STATS 326
Applied Time Series
ASSIGNMENT TWO
R & MARKING GUIDE

Question One: (20 marks)

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

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

Smoothing parameters:
 alpha: 0.9136498
 beta : 0.09744997
 gamma: 1

Coefficients:
        [,1]
a  401.1875008
b    0.6199149
s1  -0.2633082
s2  -0.1943729
s3   0.4707094
s4   0.2124992

> HW.CapeGrim.pred = predict(HW.CapeGrim,n.ahead=4)
> HW.CapeGrim.pred
        Qtr1     Qtr2     Qtr3     Qtr4
2017 401.5441 402.2330 403.5180 403.8797

> actual.2017 = CO2.ts[69:72]
> actual.2017
[1] 401.19 401.77 403.15 403.69

> RMSEP.HW.CapeGrim = sqrt(1/4*sum((actual.2017-HW.CapeGrim.pred)^2))
> RMSEP.HW.CapeGrim
[1] 0.3574505

> plot(HW.CapeGrim,HW.CapeGrim.pred,xlab="quarter",main="Holt-Winters Cape
  Grim CO2")
```
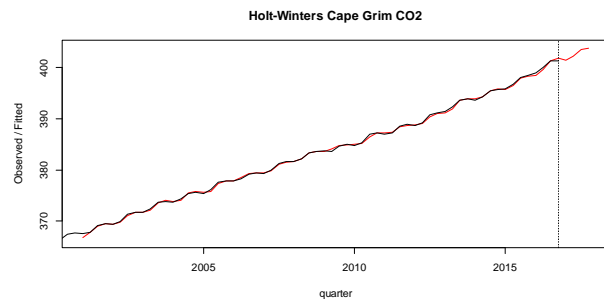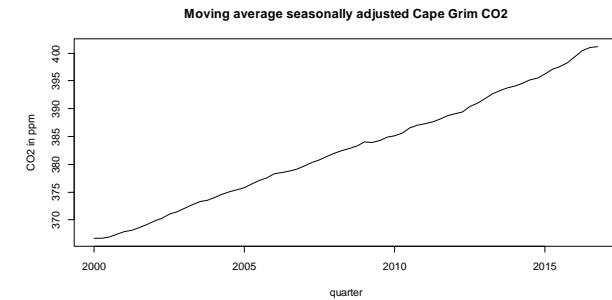

Holt-Winters Cape Grim CO2

Question Two: (30 marks)

```
> MA.CapeGrim = decompose(red.CO2.ts)

> MA.CapeGrim$figure
[1] -0.3533789 -0.2965820  0.4295117  0.2204492

> MA.CO2.ts = red.CO2.ts-MA.CapeGrim$seasonal

> plot(MA.CO2.ts,main="Moving average seasonally adjusted Cape Grim
  CO2",xlab="quarter",ylab="CO2 in ppm")
```
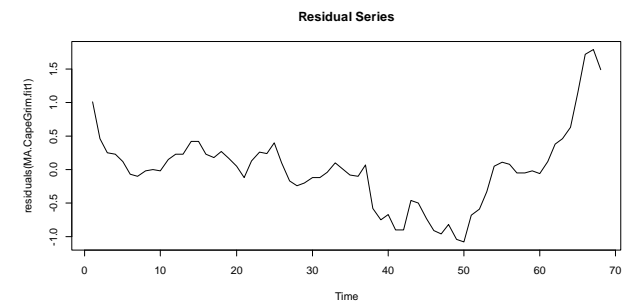

Moving average seasonally adjusted Cape Grim CO2

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


Residual Series

```
> Time.break = c(rep(0,49),Time[50:68]-Time[50])
> Time.break
 [1] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
[26] 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
[51] 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

> MA.CapeGrim.fit2 = lm(MA.CO2.ts~Time+Time.break)
> plot.ts(residuals(MA.CapeGrim.fit2),main="Residual Series")
```

Residual Series


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

Series residuals(MA.CapeGrim.fit2)


```
> MA.CapeGrim.fit3 = lm(MA.CO2.ts[-1]~Time[-1]+Time.break[-1]+
  MA.CO2.ts[-68])
> plot.ts(residuals(MA.CapeGrim.fit3),main="Residual Series")
```

Residual Series


```
> acf(residuals(MA.CapeGrim.fit3))
```

Series residuals(MA.CapeGrim.fit3)


```
> normcheck(residuals(MA.CapeGrim.fit3),shapiro.wilk=T)
```

Normal Q-Q Plot   **residuals(MA.CapeGrim.fit3)**

Shapiro-Wilk normality test
W = 0.9935
P-value = 0.98


```
> summary(MA.CapeGrim.fit3)

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

Residuals:
    Min      1Q  Median      3Q     Max
-0.49502 -0.12703  0.00166  0.10865  0.45032

