

Assignment 8: Time Series Analysis

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OVERVIEW

This exercise accompanies the lessons in Environmental Data Analytics on time series analysis.

Directions

1. Change “Student Name” on line 3 (above) with your name.
2. Work through the steps, **creating code and output** that fulfill each instruction.
3. Be sure to **answer the questions** in this assignment document.
4. When you have completed the assignment, **Knit** the text and code into a single PDF file.
5. After Knitting, submit the completed exercise (PDF file) to the dropbox in Sakai. Add your last name into the file name (e.g., “Salk_A06_GLMs_Week1.Rmd”) prior to submission.

The completed exercise is due on Tuesday, March 3 at 1:00 pm.

Set up

1. Set up your session:
 - Check your working directory
 - Load the tidyverse, lubridate, zoo, and trend packages
 - Set your ggplot theme
 - 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). Call these GaringerOzone201*, with the star filled in with the appropriate year in each of ten cases.

```
getwd()
```

```
## [1] "/Users/ethel/Desktop/Environ 872/Environmental_Data_Analytics_2020"
```

```
library(tidyverse)
```

```
library(lubridate)
```

```
#install.packages("zoo")
```

```
library(zoo)
```

```
#install.packages("trend")
```

```
library(trend)
```

```
GaringerOzone2010<- read.csv("../Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2010_raw.csv")
```

```
GaringerOzone2011<- read.csv("../Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2011_raw.csv")
```

```
GaringerOzone2012<- read.csv("../Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2012_raw.csv")
```

```
GaringerOzone2013<- read.csv("../Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2013_raw.csv")
```

```
GaringerOzone2014<- read.csv("../Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2014_raw.csv")
```

```
GaringerOzone2015<- read.csv("../Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2015_raw.csv")
```

```
GaringerOzone2016<- read.csv("../Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2016_raw.csv")
```

```
GaringerOzone2017<- read.csv("../Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2017_raw.csv")
```

```
GaringerOzone2018<- read.csv("../Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2018_raw.csv")
```

```
GaringerOzone2019<- read.csv("../Data/Raw/Ozone_TimeSeries/EPAair_03_GaringerNC2019_raw.csv")
```

Wrangle

2. Combine your ten datasets into one dataset called `GaringerOzone`. Think about whether you should use a join or a row bind.
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`.

```
#2
#Ozone_TimeSeries_Files = list.files(path = "Z:/872/Data/Raw/Ozone_TimeSeries/", pattern="*.csv", full.names=TRUE)
#Ozone_TimeSeries_Files

Ozone_TimeSeries_Files = list.files(path = "../Data/Raw/Ozone_TimeSeries/", pattern="*.csv", full.names=TRUE)
Ozone_TimeSeries_Files

## [1] "../Data/Raw/Ozone_TimeSeries//EPAair_03_GaringerNC2010_raw.csv"
## [2] "../Data/Raw/Ozone_TimeSeries//EPAair_03_GaringerNC2011_raw.csv"
## [3] "../Data/Raw/Ozone_TimeSeries//EPAair_03_GaringerNC2012_raw.csv"
## [4] "../Data/Raw/Ozone_TimeSeries//EPAair_03_GaringerNC2013_raw.csv"
## [5] "../Data/Raw/Ozone_TimeSeries//EPAair_03_GaringerNC2014_raw.csv"
## [6] "../Data/Raw/Ozone_TimeSeries//EPAair_03_GaringerNC2015_raw.csv"
## [7] "../Data/Raw/Ozone_TimeSeries//EPAair_03_GaringerNC2016_raw.csv"
## [8] "../Data/Raw/Ozone_TimeSeries//EPAair_03_GaringerNC2017_raw.csv"
## [9] "../Data/Raw/Ozone_TimeSeries//EPAair_03_GaringerNC2018_raw.csv"
## [10] "../Data/Raw/Ozone_TimeSeries//EPAair_03_GaringerNC2019_raw.csv"

GaringerOzone <- Ozone_TimeSeries_Files %>%
  plyr::ldply(read.csv)

# 3
GaringerOzone$Date <- as.Date(GaringerOzone$Date, format = "%m/%d/%Y")

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

# 5
Days <- data.frame(seq(as.Date("2010-01-01"), as.Date("2019-12-31"), by=1))
colnames(Days)[1] <- "Date"

# 6
GaringerOzone <- left_join(Days, GaringerOzone_Wrangle, by = 'Date')
```

