Forecasting: principles and practice

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1.2 Time series graphics

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`ts` objects and `ts` function

A time series is stored in a `ts` object in R:
- a list of numbers
- information about times those numbers were recorded.

Example

Year	Observation
2012	123
2013	39
2014	78
2015	52
2016	110

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

`ts` objects and `ts` function

For observations that are more frequent than once per year, add a `frequency` argument.

E.g., monthly data stored as a numerical vector `z`:

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

`ts` objects and `ts` function

`ts(data, frequency, start)`		
Type of data	**frequency**	**start example**
Annual		
Quarterly		
Monthly		
Daily		
Weekly		
Hourly		
Half-hourly		

`ts` objects and `ts` function

`ts(data, frequency, start)`

Type of data	frequency	start example
Annual	1	
Quarterly		
Monthly		
Daily		
Weekly		
Hourly		
Half-hourly		

`ts` objects and `ts` function

`ts(data, frequency, start)`

Type of data	frequency	start example
Annual	1	1995
Quarterly		
Monthly		
Daily		
Weekly		
Hourly		
Half-hourly		

`ts` objects and `ts` function

`ts(data, frequency, start)`

Type of data	frequency	start example
Annual	1	1995
Quarterly	4	
Monthly		
Daily		
Weekly		
Hourly		
Half-hourly		

`ts` objects and `ts` function

`ts(data, frequency, start)`

Type of data	frequency	start example
Annual	1	1995
Quarterly	4	c(1995,2)
Monthly		
Daily		
Weekly		
Hourly		
Half-hourly		

`ts` objects and `ts` function

`ts(data, frequency, start)`

Type of data	frequency	start example
Annual	1	1995
Quarterly	4	c(1995,2)
Monthly	12	
Daily		
Weekly		
Hourly		
Half-hourly		

`ts` objects and `ts` function

`ts(data, frequency, start)`		
Type of data	**frequency**	**start example**
Annual	1	1995
Quarterly	4	c(1995,2)
Monthly	12	c(1995,9)
Daily		
Weekly		
Hourly		
Half-hourly		

`ts` objects and `ts` function

`ts(data, frequency, start)`		
Type of data	**frequency**	**start example**
Annual	1	1995
Quarterly	4	c(1995,2)
Monthly	12	c(1995,9)
Daily	*7 or* 365.25	
Weekly		
Hourly		
Half-hourly		

`ts` objects and `ts` function

`ts(data, frequency, start)`		
Type of data	**frequency**	**start example**
Annual	1	1995
Quarterly	4	c(1995,2)
Monthly	12	c(1995,9)
Daily	7 *or* 365.25	1 *or* c(1995,234)
Weekly		
Hourly		
Half-hourly		

`ts` objects and `ts` function

`ts(data, frequency, start)`

Type of data	frequency	start example
Annual	1	1995
Quarterly	4	c(1995,2)
Monthly	12	c(1995,9)
Daily	7 *or* 365.25	1 *or* c(1995,234)
Weekly	52.18	
Hourly		
Half-hourly		

`ts` objects and `ts` function

`ts(data, frequency, start)`		
Type of data	**frequency**	**start example**
Annual	1	1995
Quarterly	4	c(1995,2)
Monthly	12	c(1995,9)
Daily	7 *or* 365.25	1 *or* c(1995,234)
Weekly	52.18	c(1995,23)
Hourly		
Half-hourly		

`ts` objects and `ts` function

`ts(data, frequency, start)`

Type of data	frequency	start example
Annual	1	1995
Quarterly	4	c(1995,2)
Monthly	12	c(1995,9)
Daily	7 *or* 365.25	1 *or* c(1995,234)
Weekly	52.18	c(1995,23)
Hourly	24 *or* 168 *or* 8,766	
Half-hourly		

`ts` objects and `ts` function

`ts(data, frequency, start)`

Type of data	frequency	start example
Annual	1	1995
Quarterly	4	c(1995,2)
Monthly	12	c(1995,9)
Daily	7 *or* 365.25	1 *or* c(1995,234)
Weekly	52.18	c(1995,23)
Hourly	24 *or* 168 *or* 8,766	1
Half-hourly		

`ts` objects and `ts` function

`ts(data, frequency, start)`

Type of data	frequency	start example
Annual	1	1995
Quarterly	4	c(1995,2)
Monthly	12	c(1995,9)
Daily	7 *or* 365.25	1 *or* c(1995,234)
Weekly	52.18	c(1995,23)
Hourly	24 *or* 168 *or* 8,766	1
Half-hourly	48 *or* 336 *or* 17,532	

`ts` objects and `ts` function

`ts(data, frequency, start)`

Type of data	frequency	start example
Annual	1	1995
Quarterly	4	c(1995,2)
Monthly	12	c(1995,9)
Daily	7 *or* 365.25	1 *or* c(1995,234)
Weekly	52.18	c(1995,23)
Hourly	24 *or* 168 *or* 8,766	1
Half-hourly	48 *or* 336 *or* 17,532	1

