Time Series Plots

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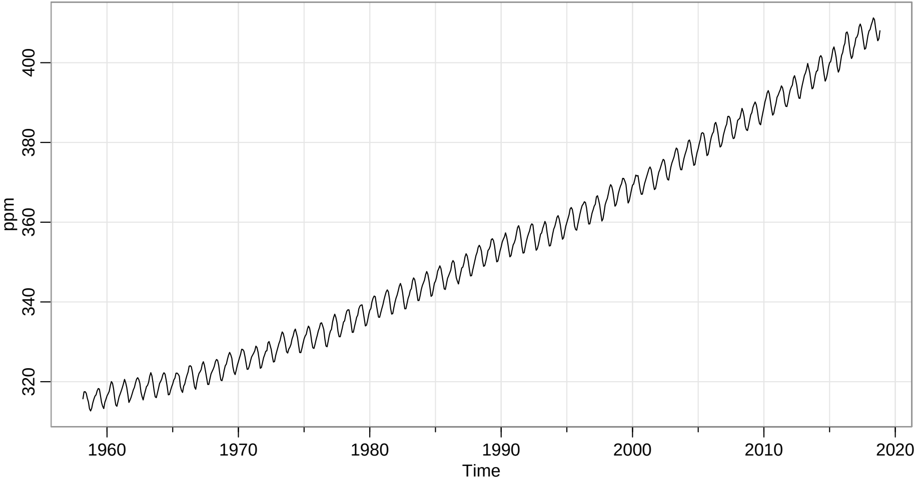
LMU, July 1 2022

Representing a time series

- A time plot is the simplest and more intuitive representation of a time series
- A time plot allows to inspect the data and find the main characteristics

Time plot of Monthly Carbon Dioxide Levels at Mauna Loa, 1958-2019



Time series components I

The the main components of a time series are:

- **trend**- long term change in the mean of the data
- **seasonality** - cycles within one year usually related to the seasons of the year; it is fixed and the frequency is known S_t
- **cycles** - raises and falls in the data with unknown frequency-
- **random** or remainder component R_t with some desirable properties that will be introduced later

Usually trend and cycle are included in the same component, a trend-cycle component T_t

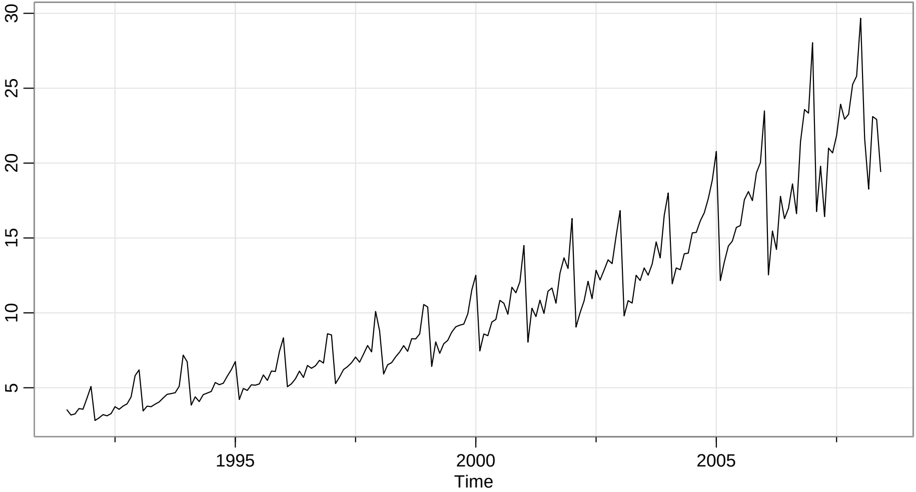
Time series components II

In this example

- the trend looks approximately linear
- the seasonal cycles have constant over time- we say that a linear model may be appropriate