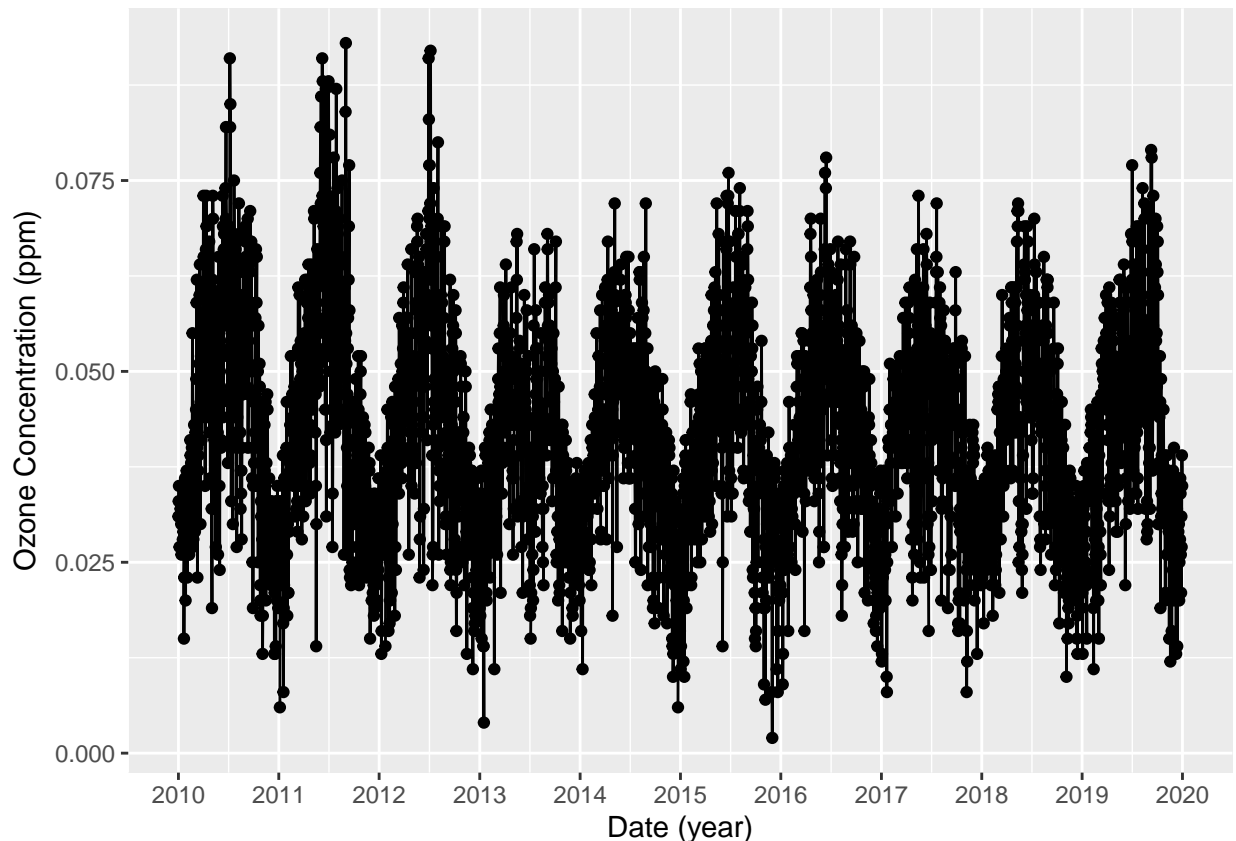
Visualize

7. Create a ggplot depicting ozone concentrations over time. In this case, we will plot actual concentrations in ppm, not AQI values. Format your axes accordingly.

```
OzoneCon <-
ggplot(GaringerOzone, aes(x = Date, y = Daily.Max.8.hour.Ozone.Concentration)) +
  geom_point() +
  geom_line() +
  labs(x = "Date (year)", y = expression("Ozone Concentration (ppm)")) +
  scale_x_date(date_breaks="1 year", date_labels="%Y")

print(OzoneCon)
```

```
## Warning: Removed 63 rows containing missing values (geom_point).
```



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?

