Assignment 8: Time Series Analysis

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Fall 2024

OVERVIEW

This exercise accompanies the lessons in Environmental Data Analytics on generalized linear models.

Directions

1. Rename this file `<FirstLast>_A08_TimeSeries.Rmd` (replacing `<FirstLast>` with your first and last name).
2. Change "Student Name" on line 3 (above) with your name.
3. Work through the steps, **creating code and output** that fulfill each instruction.
4. Be sure to **answer the questions** in this assignment document.
5. When you have completed the assignment, **Knit** the text and code into a single PDF file.

Set up

1. Set up your session:

- Check your working directory
- Load the tidyverse, lubridate, zoo, and trend packages
- Set your ggplot theme

```
getwd()
```

```
## [1] "/home/guest/EDA Fall 2024"
```

```
library(tidyverse)
```

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.4     v readr     2.1.5
## v forcats   1.0.0     v stringr   1.5.1
## v ggplot2   3.5.1     v tibble    3.2.1
## v lubridate 1.9.3     v tidyr     1.3.1
## v purrr     1.0.2
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```
library(lubridate)
library(zoo)
```

```
##
## Attaching package: 'zoo'
##
## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
```

```
library(trend)
library(here)
```

```
## here() starts at /home/guest/EDA Fall 2024
```

```
mytheme <- theme_classic(base_size = 14) +
  theme(axis.text = element_text(color = "black"),
        legend.position = "top")
theme_set(mytheme)
```

2. Import the ten datasets from the Ozone_TimeSeries folder in the Raw data folder. These contain ozone concentrations at Garinger High School in North Carolina from 2010-2019 (the EPA air database only allows downloads for one year at a time). Import these either individually or in bulk and then combine them into a single dataframe named `GaringerOzone` of 3589 observation and 20 variables.

```
#1

EPAir_O3_10<-read_csv(here("Data","Raw","Ozone_TimeSeries",
                           "EPAair_O3_GaringerNC2010_raw.csv"))
EPAir_O3_11<-read_csv(here("Data","Raw","Ozone_TimeSeries",
                           "EPAair_O3_GaringerNC2011_raw.csv"))
EPAir_O3_12<-read_csv(here("Data","Raw","Ozone_TimeSeries",
                           "EPAair_O3_GaringerNC2012_raw.csv"))
EPAir_O3_13<-read_csv(here("Data","Raw","Ozone_TimeSeries",
                           "EPAair_O3_GaringerNC2013_raw.csv"))
EPAir_O3_14<-read_csv(here("Data","Raw","Ozone_TimeSeries",
                           "EPAair_O3_GaringerNC2014_raw.csv"))
EPAir_O3_15<-read_csv(here("Data","Raw","Ozone_TimeSeries",
                           "EPAair_O3_GaringerNC2015_raw.csv"))
EPAir_O3_16<-read_csv(here("Data","Raw","Ozone_TimeSeries",
                           "EPAair_O3_GaringerNC2016_raw.csv"))
EPAir_O3_17<-read_csv(here("Data","Raw","Ozone_TimeSeries",
                           "EPAair_O3_GaringerNC2017_raw.csv"))
EPAir_O3_18<-read_csv(here("Data","Raw","Ozone_TimeSeries",
                           "EPAair_O3_GaringerNC2018_raw.csv"))
EPAir_O3_19<-read_csv(here("Data","Raw","Ozone_TimeSeries",
                           "EPAair_O3_GaringerNC2019_raw.csv"))

EPAirCombined<-rbind (EPAir_O3_19,EPAir_O3_18,EPAir_O3_17, EPAir_O3_16,
                      EPAir_O3_15,EPAir_O3_14, EPAir_O3_13, EPAir_O3_12,
                      EPAir_O3_11, EPAir_O3_10
                       )
```

Wrangle

3. Set your date column as a date class.

4. Wrangle your dataset so that it only contains the columns Date, Daily.Max.8.hour.Ozone.Concentration, and DAILY_AQI_VALUE.

5. Notice there are a few days in each year that are missing ozone concentrations. We want to generate a daily dataset, so we will need to fill in any missing days with NA. Create a new data frame that contains a sequence of dates from 2010-01-01 to 2019-12-31 (hint: `as.data.frame(seq())`). Call this new data frame Days. Rename the column name in Days to "Date".

6. Use a `left_join` to combine the data frames. Specify the correct order of data frames within this function so that the final dimensions are 3652 rows and 3 columns. Call your combined data frame GaringerOzone.

```
# 3

EPAirCombined$Date<-mdy(EPAirCombined$Date)

# 4

EPAirCombined<-EPAirCombined %>%
  select(Date, `Daily Max 8-hour Ozone Concentration`, DAILY_AQI_VALUE)

# 5

Days<-as.data.frame(seq(ymd("2010-01-01"),ymd("2019-12-31"), by='day'))
                      colnames(Days)<-"Date"

