Rain Days

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#load packages

```
suppressMessages({
  library(dplyr)
  library(stringr)
  library(mosaic)
  library(stats)
  library("DescTools")
  library(caret)
  library(klaR)
  library(rpart)
  library(rpart.plot)
})
```

```
## Warning: package 'dplyr' was built under R version 4.2.3
```

```
## Warning: package 'stringr' was built under R version 4.2.3
```

```
## Warning: package 'mosaic' was built under R version 4.2.3
```

```
## Warning: package 'DescTools' was built under R version 4.2.3
```

```
## Warning: package 'caret' was built under R version 4.2.3
```

```
## Warning: package 'klaR' was built under R version 4.2.3
```

```
## Warning: package 'rpart' was built under R version 4.2.3
```

```
## Warning: package 'rpart.plot' was built under R version 4.2.3
```

Seattle is the Emerald City because of the lush, evergreen foliage year-round, and the rain that makes the evergreens grow*. But, if you've ever been to the other Washington (D.C.), you know that the nation's capital is a place of unending rain, surprise summer thunderstorms, and the occasional hurricane. Is Seattle really a rainier city? We'll find out.

*Citations: https://www.thoughtco.com/why-is-seattle-the-emerald-city-2964993
https://www.seattlepi.com/seattlenews/slideshow/Stereotypes-and-Seattle-144731.php

Data sets: https://www.ncei.noaa.gov/access/past-weather/

Loading in Data & Data Cleaning

Lets start with some data processing. Here, we load the data sets. For data, I chose the official NOAA weather records for both Seattle and Washington, DC. They span from the

mid-1900s to present day. However, DC's records go a little further back beginning in the mid 30's, and Seattle in the late 40's. The data sets track the temperature and precipitation both for the day as well as the minimum and maximum.

```
dc <- read.csv("DC.csv", header = TRUE)
seattle <- read.csv("Seattle.csv", header = TRUE)
head(dc)
```

```
##       Date TAVG..Degrees.Fahrenheit. TMAX..Degrees.Fahrenheit.
## 1 9/1/1936                         76                         NA
## 2 9/2/1936                         72                         NA
## 3 9/3/1936                         74                         NA
## 4 9/4/1936                         75                         NA
## 5 9/5/1936                         74                         NA
## 6 9/6/1936                         73                         NA
##   TMIN..Degrees.Fahrenheit. PRCP..Inches. SNOW..Inches. SNWD..Inches.
## 1                        NA            NA            NA            NA
## 2                        NA            NA            NA            NA
## 3                        NA            NA            NA            NA
## 4                        NA            NA            NA            NA
## 5                        NA            NA            NA            NA
## 6                        NA            NA            NA            NA
```

```
head(seattle)
```

```
##       Date TAVG..Degrees.Fahrenheit. TMAX..Degrees.Fahrenheit.
## 1 1/1/1948                         NA                         51
## 2 1/2/1948                         NA                         45
## 3 1/3/1948                         NA                         45
## 4 1/4/1948                         NA                         45
## 5 1/5/1948                         NA                         45
## 6 1/6/1948                         NA                         48
##   TMIN..Degrees.Fahrenheit. PRCP..Inches. SNOW..Inches. SNWD..Inches.
## 1                        42          0.47             0             0
## 2                        36          0.59             0             0
## 3                        35          0.42             0             0
## 4                        34          0.31             0             0
## 5                        32          0.17             0             0
## 6                        39          0.44            NA            NA
```

Next, well make the data set a little easier to work with. In order to compbine them, we need to add the city name.

```
dc$city <- "dc"
seattle$city <- "seattle"
```

Both data sets have a number of empty values. Now, we find the empty cells.

```
apply(is.na(dc),2,sum)
```

```
##                       Date TAVG..Degrees.Fahrenheit.
TMAX..Degrees.Fahrenheit.
```

```
##                          0                      22565
1750
## TMIN..Degrees.Fahrenheit.             PRCP..Inches.
SNOW..Inches.
##                       1750                       1750
1751
##             SNWD..Inches.                       city
##                       2092                          0

apply(is.na(seattle),2,sum)

##                       Date TAVG..Degrees.Fahrenheit.
TMAX..Degrees.Fahrenheit.
##                          0                      21160
3
## TMIN..Degrees.Fahrenheit.             PRCP..Inches.
SNOW..Inches.
##                          4                          9
4450
##             SNWD..Inches.                       city
##                       4418                          0
```

I inserted 0 for NA's in Precipitation and Snow columns. I also removed the first rows of the DC data since most of the values are blank. This also makes the DC data set date range closer to the years of the Seattle data.

```
dc <- dc[-c(1:1749),]

dc$PRCP..Inches.[is.na(dc$PRCP..Inches.)] <- 0
dc$SNOW..Inches.[is.na(dc$SNOW..Inches.)] <- 0
dc$SNWD..Inches.[is.na(dc$SNWD..Inches.)] <- 0

seattle$PRCP..Inches.[is.na(seattle$PRCP..Inches.)] <- 0
seattle$SNOW..Inches.[is.na(seattle$SNOW..Inches.)] <- 0
seattle$SNWD..Inches.[is.na(seattle$SNWD..Inches.)] <- 0


apply(is.na(dc),2,sum)

##                       Date TAVG..Degrees.Fahrenheit.
TMAX..Degrees.Fahrenheit.
##                          0                      22565
1
## TMIN..Degrees.Fahrenheit.             PRCP..Inches.
SNOW..Inches.
##                          1                          0
0
##             SNWD..Inches.                       city
##                          0                          0

apply(is.na(seattle),2,sum)
```

```
##                       Date TAVG..Degrees.Fahrenheit.
TMAX..Degrees.Fahrenheit.
##                          0                     21160
3
## TMIN..Degrees.Fahrenheit.             PRCP..Inches.
SNOW..Inches.
##                          4                         0
0
##             SNWD..Inches.                      city
##                          0                         0
```

We also want to split up the dates. That way, they'll be easier to work with, able to be looked at as months and years separately, and be numbers instead of another data type.

```
dc$date_split <- str_split_fixed(dc$Date,"/", 3)



dc$Month <- dc$date_split[,1]
dc$Day <- dc$date_split[,2]
dc$Year <- dc$date_split[,3]



seattle$date_split <- str_split_fixed(seattle$Date,"/", 3)

seattle$Month <- seattle$date_split[,1]
seattle$Day <- seattle$date_split[,2]
seattle$Year <- seattle$date_split[,3]
```

Next, we can impute the remaining missing data. Making the temperature 0 doesn't make sense, but leaving it null could skew things. This way we can find a ballpark average for the month / year and impute the missing value with that average, and it'll probably be about right.

```
seattle[c('Month', 'Day', "Year")] <- sapply(seattle[c('Month', 'Day',
"Year")],
                                             as.numeric)

seattle.filterna <- seattle %>%
  filter(!is.na(TAVG..Degrees.Fahrenheit.))

fit.lmna <- lm(TAVG..Degrees.Fahrenheit. ~ Month + Day + Year , data =
seattle.filterna)

summary(fit.lmna)

##
## Call:
## lm(formula = TAVG..Degrees.Fahrenheit. ~ Month + Day + Year,
##     data = seattle.filterna)
##
```

```
## Residuals:
##     Min      1Q  Median      3Q     Max
## -36.977  -7.460  -0.662   7.918  37.391
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -2.97343   28.88837  -0.103   0.9180
## Month        0.56575    0.03673  15.402   <2e-16 ***
## Day          0.02665    0.01425   1.870   0.0616 .
## Year         0.02595    0.01435   1.808   0.0707 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 10.29 on 6731 degrees of freedom
## Multiple R-squared:  0.03482,    Adjusted R-squared:  0.03439
## F-statistic: 80.94 on 3 and 6731 DF,  p-value: < 2.2e-16
```

```
seattle <- seattle %>%
  mutate(pred = predict(fit.lmna, .)) %>%
  mutate(TAVG..Degrees.Fahrenheit. = ifelse(is.na(TAVG..Degrees.Fahrenheit.),
pred,
                                            TAVG..Degrees.Fahrenheit.))
```

Repeat for DC

```
dc[c('Month', 'Day', "Year")] <- sapply(dc[c('Month', 'Day', "Year")],
                                        as.numeric)

dc.filterna <- dc %>%
  filter(!is.na(TAVG..Degrees.Fahrenheit.))

fit.lmna2 <- lm(TAVG..Degrees.Fahrenheit. ~ Month + Day + Year , data =
dc.filterna)

summary(fit.lmna2)
```

```
##
## Call:
## lm(formula = TAVG..Degrees.Fahrenheit. ~ Month + Day + Year,
##     data = dc.filterna)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -52.592 -12.937   0.972  14.531  33.214
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -2.232122  13.364454  -0.167    0.867
## Month        1.231021   0.054385  22.635  < 2e-16 ***
## Day          0.002039   0.021108   0.097    0.923
```

```
## Year         0.026708   0.006678   3.999 6.41e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 16.31 on 7716 degrees of freedom
## Multiple R-squared:  0.06349,    Adjusted R-squared:  0.06312
## F-statistic: 174.4 on 3 and 7716 DF,  p-value: < 2.2e-16

dc <- dc %>%
  mutate(pred = predict(fit.lmna2, .)) %>%
  mutate(TAVG..Degrees.Fahrenheit. = ifelse(is.na(TAVG..Degrees.Fahrenheit.),
pred,
                                            TAVG..Degrees.Fahrenheit.))
```

Recheck for missing values.

```
apply(is.na(dc),2,sum)

##                       Date TAVG..Degrees.Fahrenheit.
TMAX..Degrees.Fahrenheit.
##                          0                          0
1
## TMIN..Degrees.Fahrenheit.             PRCP..Inches.
SNOW..Inches.
##                          1                          0
0
##             SNWD..Inches.                       city
##                          0                          0
0
##
Month
##                          0                          0
0
##                        Day                       Year
pred
##                          0                          0
0

apply(is.na(seattle),2,sum)

##                       Date TAVG..Degrees.Fahrenheit.
TMAX..Degrees.Fahrenheit.
##                          0                          0
3
## TMIN..Degrees.Fahrenheit.             PRCP..Inches.
SNOW..Inches.
##                          4                          0
0
##             SNWD..Inches.                       city
##                          0                          0
0
```

```
##
Month
##                           0                           0
0
##                         Day                        Year
pred
##                           0                           0
0
```

Yay! There's almost no more missing / empty values.

Next, I'm adding a days with rain / precipitation column. This is a binary value to say if it's rained or not. This will be helpful for combining days with precipitation.

```
dc$prcp_day <- ifelse(dc$PRCP..Inches. > 0 | dc$SNOW..Inches. > 0, "Yes",
"No")
seattle$prcp_day <- ifelse(seattle$PRCP..Inches. > 0 | seattle$SNOW..Inches.
> 0,
                           "Yes", "No")
```

Statistics

Now, we can do some introductory statistics to determine if Seattle or DC actually has more rain. The first step is to build a set of tables that we can then combine to quickly read across the row. We're going to look at the average temperature, the precipitation days, and the inches of snow.

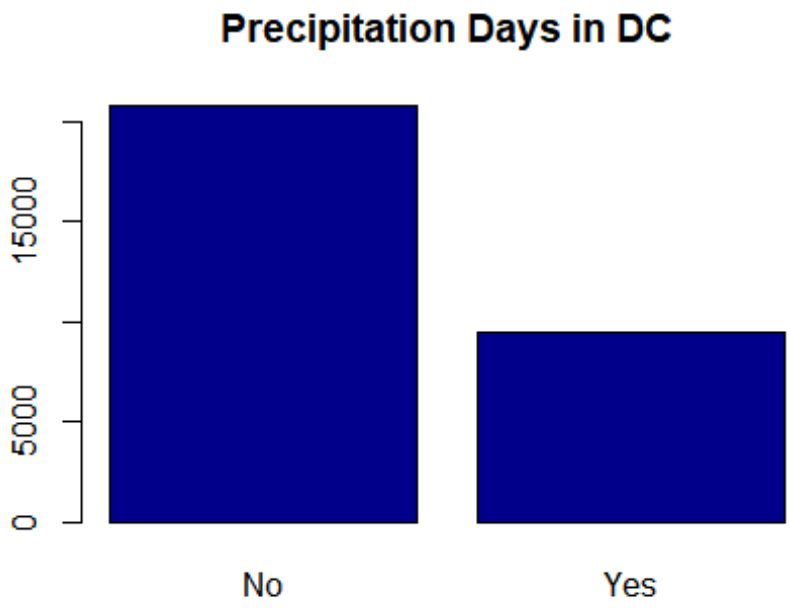
```
## Warning in fav_stats(x, ..., na.rm = na.rm): Auto-converting character to
## numeric.

## Warning in fav_stats(x, ..., na.rm = na.rm): NAs introduced by coercion

## Warning in dc_prcp$variable <- "Percipitation Day": Coercing LHS to a list

## Warning in fav_stats(x, ..., na.rm = na.rm): Auto-converting character to
## numeric.

## Warning in fav_stats(x, ..., na.rm = na.rm): NAs introduced by coercion

## Warning in sea_prcp$variable <- "Percipitation Day": Coercing LHS to a
list

##   min       Q1   median       Q3   max        mean        sd     n missing
##    13 54.16710 58.84449 63.36164 93.00 58.77640262 9.2817331 30285       0
## 1   0  0.00000  0.00000  0.03000  6.11  0.11030279 0.3167630 30285       0
## 2   0  0.00000  0.00000  0.00000 16.40  0.04209014 0.4413546 30285       0
## 3  17 50.32663 52.43804 54.56405 91.00 52.65149618 5.4537767 27895       0
## 4   0  0.00000  0.00000  0.10000  5.02  0.10618319 0.2395660 27895       0
## 5   0  0.00000  0.00000  0.00000 20.00  0.02440222 0.3181762 27895       0
##      city     variable
##        DC Average Temp
## 1      DC Precipitaion
```

```
## 2      DC  Snow Inches
## 3 Seattle Average Temp
## 4 Seattle Precipitaion
## 5 Seattle  Snow Inches
```

From the table, DC has a higher average temperature, a higher average precipitation, and a higher average snow inches. However, they're pretty similar. And Seattle does have a higher max snow inches.

Next, we can visualize some of these data points. Lets start with how many days it actually precipitated vs days it didn't.

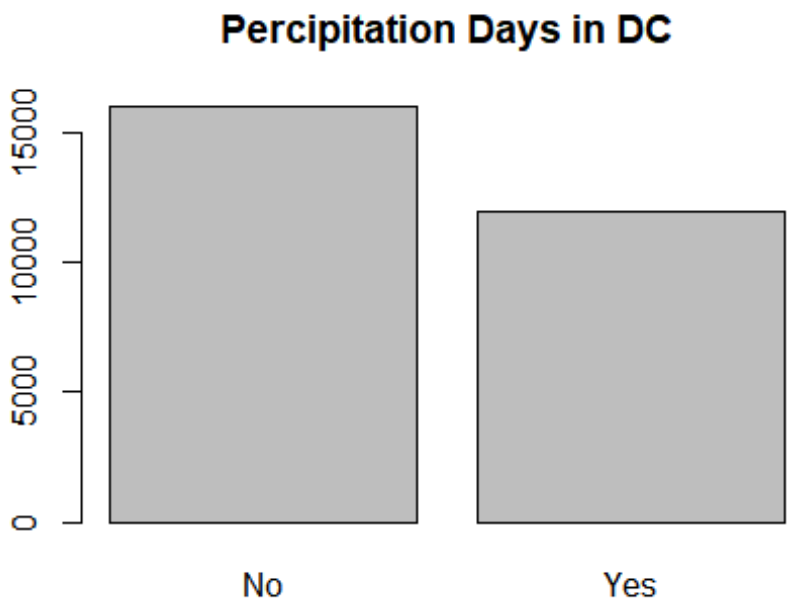
```
dc_prcp <- table(dc$prcp_day)
barplot(t(dc_prcp),
        main = "Precipitation Days in DC",
        col = c("darkblue"))
```



DC has had about 1/2 as many days with precipitation as days with no precipitation.

