

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)
```

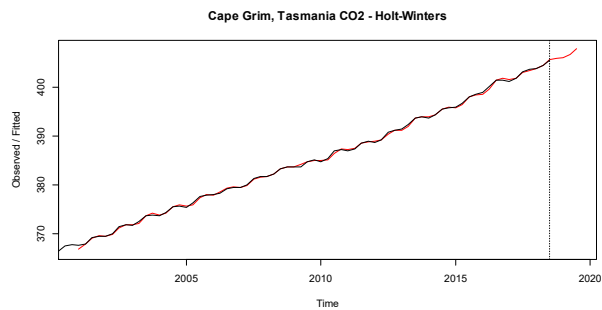
```
Smoothing parameters:
  alpha: 0.9267355
  beta : 0.0813906
  gamma: 1
```

```
Coefficients:
      [,1]
a 405.1011655
b  0.5889777
s1 0.2311236
s2 -0.2791367
s3 -0.2150001
s4 0.4588345
```

```
> HW.pred = predict(HW.fit,n.ahead=4)
> HW.pred
      Qtr1      Qtr2      Qtr3      Qtr4
2018      405.9213
2019 406.0000 406.6531 407.9159
```

```
> HW.RMSEP = sqrt(1/4*sum((actual-HW.pred)^2))
> HW.RMSEP
[1] 0.2214015
```

```
> plot(HW.fit,HW.pred,main="Cape Grim, Tasmania CO2 - Holt-Winters")
```

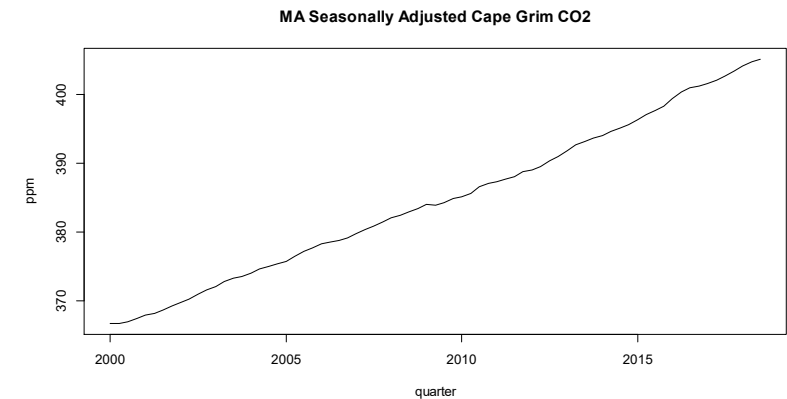


Question Two: (30 marks)

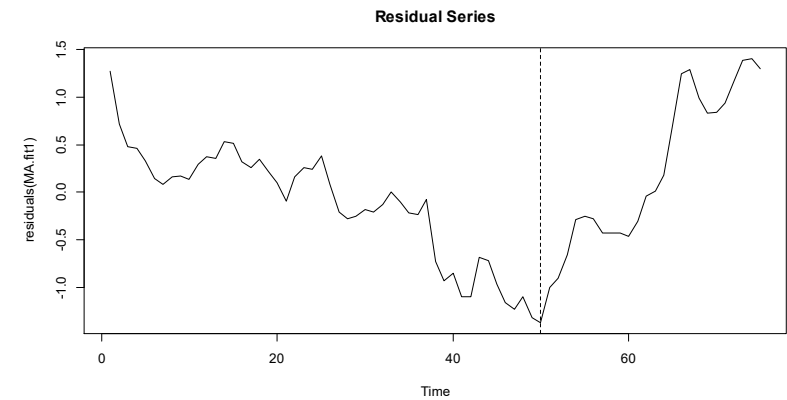
MA Seasonally Adjusted:

```
> MA.CapeGrim = decompose(red.CO2.ts)
> MA.CapeGrim$figure
[1] -0.3537786 -0.3024142  0.4383742  0.2178186

