Time Series Analysis - A Tutorial

Rosskopf,E.; Cordes, M.; Lumiko, J.

November 20, 2014

Abstract

Tutorial for time series analysis in R...

Contents

1 Introduction

Needs to be filled out properly with samples and explanations (dont forget citing !!).

- Definition time series
- examples in economy, nature, humans,....
- stochastic/deterministic with dormann revision
- stationary / non stationary
- regression: why time series regression instead of linear standrard regression
- where you need to use time series regression.

2 Getting started

First set your working directory properly, load the dataset and download and check the packages required for this tutorial.

2.1 Get started with the data

Our example 1 contains the CO2 concentration (ppm) in the Atmosphere at the station Mauna Loa on Hawaii. The dataset is composed out of mean monthly data.

```
> url<-"ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_mm_mlo.txt"
> dest<-"C:/Users/schnuri/Desktop/Neuer Ordner/Dataset/test.txt"
> download.file(url, dest )
> co2month=read.table(dest, skip=72)
> co2month
```

A few useful packages for time series analysis

```
> library(tseries)
> library(nlme)
> library(car)
> library(knitr)
> library(xtable)
> library(SweaveListingUtils)
> library(stats)
> library(forecast)
```

and in:

http://cran.r-project.org/web/views/TimeSeries.html

Another Exemple Datasets are avaliable at:

http://www.comp-engine.org/timeseries/browse-data-by-category
https://datamarket.com/data/list/?q=provider:tsdl

2.2 Transforming your data into a Time Series

The data stored as a dataframe needs to be transformed with the important columns into the class of a time series to continue working on it properly. If you have monthly data you have to set the deltat of the function ts() to deltat=1/12 describing the sampling period parts between successive values xt and xt+1. Your time series should somehow look like table 2.

```
> yourdata = co2month[,c(3,5)]
> colnames(yourdata)= c("year", "co2")
> attach(yourdata)
> xtable(head(yourdata), caption="Your original data")
```

	year	co2
1	1958.21	315.71
2	1958.29	317.45
3	1958.38	317.50
4	1958.46	317.10
5	1958.54	315.86
6	1958.62	314.93

Table 1: Your original data

```
> yourts=ts(co2, c(1958,3),c(2014,10), deltat=1/12)
> class(yourts)
```

[1] ”ts” [1] ”

