

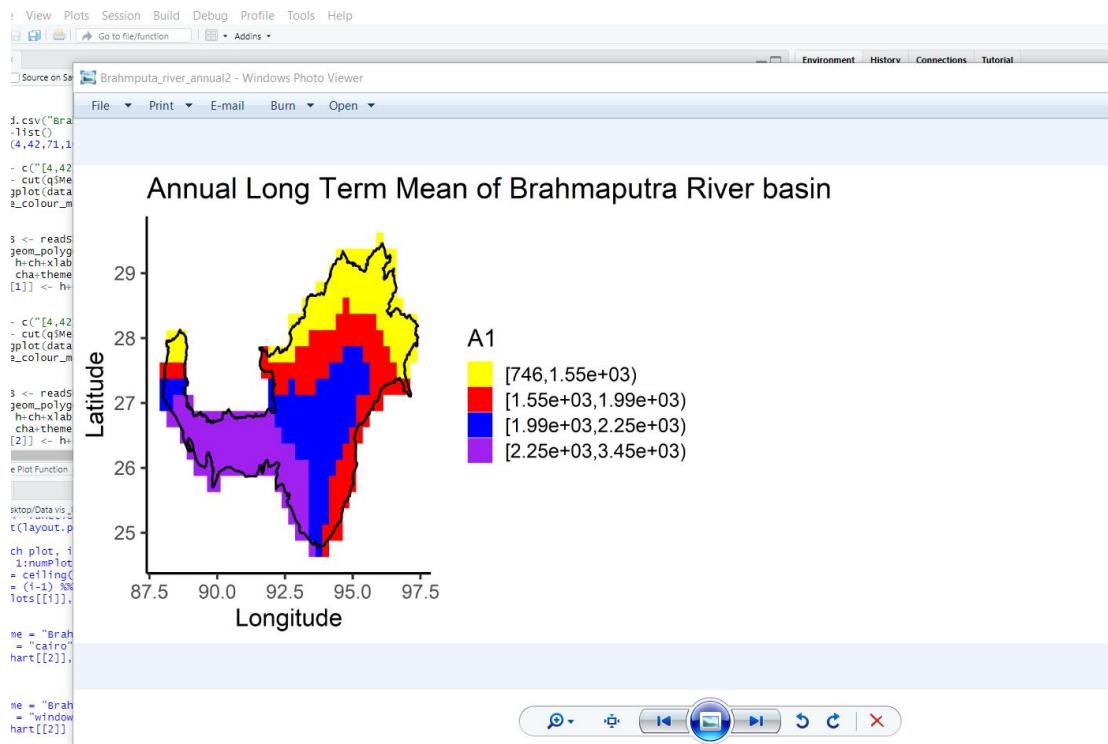
Data Visualization – CSE 3020

Name: Moukhik Misra Reg No: 19BCE2190

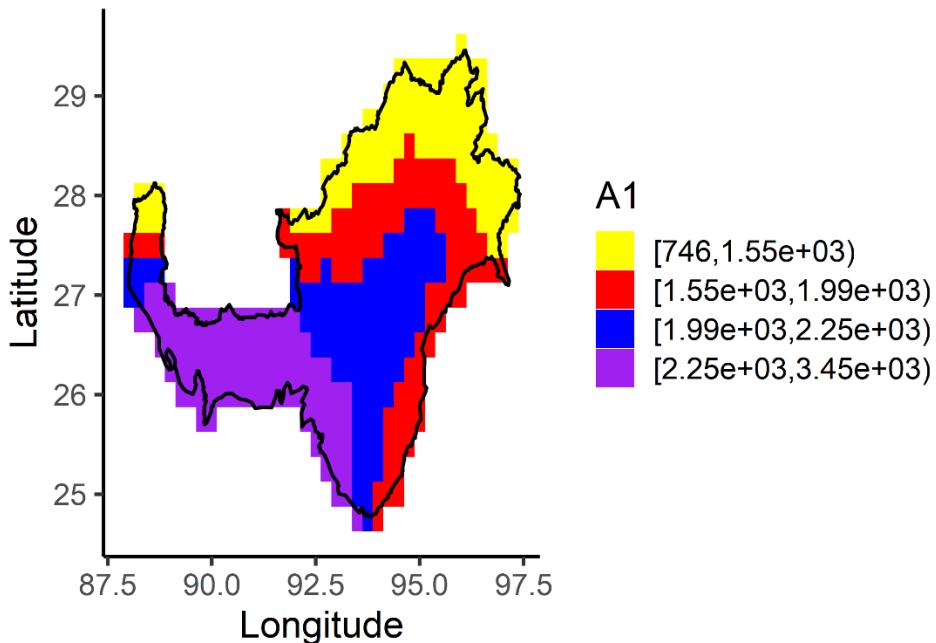
1. Brahmaputra River basin data

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:



Annual Long Term Mean of Brahmaputra River basin



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 to 1990)
- 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

AutoSave (● Off) Brahmaputra_sum_annual ▾ Search

File Home Insert Page Layout Formulas Data Review View Help

Cut Copy Paste Format Painter

Font: Calibri 11pt A A¹
B I U Alignment: General % Number: General Conditional Formatting Format as Table Cell Styles Insert Delete Format

Cells: Cells

(i) POSSIBLE DATA LOSS Some features might be lost if you save this workbook in the comma-delimited (.csv) format. To preserve these features, save it in an Excel file format. Don't show again Save As

A1 : fx

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	
2	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
3	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
4	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
5	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
6	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
7	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
8	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
9	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
10	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
11	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
12	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
13	12	2257	2031.9	1939.45	2761.35	2393.7	2237.65	2081.6	1989.5	1898.3	1867.925	3135.4	2720.35	2305.3	2218.3	2131.3	2040.45	194
14	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
15	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
16	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
17	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
18	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
19	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
20	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
21	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
22	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
23	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
24	23	2288.15	2049.4	1956.6	2743.2	2357.5	2221.8	2067.9	1979.1	1890.3	1870.825	3041.8	2633.15	2224.5	2155.45	2086.4	2001.6	191
25	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
26	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
27	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

AutoSave (● Off) Brahmaputra_mean_sd_annual - Saved

File Home Insert Page Layout Formulas Data Review View Help

Cut Copy Wrap Text
Paste
Format Painter

Clipboard Font Alignment

POSSIBLE DATA LOSS Some features might be lost if you save this workbook in the comma-delimited (.csv) format.

	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:

```
1 setwd("C:/users/mmouk/Desktop/Data vis _lab")
2 par(mar = c(10,10,10,10))
3 #par(mfrow=c(1,4))
4 library(ggplot2)
5 library(grid)
6 library(gridExtra)
7 library(extrafont)
8 library(ggmap)
9 library(maptools)
10 library(plyr)
11 library(maps)
12 counter=0;
13 summ=0;
14 ro=1;
15 i=0;
16 p <- read.csv("Brahmaputra_basin_data.csv") ## Import the data
17 ##mat<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
18 mat<-matrix(0, nrow = 115,ncol=335, byrow = FALSE)
19 for(i in 2:336)
20 {
21   for(j in 1:1380)
22   {
23     counter=counter+1;
24     summ=summ+p[j,i];
25     if(counter==12)
26     {
27       mat[ro,i-1]=summ;
28       summ=0;
29       ro=ro+1;
30       counter=0;
31 }
```

```
29       ro=ro+1;
30       counter=0;
31   }
32 }
33 }
34 }
35 ro=1;
36 counter=0;
37 summ=0;
38 }
39 }
40 }
41 mat;
42 write.csv(mat,'Brahmaputra_sum_annual.csv')
43 avg<-read.csv("Brahmaputra_sum_annual.csv")
44 t=dim(avg)
45 mat2<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
46 for(i in 1:(t[2]-1))
47 {
48   m = mean(avg[,i+1]) ## mean
49   mat2[i,1]<-m
50   s<-sd(avg[,i+1])
51   mat2[i,2]<-s      ## standard deviation
52 }
53 write.csv(mat2,'Brahmaputra_mean_sd_annual.csv')
54 q<-read.csv("Brahmaputra_mean_sd_annual.csv")
55 chart<-list()
56 w <- r(746 1 55e+03 1 99e+03 0 225e+04 0 345e+04)
57 
```

```

4 ^
5 write.csv(mat2,'Brahmaputra_mean_sd_annual.csv')
6
7 q<-read.csv("Brahmaputra_mean_sd_annual.csv")
8 chart<-list()
9 w <- c(746,1.55e+03,1.99e+03,0.225e+04,0.345e+04)
10
11 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]" =
12 q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
13 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
14   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
15
16
17 River_B <- readshapesspatial("11-9-2019-3772456")
18 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
19 cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[[i]])
20 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
21 chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Mean of Brahmaputra River basin")
22
23
24 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]" =
25 q$A2 <- cut(q$Mean,breaks = w,right = FALSE)
26 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
27   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87 ###### Multiple Plot Function #####
88
89 multiplot <- function(..., plotlist=NULL, cols) {
90   require(grid)
91
92   # Make a list from the ... arguments and plotlist
93   plots <- c(list(...), plotlist)
94
95   numPlots = length(plots)
96
97   # Make the panel
98   plotcols = cols           # Number of columns of plots
99   plotRows = ceiling(numPlots/plotcols)  # Number of rows needed, calculated from # of cols
100
101  # Set up the page
102  grid.newpage()
103  pushviewport(viewport(layout = grid.layout(plotRows, plotcols)))
104  vplayout <- function(x, y)
105    viewport(layout.pos.row = x, layout.pos.col = y)
106
107  # Make each plot, in the correct location
108  for (i in 1:numPlots) {
109    currow = ceiling(i/plotcols)
110    curcol = (i-1) %% plotcols + 1
111    print(plots[[i]], vp = vplayout(curRow, curcol ))
112  }
113}
114 tiff(filename = "Brahmaputa_river_annual2.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole =
115 multiplot(chart[[2]], cols = 2)
116 dev.off()
117

```

```

86
87 ###### Multiple Plot Function #####
88
89 multiplot <- function(..., plotlist=NULL, cols) {
90   require(grid)
91
92   # Make a list from the ... arguments and plotlist
93   plots <- c(list(...), plotlist)
94
95   numPlots = length(plots)
96
97   # Make the panel
98   plotcols = cols           # Number of columns of plots
99   plotRows = ceiling(numPlots/plotcols)  # Number of rows needed, calculated from # of cols
100
101  # Set up the page
102  grid.newpage()
103  pushviewport(viewport(layout = grid.layout(plotRows, plotcols)))
104  vplayout <- function(x, y)
105    viewport(layout.pos.row = x, layout.pos.col = y)
106
107  # Make each plot, in the correct location
108  for (i in 1:numPlots) {
109    currow = ceiling(i/plotcols)
110    curcol = (i-1) %% plotcols + 1
111    print(plots[[i]], vp = vplayout(curRow, curcol ))
112  }
113}
114 tiff(filename = "Brahmaputa_river_annual2.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole =
115 multiplot(chart[[2]], cols = 2)
116 dev.off()
117

```

```

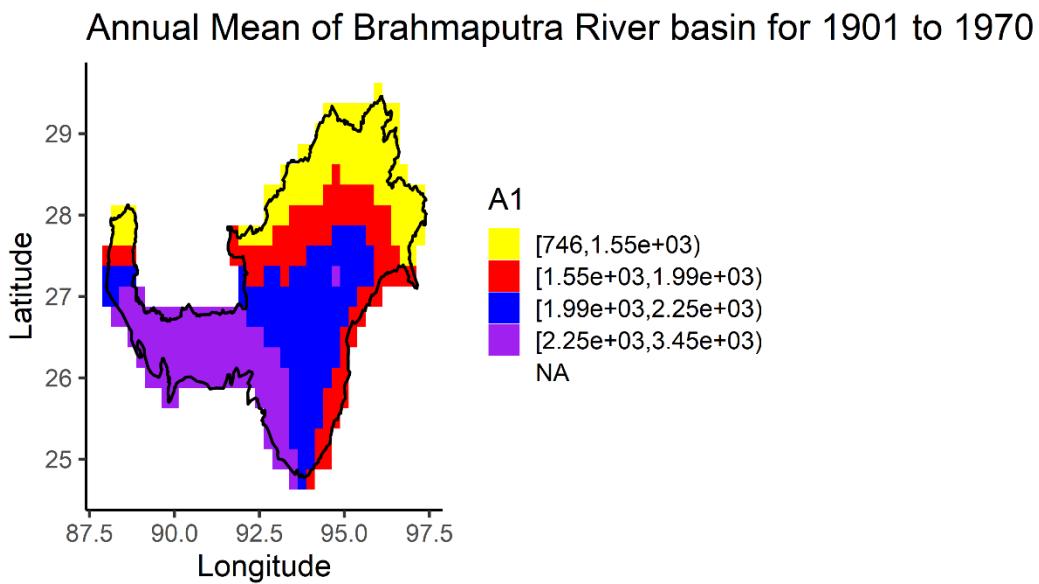
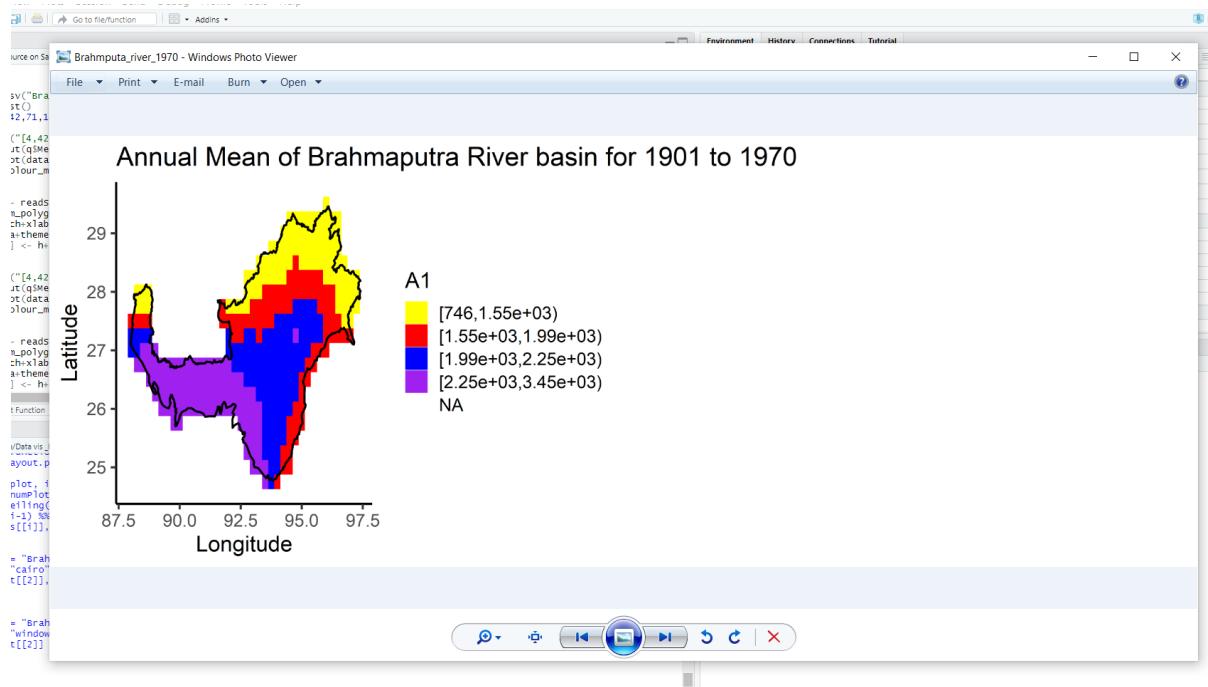
110   curcol = (i-1) %% plotcols + 1
111   print(plots[[i]], vp = vplayout(curRow, curcol ))
112 }
113}
114 tiff(filename = "Brahmaputa_river_annual2.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole =
115 multiplot(chart[[2]], cols = 2)
116 dev.off()
117 jpeg(filename = "Brahmaputa_river_annual2.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole =
118 multiplot(chart[[2]], cols = 2)
119 dev.off()

```

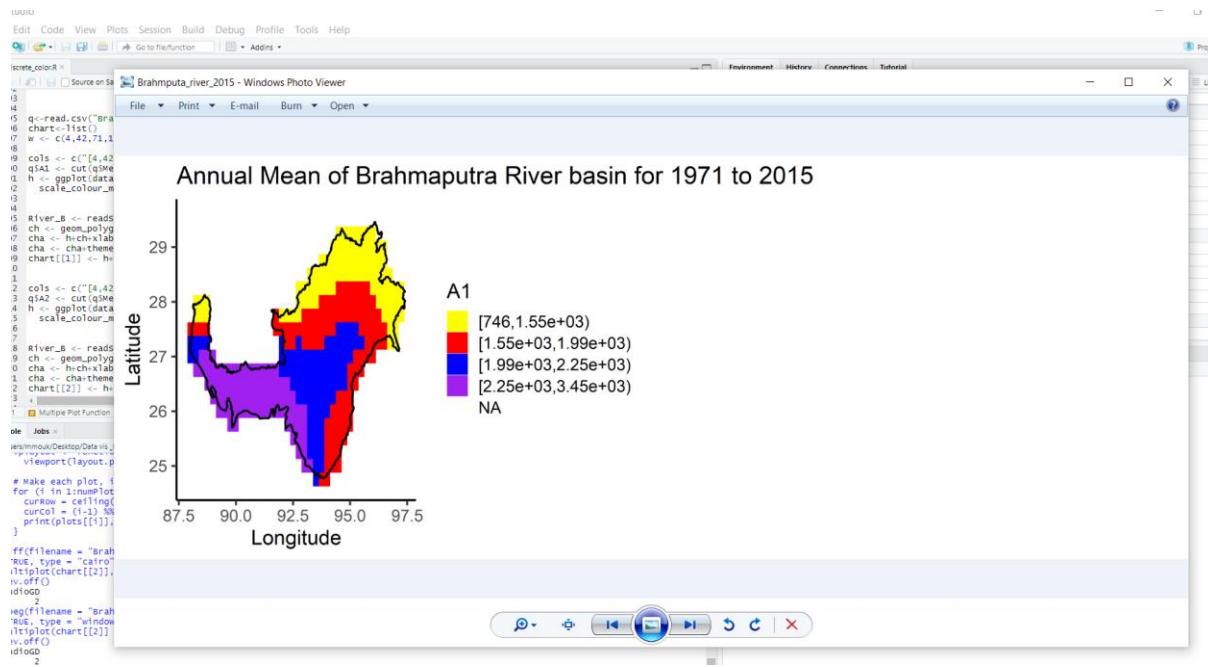
Q2. . Calculate the change in average annual rainfall with respect to global warming in each grid. Then plot the derived result.

