Tutorial for Introductory Analysis of Daily Precipitation Data with `hydroTSM`

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version 0.8, 30-Nov-2023

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

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

```
data(SanMartinoPPts)
```

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

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

- Dates of the daily values of ‘x’

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

- Amount of years in ‘x’ (needed for computations)

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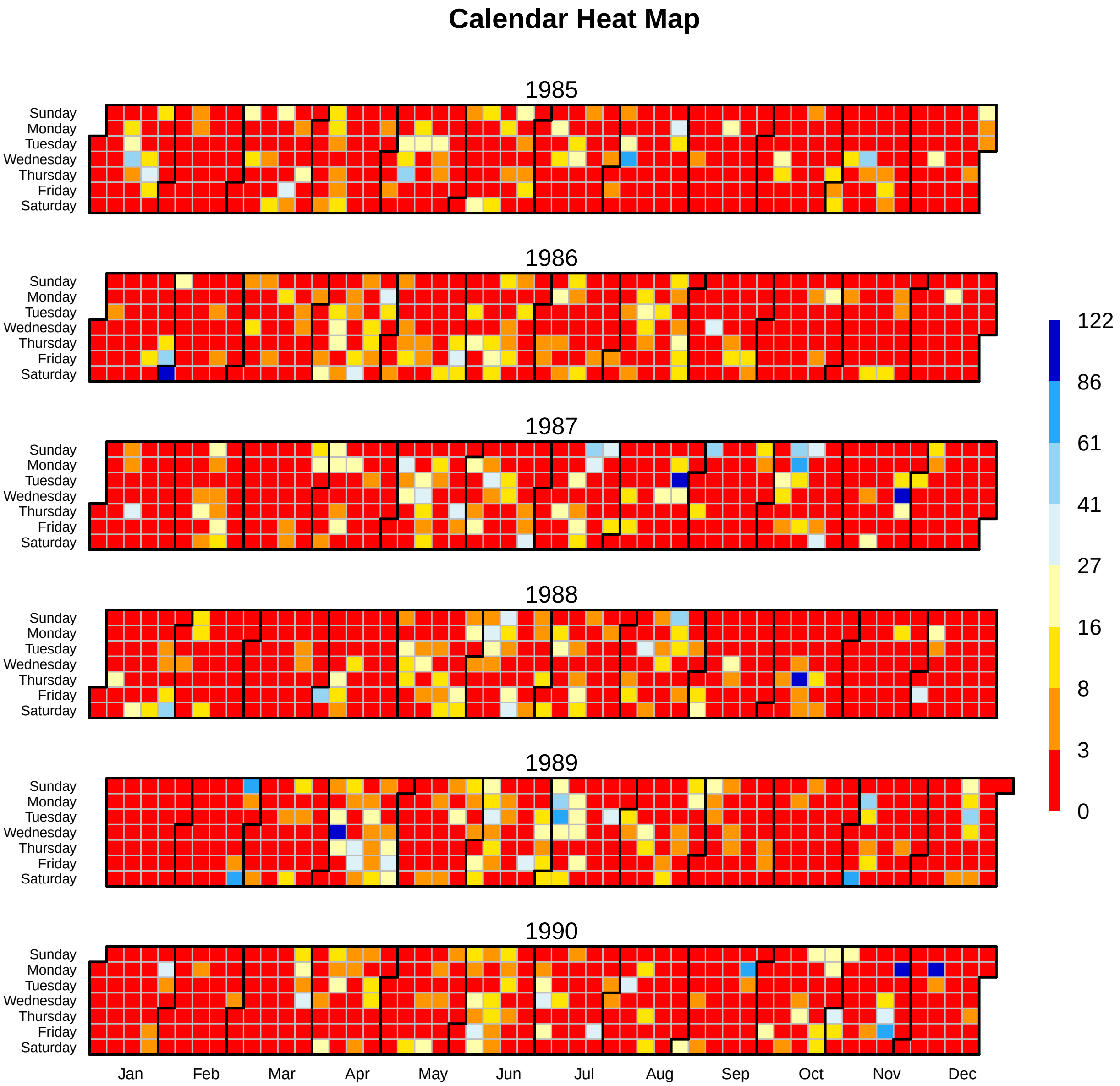
```
( nyears <- yip(from=start(x), to=end(x), out.type="nmbr" ) )
```

```
## [1] 6
```

- Global view of daily precipitation values a calendar heatmap (six years maximum):

```
calendarHeatmap(x)
```



3 Basic exploratory data analysis (EDA)

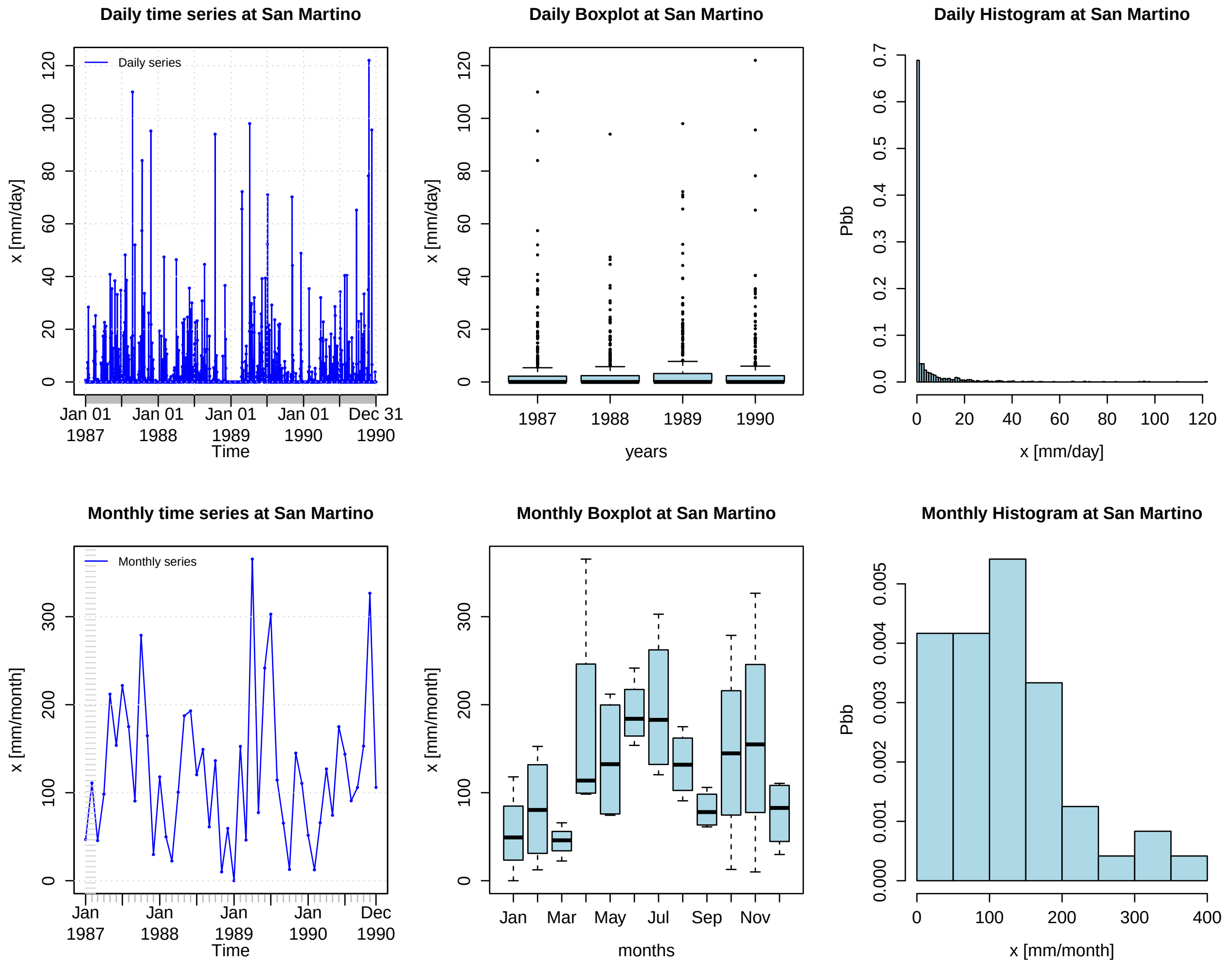
1) Summary statistics

```
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
```