Australian GDP

```r
ausgdp <- ts(x, frequency=4, start=c(1971,3))
```

- Class: "ts"
- Print and plotting methods available.

```r
ausgdp
```

```
##      Qtr1 Qtr2 Qtr3 Qtr4
## 1971           4612 4651
## 1972 4645 4615 4645 4722
## 1973 4780 4830 4887 4933
## 1974 4921 4875 4867 4905
## 1975 4938 4934 4942 4979
## 1976 5028 5079 5112 5127
```

Australian GDP

```
autoplot(ausgdp)
```
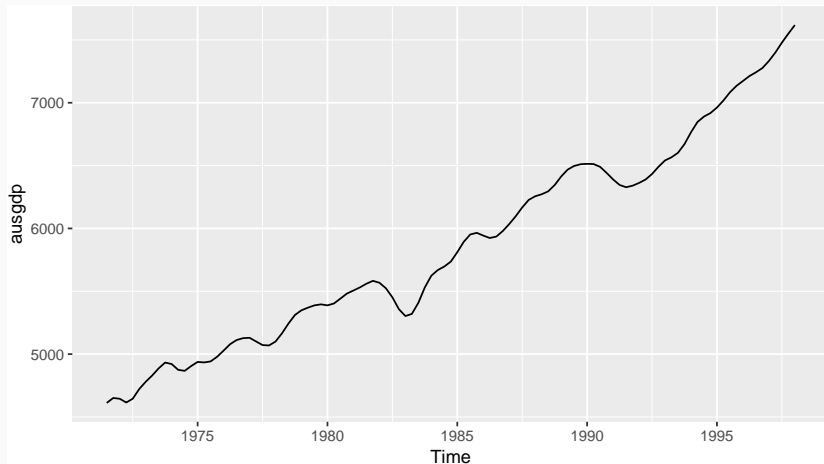
Residential electricity sales

```
elecsales
```

```
## Time Series:
## Start = 1989
## End = 2008
## Frequency = 1
##  [1] 2354.34 2379.71 2318.52 2468.99 2386.0
##  [6] 2569.47 2575.72 2762.72 2844.50 3000.7
## [11] 3108.10 3357.50 3075.70 3180.60 3221.6
## [16] 3176.20 3430.60 3527.48 3637.89 3655.0
```

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Time plots

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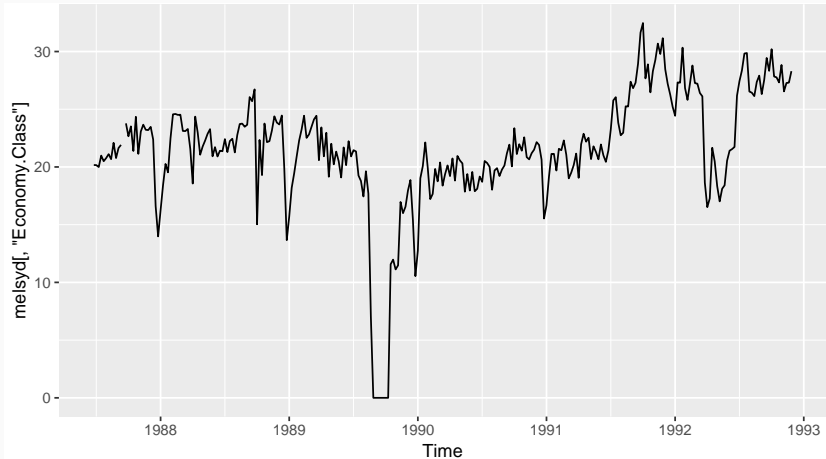
Time plots

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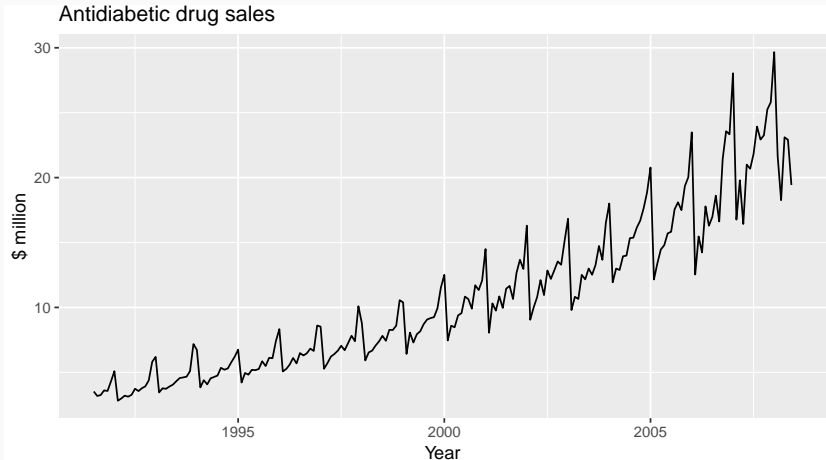

