Tutorial for Introductory Analysis of Daily Precipitation Data with hydroTSM

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1 Installation

Installing the latest stable version (from CRAN):

```
> install.packages("hydroTSM")
```

Alternatively, you can also try the under-development version (from rforge):

```
> install.packages("hydroTSM",, "http://rforge.net/", type="source")
```

2 Setting Up the Environment

1. Loading the *hydroTSM* library, which contains data and functions used in this analysis.

   ```
   > library(hydroTSM)
   ```

2. Loading daily precipitation data at the station San Martino di Castrozza, Trento Province, Italy, with data from 01/Jan/1921 to 31/Dec/1990.

   ```
   > data(SanMartinoPPts)
   ```

3. Selecting only a 6-years time slice for the analysis

   ```
   > x <- window(SanMartinoPPts, start=as.Date("1985-01-01"))
   ```

4. Monthly values of precipitation

   ```
   > ( m <- daily2monthly(x, FUN=sum) )
   ```

```
1985-01-01 1985-02-01 1985-03-01 1985-04-01 1985-05-01 1985-06-01 1985-07-01
     141.2        7.0      140.6       72.0      175.6      131.4       85.4
1985-08-01 1985-09-01 1985-10-01 1985-11-01 1985-12-01 1986-01-01 1986-02-01
     159.4       27.2       58.4      101.8       54.8       75.8      131.6
1986-03-01 1986-04-01 1986-05-01 1986-06-01 1986-07-01 1986-08-01 1986-09-01
      59.6      237.8      108.2      144.8       81.2      141.0       69.8
1986-10-01 1986-11-01 1986-12-01 1987-01-01 1987-02-01 1987-03-01 1987-04-01
      38.2       44.4       20.4       46.8      111.0       45.6       98.4
1987-05-01 1987-06-01 1987-07-01 1987-08-01 1987-09-01 1987-10-01 1987-11-01
     212.0      153.8      221.8      175.0       90.6      278.8      164.8
1987-12-01 1988-01-01 1988-02-01 1988-03-01 1988-04-01 1988-05-01 1988-06-01
      29.8      118.0       49.8       22.4      100.6      187.4      193.0
1988-07-01 1988-08-01 1988-09-01 1988-10-01 1988-11-01 1988-12-01 1989-01-01
     120.4      149.2       61.2      136.4       10.0       59.4        0.0
1989-02-01 1989-03-01 1989-04-01 1989-05-01 1989-06-01 1989-07-01 1989-08-01
     152.6       46.2      365.4       77.4      241.6      302.8      114.4
1989-09-01 1989-10-01 1989-11-01 1989-12-01 1990-01-01 1990-02-01 1990-03-01
      65.4       12.8      145.0      110.6       51.6       12.4       65.8
1990-04-01 1990-05-01 1990-06-01 1990-07-01 1990-08-01 1990-09-01 1990-10-01
     127.0       74.4      175.0      143.8       90.8      106.0      153.0
1990-11-01 1990-12-01
     326.6      106.0
```

5. Dates of the daily values of 'x'

```
> dates <- time(x)
```

6. Amount of years in 'x' (needed for computations)

```
> ( nyears <- yip(from=start(x), to=end(x), out.type="nmbr" ) )

[1] 6
```

