

ENV 790.30 - Time Series Analysis for Energy Data | Spring 2023

Assignment 3 - Due date 02/10/23

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Directions

You should open the .rmd file corresponding to this assignment on RStudio. The file is available on our class repository on Github.

Once you have the file open on your local machine the first thing you will do is rename the file such that it includes your first and last name (e.g., “LuanaLima_TSA_A02_Sp23.Rmd”). Then change “Student Name” on line 4 with your name.

Then you will start working through the assignment by **creating code and output** that answer each question. Be sure to use this assignment document. Your report should contain the answer to each question and any plots/tables you obtained (when applicable).

Please keep this R code chunk options for the report. It is easier for us to grade when we can see code and output together. And the tidy.opts will make sure that line breaks on your code chunks are automatically added for better visualization.

When you have completed the assignment, **Knit** the text and code into a single PDF file. Submit this pdf using Sakai.

Questions

Consider the same data you used for A2 from the spreadsheet “Table_10.1_Renewable_Energy_Production_and_Consumption”. The data comes from the US Energy Information and Administration and corresponds to the December 2022 **Monthly** Energy Review. Once again you will work only with the following columns: Total Biomass Energy Production, Total Renewable Energy Production, Hydroelectric Power Consumption. Create a data frame structure with these three time series only.

R packages needed for this assignment: “forecast”, “tseries”, and “Kendall”. Install these packages, if you haven’t done yet. Do not forget to load them before running your script, since they are NOT default packages.

```
#Load/install required package here
library(forecast)
```

```
## Registered S3 method overwritten by 'quantmod':
##   method      from
##   as.zoo.data.frame zoo
```

```
library(Kendall)
library(lubridate)
```

```
##
## Attaching package: 'lubridate'

## The following objects are masked from 'package:base':
##
```

```
##      date, intersect, setdiff, union
library(ggplot2)
library(dplyr)

##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##      filter, lag

## The following objects are masked from 'package:base':
##
##      intersect, setdiff, setequal, union
library(tidyr)
```

##Trend Component

Q1

Create a plot window that has one row and three columns. And then for each object on your data frame, fill the plot window with time series plot, ACF and PACF. You may use the some code form A2, but I want all three plots on the same window this time. (Hint: use par() function)

```
#Importing data set
energy_data <- read.csv(file="/Users/christine/Documents/TimeSeriesAnalysis/TimeSeriesAnalysis_Jiao/Data")
```

```
energy_data1 <- energy_data[,4:6]
head(energy_data1)
```

```
##      Total.Biomass.Energy.Production Total.Renewable.Energy.Production
## 1                                129.787                        403.981
## 2                                117.338                        360.900
## 3                                129.938                        400.161
## 4                                125.636                        380.470
## 5                                129.834                        392.141
## 6                                125.611                        377.232
##      Hydroelectric.Power.Consumption
## 1                                272.703
## 2                                242.199
## 3                                268.810
## 4                                253.185
## 5                                260.770
## 6                                249.859
```

```
ts_energy_data1 <- ts(energy_data1,frequency=12,start=c(1973,1))
head(ts_energy_data1,20)
```

```
##      Total.Biomass.Energy.Production Total.Renewable.Energy.Production
## Jan 1973                        129.787                        403.981
## Feb 1973                        117.338                        360.900
## Mar 1973                        129.938                        400.161
## Apr 1973                        125.636                        380.470
## May 1973                        129.834                        392.141
## Jun 1973                        125.611                        377.232
## Jul 1973                        129.787                        367.325
```

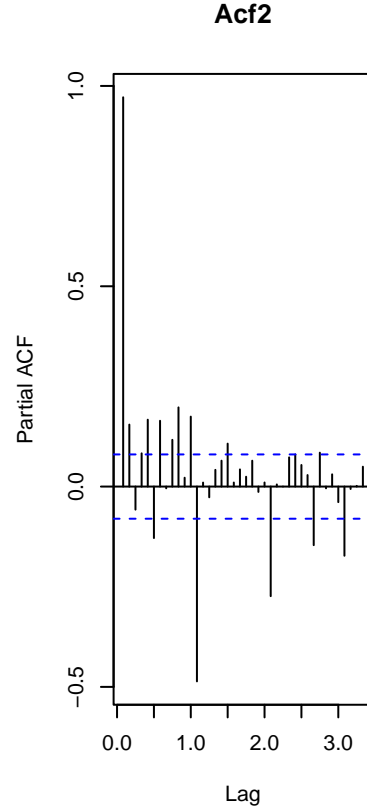
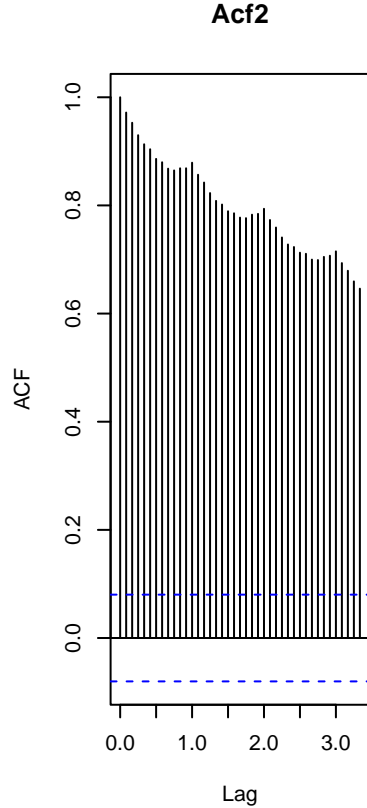
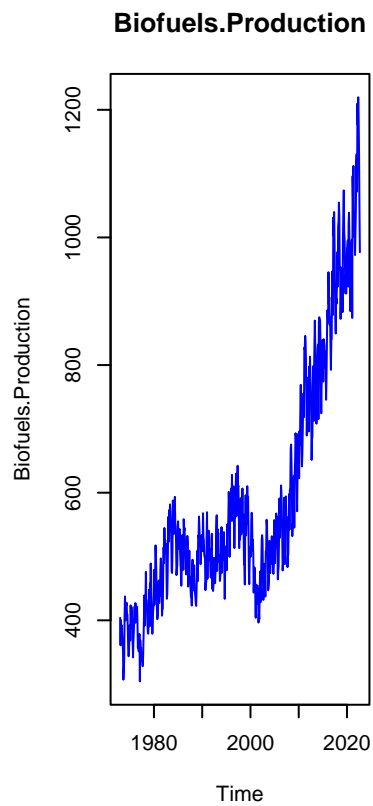
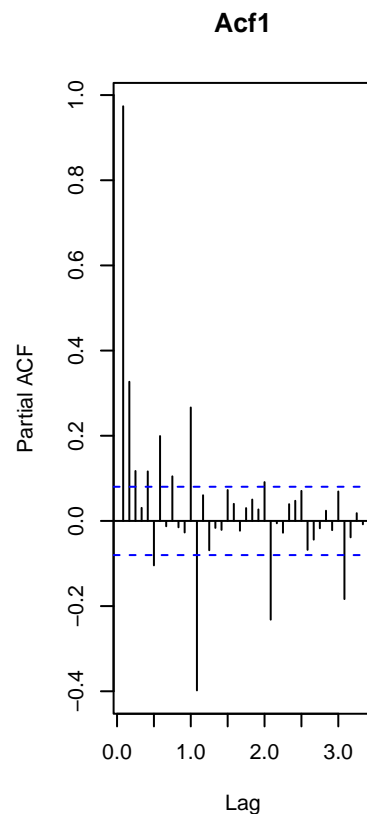
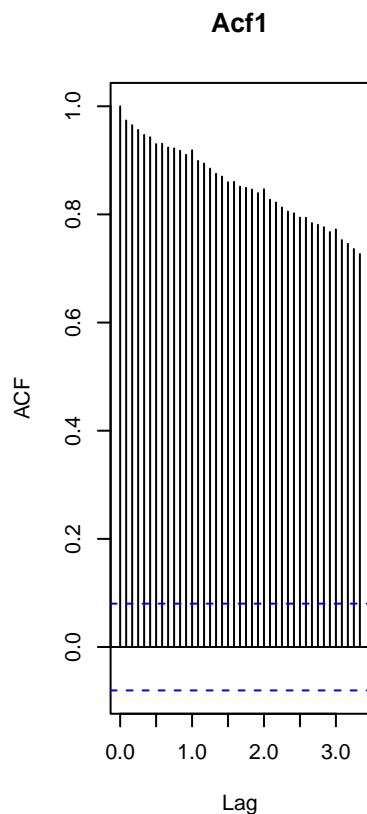
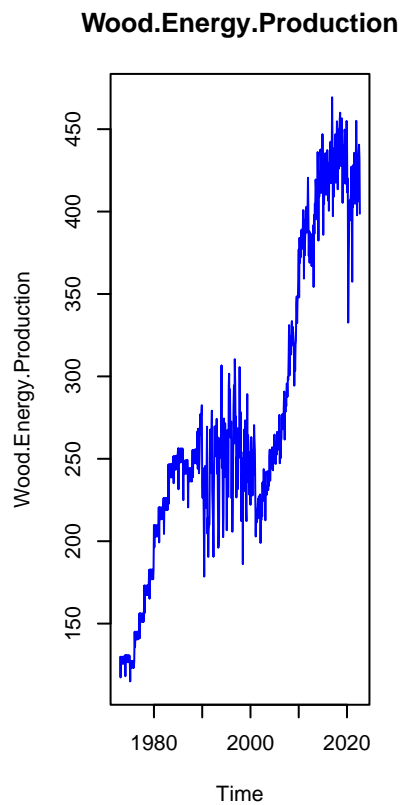
```
## Aug 1973      129.918      353.757
## Sep 1973      125.782      307.006
## Oct 1973      129.970      323.453
## Nov 1973      125.643      337.817
## Dec 1973      129.824      406.694
## Jan 1974      130.807      437.467
## Feb 1974      118.091      399.942
## Mar 1974      130.727      423.474
## Apr 1974      126.583      422.323
## May 1974      130.789      427.657
## Jun 1974      126.611      409.281
## Jul 1974      130.756      409.719
## Aug 1974      130.763      386.101
##      Hydroelectric.Power.Consumption
## Jan 1973      272.703
## Feb 1973      242.199
## Mar 1973      268.810
## Apr 1973      253.185
## May 1973      260.770
## Jun 1973      249.859
## Jul 1973      235.670
## Aug 1973      222.077
## Sep 1973      179.733
## Oct 1973      191.723
## Nov 1973      210.285
## Dec 1973      274.435
## Jan 1974      304.506
## Feb 1974      279.950
## Mar 1974      290.582
## Apr 1974      293.702
## May 1974      294.828
## Jun 1974      280.695
## Jul 1974      276.772
## Aug 1974      253.175
```

