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 Github):

```
if (!require(devtools)) install.packages("devtools")
library(devtools)
install_github("hzambran/hydroTSM")
```

2 Setting Up the Environment

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

```
library(hydroTSM)

## Loading required package:  zoo
##
## Attaching package:  'zoo'
## The following objects are masked from 'package:base':
##
##    as.Date, as.Date.numeric
## Loading required package:  xts
```

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
##      141.2        7.0      140.6       72.0      175.6      131.4
## 1985-07-01 1985-08-01 1985-09-01 1985-10-01 1985-11-01 1985-12-01
##       85.4      159.4       27.2       58.4      101.8       54.8
## 1986-01-01 1986-02-01 1986-03-01 1986-04-01 1986-05-01 1986-06-01
```

```
##       75.8      131.6       59.6      237.8      108.2      144.8
## 1986-07-01 1986-08-01 1986-09-01 1986-10-01 1986-11-01 1986-12-01
##       81.2      141.0       69.8       38.2       44.4       20.4
## 1987-01-01 1987-02-01 1987-03-01 1987-04-01 1987-05-01 1987-06-01
##       46.8      111.0       45.6       98.4      212.0      153.8
## 1987-07-01 1987-08-01 1987-09-01 1987-10-01 1987-11-01 1987-12-01
##      221.8      175.0       90.6      278.8      164.8       29.8
## 1988-01-01 1988-02-01 1988-03-01 1988-04-01 1988-05-01 1988-06-01
##      