3 Basic Exploratory Data Analysis

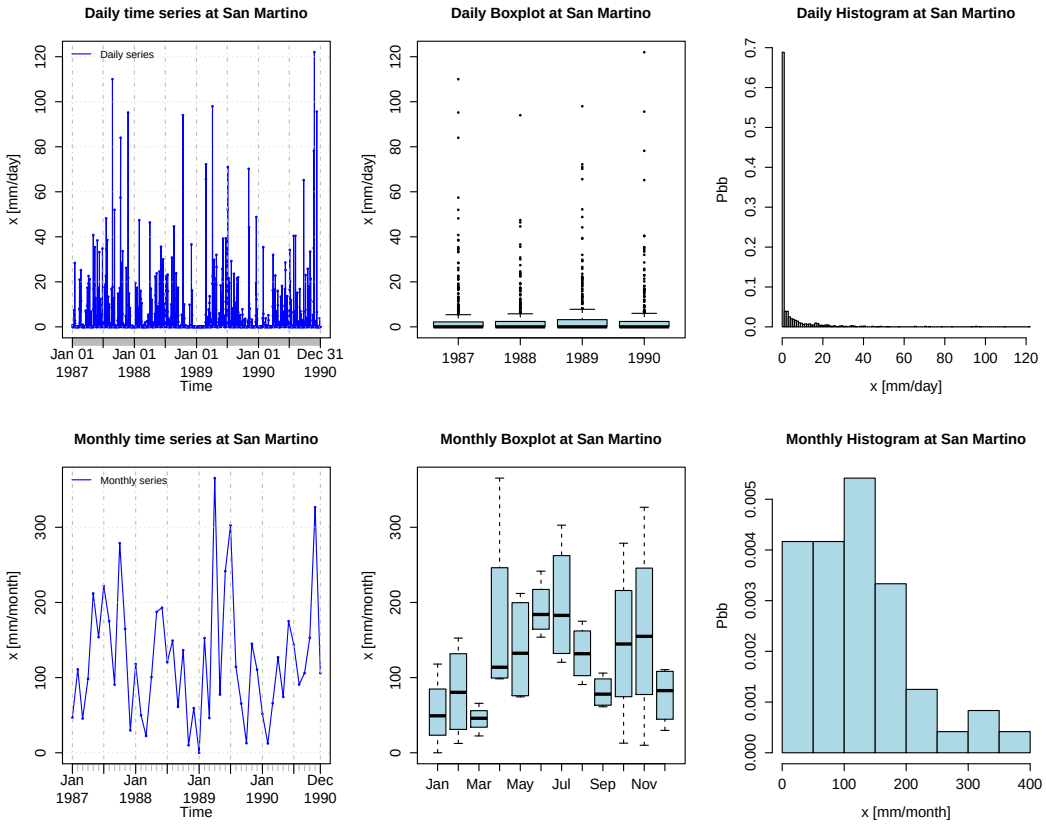
1. Summary statistics

```
> smry(x)
```

	Index	x
Min.	1985-01-01	0.0000
1st Qu.	1986-07-02	0.0000
Median	1988-01-01	0.0000
Mean	1988-01-01	3.7470
3rd Qu.	1989-07-01	2.6000
Max.	1990-12-31	122.0000
IQR	<NA>	2.6000
sd	<NA>	10.0428
cv	<NA>	2.6800
Skewness	<NA>	5.3512
Kurtosis	<NA>	39.1619
NA's	<NA>	0.0000
n	<NA>	2191.0000

2. Using the *hydroplot* function, which (by default) plots 9 different graphs: 3 ts plots, 3 boxplots and 3 histograms summarizing 'x'. For this example, only daily and monthly plots are produced, and only data starting on 01-Jan-1987 are plotted.

```
> hydroplot(x, var.type="Precipitation", main="at San Martino",
+           pfreq = "dm", from="1987-01-01")
```



3. Amount of days with information (not NA) per year

```
> dwi(x)
```

```
1985 1986 1987 1988 1989 1990
 365  365  365  366  365  365
```