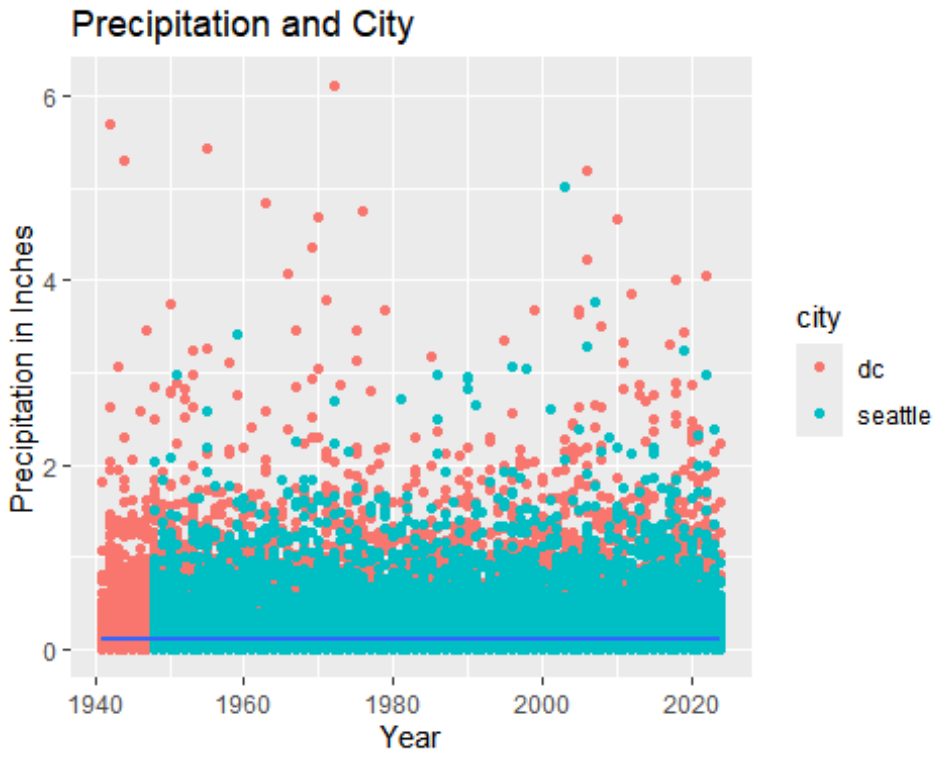
We can repeat this for Seattle.

```
sea_prcp <- table(seattle$prcp_day)

barplot(t(sea_prcp),
        main = "Percipitation Days in DC",
        col = c("gray"))
```



However, Seattle has an almost even number of precipitation vs no- precipitation days. DC has fewer days with either rain or snow.

```
comb <- rbind(dc, seattle)

options(scipen=999)
precip_corr <- ggplot(comb, aes(x=Year, y=PRCP..Inches.)) +
  geom_point(aes(col=city)) +
  geom_smooth(method="loess", se=F) +
  labs(title="Precipitation and City",
       y="Precipitation in Inches",
       x="Year")

plot(precip_corr)

## `geom_smooth()` using formula = 'y ~ x'
```



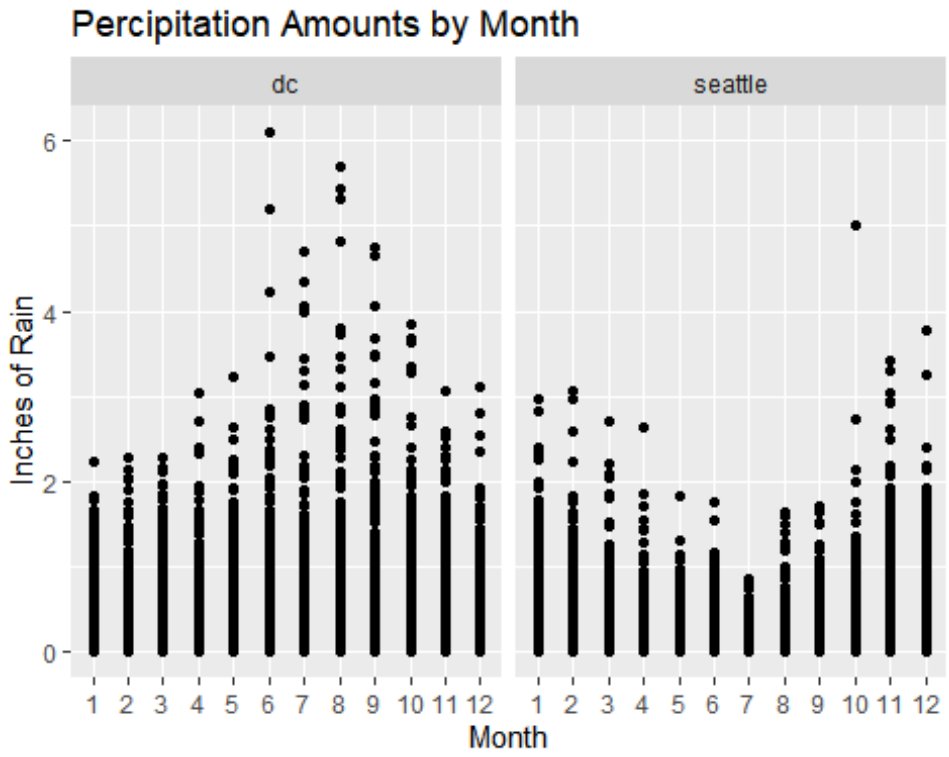
Here again, we see that there's not a huge amount of variation. However, overall, DC is surpassing Seattle in inches of precipitation year over year.

Visualizations

Next, we'll make a set of introductory graphs for each city:

#Precipitation by month

```
ggplot(comb, aes(x=factor(Month, level=c("1", "2", "3", "4", "5", "6", "7",
"8", "9", "10", "11", "12")), y=PRCP..Inches., group = Month)) +
  geom_point() +
  labs(title = "Percipitation Amounts by Month")+
  xlab("Month")+
  ylab("Inches of Rain")+
  facet_grid(. ~ city)
```

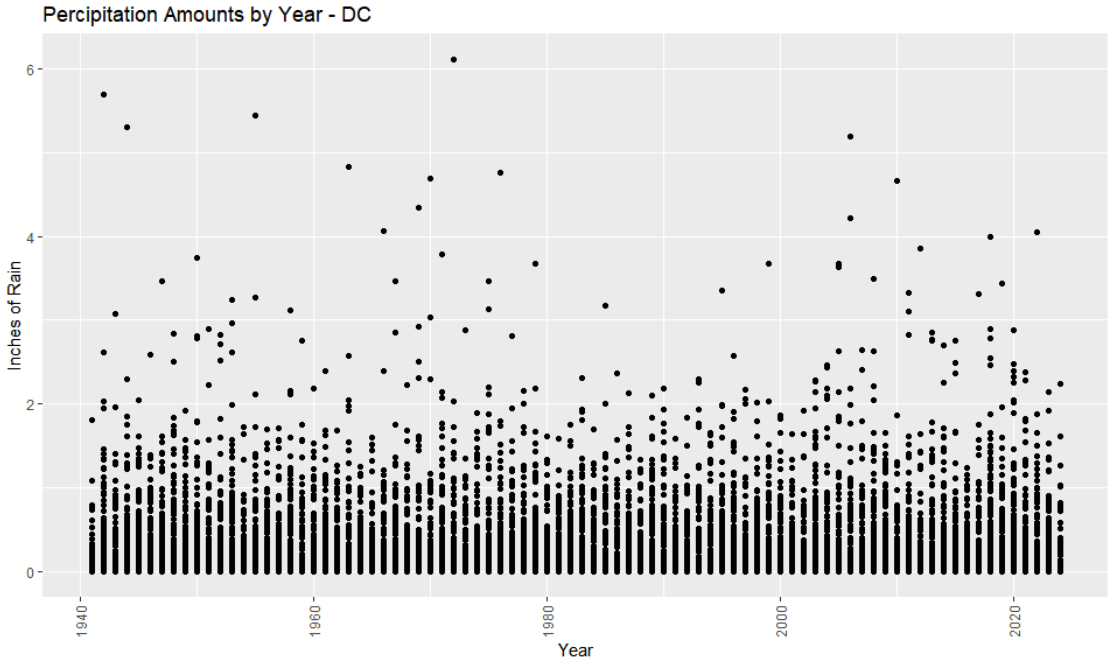


This graph counts inches of rain by month for each city. Here, we see that DC's rainiest months are in the summer, while Seattle's rainiest months are in the winter. DC also has more instances of 4 inches of rain or more than Seattle does.

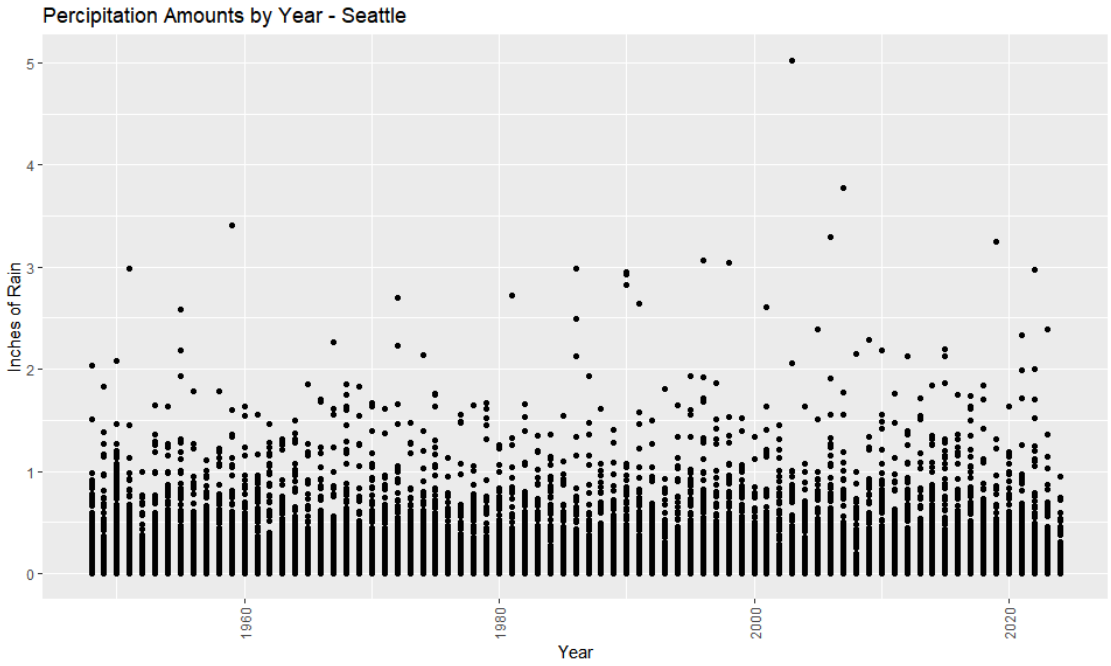
#Histogram of precipitation by year

We can take the comparative scatterplot above, and break it into a separate plot for both cities so we can see if there are any year over year trends.

```
ggplot(dc, aes(x=Year, y=PRCP..Inches., group = Month)) +
  geom_point() +
  labs(title = "Percipitation Amounts by Year - DC")+
  xlab("Year")+
  ylab("Inches of Rain")+
  theme(axis.text.x = element_text(angle=90, vjust=.5, hjust=1))
```




```r
ggplot(seattle, aes(x=Year, y=PRCP..Inches., group = Month)) +
  geom_point() +
  labs(title = "Percipitation Amounts by Year - Seattle")+
  xlab("Year")+
  ylab("Inches of Rain")+
  theme(axis.text.x = element_text(angle=90, vjust=.5, hjust=1))
```



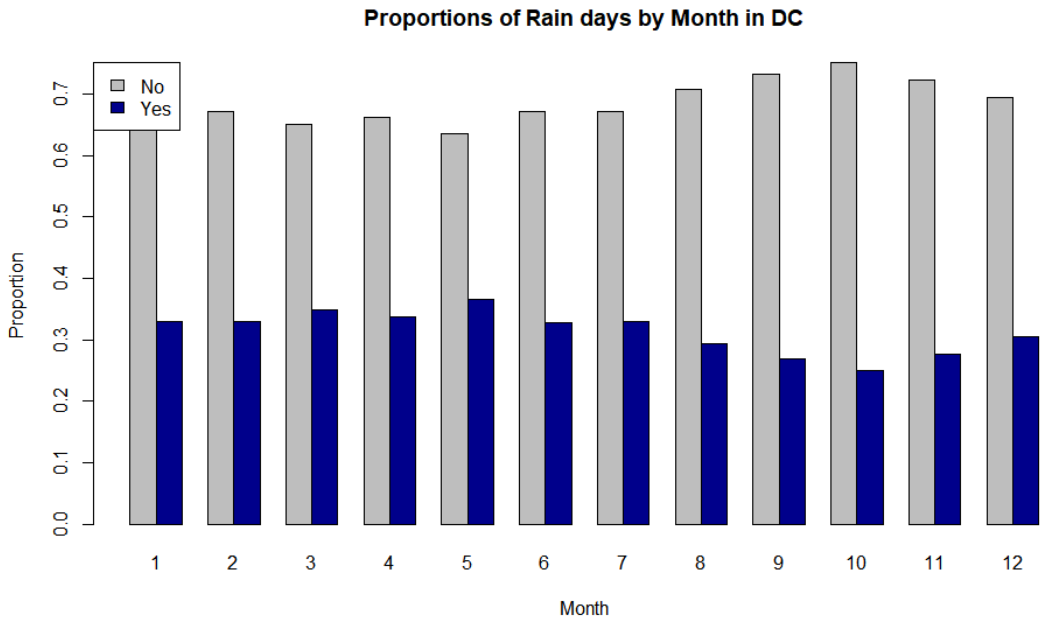
This graph looks at the inches of rain per year. Here again, the range of inches is wider in DC, so DC has more rainier years than Seattle does. There is just more rain falling in DC overall.

