

# Assignment 8: Time Series Analysis

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## 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

```
# Check working directory
getwd()
```

```
## [1] "/home/guest/EDA_Spring2025"
```

```
# Load necessary packages
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  1.9.4      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)

# Set ggplot theme
mytheme <- theme(panel.background = element_rect(fill = "cornsilk"),
  legend.title = element_text(color = "darkseagreen4"),
  axis.text.x = element_text(angle = 45),
  panel.grid.major = element_line(color = "white"))

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
# Load in Data
ozone_2010 <- read.csv("./Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2010_raw.csv",
  stringsAsFactors = TRUE)
ozone_2011 <- read.csv("./Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2011_raw.csv",
  stringsAsFactors = TRUE)
ozone_2012 <- read.csv("./Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2012_raw.csv",
  stringsAsFactors = TRUE)
ozone_2013 <- read.csv("./Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2013_raw.csv",
  stringsAsFactors = TRUE)
ozone_2014 <- read.csv("./Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2014_raw.csv",
  stringsAsFactors = TRUE)
ozone_2015 <- read.csv("./Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2015_raw.csv",
  stringsAsFactors = TRUE)
ozone_2016 <- read.csv("./Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2016_raw.csv",
  stringsAsFactors = TRUE)
ozone_2017 <- read.csv("./Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2017_raw.csv",
  stringsAsFactors = TRUE)
ozone_2018 <- read.csv("./Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2018_raw.csv",
  stringsAsFactors = TRUE)
ozone_2019 <- read.csv("./Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2019_raw.csv",
  stringsAsFactors = TRUE)

# Combine dataframes
GaringerOzone <- rbind(ozone_2010, ozone_2011, ozone_2012, ozone_2013, ozone_2014,
  ozone_2015, ozone_2016, ozone_2017, ozone_2018, ozone_2019)
```

## 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 - Set date column to date class
GaringerOzone$Date <- as.Date(GaringerOzone$Date, format = "%m/%d/%Y")

# 4 - Wrangle Data
GaringerOzone2 <- select(GaringerOzone, Date, Daily.Max.8.hour.Ozone.Concentration,
                        DAILY_AQI_VALUE)

# 5 - Create 'Days' dataframe
Date <- seq(as.Date("2010-01-01"), as.Date("2019-12-31"), by = "day",
           length.out = NULL)
Days <- as.data.frame(Date)