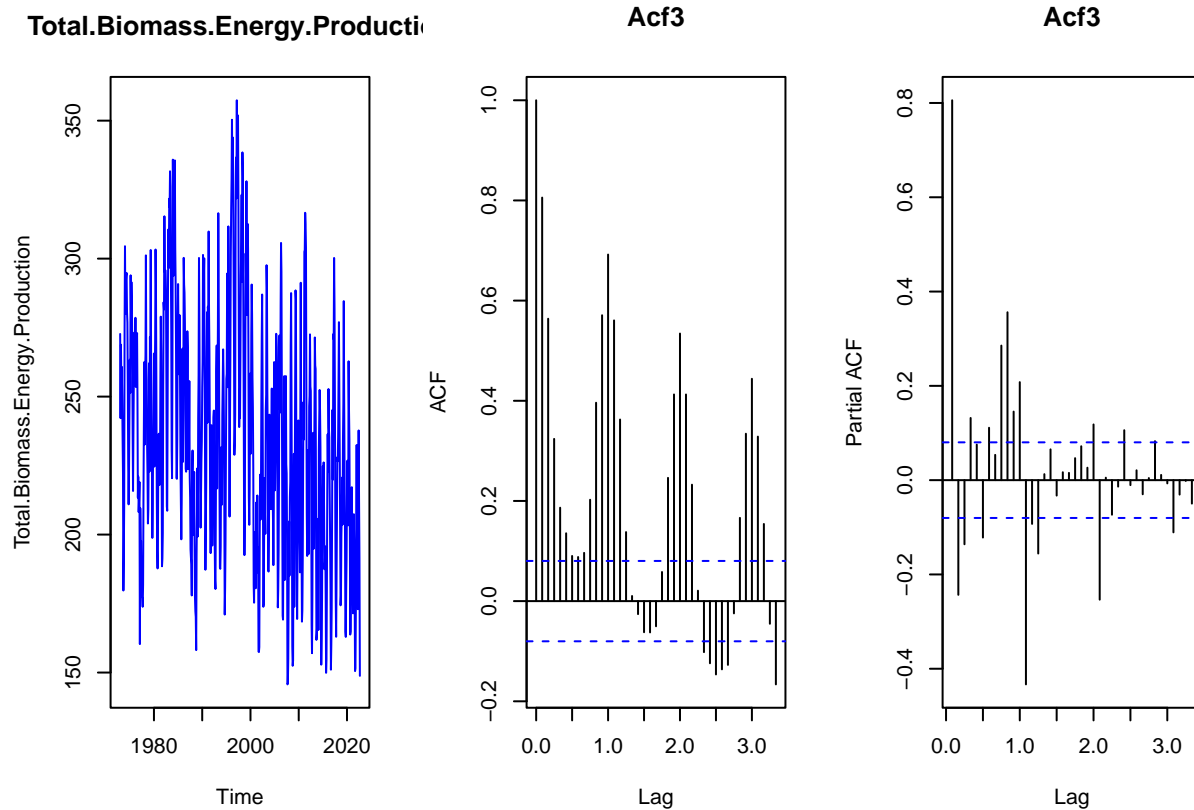
```
my_date11 <- paste(energy_data[,1],ts_energy_data1[,2],sep="-")
```

```
ed <- energy_data %>%
  separate(Month, c('year', 'month'))
```

```
my_date <- paste(ed[,2],ed[,1],sep="-")
my_date <- my(my_date)
```

```
names <- colnames(energy_data)
for(i in 1:3){
  par(mfrow=c(1,3))
  plot(ts_energy_data1[,i],type="l",col="blue",ylab=paste0(names[i+1]),main=names[i+1])
  acf(ts_energy_data1[,i],lag.max = 40, main=paste0("Acf",i))
  pacf(ts_energy_data1[,i],lag.max = 40, main=paste0("Acf",i))
}
```





Q2

From the plot in Q1, do the series Total Biomass Energy Production, Total Renewable Energy Production, Hydroelectric Power Consumption appear to have a trend? If yes, what kind of trend?

The Total Biomass Energy Production has no clear uptrend and downtrend. So it is the stationary trend. Both of the Total Renewable Energy Production and the Hydroelectric Power Consumption appear to have an upward pattern in time series. So the Total Renewable Energy Production and the Hydroelectric Power Consumption is upward trend or uptrend.

Q3

Use the `lm()` function to fit a linear trend to the three time series. Ask R to print the summary of the regression. Interpret the regression output, i.e., slope and intercept. Save the regression coefficients for further analysis.

```
nobs <- nrow(ts_energy_data1)
t <- 1:nobs
iHP <- 0
nobs

## [1] 597

#Fit a linear trend to TS of iHP
Linear_trend0 <- lm(ts_energy_data1[,iHP+1] ~ t)
summary(Linear_trend0)

##
## Call:
## lm(formula = ts_energy_data1[, iHP + 1] ~ t)
```

```
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -102.800  -23.994    5.667   32.265   82.192
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 1.337e+02  3.245e+00  41.22  <2e-16 ***
## t           4.800e-01  9.402e-03  51.05  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 39.59 on 595 degrees of freedom
## Multiple R-squared:  0.8142, Adjusted R-squared:  0.8138
## F-statistic: 2607 on 1 and 595 DF, p-value: < 2.2e-16
```

The intercept is 1.337e+02, and the slope is 4.800e-01. The relationship here is positive. The p-value here is less than 2.2e-16, which is also smaller than 0.05. Therefore, the null hypothesis is rejected, and there is a trend in Biomass energy production.

```
nobs <- nrow(ts_energy_data1)
t <- 1:nobs
iHP <- 1

#Fit a linear trend to TS of iHP
Linear_trend1 <- lm(ts_energy_data1[,iHP+1] ~ t)
summary(Linear_trend1)
```

```
##
## Call:
## lm(formula = ts_energy_data1[, iHP + 1] ~ t)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -238.75  -61.85    8.59   64.48  352.27
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 312.2475     8.4902   36.78  <2e-16 ***
## t           0.9362     0.0246   38.05  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 103.6 on 595 degrees of freedom
## Multiple R-squared:  0.7088, Adjusted R-squared:  0.7083
## F-statistic: 1448 on 1 and 595 DF, p-value: < 2.2e-16
```