Next, we'll look at the number of precipitation days by month. This is based on the proportion tables we made above.

```
dc.crosstab.prop <- prop.table(table(dc$Month, dc$prcp_day),margin=1)
print(dc.crosstab.prop)
```

```
##
##             No       Yes
##   1  0.6708123 0.3291877
##   2  0.6707889 0.3292111
##   3  0.6509911 0.3490089
##   4  0.6622490 0.3377510
##   5  0.6343371 0.3656629
##   6  0.6715152 0.3284848
##   7  0.6704236 0.3295764
##   8  0.7073455 0.2926545
##   9  0.7321285 0.2678715
##   10 0.7504858 0.2495142
##   11 0.7232932 0.2767068
##   12 0.6945200 0.3054800
```

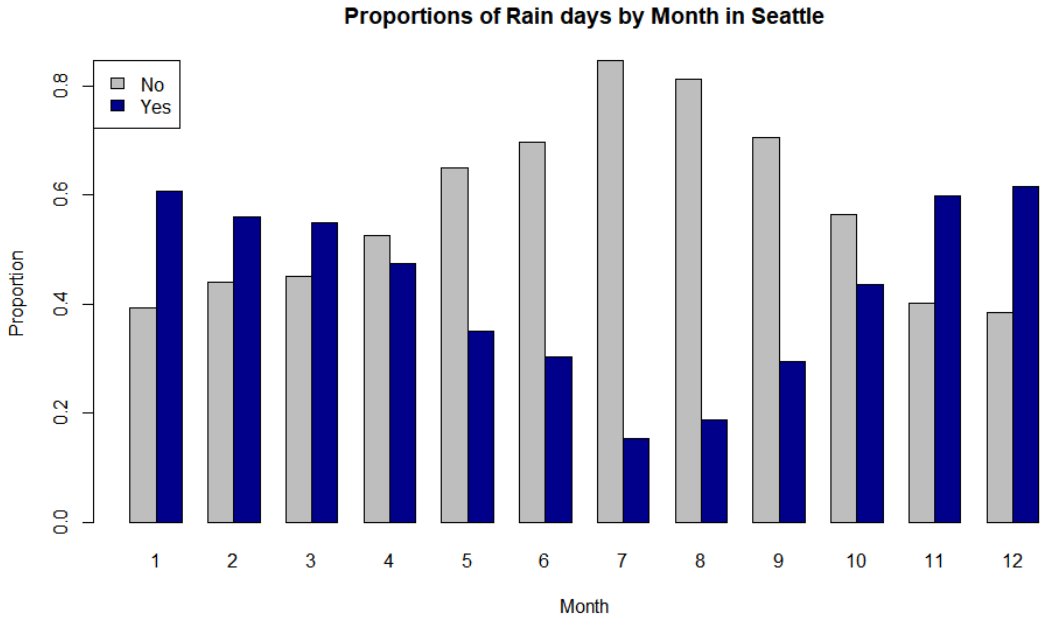
```
barplot(t(dc.crosstab.prop), beside = TRUE,
        main = "Proportions of Rain days by Month in DC",
        xlab = "Month", ylab = "Proportion",
        col = c("gray", "darkblue"))

legend("topleft", legend = colnames(dc.crosstab.prop),
       fill =  c("gray", "darkblue"))
```




```
seattle.crosstab.prop <- prop.table(table(seattle$Month,
seattle$prcp_day),margin=1)
print(seattle.crosstab.prop)
```

```
##
##             No       Yes
##    1  0.3929619 0.6070381
##    2  0.4393382 0.5606618
##    3  0.4507750 0.5492250
##    4  0.5251082 0.4748918
##    5  0.6495150 0.3504850
##    6  0.6978070 0.3021930
##    7  0.8463497 0.1536503
##    8  0.8119694 0.1880306
##    9  0.7052632 0.2947368
##    10 0.5632428 0.4367572
##    11 0.4008772 0.5991228
##    12 0.3853990 0.6146010
```

```
barplot(t(seattle.crosstab.prop), beside = TRUE,
        main = "Proportions of Rain days by Month in Seattle",
        xlab = "Month", ylab = "Proportion",
        col = c("gray", "darkblue"))

legend("topleft", legend = colnames(seattle.crosstab.prop),
       fill =  c("gray", "darkblue"))
```



Here again, we see that Seattle's rainiest months are in the winter, while DC's are in the spring and summer.

Next, we'll look at rain days by year.

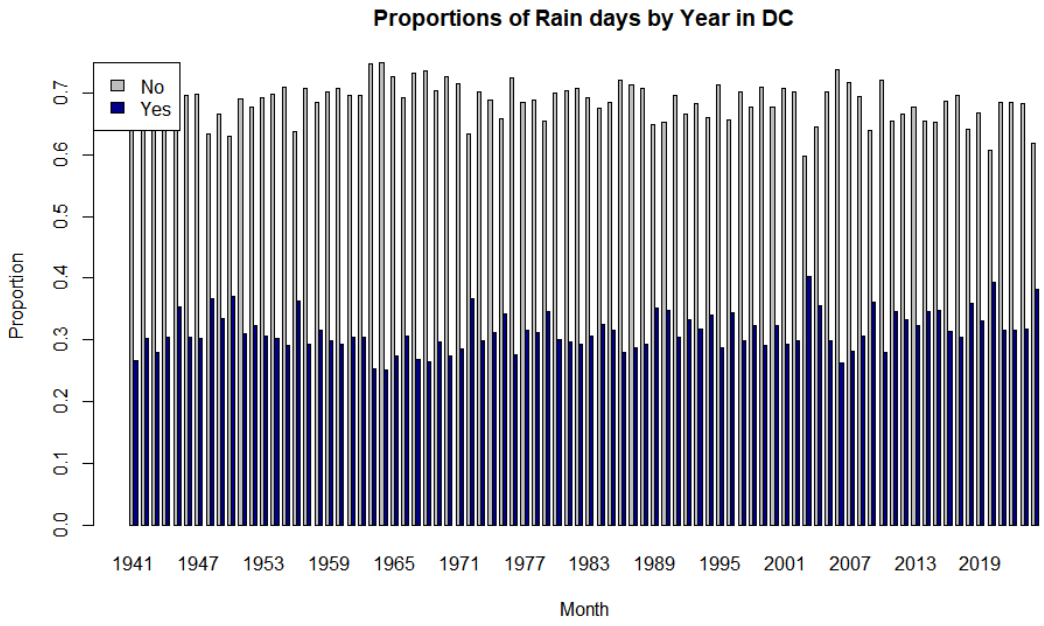
```
dc.crosstab.prop2 <- prop.table(table(dc$Year, dc$prcp_day),margin=1)
print(dc.crosstab.prop2)
```

```
##
##                No       Yes
##   1941 0.7336683 0.2663317
##   1942 0.6986301 0.3013699
##   1943 0.7205479 0.2794521
##   1944 0.6967213 0.3032787
##   1945 0.6465753 0.3534247
##   1946 0.6958904 0.3041096
##   1947 0.6986301 0.3013699
##   1948 0.6338798 0.3661202
##   1949 0.6657534 0.3342466
##   1950 0.6301370 0.3698630
##   1951 0.6904110 0.3095890
##   1952 0.6775956 0.3224044
##   1953 0.6931507 0.3068493
##   1954 0.6986301 0.3013699
##   1955 0.7095890 0.2904110
##   1956 0.6366120 0.3633880
##   1957 0.7068493 0.2931507
##   1958 0.6849315 0.3150685
##   1959 0.7013699 0.2986301
##   1960 0.7076503 0.2923497
```

```
##   1961 0.6958904 0.3041096
##   1962 0.6958904 0.3041096
##   1963 0.7479452 0.2520548
##   1964 0.7486339 0.2513661
##   1965 0.7260274 0.2739726
##   1966 0.6931507 0.3068493
##   1967 0.7315068 0.2684932
##   1968 0.7349727 0.2650273
##   1969 0.7041096 0.2958904
##   1970 0.7260274 0.2739726
##   1971 0.7150685 0.2849315
##   1972 0.6338798 0.3661202
##   1973 0.7013699 0.2986301
##   1974 0.6876712 0.3123288
##   1975 0.6575342 0.3424658
##   1976 0.7240437 0.2759563
##   1977 0.6849315 0.3150685
##   1978 0.6876712 0.3123288
##   1979 0.6547945 0.3452055
##   1980 0.6994536 0.3005464
##   1981 0.7041096 0.2958904
##   1982 0.7068493 0.2931507
##   1983 0.6931507 0.3068493
##   1984 0.6748634 0.3251366
##   1985 0.6849315 0.3150685
##   1986 0.7205479 0.2794521
##   1987 0.7123288 0.2876712
##   1988 0.7076503 0.2923497
##   1989 0.6493151 0.3506849
##   1990 0.6520548 0.3479452
##   1991 0.6958904 0.3041096
##   1992 0.6666667 0.3333333
##   1993 0.6821918 0.3178082
##   1994 0.6602740 0.3397260
##   1995 0.7123288 0.2876712
##   1996 0.6557377 0.3442623
##   1997 0.7013699 0.2986301
##   1998 0.6767123 0.3232877
##   1999 0.7095890 0.2904110
##   2000 0.6775956 0.3224044
##   2001 0.7068493 0.2931507
##   2002 0.7013699 0.2986301
##   2003 0.5972603 0.4027397
##   2004 0.6448087 0.3551913
##   2005 0.7013699 0.2986301
##   2006 0.7369863 0.2630137
##   2007 0.7178082 0.2821918
##   2008 0.6939891 0.3060109
##   2009 0.6383562 0.3616438
##   2010 0.7205479 0.2794521
```

```
##   2011 0.6547945 0.3452055
##   2012 0.6666667 0.3333333
##   2013 0.6767123 0.3232877
##   2014 0.6547945 0.3452055
##   2015 0.6520548 0.3479452
##   2016 0.6857923 0.3142077
##   2017 0.6958904 0.3041096
##   2018 0.6410959 0.3589041
##   2019 0.6684932 0.3315068
##   2020 0.6065574 0.3934426
##   2021 0.6849315 0.3150685
##   2022 0.6849315 0.3150685
##   2023 0.6821918 0.3178082
##   2024 0.6176471 0.3823529
```

```
barplot(t(dc.crosstab.prop2), beside = TRUE,
        main = "Proportions of Rain days by Year in DC",
        xlab = "Month", ylab = "Proportion",
        col = c("gray", "darkblue"))

legend("topleft", legend = colnames(dc.crosstab.prop2),
       fill =  c("gray", "darkblue"))
```

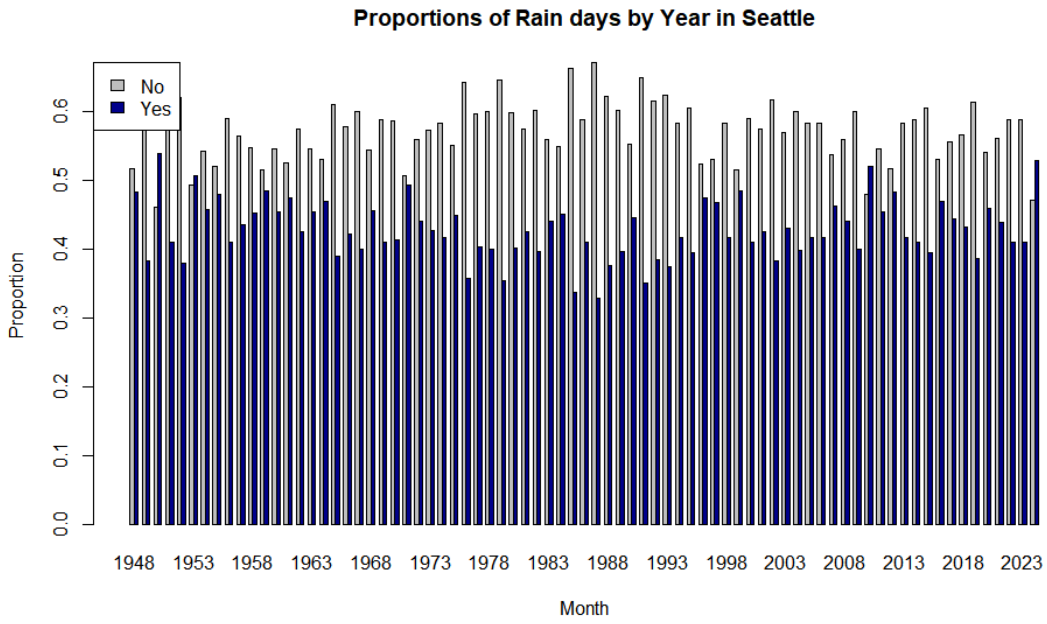



```
seattle.crosstab.prop2 <- prop.table(table(seattle$Year,
seattle$prcp_day),margin=1)
print(seattle.crosstab.prop2)
```

```
##
##               No       Yes
##   1948 0.5163934 0.4836066
```

```
##   1949 0.6164384 0.3835616
##   1950 0.4602740 0.5397260
##   1951 0.5890411 0.4109589
##   1952 0.6202186 0.3797814
##   1953 0.4931507 0.5068493
##   1954 0.5424658 0.4575342
##   1955 0.5205479 0.4794521
##   1956 0.5901639 0.4098361
##   1957 0.5643836 0.4356164
##   1958 0.5479452 0.4520548
##   1959 0.5150685 0.4849315
##   1960 0.5464481 0.4535519
##   1961 0.5260274 0.4739726
##   1962 0.5753425 0.4246575
##   1963 0.5452055 0.4547945
##   1964 0.5300546 0.4699454
##   1965 0.6109589 0.3890411
##   1966 0.5780822 0.4219178
##   1967 0.6000000 0.4000000
##   1968 0.5437158 0.4562842
##   1969 0.5890411 0.4109589
##   1970 0.5863014 0.4136986
##   1971 0.5068493 0.4931507
##   1972 0.5601093 0.4398907
##   1973 0.5726027 0.4273973
##   1974 0.5835616 0.4164384
##   1975 0.5506849 0.4493151
##   1976 0.6420765 0.3579235
##   1977 0.5972603 0.4027397
##   1978 0.6000000 0.4000000
##   1979 0.6465753 0.3534247
##   1980 0.5983607 0.4016393
##   1981 0.5753425 0.4246575
##   1982 0.6027397 0.3972603
##   1983 0.5589041 0.4410959
##   1984 0.5491803 0.4508197
##   1985 0.6630137 0.3369863
##   1986 0.5890411 0.4109589
##   1987 0.6712329 0.3287671
##   1988 0.6229508 0.3770492
##   1989 0.6027397 0.3972603
##   1990 0.5534247 0.4465753
##   1991 0.6493151 0.3506849
##   1992 0.6147541 0.3852459
##   1993 0.6246575 0.3753425
##   1994 0.5835616 0.4164384
##   1995 0.6054795 0.3945205
##   1996 0.5245902 0.4754098
##   1997 0.5315068 0.4684932
##   1998 0.5835616 0.4164384
```

```
##   1999 0.5150685 0.4849315
##   2000 0.5901639 0.4098361
##   2001 0.5753425 0.4246575
##   2002 0.6164384 0.3835616
##   2003 0.5698630 0.4301370
##   2004 0.6010929 0.3989071
##   2005 0.5835616 0.4164384
##   2006 0.5835616 0.4164384
##   2007 0.5369863 0.4630137
##   2008 0.5601093 0.4398907
##   2009 0.6000000 0.4000000
##   2010 0.4794521 0.5205479
##   2011 0.5452055 0.4547945
##   2012 0.5163934 0.4836066
##   2013 0.5835616 0.4164384
##   2014 0.5890411 0.4109589
##   2015 0.6054795 0.3945205
##   2016 0.5300546 0.4699454
##   2017 0.5561644 0.4438356
##   2018 0.5671233 0.4328767
##   2019 0.6136986 0.3863014
##   2020 0.5409836 0.4590164
##   2021 0.5616438 0.4383562
##   2022 0.5890411 0.4109589
##   2023 0.5890411 0.4109589
##   2024 0.4705882 0.5294118

barplot(t(seattle.crosstab.prop2), beside = TRUE,
        main = "Proportions of Rain days by Year in Seattle",
        xlab = "Month", ylab = "Proportion",
        col = c("gray", "darkblue"))

legend("topleft", legend = colnames(seattle.crosstab.prop2),
       fill =  c("gray", "darkblue"))
```



Overall, the proportion of rainy to non-rainy days are consistent from year to year. But you can see some drought years, and some rainy years. Here again, the proportion of rainy to non-rainy days in Seattle is much more equal than in DC. DC has fewer rainy days. This graph highlights the starker contrast between the number of days with precipitation vs without precipitation in DC as compared to Seattle. There are more days without rain in DC than there are in Seattle.

Now that we've seen that there ARE differences in the amount and proportion of precipitation days and inches of precipitation between DC and Seattle, we have to see if that is statistically significantly.

