MA 5124 Financial Time Series Analysis & Forecasting

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Contents

Course Syllabus

Module Code: MA 5124

Title: Financial Time Series Analysis & Forecasting

Credits: 4

Pre-requiites

None

Learning Objectives

- The purpose of this course is to provide students with introductory tools for the time series analysis of financial time series.
- Analyze of data series based on stochastic and non stochastic models

Learning Outcomes

- On successful completion of this course, students will be able to provide more than an introductory treatment of the topics.
- Students are encouraged to pursue further study in this area if they find that the topics covered in this course.

Outline Syllabus

- Definition and examples of time series
- back-shift and differencing-operators, - strong and weak stationarity, definition of ACF, PACF.

- Definitions and properties of the $MA(q), MA(\infty), AR(p), AR(\infty)$ and $ARMA(p, q)$,in particualr their acf's
- causal stationarity of AR
- invertibility of MA models and causal stationarity and invertibility of ARMA; - concept of spectral density function and its applications
- definition and properties of integrated $ARIMA(p, d, q)$ processes
- definition and properties of random walks with or without drift.
- Model selection following the AIC and BIC
- brief introduction to linear prediction and calculation of forecasting intervals for normal ARMA models
- point and interval forecasts for normal random walks with or without drift.
- Definition and properties of the VAR (vector autoregressive) model, arrange a univariate time series as a multivariate Markov model.
- Nonlinear properties of financial time series
- definition and properties of the well known ARCH, GARCH etc.
- Cointegration in Single Equations, Modeling and Forecasting Financial Time Series.

Method of Assessment

- Assignment 30%
- End-semester examination 70%

Lecturer

Dr. Priyanga D. Talagala

Schedule

Lectures:

- Sunday [9.00am -12.00 noon]

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Chapter 1

Intordution to Time Series Forecasting

Chapter 2

Time Series Graphics

Chapter 3

Time Series Decomposition

Chapter 4

Exponential Smoothing

Chapter 5

ARIMA models

Chapter 6

Multiple Regression and Forecasting

Chapter 7

Dynamic Regression Models

Chapter 8

Multivariate Time Series Models

- Unit root tets
- multivariate time series)
- (VAR)

Chapter 9

Cointegration

Chapter 10

Volatality Models

- (ARCH, GARCH)

Chapter 11

Time series with R

11.1 Lesson 1: Introduction to R

```
4+1
```

```
## [1] 5
```

```
mean(c(1,2,3,4))
```

```
## [1] 2.5
```

```
# These are equivalent
y=4
y<-4 #this was the original one used and that's why you will see it in many places

#load fpp2
library(fpp2)
```

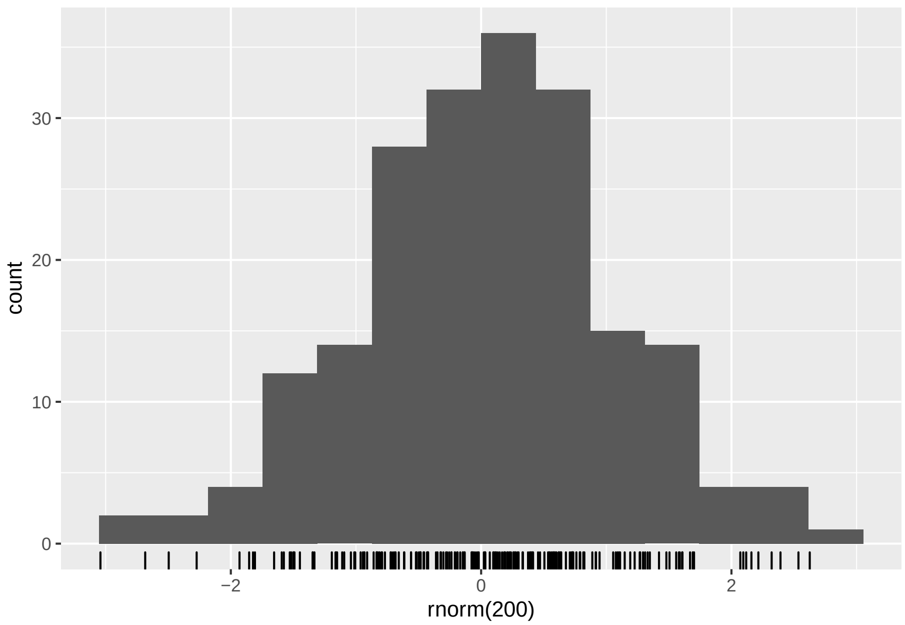
```
## Registered S3 method overwritten by 'quantmod':
##   method            from
##   as.zoo.data.frame zoo
```

```
## -- Attaching packages ---------------------------------------------- fpp2 2.4 --
```

```
## v ggplot2   3.3.2     v fma       2.4
## v forecast  8.12      v expsmooth 2.3
```

```
##
```

```
?fpp2

gghistogram(rnorm(200)) #rnorm generates random numbers from a standard normal
```



```
# Equivalent to typing in the help menu
?mean

# Example in the help menu for the mean
x <- c(0:10, 50)
length(x)
```

```
## [1] 12
```

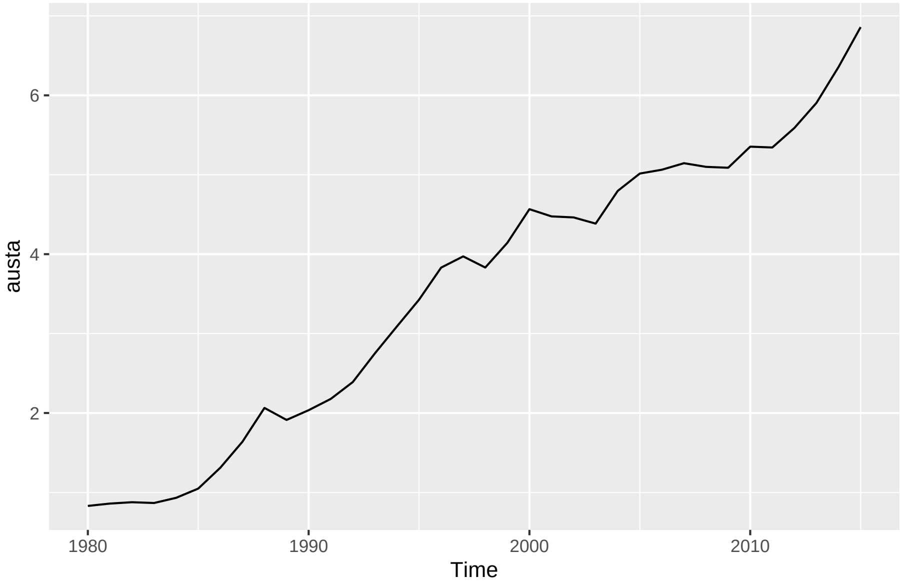
```
xm <- mean(x)


austa # what happens here?
```

```
## Time Series:
## Start = 1980
## End = 2015
## Frequency = 1
##  [1] 0.8298943 0.8595109 0.8766892 0.8667072 0.9320520 1.0482636 1.3111932
##  [8] 1.6375623 2.0641074 1.9126828 2.0354457 2.1772113 2.3896834 2.7505921
## [15] 3.0906664 3.4266403 3.8306491 3.9719086 3.8316004 4.1431010 4.5665510
## [22] 4.4754100 4.4627960 4.3848290 4.7968610 5.0150490 5.0634350 5.1454890
## [29] 5.0994360 5.0881660 5.3537020 5.3433270 5.5891620 5.9048840 6.3571830
## [36] 6.8589530
```

```
# Ignore the error message and keep going



# Lets look at some data sets from fpp
austa  #International vistors to Australia
```

```
## Time Series:
## Start = 1980
## End = 2015
## Frequency = 1
##  [1] 0.8298943 0.8595109 0.8766892 0.8667072 0.9320520 1.0482636 1.3111932
##  [8] 1.6375623 2.0641074 1.9126828 2.0354457 2.1772113 2.3896834 2.7505921
## [15] 3.0906664 3.4266403 3.8306491 3.9719086 3.8316004 4.1431010 4.5665510
## [22] 4.4754100 4.4627960 4.3848290 4.7968610 5.0150490 5.0634350 5.1454890
## [29] 5.0994360 5.0881660 5.3537020 5.3433270 5.5891620 5.9048840 6.3571830
## [36] 6.8589530
```

```
autoplot(austa)
```



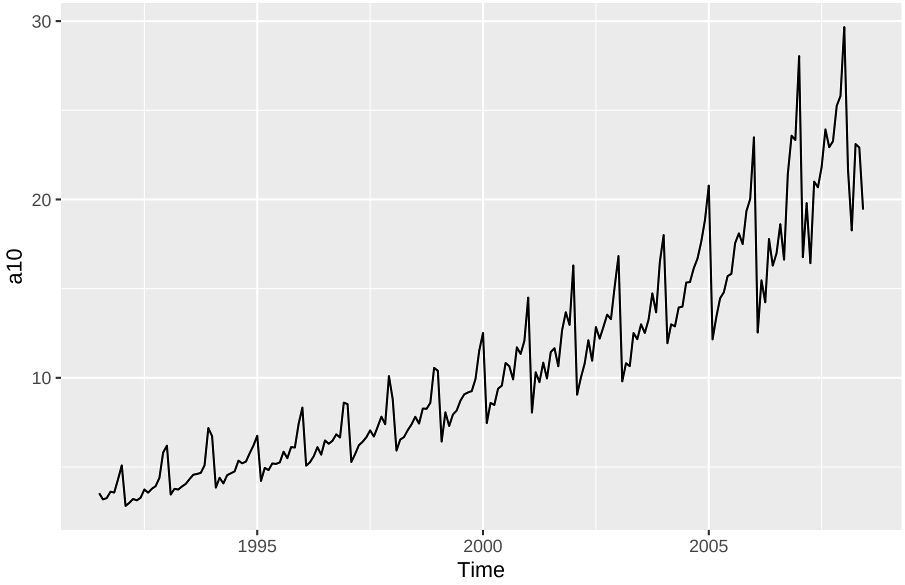
```
# Summary command: prints an appropriate summary of what you asked from
summary(austa)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
##  0.8299  2.0048  3.9018  3.5414  5.0696  6.8590
```

```
# Some monthly data
a10 # Monthly anti-diabetic drug sales in Australia from 1992 to 2008
```

```
##            Jan       Feb       Mar       Apr       May       Jun       Jul
## 1991                                                             3.526591
## 1992  5.088335  2.814520  2.985811  3.204780  3.127578  3.270523  3.737851
## 1993  6.192068  3.450857  3.772307  3.734303  3.905399  4.049687  4.315566
## 1994  6.731473  3.841278  4.394076  4.075341  4.540645  4.645615  4.752607
## 1995  6.749484  4.216067  4.949349  4.823045  5.194754  5.170787  5.256742
## 1996  8.329452  5.069796  5.262557  5.597126  6.110296  5.689161  6.486849
## 1997  8.524471  5.277918  5.714303  6.214529  6.411929  6.667716  7.050831
## 1998  8.798513  5.918261  6.534493  6.675736  7.064201  7.383381  7.813496
## 1999 10.391416  6.421535  8.062619  7.297739  7.936916  8.165323  8.717420
## 2000 12.511462  7.457199  8.591191  8.474000  9.386803  9.560399 10.834295
## 2001 14.497581  8.049275 10.312891  9.753358 10.850382  9.961719 11.443601
## 2002 16.300269  9.053485 10.002449 10.788750 12.106705 10.954101 12.844566
## 2003 16.828350  9.800215 10.816994 10.654223 12.512323 12.161210 12.998046
## 2004 18.003768 11.938030 12.997900 12.882645 13.943447 13.989472 15.339097
## 2005 20.778723 12.154552 13.402392 14.459239 14.795102 15.705248 15.829550
## 2006 23.486694 12.536987 15.467018 14.233539 17.783058 16.291602 16.980282
## 2007 28.038383 16.763869 19.792754 16.427305 21.000742 20.681002 21.834890
## 2008 29.665356 21.654285 18.264945 23.107677 22.912510 19.431740
##            Aug       Sep       Oct       Nov       Dec
## 1991  3.180891  3.252221  3.611003  3.565869  4.306371
## 1992  3.558776  3.777202  3.924490  4.386531  5.810549
## 1993  4.562185  4.608662  4.667851  5.093841  7.179962
## 1994  5.350605  5.204455  5.301651  5.773742  6.204593
## 1995  5.855277  5.490729  6.115293  6.088473  7.416598
## 1996  6.300569  6.467476  6.828629  6.649078  8.606937
## 1997  6.704919  7.250988  7.819733  7.398101 10.096233
## 1998  7.431892  8.275117  8.260441  8.596156 10.558939
## 1999  9.070964  9.177113  9.251887  9.933136 11.532974
## 2000 10.643751  9.908162 11.710041 11.340151 12.079132
## 2001 11.659239 10.647060 12.652134 13.674466 12.965735
## 2002 12.196500 12.854748 13.542004 13.287640 15.134918
## 2003 12.517276 13.268658 14.733622 13.669382 16.503966
## 2004 15.370764 16.142005 16.685754 17.636728 18.869325
## 2005 17.554701 18.100864 17.496668 19.347265 20.031291
## 2006 18.612189 16.623343 21.430241 23.575517 23.334206
## 2007 23.930204 22.930357 23.263340 25.250030 25.806090
## 2008
```

```r
autoplot(a10)
```



```r
summary(a10)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   2.815   5.844   9.319  10.694  14.290  29.665
```

```r
# You will practice reading in your own data in the tutorials this week
# and next week. This will set you up well for the assignment

# This creates a vector y of observations
y=c(1,2,3,4,5,6)
mean(y)
```

```
## [1] 3.5
```

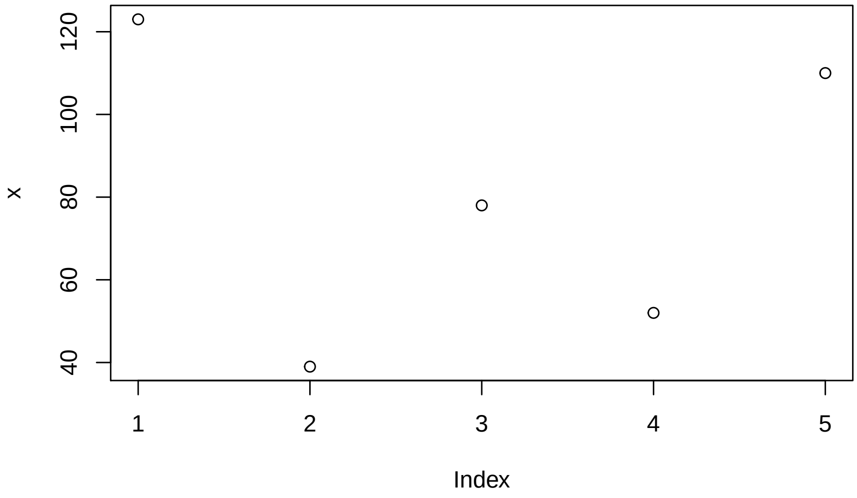
```r
# Write your own function

average<-function(x)
{
  return(sum(x)/length(x))
}

ybar<-average(y)
```

11.2 Lesson 2: Time series graphic

```
library(fpp2)

# ts objects

x <- c(123,39,78,52,110) # This is now just a column of numbers
x
```

```
## [1] 123  39  78  52 110
```

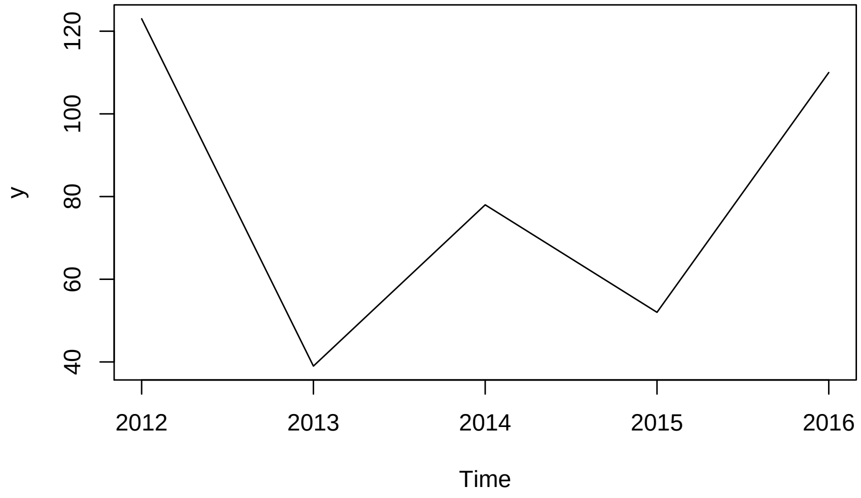
```
plot(x)
```



```
  y <- ts(c(123,39,78,52,110), start=2012)
  y
```

```
## Time Series:
## Start = 2012
## End = 2016
## Frequency = 1
## [1] 123  39  78  52 110
```

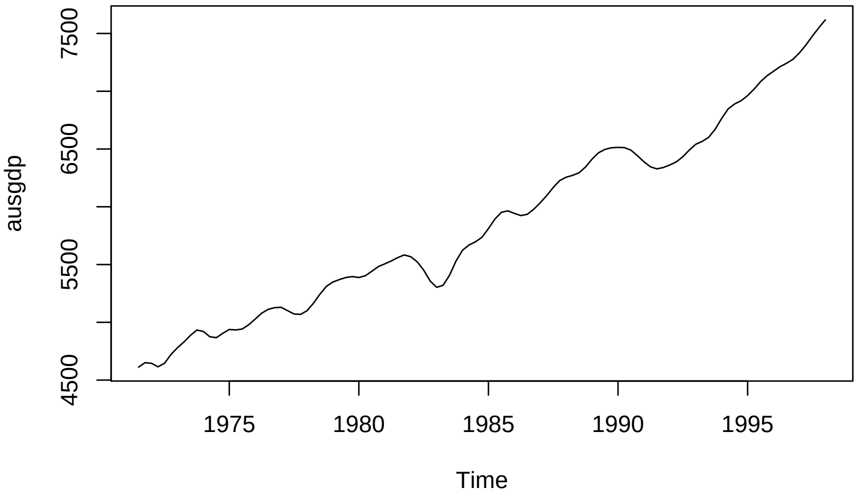
```
plot(y)
```



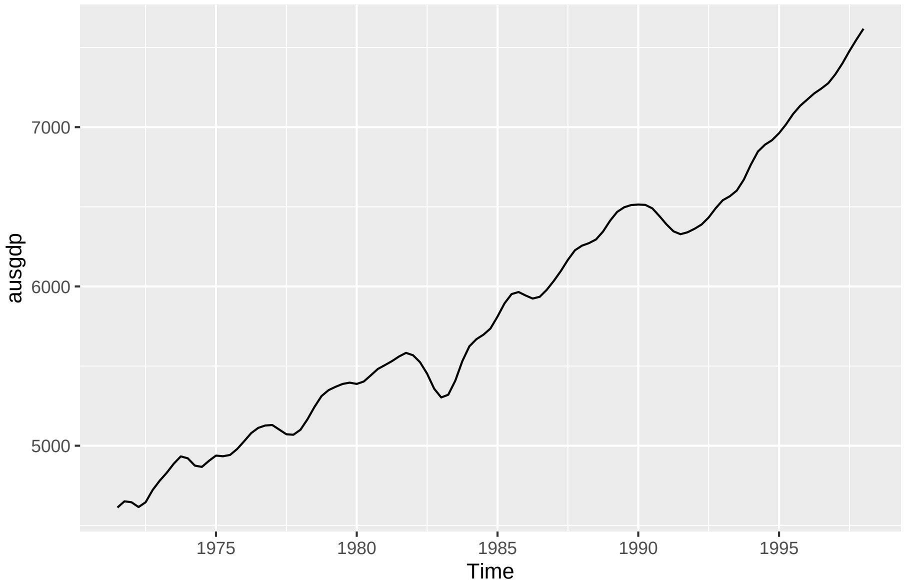
```
  z <- ts(x, frequency=12, start=c(2003,1))
  z
```

```
##      Jan Feb Mar Apr May
## 2003 123  39  78  52 110
```