Antidiabetic drug sales

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Seasonal plots

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


Seasonal plot: antidiabetic drug sales
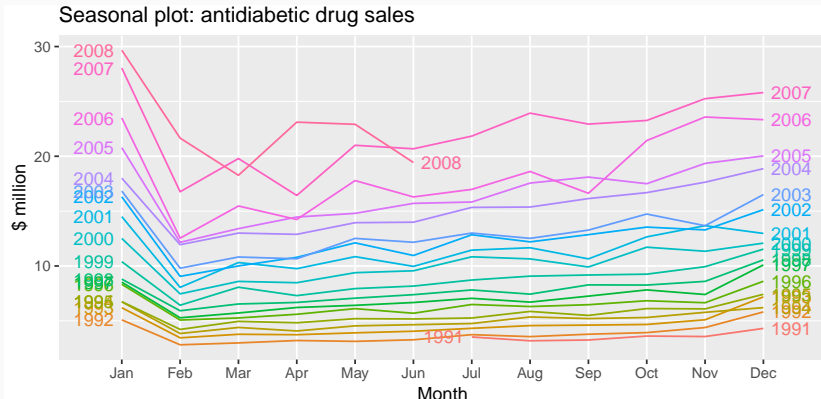
Seasonal plots

- Data plotted against the individual "seasons" in which the data were observed. (In this case a "season" is a month.)
- Something like a time plot except that the data from each season are overlapped.
- Enables the underlying seasonal pattern to be seen more clearly, and also allows any substantial departures from the seasonal pattern to be easily identified.
- In R: `ggseasonplot`

Seasonal polar plots

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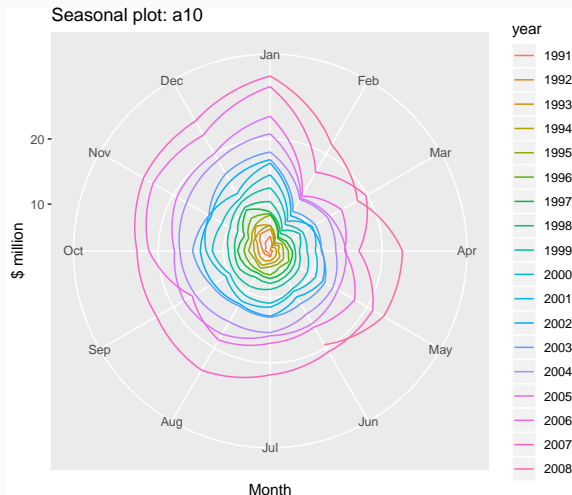
Seasonal subseries plots

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


Seasonal subseries plot: antidiabetic drug sales
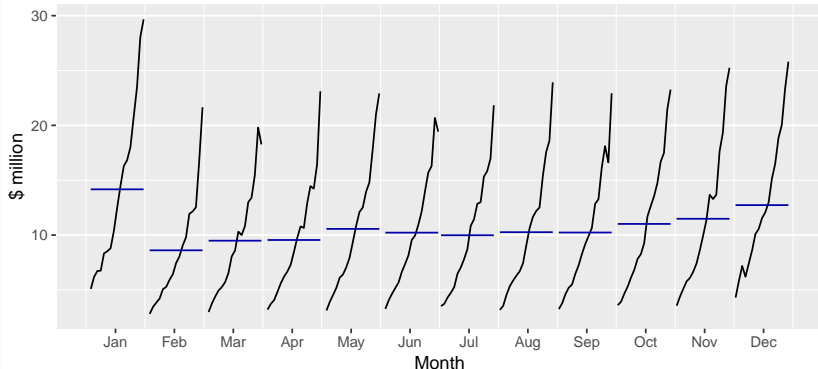
Seasonal subseries plots

- Data for each season collected together in time plot as separate time series.
- Enables the underlying seasonal pattern to be seen clearly, and changes in seasonality over time to be visualized.
- In R: `ggsubseriesplot`

Quarterly Australian Beer Production

```
beer <- window(ausbeer,start=1992)
autoplot(beer)
```
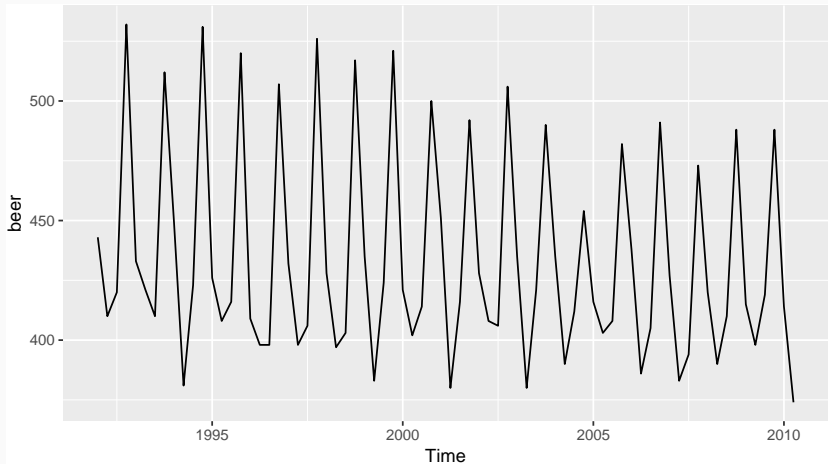
Quarterly Australian Beer Production

