra River basin for 19
```

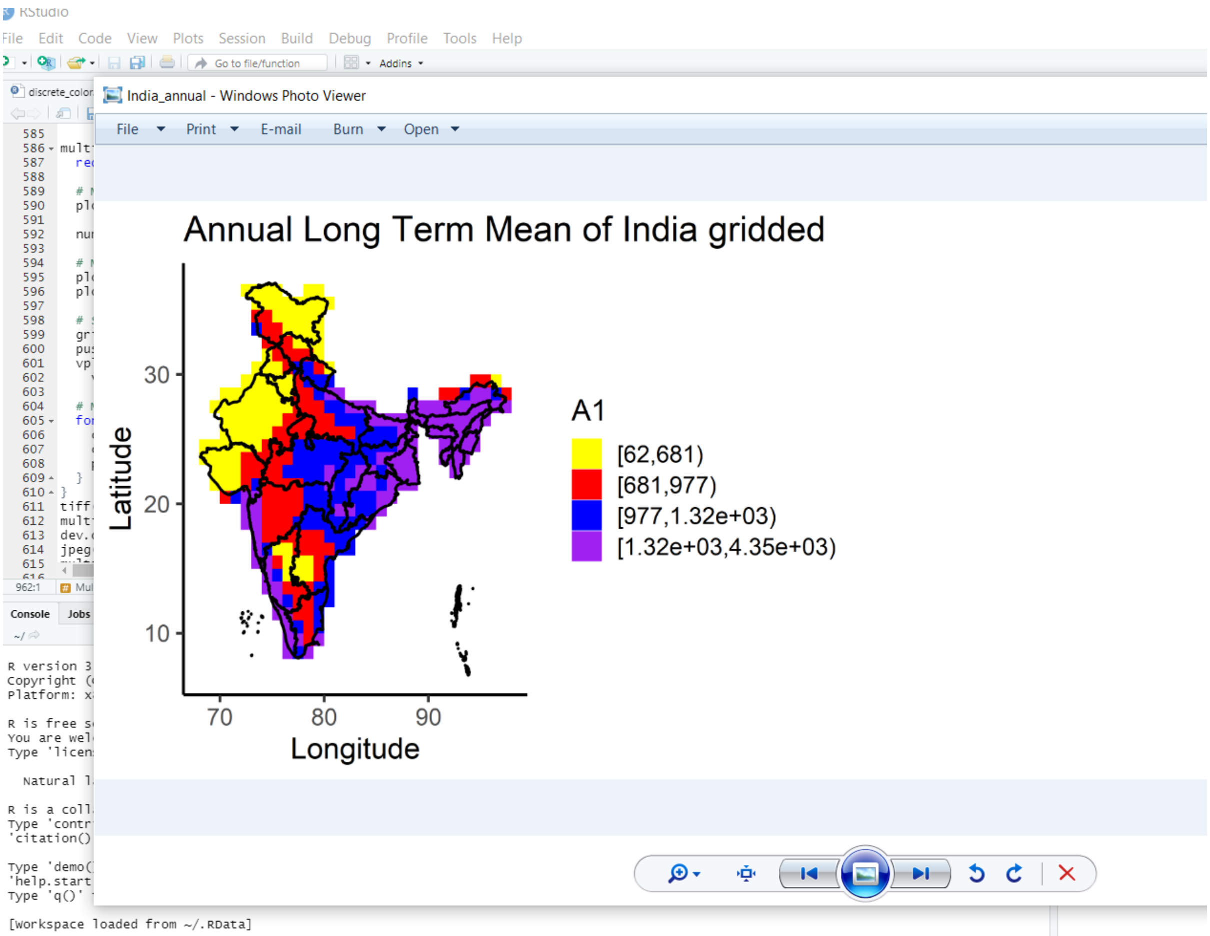


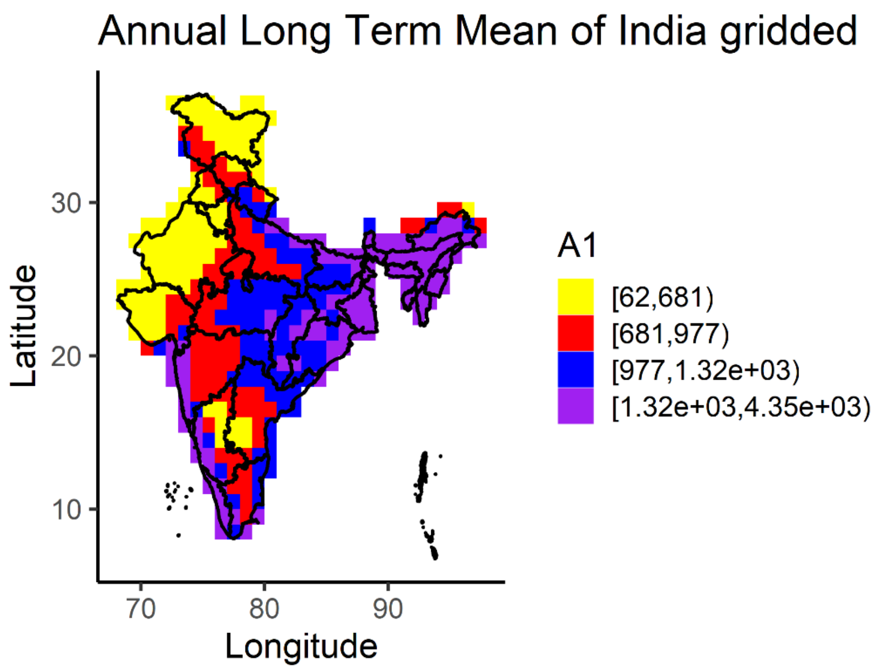
RStudio
File Edit Code View Plots Session Build Debug Profile Tools Help
Go to file/function
Addins
discrete_color.R
Source on Save
Run
Source
require(grid)
# Make a list from the ... arguments and plotlist
plots <- c(list(...), plotlist)
numPlots = length(plots)
# Make the panel
plotCols = cols # Number of columns of plots
plotRows = ceiling(numPlots/plotCols) # Number of rows needed, calculated from # of cols
# Set up the page
grid.newpage()
pushViewport(viewport(layout = grid.layout(plotRows, plotCols)))
vplayout <- function(x, y)
viewport(layout.pos.row = x, layout.pos.col = y)
# Make each plot, in the correct location
for (i in 1:numPlots) {
curRow = ceiling(i/plotCols)
curCol = (i-1) %% plotCols + 1
print(plots[[i]], vp = vplayout(curRow, curCol))
}
}
tiff(filename = "Brahmputa_river_seasonal_1901-1920.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restor
multiplot(chart[[2]], cols = 2)
dev.off()
jpeg(filename = "Brahmaputa_river_seasonal_1901-1920.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, resto
multiplot(chart[[2]] ,cols = 2)
dev.off()
961:1
Multiple Plot Function
R Script
Console
Jobs
C:/Users/mmouk/Desktop/Data vis _lab/
+ viewport(layout.pos.row = x, layout.pos.col = y)
+

India – Gridded – Data

Q1. Calculate long term mean in each of grid. Map the derived result into geographical structure with suitable color palettes.

Geographical Structure for Long Term Annual Mean from 1901-2014:





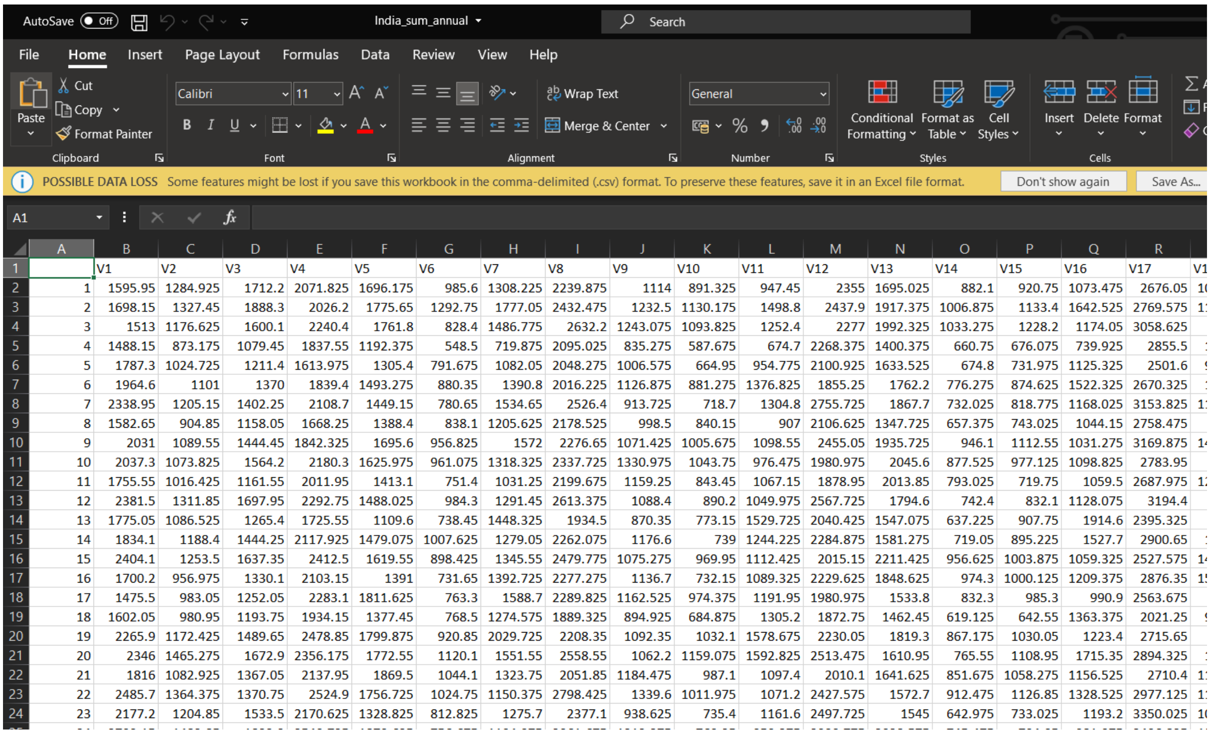
Inferences:

- The above plot represents the Annual Long Term Mean of Rainfall for India for each grid (combination of latitude and longitude) from the year 1901-2014.
- The plot is filled by colours separated by a range of values from min to quartile 1 to median to quartile 3 and max value. We have 4 subsequent colour ranges.
- Min= 62.7; Q1=681.4; Median=977.8; Q3=1326.7; Max= 4340.09 (Refer to CSV screenshot below).
- These ranges define the amount of rainfall in that particular grid by means of colour. Yellow is the range with lowest rainfall while purple is the range with highest rainfall.
- From the above plot we can see that the north western (Rajasthan, parts of Gujarat) and northern region of India(Kashmir) receives the lowest annual rainfall as they are in the yellow range. A small patch of yellow can also be seen in the southern part of India.
- The west coast receives the highest amount of rainfall, falling in the purple range.
- The southern tip of India also receives the highest range of rainfall.
- Parts of eastern India (Odisha, West Bengal and others) and the north east region of India also fall in the purple range (highest rainfall).

- A large strip of red range can be seen extending from the north all the way to the southern part of India.
- Parts of central India lie in the blue range (Madhya Pradesh, Parts of UP and others). These regions receive high annual rainfall but not the highest range.
- As expected, the coastal regions receive high amounts of rainfall , which decreases as we move to the interior.

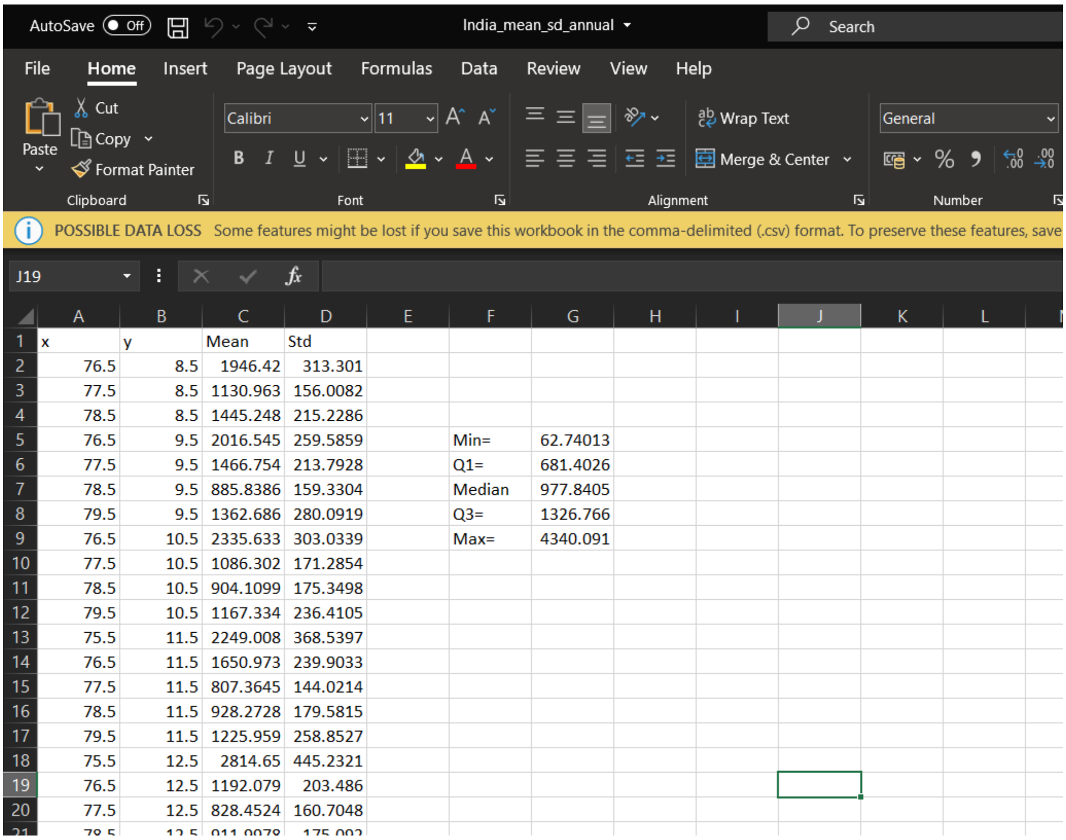
Data Screenshots of CSV:

1. Annual sum per year for every grid.



	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17
1	1595.95	1284.925	1712.2	2071.825	1696.175	985.6	1308.225	2239.875	1114	891.325	947.45	2355	1695.025	882.1	920.75	1073.475	2676.05
2	1698.15	1327.45	1888.3	2026.2	1775.65	1292.75	1777.05	2432.475	1232.5	1130.175	1498.8	2437.9	1917.375	1006.875	1133.4	1642.525	2769.575
3	1513	1176.625	1600.1	2240.4	1761.8	828.4	1486.775	2632.2	1243.075	1093.825	1252.4	2277	1992.325	1033.275	1228.2	1174.05	3058.625
4	1488.15	873.175	1079.45	1837.55	1192.375	548.5	719.875	2095.025	835.275	587.675	674.7	2268.375	1400.375	660.75	676.075	739.925	2855.5
5	1787.3	1024.725	1211.4	1613.975	1305.4	791.675	1082.05	2048.275	1006.575	664.95	954.775	2100.925	1633.525	674.8	731.975	1125.325	2501.6
6	1964.6	1101	1370	1839.4	1493.275	880.35	1390.8	2016.225	1126.875	881.275	1376.825	1855.25	1762.2	776.275	874.625	1522.325	2670.325
7	2338.95	1205.15	1402.25	2108.7	1449.15	780.65	1534.65	2526.4	913.725	718.7	1304.8	2755.725	1867.7	732.025	818.775	1168.025	3153.825
8	1582.65	904.85	1158.05	1668.25	1388.4	838.1	1205.625	2178.525	998.5	840.15	907	2106.625	1347.725	657.375	743.025	1044.15	2758.475
9	2031	1089.55	1444.45	1842.325	1695.6	956.825	1572	2276.65	1071.425	1005.675	1098.55	2455.05	1935.725	946.1	1112.55	1031.275	3169.875
10	2037.3	1073.825	1564.2	2180.3	1625.975	961.075	1318.325	2337.725	1330.975	1043.75	976.475	1980.975	2045.6	877.525	977.125	1098.825	2783.95
11	1755.55	1016.425	1161.55	2011.95	1413.1	751.4	1031.25	2199.675	1159.25	843.45	1067.15	1878.95	2013.85	793.025	719.75	1059.5	2687.975
12	2381.5	1311.85	1697.95	2292.75	1488.025	984.3	1291.45	2613.375	1088.4	890.2	1049.975	2567.725	1794.6	742.4	832.1	1128.075	3194.4
13	1775.05	1086.525	1265.4	1725.55	1109.6	738.45	1448.325	1934.5	870.35	773.15	1529.725	2040.425	1547.075	637.225	907.75	1914.6	2395.325
14	1834.1	1188.4	1444.25	2117.925	1479.075	1007.625	1279.05	2262.075	1176.6	739	1244.225	2284.875	1581.275	719.05	895.225	1527.7	2900.65
15	2404.1	1253.5	1637.35	2412.5	1619.55	898.425	1345.55	2479.775	1075.275	969.95	1112.425	2015.15	2211.425	956.625	1003.875	1059.325	2527.575
16	1700.2	956.975	1330.1	2103.15	1391	731.65	1392.725	2277.275	1136.7	732.15	1089.325	2229.625	1848.625	974.3	1000.125	1209.375	2876.35
17	1475.5	983.05	1252.05	2283.1	1811.625	763.3	1588.7	2289.825	1162.525	974.375	1191.95	1980.975	1533.8	832.3	985.3	990.9	2563.675
18	1602.05	980.95	1193.75	1934.15	1377.45	768.5	1274.575	1889.325	894.925	684.875	1305.2	1872.75	1462.45	619.125	642.55	1363.375	2021.25
19	2265.9	1172.425	1489.65	2478.85	1799.875	920.85	2029.725	2208.35	1092.35	1032.1	1578.675	2230.05	1819.3	867.175	1030.05	1223.4	2715.65
20	2346	1465.275	1672.9	2356.175	1772.55	1120.1	1551.55	2558.55	1062.2	1159.075	1592.825	2513.475	1610.95	765.55	1108.95	1715.35	2894.325
21	1816	1082.925	1367.05	2137.95	1869.5	1044.1	1323.75	2051.85	1184.475	987.1	1097.4	2010.1	1641.625	851.675	1058.275	1156.525	2710.4
22	2485.7	1364.375	1370.75	2524.9	1756.725	1024.75	1150.375	2798.425	1339.6	1011.975	1071.2	2427.575	1572.7	912.475	1126.85	1328.525	2977.125
23	2177.2	1204.85	1533.5	2170.625	1328.825	812.825	1275.7	2377.1	938.625	735.4	1161.6	2497.725	1545	642.975	733.025	1193.2	3350.025

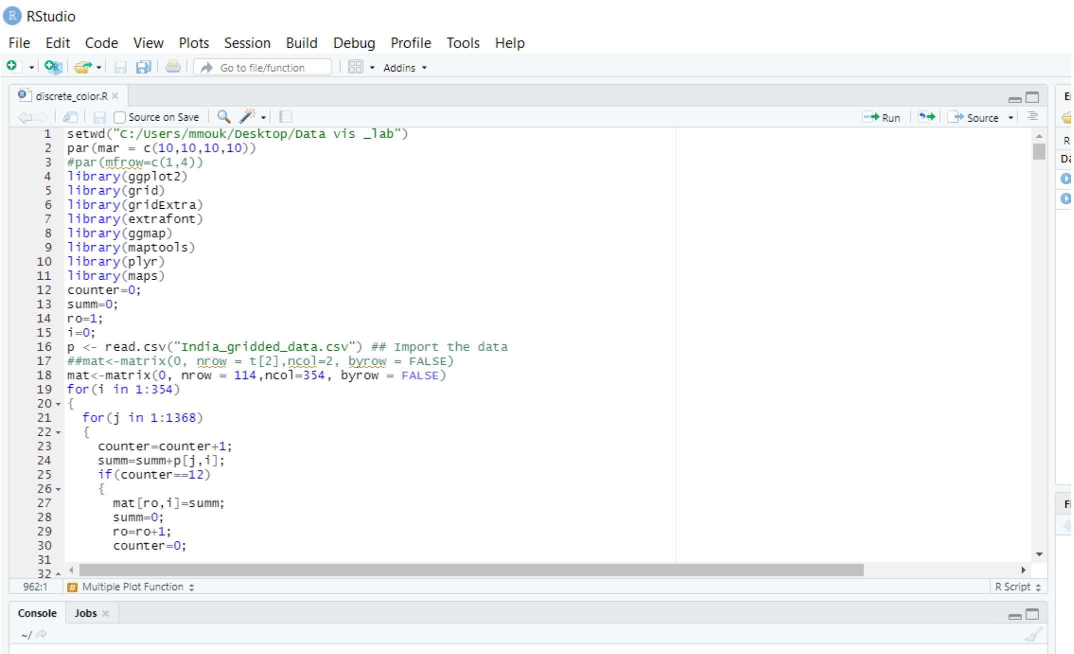
2. CSV containing the average annual mean and standard deviation per grid (longitude and latitude)



x	y	Mean	Std
76.5	8.5	1946.42	313.301
77.5	8.5	1130.963	156.0082
78.5	8.5	1445.248	215.2286
76.5	9.5	2016.545	259.5859
77.5	9.5	1466.754	213.7928
78.5	9.5	885.8386	159.3304
79.5	9.5	1362.686	280.0919
76.5	10.5	2335.633	303.0339
77.5	10.5	1086.302	171.2854
78.5	10.5	904.1099	175.3498
79.5	10.5	1167.334	236.4105
75.5	11.5	2249.008	368.5397
76.5	11.5	1650.973	239.9033
77.5	11.5	807.3645	144.0214
78.5	11.5	928.2728	179.5815
79.5	11.5	1225.959	258.8527
75.5	12.5	2814.65	445.2321
76.5	12.5	1192.079	203.486
77.5	12.5	828.4524	160.7048

Min=	62.74013
Q1=	681.4026
Median	977.8405
Q3=	1326.766
Max=	4340.091

CODE SCREENSHOTS:



```
setwd("C:/Users/mmouk/Desktop/Data vis _lab")
par(mar = c(10,10,10,10))
#par(mfrow=c(1,4))
library(ggplot2)
library(grid)
library(gridExtra)
library(extrafont)
library(ggmap)
library(maptools)
library(plyr)
library(maps)
counter=0;
summ=0;
ro=1;
i=0;
p <- read.csv("India_gridded_data.csv") ## Import the data
##mat<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
mat<-matrix(0, nrow = 114,ncol=354, byrow = FALSE)
for(i in 1:354)
{
  for(j in 1:1368)
  {
    counter=counter+1;
    summ=summ+p[j,i];
    if(counter==12)
    {
      mat[ro,i]=summ;
      summ=0;
      ro=ro+1;
      counter=0;
```

discrete_color.R

```r
i=0;
p <- read.csv("India_gridded_data.csv") ## Import the data
##mat<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
mat<-matrix(0, nrow = 114,ncol=354, byrow = FALSE)
for(i in 1:354)
{
  for(j in 1:1368)
  {
    counter=counter+1;
    summ=summ+p[j,i];
    if(counter==12)
    {
      mat[ro,i]=summ;
      summ=0;
      ro=ro+1;
      counter=0;

    }

  }
  ro=1;
  counter=0;
  summ=0;


}
mat;
write.csv(mat,'India_sum_annual.csv')

avg<-read.csv("India_sum_annual.csv")
```

962:1 Multiple Plot Function R Script

Console Jobs

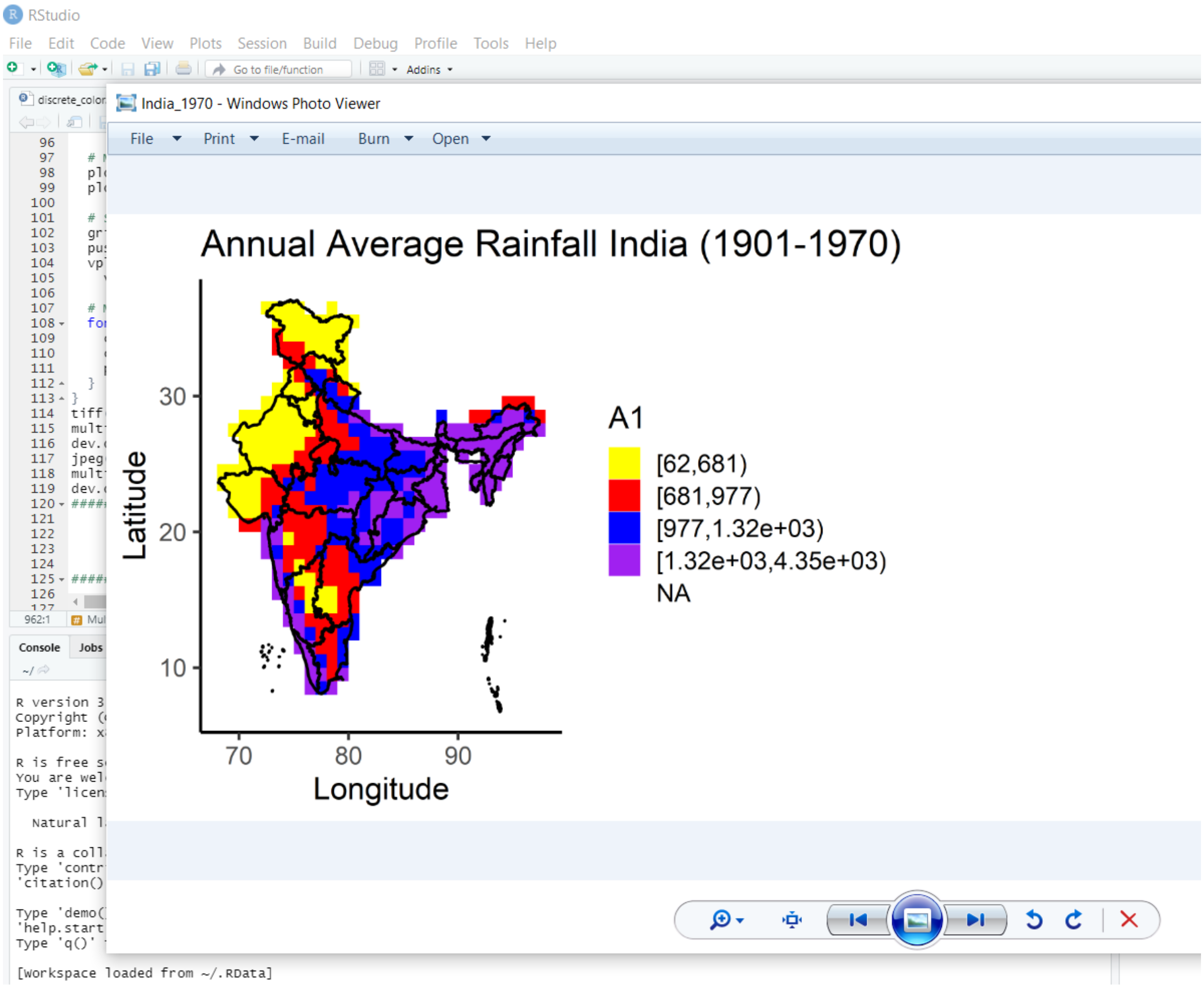
```r
avg<-read.csv("India_sum_annual.csv")

t=dim(avg)
mat2<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
for(i in 1:(t[2]-1))
{
  m = mean(avg[,i+1])   ##  mean
  mat2[i,1]<-m
  s<-sd(avg[,i+1])
  mat2[i,2]<-s        ##   standard deviation
}
write.csv(mat2,'India_mean_sd_annual.csv')

q<-read.csv("India_mean_sd_annual.csv")
chart<-list()
w <- c(62,681,977,1.32e+03,4.35e+03)

cols <- c("[62,681)" = "yellow", "[681,977)" = "red", "[977,1.32e+03)" = "blue", "[1.32e+03,4.35e+03)" = "purple")
q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("Ind")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Annual Long Term Mean of India gridded ")


 cols <- c("[62,681)" = "yellow", "[681,977)" = "red", "[977,1.32e+03)" = "blue", "[1.32e+03,4.35e+03)" = "purple")
```

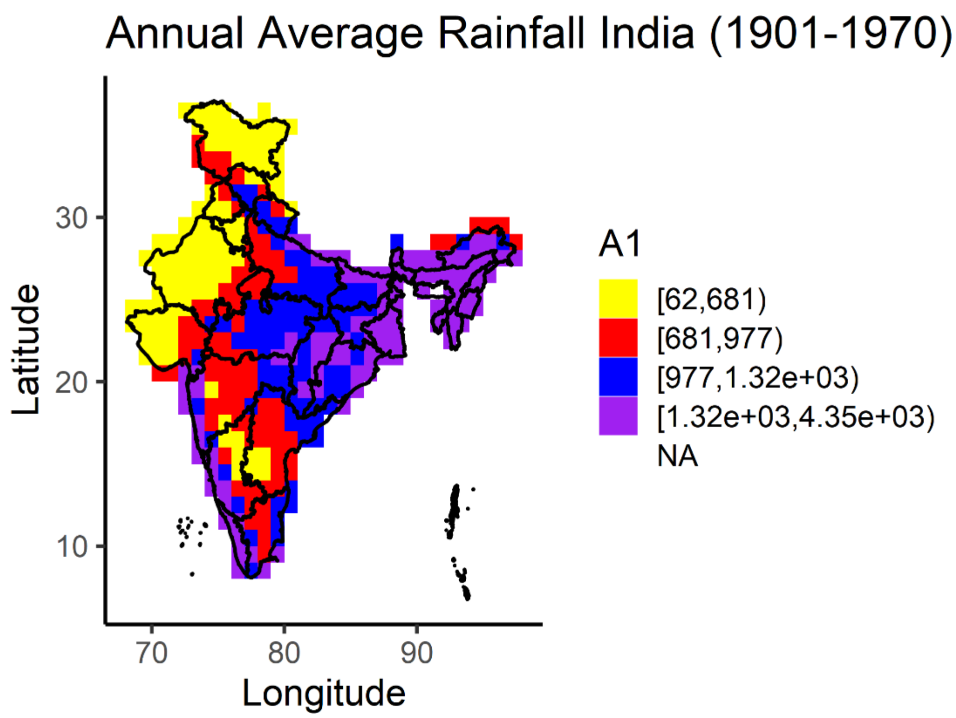
```r
  # Make the panel
  plotCols = cols                          # Number of columns of plots
  plotRows = ceiling(numPlots/plotCols)    # Number of rows needed, calculated from # of cols

  # Set up the page
  grid.newpage()
  pushViewport(viewport(layout = grid.layout(plotRows, plotCols)))
  vplayout <- function(x, y)
    viewport(layout.pos.row = x, layout.pos.col = y)

  # Make each plot, in the correct location
  for (i in 1:numPlots) {
    curRow = ceiling(i/plotCols)
    curCol = (i-1) %% plotCols + 1
    print(plots[[i]], vp = vplayout(curRow, curCol ))
  }
}
tiff(filename = "India_annual.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole = TRUE, type
multiplot(chart[[2]], cols = 2)
dev.off()
jpeg(filename = "India_annual.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE, type
multiplot(chart[[2]] ,cols = 2)
dev.off()
######################PArt A OVER##############################################