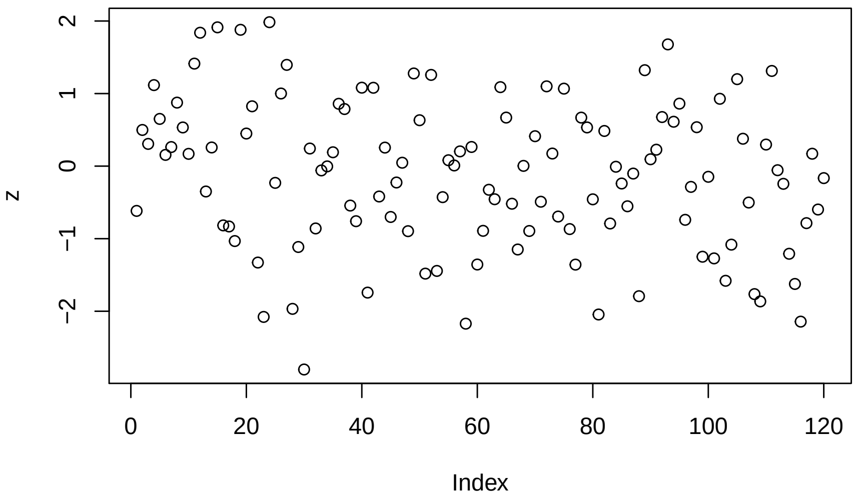
```
  # For higher frequency data use the frequency argument
  #  setwd("C:/George/Teaching/ETF3231/2018/RinLectures")
x <- scan(here::here("data","gdp.dat"))

ausgdp <- ts(x,frequency=4,
             start=1971.5) # Data starts in Q3
  plot(ausgdp) # part of base graphics
```



```r
autoplot(ausgdp)   # part of forecast and interaction with ggplot2
```



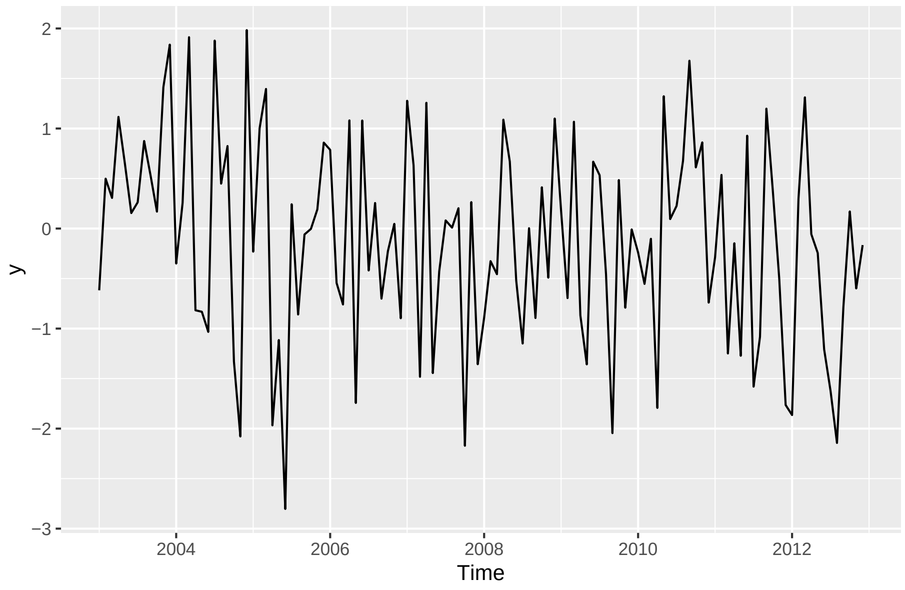
```
                    # better plots only for ts objects

z=rnorm(120)
#autoplot(z)
plot(z)
```



```
  y <- ts(z, start=2003, frequency=12)
  attributes(y)
```

```
## $tsp
## [1] 2003.000 2012.917   12.000
##
## $class
## [1] "ts"
```

```
  autoplot(y)
```



```
# Some ready ts
elecsales
```

```
## Time Series:
## Start = 1989
## End = 2008
## Frequency = 1
##  [1] 2354.34 2379.71 2318.52 2468.99 2386.09 2569.47 2575.72 2762.72 2844.50
## [10] 3000.70 3108.10 3357.50 3075.70 3180.60 3221.60 3176.20 3430.60 3527.48
## [19] 3637.89 3655.00
```

```
?elecsales
# Everyone to plot
# Also ask them to use the help command - you will need to do
# this a lot

# ? is shorthand for help()

# Ask everyone to type melsyd to see what they get

melsyd # let's have a look
```

```
## Time Series:
## Start = c(1987, 26)
## End = c(1992, 48)
## Frequency = 52
##          First.Class Business.Class Economy.Class
## 1987.481       1.912             NA        20.167
## 1987.500       1.848             NA        20.161
## 1987.519       1.856             NA        19.993
## 1987.538       2.142             NA        20.986
## 1987.558       2.118             NA        20.497
## 1987.577       2.048             NA        20.770
## 1987.596       2.111             NA        21.111
## 1987.615       2.199             NA        20.675
## 1987.635       2.231             NA        22.092
## 1987.654       2.081             NA        20.772
## 1987.673       2.213             NA        21.642
## 1987.692       2.131             NA        21.911
## 1987.712          NA             NA            NA
## 1987.731       2.131             NA        23.777
## 1987.750       2.034             NA        22.658
## 1987.769       2.190             NA        23.515
## 1987.788       2.262             NA        21.384
## 1987.808       2.579             NA        24.344
## 1987.827       2.367             NA        21.137
## 1987.846       2.432             NA        23.069
## 1987.865       2.640             NA        23.664
## 1987.885       2.614             NA        23.219
## 1987.904       2.569             NA        23.192
## 1987.923       2.523             NA        23.475
## 1987.942       2.260             NA        22.377
## 1987.962       1.117             NA        16.606
## 1987.981       0.590             NA        13.987
## 1988.000       0.966             NA        16.251
## 1988.019       1.235             NA        18.439
## 1988.038       2.001             NA        20.262
## 1988.058       1.696             NA        19.535
## 1988.077       2.089             NA        22.467
## 1988.096       2.716             NA        24.559
## 1988.115       2.483             NA        24.591
## 1988.135       2.461             NA        24.511
## 1988.154       2.533             NA        24.524
## 1988.173       2.273             NA        23.119
## 1988.192       2.273             NA        23.106
## 1988.212       2.370             NA        23.292
## 1988.231       1.782             NA        21.566
## 1988.250       1.385             NA        18.565
## 1988.269       2.322             NA        24.361
## 1988.288       2.340             NA        22.983
## 1988.308       2.203             NA        21.062
## 1988.327       2.300             NA        21.766
## 1988.346       2.125             NA        22.285
## 1988.365       2.345             NA        22.867
## 1988.385       2.224             NA        23.276
## 1988.404       1.952             NA        20.924
## 1988.423       2.212             NA        21.716
## 1988.442       2.028             NA        20.908
## 1988.462       1.906             NA        21.410
## 1988.481       1.834             NA        21.361
## 1988.500       1.797             NA        22.412
## 1988.519       1.869             NA        21.290
## 1988.538       1.886             NA        22.247
## 1988.558       2.131             NA        22.445
## 1988.577       2.021             NA        21.260
## 1988.596       2.199             NA        22.771
## 1988.615       2.140             NA        23.723
## 1988.635       2.190             NA        23.757
## 1988.654       1.917             NA        23.482
## 1988.673       2.096             NA        23.653
## 1988.692       2.254             NA        26.054
## 1988.712       2.251             NA        25.695
## 1988.731       2.072             NA        26.720
## 1988.750       0.993             NA        15.033
## 1988.769       1.675             NA        22.340
## 1988.788       1.463             NA        19.297
## 1988.808       2.256             NA        23.761
## 1988.827       2.216             NA        22.150
## 1988.846       2.218             NA        22.236
## 1988.865       2.568             NA        23.157
## 1988.885       2.483             NA        24.387
## 1988.904       2.545             NA        23.844
## 1988.923       2.599             NA        23.681
## 1988.942       2.483             NA        24.456
## 1988.962       1.793             NA        19.899
## 1988.981       0.516             NA        13.662
## 1989.000       0.873             NA        15.698
## 1989.019       1.195             NA        18.189
## 1989.038       1.525             NA        19.448
## 1989.058       1.906             NA        20.891
## 1989.077       2.246             NA        22.284
## 1989.096       2.247             NA        23.247
## 1989.115       2.316             NA        24.440
## 1989.135       2.276             NA        22.519
## 1989.154       2.403             NA        22.818
## 1989.173       2.432             NA        23.472
## 1989.192       2.490          NA       24.117
## 1989.212       2.013          NA       24.435
## 1989.231       1.508          NA       20.589
## 1989.250       2.251          NA       23.427
## 1989.269       2.079          NA       20.923
## 1989.288       2.210          NA       22.959
## 1989.308       1.960          NA       19.152
## 1989.327       2.251          NA       22.011
## 1989.346       2.013          NA       20.228
## 1989.365       2.252          NA       21.332
## 1989.385       2.067          NA       20.500
## 1989.404       1.831          NA       19.090
## 1989.423       2.069          NA       21.692
## 1989.442       1.953          NA       20.157
## 1989.462       2.199          NA       22.231
## 1989.481       1.771          NA       20.914
## 1989.500       1.696          NA       21.454
## 1989.519       1.788          NA       21.345
## 1989.538       1.636       1.524       19.260
## 1989.558       1.741       2.212       18.781
## 1989.577       1.597       1.777       17.445
## 1989.596       1.943       2.552       19.628
## 1989.615       1.660       1.889       17.692
## 1989.635       0.616       0.851        7.046
## 1989.654       0.000       0.000        0.000
## 1989.673       0.000       0.000        0.000
## 1989.692       0.000       0.000        0.000
## 1989.712       0.000       0.000        0.000
## 1989.731       0.000       0.000        0.000
## 1989.750       0.000       0.000        0.000
## 1989.769       0.000       0.000        0.000
## 1989.788       0.053       0.618       11.569
## 1989.808       0.040       0.565       11.973
## 1989.827       0.354       0.414       11.123
## 1989.846       0.505       0.543       11.479
## 1989.865       0.711       0.712       16.969
## 1989.885       0.723       0.652       15.997
## 1989.904       0.796       0.709       16.555
## 1989.923       0.856       0.793       17.959
## 1989.942       0.845       0.838       18.868
## 1989.962       0.807       0.763       15.400
## 1989.981       0.276       0.266       10.544
## 1990.000       0.339       0.362       12.755
## 1990.019       0.581       0.665       19.020
## 1990.038       0.894       0.957       20.077
## 1990.058       0.936       1.145       22.124
## 1990.077       1.111          1.312        19.920
## 1990.096       1.446          1.689        17.215
## 1990.115       1.517          1.762        17.662
## 1990.135       1.513          2.160        19.828
## 1990.154       1.508          1.877        18.754
## 1990.173       1.636          2.048        20.390
## 1990.192       1.380          1.824        18.383
## 1990.212       1.453          1.986        19.377
## 1990.231       1.459          2.032        20.133
## 1990.250       1.538          1.956        19.210
## 1990.269       1.327          1.503        20.736
## 1990.288       1.027          1.256        18.821
## 1990.308       1.365          1.752        20.952
## 1990.327       1.475          1.878        20.565
## 1990.346       1.365          1.945        20.311
## 1990.365       1.351          1.735        17.859
## 1990.385       1.231          1.825        19.385
## 1990.404       1.447          1.715        17.962
## 1990.423       1.408          1.594        19.569
## 1990.442       1.089          1.377        17.894
## 1990.462       1.357          1.686        18.114
## 1990.481       1.287          1.560        19.170
## 1990.500       1.087          1.692        18.713
## 1990.519       1.017          1.597        20.520
## 1990.538       1.090          1.729        20.345
## 1990.558       1.343          1.733        20.015
## 1990.577       1.164          1.813        18.027
## 1990.596       1.169          1.725        19.697
## 1990.615       1.465          1.909        19.897
## 1990.635       1.242          1.765        19.213
## 1990.654       1.220          1.781        19.773
## 1990.673       1.231          1.717        20.128
## 1990.692       1.266          1.884        21.181
## 1990.712       1.337          1.881        21.933
## 1990.731       1.079          1.433        20.049
## 1990.750       1.223          1.534        23.358
## 1990.769       1.351          1.926        21.120
## 1990.788       1.269          1.870        21.970
## 1990.808       1.382          1.942        21.411
## 1990.827       1.435          2.222        22.569
## 1990.846       1.371          1.909        20.849
## 1990.865       1.341          2.089        20.658
## 1990.885       1.399          2.026        21.192
## 1990.904       1.440          2.009        21.502
## 1990.923       1.236          2.034        22.152
## 1990.942       1.441          2.085        21.904
## 1990.962       0.988          1.330        20.634
## 1990.981       0.300          0.318        15.535
## 1991.000       0.401          0.522        16.690
## 1991.019       0.529          0.824        19.150
## 1991.038       0.786          1.113        21.128
## 1991.058       1.086          1.285        21.136
## 1991.077       0.725          1.107        19.693
## 1991.096       1.127          1.591        21.576
## 1991.115       1.146          1.726        21.449
## 1991.135       1.086          1.758        22.298
## 1991.154       1.134          1.883        21.056
## 1991.173       1.020          2.089        19.014
## 1991.192       1.022          2.198        19.511
## 1991.212       1.224          2.449        20.162
## 1991.231       0.895          1.739        21.158
## 1991.250       0.658          1.480        19.059
## 1991.269       0.977          2.152        21.972
## 1991.288       0.916          2.258        22.877
## 1991.308       0.830          1.776        22.190
## 1991.327       0.990          2.355        22.533
## 1991.346       0.770          2.140        20.682
## 1991.365       0.801          1.988        21.788
## 1991.385       0.839          2.083        21.299
## 1991.404       0.835          2.115        20.663
## 1991.423       0.802          1.884        21.948
## 1991.442       0.763          1.797        21.009
## 1991.462       0.770          1.944        20.443
## 1991.481       0.838          2.001        21.418
## 1991.500       0.742          1.668        23.273
## 1991.519       0.793          1.527        25.763
## 1991.538       0.900          1.477        26.045
## 1991.558       0.960          1.949        23.831
## 1991.577       0.800          1.914        22.742
## 1991.596       0.807          1.632        22.962
## 1991.615       0.841          1.796        25.253
## 1991.635       0.880          1.696        25.239
## 1991.654       0.818          1.718        27.387
## 1991.673       0.817          1.442        26.824
## 1991.692       0.819          1.713        27.294
## 1991.712       0.998          1.796        28.935
## 1991.731       1.220          1.860        31.642
## 1991.750       0.966          1.554        32.468
## 1991.769       0.895          1.623        27.673
## 1991.788       0.978          1.641        28.890
## 1991.808       0.913          1.818        26.465
## 1991.827       0.947          1.969        28.296
## 1991.846       1.002          1.886        29.274
## 1991.865       1.081          2.030        30.686
## 1991.885       0.977          1.883        29.786
## 1991.904       1.027          1.871        31.155
## 1991.923       0.895          1.910        28.459
## 1991.942       0.900          1.921        27.195
## 1991.962       0.762          1.672        26.274
## 1991.981       0.329          0.386        25.204
## 1992.000       0.351          0.446        24.434
## 1992.019       0.419          0.819        27.323
## 1992.038       0.618          1.238        27.303
## 1992.058       0.845          1.761        30.334
## 1992.077       0.727          1.650        26.833
## 1992.096       1.200          2.031        25.811
## 1992.115       1.801          2.064        27.238
## 1992.135       1.727          2.418        28.788
## 1992.154       1.992          2.171        27.263
## 1992.173       1.865          2.362        27.217
## 1992.192       1.801          2.328        26.410
## 1992.212       1.661          2.336        26.118
## 1992.231       2.366         10.301        18.642
## 1992.250       2.003          9.964        16.518
## 1992.269       2.092         10.433        17.276
## 1992.288       1.703          8.281        21.662
## 1992.308       1.337          6.128        20.473
## 1992.327       1.985          9.709        18.336
## 1992.346       1.808          8.828        17.018
## 1992.365       1.839          8.078        18.111
## 1992.385       1.714          7.527        18.410
## 1992.404       1.730          7.486        20.541
## 1992.423       1.725          6.711        21.408
## 1992.442       1.456          5.930        21.545
## 1992.462       1.447          5.462        21.732
## 1992.481       1.357          3.710        26.173
## 1992.500       1.280          2.894        27.432
## 1992.519       1.363          3.008        28.362
## 1992.538       1.228          2.829        29.827
## 1992.558       1.411          3.252        29.870
## 1992.577       1.130          3.021        26.534
## 1992.596       1.153          2.667        26.434
## 1992.615       1.257          2.740        26.137
## 1992.635       1.259          2.807        27.365
## 1992.654       1.153          2.961        27.910
## 1992.673       1.202          2.570        26.311
## 1992.692       1.185          2.671        27.538
## 1992.712       1.247          2.809        29.445
## 1992.731       1.434          2.712        28.326
## 1992.750       1.450          2.606        30.203
## 1992.769       1.227          2.500        27.838
## 1992.788       1.245          2.898        27.760
## 1992.808       1.417          3.152        27.322
## 1992.827       1.458          3.053        28.837
## 1992.846       1.398          2.745        26.548
## 1992.865       1.423          3.156        27.279
## 1992.885       1.358          3.069        27.306
## 1992.904       1.488          3.379        28.299
```

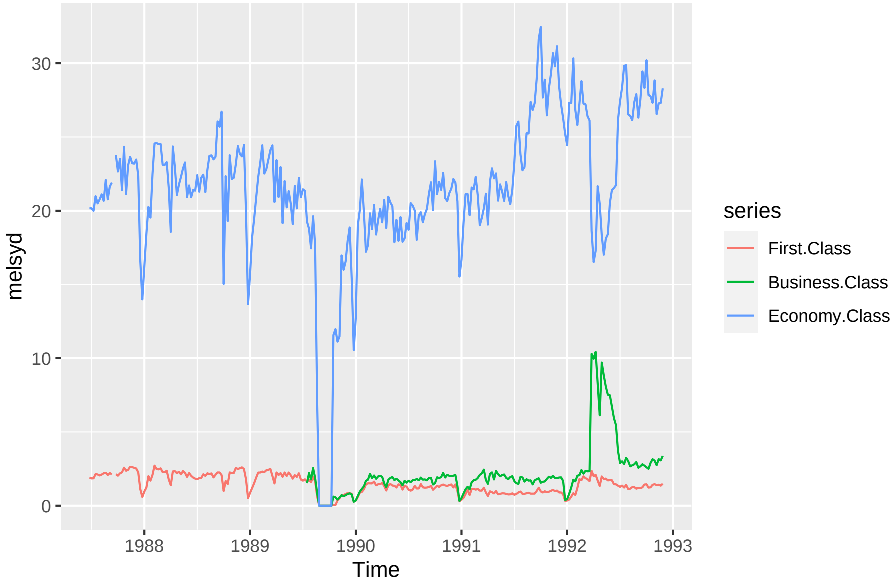
```
head(melsyd)
```

```
## Time Series:
## Start = c(1987, 26)
## End = c(1987, 31)
## Frequency = 52
##          First.Class Business.Class Economy.Class
## 1987.481       1.912             NA        20.167
## 1987.500       1.848             NA        20.161
## 1987.519       1.856             NA        19.993
## 1987.538       2.142             NA        20.986
## 1987.558       2.118             NA        20.497
## 1987.577       2.048             NA        20.770
```