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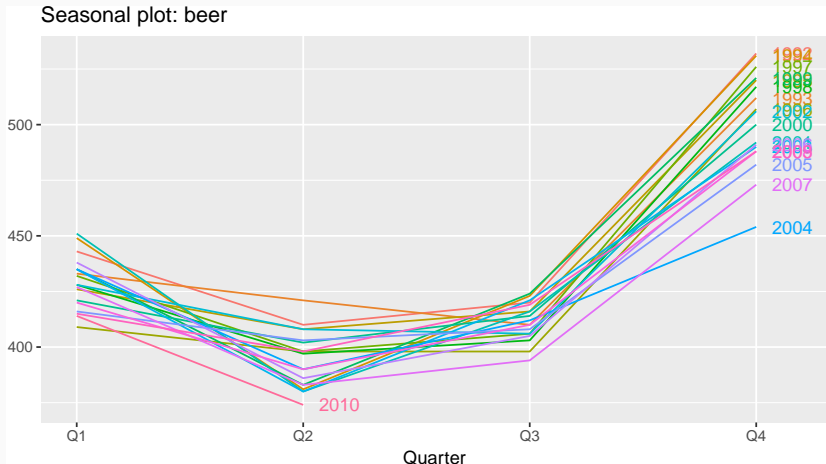

Seasonal plot: beer

Quarterly Australian Beer Production

`ggsubseriesplot`(beer)
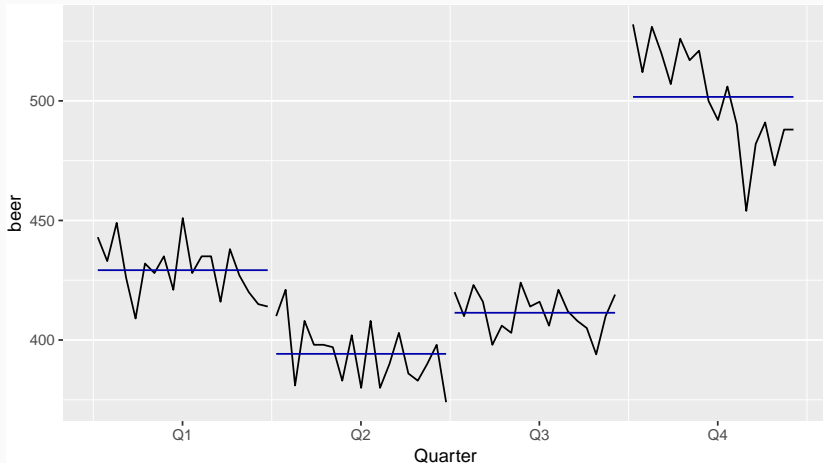
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Time series patterns

Trend pattern exists when there is a long-term increase or decrease in the data.

Seasonal pattern exists when a series is influenced by seasonal factors (e.g., the quarter of the year, the month, or day of the week).

Cyclic pattern exists when data exhibit rises and falls that are *not of fixed period* (duration usually of at least 2 years).

Differences between seasonal and cyclic patterns:

- seasonal pattern constant length; cyclic pattern variable length
- average length of cycle longer than length of seasonal pattern
- magnitude of cycle more variable than magnitude of seasonal pattern

Time series patterns

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


Australian electricity production
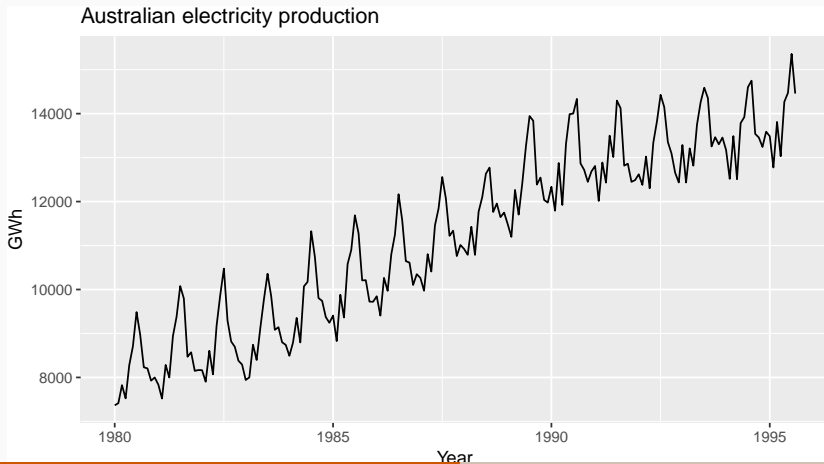
Time series patterns