$$y_t = T_t + S_t + R_t$$

Time plot of Monthly Scripts of Anti-diabetic drugs, a10



Time series components III

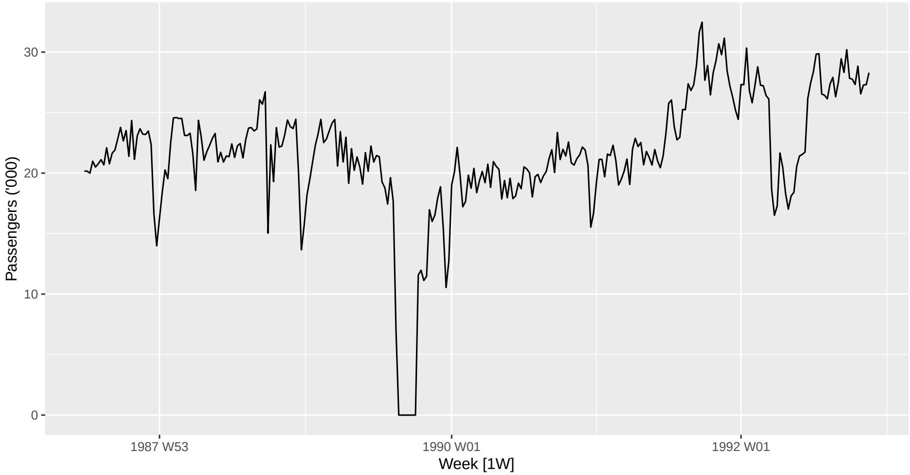
In a10 time series

- the trend is non linear
- the amplitude of the seasonal cycles grows with the trend, implying heterocedasticity (changing variance)

We need a multiplicative model to represent the relationship between the components

$$y_t = T_t S_t R_t$$

Time plot of Weekly passenger load Ansett airlines economy class: Melbourne-Sidney



Time Series Characteristics III

Interesting features

- There was a period in 1989 when no passengers were carried — this was due to an industrial dispute.
- There was a period of reduced load in 1992. This was due to a trial in which some economy class seats were replaced by business class seats.
- A large increase in passenger load occurred in the second half of 1991.
- There are some large dips in load around the start of each year. These are due to holiday effects. -There is a long-term fluctuation in the level of the series which increases during 1987, decreases in 1989, and increases again through 1990 and 1991.

Time series Characteristics IV

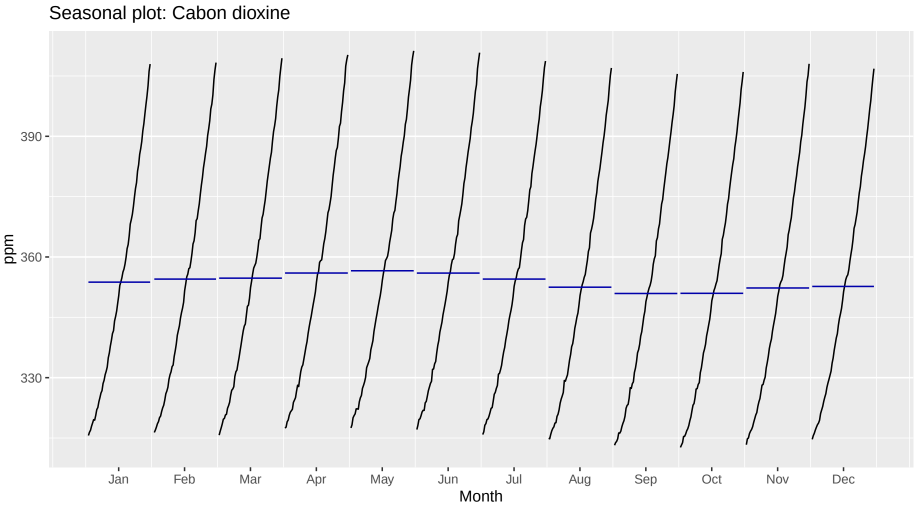
Plot the time series and check for:

- trend
- discontinuities such as level changes
- changes in variance
- seasonality
- cycles
- unusual observations- outliers

Depending on the purpose of our study, when we analyse a time series the interest may be in studying the trend, the seasonality, the cycles or the remainder component or all together!!!

Seasonal Plots I

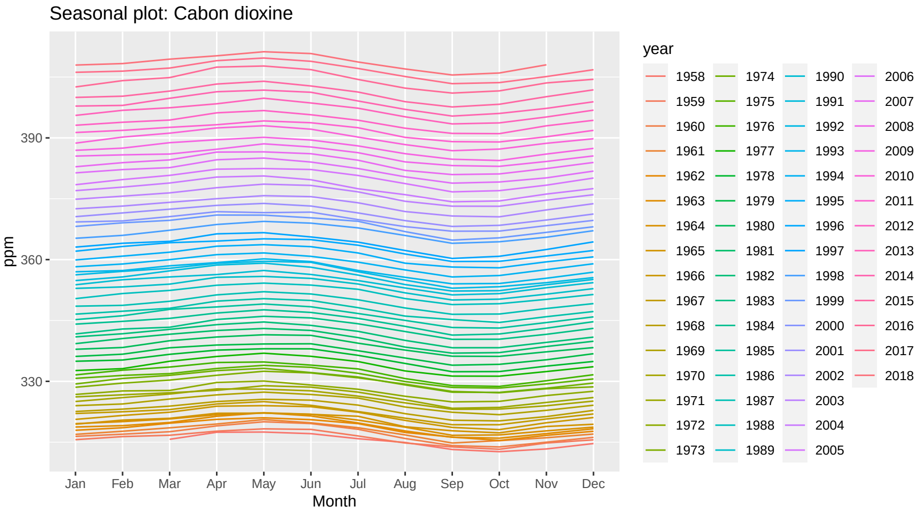
For a clear representation of the seasonal patterns we may use the seasonal plots.



