

Total energy transportation sector co2 emissions Time series Analysis

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```
rm(list=ls())
options(scipen=999,digits=4)
rm
```

```
## function (... , list = character(), pos = -1, envir = as.environment(pos),
##   inherits = FALSE)
## {
##   dots <- match.call(expand.dots = FALSE)$...
##   if (length(dots) && !all(vapply(dots, function(x) is.symbol(x) ||
##     is.character(x), NA, USE.NAMES = FALSE)))
##     stop("... must contain names or character strings")
##   names <- vapply(dots, as.character, "")
##   if (length(names) == 0L)
##     names <- character()
##   list <- .Primitive("c")(list, names)
##   .Internal(remove(list, envir, inherits))
## }
## <bytecode: 0x0000000014cdac20>
## <environment: namespace:base>
```

Load R packages

```
## Warning: package 'zoo' was built under R version 4.1.3
```

```
## Warning: package 'ggplot2' was built under R version 4.1.2
```

```
## Warning: package 'fpp2' was built under R version 4.1.3
```

```
## Warning: package 'forecast' was built under R version 4.1.3
```

```
## Warning: package 'fma' was built under R version 4.1.3
```

```
## Warning: package 'expsmooth' was built under R version 4.1.3
```

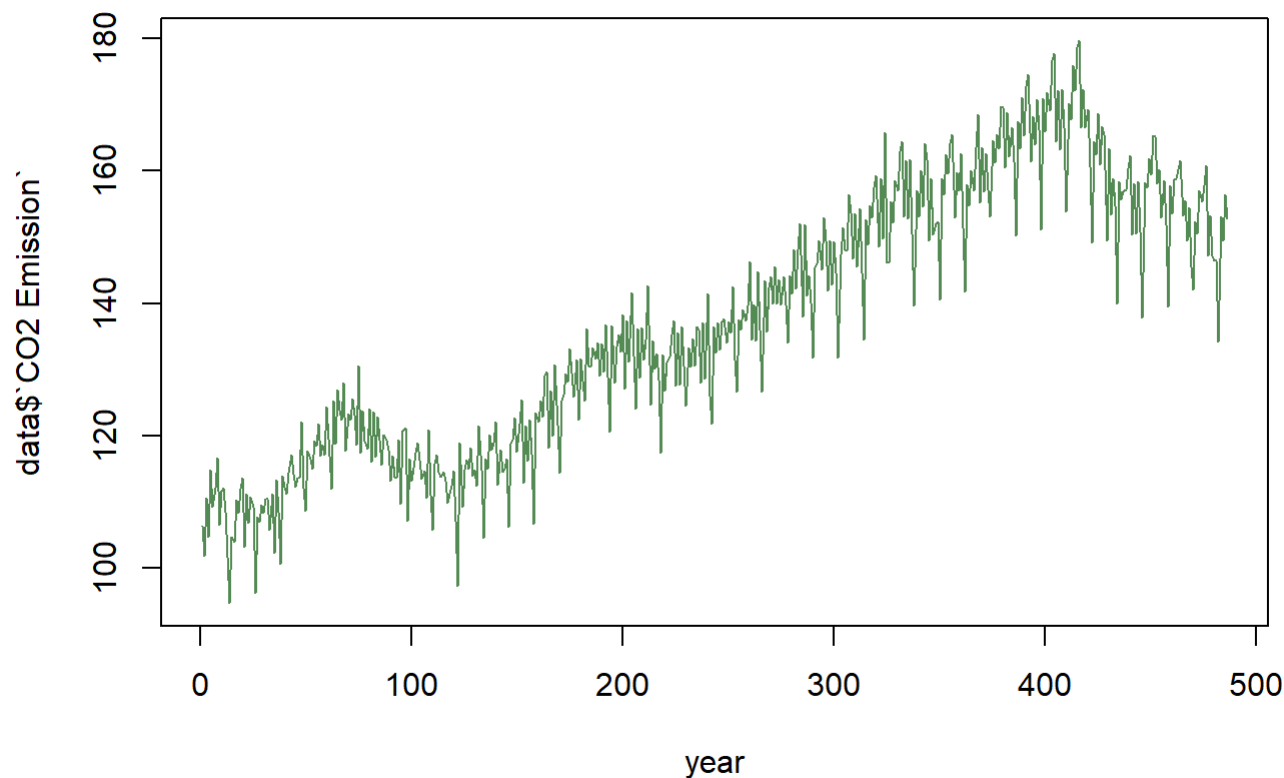
Dataset loading

```
## # A tibble: 6 x 3
##   Year Month `CO2 Emission`
##   <dbl> <chr>         <dbl>
## 1  1973 Jan          106.
## 2  1973 Feb          102.
## 3  1973 Mar          111.
## 4  1973 Apr          105.
## 5  1973 May          115.
## 6  1973 Jun          109.
```

```
## # A tibble: 6 x 3
##   Year Month `CO2 Emission`
##   <dbl> <chr>         <dbl>
## 1  2013 Jan          147.
## 2  2013 Feb          134.
## 3  2013 Mar          153.
## 4  2013 Apr          149.
## 5  2013 May          156.
## 6  2013 Jun          153.
```

```
## [1] FALSE
```

Total energy transportation sector co2 emissions and year



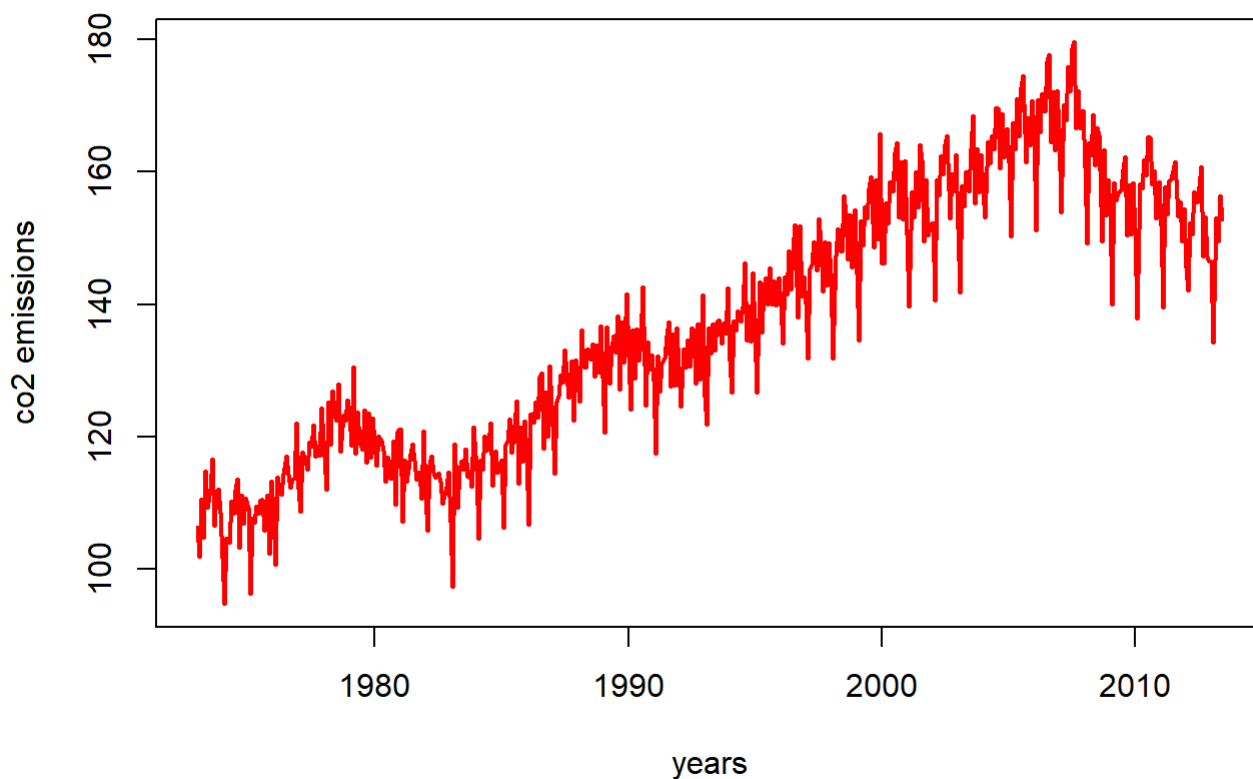
Converting to time series class and plotting the time series data

```
data_ts <- ts(data$`CO2 Emission`, start=c(1973,1), frequency = 12)
head(data_ts)
```

```
##          Jan   Feb   Mar   Apr   May   Jun
## 1973 106.4 101.8 110.6 104.7 114.9 109.2
```

```
# Plotting time series dataset
plot(data_ts, xlab="years", ylab="co2 emissions", main="Total energy transportation sector co2 e
missions vs Years",col="red",type = "l", lwd=2)
```

Total energy transportation sector co2 emissions vs Years

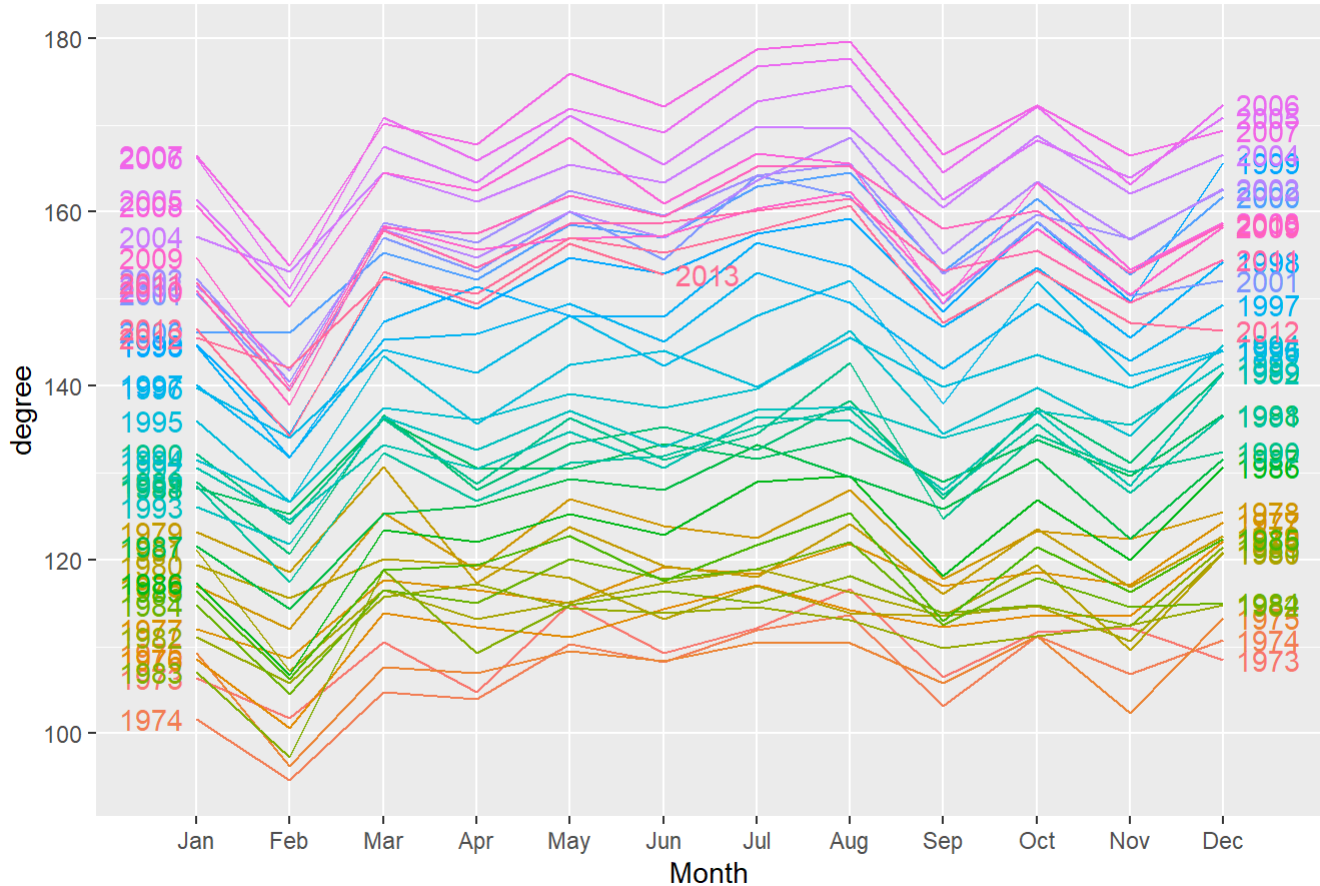


```
# Observation of the plot:
# 1. Values of the data are stored in correct order and no missing data.
# 2. There is an upward trend in the earlier years but falling in the later years. On the average, co2 emissions is going up.
# 3. Intra-year stable fluctuations are indicative of seasonal components. As trend increases, fluctuations are also increasing. Indicative of multiplicative seasonality.
# 4. Co2 emissions is beginning to fall slightly in the later years.
```

to get the seasonality better

```
ggseasonplot(data_ts, year.labels = T, year.labels.left = T) +ylab("degree") +ggtitle("Seasonal Plot: Total energy transportation sector co2 emissions vs Years")
```

Seasonal Plot: Total energy transportation sector co2 emissions vs Years



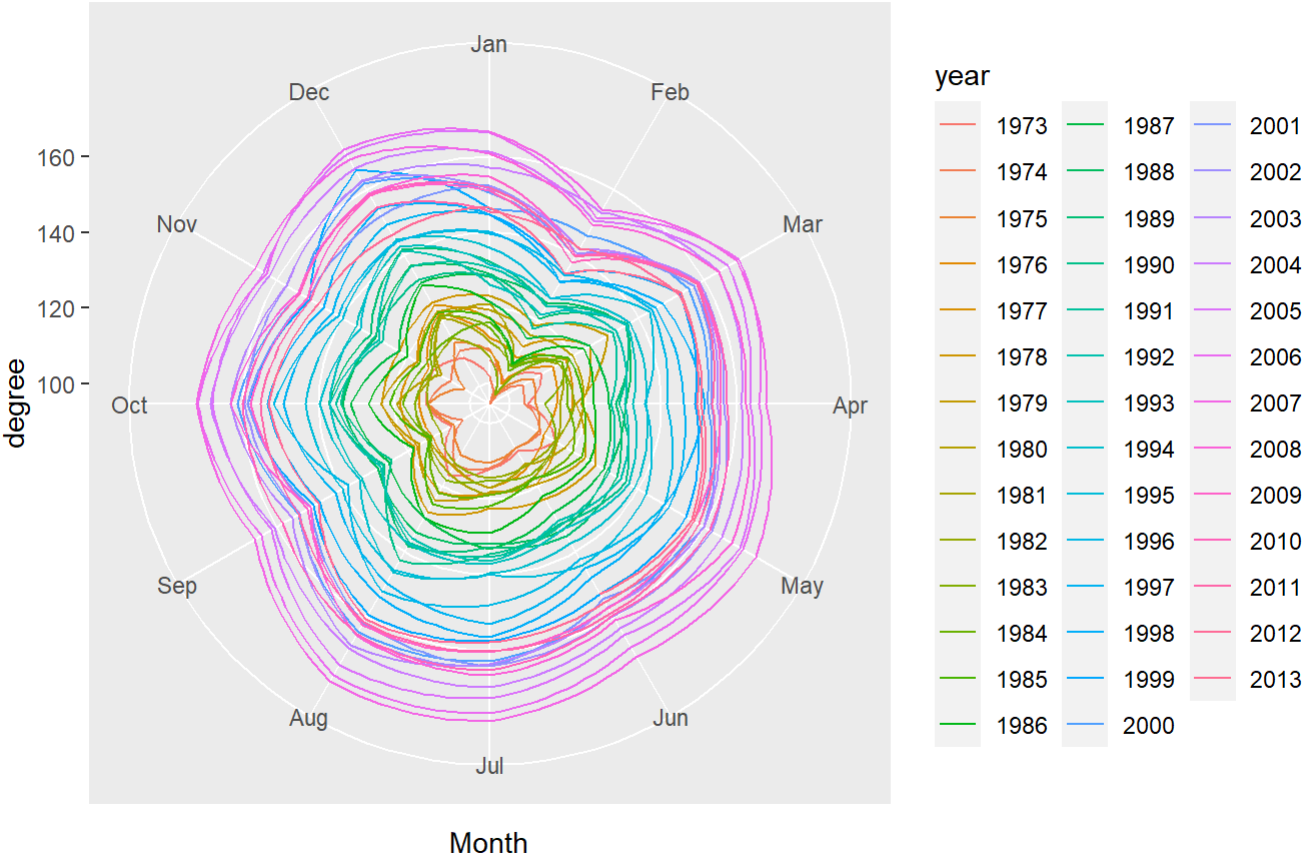
Observation:

1) as the year goes by, co2 emissions increases - indicating trend.

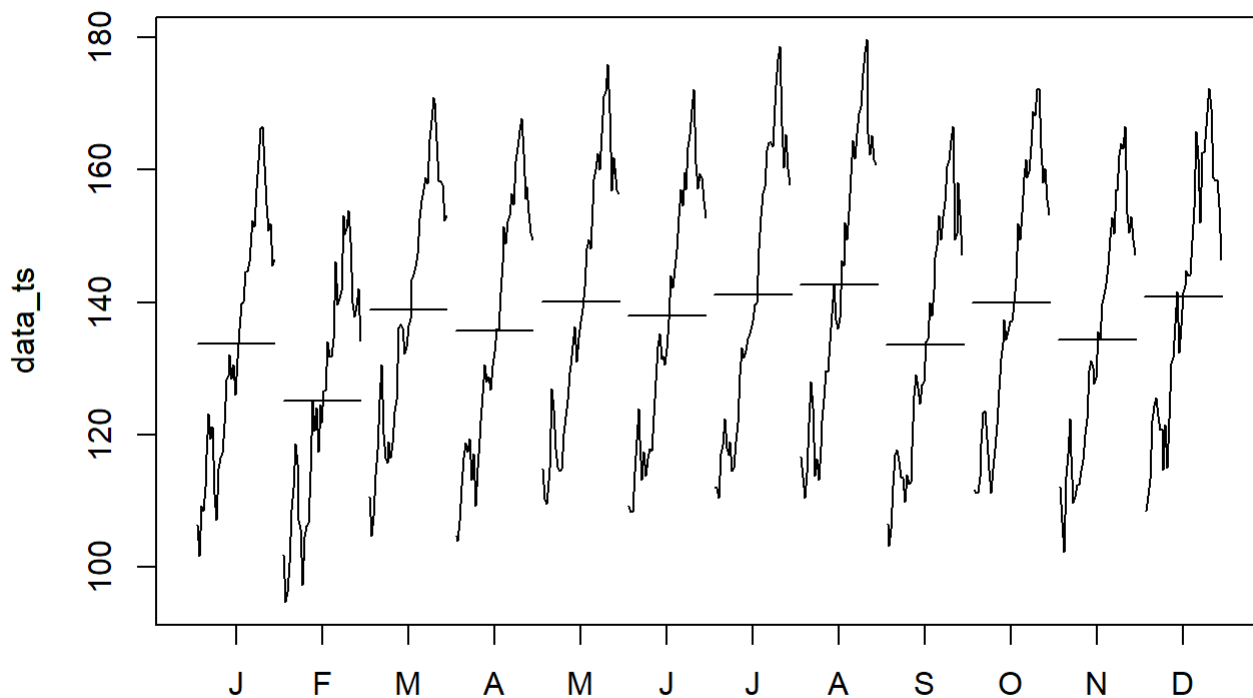
2) It is beginning to fall slightly

