Precipitation Change in the United States from 2014-2018

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Abstract:
Climate change repeatedly headlines much of today's news. Many of these reports follow weather patterns such as changes in temperature, air quality, and precipitation. In collaboration with Dr. Ping, we have studied NASA's precipitation data to better understand the changes in the weather. The goal of this project is to clean the data and create different data visualizations to understand the precipitation patterns. We analyzed the seasonal variation of the precipitation during 2014–2018 in the Midwest and other interesting states. Also, we compared the mean of the monthly total precipitation among the states. In addition, we analyzed the duration and intensity of precipitation. And finally analyzed the occurrence of heavy precipitation in each state.

Introduction:
The data that is utilized can be found on Precipitation Measurement Missions NASA website. The dataset is NASA's Tropical Rainfall Measuring Mission (TRMM) Level 3 precipitation data version 7 (TRMM_3B42_V007). While the data is available between 1997 and 2018, this project makes the use of the years 2014-2018 due to the size of the datasets. The data is collected via a satellite on a 0.25 degree latitude by 0.25 degree longitude grid every 3 hours. The data format is NetCDF.

From this dataset, there are some other variables that could have been pulled. This paper centers around the three most important features that were extracted, precipitation(mm), longitude, and latitude and the name of each file which is the date and hour of collecting data.

There has been work done on this data in the past, and from this Dr. Ping has created some deliverables. The main goals span 3 broad topics. Primarily, the seasonal and locational variation of the precipitation to analyze how time and location affect these changes. Additionally, consecutive precipitation events are studied to understand if heavier precipitation occurs over shorter periods of time. Lastly, heavy precipitation events which occur rarely are analyzed to determine where these events are occurring and the frequency in the last few years.

Methods and Analysis:

Data Cleaning:
A large portion of this project centered around cleaning and manipulating the data to produce the necessary deliverables. The data was provided in a NetCDF format and was consumed using the NetCDF4 package in R. As the data was collected every three hours at every quarter longitude and latitude point spanning the globe, the amount of data from 1997 to 2017 was too extensive to utilize. Instead, data from 2014 to 2018 was read.

Once the data was read through R, the first task was to extract the longitude, latitude, and precipitation, compile the whole data from each file to get a final data set for starting the analysis and identify the missing data. For all the missing data, values were imputed using seasonal adjustment+interpolation because our data is time series data with trend and seasonality. Once the data was complete, daily precipitation was calculated by summing all 8 records delivered every three hours for each longitude and latitude point on each day.

With some other formattings include obtaining the state names from the longitude and latitude given, extracting the date from the name of each file and subsetting the data to create a data frame with only US data, the data set was written to a csv file. This is the data that each individual used to begin the data analysis and visualization portion of the project.

Data Visualization and Analysis:
There were three different strategies implemented to address the three goals discussed above.

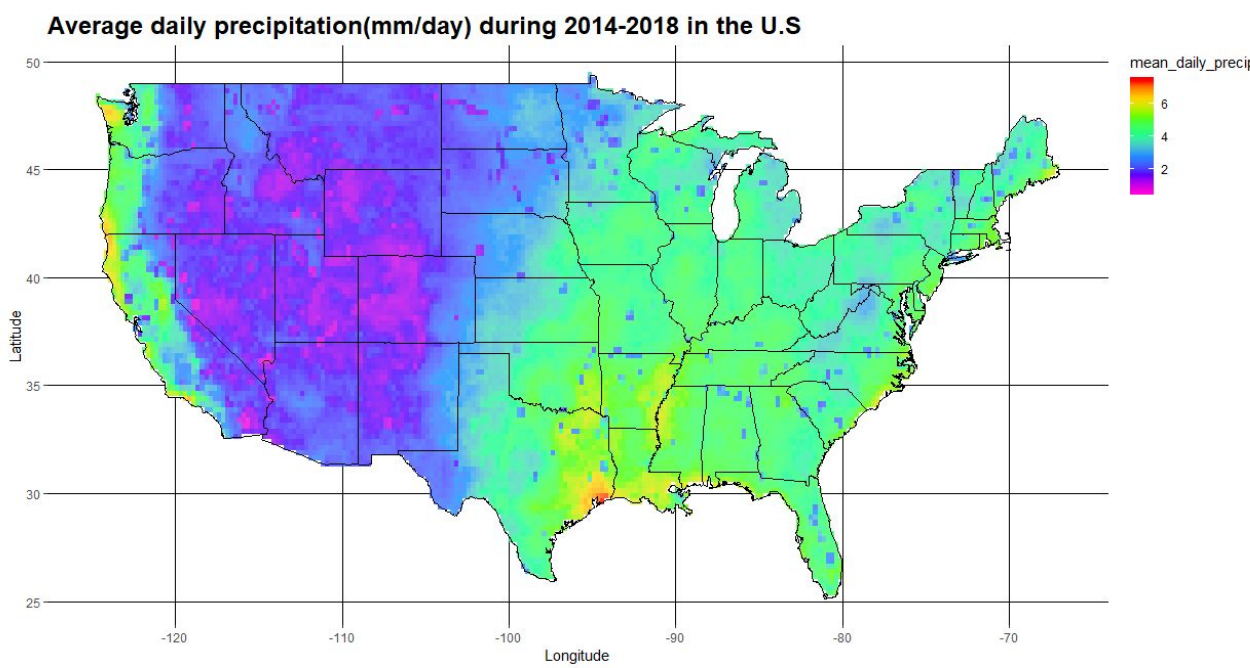
Heat maps were used to address the different seasonal and locational variation of the precipitation. The data file was subset to only consider wet days with precipitation greater than 0.254 mm and the average daily precipitation was calculated. A heat map is drawn using ggplot and different seasons and years were extracted to identify various patterns and conditions. Line graphs were also utilized to portray the trends over the five years of the average monthly precipitation within the midwest and other interesting states with high and low levels of precipitation. Additionally, pdf plots display the average daily precipitation within midwest and other states. An animated plot displays the average daily precipitation over the course of 5 years in the US.

