



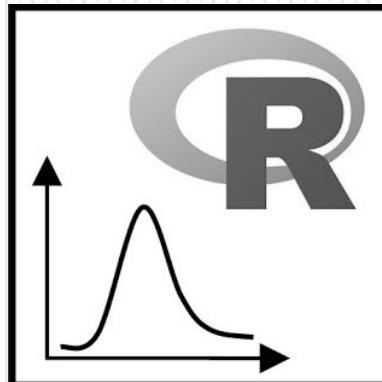
Young
Professionals
Network
Supported by
Spain Water and IWHR, China

Taller corto de verano Short summer workshop

Lima, 31 enero 2020

Introducción al análisis de series hidrológicas en R Introduction to hydrological series analysis in R

Pedro Rau, PhD
Hidrólogo



- ✓ **Instructor:**
Pedro Rau, PhD
 - Profesor full-time Universidad de Ingeniería y Tecnología UTEC - Dpto. Ambiental.
 - Investigador principal Centro de Investigación y Tecnología del Agua CITA.
 - Profesor visitante UNI - Postgrado FIC.
 - Hidrólogo investigador en redes internacionales: FR, EC, US, UK
 - Revisor para revistas científicas indexadas internacionales.
 - Consultor en Hidrología y Recursos Hídricos
- ✓ **E.mail:** praul@uni.pe
- ✓ **Sitio web:** <http://pedrorau.blogspot.com>
- ✓ **Repositorio del curso:** https://github.com/hydrocodes/Intro_R
- ✓ **Requisitos:** Conocimientos básicos en Hidrología y Estadística

Objetivos del curso

- Brindar las bases teóricas del estudio de las series de tiempo hidrológicas.
- Punto de inicio para los interesados en el sistema R y su entorno estadístico.
- Desarrollar capacidades para el empleo correcto del software libre en la hidrología.

Temáticas

1. Introducción a las series de tiempo hidrológicas
2. Entorno R y Rstudio
3. Análisis exploratorio de datos

Evaluación

Clases teóricas + prácticas

- Asistencia y desarrollo de ejercicios
5 hr presenciales + 1hr virtual

Metodología « Hands-on »

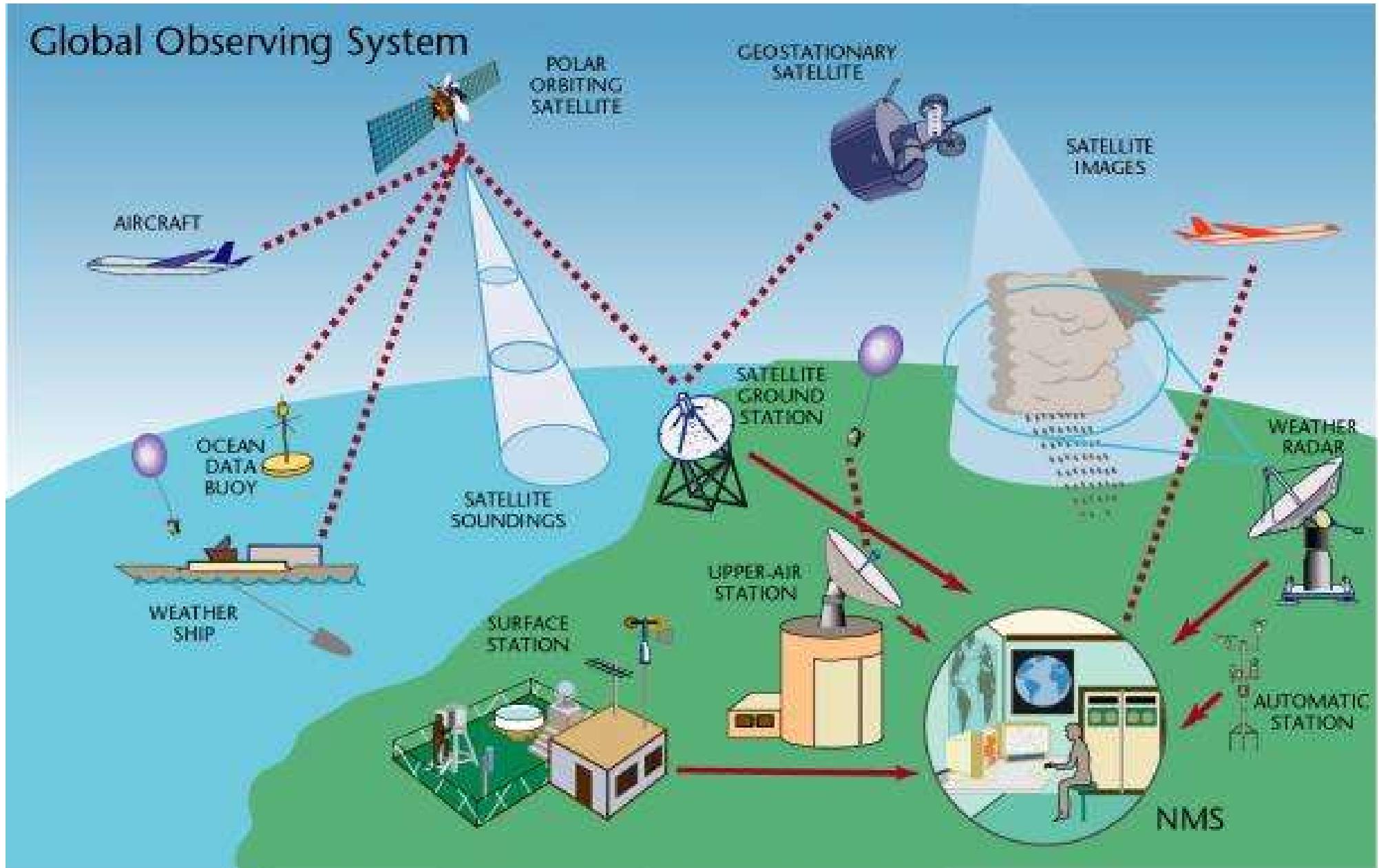
- Lecturas y papers base
- Planteamiento de ejercicios
- Creación/tipeo/interpretación de códigos *.R con semi comentarios
- Resolución de bugs
- Finalización de códigos *.R con comentarios completos al detalle (evaluado)

Total: 6hr lectivas

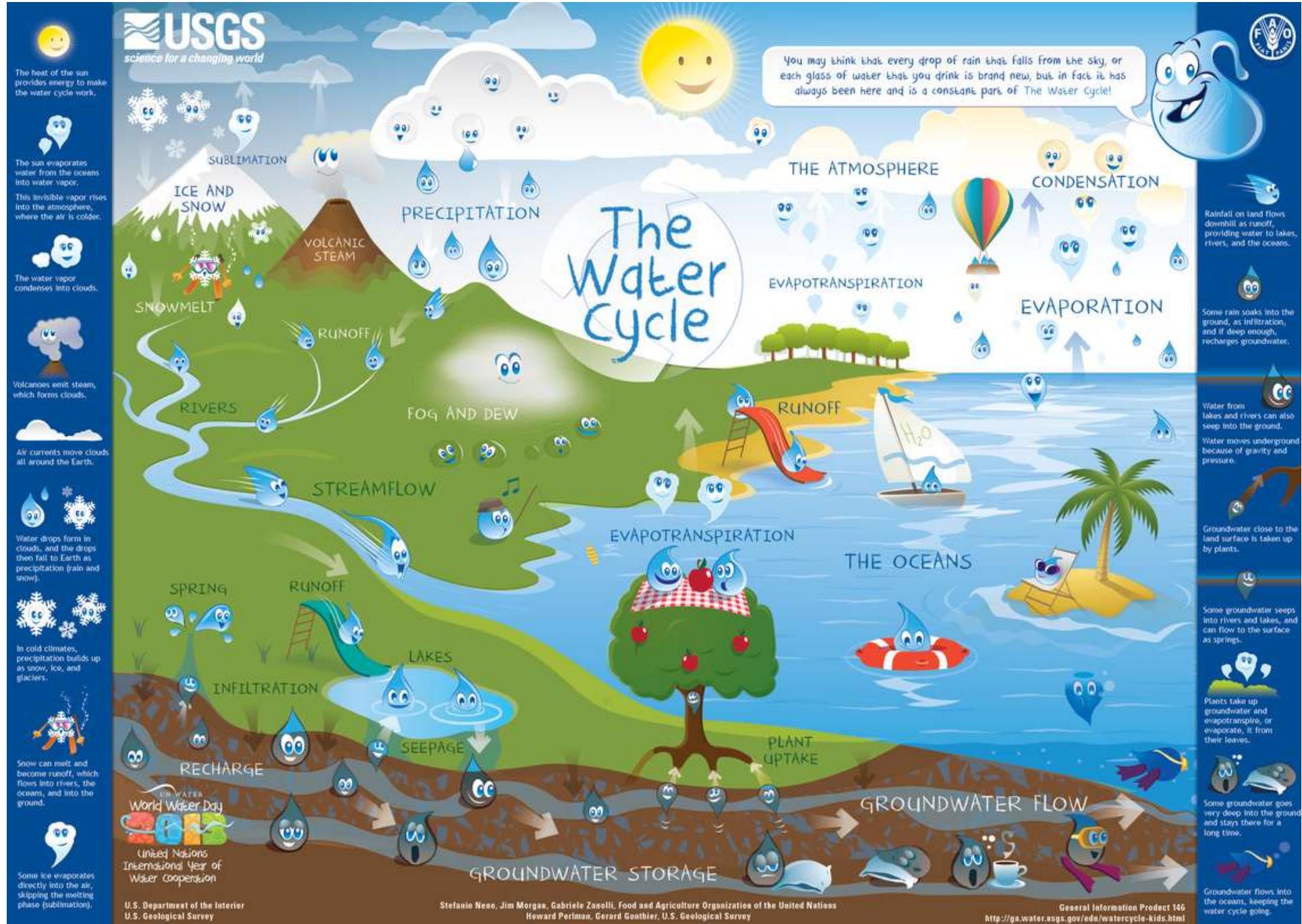
1. Introducción a las series de tiempo hidrológicas