Seasonal Plots II

The blue lines represent the mean of the corresponding month. Be careful because this mean has no meaning since the data presents trend.

Seasonal Plots III

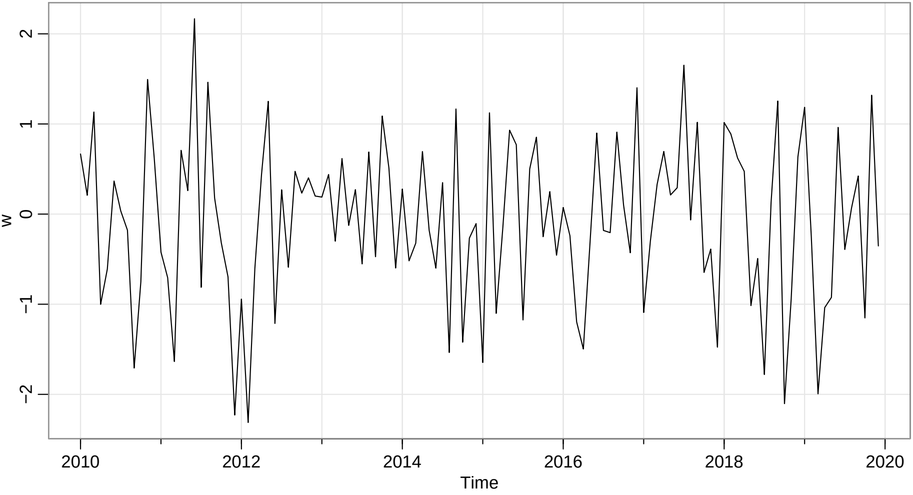


Lag Plots

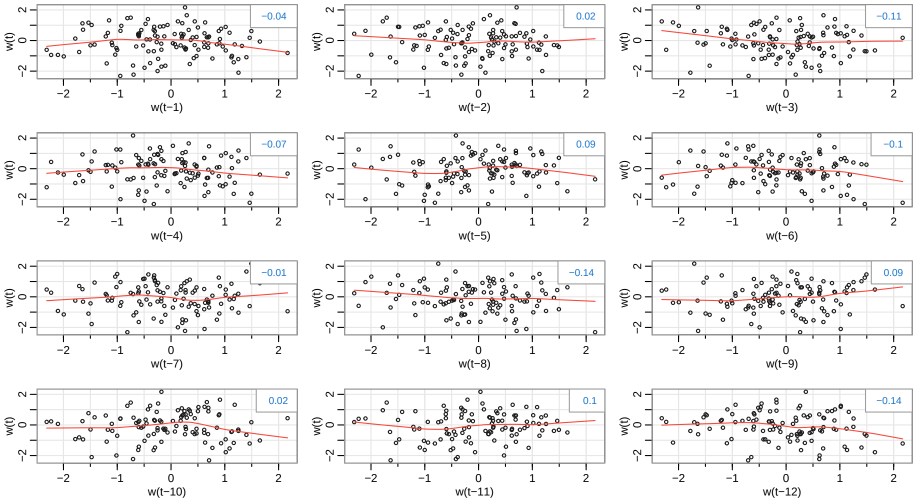
- Lag Plots are scatterplots where the horizontal axis shows lagged values of the time series.
- Each graph shows w_t plotted against w_{t-k} for different values of k
- Help to assess the relationship between values separated by k time units

