Chose Your Own Project - Machine Learning Submission

HarvardX Data Science Capstone - PH125.9x

Simon Gibson

2024-04-04

Contents

Introduction

For the 9th Course in the HarvardX Data Science course we have been asked to create two recommendation systems. The first was a Movie Recommendation System using the MovieLens dataset. The second is a "Choose your Own Project." For this a we are targetting a Workforce Recommendation System - mixing weather forecasts with Police 911 call information to see if it is possible to predict Police staffing requirements based on weather based trends.

We are using the Seattle Police Department 911 Incident Response data set found here : https://www.kaggle.com/datasets/sohier/seattle-police-department-911-incident-response

For Weather data we will use National Oceanic and Atmospheric Administration (NOAA) data. Michael Minns' tutorial is inciteful for weather analysis. It can be found here: https://michaelminn.net/tutorials/r-weather/index.html This weather data does not appear to be available via an api call or similar and is quite a manual download process. Due to download constraints we will be using a locally sourced dataset covering the years 2001 to 2002.

In order to test the results of the recommendation system we are using the root-mean-square error (RMSE) to measure the difference between the values predicted by the model and the observed values.

Method

The first step is to clear any set variables so we do not introduce anything unexpected into the data we are working with.

Then we install the packages required to manipulate the data.

```
#####################################################
# This code is divided into the following sections #
# 1. Install required packages                      #
# 2. edx code for creating data sets                #
# 3. Data set exploration                           #
#####################################################

############################################################
# 1. Install required packages and download data           #
############################################################
```

```
# Note: this process takes a couple of minutes

if(!require(tidyverse)) install.packages("tidyverse", repos = "https://cran.us.r-project.org")
if(!require(caret)) install.packages("caret", repos = "https://cran.us.r-project.org")
if(!require(dplyr)) install.packages("dplyr", repos = "https://cran.us.r-project.org")
if(!require(kableExtra)) install.packages("kableExtra", repos = "https://cran.us.r-project.org")
if(!require(lubridate)) install.packages("lubridate", repos = "https://cran.us.r-project.org")
if(!require(scales)) install.packages("scales", repos = "https://cran.us.r-project.org")
if(!require(stringr)) install.packages("stringr", repos = "http://cran.us.r-project.org")
if(!require(readr)) install.packages("readr", repos = "http://cran.us.r-project.org")
if(!require(xts)) install.packages("xts", repos = "http://cran.us.r-project.org")
if(!require(tsbox)) install.packages("tsbox", repos = "http://cran.us.r-project.org")
if(!require(forecast)) install.packages("forecast", repos = "http://cran.us.r-project.org")
if(!require(data.table)) install.packages("data.table", repos = "http://cran.us.r-project.org")
if(!require(measurements)) install.packages("measurements", repos = "http://cran.us.r-project.org")

library(tidyverse)
library(caret)
library(dplyr)
library(kableExtra)
library(lubridate)
library(scales)
library(stringr)
library(readr)
library(xts)
library(tsbox)
library(forecast)
library(data.table)
library(measurements)
```

Following that, the data is downloaded and then divided into 2 sets. The first set is used to train the algorithm and the second set is used to validate the algorithm. By dividing the data the problem of over-training and thus producing skewed results can be avoided.

The creation of the 2 sets involves the following steps. Initially required packages are installed if not installed and then loaded. Next the data is downloaded if the zip files are not found. Column names are set and the data is converted into forms more easily processed. Then the data is joined. Finally the joined data is split into 2 sets - the edx set used to train the algorithm and the final_holdout_test set that will be used to validate the algorithm and calculate the final RMSE score.

```
#Seattle Police Department 911 Incident Response
#https://www.kaggle.com/datasets/sohier/seattle-police-department-911-incident-response/download?datase

#National Oceanic and Atmospheric Administration (NOAA) data
#https://www.ncei.noaa.gov/orders/cdo/3533326.csv

options(timeout = 120)

dl <- "archive.zip"
if(!file.exists(dl))
  download.file("https://www.kaggle.com/datasets/sohier/seattle-police-department-911-incident-response/

dl <- "3533326.csv"
if(!file.exists(dl))
  download.file("https://www.ncei.noaa.gov/orders/cdo/3533326.csv", dl)
```

```
#Load Seattle 0911 Call data
Seattle_911 <- read_csv("Seattle_Police_Department_911_Incident_Response.csv")
#Load weather data
Weather <- read.csv("3533326.csv", as.is=T)
```