- 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")
```



2) Amount of days with information (not `NA`) per year

```
dwi(x)
```

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

3) 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  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
```

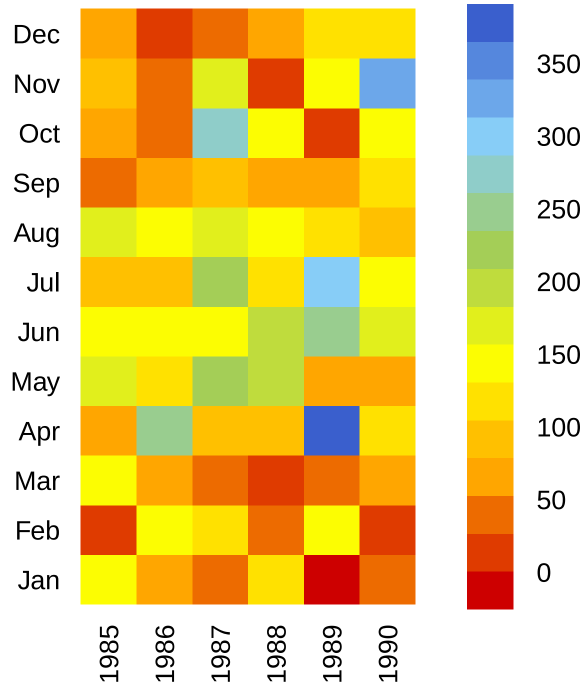
4) Plotting the monthly precipitation values for each year, useful for identifying dry/wet months.

```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
```

```r
print(matrixplot(M, ColorRamp="Precipitation",
           main="Monthly precipitation at San Martino st., [mm/month]"))
```

Monthly precipitation at San Martino st., [mm/month]



4 Annual analysis

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
```

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

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
```

Vector with the three-letter abbreviations for the month names

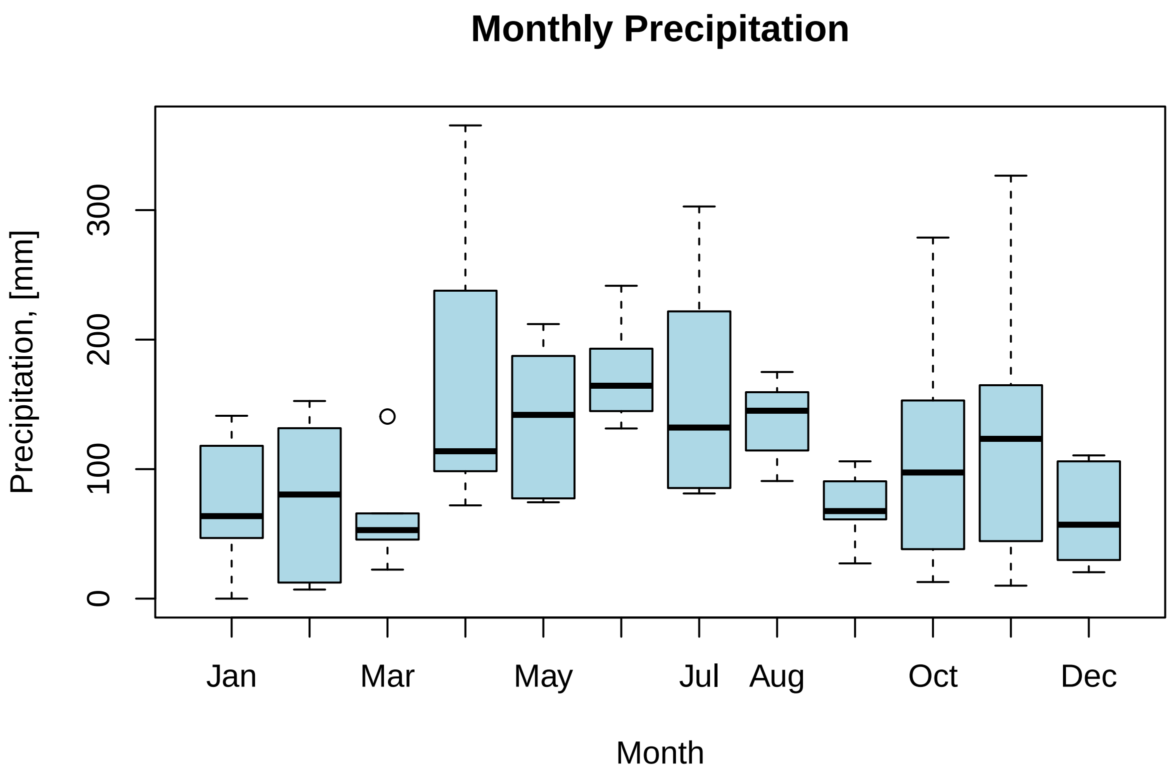
```
cmonth <- format(time(m), "%b")
```

Creating ordered monthly factors

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

Boxplot of the monthly values

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



6 Seasonal analysis

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
```

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) )
```