#######################PArt B Begins#########################################################
```

Q2. Calculate the change in average annual rainfall with respect to global warming in each grid. Then plot the derived result.

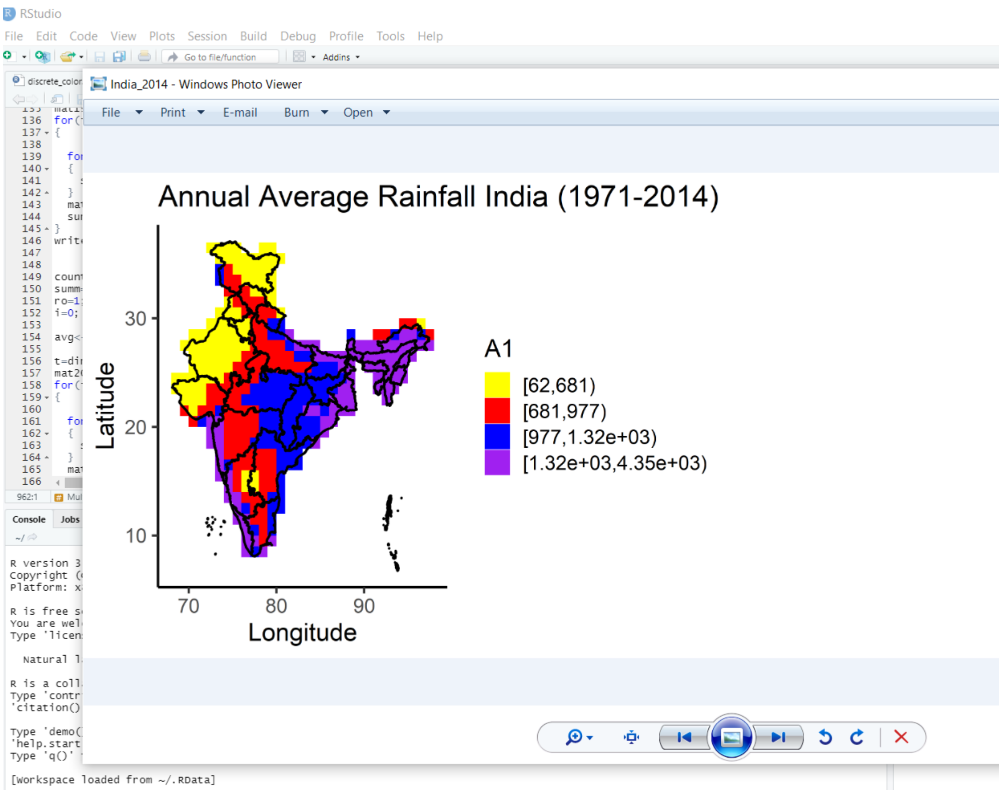
PLOTS:

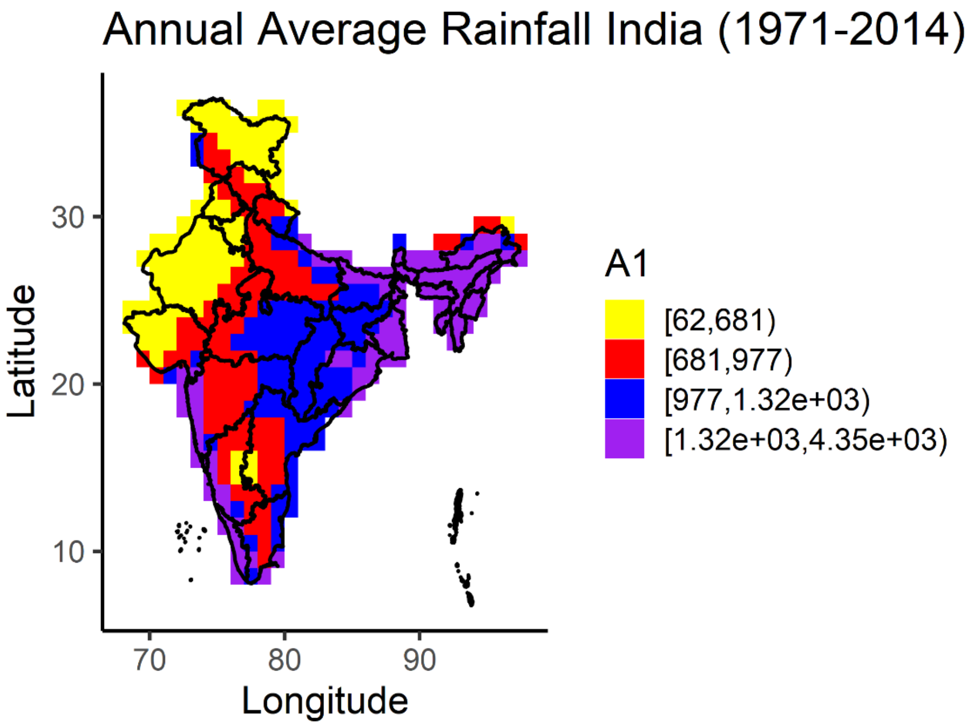
1. Average annual rainfall 1901-1970





2. Average annual rainfall 1971-2014

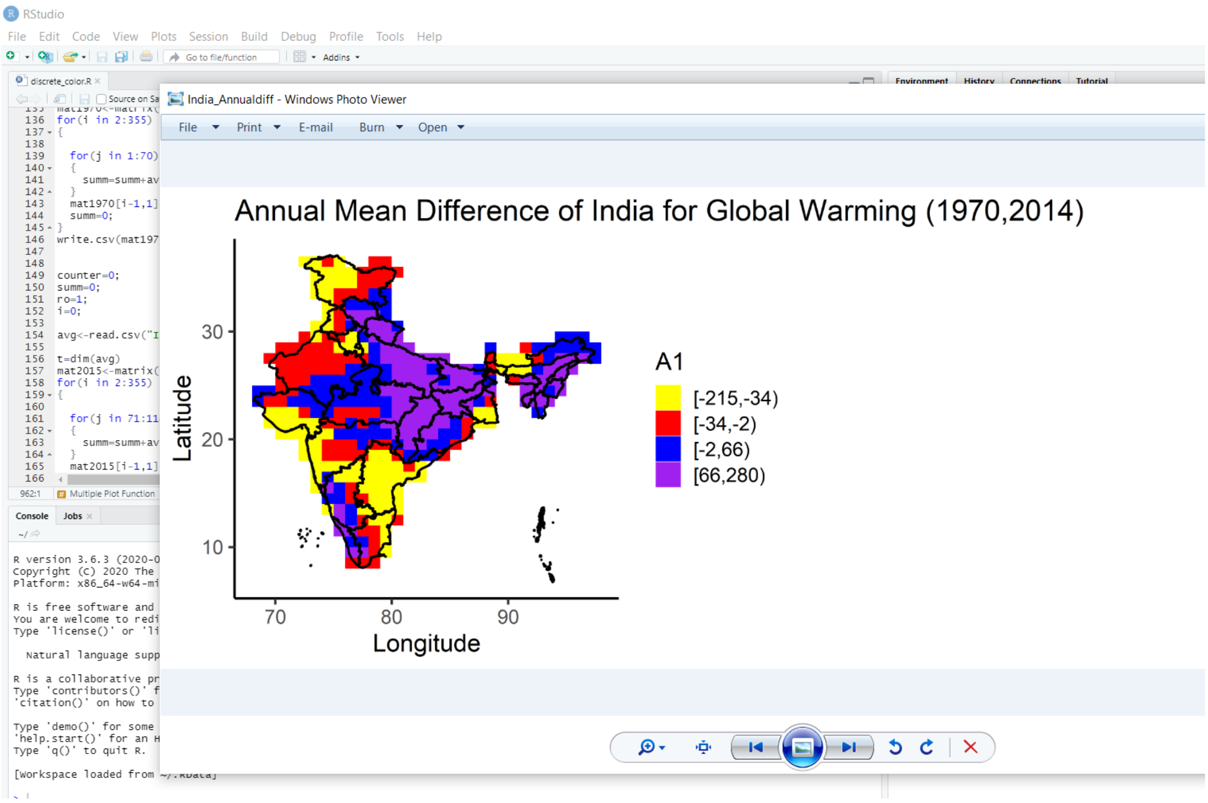


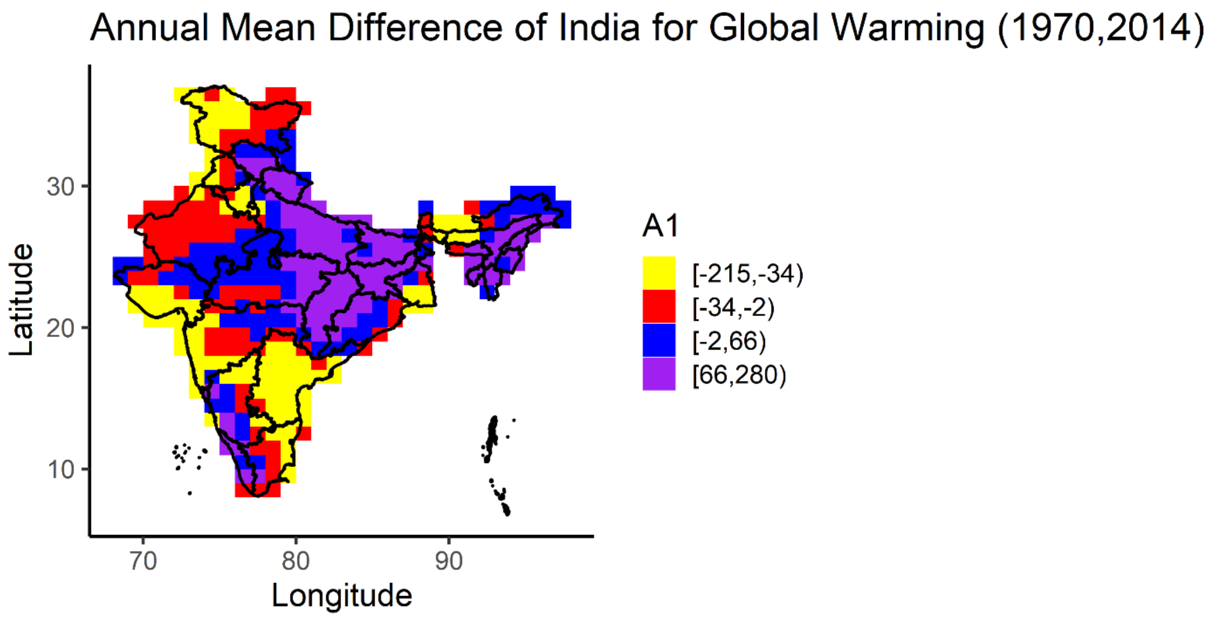


Inference from Plot 1 and Plot 2:

- Plot 1 represents the annual average rainfall of India corresponding to pre global warming (1901-1970). Plot 2 represents the annual average rainfall of India corresponding to post global warming(1971-2014).
- The same range of values is utilized to define colours as the plot still shows the annual averages of rainfall per grid. Min= 62.7; Q1=681.4; Median=977.8; Q3=1326.7; Max= 4340.09
- On brief inspection, both plot 1 and plot 2 follow a similar trend with only slight differences.
- Both plots follow a similar pattern as the plot from the previous section.
- The difference in rainfall between the two plots will be covered in the next plot (Plot 3).

3. Difference in Average Annual Rainfall between the two periods



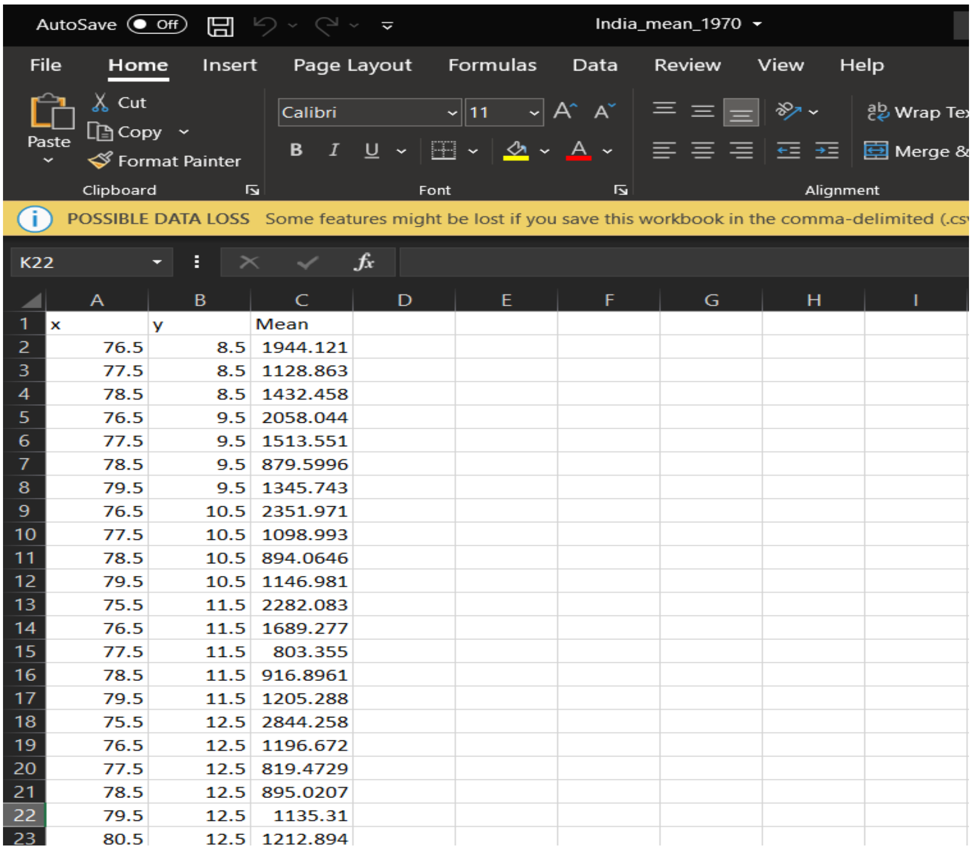


Inferences from Plot 3:

- Plot 3 represents the difference in average annual rainfall in India between the pre global warming (1901-1970) and the post global warming(1971-2014) periods.
- In the above plot 2014 values are subtracted from the 1901 data that is, if column 1 contains 1901-1970 period data and column 2 contains 1971-2014 data, the difference value is column1-column2.
- This implies that purple colour band means that there was much more rainfall in that region before global warming as compared to after it.
- Min difference= -214.806 (negative value implies that region receives more rainfall after 1971 as compared to before 1971. Quartile 1= -33.27 ; Median = -1.05; Quartile 3= 66.73; Max difference is 276.31 (Refer to screenshot of CSV below).
- In the above plot we can see a huge region filled with purple in the eastern and North eastern region of India. This implies that this region receives a lot less rainfall in the post global warming period (1971-2014) than it received in the pre global warming period (1901-1970).
- The purple patch also exists in the south from which we can infer the same as the previous point.
- Next to the purple patches are blue fills which represent that the region receives about the same or less rainfall (-2, 66) in post global warming period than it did in the pre global warming period.
- The red bands are scattered across India mostly in the western India and southern India. This band represents the regions which get more rainfall in the post global warming period(1990-2014) than the pre global warming period (1901-1970).
- The regions filled with yellow are also present which represents the region which receive a lot more rainfall (-215,-34) in the post global warming period(1990-2014) than the pre global warming period (1901-1970).

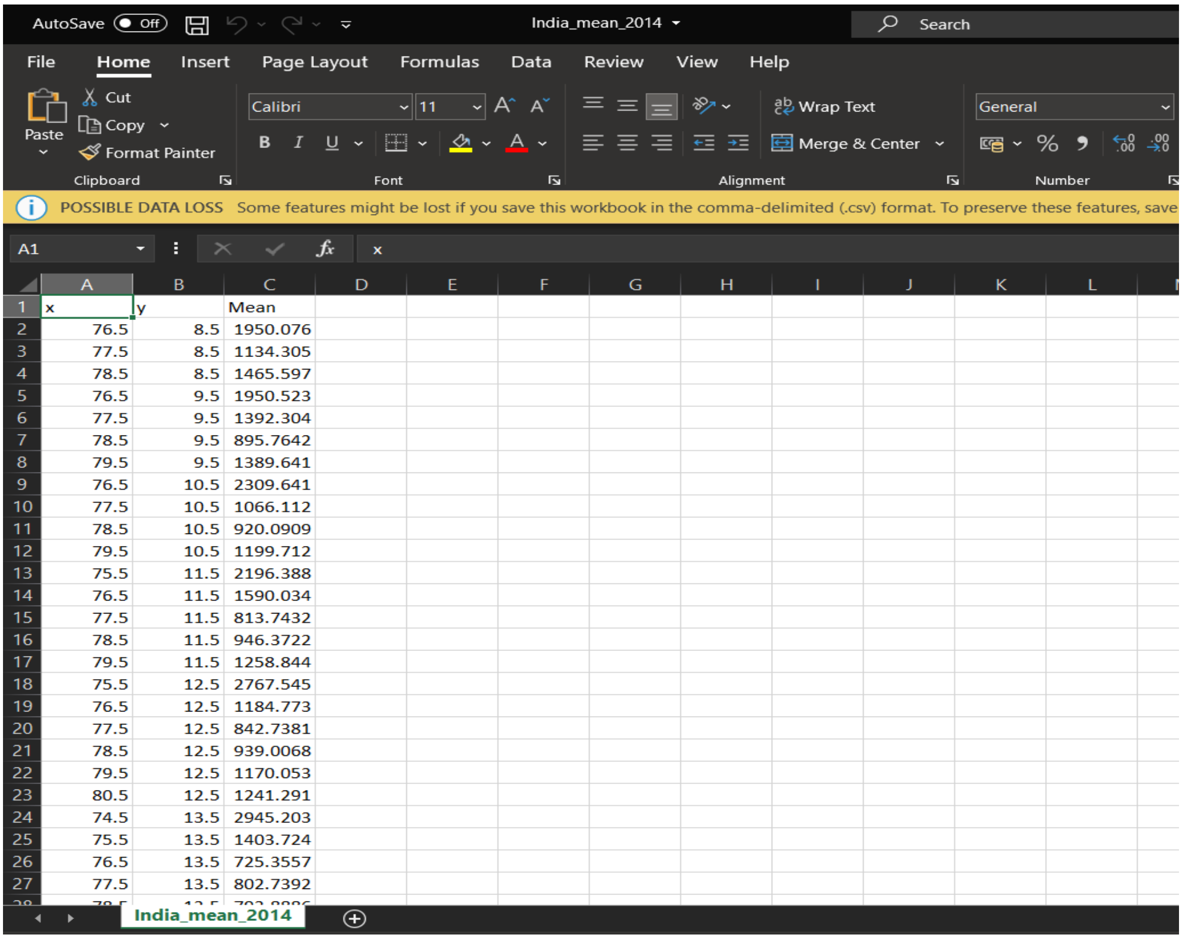
Data Screenshots from Excel CSV files:

1. Average Annual Data for 1901 to 1970



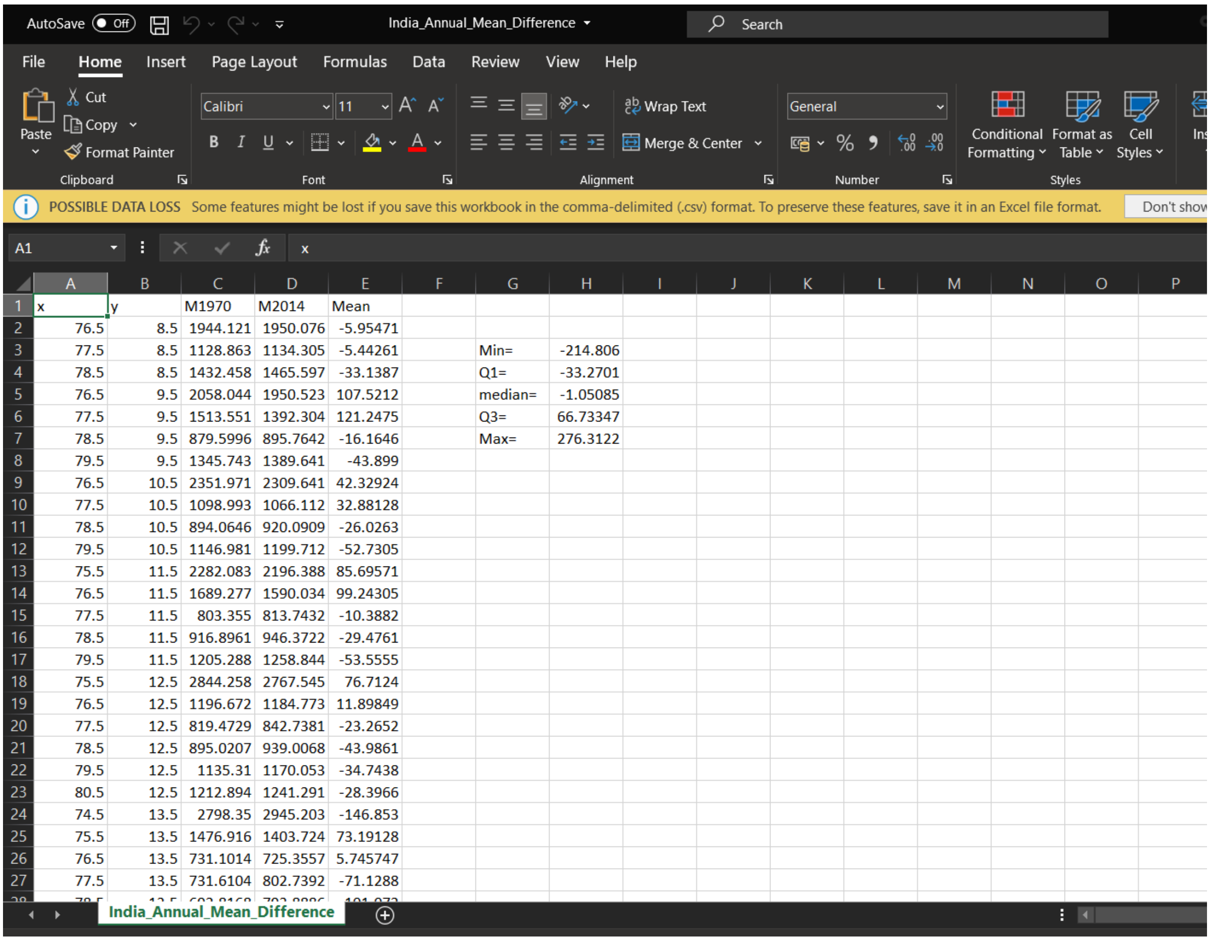
	A	B	C
1	x	y	Mean
2	76.5	8.5	1944.121
3	77.5	8.5	1128.863
4	78.5	8.5	1432.458
5	76.5	9.5	2058.044
6	77.5	9.5	1513.551
7	78.5	9.5	879.5996
8	79.5	9.5	1345.743
9	76.5	10.5	2351.971
10	77.5	10.5	1098.993
11	78.5	10.5	894.0646
12	79.5	10.5	1146.981
13	75.5	11.5	2282.083
14	76.5	11.5	1689.277
15	77.5	11.5	803.355
16	78.5	11.5	916.8961
17	79.5	11.5	1205.288
18	75.5	12.5	2844.258
19	76.5	12.5	1196.672
20	77.5	12.5	819.4729
21	78.5	12.5	895.0207
22	79.5	12.5	1135.31
23	80.5	12.5	1212.894

2. Average Annual Data for 1971 to 2014



x	y	Mean
76.5	8.5	1950.076
77.5	8.5	1134.305
78.5	8.5	1465.597
76.5	9.5	1950.523
77.5	9.5	1392.304
78.5	9.5	895.7642
79.5	9.5	1389.641
76.5	10.5	2309.641
77.5	10.5	1066.112
78.5	10.5	920.0909
79.5	10.5	1199.712
75.5	11.5	2196.388
76.5	11.5	1590.034
77.5	11.5	813.7432
78.5	11.5	946.3722
79.5	11.5	1258.844
75.5	12.5	2767.545
76.5	12.5	1184.773
77.5	12.5	842.7381
78.5	12.5	939.0068
79.5	12.5	1170.053
80.5	12.5	1241.291
74.5	13.5	2945.203
75.5	13.5	1403.724
76.5	13.5	725.3557
77.5	13.5	802.7392

3. CSV containing the difference data between the two periods with respect to global warming.



	A	B	C	D	E	F	G	H
1	x	y	M1970	M2014	Mean			
2	76.5	8.5	1944.121	1950.076	-5.95471			
3	77.5	8.5	1128.863	1134.305	-5.44261		Min=	-214.806
4	78.5	8.5	1432.458	1465.597	-33.1387		Q1=	-33.2701
5	76.5	9.5	2058.044	1950.523	107.5212		median=	-1.05085
6	77.5	9.5	1513.551	1392.304	121.2475		Q3=	66.73347
7	78.5	9.5	879.5996	895.7642	-16.1646		Max=	276.3122
8	79.5	9.5	1345.743	1389.641	-43.899			
9	76.5	10.5	2351.971	2309.641	42.32924			
10	77.5	10.5	1098.993	1066.112	32.88128			
11	78.5	10.5	894.0646	920.0909	-26.0263			
12	79.5	10.5	1146.981	1199.712	-52.7305			
13	75.5	11.5	2282.083	2196.388	85.69571			
14	76.5	11.5	1689.277	1590.034	99.24305			
15	77.5	11.5	803.355	813.7432	-10.3882			
16	78.5	11.5	916.8961	946.3722	-29.4761			
17	79.5	11.5	1205.288	1258.844	-53.5555			
18	75.5	12.5	2844.258	2767.545	76.7124			
19	76.5	12.5	1196.672	1184.773	11.89849			
20	77.5	12.5	819.4729	842.7381	-23.2652			
21	78.5	12.5	895.0207	939.0068	-43.9861			
22	79.5	12.5	1135.31	1170.053	-34.7438			
23	80.5	12.5	1212.894	1241.291	-28.3966			
24	74.5	13.5	2798.35	2945.203	-146.853			
25	75.5	13.5	1476.916	1403.724	73.19128			
26	76.5	13.5	731.1014	725.3557	5.745747			
27	77.5	13.5	731.6104	802.7392	-71.1288			

CODE SCREENSHOTS:

RStudio

File Edit Code View Plots Session Build Debug Profile Tools Help

discrete_color.R