White noise

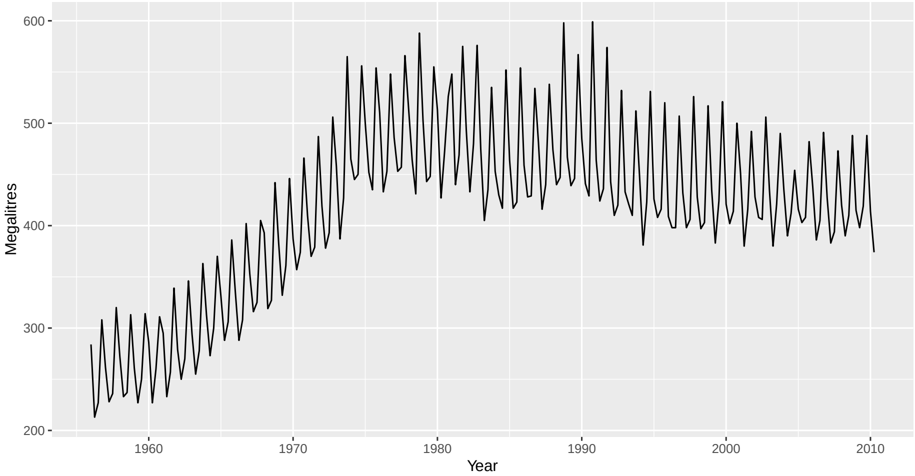
Simulate a time series that are just iid observations - **WHITE NOISE** declare it as ts object and plot.



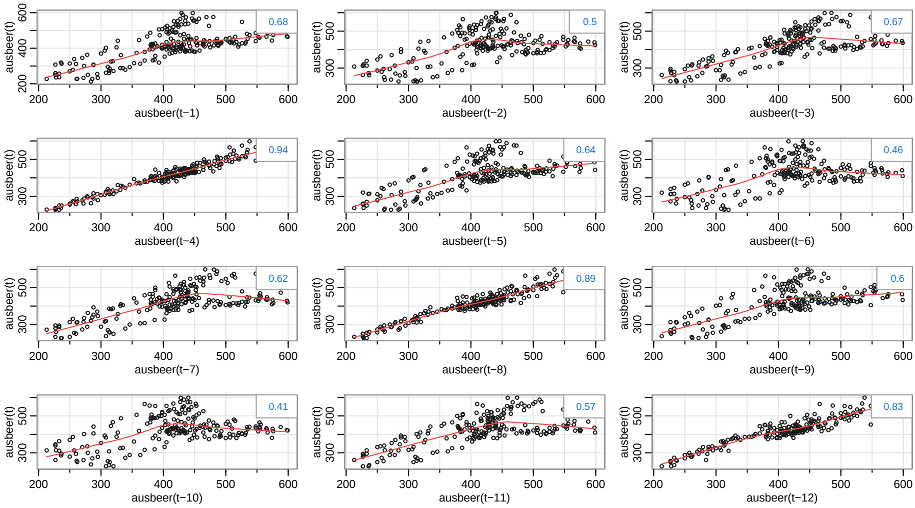
Lag Plot of white noise using package "astsa"



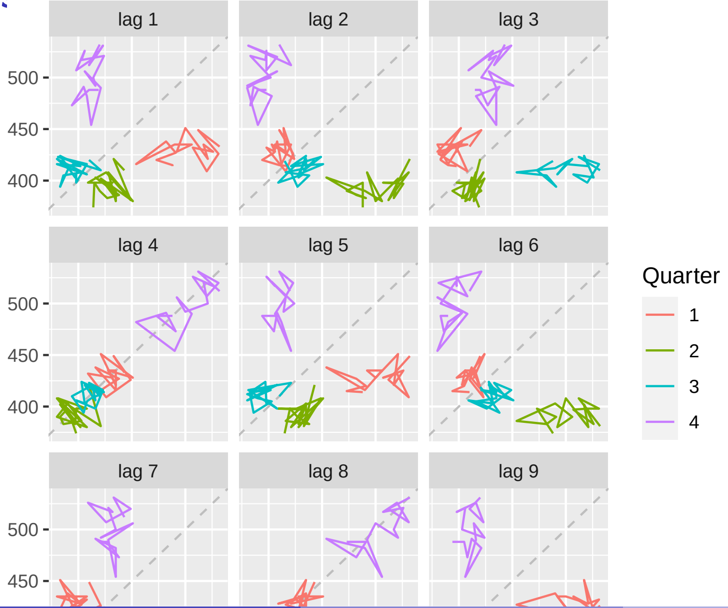
Australian quarterly beer production



Lag Plot of Australian quarterly beer production using package astsa



Lag Plot of Australian quarterly beer production since 1992



Autocorrelation Function -

- Correlation measures the extent of a linear relationship between two variables
- Autocorrelation measures the linear relationship between lagged values of a time series,