The intercept is 312.2475, and the slope is 0.9362. The relationship here is positive. The p-value here is less than 2.2e-16, which is also smaller than 0.05, therefore, the null hypothesis is rejected, and there is a trend in renewable energy production.

```
nobs <- nrow(ts_energy_data1)
t <- 1:nobs
iHP <- 2

#Fit a linear trend to TS of iHP
```

```
Linear_trend2 <- lm(ts_energy_data1[,iHP+1] ~ t)
summary(Linear_trend2)
```

```
##
## Call:
## lm(formula = ts_energy_data1[, iHP + 1] ~ t)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -95.42 -31.20  -2.56   27.32 121.61
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 259.898013   3.427300  75.832  < 2e-16 ***
## t           -0.082888   0.009931  -8.346 4.94e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 41.82 on 595 degrees of freedom
## Multiple R-squared:  0.1048, Adjusted R-squared:  0.1033
## F-statistic: 69.66 on 1 and 595 DF,  p-value: 4.937e-16
```

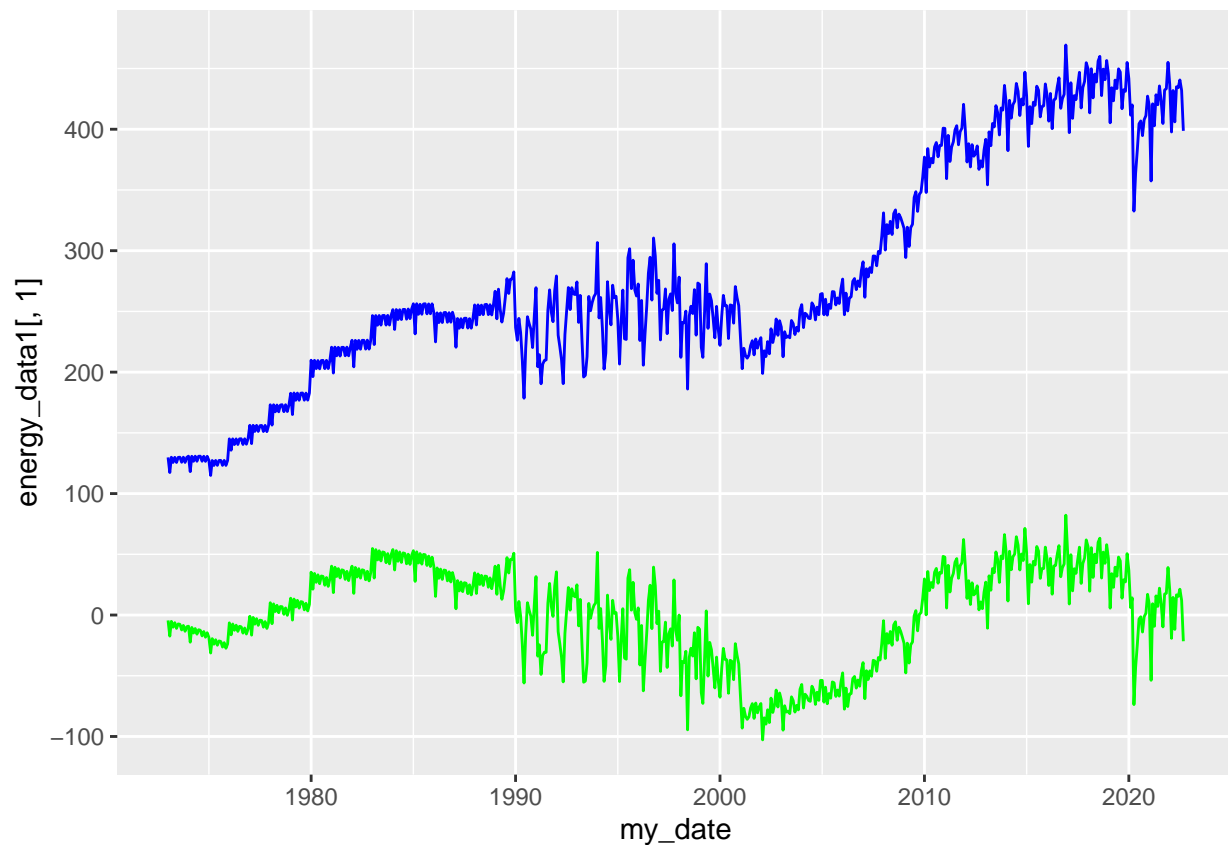
The intercept is 259.898013, and the slope is -0.082888. The relationship here is negative. The p-value here is 4.937e-16, which is smaller than 0.05, therefore, the null hypothesis is rejected, and there is a trend in Hydroelectric Power Consumption

Q4

Use the regression coefficients from Q3 to detrend the series. Plot the detrended series and compare with the plots from Q1. What happened? Did anything change?

```
beta0 <- Linear_trend0$coefficients[1]
beta1 <- Linear_trend0$coefficients[2]
detrend_energy_data0 <- energy_data1[,1]-(beta0+beta1*t)

ggplot(energy_data1, aes(x=my_date, y=energy_data1[,1]))+
  geom_line(color="blue")+
  geom_line(aes(y=detrend_energy_data0), col="green")
```

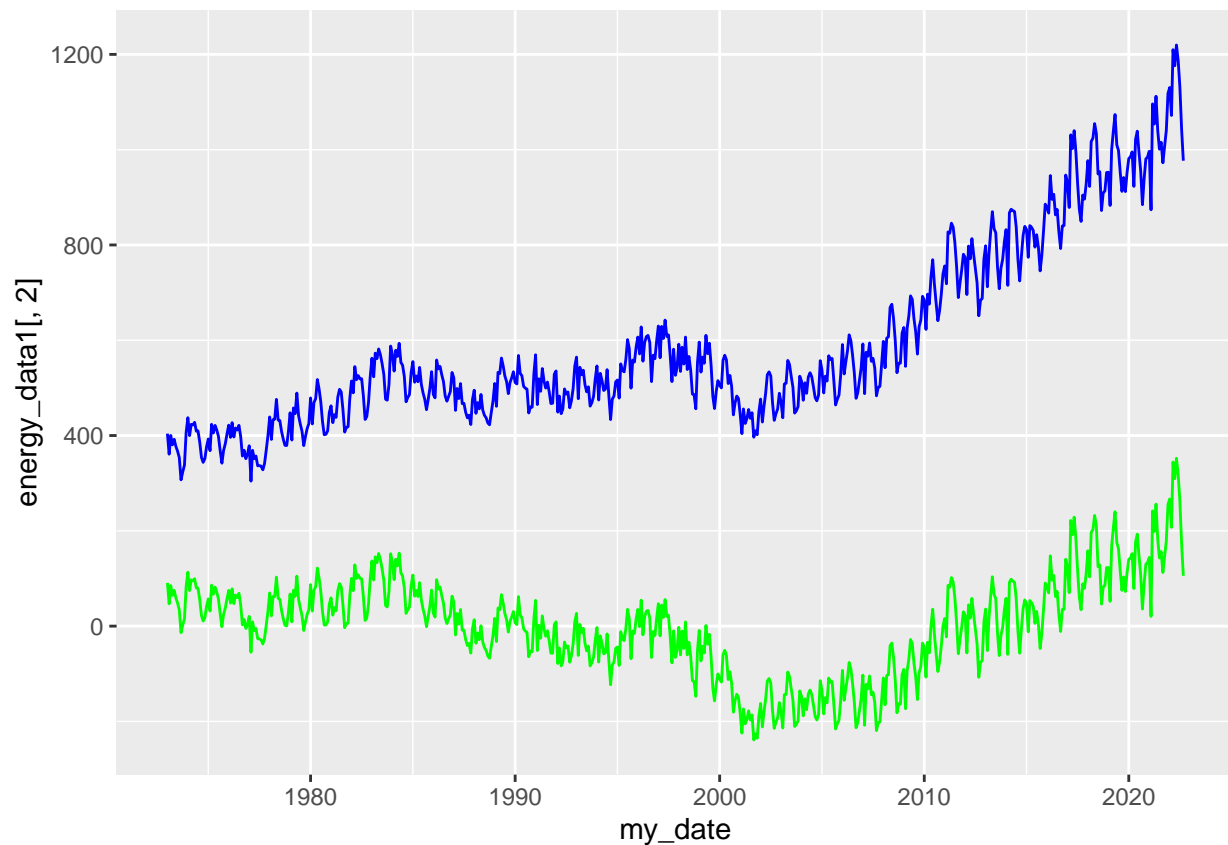


```
ylab(paste0("Production", colnames(energy_data1)[iHP+1], sep=""))
```

```
## $y
## [1] "ProductionHydroelectric.Power.Consumption"
##
## attr(,"class")
## [1] "labels"

beta0 <- Linear_trend1$coefficients[1]
beta1 <- Linear_trend1$coefficients[2]
detrend_energy_data1 <- energy_data1[,2]-(beta0+beta1*t)

ggplot(energy_data1, aes(x=my_date, y=energy_data1[,2]))+
  geom_line(color="blue")+
  geom_line(aes(y=detrend_energy_data1), col="green")
```