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1958			315.71	317.45	317.50	317.10	315.86	314.93	313.20	312.66	313.33	314.67
1959	315.62	316.38	316.71	317.72	318.29	318.15	316.54	314.80	313.84	313.26	314.80	315.58
1960	316.43	316.97	317.58	319.02	320.03	319.59	318.18	315.91	314.16	313.83	315.00	316.19
1961	316.93	317.70	318.54	319.48	320.58	319.77	318.57	316.79	314.80	315.38	316.10	317.01
1962	317.94	318.56	319.68	320.63	321.01	320.55	319.58	317.40	316.26	315.42	316.69	317.69
1963	318.74	319.08	319.86	321.39	322.25	321.47	319.74	317.77	316.21	315.99	317.12	318.31
1964	319.57	320.07	320.73	321.77	322.25	321.89	320.44	318.70	316.70	316.79	317.79	318.71
1965	319.44	320.44	320.89	322.13	322.16	321.87	321.39	318.81	317.81	317.30	318.87	319.42
1966	320.62	321.59	322.39	323.87	324.01	323.75	322.39	320.37	318.64	318.10	319.79	321.08
1967	322.07	322.50	323.04	324.42	325.00	324.09	322.55	320.92	319.31	319.31	320.72	321.96
1968	322.57	323.15	323.89	325.02	325.57	325.36	324.14	322.03	320.41	320.25	321.31	322.84
1969	324.00	324.42	325.64	326.66	327.34	326.76	325.88	323.67	322.38	321.78	322.85	324.11
1970	325.03	325.99	326.87	328.13	328.07	327.66	326.35	324.69	323.10	323.16	323.98	325.13
1971	326.17	326.68	327.18	327.78	328.92	328.57	327.34	325.46	323.36	323.57	324.80	326.01
1972	326.77	327.63	327.75	329.72	330.07	329.09	328.05	326.32	324.93	325.06	326.50	327.55
1973	328.54	329.56	330.30	331.50	332.48	332.07	330.87	329.31	327.51	327.18	328.16	328.64
1974	329.35	330.71	331.48	332.65	333.19	332.12	330.99	329.17	327.41	327.21	328.34	329.50
1975	330.68	331.41	331.85	333.29	333.91	333.40	331.74	329.88	328.57	328.36	329.33	330.59
1976	331.66	332.75	333.46	334.78	334.78	334.06	332.95	330.64	328.96	328.77	330.18	331.65
1977	332.69	333.23	334.97	336.03	336.82	336.10	334.79	332.53	331.19	331.21	332.35	333.47
1978	335.10	335.26	336.61	337.77	338.01	337.98	336.48	334.37	332.33	332.41	333.76	334.83
1979	336.21	336.65	338.13	338.94	339.00	339.20	337.60	335.56	333.93	334.12	335.26	336.78
1980	337.80	338.28	340.04	340.86	341.47	341.26	339.34	337.45	336.10	336.05	337.21	338.29
1981	339.36	340.51	341.57	342.56	343.01	342.49	340.68	338.49	336.92	337.12	338.59	339.90
1982	340.92	341.69	342.85	343.92	344.67	343.78	342.23	340.11	338.32	338.39	339.48	340.88
1983	341.64	342.87	343.59	345.25	345.96	345.52	344.15	342.25	340.17	340.30	341.53	343.07
1984	344.05	344.77	345.46	346.77	347.55	346.98	345.55	343.20	341.35	341.68	343.06	344.54
1985	345.25	346.06	347.66	348.20	348.92	348.40	346.66	344.85	343.20	343.08	344.40	345.82