##Data Investigation

```
head(Weather)
```

```
##       STATION              NAME       DATE PRCP SNOW TAVG TMAX TMIN TSUN WT01
## 1 USC00450872 BREMERTON, WA US 2000-01-01 0.23    0   NA   44   38   NA   NA
## 2 USC00450872 BREMERTON, WA US 2000-01-02 0.00    0   NA   44   31   NA   NA
## 3 USC00450872 BREMERTON, WA US 2000-01-03 0.10    0   NA   45   32   NA   NA
## 4 USC00450872 BREMERTON, WA US 2000-01-04 1.38    0   NA   47   35   NA   NA
## 5 USC00450872 BREMERTON, WA US 2000-01-05 0.02    0   NA   51   30   NA   NA
## 6 USC00450872 BREMERTON, WA US 2000-01-06 0.01    0   NA   44   34   NA   NA
##   WT02 WT03 WT04 WT05 WT06 WT07 WT08 WT09 WT11 WT13 WT14 WT15 WT16 WT17 WT18
## 1   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA
## 2   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA
## 3   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA
## 4   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA
## 5   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA
## 6   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA   NA
##   WT19 WT21 WT22 WV01 WV03
## 1   NA   NA   NA   NA   NA
## 2   NA   NA   NA   NA   NA
## 3   NA   NA   NA   NA   NA
## 4   NA   NA   NA   NA   NA
## 5   NA   NA   NA   NA   NA
## 6   NA   NA   NA   NA   NA
```

```
names(Weather)
```

```
##  [1] "STATION" "NAME"    "DATE"    "PRCP"    "SNOW"    "TAVG"    "TMAX"
##  [8] "TMIN"    "TSUN"    "WT01"    "WT02"    "WT03"    "WT04"    "WT05"
## [15] "WT06"    "WT07"    "WT08"    "WT09"    "WT11"    "WT13"    "WT14"
## [22] "WT15"    "WT16"    "WT17"    "WT18"    "WT19"    "WT21"    "WT22"
## [29] "WV01"    "WV03"
```

```
min(range(Weather$DATE))
```

```
## [1] "2000-01-01"
```

```
max(range(Weather$DATE))
```