Plot:

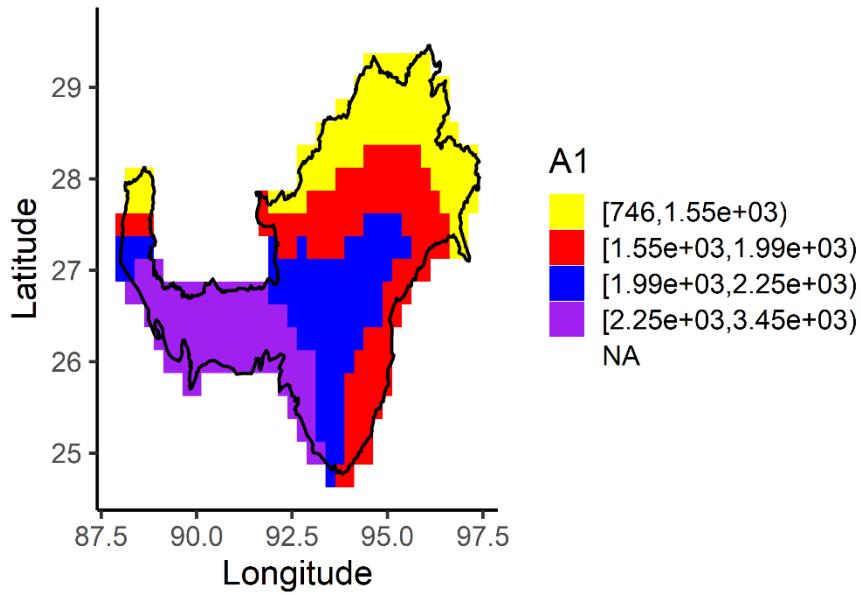
1. 1901-1970 Annual Average Rainfall



2.. 1971-2015 Annual Average Rainfall



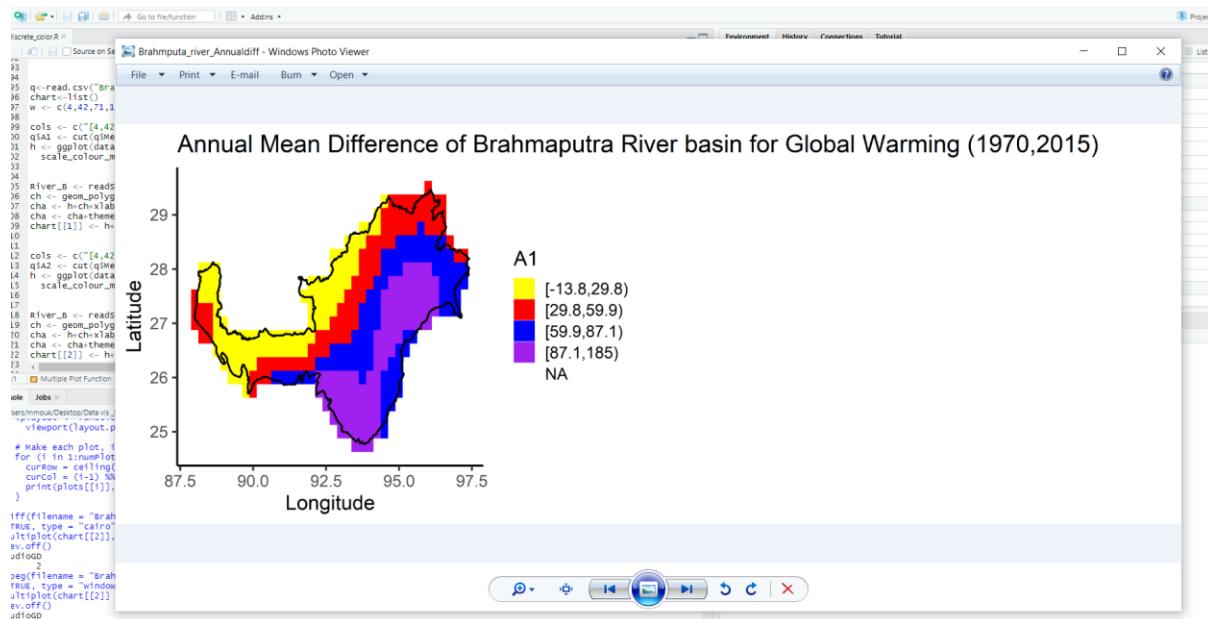
Annual Mean of Brahmaputra River basin for 1971 to 2015

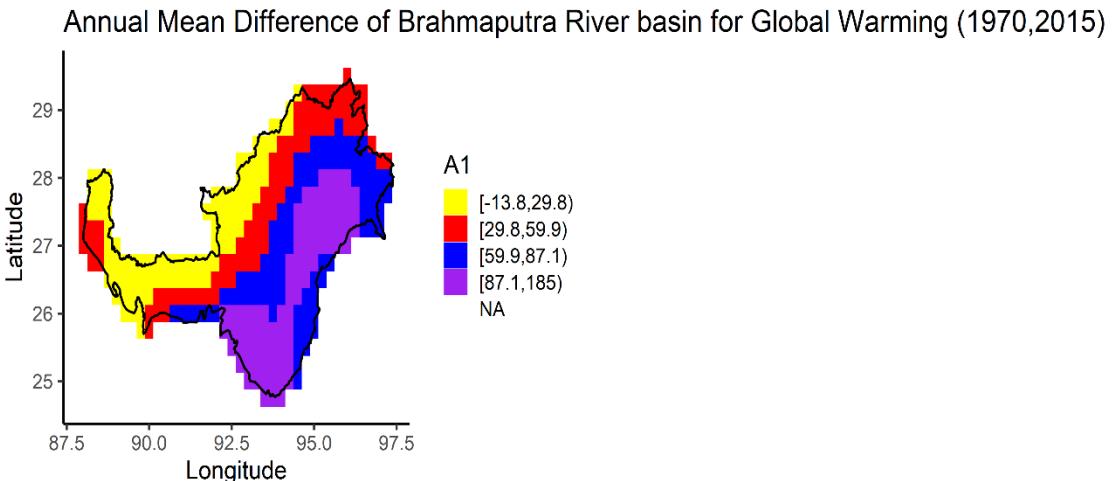


Inference from Plot 1 and Plot 2:

- Plot 1 shows 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 slightly 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

	A	B	C	D	E	F	G	H	I
1	x	y	Mean						
2	93.5	24.75	2302.375						
3	93.75	24.75	2060.051						
4	94	24.75	1972.091						
5	93	25	2862.46						
6	93.25	25	2439.251						
7	93.5	25	2274.612						
8	93.75	25	2109.974						
9	94	25	2022.949						
10	94.25	25	1935.924						
11	94.5	25	1902.914						
12	92.75	25.25	3271.03						
13	93	25.25	2802.416						
14	93.25	25.25	2333.803						
15	93.5	25.25	2246.849						
16	93.75	25.25	2159.896						
17	94	25.25	2073.807						
18	94.25	25.25	1987.719						
19	94.5	25.25	1942.843						
20	92.5	25.5	3498.227						
21	92.75	25.5	3001.134						
22	93	25.5	2668.673						
23	93.25	25.5	2336.211						
24	93.5	25.5	2237.702						
25	93.75	25.5	2237.702						

1971- 2015 Annual Rainfall Avg

	A	B	C	D	E	F	G	H	I	J	K
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	I	J
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:

RStudio interface showing the 'discrete_color.R' script. The code reads a CSV file, calculates averages for each row, and writes them to a new CSV file. The RStudio interface includes tabs for 'Console' and 'Jobs'.

```
126 counter=0;
128 summ=0;
129 ro=1;
130 i=0;
131
132 avg<-read.csv("Brahmaputra_sum_annual.csv")
133
134 t=dim(avg)
135 mat1970<-matrix(0, nrow = 335,ncol=1, byrow = FALSE)
136 for(i in 2:336)
137 {
138
139   for(j in 1:70)
140   {
141     summ=summ+avg[j,i];
142   }
143   mat1970[i-1,1]<-summ/70;
144   summ=0;
145 }
146 write.csv(mat1970,'Brahmaputra_mean_1970.csv')
147
148
149 counter=0;
150 summ=0;
151 ro=1;
152 i=0;
153
154 avg<-read.csv("Brahmaputra_sum_annual.csv")
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
```

RStudio interface showing the continuation of the 'discrete_color.R' script. This part of the code reads a CSV file, calculates averages for each row, and writes them to a new CSV file. It then reads another CSV file, creates a color scale, and plots the data using ggplot2. The RStudio interface includes tabs for 'Console' and 'Jobs'.

```
154 avg<-read.csv("Brahmaputra_sum_annual.csv")
155
156 t=dim(avg)
157 mat2015<-matrix(0, nrow = 335,ncol=1, byrow = FALSE)
158 for(i in 2:336)
159 {
160
161   for(j in 71:115)
162   {
163     summ=summ+avg[j,i];
164   }
165   mat2015[i-1,1]<-summ/45;
166   summ=0;
167 }
168
169 write.csv(mat2015,'Brahmaputra_mean_2015.csv')
170
171
172
173
174
175 q<-read.csv("Brahmaputra_mean_2015.csv")
176 chart<-list()
177 w <- c(746,1.55e+03,1.99e+03,0.225e+04,0.345e+04)
178
179 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]")
180 q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
181 h <- ggplot(data = q, aes(x = x,y = y,fill = A1)) + geom_tile(aes()) +
182   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
```

```

178 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)"
179 q$A1 <- cut(q$mean,breaks = w,right = FALSE)
180 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
181   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
182
183
184
185 River_B <- readshapesspatial("11-9-2019-3772456")
186 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
187 cha <- h+ch+xlab("Longitude")#+ labs(title= z[[1]])
188 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
189 chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Mean of Brahmaputra River basin")
190
191
192 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)" = "
193 q$A2 <- cut(q$mean,breaks = w,right = FALSE)
194 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
195   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
196
197
198 River_B <- readshapesspatial("11-9-2019-3772456")
199 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
200 cha <- h+ch+xlab("Longitude")#+ labs(title= z[[1]])
201 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
202 chart[[2]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Annual Mean of Brahmaputra River basin for 1971 to 2015 ")
203
204
205
206 #### Multiple Plot Function #####
207
208 multiplot <- function(..., plotlist=NULL, cols) {
209   #

```

```

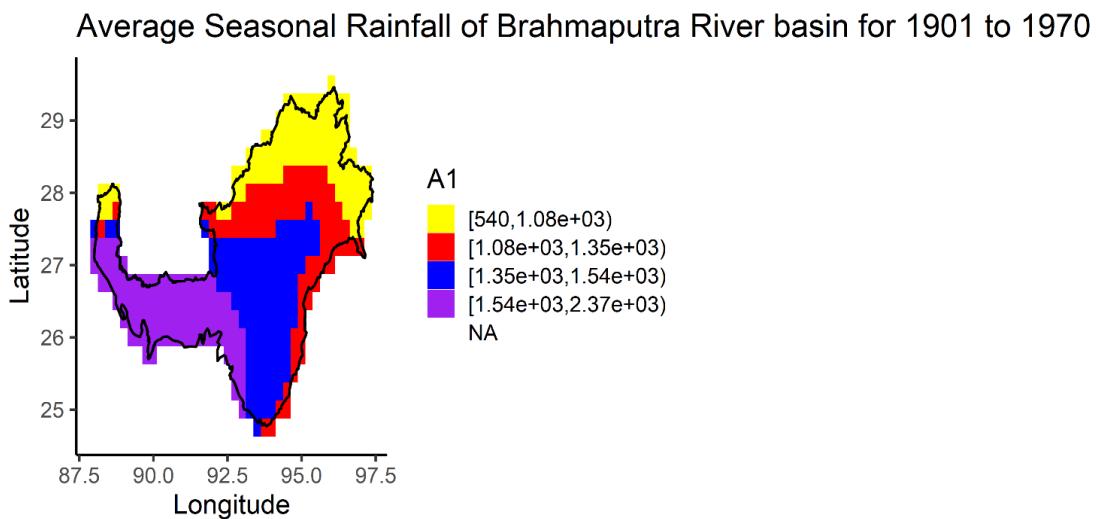
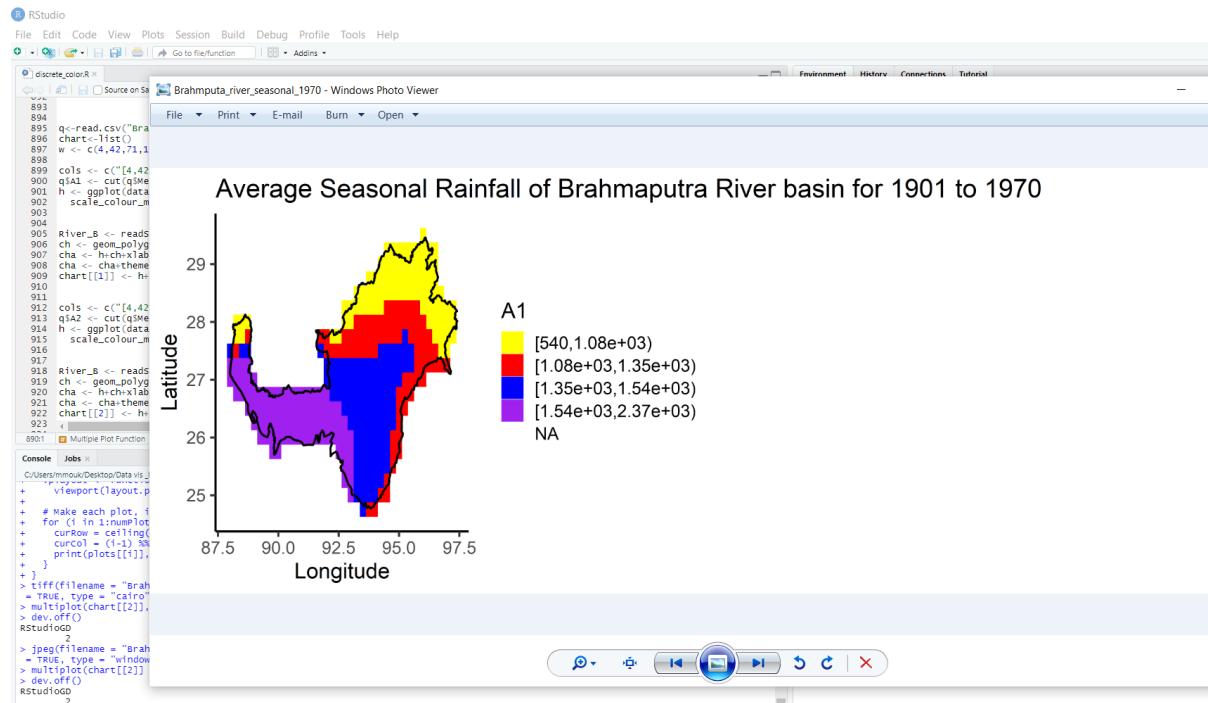
210
211 # Make a list from the ... arguments and plotlist
212 plots <- c(list(...), plotlist)
213
214 numPlots = length(plots)
215
216 # Make the panel
217 plotCols = cols          # Number of columns of plots
218 plotRows = ceiling(numPlots/plotcols) # Number of rows needed, calculated from # of cols
219
220 # Set up the page
221 grid.newpage()
222 pushviewport(viewport(layout = grid.layout(plotRows, plotcols)))
223 vplayout <- function(x, y)
224   viewport(layout.pos.row = x, layout.pos.col = y)
225
226 # Make each plot, in the correct location
227 for (i in 1:numPlots) {
228   curRow = ceiling(i/plotcols)
229   curcol = (i-1) %> plotcols + 1
230   print(plots[[i]], vp = vplayout(curRow, curcol ))
231 }
232
233 tiff(filename = "Brahmputa_river_2015.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole = TRUE)
234 multiplot(chart[[2]], cols = 2)
235 dev.off()
236 jpeg(filename = "Brahmaputa_river_2015.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE)
237 multiplot(chart[[2]], cols = 2)
238 dev.off()
239
240
241

```

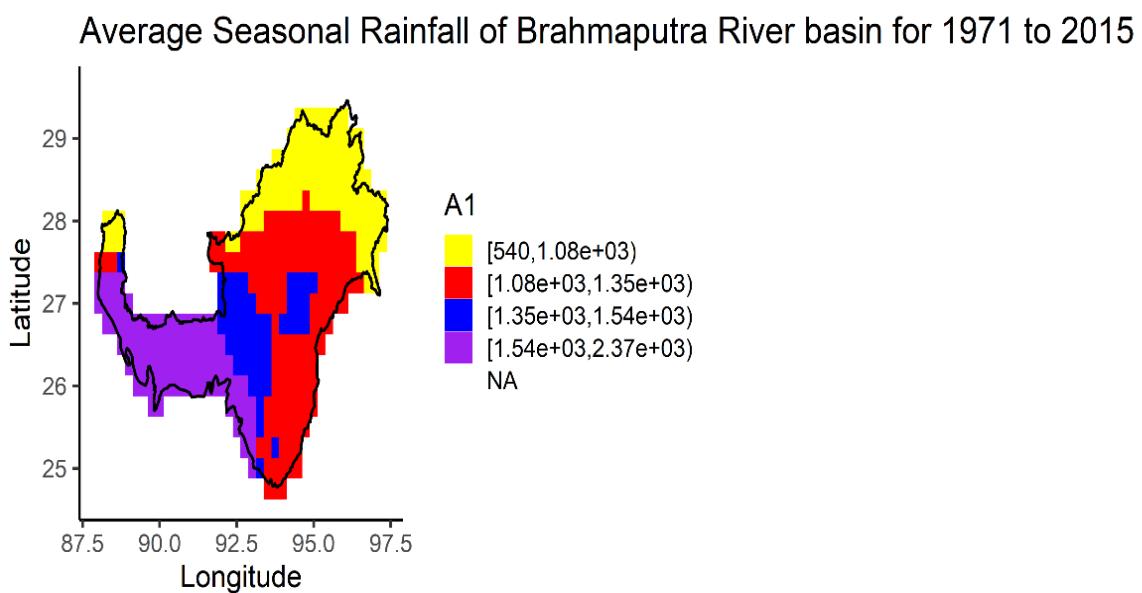
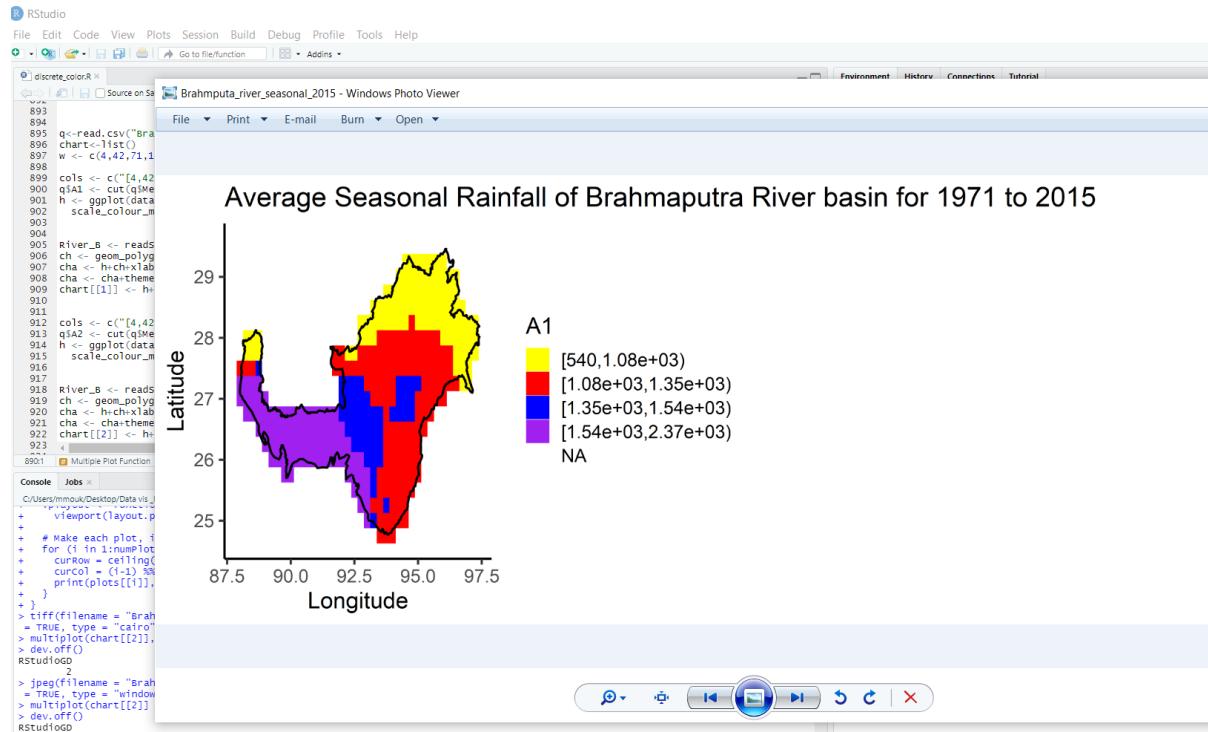
Q3. Calculate the change in seasonal average rainfall with respect to global warming in each of grids. Plot the derived results.