```
ggseasonplot(data_ts, polar = T) +ylab("degree") +ggtitle("Polar plot: Total energy transportation sector co2 emissions vs Years")
```

Polar plot: Total energy transportation sector co2 emissions vs Years



```
monthplot(data_ts)
```



Average co2 emissions was a little bit higher in the month of August, July and December. ALL months showed some irregularities (the bump) but it was most pronounced in the month of February and December.

Average co2 emissions was a little bit lower in the month of February.

Decomposition of plot: Mutiplicative Seasonal correction/adjustment

```
data_decompose <- decompose(data_ts, type = "multiplicative")  
head(data_decompose)
```

```

## $x
##      Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct
## 1973 106.36 101.76 110.55 104.73 114.90 109.24 112.14 116.68 106.56 111.66
## 1974 101.70  94.70 104.72 103.96 110.26 108.27 111.90 113.59 103.15 111.24
## 1975 109.28  96.31 107.67 106.92 109.49 108.37 110.53 110.38 105.81 111.23
## 1976 108.55 100.67 113.87 112.31 111.17 114.37 117.05 114.18 112.27 113.61
## 1977 112.07 108.66 117.71 116.51 114.99 119.16 118.41 121.82 117.01 118.56
## 1978 117.02 112.04 125.33 118.81 126.99 123.86 122.47 127.99 117.73 123.35
## 1979 123.17 118.58 130.63 117.36 123.73 119.24 118.05 124.07 116.09 123.56
## 1980 119.45 115.62 120.08 119.44 117.93 113.24 117.03 113.83 113.57 119.43
## 1981 121.17 107.20 116.47 113.18 115.11 117.35 118.90 116.31 113.49 114.72
## 1982 111.09 105.83 115.76 117.17 114.47 113.82 114.52 113.12 109.83 111.20
## 1983 107.06  97.34 118.86 109.28 114.81 116.41 115.01 118.12 113.91 114.79
## 1984 114.81 104.54 116.51 115.04 120.14 117.84 118.90 122.06 112.52 117.92
## 1985 116.44 106.28 118.77 119.34 122.78 117.50 121.75 125.36 112.94 121.42
## 1986 117.28 106.74 123.48 122.08 125.32 122.83 129.00 129.59 118.16 126.85
## 1987 121.64 114.37 125.25 126.19 129.34 128.08 133.17 129.56 125.85 131.55
## 1988 128.30 125.31 136.19 130.54 130.40 133.33 131.66 134.05 129.00 133.83
## 1989 128.92 120.63 136.68 128.05 133.39 135.31 132.66 138.34 127.05 137.42
## 1990 132.13 124.11 136.18 128.73 136.30 131.49 134.46 142.69 124.65 134.33
## 1991 128.47 117.44 132.30 126.80 131.10 131.91 135.30 137.31 127.51 135.62
## 1992 130.57 124.53 133.24 130.47 134.71 130.52 136.46 135.96 128.07 137.06
## 1993 126.06 121.78 136.49 132.60 137.13 132.95 137.27 137.63 134.00 137.17
## 1994 131.53 126.60 137.52 136.05 139.11 137.44 139.61 146.29 134.50 139.79
## 1995 136.02 126.67 143.43 135.65 142.40 144.02 139.95 145.59 139.90 143.57
## 1996 139.74 133.99 144.15 141.49 148.12 142.27 148.11 152.04 137.94 151.93
## 1997 140.13 131.82 145.34 146.01 149.48 145.10 153.02 149.52 141.95 149.47
## 1998 144.66 131.74 147.41 151.44 148.09 147.92 156.50 153.66 146.78 153.59
## 1999 144.71 134.45 152.61 148.93 154.71 152.88 157.50 159.27 148.57 158.88
## 2000 146.20 146.09 155.35 152.26 158.52 157.02 162.88 164.48 153.13 161.53
## 2001 150.55 139.58 157.03 153.09 160.00 154.54 164.19 161.74 149.50 158.85
## 2002 152.35 140.49 158.83 156.50 162.44 159.59 164.21 165.52 152.95 159.75
## 2003 151.49 141.78 157.91 154.79 160.10 157.00 163.59 168.58 155.15 163.51
## 2004 157.16 153.16 164.53 161.22 165.49 163.38 169.78 169.56 160.53 168.76
## 2005 161.37 150.28 167.52 163.38 171.07 165.42 172.75 174.58 161.38 168.18
## 2006 166.28 151.19 170.91 165.90 171.87 169.08 176.75 177.70 164.50 172.14
## 2007 166.54 153.85 170.15 167.81 175.93 172.10 178.72 179.66 166.60 172.30
## 2008 160.71 149.15 164.51 162.43 168.61 160.98 166.71 165.54 149.45 163.37
## 2009 154.71 139.94 158.40 155.67 156.92 157.24 160.42 162.31 150.39 158.03
## 2010 150.90 137.77 158.17 157.46 161.83 159.50 165.28 165.18 158.13 160.18
## 2011 151.85 139.49 157.84 153.55 158.64 158.83 160.19 161.57 153.19 155.55
## 2012 145.57 142.10 152.38 150.60 157.03 155.37 157.85 160.75 147.24 153.26
## 2013 146.52 134.24 153.08 149.44 156.36 152.81
##      Nov      Dec
## 1973 112.11 108.50
## 1974 106.85 110.75
## 1975 102.31 113.27
## 1976 113.58 122.12
## 1977 117.09 124.40
## 1978 122.42 125.52
## 1979 116.88 122.79
## 1980 109.65 120.81

```

```

## 1981 110.62 120.85
## 1982 112.45 114.75
## 1983 112.35 121.43
## 1984 114.59 115.04
## 1985 116.27 122.39
## 1986 119.99 130.72
## 1987 122.37 131.62
## 1988 129.66 136.71
## 1989 131.18 141.62
## 1990 130.12 132.45
## 1991 127.70 136.50
## 1992 128.53 141.49
## 1993 135.55 142.56
## 1994 134.28 144.75
## 1995 139.77 144.02
## 1996 141.13 144.19
## 1997 142.89 149.37
## 1998 145.58 154.34
## 1999 149.73 165.73
## 2000 152.83 161.74
## 2001 150.34 152.10
## 2002 156.98 162.61
## 2003 156.84 162.67
## 2004 162.13 166.62
## 2005 163.95 170.87
## 2006 163.19 172.37
## 2007 166.54 169.31
## 2008 153.35 158.83
## 2009 150.46 158.36
## 2010 152.97 158.60
## 2011 149.54 154.53
## 2012 147.26 146.39
## 2013
##

```

```
## $seasonal
```

```

##      Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct
## 1973 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1974 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1975 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1976 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1977 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1978 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1979 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1980 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1981 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1982 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1983 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1984 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1985 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1986 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1987 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1988 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206

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## 1989 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1990 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1991 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1992 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1993 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1994 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1995 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1996 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1997 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1998 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 1999 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 2000 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 2001 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 2002 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 2003 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 2004 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 2005 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 2006 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 2007 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 2008 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 2009 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 2010 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 2011 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 2012 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## 2013 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065
##          Nov      Dec
## 1973 0.9792 1.0270
## 1974 0.9792 1.0270
## 1975 0.9792 1.0270
## 1976 0.9792 1.0270
## 1977 0.9792 1.0270
## 1978 0.9792 1.0270
## 1979 0.9792 1.0270
## 1980 0.9792 1.0270
## 1981 0.9792 1.0270
## 1982 0.9792 1.0270
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## 1992 0.9792 1.0270
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## 1994 0.9792 1.0270
## 1995 0.9792 1.0270
## 1996 0.9792 1.0270
## 1997 0.9792 1.0270
## 1998 0.9792 1.0270

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## 1999 0.9792 1.0270
## 2000 0.9792 1.0270
## 2001 0.9792 1.0270
## 2002 0.9792 1.0270
## 2003 0.9792 1.0270
## 2004 0.9792 1.0270
## 2005 0.9792 1.0270
## 2006 0.9792 1.0270
## 2007 0.9792 1.0270
## 2008 0.9792 1.0270
## 2009 0.9792 1.0270
## 2010 0.9792 1.0270
## 2011 0.9792 1.0270
## 2012 0.9792 1.0270
## 2013
##
## $trend
##      Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov   Dec
## 1973   NA    NA    NA    NA    NA    NA  109.4 108.9 108.4 108.1 107.9 107.6
## 1974 107.6 107.5 107.2 107.0 106.8 106.7 107.1 107.5 107.6 107.9 108.0 108.0
## 1975 107.9 107.7 107.7 107.8 107.6 107.5 107.6 107.8 108.2 108.7 109.0 109.3
## 1976 109.8 110.2 110.7 111.0 111.6 112.4 113.0 113.4 113.9 114.3 114.6 115.0
## 1977 115.2 115.6 116.1 116.5 116.9 117.1 117.4 117.8 118.2 118.6 119.2 119.9
## 1978 120.3 120.7 121.0 121.2 121.6 121.9 122.2 122.7 123.2 123.4 123.2 122.9
## 1979 122.5 122.2 121.9 121.9 121.6 121.3 121.0 120.7 120.2 119.8 119.7 119.2
## 1980 118.9 118.4 117.9 117.6 117.1 116.8 116.7 116.5 116.0 115.6 115.2 115.2
## 1981 115.5 115.7 115.8 115.6 115.4 115.4 115.0 114.6 114.5 114.6 114.7 114.6
## 1982 114.2 113.9 113.6 113.3 113.3 113.1 112.7 112.1 111.9 111.7 111.4 111.5
## 1983 111.7 111.9 112.3 112.6 112.7 113.0 113.6 114.2 114.4 114.6 115.0 115.3
## 1984 115.5 115.9 116.0 116.0 116.3 116.1 115.9 116.0 116.2 116.5 116.8 116.9
## 1985 117.0 117.2 117.4 117.5 117.8 118.1 118.5 118.5 118.7 119.1 119.3 119.6
## 1986 120.1 120.6 121.0 121.4 121.8 122.3 122.9 123.4 123.7 124.0 124.3 124.7
## 1987 125.1 125.3 125.6 126.1 126.4 126.5 126.9 127.6 128.5 129.1 129.4 129.6
## 1988 129.8 129.9 130.2 130.5 130.9 131.4 131.6 131.4 131.3 131.2 131.2 131.4
## 1989 131.5 131.8 131.8 131.9 132.1 132.4 132.7 133.0 133.1 133.1 133.3 133.3
## 1990 133.2 133.4 133.5 133.3 133.1 132.7 132.2 131.7 131.3 131.0 130.7 130.5
## 1991 130.6 130.4 130.3 130.5 130.4 130.5 130.7 131.1 131.5 131.7 132.0 132.1
## 1992 132.0 132.0 132.0 132.1 132.2 132.4 132.4 132.1 132.2 132.4 132.6 132.8
## 1993 132.9 133.0 133.3 133.6 133.9 134.2 134.5 134.9 135.2 135.4 135.6 135.8
## 1994 136.1 136.6 137.0 137.1 137.2 137.2 137.5 137.7 137.9 138.1 138.3 138.7
## 1995 139.0 138.9 139.1 139.5 139.9 140.1 140.2 140.7 141.0 141.3 141.8 142.0
## 1996 142.2 142.8 143.0 143.3 143.7 143.8 143.8 143.7 143.7 143.9 144.1 144.3
## 1997 144.6 144.7 144.8 144.9 144.8 145.1 145.5 145.7 145.8 146.1 146.3 146.3
## 1998 146.6 146.9 147.3 147.7 147.9 148.3 148.5 148.6 148.9 149.0 149.2 149.7
## 1999 149.9 150.2 150.5 150.8 151.2 151.9 152.4 152.9 153.5 153.8 154.1 154.4
## 2000 154.8 155.3 155.7 156.0 156.2 156.2 156.2 156.1 155.9 156.0 156.1 156.1
## 2001 156.0 155.9 155.7 155.4 155.2 154.7 154.4 154.5 154.6 154.8 155.1 155.4
## 2002 155.6 155.7 156.0 156.2 156.5 157.2 157.6 157.7 157.7 157.6 157.4 157.2
## 2003 157.1 157.2 157.4 157.6 157.8 157.8 158.0 158.7 159.5 160.0 160.5 161.0
## 2004 161.5 161.8 162.1 162.5 163.0 163.4 163.7 163.8 163.8 164.0 164.3 164.6
## 2005 164.8 165.2 165.4 165.4 165.5 165.7 166.1 166.3 166.5 166.8 166.9 167.1
## 2006 167.4 167.7 168.0 168.3 168.4 168.4 168.5 168.6 168.7 168.7 169.0 169.3