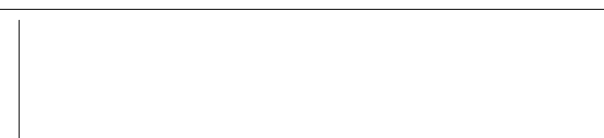
> MA.red.CO2.ts = red.CO2.ts-MA.CapeGrim$seasonal
> plot(MA.red.CO2.ts,main="MA Seasonally Adjusted Cape Grim
CO2",xlab="quarter",ylab="ppm")
```



```
> MA.fit1 = lm(MA.red.CO2.ts~red.Time)
> plot.ts(residuals(MA.fit1),main="Residual Series")
> abline(v=50,lty=2)
```



The plot, titled "Residual Series", shows the residuals of a fitted MA(2) model over time. The y-axis is labeled "residuals(MA.fit2)" and ranges from -0.4 to 0.4. The x-axis is labeled "Time" and ranges from 0 to 70. The residuals exhibit high volatility, with several large positive and negative spikes, suggesting the model does not adequately capture the underlying data structure.



Series residuals(MA.fit2)

ACF

Lag

This ACF plot shows the autocorrelation of residuals at various lags. The y-axis, labeled 'ACF', ranges from -0.4 to 1.0. The x-axis, labeled 'Lag', ranges from 0 to 18. A prominent spike is visible at lag 0 with an ACF of 1.0. Subsequent spikes at lags 1 and 11 are within the 95% confidence interval, indicated by dashed blue horizontal lines at approximately ±0.25. All other spikes are within the bounds of the confidence interval, suggesting the residuals are uncorrelated.

Shapiro-Wilk normality test
 $W = 0.9911$
 $P\text{-value} = 0.889$

Sample Quantiles

Theoretical Quantiles

residuals(MA.fit2)

```
Call:
lm(formula = MA.red.CO2.ts[-1] ~ red.Time[-1] + red.Time.break[-1] +
    MA.red.CO2.ts[-75])
```

```
Residuals:
```

Min	1Q	Median	3Q	Max
-0.49708	-0.12360	-0.00111	0.11456	0.53291

```

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  109.60178   28.73023   3.815 0.000291 ***
red.Time[-1]    0.14586    0.03774   3.865 0.000246 ***
red.Time.break[-1] 0.04186    0.01170   3.578 0.000633 ***
MA.red.CO2.ts[-75] 0.70111    0.07865   8.915 3.79e-13 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