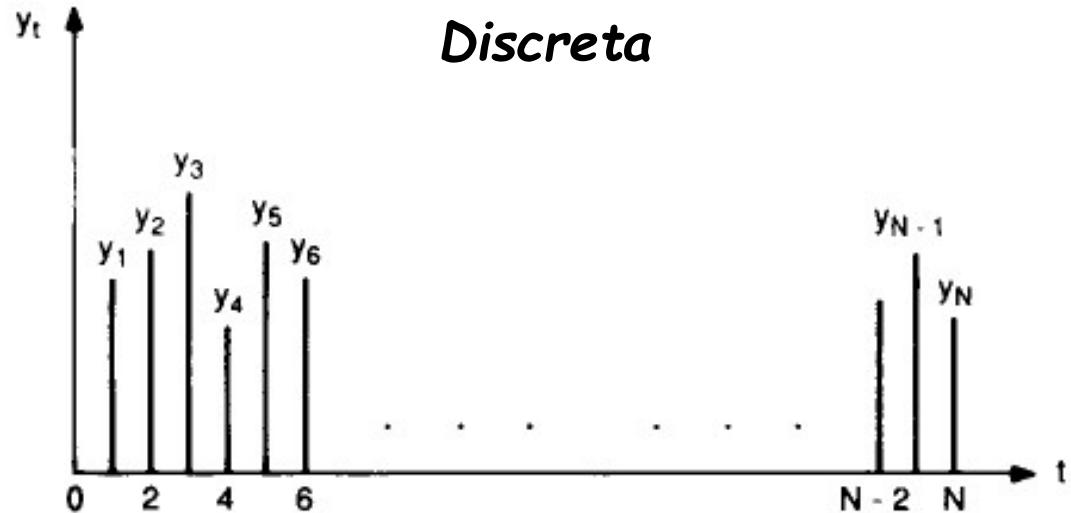
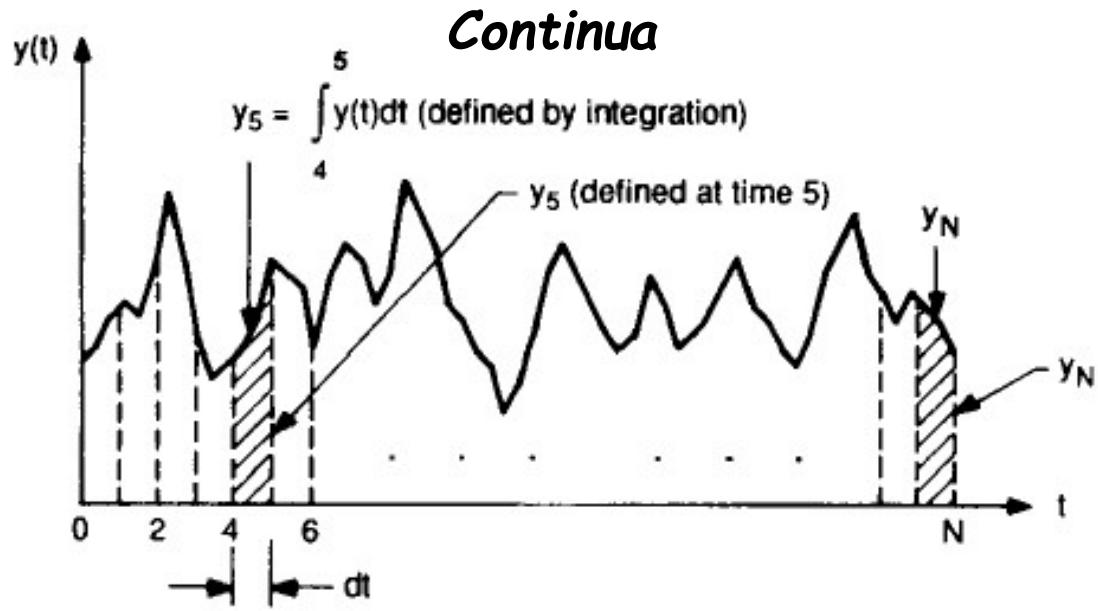
1.1 Sistema de observación global



1.2 El ciclo hidrológico



1.3 Tipos o categorías de series de tiempo

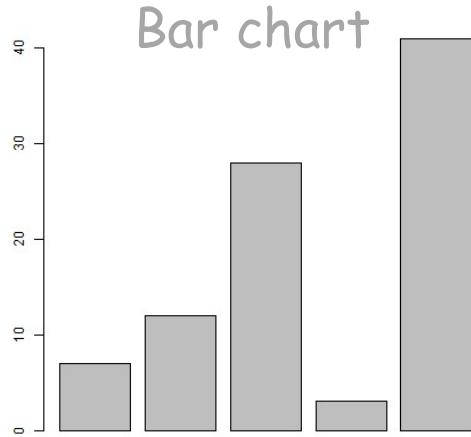


- ✓ Unicas
- ✓ Multiples
- ✓ Independientes, no correlacionadas; autocorrelacionados o dependientes
- ✓ Intermitentes
- ✓ De conteo
- ✓ Regulares o irregulares en espacios de tiempo
- ✓ Estacionarias (sin tendencia, ni salto ni ciclicidad / periodicidad) y no-estacionarias

1.6 Análisis preliminar de datos hidrológicos

a. Representación gráfica

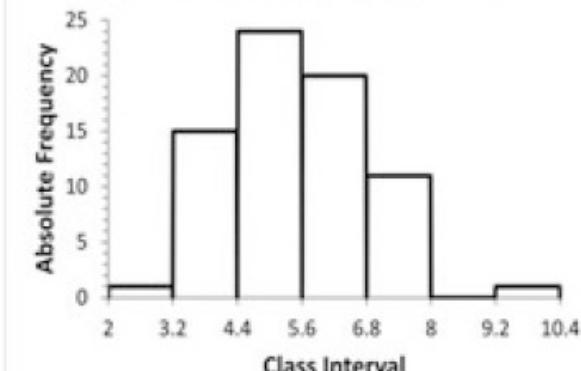
Diagrama de barras
Bar chart



Histograma

Histogram

(a) Annual Mean Daily Flows (m^3/s)



Polígonos de frecuencia
Frequency Polygon

Paraopeba River at Ponte Nova do Paraopeba (Brazil)
Frequency Polygon of Annual Mean Daily Flows (m^3/s) - 1938-1999

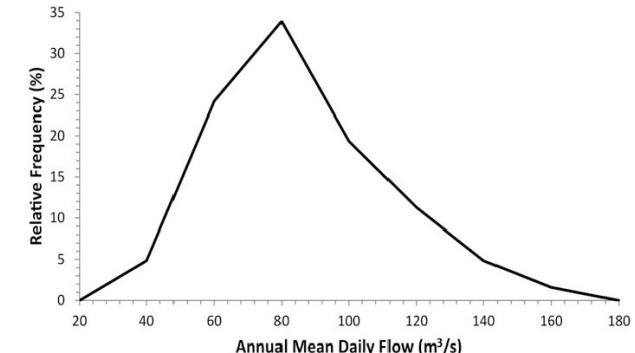
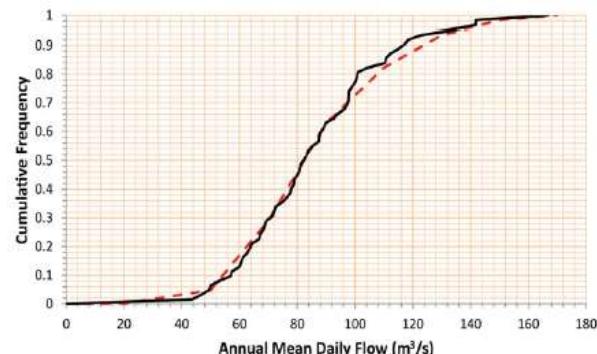