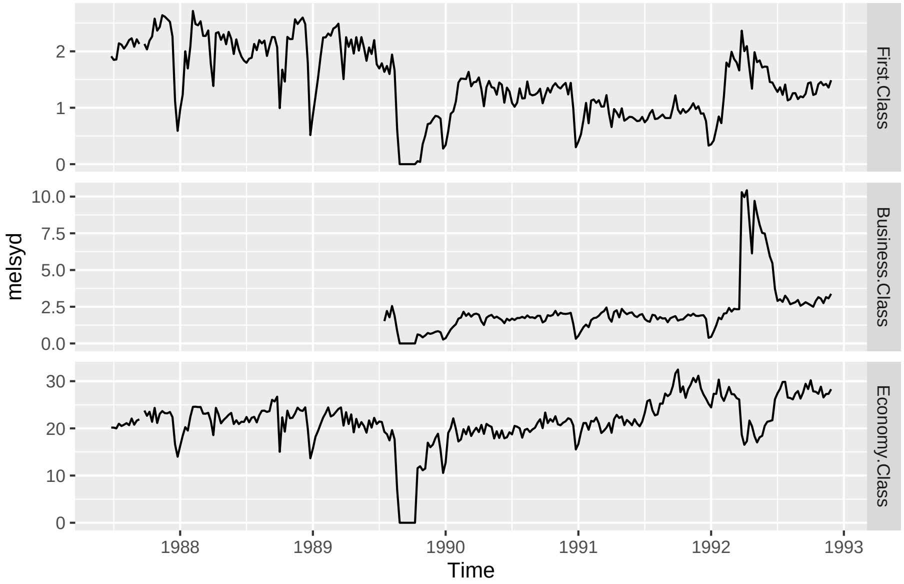
```
tail(melsyd)
```

```
## Time Series:
## Start = c(1992, 43)
## End = c(1992, 48)
## Frequency = 52
##          First.Class Business.Class Economy.Class
## 1992.808       1.417          3.152        27.322
## 1992.827       1.458          3.053        28.837
## 1992.846       1.398          2.745        26.548
## 1992.865       1.423          3.156        27.279
## 1992.885       1.358          3.069        27.306
## 1992.904       1.488          3.379        28.299
```

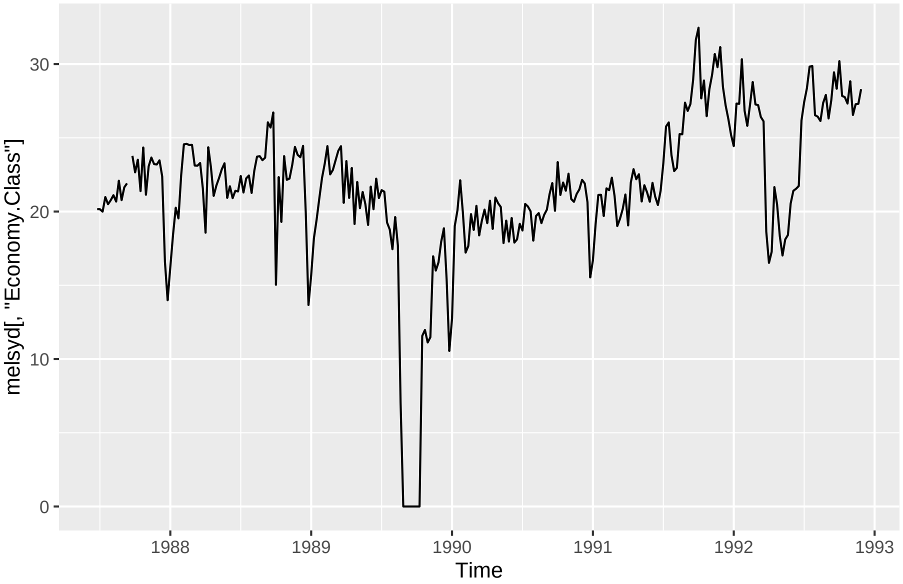
```
autoplot(melsyd)
```



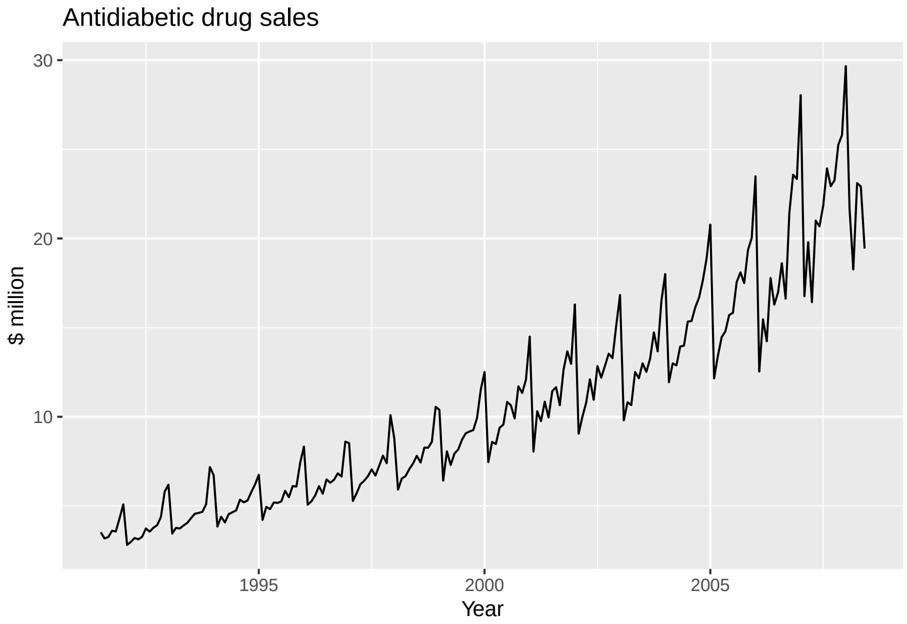
```r
autoplot(melsyd,facets = TRUE)
```



```
# Back to slides

  # Time plot
  autoplot(melsyd[,"Economy.Class"])
```



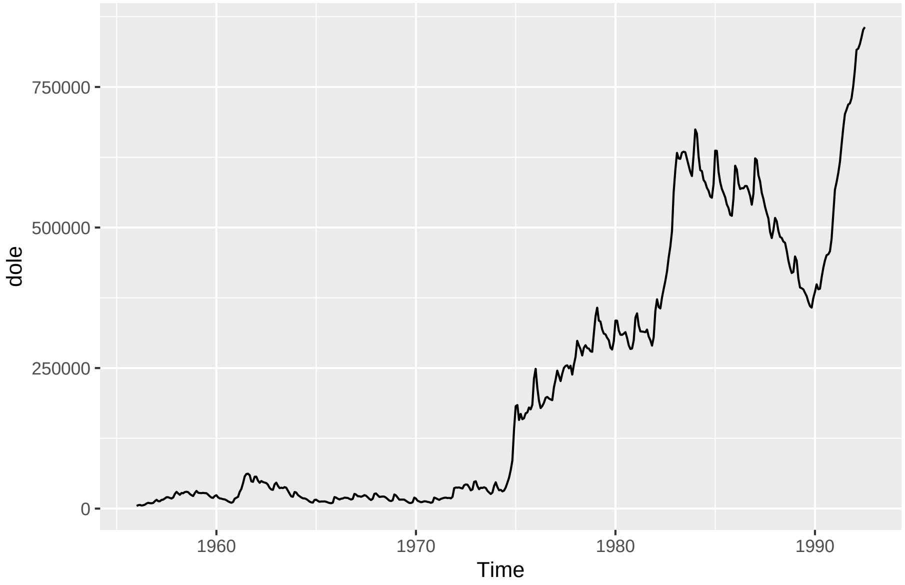
```
  # Adding main title and
  # also add labels to the x and y axes

  autoplot(a10) + ylab("$ million") + xlab("Year") +
    ggtitle("Antidiabetic drug sales")
```



```
?autoplot
```

```
## Help on topic 'autoplot' was found in the following packages:
##
##   Package               Library
##   forecast              /Library/Frameworks/R.framework/Versions/4.0/Resources/library
##   ggplot2               /Library/Frameworks/R.framework/Versions/4.0/Resources/library
##
##
## Using the first match ...
```

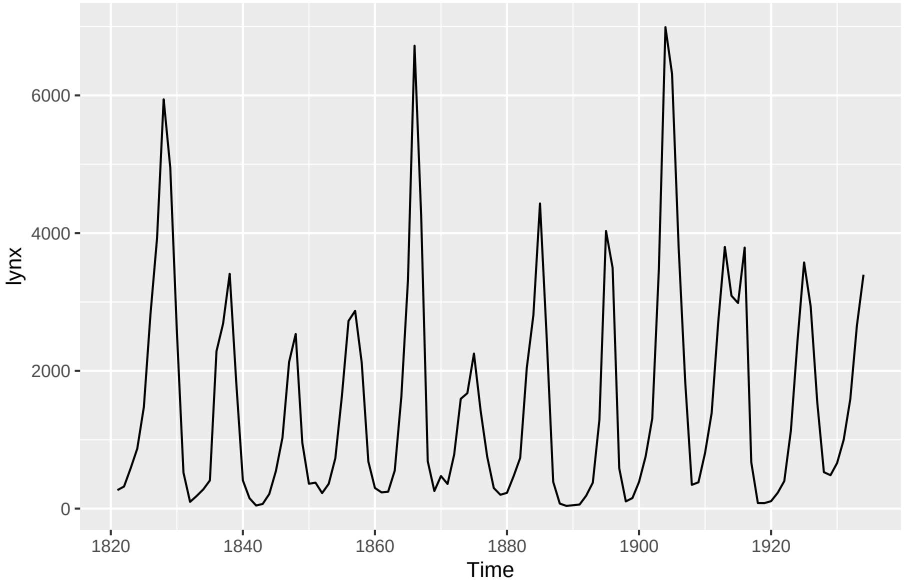
```
# Your turn

  ?dole
  autoplot(dole)
```



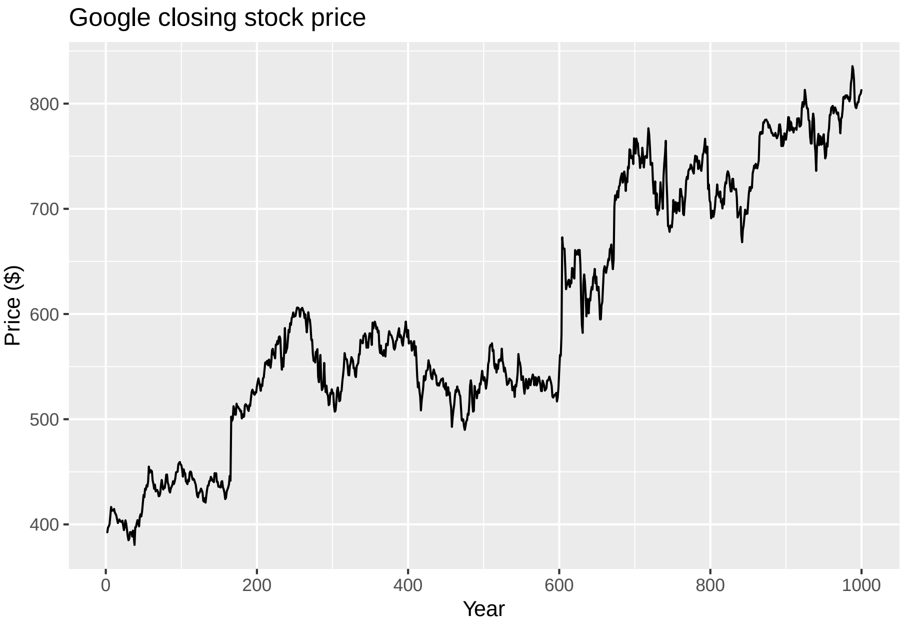
```
?lynx
```

```
## Help on topic 'lynx' was found in the following packages:
##
##   Package               Library
##   fma                   /Library/Frameworks/R.framework/Versions/4.0/Resources/libra
##   datasets              /Library/Frameworks/R.framework/Versions/4.0/Resources/libra
##
##
## Using the first match ...
```

```
autoplot(lynx)
```



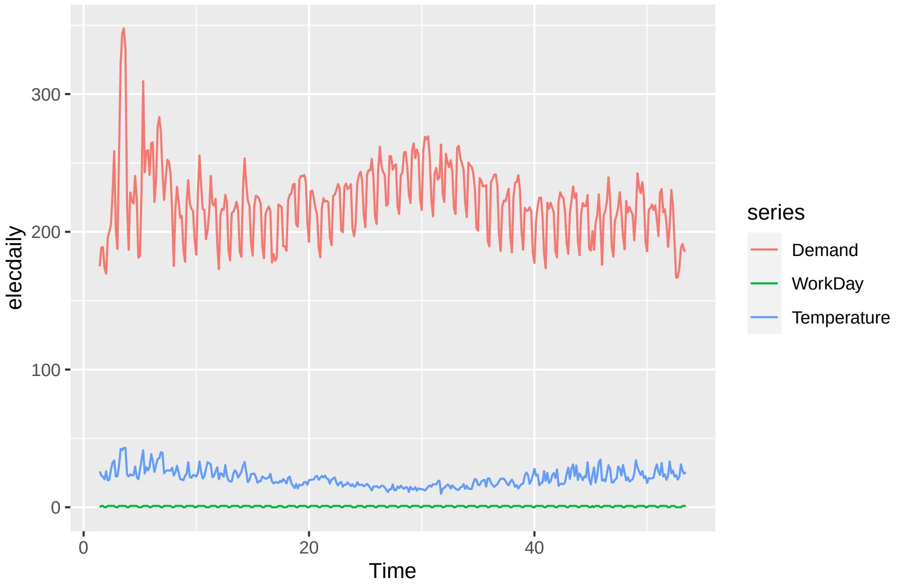
```
?goog

autoplot(goog)+
  xlab("Year") + ylab("Price ($)") +
  ggtitle("Google closing stock price")
```



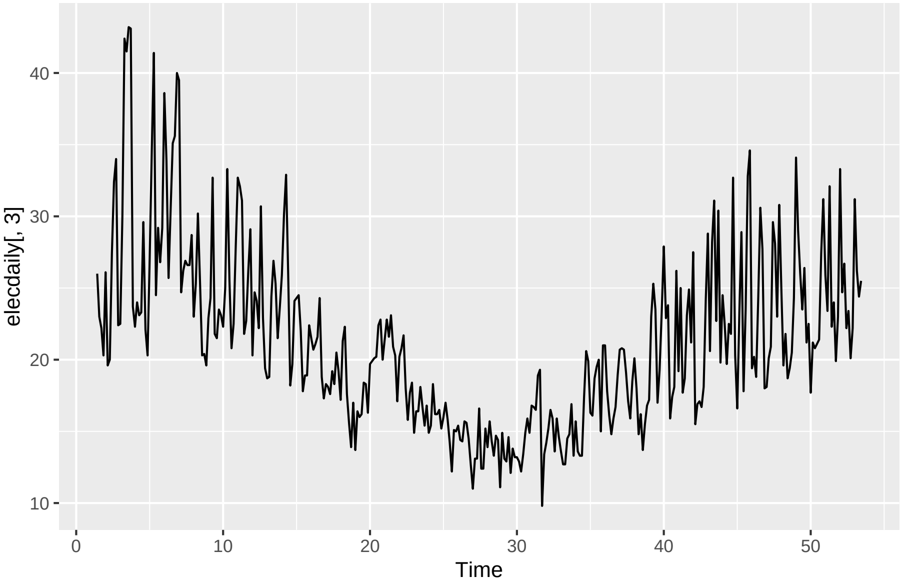
```
# Back to slides

  # The elecdaily data
  ?elecdaily
  head(elecdaily,15)
```

```
## Time Series:
## Start = c(1, 4)
## End = c(3, 4)
## Frequency = 7
##             Demand WorkDay Temperature
## 1.428571 174.8963       0        26.0
## 1.571429 188.5909       1        23.0
## 1.714286 188.9169       1        22.2
## 1.857143 173.8142       0        20.3
## 2.000000 169.5152       0        26.1
## 2.142857 195.7288       1        19.6
## 2.285714 199.9029       1        20.0
## 2.428571 205.3375       1        27.4
## 2.571429 228.0782       1        32.4
## 2.714286 258.5984       1        34.0
## 2.857143 201.7970       0        22.4
## 3.000000 187.6298       0        22.5
## 3.142857 254.6636       1        30.0
## 3.285714 322.2323       1         42.4
## 3.428571 343.9934       1         41.5
```

```
autoplot(elecdaily)
```