# 6 - Combine dataframes
GaringerOzone <- left_join(Days, GaringerOzone2)
```

```
## Joining with 'by = join_by(Date)'
```

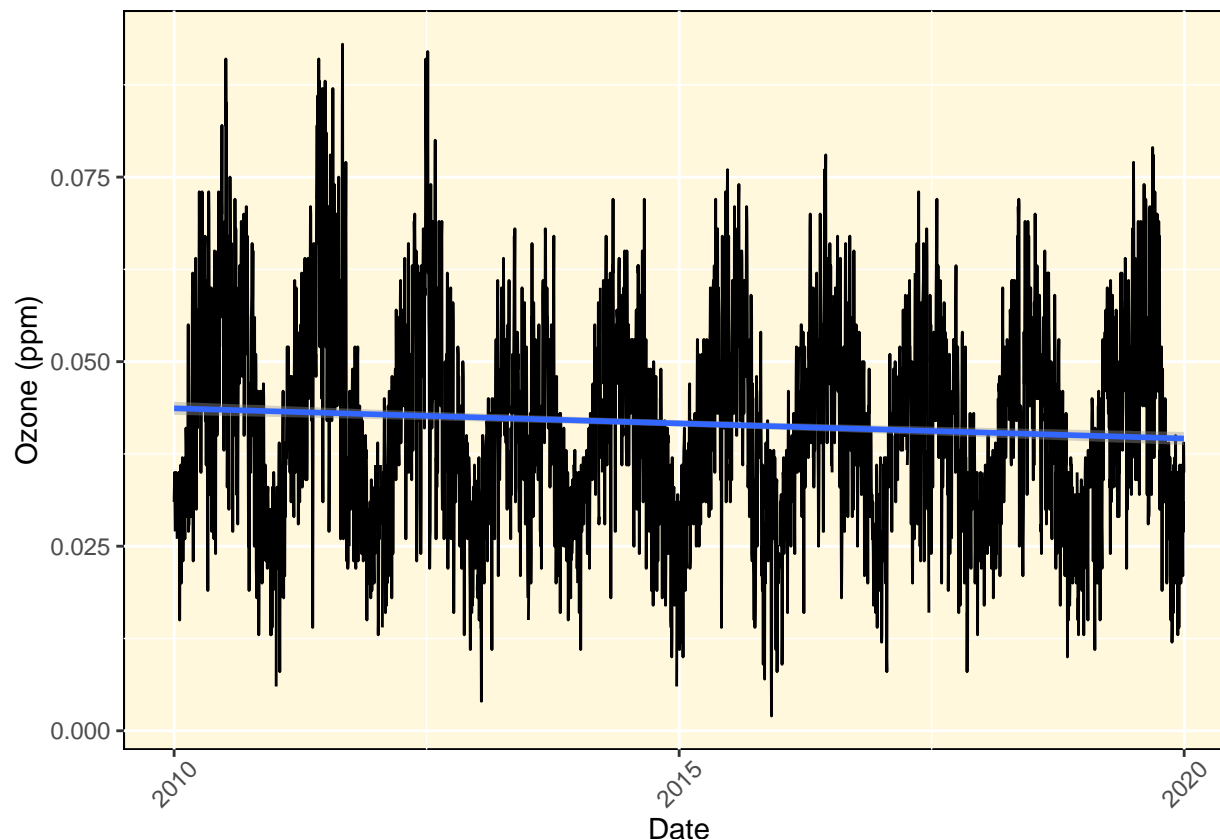
## Visualize

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
ggplot(GaringerOzone, aes(x = Date, y = Daily.Max.8.hour.Ozone.Concentration))+
  geom_line()+
  geom_smooth(method = "lm")+
  labs(x = "Date", y = "Ozone (ppm)")+
  theme
```

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

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



Answer: There seems to be a slight decrease in ozone concentrations over time.

## 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
GaringerOzone_clean <- GaringerOzone %>%
  mutate(ozone_clean = zoo::na.approx(Daily.Max.8.hour.Ozone.Concentration))
summary(GaringerOzone_clean$ozone_clean) # Check for NAs
```

```
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
## 0.00200 0.03200 0.04100 0.04151 0.05100 0.09300
```

Answer: The piecewise constant wouldn't have been good in this case because we can't assume ozone levels were the same on different days. The data follow a linear trend closer than they do a quadratic trend so spline interpolation is also inappropriate.

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 <- GaringerOzone_clean %>%
  mutate(month = month(GaringerOzone_clean$Date),
         year = year(GaringerOzone_clean$Date)) %>%
  group_by(month, year) %>%
  summarize(monthly_mean = mean(ozone_clean)) %>%
  mutate(Date = as.Date(paste(year, month, "01", sep = "-")))
```