1986	346.54	347.13	348.05	349.77	350.53	349.90	348.11	346.09	345.01	344.47	345.86	347.15
1987	348.38	348.70	349.72	351.32	352.14	351.61	349.91	347.84	346.52	346.65	347.96	349.18
1988	350.38	351.68	352.24	353.66	354.18	353.68	352.58	350.66	349.03	349.08	350.15	351.44
1989	352.89	353.24	353.80	355.59	355.89	355.30	353.98	351.53	350.02	350.29	351.44	352.84
1990	353.79	354.88	355.65	356.27	357.29	356.32	354.88	352.89	351.28	351.59	353.05	354.27
1991	354.87	355.68	357.06	358.51	359.09	358.10	356.12	353.89	352.30	352.32	353.79	355.07
1992	356.17	356.93	357.82	359.00	359.55	359.32	356.85	354.91	352.93	353.31	354.27	355.53
1993	356.86	357.27	358.36	359.27	360.19	359.52	357.42	355.46	354.10	354.12	355.40	356.84
1994	358.22	358.98	359.91	361.32	361.68	360.80	359.39	357.42	355.63	356.09	357.56	358.87
1995	359.87	360.79	361.77	363.23	363.77	363.22	361.70	359.11	358.11	357.97	359.40	360.61
1996	362.04	363.17	364.17	364.51	365.16	364.93	363.53	361.38	359.60	359.54	360.84	362.18
1997	363.04	364.09	364.47	366.25	366.69	365.59	364.34	362.20	360.31	360.71	362.44	364.33
1998	365.18	365.98	367.13	368.61	369.49	368.95	367.74	365.79	364.01	364.35	365.52	367.08
1999	368.12	368.98	369.60	370.96	370.77	370.33	369.28	366.86	364.94	365.35	366.68	368.04
2000	369.25	369.50	370.56	371.82	371.51	371.71	369.85	368.20	366.91	366.99	368.33	369.67
2001	370.52	371.49	372.53	373.37	373.82	373.18	371.57	369.63	368.16	368.42	369.69	371.18
2002	372.45	373.14	373.93	375.00	375.65	375.50	374.00	371.83	370.66	370.51	372.20	373.71
2003	374.87	375.62	376.48	377.74	378.50	378.18	376.72	374.31	373.20	373.10	374.64	375.93
2004	377.00	377.87	378.73	380.41	380.63	379.56	377.61	376.15	374.11	374.44	375.93	377.45
2005	378.47	379.76	381.14	382.20	382.47	382.20	380.78	378.73	376.66	376.98	378.29	379.92
2006	381.35	382.16	382.66	384.73	384.98	384.09	382.38	380.45	378.92	379.16	380.18	381.79
2007	382.93	383.81	384.56	386.40	386.58	386.05	384.49	382.00	380.90	381.14	382.42	383.89
2008	385.44	385.73	385.97	387.16	388.50	387.88	386.43	384.15	383.09	382.99	384.13	385.56
2009	386.94	387.42	388.77	389.44	390.19	389.45	387.78	385.92	384.79	384.39	386.00	387.31
2010	388.50	389.94	391.09	392.52	393.04	392.15	390.22	388.26	386.83	387.20	388.65	389.73
2011	391.25	391.82	392.49	393.34	394.21	393.72	392.42	390.19	389.04	388.96	390.24	391.83
2012	393.12	393.60	394.45	396.18	396.78	395.83	394.30	392.41	391.06	391.01	392.81	394.28
2013	395.54	396.80	397.31	398.35	399.76	398.58	397.20	395.15	393.51	393.66	395.11	396.81
2014	397.80	397.90	399.59	401.29	401.75	401.15	399.00	397.01	395.29	395.93		