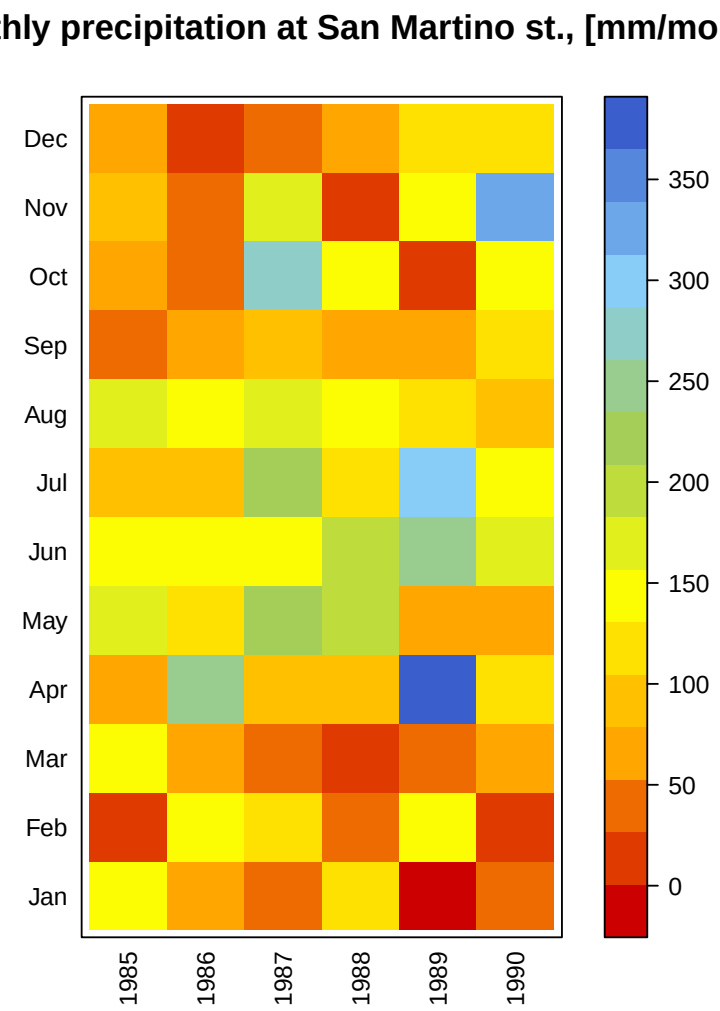
4. Amount of days with information (not NA) per month per year

```
> dwi(x, out.unit="mpy")
```

```
     Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
1985  31  28  31  30  31  30  31  31  30  31  30  31
1986  31  28  31  30  31  30  31  31  30  31  30  31
1987  31  28  31  30  31  30  31  31  30  31  30  31
1988  31  29  31  30  31  30  31  31  30  31  30  31
1989  31  28  31  30  31  30  31  31  30  31  30  31
1990  31  28  31  30  31  30  31  31  30  31  30  31
```

5. Plotting the monthly precipitation values for each year, useful for identifying dry/wet months.

```
> # Daily zoo to monthly zoo
> m <- daily2monthly(x, FUN=sum, na.rm=TRUE)
> # Creating a matrix with monthly values per year in each column
> M <- matrix(m, ncol=12, byrow=TRUE)
> colnames(M) <- month.abb
> rownames(M) <- unique(format(time(m), "%Y"))
> # Plotting the monthly precipitation values
> require(lattice)
> print(matrixplot(M, ColorRamp="Precipitation",
+            main="Monthly precipitation at San Martino st., [mm/month]"))
```



4 Annual Analysis

1. Annual values of precipitation

```
> daily2annual(x, FUN=sum, na.rm=TRUE)

1985-01-01 1986-01-01 1987-01-01 1988-01-01 1989-01-01 1990-01-01
    1154.8     1152.8     1628.4     1207.8     1634.2     1432.4
```

2. Average annual precipitation

   Obvious way:

```
> mean( daily2annual(x, FUN=sum, na.rm=TRUE) )

[1] 1368.4
```

   Another way (more useful for streamflows, where `FUN=mean`):

   The function *annualfunction* applies `FUN` twice over `x`: (i) firstly, over all the elements of `x` belonging to the same year, in order to obtain the corresponding annual values, and (ii) secondly, over all the annual values of `x` previously obtained, in order to obtain a single annual value.

```
> annualfunction(x, FUN=sum, na.rm=TRUE) / nyears

 value
1368.4
```

5 Monthly Analysis

1. Median of the monthly values at station 'x'. Not needed, just for looking at these values in the boxplot.

```
> monthlyfunction(m, FUN=median, na.rm=TRUE)

  Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct   Nov   Dec
 63.7  80.4  52.9 113.8 141.9 164.4 132.1 145.1  67.6  97.4 123.4  57.1
```