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)     106.54020   29.54245   3.606 0.000615 ***
Time[-1]          0.14124    0.03881   3.639 0.000554 ***
Time.break[-1]    0.04722    0.01288   3.666 0.000508 ***
MA.CO2.ts[-68]    0.70952    0.08087   8.774 1.6e-12 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.1885 on 63 degrees of freedom
Multiple R-squared:  0.9997,    Adjusted R-squared:  0.9996
F-statistic: 6.093e+04 on 3 and 63 DF,  p-value: < 2.2e-16
```

```
> t69.ma.pred = MA.CapeGrim.fit3$coef[1]+MA.CapeGrim.fit3$coef[2]*69+
  MA.CapeGrim.fit3$coef[3]*19+MA.CapeGrim.fit3$coef[4]*MA.CO2.ts[68]
> t69.ma.pred
(Intercept)
   401.8286
> t69.pred = t69.ma.pred+MA.CapeGrim$figure[1]
> t69.pred
(Intercept)
   401.4753

> t70.ma.pred = MA.CapeGrim.fit3$coef[1]+MA.CapeGrim.fit3$coef[2]*70+
  MA.CapeGrim.fit3$coef[3]*20+MA.CapeGrim.fit3$coef[4]*t69.ma.pred
> t70.ma.pred
(Intercept)
   402.4776
> t70.pred = t70.ma.pred+MA.CapeGrim$figure[2]
> t70.pred
(Intercept)
   402.1811

> t71.ma.pred = MA.CapeGrim.fit3$coef[1]+MA.CapeGrim.fit3$coef[2]*71+
  MA.CapeGrim.fit3$coef[3]*21+MA.CapeGrim.fit3$coef[4]*t70.ma.pred
> t71.ma.pred
(Intercept)
   403.1266
> t71.pred = t71.ma.pred+MA.CapeGrim$figure[3]
> t71.pred
(Intercept)
   403.5561

> t72.ma.pred = MA.CapeGrim.fit3$coef[1]+MA.CapeGrim.fit3$coef[2]*72+
  MA.CapeGrim.fit3$coef[3]*22+MA.CapeGrim.fit3$coef[4]*t71.ma.pred
> t72.ma.pred
(Intercept)
   403.7755
> t72.pred = t72.ma.pred+MA.CapeGrim$figure[4]
> t72.pred
(Intercept)
   403.9959

> MA.pred = c(t69.pred,t70.pred,t71.pred,t72.pred)
> names(MA.pred) = c("2017.1","2017.2","2017.3","2017.4")
> MA.pred
  2017.1   2017.2   2017.3   2017.4
401.4753 402.1811 403.5561 403.9959

> RMSEP.MA.CapeGrim = sqrt(1/4*sum((actual.2017-MA.pred)^2))
> RMSEP.MA.CapeGrim
[1] 0.3566682
```
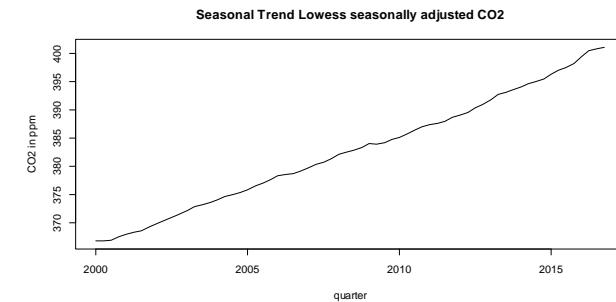
```
> STL.CapeGrim = stl(red.CO2.ts,s.window="periodic")

> STL.CapeGrim$time.series[1:4,1]
[1] -0.4070014 -0.3570879  0.4957070  0.2683823

> STL.CO2.ts = red.CO2.ts-STL.CapeGrim$time.series[,1]