Table 2: Your time series for monthly mean data

2.3 Data Visualization

It is important to get a quick overview of your data. Some simple plots for visualization are quite helpful.

The red line in plot **??** was computed with a simple moving average. It is not enough to just run a MA.

3 Decomposition of Time Series

A time serie consists ofo 3 components; a trend component, an irregular (random) component and (if it is a seosonal ts) seasonal component. We can decompose the ts and plot these components:

It seems that our data can probably be described using an additive model, since the random fluctuations in the data are roughly constant in size over time (constant seasonal component)

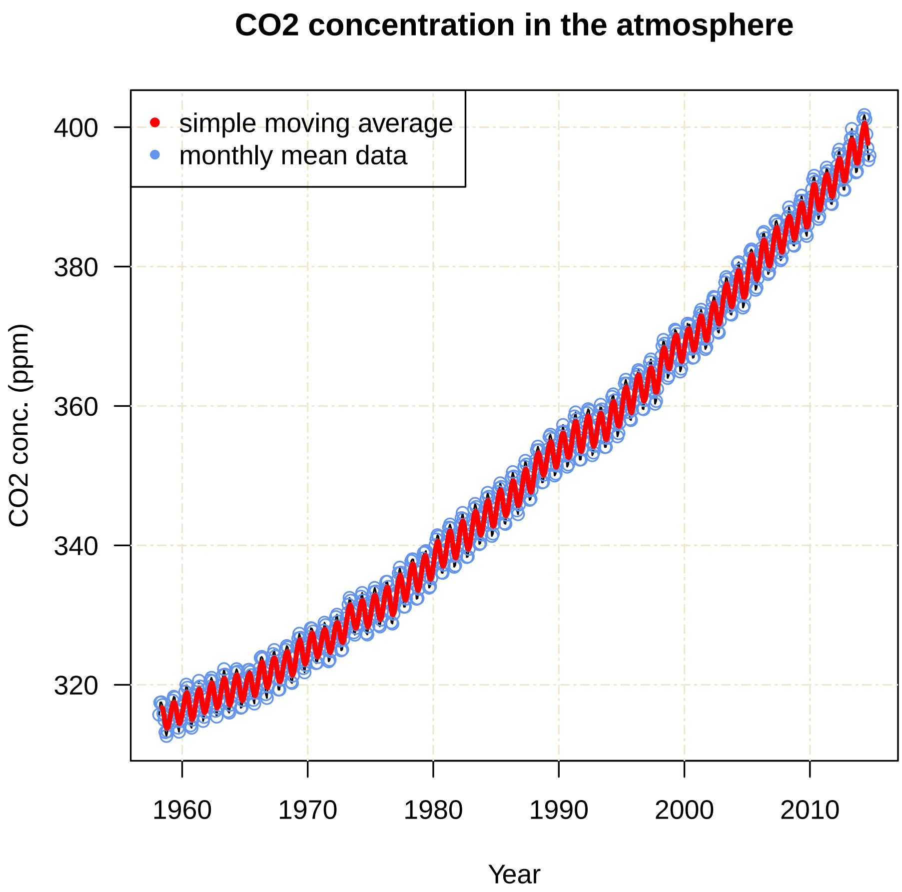


Figure 1: Visualization of the CO2 Concentrations

3.1 Decomposing Non-Seasonal Data

3.2 Decomposing Seasonal Data

We can see each component with:

```
> yourts.components<- decompose(yourts)
```

	Jan	Feb	Mar	Apr	May	Jun
1958			1.44050740	2.56300740	2.99546099	2.31164281
1959	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1960	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1961	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1962	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1963	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1964	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1965	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1966	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1967	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1968	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1969	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1970	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1971	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1972	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1973	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1974	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1975	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281

```
> plot(decompose(yourts))
>
```

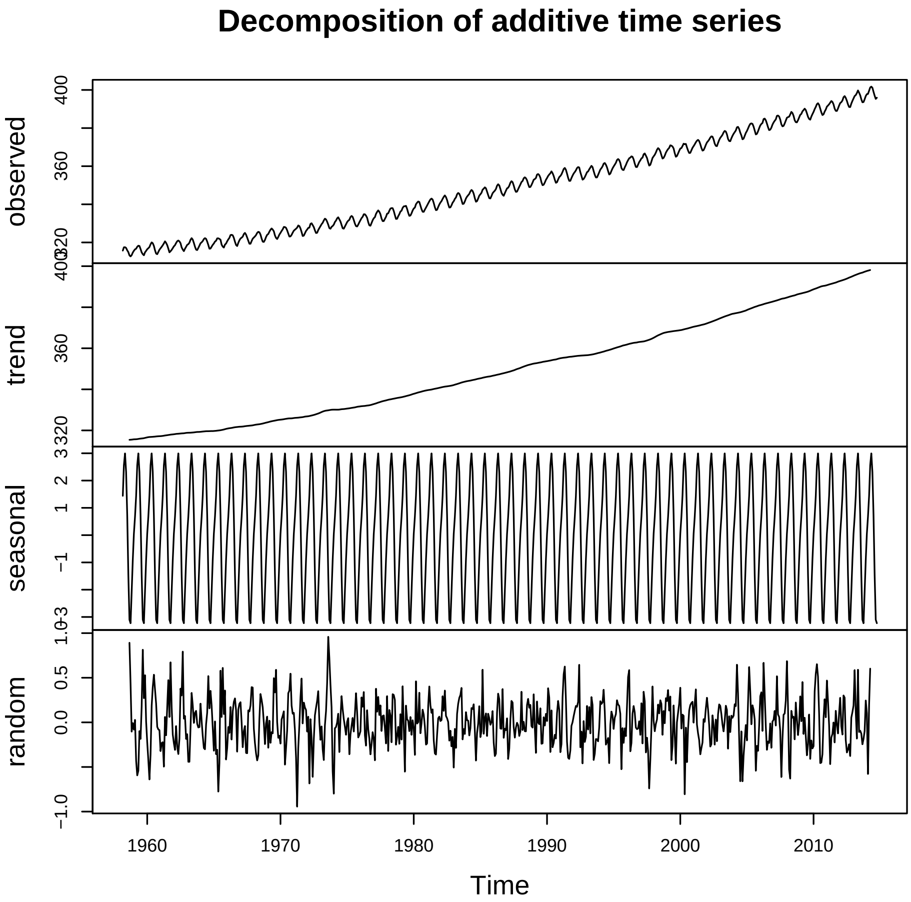


Figure 2: Decomposition of the CO2 Time Series

1976	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1977	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1978	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1979	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1980	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1981	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1982	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1983	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1984	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1985	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1986	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1987	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1988	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1989	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1990	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1991	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1992	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1993	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1994	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1995	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1996	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1997	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281