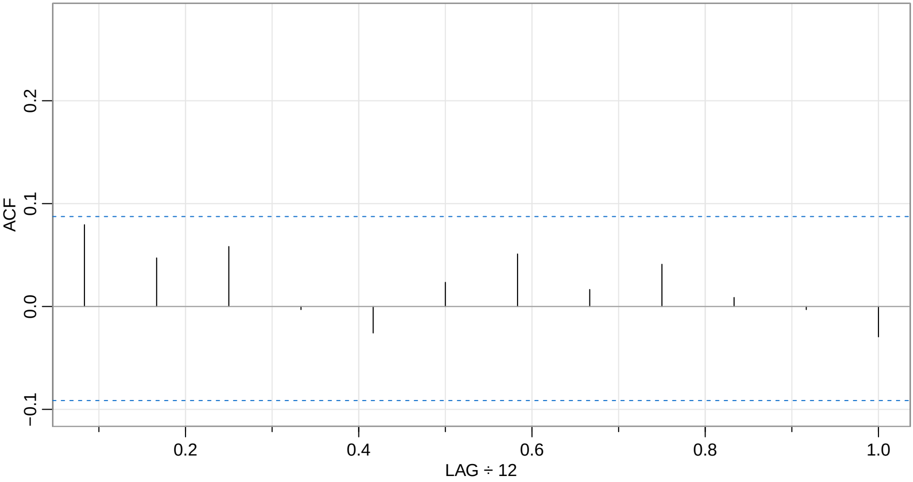
Some notation - time series : $y_t,\ t = 1, \dots, n$ or $y_1, y_2, \dots, y_T$

- There are several autocorrelation coefficients, one corresponding to each panel in the lag plot:
  - r_1 measures the correlation between y_t and y_{t-1}
  - r_2 measures the correlation between y_t and y_{t-2}
  - in general, r_k measures the correlation between y_t and y_{t-k}

where

$$r_k = \frac{\sum_{t=k+1}^{T}(y_t - \bar{y})(y_{t-k} - \bar{y})}{\sum_1^T (y_t - \bar{y})^2}$$

Autocorrelation of White Noise

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## [1] 0.08 0.05 0.06 0.00 -0.03 0.02 0.05 0.02 0.04
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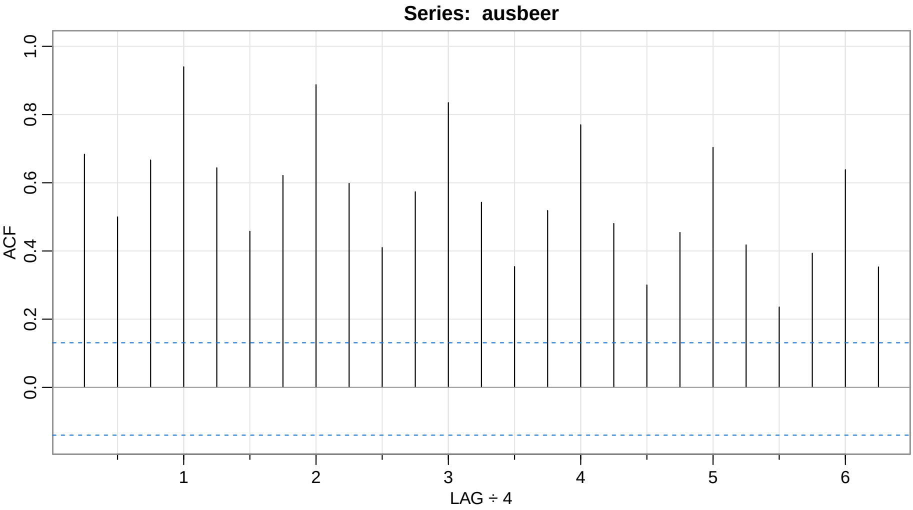
Autocorrelation of Beer data



Autocorrelation, ACF characteristics

- ACF reflets the characteristics of the time series
  - When data have a trend, the nautocorrelations for small lags tend to be large and positive.
  - When data are seasonal, the autocorrelations will be larger at the seasonal lags (i.e., at multiples of the seasonal frequency)
  - When data are trended and seasonal, you see a combination of these effects.
- ACF of White Noise
  - Sample autocorrelations for white noise series.
  - Expect each autocorrelation to be close to zero.
  - Blue lines show 95% critical values - when correlations exceed the critical values they indicate departure from white noise