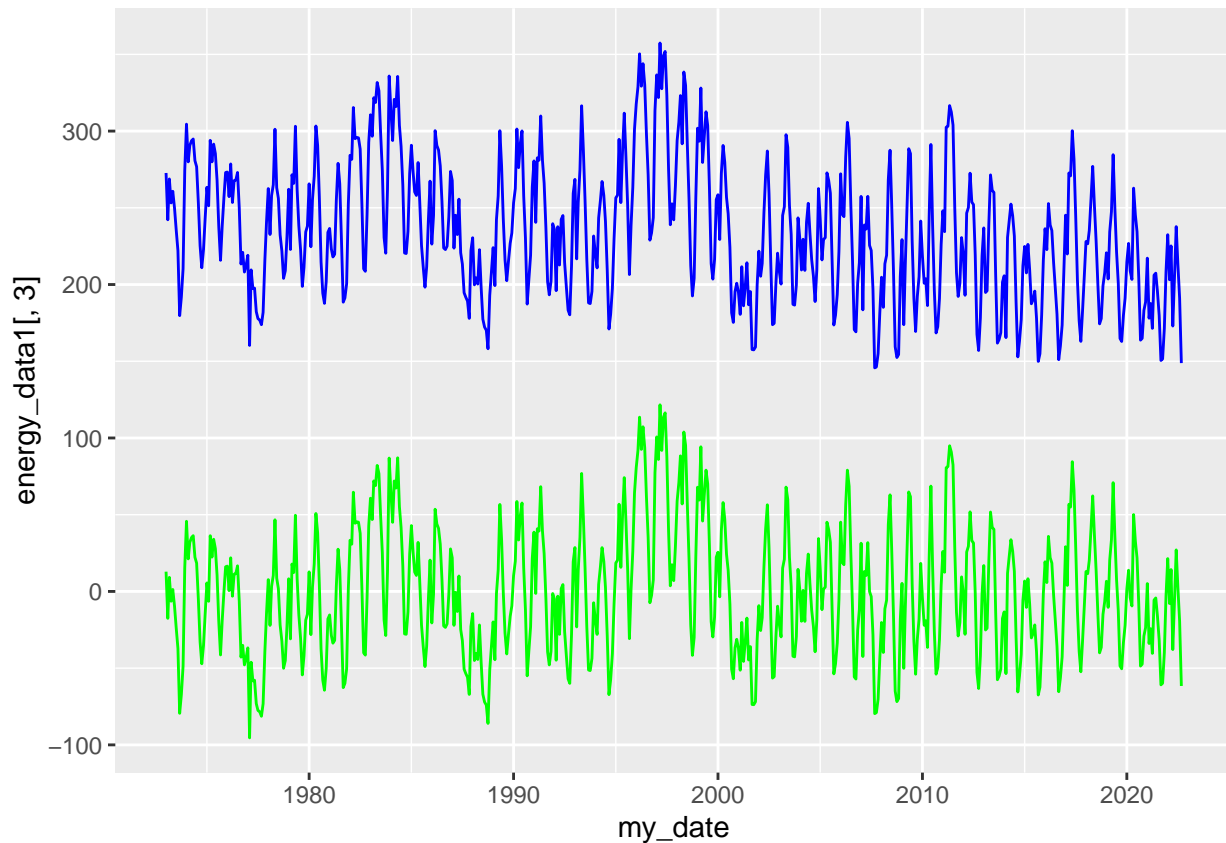



```
ylab(paste0("Production", colnames(energy_data1)[iHP+1], sep=""))
```

```
## $y
## [1] "ProductionHydroelectric.Power.Consumption"
##
## attr(,"class")
## [1] "labels"

beta0 <- Linear_trend2$coefficients[1]
beta1 <- Linear_trend2$coefficients[2]
detrend_energy_data2 <- energy_data1[,3]-(beta0+beta1*t)

ggplot(energy_data1, aes(x=my_date, y=energy_data1[,3]))+
  geom_line(color="blue")+
  geom_line(aes(y=detrend_energy_data2), col="green")
```



```
ylab(paste0("Production", colnames(energy_data1)[iHP+1], sep=""))
```

```
## $y
## [1] "ProductionHydroelectric.Power.Consumption"
##
## attr(,"class")
## [1] "labels"
```

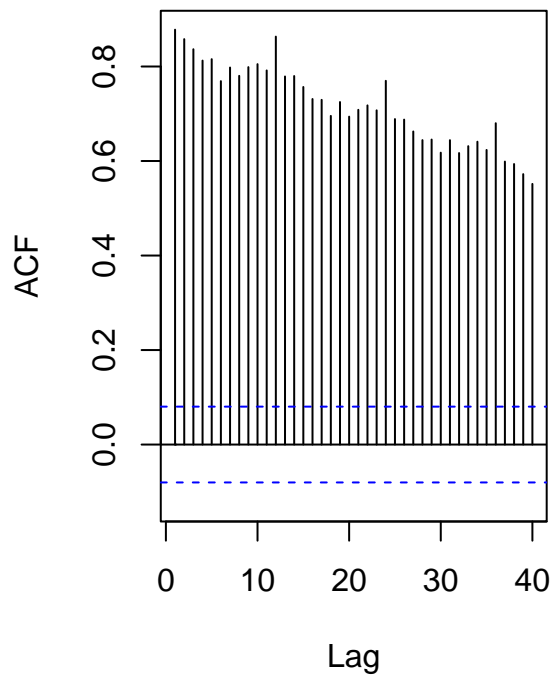
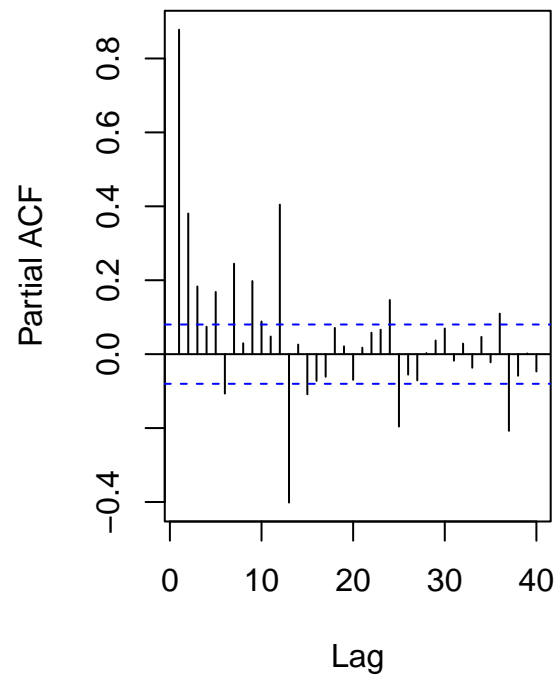
After the detrend, first two diagrams lose their trends. They used to have upward trends, but they do not have any trends now. For the third graph, there is no obvious change.

Q5

Plot ACF and PACF for the detrended series and compare with the plots from Q1. Did the plots change? How?