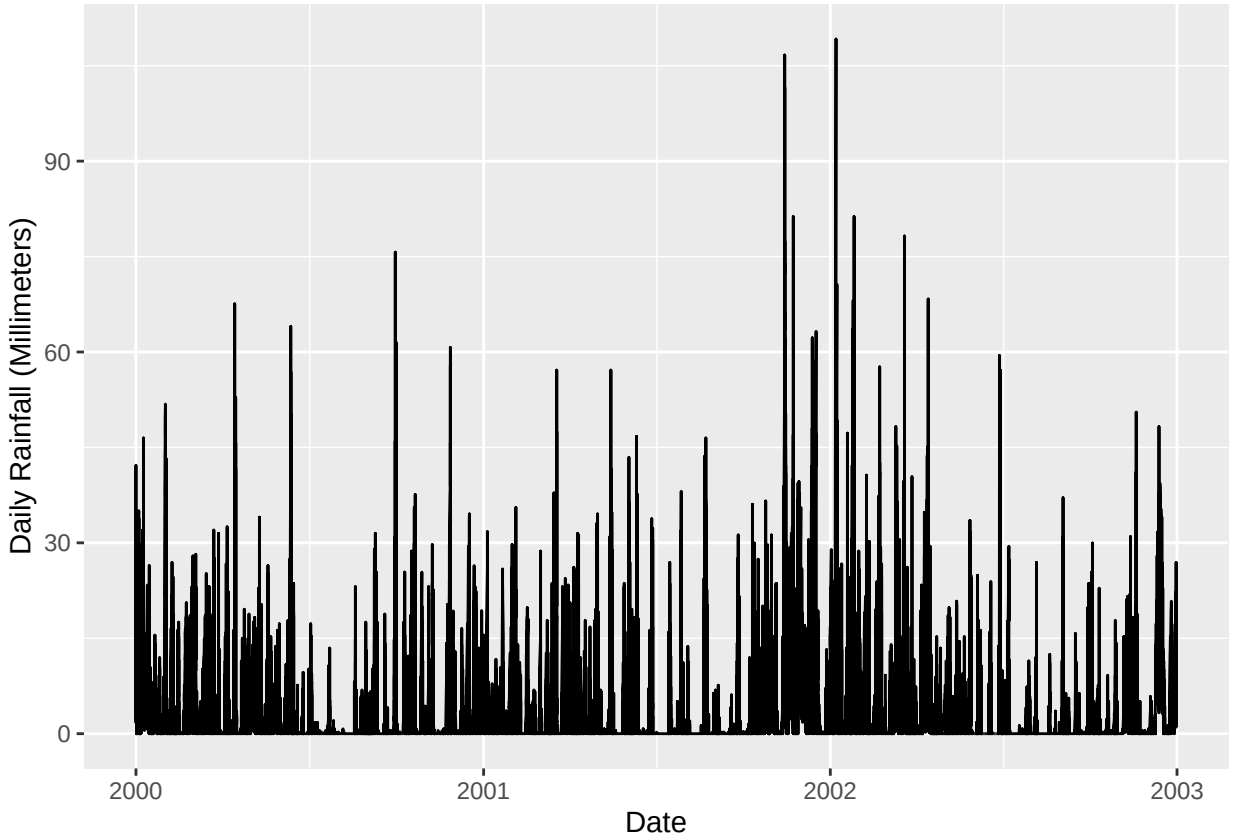
```
## [1] "2002-12-31"
```

Our data range starts from 2000-01-01 and ends 2002-12-31.

```
#Seattle_Weather <- xts(Weather["Weather$STATION" == 'USC00450872',c("TMAX","TMIN","PRCP")], order.by=a
Seattle_Weather <- xts(Weather[,c("NAME","STATION","DATE","TMAX","TMIN","PRCP")], order.by=as.Date(Weatl

Seattle_Weather <- as.data.frame(Seattle_Weather)
#Seattle_Weather = window(Seattle_Weather, start=as.Date("2000-01-01"), end=as.Date("2002-12-31"))

class(Seattle_Weather)
```

```
## [1] "data.frame"
```

```r
Seattle_Weather$DATE <- as.Date(Seattle_Weather$DATE)
Seattle_Weather$PRCP <- as.numeric(Seattle_Weather$PRCP)

#Convert Precipitation from Imperial to Metric
Seattle_Weather$PRCP <- conv_unit(Seattle_Weather$PRCP, "inch", "mm")


Seattle_Weather$TMAX <- as.numeric(Seattle_Weather$TMAX)
Seattle_Weather$TMIN <- as.numeric(Seattle_Weather$TMIN)
#hist(x = Seattle_Weather$TMIN, xlab = "Precipitation", ylab ='Frequency of readings', main = #paste("N

ggplot(Seattle_Weather, aes(x=Seattle_Weather$DATE,y=Seattle_Weather$PRCP)) +
  geom_line() +
  xlab("Date") +
  ylab("Daily Rainfall (Millimeters)")
```