> plot(STL.CO2.ts,main="Seasonal Trend Lowess seasonally adjusted
  CO2",xlab="quarter",ylab="CO2 in ppm")
```
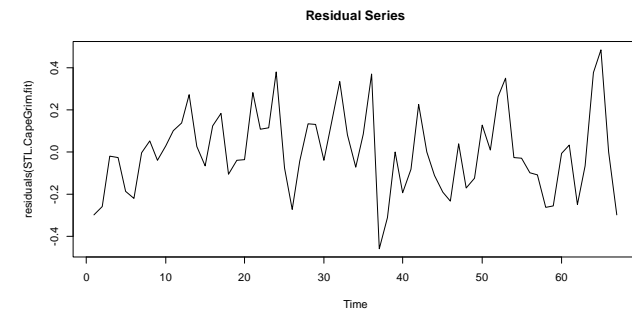

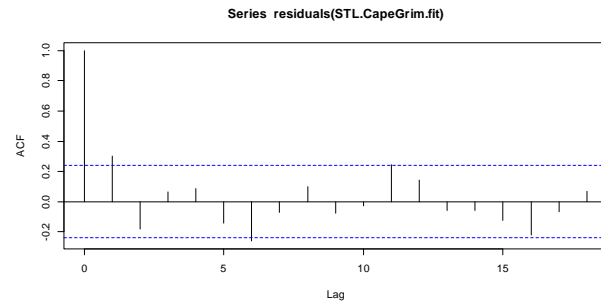Seasonal Trend Lowess seasonally adjusted CO2

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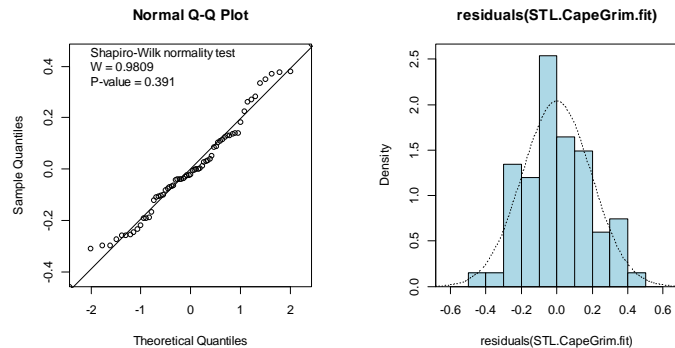

Residual Series

```
> acf(residuals(STL.CapeGrim.fit))
```

Series residuals(STL.CapeGrim.fit)


```
> normcheck(residuals(STL.CapeGrim.fit),shapiro.wilk=T)
```

Normal Q-Q Plot **residuals(STL.CapeGrim.fit)**

Shapiro-Wilk normality test
W = 0.9809
P-value = 0.391

```
> summary(STL.CapeGrim.fit)

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

Residuals:
     Min       1Q   Median       3Q      Max
-0.45793 -0.10879 -0.01938  0.12045  0.48695

Coefficients:
                Estimate Std. Error t value Pr(>|t|)
(Intercept)    116.42772   30.63149   3.801 0.000328 ***
Time[-1]         0.15435    0.04024   3.836 0.000292 ***
Time.break[-1]   0.05016    0.01345   3.729 0.000414 ***
STL.CO2.ts[-68]  0.68245    0.08385   8.139 2.04e-11 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2001 on 63 degrees of freedom
Multiple R-squared:  0.9996,    Adjusted R-squared:  0.9996
F-statistic: 5.403e+04 on 3 and 63 DF,  p-value: < 2.2e-16
```

```
> t69.stl.pred = STL.CapeGrim.fit$coef[1]+STL.CapeGrim.fit$coef[2]*69+
   STL.CapeGrim.fit$coef[3]*19+STL.CapeGrim.fit$coef[4]*STL.CO2.ts[68]
> t69.stl.pred
(Intercept)
   401.7811
> t69.pred = t69.stl.pred+STL.CapeGrim$time.series[1,1]
> t69.pred
(Intercept)
   401.3741

> t70.stl.pred = STL.CapeGrim.fit$coef[1]+STL.CapeGrim.fit$coef[2]*70+
   STL.CapeGrim.fit$coef[3]*20+STL.CapeGrim.fit$coef[4]*t69.stl.pred
> t70.stl.pred
(Intercept)
   402.4288
> t70.pred = t70.stl.pred+STL.CapeGrim$time.series[2,1]
> t70.pred
(Intercept)
   402.0717

> t71.stl.pred = STL.CapeGrim.fit$coef[1]+STL.CapeGrim.fit$coef[2]*71+
   STL.CapeGrim.fit$coef[3]*21+STL.CapeGrim.fit$coef[4]*t70.stl.pred
> t71.stl.pred
(Intercept)
   403.0753
> t71.pred = t71.stl.pred+STL.CapeGrim$time.series[3,1]
> t71.pred
(Intercept)
    403.571

> t72.stl.pred = STL.CapeGrim.fit$coef[1]+STL.CapeGrim.fit$coef[2]*72+
   STL.CapeGrim.fit$coef[3]*22+STL.CapeGrim.fit$coef[4]*t71.stl.pred
> t72.stl.pred
(Intercept)
   403.7211
> t72.pred = t72.stl.pred+STL.CapeGrim$time.series[4,1]
> t72.pred
(Intercept)
   403.9894

> STL.pred = c(t69.pred,t70.pred,t71.pred,t72.pred)
> names(STL.pred) = c("2017.1","2017.2","2017.3","2017.4")
> STL.pred
  2017.1   2017.2   2017.3   2017.4
401.3741 402.0717 403.5710 403.9894