2. Vector with the three-letter abbreviations for the month names

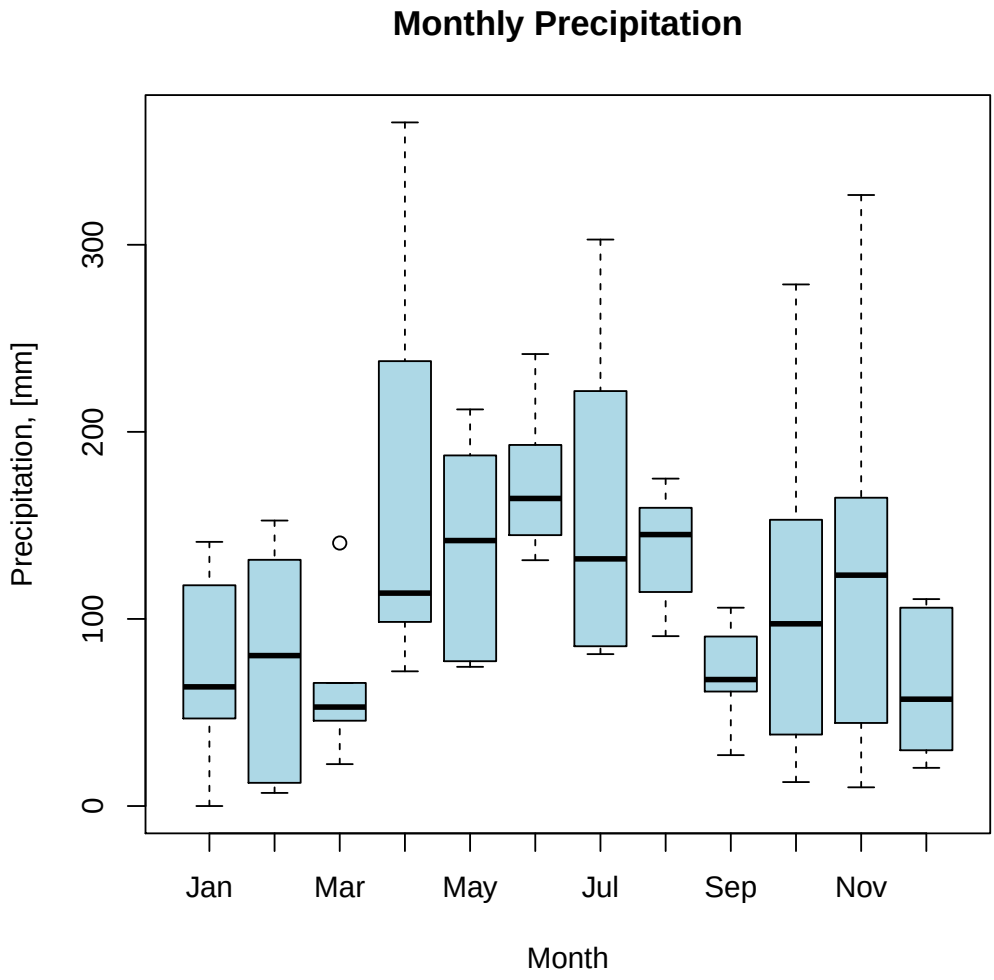
```
> cmonth <- format(time(m), "%b")
```

3. Creating ordered monthly factors

```
> months <- factor(cmonth, levels=unique(cmonth), ordered=TRUE)
```

4. Boxplot of the monthly values

```
> boxplot( coredata(m) ~ months, col="lightblue", main="Monthly Precipitation",
+          ylab="Precipitation, [mm]", xlab="Month")
```