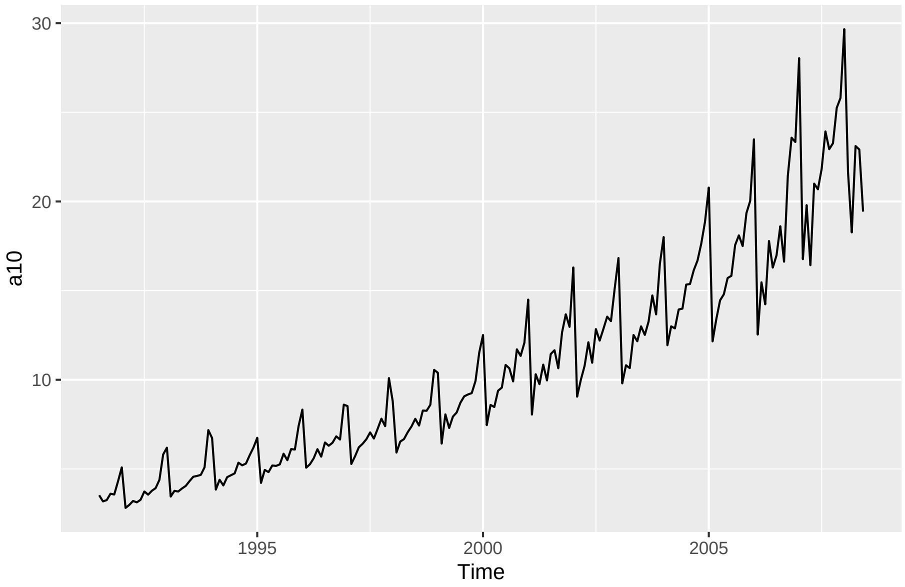
```
autoplot(elecdaily[,3])
```



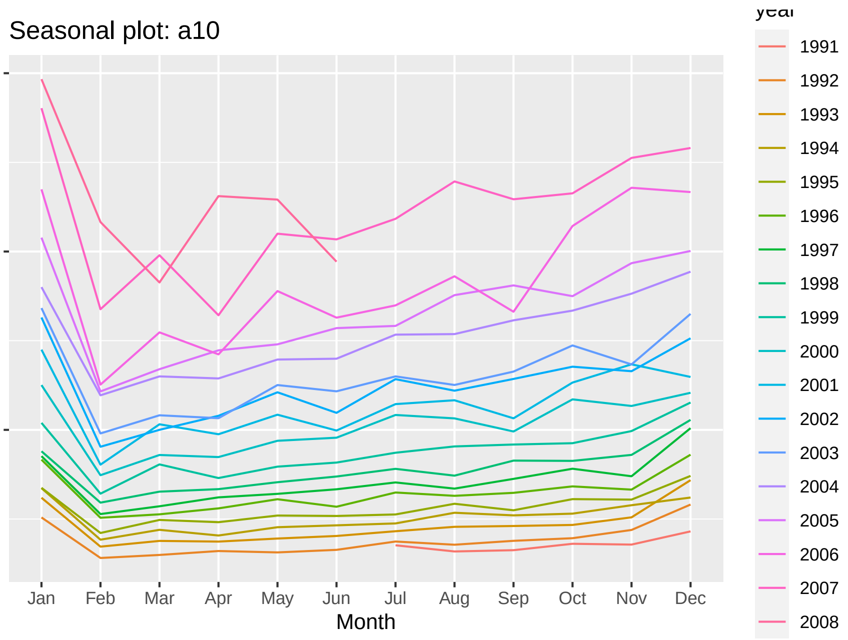
```
time(elecdaily)
```

```
## Time Series:
## Start = c(1, 4)
## End = c(53, 4)
## Frequency = 7
##   [1]  1.428571  1.571429  1.714286  1.857143  2.000000  2.142857  2.285714
##   [8]  2.428571  2.571429  2.714286  2.857143  3.000000  3.142857  3.285714
##  [15]  3.428571  3.571429  3.714286  3.857143  4.000000  4.142857  4.285714
##  [22]  4.428571  4.571429  4.714286  4.857143  5.000000  5.142857  5.285714
##  [29]  5.428571  5.571429  5.714286  5.857143  6.000000  6.142857  6.285714
##  [36]  6.428571  6.571429  6.714286  6.857143  7.000000  7.142857  7.285714
##  [43]  7.428571  7.571429  7.714286  7.857143  8.000000  8.142857  8.285714
##  [50]  8.428571  8.571429  8.714286  8.857143  9.000000  9.142857  9.285714
##  [57]  9.428571  9.571429  9.714286  9.857143 10.000000 10.142857 10.285714
##  [64] 10.428571 10.571429 10.714286 10.857143 11.000000 11.142857 11.285714
##  [71] 11.428571 11.571429 11.714286 11.857143 12.000000 12.142857 12.285714
##  [78] 12.428571 12.571429 12.714286 12.857143 13.000000 13.142857 13.285714
##  [85] 13.428571 13.571429 13.714286 13.857143 14.000000 14.142857 14.285714
##  [92] 14.428571 14.571429 14.714286 14.857143 15.000000 15.142857 15.285714
##  [99] 15.428571 15.571429 15.714286 15.857143 16.000000 16.142857 16.285714
## [106] 16.428571 16.571429 16.714286 16.857143 17.000000 17.142857 17.285714
## [113] 17.428571 17.571429 17.714286 17.857143 18.000000 18.142857 18.285714
## [120] 18.428571 18.571429 18.714286 18.857143 19.000000 19.142857 19.285714
## [127] 19.428571 19.571429 19.714286 19.857143 20.000000 20.142857 20.285714
## [134] 20.428571 20.571429 20.714286 20.857143 21.000000 21.142857 21.285714
## [141] 21.428571 21.571429 21.714286 21.857143 22.000000 22.142857 22.285714
## [148] 22.428571 22.571429 22.714286 22.857143 23.000000 23.142857 23.285714
## [155] 23.428571 23.571429 23.714286 23.857143 24.000000 24.142857 24.285714
## [162] 24.428571 24.571429 24.714286 24.857143 25.000000 25.142857 25.285714
## [169] 25.428571 25.571429 25.714286 25.857143 26.000000 26.142857 26.285714
## [176] 26.428571 26.571429 26.714286 26.857143 27.000000 27.142857 27.285714
## [183] 27.428571 27.571429 27.714286 27.857143 28.000000 28.142857 28.285714
## [190] 28.428571 28.571429 28.714286 28.857143 29.000000 29.142857 29.285714
## [197] 29.428571 29.571429 29.714286 29.857143 30.000000 30.142857 30.285714
## [204] 30.428571 30.571429 30.714286 30.857143 31.000000 31.142857 31.285714
## [211] 31.428571 31.571429 31.714286 31.857143 32.000000 32.142857 32.285714
## [218] 32.428571 32.571429 32.714286 32.857143 33.000000 33.142857 33.285714
## [225] 33.428571 33.571429 33.714286 33.857143 34.000000 34.142857 34.285714
## [232] 34.428571 34.571429 34.714286 34.857143 35.000000 35.142857 35.285714
## [239] 35.428571 35.571429 35.714286 35.857143 36.000000 36.142857 36.285714
## [246] 36.428571 36.571429 36.714286 36.857143 37.000000 37.142857 37.285714
## [253] 37.428571 37.571429 37.714286 37.857143 38.000000 38.142857 38.285714
## [260] 38.428571 38.571429 38.714286 38.857143 39.000000 39.142857 39.285714
## [267] 39.428571 39.571429 39.714286 39.857143 40.000000 40.142857 40.285714
## [274] 40.428571 40.571429 40.714286 40.857143 41.000000 41.142857 41.285714
## [281] 41.428571 41.571429 41.714286 41.857143 42.000000 42.142857 42.285714
## [288] 42.428571 42.571429 42.714286 42.857143 43.000000 43.142857 43.285714
## [295] 43.428571 43.571429 43.714286 43.857143 44.000000 44.142857 44.285714
## [302] 44.428571 44.571429 44.714286 44.857143 45.000000 45.142857 45.285714
## [309] 45.428571 45.571429 45.714286 45.857143 46.000000 46.142857 46.285714
## [316] 46.428571 46.571429 46.714286 46.857143 47.000000 47.142857 47.285714
## [323] 47.428571 47.571429 47.714286 47.857143 48.000000 48.142857 48.285714
## [330] 48.428571 48.571429 48.714286 48.857143 49.000000 49.142857 49.285714
## [337] 49.428571 49.571429 49.714286 49.857143 50.000000 50.142857 50.285714
## [344] 50.428571 50.571429 50.714286 50.857143 51.000000 51.142857 51.285714
## [351] 51.428571 51.571429 51.714286 51.857143 52.000000 52.142857 52.285714
## [358] 52.428571 52.571429 52.714286 52.857143 53.000000 53.142857 53.285714
## [365] 53.428571
```

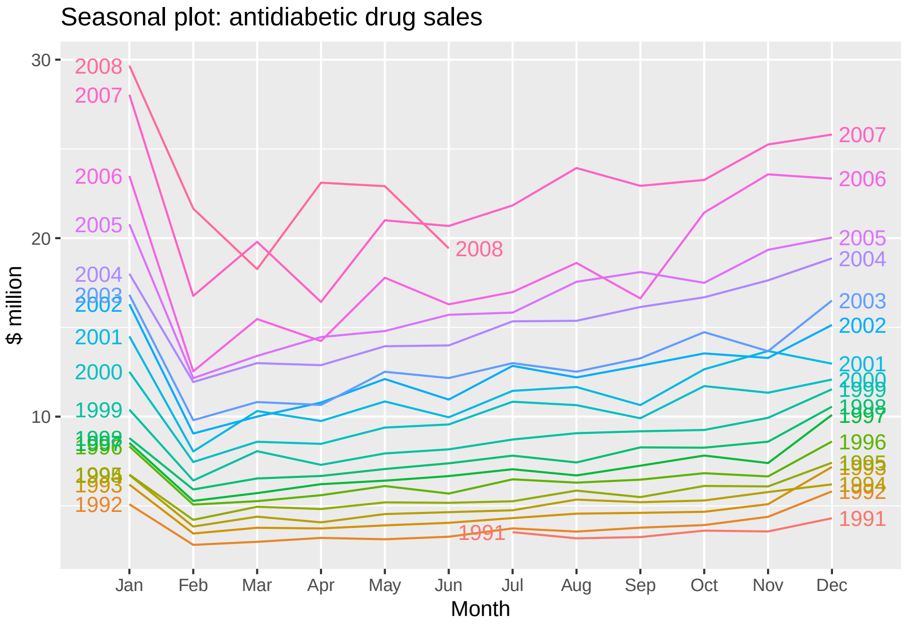
```r
# Seasonal plots

  autoplot(a10)
```



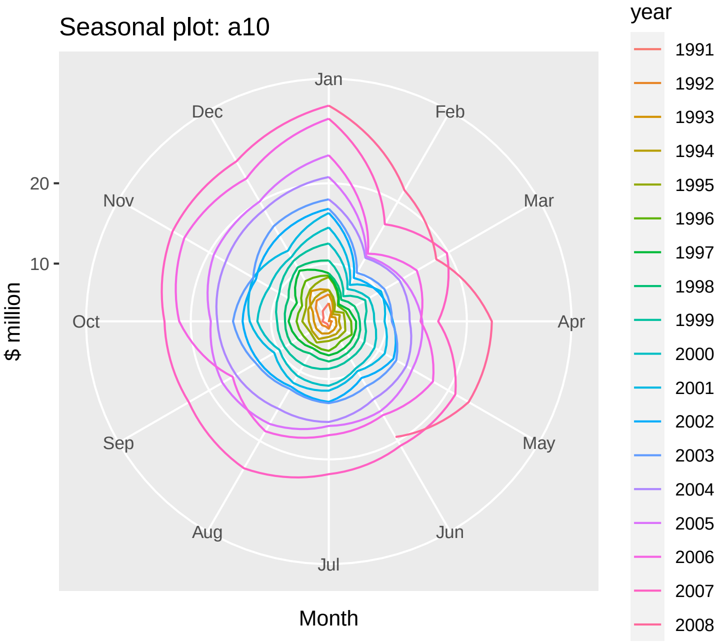
```
ggseasonplot(a10)
```



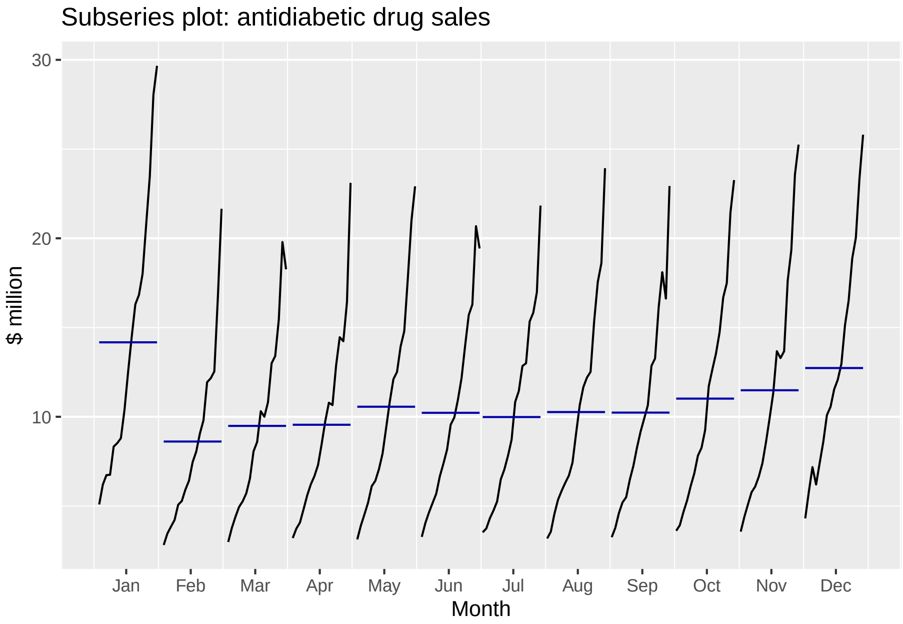
```
ggseasonplot(a10, year.labels=TRUE, year.labels.left=TRUE) +
  ylab("$ million") +
  ggtitle("Seasonal plot: antidiabetic drug sales")
```



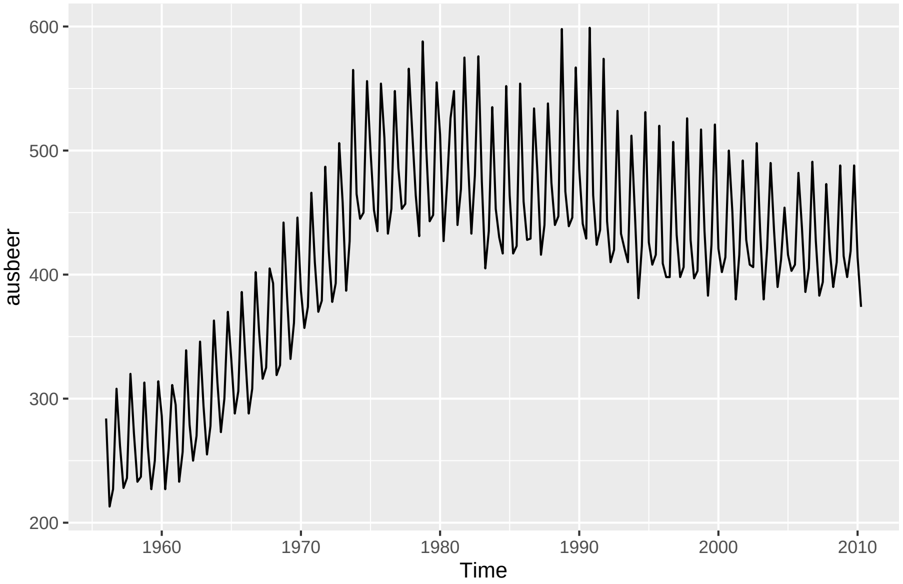
```
ggseasonplot(a10, polar=TRUE) + ylab("$ million")
```



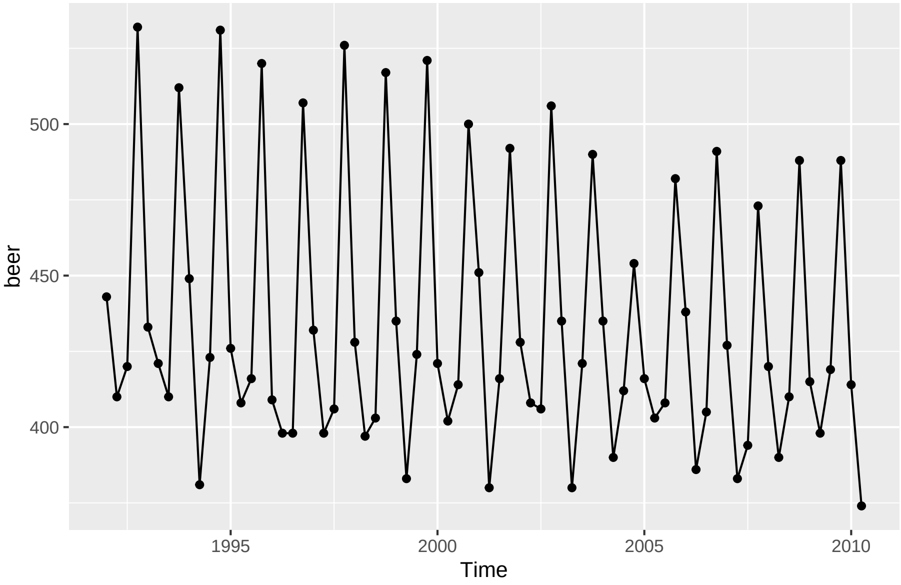
```r
# Seasonal subseries plots
  ggsubseriesplot(a10) + ylab("$ million") +
    ggtitle("Subseries plot: antidiabetic drug sales")
```



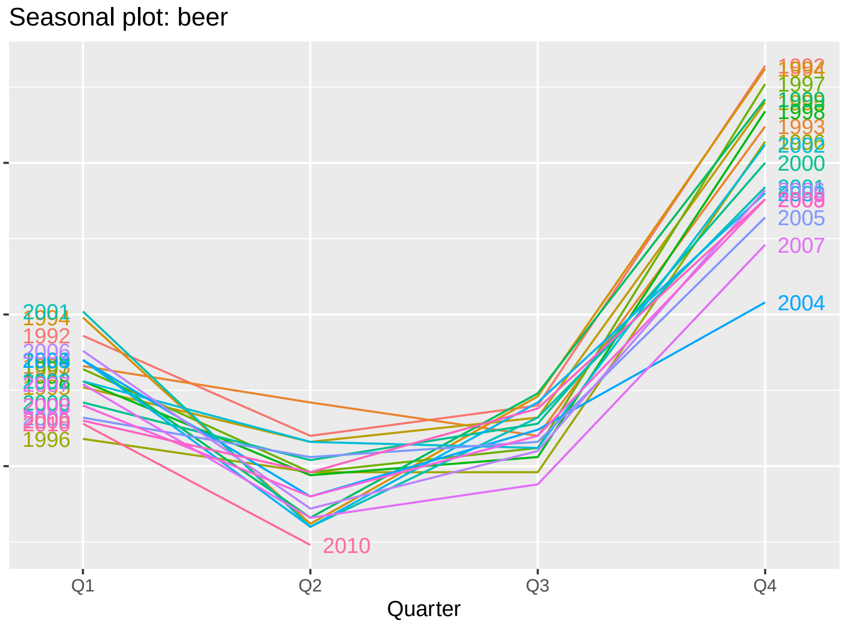
```
# Australian quarterly beer production 1956:Q1 to 2008:Q3.
  autoplot(ausbeer)
```



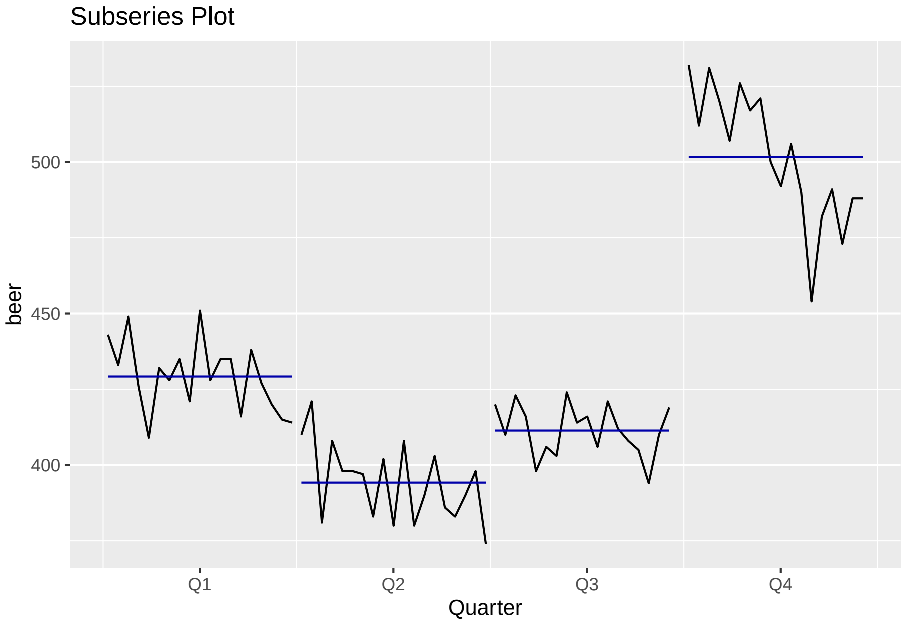
```
  # Take a window of it starting in 1992
  beer=window(ausbeer,start=1992)

  autoplot(beer)+geom_point()
```



```r
ggseasonplot(beer, year.labels=TRUE,
             year.labels.left=TRUE)
```



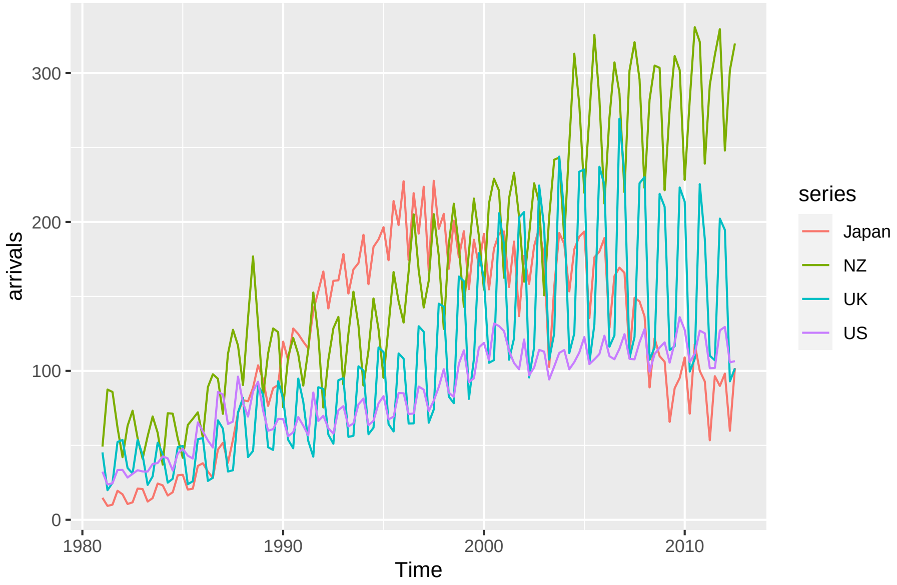
```
ggsubseriesplot(beer)+ggtitle("Subseries Plot")
```