# 6

GaringerOzone<-left_join(
  Days,
  EPAirCombined,
  by= 'Date'
)
```

Visualize

7. Create a line plot depicting ozone concentrations over time. In this case, we will plot actual concentrations in ppm, not AQI values. Format your axes accordingly. Add a smoothed line showing any linear trend of your data. Does your plot suggest a trend in ozone concentration over time?

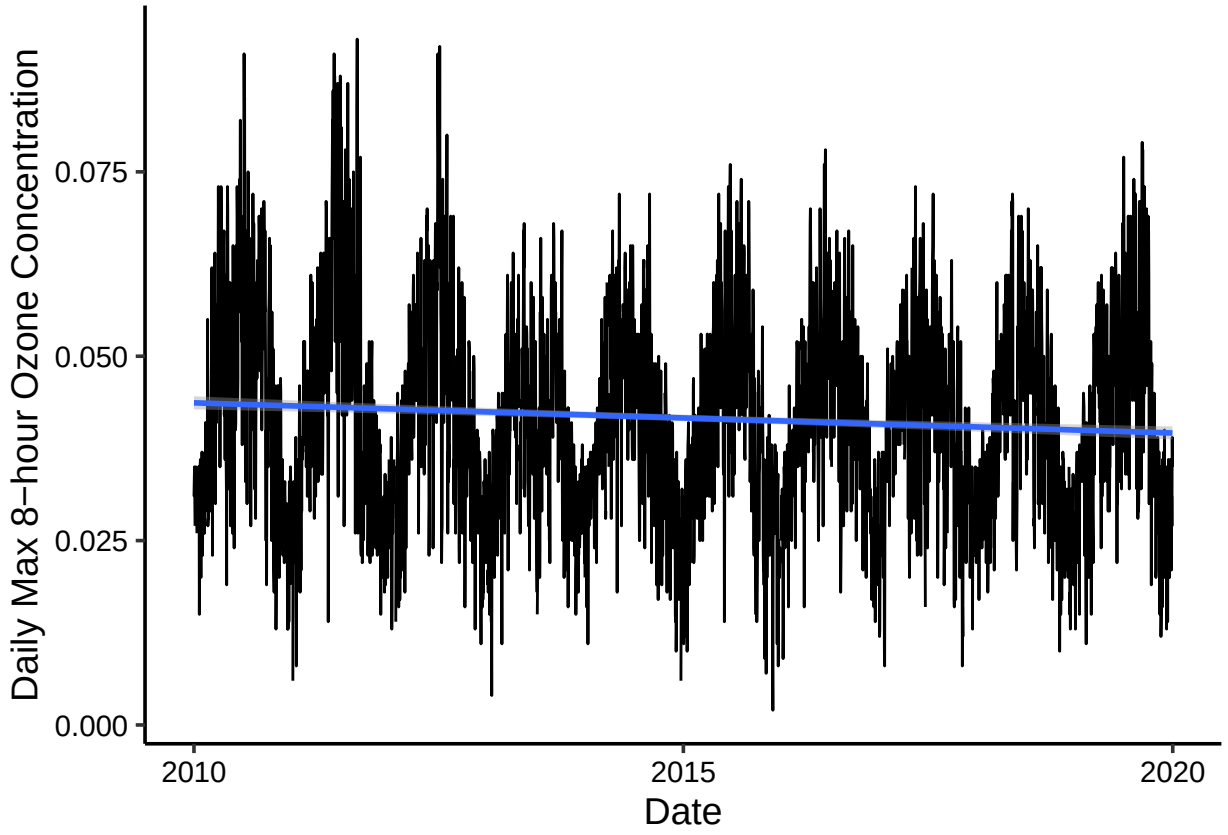
```
#7

GaringerPlot<-ggplot(GaringerOzone, aes(x=Date, y=`Daily Max 8-hour Ozone Concentration`)
       )+
  geom_line()+
  geom_smooth(method="lm")

print(GaringerPlot)
```

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

```
## Warning: Removed 63 rows containing non-finite outside the scale range
## (‘stat_smooth()‘).
```



Answer: Yes, the trend appears to be slighlty downward over the course of time according to the lm method. There also appears to be an overall seasonality from year to year.

Time Series Analysis

Study question: Have ozone concentrations changed over the 2010s at this station?

8. Use a linear interpolation to fill in missing daily data for ozone concentration. Why didn't we use a piecewise constant or spline interpolation?

```
#8

GaringerOzoneLinearClean<- GaringerOzone %>%
  mutate(DailyMaxClean=na.approx(`Daily Max 8-hour Ozone Concentration`),
         DailyAQIClean=na.approx(DAILY_AQI_VALUE))
```

Answer:

Applying a linear approx creates a smooth and simple relationship between values, which based on our graph appears to be the case. Stepwise could have created discontinuities, which would have not been adventageous for Time Series, and spline risked over fitting or creating articial peaks or troughs.

9. Create a new data frame called `GaringerOzone.monthly` that contains aggregated data: mean ozone concentrations for each month. In your pipe, you will need to first add columns for year and month to form the groupings. In a separate line of code, create a new Date column with each month-year combination being set as the first day of the month (this is for graphing purposes only)

```
#9

GaringerOzone.monthly<-GaringerOzoneLinearClean %>%
  mutate(Year_Month=format(Date, "%Y-%m")) %>%
  group_by(Year_Month) %>%
  summarize(MonthlyMean=mean(`DailyMaxClean`, na.rm=T))

GaringerOzone.monthly<-GaringerOzone.monthly %>%
  mutate(Date=ymd(paste0(Year_Month,"-01")))
```

10. Generate two time series objects. Name the first `GaringerOzone.daily.ts` and base it on the dataframe of daily observations. Name the second `GaringerOzone.monthly.ts` and base it on the monthly average ozone values. Be sure that each specifies the correct start and end dates and the frequency of the time series.

```
#10

GaringerOzone.daily.ts<-ts(
  GaringerOzoneLinearClean$DailyMaxClean,
  start= c(2010,1), frequency=365)

print(GaringerOzone.daily.ts)
```

```
## Time Series:
## Start = c(2010, 1)
## End = c(2020, 2)
## Frequency = 365
##    [1] 0.03100000 0.03300000 0.03500000 0.03100000 0.02700000 0.03000000
##    [7] 0.03300000 0.03500000 0.03200000 0.03200000 0.03000000 0.02600000
##   [13] 0.02825000 0.03050000 0.03275000 0.03500000 0.02800000 0.03500000
##   [19] 0.02900000 0.03500000 0.01500000 0.02300000 0.02600000 0.03500000
##   [25] 0.03600000 0.02800000 0.02000000 0.03100000 0.03300000 0.03200000
##   [31] 0.03700000 0.03400000 0.02300000 0.02900000 0.03000000 0.02900000
##   [37] 0.02600000 0.03200000 0.03000000 0.02600000 0.03600000 0.03700000
##   [43] 0.02900000 0.04100000 0.03900000 0.03400000 0.03800000 0.03700000
##   [49] 0.03900000 0.04000000 0.04100000 0.05500000 0.02700000 0.02800000
##   [55] 0.02800000 0.03600000 0.04100000 0.04300000 0.03700000 0.03300000
##   [61] 0.02900000 0.03400000 0.04200000 0.04300000 0.04500000 0.04900000
##   [67] 0.05900000 0.06200000 0.04000000 0.02300000 0.03700000 0.04400000
##   [73] 0.03700000 0.03900000 0.03500000 0.04900000 0.05100000 0.06000000
##   [79] 0.06400000 0.04900000 0.03000000 0.04600000 0.05200000 0.05700000
##   [85] 0.04100000 0.04600000 0.04400000 0.04500000 0.04600000 0.05100000
##   [91] 0.06100000 0.07300000 0.06500000 0.06500000 0.05700000 0.05400000
##   [97] 0.05600000 0.03500000 0.05000000 0.05800000 0.06600000 0.07300000
##  [103] 0.06900000 0.04400000 0.05900000 0.06600000 0.05500000 0.05400000
##  [109] 0.04600000 0.05200000 0.04800000 0.06500000 0.06700000 0.04200000
##  [115] 0.04400000 0.04400000 0.03600000 0.04500000 0.05900000 0.06100000
##  [121] 0.03600000 0.03200000 0.01900000 0.05700000 0.06200000 0.07300000
```