6 Seasonal Analysis

1. Average seasonal values of precipitation

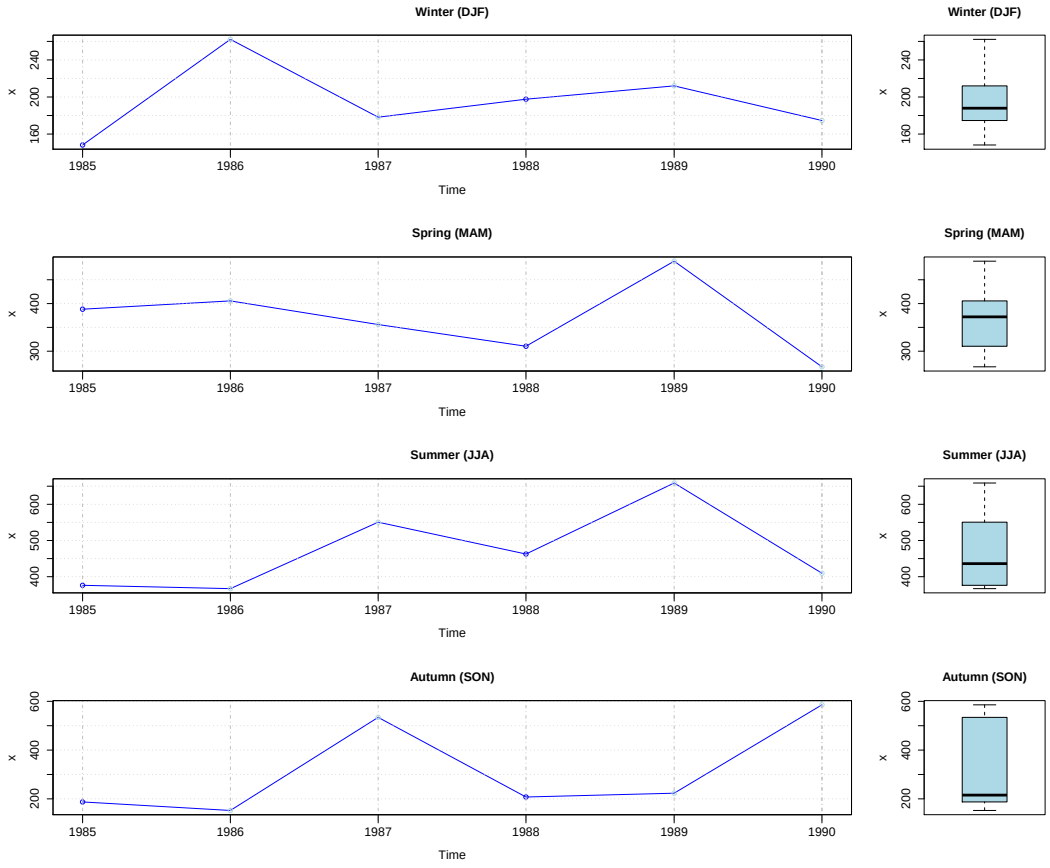
```
> seasonalfunction(x, FUN=sum, na.rm=TRUE) / nyears

     DJF      MAM      JJA      SON
213.1333 369.4000 470.8000 315.0667
```

2. Extracting the seasonal values for each year

```
> ( DJF <- dm2seasonal(x, season="DJF", FUN=sum) )

 1985  1986  1987  1988  1989  1990
148.2 262.2 178.2 197.6 212.0 174.6

> ( MAM <- dm2seasonal(m, season="MAM", FUN=sum) )

 1985  1986  1987  1988  1989  1990
388.2 405.6 356.0 310.4 489.0 267.2

> ( JJA <- dm2seasonal(m, season="JJA", FUN=sum) )

 1985  1986  1987  1988  1989  1990
376.2 367.0 550.6 462.6 658.8 409.6

> ( SON <- dm2seasonal(m, season="SON", FUN=sum) )

 1985  1986  1987  1988  1989  1990
187.4 152.4 534.2 207.6 223.2 585.6
```

3. Plotting the time evolution of the seasonal precipitation values

```
> hydroplot(x, pfreq="seasonal", FUN=sum, stype="default")
```



7 Some Extreme Indices

Common steps for the analysis of this section:

1. Loading daily precipitation data at the station San Martino di Castrozza, Trento Province, Italy, with data from 01/Jan/1921 to 31/Dec/1990.