```
########################PArt B Begins#####################################################

counter=0;
summ=0;
ro=1;
i=0;

avg<-read.csv("India_sum_annual.csv")

t=dim(avg)
mat1970<-matrix(0, nrow = 354,ncol=1, byrow = FALSE)
for(i in 2:355)
{

  for(j in 1:70)
  {
    summ=summ+avg[j,i];
  }
  mat1970[i-1,1]<-summ/70;
  summ=0;
}
write.csv(mat1970,'India_mean_1970.csv')


counter=0;
summ=0;
ro=1;
```

discrete_color.R

```
avg<-read.csv("India_sum_annual.csv")

t=dim(avg)
mat2015<-matrix(0, nrow = 354,ncol=1, byrow = FALSE)
for(i in 2:355)
{

  for(j in 71:114)
  {
    summ=summ+avg[j,i];
  }
  mat2015[i-1,1]<-summ/44;
  summ=0;
}

write.csv(mat2015,'India_mean_2015.csv')





q<-read.csv("India_mean_2014.csv")
chart<-list()
w <- c(62,681,977,1.32e+03,4.35e+03)

cols <- c("[62,681)" = "yellow", "[681,977)" = "red", "[977,1.32e+03)" = "blue", "[1.32e+03,4.35e+03)" = "purple")
q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
```

175:29 PArt B Begins R Script

discrete_color.R

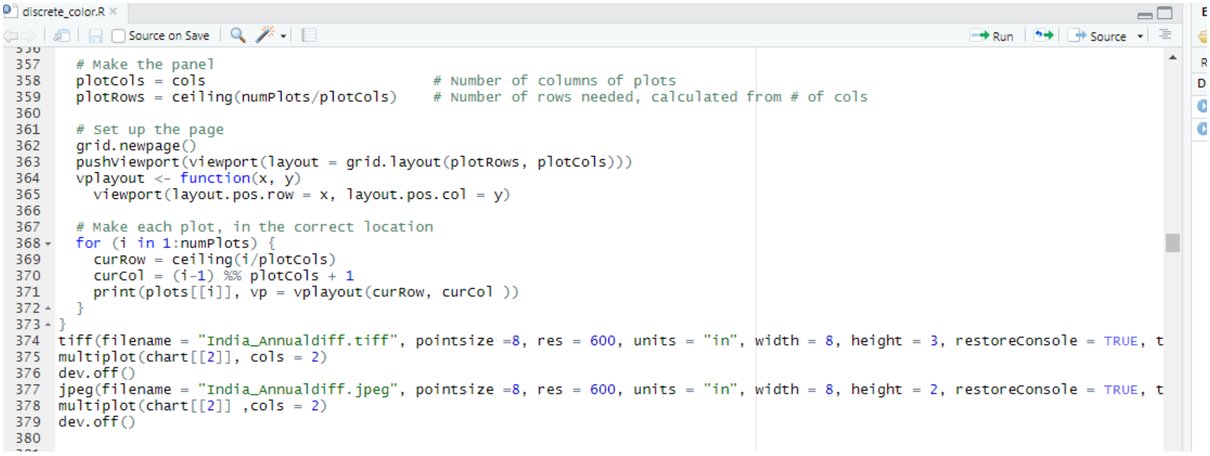
```r
    print(plots[[i]], vp = vplayout(curRow, curCol ))
  }
}
tiff(filename = "India_2014.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole = TRUE, type =
multiplot(chart[[2]], cols = 2)
dev.off()
jpeg(filename = "India_2014.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE, type =
multiplot(chart[[2]] ,cols = 2)
dev.off()




q<-read.csv("India_mean_1970.csv")
chart<-list()
w <- c(62,681,977,1.32e+03,4.35e+03)

cols <- c("[62,681)" = "yellow", "[681,977)" = "red", "[977,1.32e+03)" = "blue", "[1.32e+03,4.35e+03)" = "purple")
q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("Ind")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Annual Average Rainfall India (1901-1970)")


cols <- c("[62,681)" = "yellow", "[681,977)" = "red", "[977,1.32e+03)" = "blue", "[1.32e+03,4.35e+03)" = "purple")
```

175:29 PArt B Begins R Script

```r
##### Multiple Plot Function #####

multiplot <- function(..., plotlist=NULL, cols) {
  require(grid)

  # Make a list from the ... arguments and plotlist
  plots <- c(list(...), plotlist)

  numPlots = length(plots)

  # Make the panel
  plotCols = cols                          # Number of columns of plots
  plotRows = ceiling(numPlots/plotCols)    # Number of rows needed, calculated from # of cols

  # Set up the page
  grid.newpage()
  pushViewport(viewport(layout = grid.layout(plotRows, plotCols)))
  vplayout <- function(x, y)
    viewport(layout.pos.row = x, layout.pos.col = y)

  # Make each plot, in the correct location
  for (i in 1:numPlots) {
    curRow = ceiling(i/plotCols)
    curCol = (i-1) %% plotCols + 1
    print(plots[[i]], vp = vplayout(curRow, curCol ))
  }
}
tiff(filename = "India_1970.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole = TRUE, type =
multiplot(chart[[2]], cols = 2)
dev.off()
jpeg(filename = "India_1970.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE, type =
```

175:29 PArt B Begins R Script

```r
jpeg(filename = "India_1970.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE, type =
multiplot(chart[[2]] ,cols = 2)
dev.off()









q<-read.csv("India_Annual_Mean_Difference.csv")
chart<-list()
w <- c(-215,-34,-2,66,280)

cols <- c("[-215,-34)" = "yellow", "[-34,-2)" = "red", "[-2,66)" = "blue", "[66,280)" = "purple")
q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("Ind")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Annual Mean Difference of India for Global Warming (1970,20


cols <- c("[-215,-34)" = "yellow", "[-34,-2)" = "red", "[-2,66)" = "blue", "[66,280)" = "purple")
```

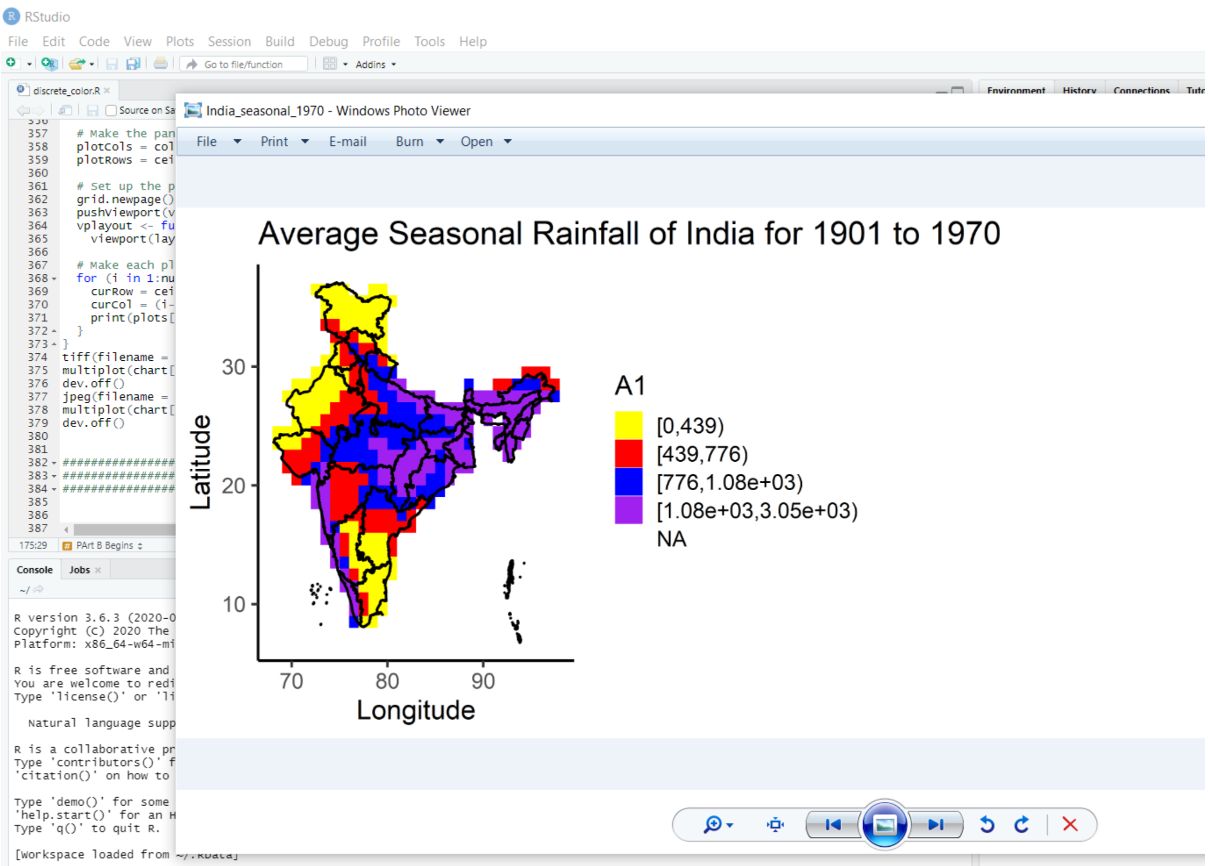


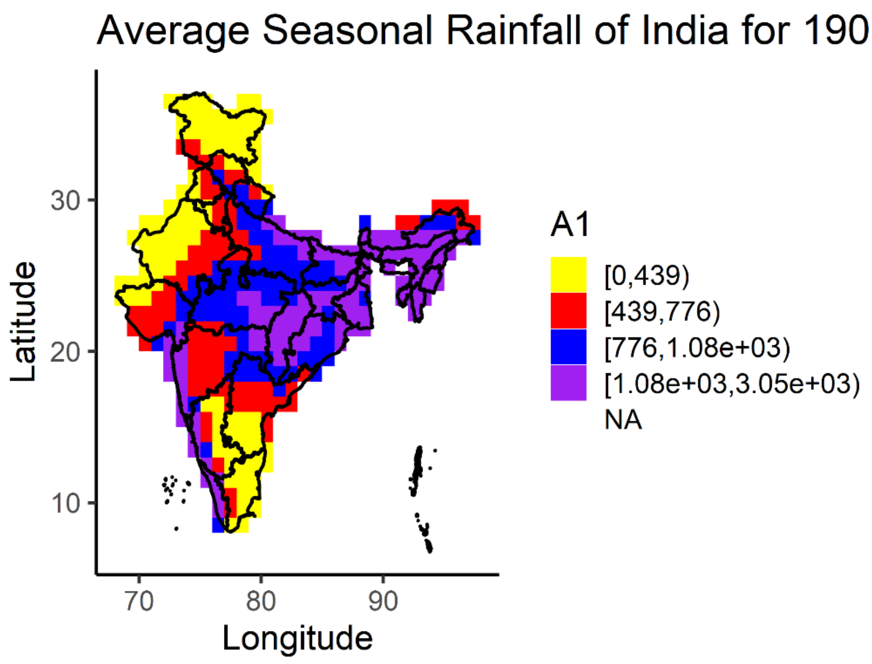
```
  # Make the panel
  plotCols = cols                          # Number of columns of plots
  plotRows = ceiling(numPlots/plotCols)    # Number of rows needed, calculated from # of cols

  # Set up the page
  grid.newpage()
  pushViewport(viewport(layout = grid.layout(plotRows, plotCols)))
  vplayout <- function(x, y)
    viewport(layout.pos.row = x, layout.pos.col = y)