```
##  [127] 0.07000000 0.05500000 0.04400000 0.05100000 0.03200000 0.04100000
##  [133] 0.05000000 0.05400000 0.06000000 0.04800000 0.02700000 0.04200000
##  [139] 0.04300000 0.05400000 0.05000000 0.04600000 0.04900000 0.04200000
##  [145] 0.02600000 0.05500000 0.06500000 0.05800000 0.04500000 0.03500000
##  [151] 0.02400000 0.05000000 0.04800000 0.05300000 0.04400000 0.04000000
##  [157] 0.04100000 0.05300000 0.06500000 0.05200000 0.04600000 0.07300000
##  [163] 0.06900000 0.04400000 0.04700000 0.06600000 0.06800000 0.05600000
##  [169] 0.06100000 0.06400000 0.05700000 0.07400000 0.07000000 0.08200000
##  [175] 0.06200000 0.06100000 0.06800000 0.06200000 0.05200000 0.06100000
##  [181] 0.03800000 0.06300000 0.05700000 0.06400000 0.06900000 0.05800000
##  [187] 0.06000000 0.09100000 0.08200000 0.08500000 0.05400000 0.06200000
##  [193] 0.03300000 0.04100000 0.05500000 0.06700000 0.05300000 0.04000000
##  [199] 0.03000000 0.04700000 0.05400000 0.05600000 0.07500000 0.06800000
##  [205] 0.04400000 0.04800000 0.05900000 0.05500000 0.06600000 0.05400000
##  [211] 0.05900000 0.04200000 0.02700000 0.04100000 0.04400000 0.04000000
##  [217] 0.04700000 0.05900000 0.06000000 0.05400000 0.07200000 0.06300000
##  [223] 0.05500000 0.06800000 0.05900000 0.04200000 0.03200000 0.03700000
##  [229] 0.03400000 0.03700000 0.02800000 0.04000000 0.04700000 0.05400000
##  [235] 0.06000000 0.04700000 0.05900000 0.06300000 0.05500000 0.05100000
##  [241] 0.05100000 0.05300000 0.06400000 0.06900000 0.06700000 0.06500000
##  [247] 0.05500000 0.04800000 0.05600000 0.06300000 0.05100000 0.06700000
##  [253] 0.07000000 0.04000000 0.04700000 0.05400000 0.06500000 0.06400000
##  [259] 0.05100000 0.06700000 0.06300000 0.07100000 0.06700000 0.05800000
##  [265] 0.05600000 0.06700000 0.05700000 0.05000000 0.03600000 0.02500000
##  [271] 0.04000000 0.01900000 0.03500000 0.04600000 0.04700000 0.03800000
##  [277] 0.03500000 0.03500000 0.04200000 0.05600000 0.05700000 0.05900000
##  [283] 0.06600000 0.05600000 0.05900000 0.06500000 0.04000000 0.04500000
##  [289] 0.04200000 0.05000000 0.02500000 0.05600000 0.03500000 0.04800000
##  [295] 0.04100000 0.05100000 0.04800000 0.02200000 0.02000000 0.01800000
##  [301] 0.03300000 0.03100000 0.03800000 0.04600000 0.03800000 0.02800000
##  [307] 0.01300000 0.01800000 0.03000000 0.03200000 0.03300000 0.03000000
##  [313] 0.04600000 0.04300000 0.03700000 0.02900000 0.03200000 0.04600000
##  [319] 0.02000000 0.03100000 0.03800000 0.02900000 0.03600000 0.04700000
##  [325] 0.04500000 0.03000000 0.02800000 0.03300000 0.02400000 0.03200000
##  [331] 0.03600000 0.03000000 0.02300000 0.02900000 0.02700000 0.02600000
##  [337] 0.02900000 0.02200000 0.03200000 0.03300000 0.03000000 0.02300000
##  [343] 0.02800000 0.02600000 0.02900000 0.02400000 0.02800000 0.03000000
##  [349] 0.02900000 0.01300000 0.02100000 0.01300000 0.02400000 0.02700000
##  [355] 0.01400000 0.02500000 0.03300000 0.02900000 0.02000000 0.03000000
##  [361] 0.03500000 0.03300000 0.03100000 0.01900000 0.02100000 0.02300000
##  [367] 0.02700000 0.02000000 0.01300000 0.00600000 0.03200000 0.02700000
##  [373] 0.03300000 0.02800000 0.03000000 0.02200000 0.03200000 0.03100000
##  [379] 0.02700000 0.03500000 0.03900000 0.01700000 0.00800000 0.01900000
##  [385] 0.02200000 0.03600000 0.03100000 0.03100000 0.02666667 0.02233333
##  [391] 0.01800000 0.02600000 0.03100000 0.04000000 0.04600000 0.02600000
##  [397] 0.01800000 0.03000000 0.03000000 0.02100000 0.02100000 0.03600000
##  [403] 0.02900000 0.03900000 0.03600000 0.03800000 0.03700000 0.04300000
##  [409] 0.04300000 0.05200000 0.04000000 0.04600000 0.04600000 0.05200000
##  [415] 0.04700000 0.04400000 0.04200000 0.03800000 0.03900000 0.03500000
##  [421] 0.04200000 0.04400000 0.04800000 0.03100000 0.04400000 0.04800000
##  [427] 0.04300000 0.04500000 0.03600000 0.03200000 0.04200000 0.04500000
##  [433] 0.03300000 0.02900000 0.04400000 0.05300000 0.06100000 0.04600000
##  [439] 0.03500000 0.04100000 0.04700000 0.06000000 0.05300000 0.04900000
##  [445] 0.04800000 0.05400000 0.05100000 0.04200000 0.04400000 0.02800000
```