This is an ANOVA of city and Rainfall.

```
#ANOVA
out_percip <- aov(comb$PRCP..Inches.~comb$city)
PostHocTest(out_percip,method="lsd")

##
##   Posthoc multiple comparisons of means : Fisher LSD
##     95% family-wise confidence level
##
## $`comb$city`
##                     diff       lwr.ci       upr.ci   pval
## seattle-dc -0.004119603 -0.008712911 0.0004737045 0.0788 .
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
#Chi-Squared
prcp_tab <- table(comb$prcp_day, comb$city)
print(prcp_tab)
```

```
##
##          dc seattle
##   No  20794   15978
##   Yes  9491   11917
```

```r
chisq.test(prcp_tab)
```

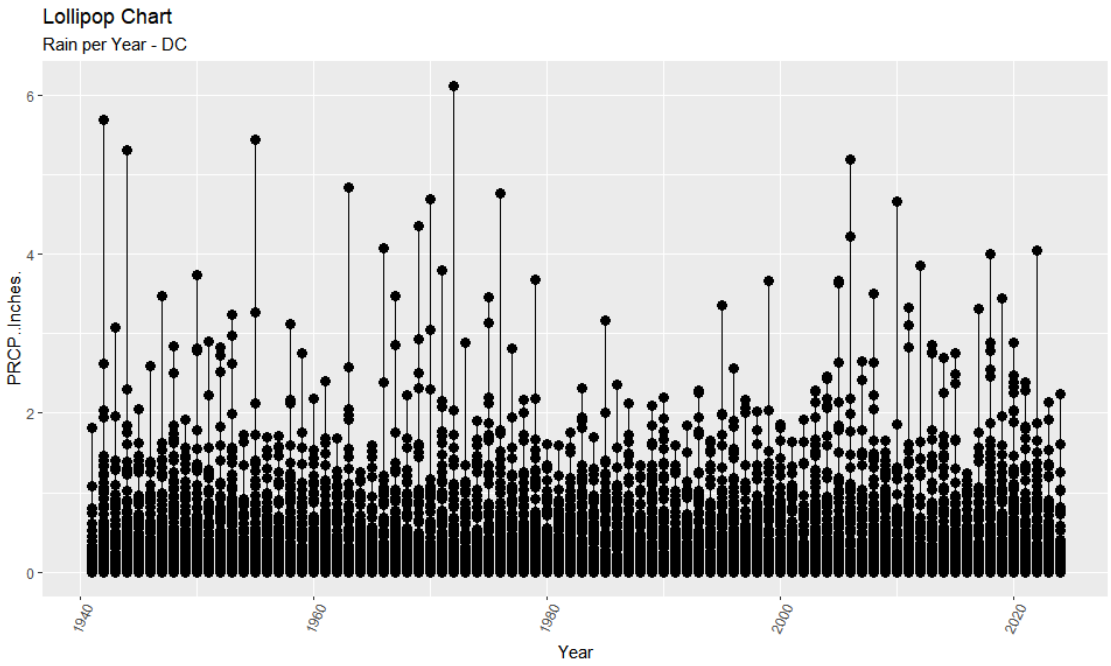
```
##
##  Pearson's Chi-squared test with Yates' continuity correction
##
## data:  prcp_tab
## X-squared = 808.36, df = 1, p-value < 0.00000000000000022
```

The interaction of city and inches and days of precipitation is significant! This means that there IS a difference between DC and Seattle in terms of both the number of precipitation days, and the actual amount of precipitation received.

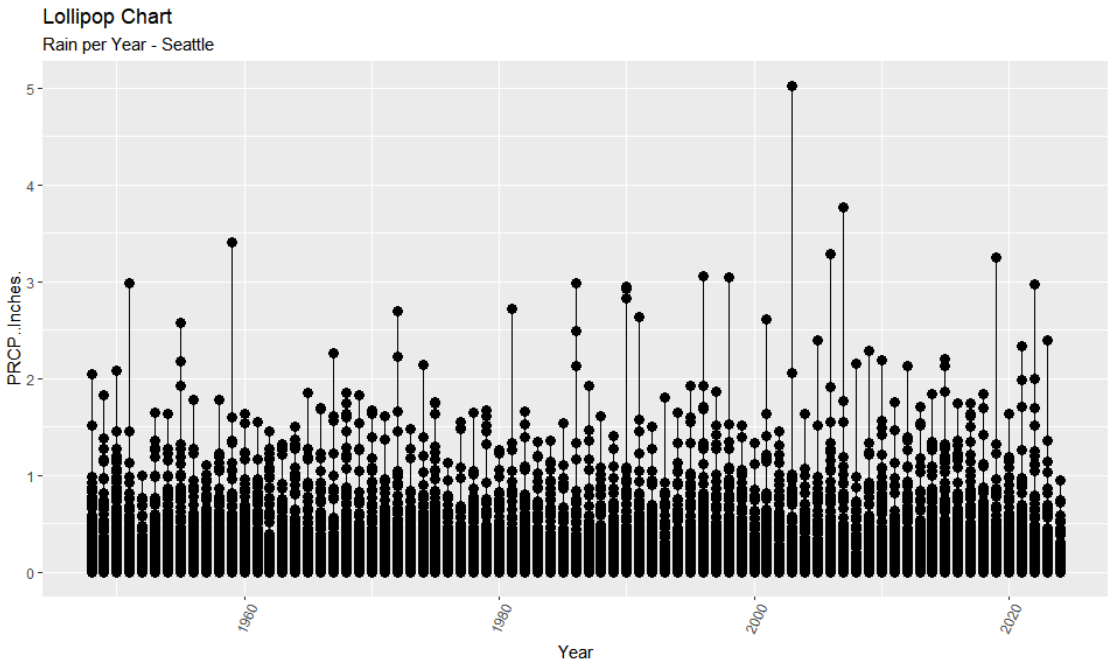
Now we can move on to some fancy graphs.

First! This is a lollipop graph of years with above average rainfall.

```r
ggplot(dc, aes(x=Year, y=PRCP..Inches.)) +
  geom_point(size=3) +
  geom_segment(aes(x=Year,
                   xend=Year,
                   y=0,
                   yend=PRCP..Inches.)) +
  labs(title="Lollipop Chart",
       subtitle="Rain per Year - DC") +
  theme(axis.text.x = element_text(angle=65, vjust=0.6))
```




```
ggplot(seattle, aes(x=Year, y=PRCP..Inches.)) +
  geom_point(size=3) +
  geom_segment(aes(x=Year,
                   xend=Year,
                   y=0,
                   yend=PRCP..Inches.)) +
  labs(title="Lollipop Chart",
       subtitle="Rain per Year - Seattle ") +
  theme(axis.text.x = element_text(angle=65, vjust=0.6))
```

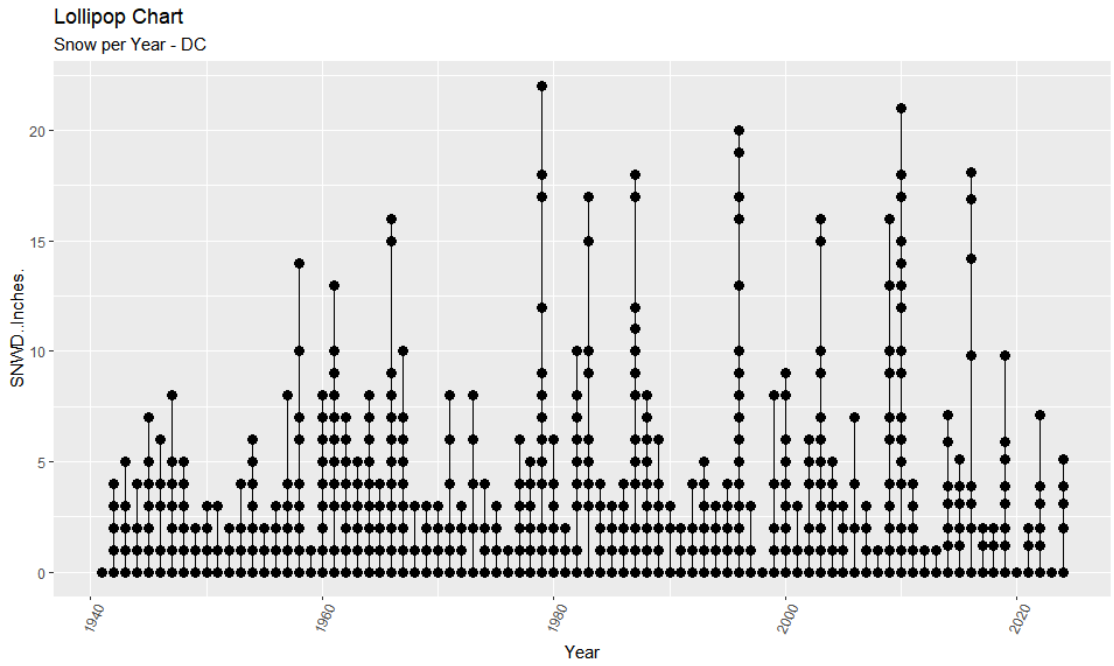


This graph looks very similar to the one above. But the lollipop ends are fun.

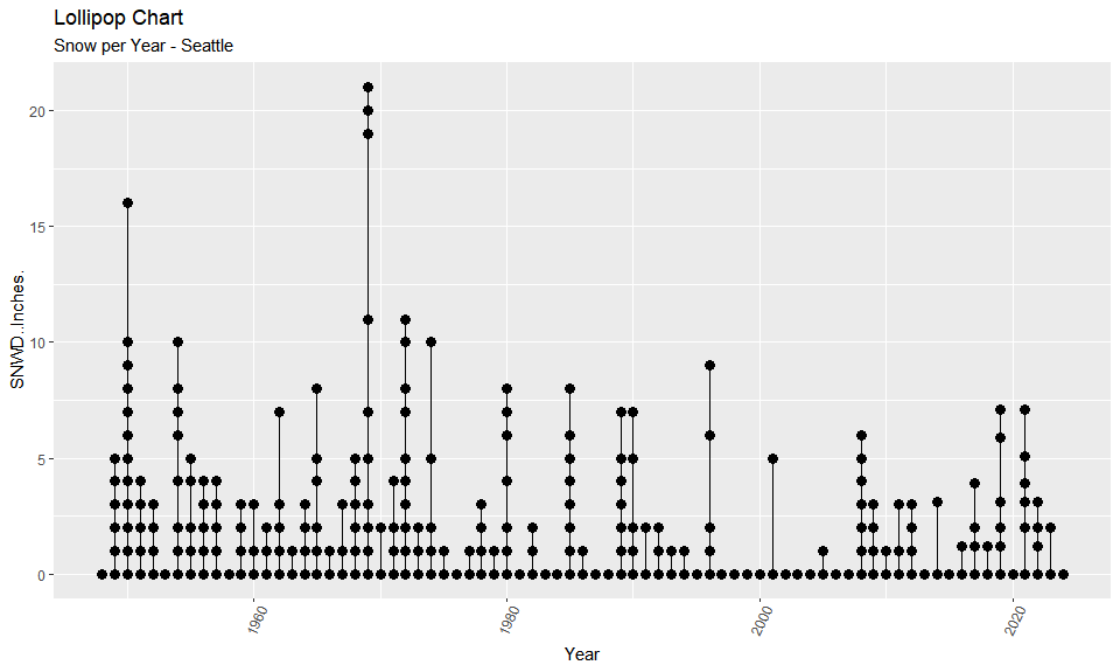
#Snow

Now, we can take a quick look at the amount of snow, specifically. Until now, we've been lopping snow and rain in together.

```
ggplot(dc, aes(x=Year, y=SNWD..Inches.)) +
  geom_point(size=3) +
  geom_segment(aes(x=Year,
                   xend=Year,
                   y=0,
                   yend=SNWD..Inches.)) +
  labs(title="Lollipop Chart",
       subtitle="Snow per Year - DC") +
  theme(axis.text.x = element_text(angle=65, vjust=0.6))
```




```
ggplot(seattle, aes(x=Year, y=SNWD..Inches.)) +
  geom_point(size=3) +
  geom_segment(aes(x=Year,
                   xend=Year,
                   y=0,
                   yend=SNWD..Inches.)) +
  labs(title="Lollipop Chart",
       subtitle="Snow per Year - Seattle") +
  theme(axis.text.x = element_text(angle=65, vjust=0.6))
```



DC is getting more snow over the last few years, but Seattle is getting less. DC also gets more snow on average overall. It's snowier in DC. This makes sense given what we've seen; DC has a more extreme climate compared to Seattle's more mild climate.

Predicting City based on rain

As a final step we can see if it's possible to use the weather data available to predict the city. This will confirm if the two cities do have significantly different weather; different enough to use it to indicate one city vs the other.

Because we are predicting between cities, we'll use classification models. There are a couple different ones we could choose. Let's try a couple different ones.

Logistic Model

The first model is going to be a Logistic Model. First, let's set up the data. For log models, we can use 0 and 1 for prediction. That's a little weird for our scenario, but, in this case DC is 0 and Seattle is 1.

```
comb1 <- comb[,c("TAVG..Degrees.Fahrenheit.", "TMAX..Degrees.Fahrenheit.",
                 "TMIN..Degrees.Fahrenheit.", "PRCP..Inches.",
"SNOW..Inches.", "SNWD..Inches.",
                 "city", "Month", "Day", "Year", "pred", "prcp_day")]

comb1 <- na.exclude(comb1)
set.seed(1234)

comb1$city <- ifelse(comb1$city == "dc", 0, 1)

#test and train
train1 <- sample(1:nrow(comb1), 0.7 * nrow(comb1)) # Train index vector
test1 <- seq(1:nrow(comb1))[-train1] # Test index vector

#the model
log.city <- glm(city ~ PRCP..Inches. + prcp_day + SNOW..Inches. +
SNWD..Inches. + Month + Day + Year + TAVG..Degrees.Fahrenheit., family =
binomial(link = "logit"), data = comb1[train1,])

log.city <- glm(city ~ PRCP..Inches. + prcp_day + SNOW..Inches. +
SNWD..Inches. + Month + Day + Year + TAVG..Degrees.Fahrenheit., family =
"binomial", data = comb1[train1,])

summary(log.city)

##
## Call:
## glm(formula = city ~ PRCP..Inches. + prcp_day + SNOW..Inches. +
##     SNWD..Inches. + Month + Day + Year + TAVG..Degrees.Fahrenheit.,
```

```
##     family = "binomial", data = comb1[train1, ])
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -4.0912  -0.9052  -0.1988   0.9756   3.6093
##
## Coefficients:
##                              Estimate  Std. Error z value
Pr(>|z|)
## (Intercept)               -11.8073895   1.0121121 -11.666 <
0.0000000000000002
## PRCP..Inches.              -0.6264419   0.0513618 -12.197 <
0.0000000000000002
## prcp_dayYes                 0.5570229   0.0273224  20.387 <
0.0000000000000002
## SNOW..Inches.              -0.2147844   0.0417723  -5.142
0.000000272
## SNWD..Inches.              -0.2800487   0.0270636 -10.348 <
0.0000000000000002
## Month                       0.1611490   0.0040303  39.984 <
0.0000000000000002
## Day                         0.0029197   0.0012671   2.304
0.0212
## Year                        0.0101924   0.0005145  19.810 <
0.0000000000000002
## TAVG..Degrees.Fahrenheit.  -0.1740443   0.0024968 -69.707 <
0.0000000000000002
##
## (Intercept)               ***
## PRCP..Inches.             ***
## prcp_dayYes               ***
## SNOW..Inches.             ***
## SNWD..Inches.             ***
## Month                     ***
## Day                       *
## Year                      ***
## TAVG..Degrees.Fahrenheit. ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 56399  on 40720  degrees of freedom
## Residual deviance: 46955  on 40712  degrees of freedom
## AIC: 46973
##
## Number of Fisher Scoring iterations: 5
```

```
logs <- c("2LL" = -2 * logLik(log.city), "Deviance" = deviance(log.city),
"AIC" = AIC(log.city))
logs
```

```
##      2LL Deviance      AIC
## 46955.15 46955.15 46973.15
```

```
log.odds <- coef(log.city) # Log-odds coefficients
odds <- exp(coef(log.city)) # Converted to odds

round(cbind("Log-Odds" = log.odds, "Odds" = odds), digits = 3)
```

```
##                            Log-Odds  Odds
## (Intercept)                 -11.807 0.000
## PRCP..Inches.                -0.626 0.534
## prcp_dayYes                   0.557 1.745
## SNOW..Inches.                -0.215 0.807
## SNWD..Inches.                -0.280 0.756
## Month                         0.161 1.175
## Day                           0.003 1.003
## Year                          0.010 1.010
## TAVG..Degrees.Fahrenheit.    -0.174 0.840
```

From this model, we can see that all of the variables used are incredibly significant, except for Day, which is slightly less significant, but still significant.