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## 2007 169.5 169.7 169.8 169.9 170.1 170.1 169.7 169.3 168.8 168.4 167.9 167.1
## 2008 166.1 165.0 163.7 162.6 161.7 160.7 160.1 159.4 158.8 158.2 157.5 156.8
## 2009 156.4 156.0 155.9 155.7 155.4 155.3 155.1 154.8 154.7 154.8 155.1 155.4
## 2010 155.7 156.0 156.4 156.8 157.0 157.2 157.2 157.3 157.4 157.2 156.9 156.7
## 2011 156.5 156.1 155.8 155.4 155.0 154.7 154.3 154.1 154.0 153.7 153.5 153.3
## 2012 153.0 152.9 152.6 152.3 152.1 151.7 151.4 151.1 150.8 150.8 150.7 150.5
## 2013 NA NA NA NA NA NA
##
## $random
## Jan Feb Mar Apr May Jun Jul Aug Sep Oct
## 1973 NA NA NA NA NA NA 0.9952 1.0292 1.0089 1.0120
## 1974 0.9655 0.9628 0.9623 0.9796 1.0120 1.0085 1.0147 1.0156 0.9833 1.0102
## 1975 1.0345 0.9769 0.9848 1.0003 0.9972 1.0013 0.9974 0.9842 1.0035 1.0029
## 1976 1.0098 0.9977 1.0135 1.0201 0.9762 1.0106 1.0061 0.9670 1.0111 0.9741
## 1977 0.9936 1.0270 0.9986 1.0085 0.9644 1.0110 0.9792 0.9939 1.0157 0.9793
## 1978 0.9937 1.0141 1.0203 0.9884 1.0232 1.0093 0.9730 1.0018 0.9803 0.9794
## 1979 1.0270 1.0606 1.0554 0.9713 0.9969 0.9767 0.9471 0.9872 0.9912 1.0103
## 1980 1.0263 1.0667 1.0033 1.0242 0.9867 0.9636 0.9733 0.9390 1.0050 1.0127
## 1981 1.0718 1.0126 0.9911 0.9877 0.9776 1.0099 1.0037 0.9755 1.0174 0.9808
## 1982 0.9934 1.0149 1.0034 1.0426 0.9905 1.0000 0.9870 0.9691 1.0070 0.9752
## 1983 0.9794 0.9505 1.0429 0.9789 0.9982 1.0235 0.9830 0.9935 1.0215 0.9817
## 1984 1.0151 0.9857 0.9896 0.9998 1.0127 1.0085 0.9962 1.0106 0.9936 0.9920
## 1985 1.0169 0.9905 0.9967 1.0240 1.0219 0.9883 0.9979 1.0161 0.9760 0.9993
## 1986 0.9973 0.9670 1.0052 1.0138 1.0083 0.9977 1.0195 1.0094 0.9798 1.0024
## 1987 0.9931 0.9974 0.9822 1.0091 1.0029 1.0056 1.0193 0.9756 1.0049 0.9981
## 1988 1.0097 1.0538 1.0301 1.0092 0.9767 1.0084 0.9713 0.9798 1.0084 0.9996
## 1989 1.0012 1.0003 1.0210 0.9789 0.9894 1.0154 0.9704 0.9992 0.9791 1.0112
## 1990 1.0134 1.0162 1.0046 0.9741 1.0036 0.9846 0.9879 1.0408 0.9743 1.0044
## 1991 1.0049 0.9839 1.0001 0.9801 0.9851 1.0043 1.0048 1.0060 0.9952 1.0093
## 1992 1.0101 1.0303 0.9942 0.9962 0.9988 0.9792 1.0004 0.9885 0.9943 1.0144
## 1993 0.9688 1.0002 1.0083 1.0011 1.0039 0.9841 0.9910 0.9800 1.0173 0.9929
## 1994 0.9869 1.0126 0.9889 1.0008 0.9940 0.9953 0.9860 1.0209 1.0007 0.9915
## 1995 0.9999 0.9959 1.0153 0.9805 0.9975 1.0212 0.9690 0.9942 1.0179 0.9955
## 1996 1.0037 1.0249 0.9928 0.9959 1.0103 0.9833 1.0003 1.0165 0.9853 1.0345
## 1997 0.9896 0.9950 0.9886 1.0165 1.0115 0.9933 1.0210 0.9858 0.9990 1.0023
## 1998 1.0079 0.9796 0.9858 1.0343 0.9810 0.9912 1.0234 0.9935 1.0114 1.0097
## 1999 0.9859 0.9779 0.9986 0.9959 1.0028 1.0003 1.0035 1.0005 0.9929 1.0122
## 2000 0.9646 1.0279 0.9830 0.9846 0.9946 0.9990 1.0126 1.0124 1.0079 1.0146
## 2001 0.9857 0.9779 0.9935 0.9934 1.0104 0.9926 1.0328 1.0059 0.9923 1.0053
## 2002 1.0003 0.9855 1.0026 1.0103 1.0171 1.0083 1.0114 1.0086 0.9953 0.9933
## 2003 0.9852 0.9855 0.9883 0.9903 0.9945 0.9886 1.0052 1.0204 0.9983 1.0012
## 2004 0.9939 1.0340 0.9998 1.0003 0.9952 0.9936 1.0070 0.9948 1.0059 1.0084
## 2005 1.0001 0.9941 0.9976 0.9961 1.0133 0.9917 1.0098 1.0083 0.9944 0.9881
## 2006 1.0146 0.9849 1.0022 0.9943 1.0003 0.9974 1.0185 1.0125 1.0005 0.9995
## 2007 1.0036 0.9907 0.9868 0.9959 1.0139 1.0053 1.0225 1.0197 1.0125 1.0026
## 2008 0.9882 0.9874 0.9896 1.0072 1.0218 0.9950 1.0114 0.9977 0.9658 1.0115
## 2009 1.0104 0.9799 1.0006 1.0081 0.9897 1.0062 1.0044 1.0072 0.9973 1.0003
## 2010 0.9902 0.9649 0.9959 1.0124 1.0100 1.0084 1.0209 1.0088 1.0310 0.9984
## 2011 0.9911 0.9760 0.9980 0.9967 1.0028 1.0198 1.0080 1.0070 1.0205 0.9917
## 2012 0.9716 1.0153 0.9834 0.9974 1.0119 1.0179 1.0127 1.0223 1.0021 0.9961
## 2013 NA NA NA NA NA NA
## Nov Dec

```

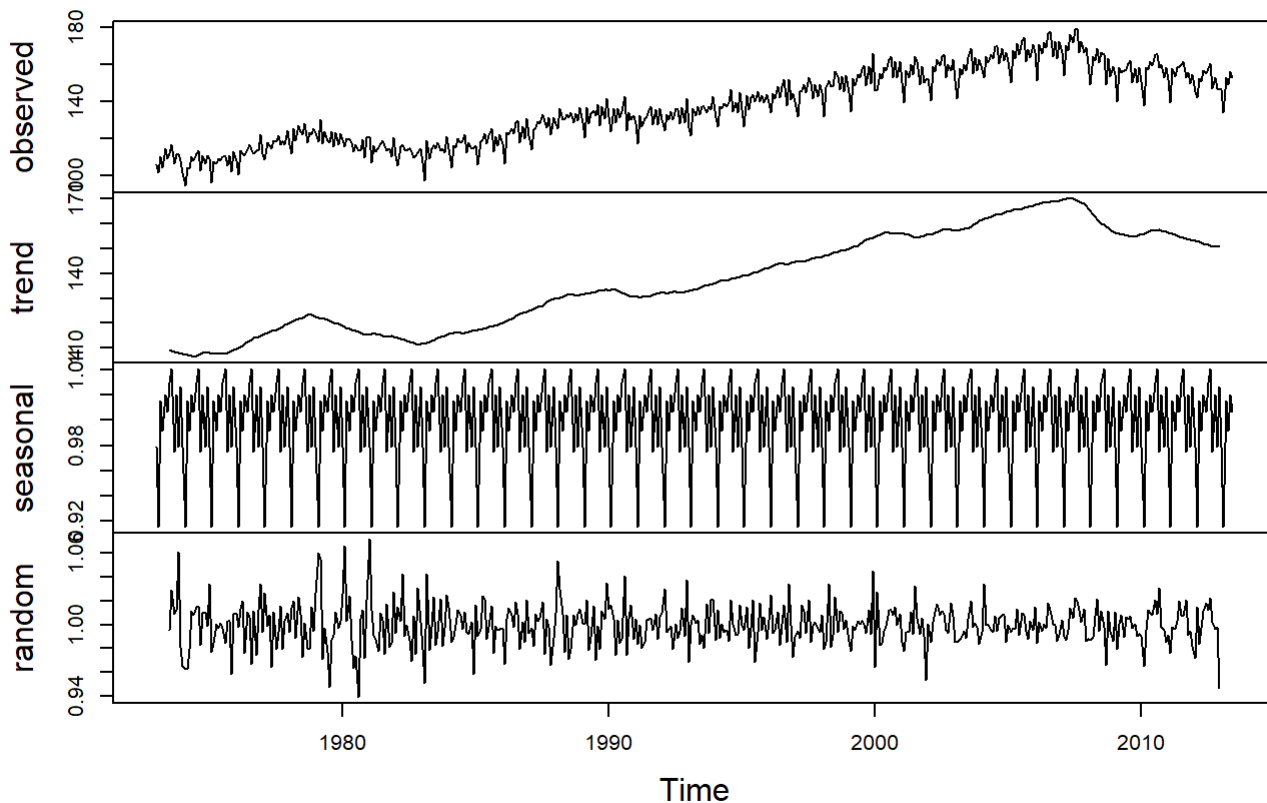
```
## 1973 1.0613 0.9815
## 1974 1.0106 0.9990
## 1975 0.9588 1.0092
## 1976 1.0122 1.0344
## 1977 1.0030 1.0102
## 1978 1.0148 0.9947
## 1979 0.9974 1.0032
## 1980 0.9723 1.0209
## 1981 0.9846 1.0272
## 1982 1.0308 1.0019
## 1983 0.9974 1.0253
## 1984 1.0022 0.9586
## 1985 0.9955 0.9965
## 1986 0.9856 1.0207
## 1987 0.9660 0.9887
## 1988 1.0093 1.0130
## 1989 1.0050 1.0348
## 1990 1.0164 0.9880
## 1991 0.9882 1.0065
## 1992 0.9901 1.0376
## 1993 1.0210 1.0218
## 1994 0.9918 1.0164
## 1995 1.0068 0.9879
## 1996 0.9999 0.9729
## 1997 0.9976 0.9939
## 1998 0.9965 1.0040
## 1999 0.9924 1.0451
## 2000 0.9999 1.0092
## 2001 0.9903 0.9532
## 2002 1.0186 1.0072
## 2003 0.9978 0.9838
## 2004 1.0078 0.9856
## 2005 1.0032 0.9957
## 2006 0.9862 0.9914
## 2007 1.0132 0.9867
## 2008 0.9945 0.9861
## 2009 0.9909 0.9925
## 2010 0.9957 0.9853
## 2011 0.9950 0.9817
## 2012 0.9981 0.9469
## 2013
##
## $figure
## [1] 0.9790 0.9153 1.0153 0.9916 1.0203 1.0065 1.0299 1.0409 0.9745 1.0206
## [11] 0.9792 1.0270
##
## $type
## [1] "multiplicative"
```

On the seasonal part in January for all years, CO2 emissions will be 97% of your annual trend (and 3% less) and etc. In August, CO2 emissions will be about 4% more, in December, 2.7% more.

On the random part: January, 1974, CO2 emissions was about 4% left than where it should be after accounting for trend and seasonality. August, 1974; CO2 emissions was about 1.5% more than the trend and seasonality forecast.

```
plot(data_decompose)
```

Decomposition of multiplicative time series



the trend is increasing though there is a flattening in 1981, 2001, 1991 and slightly down in 2012.

The seasonal part is repeating.

On random: My unpredictable error is about 6% (0.94). In the future, i don't know what the number will be, but my best guess is in the middle (1).

Splitting data into training and test sets and test the last 2 years

```
data_train <- window(data_ts, start=c(1973,1),end=c(2011,12), freq=12)
head(data_train)
```

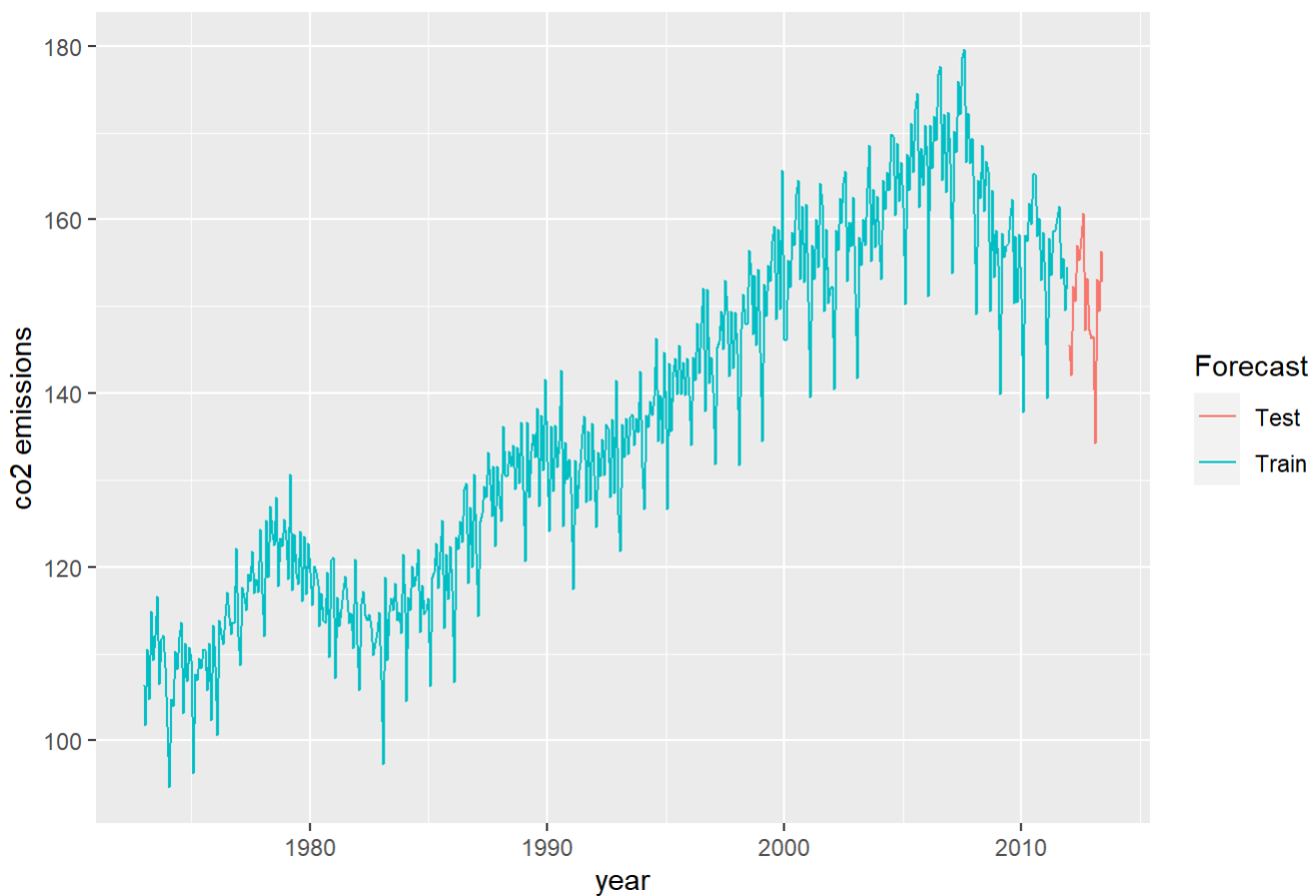
```
##          Jan   Feb   Mar   Apr   May   Jun
## 1973 106.4 101.8 110.6 104.7 114.9 109.2
```

```
data_test <- window(data_ts, start=c(2012,1), freq=12)
head(data_test)
```

```
##          Jan   Feb   Mar   Apr   May   Jun
## 2012 145.6 142.1 152.4 150.6 157.0 155.4
```

```
autoplot(data_train, series = "Train") + autolayer(data_test, series = "Test") + ggtitle("Total
  energy transportation sector co2 emissions train and test set") + xlab("year") + ylab("co2 emissi
  ons")+guides(colour=guide_legend(title = "Forecast"))
```

Total energy transportation sector co2 emissions train and test set



Data Forecast using Seasonal Naive Method

```
data_naive <- snaive(data_ts, level = c(95), h = 12*12)
head(data_naive)
```

```
## $method
## [1] "Seasonal naive method"
##
## $model
## Call: snaive(y = data_ts, h = 12 * 12, level = c(95))
##
## Residual sd: 4.5712
##
## $lambda
## NULL
##
## $x
##      Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct
## 1973 106.36 101.76 110.55 104.73 114.90 109.24 112.14 116.68 106.56 111.66
## 1974 101.70  94.70 104.72 103.96 110.26 108.27 111.90 113.59 103.15 111.24
## 1975 109.28  96.31 107.67 106.92 109.49 108.37 110.53 110.38 105.81 111.23
## 1976 108.55 100.67 113.87 112.31 111.17 114.37 117.05 114.18 112.27 113.61
## 1977 112.07 108.66 117.71 116.51 114.99 119.16 118.41 121.82 117.01 118.56
## 1978 117.02 112.04 125.33 118.81 126.99 123.86 122.47 127.99 117.73 123.35
## 1979 123.17 118.58 130.63 117.36 123.73 119.24 118.05 124.07 116.09 123.56
## 1980 119.45 115.62 120.08 119.44 117.93 113.24 117.03 113.83 113.57 119.43
## 1981 121.17 107.20 116.47 113.18 115.11 117.35 118.90 116.31 113.49 114.72
## 1982 111.09 105.83 115.76 117.17 114.47 113.82 114.52 113.12 109.83 111.20
## 1983 107.06  97.34 118.86 109.28 114.81 116.41 115.01 118.12 113.91 114.79
## 1984 114.81 104.54 116.51 115.04 120.14 117.84 118.90 122.06 112.52 117.92
## 1985 116.44 106.28 118.77 119.34 122.78 117.50 121.75 125.36 112.94 121.42
## 1986 117.28 106.74 123.48 122.08 125.32 122.83 129.00 129.59 118.16 126.85
## 1987 121.64 114.37 125.25 126.19 129.34 128.08 133.17 129.56 125.85 131.55
## 1988 128.30 125.31 136.19 130.54 130.40 133.33 131.66 134.05 129.00 133.83
## 1989 128.92 120.63 136.68 128.05 133.39 135.31 132.66 138.34 127.05 137.42
## 1990 132.13 124.11 136.18 128.73 136.30 131.49 134.46 142.69 124.65 134.33
## 1991 128.47 117.44 132.30 126.80 131.10 131.91 135.30 137.31 127.51 135.62
## 1992 130.57 124.53 133.24 130.47 134.71 130.52 136.46 135.96 128.07 137.06
## 1993 126.06 121.78 136.49 132.60 137.13 132.95 137.27 137.63 134.00 137.17
## 1994 131.53 126.60 137.52 136.05 139.11 137.44 139.61 146.29 134.50 139.79
## 1995 136.02 126.67 143.43 135.65 142.40 144.02 139.95 145.59 139.90 143.57
## 1996 139.74 133.99 144.15 141.49 148.12 142.27 148.11 152.04 137.94 151.93
## 1997 140.13 131.82 145.34 146.01 149.48 145.10 153.02 149.52 141.95 149.47
## 1998 144.66 131.74 147.41 151.44 148.09 147.92 156.50 153.66 146.78 153.59
## 1999 144.71 134.45 152.61 148.93 154.71 152.88 157.50 159.27 148.57 158.88
## 2000 146.20 146.09 155.35 152.26 158.52 157.02 162.88 164.48 153.13 161.53
## 2001 150.55 139.58 157.03 153.09 160.00 154.54 164.19 161.74 149.50 158.85
## 2002 152.35 140.49 158.83 156.50 162.44 159.59 164.21 165.52 152.95 159.75
## 2003 151.49 141.78 157.91 154.79 160.10 157.00 163.59 168.58 155.15 163.51
## 2004 157.16 153.16 164.53 161.22 165.49 163.38 169.78 169.56 160.53 168.76
## 2005 161.37 150.28 167.52 163.38 171.07 165.42 172.75 174.58 161.38 168.18
## 2006 166.28 151.19 170.91 165.90 171.87 169.08 176.75 177.70 164.50 172.14
## 2007 166.54 153.85 170.15 167.81 175.93 172.10 178.72 179.66 166.60 172.30
## 2008 160.71 149.15 164.51 162.43 168.61 160.98 166.71 165.54 149.45 163.37
## 2009 154.71 139.94 158.40 155.67 156.92 157.24 160.42 162.31 150.39 158.03
## 2010 150.90 137.77 158.17 157.46 161.83 159.50 165.28 165.18 158.13 160.18
## 2011 151.85 139.49 157.84 153.55 158.64 158.83 160.19 161.57 153.19 155.55
```

```

## 2012 145.57 142.10 152.38 150.60 157.03 155.37 157.85 160.75 147.24 153.26
## 2013 146.52 134.24 153.08 149.44 156.36 152.81
##           Nov      Dec
## 1973 112.11 108.50
## 1974 106.85 110.75
## 1975 102.31 113.27
## 1976 113.58 122.12
## 1977 117.09 124.40
## 1978 122.42 125.52
## 1979 116.88 122.79
## 1980 109.65 120.81
## 1981 110.62 120.85
## 1982 112.45 114.75
## 1983 112.35 121.43
## 1984 114.59 115.04
## 1985 116.27 122.39
## 1986 119.99 130.72
## 1987 122.37 131.62
## 1988 129.66 136.71
## 1989 131.18 141.62
## 1990 130.12 132.45
## 1991 127.70 136.50
## 1992 128.53 141.49
## 1993 135.55 142.56
## 1994 134.28 144.75
## 1995 139.77 144.02
## 1996 141.13 144.19
## 1997 142.89 149.37
## 1998 145.58 154.34
## 1999 149.73 165.73
## 2000 152.83 161.74
## 2001 150.34 152.10
## 2002 156.98 162.61
## 2003 156.84 162.67
## 2004 162.13 166.62
## 2005 163.95 170.87
## 2006 163.19 172.37
## 2007 166.54 169.31
## 2008 153.35 158.83
## 2009 150.46 158.36
## 2010 152.97 158.60
## 2011 149.54 154.53
## 2012 147.26 146.39
## 2013
##
## $fitted
##           Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct
## 1973         NA         NA         NA         NA         NA         NA         NA         NA         NA         NA
## 1974 106.36 101.76 110.55 104.73 114.90 109.24 112.14 116.68 106.56 111.66
## 1975 101.70  94.70 104.72 103.96 110.26 108.27 111.90 113.59 103.15 111.24
## 1976 109.28  96.31 107.67 106.92 109.49 108.37 110.53 110.38 105.81 111.23
## 1977 108.55 100.67 113.87 112.31 111.17 114.37 117.05 114.18 112.27 113.61

```