1998	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
1999	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
2000	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
2001	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
2002	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
2003	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
2004	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
2005	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
2006	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
2007	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
2008	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
2009	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
2010	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
2011	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
2012	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
2013	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281
2014	0.04630353	0.67408626	1.44050740	2.56300740	2.99546099	2.31164281

	Jul	Aug	Sep	Oct	Nov	Dec
1958	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1959	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1960	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1961	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1962	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1963	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1964	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1965	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1966	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1967	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1968	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1969	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1970	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1971	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1972	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1973	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1974	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1975	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1976	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1977	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1978	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1979	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1980	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1981	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1982	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1983	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1984	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1985	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1986	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1987	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1988	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1989	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1990	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1991	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1992	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1993	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1994	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1995	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1996	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1997	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630
1998	0.71752160	-1.44085719	-3.10118159	-3.22900897	-2.07282594	-0.90465630

```
1999  0.71752160 -1.44085719 -3.10118159 -3.22900897 -2.07282594 -0.90465630
2000  0.71752160 -1.44085719 -3.10118159 -3.22900897 -2.07282594 -0.90465630
2001  0.71752160 -1.44085719 -3.10118159 -3.22900897 -2.07282594 -0.90465630
2002  0.71752160 -1.44085719 -3.10118159 -3.22900897 -2.07282594 -0.90465630
2003  0.71752160 -1.44085719 -3.10118159 -3.22900897 -2.07282594 -0.90465630
2004  0.71752160 -1.44085719 -3.10118159 -3.22900897 -2.07282594 -0.90465630
2005  0.71752160 -1.44085719 -3.10118159 -3.22900897 -2.07282594 -0.90465630
2006  0.71752160 -1.44085719 -3.10118159 -3.22900897 -2.07282594 -0.90465630
2007  0.71752160 -1.44085719 -3.10118159 -3.22900897 -2.07282594 -0.90465630
2008  0.71752160 -1.44085719 -3.10118159 -3.22900897 -2.07282594 -0.90465630
2009  0.71752160 -1.44085719 -3.10118159 -3.22900897 -2.07282594 -0.90465630
2010  0.71752160 -1.44085719 -3.10118159 -3.22900897 -2.07282594 -0.90465630
2011  0.71752160 -1.44085719 -3.10118159 -3.22900897 -2.07282594 -0.90465630
2012  0.71752160 -1.44085719 -3.10118159 -3.22900897 -2.07282594 -0.90465630
2013  0.71752160 -1.44085719 -3.10118159 -3.22900897 -2.07282594 -0.90465630
2014  0.71752160 -1.44085719 -3.10118159 -3.22900897
```

It seems that our seasonal component is positiv until the sommer months, were it turns to be negativ and turning to be positiv again in the winter

4 Forecasts

We have three different options to make (up to now)

1. predict
2. Holt Winters
3. Arima forecasts

4.1 Forecasting using Exponential Smoothing

4.2 Holt-Winters Exponential Smoothing

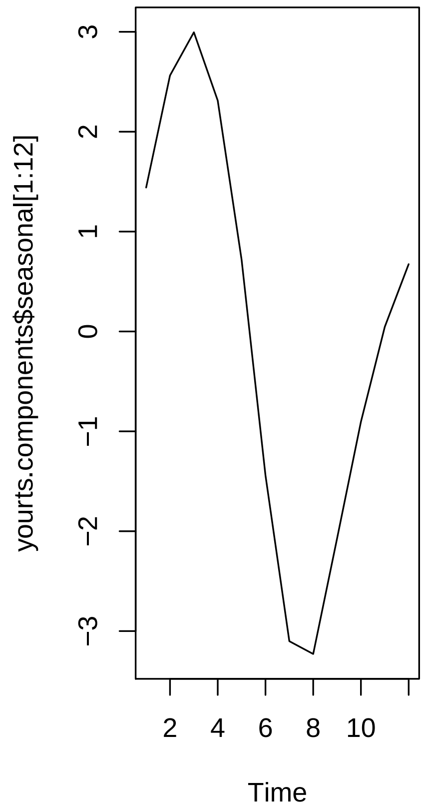
If we have a time series that can be described using an additive model,we can short-time forecast using exponential smoothing.
Preconditions:forecast errors are uncorrelated and are normally distributed with mean zero and constant variance.

```
> hw<-HoltWinters(yourts)
> #the alpha value tells us the weight of the previous values for the forecasting
> #values of alpha that are close to 0 mean that little weight is placed on the most recen
> #gamma is for the seasonality
> plot(hw)
>
```