We have data from 20 stations: BREMERTON, WA US, EVERETT, WA US, MONROE, WA US, TOLT SOUTH FORK RESERVOIR, WA US, OLALLA 1.4 WNW, WA US, GIG HARBOR 3.4 NW, WA US, RENTON MUNICIPAL AIRPORT, WA US, KENT, WA US, TACOMA NUMBER 1, WA US, LANDSBURG, WA US, CEDAR LAKE, WA US, SNOQUALMIE FALLS, WA US, WAUNA 3 W, WA US, WOODINVILLE 0.9 ENE, WA US, PALMER 3 ESE, WA US, TACOMA NARROWS AIRPORT, WA US, EVERETT SNOHOMISH CO AIRPORT, WA US, SEATTLE TACOMA AIRPORT, WA US, SEATTLE SAND POINT WEATHER FORECAST OFFICE, WA US, SEATTLE BOEING FIELD, WA US. Of 17773 rainfall measurements, 7869 recorded rainfall, and 9794 recorded no rainfall. The maximum rainfall during this period was 109.22mm which fell on 2002-01-07. Heavy rainfall is defined by NIWA as rainfall of over 100mm in 24 hours and this occurred 3 times during the period we have data for.

```
Seattle_Weather %>% group_by(Seattle_Weather$STATION)
```

```
## # A tibble: 17,773 x 7
## # Groups:   Seattle_Weather$STATION [20]
##    NAME              STATION DATE        TMAX  TMIN  PRCP Seattle_Weather$STAT~1
##    <chr>             <chr>   <date>     <dbl> <dbl> <dbl> <chr>
##  1 BREMERTON, WA US  USC004~ 2000-01-01    44    38  5.84 USC00450872
##  2 EVERETT, WA US    USC004~ 2000-01-01    NA    NA 12.7  USC00452675
##  3 MONROE, WA US     USC004~ 2000-01-01    45    38  4.06 USC00455525
##  4 TOLT SOUTH FORK ~ USC004~ 2000-01-01    NA    NA 42.2  USC00458508
##  5 RENTON MUNICIPAL~ USW000~ 2000-01-01    45    39  6.86 USW00094248
##  6 KENT, WA US       USC004~ 2000-01-01    47    36  8.13 USC00454169
##  7 TACOMA NUMBER 1,~ USC004~ 2000-01-01    47    37 10.9  USC00458278
##  8 LANDSBURG, WA US  USC004~ 2000-01-01    43    36  8.13 USC00454486
##  9 CEDAR LAKE, WA US USC004~ 2000-01-01    41    31 19.8  USC00451233
## 10 SNOQUALMIE FALLS~ USC004~ 2000-01-01    44    36 18.3  USC00457773
## # i 17,763 more rows
## # i abbreviated name: 1: `Seattle_Weather$STATION`
```

```
summary(Seattle_911)
```

```
##   CAD CDW ID        CAD Event Number    General Offense Number
##  Length:1433853     Min.   :9.000e+09   Min.   :2.011e+04
##  Class :character   1st Qu.:1.200e+10   1st Qu.:2.010e+09
##  Mode  :character   Median :1.400e+10   Median :2.012e+09
##                     Mean   :1.366e+10   Mean   :1.641e+09
##                     3rd Qu.:1.600e+10   3rd Qu.:2.015e+09
##                     Max.   :1.700e+10   Max.   :2.012e+10
##
##  Event Clearance Code Event Clearance Description Event Clearance SubGroup
##  Length:1433853       Length:1433853              Length:1433853
##  Class :character     Class :character            Class :character
##  Mode  :character     Mode  :character            Mode  :character
##
##
##
##
##  Event Clearance Group Event Clearance Date Hundred Block Location
##  Length:1433853        Length:1433853       Length:1433853
##  Class :character      Class :character     Class :character
##  Mode  :character      Mode  :character     Mode  :character
##
##
##
##
##  District/Sector     Zone/Beat          Census Tract         Longitude
##  Length:1433853     Length:1433853     Length:1433853     Min.   :-122.4
##  Class :character   Class :character   Class :character   1st Qu.:-122.3
##  Mode  :character   Mode  :character   Mode  :character   Median :-122.3
##                                                           Mean   :-122.3
##                                                           3rd Qu.:-122.3
##                                                           Max.   :-122.2
##                                                           NA's   :1
##     Latitude     Incident Location  Initial Type Description
```