Answer: In linear interpolation, the estimated point is assumed to lie on the line joining the nearest points to the left and right. For this question, I would like to see nearest ozone concentration to that of previous day and that of next day, so we need to use linear interpolation.

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)
10. Generate a time series called `GaringerOzone.monthly.ts`, with a monthly frequency that specifies the

correct start and end dates.

11. Run a time series analysis. In this case the seasonal Mann-Kendall is most appropriate; why is this?

Answer: I think the seasonal Mann-Kendall is most appropriate, because we would like to test null hypothesis “true slop is not equal to 0”, and see the overall trend from 2010 to 2019. Moreover, seasonal Mann-Kendall can break down the potential seasonal trend into more interpretable components, and see the seaaonality.

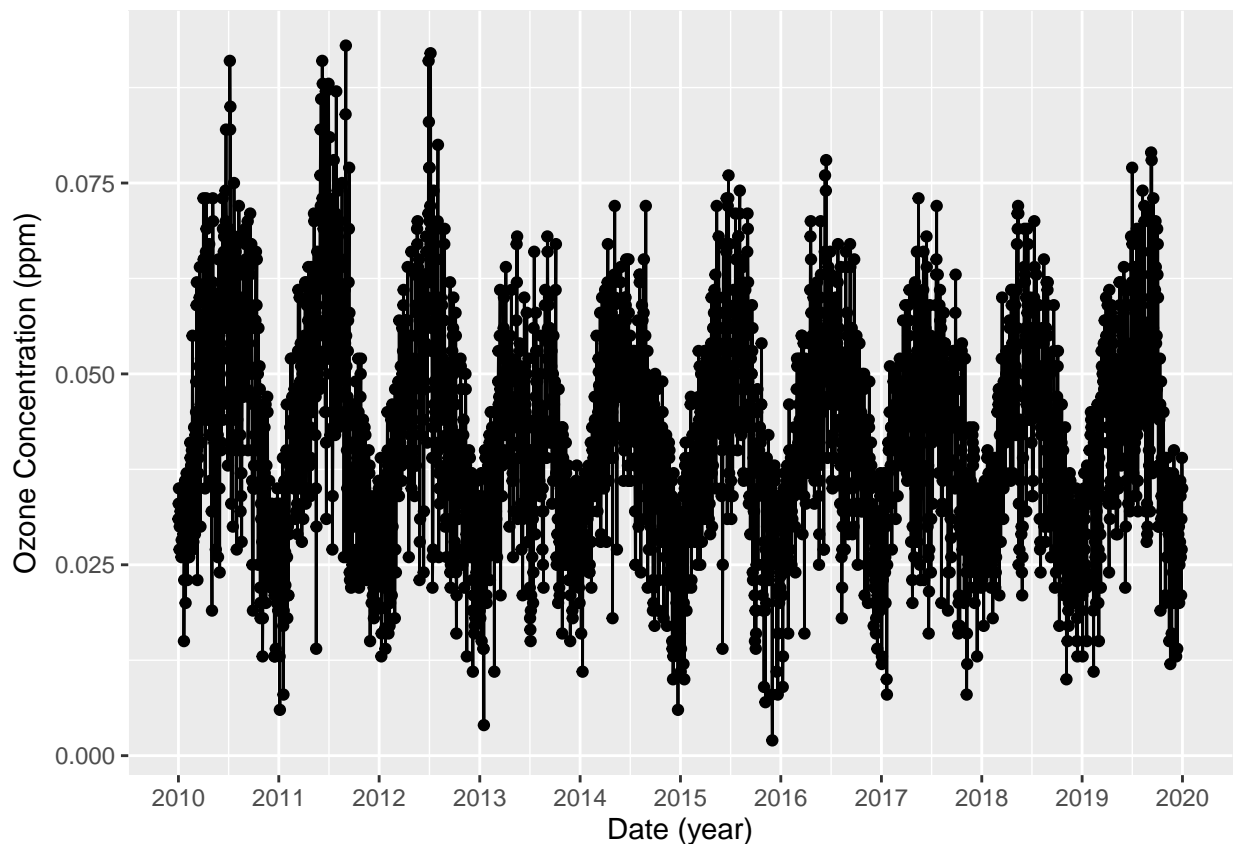
12. To figure out the slope of the trend, run the function `sea.sens.slope` on the time series dataset.