Holtwinters just makes forecasts for the time period covered by the original data.If we want to forecast for the future, we need the packeged "forecast"

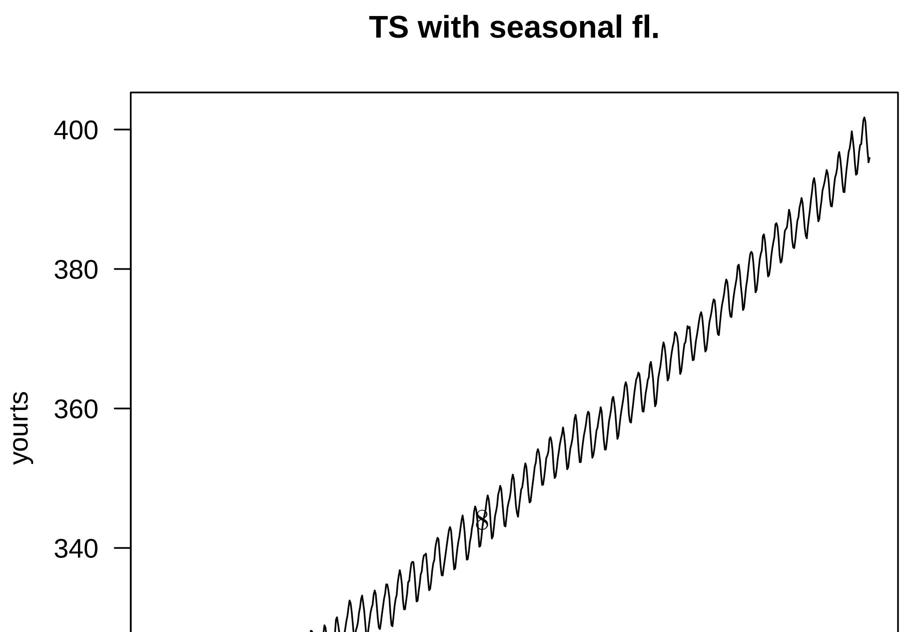
```
> hw1<- forecast.HoltWinters(hw, h=12)
> plot(hw1)
> #for the next year
> plot.forecast(hw1, main="Prediction for the next year")
> #for next 10 years
> hw10<- forecast.HoltWinters(hw, h=120)
> plot.forecast(hw10, main="Prediction for the next year")
>
```