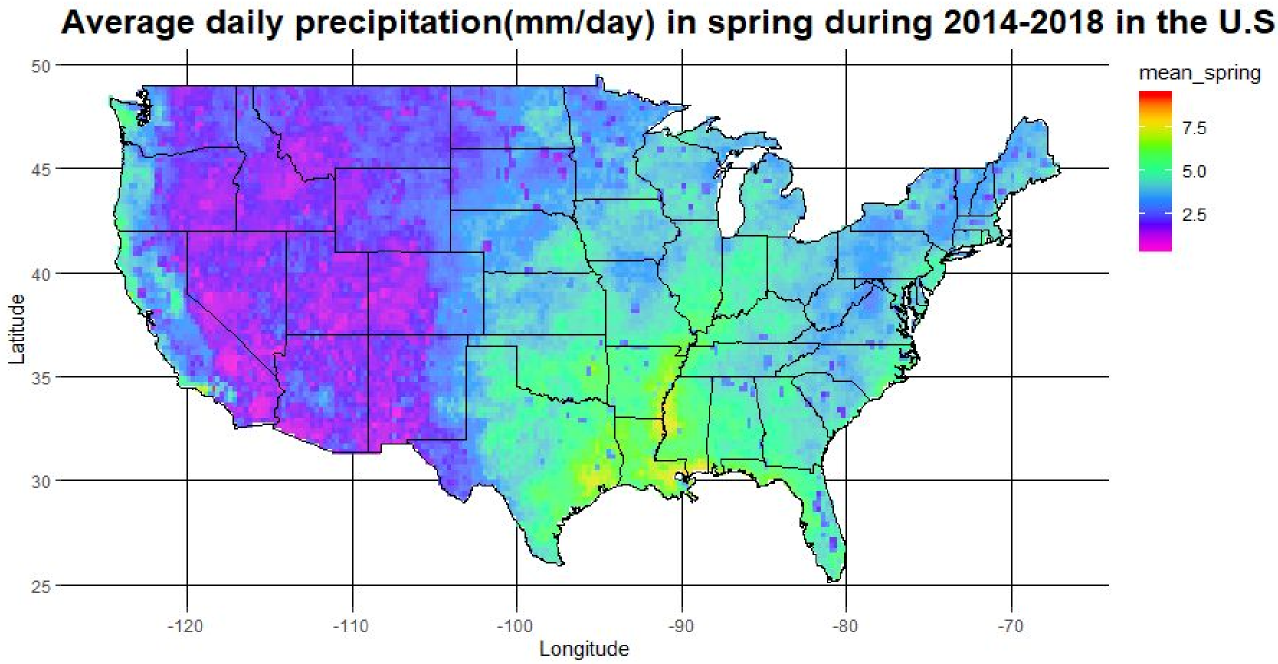
Bar charts were used to visualize consecutive precipitation events to understand if heavier precipitation occurs over shorter periods of time. The data frame was manipulated for the dates of wet days to only consider consecutive wet days. This subsetted data was then used to graph the number of consecutive wet days by each year to understand if the duration of wet days was increasing or decreasing over the years. Additionally, the maximum intensity of precipitation in the Midwest and other states of interest are captured in line graphs.

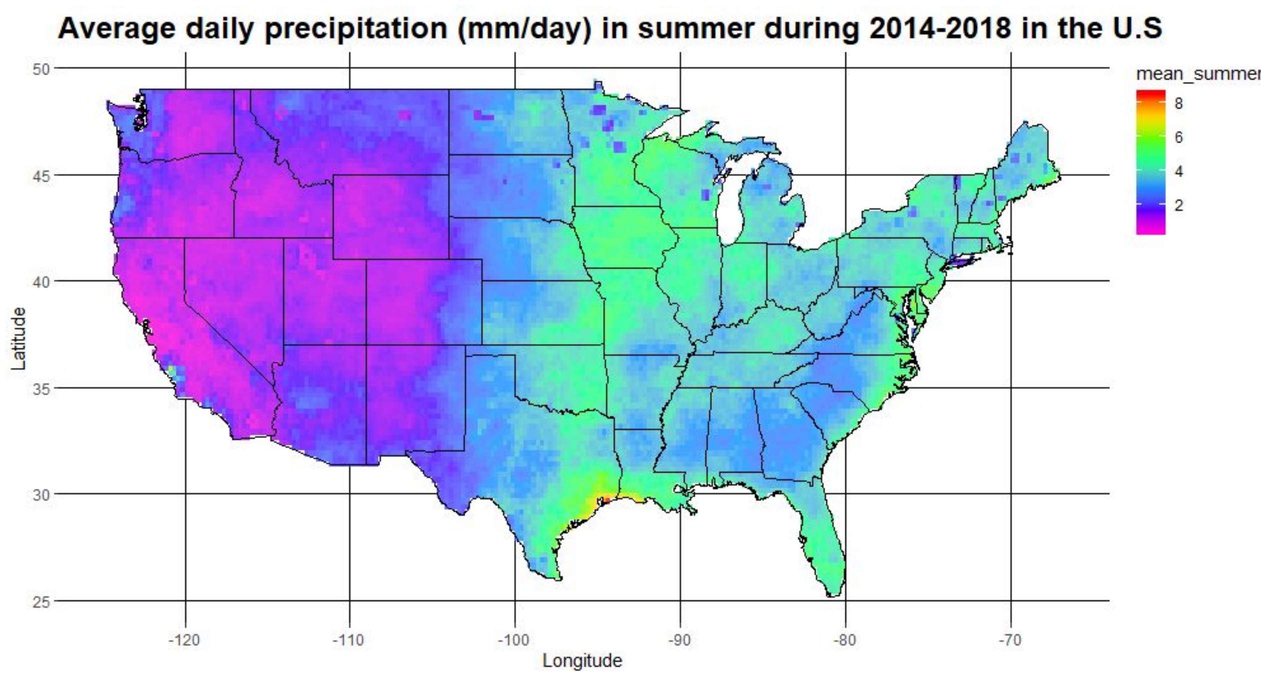
Lastly, bar charts were used to visualize heavy precipitation days during this five years period. Heavy Precipitation is defined by a day where the precipitation is greater than the threshold amount provided by Dr. Ping by previous research. The data was subsetted and manipulated using ggplot to produce these charts. The counts of these events are displayed by year, month and season for the midwest and other states of interest. Additionally, animated plots using gganimate are able to capture the amount of precipitation caused by heavy precipitation events by day. Analysis was done to determine the number of consecutive days of heavy precipitation but there were not many consecutive heavy precipitation days.

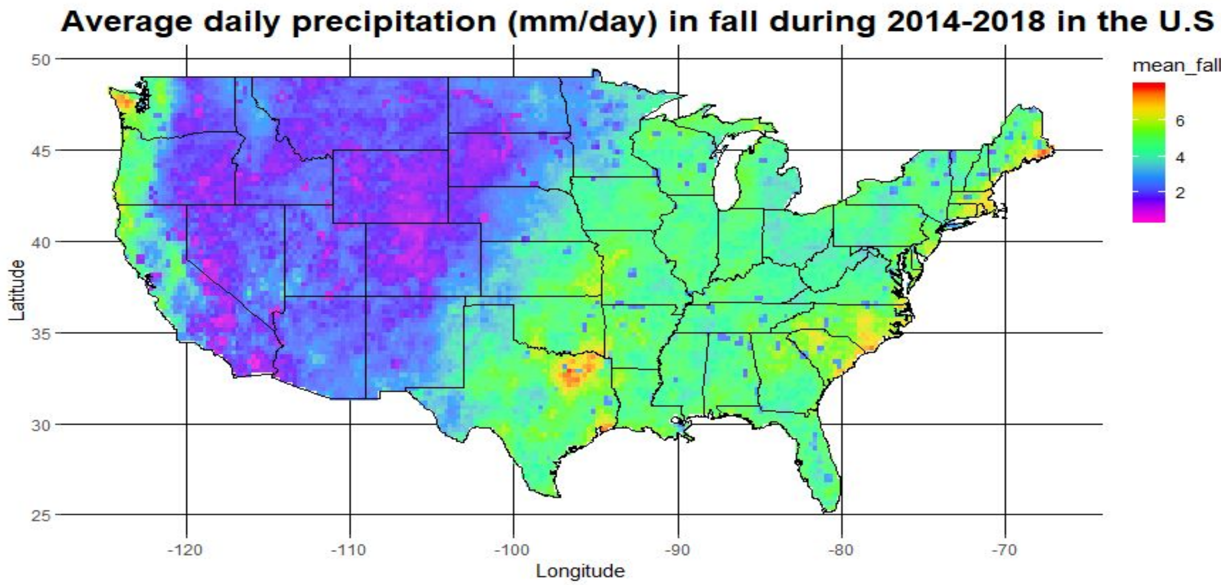
Results:

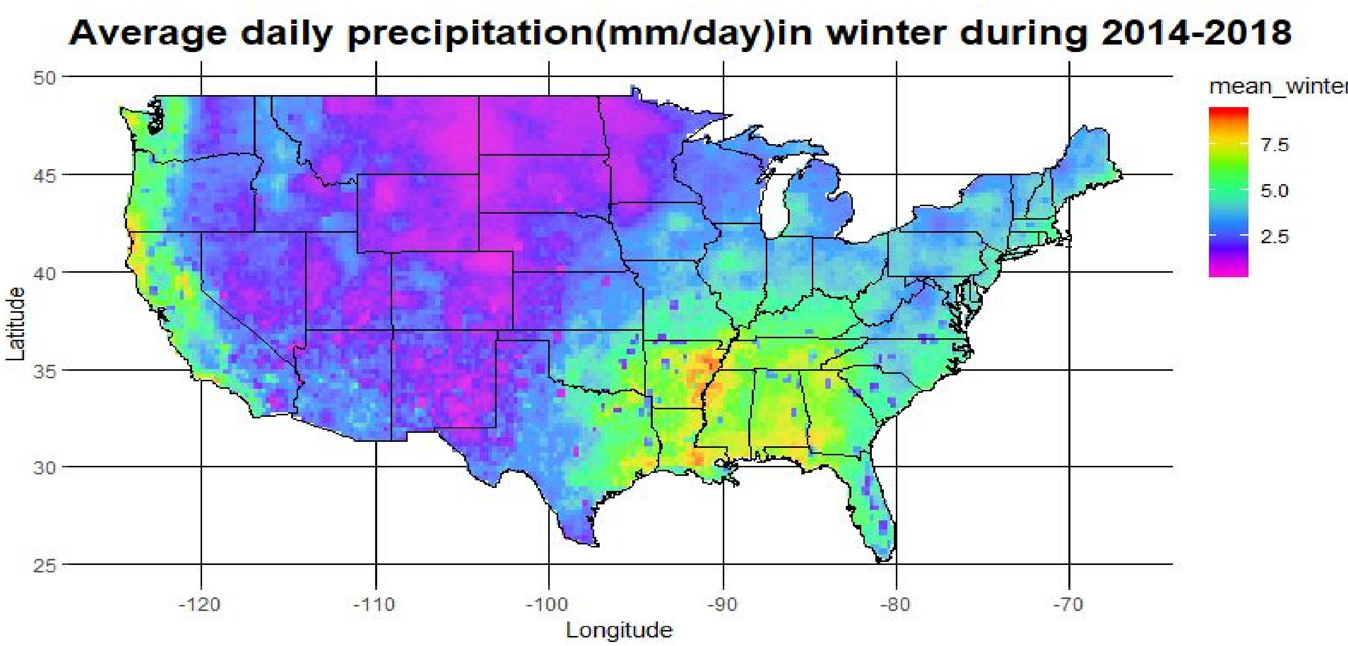
Goal 1:



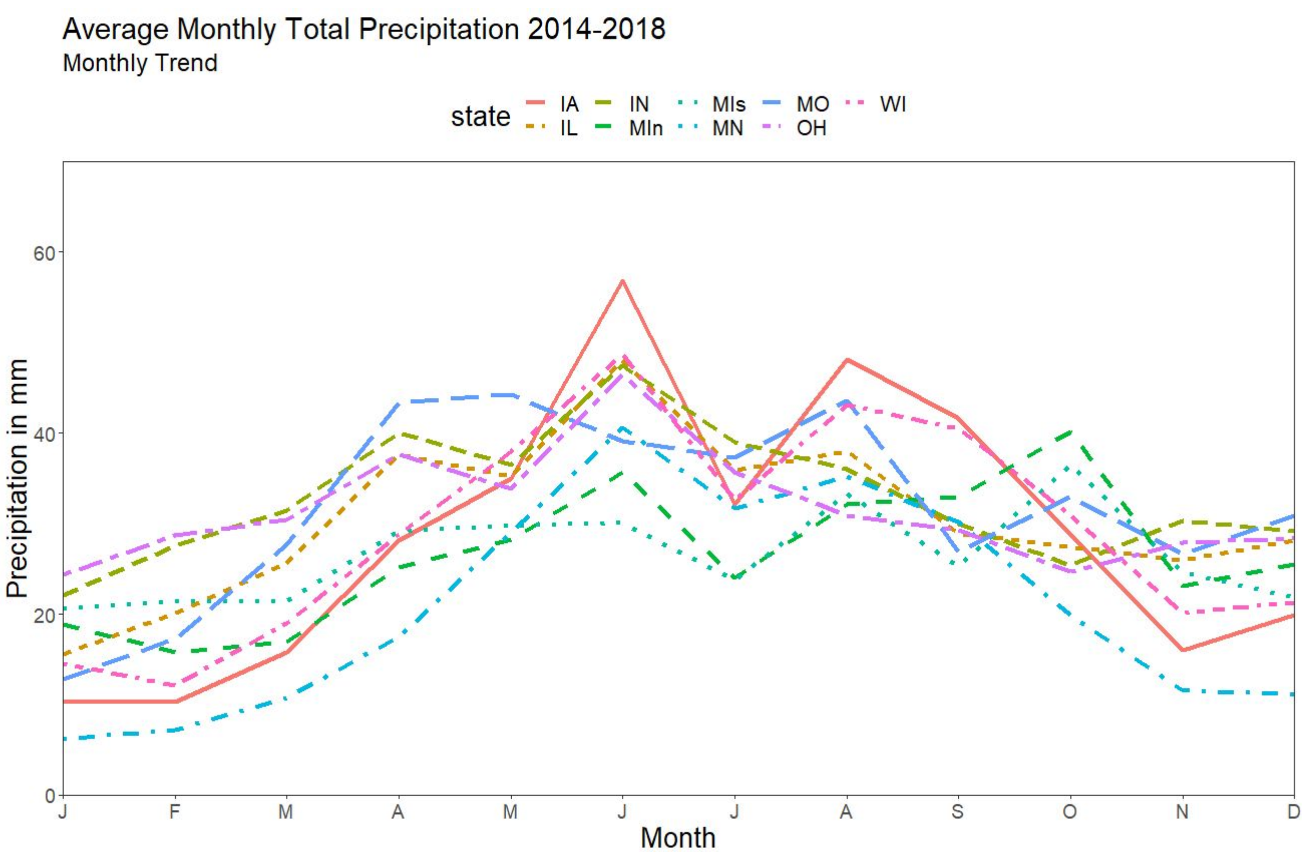

Average daily precipitation(mm/day) in spring during 2014-2018 in the U.S
mean_spring
7.5
5.0
2.5
50
45
40
35
30
25
Latitude
-120
-110
-100
-90
-80
-70
Longitude