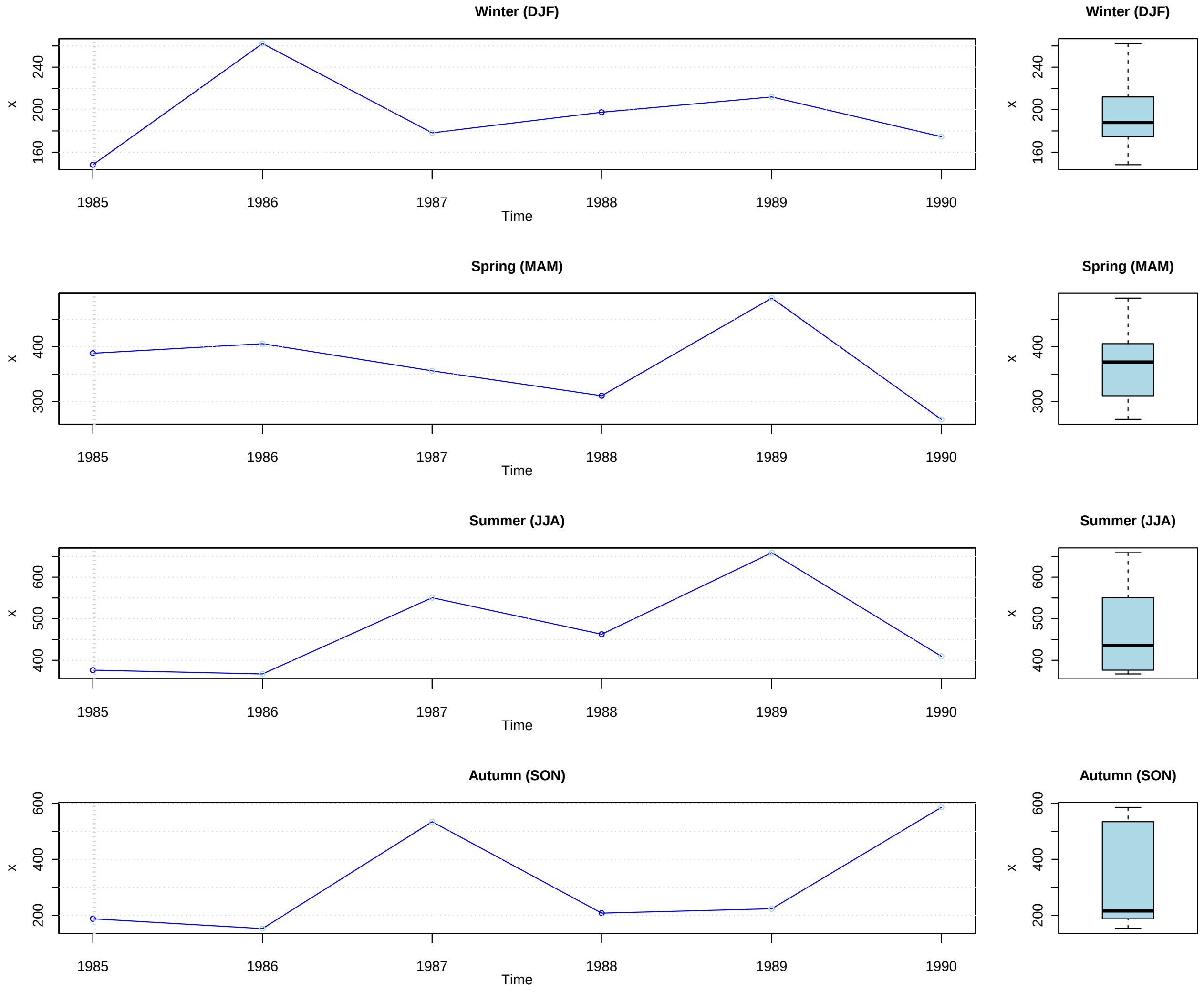
```
##  1985  1986  1987  1988  1989  1990
## 376.2 367.0 550.6 462.6 658.8 409.6
```

```
( 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
```

Plotting the time evolution of the seasonal precipitation values

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



7 Some extreme indices

Common steps for the analysis of this section:

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

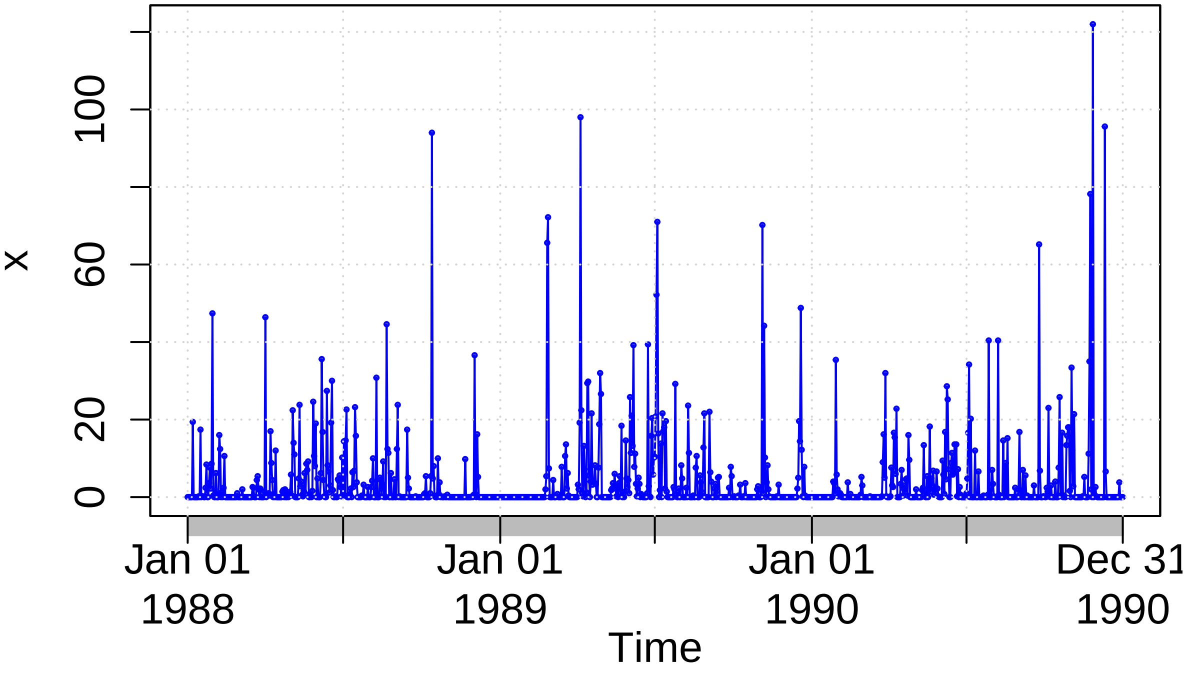
```r
data(SanMartinoPPts)
```

Selecting only a three-year time slice for the analysis

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

Plotting the selected time series

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



7.1 Heavy precipitation days (R10mm)

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

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

```
## [1] 127
```

7.2 Very wet days (R95p)

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

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

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

```r
( 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.

- Identifying the very wet days (daily precipitation >= *PRwn95*)

```r
(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
```

- Computing the total precipitation on the very wet days:

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

```
## [1] 1196.4
```

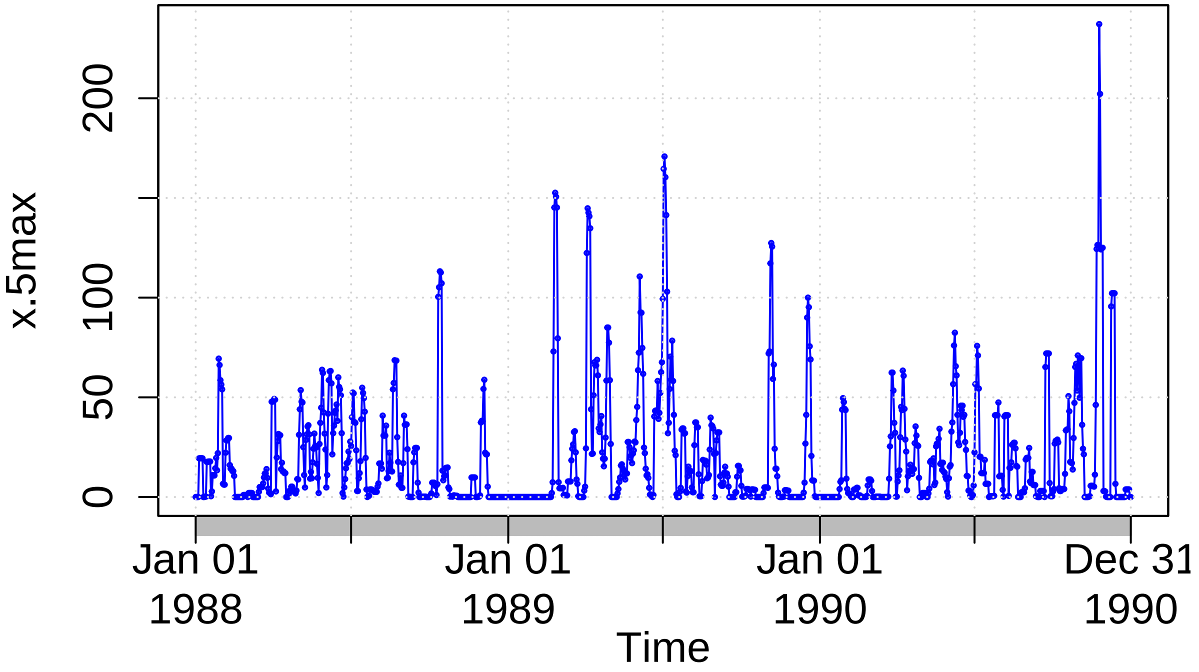
Note 3: this computation was carried out for the three-year time period 1988-1990, not the 30-year period 1961-1990 commonly used

7.3 5-day total precipitation

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']
```



Maximum annual value of 5-day total precipitation

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

```
## 1988-10-13 1989-07-03 1990-11-24
##      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

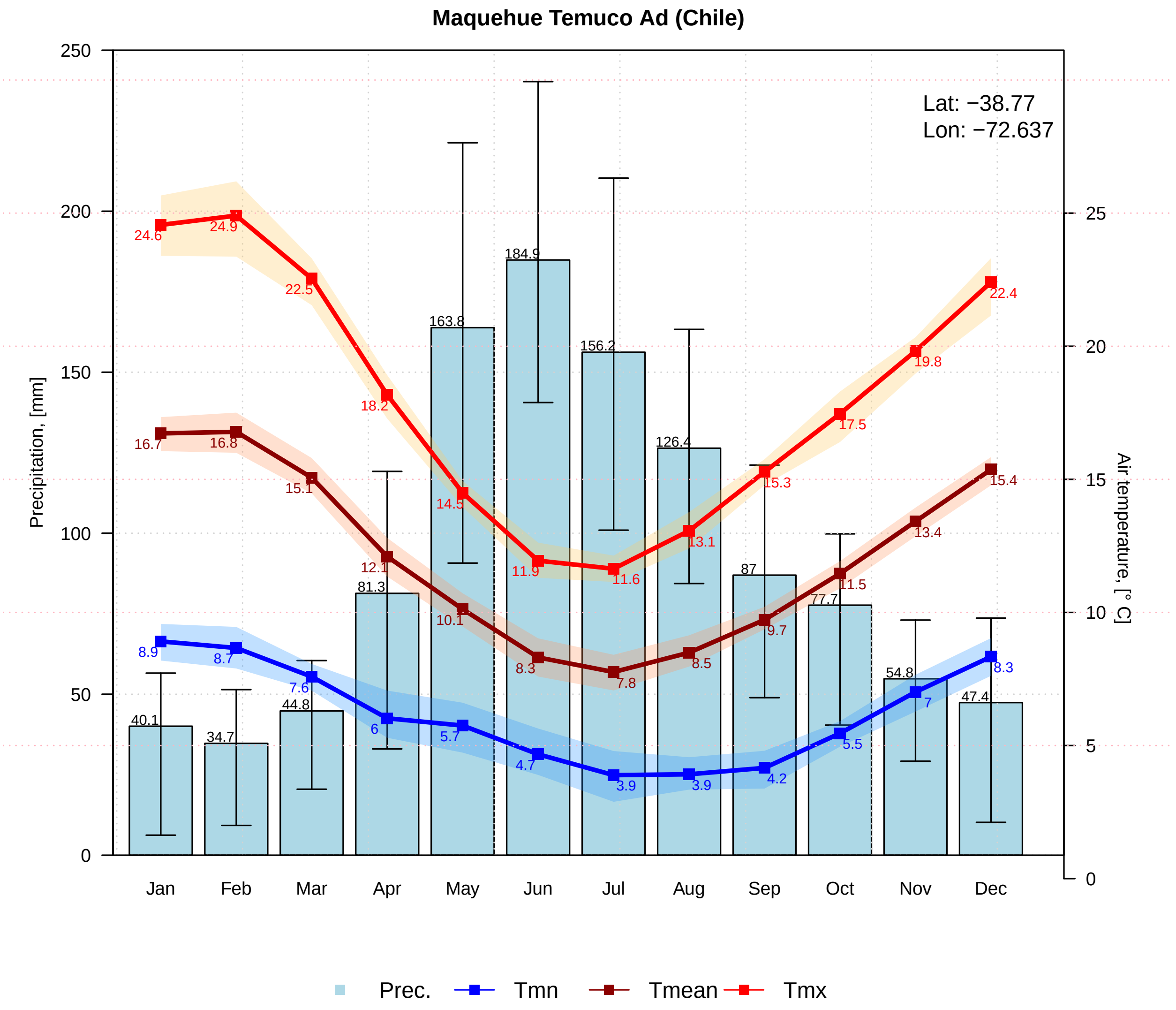
8 Climograph

Since v0.5-0, hydroTSM includes a function to plot a climograph, considering not only precipitation but air temperature data as well.