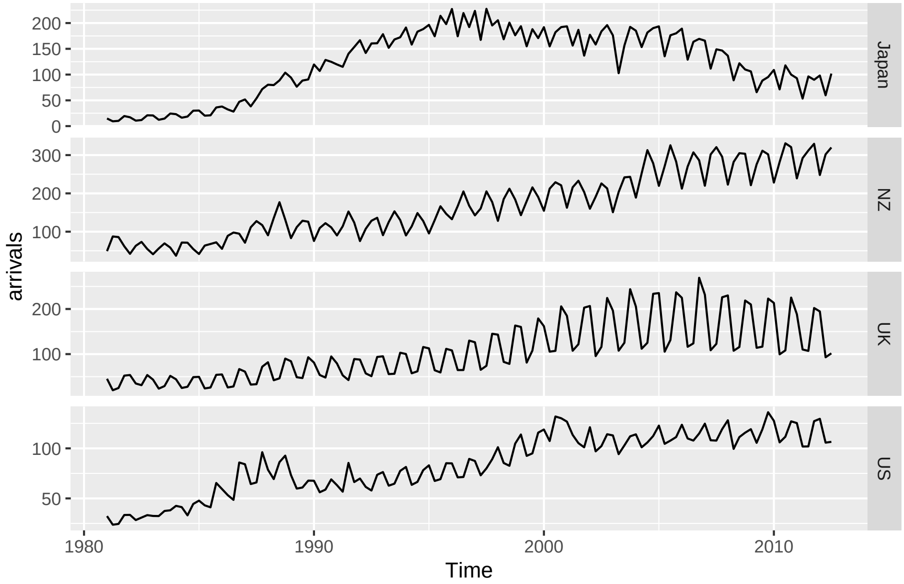
```
# Students to run arrivals code below
  # Your turn 1
  ?arrivals
  head(arrivals)
```

```
##           Japan     NZ     UK     US
## 1981 Q1 14.763 49.140 45.266 32.316
## 1981 Q2  9.321 87.467 19.886 23.721
## 1981 Q3 10.166 85.841 24.839 24.533
## 1981 Q4 19.509 61.882 52.264 33.438
## 1982 Q1 17.117 42.045 53.636 33.527
## 1982 Q2 10.617 63.081 34.802 28.366
```

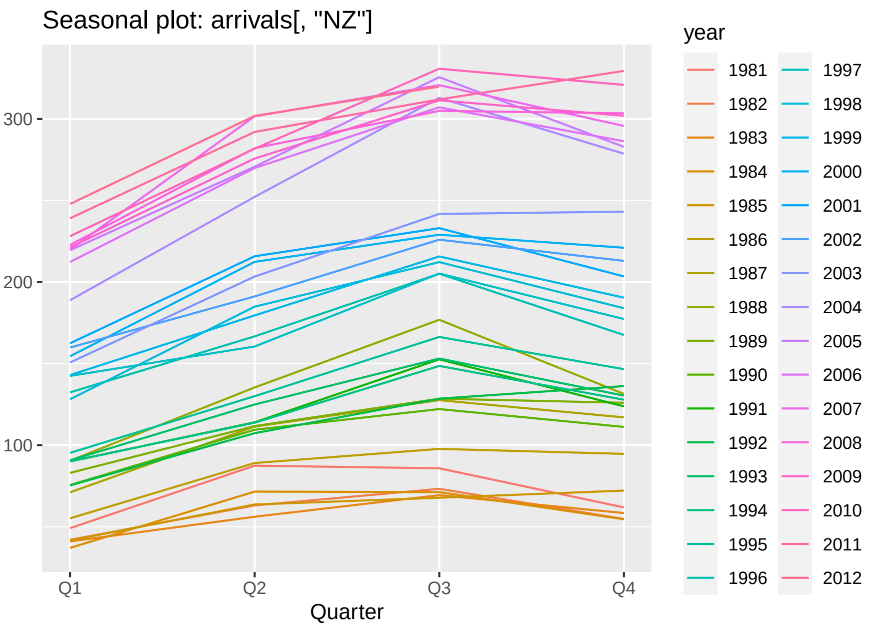
```
  autoplot(arrivals)
```



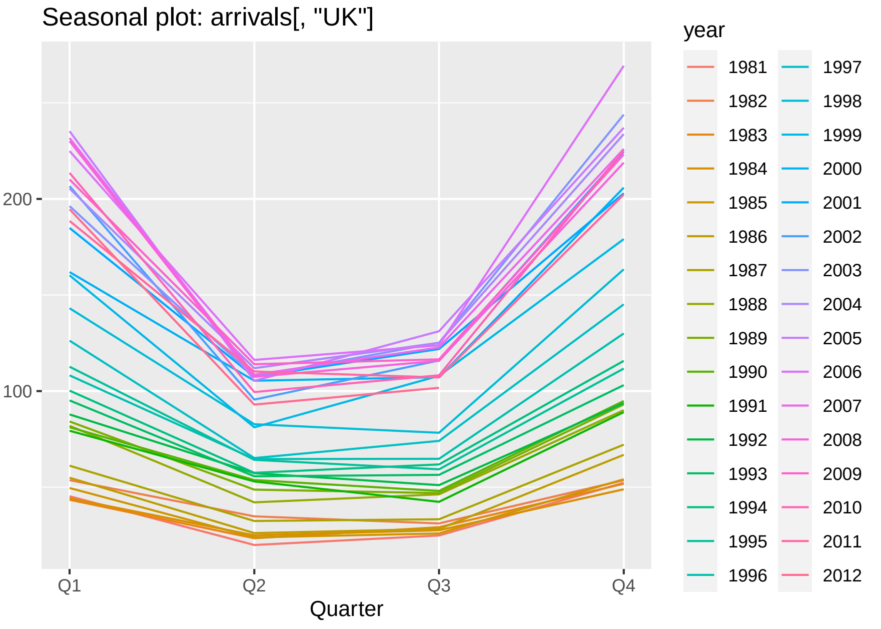
```r
autoplot(arrivals, facets = TRUE)
```



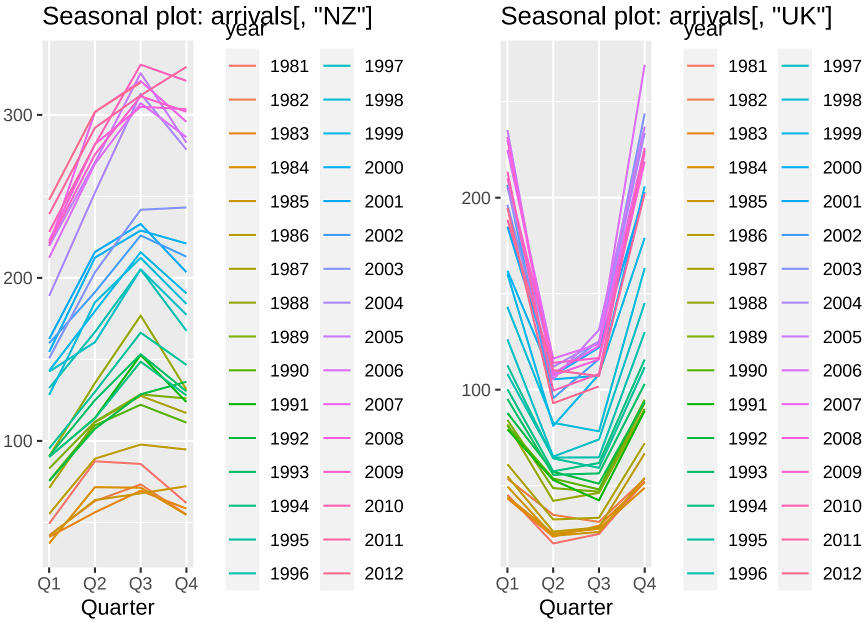
```r
ggseasonplot(arrivals[,"NZ"])
```



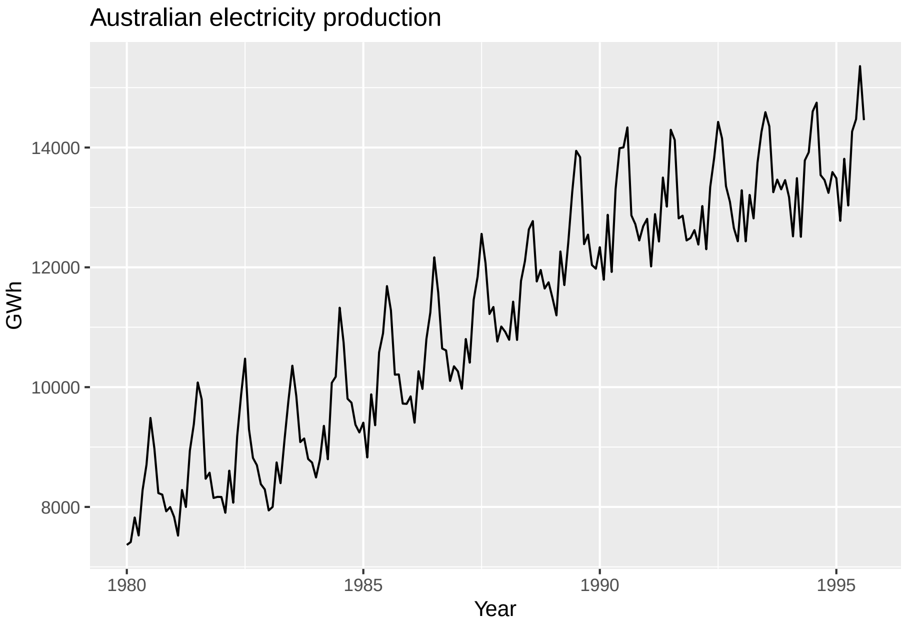
```r
ggseasonplot(arrivals[,"UK"])
```



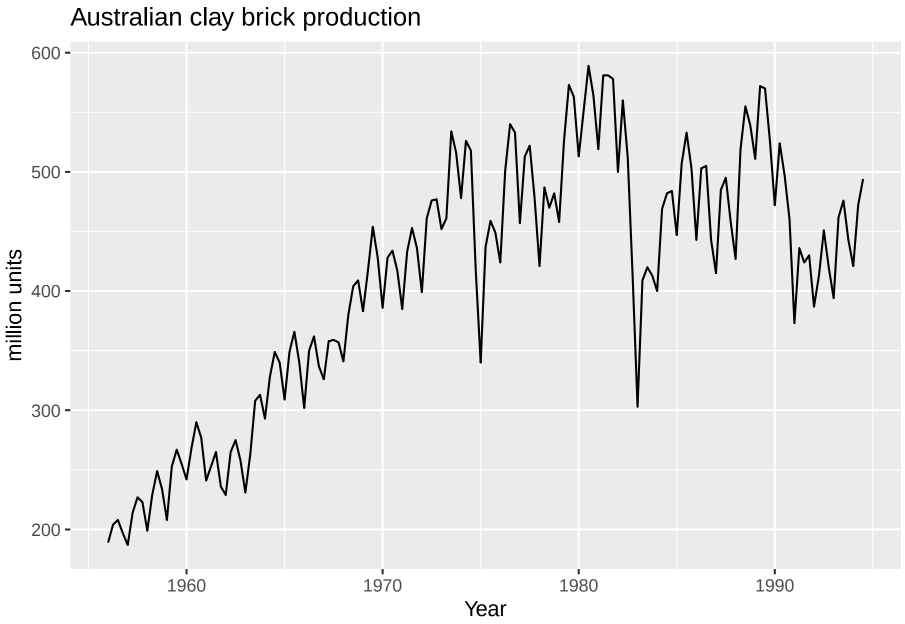
```
# Plot these together to have a closer look
p1 <- ggseasonplot(arrivals[,"NZ"])
p2 <- ggseasonplot(arrivals[,"UK"])
gridExtra::grid.arrange(p1,p2,nrow=1)
```



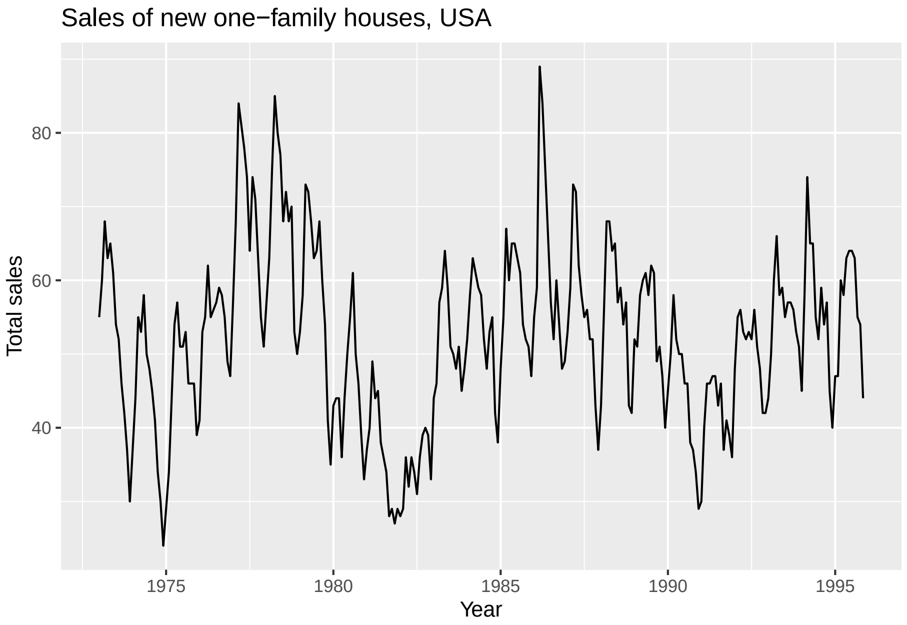
```
#Back to lecture slides

  # Time series patterns
  autoplot(window(elec, start=1980)) +
    ggtitle("Australian electricity production") +
    xlab("Year") + ylab("GWh")
```



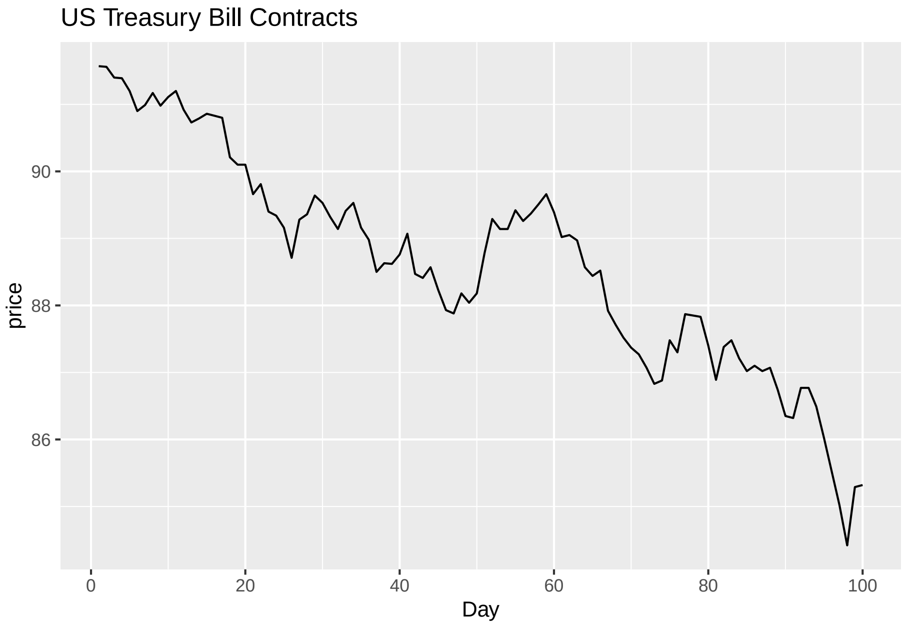
```r
autoplot(bricksq) +
  ggtitle("Australian clay brick production") +
  xlab("Year") + ylab("million units")
```



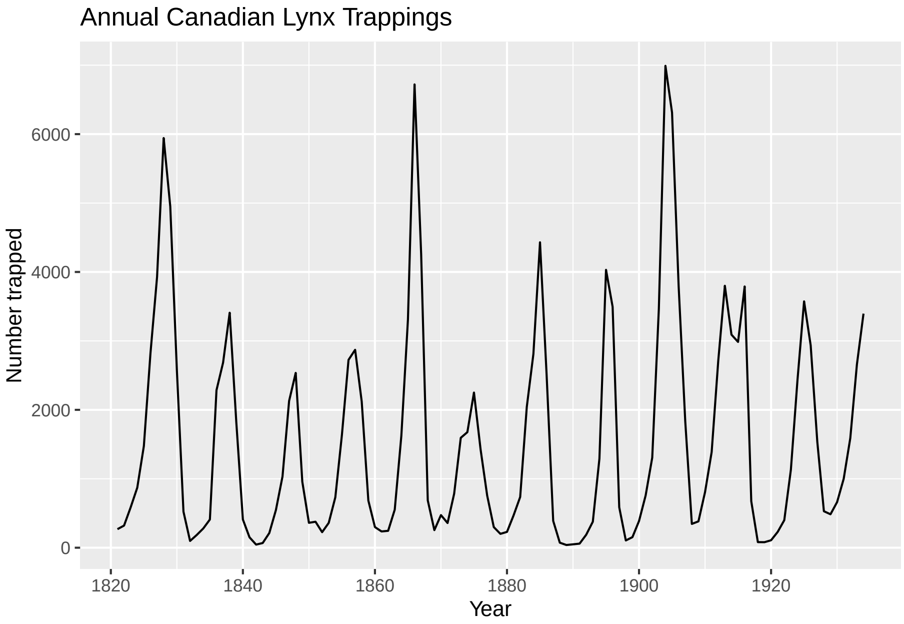
```
autoplot(hsales) +
  ggtitle("Sales of new one-family houses, USA") +
  xlab("Year") + ylab("Total sales")
```



```
autoplot(ustreas) +
  ggtitle("US Treasury Bill Contracts") +
  xlab("Day") + ylab("price")
```



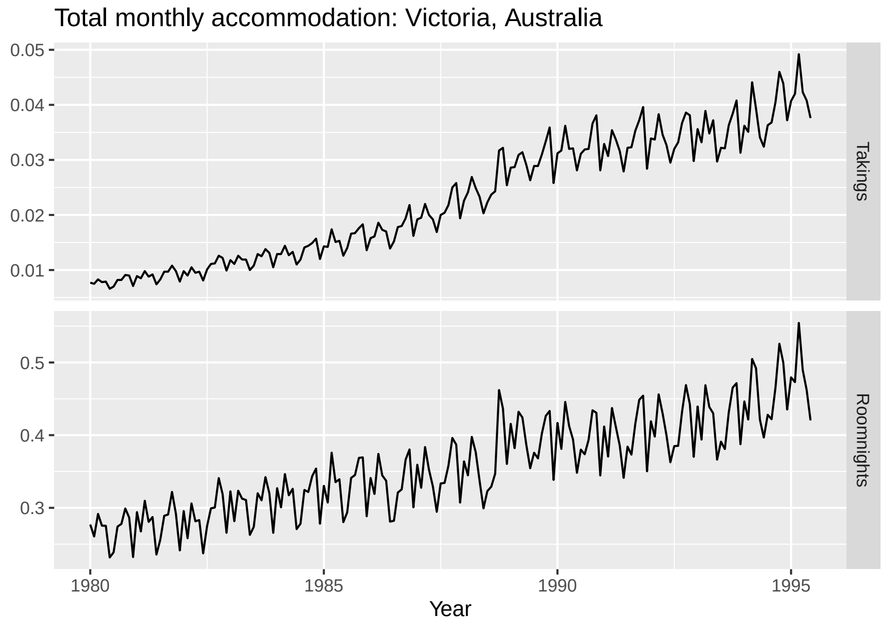
```r
autoplot(lynx) +
  ggtitle("Annual Canadian Lynx Trappings") +
  xlab("Year") + ylab("Number trapped")
```