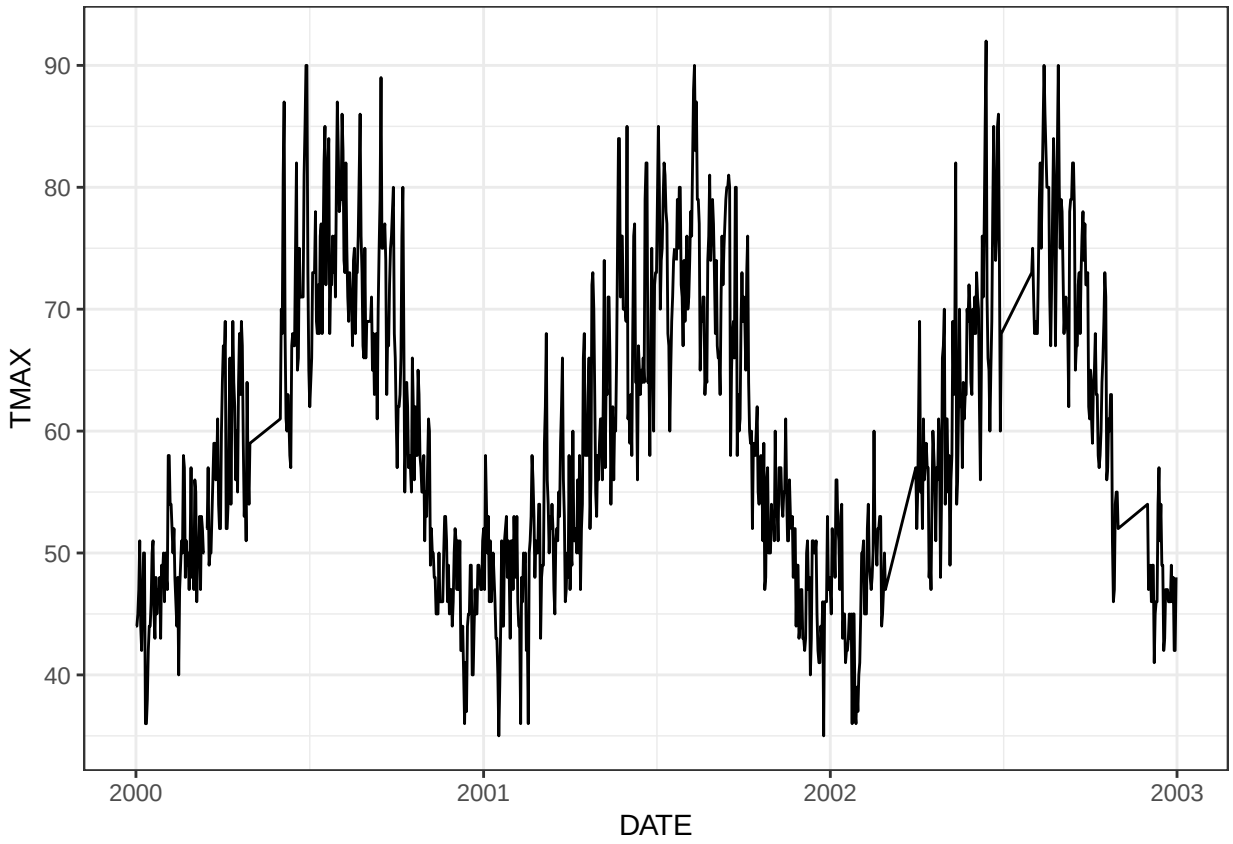
```
##  Min.   :47.45   Length:1433853     Length:1433853
##  1st Qu.:47.59   Class :character   Class :character
##  Median :47.61   Mode  :character   Mode  :character
##  Mean   :47.62
##  3rd Qu.:47.66
##  Max.   :47.78
##  NA's   :1
##  Initial Type Subgroup Initial Type Group At Scene Time
##  Length:1433853        Length:1433853     Length:1433853
##  Class :character      Class :character   Class :character
##  Mode  :character      Mode  :character   Mode  :character
##
##
##
##
```

```
summary(Weather)
```