Diagrama de puntos
Dot chart

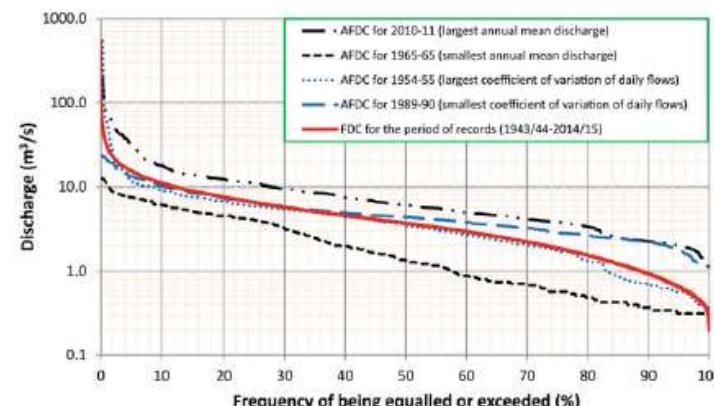


Frecuencia relativa acumulada

Cumulative Relative Frequency Diagram



Curvas de duración
Duration curves



Nagettini (2017)

b. Estadísticos descriptivos

c. Métodos exploratorios

Parámetro de la población

1. Punto medio

Media aritmética

$$\mu = E(X) = \int_{-\infty}^{\infty} xf(x) dx$$

Estadística de la muestra

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

Mediana

$$x \text{ tal que } F(x) = 0.5$$

Valor de la información en el 50o. percentil

Media geométrica

$$\text{antilog } [E(\log x)]$$

$$\left(\prod_{i=1}^n x_i \right)^{1/n}$$

2. Variabilidad

Varianza

$$\sigma^2 = E[(x - \mu)^2]$$

$$s^2 = \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2$$

Desviación estándar

$$\sigma = \{E[(x - \mu)^2]\}^{1/2}$$

$$s = \left[\frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2 \right]^{1/2}$$

Coeficiente de variación

$$CV = \frac{\sigma}{\mu}$$

$$CV = \frac{s}{\bar{x}}$$

3. Simetría

Coeficiente de asimetría (oblicuidad)

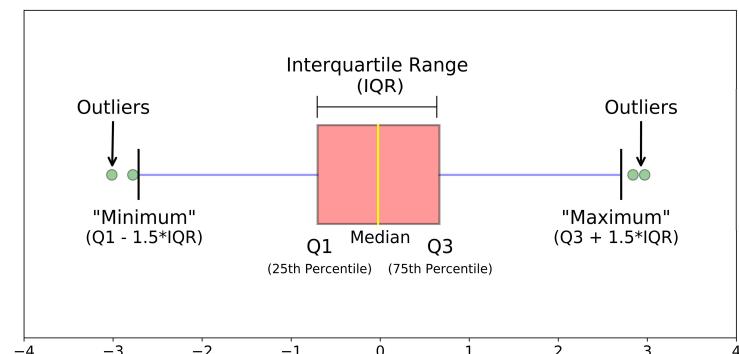
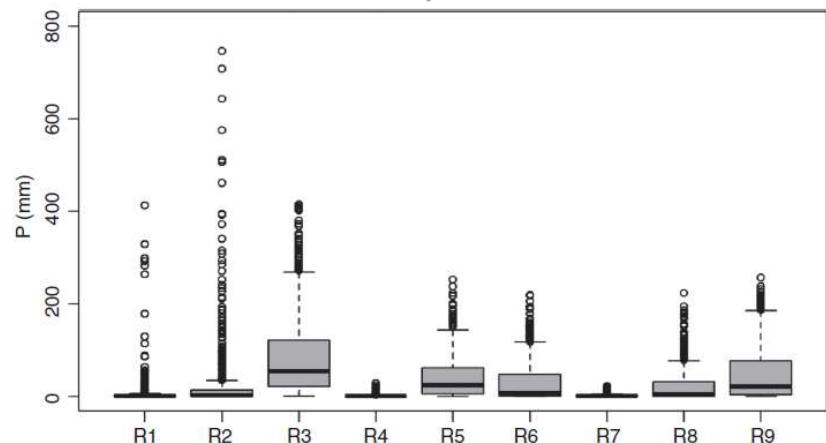
$$\gamma = \frac{E[(x - \mu)^3]}{\sigma^3}$$

$$C_s = \frac{n \sum_{i=1}^n (x_i - \bar{x})^3}{(n-1)(n-2)s^3}$$

Chow (1994)

Diagrama de cajas

Box plot



| Stem | Leaf |
|------|-------------------|
| 2 | 36 |
| 3 | 68 94 |
| 3 | 01 31 |
| 4 | 70 73 99 |
| 4 | 06 12 26 36 42 |
| 5 | 68 72 82 87 93 |
| 5 | 16 20 24 48 |
| 6 | 64 76 80 89 90 |
| 6 | 02 09 11 22 32 38 |
| 7 | 51 74 76 81 92 98 |
| 7 | 27 39 |
| 8 | 63 73 78 79 80 91 |
| 8 | 02 07 10 43 |
| 9 | 04 08 22 49 |
| 9 | 71 84 |
| 10 | 28 |
| 11 | 34 |
| 12 | 17 18 |
| 13 | 14 |
| 14 | 15 |
| 15 | 16 |
| 16 | 69 |
| 17 | |

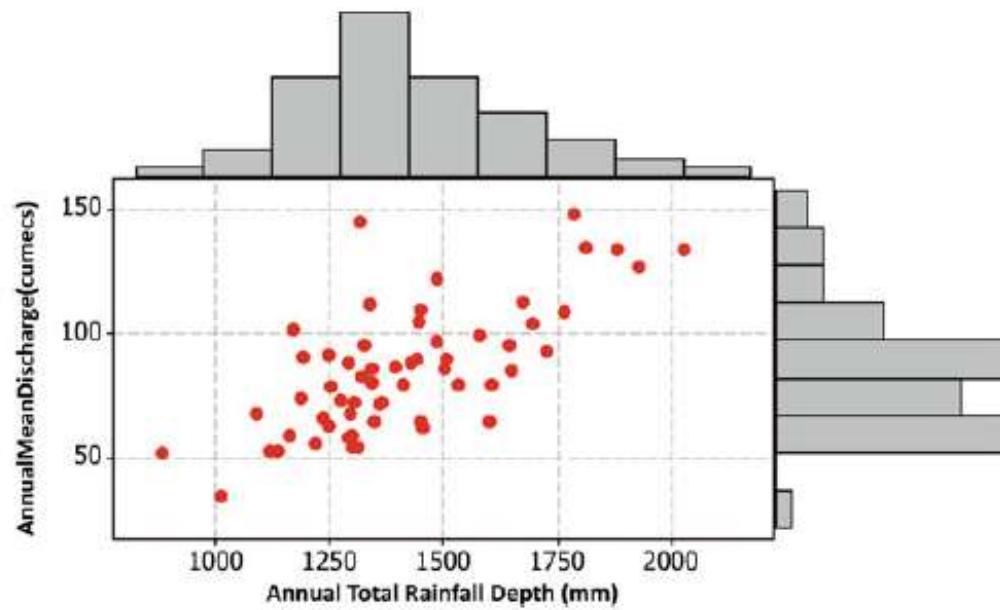
Diagrama de
tallos y hojas
Stem-and-leaf
Diagram

Rau et al (2017)

Naghettini (2017)

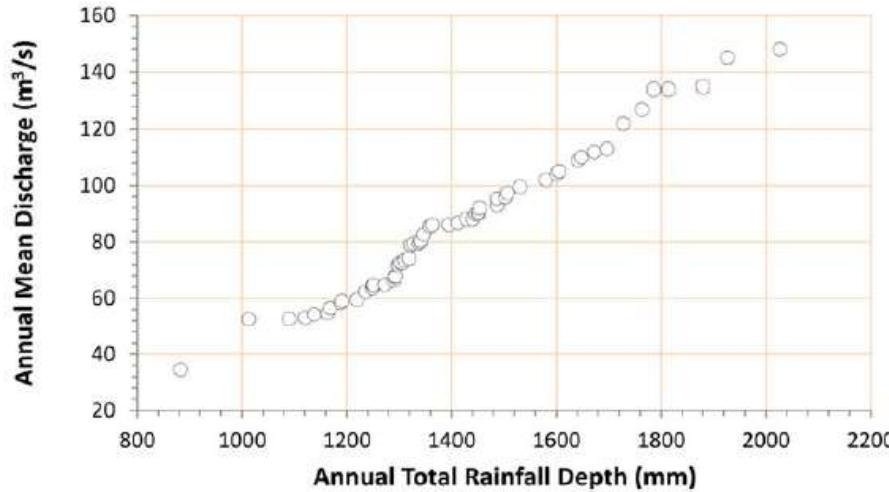
d. Asociación de datos

Gráfico de dispersión
Scatter plot



Naghettini (2017)