## 'summarise()' has grouped output by 'month'. You can override using the  
## '.groups' argument.

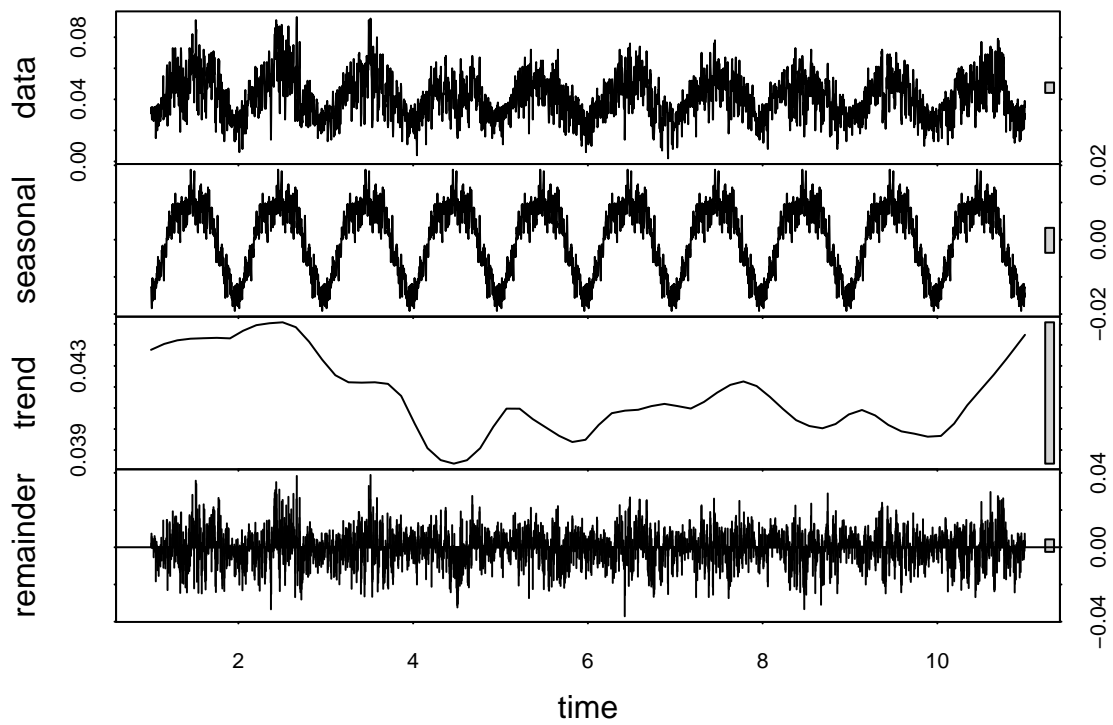
10. Generate two time series objects. Name the first `GaringerOzone.daily.ts` and base it on the dataframe of daily observations. Name the second `GaringerOzone.monthly.ts` and base it on the monthly average ozone values. Be sure that each specifies the correct start and end dates and the frequency of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

```
#10
GaringerOzone.daily.ts <- ts(GaringerOzone_clean$ozone_clean,
                             start=c(2010, 1), frequency = 365)

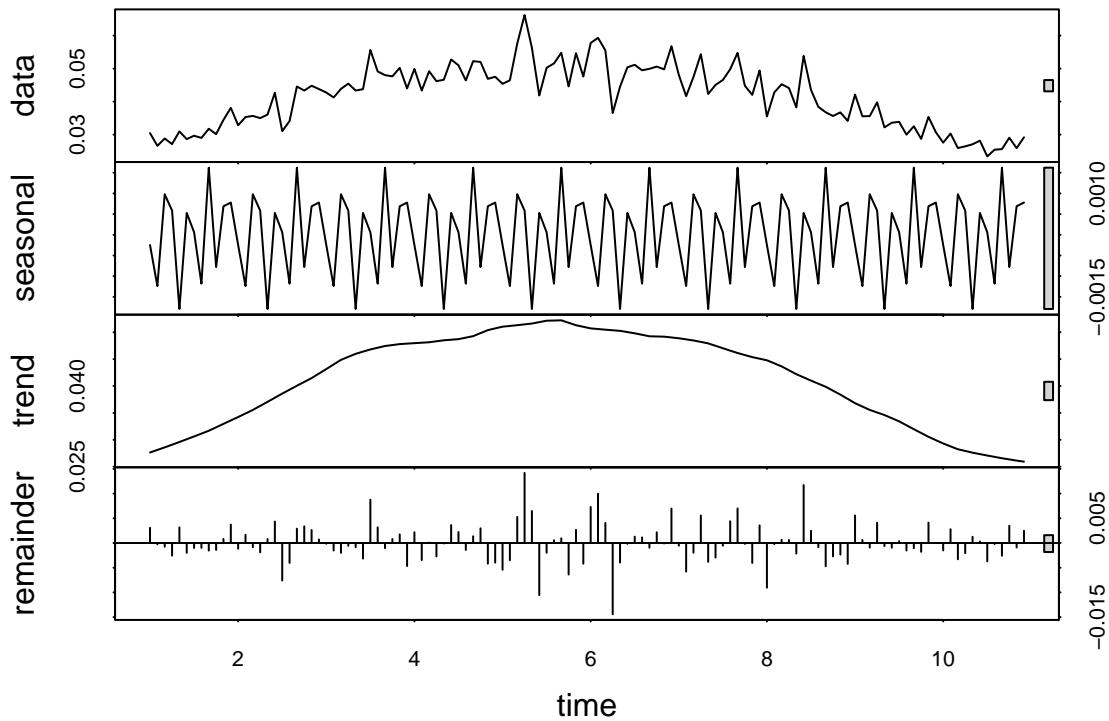
GaringerOzone.monthly.ts <- ts(GaringerOzone.monthly$monthly_mean,
                               start=c(2010, 1), frequency = 12)
```