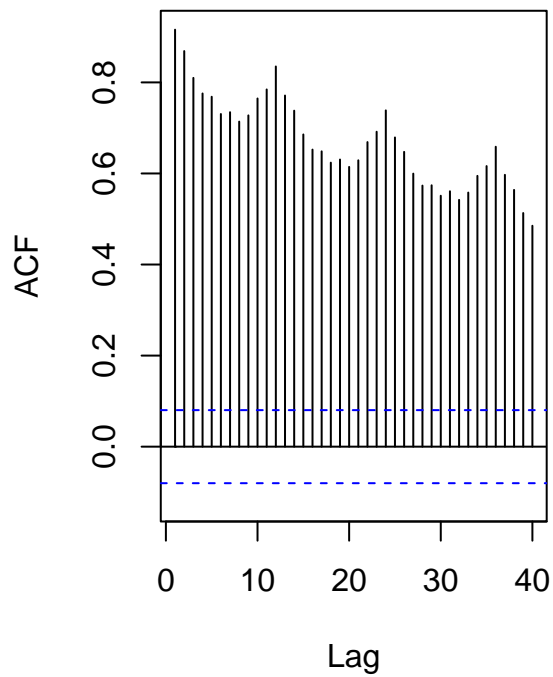
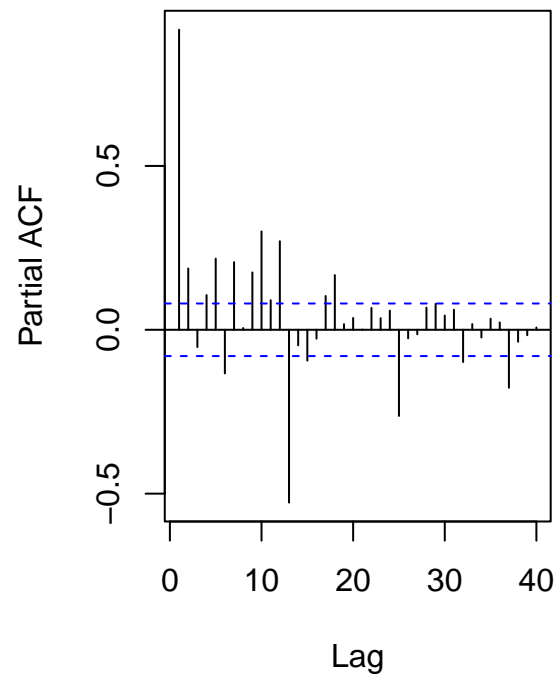
```
ncol_data <- ncol(energy_data1)-1

par(mfrow=c(1,2))
Acf(detrend_energy_data0, lag.max=40, main=paste0("ACF", i))
Pacf(detrend_energy_data0, lag.max=40, main=paste0("PACF", i))
```

ACF3**PACF3**

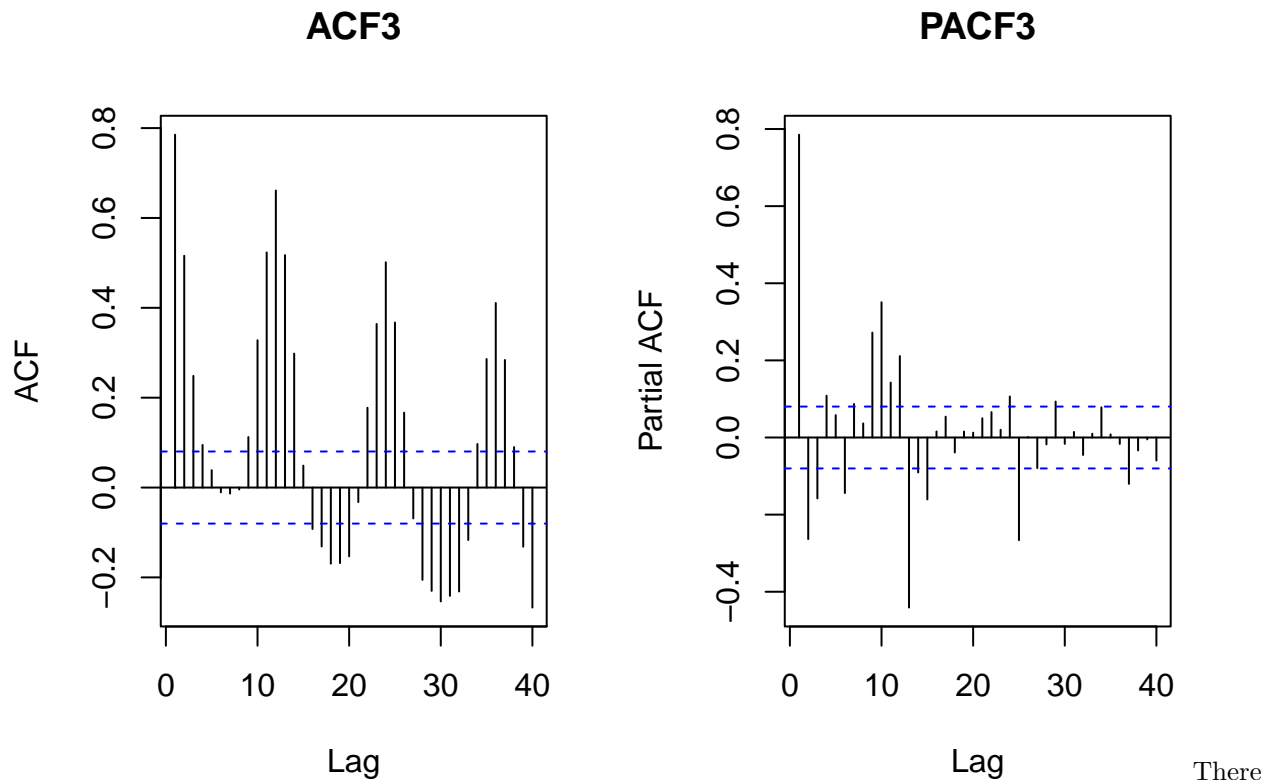
```
ncol_data <- ncol(energy_data1)-1

par(mfrow=c(1,2))
Acf(detrend_energy_data1,lag.max=40,main=paste0("ACF",i))
Pacf(detrend_energy_data1,lag.max=40,main=paste0("PACF",i))
```

ACF3**PACF3**

```
ncol_data <- ncol(energy_data1)-1

par(mfrow=c(1,2))
Acf(detrend_energy_data2,lag.max=40,main=paste0("ACF",i))
Pacf(detrend_energy_data2,lag.max=40,main=paste0("PACF",i))
```



are not very obvious changes.

Seasonal Component

Set aside the detrended series and consider the original series again from Q1 to answer Q6 to Q8.

Q6

Do the series seem to have a seasonal trend? Which serie/series? Use function *lm()* to fit a seasonal means model (i.e. using the seasonal dummies) to this/these time series. Ask R to print the summary of the regression. Interpret the regression output. Save the regression coefficients for further analysis.

```
iHP_0=1
dummies_0 <- seasonaldummy(ts_energy_data1[,iHP_0])
seas_means_model_Biomass=lm(energy_data1[, (iHP_0)]~dummies_0)

summary(seas_means_model_Biomass)
```

```
##
## Call:
## lm(formula = energy_data1[, (iHP_0)] ~ dummies_0)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -160.74  -53.67  -24.36   90.73  181.34
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    288.020     13.163   21.881  <2e-16 ***
## dummies_0Jan     -1.793     18.522   -0.097   0.9229
## dummies_0Feb    -31.102     18.522  -1.679   0.0936 .
##
```

```
## dummies_0Mar    -9.104    18.522   -0.492    0.6232
## dummies_0Apr   -21.502    18.522   -1.161    0.2462
## dummies_0May   -14.238    18.522   -0.769    0.4424
## dummies_0Jun   -19.602    18.522   -1.058    0.2904
## dummies_0Jul    -3.674    18.522   -0.198    0.8428
## dummies_0Aug    -0.612    18.522   -0.033    0.9737
## dummies_0Sep   -13.335    18.522   -0.720    0.4718
## dummies_0Oct    -4.030    18.615   -0.216    0.8287
## dummies_0Nov    -9.849    18.615   -0.529    0.5970
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 92.14 on 585 degrees of freedom
## Multiple R-squared:  0.01018,    Adjusted R-squared:  -0.008437
## F-statistic: 0.5467 on 11 and 585 DF,  p-value: 0.8714
```