```
##  [451] 0.03500000 0.03500000 0.05000000 0.04000000 0.03100000 0.05000000
##  [457] 0.05200000 0.05400000 0.05500000 0.04600000 0.05200000 0.06200000
##  [463] 0.04500000 0.03300000 0.03500000 0.03500000 0.04900000 0.05900000
##  [469] 0.06200000 0.05900000 0.05100000 0.05300000 0.05700000 0.06400000
##  [475] 0.05200000 0.04800000 0.03400000 0.03800000 0.04500000 0.04300000
##  [481] 0.03400000 0.03900000 0.04900000 0.05500000 0.06400000 0.05800000
##  [487] 0.05400000 0.04500000 0.05200000 0.05500000 0.05300000 0.05900000
##  [493] 0.06200000 0.07100000 0.07000000 0.05600000 0.04800000 0.05600000
##  [499] 0.04200000 0.04700000 0.03500000 0.01400000 0.03000000 0.05200000
##  [505] 0.05900000 0.06600000 0.06100000 0.05000000 0.05000000 0.05300000
##  [511] 0.05700000 0.04900000 0.05100000 0.04800000 0.06200000 0.07100000
##  [517] 0.07600000 0.08200000 0.07200000 0.08600000 0.06600000 0.07000000
##  [523] 0.07600000 0.09100000 0.07300000 0.08800000 0.06300000 0.05200000
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##  [553] 0.06300000 0.04200000 0.05200000 0.05000000 0.05300000 0.06800000
##  [559] 0.07100000 0.05300000 0.02700000 0.03400000 0.04300000 0.06800000
##  [565] 0.06600000 0.07800000 0.06800000 0.05600000 0.05500000 0.05500000
##  [571] 0.04200000 0.05700000 0.07100000 0.06300000 0.08700000 0.06000000
##  [577] 0.04800000 0.06100000 0.07000000 0.07400000 0.06800000 0.04300000
##  [583] 0.06100000 0.05400000 0.06200000 0.05600000 0.07000000 0.05200000
##  [589] 0.05600000 0.04400000 0.04700000 0.05300000 0.06500000 0.06100000
##  [595] 0.06400000 0.07500000 0.05600000 0.05200000 0.05100000 0.05300000
##  [601] 0.05900000 0.05200000 0.02600000 0.04500000 0.05700000 0.06100000
##  [607] 0.05400000 0.05800000 0.08400000 0.09300000 0.05500000 0.05100000
##  [613] 0.02600000 0.04000000 0.03500000 0.04700000 0.05300000 0.05700000
##  [619] 0.05800000 0.06200000 0.06900000 0.07700000 0.05800000 0.02400000
##  [625] 0.02300000 0.03300000 0.03100000 0.03200000 0.02200000 0.02300000
##  [631] 0.03700000 0.02700000 0.02600000 0.02500000 0.04100000 0.04600000
##  [637] 0.04500000 0.04400000 0.03000000 0.03700000 0.03700000 0.04500000
##  [643] 0.04400000 0.04400000 0.04600000 0.04900000 0.03800000 0.04300000
##  [649] 0.04000000 0.02300000 0.02700000 0.03900000 0.04400000 0.04100000
##  [655] 0.05200000 0.04500000 0.02300000 0.02200000 0.02700000 0.03500000
##  [661] 0.04400000 0.03900000 0.04700000 0.05000000 0.05200000 0.02300000
##  [667] 0.03200000 0.03900000 0.03400000 0.04000000 0.04200000 0.04400000
##  [673] 0.03600000 0.03400000 0.03200000 0.03400000 0.04000000 0.04300000
##  [679] 0.02400000 0.03500000 0.04200000 0.03700000 0.03700000 0.03100000
##  [685] 0.02300000 0.02800000 0.03200000 0.03000000 0.03200000 0.02400000
##  [691] 0.03200000 0.02900000 0.04000000 0.03700000 0.03700000 0.03800000
##  [697] 0.03400000 0.01500000 0.02600000 0.02300000 0.02700000 0.02700000
##  [703] 0.02900000 0.02000000 0.03000000 0.02500000 0.02700000 0.02100000
##  [709] 0.03100000 0.03100000 0.02200000 0.01800000 0.02500000 0.03400000
##  [715] 0.02500000 0.01900000 0.02900000 0.03300000 0.02200000 0.02500000
##  [721] 0.02400000 0.03000000 0.02300000 0.02000000 0.03100000 0.02800000
##  [727] 0.02600000 0.02400000 0.03600000 0.03500000 0.03400000 0.03400000
##  [733] 0.02800000 0.02700000 0.03200000 0.02900000 0.03900000 0.02600000
##  [739] 0.01300000 0.01600000 0.02600000 0.03000000 0.02600000 0.03100000
##  [745] 0.03300000 0.03450000 0.03600000 0.03000000 0.02733333 0.02466667
##  [751] 0.02200000 0.01933333 0.01666667 0.01400000 0.03100000 0.02800000
##  [757] 0.03500000 0.03400000 0.03500000 0.03700000 0.04500000 0.04000000
##  [763] 0.03800000 0.03400000 0.01600000 0.02300000 0.02300000 0.03200000
##  [769] 0.01700000 0.02500000 0.02000000 0.03300000 0.03600000 0.03400000
```