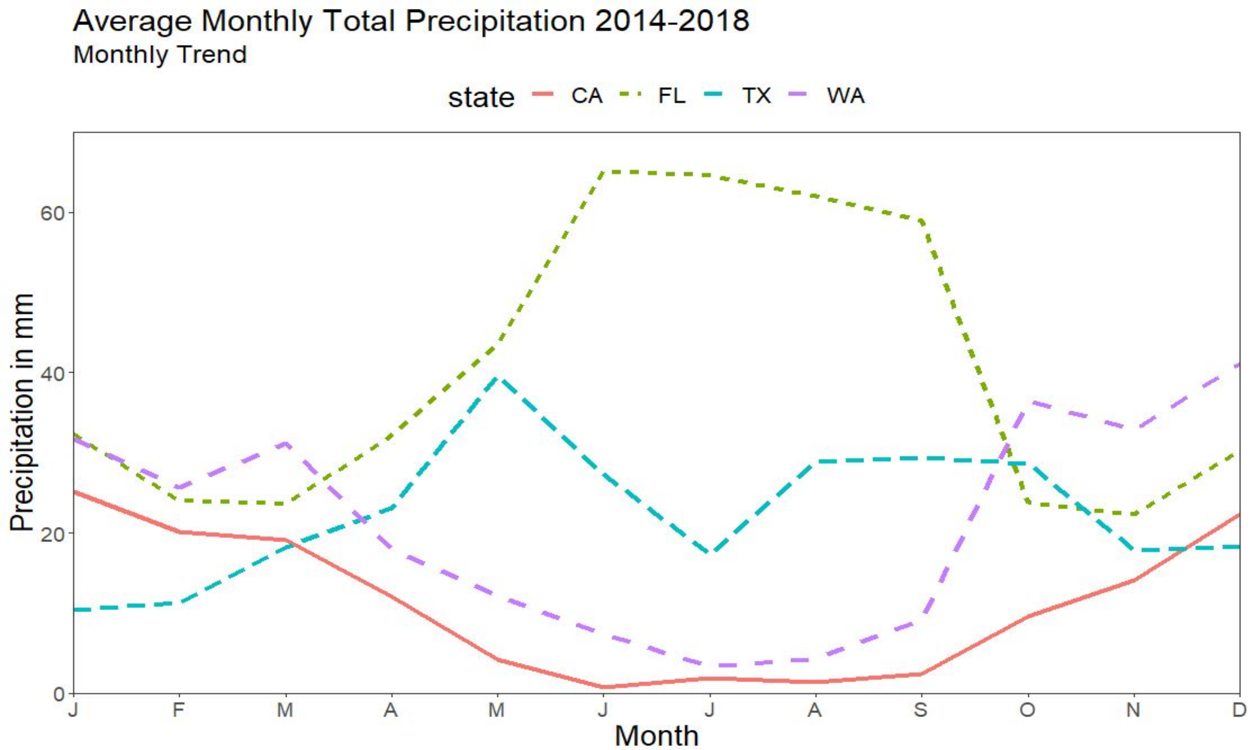

Average daily precipitation (mm/day) in summer during 2014-2018 in the U.S
mean_summer
8
6
4
2
50
45
40
35
30
25
Latitude
-120
-110
-100
-90
-80
-70
Longitude


Average daily precipitation (mm/day) in fall during 2014-2018 in the U.S
mean_fall
6
4
2
50
45
40
35
30
25
Latitude
-120
-110
-100
-90
-80
-70
Longitude

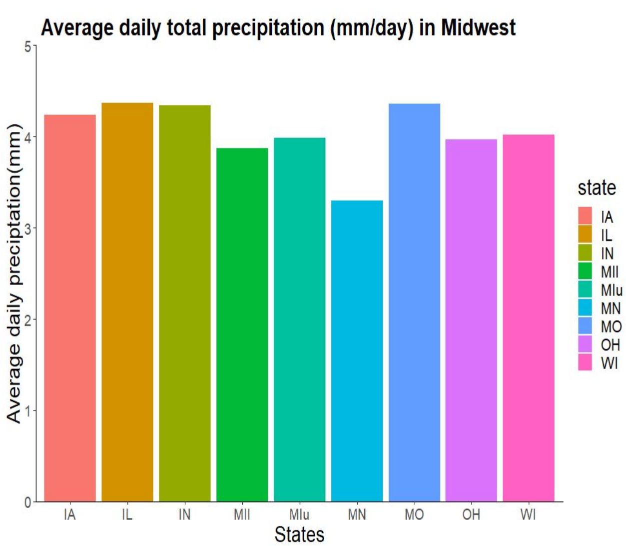

Average daily precipitation(mm/day)in winter during 2014-2018
mean_winter
7.5
5.0
2.5
50
45
40
35
30
25
Latitude
-120
-110
-100
-90
-80
-70
Longitude

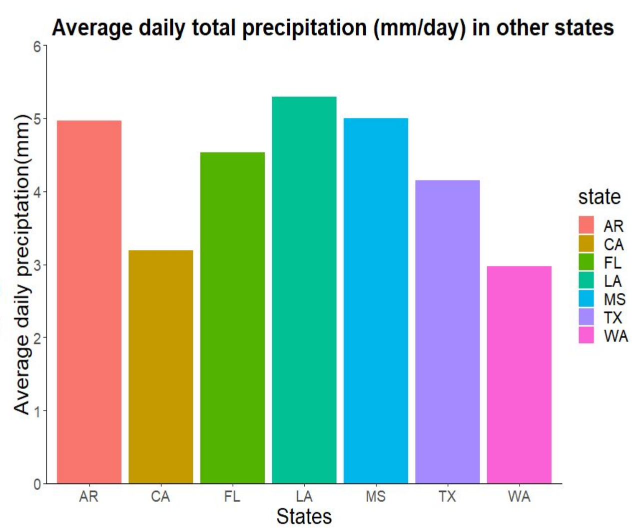
From the graphs above, we obtain the following conclusions:
-The heat maps portray the stark difference between the east and west US, with the west having much less precipitation
-Texas and Florida have higher precipitation points in cities where natural disasters have occurred in the recent years
-During winter there is more precipitation around Mississippi river.
-During winter and fall, there is a significant difference between west and east part of Washington, Oregon and California states because of mountain range in those areas which is called rain shadow desert effect. It means that a patch of land that has been forced to become a desert because mountain ranges blocked all plant-growing, rainy weather. On one side of the mountain, wet weather systems drop rain and snow. On the other side of the mountain—the rain shadow side—all that precipitation is blocked.





From the graphs above, we obtain the following conclusions:
-The highest amount of precipitation in the midwest is in the Jun
-Florida has higher precipitation in the summer months, while California has less precipitation in the summer months



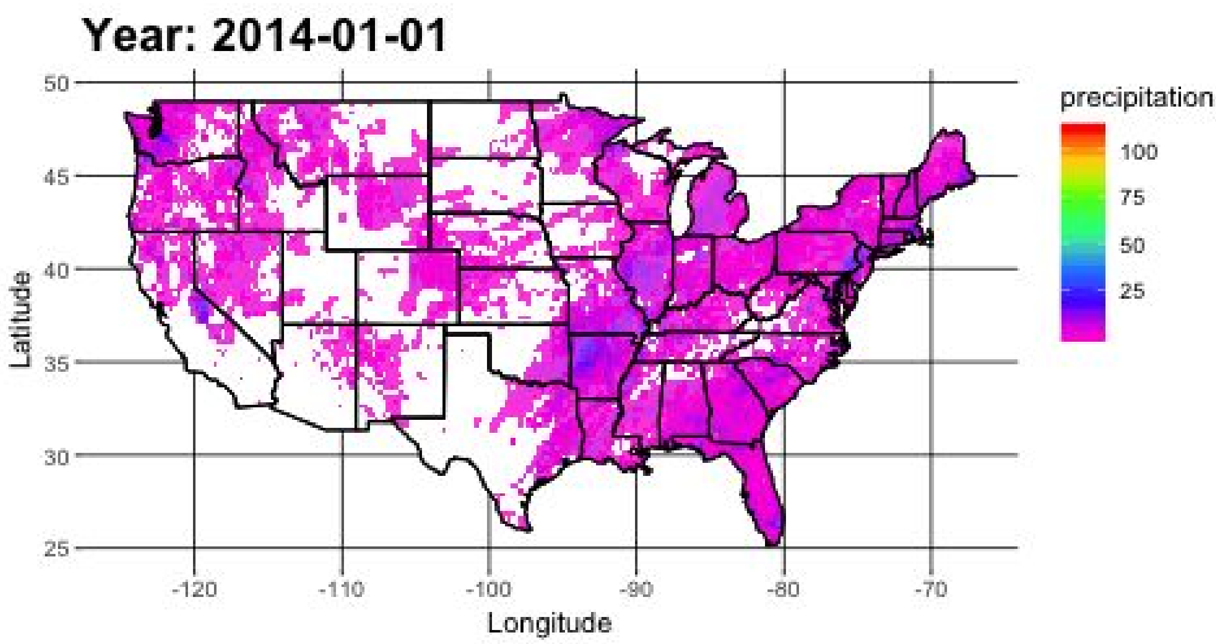


From the graphs above, we obtain the following conclusions:

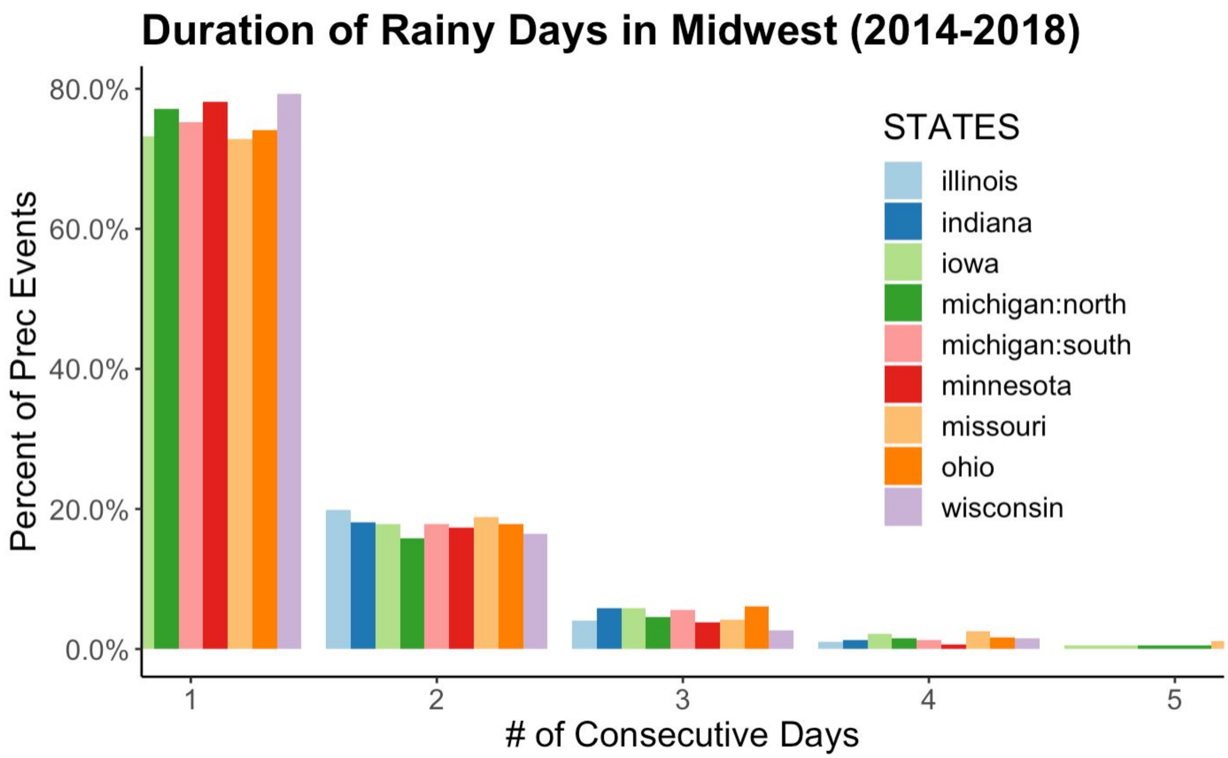
-The average daily total precipitation in the midwest is roughly the same and ranges from 3.5mm to 4.3 mm

-The average daily total precipitation in Arkansas and Louisiana tend to be higher with the average daily total precipitation around 5mm and California is lower with around 3mm average daily total precipitation

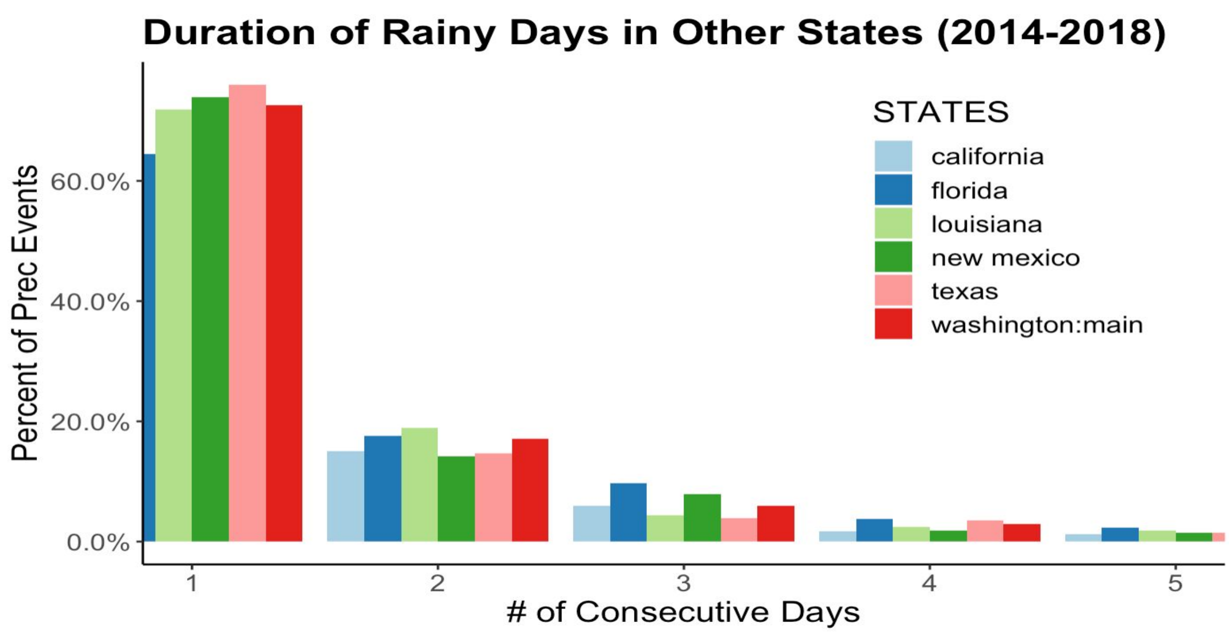
Average daily precipitation over the course of 5 years in the US:



Goal 2:



Duration of Rainy Days in Midwest (2014-2018)
80.0%
60.0%
40.0%
20.0%
0.0%
Percent of Prec Events
1
2
3
4
5
# of Consecutive Days
STATES
illinois
indiana
iowa
michigan:north
michigan:south
minnesota
missouri
ohio
wisconsin