Diagrama Cuantil-Cuantil
Empirical Quantile-
Quantile Diagram
Q-Q Plot





2. *Entorno R y Rstudio*



O'REILLY®



R for Data Science

VISUALIZE, MODEL, TRANSFORM, TIDY, AND IMPORT DATA

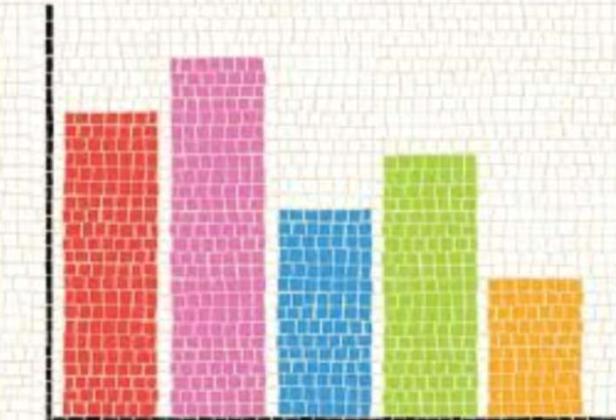
Hadley Wickham &
Garrett Grolemund

<https://r4ds.had.co.nz/>

<https://github.com/jrnold/r4ds-exercise-solutions/blob/master/README.md>

The Art of Data Science

A Guide for Anyone Who Works with Data



Roger D. Peng & Elizabeth Matsui

<https://bookdown.org/rdpeng/artofdatascience/>

<https://github.com/waldronlab/The-Art-of-Data-Science/blob/master/README.md>

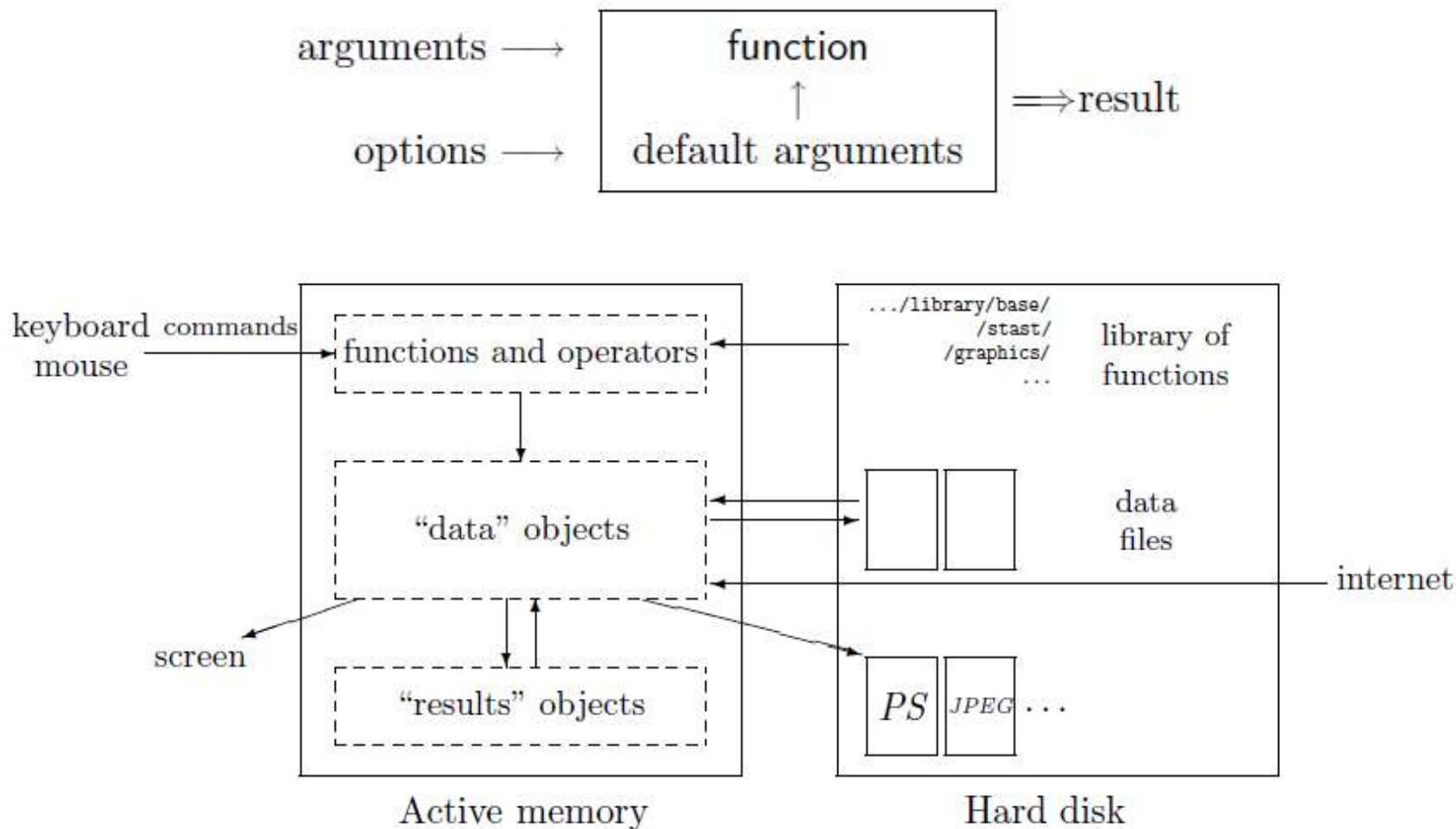
R-3.6.2 for Windows (32/64 bit) - Diciembre 2019



<https://cran.r-project.org/bin/windows/base/>

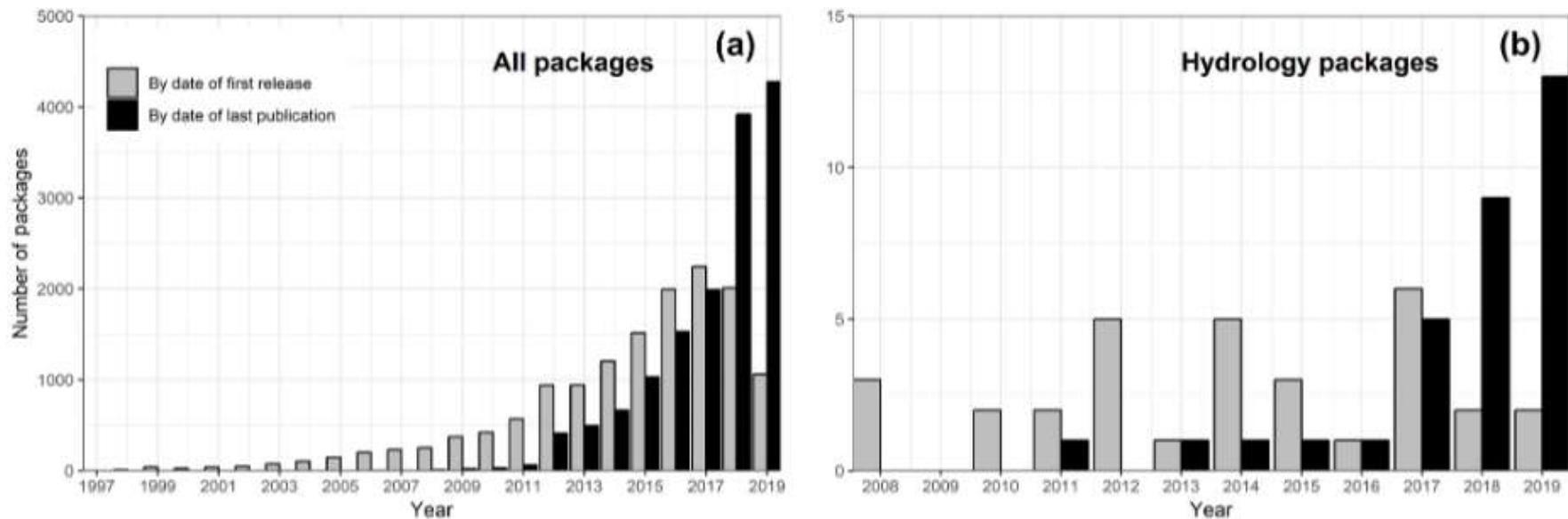
- ✓ Sistema para el análisis estadístico y graficación (Ihaka y Gentleman, 1996)
- ✓ Lenguaje interpretado, no es un lenguaje compilado
- ✓ Facil e intuitivo, estrictamente « no es un lenguaje de programación »

Paradis (2002)

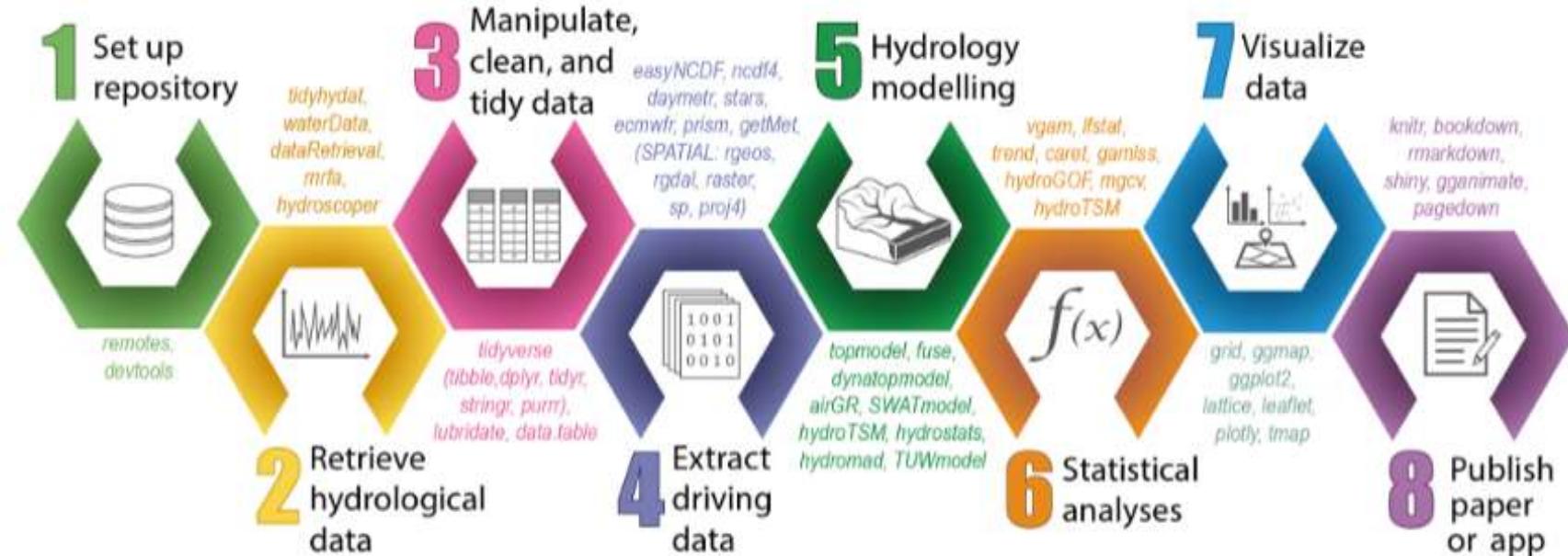


The Comprehensive R Archive Net-work (CRAN)