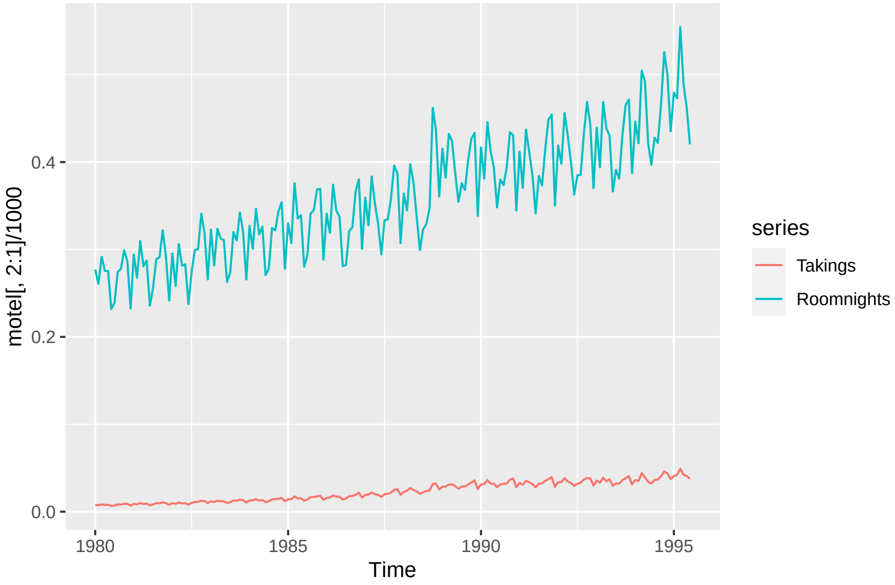
```
#Back to lecture slides

# Scatterplots
  head(motel)
```

```
##          Roomnights Takings
## Jan 1980      277.0     7.7
## Feb 1980      260.6     7.5
## Mar 1980      291.6     8.3
## Apr 1980      275.4     7.8
## May 1980      275.3     7.9
## Jun 1980      231.7     6.6
```

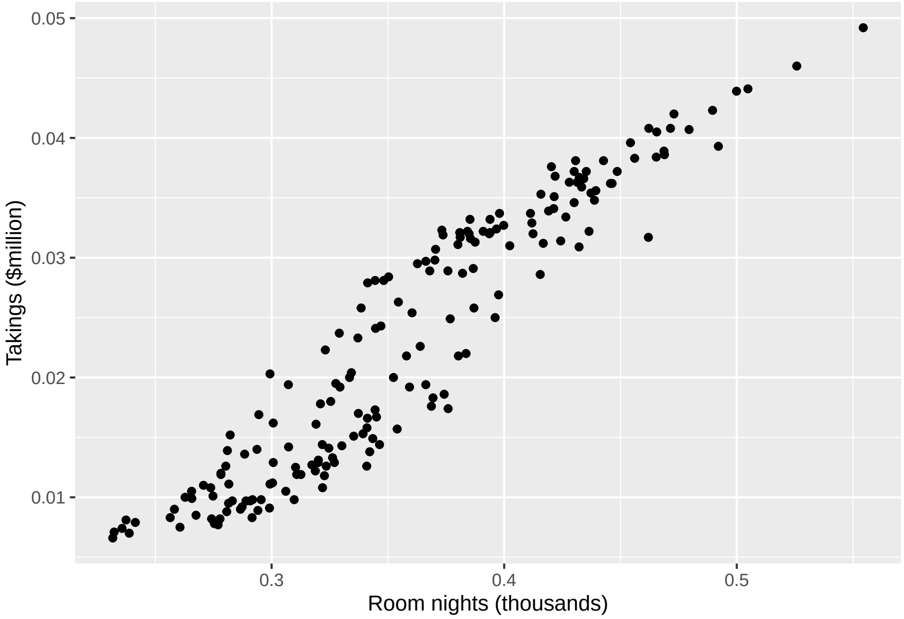
```
    autoplot(motel[,2:1]/1000, facet=TRUE) +
    xlab("Year") + ylab("") +
    ggtitle("Total monthly accommodation: Victoria, Australia")
```



```
    # See what happens without the facet=TRUE argument
    autoplot(motel[,2:1]/1000)
```



```
  # doesn't make much sense because of the differences in scale

qplot(Roomnights/1000, Takings/1000, data=as.data.frame(motel)) +
  ylab("Takings ($million)") + xlab("Room nights (thousands)")
```



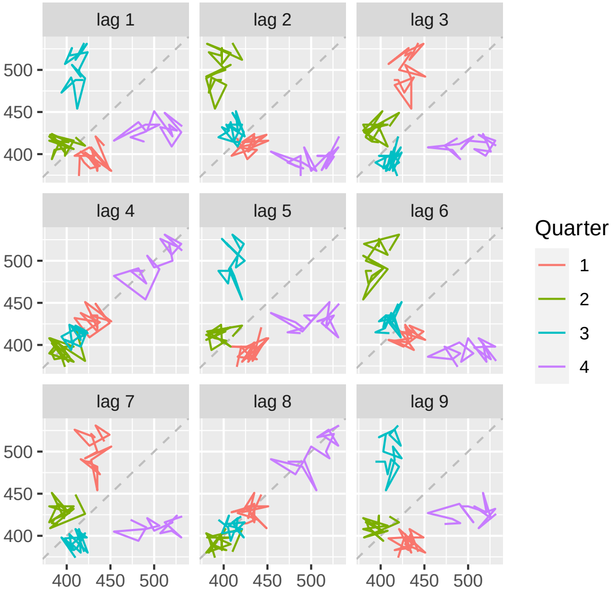
```r
  head(motel)
```

```
##          Roomnights Takings
## Jan 1980      277.0     7.7
## Feb 1980      260.6     7.5
## Mar 1980      291.6     8.3
## Apr 1980      275.4     7.8
## May 1980      275.3     7.9
## Jun 1980      231.7     6.6
```

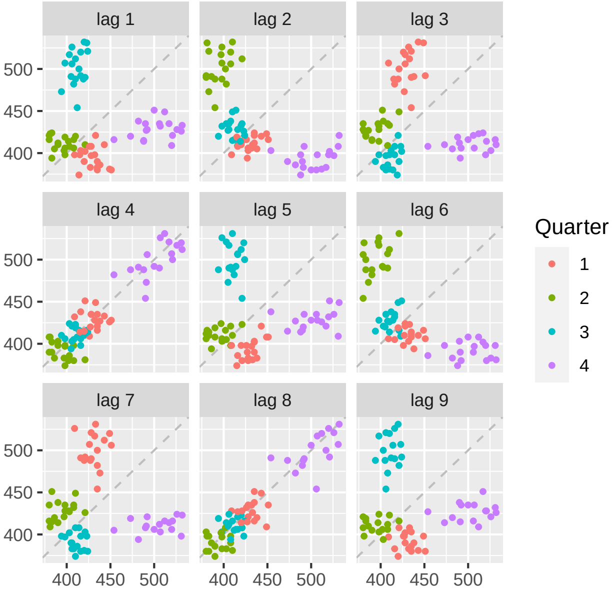
```r
  head(as.data.frame(motel))
```

```
##   Roomnights Takings
## 1      277.0     7.7
## 2      260.6     7.5
## 3      291.6     8.3
## 4      275.4     7.8
## 5      275.3     7.9
## 6      231.7     6.6
```

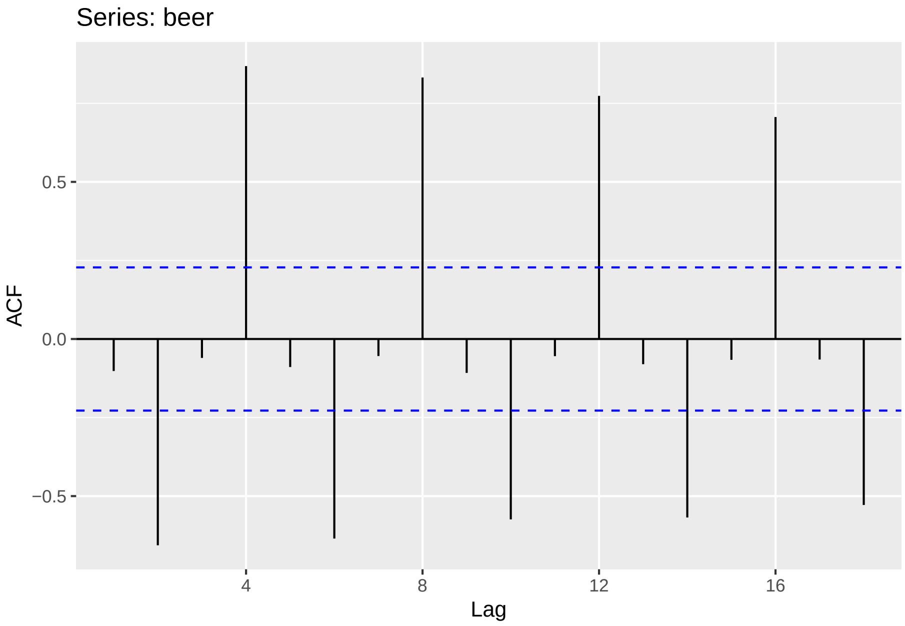
```r
#Back to slides

# Lag plots and autocorrelation
  beer <- window(ausbeer, start=1992)
  gglagplot(beer, lags=9)
```



```
# What does the 'do.lines=FALSE' do?
gglagplot(beer, lags=9, do.lines=FALSE)
```



```
# ACF
  ggAcf(beer) #from forecast package
```



```
  r<-ggAcf(beer)
  attributes(r)
```

```
## $names
## [1] "data"        "layers"      "scales"      "mapping"     "theme"
## [6] "coordinates" "facet"       "plot_env"    "labels"
##
## $class
## [1] "gg"     "ggplot"
```

```
  r$data
```

```
##    Var2 Var3        Freq lag
## 2     A    A -0.10190904   1
## 3     A    A -0.65661956   2
## 4     A    A -0.06027634   3
## 5     A    A  0.86852930   4
## 6     A    A -0.08915021   5
## 7     A    A -0.63513179   6
## 8     A    A -0.05416215   7
## 9      A     A  0.83224495   8
## 10     A     A -0.10787557   9
## 11     A     A -0.57419959  10
## 12     A     A -0.05460320  11
## 13     A     A  0.77379390  12
## 14     A     A -0.08019609  13
## 15     A     A -0.56805745  14
## 16     A     A -0.06626388  15
## 17     A     A  0.70642954  16
## 18     A     A -0.06535949  17
## 19     A     A -0.52825861  18
```

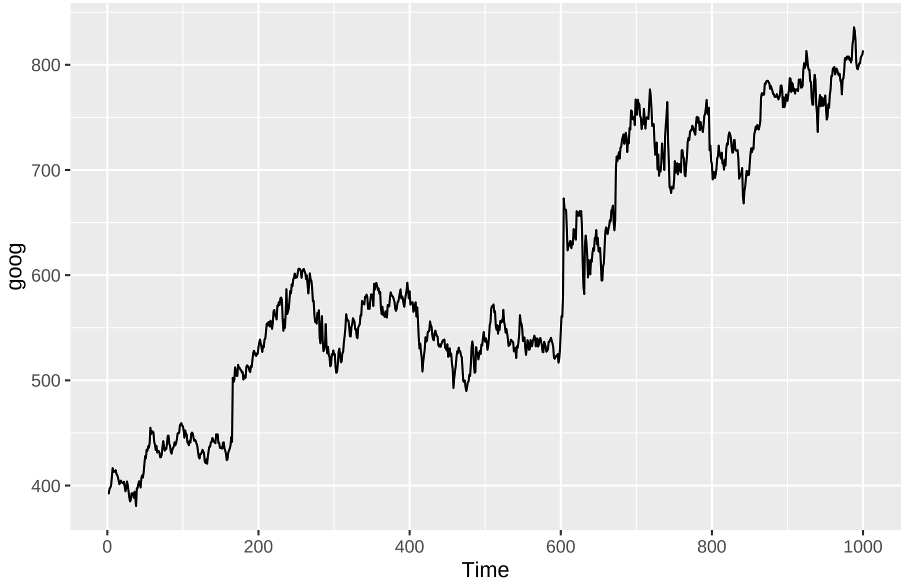
```
  r$data$Freq
```

```
##  [1] -0.10190904 -0.65661956 -0.06027634  0.86852930 -0.08915021 -0.63513179
##  [7] -0.05416215  0.83224495 -0.10787557 -0.57419959 -0.05460320  0.77379390
## [13] -0.08019609 -0.56805745 -0.06626388  0.70642954 -0.06535949 -0.52825861
```

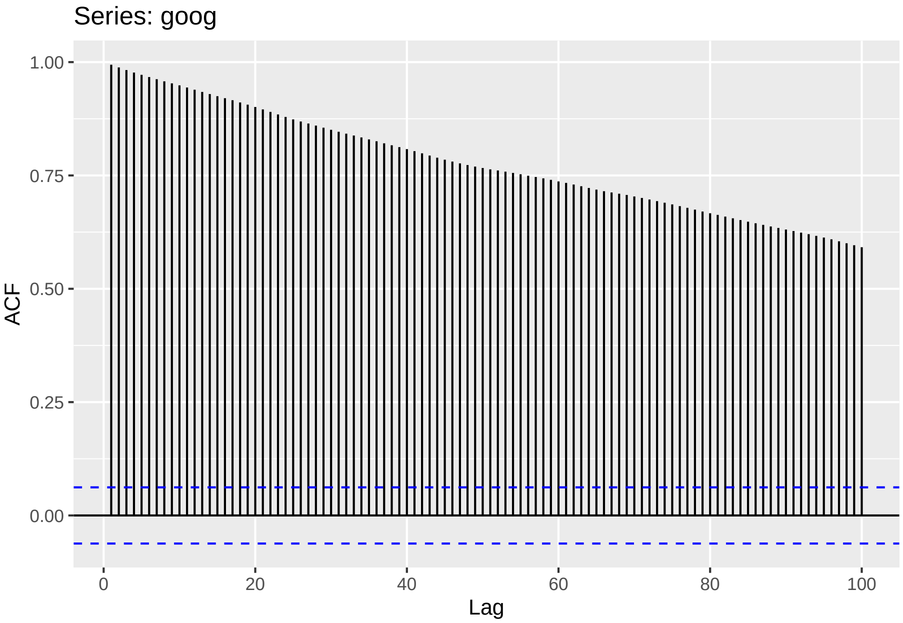
```
  r$data$Freq[4]
```

```
## [1] 0.8685293
```

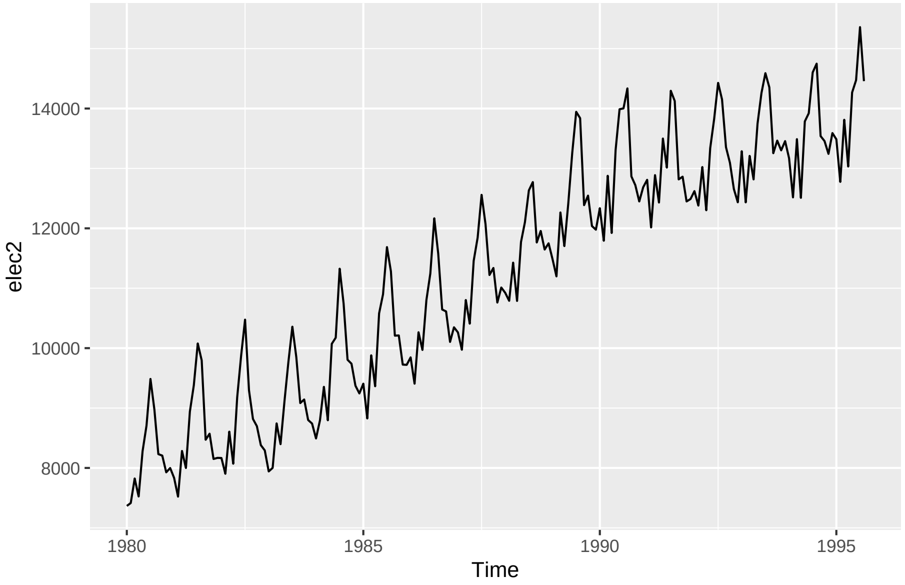
```
# Back to slides

  autoplot(goog)
```



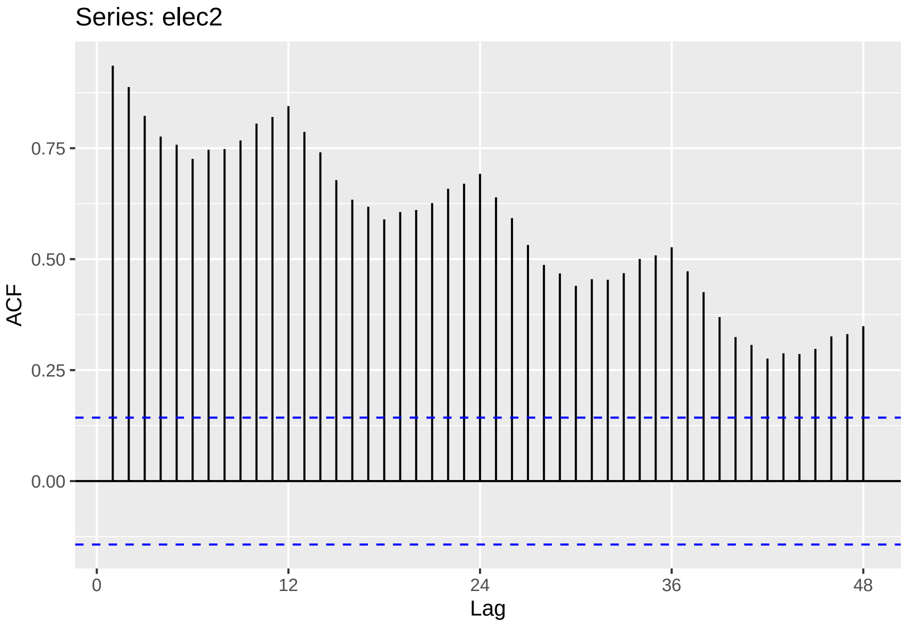
```
ggAcf(goog, lag.max=100)
```



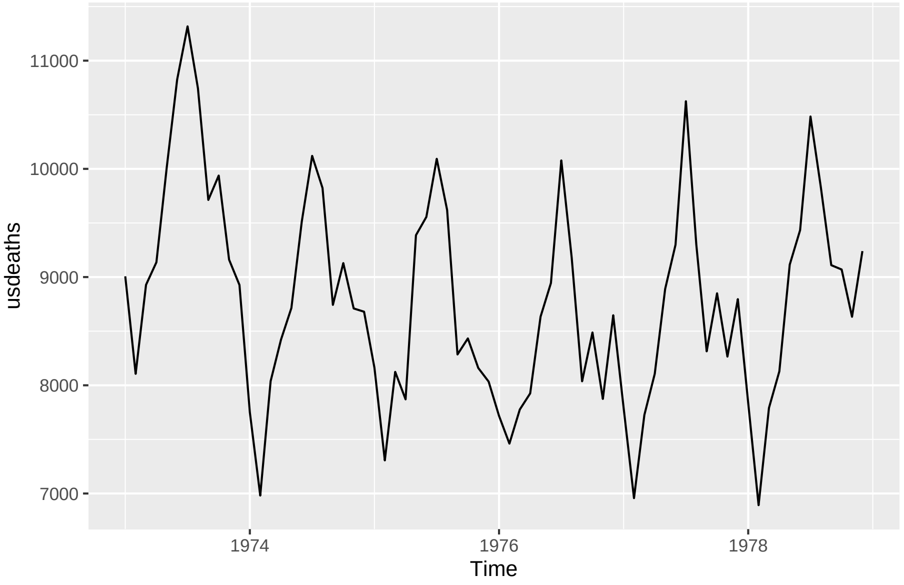
```
elec2 <- window(elec, start=1980)
autoplot(elec2)
```