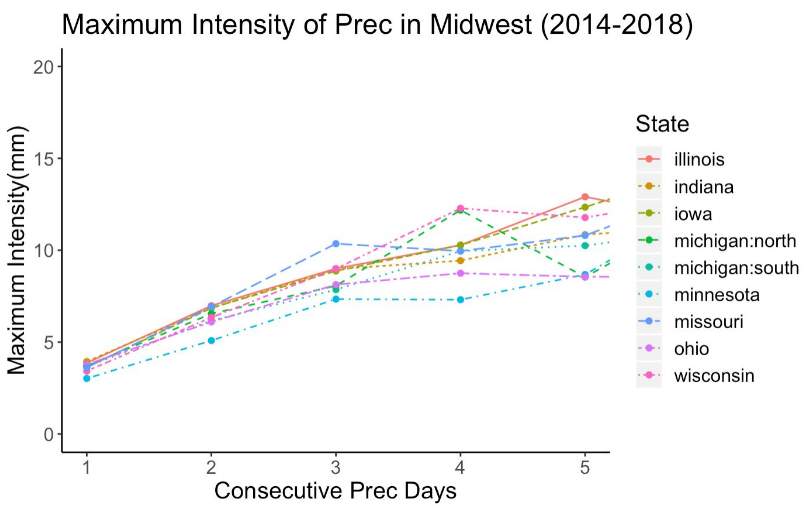


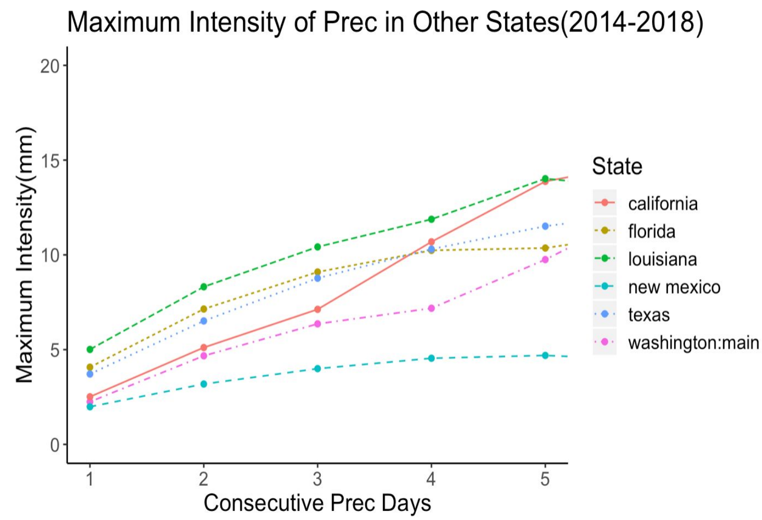
Duration of Rainy Days in Other States (2014-2018)
60.0%
40.0%
20.0%
0.0%
Percent of Prec Events
1
2
3
4
5
# of Consecutive Days
STATES
california
florida
louisiana
new mexico
texas
washington:main

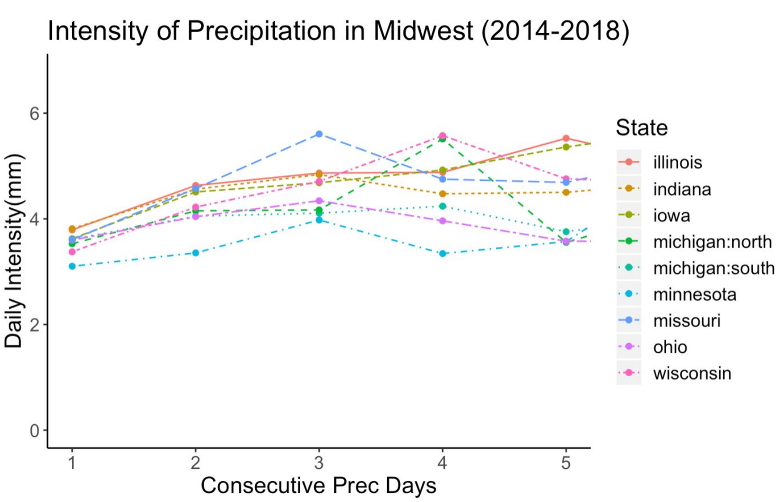
From the graphs above, we obtain the following conclusions:

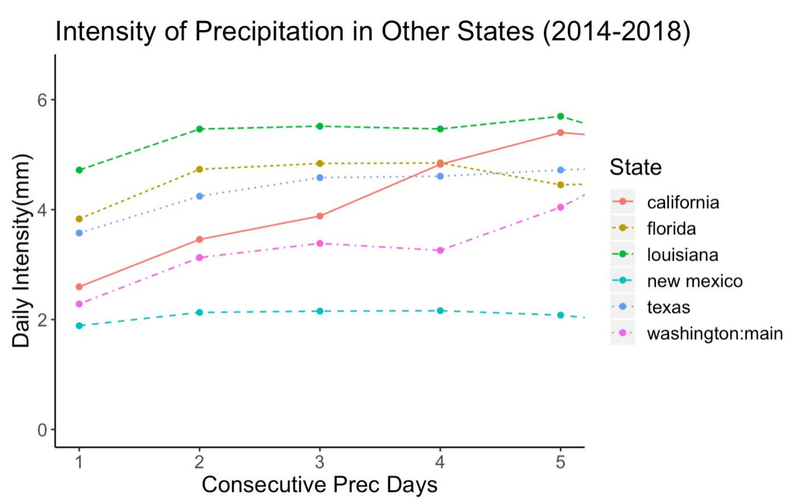
-Most rainy days last for shorter period of time

-Distribution of duration of rainy days is same across the Midwest









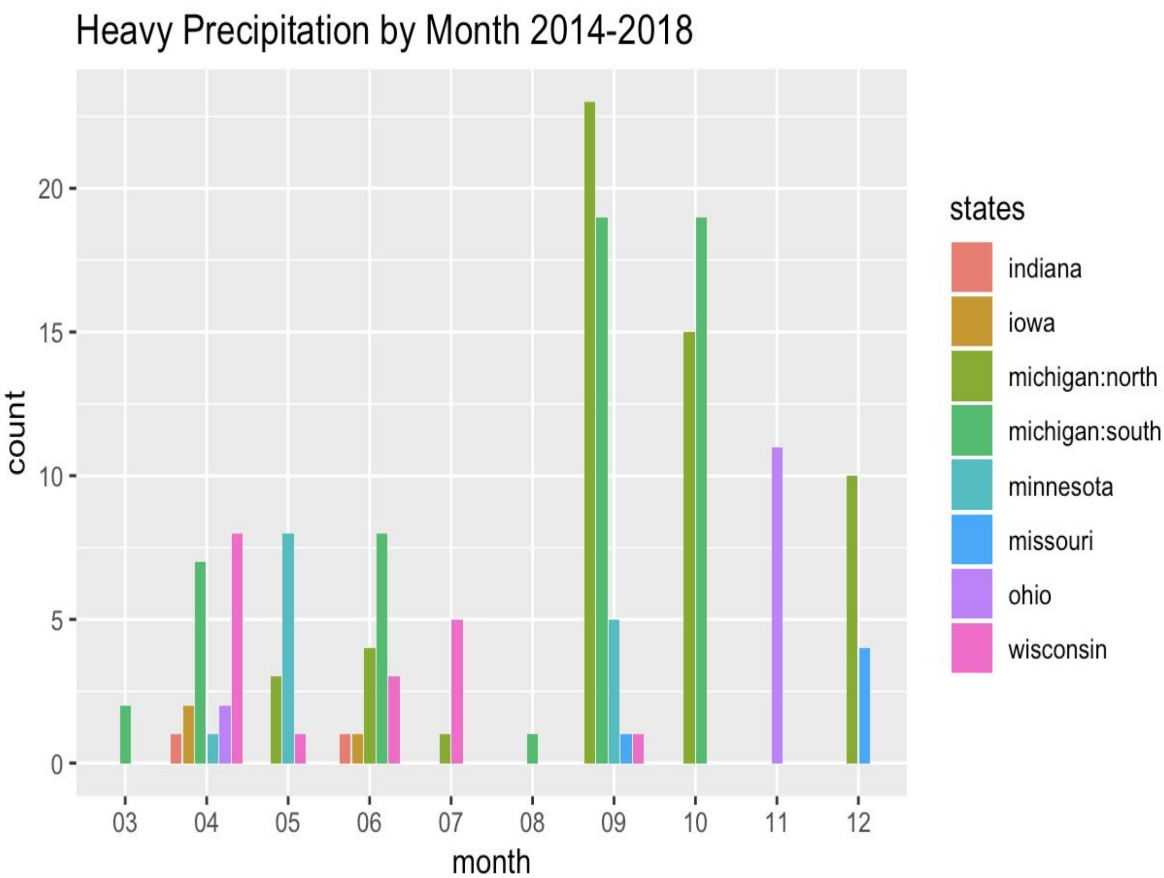
From the graphs above, we obtain the following conclusions:

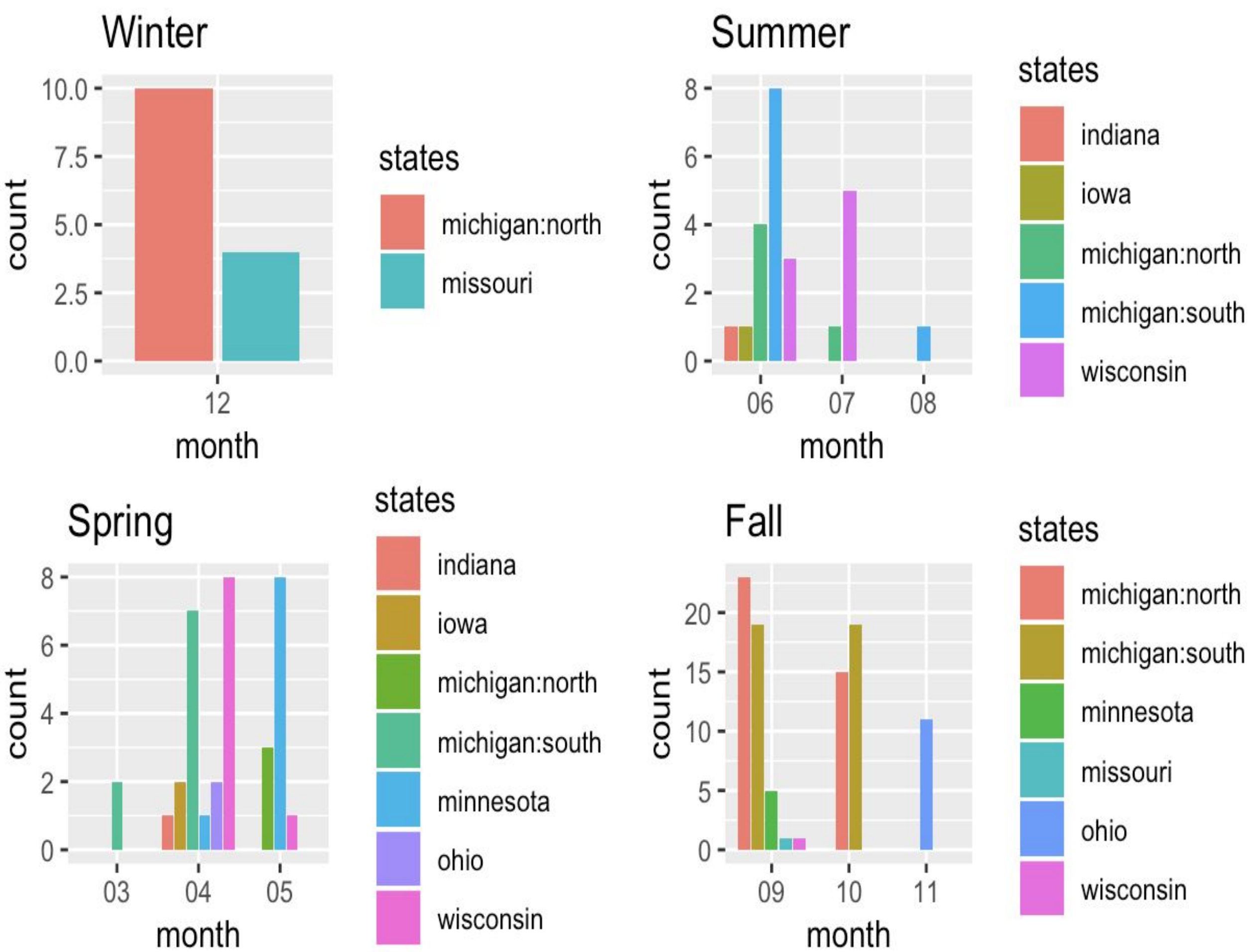
-The Maximum Intensity of Precipitation in the Midwest graph suggests that the events that last longer includes some of the heaviest precipitation

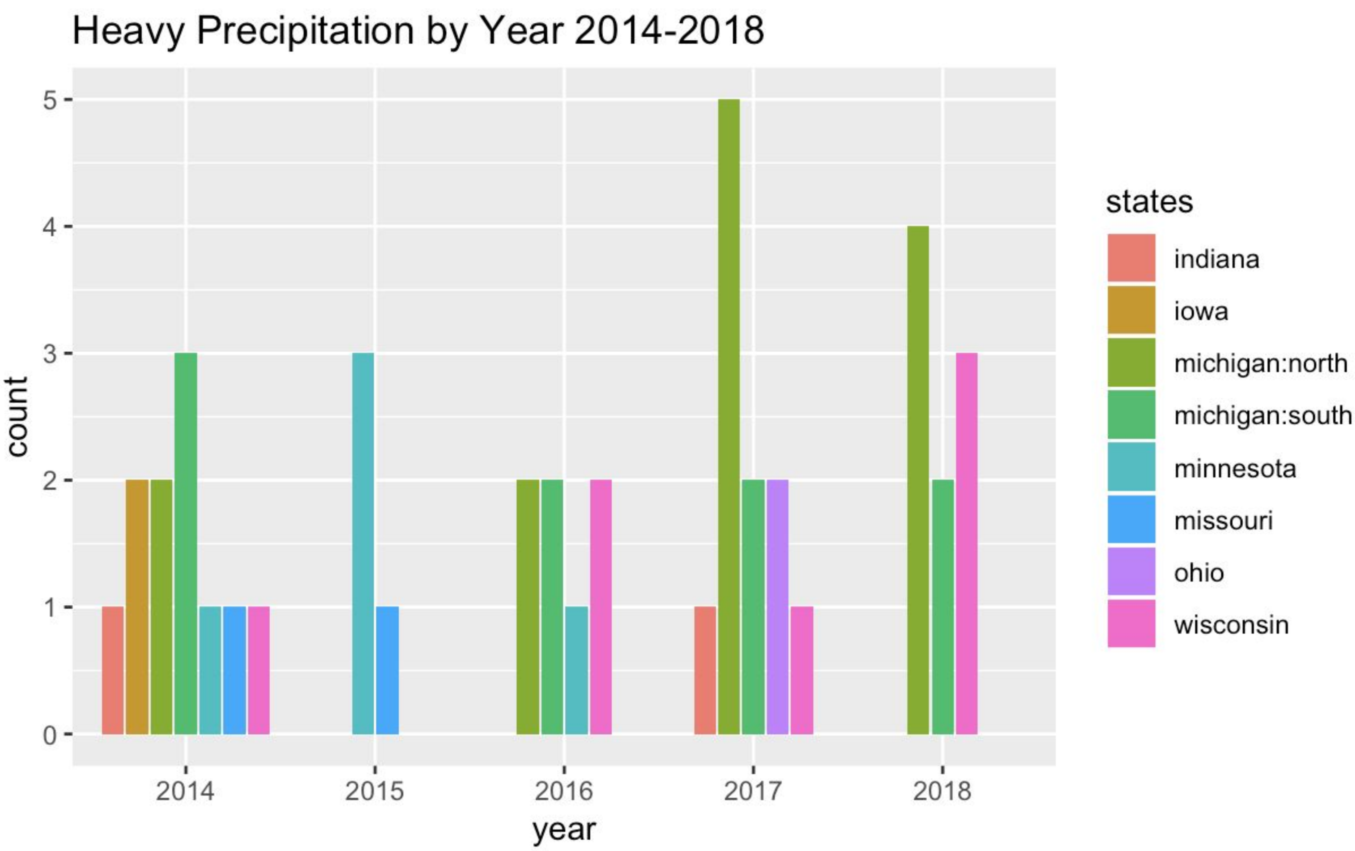
-The Maximum Intensity of Precipitation in other states suggests the longer durations of rainy days contains some of the heaviest precipitation. In 2017, LouIsiana saw the record high precipitation and flooding