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


Australian clay brick production
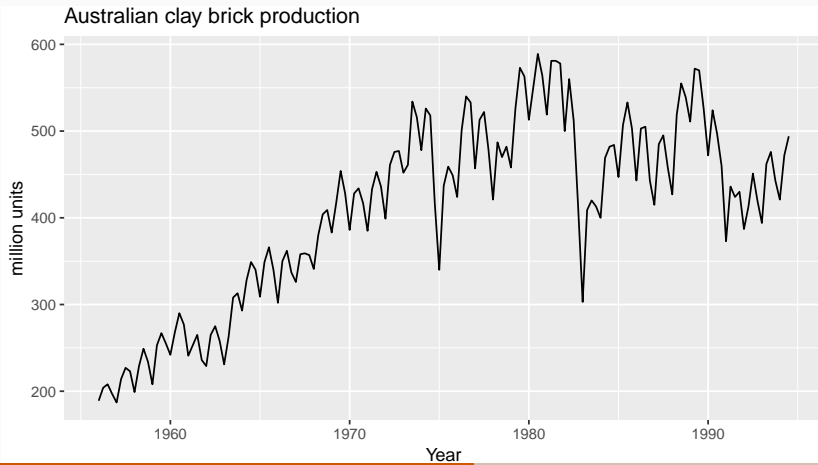
Time series patterns

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


Sales of new one-family houses, USA
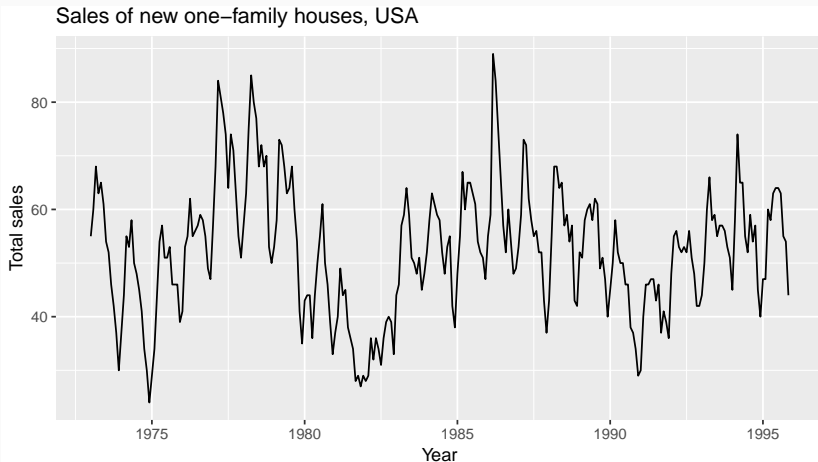
Time series patterns

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


US Treasury Bill Contracts
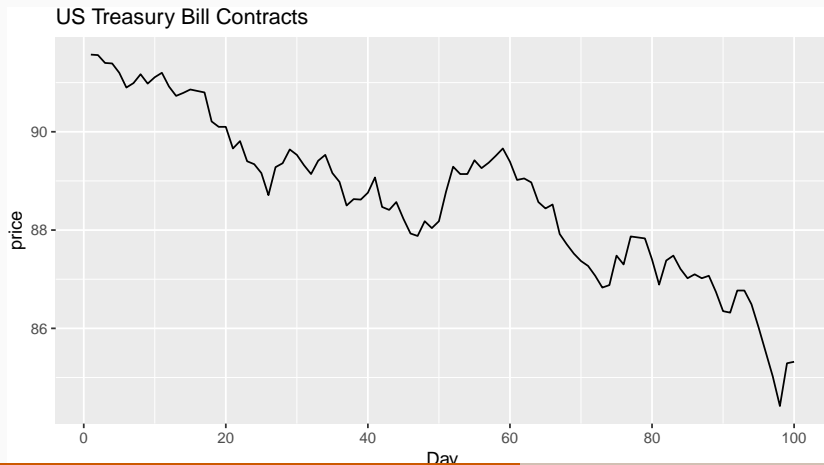
Time series patterns

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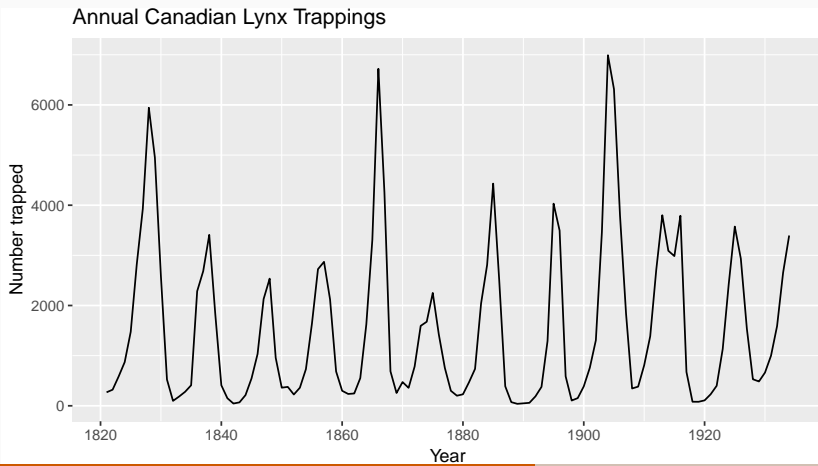

Annual Canadian Lynx Trappings

Seasonal or cyclic?