The intercept is 288.020. The p-value here is 0.8714, which is bigger than 0.05, therefore, there is no need for deseason in Biomass Energy production.

```
iHP_1=1
dummies_1 <- seasonaldummy(ts_energy_data1[,iHP_1])
seas_means_model_Renewable=lm(energy_data1[, (iHP_1+1)]~dummies_1)

summary(seas_means_model_Renewable)
```

```
##
## Call:
## lm(formula = energy_data1[, (iHP_1 + 1)] ~ dummies_1)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -284.92 -122.23  -68.42   91.22  585.68
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    601.022     27.260   22.048  <2e-16 ***
## dummies_1Jan     11.468     38.358    0.299    0.765
## dummies_1Feb    -41.456     38.358   -1.081    0.280
## dummies_1Mar     23.130     38.358    0.603    0.547
## dummies_1Apr      9.959     38.358    0.260    0.795
## dummies_1May     38.853     38.358    1.013    0.312
## dummies_1Jun     20.378     38.358    0.531    0.595
## dummies_1Jul      8.298     38.358    0.216    0.829
## dummies_1Aug    -19.450     38.358   -0.507    0.612
## dummies_1Sep    -63.770     38.358   -1.662    0.097 .
## dummies_1Oct    -52.612     38.551   -1.365    0.173
## dummies_1Nov    -42.537     38.551   -1.103    0.270
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 190.8 on 585 degrees of freedom
## Multiple R-squared:  0.02844,    Adjusted R-squared:  0.01017
## F-statistic: 1.557 on 11 and 585 DF,  p-value: 0.1076
```

The intercept is 601.022. The p-value here is 0.1076, which is bigger than 0.05, therefore, there is no need for deseason in Renewable Energy production.

```
iHP_2=2
dummies_2 <- seasonaldummy(ts_energy_data1[,iHP_2])
seas_means_model_Consumption=lm(energy_data1[, (iHP_2+1)]~dummies_2)

summary(seas_means_model_Consumption)
```

```
##
## Call:
## lm(formula = energy_data1[, (iHP_2 + 1)] ~ dummies_2)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -88.99 -23.47  -2.81   21.99  100.18
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   237.225     4.878   48.634 < 2e-16 ***
## dummies_2Jan    13.594     6.864    1.981  0.04811 *
## dummies_2Feb   -8.254     6.864   -1.203  0.22964
## dummies_2Mar    19.980     6.864    2.911  0.00374 **
## dummies_2Apr    15.649     6.864    2.280  0.02297 *
## dummies_2May    39.210     6.864    5.713 1.77e-08 ***
## dummies_2Jun    31.209     6.864    4.547 6.61e-06 ***
## dummies_2Jul    10.436     6.864    1.520  0.12895
## dummies_2Aug   -17.909     6.864   -2.609  0.00931 **
## dummies_2Sep   -50.173     6.864   -7.310 8.82e-13 ***
## dummies_2Oct   -48.262     6.898   -6.996 7.22e-12 ***
## dummies_2Nov   -32.285     6.898   -4.680 3.56e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 34.14 on 585 degrees of freedom
## Multiple R-squared:  0.4132, Adjusted R-squared:  0.4022
## F-statistic: 37.45 on 11 and 585 DF,  p-value: < 2.2e-16
```

The intercept is 237.225. The p-value here less than 0.05, therefore, it is significant and there is need for deseason in Hydroelectric Power Consumption.

```
beta_int_Biomass=seas_means_model_Biomass$coefficients[1]
beta_coeff_Biomass=seas_means_model_Biomass$coefficients[2:12]

beta_int_Renewable=seas_means_model_Renewable$coefficients[1]
beta_coeff_Renewable=seas_means_model_Renewable$coefficients[2:12]

beta_int_Consumption=seas_means_model_Consumption$coefficients[1]
beta_coeff_Consumption=seas_means_model_Consumption$coefficients[2:12]
```

Q7

Use the regression coefficients from Q6 to deseason the series. Plot the deseason series and compare with the plots from part Q1. Did anything change?

```
energy_Biomass_seas_comp=array(0,nobs)
for(i in 1:nobs){
  energy_Biomass_seas_comp[i]=(beta_int_Biomass+beta_coeff_Biomass%%dummies_0[i,])
```

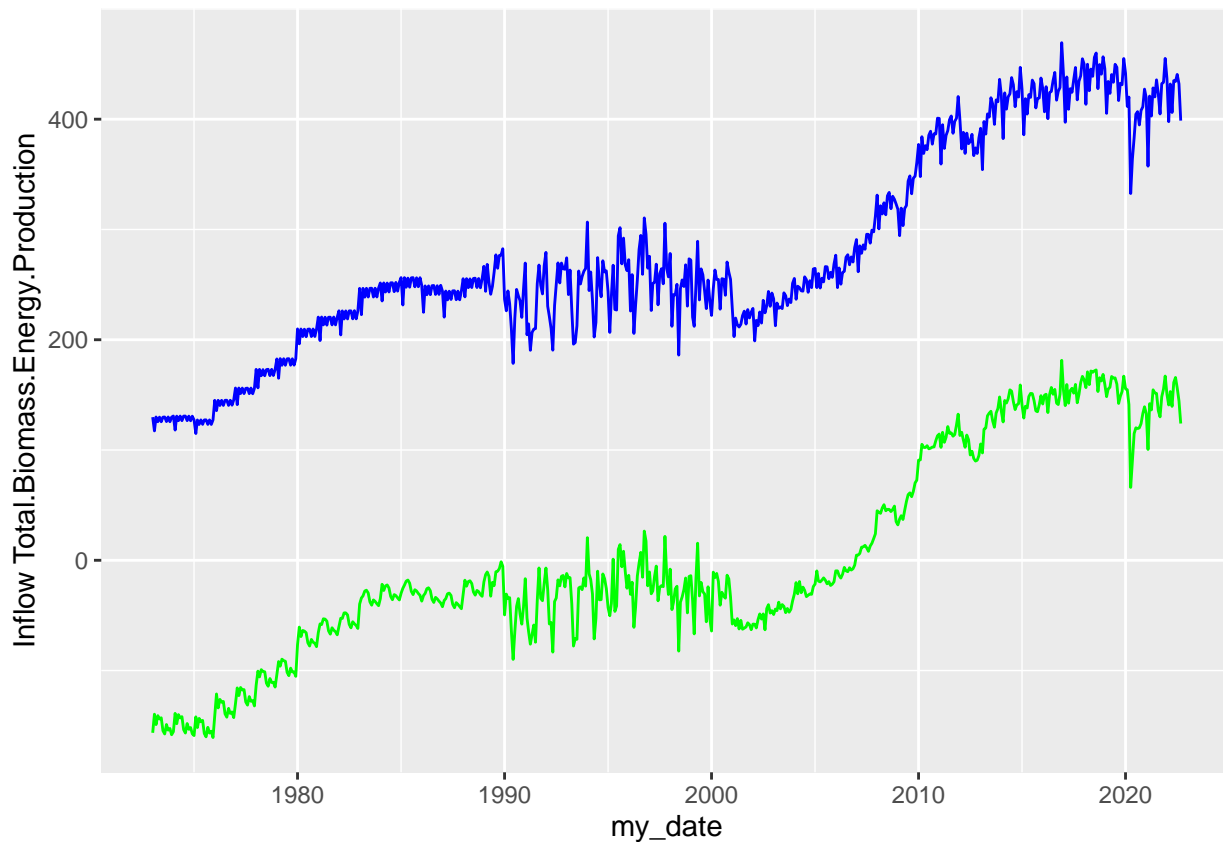
```

}

deseason_energy_Biomass_seas_comp <- energy_data1[, (iHP_1)] - energy_Biomass_seas_comp

ggplot(energy_data1, aes(x=my_date, y=energy_data1[, (iHP_1)])) +
  geom_line(color="blue") +
  ylab(paste0("Inflow ", colnames(energy_data1)[(iHP_1)], sep="")) +
  geom_line(aes(y=deseason_energy_Biomass_seas_comp), col="green")