Plot:

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



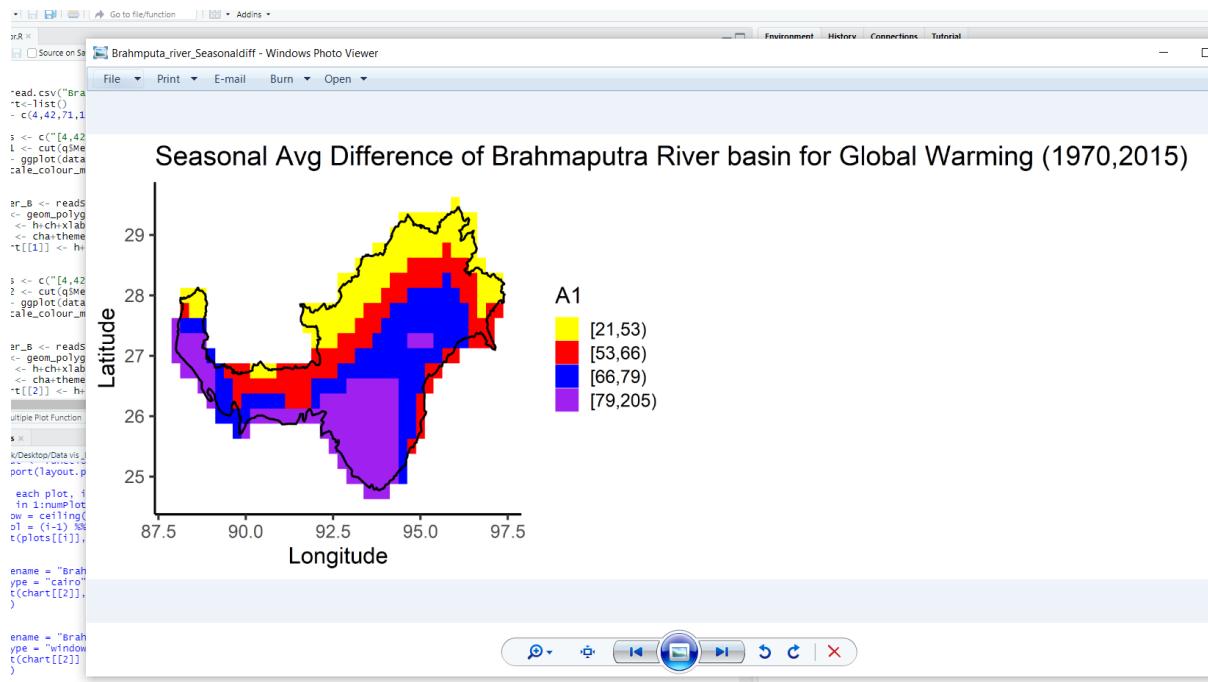
2. 1971-2015 seasonal rainfall average(June to Sept)



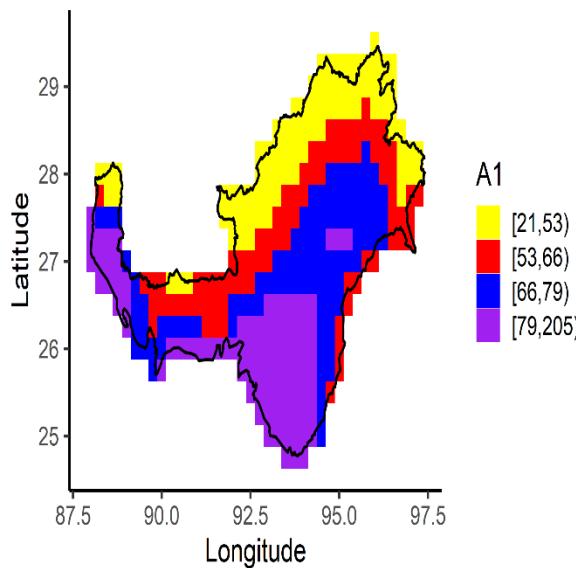
Inferences from Plot 1 and Plot 2:

- 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



Seasonal Avg Difference of Brahmaputra River basin for Global Warming (1970,2015)



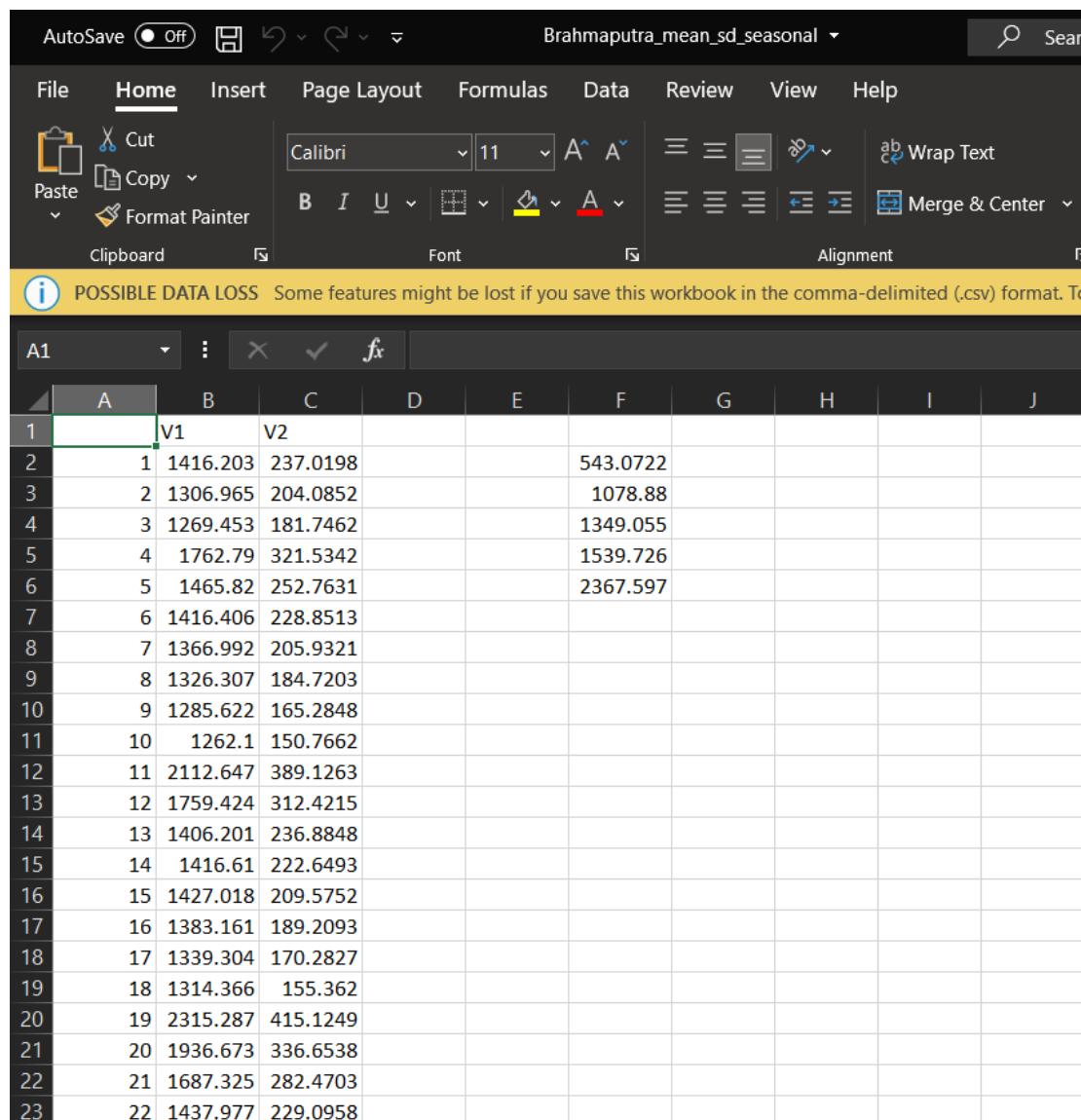
Inference from Plot 3:

- 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



The screenshot shows a Microsoft Excel spreadsheet titled "Brahmaputra_mean_sd_seasonal". The ribbon menu is visible at the top, showing tabs for File, Home, Insert, Page Layout, Formulas, Data, Review, View, and Help. The "Home" tab is selected. The status bar at the bottom indicates "POSSIBLE DATA LOSS" and suggests saving as a CSV file. The data is organized in a table with columns labeled A through J and rows numbered 1 through 23. Column A contains row numbers, while columns B and C contain data values. Columns D through J are mostly empty or contain small values.

	A	B	C	D	E	F	G	H	I	J
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

A screenshot of a Microsoft Excel spreadsheet titled "Brahmaputra_mean_1970_seasonal". The data is organized into three columns: 'x' (containing values like 93.5, 93.75, 94, etc.), 'y' (containing values like 24.75, 24.75, 24.75, etc.), and 'Mean' (containing values like 1464.583, 1349.181, 1306.504, etc.). The 'Mean' column shows the seasonal average rainfall for each corresponding 'x' value. The Excel ribbon at the top includes tabs for File, Home, Insert, Page Layout, Formulas, Data, Review, View, and Help. The 'Home' tab is selected. The font is set to Calibri, size 11, and the alignment is centered.

	A	B	C	D	E	F	G	H	I	J	K
1	x	y	Mean								
2	93.5	24.75	1464.583								
3	93.75	24.75	1349.181								
4	94	24.75	1306.504								
5	93	25	1829.299								
6	93.25	25	1516.625								
7	93.5	25	1462.383								
8	93.75	25	1408.14								
9	94	25	1363.445								
10	94.25	25	1318.751								
11	94.5	25	1289.403								
12	92.75	25.25	2191.729								
13	93	25.25	1822.497								
14	93.25	25.25	1453.266								
15	93.5	25.25	1460.182								
16	93.75	25.25	1467.099								
17	94	25.25	1420.386								
18	94.25	25.25	1373.674								
19	94.5	25.25	1343.037								
20	92.5	25.5	2391.939								
21	92.75	25.5	2001.411								
22	93	25.5	1741.749								
23	93.25	25.5	1482.086								
24	93.5	25.5	1452.484								

3. 1971- 2015 Seasonal Average Rainfall

A screenshot of a Microsoft Excel spreadsheet titled "Brahmaputra_mean_2015_seasonal". The data is organized into three columns: 'x' (containing values like 93.5, 93.75, 94, etc.), 'y' (containing values like 24.75, 24.75, 24.75, etc.), and 'Mean' (containing values like 1340.944, 1241.296, 1211.818, etc.). The 'Mean' column shows the seasonal average rainfall for each corresponding 'x' value. The Excel ribbon at the top includes tabs for File, Home, Insert, Page Layout, Formulas, Data, Review, View, and Help. The 'Home' tab is selected. The font is set to Calibri, size 11, and the alignment is centered.

	A	B	C	D	E	F	G	H	I	J
1	x	y	Mean							
2	93.5	24.75	1340.944							
3	93.75	24.75	1241.296							
4	94	24.75	1211.818							
5	93	25	1659.332							
6	93.25	25	1386.791							
7	93.5	25	1344.887							
8	93.75	25	1302.983							
9	94	25	1268.536							
10	94.25	25	1234.089							
11	94.5	25	1219.629							
12	92.75	25.25	1989.631							
13	93	25.25	1661.31							
14	93.25	25.25	1332.989							
15	93.5	25.25	1348.83							
16	93.75	25.25	1364.671							
17	94	25.25	1325.254							
18	94.25	25.25	1285.838							
19	94.5	25.25	1269.766							

4. Difference wrt Global warming between the two periods

The screenshot shows an Excel spreadsheet titled "Brahmaputra_Seasonal_Mean_Difference". The ribbon menu is visible at the top, showing tabs for File, Home, Insert, Page Layout, Formulas, Data, Review, View, and Help. The "Home" tab is selected. The "Clipboard" group contains Paste, Cut, Copy, and Format Painter buttons. The "Font" group includes Calibri, 11pt, Bold (B), Italic (I), Underline (U), and various color and style options. The "Alignment" group includes horizontal and vertical alignment, wrap text, and merge & center buttons. A status bar at the bottom indicates "POSSIBLE DATA LOSS Some features might be lost if you save this workbook in the comma-delimited (.csv) fo".

	A	B	C	D	E	F	G	H	I
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:

The screenshot shows an RStudio interface with an R script file named "discrete_color.R" open. The code implements a seasonal check logic for a dataset. It reads a CSV file ("Brahmaputra_basin_data.csv") and processes it row by row. The script uses a counter to track seasonal changes and a seasonalcheck variable to determine when a seasonal period ends. It sums values for each period and stores them in a matrix. The code is annotated with line numbers from 390 to 919.

```

390
391 counter=0;
392 seasonalcheck=0;
393 summ=0;
394 ro=1;
395 i=0;
396 p <- read.csv("Brahmaputra_basin_data.csv") ## Import the data
397 ##mat<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
398 mat<-matrix(0, nrow = 115,ncol=335, byrow = FALSE)
399 for(i in 2:336){
400 {
401   for(j in 1:1380)
402   {
403     seasonalcheck=seasonalcheck+1;
404     counter=counter+1;
405     if(seasonalcheck>=6 && seasonalcheck<=9){
406       summ=summ+p[j,i];
407     }
408     if(counter==12)
409     {
410       mat[ro,i-1]=summ;
411       summ=0;
412       ro=ro+1;
413       counter=0;
414       seasonalcheck=0;
415     }
416   }
417 }
418 }
419 seasonalcheck=0;
420

```

RStudio

File Edit Code View Plots Session Build Debug Profile Tools Help

discrete_color.R

```

417 }
418 seasonalcheck=0;
419 ro=1;
420 counter=0;
421 summ=0;
422
423
424 }
425 mat;
426 write.csv(mat,'Brahmaputra_sum_seasonal.csv')
427
428
429
430
431
432 counter=0;
433 summ=0;
434 ro=1;
435 i=0;
436
437 avg<-read.csv("Brahmaputra_sum_seasonal.csv")
438
439 t=dim(avg)
440 mat2<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
441 for(i in 1:(t[2]-1))
442 {
443   m = mean(avg[,i+1])  ##  mean
444   mat2[i,1]<-m
445   s<-sd(avg[,i+1])
446   mat2[i,2]<-s          ##  standard deviation
447 }
448

```

961:1 Multiple Plot Function

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

```

discrete_color.R

```

442 {
443   m = mean(avg[,i+1])  ##  mean
444   mat2[i,1]<-m
445   s<-sd(avg[,i+1])
446   mat2[i,2]<-s          ##  standard deviation
447 }
448 write.csv(mat2,'Brahmaputra_mean_sd_seasonal.csv')
449
450 t=dim(avg)
451 mat1970<-matrix(0, nrow = 335,ncol=1, byrow = FALSE)
452 for(i in 2:336)
453 {
454
455   for(j in 1:70)
456   {
457     summ=summ+avg[j,i];
458   }
459   mat1970[i-1,1]<-summ/70;
460   summ=0;
461 }
462 write.csv(mat1970,'Brahmaputra_mean_1970_seasonal.csv')
463
464
465 counter=0;
466 summ=0;
467 ro=1;
468 i=0;
469
470 avg<-read.csv("Brahmaputra_sum_seasonal.csv")
471
472

```

961:1 Multiple Plot Function

Console Jobs

Screenshot of RStudio showing the code for generating a choropleth map of Brahmaputra mean rainfall for 2015. The code reads a CSV file, calculates averages, and creates a ggplot2 map.

```

472 t=dim(avg)
473 mat2015<-matrix(0, nrow = 335,ncol=1, byrow = FALSE)
474 for(i in 2:336)
475 {
476
477   for(j in 71:115)
478   {
479     summ=summ+avg[j,i];
480   }
481   mat2015[i-1,1]<-summ/45;
482   summ=0;
483 }
484 write.csv(mat2015, 'Brahmaputra_mean_2015_seasonal.csv')
485
486
487 q<-read.csv("Brahmaputra_mean_2015_seasonal.csv")
488 chart<-list()
489 w <- c(540,1.08e+03,1.35e+03,1.54e+03,2.37e+03)
490
491 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]" = "purple")
492 q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
493 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
494   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
495
496 River_B <- readshpspatial("11-9-2019-3772456")
497 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
498 cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
499 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
500 chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average seasonal Rainfall of Brahmaputra River basin for 1996-2015")
501
502

```

Screenshot of RStudio showing the code for creating a multi-plot function. The code sets up a grid of plots, pushes a viewport, and prints plots to a TIFF file.

```

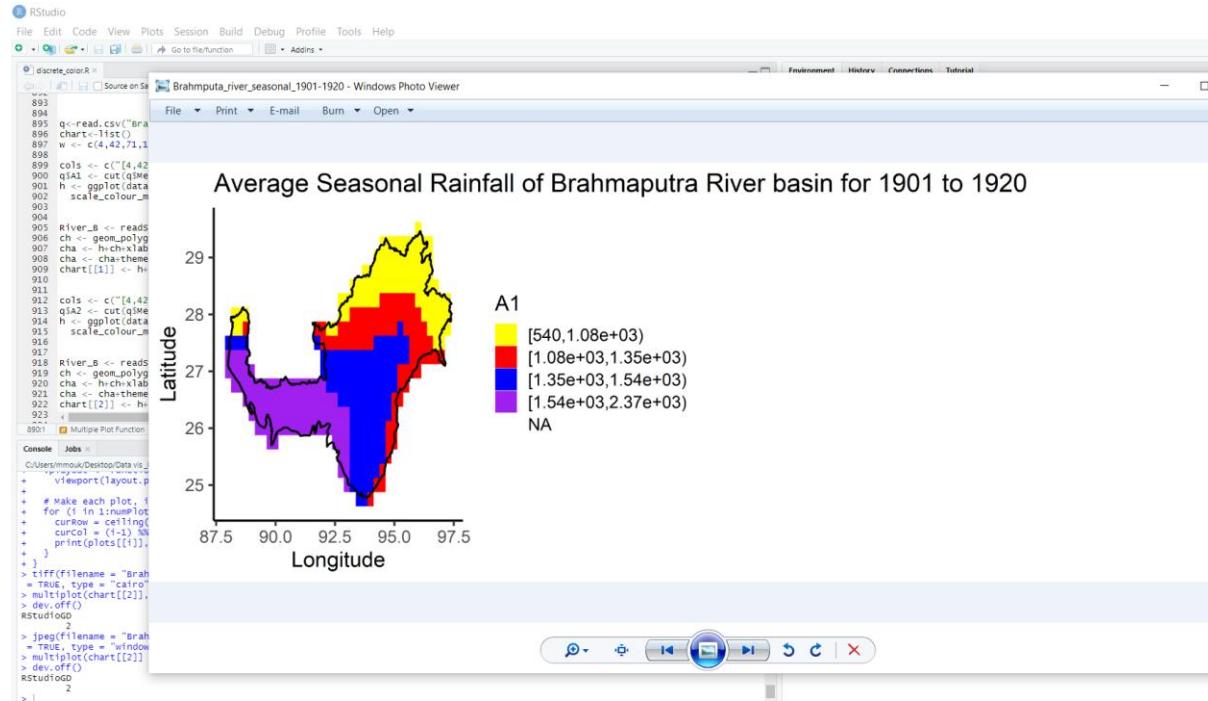
669 # Make a list from the ... arguments and plotlist
670 plots <- c(list(...), plotlist)
671
672 numPlots = length(plots)
673
674 # Make the panel
675 plotCols = cols # Number of columns of plots
676 plotRows = ceiling(numPlots/plotcols) # Number of rows needed, calculated from # of cols
677
678 # Set up the page
679 grid.newpage()
680 pushViewport(viewport(layout = grid.layout(plotRows, plotcols)))
681 vplayout <- function(x, y)
682   viewport(layout.pos.row = x, layout.pos.col = y)
683
684 # Make each plot, in the correct location
685 for (i in 1:numPlots) {
686   curRow = ceiling(i/plotcols)
687   curcol = (i-1) %% plotcols + 1
688   print(plots[[i]], vp = vplayout(curRow, curcol ))
689 }
690
691 tiff(filename = "Brahmaputra_river_Seasonaldiff.tiff", pointsize = 8, res = 600, units = "in", width = 8, height = 3, restoreConsole = TRUE)
692 multiplot(chart[[2]], cols = 2)
693 dev.off()
694 jpeg(filename = "Brahmaputra_river_Seasonaldiff.jpeg", pointsize = 8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE)
695 multiplot(chart[[2]], cols = 2)
696 dev.off()
697
698
699
700