```
##  [775] 0.04400000 0.03800000 0.02100000 0.03400000 0.04600000 0.03000000
##  [781] 0.03800000 0.04000000 0.04300000 0.04100000 0.03400000 0.03900000
##  [787] 0.04000000 0.01800000 0.04800000 0.02700000 0.04300000 0.02400000
##  [793] 0.03500000 0.04200000 0.03900000 0.04300000 0.04100000 0.03900000
##  [799] 0.03900000 0.04800000 0.04900000 0.04500000 0.03400000 0.05700000
##  [805] 0.04800000 0.04500000 0.04900000 0.04100000 0.04900000 0.05100000
##  [811] 0.04300000 0.04300000 0.03800000 0.03600000 0.05600000 0.05000000
##  [817] 0.05000000 0.05300000 0.05900000 0.06100000 0.03900000 0.04400000
##  [823] 0.04400000 0.04900000 0.04800000 0.04400000 0.04600000 0.05700000
##  [829] 0.05700000 0.05700000 0.05400000 0.05000000 0.04400000 0.05700000
##  [835] 0.06400000 0.04400000 0.04600000 0.05500000 0.02600000 0.04000000
##  [841] 0.04800000 0.04800000 0.04000000 0.04200000 0.04900000 0.05200000
##  [847] 0.04600000 0.06600000 0.03500000 0.04600000 0.04300000 0.03900000
##  [853] 0.04900000 0.05000000 0.04400000 0.05100000 0.04600000 0.04800000
##  [859] 0.04000000 0.03400000 0.05200000 0.06300000 0.05500000 0.03800000
##  [865] 0.03800000 0.05100000 0.05900000 0.05800000 0.06900000 0.06700000
##  [871] 0.07000000 0.06400000 0.06300000 0.05900000 0.05800000 0.06500000
##  [877] 0.05000000 0.02300000 0.02800000 0.03100000 0.05600000 0.06300000
##  [883] 0.04200000 0.04900000 0.05500000 0.05700000 0.04800000 0.04400000
##  [889] 0.05700000 0.05700000 0.06200000 0.04400000 0.02400000 0.03200000
##  [895] 0.06300000 0.05800000 0.04800000 0.06300000 0.05800000 0.05400000
##  [901] 0.06300000 0.06800000 0.06600000 0.05300000 0.06000000 0.04100000
##  [907] 0.06000000 0.05900000 0.05900000 0.07100000 0.09100000 0.08300000
##  [913] 0.07700000 0.07000000 0.07700000 0.06300000 0.07200000 0.09200000
##  [919] 0.06700000 0.06200000 0.06900000 0.05600000 0.05300000 0.03900000
##  [925] 0.02200000 0.02600000 0.02700000 0.04300000 0.07400000 0.05700000
##  [931] 0.04600000 0.04900000 0.04100000 0.04400000 0.04500000 0.04800000
##  [937] 0.06900000 0.05700000 0.04500000 0.06500000 0.06500000 0.05600000
##  [943] 0.04500000 0.07000000 0.08000000 0.05700000 0.04000000 0.02600000
##  [949] 0.03700000 0.03500000 0.03300000 0.03800000 0.03500000 0.03500000
##  [955] 0.04900000 0.06000000 0.05300000 0.04800000 0.06900000 0.05900000
##  [961] 0.05700000 0.04700000 0.05200000 0.05100000 0.04400000 0.05100000
##  [967] 0.05700000 0.06700000 0.06900000 0.03400000 0.03000000 0.03600000
##  [973] 0.03100000 0.04100000 0.04200000 0.03100000 0.02600000 0.03000000
##  [979] 0.03700000 0.03500000 0.05000000 0.04200000 0.03900000 0.04600000
##  [985] 0.04600000 0.05100000 0.04300000 0.04900000 0.06200000 0.02400000
##  [991] 0.02200000 0.02500000 0.03900000 0.04700000 0.04300000 0.04700000
##  [997] 0.05300000 0.04800000 0.05500000 0.05600000 0.06000000 0.05000000
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## [2533] 0.02200000 0.02800000 0.02700000 0.02300000 0.02600000 0.01600000
## [2539] 0.01800000 0.02200000 0.03600000 0.03000000 0.01400000 0.02100000
## [2545] 0.02200000 0.02100000 0.02000000 0.03200000 0.03100000 0.03000000
## [2551] 0.02900000 0.02900000 0.01900000 0.03400000 0.03700000 0.03600000
## [2557] 0.02900000 0.02200000 0.01200000 0.01300000 0.02300000 0.02700000
## [2563] 0.02300000 0.03500000 0.03600000 0.03100000 0.03200000 0.02400000
## [2569] 0.03700000 0.03100000 0.02400000 0.02600000 0.02000000 0.03000000
## [2575] 0.03700000 0.03100000 0.01000000 0.00800000 0.02500000 0.03300000
## [2581] 0.03300000 0.03700000 0.04100000 0.03300000 0.04000000 0.04000000
## [2587] 0.04000000 0.04500000 0.05100000 0.04100000 0.03300000 0.03800000
## [2593] 0.04300000 0.04300000 0.04300000 0.02700000 0.04000000 0.04150000
## [2599] 0.04300000 0.04200000 0.04500000 0.04900000 0.04100000 0.04300000
## [2605] 0.04400000 0.04300000 0.04600000 0.05000000 0.04800000 0.03100000
## [2611] 0.04600000 0.04500000 0.04800000 0.04400000 0.04500000 0.04200000
## [2617] 0.03400000 0.04300000 0.04400000 0.04300000 0.04500000 0.04300000
## [2623] 0.04600000 0.05100000 0.05200000 0.04800000 0.04100000 0.04400000
## [2629] 0.03800000 0.03900000 0.04400000 0.04700000 0.04900000 0.04600000
## [2635] 0.03800000 0.04500000 0.05700000 0.04800000 0.05100000 0.04800000
## [2641] 0.04600000 0.04000000 0.04300000 0.05100000 0.05900000 0.04000000
## [2647] 0.04600000 0.04700000 0.04300000 0.03800000 0.03700000 0.03600000
## [2653] 0.03800000 0.04500000 0.05500000 0.05900000 0.05500000 0.05200000
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## [2665] 0.04100000 0.02800000 0.04100000 0.05000000 0.05000000 0.02300000
## [2671] 0.02000000 0.03000000 0.04900000 0.04400000 0.03900000 0.03800000
## [2677] 0.02600000 0.02800000 0.05100000 0.06200000 0.04850000 0.03500000
## [2683] 0.04400000 0.04600000 0.06000000 0.05500000 0.06600000 0.05300000
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## [2695] 0.04400000 0.04800000 0.04800000 0.02500000 0.03800000 0.02300000
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## [2707] 0.04500000 0.05800000 0.05900000 0.06100000 0.06600000 0.03600000
## [2713] 0.02300000 0.05100000 0.04300000 0.04900000 0.05600000 0.05600000
```

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## [2719] 0.05000000 0.04800000 0.04700000 0.06800000 0.06400000 0.05400000
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## [2815] 0.04300000 0.04400000 0.04300000 0.04400000 0.05300000 0.05000000
## [2821] 0.05100000 0.05200000 0.05300000 0.04800000 0.05200000 0.03500000
## [2827] 0.05800000 0.06300000 0.05100000 0.04900000 0.03600000 0.04400000
## [2833] 0.04900000 0.05200000 0.04800000 0.04500000 0.01700000 0.01600000
## [2839] 0.02000000 0.02100000 0.03000000 0.03800000 0.01700000 0.03200000
## [2845] 0.02900000 0.03100000 0.03700000 0.04000000 0.04200000 0.05300000
## [2851] 0.05400000 0.04300000 0.02700000 0.03700000 0.03700000 0.03700000
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## [2869] 0.01600000 0.01200000 0.03500000 0.03400000 0.03100000 0.02800000
## [2875] 0.02500000 0.02900000 0.03100000 0.02800000 0.04300000 0.02700000
## [2881] 0.03000000 0.02200000 0.03600000 0.03000000 0.03400000 0.03000000
## [2887] 0.03900000 0.03500000 0.04200000 0.04100000 0.03800000 0.04300000
## [2893] 0.03400000 0.04000000 0.03900000 0.03200000 0.02000000 0.02400000
## [2899] 0.02600000 0.02500000 0.02800000 0.02700000 0.03200000 0.03500000
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## [2911] 0.02400000 0.02600000 0.02800000 0.02400000 0.02300000 0.03200000
## [2917] 0.03500000 0.02700000 0.03100000 0.02200000 0.03100000 0.03300000
## [2923] 0.03500000 0.03300000 0.02300000 0.03200000 0.03200000 0.03300000
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## [3037] 0.04400000 0.04200000 0.04600000 0.06100000 0.04800000 0.05400000
```