```



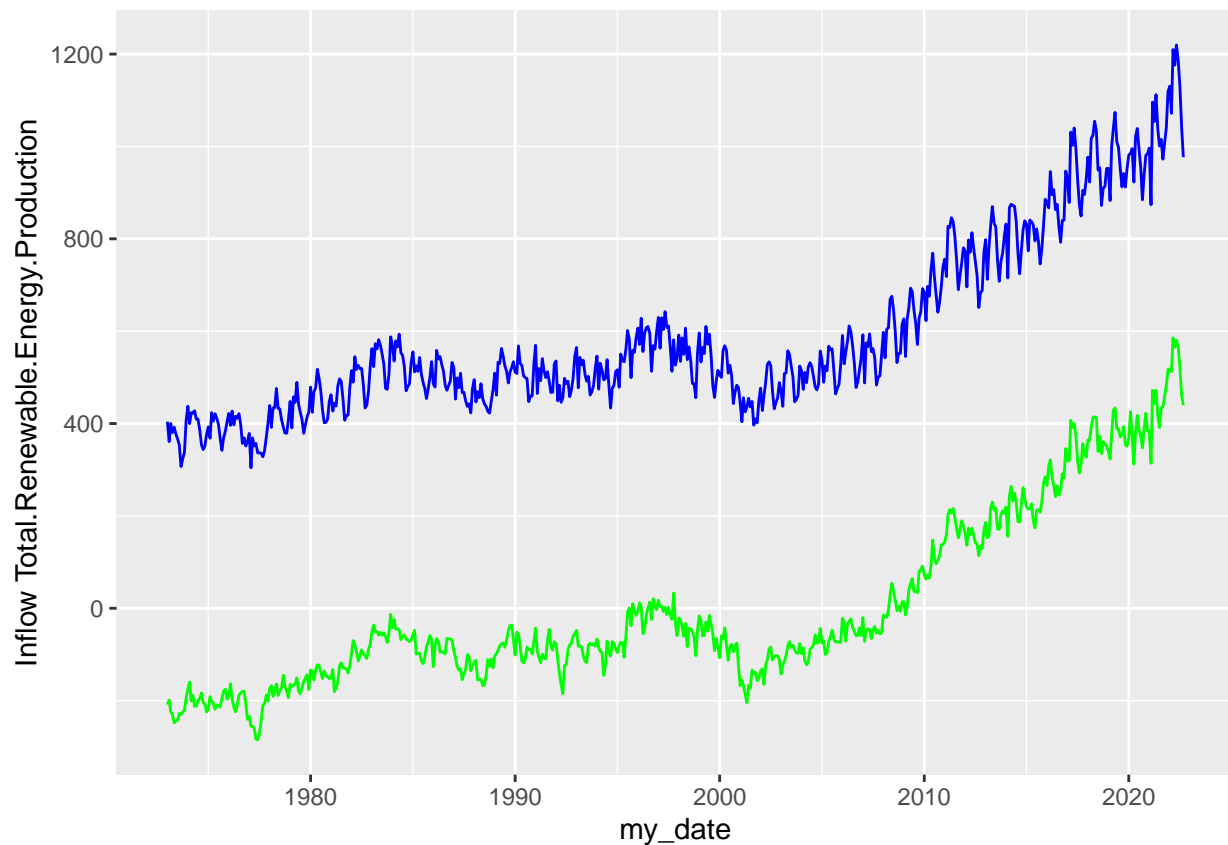
```

energy_Renewable_seas_comp=array(0,nobs)
for(i in 1:nobs){
  energy_Renewable_seas_comp[i]=(beta_int_Renewable+beta_coeff_Renewable%*%dummies_1[i,])
}

deseason_energy_Renewable_seas_comp <- energy_data1[, (1+iHP_1)] - energy_Renewable_seas_comp

ggplot(energy_data1, aes(x=my_date, y=energy_data1[, (1+iHP_1)])) +
  geom_line(color="blue") +
  ylab(paste0("Inflow ", colnames(energy_data1)[(1+iHP_1)], sep="")) +
  geom_line(aes(y=deseason_energy_Renewable_seas_comp), col="green")

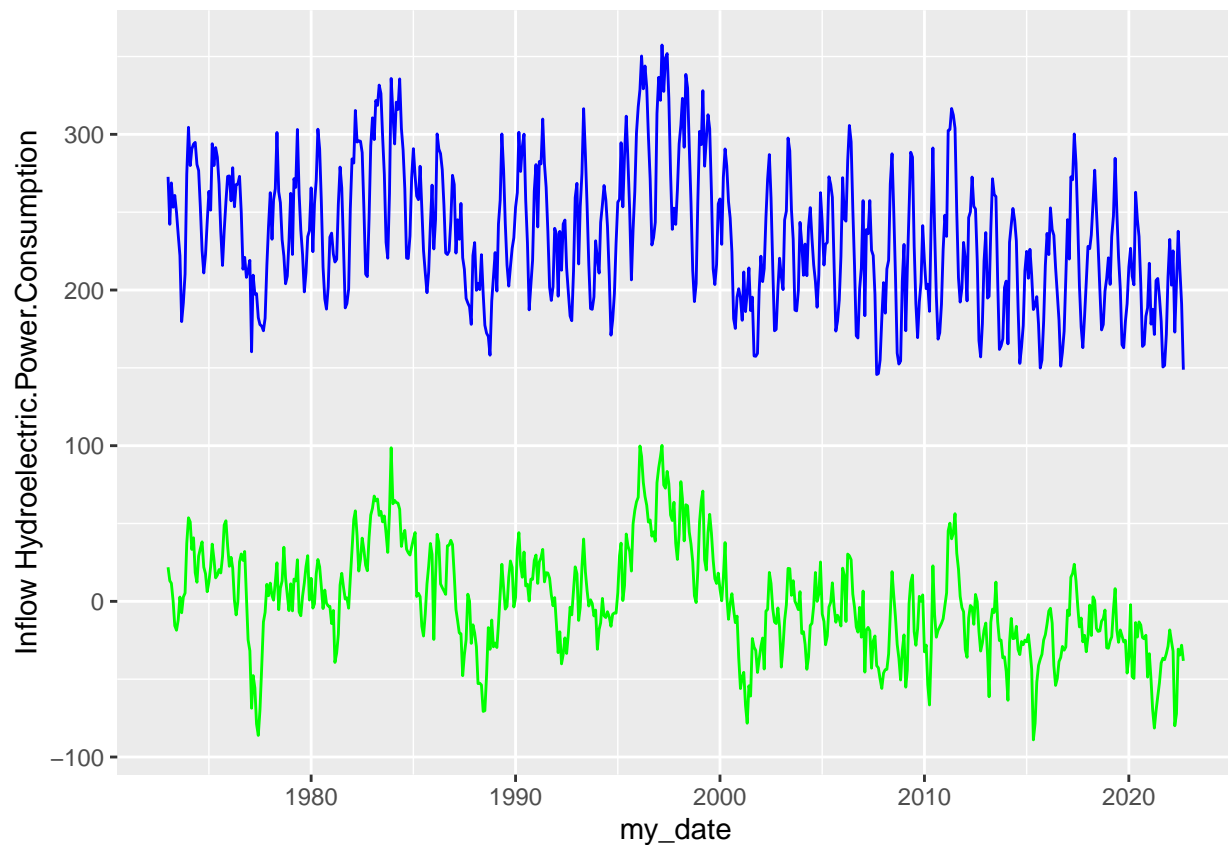
```

```
energy_Consumption_seas_comp=array(0,nobs)
for(i in 1:nobs){
  energy_Consumption_seas_comp[i]=(beta_int_Consumption+beta_coeff_Consumption%%dummies_2[i,])
}

deseason_energy_Consumption_seas_comp <- energy_data1[, (1+iHP_2)]-energy_Consumption_seas_comp

ggplot(energy_data1, aes(x=my_date, y=energy_data1[, (1+iHP_2)])) +
  geom_line(color="blue") +
  ylab(paste0("Inflow ", colnames(energy_data1)[(1+iHP_2)], sep="")) +
  geom_line(aes(y=deseason_energy_Consumption_seas_comp ), col="green")
```