<https://cran.r-project.org>



Tipico Flujo de trabajo en R en hidrologia



Slater et al (2019)

<-

“Clases” de objetos básicos o “atomic” en R:

- numeric (real numbers)
- integer
- complex
- logical (True/False)

()

Tipos de objetos en R para representar a los datos

| object | modes | several modes possible in the same object? | |
|------------|--|--|--------------|
| vector | numeric, character, complex <i>or</i> logical | No | c() |
| factor | numeric <i>or</i> character | No | factor() |
| array | numeric, character, complex <i>or</i> logical | No | array() |
| matrix | numeric, character, complex <i>or</i> logical | No | matrix() |
| data frame | numeric, character, complex <i>or</i> logical | Yes | data.frame() |
| ts | numeric, character, complex <i>or</i> logical | No | ts() |
| list | numeric, character, complex, logical, function, expression, ... | Yes | list() |

#

Convirtiendo clases de objetos

| Conversion to | Function | Rules |
|---------------|--------------|--|
| numeric | as.numeric | FALSE → 0 TRUE → 1 "1", "2", ... → 1, 2, ... "A", ... → NA |
| logical | as.logical | 0 → FALSE other numbers → TRUE "FALSE", "F" → FALSE "TRUE", "T" → TRUE other characters → NA |
| character | as.character | 1, 2, ... → "1", "2", ... FALSE → "FALSE" TRUE → "TRUE" |

Funciones de probabilidad

| Distribución/función | función |
|------------------------------|-------------------------------------|
| Gausse (normal) | rnorm(n, mean=0, sd=1) |
| exponencial | rexp(n, rate=1) |
| gamma | rgamma(n, shape, scale=1) |
| Poisson | rpois(n, lambda) |
| Weibull | rweibull(n, shape, scale=1) |
| Cauchy | rcauchy(n, location=0, scale=1) |
| beta | rbeta(n, shape1, shape2) |
| 'Student' (<i>t</i>) | rt(n, df) |
| Fisher-Snedecor (<i>F</i>) | rf(n, df1, df2) |
| Pearson (χ^2) | rchisq(n, df) |
| binomial | rbinom(n, size, prob) |
| geométrica | rgeom(n, prob) |
| hypergeométrica | rhyper(nn, m, n, k) |
| logística | rlogis(n, location=0, scale=1) |
| lognormal | rlnorm(n, meanlog=0, sdlog=1) |
| binomial negativa | rnbinom(n, size, prob) |
| uniforme | runif(n, min=0, max=1) |
| Estadístico de Wilcoxon's | rwilcox(nn, m, n), rsignrank(nn, n) |

Operadores en R

| Operators | | | | |
|------------|------------------|------------|--------------------------|------------------------|
| Arithmetic | | Comparison | | Logical |
| + | addition | < | lesser than | ! x logical NOT |
| - | subtraction | > | greater than | x & y logical AND |
| * | multiplication | <= | lesser than or equal to | x && y id. |
| / | division | >= | greater than or equal to | x y logical OR |
| ^ | power | == | equal | x y id. |
| %% | modulo | != | different | xor(x, y) exclusive OR |
| %%/ | integer division | | | |

| | |
|--|---|
| <code>plot(x)</code> | plot of the values of <code>x</code> (on the <code>y</code> -axis) ordered on the <code>x</code> -axis |
| <code>plot(x, y)</code> | bivariate plot of <code>x</code> (on the <code>x</code> -axis) and <code>y</code> (on the <code>y</code> -axis) |
| <code>sunflowerplot(x, y)</code> | id. but the points with similar coordinates are drawn as a flower which petal number represents the number of points |
| <code>pie(x)</code> | circular pie-chart |
| <code>boxplot(x)</code> | "box-and-whiskers" plot |
| <code>stripchart(x)</code> | plot of the values of <code>x</code> on a line (an alternative to <code>boxplot()</code> for small sample sizes) |
| <code>coplot(x~y z)</code> | bivariate plot of <code>x</code> and <code>y</code> for each value (or interval of values) of <code>z</code> |
| <code>interaction.plot(f1, f2, y)</code> | if <code>f1</code> and <code>f2</code> are factors, plots the means of <code>y</code> (on the <code>y</code> -axis) with respect to the values of <code>f1</code> (on the <code>x</code> -axis) and of <code>f2</code> (different curves); the option <code>fun</code> allows to choose the summary statistic of <code>y</code> (by default <code>fun=mean</code>) |
| <code>matplot(x,y)</code> | bivariate plot of the first column of <code>x</code> vs. the first one of <code>y</code> , the second one of <code>x</code> vs. the second one of <code>y</code> , etc. |
| <code>dotchart(x)</code> | if <code>x</code> is a data frame, plots a Cleveland dot plot (stacked plots line-by-line and column-by-column) |
| <code>fourfoldplot(x)</code> | visualizes, with quarters of circles, the association between two dichotomous variables for different populations (<code>x</code> must be an array with <code>dim=c(2, 2, k)</code> , or a matrix with <code>dim=c(2, 2)</code> if <code>k = 1</code>) |
| <code>assocplot(x)</code> | Cohen-Friendly graph showing the deviations from independence of rows and columns in a two dimensional contingency table |
| <code>mosaicplot(x)</code> | 'mosaic' graph of the residuals from a log-linear regression of a contingency table |
| <code>pairs(x)</code> | if <code>x</code> is a matrix or a data frame, draws all possible bivariate plots between the columns of <code>x</code> |
| <code>plot.ts(x)</code> | if <code>x</code> is an object of class "ts", plot of <code>x</code> with respect to time, <code>x</code> may be multivariate but the series must have the same frequency and dates |
| <code>ts.plot(x)</code> | id. but if <code>x</code> is multivariate the series may have different dates and must have the same frequency |
| <code>hist(x)</code> | histogram of the frequencies of <code>x</code> |
| <code>barplot(x)</code> | histogram of the values of <code>x</code> |
| <code>qqnorm(x)</code> | quantiles of <code>x</code> with respect to the values expected under a normal law |
| <code>qqplot(x, y)</code> | quantiles of <code>y</code> with respect to the quantiles of <code>x</code> |
| <code>contour(x, y, z)</code> | contour plot (data are interpolated to draw the curves), <code>x</code> and <code>y</code> must be vectors and <code>z</code> must be a matrix so that <code>dim(z)=c(length(x), length(y))</code> (<code>x</code> and <code>y</code> may be omitted) |
| <code>filled.contour (x, y, z)</code> | id. but the areas between the contours are coloured, and a legend of the colours is drawn as well |
| <code>image(x, y, z)</code> | id. but the actual data are represented with colours |
| <code>persp(x, y, z)</code> | id. but in perspective |
| <code>stars(x)</code> | if <code>x</code> is a matrix or a data frame, draws a graph with segments or a star where each row of <code>x</code> is represented by a star and the columns are the lengths of the segments |
| <code>symbols(x, y, ...)</code> | draws, at the coordinates given by <code>x</code> and <code>y</code> , symbols (circles, squares, rectangles, stars, thermometers or "boxplots") which sizes, colours, etc, are specified by supplementary arguments |
| <code>termplot(mod.obj)</code> | plot of the (partial) effects of a regression model (<code>mod.obj</code>) |

Ploteando gráficos

`add=FALSE` if TRUE superposes the plot on the previous one (if it exists)

`axes=TRUE` if FALSE does not draw the axes and the box

`type="p"` species the type of plot, "`p`": points, "`l`": lines, "`b`": points connected by lines, "`o`": id. but the lines are over the points, "`h`": vertical lines, "`s`": steps, the data are represented by the top of the vertical lines, "`S`": id. But the data are represented by the bottom of the vertical lines

`xlim=`, `ylim=` species the lower and upper limits of the axes, for example
with `xlim=c(1, 10)` or `xlim=range(x)`

`xlab=`, `ylab=` annotates the axes, must be variables of mode character

`main=` main title, must be a variable of mode character

`sub=` sub-title (written in a smaller font)

RStudio Desktop 1.2.5033

<https://rstudio.com/products/rstudio/download/#download>



Entorno de desarrollo integrado para el lenguaje de programación R

The screenshot shows the RStudio desktop application interface. On the left, the 'Code Editor' displays an R script with several lines of code. A red box highlights the first two lines: '# Extraccion de una variable del CMIP5 (o cualquier archivo .NC)' and 'library(raster)'. Below the editor is the 'Console' tab, which shows the execution of the script, including the creation of a data frame 'df' and its head. Another red box highlights the output of the 'head(df)' command, showing a small portion of the data frame. To the right of the editor is the 'Environment' browser, listing various objects like 'vals', 'Variab', 'Variables', etc., with their types and dimensions. A red box highlights the 'vals' object. At the bottom right is a 'Plots' viewer showing a time series plot of 'Tmin (°C/d)' over 'Años' from 2005 to 2030. A red box highlights the plot area.