Differences between seasonal and cyclic patterns:

- seasonal pattern constant length; cyclic pattern variable length
- average length of cycle longer than length of seasonal pattern
- magnitude of cycle more variable than magnitude of seasonal pattern

Seasonal or cyclic?

Differences between seasonal and cyclic patterns:

- seasonal pattern constant length; cyclic pattern variable length
- average length of cycle longer than length of seasonal pattern
- magnitude of cycle more variable than magnitude of seasonal pattern

The timing of peaks and troughs is predictable with seasonal data, but unpredictable in the long term with cyclic data.

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Example: Beer production

```
beer <- window(ausbeer, start=1992)
gglagplot(beer, lags=9, do.lines=FALSE,
  continuous=FALSE)
```

Example: Beer production
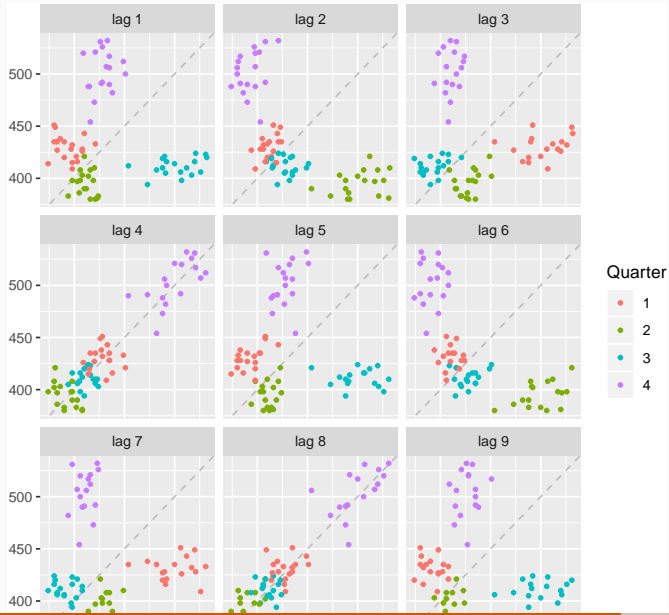
Lagged scatterplots

- Each graph shows y_t plotted against y_{t-k} for different values of k.
- The autocorrelations are the correlations associated with these scatterplots.
- ACF (autocorrelation function):
  - r_1 = Correlation(y_t, y_{t-1})
  - r_2 = Correlation(y_t, y_{t-2})
  - r_3 = Correlation(y_t, y_{t-3})
  - etc.
- If there is **seasonality**, the ACF at the seasonal lag (e.g., 12 for monthly data) will be **large and positive**. 35

Autocorrelation

Results for first 9 lags for beer data:

r_1	r_2	r_3	r_4	r_5	r_6	r_7	r_8	r_9
-0.102	-0.657	-0.060	0.869	-0.089	-0.635	-0.054	0.832	-0.108

```
ggAcf(beer)
```
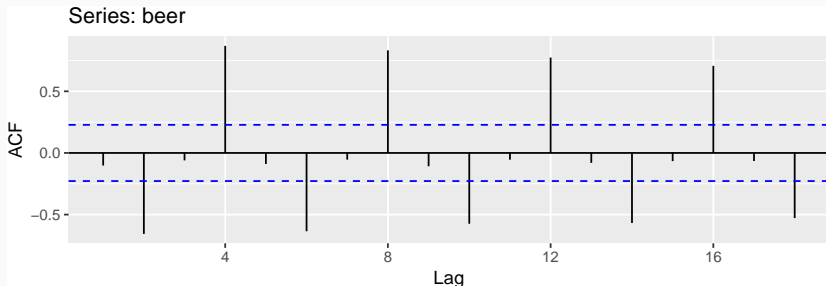
Aus monthly electricity production

```
elec2 <- window(elec, start=1980)
autoplot(elec2)
```
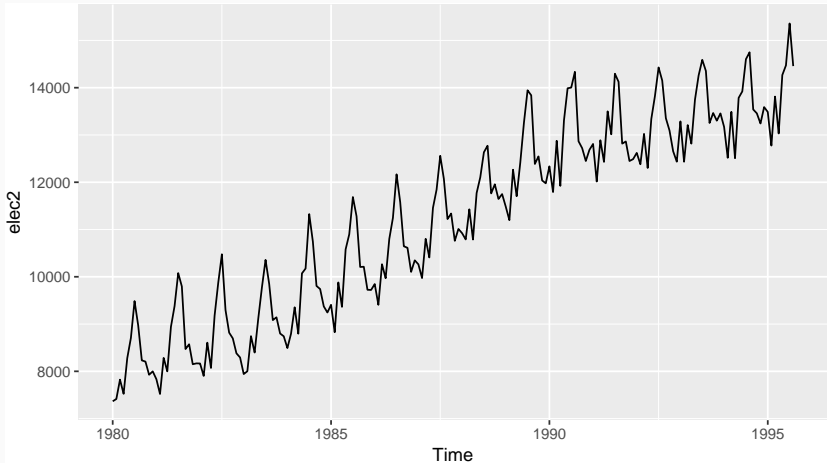
Aus monthly electricity production