We can see that every increase in the temperature decreases the probability of the city being Seattle, as does increases in the presence of snow, while increases in the other variables increase the probability of the city in question being Seattle.

Let's see how the model does with predictions and how accurate it is.

```
#McFadden R-Squared
pscl::pR2(log.city)["McFadden"]
```

```
## fitting null model for pseudo-r2
```

```
##  McFadden
## 0.1674536
```

```
#VarImp
caret::varImp(log.city)
```

```
##                              Overall
## PRCP..Inches.              12.196647
## prcp_dayYes                20.387066
## SNOW..Inches.               5.141787
## SNWD..Inches.              10.347781
## Month                      39.983986
## Day                         2.304242
## Year                       19.809827
## TAVG..Degrees.Fahrenheit. 69.707471
```

```r
#VIF
car::vif(log.city)
```

```
##             PRCP..Inches.                   prcp_day
SNOW..Inches.
##                  1.396101                   1.405687
1.098670
##             SNWD..Inches.                      Month
Day
##                  1.088666                   1.525571
1.001476
##                      Year TAVG..Degrees.Fahrenheit.
##                  1.018901                   1.549843
```

```r
#ROC
suppressMessages({library(ROCR)})
```

```
## Warning: package 'ROCR' was built under R version 4.2.3
```

```r
comb.test1 <- comb1[test1,]
predicted1 <- predict(log.city, comb.test1, type = "response")
names(predicted1)
```

```
##     [1] "1750"   "1752"   "1753"   "1764"   "1770"   "1771"   "1783"
"1785"
##     [9] "1786"   "1787"   "1788"   "1797"   "1798"   "1801"   "1808"
"1813"
##    [17] "1814"   "1815"   "1816"   "1823"   "1824"   "1825"   "1827"
"1828"
##    [25] "1829"   "1833"   "1838"   "1840"   "1841"   "1854"   "1858"
"1864"
##    [33] "1865"   "1866"   "1867"   "1871"   "1872"   "1878"   "1880"
"1881"
##    [41] "1886"   "1891"   "1892"   "1896"   "1897"   "1909"   "1911"
"1912"
##    [49] "1913"   "1921"   "1926"   "1927"   "1941"   "1946"   "1947"
"1949"
##    [57] "1953"   "1955"   "1958"   "1959"   "1960"   "1961"   "1962"
"1963"
##    [65] "1968"   "1969"   "1976"   "1985"   "1988"   "2001"   "2002"
"2006"
##    [73] "2018"   "2020"   "2021"   "2023"   "2030"   "2031"   "2034"
"2035"
##    [81] "2037"   "2044"   "2048"   "2051"   "2061"   "2062"   "2068"
"2070"
##    [89] "2072"   "2077"   "2083"   "2084"   "2088"   "2096"   "2098"
"2100"
##    [97] "2102"   "2103"   "2104"   "2106"   "2107"   "2110"   "2111"
"2112"
##   [105] "2113"   "2115"   "2119"   "2120"   "2121"   "2122"   "2130"
"2133"
```

```
##   [113] "2136"   "2146"   "2149"   "2150"   "2152"   "2155"   "2158"
"2160"
##   [121] "2166"   "2179"   "2182"   "2183"   "2184"   "2185"   "2186"
"2194"
##   [129] "2195"   "2197"   "2200"   "2202"   "2203"   "2204"   "2205"
"2208"
##   [137] "2217"   "2223"   "2226"   "2228"   "2233"   "2238"   "2240"
"2242"
##   [145] "2247"   "2248"   "2251"   "2253"   "2260"   "2263"   "2266"
"2268"
##   [153] "2271"   "2274"   "2279"   "2282"   "2284"   "2285"   "2286"
"2287"
##   [161] "2288"   "2291"   "2292"   "2293"   "2300"   "2302"   "2303"
"2307"
##   [169] "2308"   "2311"   "2314"   "2315"   "2318"   "2321"   "2325"
"2335"
##   [177] "2336"   "2342"   "2346"   "2348"   "2353"   "2354"   "2360"
"2363"
##   [185] "2367"   "2368"   "2369"   "2374"   "2379"   "2380"   "2384"
"2387"
##   [193] "2392"   "2394"   "2396"   "2398"   "2401"   "2406"   "2409"
"2410"
##   [201] "2418"   "2419"   "2424"   "2429"   "2432"   "2442"   "2447"
"2452"
##   [209] "2453"   "2460"   "2468"   "2471"   "2472"   "2473"   "2478"
"2479"
##   [217] "2482"   "2485"   "2486"   "2491"   "2493"   "2495"   "2500"
"2502"
##   [225] "2503"   "2504"   "2505"   "2507"   "2511"   "2535"   "2538"
"2543"
##   [233] "2547"   "2551"   "2563"   "2564"   "2569"   "2570"   "2572"
"2574"
##   [241] "2575"   "2578"   "2579"   "2584"   "2585"   "2591"   "2592"
"2596"
##   [249] "2598"   "2601"   "2606"   "2610"   "2618"   "2619"   "2627"
"2629"
##   [257] "2633"   "2635"   "2638"   "2639"   "2647"   "2649"   "2652"
"2655"
##   [265] "2659"   "2661"   "2669"   "2671"   "2676"   "2680"   "2685"
"2688"
##   [273] "2689"   "2693"   "2694"   "2696"   "2702"   "2706"   "2707"
"2708"
##   [281] "2711"   "2713"   "2716"   "2718"   "2719"   "2727"   "2728"
"2731"
##   [289] "2732"   "2735"   "2736"   "2740"   "2742"   "2746"   "2748"
"2751"
##   [297] "2753"   "2762"   "2769"   "2773"   "2775"   "2776"   "2777"
"2778"
##   [305] "2782"   "2784"   "2786"   "2787"   "2789"   "2792"   "2796"
"2797"
```

```
##   [313] "2801"   "2805"   "2806"   "2807"   "2808"   "2809"   "2810"
"2812"
##   [321] "2813"   "2816"   "2817"   "2822"   "2823"   "2825"   "2826"
"2834"
##   [329] "2836"   "2839"   "2841"   "2844"   "2848"   "2849"   "2856"
"2857"
##   [337] "2858"   "2859"   "2861"   "2863"   "2866"   "2870"   "2873"
"2882"
##   [345] "2891"   "2894"   "2897"   "2900"   "2906"   "2907"   "2911"
"2912"
##   [353] "2915"   "2916"   "2919"   "2924"   "2925"   "2928"   "2929"
"2930"
##   [361] "2933"   "2953"   "2956"   "2957"   "2960"   "2963"   "2965"
"2970"
##   [369] "2972"   "2975"   "2976"   "2978"   "2982"   "2983"   "2987"
"2995"
##   [377] "2996"   "2998"   "3003"   "3011"   "3013"   "3018"   "3020"
"3022"
##   [385] "3024"   "3026"   "3027"   "3030"   "3031"   "3036"   "3038"
"3041"
##   [393] "3043"   "3044"   "3046"   "3047"   "3049"   "3055"   "3059"
"3060"
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```

```
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"278761"
## [17449] "278791" "278811" "278831" "278861" "278941"
```
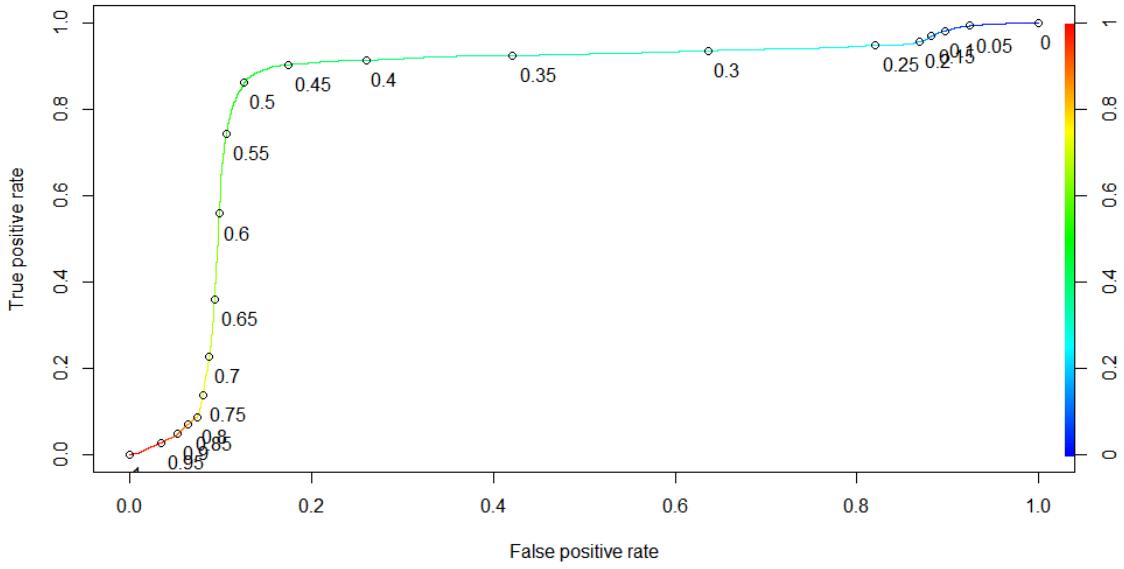

```r
roc_pred <- prediction(predictions = predicted1  , labels = comb.test1$city)
roc_perf <- performance(roc_pred , "tpr" , "fpr")
plot(roc_perf,
     colorize = TRUE,
     print.cutoffs.at= seq(0,1,0.05),
     text.adj=c(-0.2,1.7))
```



From the VarImp, we can see that the average temperature, month, and if it's a percipitation day are the most impactful for for prediction. However, that's kind of weird, and doesn't really make sense. Both DC and Seattle have the same days and months, and the model isn't powerful enough to navigate the correlations between date and weather. We should redo this without dates! However, despite the interaction of date and weather, the VIF reveals that there IS NOT a (severe) multicollinearity problem!

The ROC curve shows us that it's not a bad model!

LDA

Another popular classification model is Linear Discriminant Analysis.

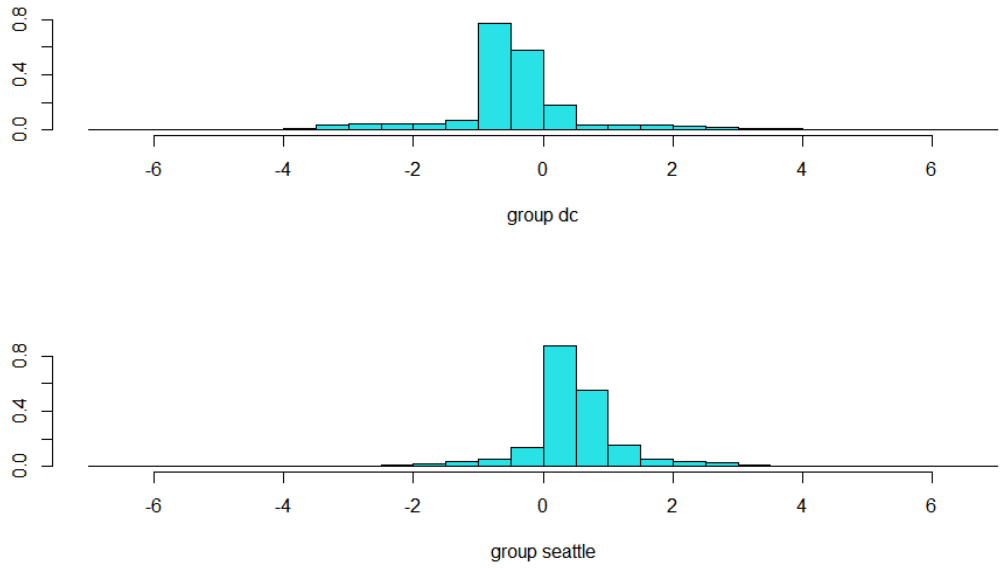
```
detach("package:klaR")
detach("package:MASS")


comb_pred1 <- comb %>% select(-c(Date, date_split))
comb_pred1$city <- as.factor(comb_pred1$city)

library(klaR)

## Warning: package 'klaR' was built under R version 4.2.3

## Loading required package: MASS

##
## Attaching package: 'MASS'
```

```
## The following object is masked from 'package:dplyr':
##
##     select
```

```
library(MASS) #masks dplyr!

#train and test sets
train <- sample(1:nrow(comb_pred1), 0.7 * nrow(comb_pred1)) # Train index
vector
test <- seq(1:nrow(comb_pred1))[-train] # Test index vector


#lda model
city.lda <- lda(city ~ PRCP..Inches. + prcp_day + SNOW..Inches. +
SNWD..Inches. +
                  Month + Day + Year + TAVG..Degrees.Fahrenheit. ,data =
comb_pred1[train,])
city.lda
```

```
## Call:
## lda(city ~ PRCP..Inches. + prcp_day + SNOW..Inches. + SNWD..Inches. +
##     Month + Day + Year + TAVG..Degrees.Fahrenheit., data =
comb_pred1[train,
##     ])
##
## Prior probabilities of groups:
##       dc  seattle
## 0.518293 0.481707
##
## Group means:
##         PRCP..Inches. prcp_dayYes SNOW..Inches. SNWD..Inches.    Month
Day
## dc          0.1105623   0.3122039    0.04401175    0.10896343 6.547044
15.69187
## seattle     0.1064094   0.4241513    0.02492609    0.04352635 6.515190
15.72072
##             Year TAVG..Degrees.Fahrenheit.
## dc      1982.295                  58.75202
## seattle 1985.718                  52.65922
##
## Coefficients of linear discriminants:
##                                    LD1
## PRCP..Inches.              -0.610687475
## prcp_dayYes                 0.647953224
## SNOW..Inches.              -0.168392595
## SNWD..Inches.              -0.207330175
## Month                       0.118956673
## Day                         0.002833143
## Year                        0.010174493
## TAVG..Degrees.Fahrenheit. -0.134081708
```

```r
#use model to make predictions
comb.test <- comb_pred1[test,]


predicted <- predict(city.lda, comb.test)
names(predicted)

## [1] "class"     "posterior" "x"

#accuracy of model
mean(predicted$class==comb.test$city)

## [1] 0.824281

#plotting the model
#define data to plot
lda_plot <- cbind(comb_pred1[train,], predict(city.lda)$x)

#histogram
p <- predict(city.lda, comb_pred1[train,])
ldahist(data = p$x[,1], g = comb_pred1[train,]$city)
```




```r
#partition plot
#partimat(city ~ PRCP..Inches. + prcp_day + SNOW..Inches. + SNWD..Inches. +
           #Month + Day + Year + TAVG..Degrees.Fahrenheit. ,data =
comb_pred1[train,],
         #method = "lda")

#confusion matrix
```

```
p1 <- predict(city.lda, comb.test)$class
tab <- table(Predicted = p1, Actual = comb.test$city)
tab
```

```
##           Actual
## Predicted   dc seattle
##   dc      7708    1598
##   seattle 1469    6679
```

```
#confusion matrix stats
TruN <- tab[1, 1] # True negatives;
TruP <- tab[2, 2] # True positives
FalN <- tab[1, 2] # False negatives;
FalP <- tab[2, 1] # False positives
TotN <- TruN + FalP  # Total negatives
TotP <- TruP + FalN  # Total positives
Tot <- TotN + TotP # Total