Editor de código
Consola de scripts

Area de objetos e historial

Consola R
Consola de resultados

Figuras y archivos

```
1 # Extraccion de una variable del CMIP5 (o cualquier archivo .NC)
2 library(raster)
3 
4 # Comando brick lee todas las capas contenidas en el archivo nc, Ejm: pr:precipitacion
5 b <- brick('C:/1 THESE_SDUE/3 SIG/ccmodels/hadgem2-es/tasmin_Amon_HadGEM2-ES_rcp45_r1i1p1_20
6 
7 # Asignando indices
8 idx <- set7(b)
9 
10 # Indicar coordenadas para leer los valores correspondientes
11 coords <- data.frame(xc(85.1), xc(-11.8), yc(2), yc(-11.8)) # la longitud y -11.8 la latitud
12 vals <- extract(b, coords, df=T)-273.15
13 
14 # Fijar fechas y datos en un solo archivo dataframe
15 df <- data.frame(idx, vals)
16 rownames(df) <- NULL
17 names(df) <- c('date','value')
18 
19 # Dar un vistazo al archivo
20 head(df)
21 
22 # Plotear la serie
23 plot(df, type="l", xlab="Años", ylab="Tmin (°C/d)")
24
```

```
> # Fijar fechas y datos en un solo archivo dataframe
> df <- data.frame(idx, t(vals)[-1,])
> rownames(df) <- NULL
> names(df) <- c('date', 'value')
>
> # Dar un vistazo al archivo
> head(df)
> date
1 2005-12-16 14.42645
2 2006-01-15 16.42248
3 2006-02-14 16.47473
4 2006-03-16 16.1
5 2006-04-15 16.1
6 2006-05-15 15.08361
>
> # Plotear la serie
> plot(df, type="l", xlab="Años", ylab="Tmin (°C/d)")
```

Environment History Connections

Global Environment

vals 1 obs. of 301 variables

Variab 36 obs. of 1 variable

Variables 36 obs. of 1 variable

VPPgis 7 obs. of 3 variables

VPPMonth 4 obs. of 1 variable

xorig 36 obs. of 1 variable

XParameter 36 obs. of 8 variables

xy For data class SpatialPointsDataFrame

Values

AET num [1:40] 347 466 283 322 223 ...

Convertrun chr [1:4] "sum" "sum" "mean" "sum"

date_ATSM POSIXct[1:1392], format: "1900-01-01" "1900-02-01" "1900-03-01" "1900-04-01" "1900-05-01" "1900-06-01" "1900-07-01" "1900-08-01" "1900-09-01" "1900-10-01" "1900-11-01" "1900-12-01" "1901-01-01" "1901-02-01" "1901-03-01" "1901-04-01" "1901-05-01" "1901-06-01" "1901-07-01" "1901-08-01" "1901-09-01" "1901-10-01" "1901-11-01" "1901-12-01" "1902-01-01" "1902-02-01" "1902-03-01" "1902-04-01" "1902-05-01" "1902-06-01" "1902-07-01" "1902-08-01" "1902-09-01" "1902-10-01" "1902-11-01" "1902-12-01" "1903-01-01" "1903-02-01" "1903-03-01" "1903-04-01" "1903-05-01" "1903-06-01" "1903-07-01" "1903-08-01" "1903-09-01" "1903-10-01" "1903-11-01" "1903-12-01" "1904-01-01" "1904-02-01" "1904-03-01" "1904-04-01" "1904-05-01" "1904-06-01" "1904-07-01" "1904-08-01" "1904-09-01" "1904-10-01" "1904-11-01" "1904-12-01" "1905-01-01" "1905-02-01" "1905-03-01" "1905-04-01" "1905-05-01" "1905-06-01" "1905-07-01" "1905-08-01" "1905-09-01" "1905-10-01" "1905-11-01" "1905-12-01" "1906-01-01" "1906-02-01" 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A. Comandos y códigos en el entorno Rstudio

Ejercicio A.1

En la consola de resultados, efectuar las siguientes operaciones:

- 1) $3^2 - 5 * 9 * (25 - 18)$
- 2) Crear una serie consecutiva del 1 al 8
- 3) Crear una serie consecutiva de 8 letras comenzando por "a"
- 4) Asignar la operación $8 * 5^2$ al objeto *value*
- 5) Visualizar el objeto *value* creado
- 6) Crear el objeto *p*, almacenando una secuencia desde 5 hasta 15 de 2 en 2
- 7) Visualizar *p*
- 8) Almacenar los siguientes valores de lluvia anual: 20, 21.2, 49, 10.5, 15.1, 19, 31 y 20.2 en el objeto *rain*.
- 9) Visualizar *rain*
- 10) Obtener el 5to elemento de *rain*
- 11) Almacenar los siguientes valores anuales de índice SOI El Niño: 0.2, 0.4, 1.5, -0.1, 0.15, 0.3, 0.9 y 1.1 en el objeto *soi*.
- 12) Visualizar *soi*.

Respuestas A.1

```
> 3^2-5*9*(25-18)
[1] -306
> 1:8
[1] 1 2 3 4 5 6 7 8
> letters[1:8]
[1] "a" "b" "c" "d" "e" "f" "g" "h"
> value<-8*5^2 #Asignamos una operación al objeto value
> value #Escribimos el objeto "value"
[1] 200
> p<-seq(from=5, to=15, by=2) #secuencia desde 5 hasta 15 de 2 en 2
> print (p)
> rain<-c(20, 21.2, 49, 10.5, 15.1, 19, 31, 20.2) #Uso de función c(combine)
asignar datos al objeto rain
> rain #Escribimos el objeto "rain"
[1] 20.0 21.2 49.0 10.5 15.1 19.0 31.0 20.2
> rain[5] #Obtenemos el 5to elemento del objeto rain
[1] 15.1
> soi<-c(0.2, 0.4, 1.5, -0.1, 0.15, 0.3, 0.9, 1.1) # Ejemplo de valores del índice
SOI para El Niño
> soi #Escribimos el objeto "soi"
[1] 0.20 0.40 1.50 -0.10 0.15 0.30 0.90 1.10
```

Ejercicio A.2

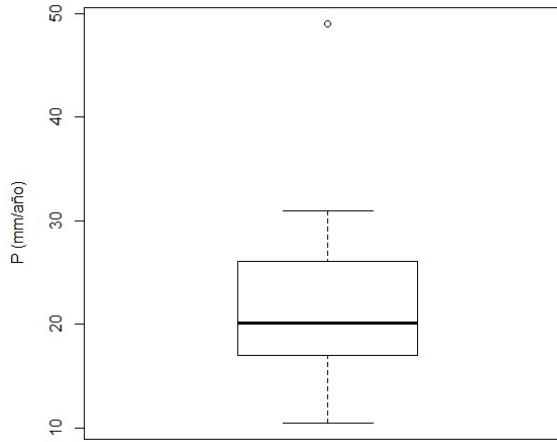
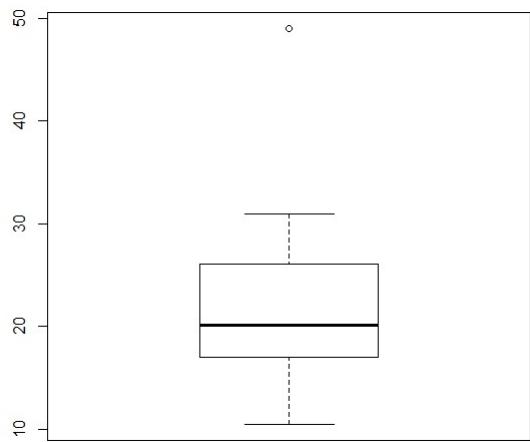
En la consola de resultados, efectuar las siguientes operaciones:

- 1) Obtener la media, mediana, desviación estándar, varianza del objeto rain (del ejercicio A.1)
- 2) Visualizar un resumen de los estadísticos notables
- 3) Plotear un diagrama de cajas con los valores del objeto rain. interpretar
- 4) Plotear lo anterior con una etiqueta en el eje vertical indicando: P (mm/año)

Respuestas A.2

```
> mean(rain)
[1] 23.25
> median(rain)
[1] 20.1
> sd(rain)
[1] 11.91781
> var(rain)
[1] 142.0343
> summary(rain)
   Min. 1st Qu. Median Mean 3rd Qu. Max.
10.50  18.02  20.10  23.25  23.65  49.00
```

```
> boxplot(rain) #Grafico de cajas
> boxplot(rain, ylab="P (mm/año)") #Grafico de cajas y etiqueta
```