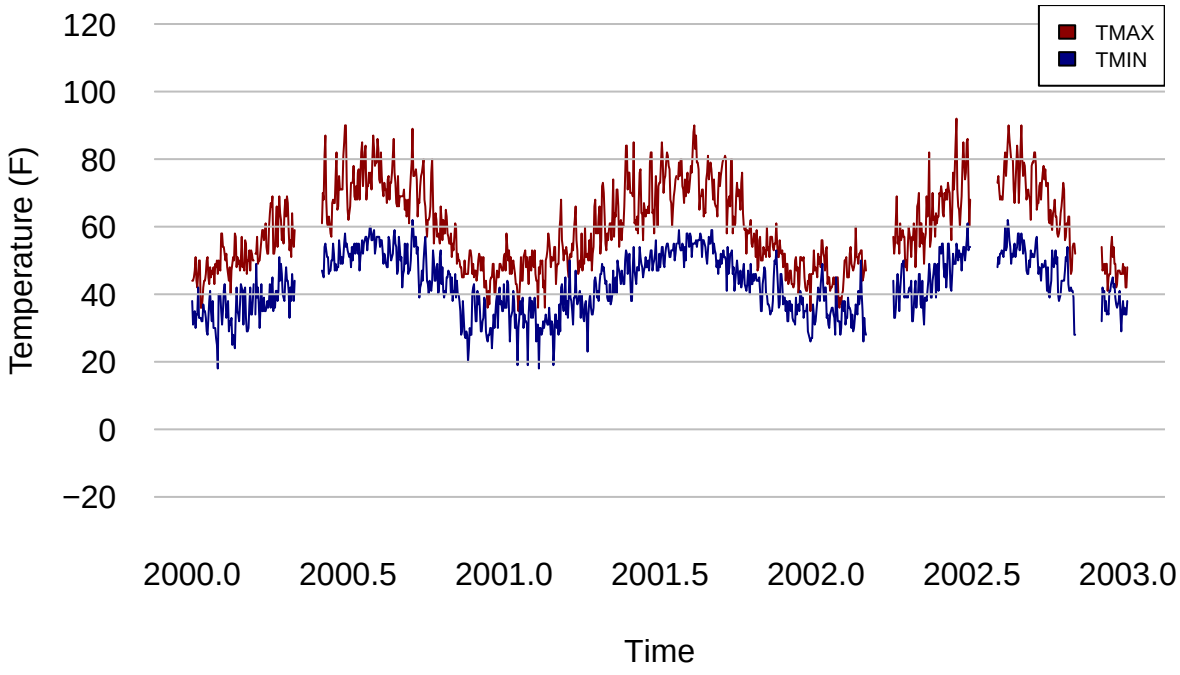
```
##    STATION              NAME               DATE                PRCP
##  Length:17773       Length:17773       Length:17773       Min.   :0.0000
##  Class :character   Class :character   Class :character   1st Qu.:0.0000
##  Mode  :character   Mode  :character   Mode  :character   Median :0.0000
##                                                           Mean   :0.1278
##                                                           3rd Qu.:0.1200
##                                                           Max.   :4.3000
##                                                           NA's   :110
##       SNOW             TAVG            TMAX            TMIN
##  Min.   : 0.000   Min.   : 0.00   Min.   : 0.00   Min.   :-16.00
##  1st Qu.: 0.000   1st Qu.:44.00   1st Qu.:50.00   1st Qu.: 36.00
##  Median : 0.000   Median :51.00   Median :58.00   Median : 43.00
##  Mean   : 0.042   Mean   :52.27   Mean   :59.14   Mean   : 43.21
##  3rd Qu.: 0.000   3rd Qu.:60.00   3rd Qu.:68.00   3rd Qu.: 50.00
##  Max.   :24.000   Max.   :82.00   Max.   :99.00   Max.   : 77.00
##  NA's   :7233     NA's   :11397   NA's   :2511    NA's   :2537
##       TSUN             WT01            WT02            WT03
##  Min.   :  0.00   Min.   :1       Min.   :1       Min.   :1
##  1st Qu.:  0.00   1st Qu.:1       1st Qu.:1       1st Qu.:1
##  Median :  0.00   Median :1       Median :1       Median :1
##  Mean   : 31.76   Mean   :1       Mean   :1       Mean   :1
##  3rd Qu.:  0.00   3rd Qu.:1       3rd Qu.:1       3rd Qu.:1
##  Max.   :931.00   Max.   :1       Max.   :1       Max.   :1
##  NA's   :14935    NA's   :16900   NA's   :17707   NA's   :17755
##       WT04            WT05            WT06          WT07              WT08
##  Min.   :1       Min.   :1       Min.   :1       Mode:logical   Min.   :1
##  1st Qu.:1       1st Qu.:1       1st Qu.:1       NA's:17773     1st Qu.:1
##  Median :1       Median :1       Median :1                      Median :1
##  Mean   :1       Mean   :1       Mean   :1                      Mean   :1
##  3rd Qu.:1       3rd Qu.:1       3rd Qu.:1                      3rd Qu.:1
##  Max.   :1       Max.   :1       Max.   :1                      Max.   :1
##  NA's   :17766   NA's   :17761   NA's   :17772                  NA's   :17752
##    WT09            WT11              WT13            WT14          WT15
##  Mode:logical   Mode:logical   Min.   :1       Min.   :1       Mode:logical
##  NA's:17773     NA's:17773     1st Qu.:1       1st Qu.:1       NA's:17773
##                                Median :1       Median :1
##                                Mean   :1       Mean   :1
```

```
##                                3rd Qu.:1       3rd Qu.:1
##                                Max.   :1       Max.   :1
##                                NA's   :17286   NA's   :17688
##       WT16            WT17            WT18            WT19
##  Min.   :1       Min.   :1       Min.   :1       Min.   :1
##  1st Qu.:1       1st Qu.:1       1st Qu.:1       1st Qu.:1
##  Median :1       Median :1       Median :1       Median :1
##  Mean   :1       Mean   :1       Mean   :1       Mean   :1
##  3rd Qu.:1       3rd Qu.:1       3rd Qu.:1       3rd Qu.:1
##  Max.   :1       Max.   :1       Max.   :1       Max.   :1
##  NA's   :17209   NA's   :17772   NA's   :17748   NA's   :17771
##       WT21            WT22            WV01            WV03
##  Min.   :1       Min.   :1       Min.   :1       Min.   :1
##  1st Qu.:1       1st Qu.:1       1st Qu.:1       1st Qu.:1
##  Median :1       Median :1       Median :1       Median :1
##  Mean   :1       Mean   :1       Mean   :1       Mean   :1
##  3rd Qu.:1       3rd Qu.:1       3rd Qu.:1       3rd Qu.:1
##  Max.   :1       Max.   :1       Max.   :1       Max.   :1
##  NA's   :17725   NA's   :17766   NA's   :17767   NA's   :17771
```