```

## 1978 112.07 108.66 117.71 116.51 114.99 119.16 118.41 121.82 117.01 118.56
## 1979 117.02 112.04 125.33 118.81 126.99 123.86 122.47 127.99 117.73 123.35
## 1980 123.17 118.58 130.63 117.36 123.73 119.24 118.05 124.07 116.09 123.56
## 1981 119.45 115.62 120.08 119.44 117.93 113.24 117.03 113.83 113.57 119.43
## 1982 121.17 107.20 116.47 113.18 115.11 117.35 118.90 116.31 113.49 114.72
## 1983 111.09 105.83 115.76 117.17 114.47 113.82 114.52 113.12 109.83 111.20
## 1984 107.06 97.34 118.86 109.28 114.81 116.41 115.01 118.12 113.91 114.79
## 1985 114.81 104.54 116.51 115.04 120.14 117.84 118.90 122.06 112.52 117.92
## 1986 116.44 106.28 118.77 119.34 122.78 117.50 121.75 125.36 112.94 121.42
## 1987 117.28 106.74 123.48 122.08 125.32 122.83 129.00 129.59 118.16 126.85
## 1988 121.64 114.37 125.25 126.19 129.34 128.08 133.17 129.56 125.85 131.55
## 1989 128.30 125.31 136.19 130.54 130.40 133.33 131.66 134.05 129.00 133.83
## 1990 128.92 120.63 136.68 128.05 133.39 135.31 132.66 138.34 127.05 137.42
## 1991 132.13 124.11 136.18 128.73 136.30 131.49 134.46 142.69 124.65 134.33
## 1992 128.47 117.44 132.30 126.80 131.10 131.91 135.30 137.31 127.51 135.62
## 1993 130.57 124.53 133.24 130.47 134.71 130.52 136.46 135.96 128.07 137.06
## 1994 126.06 121.78 136.49 132.60 137.13 132.95 137.27 137.63 134.00 137.17
## 1995 131.53 126.60 137.52 136.05 139.11 137.44 139.61 146.29 134.50 139.79
## 1996 136.02 126.67 143.43 135.65 142.40 144.02 139.95 145.59 139.90 143.57
## 1997 139.74 133.99 144.15 141.49 148.12 142.27 148.11 152.04 137.94 151.93
## 1998 140.13 131.82 145.34 146.01 149.48 145.10 153.02 149.52 141.95 149.47
## 1999 144.66 131.74 147.41 151.44 148.09 147.92 156.50 153.66 146.78 153.59
## 2000 144.71 134.45 152.61 148.93 154.71 152.88 157.50 159.27 148.57 158.88
## 2001 146.20 146.09 155.35 152.26 158.52 157.02 162.88 164.48 153.13 161.53
## 2002 150.55 139.58 157.03 153.09 160.00 154.54 164.19 161.74 149.50 158.85
## 2003 152.35 140.49 158.83 156.50 162.44 159.59 164.21 165.52 152.95 159.75
## 2004 151.49 141.78 157.91 154.79 160.10 157.00 163.59 168.58 155.15 163.51
## 2005 157.16 153.16 164.53 161.22 165.49 163.38 169.78 169.56 160.53 168.76
## 2006 161.37 150.28 167.52 163.38 171.07 165.42 172.75 174.58 161.38 168.18
## 2007 166.28 151.19 170.91 165.90 171.87 169.08 176.75 177.70 164.50 172.14
## 2008 166.54 153.85 170.15 167.81 175.93 172.10 178.72 179.66 166.60 172.30
## 2009 160.71 149.15 164.51 162.43 168.61 160.98 166.71 165.54 149.45 163.37
## 2010 154.71 139.94 158.40 155.67 156.92 157.24 160.42 162.31 150.39 158.03
## 2011 150.90 137.77 158.17 157.46 161.83 159.50 165.28 165.18 158.13 160.18
## 2012 151.85 139.49 157.84 153.55 158.64 158.83 160.19 161.57 153.19 155.55
## 2013 145.57 142.10 152.38 150.60 157.03 155.37
##      Nov      Dec
## 1973      NA      NA
## 1974 112.11 108.50
## 1975 106.85 110.75
## 1976 102.31 113.27
## 1977 113.58 122.12
## 1978 117.09 124.40
## 1979 122.42 125.52
## 1980 116.88 122.79
## 1981 109.65 120.81
## 1982 110.62 120.85
## 1983 112.45 114.75
## 1984 112.35 121.43
## 1985 114.59 115.04
## 1986 116.27 122.39
## 1987 119.99 130.72

```

```

## 1988 122.37 131.62
## 1989 129.66 136.71
## 1990 131.18 141.62
## 1991 130.12 132.45
## 1992 127.70 136.50
## 1993 128.53 141.49
## 1994 135.55 142.56
## 1995 134.28 144.75
## 1996 139.77 144.02
## 1997 141.13 144.19
## 1998 142.89 149.37
## 1999 145.58 154.34
## 2000 149.73 165.73
## 2001 152.83 161.74
## 2002 150.34 152.10
## 2003 156.98 162.61
## 2004 156.84 162.67
## 2005 162.13 166.62
## 2006 163.95 170.87
## 2007 163.19 172.37
## 2008 166.54 169.31
## 2009 153.35 158.83
## 2010 150.46 158.36
## 2011 152.97 158.60
## 2012 149.54 154.53
## 2013
##

```

```
## $residuals
```

##	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
## 1973	NA	NA	NA	NA	NA	NA	NA	NA	NA
## 1974	-4.661	-7.061	-5.831	-0.771	-4.635	-0.969	-0.243	-3.093	-3.404
## 1975	7.576	1.612	2.946	2.958	-0.771	0.095	-1.368	-3.208	2.651
## 1976	-0.727	4.363	6.203	5.388	1.674	6.008	6.523	3.797	6.462
## 1977	3.521	7.987	3.843	4.199	3.821	4.786	1.354	7.642	4.747
## 1978	4.943	3.381	7.618	2.302	12.006	4.695	4.070	6.167	0.717
## 1979	6.152	6.538	5.298	-1.450	-3.265	-4.618	-4.422	-3.918	-1.637
## 1980	-3.716	-2.960	-10.547	2.080	-5.798	-6.001	-1.027	-10.242	-2.520
## 1981	1.719	-8.421	-3.610	-6.262	-2.822	4.112	1.877	2.487	-0.087
## 1982	-10.075	-1.367	-0.717	3.988	-0.640	-3.529	-4.382	-3.192	-3.653
## 1983	-4.039	-8.490	3.107	-7.885	0.339	2.593	0.485	4.997	4.077
## 1984	7.759	7.200	-2.349	5.761	5.333	1.433	3.896	3.941	-1.393
## 1985	1.622	1.734	2.254	4.301	2.637	-0.340	2.852	3.297	0.419
## 1986	0.848	0.467	4.714	2.736	2.546	5.327	7.244	4.235	5.224
## 1987	4.350	7.630	1.764	4.106	4.022	5.251	4.175	-0.028	7.693
## 1988	6.661	10.937	10.943	4.352	1.054	5.247	-1.517	4.483	3.141
## 1989	0.622	-4.684	0.487	-2.490	2.989	1.985	1.002	4.291	-1.950
## 1990	3.212	3.486	-0.496	0.687	2.914	-3.822	1.804	4.353	-2.395
## 1991	-3.655	-6.674	-3.877	-1.938	-5.205	0.413	0.839	-5.386	2.857
## 1992	2.100	7.089	0.941	3.678	3.615	-1.382	1.162	-1.342	0.565
## 1993	-4.518	-2.752	3.246	2.131	2.420	2.426	0.807	1.665	5.926
## 1994	5.473	4.823	1.027	3.446	1.977	4.490	2.338	8.662	0.499
## 1995	4.494	0.069	5.908	-0.397	3.294	6.576	0.338	-0.701	5.403

##	1996	3.719	7.322	0.721	5.833	5.714	-1.746	8.164	6.453	-1.958
##	1997	0.388	-2.164	1.191	4.519	1.366	2.829	4.912	-2.520	4.010
##	1998	4.527	-0.083	2.073	5.439	-1.395	2.817	3.476	4.132	4.830
##	1999	0.049	2.705	5.197	-2.519	6.621	4.969	1.000	5.619	1.784
##	2000	1.494	11.638	2.747	3.337	3.812	4.138	5.381	5.210	4.563
##	2001	4.346	-6.506	1.671	0.828	1.485	-2.481	1.314	-2.749	-3.629
##	2002	1.801	0.908	1.806	3.406	2.436	5.047	0.012	3.787	3.446
##	2003	-0.862	1.290	-0.918	-1.710	-2.345	-2.592	-0.613	3.059	2.207
##	2004	5.678	11.386	6.620	6.434	5.390	6.381	6.188	0.974	5.382
##	2005	4.208	-2.880	2.990	2.155	5.584	2.041	2.966	5.022	0.845
##	2006	4.906	0.905	3.385	2.522	0.800	3.663	4.002	3.120	3.116
##	2007	0.261	2.661	-0.758	1.909	4.063	3.021	1.968	1.962	2.107
##	2008	-5.831	-4.696	-5.639	-5.378	-7.325	-11.123	-12.005	-14.115	-17.153
##	2009	-5.994	-9.216	-6.110	-6.755	-11.688	-3.739	-6.293	-3.233	0.939
##	2010	-3.810	-2.165	-0.228	1.781	4.913	2.262	4.861	2.870	7.737
##	2011	0.947	1.716	-0.336	-3.901	-3.191	-0.675	-5.093	-3.606	-4.934
##	2012	-6.285	2.610	-5.457	-2.952	-1.609	-3.456	-2.331	-0.826	-5.951
##	2013	0.951	-7.855	0.698	-1.160	-0.677	-2.558			
##		Oct	Nov	Dec						
##	1973	NA	NA	NA						
##	1974	-0.417	-5.259	2.247						
##	1975	-0.005	-4.544	2.520						
##	1976	2.375	11.276	8.845						
##	1977	4.954	3.503	2.286						
##	1978	4.791	5.337	1.115						
##	1979	0.206	-5.541	-2.728						
##	1980	-4.126	-7.237	-1.985						
##	1981	-4.715	0.975	0.048						
##	1982	-3.521	1.829	-6.103						
##	1983	3.596	-0.101	6.678						
##	1984	3.127	2.239	-6.384						
##	1985	3.501	1.678	7.350						
##	1986	5.430	3.722	8.330						
##	1987	4.700	2.380	0.895						
##	1988	2.277	7.296	5.091						
##	1989	3.592	1.513	4.913						
##	1990	-3.091	-1.059	-9.171						
##	1991	1.292	-2.421	4.048						
##	1992	1.441	0.832	4.989						
##	1993	0.105	7.019	1.071						
##	1994	2.624	-1.267	2.188						
##	1995	3.782	5.490	-0.731						
##	1996	8.356	1.359	0.171						
##	1997	-2.460	1.762	5.180						
##	1998	4.116	2.689	4.975						
##	1999	5.291	4.152	11.390						
##	2000	2.658	3.100	-3.993						
##	2001	-2.688	-2.488	-9.644						
##	2002	0.899	6.639	10.512						
##	2003	3.770	-0.147	0.058						
##	2004	5.245	5.290	3.953						
##	2005	-0.576	1.821	4.250						

```
## 2006    3.955   -0.760    1.499
## 2007    0.161    3.352   -3.057
## 2008   -8.927  -13.194  -10.484
## 2009   -5.342   -2.888   -0.466
## 2010    2.152    2.510    0.235
## 2011   -4.633   -3.432   -4.065
## 2012   -2.285   -2.271   -8.141
## 2013
```

```
print(summary(data_naive))
```

```
##
## Forecast method: Seasonal naive method
##
## Model Information:
## Call: snaive(y = data_ts, h = 12 * 12, level = c(95))
##
## Residual sd: 4.5712
##
## Error measures:
##           ME  RMSE   MAE    MPE  MAPE  MASE   ACF1
## Training set 1.034 4.571 3.715 0.7425 2.755    1 0.5329
##
## Forecasts:
##           Point Forecast Lo 95 Hi 95
## Jul 2013           157.9 148.9 166.8
## Aug 2013           160.7 151.8 169.7
## Sep 2013           147.2 138.3 156.2
## Oct 2013           153.3 144.3 162.2
## Nov 2013           147.3 138.3 156.2
## Dec 2013           146.4 137.4 155.3
## Jan 2014           146.5 137.6 155.5
## Feb 2014           134.2 125.3 143.2
## Mar 2014           153.1 144.1 162.0
## Apr 2014           149.4 140.5 158.4
## May 2014           156.4 147.4 165.3
## Jun 2014           152.8 143.9 161.8
## Jul 2014           157.9 145.2 170.5
## Aug 2014           160.7 148.1 173.4
## Sep 2014           147.2 134.6 159.9
## Oct 2014           153.3 140.6 165.9
## Nov 2014           147.3 134.6 159.9
## Dec 2014           146.4 133.7 159.1
## Jan 2015           146.5 133.8 159.2
## Feb 2015           134.2 121.6 146.9
## Mar 2015           153.1 140.4 165.7
## Apr 2015           149.4 136.8 162.1
## May 2015           156.4 143.7 169.0
## Jun 2015           152.8 140.1 165.5
## Jul 2015           157.9 142.3 173.4
## Aug 2015           160.7 145.2 176.3
## Sep 2015           147.2 131.7 162.8
## Oct 2015           153.3 137.7 168.8
## Nov 2015           147.3 131.7 162.8
## Dec 2015           146.4 130.9 161.9
## Jan 2016           146.5 131.0 162.0
## Feb 2016           134.2 118.7 149.8
## Mar 2016           153.1 137.6 168.6
## Apr 2016           149.4 133.9 165.0
## May 2016           156.4 140.8 171.9
## Jun 2016           152.8 137.3 168.3
## Jul 2016           157.9 139.9 175.8
## Aug 2016           160.7 142.8 178.7
```

## Sep 2016	147.2	129.3	165.2
## Oct 2016	153.3	135.3	171.2
## Nov 2016	147.3	129.3	165.2
## Dec 2016	146.4	128.5	164.3
## Jan 2017	146.5	128.6	164.4
## Feb 2017	134.2	116.3	152.2
## Mar 2017	153.1	135.2	171.0
## Apr 2017	149.4	131.5	167.4
## May 2017	156.4	138.4	174.3
## Jun 2017	152.8	134.9	170.7
## Jul 2017	157.9	137.8	177.9
## Aug 2017	160.7	140.7	180.8
## Sep 2017	147.2	127.2	167.3
## Oct 2017	153.3	133.2	173.3
## Nov 2017	147.3	127.2	167.3
## Dec 2017	146.4	126.4	166.4
## Jan 2018	146.5	126.5	166.6
## Feb 2018	134.2	114.2	154.3
## Mar 2018	153.1	133.0	173.1
## Apr 2018	149.4	129.4	169.5
## May 2018	156.4	136.3	176.4
## Jun 2018	152.8	132.8	172.8
## Jul 2018	157.9	135.9	179.8
## Aug 2018	160.7	138.8	182.7
## Sep 2018	147.2	125.3	169.2
## Oct 2018	153.3	131.3	175.2
## Nov 2018	147.3	125.3	169.2
## Dec 2018	146.4	124.4	168.3
## Jan 2019	146.5	124.6	168.5
## Feb 2019	134.2	112.3	156.2
## Mar 2019	153.1	131.1	175.0
## Apr 2019	149.4	127.5	171.4
## May 2019	156.4	134.4	178.3
## Jun 2019	152.8	130.9	174.8
## Jul 2019	157.9	134.2	181.6
## Aug 2019	160.7	137.0	184.5
## Sep 2019	147.2	123.5	170.9
## Oct 2019	153.3	129.6	177.0
## Nov 2019	147.3	123.6	171.0
## Dec 2019	146.4	122.7	170.1
## Jan 2020	146.5	122.8	170.2
## Feb 2020	134.2	110.5	157.9
## Mar 2020	153.1	129.4	176.8
## Apr 2020	149.4	125.7	173.1
## May 2020	156.4	132.7	180.1
## Jun 2020	152.8	129.1	176.5
## Jul 2020	157.9	132.5	183.2
## Aug 2020	160.7	135.4	186.1
## Sep 2020	147.2	121.9	172.6
## Oct 2020	153.3	127.9	178.6
## Nov 2020	147.3	121.9	172.6
## Dec 2020	146.4	121.0	171.7

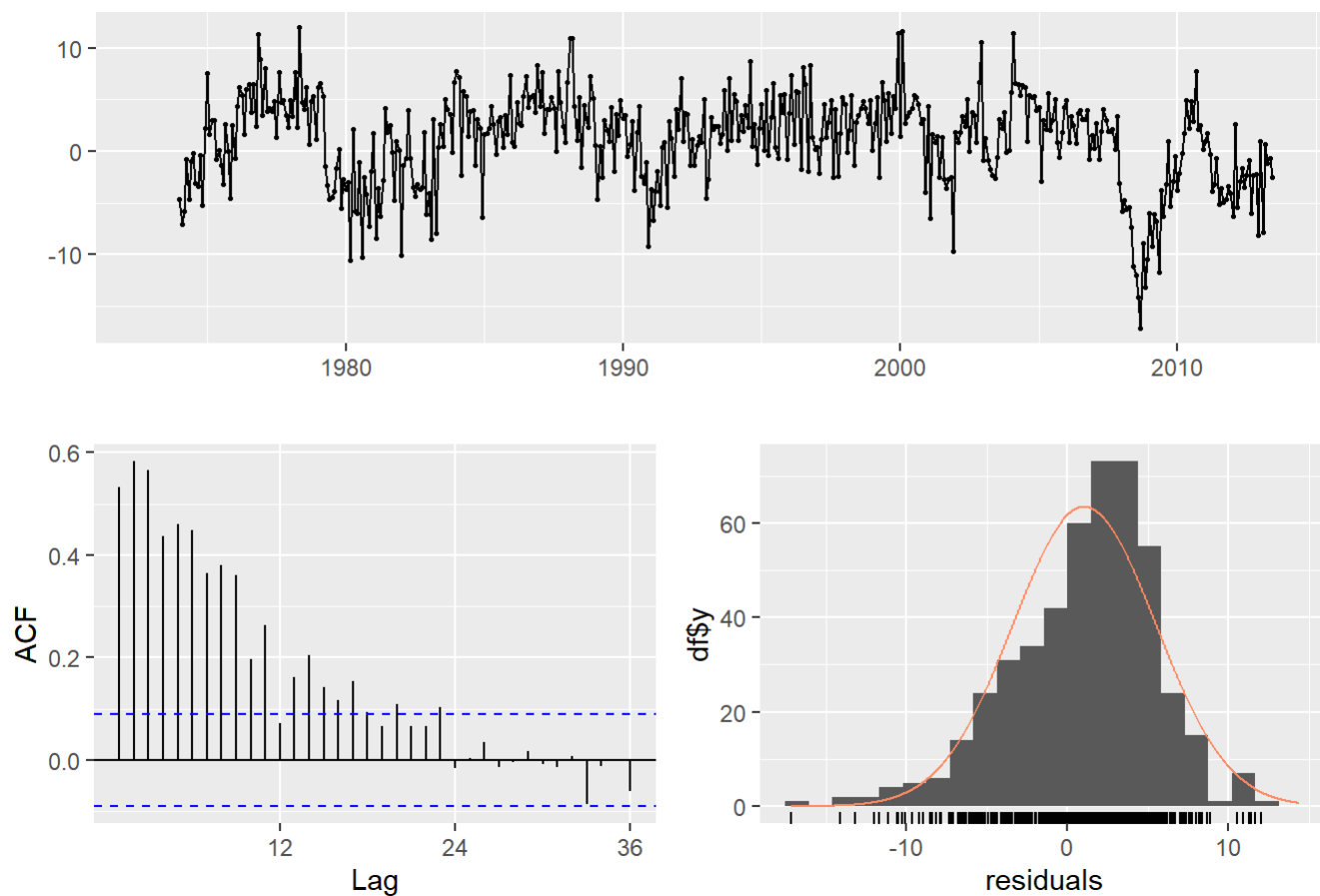
## Jan 2021	146.5	121.2	171.9
## Feb 2021	134.2	108.9	159.6
## Mar 2021	153.1	127.7	178.4
## Apr 2021	149.4	124.1	174.8
## May 2021	156.4	131.0	181.7
## Jun 2021	152.8	127.5	178.2
## Jul 2021	157.9	131.0	184.7
## Aug 2021	160.7	133.9	187.6
## Sep 2021	147.2	120.4	174.1
## Oct 2021	153.3	126.4	180.1
## Nov 2021	147.3	120.4	174.1
## Dec 2021	146.4	119.5	173.3
## Jan 2022	146.5	119.6	173.4
## Feb 2022	134.2	107.4	161.1
## Mar 2022	153.1	126.2	180.0
## Apr 2022	149.4	122.6	176.3
## May 2022	156.4	129.5	183.2
## Jun 2022	152.8	125.9	179.7
## Jul 2022	157.9	129.5	186.2
## Aug 2022	160.7	132.4	189.1
## Sep 2022	147.2	118.9	175.6
## Oct 2022	153.3	124.9	181.6
## Nov 2022	147.3	118.9	175.6
## Dec 2022	146.4	118.1	174.7
## Jan 2023	146.5	118.2	174.8
## Feb 2023	134.2	105.9	162.6
## Mar 2023	153.1	124.7	181.4
## Apr 2023	149.4	121.1	177.8
## May 2023	156.4	128.0	184.7
## Jun 2023	152.8	124.5	181.1
## Jul 2023	157.9	128.1	187.6
## Aug 2023	160.7	131.0	190.5
## Sep 2023	147.2	117.5	177.0
## Oct 2023	153.3	123.6	183.0
## Nov 2023	147.3	117.6	177.0
## Dec 2023	146.4	116.7	176.1
## Jan 2024	146.5	116.8	176.2
## Feb 2024	134.2	104.5	164.0
## Mar 2024	153.1	123.4	182.8
## Apr 2024	149.4	119.7	179.2
## May 2024	156.4	126.6	186.1
## Jun 2024	152.8	123.1	182.5
## Jul 2024	157.9	126.8	188.9
## Aug 2024	160.7	129.7	191.8
## Sep 2024	147.2	116.2	178.3
## Oct 2024	153.3	122.2	184.3
## Nov 2024	147.3	116.2	178.3
## Dec 2024	146.4	115.4	177.4
## Jan 2025	146.5	115.5	177.6
## Feb 2025	134.2	103.2	165.3
## Mar 2025	153.1	122.0	184.1
## Apr 2025	149.4	118.4	180.5