Ejercicio A.3

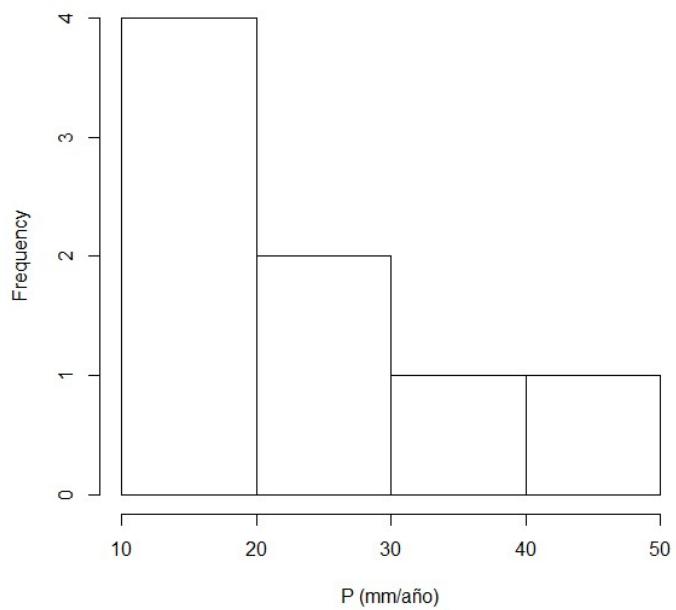
En la consola de resultados, efectuar las siguientes operaciones:

- 1) Plotear un histograma de frecuencias para rain, empleando la frecuencia
- 2) Plotear un histograma de frecuencias para rain, empleando la densidad
- 3) Agregar al histograma una curva de distribución normal en color rojo con la media y desviación estimados anteriormente
- 4) Agregar en un solo grafico (1filas x 2 columnas), el grafico de cajas anterior y el histograma
- 5) Separar los graficos anteriores
- 6) Calcular la covarianza entre la lluvia y el índice soi
- 7) Calcular el coeficiente de correlación entre la lluvia y el índice soi
- 8) Calcular la ecuación de regresión lineal entre la lluvia y soi
- 9) Plotear un grafico de dispersión entre la lluvia y el índice soi
- 10) Agregar la línea de tendencia al grafico anterior.

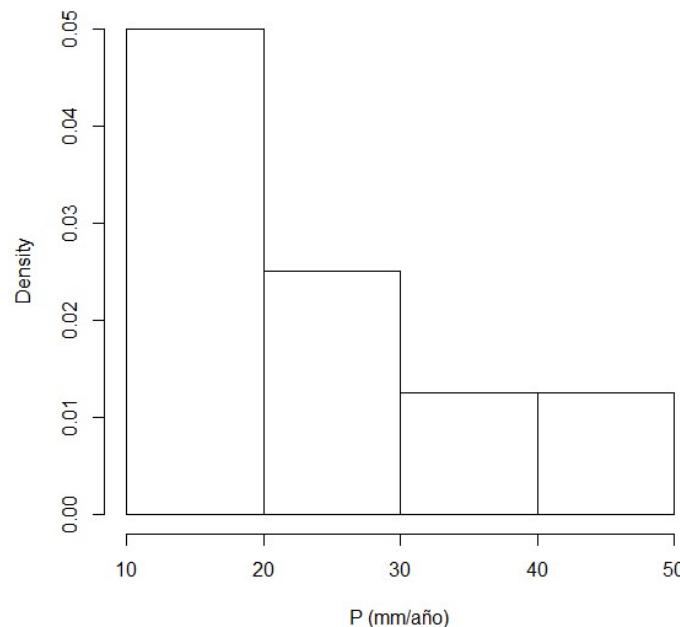
Respuestas A.3

```
> hist(rain, main="Precipitacion anual", xlab="P (mm/año)", freq=F) # Grafico de histograma, F(False) no usar frecuencia
> curve(dnorm(x, mean(rain, na.rm = T), sd(rain, na.rm = T)), add = TRUE, col="red") # Agregar curva distribucion r normal en color rojo
> split.screen(c(1,2)) #usar este comando para ordenar el espacio de figuras, aquí 2 figuras en una fila
> screen(2) #usar este comando antes de plotear la segunda figura
> close.screen(all=TRUE) # comando para regresar a las condiciones iniciales de una figura por ventana
> cov(rain,soi) #covarianza
[1] 5.650357
> cor(rain,soi) #coeficiente de correlación r
[1] 0.8620822
> lm(soi ~ rain) #ecuación de regresión lineal
Call:
lm(formula = soi ~ rain)
Coefficients:
(Intercept)      rain
-0.36867     0.03978
> plot(rain,soi,main="ENSO-rainfall relationship",xlab="rainfall", ylab="SOI index")
> abline(lm(soi~rain))
```

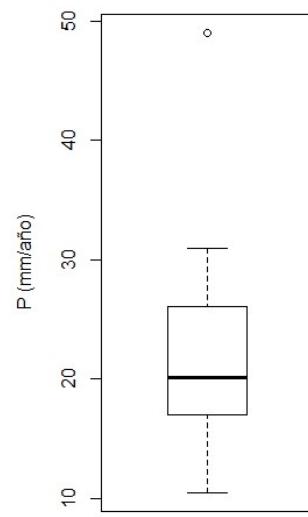
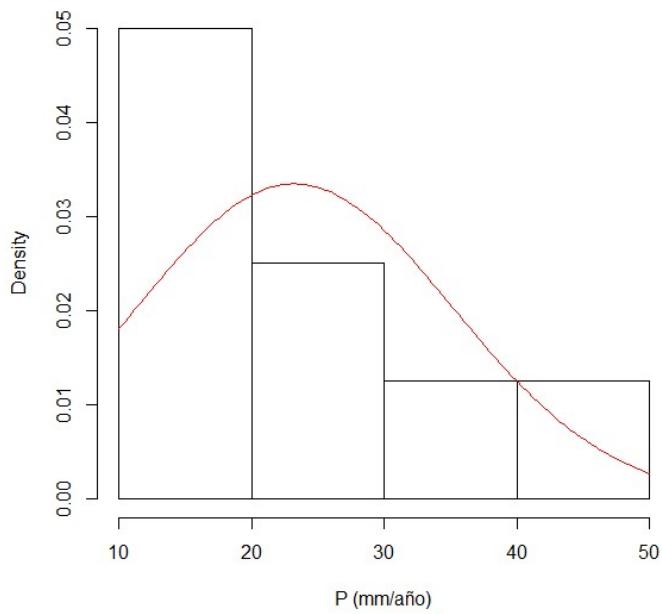
Precipitacion anual



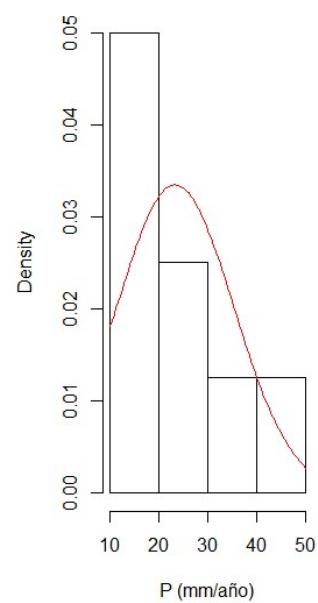
Precipitacion anual



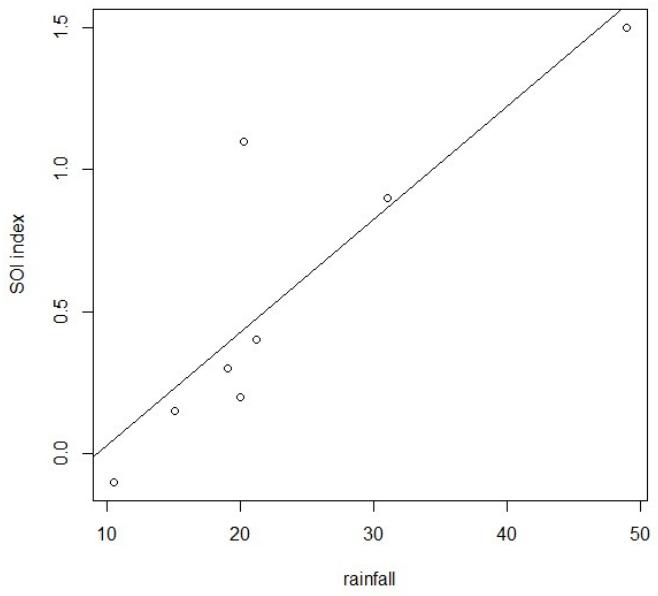
Precipitacion anual



Precipitacion anual



ENSO-rainfall relationship



Ejercicio A.4

En la consola de scripts:

- 1) Crear una función que calcule la velocidad de un río ancho por el método de Manning: datos de ingreso el tirante, la pendiente y el coeficiente de Manning en el S.I.
- 2) Calcular la velocidad para para un tirante de 1.5m, pendiente de 1% y un coeficiente de Manning de 0.035.
- 3) Calcular la velocidad para un tirante de 1.5m, pendiente de 0.5% y un coeficiente de Manning de 0.035

Respuestas A.4

$$V = \frac{1}{n} R_h^{\frac{2}{3}} \cdot S^{\frac{1}{2}}$$

V: Velocidad

Rh: Radio Hidraulico

S: Pendiente

n: Coeficiente de Manning

```
vel.manning<- function(y,s,n) #creando la funcion vel.manning  
con tres argumentos
```

```
{ result <- y^(2/3)*s^0.5/n #definiendo las operaciones  
print(result) }
```

```
vel.manning(1.5,0.01,0.035) # calculo de la velocidad en m/s  
[1] 3.743916
```

```
vel.manning(1.5,0.005,0.035) # calculo de la velocidad en m/s  
[1] 2.647349
```

3. Análisis exploratorio de datos



My code doesn't work

```

read.table(file, header = FALSE, sep = "", quote = "\"\"", dec = ".", row.names,
col.names, as.is = FALSE, na.strings = "NA", colClasses = NA, nrows = -1, skip = 0,
check.names = TRUE, fill = !blank.lines.skip, strip.white = FALSE, blank.lines.skip =
TRUE, comment.char = "#")

read.csv(file, header = TRUE, sep = ",", quote = "\"\"", dec = ".", fill = TRUE, ...)