```
# Loading daily ts of precipitation, maximum and minimum temperature
data(MaquehueTemuco)

# extracting individual ts of precipitation, maximum and minimum temperature
pcp <- MaquehueTemuco[, 1]
tmx <- MaquehueTemuco[, 2]
tmn <- MaquehueTemuco[, 3]
```

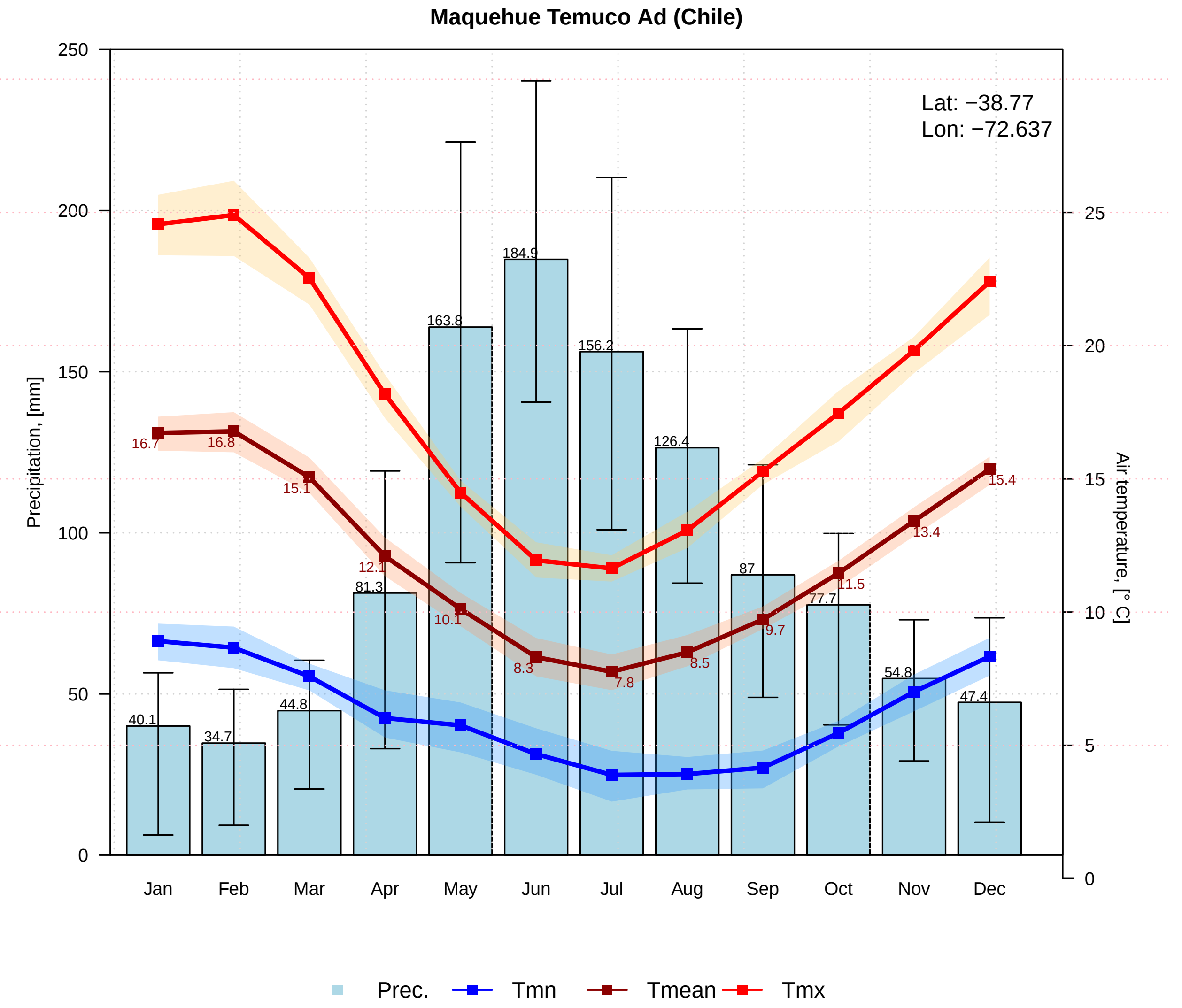
Plotting a full climograph:

```
m <- climograph(pcp=pcp, tmx=tmx, tmn=tmn, na.rm=TRUE,
                main="Maquehue Temuco Ad (Chile)", lat=-38.770, lon=-72.637)
```



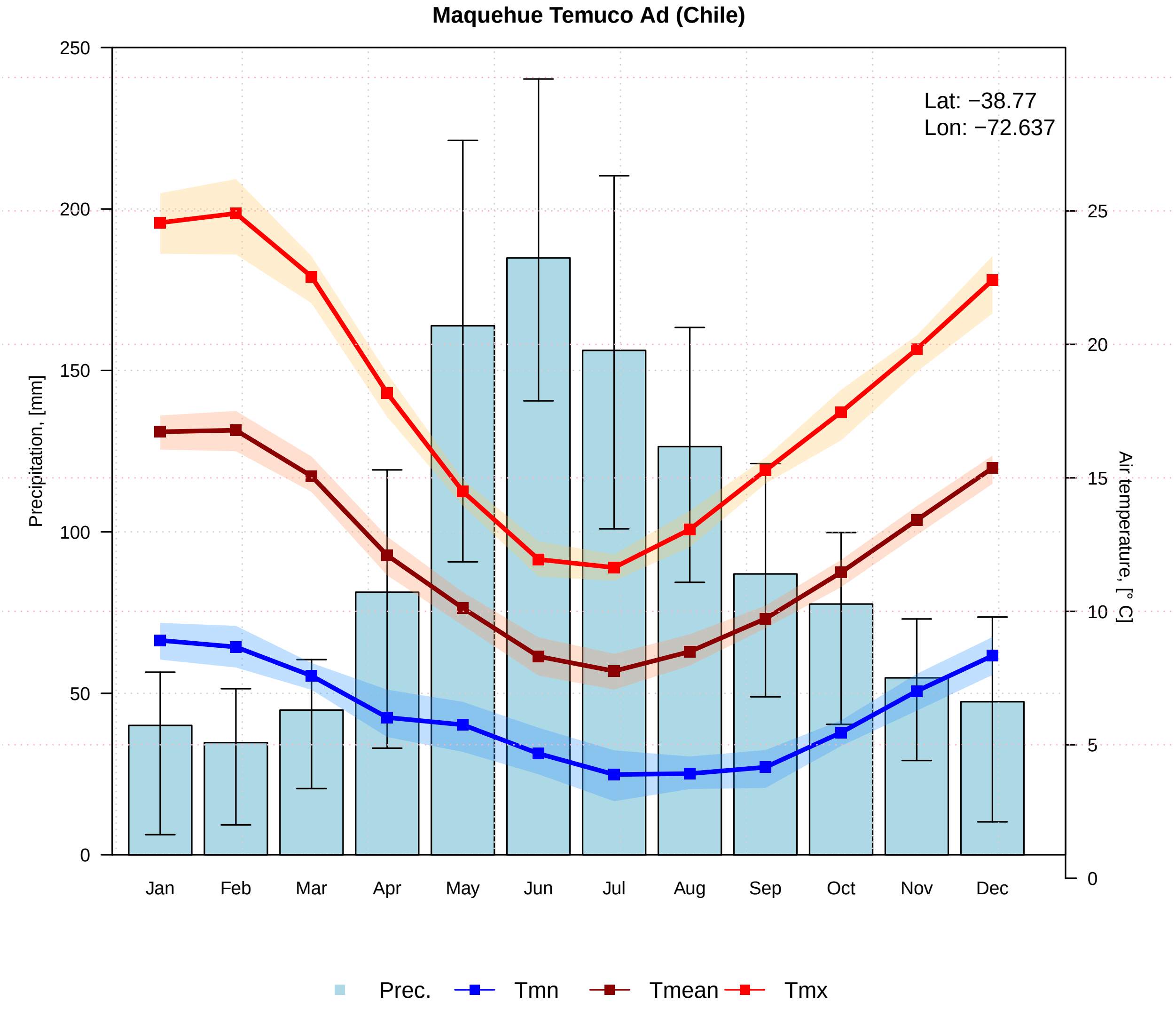
Plotting a climograph with uncertainty bands around mean values, but with no labels for tmx and tmn:

```
m <- climograph(pcp=pcp, tmx=tmx, tmn=tmn, na.rm=TRUE, tmx.labels=FALSE, tmn.labels=FALSE,
                main="Maquehue Temuco Ad (Chile)", lat=-38.770, lon=-72.637)
```



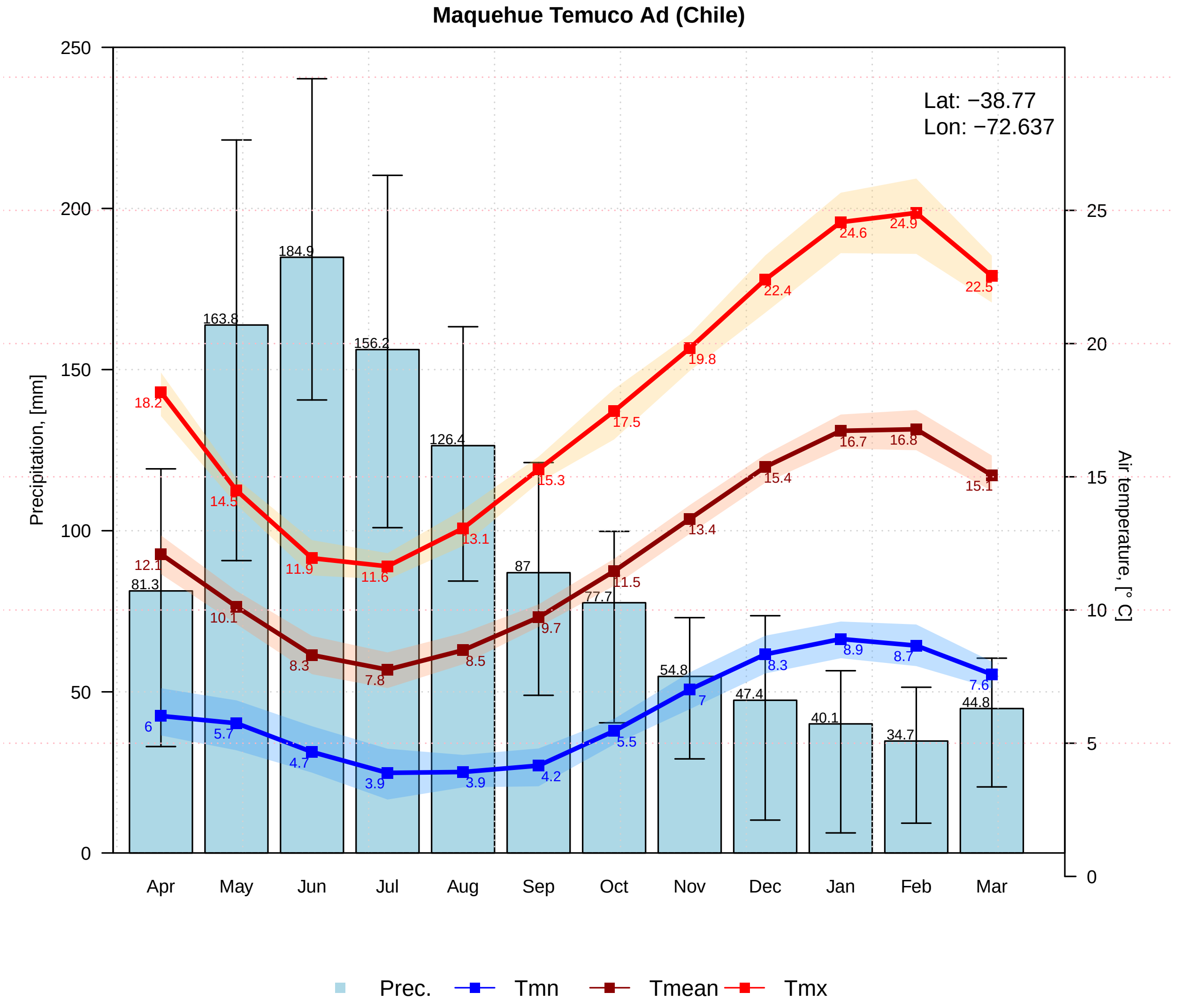
Plotting a climograph with uncertainty bands around mean values, but with no labels for tmx, tmn and pcp:

```
m <- climograph(pcp=pcp, tmx=tmx, tmn=tmn, na.rm=TRUE,
                pcp.labels=FALSE, tmean.labels=FALSE, tmx.labels=FALSE, tmn.labels=FALSE,
                main="Maquehue Temuco Ad (Chile)", lat=-38.770, lon=-72.637)
```



To better represent the hydrological year in Chile (South America), the following figure will plot a full climograph starting in April (`start.month=4`) instead of January (`start.month=1`):

```r
m <- climograph(pcp=pcp, tmx=tmx, tmn=tmn, na.rm=TRUE,
                start.month=4, temp.labels.dx=c(rep(-0.2,4), rep(0.2,6),rep(-0.2,2)),
                main="Maquehue Temuco Ad (Chile)", lat=-38.770, lon=-72.637)
```



9 Software details

This tutorial was built under:

```
## [1] "aarch64-apple-darwin20 (64-bit)"
```

```
## [1] "R version 4.3.2 (2023-10-31)"
```

```
## [1] "hydroTSM 0.6-33"
```

10 Version history

- v0.8: Nov 2023
- v0.7: Mar 2020

- v0.6: Aug 2017
- v0.5: May 2013
- v0.4: Aug 2011
- v0.3: Apr 2011
- v0.2: Oct 2010
- v0.1: 30-May-2013

11 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.

11.1 Editors, GUI

- **GNU/Linux only**: ESS (https://ess.r-project.org/)
- **Windows only** : NppToR (https://sourceforge.net/projects/npptor/)
- **Multi-platform**: Sublime Text (https://sublime.weberup.com/) ; RStudio (https://www.rstudio.com/)

11.2 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`.
- `?zoo::read.zoo`, `?zoo::write.zoo`: functions for reading and writing time series from/to text files, respectively.
- **R Data Import/Export**: https://cran.r-project.org/doc/manuals/r-release/R-data.html
- **foreign** R package: read data stored in several R-external formats (dBase, Minitab, S, SAS, SPSS, Stata, Systat, Weka, . . .)
- **readxl** R package: Import MS Excel files into R.
- **some examples**: https://www.statmethods.net/input/importingdata.html

11.3 Useful Websites

- **Quick R**: https://www.statmethods.net/
- **Time series in R**: https://cran.r-project.org/web/views/TimeSeries.html
- **Quick reference for the `zoo` package**: https://cran.r-project.org/web/packages/zoo/vignettes/zoo-quickref.pdf

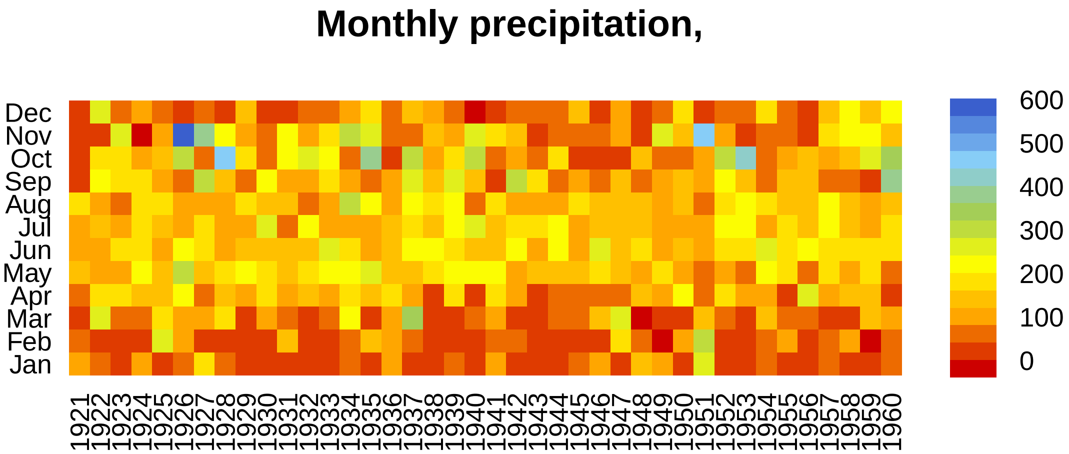
11.4 F.A.Q.

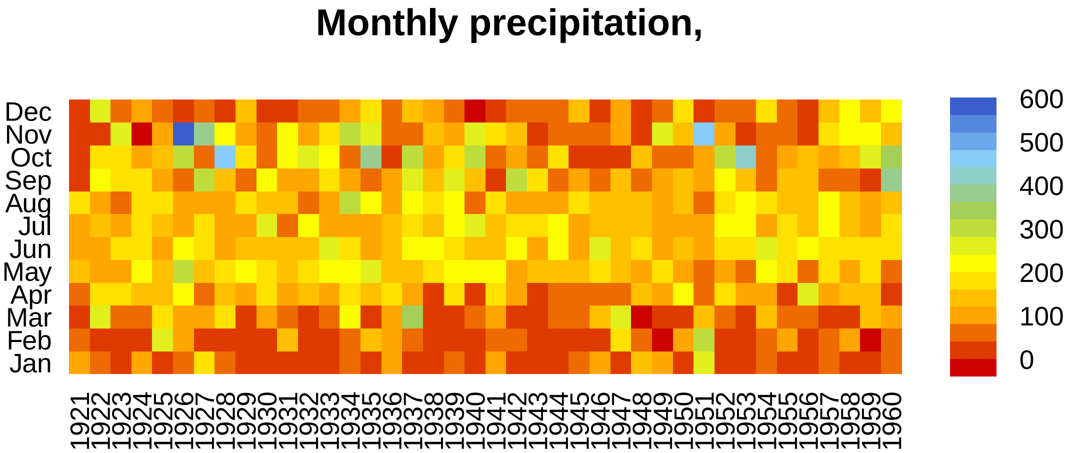
12 How to print more than one `matrixplot` in a single Figure?

Beacuase `matrixplot` is based on lattice graphs, normal plotting commands included in base R does not work. Therefore, for plotting ore than 1 matrixplot ina single figure, you need to save the individual plots in an R object and then print them as you want.

Int he following sequential lines of code, you can see two examples that show you how to plot two matrixplots in a single Figure:

```r
library(hydroTSM)
data(SanMartinoPPts)
x <- window(SanMartinoPPts, end=as.Date("1960-12-31"))
m <- daily2monthly(x, FUN=sum, na.rm=TRUE)
M <- matrix(m, ncol=12, byrow=TRUE)
colnames(M) <- month.abb
rownames(M) <- unique(format(time(m), "%Y"))
p <- matrixplot(M, ColorRamp="Precipitation", main="Monthly precipitation,")

print(p, position=c(0, .6, 1, 1), more=TRUE)
print(p, position=c(0, 0, 1, .4))
```



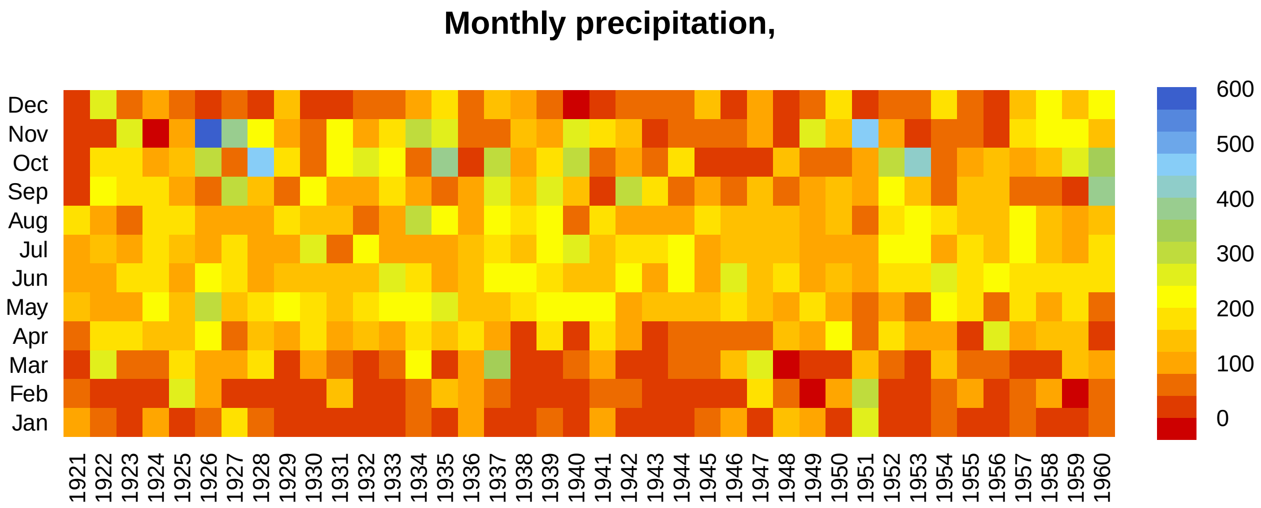


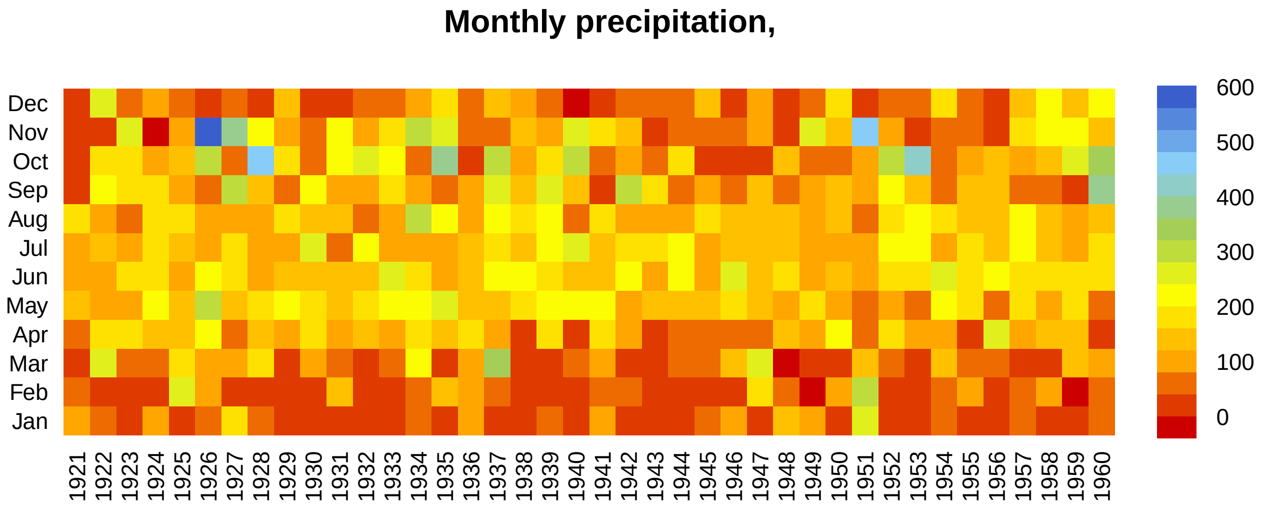
The second and easier way allows you to obtain the same previous figure (not shown here), but you are required to install the `gridExtra` package:

```
if (!require(gridExtra)) install.packages("gridExtra")
```

```
## Loading required package: gridExtra
```

```
require(gridExtra) # also loads grid
require(lattice)

grid.arrange(p, p, nrow=2)
```


Monthly precipitation,
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
Jan


Monthly precipitation,
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
Jan