13. Create a plot depicting mean monthly ozone concentrations over time, with both a `geom_point` and a `geom_line` layer. No need to add a line for the seasonal Sen’s slope; this is difficult to apply to a graph with time as the x axis. Edit your axis labels accordingly.

```
# 8
GaringerOzone$Daily.Max.8.hour.Ozone.Concentration <-
  na.approx(GaringerOzone$Daily.Max.8.hour.Ozone.Concentration)

GaringerOzone.interpolated <-
ggplot(GaringerOzone, aes(x = Date, y = Daily.Max.8.hour.Ozone.Concentration)) +
  geom_point() +
  geom_line() +
  labs(x = "Date (year)", y = expression("Ozone Concentration (ppm)")) +
  scale_x_date(date_breaks="1 year", date_labels="%Y")

print(GaringerOzone.interpolated)
```



```

# 9
GaringerOzone.monthly <- GaringerOzone %>%
  mutate (Year = year(Date), Month = month(Date)) %>%
  group_by(Year, Month) %>%
  summarise(OzoneConcentration = mean(Daily.Max.8.hour.Ozone.Concentration, n = n()))
##n=n() means that a variable named n will be assigned the number of rows (think number of observations)

GaringerOzone.monthly$Date <- as.Date(paste(GaringerOzone.monthly$Year,
                                           GaringerOzone.monthly$Month, 1, sep="-"),
                                     format = "%Y-%m-%d")

# 10
GaringerOzone.monthly.ts <- ts(GaringerOzone.monthly$OzoneConcentration,
                              frequency = 12, start = c(2010, 1, 1), end = c(2019, 12, 1))

# 11
GaringerOzone.monthly.trend <- smk.test(GaringerOzone.monthly.ts)
GaringerOzone.monthly.trend

##
## Seasonal Mann-Kendall trend test (Hirsch-Slack test)
##
## data: GaringerOzone.monthly.ts
## z = -1.963, p-value = 0.04965
## alternative hypothesis: true S is not equal to 0
## sample estimates:
##      S varS
##    -77 1499

summary(GaringerOzone.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   15  125  0.333  1.252  0.21050
## Season 2:  S = 0  -1  125 -0.022  0.000  1.00000
## Season 3:  S = 0  -4  124 -0.090 -0.269  0.78762
## Season 4:  S = 0 -17  125 -0.378 -1.431  0.15241
## Season 5:  S = 0 -15  125 -0.333 -1.252  0.21050
## Season 6:  S = 0 -17  125 -0.378 -1.431  0.15241
## Season 7:  S = 0 -11  125 -0.244 -0.894  0.37109
## Season 8:  S = 0  -7  125 -0.156 -0.537  0.59151
## Season 9:  S = 0  -5  125 -0.111 -0.358  0.72051
## Season 10: S = 0 -13  125 -0.289 -1.073  0.28313
## Season 11: S = 0 -13  125 -0.289 -1.073  0.28313
## Season 12: S = 0  11  125  0.244  0.894  0.37109
## ---