Residual standard error: 0.1849 on 70 degrees of freedom
Multiple R-squared: 0.9997, Adjusted R-squared: 0.9997
F-statistic: 8.928e+04 on 3 and 70 DF, p-value: < 2.2e-16

```

> t.76.ma.pred = MA.fit2$coef[1]+MA.fit2$coef[2]*76+MA.fit2$coef[3]*26+
  MA.fit2$coef[4]*MA.red.CO2.ts[75]
> t.76.ma.pred
(Intercept)
  405.8117
> t.76.pred = t.76.ma.pred+MA.CapeGrim$figure[4]
> t.76.pred
(Intercept)
  406.0296

> t.77.ma.pred = MA.fit2$coef[1]+MA.fit2$coef[2]*77+MA.fit2$coef[3]*27+
  MA.fit2$coef[4]*t.76.ma.pred
> t.77.ma.pred
(Intercept)
  406.4833
> t.77.pred = t.77.ma.pred+MA.CapeGrim$figure[1]
> t.77.pred
(Intercept)
  406.1295

> t.78.ma.pred = MA.fit2$coef[1]+MA.fit2$coef[2]*78+MA.fit2$coef[3]*28+
  MA.fit2$coef[4]*t.77.ma.pred
> t.78.ma.pred
(Intercept)
  407.1419
> t.78.pred = t.78.ma.pred+MA.CapeGrim$figure[2]
> t.78.pred
(Intercept)
  406.8395

> t.79.ma.pred = MA.fit2$coef[1]+MA.fit2$coef[2]*79+MA.fit2$coef[3]*29+
  MA.fit2$coef[4]*t.78.ma.pred
> t.79.ma.pred
(Intercept)
  407.7913
> t.79.pred = t.79.ma.pred+MA.CapeGrim$figure[3]
> t.79.pred
(Intercept)
  408.2297

> MA.pred = c(t.76.pred,t.77.pred,t.78.pred,t.79.pred)
> names(MA.pred) = c("2018.4","2019.1","2019.2","2019.3")
> MA.pred
  2018.4  2019.1  2019.2  2019.3
406.0296 406.1295 406.8395 408.2297

> actual
2018.4 2019.1 2019.2 2019.3
405.83 405.73 406.71 408.25

> MA.RMSEP = sqrt(1/4*sum((actual-MA.pred)^2))
> MA.RMSEP
[1] 0.2327083

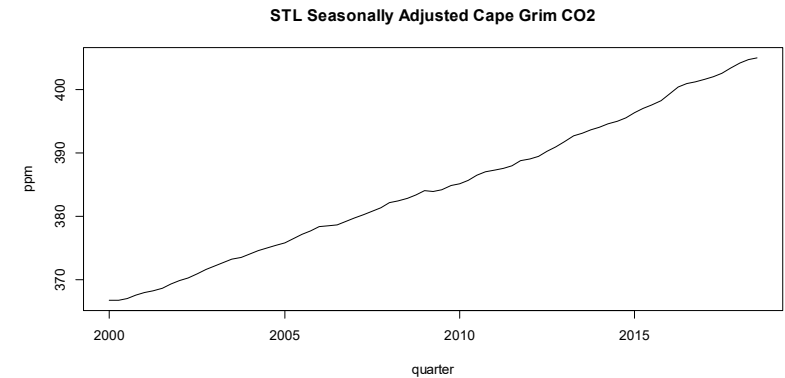
```

STL Seasonally Adjusted:

```

> STL.CapeGrim = stl(red.CO2.ts,s.window="periodic")
> STL.CapeGrim$time.series[1:4,1]
[1] -0.3906880 -0.3028320  0.4787971  0.2147230
> STL.red.CO2.ts = red.CO2.ts-STL.CapeGrim$time.series[,1]
> plot(STL.red.CO2.ts,main="STL Seasonally Adjusted Cape Grim
  CO2",xlab="quarter",ylab="ppm")

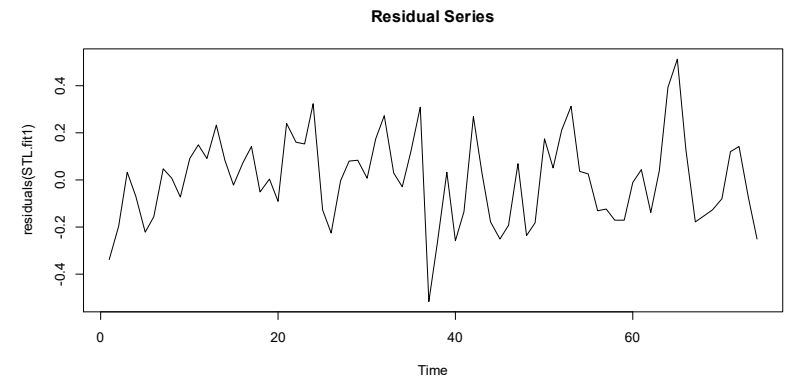
```