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
##      120.4      149.2       61.2      136.4       10.0       59.4
## 1989-01-01 1989-02-01 1989-03-01 1989-04-01 1989-05-01 1989-06-01
##        0.0      152.6       46.2      365.4       77.4      241.6
## 1989-07-01 1989-08-01 1989-09-01 1989-10-01 1989-11-01 1989-12-01
##      302.8      114.4       65.4       12.8      145.0      110.6
## 1990-01-01 1990-02-01 1990-03-01 1990-04-01 1990-05-01 1990-06-01
##       51.6       12.4       65.8      127.0       74.4      175.0
## 1990-07-01 1990-08-01 1990-09-01 1990-10-01 1990-11-01 1990-12-01
##      143.8       90.8      106.0      153.0      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
```

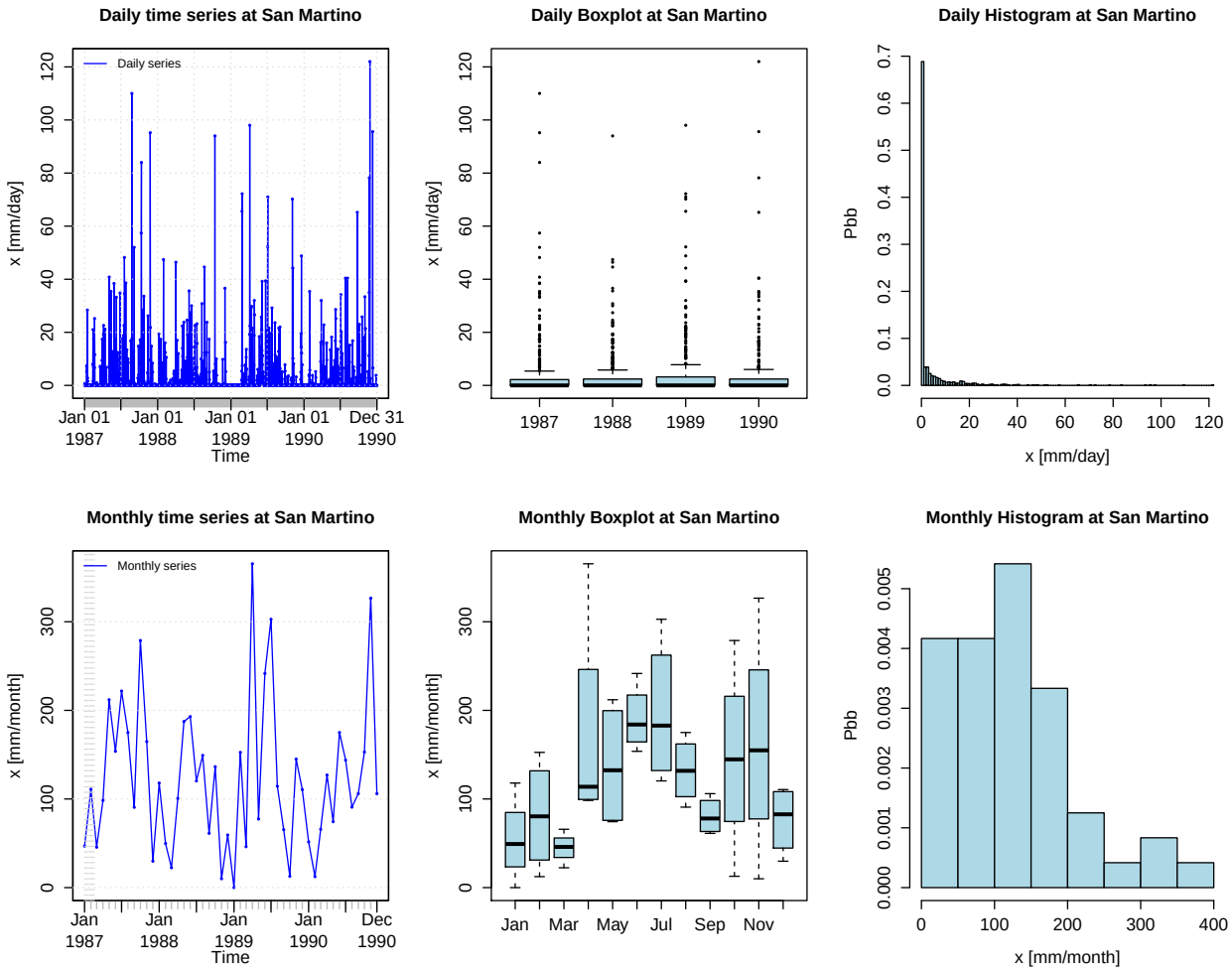
3 Basic Exploratory Data Analysis

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
```

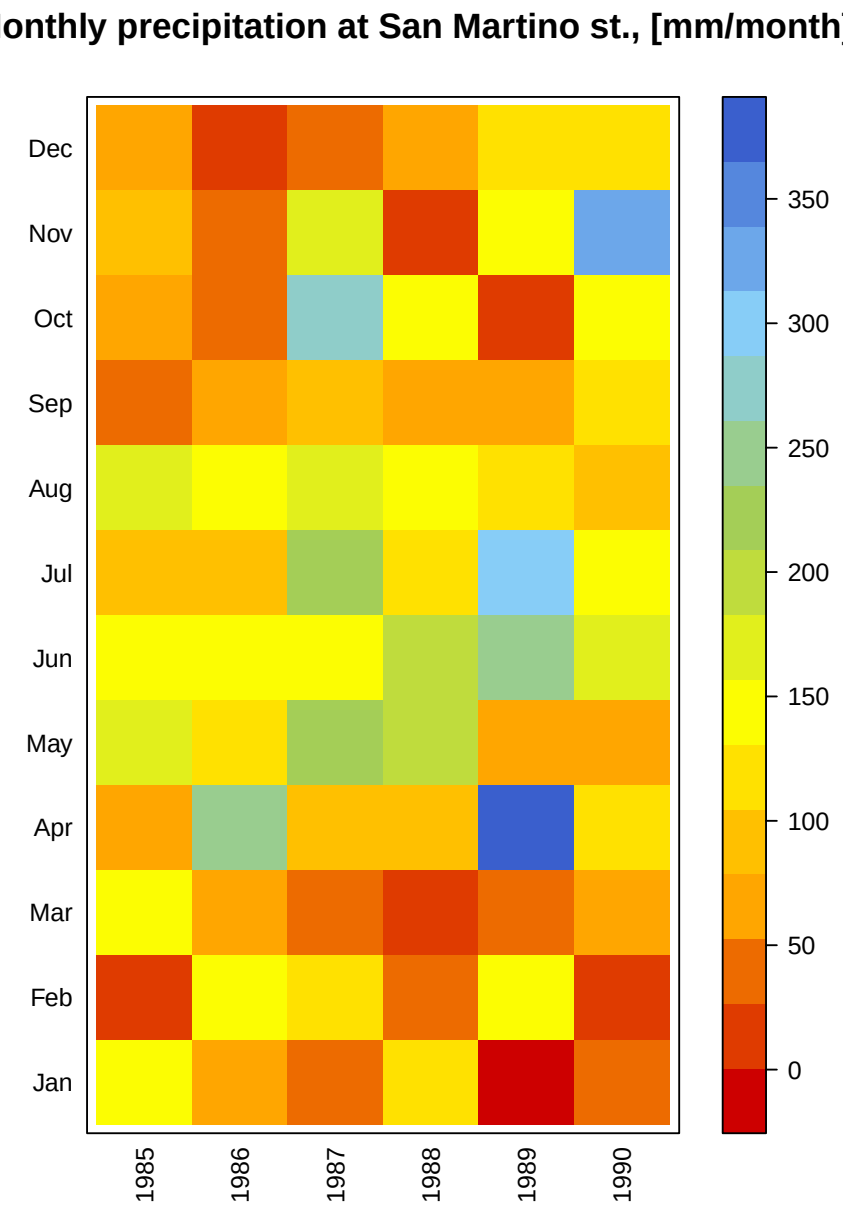
4. Amount of days with information (not `NA`) per month per year

```
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)

## Loading required package:  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

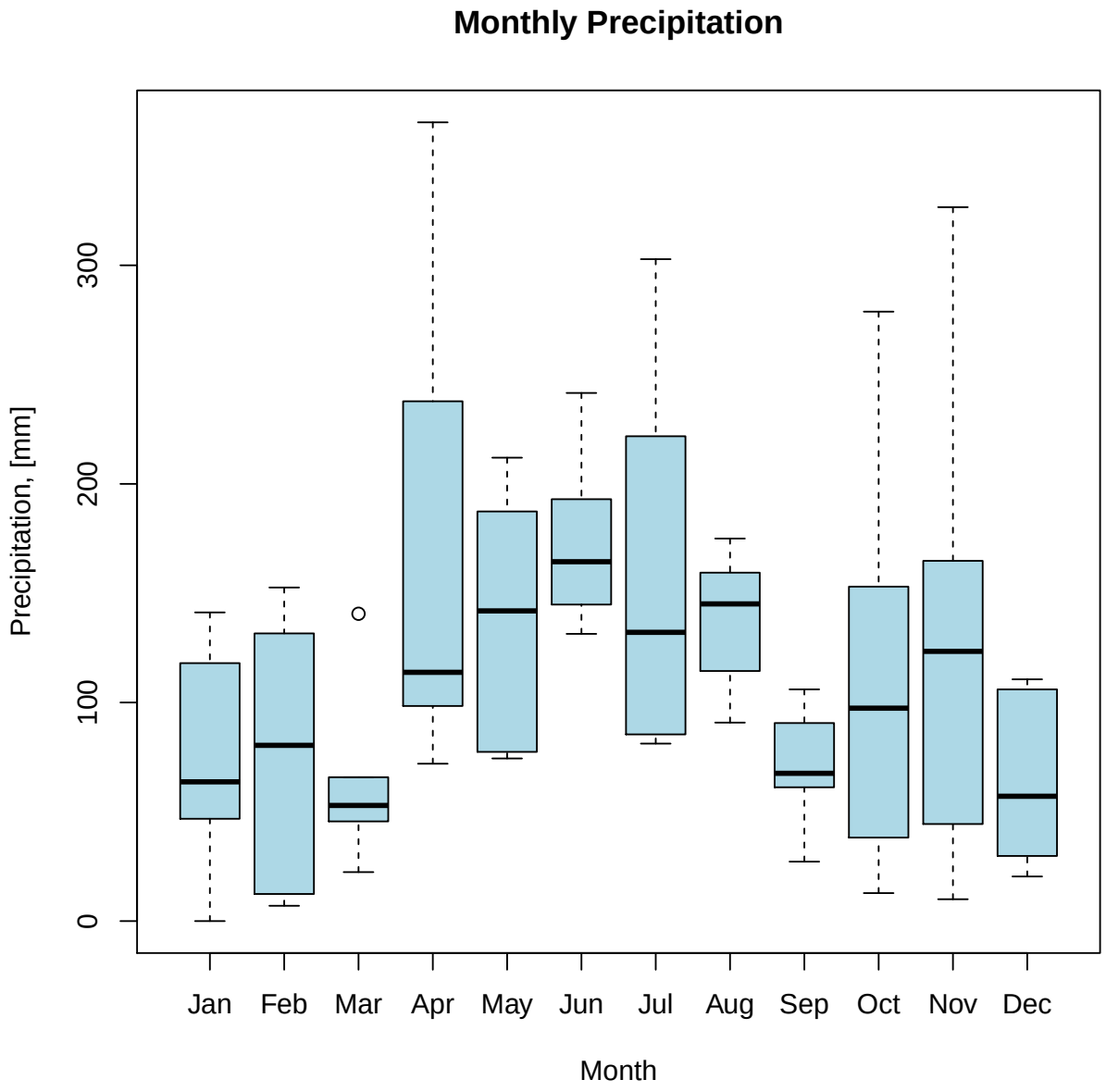
```
cmonth <- format(time(m), "%b")
```

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
```

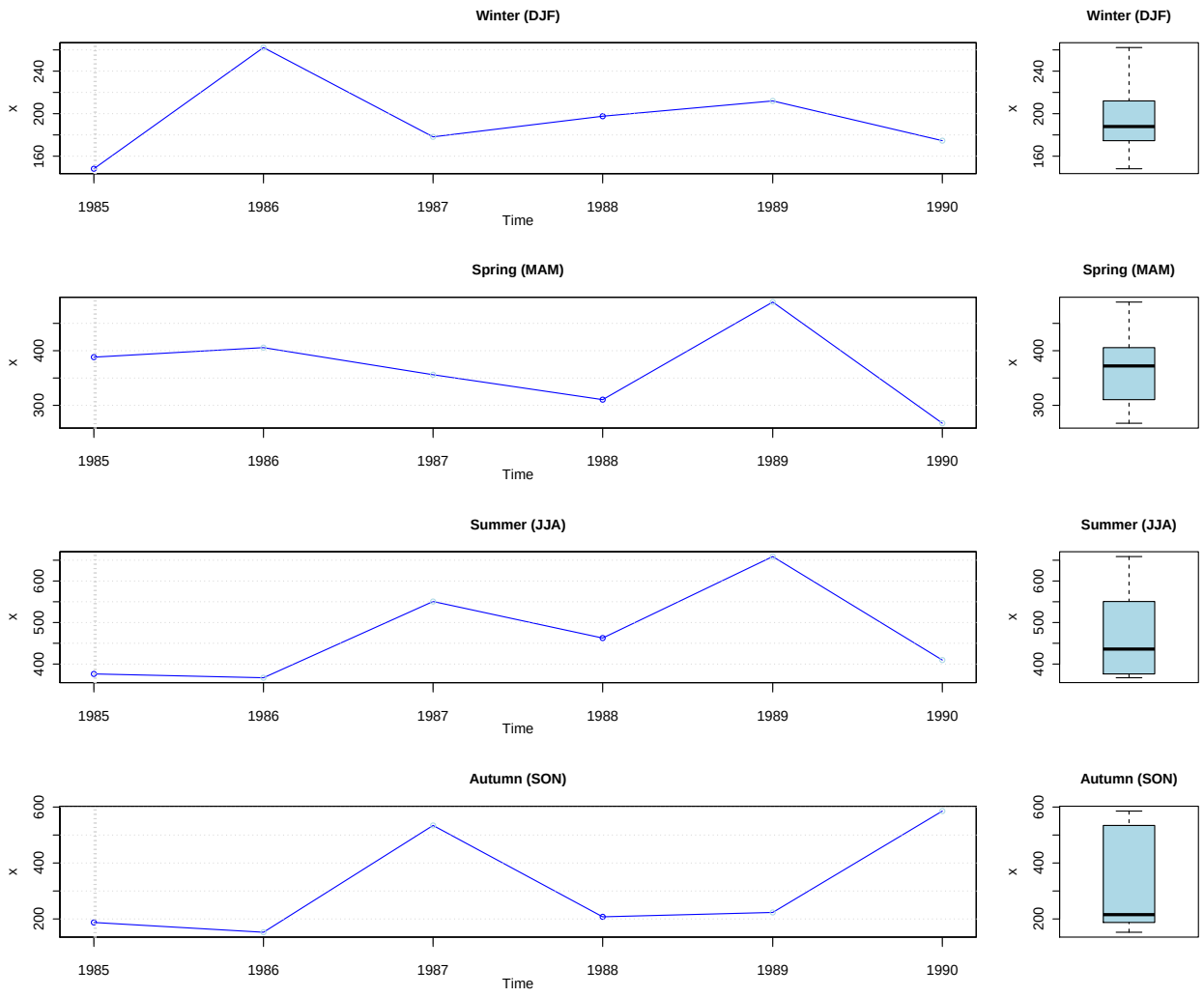
2. Extracting the seasonal values for each year

```
( 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.