  # Make each plot, in the correct location
  for (i in 1:numPlots) {
    curRow = ceiling(i/plotCols)
    curCol = (i-1) %% plotCols + 1
    print(plots[[i]], vp = vplayout(curRow, curCol ))
  }
}
tiff(filename = "India_Annualdiff.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole = TRUE, t
multiplot(chart[[2]], cols = 2)
dev.off()
jpeg(filename = "India_Annualdiff.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE, t
multiplot(chart[[2]] ,cols = 2)
dev.off()
```

Q3. Calculate the change in seasonal average rainfall with respect to global warming in each of grids. Plot the derived results.

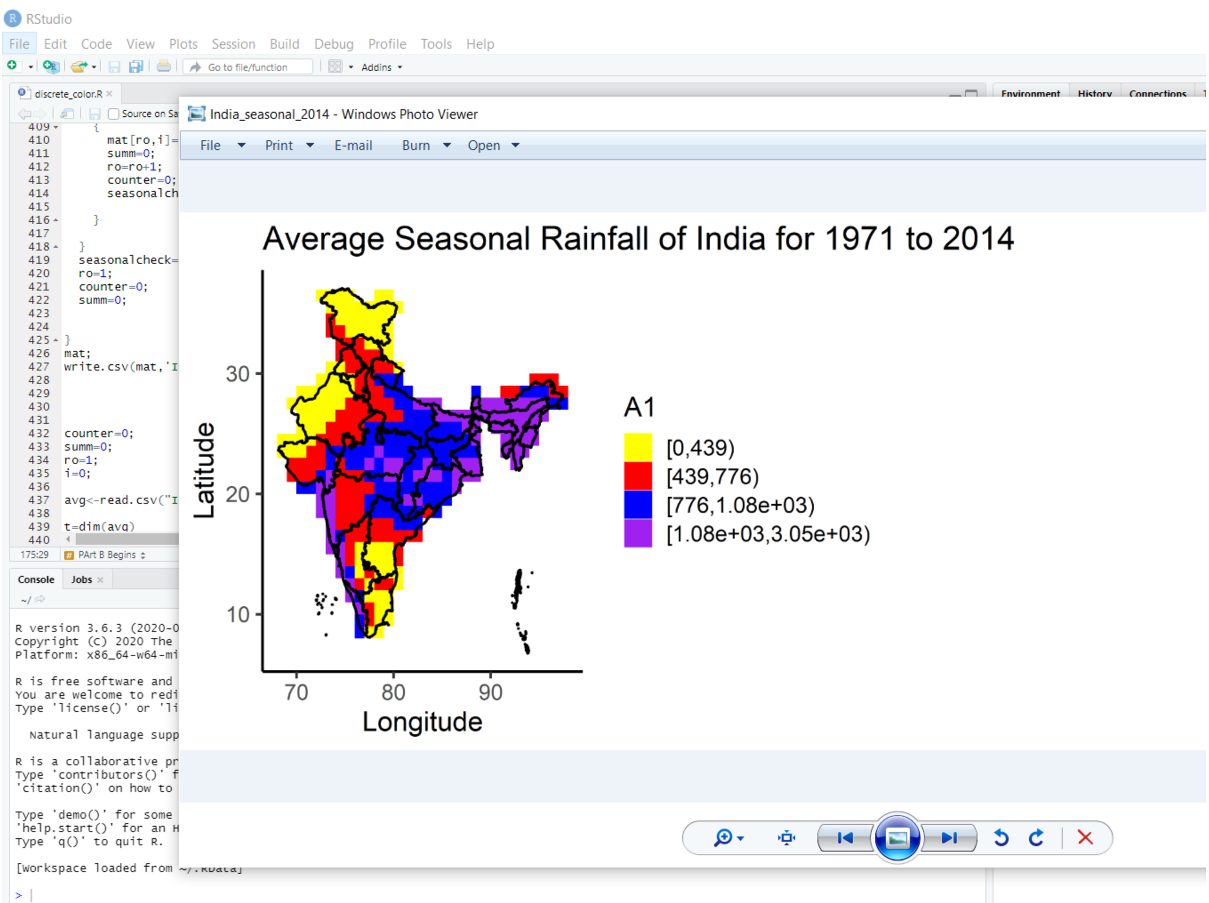
PLOTS:

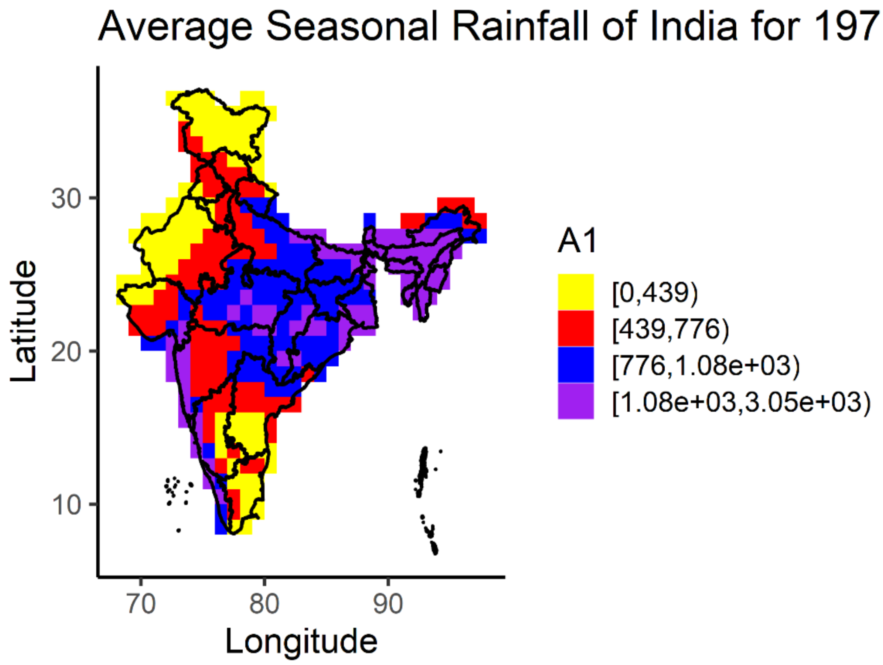
1. Average seasonal (June to Sept period per year) rainfall 1901-1970





2. **Average seasonal (June to Sept period per year) rainfall 1971-2014**

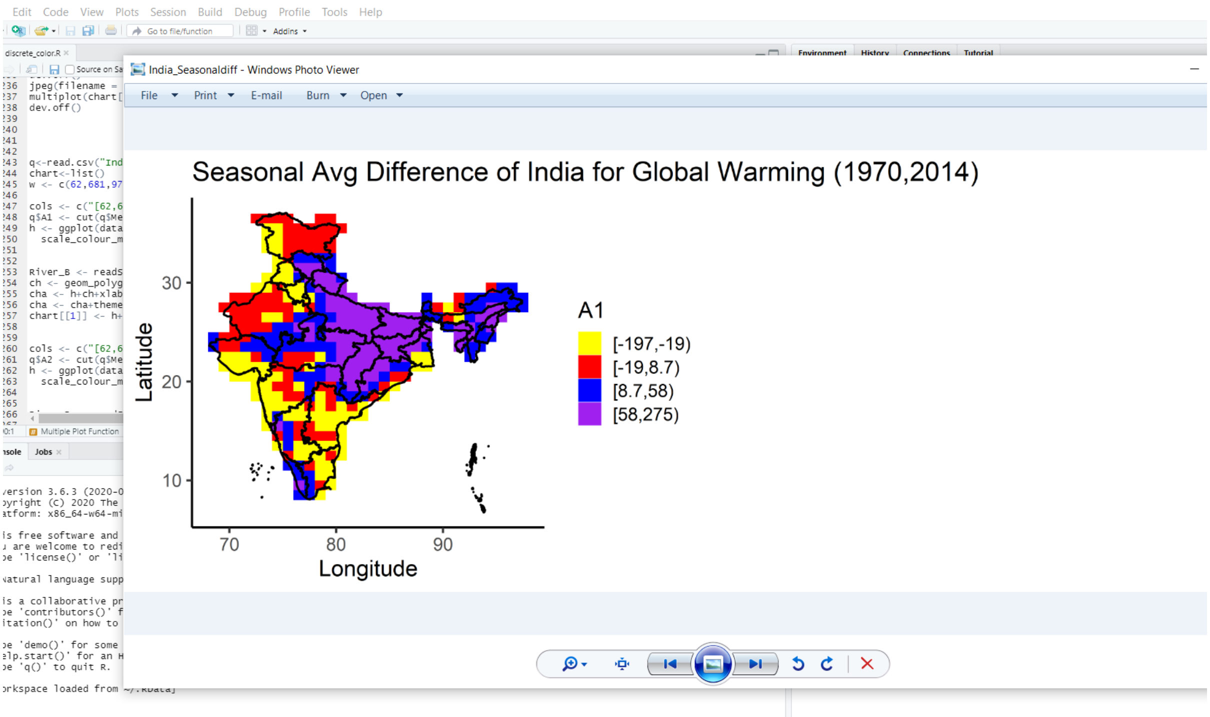


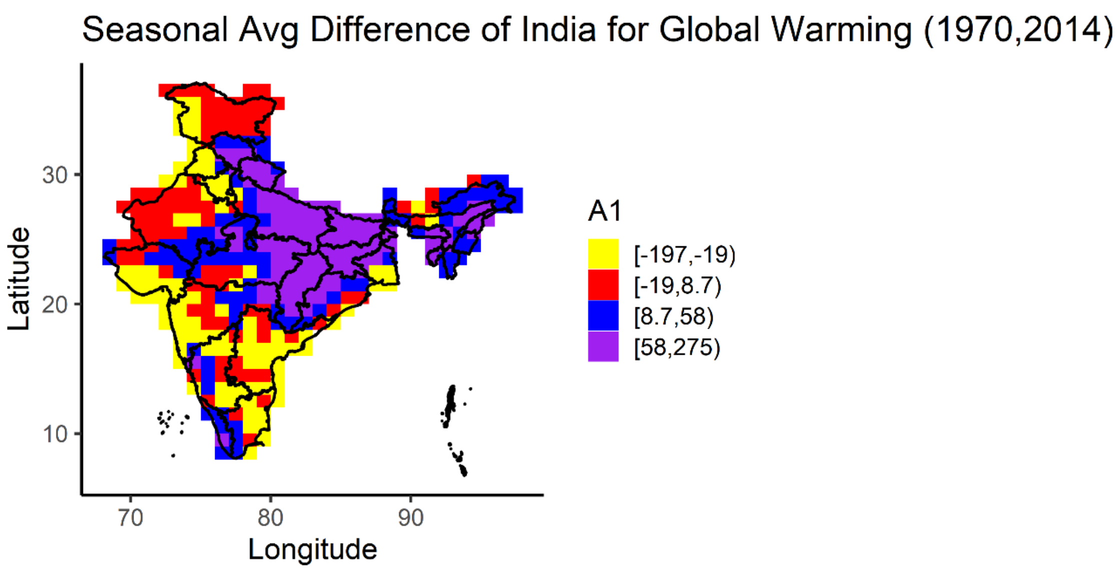


Inferences from Plot 1 and Plot 2:

- Plot 1 shows the average seasonal rainfall for each grid which is the sum of the rainfall from months (June to September) averaged out over a period of 70 years for each grid from 1901 to 1970 (referred to as pre global warming) for India.
- Plot 2 shows the average seasonal rainfall for each grid which is the sum of the rainfall from months (June to September) averaged out over a period of 44 years for each grid from 1971 to 2014 (referred to as post global warming) for India.
- Both the plots utilize the same range for min, quartile, median, max values from the average seasonal rainfall from 1901 to 2014
- Min=0.734 ; Q1=439 Median=776.7 ; Q3=1085.5 ; Max = 3036.035 (Refer to CSV screenshots (2nd screenshot) below).
- Both the plots follow similar trends mostly differing in central India which is more blue in the post global warming period.
- Both the plots also somewhat resemble their respective annual plots except in South India which does not receive maximum rainfall between June to September.

3. Change in average seasonal rainfall between the two periods with respect to global warming



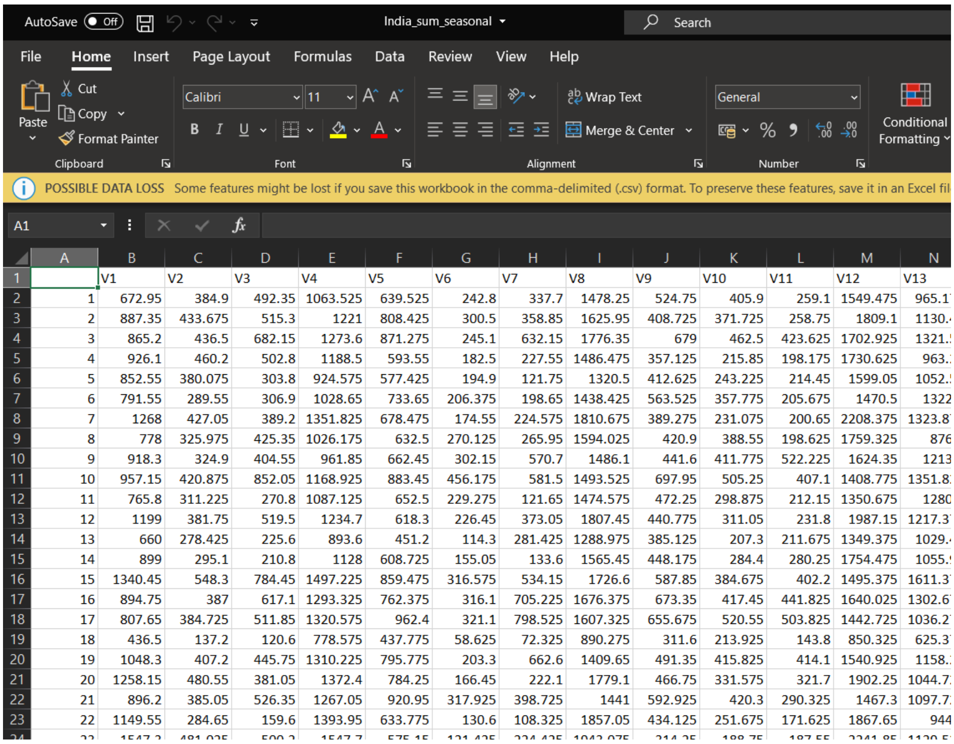


Inferences from Plot 3:

- Plot 3 represents the difference in average seasonal rainfall in India between the pre global warming (1901-1970) and the post global warming(1971-2014) periods.
- In the above plot 2014 values are subtracted from the 1901 data that is, if column 1 contains 1901-1970 period data and column 2 contains 1971-2014 data, the difference value is column1-column2.
- This implies that purple colour band means that there was much more rainfall in that region before global warming as compared to after it.
- Min difference= -196.043 (negative value implies that region receives more rainfall after 1971 as compared to before 1971. Quartile 1= -18.999; Median = 8.76; Quartile 3= 58.09; Max difference is 274.955 (Refer to screenshot of CSV (screenshot(5) below).
- In the above plot we can see a huge region filled with purple in the North, East and somewhat in the North eastern region of India. This implies that this region receives a lot less rainfall(58,275) in the post global warming period (1971-2014) than it received in the pre global warming period (1901-1970).
- The purple patch also slight exists in patches the south from which we can infer the same as the previous point.
- Next to the purple patches are blue bands which represent that the region receives about less rainfall (8.7,58) in post global warming (1971-2014) period than it did in the pre global warming period (1901-1970).
- The red bands are scattered across India mostly in the western India and Kashmir region as well as in small patches in southern India. This band represents the regions which get about the same amount or slightly more rainfall (-19,8.7)in the post global warming period(1990-2014) than the pre global warming period (1901-1970).
- The regions filled with yellow are also present mostly in Maharashtra , South India and other patches in the rest of India, which represents the region which receive a lot more rainfall (-197,-19) in the post global warming period(1990-2014) than the pre global warming period (1901-1970).

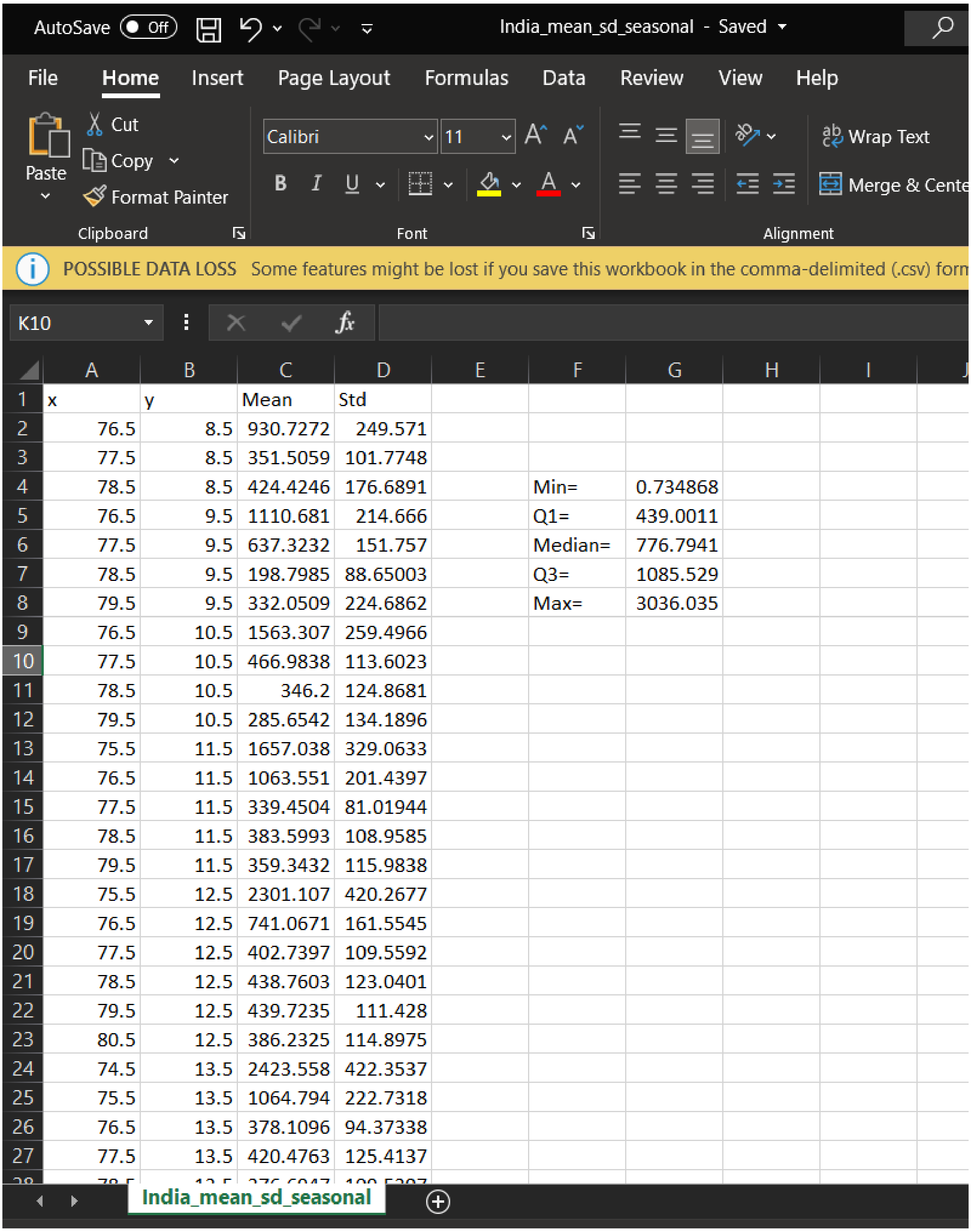
CSV Data screenshots:

1. Sum of seasonal rainfall for each grid per year



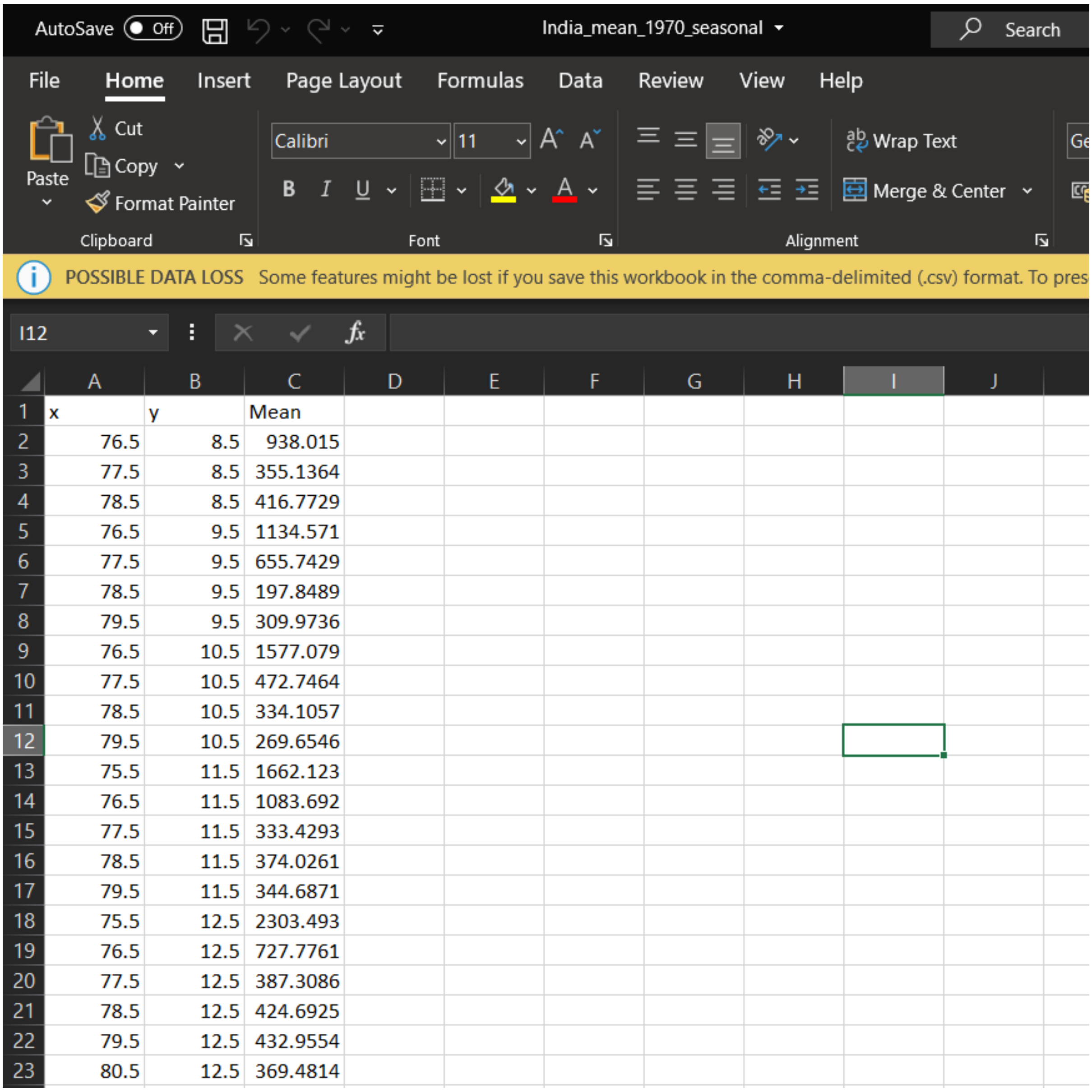
	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13
1	672.95	384.9	492.35	1063.525	639.525	242.8	337.7	1478.25	524.75	405.9	259.1	1549.475	965.1
2	887.35	433.675	515.3	1221	808.425	300.5	358.85	1625.95	408.725	371.725	258.75	1809.1	1130.
3	865.2	436.5	682.15	1273.6	871.275	245.1	632.15	1776.35	679	462.5	423.625	1702.925	1321.
4	926.1	460.2	502.8	1188.5	593.55	182.5	227.55	1486.475	357.125	215.85	198.175	1730.625	963.
5	852.55	380.075	303.8	924.575	577.425	194.9	121.75	1320.5	412.625	243.225	214.45	1599.05	1052.
6	791.55	289.55	306.9	1028.65	733.65	206.375	198.65	1438.425	563.525	357.775	205.675	1470.5	1322
7	1268	427.05	389.2	1351.825	678.475	174.55	224.575	1810.675	389.275	231.075	200.65	2208.375	1323.8
8	778	325.975	425.35	1026.175	632.5	270.125	265.95	1594.025	420.9	388.55	198.625	1759.325	876
9	918.3	324.9	404.55	961.85	662.45	302.15	570.7	1486.1	441.6	411.775	522.225	1624.35	1213
10	957.15	420.875	852.05	1168.925	883.45	456.175	581.5	1493.525	697.95	505.25	407.1	1408.775	1351.8
11	765.8	311.225	270.8	1087.125	652.5	229.275	121.65	1474.575	472.25	298.875	212.15	1350.675	1280
12	1199	381.75	519.5	1234.7	618.3	226.45	373.05	1807.45	440.775	311.05	231.8	1987.15	1217.3
13	660	278.425	225.6	893.6	451.2	114.3	281.425	1288.975	385.125	207.3	211.675	1349.375	1029.
14	899	295.1	210.8	1128	608.725	155.05	133.6	1565.45	448.175	284.4	280.25	1754.475	1055.
15	1340.45	548.3	784.45	1497.225	859.475	316.575	534.15	1726.6	587.85	384.675	402.2	1495.375	1611.3
16	894.75	387	617.1	1293.325	762.375	316.1	705.225	1676.375	673.35	417.45	441.825	1640.025	1302.6
17	807.65	384.725	511.85	1320.575	962.4	321.1	798.525	1607.325	655.675	520.55	503.825	1442.725	1036.2
18	436.5	137.2	120.6	778.575	437.775	58.625	72.325	890.275	311.6	213.925	143.8	850.325	625.3
19	1048.3	407.2	445.75	1310.225	795.775	203.3	662.6	1409.65	491.35	415.825	414.1	1540.925	1158.
20	1258.15	480.55	381.05	1372.4	784.25	166.45	222.1	1779.1	466.75	331.575	321.7	1902.25	1044.7
21	896.2	385.05	526.35	1267.05	920.95	317.925	398.725	1441	592.925	420.3	290.325	1467.3	1097.7
22	1149.55	284.65	159.6	1393.95	633.775	130.6	108.325	1857.05	434.125	251.675	171.625	1867.65	944

2. Average seasonal rainfall for each grid from 1901 to 2014



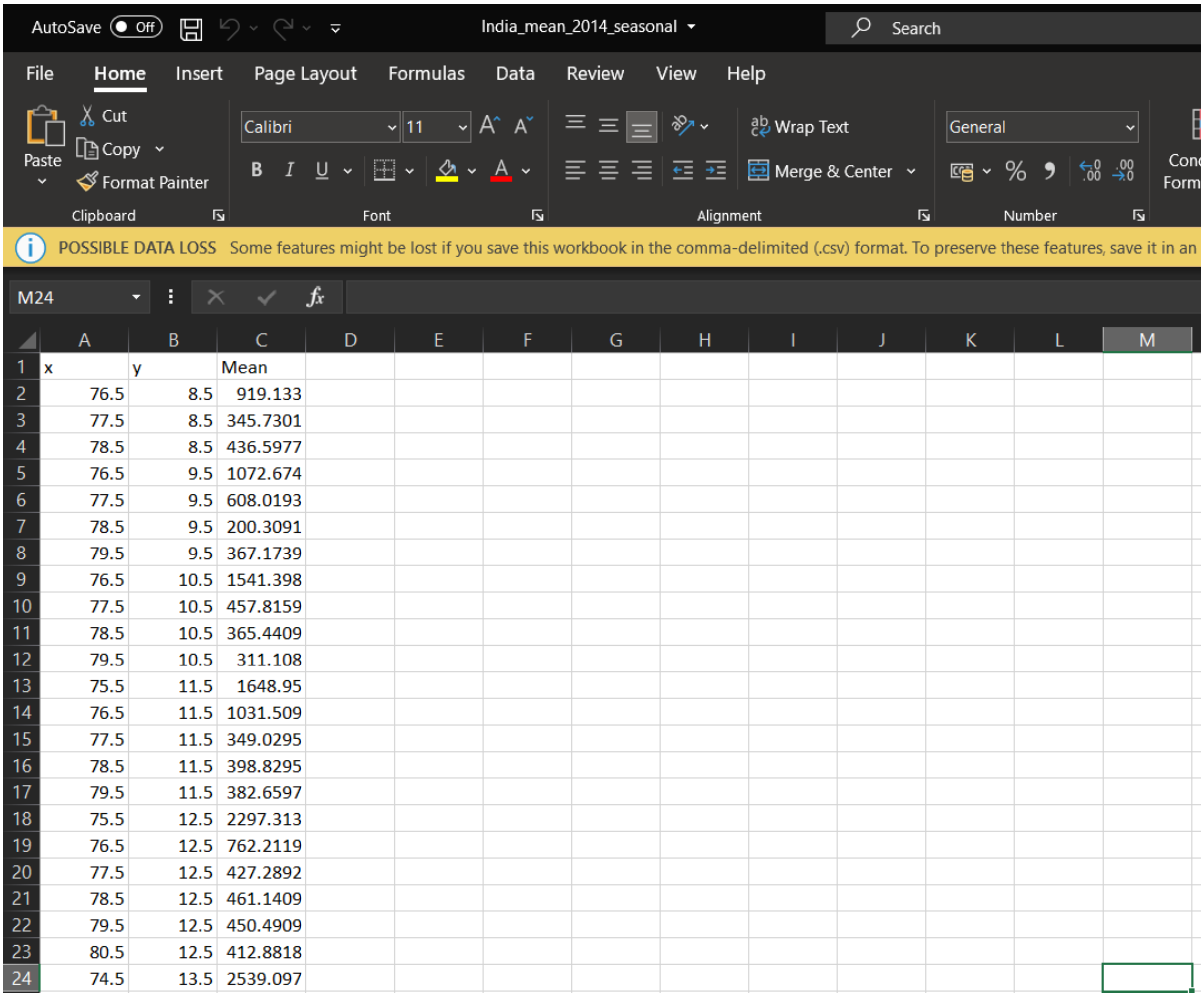
	A	B	C	D	E	F	G
1	x	y	Mean	Std			
2	76.5	8.5	930.7272	249.571			
3	77.5	8.5	351.5059	101.7748			
4	78.5	8.5	424.4246	176.6891		Min=	0.734868
5	76.5	9.5	1110.681	214.666		Q1=	439.0011
6	77.5	9.5	637.3232	151.757		Median=	776.7941
7	78.5	9.5	198.7985	88.65003		Q3=	1085.529
8	79.5	9.5	332.0509	224.6862		Max=	3036.035
9	76.5	10.5	1563.307	259.4966			
10	77.5	10.5	466.9838	113.6023			
11	78.5	10.5	346.2	124.8681			
12	79.5	10.5	285.6542	134.1896			
13	75.5	11.5	1657.038	329.0633			
14	76.5	11.5	1063.551	201.4397			
15	77.5	11.5	339.4504	81.01944			
16	78.5	11.5	383.5993	108.9585			
17	79.5	11.5	359.3432	115.9838			
18	75.5	12.5	2301.107	420.2677			
19	76.5	12.5	741.0671	161.5545			
20	77.5	12.5	402.7397	109.5592			
21	78.5	12.5	438.7603	123.0401			
22	79.5	12.5	439.7235	111.428			
23	80.5	12.5	386.2325	114.8975			
24	74.5	13.5	2423.558	422.3537			
25	75.5	13.5	1064.794	222.7318			
26	76.5	13.5	378.1096	94.37338			
27	77.5	13.5	420.4763	125.4137			

3. Average Seasonal Rainfall from 1901-1970



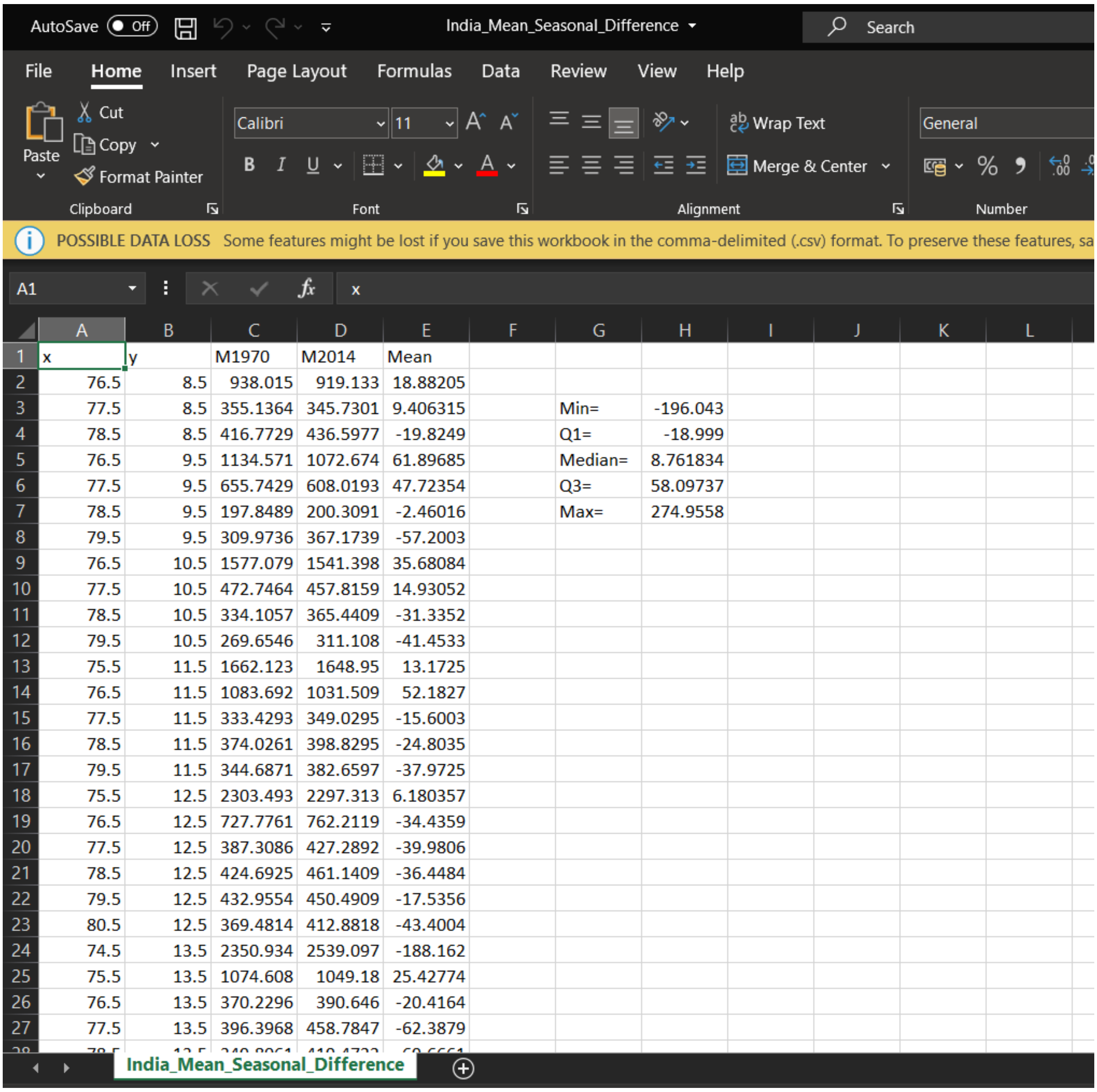
x	y	Mean
76.5	8.5	938.015
77.5	8.5	355.1364
78.5	8.5	416.7729
76.5	9.5	1134.571
77.5	9.5	655.7429
78.5	9.5	197.8489
79.5	9.5	309.9736
76.5	10.5	1577.079
77.5	10.5	472.7464
78.5	10.5	334.1057
79.5	10.5	269.6546
75.5	11.5	1662.123
76.5	11.5	1083.692
77.5	11.5	333.4293
78.5	11.5	374.0261
79.5	11.5	344.6871
75.5	12.5	2303.493
76.5	12.5	727.7761
77.5	12.5	387.3086
78.5	12.5	424.6925
79.5	12.5	432.9554
80.5	12.5	369.4814

4. Average Seasonal Rainfall from 1971-2014



x	y	Mean
76.5	8.5	919.133
77.5	8.5	345.7301
78.5	8.5	436.5977
76.5	9.5	1072.674
77.5	9.5	608.0193
78.5	9.5	200.3091
79.5	9.5	367.1739
76.5	10.5	1541.398
77.5	10.5	457.8159
78.5	10.5	365.4409
79.5	10.5	311.108
75.5	11.5	1648.95
76.5	11.5	1031.509
77.5	11.5	349.0295
78.5	11.5	398.8295
79.5	11.5	382.6597
75.5	12.5	2297.313
76.5	12.5	762.2119
77.5	12.5	427.2892
78.5	12.5	461.1409
79.5	12.5	450.4909
80.5	12.5	412.8818
74.5	13.5	2539.097

5. Difference in Rainfall between the two periods



	A	B	C	D	E	F	G	H
1	x	y	M1970	M2014	Mean			
2	76.5	8.5	938.015	919.133	18.88205			
3	77.5	8.5	355.1364	345.7301	9.406315		Min=	-196.043
4	78.5	8.5	416.7729	436.5977	-19.8249		Q1=	-18.999
5	76.5	9.5	1134.571	1072.674	61.89685		Median=	8.761834
6	77.5	9.5	655.7429	608.0193	47.72354		Q3=	58.09737
7	78.5	9.5	197.8489	200.3091	-2.46016		Max=	274.9558
8	79.5	9.5	309.9736	367.1739	-57.2003			
9	76.5	10.5	1577.079	1541.398	35.68084			
10	77.5	10.5	472.7464	457.8159	14.93052			
11	78.5	10.5	334.1057	365.4409	-31.3352			
12	79.5	10.5	269.6546	311.108	-41.4533			
13	75.5	11.5	1662.123	1648.95	13.1725			
14	76.5	11.5	1083.692	1031.509	52.1827			
15	77.5	11.5	333.4293	349.0295	-15.6003			
16	78.5	11.5	374.0261	398.8295	-24.8035			
17	79.5	11.5	344.6871	382.6597	-37.9725			
18	75.5	12.5	2303.493	2297.313	6.180357			
19	76.5	12.5	727.7761	762.2119	-34.4359			
20	77.5	12.5	387.3086	427.2892	-39.9806			
21	78.5	12.5	424.6925	461.1409	-36.4484			
22	79.5	12.5	432.9554	450.4909	-17.5356			
23	80.5	12.5	369.4814	412.8818	-43.4004			
24	74.5	13.5	2350.934	2539.097	-188.162			
25	75.5	13.5	1074.608	1049.18	25.42774			
26	76.5	13.5	370.2296	390.646	-20.4164			
27	77.5	13.5	396.3968	458.7847	-62.3879			

CODE SCREENSHOTS:

```r

counter=0;
seasonalcheck=0;
summ=0;
ro=1;
i=0;
p <- read.csv("India_gridded_data.csv") ## Import the data
##mat<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
mat<-matrix(0, nrow = 114,ncol=354, byrow = FALSE)
for(i in 1:354)
{
  for(j in 1:1368)
  {
    seasonalcheck=seasonalcheck+1;
    counter=counter+1;
    if(seasonalcheck>=6 && seasonalcheck<=9){
      summ=summ+p[j,i];
    }
    if(counter==12)
    {
      mat[ro,i]=summ;
      summ=0;
      ro=ro+1;
      counter=0;
      seasonalcheck=0;

    }

  }
```

652:72 Multiple Plot Function R Script

Console Jobs

C:/Users/mmouk/Desktop/Data vis lab/

```r
      ro=ro+1;
      counter=0;
      seasonalcheck=0;

    }

  }
  seasonalcheck=0;
  ro=1;
  counter=0;
  summ=0;


}
mat;
write.csv(mat,'India_sum_seasonal.csv')




counter=0;
summ=0;
ro=1;
i=0;

avg<-read.csv("India_sum_seasonal.csv")

t=dim(avg)
mat2<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
```

652:72 Multiple Plot Function R Script

discrete_color.R

```r
counter=0;
summ=0;
ro=1;
i=0;

avg<-read.csv("India_sum_seasonal.csv")

t=dim(avg)
mat2<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
for(i in 1:(t[2]-1))
{
  m = mean(avg[,i+1])   ##  mean
  mat2[i,1]<-m
  s<-sd(avg[,i+1])
  mat2[i,2]<-s          ##   standard deviation
}
write.csv(mat2,'India_mean_sd_seasonal.csv')

t=dim(avg)
mat1970<-matrix(0, nrow = 354,ncol=1, byrow = FALSE)
for(i in 2:355)
{

  for(j in 1:70)
  {
    summ=summ+avg[j,i];
  }
  mat1970[i-1,1]<-summ/70;
  summ=0;
}
write.csv(mat1970,'India_mean_1970_seasonal.csv')

```

652:72 Multiple Plot Function R Script

Console Jobs

```r
  }
  mat1970[i-1,1]<-summ/70;
  summ=0;
}
write.csv(mat1970,'India_mean_1970_seasonal.csv')


counter=0;
summ=0;
ro=1;
i=0;

avg<-read.csv("India_sum_seasonal.csv")

t=dim(avg)
mat2015<-matrix(0, nrow = 354,ncol=1, byrow = FALSE)
for(i in 2:355)
{

  for(j in 71:114)
  {
    summ=summ+avg[j,i];
  }
  mat2015[i-1,1]<-summ/44;
  summ=0;
}
write.csv(mat2015,'India_mean_2014_seasonal.csv')


q<-read.csv("India_mean_2014_seasonal.csv")
chart<-list()
```

652:72 Multiple Plot Function R Script

```r
}
write.csv(mat2015,'India_mean_2014_seasonal.csv')


q<-read.csv("India_mean_2014_seasonal.csv")
chart<-list()
w <- c(0,439,776,1.08e+03,3.05e+03)

cols <- c("[0,439)" = "yellow", "[439,776)" = "red", "[776,1.08e+03)" = "blue", "[1.08e+03,3.05e+03)" = "purple")
q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("Ind")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average Seasonal Rainfall of India for 1971 to 2014")


cols <- c("[0,439)" = "yellow", "[439,776)" = "red", "[776,1.08e+03)" = "blue", "[1.08e+03,3.05e+03)" = "purple")
q$A2 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
```

```r
multiplot <- function(..., plotlist=NULL, cols) {
  require(grid)

  # Make a list from the ... arguments and plotlist
  plots <- c(list(...), plotlist)

  numPlots = length(plots)

  # Make the panel
  plotCols = cols                          # Number of columns of plots
  plotRows = ceiling(numPlots/plotCols)    # Number of rows needed, calculated from # of cols

  # Set up the page
  grid.newpage()
  pushViewport(viewport(layout = grid.layout(plotRows, plotCols)))
  vplayout <- function(x, y)
    viewport(layout.pos.row = x, layout.pos.col = y)

  # Make each plot, in the correct location
  for (i in 1:numPlots) {
    curRow = ceiling(i/plotCols)
    curCol = (i-1) %% plotCols + 1
    print(plots[[i]], vp = vplayout(curRow, curCol ))
  }
}
tiff(filename = "India_seasonal_2014.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole = TRUE
multiplot(chart[[2]], cols = 2)
dev.off()
jpeg(filename = "India_seasonal_2014.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE
multiplot(chart[[2]] ,cols = 2)
```

```r


q<-read.csv("India_mean_1970_seasonal.csv")
chart<-list()
w <- c(0,439,776,1.08e+03,3.05e+03)

cols <- c("[0,439)" = "yellow", "[439,776)" = "red", "[776,1.08e+03)" = "blue", "[1.08e+03,3.05e+03)" = "purple")
q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("Ind")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average Seasonal Rainfall of India for 1901 to 1970 ")


cols <- c("[0,439)" = "yellow", "[439,776)" = "red", "[776,1.08e+03)" = "blue", "[1.08e+03,3.05e+03)" = "purple")
q$A2 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()

```