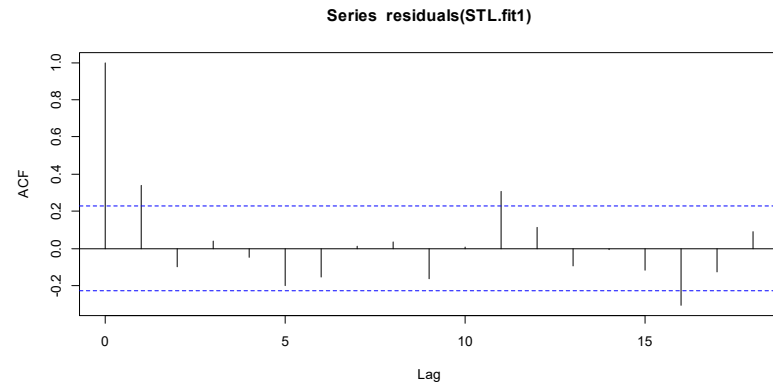
```

> STL.fit1 = lm(STL.red.CO2.ts[-1]~red.Time[-1]+red.Time.break[-1]+
  STL.red.CO2.ts[-75])
> plot.ts(residuals(STL.fit1),main="Residual Series")

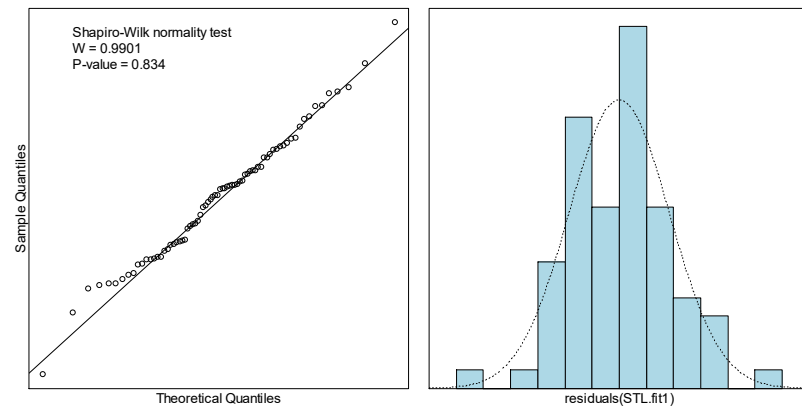
```



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



```
> normcheck(residuals(STL.fit1),shapiro.wilk=T)
```



```
> summary(STL.fit1)
```

```
Call:
lm(formula = STL.red.CO2.ts[-1] ~ red.Time[-1] + red.Time.break[-1] +
    STL.red.CO2.ts[-75])
```

```
Residuals:
    Min       1Q   Median       3Q      Max
-0.51687 -0.13691  0.01665  0.11813  0.51237
```

```
Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)    113.68138    29.12337   3.903 0.000216 ***
red.Time[-1]     0.15131     0.03826   3.955 0.000181 ***
red.Time.break[-1] 0.04304     0.01189   3.620 0.000554 ***
STL.red.CO2.ts[-75] 0.68994     0.07972   8.654 1.14e-12 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Residual standard error: 0.189 on 70 degrees of freedom
Multiple R-squared:  0.9997,    Adjusted R-squared:  0.9997
F-statistic: 8.543e+04 on 3 and 70 DF,  p-value: < 2.2e-16
```

```
> t.76.stl.pred = STL.fit1$coef[1]+STL.fit1$coef[2]*76+STL.fit1$coef[3]*26+
  STL.fit1$coef[4]*STL.red.CO2.ts[75]
> t.76.stl.pred
(Intercept)
  405.7808
> t.76.pred = t.76.stl.pred+STL.CapeGrim$time.series[4,1]
> t.76.pred
(Intercept)
  405.9955

> t.77.stl.pred = STL.fit1$coef[1]+STL.fit1$coef[2]*77+STL.fit1$coef[3]*27+
  STL.fit1$coef[4]*t.76.stl.pred
> t.77.stl.pred
(Intercept)
  406.4578
> t.77.pred = t.77.stl.pred+STL.CapeGrim$time.series[1,1]
> t.77.pred
(Intercept)
  406.0671

> t.78.stl.pred = STL.fit1$coef[1]+STL.fit1$coef[2]*78+STL.fit1$coef[3]*28+
  STL.fit1$coef[4]*t.77.stl.pred
> t.78.stl.pred
(Intercept)
  407.1193
> t.78.pred = t.78.stl.pred+STL.CapeGrim$time.series[2,1]
> t.78.pred
(Intercept)
  406.8164
```

```

> t.79.stl.pred = STL.fit1$coef[1]+STL.fit1$coef[2]*79+STL.fit1$coef[3]*29+
  STL.fit1$coef[4]*t.78.stl.pred
> t.79.ma.pred
(Intercept)
  407.7709
> t.79.pred = t.79.stl.pred+STL.CapeGrim$time.series[3,1]
> t.79.pred
(Intercept)
  408.2488

> STL.pred = c(t.76.pred,t.77.pred,t.78.pred,t.79.pred)
> names(STL.pred) = c("2018.4","2019.1","2019.2","2019.3")
> STL.pred
  2018.4  2019.1  2019.2  2019.3
405.9955 406.0671 406.8164 408.2488

> STL.RMSEP = sqrt(1/4*sum((actual-STL.pred)^2))
> STL.RMSEP
[1] 0.1951761

