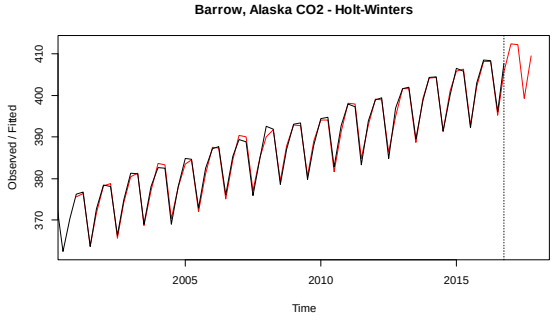
STATS 326
Applied Time Series
ASSIGNMENT TWO
R & MARKING GUIDE

Question One: (20 marks)

Holt-Winters:

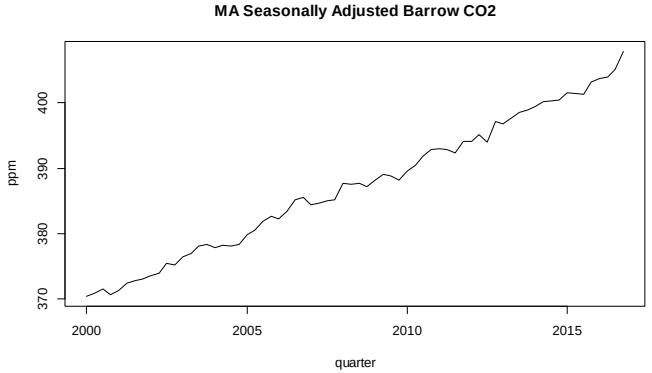
```
> HW.fit = HoltWinters(red.CO2.ts)
> HW.fit
Holt-Winters exponential smoothing with trend and additive seasonal
component.

Call:
HoltWinters(x = red.CO2.ts)

Smoothing parameters:
 alpha: 0.5732177
 beta : 0.03867122
 gamma: 0.4140589

Coefficients:
          [,1]
a  406.4502058
b    0.5868941
s1   5.3662780
s2   4.6109173
s3  -8.8837987
s4   0.7093982

> HW.pred = predict(HW.fit,n.ahead=4)
> HW.pred
         Qtr1     Qtr2     Qtr3     Qtr4
2017 412.4034 412.2349 399.3271 409.5072

> HW.RMSEP = sqrt(1/4*sum((actual-HW.pred)^2))
> HW.RMSEP
[1] 0.9645109

> plot(HW.fit,HW.pred,main="Barrow, Alaska CO2 - Holt-Winters")
```



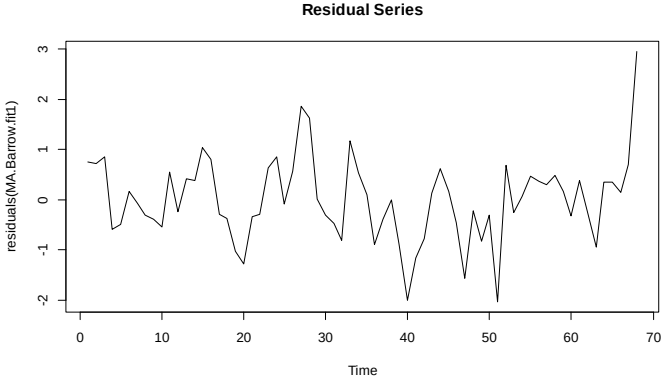
Question Two: (30 marks)

MA Seasonally Adjusted:

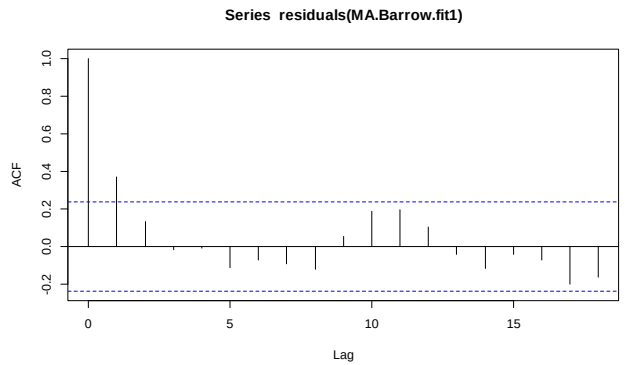
```
> MA.Barrow = decompose(red.CO2.ts)
> MA.Barrow$figure
[1]  4.9286328  4.3242578 -9.0356641 -0.2172266

> MA.CO2.ts = red.CO2.ts-MA.Barrow$seasonal
> plot(MA.CO2.ts,main="MA Seasonally Adjusted Barrow
  CO2",xlab="quarter",ylab="ppm")
```