```
## May 2025      156.4 125.3 187.4
## Jun 2025      152.8 121.8 183.8
```

```
#Residual sd: 4.5712
```

```
checkresiduals(data_naive)
```

Residuals from Seasonal naive method



```
##
## Ljung-Box test
##
## data: Residuals from Seasonal naive method
## Q* = 1077, df = 24, p-value <0.0000000000000002
##
## Model df: 0. Total lags used: 24
```

Data forecasting methods using Holt's Winter

```
data_hw <- hw(data_ts, level = c(95), h=144) #seasonal = "multiplicative"
head(data_hw)
```



```
## $model
## Holt-Winters' additive method
##
## Call:
## hw(y = data_ts, h = 144, level = c(95))
##
## Smoothing parameters:
##   alpha = 0.3242
##   beta  = 0.0001
##   gamma = 0.1582
##
## Initial states:
##   l = 109.687
##   b = 0.0872
##   s = 4.606 -1.299 2.938 -3.192 4.564 3.103
##         0.2119 3.379 -2.103 0.618 -9.895 -2.932
##
## sigma: 2.858
##
## AIC AICc BIC
## 4045 4046 4116
##
## $mean
##      Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov   Dec
## 2013                157.3 158.6 147.1 153.6 147.1 152.4
## 2014 147.2 136.9 153.7 151.0 156.6 153.9 158.3 159.6 148.2 154.6 148.1 153.4
## 2015 148.2 137.9 154.7 152.0 157.6 155.0 159.4 160.6 149.2 155.7 149.2 154.5
## 2016 149.3 138.9 155.8 153.1 158.7 156.0 160.4 161.7 150.3 156.7 150.2 155.5
## 2017 150.3 140.0 156.8 154.1 159.7 157.0 161.4 162.7 151.3 157.7 151.3 156.6
## 2018 151.3 141.0 157.8 155.1 160.7 158.1 162.5 163.8 152.3 158.8 152.3 157.6
## 2019 152.4 142.1 158.9 156.2 161.8 159.1 163.5 164.8 153.4 159.8 153.3 158.6
## 2020 153.4 143.1 159.9 157.2 162.8 160.2 164.6 165.8 154.4 160.9 154.4 159.7
## 2021 154.5 144.1 161.0 158.3 163.9 161.2 165.6 166.9 155.4 161.9 155.4 160.7
## 2022 155.5 145.2 162.0 159.3 164.9 162.2 166.6 167.9 156.5 162.9 156.5 161.8
## 2023 156.5 146.2 163.0 160.3 165.9 163.3 167.7 169.0 157.5 164.0 157.5 162.8
## 2024 157.6 147.3 164.1 161.4 167.0 164.3 168.7 170.0 158.6 165.0 158.5 163.8
## 2025 158.6 148.3 165.1 162.4 168.0 165.3
##
## $level
## [1] 95
##
## $x
##      Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct
## 1973 106.36 101.76 110.55 104.73 114.90 109.24 112.14 116.68 106.56 111.66
## 1974 101.70  94.70 104.72 103.96 110.26 108.27 111.90 113.59 103.15 111.24
## 1975 109.28  96.31 107.67 106.92 109.49 108.37 110.53 110.38 105.81 111.23
## 1976 108.55 100.67 113.87 112.31 111.17 114.37 117.05 114.18 112.27 113.61
## 1977 112.07 108.66 117.71 116.51 114.99 119.16 118.41 121.82 117.01 118.56
## 1978 117.02 112.04 125.33 118.81 126.99 123.86 122.47 127.99 117.73 123.35
## 1979 123.17 118.58 130.63 117.36 123.73 119.24 118.05 124.07 116.09 123.56
## 1980 119.45 115.62 120.08 119.44 117.93 113.24 117.03 113.83 113.57 119.43
## 1981 121.17 107.20 116.47 113.18 115.11 117.35 118.90 116.31 113.49 114.72
```

```

## 1982 111.09 105.83 115.76 117.17 114.47 113.82 114.52 113.12 109.83 111.20
## 1983 107.06 97.34 118.86 109.28 114.81 116.41 115.01 118.12 113.91 114.79
## 1984 114.81 104.54 116.51 115.04 120.14 117.84 118.90 122.06 112.52 117.92
## 1985 116.44 106.28 118.77 119.34 122.78 117.50 121.75 125.36 112.94 121.42
## 1986 117.28 106.74 123.48 122.08 125.32 122.83 129.00 129.59 118.16 126.85
## 1987 121.64 114.37 125.25 126.19 129.34 128.08 133.17 129.56 125.85 131.55
## 1988 128.30 125.31 136.19 130.54 130.40 133.33 131.66 134.05 129.00 133.83
## 1989 128.92 120.63 136.68 128.05 133.39 135.31 132.66 138.34 127.05 137.42
## 1990 132.13 124.11 136.18 128.73 136.30 131.49 134.46 142.69 124.65 134.33
## 1991 128.47 117.44 132.30 126.80 131.10 131.91 135.30 137.31 127.51 135.62
## 1992 130.57 124.53 133.24 130.47 134.71 130.52 136.46 135.96 128.07 137.06
## 1993 126.06 121.78 136.49 132.60 137.13 132.95 137.27 137.63 134.00 137.17
## 1994 131.53 126.60 137.52 136.05 139.11 137.44 139.61 146.29 134.50 139.79
## 1995 136.02 126.67 143.43 135.65 142.40 144.02 139.95 145.59 139.90 143.57
## 1996 139.74 133.99 144.15 141.49 148.12 142.27 148.11 152.04 137.94 151.93
## 1997 140.13 131.82 145.34 146.01 149.48 145.10 153.02 149.52 141.95 149.47
## 1998 144.66 131.74 147.41 151.44 148.09 147.92 156.50 153.66 146.78 153.59
## 1999 144.71 134.45 152.61 148.93 154.71 152.88 157.50 159.27 148.57 158.88
## 2000 146.20 146.09 155.35 152.26 158.52 157.02 162.88 164.48 153.13 161.53
## 2001 150.55 139.58 157.03 153.09 160.00 154.54 164.19 161.74 149.50 158.85
## 2002 152.35 140.49 158.83 156.50 162.44 159.59 164.21 165.52 152.95 159.75
## 2003 151.49 141.78 157.91 154.79 160.10 157.00 163.59 168.58 155.15 163.51
## 2004 157.16 153.16 164.53 161.22 165.49 163.38 169.78 169.56 160.53 168.76
## 2005 161.37 150.28 167.52 163.38 171.07 165.42 172.75 174.58 161.38 168.18
## 2006 166.28 151.19 170.91 165.90 171.87 169.08 176.75 177.70 164.50 172.14
## 2007 166.54 153.85 170.15 167.81 175.93 172.10 178.72 179.66 166.60 172.30
## 2008 160.71 149.15 164.51 162.43 168.61 160.98 166.71 165.54 149.45 163.37
## 2009 154.71 139.94 158.40 155.67 156.92 157.24 160.42 162.31 150.39 158.03
## 2010 150.90 137.77 158.17 157.46 161.83 159.50 165.28 165.18 158.13 160.18
## 2011 151.85 139.49 157.84 153.55 158.64 158.83 160.19 161.57 153.19 155.55
## 2012 145.57 142.10 152.38 150.60 157.03 155.37 157.85 160.75 147.24 153.26
## 2013 146.52 134.24 153.08 149.44 156.36 152.81

```

```

##          Nov      Dec

```

```

## 1973 112.11 108.50
## 1974 106.85 110.75
## 1975 102.31 113.27
## 1976 113.58 122.12
## 1977 117.09 124.40
## 1978 122.42 125.52
## 1979 116.88 122.79
## 1980 109.65 120.81
## 1981 110.62 120.85
## 1982 112.45 114.75
## 1983 112.35 121.43
## 1984 114.59 115.04
## 1985 116.27 122.39
## 1986 119.99 130.72
## 1987 122.37 131.62
## 1988 129.66 136.71
## 1989 131.18 141.62
## 1990 130.12 132.45
## 1991 127.70 136.50

```

```

## 1992 128.53 141.49
## 1993 135.55 142.56
## 1994 134.28 144.75
## 1995 139.77 144.02
## 1996 141.13 144.19
## 1997 142.89 149.37
## 1998 145.58 154.34
## 1999 149.73 165.73
## 2000 152.83 161.74
## 2001 150.34 152.10
## 2002 156.98 162.61
## 2003 156.84 162.67
## 2004 162.13 166.62
## 2005 163.95 170.87
## 2006 163.19 172.37
## 2007 166.54 169.31
## 2008 153.35 158.83
## 2009 150.46 158.36
## 2010 152.97 158.60
## 2011 149.54 154.53
## 2012 147.26 146.39

```

```
## 2013
```

```
##
```

```
## $upper
```

```

##      Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov   Dec
## 2013                162.9 164.5 153.3 160.0 153.8 159.3
## 2014 154.3 144.3 161.3 158.8 164.6 162.2 167.0 168.5 157.2 163.9 157.5 163.0
## 2015 158.0 147.8 164.8 162.3 168.0 165.5 170.3 171.7 160.4 167.0 160.7 166.1
## 2016 161.1 150.9 167.8 165.3 171.0 168.5 173.2 174.6 163.3 169.9 163.5 169.0
## 2017 163.9 153.7 170.6 168.0 173.8 171.2 175.9 177.3 166.0 172.5 166.2 171.6
## 2018 166.5 156.3 173.2 170.6 176.3 173.8 178.4 179.8 168.5 175.0 168.6 174.0
## 2019 168.9 158.7 175.6 173.0 178.7 176.2 180.8 182.2 170.8 177.4 171.0 176.4
## 2020 171.3 161.1 178.0 175.4 181.1 178.5 183.1 184.5 173.1 179.7 173.3 178.7
## 2021 173.6 163.3 180.2 177.6 183.3 180.7 185.3 186.7 175.4 181.9 175.5 180.9
## 2022 175.8 165.5 182.4 179.8 185.5 182.9 187.5 188.9 177.5 184.1 177.7 183.1
## 2023 177.9 167.7 184.6 182.0 187.7 185.1 189.6 191.0 179.7 186.2 179.8 185.2
## 2024 180.0 169.8 186.7 184.1 189.7 187.2 191.7 193.1 181.7 188.3 181.9 187.2
## 2025 182.1 171.8 188.7 186.1 191.8 189.2

```

```
##
```

```
## $lower
```

```

##      Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov   Dec
## 2013                151.7 152.7 141.0 147.2 140.4 145.5
## 2014 140.0 129.5 146.1 143.2 148.6 145.7 149.7 150.8 139.1 145.4 138.7 143.9
## 2015 138.5 128.0 144.6 141.8 147.2 144.4 148.4 149.6 138.0 144.3 137.7 142.8
## 2016 137.5 127.0 143.7 140.8 146.3 143.5 147.6 148.8 137.2 143.5 136.9 142.1
## 2017 136.7 126.3 143.0 140.2 145.7 142.9 147.0 148.2 136.6 143.0 136.4 141.6
## 2018 136.2 125.8 142.5 139.7 145.2 142.4 146.6 147.7 136.2 142.5 136.0 141.2
## 2019 135.8 125.4 142.1 139.3 144.8 142.1 146.2 147.4 135.9 142.2 135.7 140.9
## 2020 135.5 125.1 141.9 139.1 144.6 141.8 146.0 147.2 135.7 142.0 135.5 140.7
## 2021 135.4 124.9 141.7 138.9 144.4 141.6 145.8 147.0 135.5 141.9 135.3 140.5
## 2022 135.2 124.8 141.5 138.8 144.3 141.5 145.7 147.0 135.4 141.8 135.2 140.4
## 2023 135.1 124.7 141.5 138.7 144.2 141.5 145.7 146.9 135.4 141.8 135.2 140.4

```

```
## 2024 135.1 124.7 141.5 138.7 144.2 141.5 145.7 146.9 135.4 141.8 135.2 140.4  
## 2025 135.1 124.7 141.5 138.7 144.2 141.5
```