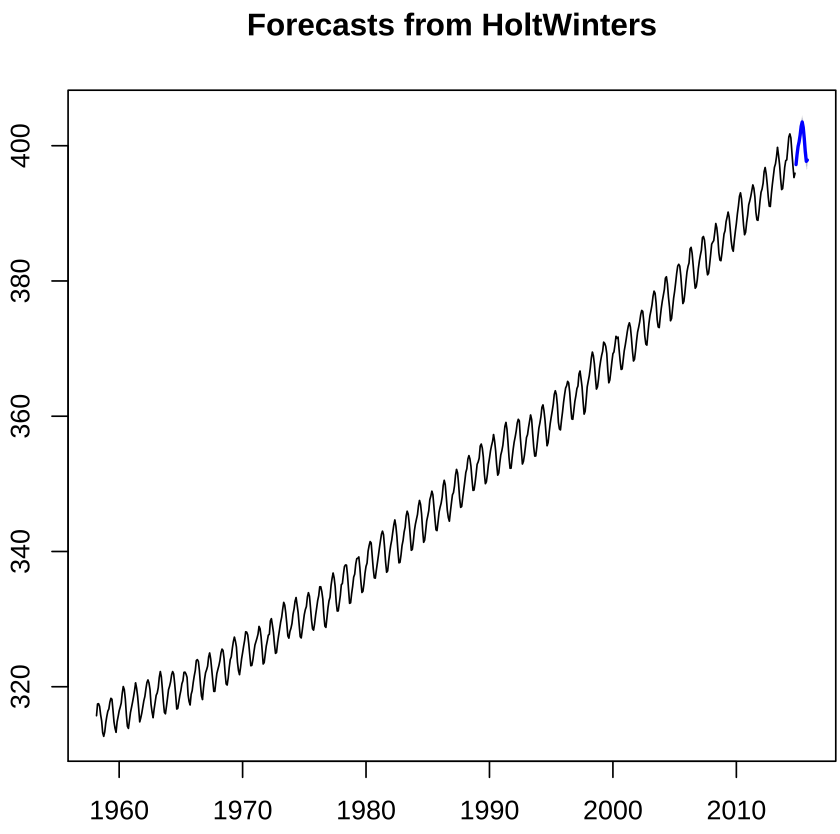
```
> par(mfrow=c(1,2))
> #we can see the trend for the first year:
> ts.plot(yourts.components$seasonal[1:12])
>
```




```
> ts.plot(aggregate(yourts.components$seasonal))
> #and we can see that this seasonal component is constant over all the years
>
> yourts.seasonallyadjusted <- yourts - yourts.components$seasonal
> #We can then plot the seasonally adjusted time series using "plot()"

> plot(yourts, main="TS with seasonal fl.", las=1)
```

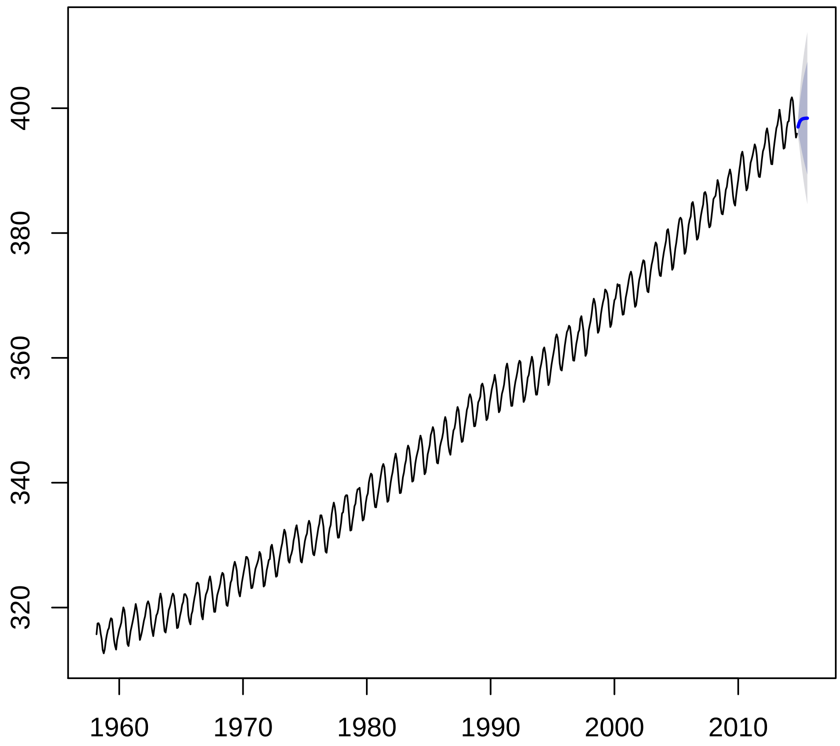




4.3 ARIMA Models

```
> au=auto.arima(yourts, ic = "bic")
> arima1=arima(yourts, order = c(au$arma[1],au$arma[6],au$arma[2]))
> fore1=forecast.Arima(arima1,h=10)
> plot.forecast(fore1)
>
```

Forecasts from ARIMA(1,1,1)



4.4 Selecting a Candidate ARIMA Model

4.5 Forecasting Using an ARIMA Model

5 Links and Further Reading

6 Acknowledgements

Don't forget to thank TeX and R and other opensource communities if you use their products! The correct way to cite R is shown when typing "`citation()`", and "`citation("mgcv")`" for packages.