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


Series: elec2
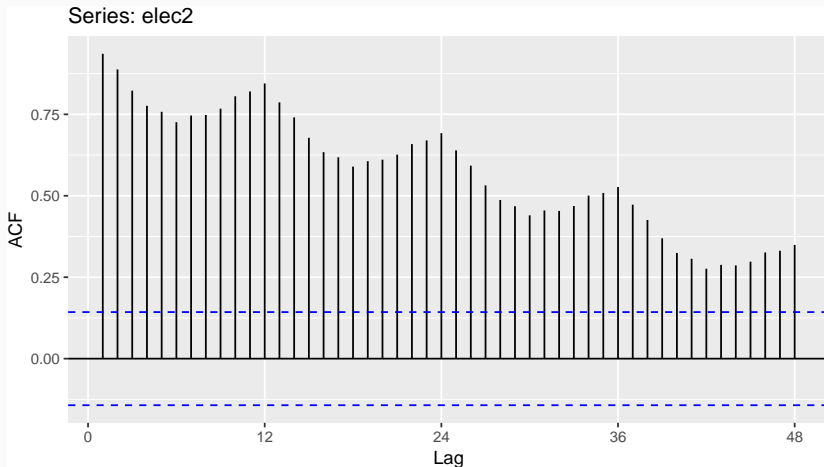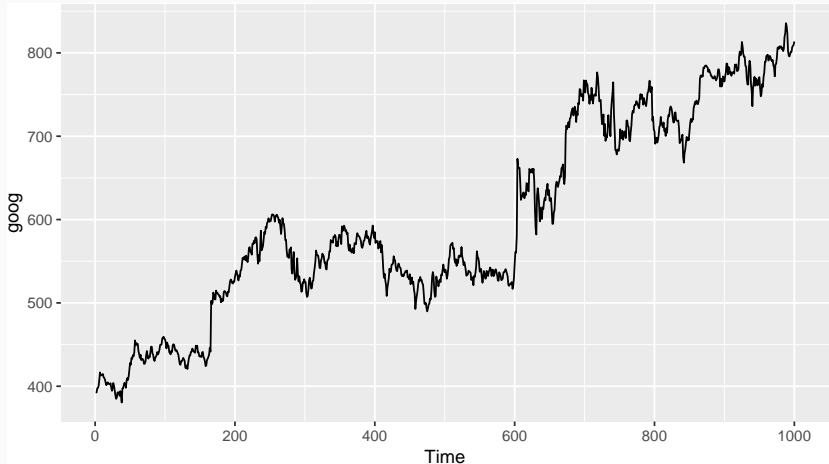
Google stock price

Google stock price

ggAcf(goog, lag.max=100)
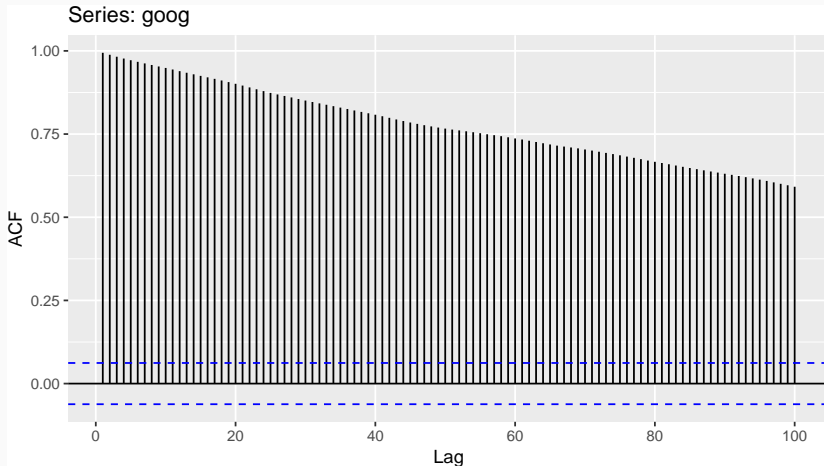
Which is which?