```
print(summary(data_hw))
```

```
##
## Forecast method: Holt-Winters' additive method
##
## Model Information:
## Holt-Winters' additive method
##
## Call:
## hw(y = data_ts, h = 144, level = c(95))
##
## Smoothing parameters:
##   alpha = 0.3242
##   beta  = 0.0001
##   gamma = 0.1582
##
## Initial states:
##   l = 109.687
##   b = 0.0872
##   s = 4.606 -1.299 2.938 -3.192 4.564 3.103
##       0.2119 3.379 -2.103 0.618 -9.895 -2.932
##
## sigma: 2.858
##
## AIC AICc BIC
## 4045 4046 4116
##
## Error measures:
##           ME RMSE  MAE      MPE MAPE  MASE      ACF1
## Training set -0.0135 2.811 2.259 -0.04315 1.709 0.608 -0.05733
##
## Forecasts:
##           Point Forecast Lo 95 Hi 95
## Jul 2013           157.3 151.7 162.9
## Aug 2013           158.6 152.7 164.5
## Sep 2013           147.1 141.0 153.3
## Oct 2013           153.6 147.2 160.0
## Nov 2013           147.1 140.4 153.8
## Dec 2013           152.4 145.5 159.3
## Jan 2014           147.2 140.0 154.3
## Feb 2014           136.9 129.5 144.3
## Mar 2014           153.7 146.1 161.3
## Apr 2014           151.0 143.2 158.8
## May 2014           156.6 148.6 164.6
## Jun 2014           153.9 145.7 162.2
## Jul 2014           158.3 149.7 167.0
## Aug 2014           159.6 150.8 168.5
## Sep 2014           148.2 139.1 157.2
## Oct 2014           154.6 145.4 163.9
## Nov 2014           148.1 138.7 157.5
## Dec 2014           153.4 143.9 163.0
## Jan 2015           148.2 138.5 158.0
## Feb 2015           137.9 128.0 147.8
## Mar 2015           154.7 144.6 164.8
```

## Apr 2015	152.0	141.8	162.3
## May 2015	157.6	147.2	168.0
## Jun 2015	155.0	144.4	165.5
## Jul 2015	159.4	148.4	170.3
## Aug 2015	160.6	149.6	171.7
## Sep 2015	149.2	138.0	160.4
## Oct 2015	155.7	144.3	167.0
## Nov 2015	149.2	137.7	160.7
## Dec 2015	154.5	142.8	166.1
## Jan 2016	149.3	137.5	161.1
## Feb 2016	138.9	127.0	150.9
## Mar 2016	155.8	143.7	167.8
## Apr 2016	153.1	140.8	165.3
## May 2016	158.7	146.3	171.0
## Jun 2016	156.0	143.5	168.5
## Jul 2016	160.4	147.6	173.2
## Aug 2016	161.7	148.8	174.6
## Sep 2016	150.3	137.2	163.3
## Oct 2016	156.7	143.5	169.9
## Nov 2016	150.2	136.9	163.5
## Dec 2016	155.5	142.1	169.0
## Jan 2017	150.3	136.7	163.9
## Feb 2017	140.0	126.3	153.7
## Mar 2017	156.8	143.0	170.6
## Apr 2017	154.1	140.2	168.0
## May 2017	159.7	145.7	173.8
## Jun 2017	157.0	142.9	171.2
## Jul 2017	161.4	147.0	175.9
## Aug 2017	162.7	148.2	177.3
## Sep 2017	151.3	136.6	166.0
## Oct 2017	157.7	143.0	172.5
## Nov 2017	151.3	136.4	166.2
## Dec 2017	156.6	141.6	171.6
## Jan 2018	151.3	136.2	166.5
## Feb 2018	141.0	125.8	156.3
## Mar 2018	157.8	142.5	173.2
## Apr 2018	155.1	139.7	170.6
## May 2018	160.7	145.2	176.3
## Jun 2018	158.1	142.4	173.8
## Jul 2018	162.5	146.6	178.4
## Aug 2018	163.8	147.7	179.8
## Sep 2018	152.3	136.2	168.5
## Oct 2018	158.8	142.5	175.0
## Nov 2018	152.3	136.0	168.6
## Dec 2018	157.6	141.2	174.0
## Jan 2019	152.4	135.8	168.9
## Feb 2019	142.1	125.4	158.7
## Mar 2019	158.9	142.1	175.6
## Apr 2019	156.2	139.3	173.0
## May 2019	161.8	144.8	178.7
## Jun 2019	159.1	142.1	176.2
## Jul 2019	163.5	146.2	180.8

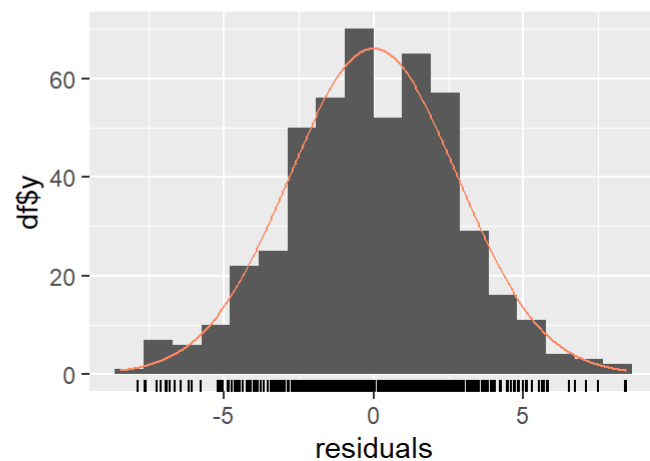
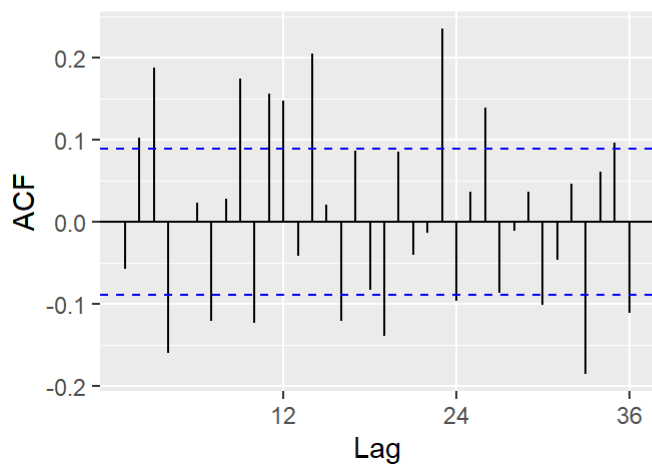
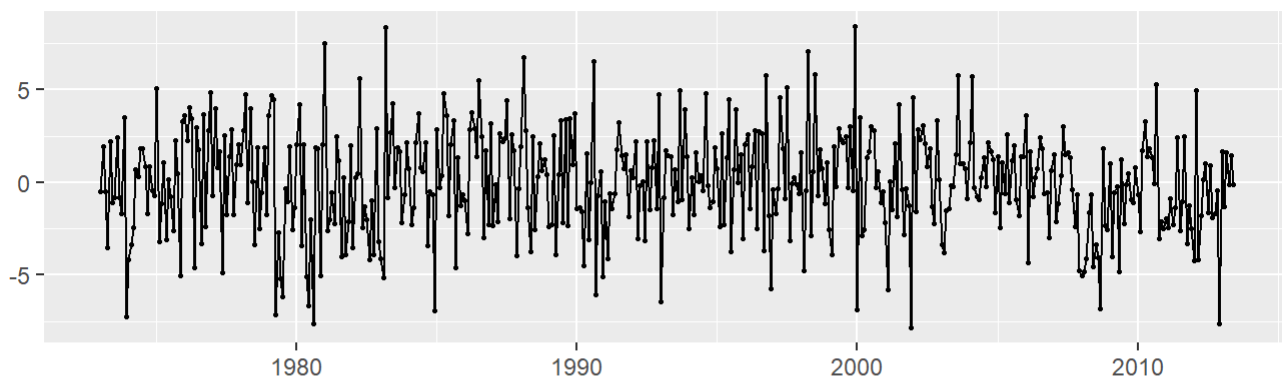
## Aug 2019	164.8	147.4	182.2
## Sep 2019	153.4	135.9	170.8
## Oct 2019	159.8	142.2	177.4
## Nov 2019	153.3	135.7	171.0
## Dec 2019	158.6	140.9	176.4
## Jan 2020	153.4	135.5	171.3
## Feb 2020	143.1	125.1	161.1
## Mar 2020	159.9	141.9	178.0
## Apr 2020	157.2	139.1	175.4
## May 2020	162.8	144.6	181.1
## Jun 2020	160.2	141.8	178.5
## Jul 2020	164.6	146.0	183.1
## Aug 2020	165.8	147.2	184.5
## Sep 2020	154.4	135.7	173.1
## Oct 2020	160.9	142.0	179.7
## Nov 2020	154.4	135.5	173.3
## Dec 2020	159.7	140.7	178.7
## Jan 2021	154.5	135.4	173.6
## Feb 2021	144.1	124.9	163.3
## Mar 2021	161.0	141.7	180.2
## Apr 2021	158.3	138.9	177.6
## May 2021	163.9	144.4	183.3
## Jun 2021	161.2	141.6	180.7
## Jul 2021	165.6	145.8	185.3
## Aug 2021	166.9	147.0	186.7
## Sep 2021	155.4	135.5	175.4
## Oct 2021	161.9	141.9	181.9
## Nov 2021	155.4	135.3	175.5
## Dec 2021	160.7	140.5	180.9
## Jan 2022	155.5	135.2	175.8
## Feb 2022	145.2	124.8	165.5
## Mar 2022	162.0	141.5	182.4
## Apr 2022	159.3	138.8	179.8
## May 2022	164.9	144.3	185.5
## Jun 2022	162.2	141.5	182.9
## Jul 2022	166.6	145.7	187.5
## Aug 2022	167.9	147.0	188.9
## Sep 2022	156.5	135.4	177.5
## Oct 2022	162.9	141.8	184.1
## Nov 2022	156.5	135.2	177.7
## Dec 2022	161.8	140.4	183.1
## Jan 2023	156.5	135.1	177.9
## Feb 2023	146.2	124.7	167.7
## Mar 2023	163.0	141.5	184.6
## Apr 2023	160.3	138.7	182.0
## May 2023	165.9	144.2	187.7
## Jun 2023	163.3	141.5	185.1
## Jul 2023	167.7	145.7	189.6
## Aug 2023	169.0	146.9	191.0
## Sep 2023	157.5	135.4	179.7
## Oct 2023	164.0	141.8	186.2
## Nov 2023	157.5	135.2	179.8

```
## Dec 2023      162.8 140.4 185.2
## Jan 2024      157.6 135.1 180.0
## Feb 2024      147.3 124.7 169.8
## Mar 2024      164.1 141.5 186.7
## Apr 2024      161.4 138.7 184.1
## May 2024      167.0 144.2 189.7
## Jun 2024      164.3 141.5 187.2
## Jul 2024      168.7 145.7 191.7
## Aug 2024      170.0 146.9 193.1
## Sep 2024      158.6 135.4 181.7
## Oct 2024      165.0 141.8 188.3
## Nov 2024      158.5 135.2 181.9
## Dec 2024      163.8 140.4 187.2
## Jan 2025      158.6 135.1 182.1
## Feb 2025      148.3 124.7 171.8
## Mar 2025      165.1 141.5 188.7
## Apr 2025      162.4 138.7 186.1
## May 2025      168.0 144.2 191.8
## Jun 2025      165.3 141.5 189.2
```

```
# std deviation: 0.0216/ 2.858
```

```
checkresiduals(data_hw)
```

Residuals from Holt-Winters' additive method

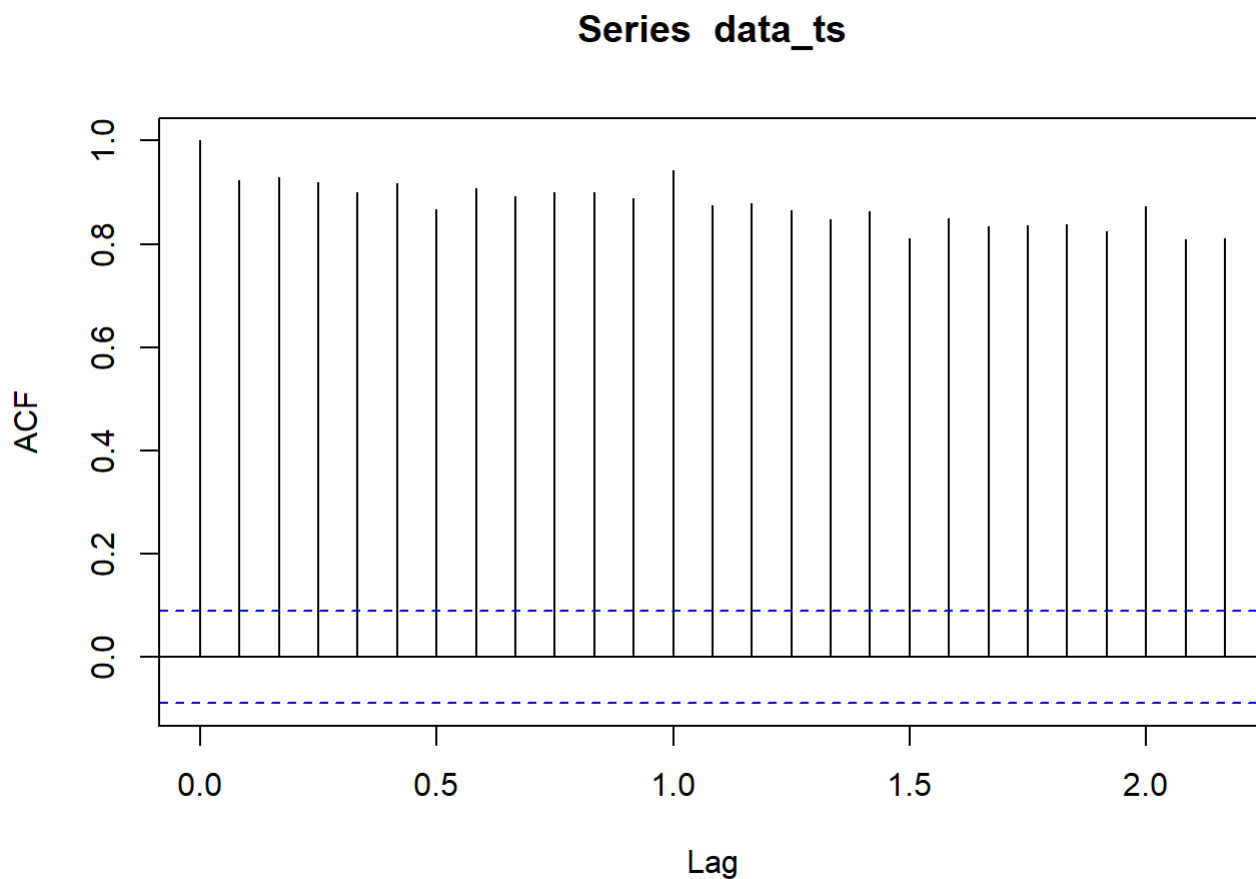



```
##  
##  Ljung-Box test  
##  
## data:  Residuals from Holt-Winters' additive method  
## Q* = 175, df = 8, p-value <0.000000000000002  
##  
## Model df: 16.    Total lags used: 24
```

Data Forecasting Using ARIMA methods

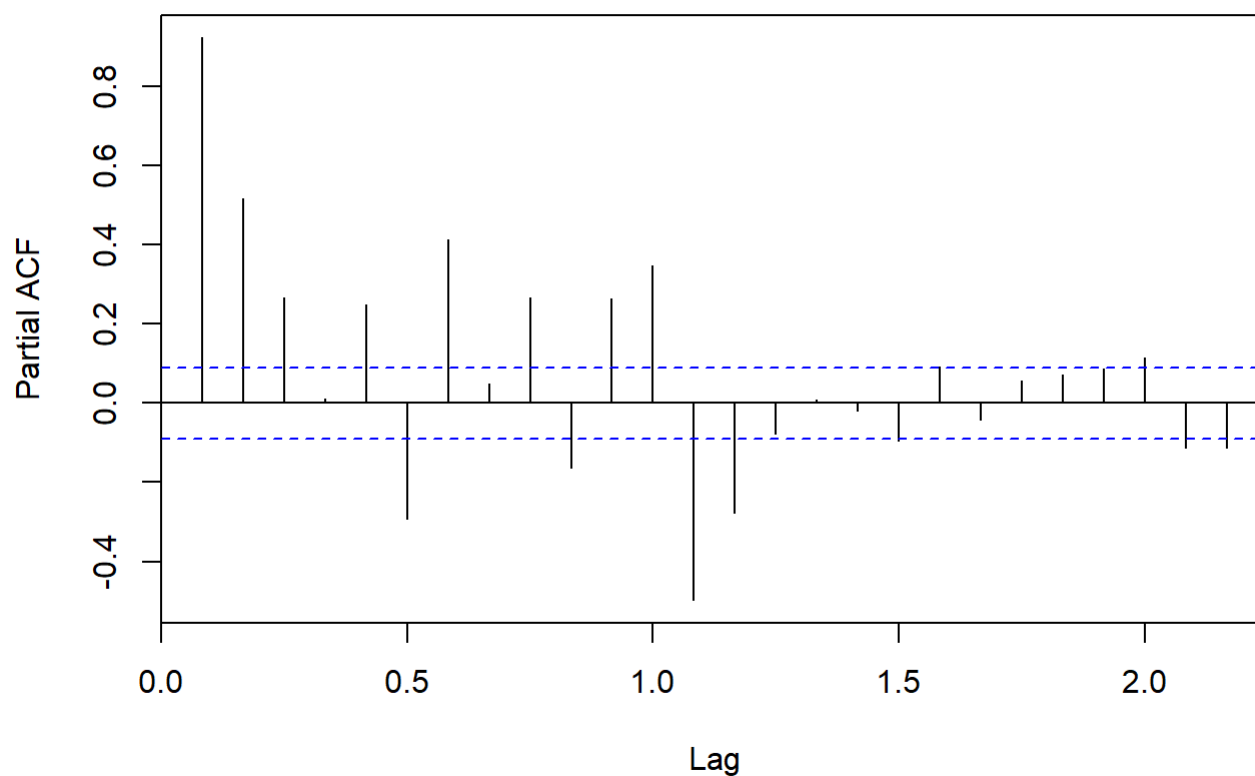
To check for stationarity

```
acf(data_ts)
```



```
# it is not stationary (auto correlation because the spikes cross above the blue lines)  
pacf(data_ts)
```

Series data_ts



it is not stationary (partial-auto correlation because the spikes cross above the blue lines)

```
adf.test(data_ts)
```

```
##
## Augmented Dickey-Fuller Test
##
## data: data_ts
## Dickey-Fuller = -2.2, Lag order = 7, p-value = 0.5
## alternative hypothesis: stationary
```

p-value = 0.05

Converting non-stationary data to stationary data

```
new_arima <- auto.arima(data_ts, d=1, D=1, stepwise = F, approximation = F, trace = T)
```

```

##
## ARIMA(0,1,0)(0,1,0)[12] : 2724
## ARIMA(0,1,0)(0,1,1)[12] : 2547
## ARIMA(0,1,0)(0,1,2)[12] : Inf
## ARIMA(0,1,0)(1,1,0)[12] : 2680
## ARIMA(0,1,0)(1,1,1)[12] : Inf
## ARIMA(0,1,0)(1,1,2)[12] : Inf
## ARIMA(0,1,0)(2,1,0)[12] : 2644
## ARIMA(0,1,0)(2,1,1)[12] : 2523
## ARIMA(0,1,0)(2,1,2)[12] : 2507
## ARIMA(0,1,1)(0,1,0)[12] : 2502
## ARIMA(0,1,1)(0,1,1)[12] : 2345
## ARIMA(0,1,1)(0,1,2)[12] : 2332
## ARIMA(0,1,1)(1,1,0)[12] : 2450
## ARIMA(0,1,1)(1,1,1)[12] : 2335
## ARIMA(0,1,1)(1,1,2)[12] : 2334
## ARIMA(0,1,1)(2,1,0)[12] : 2416
## ARIMA(0,1,1)(2,1,1)[12] : 2329
## ARIMA(0,1,1)(2,1,2)[12] : 2324
## ARIMA(0,1,2)(0,1,0)[12] : 2493
## ARIMA(0,1,2)(0,1,1)[12] : 2335
## ARIMA(0,1,2)(0,1,2)[12] : 2324
## ARIMA(0,1,2)(1,1,0)[12] : 2437
## ARIMA(0,1,2)(1,1,1)[12] : 2327
## ARIMA(0,1,2)(1,1,2)[12] : 2326
## ARIMA(0,1,2)(2,1,0)[12] : 2400
## ARIMA(0,1,2)(2,1,1)[12] : 2322
## ARIMA(0,1,3)(0,1,0)[12] : 2494
## ARIMA(0,1,3)(0,1,1)[12] : 2334
## ARIMA(0,1,3)(0,1,2)[12] : 2323
## ARIMA(0,1,3)(1,1,0)[12] : 2438
## ARIMA(0,1,3)(1,1,1)[12] : 2326
## ARIMA(0,1,3)(2,1,0)[12] : 2400
## ARIMA(0,1,4)(0,1,0)[12] : 2490
## ARIMA(0,1,4)(0,1,1)[12] : 2320
## ARIMA(0,1,4)(1,1,0)[12] : 2431
## ARIMA(0,1,5)(0,1,0)[12] : 2487
## ARIMA(1,1,0)(0,1,0)[12] : 2550
## ARIMA(1,1,0)(0,1,1)[12] : 2385
## ARIMA(1,1,0)(0,1,2)[12] : Inf
## ARIMA(1,1,0)(1,1,0)[12] : 2505
## ARIMA(1,1,0)(1,1,1)[12] : Inf
## ARIMA(1,1,0)(1,1,2)[12] : 2372
## ARIMA(1,1,0)(2,1,0)[12] : 2467
## ARIMA(1,1,0)(2,1,1)[12] : 2363
## ARIMA(1,1,0)(2,1,2)[12] : 2355
## ARIMA(1,1,1)(0,1,0)[12] : 2493
## ARIMA(1,1,1)(0,1,1)[12] : 2335
## ARIMA(1,1,1)(0,1,2)[12] : 2324
## ARIMA(1,1,1)(1,1,0)[12] : 2438
## ARIMA(1,1,1)(1,1,1)[12] : 2327
## ARIMA(1,1,1)(1,1,2)[12] : 2326

```