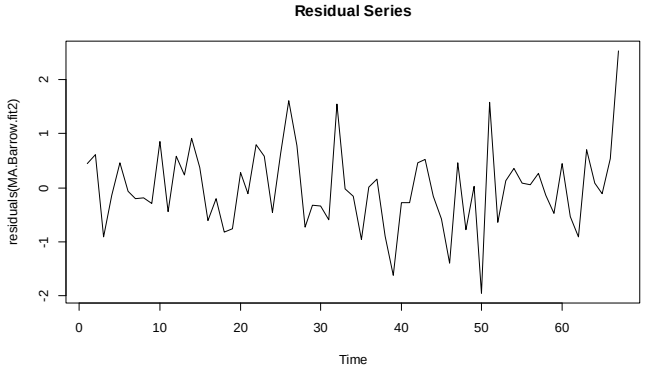

```
> Time = 1:68
> MA.Barrow.fit1 = lm(MA.CO2.ts~Time)
> plot.ts(residuals(MA.Barrow.fit1),main="Residual Series")
```



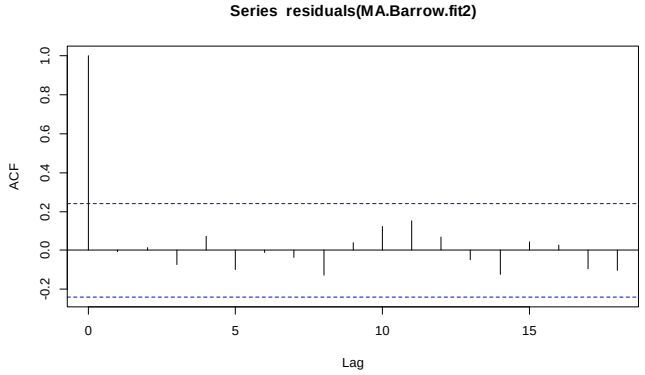
```
> acf(residuals(MA.Barrow.fit1))
```



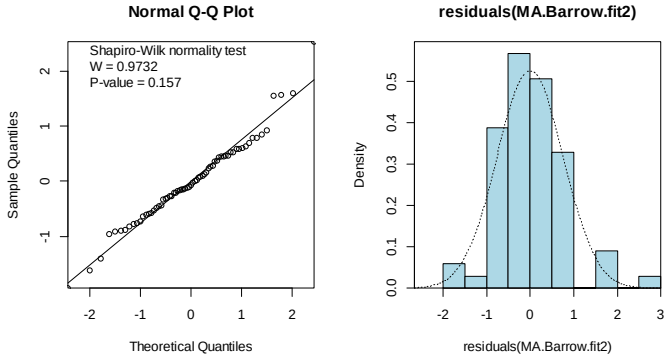

```
> MA.Barrow.fit2 = lm(MA.CO2.ts[-1]~Time[-1]+MA.CO2.ts[-68])
> plot.ts(residuals(MA.Barrow.fit2),main="Residual Series")
```




```
> acf(residuals(MA.Barrow.fit2))
```




```
> normcheck(residuals(MA.Barrow.fit2),shapiro.wilk=T)
```