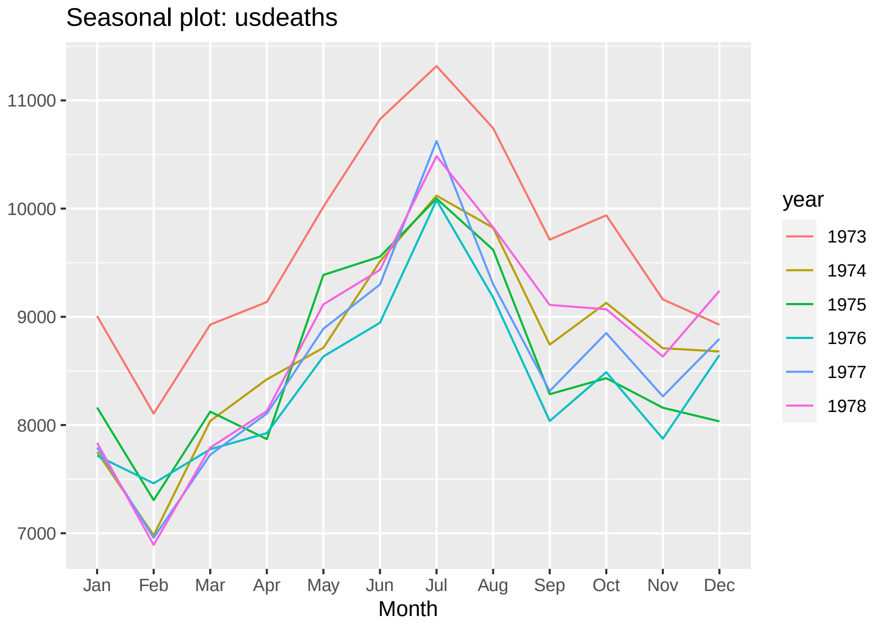
```
ggAcf(elec2, lag.max=48)
```



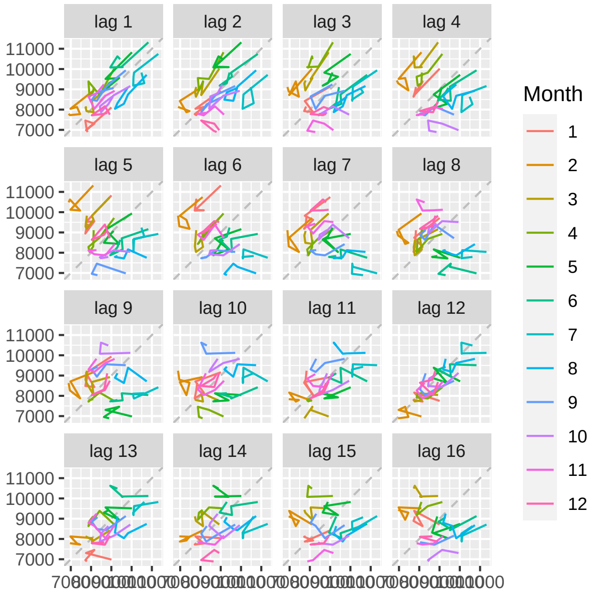
```r
# Students to run
  ?usdeaths
  autoplot(usdeaths)
```



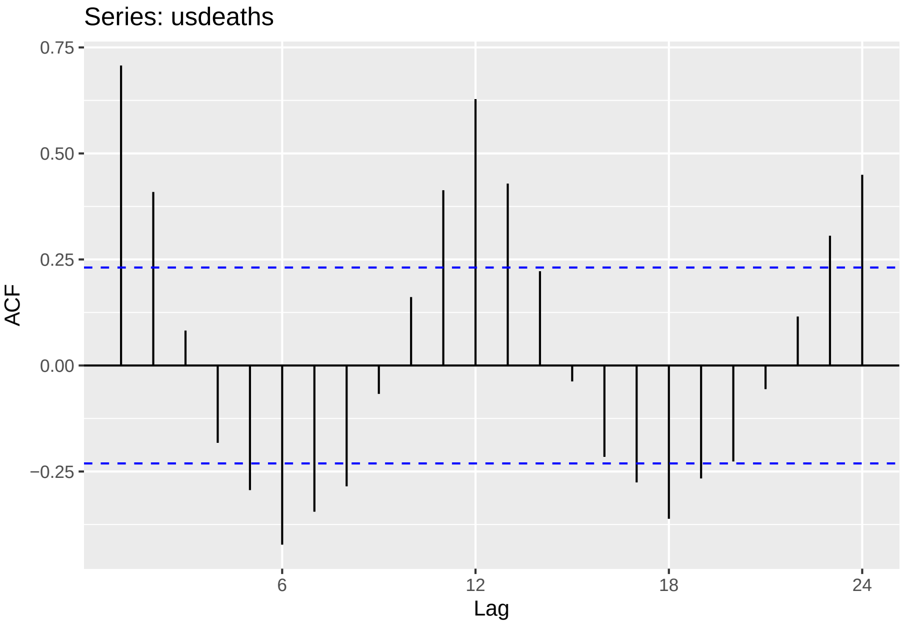
```r
  ggseasonplot(usdeaths)
```



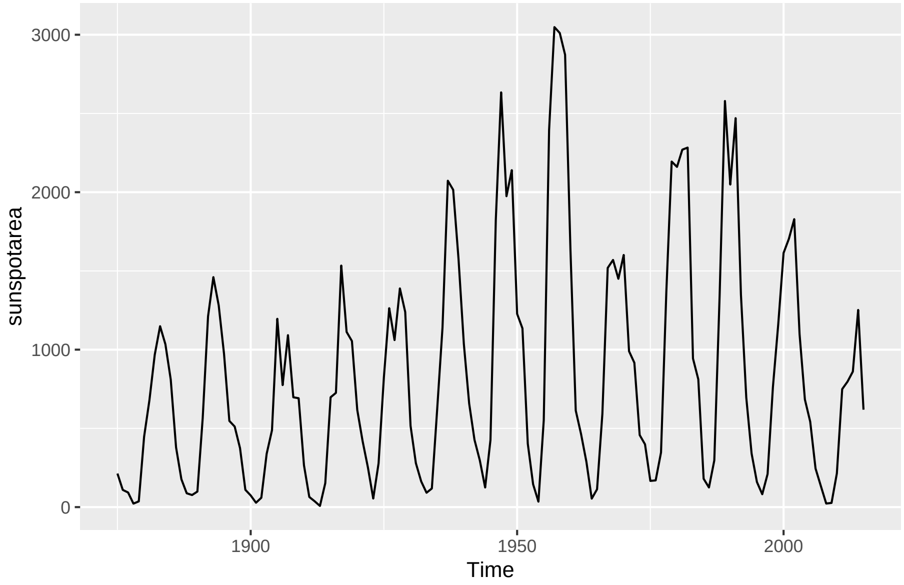
```
gglagplot(usdeaths)
```



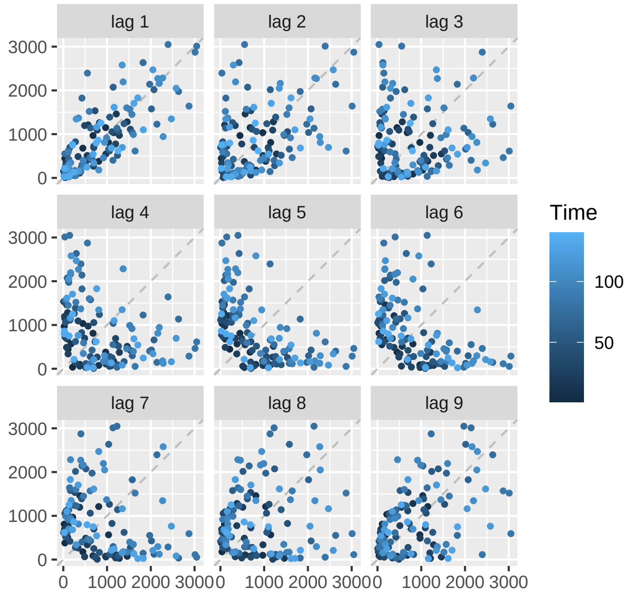
```
ggAcf(usdeaths)
```



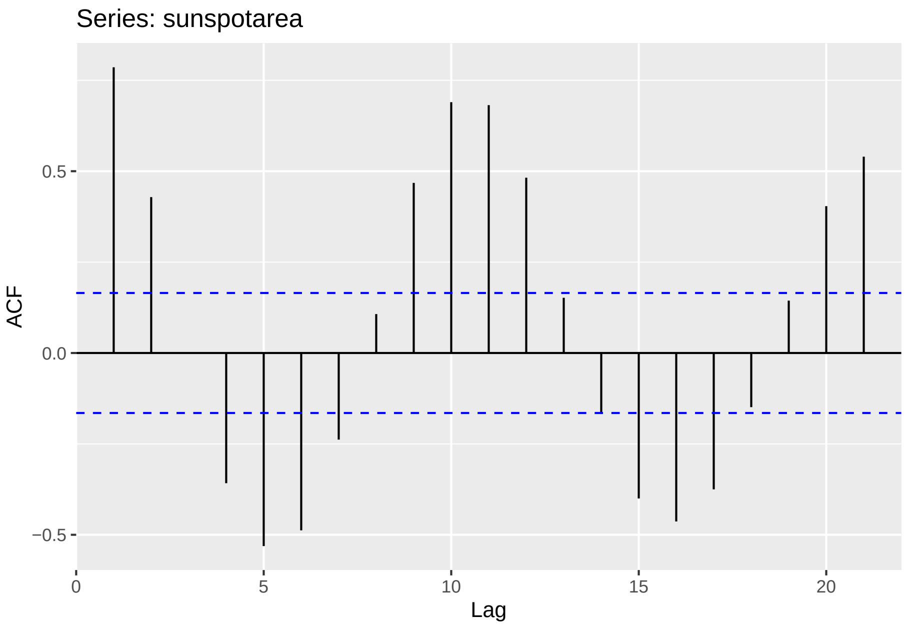
```
?sunspotarea
autoplot(sunspotarea)
```



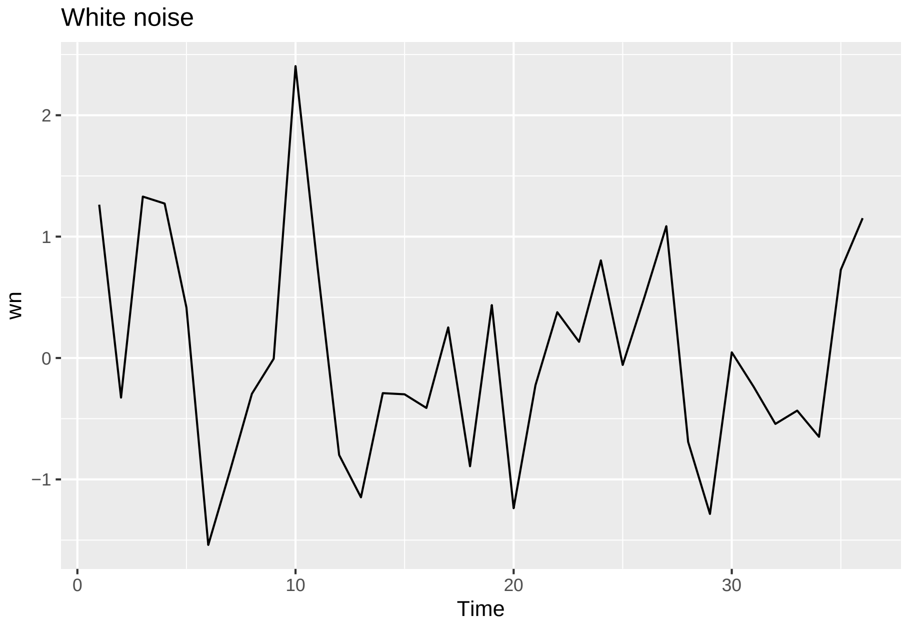
```r
gglagplot(sunspotarea, do.lines=FALSE)
```



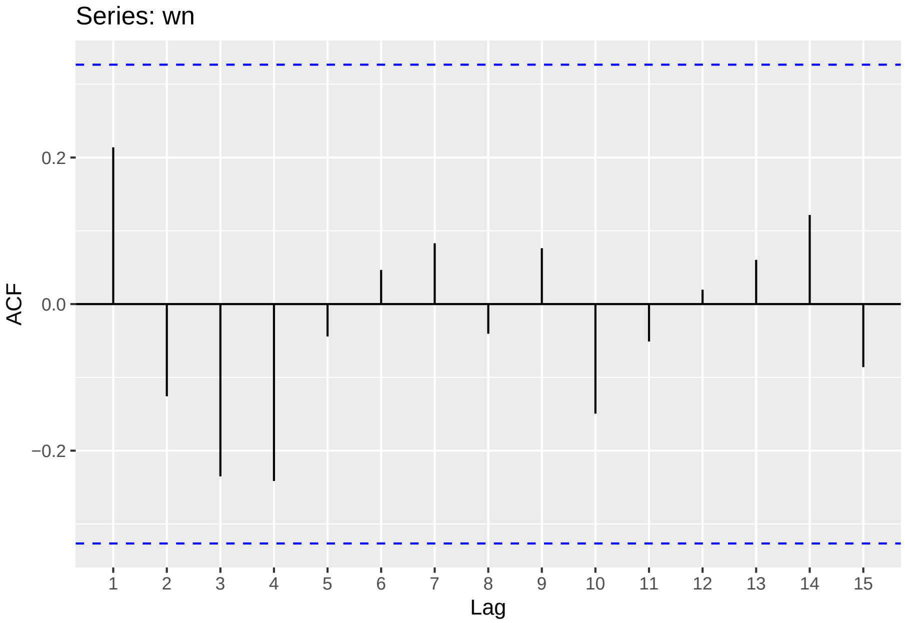
```
ggAcf(sunspotarea)
```



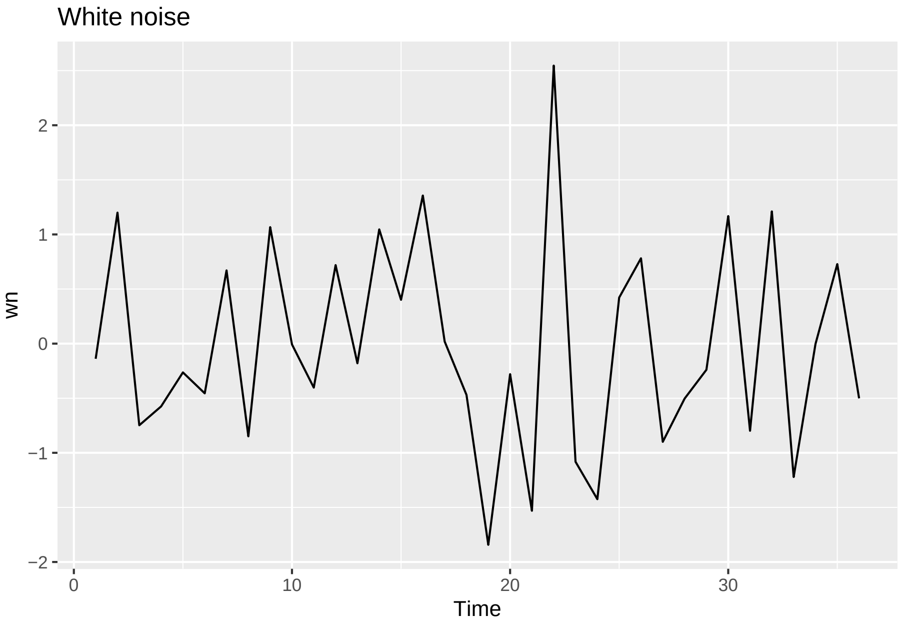
```
# bAck to slides.

# White noise

  # Set the seed for the random number generator in R
  # This guarantees the same random numbers every time

  set.seed(0)
  wn <- ts(rnorm(36)) #rnorm(n, mean = 0, sd = 1)
  autoplot(wn)+ggtitle("White noise")
```


White noise
wn
2
1
0
−1
0
10
20
30
Time

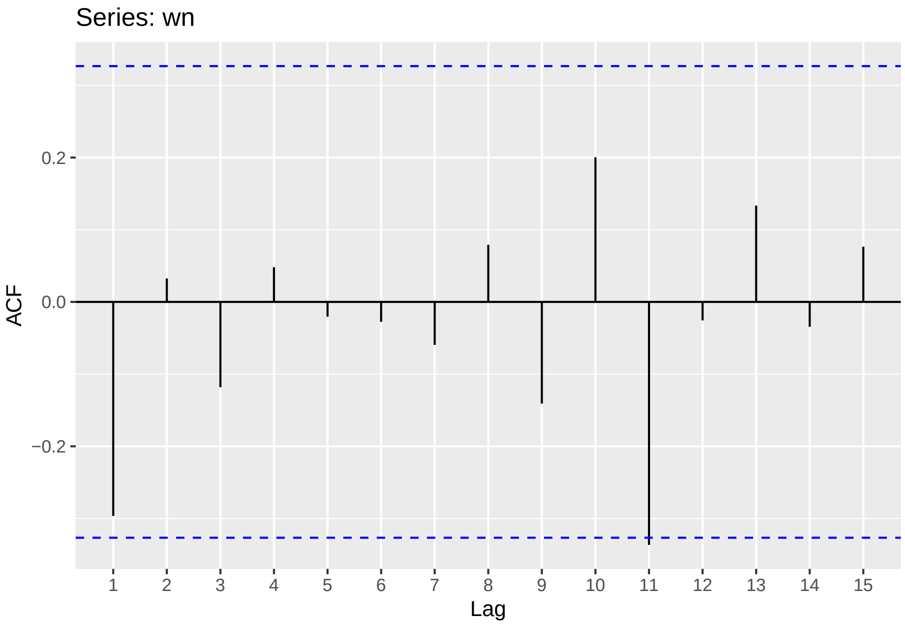
```r
ggAcf(wn)
```


Series: wn
ACF
0.2
0.0
−0.2
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Lag