```

STL Seasonally Adjusted (Full):

```

> STL.CapeGrim.Full = stl(full.CO2.ts,s.window="periodic")
> STL.CapeGrim.Full$time.series[1:4,1]
[1] -0.4048721 -0.3002874  0.4920871  0.2130726

> STL.full.CO2.ts = full.CO2.ts-STL.CapeGrim.Full$time.series[,1]
> full.Time.break = c(rep(0,49),full.Time[50:79]-full.Time[50])

> STL.fit = lm(STL.full.CO2.ts[-1]~full.Time[-1]+full.Time.break[-1]+
  STL.full.CO2.ts[-79])

> summary(STL.fit)

```

```

Call:
lm(formula = STL.full.CO2.ts[-1] ~ full.Time[-1] + full.Time.break[-1] +
    STL.full.CO2.ts[-79])

```

```

Residuals:
    Min       1Q   Median       3Q      Max
-0.5294 -0.1417  0.0186  0.1271  0.5095

```

```

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)      114.64012    28.54054   4.017 0.000140 ***
full.Time[-1]       0.15269     0.03754   4.067 0.000118 ***
full.Time.break[-1]  0.04254     0.01109   3.837 0.000260 ***
STL.full.CO2.ts[-79]  0.68731     0.07813   8.797 4.02e-13 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

```

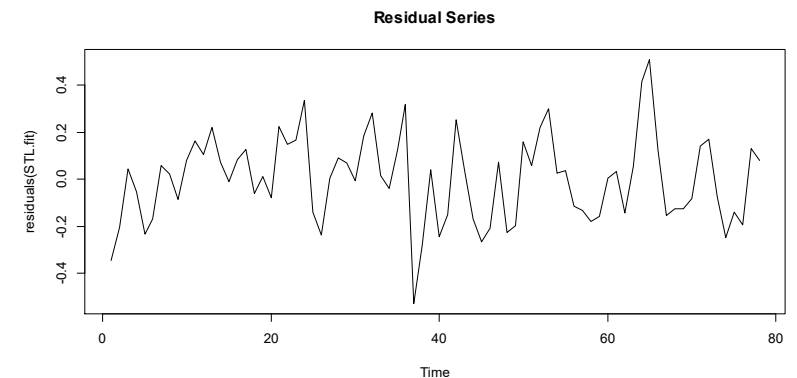
Residual standard error: 0.1896 on 74 degrees of freedom
Multiple R-squared:  0.9998,    Adjusted R-squared:  0.9997
F-statistic: 1.016e+05 on 3 and 74 DF,  p-value: < 2.2e-16

```

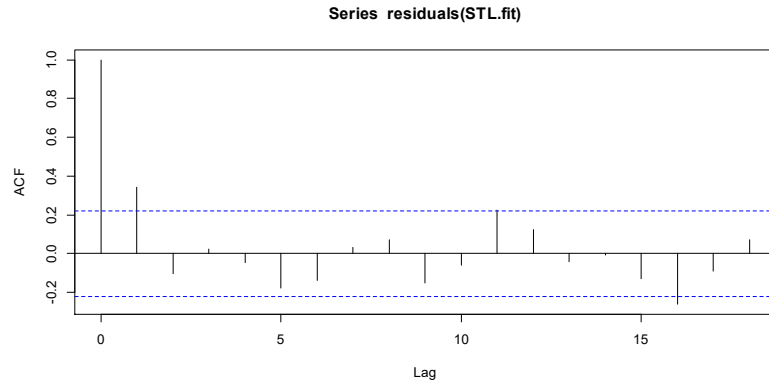
```