Accuracy.Rate <- (TruN + TruP) / Tot;
Error.Rate <- (FalN + FalP) / Tot
Sensitivity  <-  TruP / TotP;
Specificity <- TruN / TotN;
FalP.Rate <- 1 - Specificity

lda.rates.50 <- c(Accuracy.Rate, Error.Rate, Sensitivity, Specificity,
FalP.Rate)

names(lda.rates.50) <- c("Accuracy Rate", "Error Rate", "Sensitivity",
"Specificity", "False Positives")

lda.rates.50
```

```
##   Accuracy Rate      Error Rate     Sensitivity     Specificity False
Positives
##       0.8242810       0.1757190       0.8069349       0.8399259
0.1600741
```

This model is fairly accurate! So that's very exciting. It gets the right city from the weather data about 82% of the time. From the confusion matrix, we can see that the model predicts Seattle incorrectly as DC more often than it predicts DC as Seattle. It is very good at predicting DC accurately. Because DC was set as 0 and Seattle as 1, it is more often falling into a Type 1 error: falsely rejecting the null. In this case: falsely rejecting that the weather is from a city that isn't Seattle.

The two histograms show the overlap between the discriminant functions. LDA works by finding orthogonal, straight lines within a multidimensional data space. Ideally, there isn't any overlap, and it's able to clearly group the data points. We see from the histograms here, that this isn't the case. There is actually a good bit of overlap between DC and Seattle. This may explain the difficulties the model has correctly predicting Seattle.

Trees

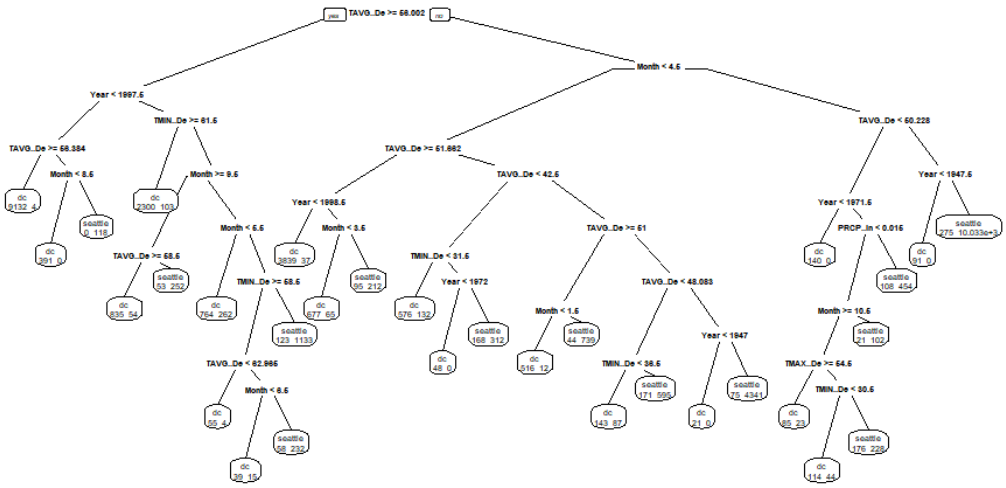
And finally, you can't have classification models without having trees!

```
detach("package:klaR")
detach("package:DescTools")
detach("package:caret")
detach("package:MASS")

comb1 <- comb %>% select(-c(Date, date_split, pred))
comb1[c('city')] <- sapply(comb1[c('city')], as.factor)

train <- sample(1:nrow(comb1), 0.7 * nrow(comb1)) # Train index vector
test <- seq(1:nrow(comb1))[-train] # Test index vector

comb1_train <- comb1[train,]
comb1_test <- comb1[test,]

tree <- rpart(city~., data=comb1_train, control=rpart.control(cp=.001))
printcp(tree)
```

```
##
## Classification tree:
## rpart(formula = city ~ ., data = comb1_train, control = rpart.control(cp =
0.001))
##
## Variables actually used in tree construction:
## [1] Month                       PRCP..Inches.
## [3] TAVG..Degrees.Fahrenheit. TMAX..Degrees.Fahrenheit.
## [5] TMIN..Degrees.Fahrenheit. Year
##
## Root node error: 19593/40726 = 0.48109
##
## n= 40726
##
##           CP nsplit rel error  xerror      xstd
## 1  0.5120706      0   1.00000 1.00000 0.0051463
## 2  0.1096565      1   0.48793 0.48798 0.0043656
## 3  0.0177614      3   0.26862 0.26994 0.0034624
## 4  0.0128617      4   0.25085 0.25249 0.0033647
## 5  0.0103268      6   0.22513 0.22779 0.0032174
## 6  0.0101567     10   0.16853 0.19206 0.0029827
## 7  0.0048997     11   0.15837 0.15960 0.0027423
## 8  0.0039300     12   0.15347 0.15679 0.0027201
## 9  0.0030113     15   0.14168 0.14347 0.0026110
## 10 0.0029858     17   0.13566 0.14015 0.0025828
## 11 0.0024499     19   0.12969 0.13403 0.0025297
## 12 0.0020415     20   0.12724 0.13193 0.0025112
## 13 0.0014291     22   0.12316 0.12627 0.0024603
## 14 0.0013270     24   0.12030 0.12453 0.0024444
```

```
## 15 0.0013015     26   0.11764 0.12300 0.0024303
## 16 0.0012249     28   0.11504 0.12234 0.0024242
## 17 0.0010718     29   0.11382 0.12091 0.0024108
## 18 0.0010000     30   0.11274 0.11805 0.0023839
```

```
best <- tree$cptable[which.min(tree$cptable[,"xerror"]),"CP"]

#produce a pruned tree based on the best cp value
pruned_tree <- prune(tree, cp=best)

#plot the pruned tree
prp(pruned_tree,
    faclen=0,
    extra=1,
    roundint=F,
    digits=5)
```




```
summary(pruned_tree)
```

```
## Call:
## rpart(formula = city ~ ., data = comb1_train, control = rpart.control(cp =
0.001))
##   n= 40726
##
##             CP nsplit rel error    xerror        xstd
## 1  0.512070637      0 1.0000000 1.0000000 0.005146290
## 2  0.109656510      1 0.4879294 0.4879804 0.004365645
## 3  0.017761445      3 0.2686163 0.2699433 0.003462410
## 4  0.012861736      4 0.2508549 0.2524881 0.003364715
## 5  0.010326817      6 0.2251314 0.2277854 0.003217425
## 6  0.010156689     10 0.1685296 0.1920584 0.002982730
## 7  0.004899709     11 0.1583729 0.1595978 0.002742302
## 8  0.003929975     12 0.1534732 0.1567907 0.002720065
```

```
## 9  0.003011280     15 0.1416833 0.1434696 0.002610953
## 10 0.002985760     17 0.1356607 0.1401521 0.002582801
## 11 0.002449855     19 0.1296892 0.1340275 0.002529723
## 12 0.002041545     20 0.1272393 0.1319349 0.002511247
## 13 0.001429082     22 0.1231562 0.1262696 0.002460312
## 14 0.001327005     24 0.1202981 0.1245343 0.002444433
## 15 0.001301485     26 0.1176441 0.1230031 0.002430311
## 16 0.001224927     28 0.1150411 0.1223396 0.002424158
## 17 0.001071811     29 0.1138162 0.1209105 0.002410838
## 18 0.001000000     30 0.1127443 0.1180524 0.002383911
##
## Variable importance
## TAVG..Degrees.Fahrenheit. TMIN..Degrees.Fahrenheit.
TMAX..Degrees.Fahrenheit.
##                        41                        19
17
##                     Month                      Year
PRCP..Inches.
##                        16                         7
1
##
## Node number 1: 40726 observations,    complexity param=0.5120706
##   predicted class=dc       expected loss=0.4810932  P(node) =1
##     class counts: 21133 19593
##    probabilities: 0.519 0.481
##   left son=2 (15927 obs) right son=3 (24799 obs)
##   Primary splits:
##       TAVG..Degrees.Fahrenheit. < 56.00189 to the right,
improve=6205.0540, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 60.5     to the right,
improve=3367.7850, (3 missing)
##       TMAX..Degrees.Fahrenheit. < 78.5     to the right,
improve=1850.4680, (3 missing)
##       Year                      < 1947.5   to the left,  improve=
788.4989, (0 missing)
##       PRCP..Inches.             < 0.005    to the left,  improve=
297.9224, (0 missing)
##   Surrogate splits:
##       TMIN..Degrees.Fahrenheit. < 55.5     to the right, agree=0.795,
adj=0.477, (0 split)
##       TMAX..Degrees.Fahrenheit. < 70.5     to the right, agree=0.777,
adj=0.429, (0 split)
##       Month                     < 4.5      to the right, agree=0.692,
adj=0.213, (0 split)
##       Year                      < 1947.5   to the left,  agree=0.616,
adj=0.018, (0 split)
##       PRCP..Inches.             < 1.215    to the right, agree=0.611,
adj=0.004, (0 split)
##
## Node number 2: 15927 observations,    complexity param=0.01032682
```

```
##   predicted class=dc       expected loss=0.1366861  P(node) =0.391077
##     class counts: 13750  2177
##    probabilities: 0.863 0.137
##   left son=4 (9645 obs) right son=5 (6282 obs)
##   Primary splits:
##       Year                       < 1997.5   to the left,
improve=752.43920, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 61.5     to the right,
improve=328.99460, (1 missing)
##       TMAX..Degrees.Fahrenheit. < 81.5     to the right,
improve=128.67160, (1 missing)
##       TAVG..Degrees.Fahrenheit. < 57.0004  to the right, improve=
71.67142, (0 missing)
##       Month                      < 9.5      to the right, improve=
33.24020, (0 missing)
##   Surrogate splits:
##       TAVG..Degrees.Fahrenheit. < 65.96912 to the left,  agree=0.752,
adj=0.371, (0 split)
##       Month                      < 4.5      to the right, agree=0.631,
adj=0.063, (0 split)
##       TMIN..Degrees.Fahrenheit. < 77.5     to the left,  agree=0.607,
adj=0.003, (0 split)
##       TMAX..Degrees.Fahrenheit. < 101.5    to the left,  agree=0.606,
adj=0.001, (0 split)
##       SNWD..Inches.             < 9        to the left,  agree=0.606,
adj=0.000, (0 split)
##
## Node number 3: 24799 observations,    complexity param=0.1096565
##   predicted class=seattle  expected loss=0.2977136  P(node) =0.608923
##     class counts:  7383 17416
##    probabilities: 0.298 0.702
##   left son=6 (12905 obs) right son=7 (11894 obs)
##   Primary splits:
##       Month                      < 4.5      to the left,
improve=2069.9720, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 32.5     to the left,
improve=1364.2860, (2 missing)
##       Year                       < 1947.5   to the left,  improve=
686.5434, (0 missing)
##       TMAX..Degrees.Fahrenheit. < 42.5     to the left,  improve=
640.0211, (2 missing)
##       TAVG..Degrees.Fahrenheit. < 37.5     to the left,  improve=
401.2974, (0 missing)
##   Surrogate splits:
##       TMIN..Degrees.Fahrenheit. < 44.5     to the left,  agree=0.745,
adj=0.469, (0 split)
##       TAVG..Degrees.Fahrenheit. < 51.5736  to the left,  agree=0.698,
adj=0.371, (0 split)
##       TMAX..Degrees.Fahrenheit. < 57.5     to the left,  agree=0.696,
adj=0.365, (0 split)
```

```
##       prcp_day                  splits as  RL,           agree=0.530,
adj=0.020, (0 split)
##       PRCP..Inches.             < 0.005    to the right, agree=0.529,
adj=0.019, (0 split)
##
## Node number 4: 9645 observations,    complexity param=0.00301128
##   predicted class=dc       expected loss=0.01264904  P(node) =0.2368266
##     class counts:  9523   122
##    probabilities: 0.987 0.013
##   left son=8 (9136 obs) right son=9 (509 obs)
##   Primary splits:
##       TAVG..Degrees.Fahrenheit. < 56.38379 to the right,
improve=51.628340, (0 missing)
##       Month                     < 11.5     to the left,
improve=20.501590, (0 missing)
##       TMAX..Degrees.Fahrenheit. < 52.5     to the right,
improve=16.149070, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 42.5     to the right, improve=
8.327751, (0 missing)
##       Year                      < 1984.5   to the left,  improve=
7.526779, (0 missing)
##   Surrogate splits:
##       Month < 4.5      to the right, agree=0.948, adj=0.016, (0 split)
##
## Node number 5: 6282 observations,    complexity param=0.01032682
##   predicted class=dc       expected loss=0.3271251  P(node) =0.1542504
##     class counts:  4227  2055
##    probabilities: 0.673 0.327
##   left son=10 (2403 obs) right son=11 (3879 obs)
##   Primary splits:
##       TMIN..Degrees.Fahrenheit. < 61.5     to the right,
improve=628.51420, (1 missing)
##       TMAX..Degrees.Fahrenheit. < 81.5     to the right,
improve=250.92610, (1 missing)
##       TAVG..Degrees.Fahrenheit. < 73.5     to the right,
improve=213.92350, (0 missing)
##       Year                      < 2012.5   to the left,  improve=
56.66294, (0 missing)
##       Month                     < 4.5      to the left,  improve=
47.68394, (0 missing)
##   Surrogate splits:
##       TMAX..Degrees.Fahrenheit. < 80.5     to the right, agree=0.859,
adj=0.633, (0 split)
##       TAVG..Degrees.Fahrenheit. < 72.5     to the right, agree=0.822,
adj=0.535, (1 split)
##       PRCP..Inches.             < 0.655    to the right, agree=0.622,
adj=0.012, (0 split)
##
## Node number 6: 12905 observations,    complexity param=0.1096565
##   predicted class=seattle  expected loss=0.4938396  P(node) =0.3168737
```

```
##     class counts:  6373  6532
##    probabilities: 0.494 0.506
##   left son=12 (4925 obs) right son=13 (7980 obs)
##   Primary splits:
##       TAVG..Degrees.Fahrenheit. < 51.66162 to the right,
improve=3117.6660, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 30.5     to the left,  improve=
531.4329, (1 missing)
##       TMAX..Degrees.Fahrenheit. < 62.5     to the right, improve=
335.8681, (0 missing)
##       PRCP..Inches.             < 0.005    to the left,  improve=
313.4668, (0 missing)
##       prcp_day                  splits as  LR,           improve=
310.0950, (0 missing)
##   Surrogate splits:
##       TMAX..Degrees.Fahrenheit. < 59.5     to the right, agree=0.703,
adj=0.222, (0 split)
##       TMIN..Degrees.Fahrenheit. < 46.5     to the right, agree=0.663,
adj=0.118, (0 split)
##       SNWD..Inches.             < 9.9      to the right, agree=0.620,
adj=0.003, (0 split)
##       SNOW..Inches.             < 13.65    to the right, agree=0.618,
adj=0.000, (0 split)
##
## Node number 7: 11894 observations,    complexity param=0.003929975
##   predicted class=seattle  expected loss=0.08491676  P(node) =0.2920493
##     class counts:  1010 10884
##    probabilities: 0.085 0.915
##   left son=14 (1495 obs) right son=15 (10399 obs)
##   Primary splits:
##       TAVG..Degrees.Fahrenheit. < 50.22793 to the left,
improve=409.06220, (0 missing)
##       Year                      < 1947.5   to the left,
improve=394.53070, (0 missing)
##       Month                     < 10.5     to the right,
improve=156.09930, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 40.5     to the left,
improve=122.47370, (1 missing)
##       TMAX..Degrees.Fahrenheit. < 64.5     to the left,  improve=
51.09588, (2 missing)
##   Surrogate splits:
##       Year                      < 2012.5   to the right, agree=0.900,
adj=0.203, (0 split)
##       TMIN..Degrees.Fahrenheit. < 26.5     to the left,  agree=0.875,
adj=0.007, (0 split)
##
## Node number 8: 9136 observations
##   predicted class=dc       expected loss=0.0004378284  P(node) =0.2243284
##     class counts:  9132     4
##    probabilities: 1.000 0.000
```