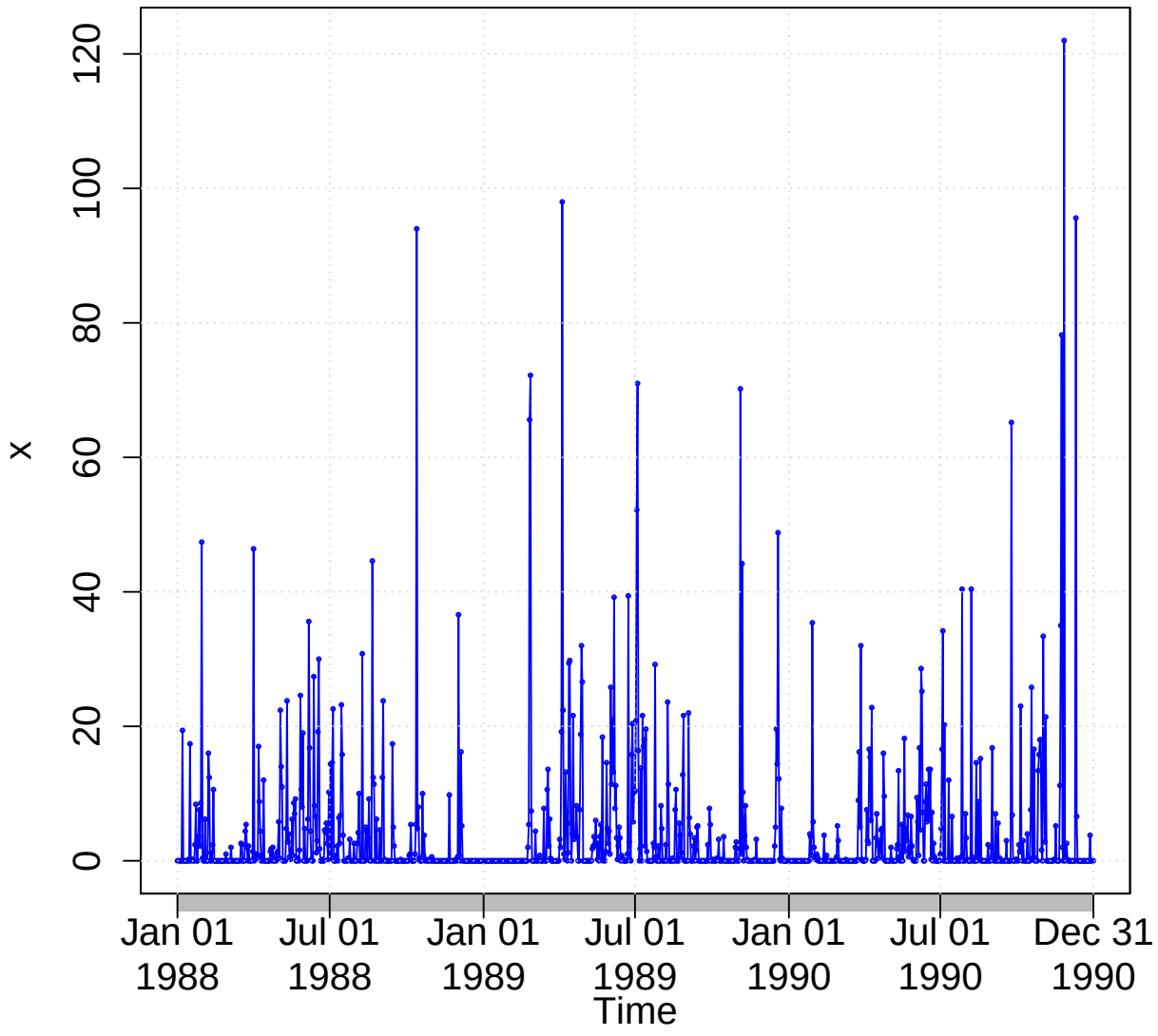
```
data(SanMartinoPPts)
```

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
## [15]  998 1058 1061 1075
```

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

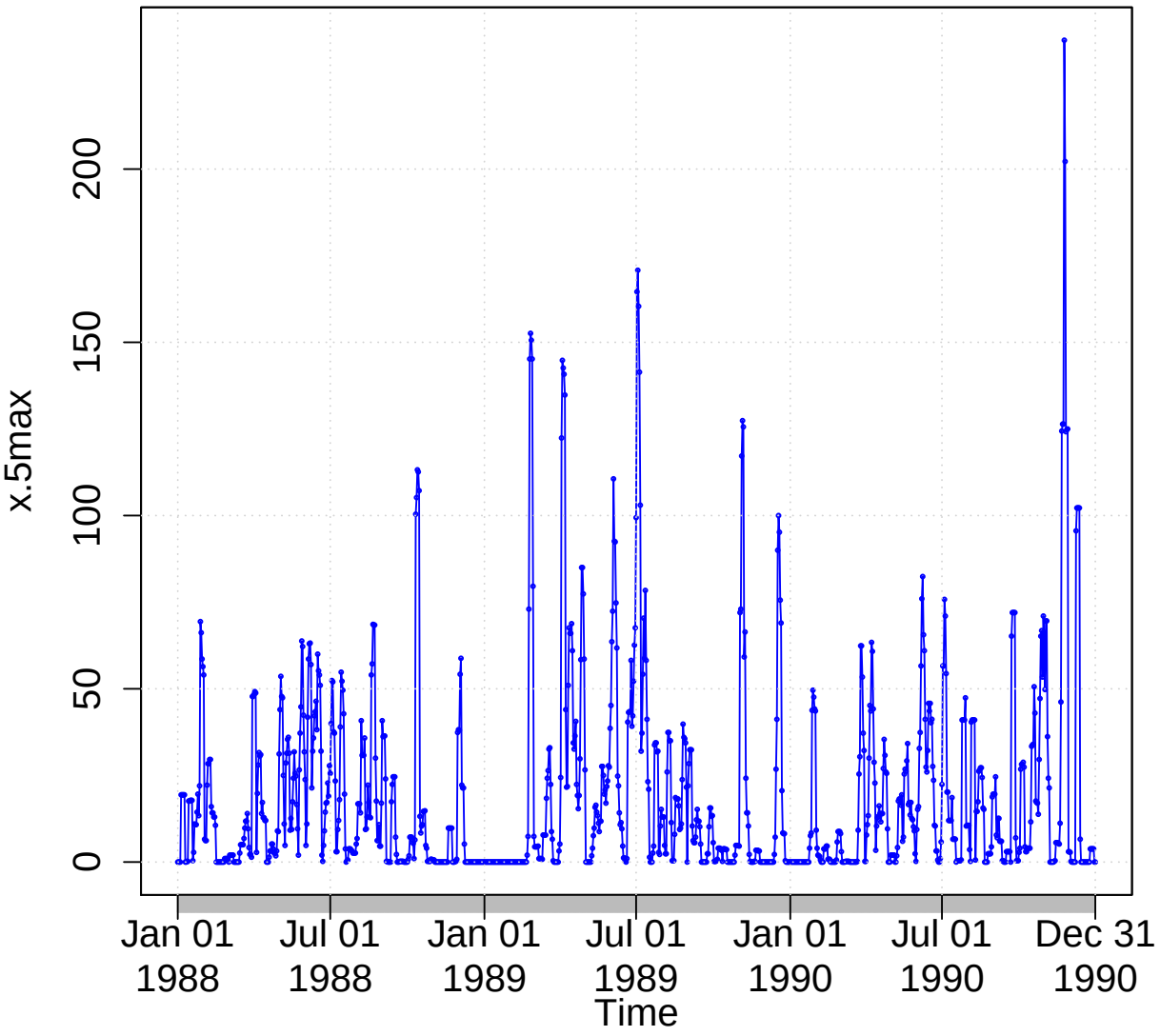
```
( R95p <- sum(x[very.wet.index]) )

## [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")

## [Note:  pfreq='o' => ptype has been changed to 'ts']
```



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-pc-linux-gnu (64-bit)"
## [1] "R version 3.4.1 (2017-06-30)"
## [1] "hydroTSM 0.5-1"
```

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