1 Installation

Installing the latest stable version (from CRAN):

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

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

```r
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.

```r
library(hydroTSM)
```

```r
## 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.

```r
data(SanMartinoPPts)
```

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

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

4. Monthly values of precipitation

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

```r
## 141.2 7.0 140.6 72.0 175.6 131.4 85.4 159.4 27.2 58.4 101.8 54.8 141.2 7.0 140.6 72.0 175.6 131.4 85.4 159.4 27.2 58.4 101.8 54.8
```
##  75.8 131.6  59.6 237.8 108.2 144.8
##  81.2 141.0  69.8  38.2  44.4  20.4
##  46.8 111.0  45.6  98.4 212.0 153.8
## 221.8 175.0  90.6 278.8 164.8  29.8
## 118.0  49.8  22.4 100.6 187.4 193.0
## 120.4 149.2  61.2 136.4  10.0  59.4
##  0.0 152.6  46.2 365.4  77.4 241.6
## 302.8 114.4  65.4  12.8 145.0  110.6
##  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="nmb") )

## [1] 6

3 Basic Exploratory Data Analysis

1. Summary statistics

```r
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.

```r
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

```r
dwi(x)
```
```
## 365 365 366 365 365
```

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

```r
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 30 31 30 31
## 1986 31 28 31 30 31 30 31 30 31 30 31
## 1987 31 28 31 30 31 30 31 30 31 30 31
## 1988 31 29 31 30 31 30 31 30 31 30 31
## 1989 31 28 31 30 31 30 31 30 31 30 31
## 1990 31 28 31 30 31 30 31 30 31 30 31
```

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

```r
# 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)

   ##  1154.8   1152.8    1628.4   1207.8   1634.2   1432.4

2. Average annual precipitation

   Obvious way:
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

\[
\text{seasonalfunction}(x, \text{FUN}=\text{sum, na.rm=TRUE}) / \text{nyears}
\]

<table>
<thead>
<tr>
<th>Season</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DJF</td>
<td>213.1333</td>
</tr>
<tr>
<td>MAM</td>
<td>369.4000</td>
</tr>
<tr>
<td>JJA</td>
<td>470.8000</td>
</tr>
<tr>
<td>SON</td>
<td>315.0667</td>
</tr>
</tbody>
</table>

2. Extracting the seasonal values for each year

\[
(\text{DJF} <\text{dm2seasonal}(x, \text{season}="\text{DJF}", \text{FUN}=\text{sum}))
\]

<table>
<thead>
<tr>
<th>Year</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>148.2</td>
</tr>
<tr>
<td>1986</td>
<td>262.2</td>
</tr>
<tr>
<td>1987</td>
<td>178.2</td>
</tr>
<tr>
<td>1988</td>
<td>197.6</td>
</tr>
<tr>
<td>1989</td>
<td>212.0</td>
</tr>
<tr>
<td>1990</td>
<td>174.6</td>
</tr>
</tbody>
</table>

\[
(\text{MAM} <\text{dm2seasonal}(m, \text{season}="\text{MAM}", \text{FUN}=\text{sum}))
\]

<table>
<thead>
<tr>
<th>Year</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>388.2</td>
</tr>
<tr>
<td>1986</td>
<td>405.6</td>
</tr>
<tr>
<td>1987</td>
<td>356.0</td>
</tr>
<tr>
<td>1988</td>
<td>310.4</td>
</tr>
<tr>
<td>1989</td>
<td>489.0</td>
</tr>
<tr>
<td>1990</td>
<td>267.2</td>
</tr>
</tbody>
</table>
3. Plotting the time evolution of the seasonal precipitation values

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

```r
# JJA <- dm2seasonal(m, season="JJA", FUN=sum) )
## 376.2 367.0 550.6 462.6 658.8 409.6

# SON <- dm2seasonal(m, season="SON", FUN=sum) )
## 187.4 152.4 534.2 207.6 223.2 585.6
```
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.

   ```r
   data(SanMartinoPPts)
   ```

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

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

3. Plotting the selected time series

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

![Graph of daily precipitation data](image)

7.1 Heavy Precipitation Days (R10mm)

1. Counting and plotting the number of days in the period where precipitation is > 10 [mm]
7.2 Very Wet Days (R95p)

1. Identifying the wet days (daily precipitation $\xi = 1$ mm):

\[
\text{wet.index} <- \text{which}(x \geq 1)
\]

2. Computing the 95th percentile of precipitation on wet days ($PR_{wn95}$):

\[
PR_{wn95} <- \text{quantile}(x[\text{wet.index}], \text{probs}=0.95, \text{na.rm}=\text{TRUE})
\]

## 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 $\xi = PR_{wn95}$)

\[
\text{very.wet.index} <- \text{which}(x \geq PR_{wn95})
\]

## [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:

\[
R95p <- \text{sum}(x[\text{very.wet.index}])
\]

## [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

\[
x.5max <- \text{rollapply}(\text{data}=x, \text{width}=5, \text{FUN}=\text{sum}, \text{fill}=\text{NA}, \text{partial}=\text{TRUE}, \text{align}="\text{center}"
\]

\[
\text{hydroplot}(x.5max, \text{ptype}="\text{ts+boxplot"}, \text{pfreq}="o", \text{var.unit}="\text{mm}
\]

## [Note: pfreq='o' => ptype has been changed to 'ts']
2. Maximum annual value of 5-day total precipitation

\[
\text{(x.5max.annual <- daily2annual(x.5max, FUN=max, na.rm=TRUE))}
\]

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>113.2</td>
<td>170.8</td>
<td>237.2</td>
<td></td>
</tr>
</tbody>
</table>

**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: Redit, 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.

A.3 Useful Websites
- Quick R
- Time series in R
- Quick reference for the `zoo` package
- Manipulating time series with the `xts` package