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

```
#11
Garinger.daily.decomp <- stl(GaringerOzone.daily.ts, s.window = "periodic")
plot(Garinger.daily.decomp)
```



```
Garinger.monthly.decomp <- stl(GaringerOzone.monthly.ts, s.window = "periodic")
plot(Garinger.monthly.decomp)
```



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

```
monthly_trend <- trend::smk.test(GaringerOzone.monthly.ts)
monthly_trend
```

```
##
## Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data: GaringerOzone.monthly.ts
## z = -1.3685, p-value = 0.1712
## alternative hypothesis: true S is not equal to 0
## sample estimates:
## S varS
## -54 1500
```

```
summary(monthly_trend)
```

```
##
## Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data: GaringerOzone.monthly.ts
```

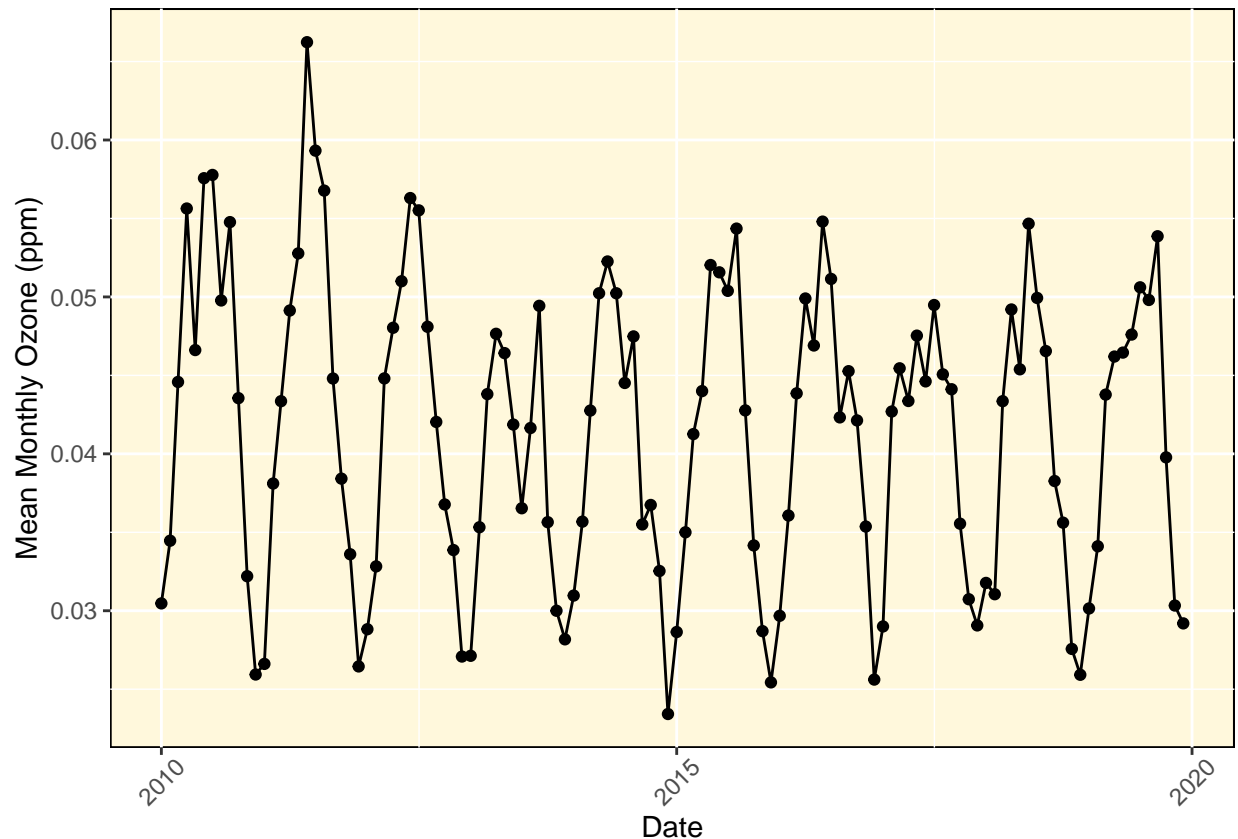
```
## alternative hypothesis: two.sided
##
## Statistics for individual seasons
##
## H0
##
##      S varS      tau      z Pr(>|z|)
## Season 1:  S = 0      1 125  0.022  0.000  1.00000
## Season 2:  S = 0      5 125  0.111  0.358  0.72051
## Season 3:  S = 0     -3 125 -0.067 -0.179  0.85803
## Season 4:  S = 0      1 125  0.022  0.000  1.00000
## Season 5:  S = 0     -9 125 -0.200 -0.716  0.47427
## Season 6:  S = 0      1 125  0.022  0.000  1.00000
## Season 7:  S = 0    -11 125 -0.244 -0.894  0.37109
## Season 8:  S = 0     -3 125 -0.067 -0.179  0.85803
## Season 9:  S = 0     -5 125 -0.111 -0.358  0.72051
## Season 10:  S = 0   -11 125 -0.244 -0.894  0.37109
## Season 11:  S = 0   -15 125 -0.333 -1.252  0.21050
## Season 12:  S = 0     -5 125 -0.111 -0.358  0.72051
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Answer: This is the only monotonic trend analysis with seasonality, we know there is seasonality due to the up and down trend seen on data plots.