```

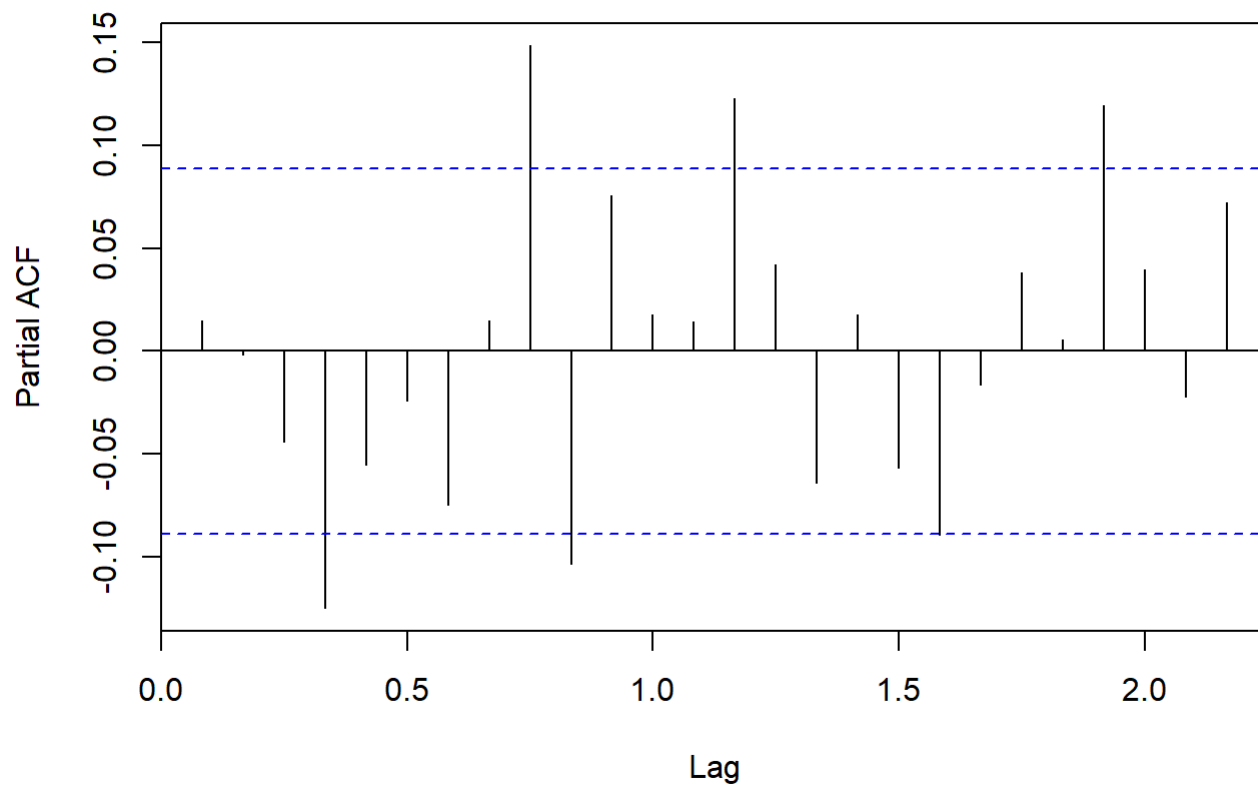
## ARIMA(1,1,1)(2,1,0)[12] : 2402
## ARIMA(1,1,1)(2,1,1)[12] : 2322
## ARIMA(1,1,2)(0,1,0)[12] : 2495
## ARIMA(1,1,2)(0,1,1)[12] : 2336
## ARIMA(1,1,2)(0,1,2)[12] : 2326
## ARIMA(1,1,2)(1,1,0)[12] : 2439
## ARIMA(1,1,2)(1,1,1)[12] : 2328
## ARIMA(1,1,2)(2,1,0)[12] : 2402
## ARIMA(1,1,3)(0,1,0)[12] : 2494
## ARIMA(1,1,3)(0,1,1)[12] : 2332
## ARIMA(1,1,3)(1,1,0)[12] : 2423
## ARIMA(1,1,4)(0,1,0)[12] : Inf
## ARIMA(2,1,0)(0,1,0)[12] : 2493
## ARIMA(2,1,0)(0,1,1)[12] : 2319
## ARIMA(2,1,0)(0,1,2)[12] : 2313
## ARIMA(2,1,0)(1,1,0)[12] : 2426
## ARIMA(2,1,0)(1,1,1)[12] : 2315
## ARIMA(2,1,0)(1,1,2)[12] : 2315
## ARIMA(2,1,0)(2,1,0)[12] : 2382
## ARIMA(2,1,0)(2,1,1)[12] : 2312
## ARIMA(2,1,1)(0,1,0)[12] : 2494
## ARIMA(2,1,1)(0,1,1)[12] : 2319
## ARIMA(2,1,1)(0,1,2)[12] : 2314
## ARIMA(2,1,1)(1,1,0)[12] : 2428
## ARIMA(2,1,1)(1,1,1)[12] : 2316
## ARIMA(2,1,1)(2,1,0)[12] : 2383
## ARIMA(2,1,2)(0,1,0)[12] : Inf
## ARIMA(2,1,2)(0,1,1)[12] : 2321
## ARIMA(2,1,2)(1,1,0)[12] : 2428
## ARIMA(2,1,3)(0,1,0)[12] : Inf
## ARIMA(3,1,0)(0,1,0)[12] : 2495
## ARIMA(3,1,0)(0,1,1)[12] : 2320
## ARIMA(3,1,0)(0,1,2)[12] : 2314
## ARIMA(3,1,0)(1,1,0)[12] : 2428
## ARIMA(3,1,0)(1,1,1)[12] : 2316
## ARIMA(3,1,0)(2,1,0)[12] : 2383
## ARIMA(3,1,1)(0,1,0)[12] : Inf
## ARIMA(3,1,1)(0,1,1)[12] : 2321
## ARIMA(3,1,1)(1,1,0)[12] : Inf
## ARIMA(3,1,2)(0,1,0)[12] : Inf
## ARIMA(4,1,0)(0,1,0)[12] : 2492
## ARIMA(4,1,0)(0,1,1)[12] : 2320
## ARIMA(4,1,0)(1,1,0)[12] : 2427
## ARIMA(4,1,1)(0,1,0)[12] : 2487
## ARIMA(5,1,0)(0,1,0)[12] : 2484
##
##
##
## Best model: ARIMA(2,1,0)(2,1,1)[12]

```

```
head(new_arima)
```

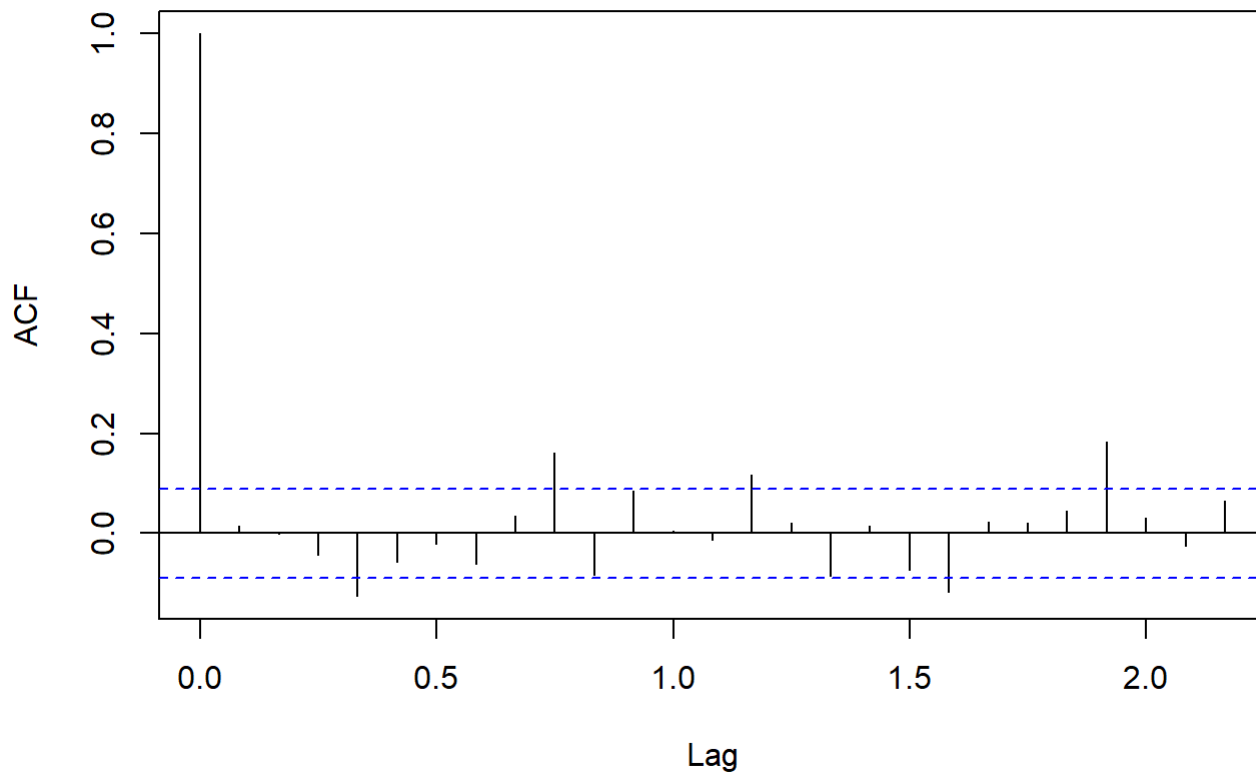
```
## $coef
##      ar1      ar2      sar1      sar2      sma1
## -0.7241 -0.3378  0.1173 -0.1241 -0.8231
##
## $sigma2
## [1] 7.417
##
## $var.coef
##           ar1           ar2           sar1           sar2           sma1
## ar1  0.00193671  0.0010996  0.00008707 -0.0003353 -0.00008036
## ar2  0.00109958  0.0019932  0.00026666 -0.0004188 -0.00012918
## sar1 0.00008707  0.0002667  0.00311632  0.0004817 -0.00101776
## sar2 -0.00033531 -0.0004188  0.00048170  0.0028485 -0.00075243
## sma1 -0.00008036 -0.0001292 -0.00101776 -0.0007524  0.00118787
##
## $mask
## [1] TRUE TRUE TRUE TRUE TRUE
##
## $loglik
## [1] -1150
##
## $aic
## [1] 2311
```

```
# To check if the new model is stationary
pacf(new_arma$residuals)
```

Series new_arma\$residuals

```
acf(new_arma$residuals)
```

Series new_arima\$residuals



```
# ALL okay
```

```
adf.test(new_arima$residuals)
```

```
## Warning in adf.test(new_arima$residuals): p-value smaller than printed p-value
```

```
##
## Augmented Dickey-Fuller Test
##
## data: new_arima$residuals
## Dickey-Fuller = -9.3, Lag order = 7, p-value = 0.01
## alternative hypothesis: stationary
```

```
# the P-value is Lower than 0.05
```

Total energy transportation sector co2 emissions forecasting

```
data_forecast <- forecast(new_arima, level = c(95), h=12*12)
head(data_forecast)
```



```

## $method
## [1] "ARIMA(2,1,0)(2,1,1)[12]"
##
## $model
## Series: data_ts
## ARIMA(2,1,0)(2,1,1)[12]
##
## Coefficients:
##          ar1      ar2    sar1    sar2    sma1
##        -0.724  -0.338   0.117  -0.124  -0.823
## s.e.    0.044   0.045   0.056   0.053   0.034
##
## sigma^2 = 7.42:  log likelihood = -1150
## AIC=2311   AICc=2312   BIC=2336
##
## $level
## [1] 95
##
## $mean
##      Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov   Dec
## 2013                                157.7 159.3 147.1 154.1 147.2 151.4
## 2014 146.7 134.8 152.5 149.4 155.0 152.2 157.1 158.2 146.9 153.5 146.5 152.1
## 2015 145.7 135.0 151.4 148.6 154.0 151.5 156.1 157.4 146.0 152.4 145.6 150.6
## 2016 144.6 134.0 150.5 147.6 153.1 150.6 155.2 156.5 145.0 151.4 144.6 149.4
## 2017 143.7 132.9 149.6 146.7 152.2 149.6 154.3 155.5 144.1 150.5 143.7 148.5
## 2018 142.8 132.0 148.6 145.8 151.3 148.7 153.3 154.6 143.2 149.6 142.8 147.6
## 2019 141.9 131.1 147.7 144.9 150.4 147.8 152.4 153.7 142.2 148.7 141.9 146.7
## 2020 140.9 130.2 146.8 143.9 149.5 146.9 151.5 152.8 141.3 147.8 140.9 145.8
## 2021 140.0 129.3 145.9 143.0 148.5 146.0 150.6 151.9 140.4 146.9 140.0 144.9
## 2022 139.1 128.3 145.0 142.1 147.6 145.1 149.7 151.0 139.5 146.0 139.1 144.0
## 2023 138.2 127.4 144.1 141.2 146.7 144.1 148.8 150.0 138.6 145.0 138.2 143.1
## 2024 137.3 126.5 143.1 140.3 145.8 143.2 147.8 149.1 137.7 144.1 137.3 142.1
## 2025 136.3 125.6 142.2 139.4 144.9 142.3
##
## $lower
##      Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct
## 2013                                152.37 153.79 141.02 147.27
## 2014 138.60 126.36 143.65 140.19 145.41 142.26 146.35 147.05 135.27 141.34
## 2015 132.18 121.07 137.16 133.97 138.95 136.10 140.26 141.10 129.37 135.39
## 2016 126.47 115.50 131.65 128.48 133.64 130.78 134.89 135.83 123.98 130.04
## 2017 121.20 110.10 126.40 123.19 128.39 125.49 129.61 130.53 118.66 124.73
## 2018 115.85 104.70 121.00 117.78 122.95 120.02 124.15 125.05 113.18 119.24
## 2019 110.30  99.16 115.42 112.19 117.34 114.40 118.52 119.40 107.53 113.57
## 2020 104.59  93.44 109.69 106.43 111.57 108.62 112.73 113.60 101.71 107.74
## 2021  98.73  87.56 103.79 100.52 105.65 102.68 106.78 107.64  95.74 101.75
## 2022  92.69  81.51  97.73  94.45  99.56  96.58 100.67 101.51  89.60  95.60
## 2023  86.50  75.30  91.51  88.21  93.31  90.31  94.39  95.22  83.30  89.28
## 2024  80.14  68.93  85.13  81.82  86.89  83.89  87.96  88.77  76.83  82.81
## 2025  73.63  62.40  78.58  75.26  80.33  77.30
##
##      Nov   Dec
## 2013 140.05 143.73
## 2014 133.94 139.00

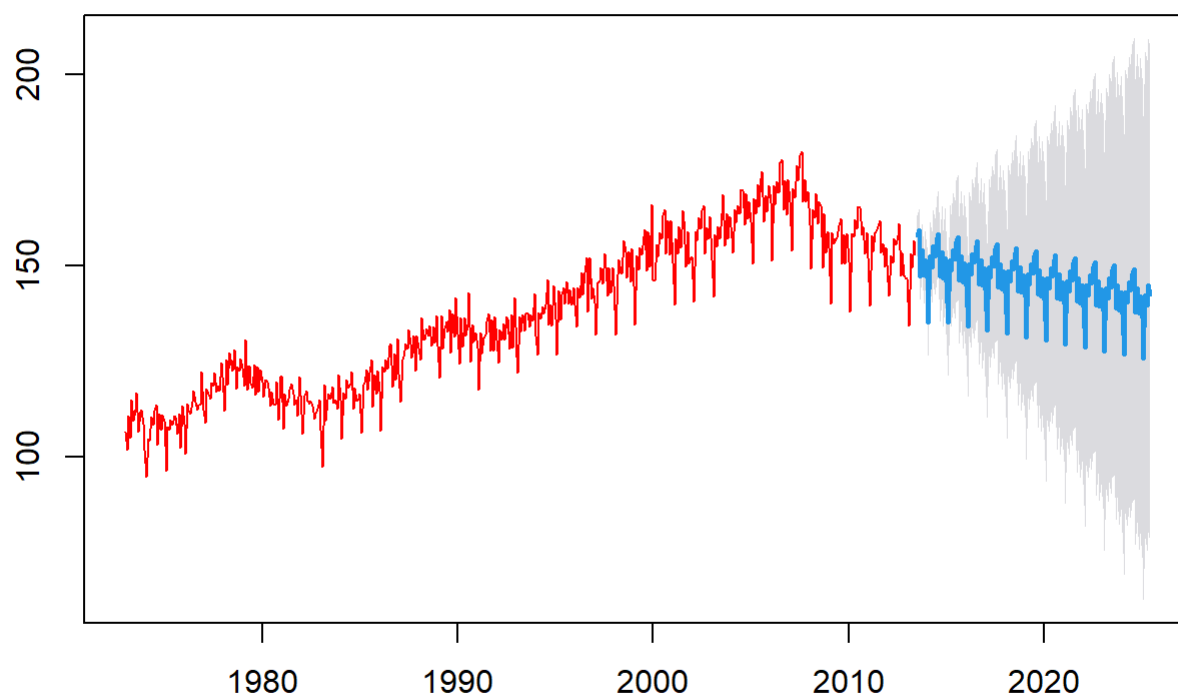
```

```
## 2015 128.15 132.83
## 2016 122.84 127.30
## 2017 117.51 121.98
## 2018 111.99 116.48
## 2019 106.31 110.79
## 2020 100.47 104.93
## 2021 94.47 98.91
## 2022 88.30 92.73
## 2023 81.97 86.39
## 2024 75.48 79.89
## 2025
##
## $upper
##      Jan      Feb      Mar      Apr      May      Jun      Jul      Aug      Sep      Oct      Nov      Dec
## 2013                                163.0 164.9 153.1 160.8 154.4 159.0
## 2014 154.8 143.3 161.4 158.7 164.6 162.1 167.9 169.4 158.6 165.7 159.2 165.1
## 2015 159.1 148.8 165.7 163.3 169.0 166.9 172.0 173.6 162.7 169.5 163.0 168.4
## 2016 162.7 152.4 169.3 166.8 172.6 170.4 175.5 177.1 166.0 172.8 166.3 171.5
## 2017 166.1 155.7 172.7 170.2 176.0 173.8 178.9 180.6 169.5 176.3 169.9 175.1
## 2018 169.7 159.3 176.3 173.8 179.6 177.4 182.5 184.2 173.1 180.0 173.5 178.8
## 2019 173.4 163.0 180.0 177.5 183.4 181.2 186.3 188.0 177.0 183.8 177.4 182.7
## 2020 177.3 166.9 183.9 181.5 187.3 185.2 190.3 192.0 180.9 187.8 181.4 186.7
## 2021 181.3 170.9 188.0 185.5 191.4 189.3 194.4 196.1 185.1 192.0 185.6 190.9
## 2022 185.5 175.2 192.2 189.8 195.7 193.5 198.7 200.4 189.4 196.3 189.9 195.2
## 2023 189.9 179.5 196.6 194.2 200.1 198.0 203.1 204.8 193.9 200.8 194.4 199.7
## 2024 194.4 184.1 201.2 198.7 204.7 202.5 207.7 209.5 198.5 205.4 199.0 204.4
## 2025 199.1 188.8 205.9 203.4 209.4 207.3
```

Interpretation: July, 2013: The point forecast is 157.7. the Lo 95 and high 95 is the confidence level, if it is low, it will be 152.37, if high, it will be 163. It is safe to go with the minimum.