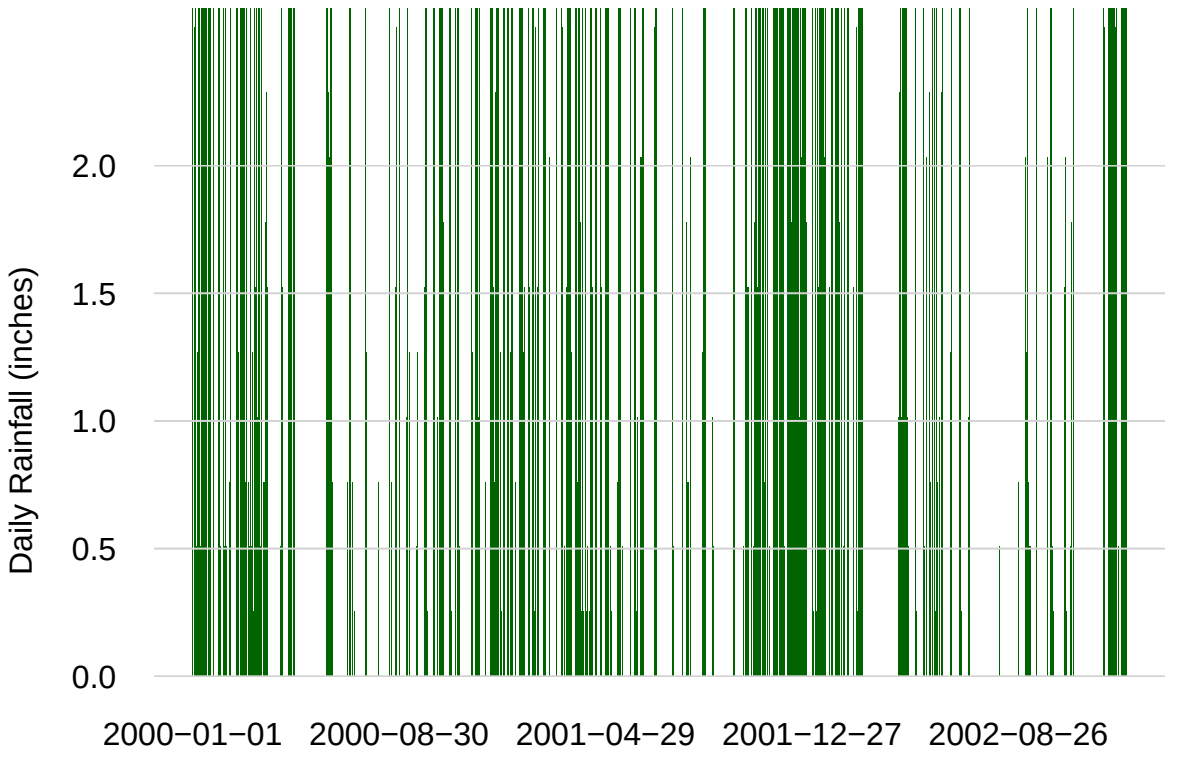
```r
# Group Data by weather station
weather_data_grouped <- Seattle_Weather %>%
  group_by(STATION)

# find average maximum temperature
average_max_temp <- weather_data_grouped %>%
  summarise(avg_max_temp = mean(TMAX, na.rm = TRUE))

# Get unique station codes
station_codes <- unique(Seattle_Weather$STATION)

# Create a list to store data frames for each station
station_data_list <- list()

# Loop through each station code and filter data for that station
for (station_code in station_codes) {
  station_data <- filter(Seattle_Weather, STATION == station_code)
  station_data_list[[station_code]] <- station_data
}
ggplot(station_data_list[["USC00450872"]], aes(x=DATE, y=TMAX)) +
 geom_line() +
 theme_bw()
```




```
 USC00450872 <- station_data_list[["USC00450872"]]

historical = xts(USC00450872[,c("TMAX","TMIN","PRCP")], order.by=as.Date(USC00450872$DATE))

historical = ts_regular(historical)

historical = suppressWarnings(na.fill(historical, "extend"))

historical = window(historical, start=as.Date("2000-01-01"), end=as.Date("2020-12-31"))



plot(ts_ts(historical$TMAX), col="darkred", bty="n", las=1, fg=NA,
    ylim=c(-20, 120), ylab="Temperature (F)")

lines(ts_ts(historical$TMIN), col="navy")

grid(nx=NA, ny=NULL, lty=1, col="gray")

legend("topright", fill=c("darkred", "navy"), cex=0.7,
    legend=c("TMAX", "TMIN"), bg="white")
```




```
barplot(historical$PRCP, border=NA, col="darkgreen", ylim=c(0, 2),
    space=0, bty="n", las=1, fg=NA, ylab="Daily Rainfall (inches)")

grid(nx=NA, ny=NULL, lty=1)
```



References

1.
2.

3.
4. https://www.neonscience.org/resources/learning-hub/tutorials/da-viz-coop-precip-data-r