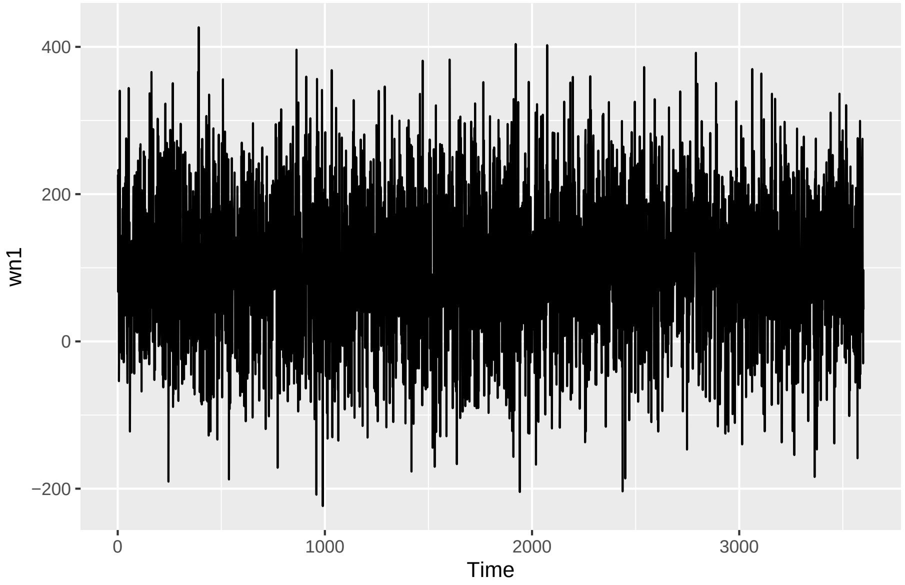
```
set.seed(34)
wn <- ts(rnorm(36)) #rnorm(n, mean = 0, sd = 1)
autoplot(wn)+ggtitle("White noise")
```



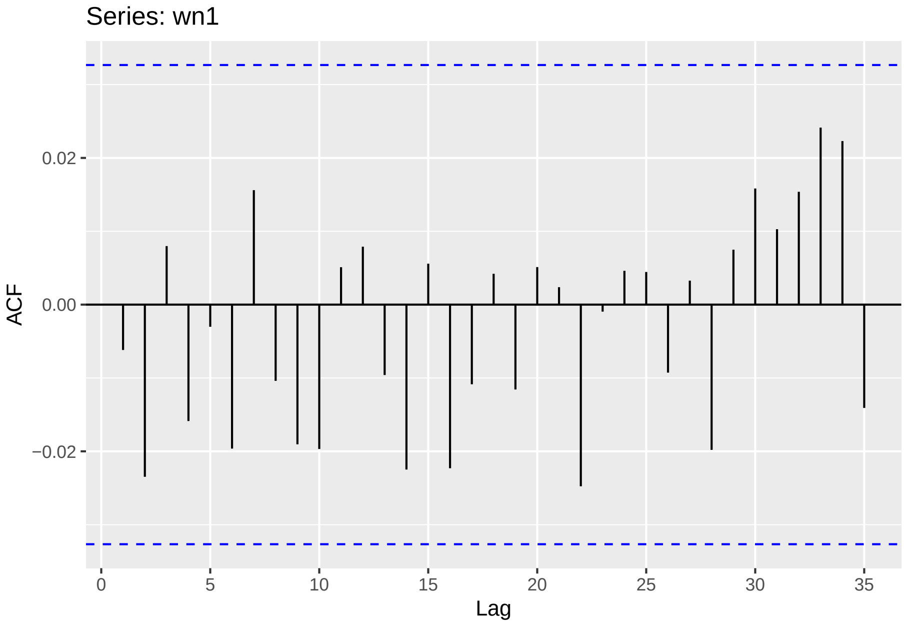
```
ggAcf(wn)
```



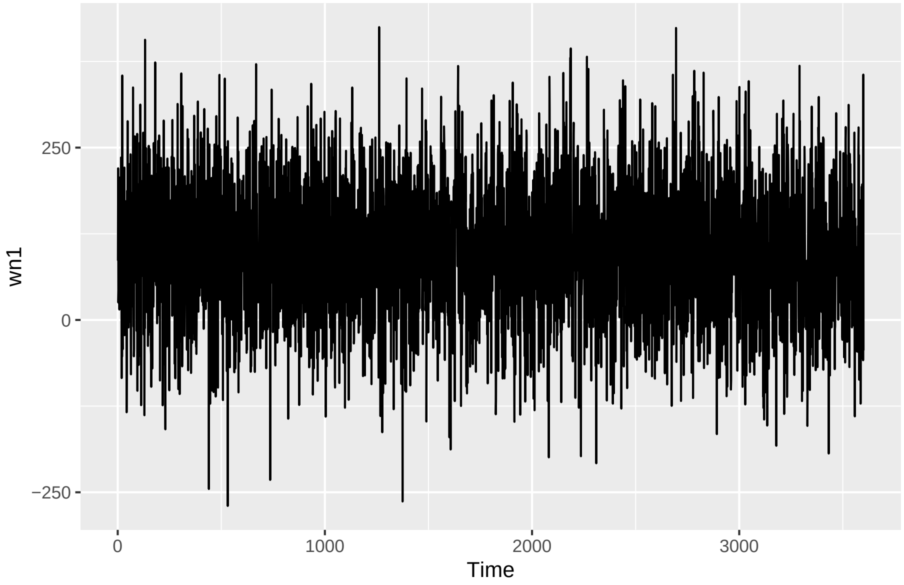
```r
set.seed(0)
wn1=ts(rnorm(3600,mean=100,sd=100))
autoplot(wn1)
```



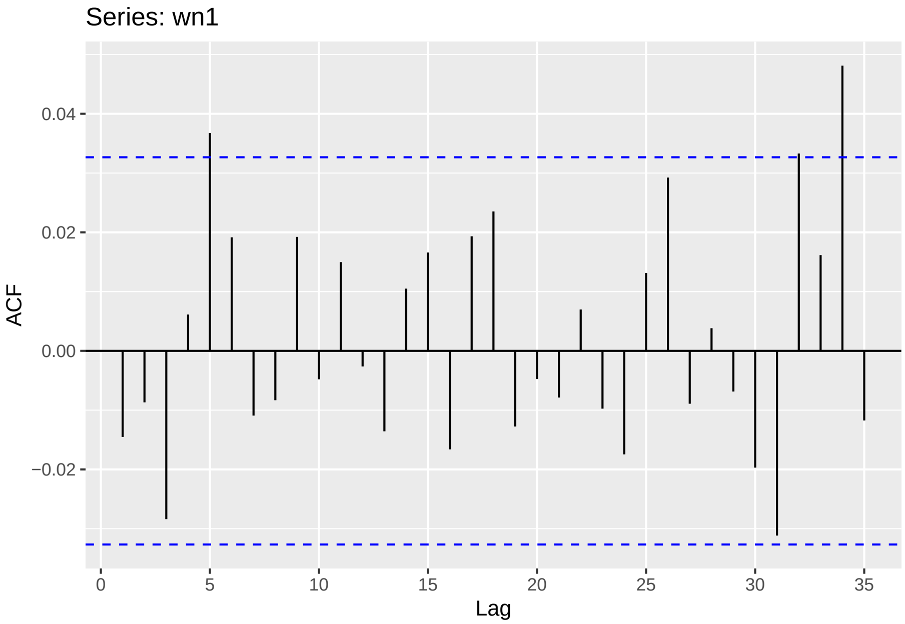
```
ggAcf(wn1) #lag.max
```



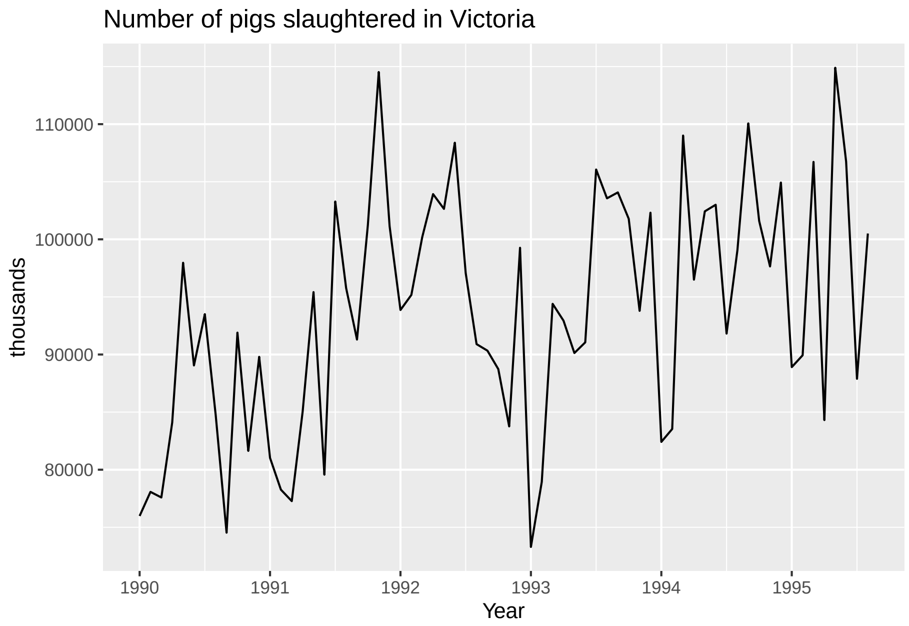
```
set.seed(34)
wn1=ts(rnorm(3600,mean=100,sd=100))
autoplot(wn1)
```


wn1
250
0
−250
0
1000
2000
3000
Time

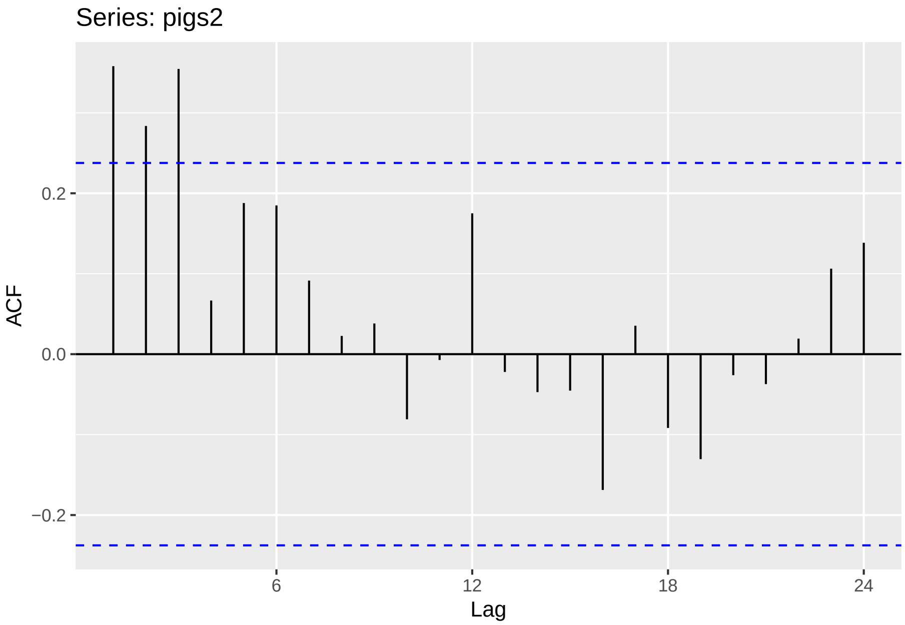
```r
ggAcf(wn1)
```


Series: wn1
ACF
0.04
0.02
0.00
−0.02
0
5
10
15
20
25
30
35
Lag

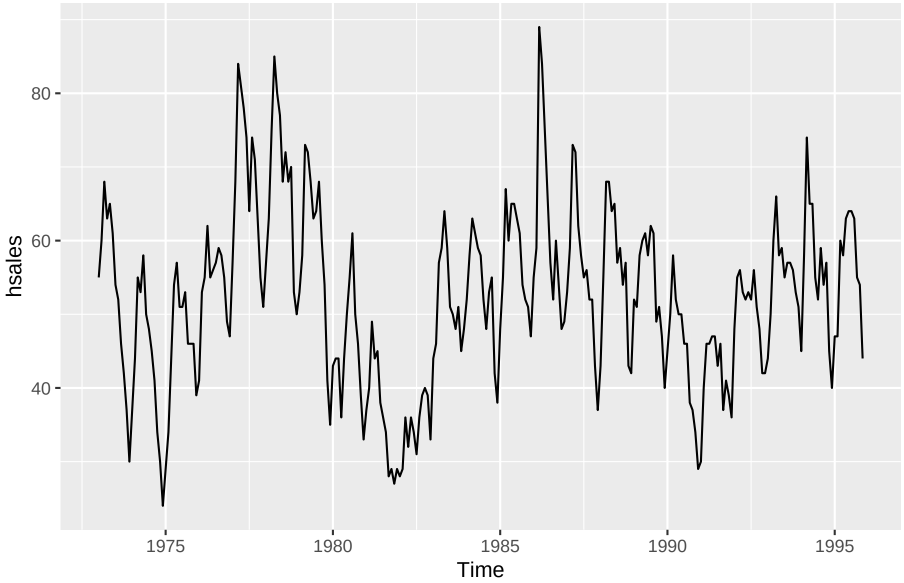
```
# Back to slides
# Pigs
  pigs2 <- window(pigs, start=1990)
  autoplot(pigs2) +
    xlab("Year") + ylab("thousands") +
    ggtitle("Number of pigs slaughtered in Victoria")
```



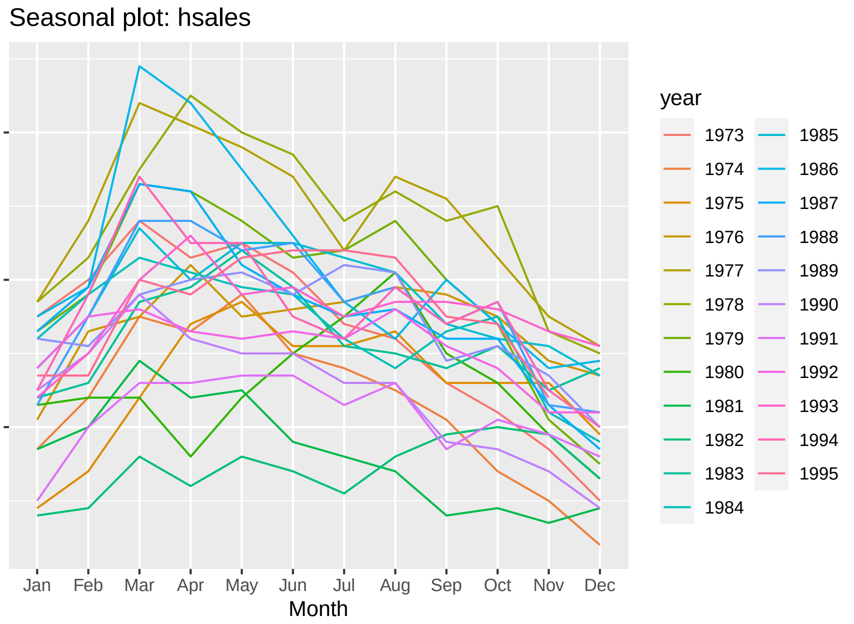
```
  ggAcf(pigs2)
```



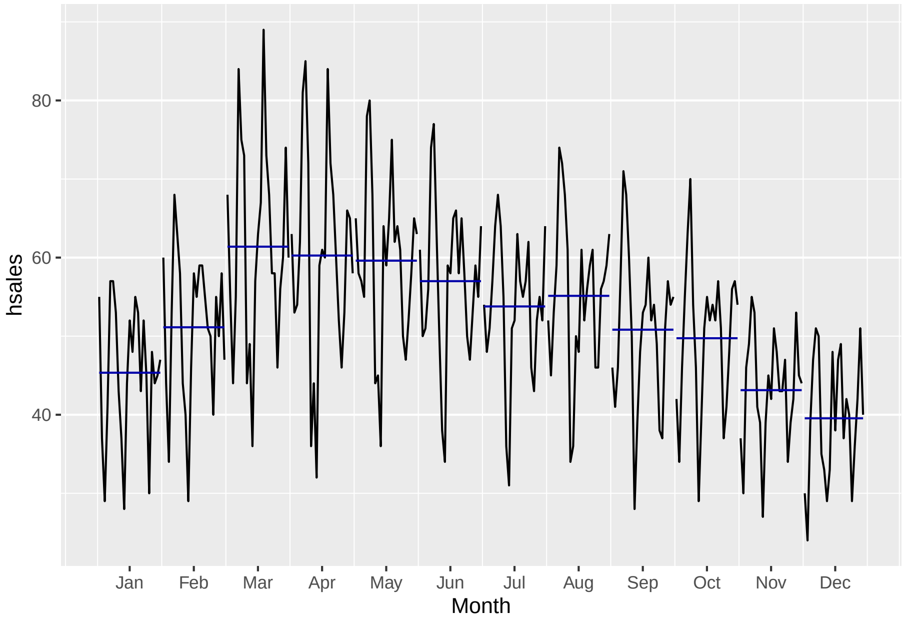
```
# Your turn 2
  autoplot(hsales)
```



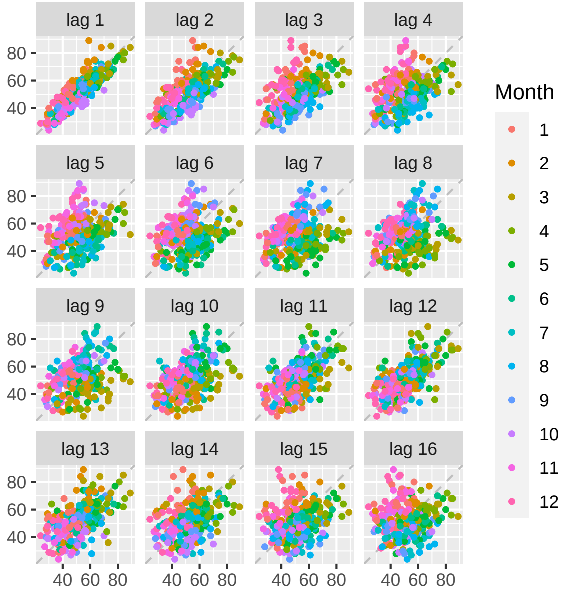
```
ggseasonplot(hsales)
```



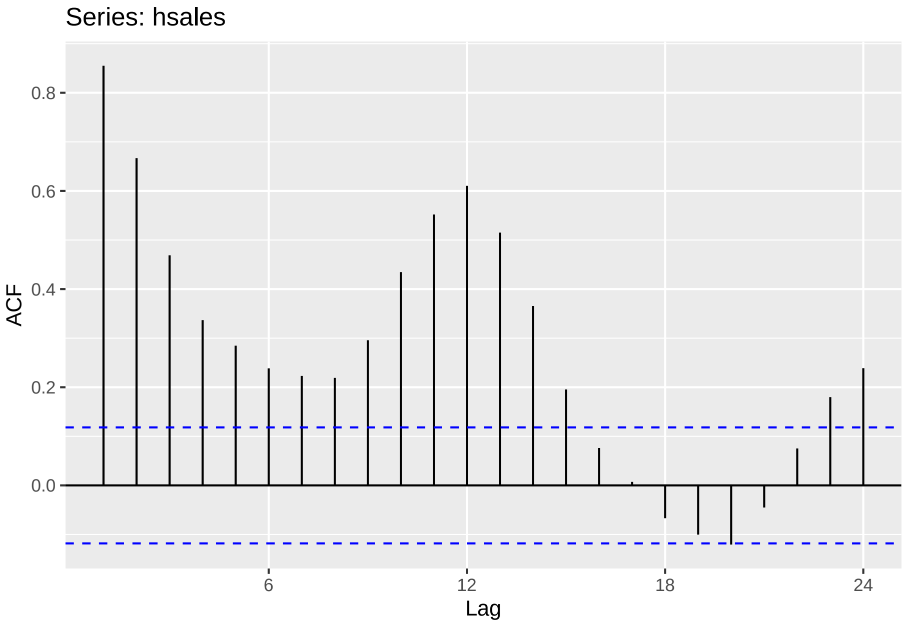
```
ggsubseriesplot(hsales)
```



```
gglagplot(hsales,do.lines=FALSE)
```



```
ggAcf(hsales)
```



```
# + Seasonality evident in all plots
# + Cyclicity seen in first two plots
# + No trend
# + ACF only shows seasonality. Cycle length too long to show up here.
```