-From the Intensity of Precipitation in the Midwest graph, the average Intensity of precipitation remains constant no matter the length of rain events
-From Intensity of Precipitation in Other States graph, intensity of precipitation remains constant no matter the length of rain events

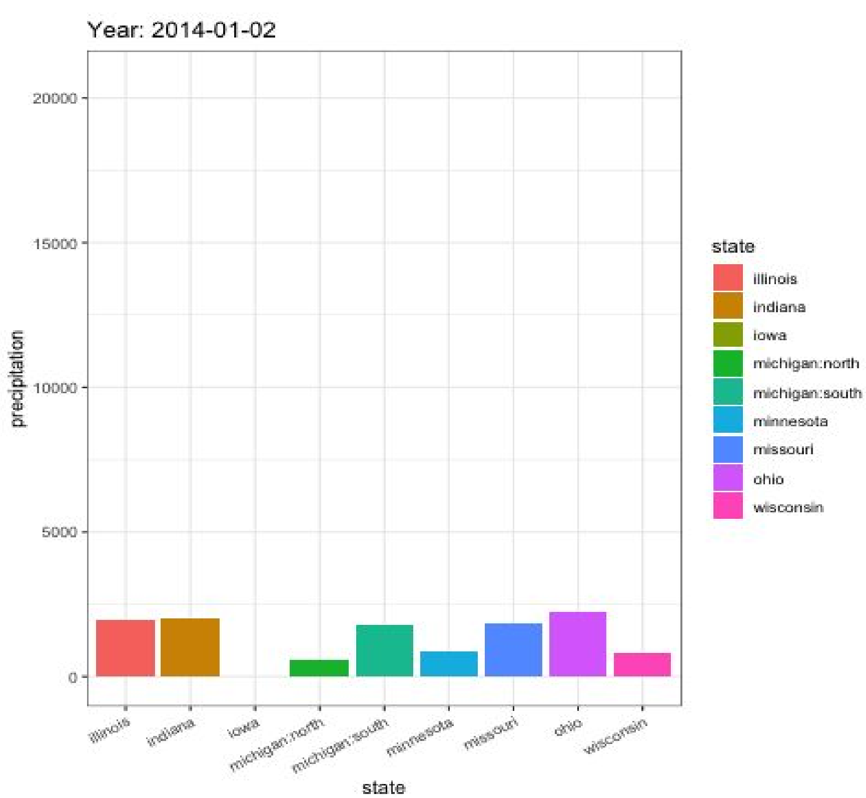
<u>Goal #3</u>




Winter
10.0
7.5
5.0
2.5
0.0
count
12
month
states
michigan:north
missouri
Summer
8
6
4
2
0
count
06
07
08
month
states
indiana
iowa
michigan:north
michigan:south
wisconsin
Spring
8
6
4
2
0
count
03
04
05
month
states
indiana
iowa
michigan:north
michigan:south
minnesota
ohio
wisconsin
Fall
20
15
10
5
0
count
09
10
11
month
states
michigan:north
michigan:south
minnesota
missouri
ohio
wisconsin



Amount of precipitation caused by heavy precipitation events by day



From the graphs above, we obtain the following conclusions:
-Heaviest precipitation days occur in September and October, particularly in North and South Michigan
-There were more states in 2014 that had heavy precipitation days
-Many heavy precipitation days have caused newsworthy events and much damage such as the heavy precipitation in Michigan 2017
-Illinois did not have any heavy precipitation days in the last 5 years
-There were not many consecutive days of heavy precipitation in this 5 years

Conclusion:
Through this project, several discoveries were made regarding precipitation patterns in the Midwest and other regions. The average daily precipitation tends to be the highest in the summer months but the heavy precipitation days tend to be in the Fall. Additionally, the number of rainy days last for a shorter period of time. There was not enough data to truly conclude if there is an upward or downward trend of precipitation in the Midwest and other states; however, the code we have can be applied to any region and any amount of data so this future work of a wider timeframe is possible.

Meetings with Client
Meeting 1 in September 10th consisted of an outline of the project and the data. Meeting 2 in september 19th consisted of the further exploration of questions. Meeting 3 in November 4th consisted of an update of some results after our second presentation. Additionally, we each had individual meetings and communication with Dr. Ping regarding our different goals.

Individual Contributions
Raheleh lead the initiatives on downloading all the files at the same time(about 14600 files), data reading, finding a way to get the states from longitude and latitude and data cleaning. She also primarily worked on Goal 1 and created heat maps and other visualizations regarding the average daily precipitation trends in the Midwest and other states of interest. Also she edited the final paper.

Joselyne assisted with extracting variables from data and developed methods to answer Goal 2. She developed the logic to determine consecutive days in the Midwest and other states of interest, along with questions surrounding the intensity of precipitation.

Kajal completed Goal 3 by subsetting the data to determine heavy precipitation days in the Midwest and trends centering around the timing of these events. Additionally, she led efforts on animated plots and created an animated bar chart and heat map. Also she wrote the final paper.

References and Appendix

Background Information:

- A wet day is a day with >0.254 mm precipitation.
- A precipitation event ("event") is constituted of consecutive wet days.
- An extreme precipitation day is a day in which the daily precipitation amount (mm/day) is ⩾ the extreme threshold, which is the lowest of the top 1% of daily precipitation amounts of all wet days within a state between 1950 and 1979.
- An extreme event is an event in which the total precipitation amount (mm) is ⩾ the extreme threshold, which is the lowest of the top 1% of total precipitation amounts of all events within a state between 1950 and 1979.

Table 2. Extreme Thresholds

State	Day (mm)	Event (mm)
OH	35.0	79.7
IN	42.0	93.7
IL	46.6	96.9
WI	39.4	82.5
MO	52.3	108.4
MIu	32.5	70.9
MIl	33.7	70.2
IA	46.5	93.7
MN	39.0	78.4

-https://pmm.nasa.gov/data-access/downloads/trmm

-https://disc.gsfc.nasa.gov/datasets/TRMM_3B42_V7/summary

- https://stackoverflow.com/questions/8751497/latitude-longitude-coordinates-to-state-code-in-r

- https://www.datacamp.com/enterprise/statistical-consulting/my-assignments