```
##
## Node number 9: 509 observations,    complexity param=0.00301128
##   predicted class=dc       expected loss=0.2318271  P(node) =0.01249816
##     class counts:   391   118
##    probabilities: 0.768 0.232
##   left son=18 (391 obs) right son=19 (118 obs)
##   Primary splits:
##       Month                      < 8.5      to the left,
improve=181.28880, (0 missing)
##       TMAX..Degrees.Fahrenheit. < 53.5     to the right,
improve=156.47550, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 42.5     to the right,
improve=123.42950, (0 missing)
##       Year                       < 1972     to the left,  improve=
98.29979, (0 missing)
##       Day                        < 18.5     to the left,  improve=
30.66891, (0 missing)
##   Surrogate splits:
##       TMAX..Degrees.Fahrenheit. < 53.5     to the right, agree=0.974,
adj=0.890, (0 split)
##       TMIN..Degrees.Fahrenheit. < 42.5     to the right, agree=0.935,
adj=0.720, (0 split)
##       Year                       < 1972     to the left,  agree=0.874,
adj=0.458, (0 split)
##       SNWD..Inches.              < 0.5      to the left,  agree=0.780,
adj=0.051, (0 split)
##       SNOW..Inches.              < 0.15     to the left,  agree=0.774,
adj=0.025, (0 split)
##
## Node number 10: 2403 observations
##   predicted class=dc       expected loss=0.04286309  P(node) =0.05900408
##     class counts:  2300   103
##    probabilities: 0.957 0.043
##
## Node number 11: 3879 observations,    complexity param=0.01032682
##   predicted class=seattle  expected loss=0.4967775  P(node) =0.09524628
##     class counts:  1927  1952
##    probabilities: 0.497 0.503
##   left son=22 (1194 obs) right son=23 (2685 obs)
##   Primary splits:
##       Month                      < 9.5      to the right,
improve=210.37610, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 49.5     to the left,
improve=111.25190, (1 missing)
##       Year                       < 2012.5   to the left,  improve=
66.07034, (0 missing)
##       TAVG..Degrees.Fahrenheit. < 56.26913 to the right, improve=
44.07923, (0 missing)
##       TMAX..Degrees.Fahrenheit. < 61.5     to the left,  improve=
39.21824, (1 missing)
```

```
##   Surrogate splits:
##       TMAX..Degrees.Fahrenheit. < 60.5     to the left,  agree=0.821,
adj=0.417, (0 split)
##       TMIN..Degrees.Fahrenheit. < 45.5     to the left,  agree=0.815,
adj=0.400, (0 split)
##       TAVG..Degrees.Fahrenheit. < 56.26913 to the left,  agree=0.716,
adj=0.076, (0 split)
##       SNWD..Inches.             < 0.5      to the right, agree=0.698,
adj=0.018, (0 split)
##       SNOW..Inches.             < 0.05     to the right, agree=0.698,
adj=0.018, (0 split)
##
## Node number 12: 4925 observations,    complexity param=0.00298576
##   predicted class=dc       expected loss=0.06375635  P(node) =0.1209301
##     class counts:  4611   314
##    probabilities: 0.936 0.064
##   left son=24 (3876 obs) right son=25 (1049 obs)
##   Primary splits:
##       Year                      < 1998.5   to the left,
improve=106.95720, (0 missing)
##       TAVG..Degrees.Fahrenheit. < 52.14194 to the right, improve=
73.43590, (0 missing)
##       Month                     < 3.5      to the left,  improve=
50.68141, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 40.5     to the left,  improve=
37.89801, (0 missing)
##       TMAX..Degrees.Fahrenheit. < 51.5     to the left,  improve=
20.34511, (0 missing)
##   Surrogate splits:
##       TAVG..Degrees.Fahrenheit. < 55.99998 to the left,  agree=0.798,
adj=0.051, (0 split)
##
## Node number 13: 7980 observations,    complexity param=0.01776145
##   predicted class=seattle  expected loss=0.220802  P(node) =0.1959436
##     class counts:  1762  6218
##    probabilities: 0.221 0.779
##   left son=26 (1236 obs) right son=27 (6744 obs)
##   Primary splits:
##       TAVG..Degrees.Fahrenheit. < 42.5     to the left,  improve=515.9172,
(0 missing)
##       TMIN..Degrees.Fahrenheit. < 31.5     to the left,  improve=437.9549,
(1 missing)
##       Year                      < 1947.5   to the left,  improve=357.5871,
(0 missing)
##       TMAX..Degrees.Fahrenheit. < 41.5     to the left,  improve=243.5724,
(0 missing)
##       Month                     < 1.5      to the left,  improve=169.3067,
(0 missing)
##   Surrogate splits:
##       Year          < 1945.5   to the left,  agree=0.860, adj=0.097, (0
```

```
split)
##       SNOW..Inches. < 8.15     to the right, agree=0.845, adj=0.001, (0
split)
##       SNWD..Inches. < 12.6     to the right, agree=0.845, adj=0.001, (0
split)
##
## Node number 14: 1495 observations,    complexity param=0.003929975
##   predicted class=seattle  expected loss=0.4307692  P(node) =0.03670874
##     class counts:   644   851
##    probabilities: 0.431 0.569
##   left son=28 (140 obs) right son=29 (1355 obs)
##   Primary splits:
##       Year                       < 1971.5   to the left,
improve=100.10060, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 34.5     to the left,  improve=
78.14553, (1 missing)
##       PRCP..Inches.             < 0.015    to the left,  improve=
74.23834, (0 missing)
##       prcp_day                   splits as  LR,           improve=
72.16059, (0 missing)
##       TAVG..Degrees.Fahrenheit. < 37.5     to the left,  improve=
43.92280, (0 missing)
##   Surrogate splits:
##       TMAX..Degrees.Fahrenheit. < 67.5     to the right, agree=0.908,
adj=0.021, (0 split)
##       TAVG..Degrees.Fahrenheit. < 19.5     to the left,  agree=0.907,
adj=0.007, (0 split)
##       TMIN..Degrees.Fahrenheit. < 5.5      to the left,  agree=0.907,
adj=0.007, (0 split)
##
## Node number 15: 10399 observations,    complexity param=0.003929975
##   predicted class=seattle  expected loss=0.03519569  P(node) =0.2553406
##     class counts:   366 10033
##    probabilities: 0.035 0.965
##   left son=30 (91 obs) right son=31 (10308 obs)
##   Primary splits:
##       Year                       < 1947.5   to the left,
improve=170.909800, (0 missing)
##       TAVG..Degrees.Fahrenheit. < 55.89757 to the right, improve=
84.722380, (0 missing)
##       Month                      < 9.5      to the right, improve=
11.127050, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 48.5     to the left,  improve=
6.135506, (0 missing)
##       TMAX..Degrees.Fahrenheit. < 54.5     to the right, improve=
5.934496, (1 missing)
##
## Node number 18: 391 observations
##   predicted class=dc       expected loss=0  P(node) =0.009600746
##     class counts:   391     0
```

```
##    probabilities: 1.000 0.000
##
## Node number 19: 118 observations
##   predicted class=seattle  expected loss=0  P(node) =0.002897412
##     class counts:     0   118
##    probabilities: 0.000 1.000
##
## Node number 22: 1194 observations,    complexity param=0.01015669
##   predicted class=dc       expected loss=0.2562814  P(node) =0.02931788
##     class counts:   888   306
##    probabilities: 0.744 0.256
##   left son=44 (889 obs) right son=45 (305 obs)
##   Primary splits:
##       TAVG..Degrees.Fahrenheit. < 58.5     to the right,
improve=266.13560, (0 missing)
##       TMAX..Degrees.Fahrenheit. < 49.5     to the right, improve=
55.10568, (0 missing)
##       Month                     < 11.5     to the left,  improve=
29.81115, (0 missing)
##       PRCP..Inches.             < 0.005    to the left,  improve=
21.93850, (0 missing)
##       prcp_day                  splits as  LR,           improve=
21.71124, (0 missing)
##   Surrogate splits:
##       TMAX..Degrees.Fahrenheit. < 45.5     to the right, agree=0.750,
adj=0.020, (0 split)
##       TMIN..Degrees.Fahrenheit. < 21.5     to the right, agree=0.747,
adj=0.010, (0 split)
##       SNOW..Inches.             < 2.05     to the left,  agree=0.747,
adj=0.010, (0 split)
##       SNWD..Inches.             < 0.5      to the left,  agree=0.746,
adj=0.007, (0 split)
##
## Node number 23: 2685 observations,    complexity param=0.01032682
##   predicted class=seattle  expected loss=0.3869646  P(node) =0.0659284
##     class counts:  1039  1646
##    probabilities: 0.387 0.613
##   left son=46 (1026 obs) right son=47 (1659 obs)
##   Primary splits:
##       Month                     < 5.5      to the left,
improve=424.86590, (0 missing)
##       TAVG..Degrees.Fahrenheit. < 57.84862 to the left,
improve=128.03570, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 47.5     to the left,  improve=
63.67711, (1 missing)
##       Year                      < 2012.5   to the left,  improve=
45.15954, (0 missing)
##       PRCP..Inches.             < 0.295    to the right, improve=
37.72696, (0 missing)
##   Surrogate splits:
```

```
##       TAVG..Degrees.Fahrenheit. < 58.36871 to the left,  agree=0.737,
adj=0.312, (0 split)
##       TMIN..Degrees.Fahrenheit. < 52.5     to the left,  agree=0.723,
adj=0.276, (0 split)
##       TMAX..Degrees.Fahrenheit. < 63.5     to the left,  agree=0.646,
adj=0.073, (0 split)
##       PRCP..Inches.             < 0.105    to the right, agree=0.632,
adj=0.038, (0 split)
##       Year                      < 2023.5   to the right, agree=0.628,
adj=0.026, (0 split)
##
## Node number 24: 3876 observations
##   predicted class=dc       expected loss=0.009545924  P(node) =0.09517262
##     class counts:  3839    37
##    probabilities: 0.990 0.010
##
## Node number 25: 1049 observations,    complexity param=0.00298576
##   predicted class=dc       expected loss=0.264061  P(node) =0.0257575
##     class counts:   772   277
##    probabilities: 0.736 0.264
##   left son=50 (742 obs) right son=51 (307 obs)
##   Primary splits:
##       Month                     < 3.5      to the left,
improve=157.89310, (0 missing)
##       TAVG..Degrees.Fahrenheit. < 52.38678 to the right,
improve=142.91520, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 40.5     to the left,  improve=
66.18418, (0 missing)
##       TMAX..Degrees.Fahrenheit. < 47.5     to the left,  improve=
40.01243, (0 missing)
##       PRCP..Inches.             < 0.035    to the left,  improve=
15.69808, (0 missing)
##   Surrogate splits:
##       TAVG..Degrees.Fahrenheit. < 52.38678 to the right, agree=0.796,
adj=0.303, (0 split)
##       Year                      < 2004.5   to the right, agree=0.732,
adj=0.085, (0 split)
##       PRCP..Inches.             < 1.86     to the left,  agree=0.708,
adj=0.003, (0 split)
##
## Node number 26: 1236 observations,    complexity param=0.004899709
##   predicted class=dc       expected loss=0.3592233  P(node) =0.03034916
##     class counts:   792   444
##    probabilities: 0.641 0.359
##   left son=52 (708 obs) right son=53 (528 obs)
##   Primary splits:
##       TMIN..Degrees.Fahrenheit. < 31.5     to the left,  improve=98.95732,
(0 missing)
##       TAVG..Degrees.Fahrenheit. < 35.5     to the left,  improve=68.21723,
(0 missing)
```

```
##       Year                       < 1972     to the left,  improve=54.72724,
(0 missing)
##       TMAX..Degrees.Fahrenheit. < 42.5     to the left,  improve=43.59659,
(0 missing)
##       SNWD..Inches.             < 0.5      to the right, improve=17.42223,
(0 missing)
##   Surrogate splits:
##       TAVG..Degrees.Fahrenheit. < 37.5     to the left,  agree=0.812,
adj=0.561, (0 split)
##       TMAX..Degrees.Fahrenheit. < 42.5     to the left,  agree=0.709,
adj=0.318, (0 split)
##       PRCP..Inches.             < 0.005    to the left,  agree=0.659,
adj=0.203, (0 split)
##       prcp_day                  splits as  LR,           agree=0.653,
adj=0.188, (0 split)
##       Year                      < 2017.5   to the left,  agree=0.608,
adj=0.083, (0 split)
##
## Node number 27: 6744 observations,    complexity param=0.01286174
##   predicted class=seattle  expected loss=0.1438316  P(node) =0.1655945
##     class counts:   970  5774
##    probabilities: 0.144 0.856
##   left son=54 (1311 obs) right son=55 (5433 obs)
##   Primary splits:
##       TAVG..Degrees.Fahrenheit. < 50.99979 to the right, improve=261.2613,
(0 missing)
##       Year                      < 1947.5   to the left,  improve=153.3450,
(0 missing)
##       Month                     < 1.5      to the left,  improve=126.0043,
(0 missing)
##       TMIN..Degrees.Fahrenheit. < 26.5     to the left,  improve=113.1638,
(1 missing)
##       TMAX..Degrees.Fahrenheit. < 39.5     to the left,  improve= 57.0962,
(0 missing)
##   Surrogate splits:
##       TMIN..Degrees.Fahrenheit. < 22.5     to the left,  agree=0.812,
adj=0.031, (0 split)
##       TMAX..Degrees.Fahrenheit. < 66.5     to the right, agree=0.810,
adj=0.024, (0 split)
##
## Node number 28: 140 observations
##   predicted class=dc       expected loss=0  P(node) =0.003437607
##     class counts:   140     0
##    probabilities: 1.000 0.000
##
## Node number 29: 1355 observations,    complexity param=0.002041545
##   predicted class=seattle  expected loss=0.3719557  P(node) =0.03327113
##     class counts:   504   851
##    probabilities: 0.372 0.628
##   left son=58 (793 obs) right son=59 (562 obs)
```

```
##   Primary splits:
##       PRCP..Inches.             < 0.015    to the left,  improve=62.07816,
(0 missing)
##       prcp_day                  splits as  LR,           improve=59.42114,
(0 missing)
##       TMIN..Degrees.Fahrenheit. < 34.5     to the left,  improve=53.76067,
(1 missing)
##       Month                     < 10.5     to the right, improve=30.10674,
(0 missing)
##       TAVG..Degrees.Fahrenheit. < 36.5     to the left,  improve=29.97961,
(0 missing)
##   Surrogate splits:
##       prcp_day                  splits as  LR,           agree=0.967,
adj=0.920, (0 split)
##       TMIN..Degrees.Fahrenheit. < 41.5     to the left,  agree=0.690,
adj=0.253, (0 split)
##       TAVG..Degrees.Fahrenheit. < 47.5     to the left,  agree=0.607,
adj=0.053, (0 split)
##       SNOW..Inches.             < 0.05     to the left,  agree=0.602,
adj=0.041, (0 split)
##       SNWD..Inches.             < 0.5      to the left,  agree=0.586,
adj=0.002, (0 split)
##
## Node number 30: 91 observations
##   predicted class=dc       expected loss=0  P(node) =0.002234445
##     class counts:    91     0
##    probabilities: 1.000 0.000
##
## Node number 31: 10308 observations
##   predicted class=seattle  expected loss=0.02667831  P(node) =0.2531061
##     class counts:   275 10033
##    probabilities: 0.027 0.973
##
## Node number 44: 889 observations
##   predicted class=dc       expected loss=0.06074241  P(node) =0.02182881
##     class counts:   835    54
##    probabilities: 0.939 0.061
##
## Node number 45: 305 observations
##   predicted class=seattle  expected loss=0.1737705  P(node) =0.007489073
##     class counts:    53   252
##    probabilities: 0.174 0.826
##
## Node number 46: 1026 observations
##   predicted class=dc       expected loss=0.2553606  P(node) =0.02519275
##     class counts:   764   262
##    probabilities: 0.745 0.255
##
## Node number 47: 1659 observations,    complexity param=0.001301485
##   predicted class=seattle  expected loss=0.1657625  P(node) =0.04073565
```