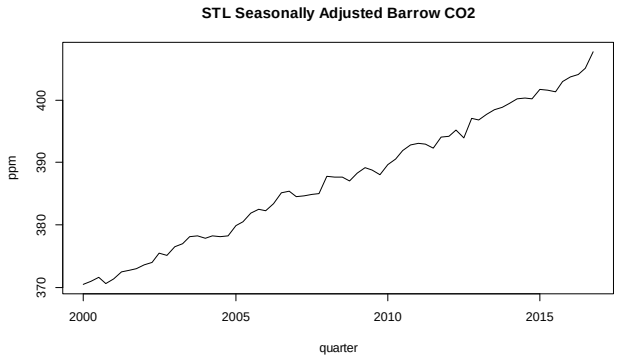



```
> summary(MA.Barrow.fit2)

Call:
lm(formula = MA.CO2.ts[-1] ~ Time[-1] + MA.CO2.ts[-68])

Residuals:
    Min      1Q  Median      3Q     Max
-1.9475 -0.4709 -0.0720  0.4565  2.5262

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  198.50565   46.50963   4.268 6.65e-05 ***
Time[-1]       0.28589    0.06611   4.324 5.46e-05 ***
MA.CO2.ts[-68]   0.46263    0.12615   3.667    5e-04 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.7696 on 64 degrees of freedom
Multiple R-squared:  0.9946,    Adjusted R-squared:  0.9944
F-statistic:  5897 on 2 and 64 DF,  p-value: < 2.2e-16

> t.69.ma.pred = MA.Barrow.fit2$coef[1]+MA.Barrow.fit2$coef[2]*69+
  MA.Barrow.fit2$coef[3]*MA.CO2.ts[68]
> t.69.ma.pred
(Intercept)
   406.9338
> t.69.pred = t.69.ma.pred+MA.Barrow$figure[1]
> t.69.pred
(Intercept)
   411.8624
> t.70.ma.pred = MA.Barrow.fit2$coef[1]+MA.Barrow.fit2$coef[2]*70+
  MA.Barrow.fit2$coef[3]*t.69.ma.pred
> t.70.ma.pred
(Intercept)
   406.7786
> t.70.pred = t.70.ma.pred+MA.Barrow$figure[2]
> t.70.pred
(Intercept)
   411.1028
```

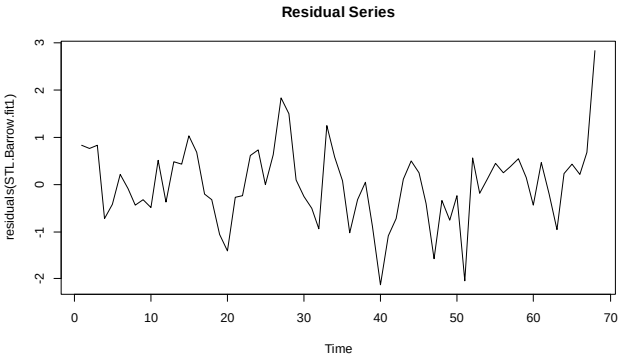
```
> t.71.ma.pred = MA.Barrow.fit2$coef[1]+MA.Barrow.fit2$coef[2]*71+
   MA.Barrow.fit2$coef[3]*t.70.ma.pred
> t.71.ma.pred
(Intercept)
   406.9927
> t.71.pred = t.71.ma.pred+MA.Barrow$figure[3]
> t.71.pred
(Intercept)
    397.957
> t.72.ma.pred = MA.Barrow.fit2$coef[1]+MA.Barrow.fit2$coef[2]*72+
   MA.Barrow.fit2$coef[3]*t.71.ma.pred
> t.72.ma.pred
(Intercept)
   407.3776
> t.72.pred = t.72.ma.pred+MA.Barrow$figure[4]
> t.72.pred
(Intercept)
   407.1604

> MA.pred = c(t.69.pred,t.70.pred,t.71.pred,t.72.pred)
> names(MA.pred) = c("2017.1","2017.2","2017.3","2017.4")
> MA.pred
  2017.1   2017.2   2017.3   2017.4
411.8624 411.1028 397.9570 407.1604

> RMSEP.MA.Barrow = sqrt(1/4*sum((actual-MA.pred)^2))
> RMSEP.MA.Barrow
[1] 1.341502
```

STL Seasonally Adjusted:

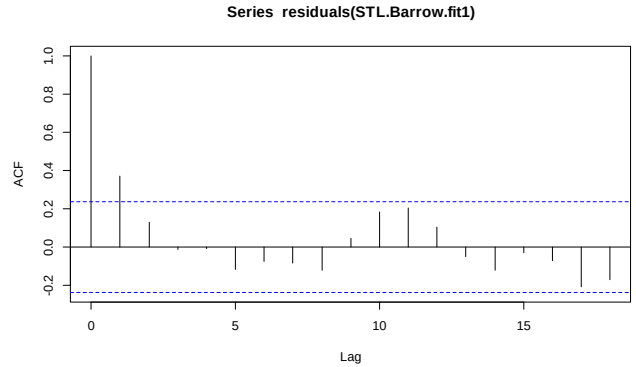
```
> STL.Barrow = stl(red.CO2.ts,s.window="periodic")
> STL.Barrow$time.series[1:4,1]
[1]  4.85060732  4.26390951 -9.02024922 -0.09426758
> STL.CO2.ts = red.CO2.ts-STL.Barrow$time.series[,1]
> plot(STL.CO2.ts,main="STL Seasonally Adjusted Barrow
   CO2",xlab="quarter",ylab="ppm")
```