```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# 12
```

```
sea.sens.slope(GaringerOzone.monthly.ts)
```

```
## [1] -0.0002044163
```

```
# 13
```

```
GaringerOzone.monthly.interpolated <-
```

```
ggplot(GaringerOzone.monthly, aes(x = Date, y = OzoneConcentration)) +
```

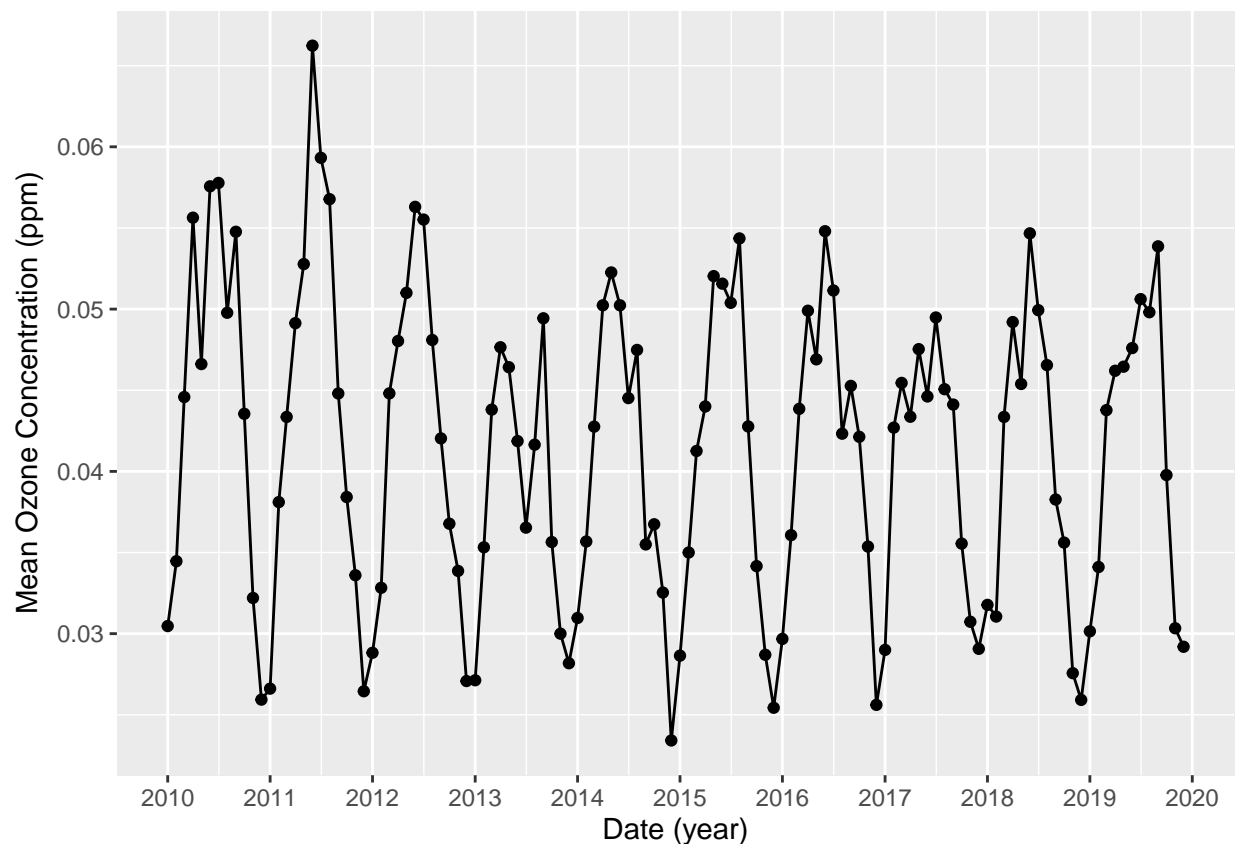
```
  geom_point() +
```

```
  geom_line() +
```

```
  labs(x = "Date (year)", y = expression("Mean Ozone Concentration (ppm)")) +
```

```
  scale_x_date(date_breaks="1 year", date_labels="%Y")
```

```
print(GaringerOzone.monthly.interpolated)
```



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: First, seasonal variations of ozone concentration repeat over a specific period about one year; Second, trend variations ozone concentration move up in first six months of year and move down in second six months of year, which is a reasonably predictable pattern. However, the maximum of ozone concentration varies a lot, which is a slight decrease trend ($S = -0.0002044163$), but overall ozone concentrations have no significant changed over the 2010s at this station ($z = -1.963$, $p\text{-value} = 0.04965$).