```
##     class counts:   275  1384
##    probabilities: 0.166 0.834
##   left son=94 (403 obs) right son=95 (1256 obs)
##   Primary splits:
##       TMIN..Degrees.Fahrenheit. < 58.5     to the right,
improve=47.581430, (0 missing)
##       Month                     < 8.5      to the right,
improve=43.618300, (0 missing)
##       Year                      < 2012.5   to the left,
improve=10.972010, (0 missing)
##       PRCP..Inches.             < 0.645    to the right,
improve=10.000690, (0 missing)
##       TAVG..Degrees.Fahrenheit. < 62.20495 to the right, improve=
7.775226, (0 missing)
##   Surrogate splits:
##       TAVG..Degrees.Fahrenheit. < 68.5     to the right, agree=0.814,
adj=0.233, (0 split)
##       TMAX..Degrees.Fahrenheit. < 83.5     to the right, agree=0.786,
adj=0.119, (0 split)
##       PRCP..Inches.             < 0.825    to the right, agree=0.759,
adj=0.010, (0 split)
##
## Node number 50: 742 observations
##   predicted class=dc       expected loss=0.08760108  P(node) =0.01821932
##     class counts:   677    65
##    probabilities: 0.912 0.088
##
## Node number 51: 307 observations
##   predicted class=seattle  expected loss=0.3094463  P(node) =0.007538182
##     class counts:    95   212
##    probabilities: 0.309 0.691
##
## Node number 52: 708 observations
##   predicted class=dc       expected loss=0.1864407  P(node) =0.01738447
##     class counts:   576   132
##    probabilities: 0.814 0.186
##
## Node number 53: 528 observations,    complexity param=0.002449855
##   predicted class=seattle  expected loss=0.4090909  P(node) =0.01296469
##     class counts:   216   312
##    probabilities: 0.409 0.591
##   left son=106 (48 obs) right son=107 (480 obs)
##   Primary splits:
##       Year                      < 1972     to the left,
improve=36.872730, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 34.5     to the left,
improve=13.019640, (0 missing)
##       SNOW..Inches.             < 0.05     to the right, improve=
9.050505, (0 missing)
##       PRCP..Inches.             < 0.325    to the right, improve=
```

```
5.403181, (0 missing)
##       SNWD..Inches.             < 0.6      to the right, improve=
4.831782, (0 missing)
##
## Node number 54: 1311 observations,    complexity param=0.01286174
##   predicted class=seattle  expected loss=0.4271548  P(node) =0.03219074
##     class counts:   560   751
##    probabilities: 0.427 0.573
##   left son=108 (528 obs) right son=109 (783 obs)
##   Primary splits:
##       Month                     < 1.5      to the left,
improve=535.07710, (0 missing)
##       Year                      < 1970.5   to the left,
improve=519.95500, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 32.5     to the left,
improve=304.91550, (0 missing)
##       TMAX..Degrees.Fahrenheit. < 46.5     to the left,
improve=235.47560, (0 missing)
##       SNWD..Inches.             < 0.5      to the right, improve=
52.02098, (0 missing)
##   Surrogate splits:
##       Year                      < 1970.5   to the left,  agree=0.962,
adj=0.905, (0 split)
##       TMIN..Degrees.Fahrenheit. < 32.5     to the left,  agree=0.867,
adj=0.669, (0 split)
##       TMAX..Degrees.Fahrenheit. < 46.5     to the left,  agree=0.827,
adj=0.570, (0 split)
##       SNWD..Inches.             < 0.5      to the right, agree=0.655,
adj=0.144, (0 split)
##       SNOW..Inches.             < 0.05     to the right, agree=0.638,
adj=0.100, (0 split)
##
## Node number 55: 5433 observations,    complexity param=0.001429082
##   predicted class=seattle  expected loss=0.07546475  P(node) =0.1334037
##     class counts:   410  5023
##    probabilities: 0.075 0.925
##   left son=110 (996 obs) right son=111 (4437 obs)
##   Primary splits:
##       TAVG..Degrees.Fahrenheit. < 48.08345 to the left,
improve=140.257000, (0 missing)
##       Year                      < 1947     to the left,
improve=103.717300, (0 missing)
##       TMAX..Degrees.Fahrenheit. < 52.5     to the right, improve=
24.906620, (0 missing)
##       prcp_day                  splits as  LR,           improve=
6.572514, (0 missing)
##       PRCP..Inches.             < 0.005    to the left,  improve=
6.510541, (0 missing)
##   Surrogate splits:
##       Year < 2013.5   to the right, agree=0.892, adj=0.409, (0 split)
```

```
##
## Node number 58: 793 observations,    complexity param=0.002041545
##   predicted class=seattle  expected loss=0.4993695  P(node) =0.01947159
##     class counts:   396   397
##    probabilities: 0.499 0.501
##   left son=116 (670 obs) right son=117 (123 obs)
##   Primary splits:
##       Month                      < 10.5     to the right,
improve=31.446220, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 30.5     to the left,
improve=19.649730, (1 missing)
##       TAVG..Degrees.Fahrenheit. < 36.5     to the left,
improve=13.664430, (0 missing)
##       Year                       < 2022.5   to the left,
improve=12.343320, (0 missing)
##       TMAX..Degrees.Fahrenheit. < 36.5     to the left,  improve=
7.133313, (1 missing)
##   Surrogate splits:
##       TMIN..Degrees.Fahrenheit. < 44.5     to the left,  agree=0.851,
adj=0.041, (0 split)
##       TAVG..Degrees.Fahrenheit. < 49.5     to the left,  agree=0.850,
adj=0.033, (0 split)
##       Year                       < 2023.5   to the left,  agree=0.849,
adj=0.024, (0 split)
##
## Node number 59: 562 observations
##   predicted class=seattle  expected loss=0.1921708  P(node) =0.01379954
##     class counts:   108   454
##    probabilities: 0.192 0.808
##
## Node number 94: 403 observations,    complexity param=0.001301485
##   predicted class=seattle  expected loss=0.3771712  P(node) =0.009895399
##     class counts:   152   251
##    probabilities: 0.377 0.623
##   left son=188 (59 obs) right son=189 (344 obs)
##   Primary splits:
##       TAVG..Degrees.Fahrenheit. < 62.96469 to the left,  improve=42.58581,
(0 missing)
##       Month                      < 6.5      to the left,  improve=33.90932,
(0 missing)
##       Year                       < 2012.5   to the left,  improve=27.35277,
(0 missing)
##       TMAX..Degrees.Fahrenheit. < 83.5     to the left,  improve=15.14443,
(0 missing)
##       TMIN..Degrees.Fahrenheit. < 60.5     to the right, improve=14.35268,
(0 missing)
##   Surrogate splits:
##       TMAX..Degrees.Fahrenheit. < 65.5     to the left,  agree=0.861,
adj=0.051, (0 split)
##
```

```
## Node number 95: 1256 observations
##   predicted class=seattle  expected loss=0.09792994  P(node) =0.03084025
##     class counts:   123  1133
##    probabilities: 0.098 0.902
##
## Node number 106: 48 observations
##   predicted class=dc       expected loss=0  P(node) =0.001178608
##     class counts:    48     0
##    probabilities: 1.000 0.000
##
## Node number 107: 480 observations
##   predicted class=seattle  expected loss=0.35  P(node) =0.01178608
##     class counts:   168   312
##    probabilities: 0.350 0.650
##
## Node number 108: 528 observations
##   predicted class=dc       expected loss=0.02272727  P(node) =0.01296469
##     class counts:   516    12
##    probabilities: 0.977 0.023
##
## Node number 109: 783 observations
##   predicted class=seattle  expected loss=0.05619413  P(node) =0.01922605
##     class counts:    44   739
##    probabilities: 0.056 0.944
##
## Node number 110: 996 observations,    complexity param=0.001429082
##   predicted class=seattle  expected loss=0.315261  P(node) =0.02445612
##     class counts:   314   682
##    probabilities: 0.315 0.685
##   left son=220 (230 obs) right son=221 (766 obs)
##   Primary splits:
##       TMIN..Degrees.Fahrenheit. < 36.5     to the left,  improve=56.18071,
(0 missing)
##       TMAX..Degrees.Fahrenheit. < 56.5     to the right, improve=40.97718,
(0 missing)
##       Year                      < 1971.5   to the left,  improve=38.06204,
(0 missing)
##       PRCP..Inches.             < 0.005    to the left,  improve=24.00985,
(0 missing)
##       prcp_day                  splits as  LR,           improve=24.00985,
(0 missing)
##   Surrogate splits:
##       TMAX..Degrees.Fahrenheit. < 59.5     to the right, agree=0.786,
adj=0.074, (0 split)
##       SNOW..Inches.             < 0.1      to the right, agree=0.772,
adj=0.013, (0 split)
##       SNWD..Inches.             < 0.6      to the right, agree=0.771,
adj=0.009, (0 split)
##       Year                      < 1971.5   to the left,  agree=0.770,
adj=0.004, (0 split)
```

```
##
## Node number 111: 4437 observations,    complexity param=0.001071811
##   predicted class=seattle  expected loss=0.02163624  P(node) =0.1089476
##     class counts:    96  4341
##    probabilities: 0.022 0.978
##   left son=222 (21 obs) right son=223 (4416 obs)
##   Primary splits:
##       Year                       < 1947     to the left,
improve=40.3934000, (0 missing)
##       TAVG..Degrees.Fahrenheit. < 49.00073 to the left,  improve=
5.9725120, (0 missing)
##       TMAX..Degrees.Fahrenheit. < 56.5     to the right, improve=
5.6804600, (0 missing)
##       Month                      < 3.5      to the right, improve=
0.6700182, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 33.5     to the right, improve=
0.5201708, (1 missing)
##
## Node number 116: 670 observations,    complexity param=0.001327005
##   predicted class=dc       expected loss=0.4402985  P(node) =0.01645141
##     class counts:   375   295
##    probabilities: 0.560 0.440
##   left son=232 (108 obs) right son=233 (562 obs)
##   Primary splits:
##       TMAX..Degrees.Fahrenheit. < 54.5     to the right,
improve=13.308430, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 27.5     to the left,
improve=13.182230, (0 missing)
##       Year                       < 2022.5   to the left,
improve=10.269750, (0 missing)
##       TAVG..Degrees.Fahrenheit. < 33.5     to the left,  improve=
7.968491, (0 missing)
##       Month                      < 11.5     to the right, improve=
2.230625, (0 missing)
##   Surrogate splits:
##       TAVG..Degrees.Fahrenheit. < 47.5     to the right, agree=0.888,
adj=0.306, (0 split)
##
## Node number 117: 123 observations
##   predicted class=seattle  expected loss=0.1707317  P(node) =0.003020184
##     class counts:    21   102
##    probabilities: 0.171 0.829
##
## Node number 188: 59 observations
##   predicted class=dc       expected loss=0.06779661  P(node) =0.001448706
##     class counts:    55     4
##    probabilities: 0.932 0.068
##
## Node number 189: 344 observations,    complexity param=0.001224927
##   predicted class=seattle  expected loss=0.2819767  P(node) =0.008446693
```

```
##     class counts:    97   247
##    probabilities: 0.282 0.718
##   left son=378 (54 obs) right son=379 (290 obs)
##   Primary splits:
##       Month                      < 6.5      to the left,
improve=24.829840, (0 missing)
##       Year                       < 2009     to the left,
improve=13.311320, (0 missing)
##       PRCP..Inches.              < 0.335    to the right,
improve=10.359180, (0 missing)
##       TMAX..Degrees.Fahrenheit. < 83.5     to the left,  improve=
9.378571, (0 missing)
##       TMIN..Degrees.Fahrenheit. < 60.5     to the right, improve=
7.088543, (0 missing)
##
## Node number 220: 230 observations
##   predicted class=dc       expected loss=0.3782609  P(node) =0.005647498
##     class counts:   143    87
##    probabilities: 0.622 0.378
##
## Node number 221: 766 observations
##   predicted class=seattle  expected loss=0.2232376  P(node) =0.01880862
##     class counts:   171   595
##    probabilities: 0.223 0.777
##
## Node number 222: 21 observations
##   predicted class=dc       expected loss=0  P(node) =0.0005156411
##     class counts:    21     0
##    probabilities: 1.000 0.000
##
## Node number 223: 4416 observations
##   predicted class=seattle  expected loss=0.0169837  P(node) =0.108432
##     class counts:    75  4341
##    probabilities: 0.017 0.983
##
## Node number 232: 108 observations
##   predicted class=dc       expected loss=0.212963  P(node) =0.002651869
##     class counts:    85    23
##    probabilities: 0.787 0.213
##
## Node number 233: 562 observations,    complexity param=0.001327005
##   predicted class=dc       expected loss=0.4839858  P(node) =0.01379954
##     class counts:   290   272
##    probabilities: 0.516 0.484
##   left son=466 (158 obs) right son=467 (404 obs)
##   Primary splits:
##       TMIN..Degrees.Fahrenheit. < 30.5     to the left,
improve=18.564610, (0 missing)
##       TAVG..Degrees.Fahrenheit. < 36.5     to the left,
improve=12.595460, (0 missing)
```

```
##       Year                       < 2022.5   to the left,  improve=
8.770352, (0 missing)
##       TMAX..Degrees.Fahrenheit. < 36.5     to the left,  improve=
6.517696, (0 missing)
##       Month                      < 11.5     to the right, improve=
4.071798, (0 missing)
##   Surrogate splits:
##       TAVG..Degrees.Fahrenheit. < 36.5     to the left,  agree=0.904,
adj=0.658, (0 split)
##       TMAX..Degrees.Fahrenheit. < 41.5     to the left,  agree=0.840,
adj=0.430, (0 split)
##       SNWD..Inches.              < 0.5      to the right, agree=0.728,
adj=0.032, (0 split)
##       Day                        < 30.5     to the right, agree=0.724,
adj=0.019, (0 split)
##
## Node number 378: 54 observations
##   predicted class=dc       expected loss=0.2777778  P(node) =0.001325934
##     class counts:    39    15
##    probabilities: 0.722 0.278
##
## Node number 379: 290 observations
##   predicted class=seattle  expected loss=0.2  P(node) =0.007120758
##     class counts:    58   232
##    probabilities: 0.200 0.800
##
## Node number 466: 158 observations
##   predicted class=dc       expected loss=0.278481  P(node) =0.003879586
##     class counts:   114    44
##    probabilities: 0.722 0.278
##
## Node number 467: 404 observations
##   predicted class=seattle  expected loss=0.4356436  P(node) =0.009919953
##     class counts:   176   228
##    probabilities: 0.436 0.564
```

The tree model can give us a better idea of which factors are being used to determine if a given day's weather happened in DC or Seattle. Clearly, there's a lot of decision points! From this tree, it seems that the average temperature, and the min and max temperature are the more useful weather indicators, taken in conjunction with the time of year. This is somewhat misleading though, since the tree can't interpret the date pieces as dates since we broke them out earlier. But! It does indicate that the amount of precipitation may not have been as impactfull as we thought.

Resources

https://r-statistics.co/Top50-Ggplot2-Visualizations-MasterList-R-Code.html#google_vignette https://stringr.tidyverse.org/reference/str_split.html

https://stackoverflow.com/questions/4350440/split-data-frame-string-column-into-multiple-columns https://stackoverflow.com/questions/70262484/remove-a-specific-part-of-a-string-in-r-with-stringr https://rstudiodatalab.medium.com/solve-classification-problems-with-lda-an-r-powered-guide-82cf31ef3f07 https://www.tutorialspoint.com/how-to-find-the-confusion-matrix-for-linear-discriminant-analysis-in-r https://www.r-bloggers.com/2021/05/linear-discriminant-analysis-in-r/ https://www.statology.org/linear-discriminant-analysis-in-r/ https://r-graph-gallery.com/ https://r-statistics.co/Top50-Ggplot2-Visualizations-MasterList-R-Code.html#google_vignette https://libguides.princeton.edu/R-Visualization https://www.statology.org/r-glm-predict/ https://www.theanalysisfactor.com/r-glm-plotting/ https://www.statology.org/logistic-regression-in-r/ https://exploration.stat.illinois.edu/learn/Logistic-Regression/Evaluating-your-Logistic-Regression-Model/ https://rstudio-pubs-static.s3.amazonaws.com/672367_98c2123bb6f04d13b2ba70dfc5cee3a6.html