1. Daily temperature of cow
2. Monthly accidental deaths
3. Monthly air passengers
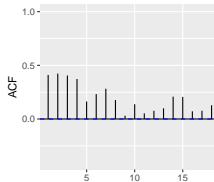4. Annual mink trappings
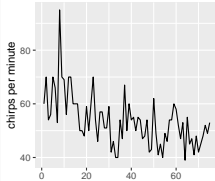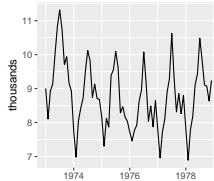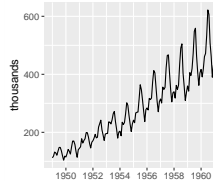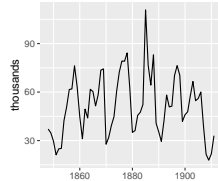
A B C D
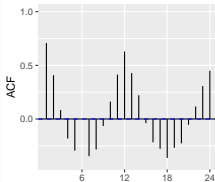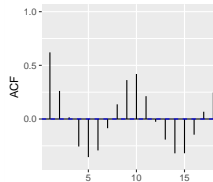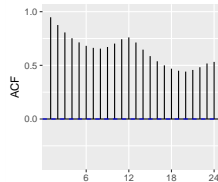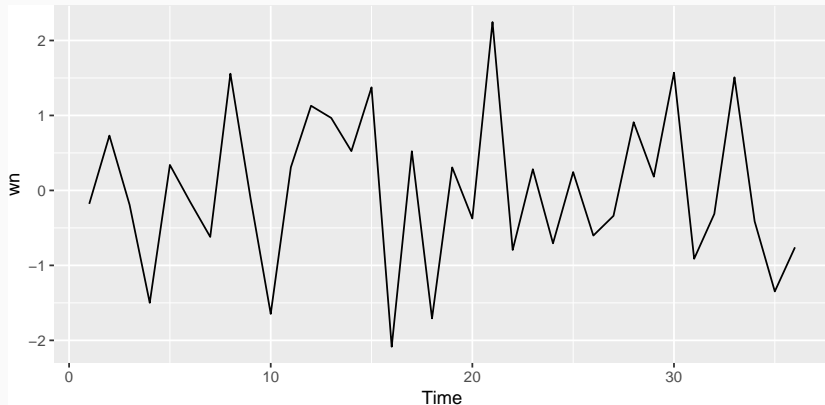
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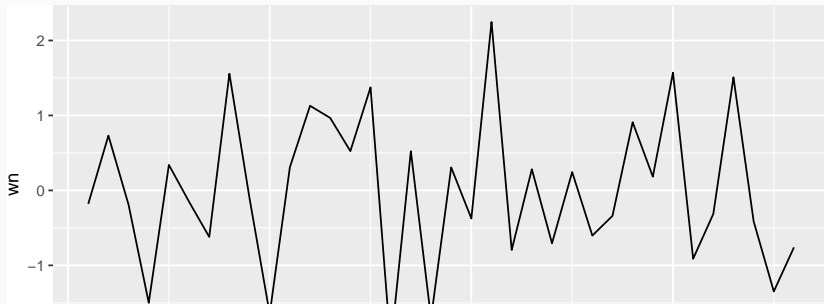# Example: White noise

```
wn <- ts(rnorm(36))
autoplot(wn)
```
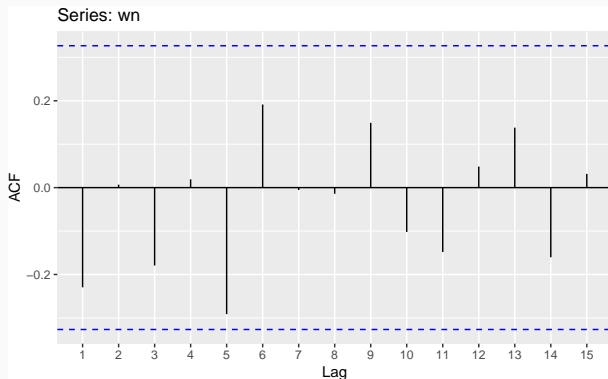
Example: White noise

```
wn <- ts(rnorm(36))
autoplot(wn)
```


White noise data is uncorrelated across time with zero mean and constant variance.
(Technically, we require independence as well7)

Example: White noise

r_1	-0.23
r_2	0.01
r_3	-0.18
r_4	0.02
r_5	-0.29
r_6	0.19
r_7	-0.01
r_8	-0.01
r_9	0.15
r_{10}	-0.10

Series: wn

- Sample autocorrelations for white noise series.
- Expect each autocorrelation to be close to zero.
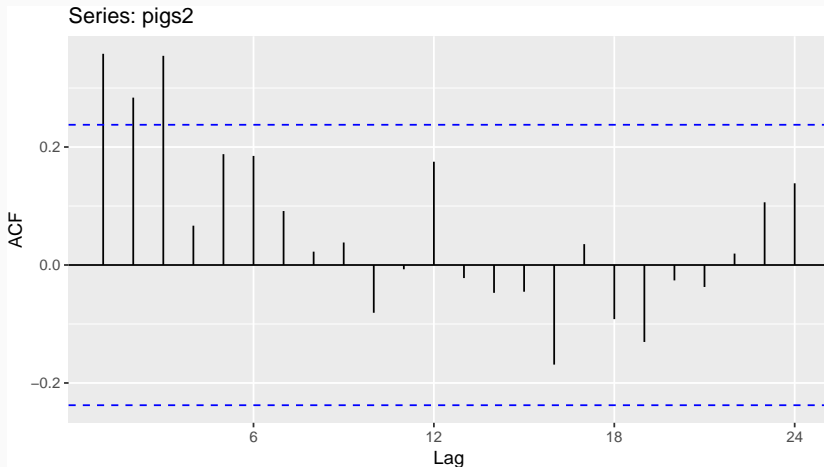- Blue lines show 95% critical values.

Example: Pigs slaughtered

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


Number of pigs slaughtered in Victoria

Example: Pigs slaughtered

`**ggAcf**(pigs2)`

Series: pigs2

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