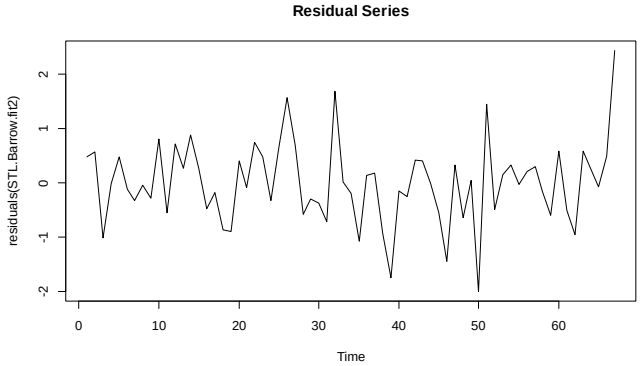

```
> STL.Barrow.fit1 = lm(STL.CO2.ts~Time)
> plot.ts(residuals(STL.Barrow.fit1),main="Residual Series")
```



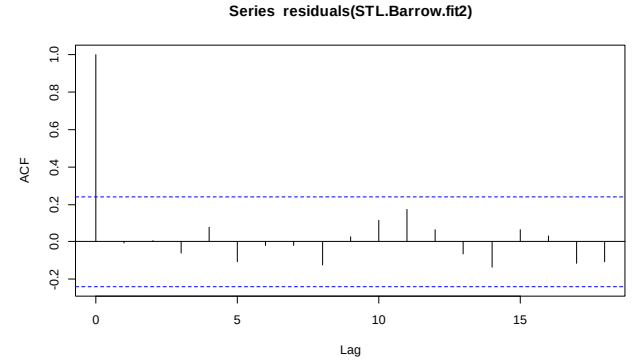
```
> acf(residuals(STL.Barrow.fit1))
```



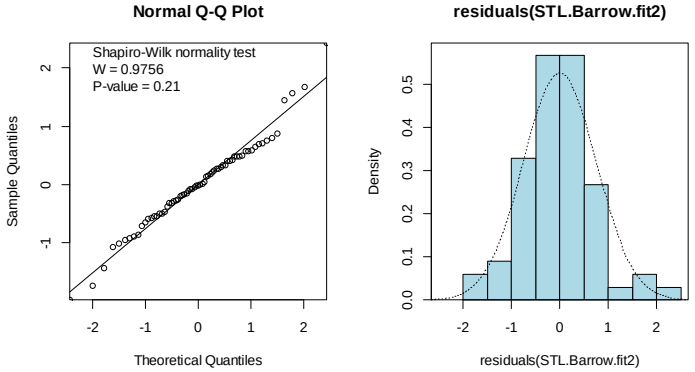

```
> STL.Barrow.fit2 = lm(STL.CO2.ts[-1]~Time[-1]+STL.CO2.ts[-68])
> plot.ts(residuals(STL.Barrow.fit2),main="Residual Series")
```




```
> acf(residuals(STL.Barrow.fit2))
```




```
> normcheck(residuals(STL.Barrow.fit2),shapiro.wilk=T)
```




```
> summary(STL.Barrow.fit2)

Call:
lm(formula = STL.CO2.ts[-1] ~ Time[-1] + STL.CO2.ts[-68])

Residuals:
     Min       1Q   Median       3Q      Max
-1.98853 -0.48582 -0.01539  0.44476  2.42309

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     201.76350   46.10705   4.376 4.56e-05 ***
Time[-1]          0.29041    0.06553   4.432 3.74e-05 ***
STL.CO2.ts[-68]   0.45380    0.12505   3.629 0.000566 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.7692 on 64 degrees of freedom
Multiple R-squared:  0.9946,    Adjusted R-squared:  0.9944
F-statistic:  5901 on 2 and 64 DF,  p-value: < 2.2e-16
```

```
> t.69.stl.pred = STL.Barrow.fit2$coef[1]+STL.Barrow.fit2$coef[2]*69+
   STL.Barrow.fit2$coef[3]*STL.CO2.ts[68]
> t.69.stl.pred
(Intercept)
   406.8451
> t.69.pred = t.69.stl.pred+STL.Barrow$time.series[1,1]
> t.69.pred
(Intercept)
   411.6957

> t.70.stl.pred = STL.Barrow.fit2$coef[1]+STL.Barrow.fit2$coef[2]*70+
   STL.Barrow.fit2$coef[3]*t.69.stl.pred
> t.70.stl.pred
(Intercept)
   406.7183
> t.70.pred = t.70.stl.pred+STL.Barrow$time.series[2,1]
> t.70.pred
(Intercept)
   410.9822

> t.71.stl.pred = STL.Barrow.fit2$coef[1]+STL.Barrow.fit2$coef[2]*71+
   STL.Barrow.fit2$coef[3]*t.70.stl.pred
> t.71.stl.pred
(Intercept)
   406.9512
> t.71.pred = t.71.stl.pred+STL.Barrow$time.series[3,1]
> t.71.pred
(Intercept)
    397.931

> t.72.stl.pred = STL.Barrow.fit2$coef[1]+STL.Barrow.fit2$coef[2]*72+
   STL.Barrow.fit2$coef[3]*t.71.stl.pred
> t.72.stl.pred
(Intercept)
   407.3473
> t.72.pred = t.72.stl.pred+STL.Barrow$time.series[4,1]
> t.72.pred
(Intercept)
   407.2531

> STL.pred = c(t.69.pred,t.70.pred,t.71.pred,t.72.pred)
> names(STL.pred) = c("2017.1","2017.2","2017.3","2017.4")
> STL.pred
  2017.1   2017.2   2017.3   2017.4
411.6957 410.9822 397.9310 407.2531

> RMSEP.STL.Barrow = sqrt(1/4*sum((actual-STL.pred)^2))
> RMSEP.STL.Barrow
[1] 1.413046
```