```r



q<-read.csv("India_Mean_Seasonal_Difference.csv")
chart<-list()
w <- c(-197,-19,8.7,58,275)

cols <- c("[-197,-19)" = "yellow", "[-19,8.7)" = "red", "[8.7,58)" = "blue", "[58,275)" = "purple")
q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("Ind")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Seasonal Avg Difference of India for Global warming (1970,2


cols <- c("[-197,-19)" = "yellow", "[-19,8.7)" = "red", "[8.7,58)" = "blue", "[58,275)" = "purple")
q$A2 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("Ind")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
```

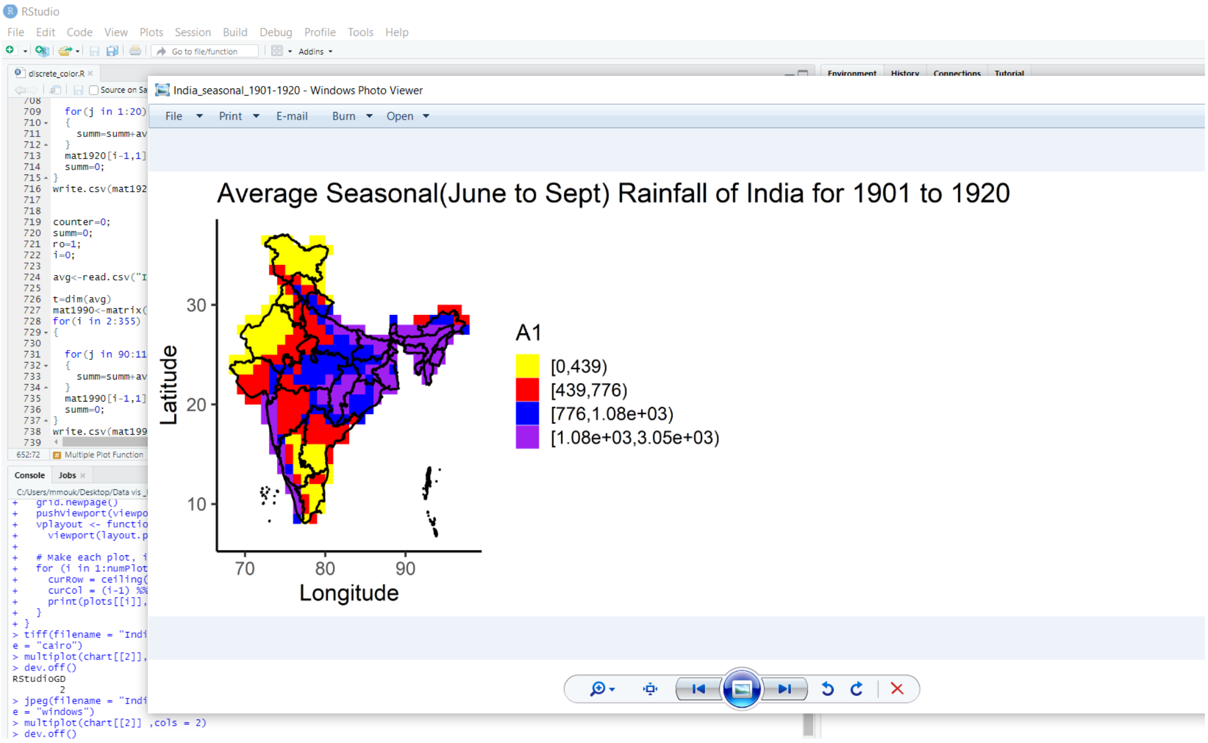
```r
    curRow = ceiling(i/plotCols)
    curCol = (i-1) %% plotCols + 1
    print(plots[[i]], vp = vplayout(curRow, curCol ))
  }
}
tiff(filename = "India_Seasonaldiff.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole = TRUE,
multiplot(chart[[2]], cols = 2)
dev.off()
jpeg(filename = "India_Seasonaldiff.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE,
multiplot(chart[[2]] ,cols = 2)
dev.off()
```

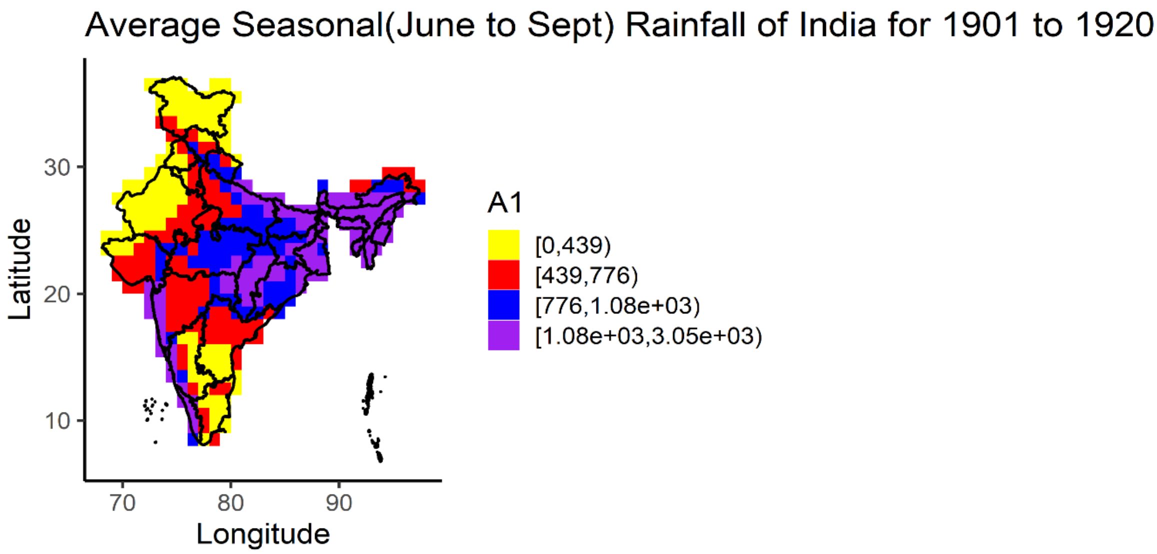
652:72 Multiple Plot Function R Script

Q4. Calculate the average seasonal (June-Sept) rainfall in each grid for the period 1901-1920. Similarly calculate the average seasonal (June-Sept) rainfall in each grid for the period 1990-last year. Calculate the change in average seasonal and plot them.

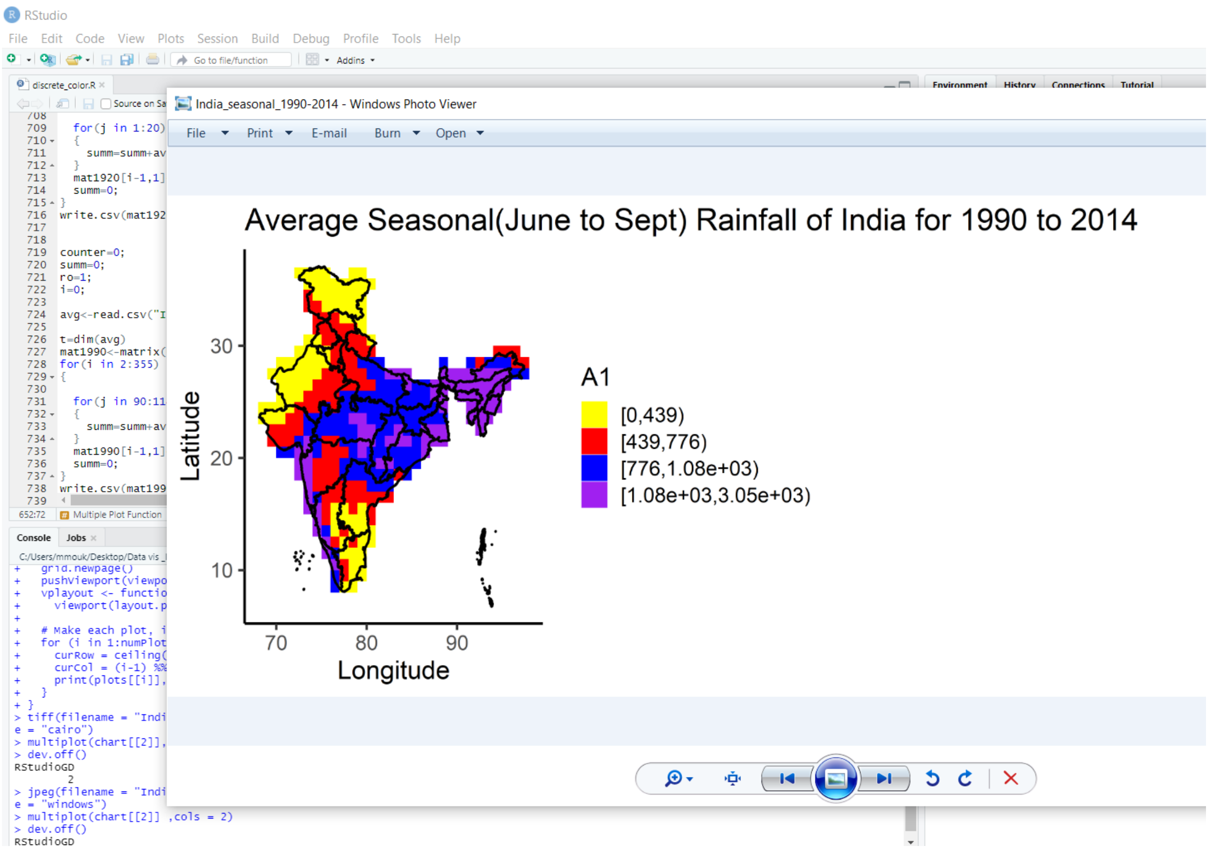
PLOTS:

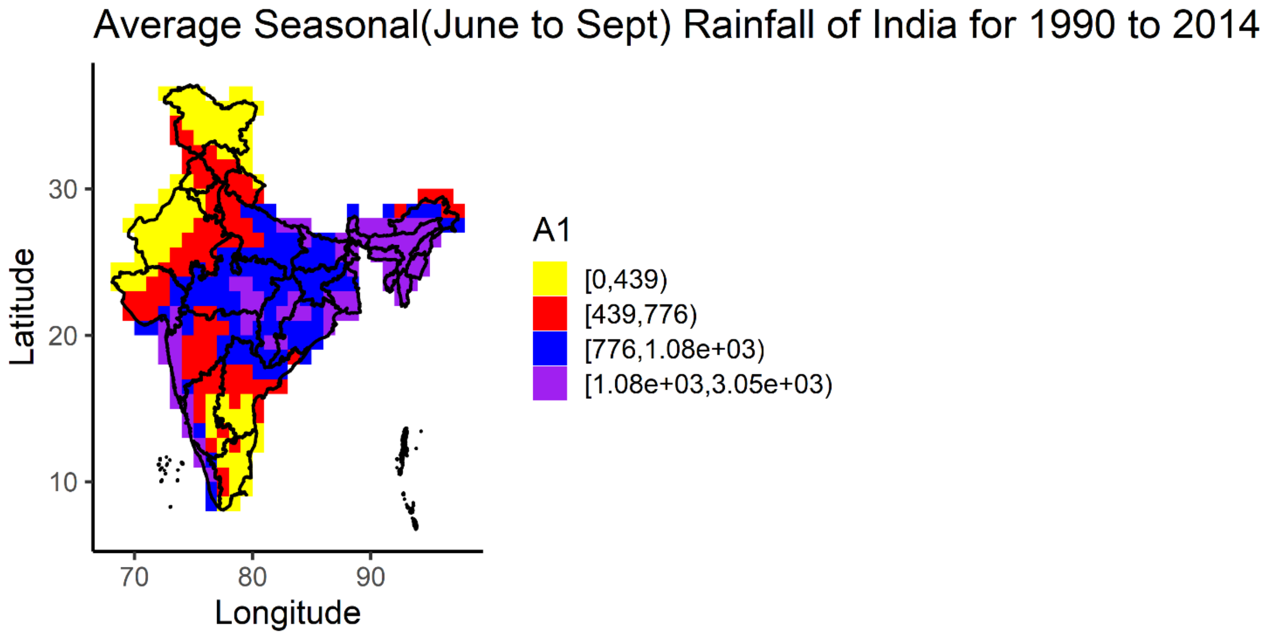
1. Average seasonal (June to Sept period per year) rainfall 1901-1920





2. Average seasonal (June to Sept period per year) rainfall 1990-2014

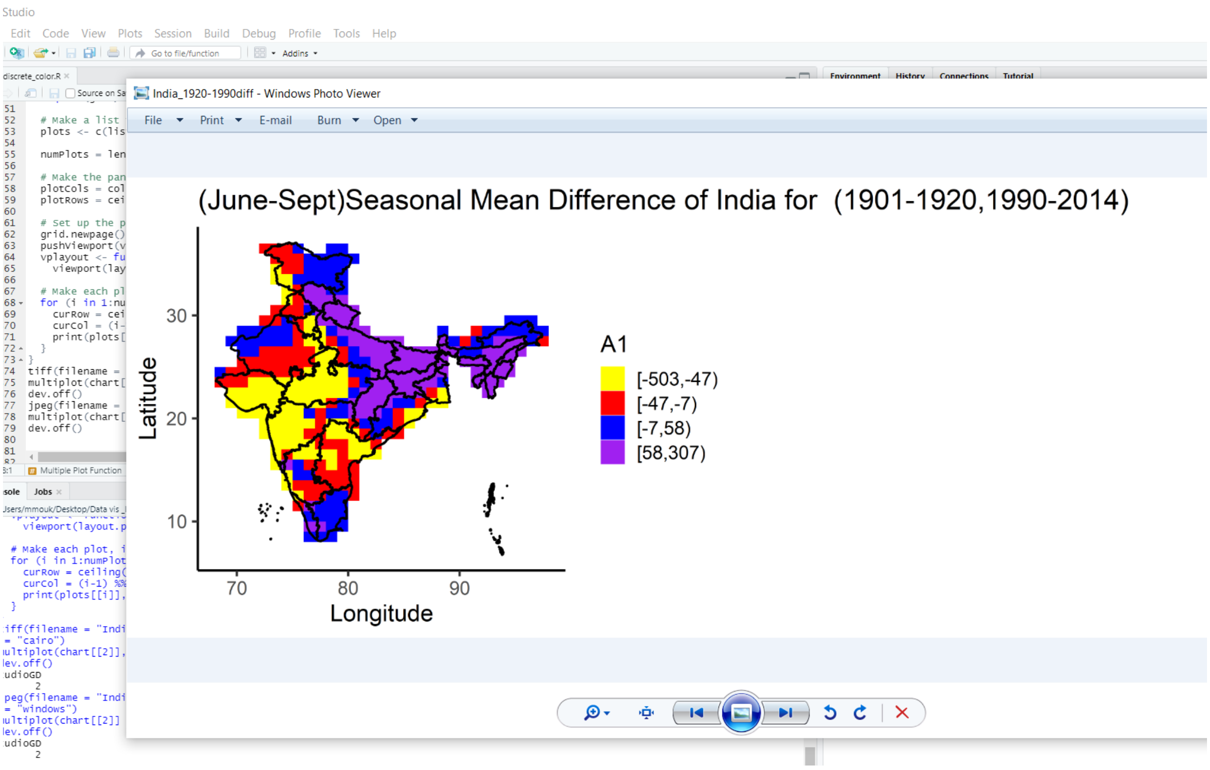


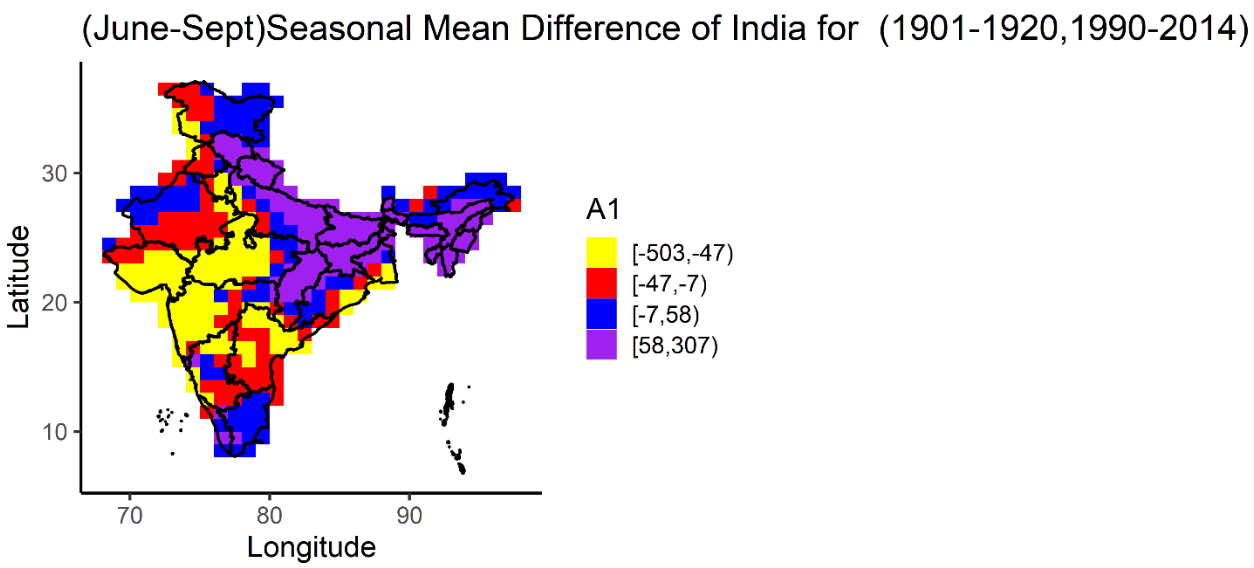


Inferences from Plot 1 and Plot 2:

- Plot 1 shows the average seasonal rainfall for each grid which is the sum of the rainfall from months (June to September) averaged out over a period of 20 years for each grid from 1901 to 1920 (referred to as Period 1) for India.
- Plot 2 shows the average seasonal rainfall for each grid which is the sum of the rainfall from months (June to September) averaged out over a period of 25 years for each grid from 1990 to 2014 (referred to as Period 2) for India.
- Both the plots utilize the same range for min, quartile, median, max values from the average seasonal rainfall from 1901 to 2014
- Min=0.734 ; Q1=439 Median=776.7 ; Q3=1085.5 ; Max = 3036.035 (from the above screenshots of CSV data)
- Both the plots follow generally similar trends in terms of colour range.
- Both the plots also somewhat resemble their respective annual plots except in South India which does not receive maximum rainfall between June to September.

3. Change in average seasonal rainfall between the two periods



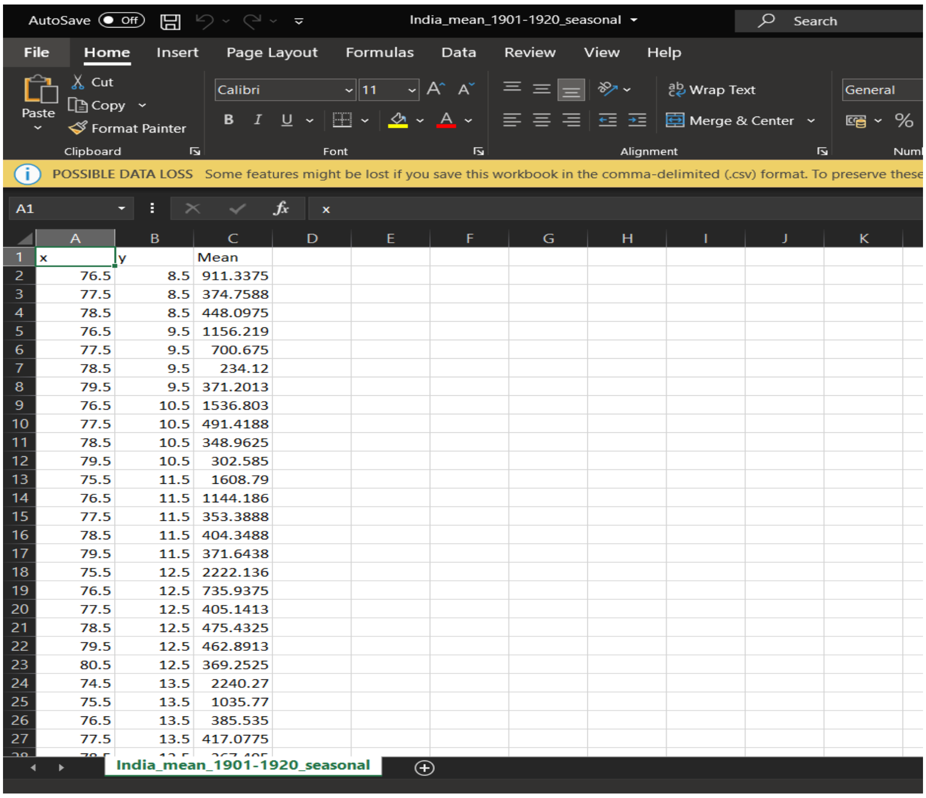


Inferences from Plot 3:

- Plot 3 represents the difference in average seasonal rainfall in India between Period 1(1901-1920) and the Period2 (1990-2014).
- In the above plot 2014 values are subtracted from the 1901 data that is, if column 1 contains 1901-1920 period data and column 2 contains 1990-2014 data, the difference value is column1-column2.
- This implies that purple colour band means that there was much more rainfall in that region in Period 1 as compared to Period 2.
- Min difference= -502.77 (negative value implies that region receives more rainfall after 1971 as compared to before 1971. Quartile 1= -47.09; Median = -6.92; Quartile 3= 57.96; Max difference is 306.97 (Refer to screenshot of CSV (screenshot(3) below).
- In the above plot we can see a region filled with purple extending along North and North eastern region of India. This implies that this region receives a lot less rainfall (58,307) in Period 2(1990-2014) than it received in Period 1(1901-1920).
- Next to the purple patches are blue bands which represent that the region receives about the same or slightly less rainfall (-7 to 58) in Period 2(1990-2014) than it received in Period 1(1901-1920).
- The said blue colour bands can also be seen the southern tip of India as well as in parts of north west India and part of Kashmir.
- The red bands are scattered across India mostly in the north-western India and Kashmir region as well as in small regions in southern India. This band represents the regions which more rainfall(-47,-7) in Period 2(1990-2014) than it received in Period 1(1901-1920).
- The regions filled with yellow are also present mostly in Maharashtra , parts of Central India and other patches in the rest of India, which represents the region which receive a lot more rainfall(-503,-47) in Period 2(1990-2014) than it received in Period 1(1901-1920).

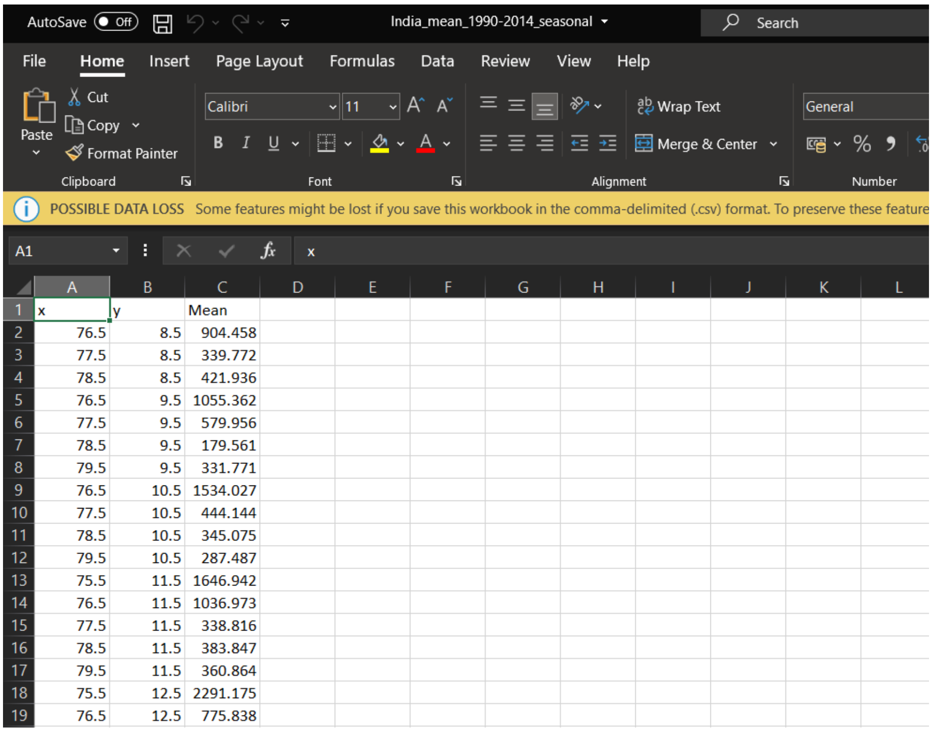
CSV Data in Excel:

1. Seasonal average for each grid from 1901 to 1920



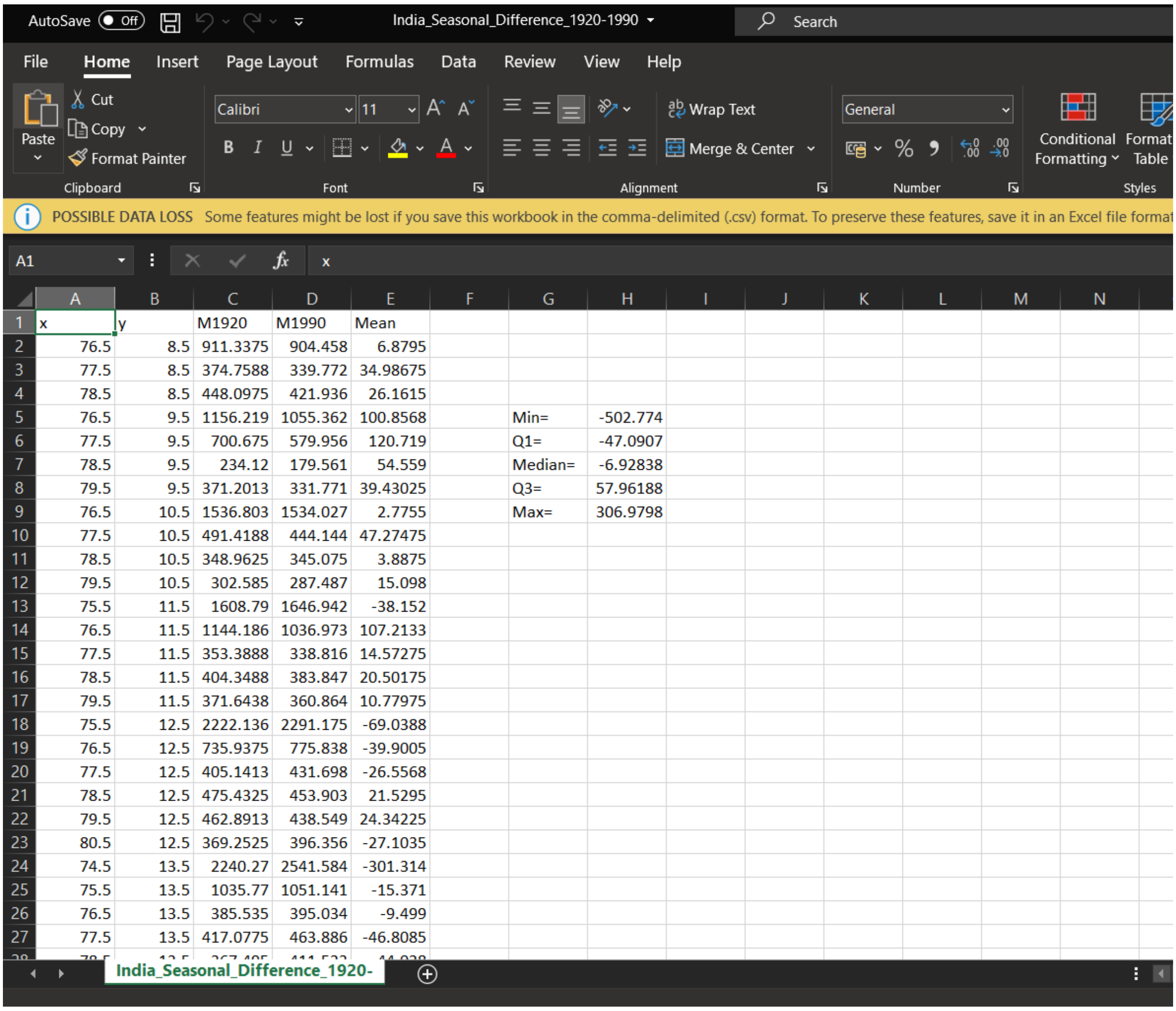
x	y	Mean
76.5	8.5	911.3375
77.5	8.5	374.7588
78.5	8.5	448.0975
76.5	9.5	1156.219
77.5	9.5	700.675
78.5	9.5	234.12
79.5	9.5	371.2013
76.5	10.5	1536.803
77.5	10.5	491.4188
78.5	10.5	348.9625
79.5	10.5	302.585
75.5	11.5	1608.79
76.5	11.5	1144.186
77.5	11.5	353.3888
78.5	11.5	404.3488
79.5	11.5	371.6438
75.5	12.5	2222.136
76.5	12.5	735.9375
77.5	12.5	405.1413
78.5	12.5	475.4325
79.5	12.5	462.8913
80.5	12.5	369.2525
74.5	13.5	2240.27
75.5	13.5	1035.77
76.5	13.5	385.535
77.5	13.5	417.0775

2. Seasonal average for each grid from 1990 to 2014



x	y	Mean
76.5	8.5	904.458
77.5	8.5	339.772
78.5	8.5	421.936
76.5	9.5	1055.362
77.5	9.5	579.956
78.5	9.5	179.561
79.5	9.5	331.771
76.5	10.5	1534.027
77.5	10.5	444.144
78.5	10.5	345.075
79.5	10.5	287.487
75.5	11.5	1646.942
76.5	11.5	1036.973
77.5	11.5	338.816
78.5	11.5	383.847
79.5	11.5	360.864
75.5	12.5	2291.175
76.5	12.5	775.838

3. Difference between the two periods.



x	y	M1920	M1990	Mean		
76.5	8.5	911.3375	904.458	6.8795		
77.5	8.5	374.7588	339.772	34.98675		
78.5	8.5	448.0975	421.936	26.1615		
76.5	9.5	1156.219	1055.362	100.8568	Min=	-502.774
77.5	9.5	700.675	579.956	120.719	Q1=	-47.0907
78.5	9.5	234.12	179.561	54.559	Median=	-6.92838
79.5	9.5	371.2013	331.771	39.43025	Q3=	57.96188
76.5	10.5	1536.803	1534.027	2.7755	Max=	306.9798
77.5	10.5	491.4188	444.144	47.27475		
78.5	10.5	348.9625	345.075	3.8875		
79.5	10.5	302.585	287.487	15.098		
75.5	11.5	1608.79	1646.942	-38.152		
76.5	11.5	1144.186	1036.973	107.2133		
77.5	11.5	353.3888	338.816	14.57275		
78.5	11.5	404.3488	383.847	20.50175		
79.5	11.5	371.6438	360.864	10.77975		
75.5	12.5	2222.136	2291.175	-69.0388		
76.5	12.5	735.9375	775.838	-39.9005		
77.5	12.5	405.1413	431.698	-26.5568		
78.5	12.5	475.4325	453.903	21.5295		
79.5	12.5	462.8913	438.549	24.34225		
80.5	12.5	369.2525	396.356	-27.1035		
74.5	13.5	2240.27	2541.584	-301.314		
75.5	13.5	1035.77	1051.141	-15.371		
76.5	13.5	385.535	395.034	-9.499		
77.5	13.5	417.0775	463.886	-46.8085		

CODE Screenshots:

```
avg<-read.csv("India_sum_seasonal.csv")
mat1920<-matrix(0, nrow = 354,ncol=1, byrow = FALSE)
for(i in 2:355)
{

  for(j in 1:20)
  {
    summ=summ+avg[j,i];
  }
  mat1920[i-1,1]<-summ/20;
  summ=0;
}
write.csv(mat1920,'India_mean_1901-1920_seasonal.csv')


counter=0;
summ=0;
ro=1;
i=0;

avg<-read.csv("India_sum_seasonal.csv")

t=dim(avg)
mat1990<-matrix(0, nrow = 354,ncol=1, byrow = FALSE)
for(i in 2:355)
{

  for(j in 90:114)
  {
    summ=summ+avg[j,i];
```

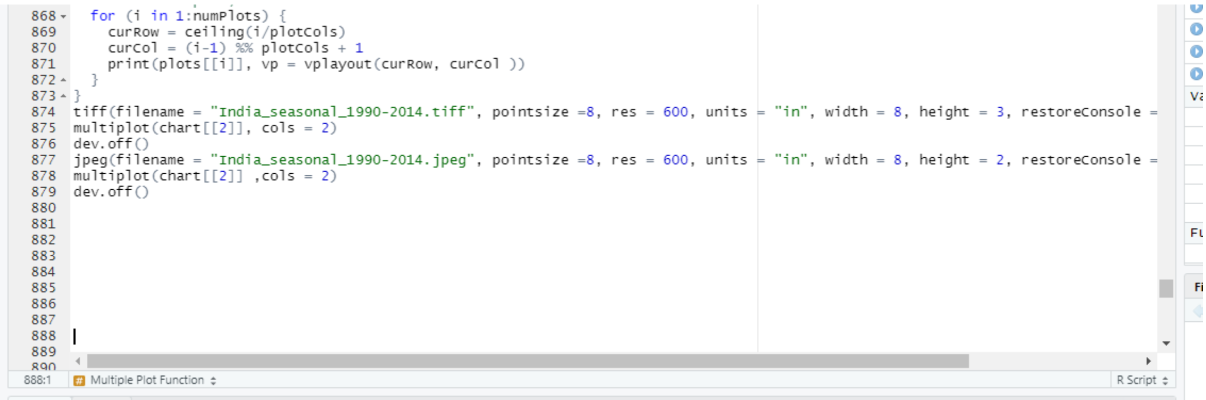
```r
q<-read.csv("India_mean_1901-1920_seasonal.csv")
chart<-list()
w <- c(0,439,776,1.08e+03,3.05e+03)

cols <- c("[0,439)" = "yellow", "[439,776)" = "red", "[776,1.08e+03)" = "blue", "[1.08e+03,3.05e+03)" = "purple")
q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("Ind")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average Seasonal(June to Sept) Rainfall of India for 1901 t


cols <- c("[0,439)" = "yellow", "[439,776)" = "red", "[776,1.08e+03)" = "blue", "[1.08e+03,3.05e+03)" = "purple")
q$A2 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
```

discrete_color.R

```r
River_B <- readShapeSpatial("Ind")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[2]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average Seasonal(June to Sept) Rainfall of India for 1901 t



##### Multiple Plot Function #####

multiplot <- function(..., plotlist=NULL, cols) {
  require(grid)

  # Make a list from the ... arguments and plotlist
  plots <- c(list(...), plotlist)

  numPlots = length(plots)

  # Make the panel
  plotCols = cols                       # Number of columns of plots
  plotRows = ceiling(numPlots/plotCols)    # Number of rows needed, calculated from # of cols

  # Set up the page
  grid.newpage()
  pushViewport(viewport(layout = grid.layout(plotRows, plotCols)))
  vplayout <- function(x, y)
    viewport(layout.pos.row = x, layout.pos.col = y)

  # Make each plot, in the correct location
  for (i in 1:numPlots) {
```

discrete_color.R

```r
  for (i in 1:numPlots) {
    curRow = ceiling(i/plotCols)
    curCol = (i-1) %% plotCols + 1
    print(plots[[i]], vp = vplayout(curRow, curCol ))
  }
}
tiff(filename = "India_seasonal_1901-1920.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole =
multiplot(chart[[2]], cols = 2)
dev.off()
jpeg(filename = "India_seasonal_1901-1920.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole =
multiplot(chart[[2]] ,cols = 2)
dev.off()




q<-read.csv("India_mean_1990-2015_seasonal.csv")
chart<-list()
w <- c(0,439,776,1.08e+03,3.05e+03)

cols <- c("[0,439)" = "yellow", "[439,776)" = "red", "[776,1.08e+03)" = "blue", "[1.08e+03,3.05e+03)" = "purple")
q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("Ind")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average Seasonal (June to Sept) Rainfall of India for 1990
```



```r
  for (i in 1:numPlots) {
    curRow = ceiling(i/plotCols)
    curCol = (i-1) %% plotCols + 1
    print(plots[[i]], vp = vplayout(curRow, curCol ))
  }
}
tiff(filename = "India_seasonal_1990-2014.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole =
multiplot(chart[[2]], cols = 2)
dev.off()
jpeg(filename = "India_seasonal_1990-2014.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole =
multiplot(chart[[2]] ,cols = 2)
dev.off()
```



```r
q<-read.csv("India_Seasonal_Difference_1920-1990.csv")
chart<-list()
w <- c(-503,-47,-7,58,307)

cols <- c("[-503,-47)" = "yellow", "[-47,-7)" = "red", "[-7,58)" = "blue", "[58,307)" = "purple")
q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("Ind")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="(June-Sept)Seasonal Mean Difference of India for (1901-1920


cols <- c("[-503,-47)" = "yellow", "[-47,-7)" = "red", "[-7,58)" = "blue", "[58,307)" = "purple")
q$A2 <- cut(q$Mean,breaks = w,right = FALSE)
h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
  scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()


River_B <- readShapeSpatial("Ind")
ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
chart[[2]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="(June-Sept)Seasonal Mean Difference of India for  (1901-192
```

```r
  # Make a list from ... arguments and plotlist
  plots <- c(list(...), plotlist)

  numPlots = length(plots)

  # Make the panel
  plotCols = cols                          # Number of columns of plots
  plotRows = ceiling(numPlots/plotCols)    # Number of rows needed, calculated from # of cols

  # Set up the page
  grid.newpage()
  pushViewport(viewport(layout = grid.layout(plotRows, plotCols)))
  vplayout <- function(x, y)
    viewport(layout.pos.row = x, layout.pos.col = y)

  # Make each plot, in the correct location
  for (i in 1:numPlots) {
    curRow = ceiling(i/plotCols)
    curCol = (i-1) %% plotCols + 1
    print(plots[[i]], vp = vplayout(curRow, curCol ))
  }
}
tiff(filename = "India_1920-1990diff.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole = TRUE
multiplot(chart[[2]], cols = 2)
dev.off()
jpeg(filename = "India_1920-1990diff.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE
multiplot(chart[[2]] ,cols = 2)
dev.off()
```