> plot.ts(residuals(STL.fit),main="Residual Series")

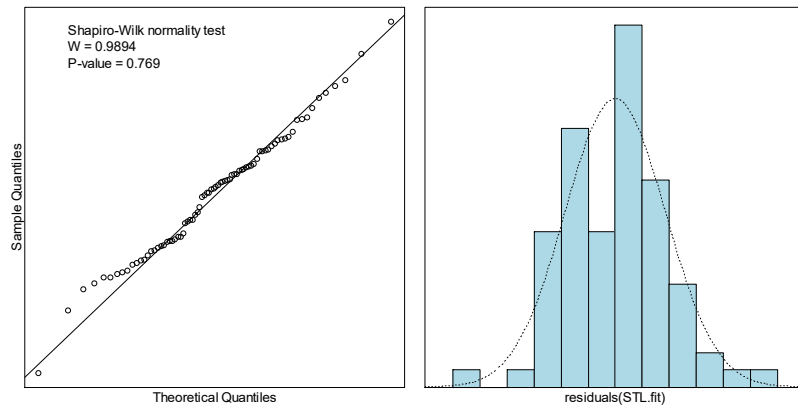
```



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



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



```
> t.80.stl.pred = STL.fit$coef[1]+STL.fit$coef[2]*80+STL.fit$coef[3]*30+
STL.fit$coef[4]*STL.full.CO2.ts[79]
> t.80.stl.pred
(Intercept)
408.3857
> t.80.pred = t.80.stl.pred+STL.CapeGrim.Full$time.series[4]
> t.80.pred
(Intercept)
408.5988

> t.81.stl.pred = STL.fit$coef[1]+STL.fit$coef[2]*81+STL.fit$coef[3]*31+
STL.fit$coef[4]*t.80.stl.pred
> t.81.stl.pred
(Intercept)
409.0124
> t.81.pred = t.81.stl.pred+STL.CapeGrim.Full$time.series[1]
> t.81.pred
(Intercept)
408.6075

> t.82.stl.pred = STL.fit$coef[1]+STL.fit$coef[2]*82+STL.fit$coef[3]*32+
STL.fit$coef[4]*t.81.stl.pred
> t.82.stl.pred
(Intercept)
409.6384
> t.82.pred = t.82.stl.pred+STL.CapeGrim.Full$time.series[2]
> t.82.pred
(Intercept)
409.3381

> t.83.stl.pred = STL.fit$coef[1]+STL.fit$coef[2]*83+STL.fit$coef[3]*33+
STL.fit$coef[4]*t.82.stl.pred
> t.83.stl.pred
(Intercept)
410.2638
> t.83.pred = t.83.stl.pred+STL.CapeGrim.Full$time.series[3]
> t.83.pred
(Intercept)
410.7559

> STL.Full.pred = c(t.80.pred,t.81.pred,t.82.pred,t.83.pred)
> names(STL.Full.pred) = c("2019.4","2020.1","2020.2","2020.3")
> STL.Full.pred
2019.4 2020.1 2020.2 2020.3
408.5988 408.6075 409.3381 410.7559
```