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## [3079] 0.06200000 0.06200000 0.06300000 0.05600000 0.05500000 0.06000000
## [3085] 0.03200000 0.04600000 0.05500000 0.06900000 0.05800000 0.05900000
## [3091] 0.06700000 0.05900000 0.05200000 0.04400000 0.05500000 0.04600000
## [3097] 0.04500000 0.06000000 0.04400000 0.04800000 0.05300000 0.05600000
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## [3127] 0.04800000 0.04500000 0.05900000 0.05900000 0.05500000 0.04900000
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## [3247] 0.02700000 0.03300000 0.03200000 0.02000000 0.02500000 0.02200000
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## [3295] 0.03500000 0.03700000 0.02700000 0.03100000 0.02900000 0.02500000
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## [3325] 0.03600000 0.04000000 0.04000000 0.03300000 0.01900000 0.01100000
## [3331] 0.04100000 0.03800000 0.03900000 0.03700000 0.02800000 0.03500000
## [3337] 0.02600000 0.02900000 0.02000000 0.03300000 0.03200000 0.04400000
## [3343] 0.04400000 0.04600000 0.02200000 0.03000000 0.02000000 0.02700000
## [3349] 0.01500000 0.03900000 0.04100000 0.04500000 0.04300000 0.02900000
## [3355] 0.02600000 0.02200000 0.04100000 0.04700000 0.05300000 0.05100000
## [3361] 0.03400000 0.04700000 0.05000000 0.05000000 0.04900000 0.05300000
```

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## [3367] 0.05400000 0.04800000 0.05400000 0.05700000 0.04800000 0.04600000
## [3373] 0.05100000 0.05700000 0.06000000 0.05500000 0.04500000 0.04800000
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## [3391] 0.03600000 0.05100000 0.05800000 0.05900000 0.04900000 0.03800000
## [3397] 0.03300000 0.03800000 0.05100000 0.05100000 0.05400000 0.04500000
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## [3409] 0.04800000 0.03300000 0.03600000 0.02900000 0.05000000 0.04600000
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## [3427] 0.04700000 0.06200000 0.04500000 0.03800000 0.05200000 0.05700000
## [3433] 0.04700000 0.04600000 0.05500000 0.05300000 0.05100000 0.05800000
## [3439] 0.05800000 0.06400000 0.06100000 0.05900000 0.04400000 0.04200000
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## [3451] 0.04500000 0.06100000 0.05400000 0.04400000 0.04300000 0.03300000
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## [3505] 0.05700000 0.06000000 0.04800000 0.07400000 0.04700000 0.04500000
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## [3517] 0.05600000 0.05000000 0.03200000 0.04400000 0.04400000 0.04700000
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## [3529] 0.07100000 0.05400000 0.04000000 0.03800000 0.05200000 0.04000000
## [3535] 0.03200000 0.05600000 0.06600000 0.06300000 0.07900000 0.05300000
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## [3559] 0.05500000 0.04800000 0.06900000 0.06300000 0.06700000 0.06000000
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## [3637] 0.03600000 0.02900000 0.03500000 0.03000000 0.02000000 0.02500000
## [3643] 0.02700000 0.02800000 0.03600000 0.03400000 0.02600000 0.02100000
## [3649] 0.03100000 0.02700000 0.03900000 0.03500000
```

```
GaringerOzone.monthly.ts<-ts(
  GaringerOzone.monthly$MonthlyMean,
  start= c(2010,1), frequency=12)

print(GaringerOzone.monthly.ts)
```

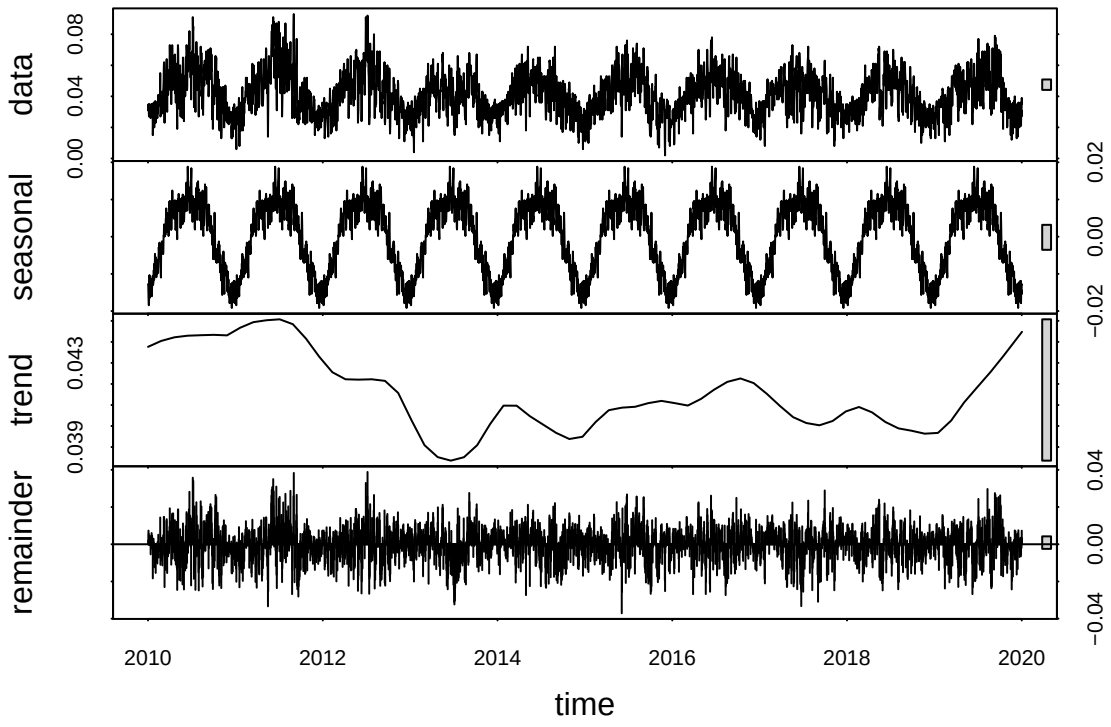
```
##             Jan        Feb        Mar        Apr        May        Jun
## 2010 0.03046774 0.03446429 0.04458065 0.05563333 0.04661290 0.05756667
## 2011 0.02661290 0.03810714 0.04335484 0.04913333 0.05277419 0.06623333
## 2012 0.02882258 0.03282759 0.04480645 0.04803333 0.05100000 0.05630000
## 2013 0.02712903 0.03532143 0.04380645 0.04765000 0.04641935 0.04186667
## 2014 0.03096774 0.03567857 0.04275806 0.05023333 0.05225806 0.05023333
## 2015 0.02864516 0.03500000 0.04125806 0.04400000 0.05203226 0.05156667
## 2016 0.02967742 0.03606897 0.04385484 0.04990000 0.04690323 0.05480000
## 2017 0.02900000 0.04269643 0.04545161 0.04336667 0.04753226 0.04461667
## 2018 0.03177419 0.03105357 0.04335484 0.04920000 0.04538710 0.05466667
## 2019 0.03014516 0.03410714 0.04377419 0.04620000 0.04645161 0.04760000
##             Jul        Aug        Sep        Oct        Nov        Dec
## 2010 0.05777419 0.04977419 0.05476667 0.04354839 0.03220000 0.02593548
## 2011 0.05932258 0.05677419 0.04480000 0.03841935 0.03360000 0.02645161
## 2012 0.05551613 0.04809677 0.04203333 0.03677419 0.03386667 0.02708065
## 2013 0.03653226 0.04164516 0.04943333 0.03564516 0.03000000 0.02817742
## 2014 0.04451613 0.04748387 0.03550000 0.03674194 0.03253333 0.02341935
## 2015 0.05038710 0.05435484 0.04276667 0.03416129 0.02870000 0.02543548
## 2016 0.05114516 0.04232258 0.04526667 0.04212903 0.03536667 0.02561290
## 2017 0.04948387 0.04506452 0.04411667 0.03554839 0.03073333 0.02906452
## 2018 0.04993548 0.04654839 0.03826667 0.03561290 0.02756667 0.02591935
## 2019 0.05061290 0.04980645 0.05386667 0.03977419 0.03033333 0.02919355
```