```
plot(data_forecast, main = "Total energy transportation sector co2 emissions for the next 12 years", col="red")
```

Total energy transportation sector co2 emissions for the next 12 years



Validation of the model

```
Box.test(data_forecast$residuals, lag =23, type = "Ljung-Box")
```

```
##  
## Box-Ljung test  
##  
## data: data_forecast$residuals  
## X-squared = 73, df = 23, p-value = 0.0000005
```

```
# Interpretation: For the Box-Ljung test, p value is less than 0.5
```

```
print(summary(data_forecast))
```

```
##
## Forecast method: ARIMA(2,1,0)(2,1,1)[12]
##
## Model Information:
## Series: data_ts
## ARIMA(2,1,0)(2,1,1)[12]
##
## Coefficients:
##          ar1      ar2    sar1    sar2    sma1
##        -0.724  -0.338   0.117  -0.124  -0.823
## s.e.    0.044   0.045   0.056   0.053   0.034
##
## sigma^2 = 7.42:  log likelihood = -1150
## AIC=2311   AICc=2312   BIC=2336
##
## Error measures:
##              ME  RMSE  MAE      MPE  MAPE  MASE   ACF1
## Training set -0.005065 2.673 2.116 -0.01735 1.593 0.5697 0.01461
##
## Forecasts:
##      Point Forecast  Lo 95 Hi 95
## Jul 2013          157.7 152.37 163.0
## Aug 2013          159.3 153.79 164.9
## Sep 2013          147.1 141.02 153.1
## Oct 2013          154.1 147.27 160.8
## Nov 2013          147.2 140.05 154.4
## Dec 2013          151.4 143.73 159.0
## Jan 2014          146.7 138.60 154.8
## Feb 2014          134.8 126.36 143.3
## Mar 2014          152.5 143.65 161.4
## Apr 2014          149.4 140.19 158.7
## May 2014          155.0 145.41 164.6
## Jun 2014          152.2 142.26 162.1
## Jul 2014          157.1 146.35 167.9
## Aug 2014          158.2 147.05 169.4
## Sep 2014          146.9 135.27 158.6
## Oct 2014          153.5 141.34 165.7
## Nov 2014          146.5 133.94 159.2
## Dec 2014          152.1 139.00 165.1
## Jan 2015          145.7 132.18 159.1
## Feb 2015          135.0 121.07 148.8
## Mar 2015          151.4 137.16 165.7
## Apr 2015          148.6 133.97 163.3
## May 2015          154.0 138.95 169.0
## Jun 2015          151.5 136.10 166.9
## Jul 2015          156.1 140.26 172.0
## Aug 2015          157.4 141.10 173.6
## Sep 2015          146.0 129.37 162.7
## Oct 2015          152.4 135.39 169.5
## Nov 2015          145.6 128.15 163.0
## Dec 2015          150.6 132.83 168.4
## Jan 2016          144.6 126.47 162.7
```

## Feb 2016	134.0	115.50	152.4
## Mar 2016	150.5	131.65	169.3
## Apr 2016	147.6	128.48	166.8
## May 2016	153.1	133.64	172.6
## Jun 2016	150.6	130.78	170.4
## Jul 2016	155.2	134.89	175.5
## Aug 2016	156.5	135.83	177.1
## Sep 2016	145.0	123.98	166.0
## Oct 2016	151.4	130.04	172.8
## Nov 2016	144.6	122.84	166.3
## Dec 2016	149.4	127.30	171.5
## Jan 2017	143.7	121.20	166.1
## Feb 2017	132.9	110.10	155.7
## Mar 2017	149.6	126.40	172.7
## Apr 2017	146.7	123.19	170.2
## May 2017	152.2	128.39	176.0
## Jun 2017	149.6	125.49	173.8
## Jul 2017	154.3	129.61	178.9
## Aug 2017	155.5	130.53	180.6
## Sep 2017	144.1	118.66	169.5
## Oct 2017	150.5	124.73	176.3
## Nov 2017	143.7	117.51	169.9
## Dec 2017	148.5	121.98	175.1
## Jan 2018	142.8	115.85	169.7
## Feb 2018	132.0	104.70	159.3
## Mar 2018	148.6	121.00	176.3
## Apr 2018	145.8	117.78	173.8
## May 2018	151.3	122.95	179.6
## Jun 2018	148.7	120.02	177.4
## Jul 2018	153.3	124.15	182.5
## Aug 2018	154.6	125.05	184.2
## Sep 2018	143.2	113.18	173.1
## Oct 2018	149.6	119.24	180.0
## Nov 2018	142.8	111.99	173.5
## Dec 2018	147.6	116.48	178.8
## Jan 2019	141.9	110.30	173.4
## Feb 2019	131.1	99.16	163.0
## Mar 2019	147.7	115.42	180.0
## Apr 2019	144.9	112.19	177.5
## May 2019	150.4	117.34	183.4
## Jun 2019	147.8	114.40	181.2
## Jul 2019	152.4	118.52	186.3
## Aug 2019	153.7	119.40	188.0
## Sep 2019	142.2	107.53	177.0
## Oct 2019	148.7	113.57	183.8
## Nov 2019	141.9	106.31	177.4
## Dec 2019	146.7	110.79	182.7
## Jan 2020	140.9	104.59	177.3
## Feb 2020	130.2	93.44	166.9
## Mar 2020	146.8	109.69	183.9
## Apr 2020	143.9	106.43	181.5
## May 2020	149.5	111.57	187.3

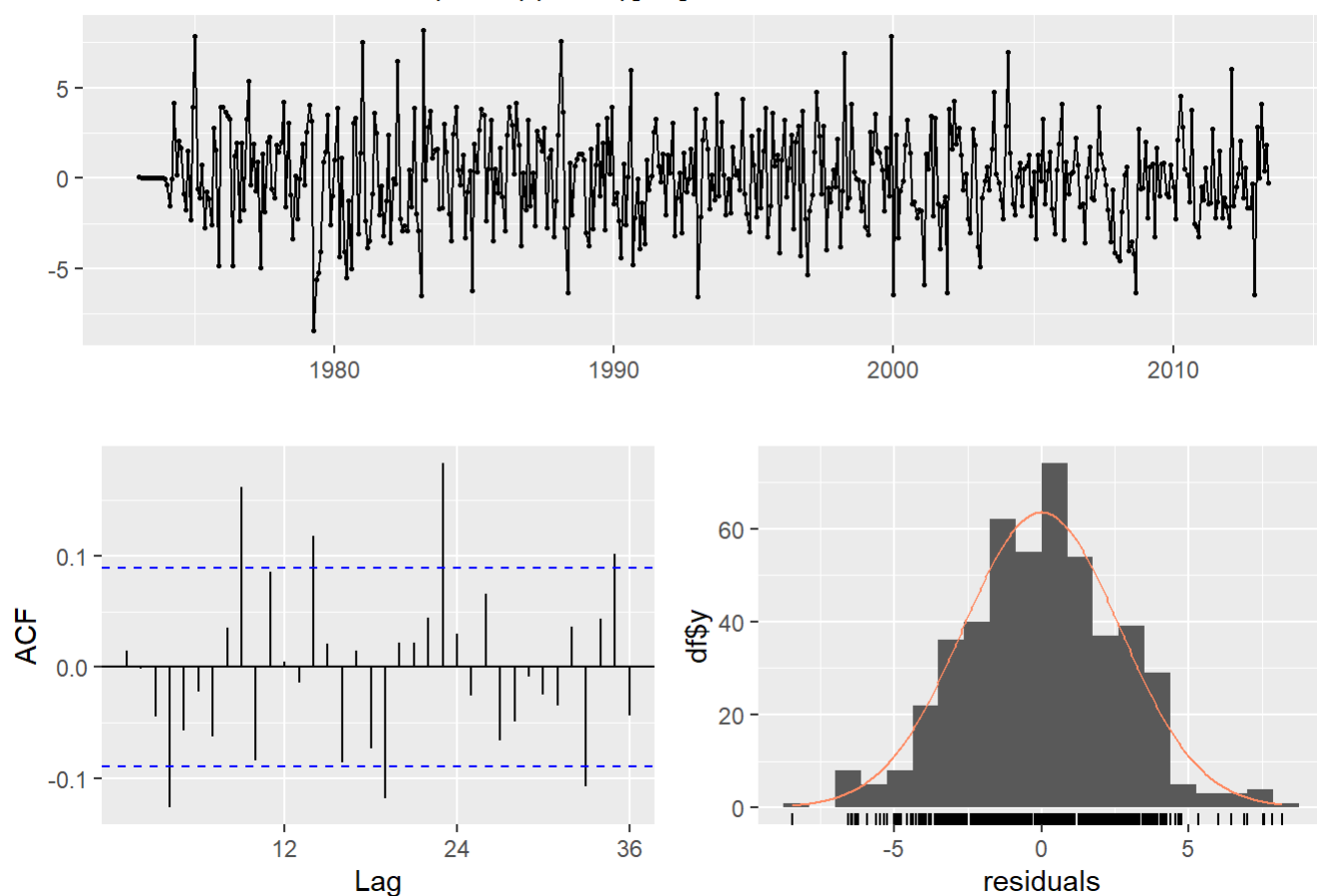
## Jun 2020	146.9	108.62	185.2
## Jul 2020	151.5	112.73	190.3
## Aug 2020	152.8	113.60	192.0
## Sep 2020	141.3	101.71	180.9
## Oct 2020	147.8	107.74	187.8
## Nov 2020	140.9	100.47	181.4
## Dec 2020	145.8	104.93	186.7
## Jan 2021	140.0	98.73	181.3
## Feb 2021	129.3	87.56	170.9
## Mar 2021	145.9	103.79	188.0
## Apr 2021	143.0	100.52	185.5
## May 2021	148.5	105.65	191.4
## Jun 2021	146.0	102.68	189.3
## Jul 2021	150.6	106.78	194.4
## Aug 2021	151.9	107.64	196.1
## Sep 2021	140.4	95.74	185.1
## Oct 2021	146.9	101.75	192.0
## Nov 2021	140.0	94.47	185.6
## Dec 2021	144.9	98.91	190.9
## Jan 2022	139.1	92.69	185.5
## Feb 2022	128.3	81.51	175.2
## Mar 2022	145.0	97.73	192.2
## Apr 2022	142.1	94.45	189.8
## May 2022	147.6	99.56	195.7
## Jun 2022	145.1	96.58	193.5
## Jul 2022	149.7	100.67	198.7
## Aug 2022	151.0	101.51	200.4
## Sep 2022	139.5	89.60	189.4
## Oct 2022	146.0	95.60	196.3
## Nov 2022	139.1	88.30	189.9
## Dec 2022	144.0	92.73	195.2
## Jan 2023	138.2	86.50	189.9
## Feb 2023	127.4	75.30	179.5
## Mar 2023	144.1	91.51	196.6
## Apr 2023	141.2	88.21	194.2
## May 2023	146.7	93.31	200.1
## Jun 2023	144.1	90.31	198.0
## Jul 2023	148.8	94.39	203.1
## Aug 2023	150.0	95.22	204.8
## Sep 2023	138.6	83.30	193.9
## Oct 2023	145.0	89.28	200.8
## Nov 2023	138.2	81.97	194.4
## Dec 2023	143.1	86.39	199.7
## Jan 2024	137.3	80.14	194.4
## Feb 2024	126.5	68.93	184.1
## Mar 2024	143.1	85.13	201.2
## Apr 2024	140.3	81.82	198.7
## May 2024	145.8	86.89	204.7
## Jun 2024	143.2	83.89	202.5
## Jul 2024	147.8	87.96	207.7
## Aug 2024	149.1	88.77	209.5
## Sep 2024	137.7	76.83	198.5

```
## Oct 2024      144.1  82.81 205.4
## Nov 2024      137.3  75.48 199.0
## Dec 2024      142.1  79.89 204.4
## Jan 2025      136.3  73.63 199.1
## Feb 2025      125.6  62.40 188.8
## Mar 2025      142.2  78.58 205.9
## Apr 2025      139.4  75.26 203.4
## May 2025      144.9  80.33 209.4
## Jun 2025      142.3  77.30 207.3
```

```
# std. deviation:2.72
```

```
checkresiduals(data_forecast)
```

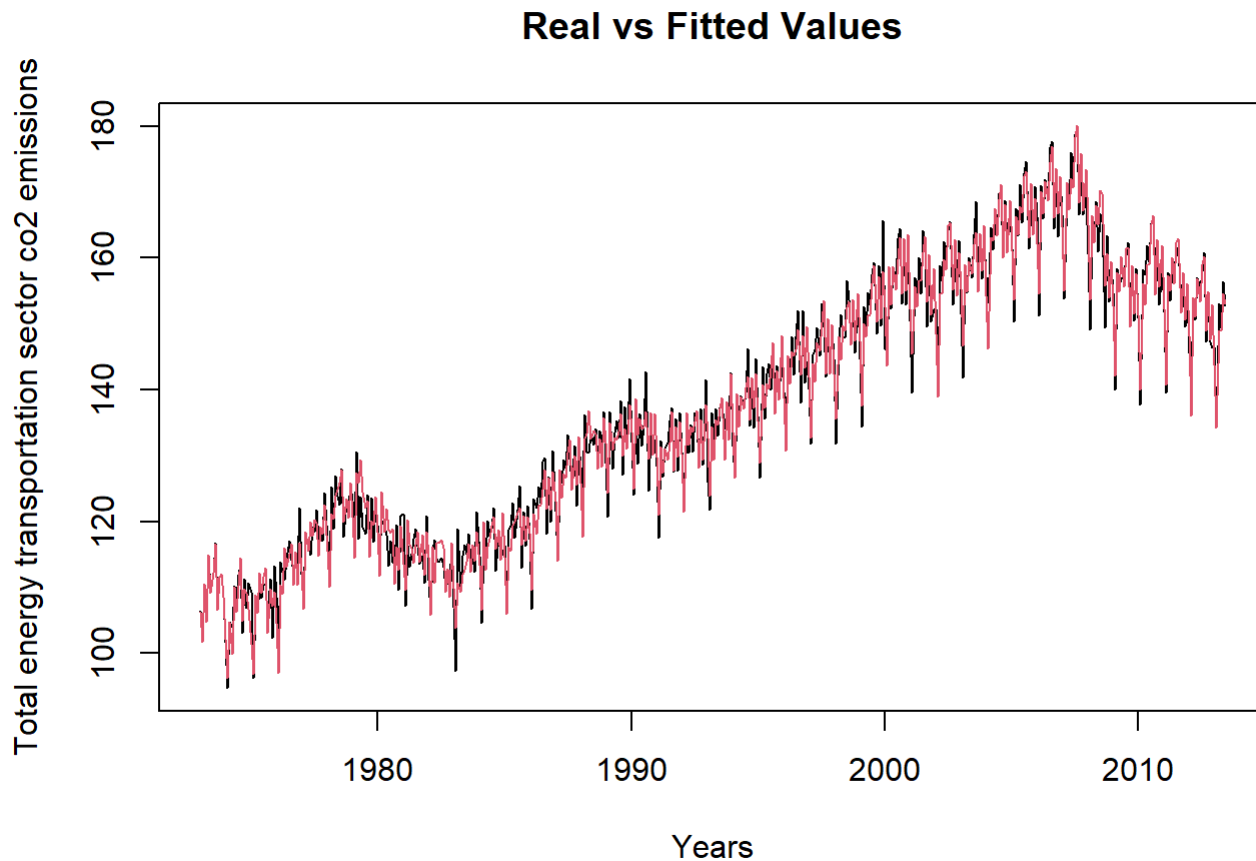
Residuals from ARIMA(2,1,0)(2,1,1)[12]



```
##
## Ljung-Box test
##
## data: Residuals from ARIMA(2,1,0)(2,1,1)[12]
## Q* = 73, df = 19, p-value = 0.00000003
##
## Model df: 5. Total lags used: 24
```

Plotting real vs Fitted Values

```
ts.plot(new_arima$x, new_arima$fitted, col=1:2, gpars = list(xlab = "Years", ylab="Total energy transportation sector co2 emissions", main= "Real vs Fitted Values"))
```



Recommendation and Conclusion:

Total energy transportation sector co2 emissions will keep growing downward slightly (a trend) and it also captures the seasonality. ARIMA model fits the best according to our end sample statistics (standard deviation: 2.72) compared to Holt's winter's model of std. deviation; 2.85 and Seasonal naive model of std. deviation: 4.57