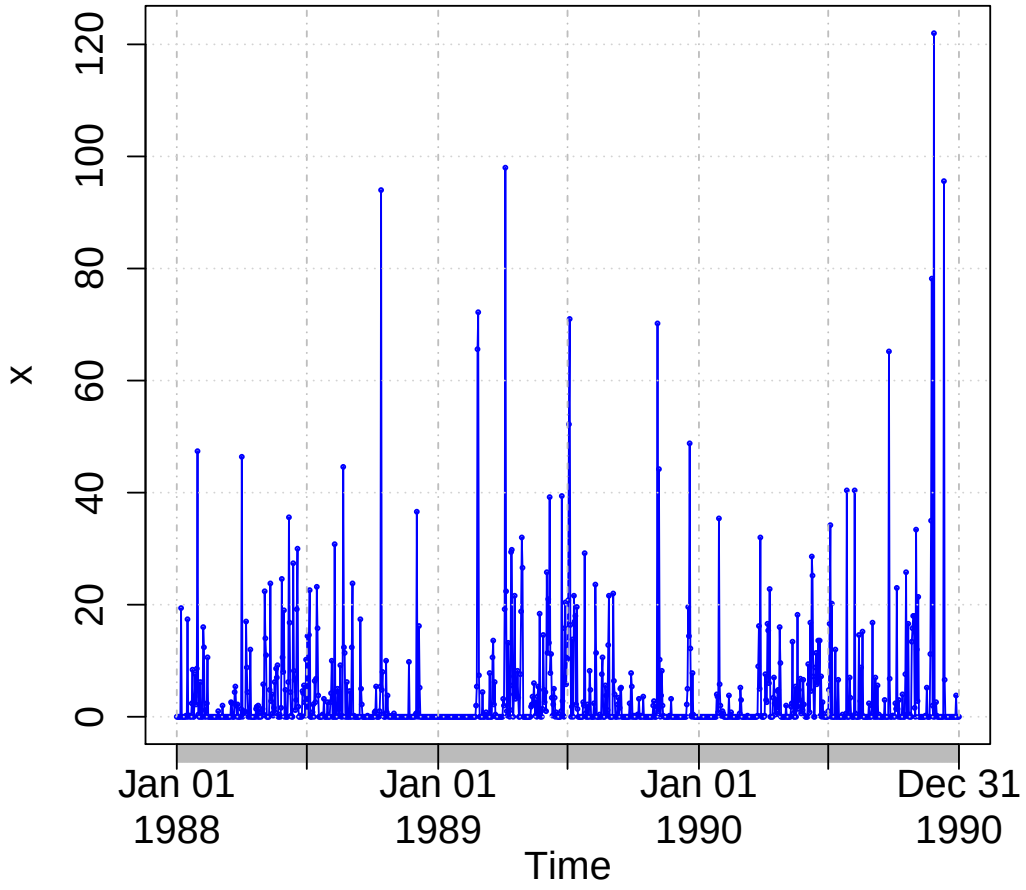
   ```
   > data(SanMartinoPPts)
   ```

2. Selecting only a three-year time slice for the analysis

   ```
   > x <- window(SanMartinoPPts, start=as.Date("1988-01-01"))
   ```

3. Plotting the selected time series

   ```
   > hydroplot(x,  ptype="ts", pfreq="o", var.unit="mm")
   ```



7.1 Heavy Precipitation Days (R10mm)

1. Counting and plotting the number of days in the period where precipitation is > 10 [mm]

   ```
   > ( R10mm <- length( x[x>10] ) )
   ```

   ```
   [1] 127
   ```

7.2 Very Wet Days (R95p)

1. Identifying the wet days (daily precipitation >= 1 mm):

   ```
   > wet.index <- which(x >= 1)
   ```

2. Computing the 95th percentile of precipitation on wet days (*PRwn95*):

```
> ( PRwn95 <- quantile(x[wet.index], probs=0.95, na.rm=TRUE) )

  95%
39.75
```

Note 1: this computation was carried out for the three-year time period 1988-1990, not the 30-year period 1961-1990 commonly used.
Note 2: missing values are removed from the computation.

3. Identifying the very wet days (daily precipitation >= $PRwn95$)

```
> (very.wet.index <- which(x >= PRwn95))

 [1]   30   92  234  287  422  423  461  550  551  674  676  719  939  950  998
[16] 1058 1061 1075
```