11. Decompose the daily and the monthly time series objects and plot the components using the `plot()` function.

```
#11

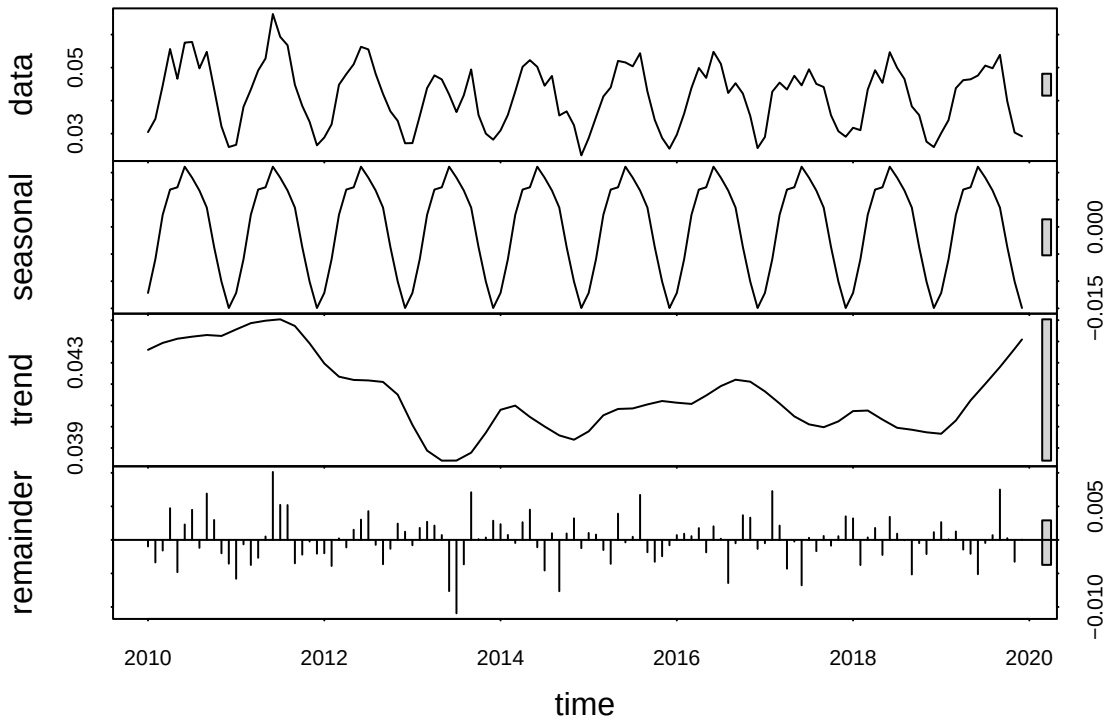
GaringerOzone.daily.ts.Decomposed<-stl(GaringerOzone.daily.ts,
                           s.window = 'periodic')

plot(GaringerOzone.daily.ts.Decomposed)
```




```
GaringerOzone.monthly.ts.Decomposed<-stl(GaringerOzone.monthly.ts,
                            s.window = 'periodic')

plot(GaringerOzone.monthly.ts.Decomposed)
```



12. Run a monotonic trend analysis for the monthly Ozone series.In this case the seasonal Mann-Kendall is most appropriate; why is this?

```
#12

trend::mk.test(GaringerOzone.monthly.ts)
```

```
##
##  Mann-Kendall trend test
##
## data:  GaringerOzone.monthly.ts
## z = -0.95947, n = 120, p-value = 0.3373
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -4.240000e+02  1.943647e+05 -5.939207e-02
```

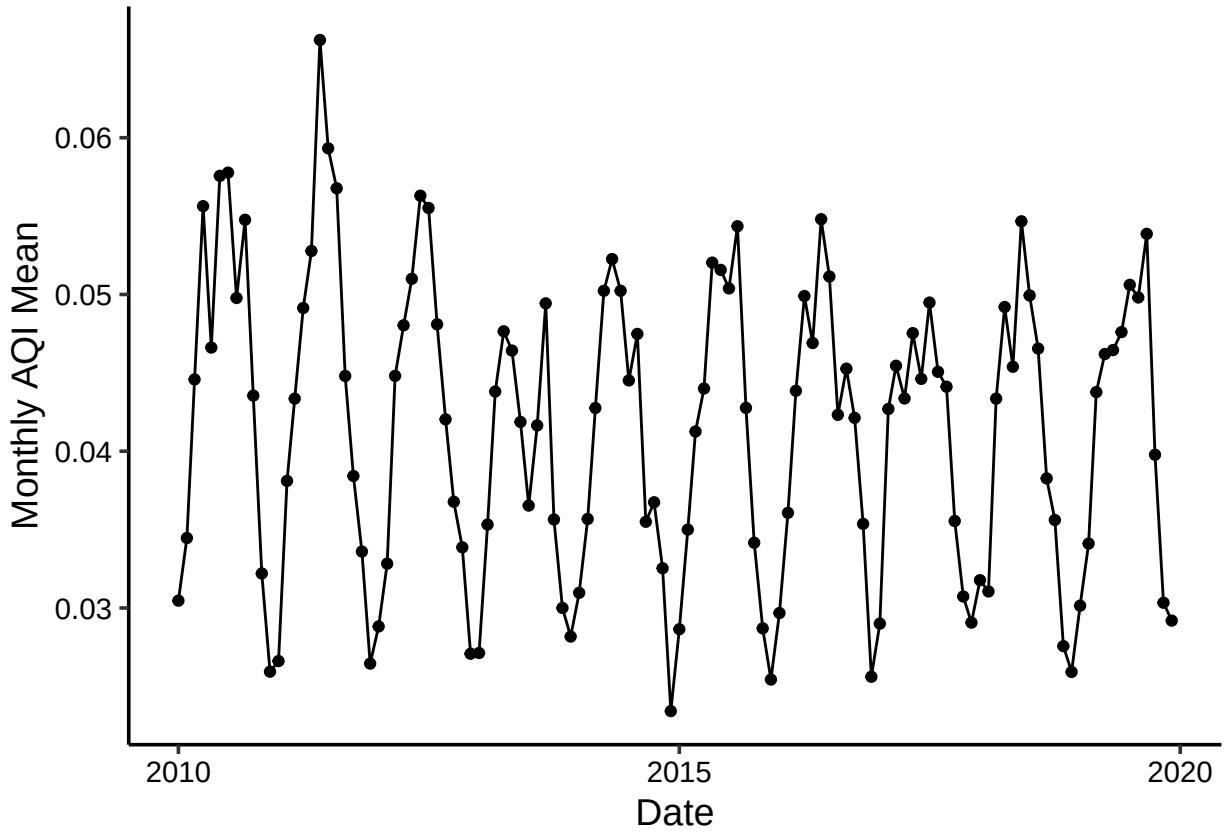
Answer: Becasue the Mann-Kendall test is robust to seasonality. We can observe some general seasonal trends in this graph.