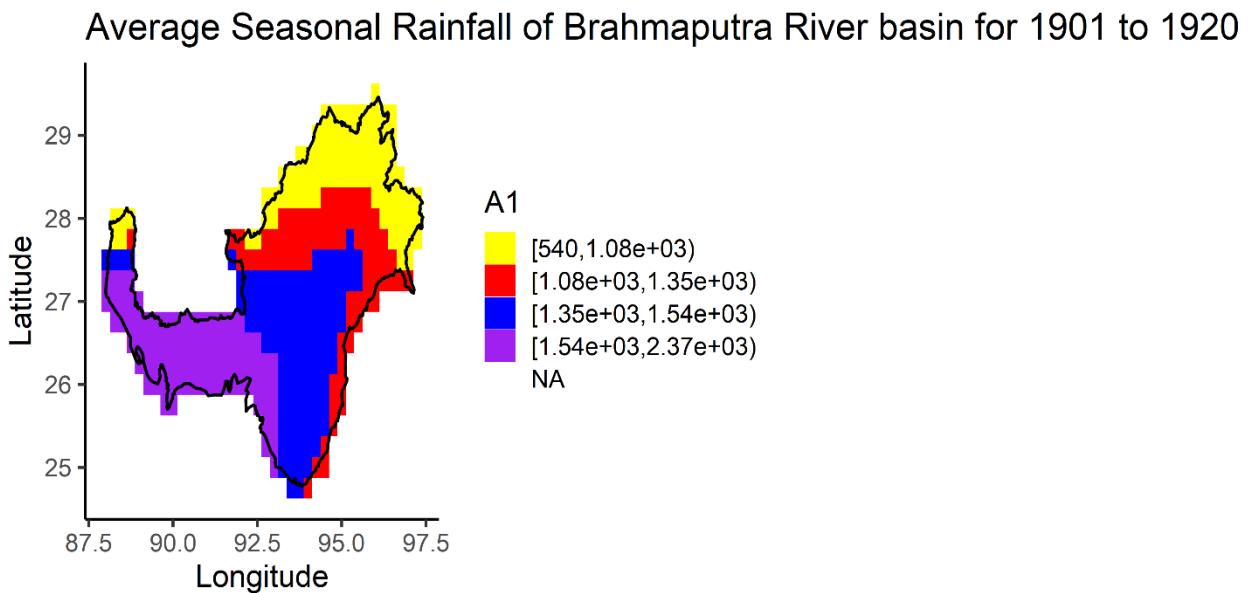
```

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

Average Seasonal Rainfall of Brahmaputra River basin for 1990 to 2015

Latitude

Longitude

A1

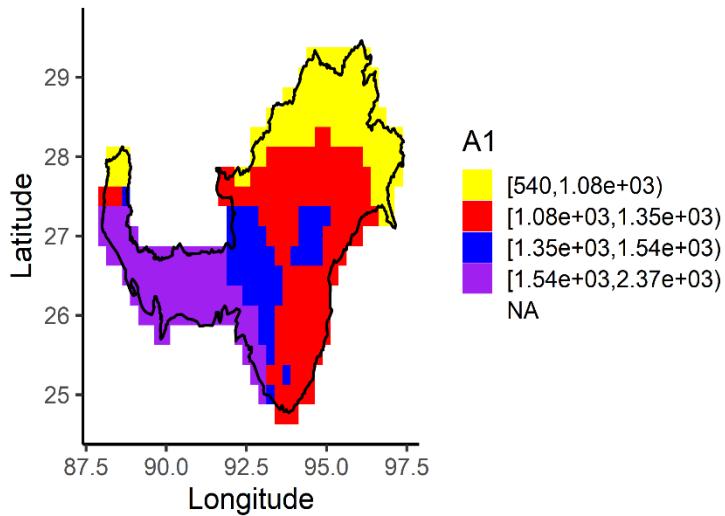
- [540, 1.08e+03]
- [1.08e+03, 1.35e+03]
- [1.35e+03, 1.54e+03]
- [1.54e+03, 2.37e+03]

NA

87.5 90.0 92.5 95.0 97.5

29
28
27
26
25

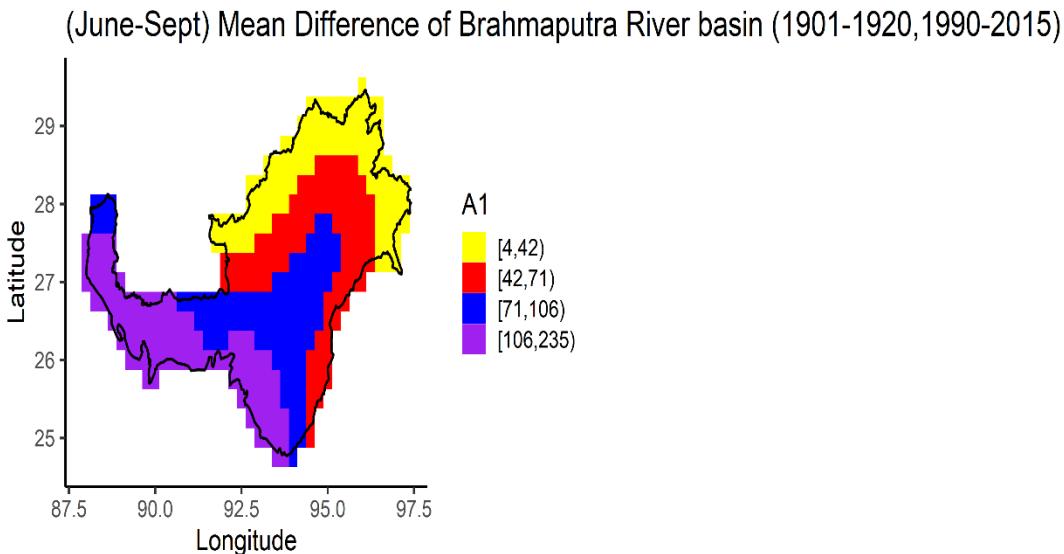
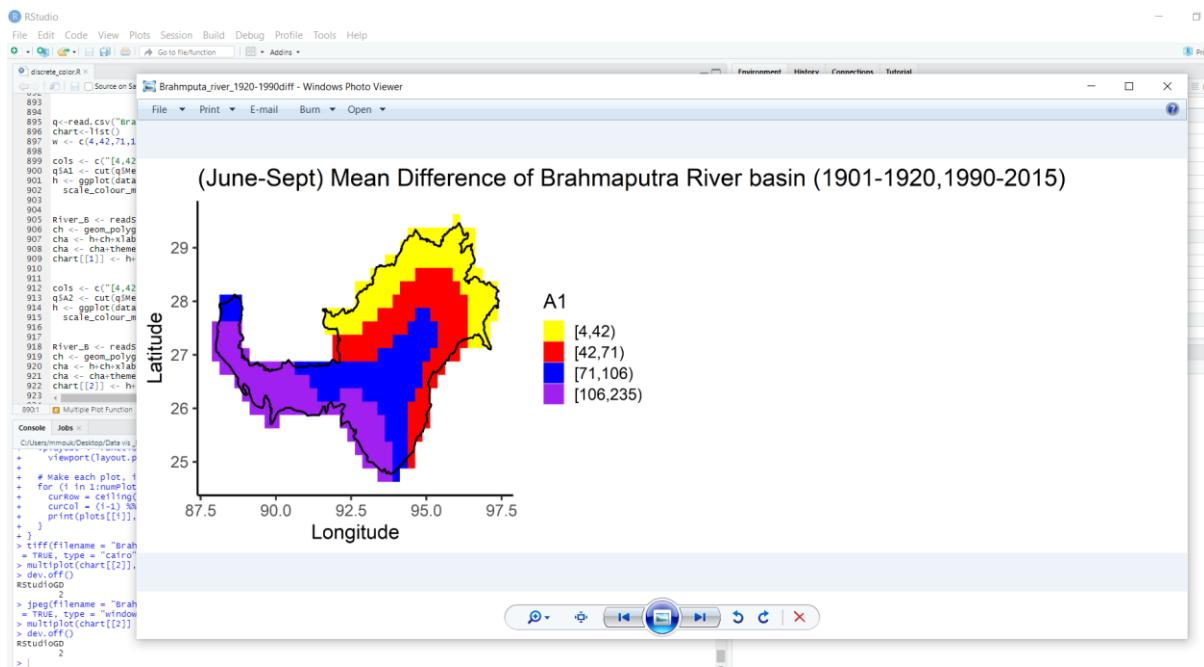
Average Seasonal Rainfall of Brahmaputra River basin for 1990 to 2015



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

This screenshot shows a Microsoft Excel spreadsheet titled "Brahmaputra_mean_1901-1920_seasonal". The data is organized into columns A through J. Column A contains row numbers from 1 to 14. Columns B and C contain numerical values. Column D is labeled "Mean". The data is as follows:

	A	B	C	D	E	F	G	H	I	J
1	x	y	Mean							
2	93.5	24.75	1476.848							
3	93.75	24.75	1359.525							
4	94	24.75	1316.398							
5	93	25	1835.124							
6	93.25	25	1526.145							
7	93.5	25	1471.271							
8	93.75	25	1416.398							
9	94	25	1370.775							
10	94.25	25	1325.153							
11	94.5	25	1299.831							
12	92.75	25.25	2193.635							
13	93	25.25	1825.878							
14	93.25	25.25	1458.12							

2. 1990-2015 Seasonal Average Rainfall

This screenshot shows a Microsoft Excel spreadsheet titled "Brahmaputra_mean_1990-2015_seasonal". The data is organized into columns A through I. Column A contains row numbers from 1 to 12. Columns B and C contain numerical values. Column D is labeled "Mean". The data is as follows:

	A	B	C	D	E	F	G	H	I
1	x	y	Mean						
2	93.5	24.75	1334.931						
3	93.75	24.75	1240.162						
4	94	24.75	1218.104						
5	93	25	1644.762						
6	93.25	25	1377.331						
7	93.5	25	1340.436						
8	93.75	25	1303.54						
9	94	25	1274.923						
10	94.25	25	1246.306						
11	94.5	25	1231.367						
12	92.75	25.25	1966.031						

3. Difference in seasonal rainfall between the two periods

The screenshot shows a Microsoft Excel spreadsheet titled "Brahmaputra_Seasonal_Difference_1920-1990". The data is organized into columns A through J. Column A contains numerical values, while columns B through J contain categorical or summary data. A warning message at the top indicates "POSSIBLE DATA LOSS" if the workbook is saved in CSV format.

	A	B	C	D	E	F	G	H	I	J
1	x	y	M1920	M1990	Mean					
2	93.5	24.75	1476.848	1334.931	141.9167					
3	93.75	24.75	1359.525	1240.162	119.3635	Min=	4.295772			
4	94	24.75	1316.398	1218.104	98.29366	Q1=	42.3601			
5	93	25	1835.124	1644.762	190.3622	median=	71.70423			
6	93.25	25	1526.145	1377.331	148.8142	Q3=	106.5434			
7	93.5	25	1471.271	1340.436	130.8357	Max=	232.8238			
8	93.75	25	1416.398	1303.54	112.8571					
9	94	25	1370.775	1274.923	95.85192					
10	94.25	25	1325.153	1246.306	78.84673					
11	94.5	25	1299.831	1231.367	68.46394					
12	92.75	25.25	2193.635	1966.031	227.6042					
13	93	25.25	1825.878	1645.496	180.3813					
14	93.25	25.25	1458.12	1324.962	133.1585					
15	93.5	25.25	1465.695	1345.94	119.7546					
16	93.75	25.25	1473.27	1366.919	106.3508					
17	94	25.25	1425.153	1331.742	93.41019					

CODE Screenshots:

The screenshot shows an RStudio interface with an R script file named "discrete_color.R". The code performs the following steps:

- Creates a matrix "mat1920" with 335 rows and 1 column, initialized to 0.
- For each row *i* from 2 to 336:
 - Creates a vector "avg" with 20 elements, all set to 0.
 - For each column *j* from 1 to 20:
 - Sums the value of "mat1920[i, j]" into "summ".
 - Updates "mat1920[i-1, 1]" with "summ/20".
 - Resets "summ" to 0.
- Writes the matrix "mat1920" to a CSV file named "Brahmaputra_mean_1901-1920_seasonal.csv".
- Initializes variables: "counter" to 0, "sum" to 0, "row" to 1, and "i" to 0.
- Reads a CSV file "Brahmaputra_sum_seasonal.csv" into a matrix "avg".
- Creates a matrix "mat1990" with 335 rows and 1 column, initialized to 0.
- For each row *i* from 2 to 336:
 - Creates a vector "avg" with 115 elements, all set to 0.
 - For each column *j* from 90 to 115:
 - Sums the value of "avg[i, j]" into "summ".
 - Updates "mat1990[i-1, 1]" with "summ".
 - Resets "summ" to 0.
- Writes the matrix "mat1990" to a CSV file named "Brahmaputra_mean_1920-1990_seasonal.csv".

discrete_color.R

```

718
719 counter=0;
720 summ=0;
721 row=1;
722 i=0;
723
724 avg<-read.csv("Brahmaputra_sum_seasonal.csv")
725
726 t=dim(avg)
727 mat1990<-matrix(0, nrow = 335,ncol=1, byrow = FALSE)
728 for(i in 2:336)
729 {
730
731 for(j in 90:115)
732 {
733 summ=summ+avg[j,i];
734 }
735 mat1990[i-1,1]<-summ/26;
736 summ=0;
737 }
738 write.csv(mat1990,'Brahmaputra_mean_1990-2015_seasonal.csv')
739
740
741
742
743
744
745
746
747
748
961:1 Multiple Plot Function

```

Environment

- R ch cha chart g h mpg q River_B Values cols w Functions multiple

Files Plots

Multiple Plot Function

```

747
748 q<-read.csv("Brahmaputra_mean_1901-1920_seasonal.csv")
749 chart<-list()
750 w <- c(540,1.08e+03,1.35e+03,1.54e+03,2.37e+03)
751
752 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)" = "purple", "[2.37e+03,540]" = "brown")
753 q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
754 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()
755
756
757 River_B <- readshapeSpatial("11-9-2019-3772456")
758 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
759 cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title=z[i])
760 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
761 chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average seasonal Rainfall of Brahmaputra River basin for 1901-1920")
762
763
764
765 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)" = "purple", "[2.37e+03,540]" = "brown")
766 q$A2 <- cut(q$Mean,breaks = w,right = FALSE)
767 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()
768
769
770 River_B <- readshapeSpatial("11-9-2019-3772456")
771 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
772 cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title=z[i])
773 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
774 chart[[2]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average seasonal Rainfall of Brahmaputra River basin for 1921-1940")
775
776
777
961:1 Multiple Plot Function

```

Console Jobs

RStudio

File Edit Code View Plots Session Build Debug Profile Tools Help

discrete_color.R

```
782 <- function(..., plotlist=NULL, cols) {
783   require(grid)
784   # Make a list from the ... arguments and plotlist
785   plots <- c(list(...), plotlist)
786
787   numPlots = length(plots)
788
789   # Make the panel
790   plotcols = cols           # Number of columns of plots
791   plotRows = ceiling(numPlots/plotcols) # Number of rows needed, calculated from # of cols
792
793   # Set up the page
794   grid.newpage()
795   pushviewport(viewport(layout = grid.layout(plotRows, plotcols)))
796   vplayout <- function(x, y)
797     viewport(layout.pos.row = x, layout.pos.col = y)
798
799   # Make each plot, in the correct location
800   for (i in 1:numPlots) {
801     curRow = ceiling(i/plotcols)
802     curcol = (i-1) %% plotcols + 1
803     print(plots[[i]], vp = vplayout(curRow, curcol))
804   }
805
806   tiff(filename = "Brahmaputra_river_seasonal_1901-1920.tiff", pointsize = 8, res = 600, units = "in", width = 8, height = 3, restore = TRUE)
807   multiplot(chart[[2]], cols = 2)
808   dev.off()
809   jpeg(filename = "Brahmaputra_river_seasonal_1901-1920.jpeg", pointsize = 8, res = 600, units = "in", width = 8, height = 2, restore = TRUE)
810   multiplot(chart[[1]], cols = 2)
811   dev.off()
812 }
```

961:1 Multiple Plot Function

Console Jobs

C:/Users/mmouk/Desktop/Data visLab/

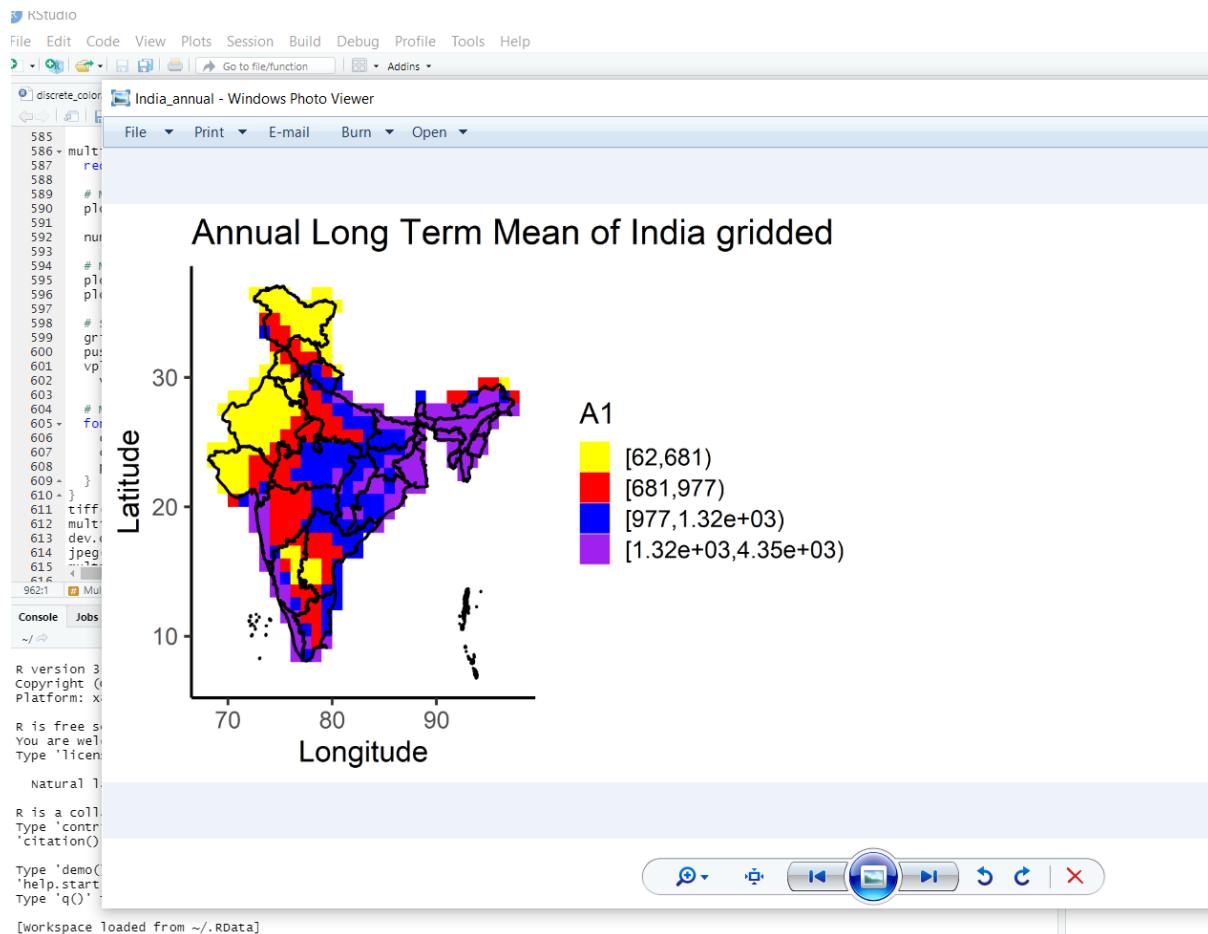
+ <function (..., plotlist = NULL, cols = 1)>

+ vplayout(layout.pos.row = x, layout.pos.col = y)

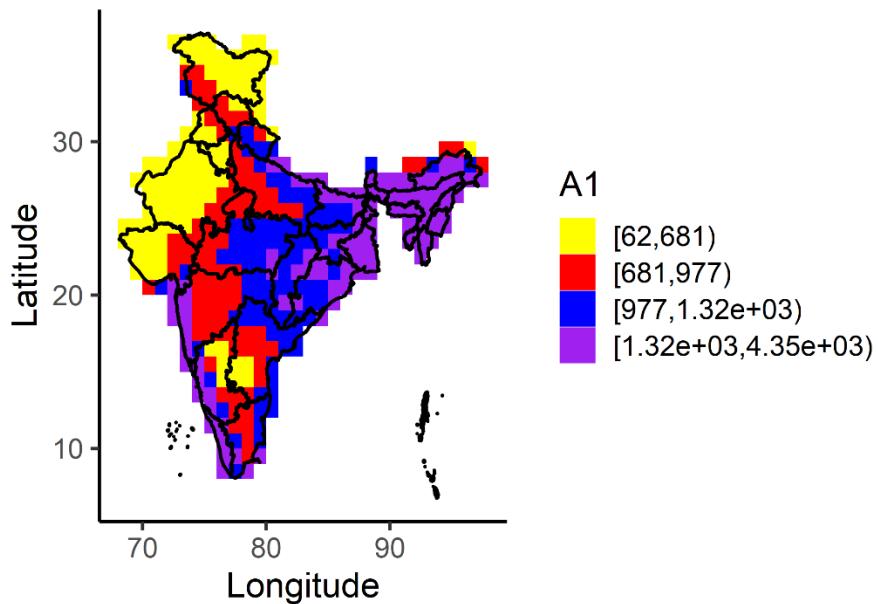
India – Gridded – Data

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:



Annual Long Term Mean of India gridded



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.

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

	A	B	C	D	E	F	G	H	I	J	K	L
1	x	y	Mean	Std								
2	76.5	8.5	1946.42	313.301								
3	77.5	8.5	1130.963	156.0082								
4	78.5	8.5	1445.248	215.2286								
5	76.5	9.5	2016.545	259.5859	Min=	62.74013						
6	77.5	9.5	1466.754	213.7928	Q1=	681.4026						
7	78.5	9.5	885.8386	159.3304	Median	977.8405						
8	79.5	9.5	1362.686	280.0919	Q3=	1326.766						
9	76.5	10.5	2335.633	303.0339	Max=	4340.091						
10	77.5	10.5	1086.302	171.2854								
11	78.5	10.5	904.1099	175.3498								
12	79.5	10.5	1167.334	236.4105								
13	75.5	11.5	2249.008	368.5397								
14	76.5	11.5	1650.973	239.9033								
15	77.5	11.5	807.3645	144.0214								
16	78.5	11.5	928.2728	179.5815								
17	79.5	11.5	1225.959	258.8527								
18	75.5	12.5	2814.65	445.2321								
19	76.5	12.5	1192.079	203.486								
20	77.5	12.5	828.4524	160.7048								
21	78.5	12.5	0.11	0.070	175.000							

CODE SCREENSHOTS:

```

RStudio
File Edit Code View Plots Session Build Debug Profile Tools Help
+ Source on Save Go to file/function Run Source
E
D
I
F
R
Discrete_color.R
1 setwd("C:/Users/mmouk/Desktop/data_vis_lab")
2 par(mar = c(10,10,10,10))
3 #par(mfrow=c(1,4))
4 library(ggplot2)
5 library(grid)
6 library(gridExtra)
7 library(extrafont)
8 library(ggrepel)
9 library(maptools)
10 library(plyr)
11 library(maps)
12 counter=0;
13 sum=0;
14 r=1;
15 i=0;
16 p <- read.csv("india_gridded_data.csv") ## Import the data
17 #mat<-matrix(0, nrow = t[2], ncol=2, byrow = FALSE)
18 mat<-matrix(0, nrow = 114, ncol=354, byrow = FALSE)
19 for(i in 1:354)
20 {
21   for(j in 1:1368)
22   {
23     counter=counter+1;
24     sum=sum+p[j,i];
25     if(counter==12)
26     {
27       mat[r,i]=sum;
28       sum=0;
29       r=r+1;
30       counter=0;
31     }
32 }
962:1 Multiple Plot Function
Console Jobs ~ / 

```

discrete_color.R

```

15 i=0;
16 p <- read.csv("India_gridded_data.csv") ## Import the data
17 ##mat<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
18 mat<-matrix(0, nrow = 114,ncol=354, byrow = FALSE)
19 for(i in 1:354)
20 {
21   for(j in 1:1368)
22   {
23     counter=counter+1;
24     summ=summ+p[j,i];
25     if(counter==12)
26     {
27       mat[ro,i]=summ;
28       summ=0;
29       ro=ro+1;
30       counter=0;
31     }
32   }
33 }
34 ro=1;
35 counter=0;
36 summ=0;
37
38
39
40 mat;
41 write.csv(mat,'India_sum_annual.csv')
42
43 avg<-read.csv("India_sum_annual.csv")
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75

```

962:1 Multiple Plot Function

Console Jobs

discrete_color.R

```

44 avg<-read.csv("India_sum_annual.csv")
45
46 t=dim(avg)
47 mat2<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
48 for(i in 1:(t[2]-1))
49 {
50   m = mean(avg[,i+1]) ## mean
51   mat2[i,1]<-m
52   s<-sd(avg[,i+1])
53   mat2[i,2]<-s ## standard deviation
54 }
55 write.csv(mat2,'India_mean_sd_annual.csv')
56
57 q<-read.csv("India_mean_sd_annual.csv")
58 chart<-list()
59 w <- c(62,681,977,1.32e+03,4.35e+03)
60
61 cols <- c("[62,681]" = "yellow", "[681,977]" = "red", "[977,1.32e+03]" = "blue", "[1.32e+03,4.35e+03]" = "purple")
62 q$A1 <- cut(q$mean,breaks = w,right = FALSE)
63 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
64   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
65
66
67 River_B <- readShapeSpatial("Ind")
68 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
69 cha <- h+ch+xlab("Longitude")#+ labs(title= z[i])
70 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
71 chart[[1]] <- h+ch+xlab("Longitude")#+ylab("Latitude") + labs(title="Annual Long Term Mean of India gridded ")
72
73
74 cols <- c("[62,681]" = "yellow", "[681,977]" = "red", "[977,1.32e+03]" = "blue", "[1.32e+03,4.35e+03]" = "purple")
75

```

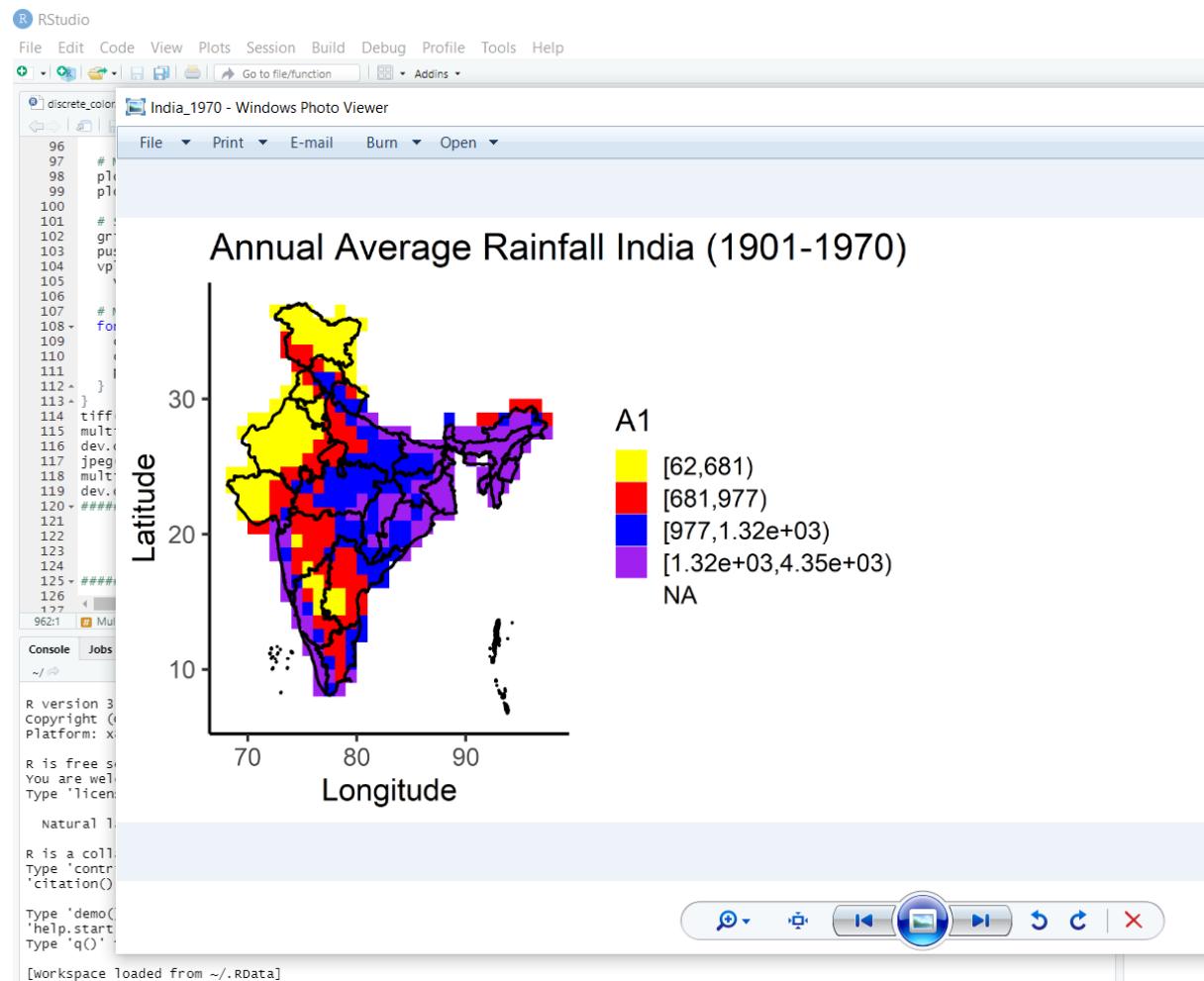
mcn:1 Additional Plot Functions

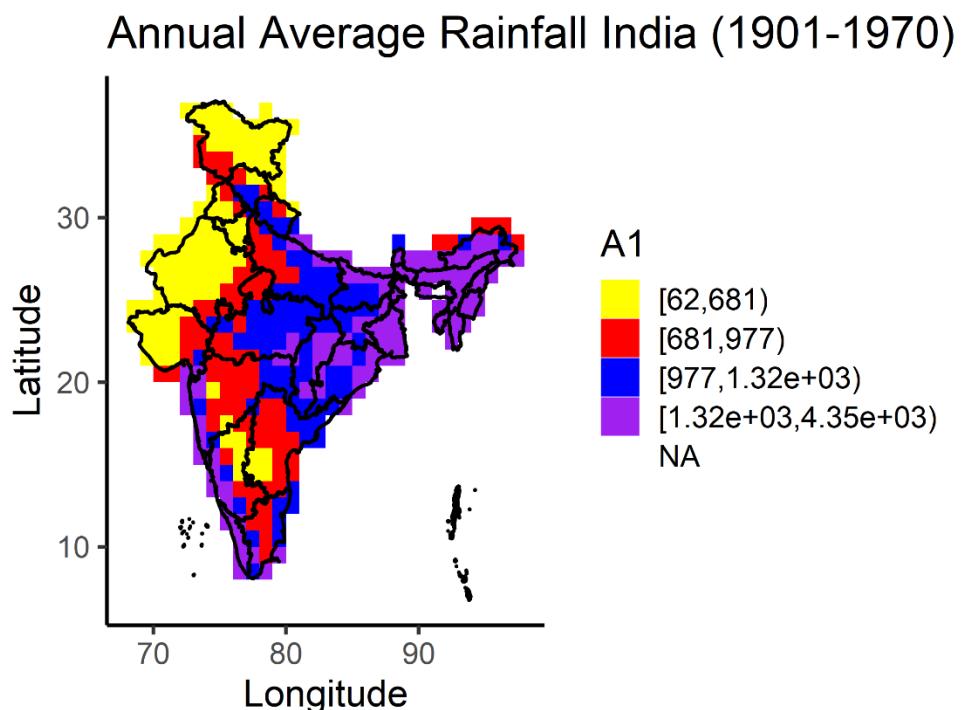
```
96
97 # Make the panel
98 plotcols = cols # Number of columns of plots
99 plotRows = ceiling(numPlots/plotcols) # Number of rows needed, calculated from # of cols
100
101 # Set up the page
102 grid.newpage()
103 pushviewport(viewport(layout = grid.layout(plotRows, plotcols)))
104 vplayout <- function(x, y)
105   viewport(layout.pos.row = x, layout.pos.col = y)
106
107 # Make each plot, in the correct location
108 for (i in 1:numPlots) {
109   curRow = ceiling(i/plotcols)
110   curCol = (i-1) %% plotcols + 1
111   print(plots[[i]], vp = vplayout(curRow, curCol))
112 }
113
114 tiff(filename = "India_annual.tiff", pointsize = 8, res = 600, units = "in", width = 8, height = 3, restoreConsole = TRUE, type
115 multiplot(chart[[2]], cols = 2)
116 dev.off()
117 jpeg(filename = "India_annual.jpeg", pointsize = 8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE, type
118 multiplot(chart[[2]], cols = 2)
119 dev.off()
120 #####Part A OVER#####
121
122
123
124
125 #####Part B Begins#####
126
127 < R Script
```

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

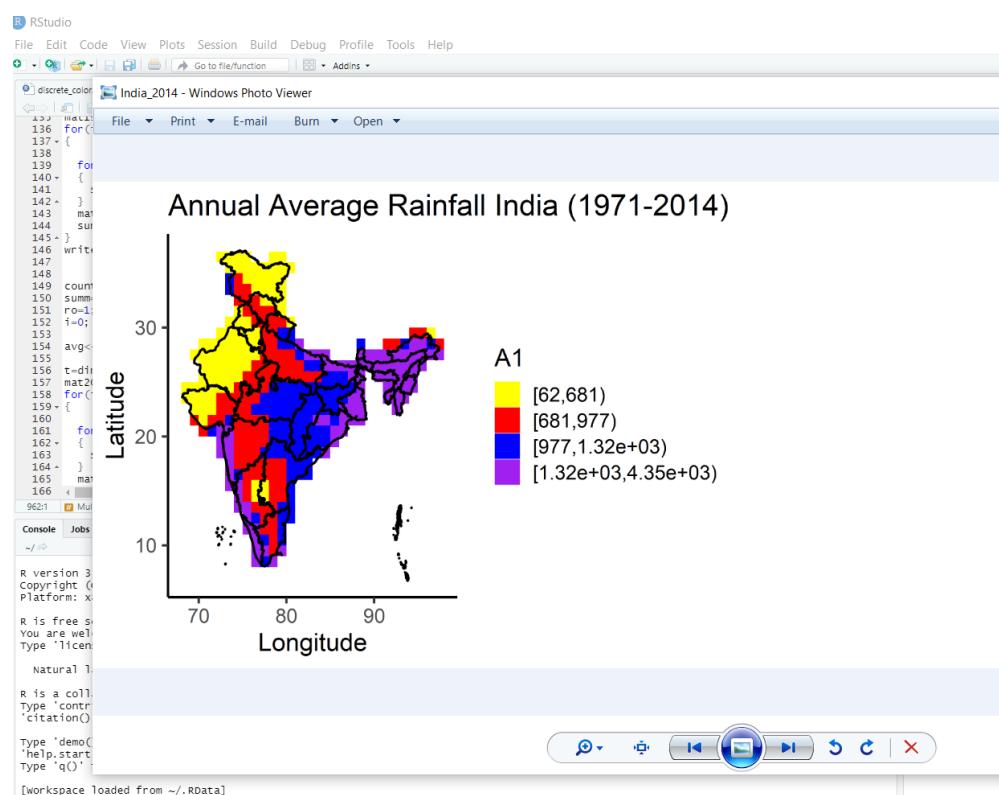
PLOTS:

1. Average annual rainfall 1901-1970

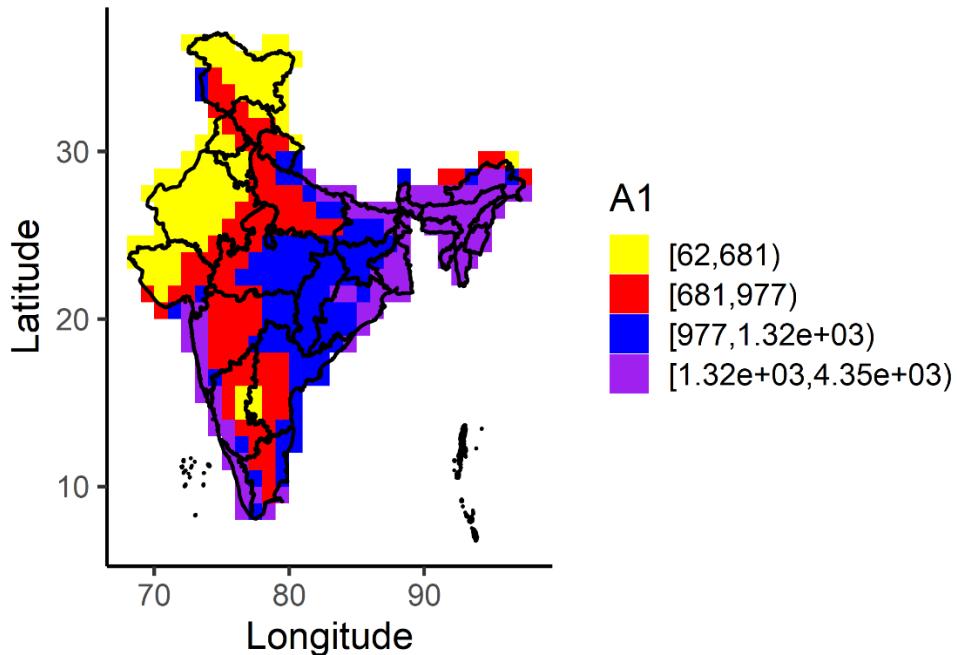




2. Average annual rainfall 1971-2014



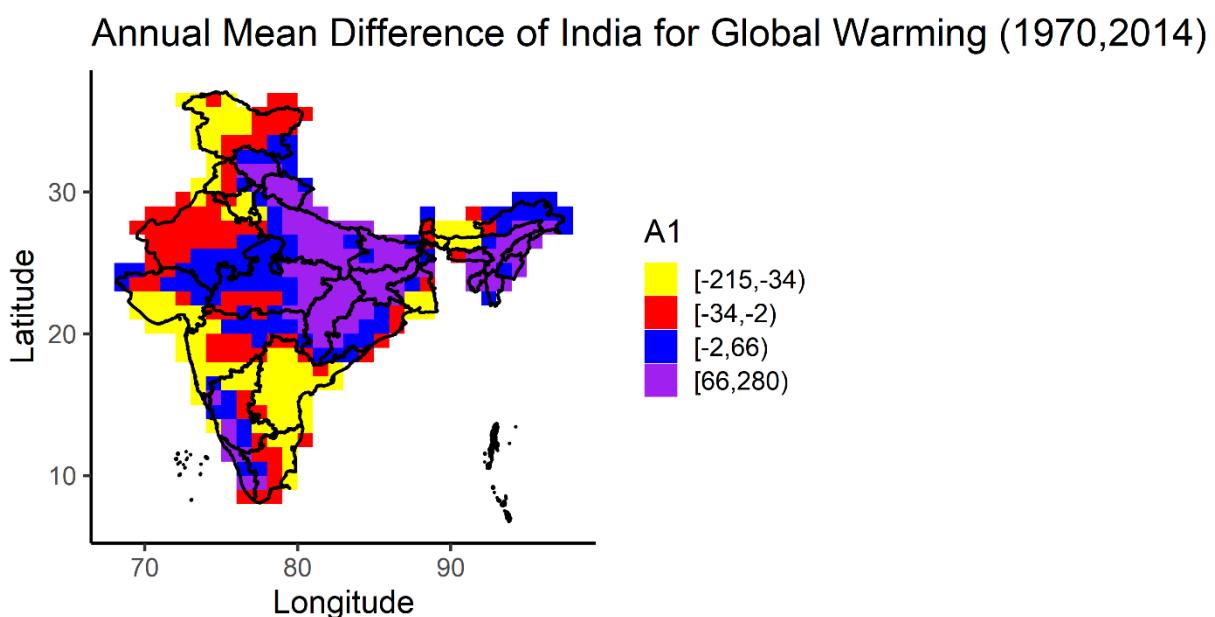
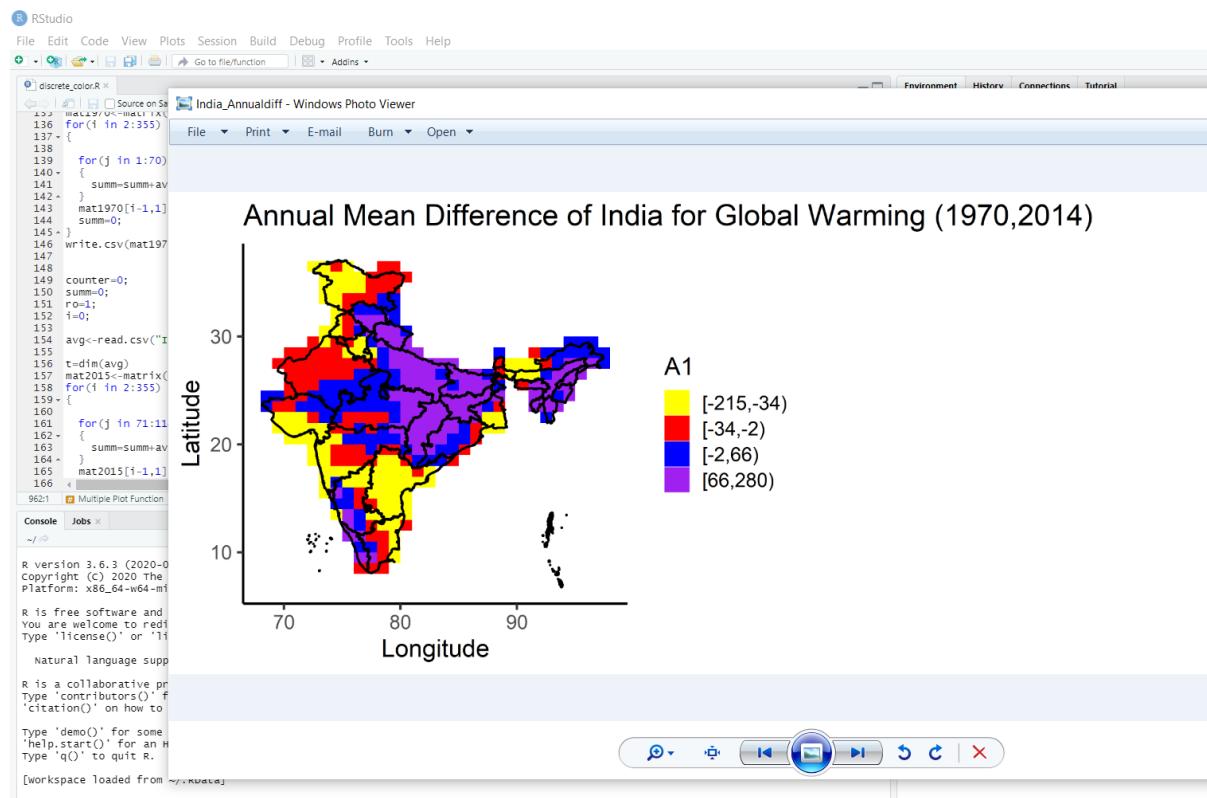
Annual Average Rainfall India (1971-2014)



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

The screenshot shows a Microsoft Excel spreadsheet titled "India_mean_1970". The ribbon menu is visible at the top, showing tabs for File, Home, Insert, Page Layout, Formulas, Data, Review, View, and Help. The "Home" tab is selected. The font and alignment tools are also visible in the ribbon. A status bar at the bottom indicates "POSSIBLE DATA LOSS Some features might be lost if you save this workbook in the comma-delimited (.csv) file format". The data is contained in a single sheet with columns labeled A through I. Column A contains values for years from 1901 to 1970. Column B contains values for x. Column C contains values for y. Column D contains the label "Mean". The data starts at row 2 and continues down to row 23.

	A	B	C	D	E	F	G	H	I
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

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

CODE SCREENSHOTS:

```
123
124
125 v #####PArt B Begins#####
126
127 counter=0;
128 summ=0;
129 r=1;
130 i=0;
131
132 avg<-read.csv("India_sum_annual.csv")
133
134 t=dim(avg)
135 mat1970<-matrix(0, nrow = 354,ncol=1, byrow = FALSE)
136 for(i in 2:355)
137 {
138
139   for(j in 1:70)
140   {
141     summ=summ+avg[j,i];
142   }
143   mat1970[i-1,1]<-summ/70;
144   summ=0;
145 }
146 write.csv(mat1970, 'India_mean_1970.csv')
147
148
149 counter=0;
150 summ=0;
151 r=1;
```



```
154 avg<-read.csv("India_sum_annual.csv")
155
156 t=dim(avg)
157 mat2015<-matrix(0, nrow = 354,ncol=1, byrow = FALSE)
158 for(i in 2:355)
159 {
160
161   for(j in 71:114)
162   {
163     summ=summ+avg[j,i];
164   }
165   mat2015[i-1,1]<-summ/44;
166   summ=0;
167 }
168
169 write.csv(mat2015, 'India_mean_2015.csv')
170
171
172
173
174
175 q<-read.csv("India_mean_2014.csv")
176 chart<-list()
177 w <- c(62,681,977,1.32e+03,4.35e+03)
178
179 cols <- c("[62,681]" = "yellow", "[681,977]" = "red", "[977,1.32e+03]" = "blue", "[1.32e+03,4.35e+03]" = "purple")
180 q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
181 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
182   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
183
184
185
175:29 PArt B Begins :
```

```

230     print(plots[[i]], vp = vplayout(curRow, curCol ))
231   }
232 }
233 tiff(filename = "India_2014.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole = TRUE, type =
234 multiplot(chart[[2]], cols = 2)
235 dev.off()
236 jpeg(filename = "India_2014.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE, type =
237 multiplot(chart[[2]], cols = 2)
238 dev.off()
239
240
241
242
243 q<-read.csv("India_mean_1970.csv")
244 chart<-list()
245 w <- c(62,681,977,1.32e+03,4.35e+03)
246
247 cols <- c("[62,681)" = "yellow", "[681,977)" = "red", "[977,1.32e+03)" = "blue", "[1.32e+03,4.35e+03)" = "purple")
248 q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
249 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()
250
251
252
253 River_B <- readShapeSpatial("Ind")
254 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
255 cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title=z[i])
256 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
257 chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Annual Average Rainfall India (1901-1970)")
258
259
260 cols <- c("[62,681)" = "yellow", "[681,977)" = "red", "[977,1.32e+03)" = "blue", "[1.32e+03,4.35e+03)" = "purple")
261
175:29 Part B Begins

```

```

274 ###### Multiple Plot Function ######
275
276 multiplot <- function(..., plotlist=NULL, cols) {
277   require(grid)
278
279   # Make a list from the ... arguments and plotlist
280   plots <- c(list(...), plotlist)
281
282   numPlots = length(plots)
283
284   # Make the panel
285   plotcols = cols           # Number of columns of plots
286   plotRows = ceiling(numPlots/plotcols)    # Number of rows needed, calculated from # of cols
287
288   # Set up the page
289   grid.newpage()
290   pushViewport(viewport(layout = grid.layout(plotRows, plotcols)))
291   vplayout <- function(x, y)
292     viewport(layout.pos.row = x, layout.pos.col = y)
293
294   # Make each plot, in the correct location
295   for (i in 1:numPlots) {
296     curRow = ceiling(i/plotcols)
297     curcol = (i-1) %% plotcols + 1
298     print(plots[[i]], vp = vplayout(curRow, curcol ))
299   }
300 }
301 tiff(filename = "India_1970.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole = TRUE, type =
302 multiplot(chart[[2]], cols = 2)
303 dev.off()
304 jpeg(filename = "India_1970.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE, type =
305
175:29 Part B Begins

```

```

304 jpeg(filename = "India_1970.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE, type =
305 multiplot(chart[[2]], cols = 2)
306 dev.off()
307
308
309
310
311
312
313
314
315
316 q<-read.csv("India_Annual_Mean_Difference.csv")
317 chart<-list()
318 w <- c(-215,-34,-2,66,280)
319
320 cols <- c("[ -215, -34)" = "yellow", "[ -34, -2)" = "red", "[ -2, 66)" = "blue", "[ 66, 280)" = "purple")
321 q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
322 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()
323
324
325
326 River_B <- readShapeSpatial("Ind")
327 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
328 cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title=z[i])
329 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
330 chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Annual Mean Difference of India for Global Warming (1970,20
331
332
333 cols <- c("[ -215, -34)" = "yellow", "[ -34, -2)" = "red", "[ -2, 66)" = "blue", "[ 66, 280)" = "purple")

```

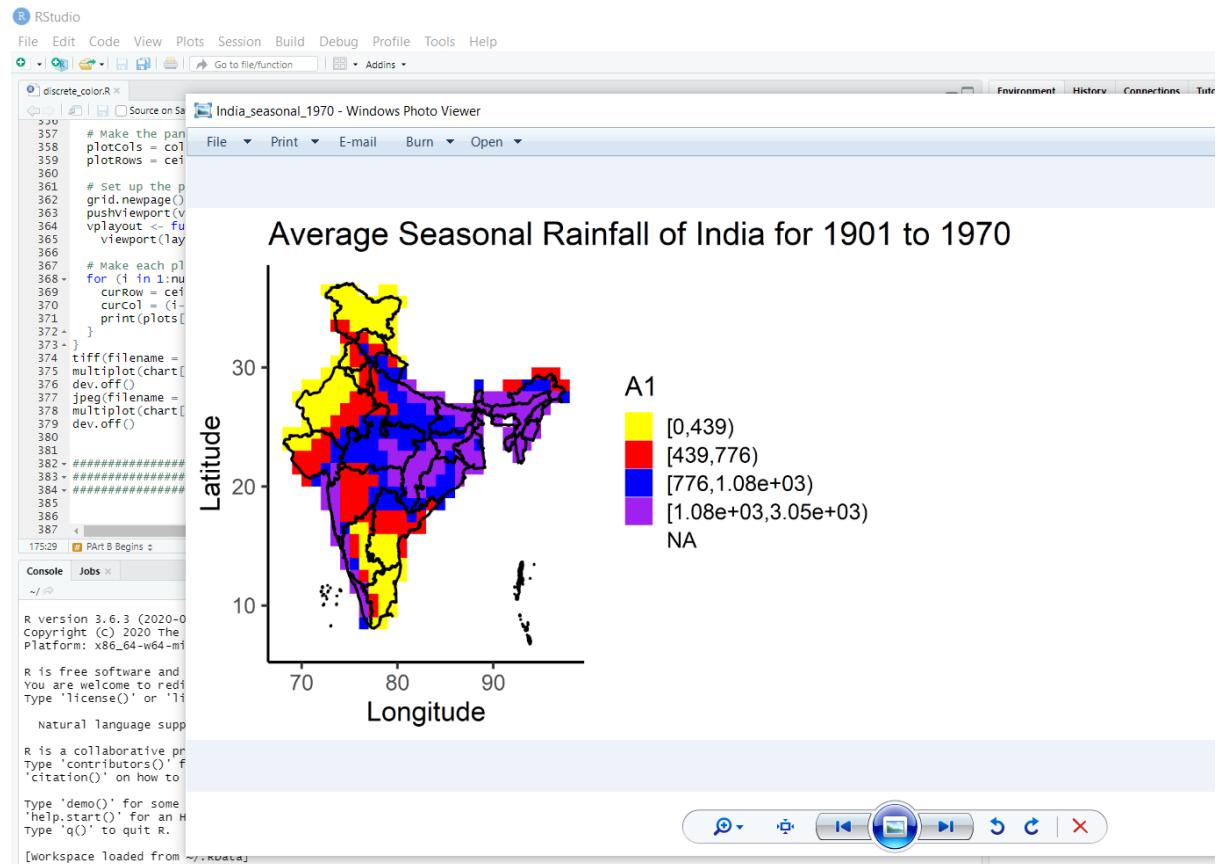
The screenshot shows the RStudio interface with the 'discrete_color.R' script open. The code is as follows:

```
discrete_color.R x
Source on Save | Run | Source | E
R D C
357 # Make the panel
358 plotcols = cols          # Number of columns of plots
359 plotRows = ceiling(numPlots/plotcols) # Number of rows needed, calculated from # of cols
360
361 # Set up the page
362 grid.newpage()
363 pushviewport(viewport(layout = grid.layout(plotRows, plotcols)))
364 vplayout <- function(x, y)
365   viewport(layout.pos.row = x, layout.pos.col = y)
366
367 # Make each plot, in the correct location
368 for (i in 1:numPlots) {
369   curRow = ceiling(i/plotcols)
370   curcol = (i-1) %% plotcols + 1
371   print(plots[[i]], vp = vplayout(curRow, curcol ))
372 }
373
374 tiff(filename = "india_Annualdiff.tiff", pointsize = 8, res = 600, units = "in", width = 8, height = 3, restoreConsole = TRUE, t
375 multiplot(chart[[2]], cols = 2)
376 dev.off()
377 jpeg(filename = "india_Annualdiff.jpeg", pointsize = 8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE, t
378 multiplot(chart[[2]], cols = 2)
379 dev.off()
380
```

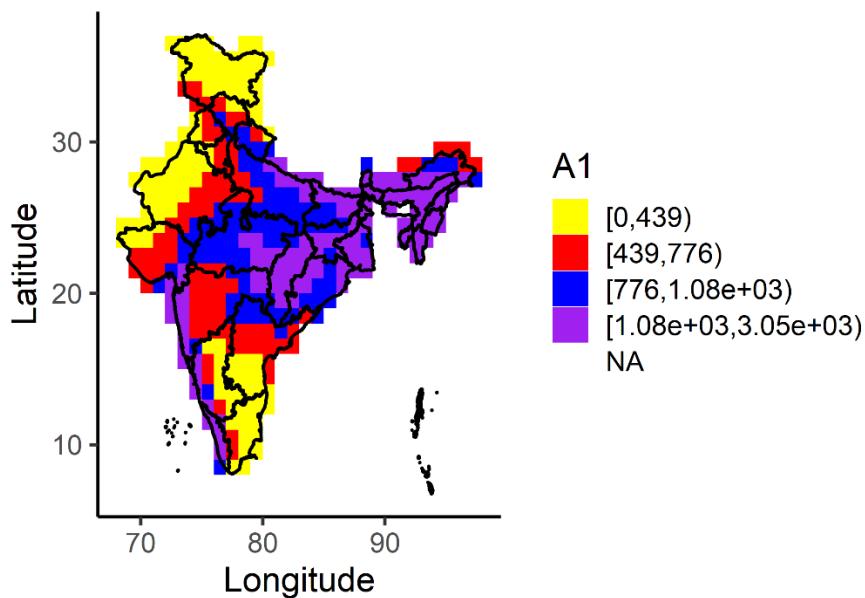
Q3. Calculate the change in seasonal average rainfall with respect to global warming in each of grids. Plot the derived results.

PLOTS:

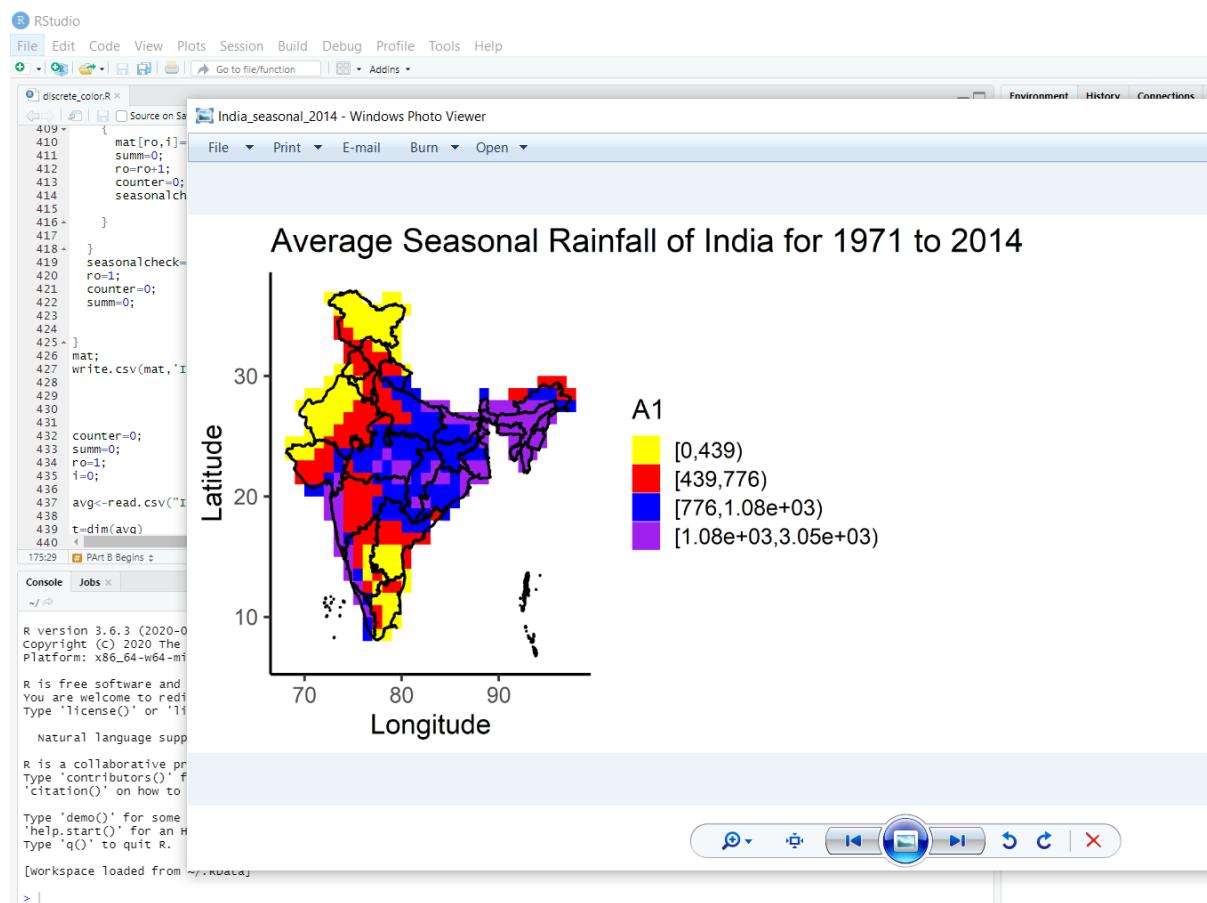
1. Average seasonal (June to Sept period per year) rainfall 1901-1970



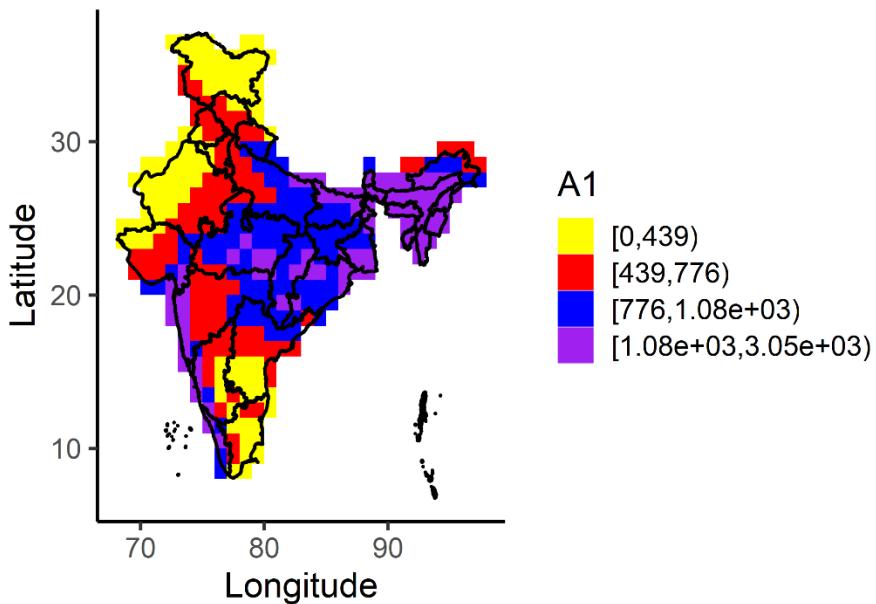
Average Seasonal Rainfall of India for 1901 to 1970



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



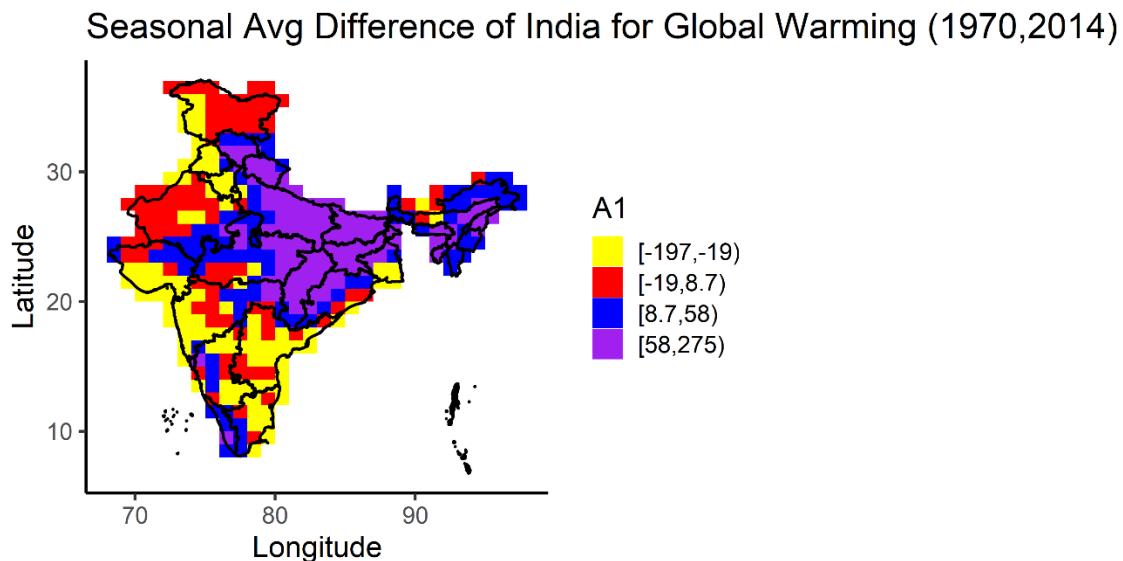
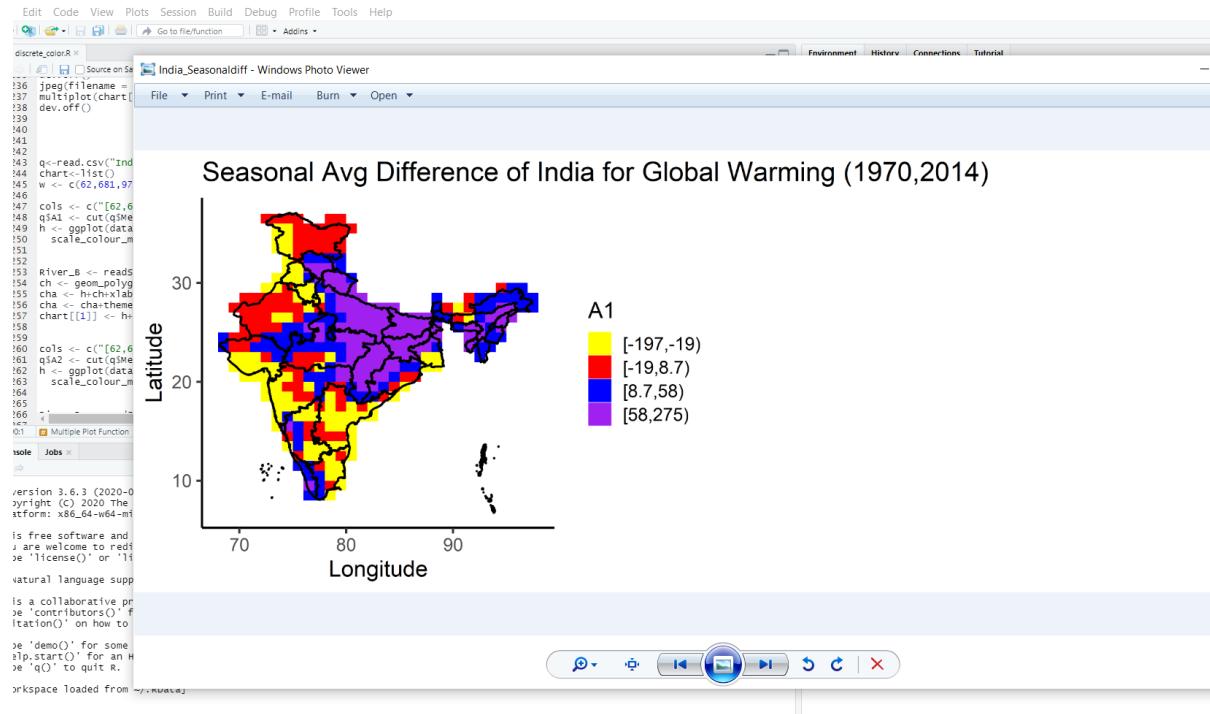
Average Seasonal Rainfall of India for 1971 to 2014



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

The screenshot shows a Microsoft Excel spreadsheet titled "India_sum_seasonal". The data is organized into columns labeled A through N, representing years from 1 to 24. The first column (A) contains the year number, and the subsequent columns (B through N) contain the sum of seasonal rainfall for each grid. The data starts at row 1 and continues down to row 24. The Excel ribbon is visible at the top, and a status bar at the bottom indicates "POSSIBLE DATA LOSS" about saving the file as a CSV.

A	B	C	D	E	F	G	H	I	J	K	L	M	N
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	128C
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
23	1547.2	481.075	500.2	1547.2	575.15	121.425	224.425	1042.075	314.25	100.75	197.55	2241.85	1120.5

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

The screenshot shows a Microsoft Excel spreadsheet titled "India_mean_sd_seasonal - Saved". The ribbon menu is visible at the top, with "Home" selected. A warning bar at the bottom left says "POSSIBLE DATA LOSS Some features might be lost if you save this workbook in the comma-delimited (.csv) form". The data is presented in a table with columns labeled "x", "y", "Mean", and "Std". The first 27 rows of data are as follows:

	x	y	Mean	Std						
1	76.5	8.5	930.7272	249.571						
2	77.5	8.5	351.5059	101.7748						
3	78.5	8.5	424.4246	176.6891						
4	76.5	9.5	1110.681	214.666	Min=	0.734868				
5	77.5	9.5	637.3232	151.757	Q1=	439.0011				
6	78.5	9.5	198.7985	88.65003	Median=	776.7941				
7	79.5	9.5	332.0509	224.6862	Q3=	1085.529				
8	76.5	10.5	1563.307	259.4966	Max=	3036.035				
9	77.5	10.5	466.9838	113.6023						
10	78.5	10.5	346.2	124.8681						
11	79.5	10.5	285.6542	134.1896						
12	75.5	11.5	1657.038	329.0633						
13	76.5	11.5	1063.551	201.4397						
14	77.5	11.5	339.4504	81.01944						
15	78.5	11.5	383.5993	108.9585						
16	79.5	11.5	359.3432	115.9838						
17	75.5	12.5	2301.107	420.2677						
18	76.5	12.5	741.0671	161.5545						
19	77.5	12.5	402.7397	109.5592						
20	78.5	12.5	438.7603	123.0401						
21	79.5	12.5	439.7235	111.428						
22	80.5	12.5	386.2325	114.8975						
23	74.5	13.5	2423.558	422.3537						
24	75.5	13.5	1064.794	222.7318						
25	76.5	13.5	378.1096	94.37338						
26	77.5	13.5	420.4763	125.4137						
27	78.5	13.5	276.6047	100.5207						

3. Average Seasonal Rainfall from 1901-1970

The screenshot shows a Microsoft Excel spreadsheet titled "India_mean_1970_seasonal". The ribbon menu is visible at the top, with "Home" selected. A warning message "POSSIBLE DATA LOSS" is displayed in a yellow bar across the middle of the screen, stating: "Some features might be lost if you save this workbook in the comma-delimited (.csv) format. To pres". The data is contained in a table with columns labeled "x", "y", and "Mean". The "Mean" column contains numerical values representing average seasonal rainfall. The table has 23 rows, starting from row 1 and ending at row 23. Row 1 is the header, and rows 2 through 23 contain data points. The "Mean" column values are: 938.015, 355.1364, 416.7729, 1134.571, 655.7429, 197.8489, 309.9736, 1577.079, 472.7464, 334.1057, 269.6546, 1662.123, 1083.692, 333.4293, 374.0261, 344.6871, 2303.493, 727.7761, 387.3086, 424.6925, 432.9554, and 369.4814.

	A	B	C	D	E	F	G	H	I	J
1	x	y	Mean							
2	76.5	8.5	938.015							
3	77.5	8.5	355.1364							
4	78.5	8.5	416.7729							
5	76.5	9.5	1134.571							
6	77.5	9.5	655.7429							
7	78.5	9.5	197.8489							
8	79.5	9.5	309.9736							
9	76.5	10.5	1577.079							
10	77.5	10.5	472.7464							
11	78.5	10.5	334.1057							
12	79.5	10.5	269.6546							
13	75.5	11.5	1662.123							
14	76.5	11.5	1083.692							
15	77.5	11.5	333.4293							
16	78.5	11.5	374.0261							
17	79.5	11.5	344.6871							
18	75.5	12.5	2303.493							
19	76.5	12.5	727.7761							
20	77.5	12.5	387.3086							
21	78.5	12.5	424.6925							
22	79.5	12.5	432.9554							
23	80.5	12.5	369.4814							

4. Average Seasonal Rainfall from 1971-2014

5. Difference in Rainfall between the two periods

The screenshot shows a Microsoft Excel spreadsheet titled "India_Mean_Seasonal_Difference". The table contains data for rainfall differences between M1970 and M2014. The columns are labeled A through L, and the rows are numbered 1 through 28. Row 1 contains column headers: "x", "y", "M1970", "M2014", and "Mean". Rows 2 through 28 contain data points. Row 3 includes descriptive statistics: "Min=" -196.043, "Q1=" -18.999, "Median=" 8.761834, "Q3=" 58.09737, and "Max=" 274.9558.

A	B	C	D	E	F	G	H	I	J	K	L
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						
28	78.5	13.5	210.8061	110.4700	60.6661						

CODE SCREENSHOTS:

```
390
391 counter=0;
392 seasonalcheck=0;
393 summ=0;
394 ro=1;
395 i=0;
396 p <- read.csv("India_gridded_data.csv") ## Import the data
397 ##mat<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
398 mat<-matrix(0, nrow = 114,ncol=354, byrow = FALSE)
399 for(i in 1:354){
400 {
401   for(j in 1:1368)
402   {
403     seasonalcheck=seasonalcheck+1;
404     counter=counter+1;
405     if(seasonalcheck>=6 && seasonalcheck<=9){
406       summ=summ+p[j,i];
407     }
408     if(counter==12)
409     {
410       mat[ro,i]=summ;
411       summ=0;
412       ro=ro+1;
413       counter=0;
414       seasonalcheck=0;
415     }
416   }
417 }
418 }
```

652:72 Multiple Plot Function ◊ R Script ◊

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

```
412   ro=ro+1;
413   counter=0;
414   seasonalcheck=0;
415 }
416 }
417 }
418 }
419 seasonalcheck=0;
420 ro=1;
421 counter=0;
422 summ=0;
423
424
425 }
426 mat;
427 write.csv(mat,'India_sum_seasonal.csv')
428
429
430
431
432 counter=0;
433 summ=0;
434 ro=1;
435 i=0;
436
437 avg<-read.csv("India_sum_seasonal.csv")
438
439 t<-dim(avg)
440 mat2<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
441 }
```

652:72 Multiple Plot Function ◊ R Script ◊

discrete_color.R

```

432 counter=0;
433 summ=0;
434 r=1;
435 i=0;
436
437 avg<-read.csv("India_sum_seasonal.csv")
438
439 t=dim(avg)
440 mat2<-matrix(0, nrow = t[2],ncol=2, byrow = FALSE)
441 for(i in 1:(t[2]-1))
442 {
443   m = mean(avg[,i+1]) ## mean
444   mat2[i,1]<-m
445   s<-sd(avg[,i+1])
446   mat2[i,2]<-s ## standard deviation
447 }
448 write.csv(mat2,'India_mean_sd_seasonal.csv')
449
450 t=dim(avg)
451 mat1970<-matrix(0, nrow = 354,ncol=1, byrow = FALSE)
452 for(i in 2:355)
453 {
454
455   for(j in 1:70)
456   {
457     summ=summ+avg[j,i];
458   }
459   mat1970[i-1,1]<-summ/70;
460   summ=0;
461 }
462 write.csv(mat1970,'India_mean_1970_seasonal.csv')
463

```

652:72 Multiple Plot Function ↴

Console Jobs

```

458 }
459 mat1970[i-1,1]<-summ/70;
460 summ=0;
461 }
462 write.csv(mat1970,'India_mean_1970_seasonal.csv')
463
464
465 counter=0;
466 summ=0;
467 r=1;
468 i=0;
469
470 avg<-read.csv("India_sum_seasonal.csv")
471
472 t=dim(avg)
473 mat2015<-matrix(0, nrow = 354,ncol=1, byrow = FALSE)
474 for(i in 2:355)
475 {
476
477   for(j in 71:114)
478   {
479     summ=summ+avg[j,i];
480   }
481   mat2015[i-1,1]<-summ/44;
482   summ=0;
483 }
484 write.csv(mat2015,'India_mean_2014_seasonal.csv')
485
486
487 q<-read.csv("India_mean_2014_seasonal.csv")
488 chart<-list()
489

```

652:72 Multiple Plot Function ↴

```

490
491 cols <- c("[0,439]" = "yellow", "[439,776]" = "red", "[776,1.08e+03]" = "blue", "[1.08e+03,3.05e+03]" = "purple")
492 q$A1 <- cut(q$mean,breaks = w,right = FALSE)
493 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
494   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
495
496
497 River_B <- readShapeSpatial("Ind")
498 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
499 cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
500 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
501 chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average Seasonal Rainfall of India for 1971 to 2014")
502
503
504 cols <- c("[0,439]" = "yellow", "[439,776]" = "red", "[776,1.08e+03]" = "blue", "[1.08e+03,3.05e+03]" = "purple")
505 q$A2 <- cut(q$mean,breaks = w,right = FALSE)
506 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
507   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
508
509

```

```

519
520 multiplot <- function(..., plotlist=NULL, cols) {
521   require(grid)
522
523   # Make a list from the ... arguments and plotlist
524   plots <- c(list(...), plotlist)
525
526   numPlots = length(plots)
527
528   # Make the panel
529   plotcols = cols           # Number of columns of plots
530   plotRows = ceiling(numPlots/plotcols)    # Number of rows needed, calculated from # of cols
531
532   # Set up the page
533   grid.newpage()
534   pushviewport(viewport(layout = grid.layout(plotRows, plotcols)))
535   vlayout <- function(x, y)
536     viewport(layout.pos.row = x, layout.pos.col = y)
537
538   # Make each plot, in the correct location
539   for (i in 1:numPlots) {
540     curRow = ceiling(i/plotcols)
541     curCol = (i-1) %% plotcols + 1
542     print(plots[[i]], vp = vlayout(curRow, curcol ))
543   }
544 }
545 tiff(filename = "India_seasonal_2014.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreconsole = TRUE
546 multiplot(chart[[2]], cols = 2)
547 dev.off()
548 jpeg(filename = "India_seasonal_2014.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreconsole = TRUE
549 multiplot(chart[[2]], cols = 2)
550

```

652:72 Multiple Plot Function R Script

```

551
552
553 q<-read.csv("India_mean_1970_seasonal.csv")
554 chart<-list()
555 w <- c(0,439,776,1.08e+03,3.05e+03)
556
557 cols <- c("[0,439)" = "yellow", "[439,776)" = "red", "[776,1.08e+03)" = "blue", "[1.08e+03,3.05e+03)" = "purple")
558 q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
559 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
560   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
561
562
563 River_B <- readshapeSpatial("Ind")
564 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
565 cha <- ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
566 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
567 chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average Seasonal Rainfall of India for 1901 to 1970 ")
568
569
570 cols <- c("[0,439)" = "yellow", "[439,776)" = "red", "[776,1.08e+03)" = "blue", "[1.08e+03,3.05e+03)" = "purple")
571 q$A2 <- cut(q$Mean,breaks = w,right = FALSE)
572 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
573   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
574

```

```

629
630
631
632 q<-read.csv("India_Mean_Seasonal_Difference.csv")
633 chart<-list()
634 w <- c(-197,-19,8.7,58,275)
635
636 cols <- c("[ -197,-19)" = "yellow", "[ -19,8.7)" = "red", "[ 8.7,58)" = "blue", "[ 58,275)" = "purple")
637 q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
638 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
639   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
640
641
642 River_B <- readshapeSpatial("Ind")
643 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
644 cha <- ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
645 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
646 chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="seasonal Avg difference of India for Global warming (1970,2014) ")
647
648
649 cols <- c("[ -197,-19)" = "yellow", "[ -19,8.7)" = "red", "[ 8.7,58)" = "blue", "[ 58,275)" = "purple")
650 q$A2 <- cut(q$Mean,breaks = w,right = FALSE)
651 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
652   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
653
654
655 River_B <- readshapeSpatial("Ind")
656 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
657 cha <- ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
658 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
659
660

```

652:72 Multiple Plot Function R Script