4. Computing the total precipitation on the very wet days:

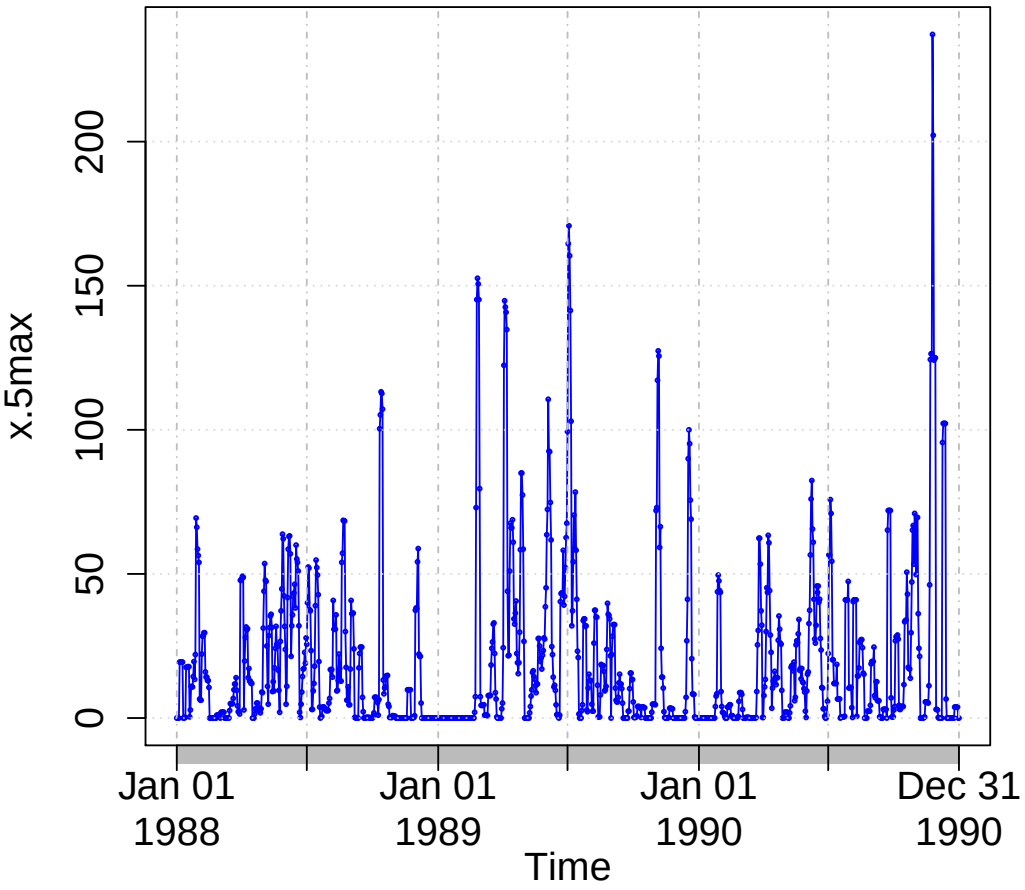
```
> ( R95p <- sum(x[very.wet.index]) )

[1] 1196.4
```

Note 3: this computation was carried out for the three-year time period 1988-1990, not the 30-year period 1961-1990 commonly used

7.3 5-day Total Precipitation

1. Computing the 5-day total (accumulated) precipitation

```
> x.5max <- rollapply(data=x, width=5, FUN=sum, fill=NA, partial= TRUE,
+                     align="center")
> hydroplot(x.5max,  ptype="ts+boxplot", pfreq="o", var.unit="mm")
```



2. Maximum annual value of 5-day total precipitation

```
> (x.5max.annual <- daily2annual(x.5max, FUN=max, na.rm=TRUE))

1988-01-01 1989-01-01 1990-01-01
     113.2      170.8      237.2
```

Note 1: for this computation, a moving window centred in the current day is used. If the user wants the 5-day total precipitation accumulated in the 4 days before the current day + the precipitation in the current day, the user have to modify the moving window.

Note 2: For the first two and last two values, the width of the window is adapted to ignore values not within the time series

8 Software Details

This tutorial was built under:

```
[1] "x86_64-unknown-linux-gnu (64-bit)"

[1] "R Under development (unstable) (2015-02-02 r67710)"

[1] "hydroTSM 0.5-0"
```

A Appendix

In order to make easier the use of `hydroTSM` for users not familiar with R, in this section a minimal set of information is provided to guide the user in the R world.

A.1 Editors, GUI

- GNU/Linux only: Rgedit, ESS
- Windows only : Tinn-R, NppToR
- Multi-platform: RStudio

A.2 Importing data

- `?read.table`, `?write.table`: allow the user to read/write a file (in ˜table format) and create a data frame from it. Related functions are `?read.csv`, `?write.csv`, `?read.csv2`, `?write.csv2`.
- foreign: read data stored in several R-external formats (dBase, Minitab, S, SAS, SPSS, Stata, Systat, Weka, ...)
- `?zoo::read.zoo`, `?zoo::write.zoo`: functions for reading and writing time series from/to text files, respectively.
- R Data Import/Export
- some examples

A.3 Useful Websites

- Quick R
- Time series in R
- Quick reference for the `zoo` package
- Manipulating time series with the `xts` package