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.

```
# 13
ggplot(GaringerOzone.monthly, aes(x = Date, y = monthly_mean))+
  geom_point()+
  geom_line()+
  labs(x = "Date", y = "Mean Monthly Ozone (ppm)")+
  mytheme
```





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 not a significant difference in ozone concentration by month ( $S = -54$ ,  $p = 0.1712$ ).

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.

#15

```
Ozone_monthly_components <- as.data.frame(Garinger.monthly.decomp$time.series[,1:3])
Ozone_monthly_nonseasonal <- GaringerOzone.monthly.ts - Ozone_monthly_components$seasonal
```

#16

```
non_seasonal_trend <- trend::mk.test(Ozone_monthly_nonseasonal)
non_seasonal_trend
```

```
##
## Mann-Kendall trend test
##
```

```
## data: Ozone_monthly_nonseasonal
## z = -1.6263, n = 120, p-value = 0.1039
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##          S          varS          tau
## -7.180000e+02  1.943667e+05 -1.005602e-01
```

```
summary(non_seasonal_trend)
```

```
##          Length Class  Mode
## data.name    1      -none- character
## p.value       1      -none- numeric
## statistic     1      -none- numeric
## null.value    1      -none- numeric
## parameter     1      -none- numeric
## estimates     3      -none- numeric
## alternative   1      -none- character
## method        1      -none- character
## pvalg         1      -none- numeric
```

Answer: Even without the seasonal component of the monthly ozone time series, there is still not a significant difference in ozone concentration ( $S = -718$ ,  $p = 0.1039$ ).