```
686 curRow = ceiling(i/plotcols)
687 curcol = (i-1) %% plotcols + 1
688 print(plots[[i]], vp = vplayout(curRow, curcol ))
689 }
690 }
691 tiff(filename = "India_Seasonaldiff.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreConsole = TRUE,
692 multiplot(chart[[2]], cols = 2)
693 dev.off()
694 jpeg(filename = "India_Seasonaldiff.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreConsole = TRUE,
695 multiplot(chart[[2]], cols = 2)
696 dev.off()
697
698
699
700
```

652:72 Multiple Plot Function ↴

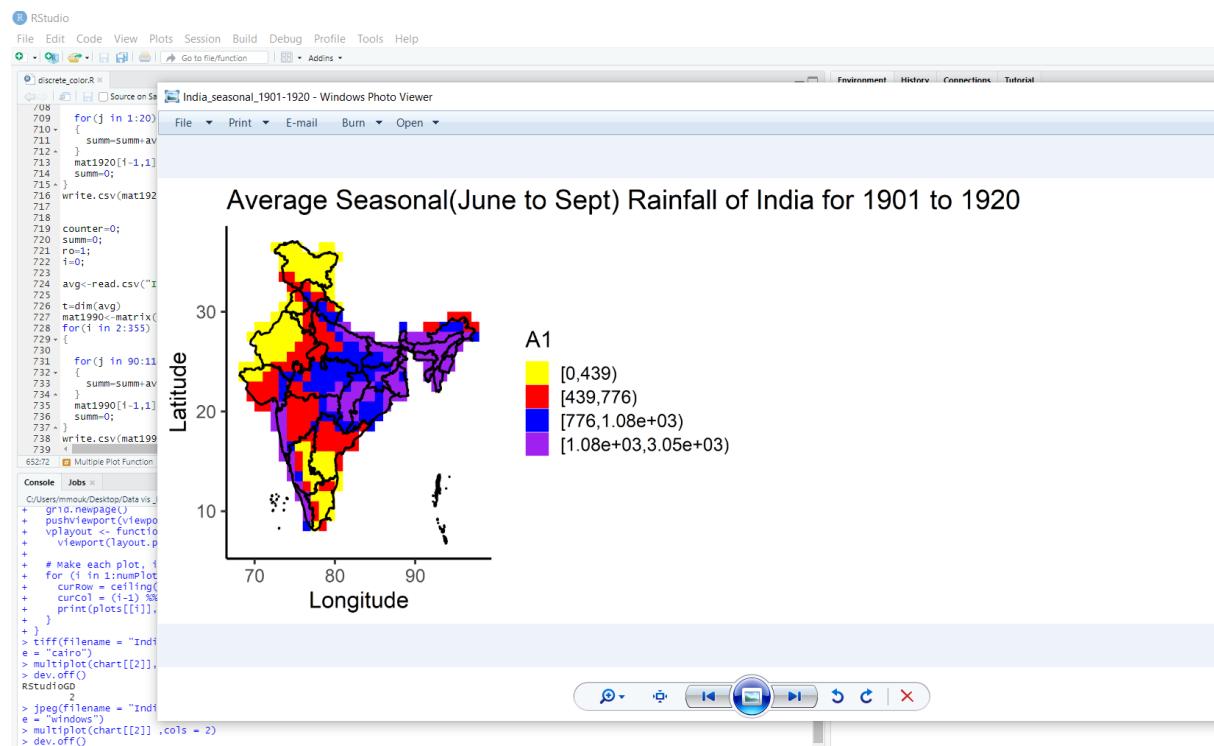
R Script ↴

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.

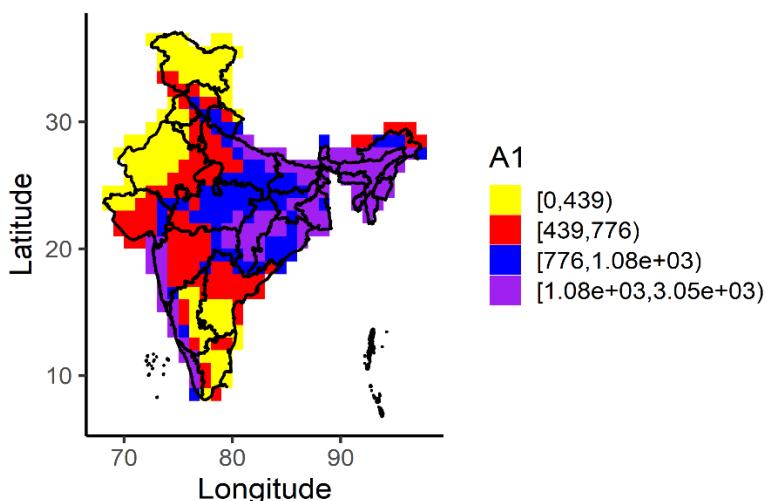
Calculate the change in average seasonal and plot them.

PLOTS:

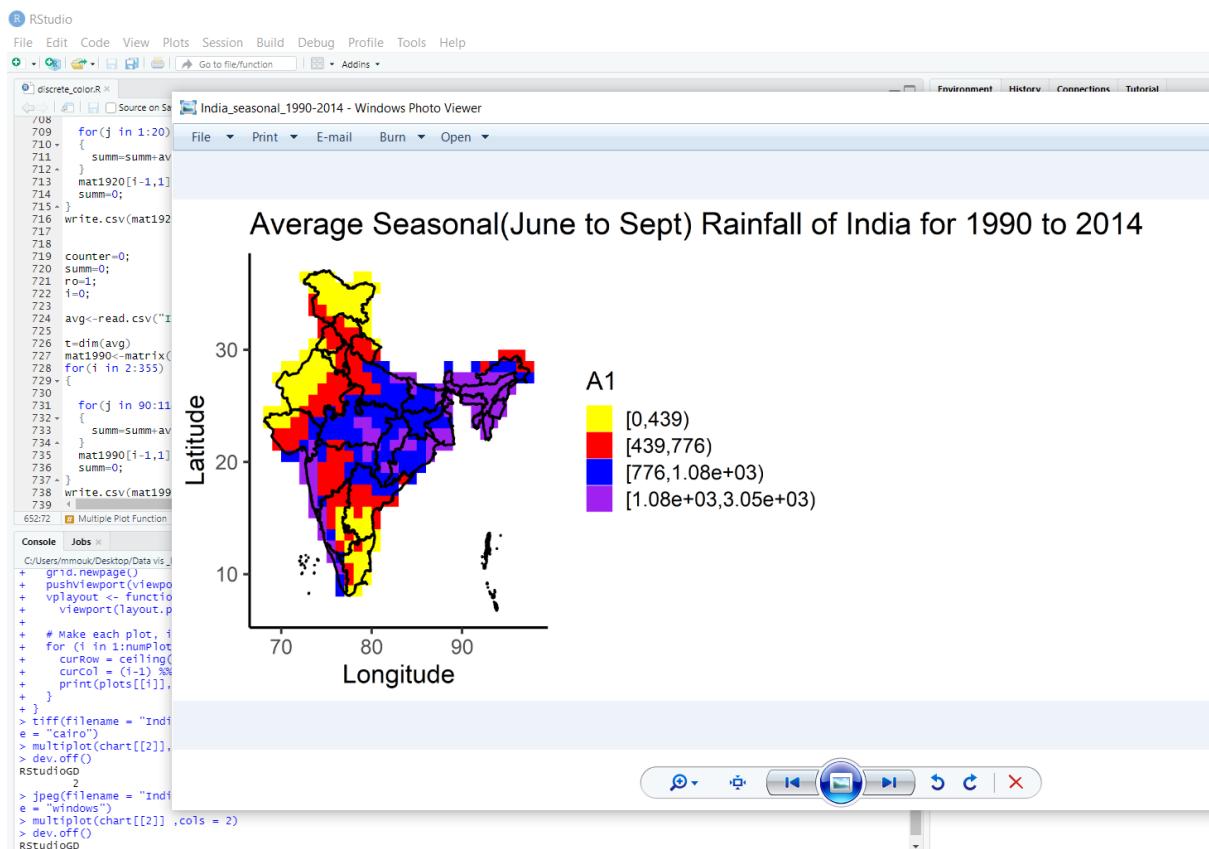
1. Average seasonal (June to Sept period per year) rainfall 1901-1920



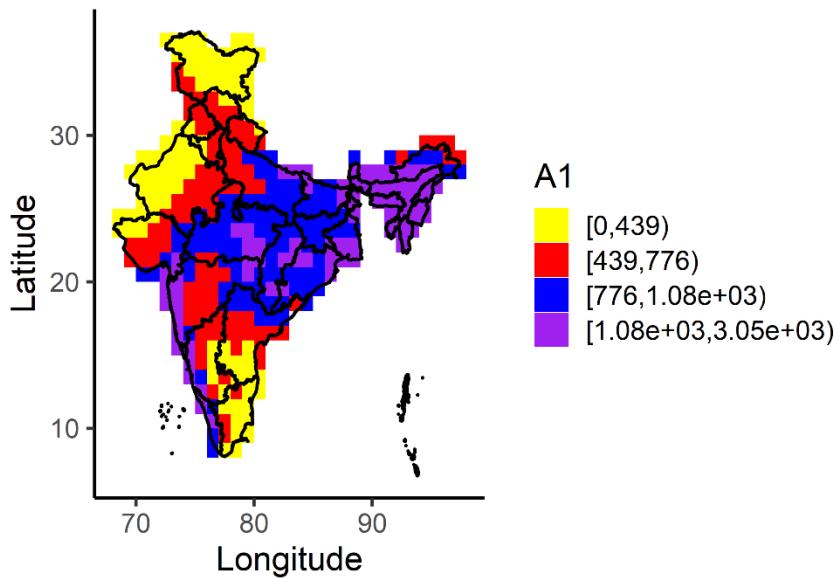
Average Seasonal(June to Sept) Rainfall of India for 1901 to 1920



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



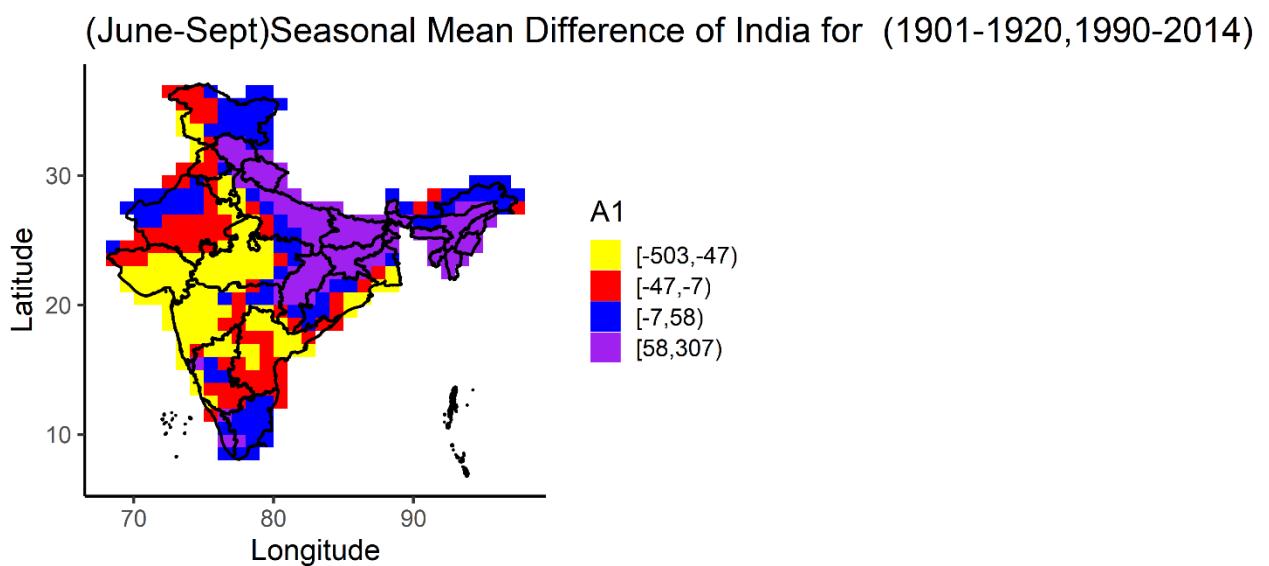
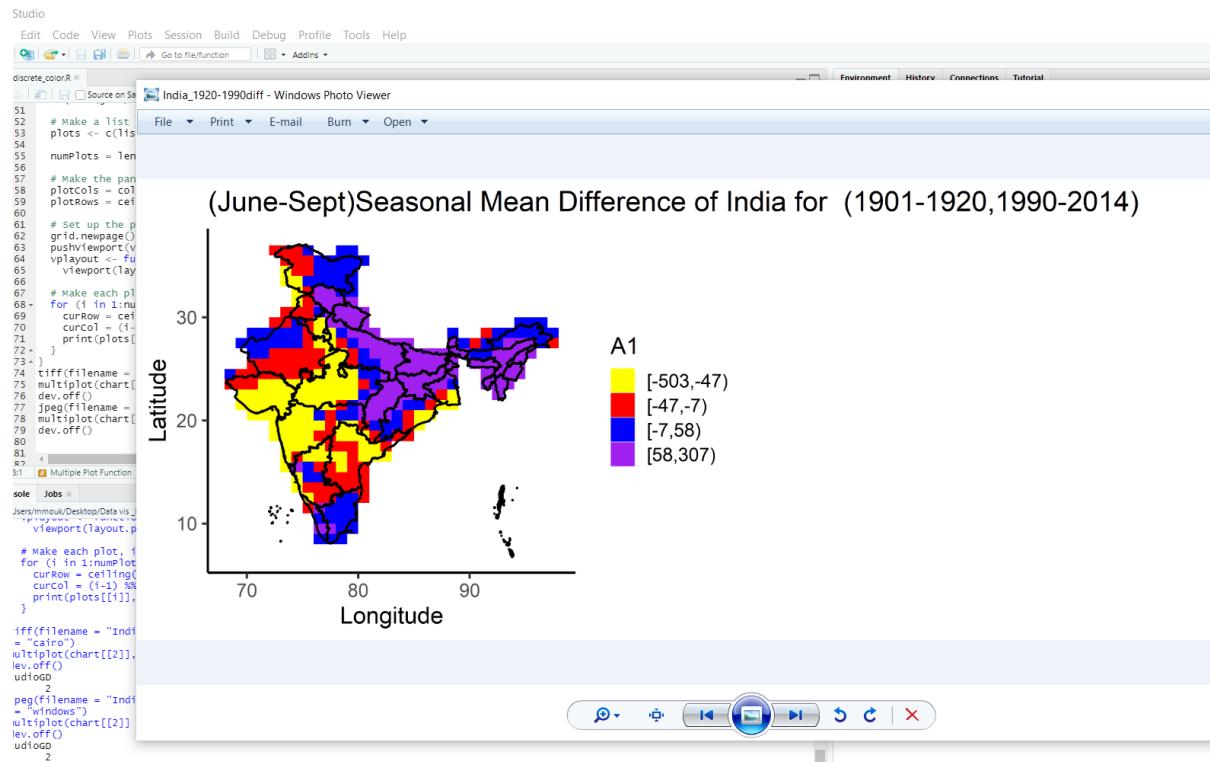
Average Seasonal(June to Sept) Rainfall of India for 1990 to 2014



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 receive 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

The screenshot shows an Excel spreadsheet titled "India_mean_1901-1920_seasonal". The data is organized into columns A, B, and C. Column A contains numerical values ranging from 76.5 to 79.5. Column B contains numerical values ranging from 8.5 to 13.5. Column C contains numerical values ranging from 911.3375 to 1608.79. The first row has headers "x" and "y", and the second row has a header "Mean". The status bar at the bottom indicates "India_mean_1901-1920_seasonal" and shows the cell address "A1".

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

The screenshot shows an Excel spreadsheet titled "India_mean_1990-2014_seasonal". The data is organized into columns A, B, and C. Column A contains numerical values ranging from 76.5 to 79.5. Column B contains numerical values ranging from 8.5 to 12.5. Column C contains numerical values ranging from 904.458 to 775.838. The first row has headers "x" and "y", and the second row has a header "Mean". The status bar at the bottom indicates "India_mean_1990-2014_seasonal" and shows the cell address "A1".

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.

A	B	C	D	E	F	G	H	I	J	K	L	M	N
x	y	M1920	M1990	Mean									
2	76.5	8.5	911.3375	904.458	8.8795								
3	77.5	8.5	374.7588	339.772	34.98675								
4	78.5	8.5	448.0975	421.936	26.1615								
5	76.5	9.5	1156.219	1055.362	100.8568	Min=	-502.774						
6	77.5	9.5	700.675	579.956	120.719	Q1=	-47.0907						
7	78.5	9.5	234.12	179.561	54.559	Median=	-6.92838						
8	79.5	9.5	371.2013	331.771	39.43025	Q3=	57.96188						
9	76.5	10.5	1536.803	1534.027	2.7755	Max=	306.9798						
10	77.5	10.5	491.4188	444.144	47.27475								
11	78.5	10.5	348.9625	345.075	3.8875								
12	79.5	10.5	302.585	287.487	15.098								
13	75.5	11.5	1608.79	1646.942	-38.152								
14	76.5	11.5	1144.186	1036.973	107.2133								
15	77.5	11.5	353.3888	338.816	14.57275								
16	78.5	11.5	404.3488	383.847	20.50175								
17	79.5	11.5	371.6438	360.864	10.77975								
18	75.5	12.5	2222.136	2291.175	-69.0388								
19	76.5	12.5	735.9375	775.838	-39.9005								
20	77.5	12.5	405.1413	431.698	-26.5568								
21	78.5	12.5	475.4325	453.903	21.5295								
22	79.5	12.5	462.8913	438.549	24.34225								
23	80.5	12.5	369.2525	396.356	-27.1035								
24	74.5	13.5	2240.27	2541.584	-301.314								
25	75.5	13.5	1035.77	1051.141	-15.371								
26	76.5	13.5	385.535	395.034	-9.499								
27	77.5	13.5	417.0775	463.886	-46.8085								
28	78.5	13.5	267.405	111.522	14.020								

CODE Screenshots:

```

704 avg<-read.csv("India_sum_seasonal.csv")
705 mat1920<-matrix(0, nrow = 354,ncol=1, byrow = FALSE)
706 for(i in 2:355)
707 {
708
709   for(j in 1:20)
710   {
711     summ=summ+avg[j,i];
712   }
713   mat1920[i-1,1]<-summ/20;
714   summ=0;
715 }
716 write.csv(mat1920,'India_mean_1901-1920_seasonal.csv')
717
718 counter=0;
719 summ=0;
720 ro=1;
721 i=0;
722
723 avg<-read.csv("India_sum_seasonal.csv")
724 t-dim(avg)
725 mat1990<-matrix(0, nrow = 354,ncol=1, byrow = FALSE)
726 for(i in 2:355)
727 {
728
729   for(j in 90:114)
730   {
731     summ=summ+avg[j,i];
732   }
733
734 }
735

```

```

739
740
741
742
743
744
745
746
747
748 q<-read.csv("India_mean_1901-1920_seasonal.csv")
749 chart<-list()
750 w <- c(0,439,776,1.08e+03,3.05e+03)
751
752 cols <- c("[0,439]" = "yellow", "[439,776]" = "red", "[776,1.08e+03]" = "blue", "[1.08e+03,3.05e+03]" = "purple")
753 q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
754 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
755   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
756
757
758 River_B <- readshapeSpatial("Ind")
759 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
760 cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[[i]])
761 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
762 chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average seasonal(June to Sept) Rainfall of India for 1901 t"
763
764
765 cols <- c("[0,439]" = "yellow", "[439,776]" = "red", "[776,1.08e+03]" = "blue", "[1.08e+03,3.05e+03]" = "purple")
766 q$A2 <- cut(q$Mean,breaks = w,right = FALSE)
767 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
768   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
769
888:1 Multiple Plot Function

```

```

discrete_color.R
771 River_B <- readshapeSpatial("Ind")
772 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
773 cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[[i]])
774 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
775 chart[[2]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average seasonal(June to Sept) Rainfall of India for 1901 t"
776
777
778
779 ##### Multiple Plot Function #####
780
781 multiplot <- function(..., plotlist=NULL, cols) {
782   require(grid)
783
784   # Make a list from the ... arguments and plotlist
785   plots <- c(list(...), plotlist)
786
787   numPlots = length(plots)
788
789   # Make the panel
790   plotCols = cols          # Number of columns of plots
791   plotRows = ceiling(numPlots/plotCols)    # Number of rows needed, calculated from # of cols
792
793   # Set up the page
794   grid.newpage()
795   pushviewport(viewport(layout = grid.layout(plotRows, plotcols)))
796   vplayout <- function(x, y)
797     viewport(layout.pos.row = x, layout.pos.col = y)
798
799   # Make each plot, in the correct location
800   for (i in 1:numPlots) {
801     print(plots[[i]])
802   }
888:1 Multiple Plot Function

```

```

discrete_color.R
801 for (i in 1:numPlots) {
802   curRow = ceiling(i/plotcols)
803   curcol = (i-1) %% plotcols + 1
804   print(plots[[i]]) ; vp = vplayout(curRow, curcol )
805 }
806 tiff(filename = "India_seasonal_1901-1920.tiff", pointsize = 8, res = 600, units = "in", width = 8, height = 3, restoreConsole =
807 multiplot(chart[[2]], cols = 2)
808 dev.off()
809 jpeg(filename = "India_seasonal_1901-1920.jpeg", pointsize = 8, res = 600, units = "in", width = 8, height = 2, restoreConsole =
810 multiplot(chart[[2]], cols = 2)
811 dev.off()
812
813
814
815
816 q<-read.csv("India_mean_1990-2015_seasonal.csv")
817 chart<-list()
818 w <- c(0,439,776,1.08e+03,3.05e+03)
819
820 cols <- c("[0,439]" = "yellow", "[439,776]" = "red", "[776,1.08e+03]" = "blue", "[1.08e+03,3.05e+03]" = "purple")
821 q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
822 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
823   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
824
825
826 River_B <- readShapeSpatial("Ind")
827 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
828 cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[[i]])
829 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
830 chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="Average seasonal (June to Sept) Rainfall of India for 1990 t"
831
888:1 Multiple Plot Function

```

```

868+ for (i in 1:humpplots) {
869+   curRow = ceiling(i/plotcols)
870+   curCol = (i-1) %% plotcols + 1
871+   print(plots[[i]], vp = vplayout(curRow, curcol ))
872+ }
873+
874 tiff(filename = "India_seasonal_1990-2014.tiff", pointsize =8, res = 600, units = "in", width = 8, height = 3, restoreconsole =
875 multiplot(chart[[2]], cols = 2)
876 dev.off()
877 jpeg(filename = "India_seasonal_1990-2014.jpeg", pointsize =8, res = 600, units = "in", width = 8, height = 2, restoreconsole =
878 multiplot(chart[[2]] ,cols = 2)
879 dev.off()
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896 q<-read.csv("India_Seasonal_difference_1920-1990.csv")
897 chart<-list()
898 w <- c(-503,-47,-7,58,307)
899
900 cols <- c("[~-503,-47]" = "yellow", "[~-47,-7]" = "red", "[~-7,58]" = "blue", "[~58,307]" = "purple")
901 q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
902 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
903   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
904
905
906 River_B <- readshpspatial("Ind")
907 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
908 cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
909 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
910 chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="(June-Sept)Seasonal Mean Difference of India for (1901-1920
911
912
913 cols <- c("[~-503,-47]" = "yellow", "[~-47,-7]" = "red", "[~-7,58]" = "blue", "[~58,307]" = "purple")
914 q$A2 <- cut(q$Mean,breaks = w,right = FALSE)
915 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
916   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
917
918
919 River_B <- readshpspatial("Ind")
920 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
921 cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
922 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
923 chart[[2]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="(June-Sept)Seasonal Mean Difference of India for (1901-192
924
925
888:1 Multiple Plot Function

```

```

894
895
896 q<-read.csv("India_Seasonal_difference_1920-1990.csv")
897 chart<-list()
898 w <- c(-503,-47,-7,58,307)
899
900 cols <- c("[~-503,-47]" = "yellow", "[~-47,-7]" = "red", "[~-7,58]" = "blue", "[~58,307]" = "purple")
901 q$A1 <- cut(q$Mean,breaks = w,right = FALSE)
902 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
903   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
904
905
906 River_B <- readshpspatial("Ind")
907 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
908 cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
909 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
910 chart[[1]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="(June-Sept)Seasonal Mean Difference of India for (1901-1920
911
912
913 cols <- c("[~-503,-47]" = "yellow", "[~-47,-7]" = "red", "[~-7,58]" = "blue", "[~58,307]" = "purple")
914 q$A2 <- cut(q$Mean,breaks = w,right = FALSE)
915 h <- ggplot(data = q, aes(x = x, y = y,fill = A1)) + geom_tile(aes()) +
916   scale_colour_manual(values = cols,aesthetics = c("colour", "fill"))+theme_classic()
917
918
919 River_B <- readshpspatial("Ind")
920 ch <- geom_polygon(data=River_B, aes(x=long, y=lat, group=group), colour="black", fill="white", alpha=0)
921 cha <- h+ch+xlab("Longitude")+ylab("Latitude") #+ labs(title= z[i])
922 cha <- cha+theme(text = element_text(family = "Times New Roman", size=16, face = "bold"))
923 chart[[2]] <- h+ch+xlab("Longitude")+ylab("Latitude") + labs(title="(June-Sept)Seasonal Mean Difference of India for (1901-192
924
925
888:1 Multiple Plot Function

```

The screenshot shows the RStudio interface with the code editor open. The file is named 'discrete_color.R'. The code is a script for generating multiple plots. It starts by creating a list from arguments and a plot list, then calculates the number of plots. It sets up a panel with columns and rows, and then iterates through each plot, setting its position in the grid. Finally, it saves the plots as TIFF and JPEG files.

```
# | discrete_color.R
932 # Make a list from the ... arguments and plotlist
933 plots <- c(list(...), plotlist)
934
935 numPlots = length(plots)
936
937 # Make the panel
938 plotcols = cols # Number of columns of plots
939 plotRows = ceiling(numPlots/plotcols) # Number of rows needed, calculated from # of cols
940
941 # set up the page
942 grid.newpage()
943 pushViewport(viewport(layout = grid.layout(plotRows, plotcols)))
944 vplayout <- function(x, y)
945   viewport(layout.pos.row = x, layout.pos.col = y)
946
947 # Make each plot, in the correct location
948 for (i in 1:numPlots) {
949   curRow = ceiling(i/plotcols)
950   curCol = (i-1) %% plotcols + 1
951   print(plots[[i]], vp = vplayout(curRow, curCol ))
952 }
953
954 tiff(filename = "India_1920-1990diff.tiff", pointsize = 8, res = 600, units = "in", width = 8, height = 3, restoreconsole = TRUE
955 multiplot(chart[[2]], cols = 2)
956 dev.off()
957 jpeg(filename = "India_1920-1990diff.jpeg", pointsize = 8, res = 600, units = "in", width = 8, height = 2, restoreconsole = TRUE
958 multiplot(chart[[2]], cols = 2)
959 dev.off()
960
961
962
963
```