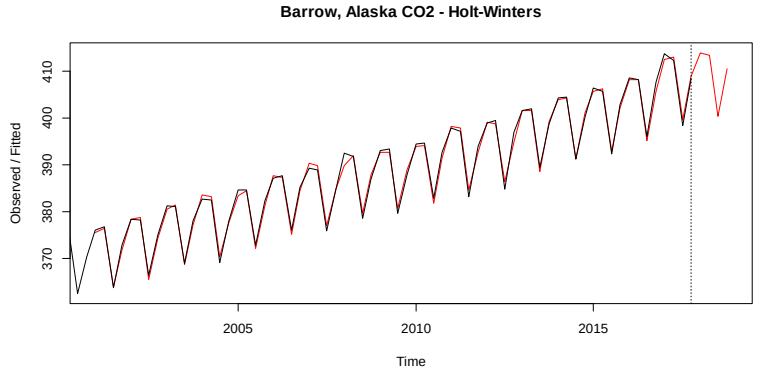
Question Three: (30 marks)

Tech Notes for MA Seasonally Adjusted model.

Question Four: (20 marks)

Holt-Winters (Full):

```
> HW.Full.fit = HoltWinters(full.CO2.ts)
> HW.Full.fit
Holt-Winters exponential smoothing with trend and additive seasonal
component.

Call:
HoltWinters(x = full.CO2.ts)

Smoothing parameters:
 alpha: 0.6655127
 beta : 0.02583596
 gamma: 0.5504329

Coefficients:
          [,1]
a  407.8598399
b    0.5251393
s1   5.6488674
s2   4.5145080
s3  -9.0761435
s4   0.6730279

> HW.Full.pred = predict(HW.Full.fit,n.ahead=4)
> HW.Full.pred
         Qtr1     Qtr2     Qtr3     Qtr4
2018 414.0338 413.4246 400.3591 410.6334

> plot(HW.Full.fit,HW.Full.pred,main="Barrow, Alaska CO2 - Holt-Winters")
```




```
> HW.full.pred.int = predict(HW.Full.fit,n.ahead=4,prediction.interval=T)
> HW.full.pred.int
                fit      upr      lwr
2018 Q1 414.0338 415.8081 412.2596
2018 Q2 413.4246 415.5729 411.2763
2018 Q3 400.3591 402.8405 397.8778
2018 Q4 410.6334 413.4219 407.8449
> 415.8081-412.2596
[1] 3.5485
> 415.5729-411.2763
[1] 4.2966
> 402.8405-397.8778
[1] 4.9627
> 413.4219-407.8449
[1] 5.577
```