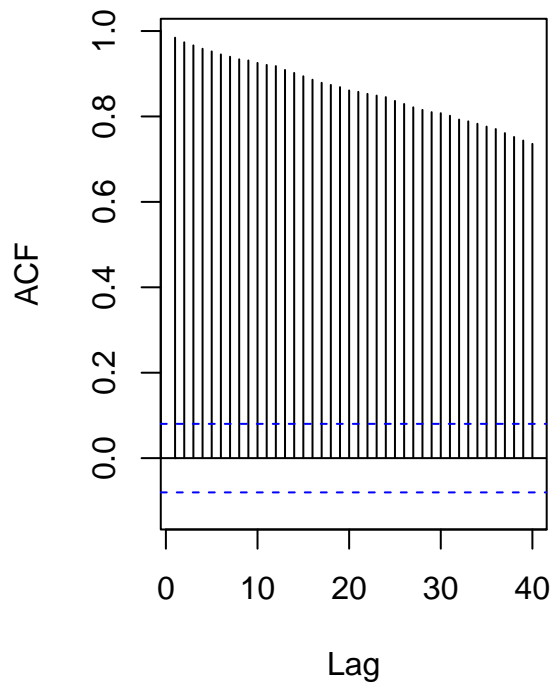
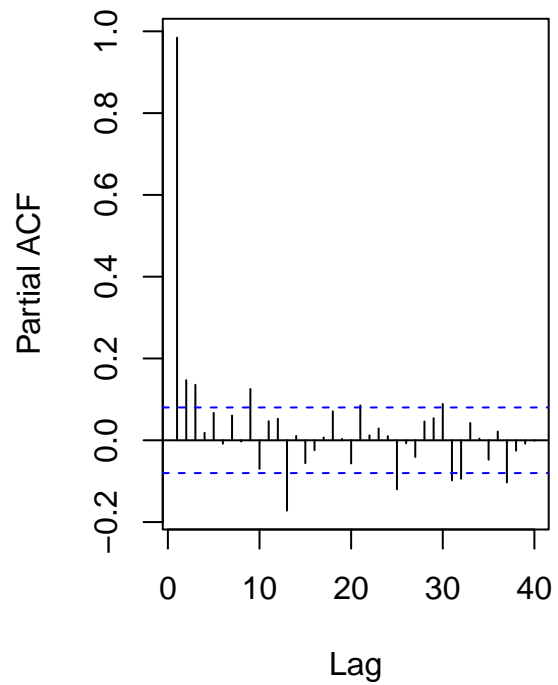
After the deseasoning, there are less fluctuation for all three graphs. Especially for the third one(hydroelectric), it is more obvious than the first two.

Q8

Plot ACF and PACF for the deseason series and compare with the plots from Q1. Did the plots change? How?

```
ncol_data <- ncol(energy_data1)-1

par(mfrow=c(1,2))
Acf(deseason_energy_Biomass_seas_comp,lag.max=40,main=paste0("ACF",i))
Pacf(deseason_energy_Biomass_seas_comp,lag.max=40,main=paste0("PACF",i))
```

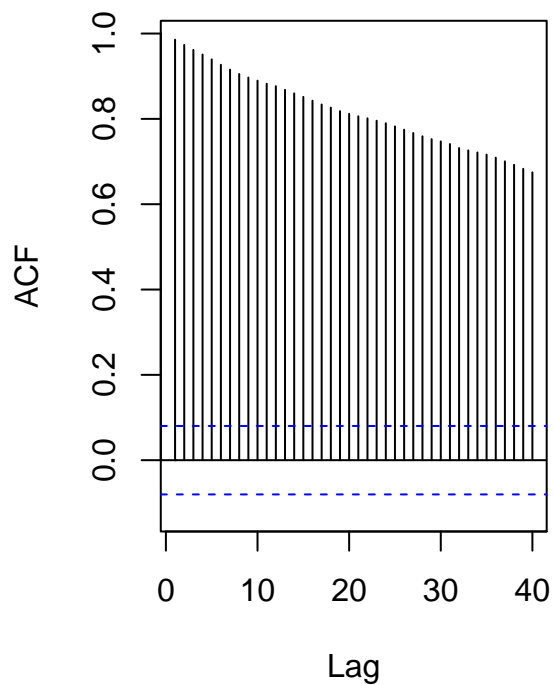
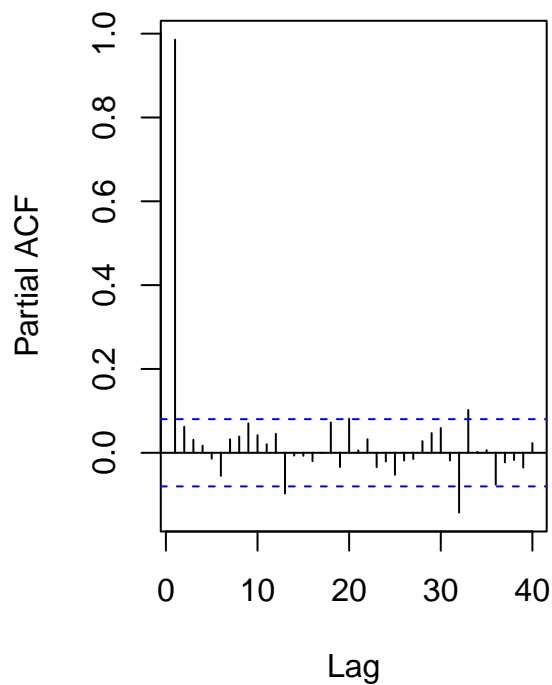
ACF597**PACF597**

```
ncol_data <- ncol(energy_data1)-1
```

```
par(mfrow=c(1,2))
```

```
Acf(deseason_energy_Renewable_seas_comp,lag.max=40,main=paste0("ACF",i))
```

```
Pacf(deseason_energy_Renewable_seas_comp,lag.max=40,main=paste0("PACF",i))
```

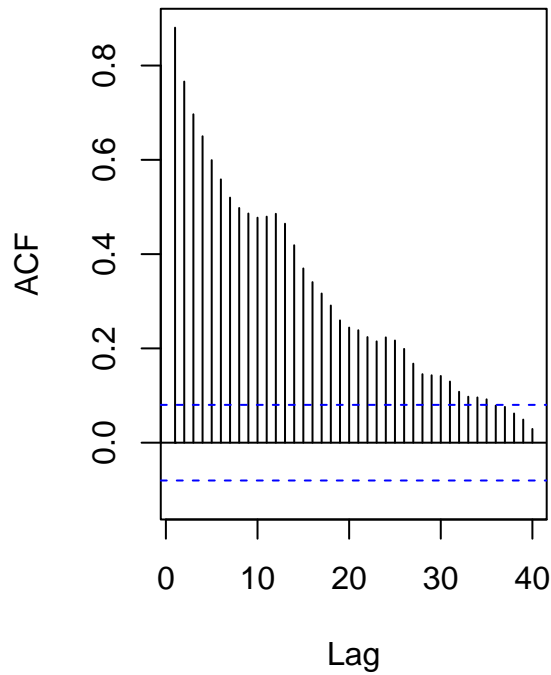
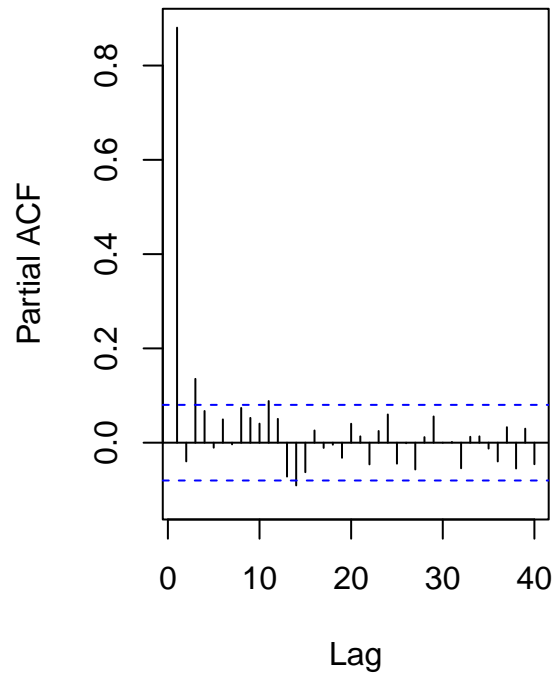
ACF597**PACF597**

```
ncol_data <- ncol(energy_data1)-1
```

```
par(mfrow=c(1,2))
```

```
Acf(deseason_energy_Consumption_seas_comp,lag.max=40,main=paste0("ACF",i))
```

```
Pacf(deseason_energy_Consumption_seas_comp,lag.max=40,main=paste0("PACF",i))
```

ACF597**PACF597**

After the deseasoning, plots of ACF and PACF have big changes. For the ACF, the graph shows a decreasing pattern. For the PACF, only first few lags are out of the dashed line area. In the previous PACF, lots of them are out of the dashed line area. Overall, they are better now.