13. Create a plot depicting mean monthly ozone concentrations over time, with both a geom_point and a geom_line layer. Edit your axis labels accordingly.

```r
# 13

MeanMonthlyOzoneLine<-GaringerOzone.monthly %>%
  ggplot(aes(x=Date, y= MonthlyMean))+
  geom_point()+
  geom_line()+
  labs(y="Monthly AQI Mean")

print(MeanMonthlyOzoneLine)
```



14. To accompany your graph, summarize your results in context of the research question. Include output from the statistical test in parentheses at the end of your sentence. Feel free to use multiple sentences in your interpretation.

    Answer: There is no significant trend to observe in this data and no reason to reject the null hypothesis that AQI is determined by Date..

data: GaringerOzone.monthly.ts z = -0.95947, n = 120, p-value = 0.3373 alternative hypothesis: true S is not equal to 0 sample estimates: S varS tau -424.00000000 194364.66666667 -0.05939207)

15. Subtract the seasonal component from the `GaringerOzone.monthly.ts`. Hint: Look at how we extracted the series components for the EnoDischarge on the lesson Rmd file.

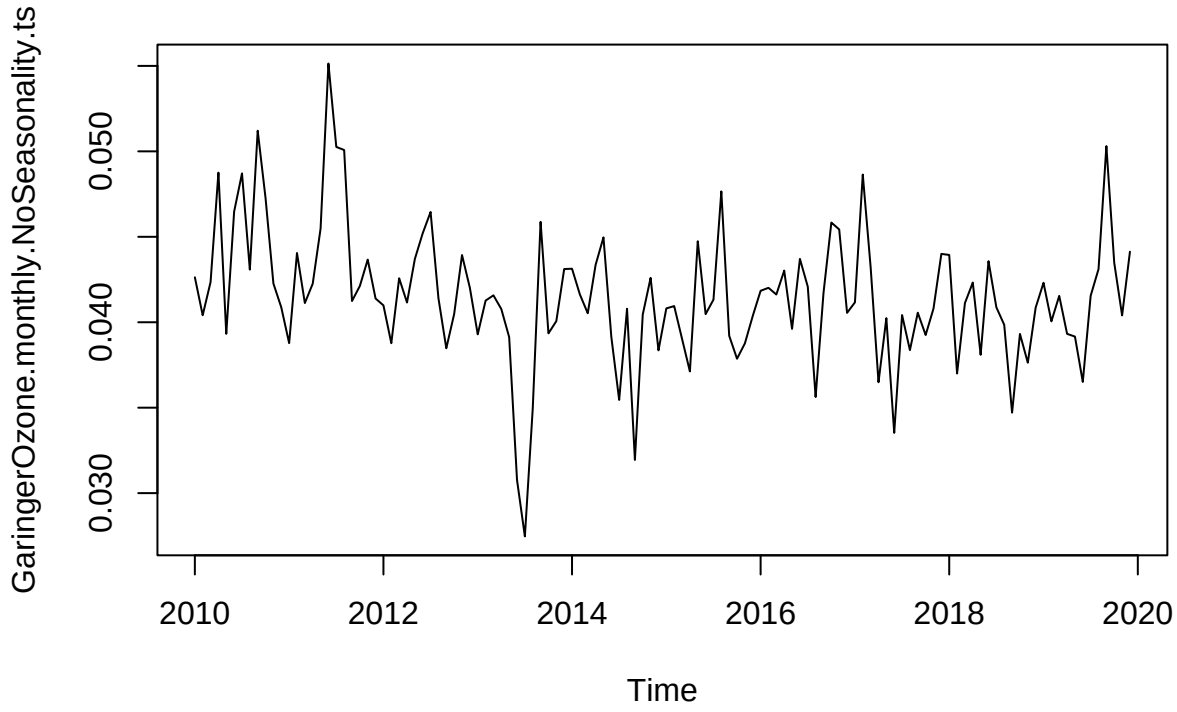
16. Run the Mann Kendall test on the non-seasonal Ozone monthly series. Compare the results with the ones obtained with the Seasonal Mann Kendall on the complete series.

```r
#15

GaringerOzone.monthly.Seasonality.ts<-
  GaringerOzone.monthly.ts.Decomposed$time.series[, 1]

GaringerOzone.monthly.NoSeasonality.ts<-GaringerOzone.monthly.ts-
  GaringerOzone.monthly.Seasonality.ts


plot(GaringerOzone.monthly.NoSeasonality.ts)
```




```r
#16

trend::mk.test(GaringerOzone.monthly.NoSeasonality.ts)
```

```
##
##  Mann-Kendall trend test
##
## data:  GaringerOzone.monthly.NoSeasonality.ts
## z = -2.672, n = 120, p-value = 0.00754
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##             S          varS           tau
## -1.179000e+03  1.943657e+05 -1.651376e-01
```

Answer: The Z value is much larger negative and the p-value is much lower. This means that the downard trend is much more pronounced without the noise of seasonality and that it is considered statistically signifigant enough to reject the null hypothesis.