> RMSEP.STL.CapeGrim = sqrt(1/4*sum((actual.2017-STL.pred)^2))
> RMSEP.STL.CapeGrim
[1] 0.3129915
```
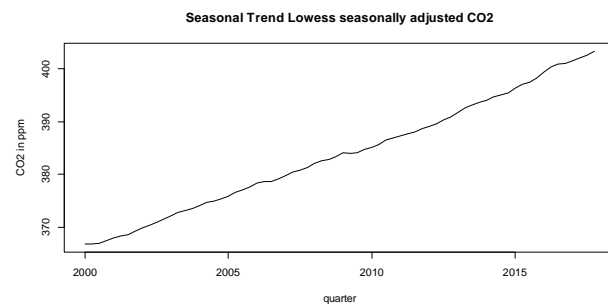
Question Three: (30 marks)

Tech Notes

Question Four: (20 marks)

```
> STL.CapeGrim.F = stl(CO2.ts,s.window="periodic")

> STL.CapeGrim.F$time.series[1:4,1]
[1] -0.4127638 -0.3688464  0.4931301  0.2884802

> STL.CO2.F.ts = CO2.ts-STL.CapeGrim.F$time.series[,1]

> plot(STL.CO2.F.ts,main="Seasonal Trend Lowess seasonally adjusted
  CO2",xlab="quarter",ylab="CO2 in ppm")
```

Seasonal Trend Lowess seasonally adjusted CO2


```
> Time.F = 1:72
> Time.break.F = c(rep(0,49),Time.F[50:72]-Time.F[50])

> STL.CapeGrim.F.fit = lm(STL.CO2.F.ts[-1]~Time.F[-1]+
  Time.break.F[-1]+STL.CO2.F.ts[-72])
> summary(STL.CapeGrim.F.fit)

Call:
lm(formula = STL.CO2.F.ts[-1] ~ Time.F[-1] + Time.break.F[-1] +
    STL.CO2.F.ts[-72])

Residuals:
    Min      1Q  Median      3Q     Max
-0.4514 -0.1029 -0.0292  0.1004  0.5497

Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)        120.25560   30.34134   3.963 0.000182 ***
Time.F[-1]           0.15975    0.03986   4.007 0.000157 ***
Time.break.F[-1]     0.04721    0.01264   3.736 0.000388 ***
STL.CO2.F.ts[-72]    0.67195    0.08306   8.090 1.65e-11 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2006 on 67 degrees of freedom
Multiple R-squared:  0.9997,    Adjusted R-squared:  0.9996
F-statistic: 6.567e+04 on 3 and 67 DF,  p-value: < 2.2e-16
```

```
> t73.stl.pred = STL.CapeGrim.F.fit$coef[1]+STL.CapeGrim.F.fit$coef[2]*73+
  STL.CapeGrim.F.fit$coef[3]*23+
  STL.CapeGrim.F.fit$coef[4]*STL.CO2.F.ts[72]
> t73.stl.pred
(Intercept)
   404.0682
> t73.pred = t73.stl.pred+STL.CapeGrim.F$time.series[1,1]
> t73.pred
(Intercept)
   403.6555

> t74.stl.pred = STL.CapeGrim.F.fit$coef[1]+STL.CapeGrim.F.fit$coef[2]*74+
  STL.CapeGrim.F.fit$coef[3]*24+STL.CapeGrim.F.fit$coef[4]*t73.stl.pred
> t74.stl.pred
(Intercept)
   404.7232
> t74.pred = t74.stl.pred+STL.CapeGrim.F$time.series[2,1]
> t74.pred
(Intercept)
   404.3543

> t75.stl.pred = STL.CapeGrim.F.fit$coef[1]+STL.CapeGrim.F.fit$coef[2]*75+
  STL.CapeGrim.F.fit$coef[3]*25+STL.CapeGrim.F.fit$coef[4]*t74.stl.pred
> t75.stl.pred
(Intercept)
   405.3702
> t75.pred = t75.stl.pred+STL.CapeGrim.F$time.series[3,1]
> t75.pred
(Intercept)
   405.8634

> t76.stl.pred = STL.CapeGrim.F.fit$coef[1]+STL.CapeGrim.F.fit$coef[2]*76+
  STL.CapeGrim.F.fit$coef[3]*26+STL.CapeGrim.F.fit$coef[4]*t75.stl.pred
> t76.stl.pred
(Intercept)
    406.012
> t76.pred = t76.stl.pred+STL.CapeGrim.F$time.series[4,1]
> t76.pred
(Intercept)
   406.3005

> STL.F.pred = c(t73.pred,t74.pred,t75.pred,t76.pred)
> names(STL.F.pred) = c("2018.1","2018.2","2018.3","2018.4")
> STL.F.pred
  2018.1   2018.2   2018.3   2018.4
403.6555 404.3543 405.8634 406.3005
```