```

Leyendo archivos, bases de datos

| | |
|-------------------------|--|
| file | the name of the file (within "" or a variable of mode character), possibly with its path (the symbol \ is not allowed and must be replaced by /, even under Windows), or a remote access to a file of type URL (http://...) |
| header | a logical (FALSE or TRUE) indicating if the file contains the names of the variables on its first line |
| sep | the field separator used in the file, for instance <code>sep="\t"</code> if it is a tabulation |
| quote | the characters used to cite the variables of mode character |
| dec | the character used for the decimal point |
| row.names | a vector with the names of the lines which can be either a vector of mode character, or the number (or the name) of a variable of the file (by default: 1, 2, 3, ...) |
| col.names | a vector with the names of the variables (by default: V1, V2, V3, ...) |
| as.is | controls the conversion of character variables as factors (if FALSE) or keeps them as characters (TRUE); <code>as.is</code> can be a logical, numeric or character vector specifying the variables to be kept as character |
| na.strings | the value given to missing data (converted as NA) |
| colClasses | a vector of mode character giving the classes to attribute to the columns |
| nrows | the maximum number of lines to read (negative values are ignored) |
| skip | the number of lines to be skipped before reading the data |
| check.names | if TRUE, checks that the variable names are valid for R |
| fill | if TRUE and all lines do not have the same number of variables, "blanks" are added |
| strip.white | (conditional to <code>sep</code>) if TRUE, deletes extra spaces before and after the character variables |
| blank.lines.skip | if TRUE, ignores "blank" lines |
| comment.char | a character defining comments in the data file, the rest of the line after this character is ignored (to disable this argument, use <code>comment.char = ""</code>) |

Configurando Series de tiempo

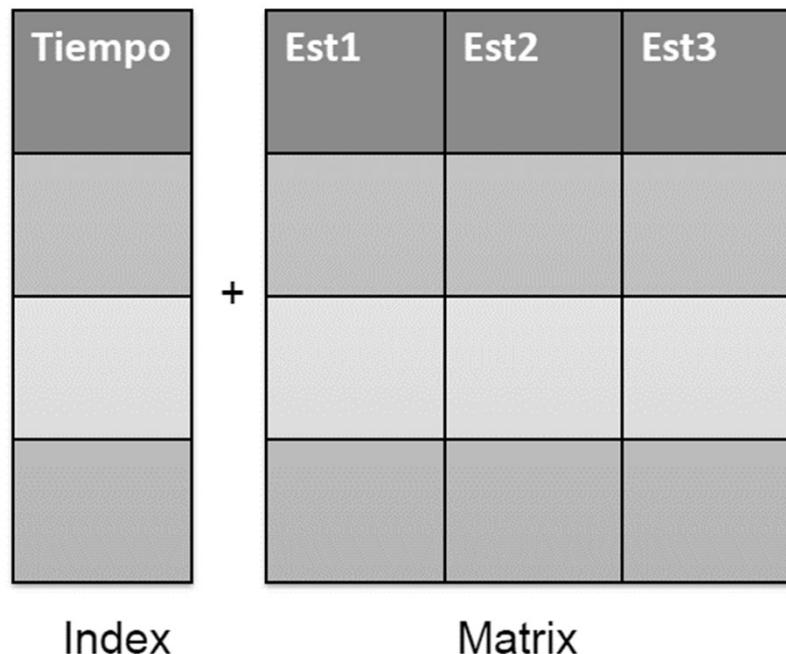
```
ts(data = NA, start = 1, end = numeric(0), frequency = 1, deltat = 1, ts.eps =  
getOption("ts.eps"), class, names)
```

| | |
|-----------|--|
| data | a vector or a matrix |
| start | the time of the first observation, either a number, or a vector of two integers (see the examples below) |
| end | the time of the last observation specified in the same way than start |
| frequency | the number of observations per time unit |
| deltat | the fraction of the sampling period between successive observations (ex. 1/12 for monthly data); only one of frequency or deltat must be given |
| ts.eps | tolerance for the comparison of series. The frequencies are considered equal if their difference is less than ts.eps |
| class | class to give to the object; the default is "ts" for a single series, and c("mts", "ts") for a multivariate series |
| names | a vector of mode character with the names of the individual series in the case of a multivariate series; by default the names of the columns of data, or Series 1, Series 2, ... |

Zoo y xts

```
zoo(x = NULL, order.by = index(x), frequency = NULL, calendar =  
getOption("zoo.calendar", TRUE))  
# S3 method for zoo  
print(x, style = , quote = FALSE, ...)
```

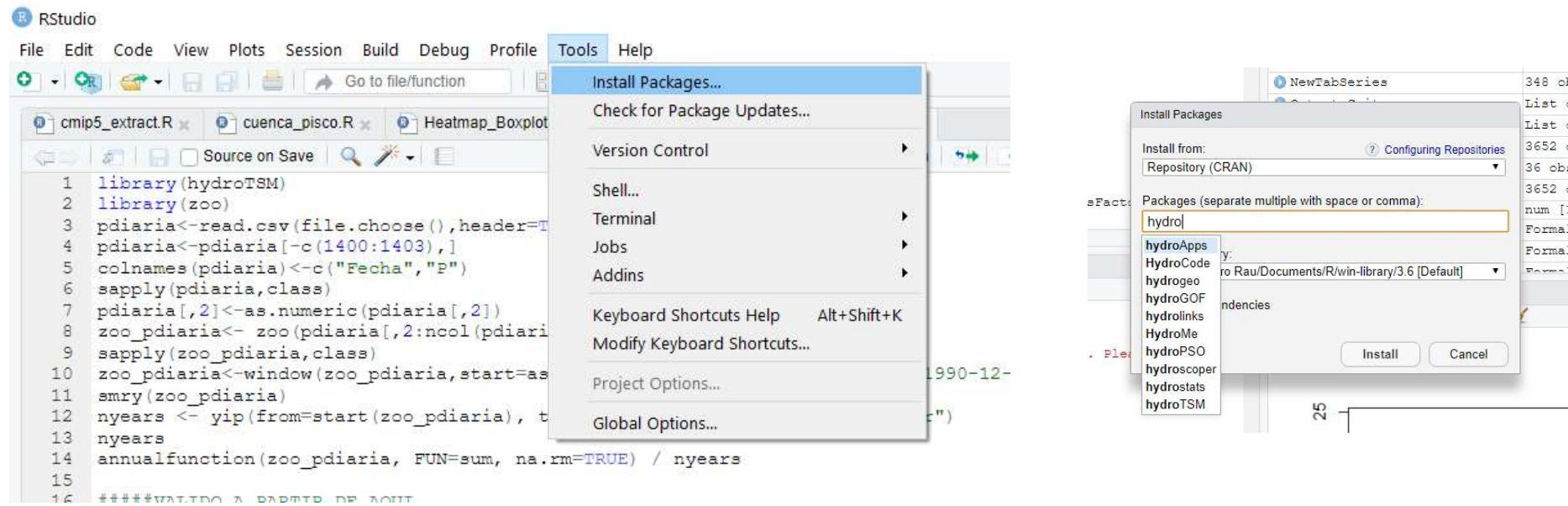
```
xts(x = NULL, order.by = index(x), frequency = NULL, unique = TRUE, tzone =  
Sys.getenv("TZ"), ...)  
is.xts(x)
```



B. Explorando datos de precipitación mensual almacenados en una matriz de una sola estación

Uso de las librerías: *lattice*, *zoo*, *hydroTSM*

- Instalar librerías TOOLS - INSTALL PACKAGES: lattice, zoo, hydroTSM
- Descargar archivo "pmensual.txt"
<https://drive.google.com/file/d/1Z1k6QOpFeyaOBvRyzgb5kH4Od8pLOpKS/view?usp=sharing>
- Revisión de archivo texto (guardado desde el excel)



Ejercicio B

En la consola de scripts, crear un código que realice lo siguiente:

- 1) Leer el archivo de precipitaciones mensuales "pmensual.txt" almacenados en formato matriz de 13 columnas (año mes1 mes 2 mes 12) y 45 filas (nombre valor1 valor2 ...).
- 2) Plotear toda la serie de tiempo
- 3) Agregar una curva de tendencia
- 4) Plotear un gráfico de calor "heatmap"

Grabar y dar nombre al script: Analisis_mensual.R

Respuestas B

```
library("lattice") #llamar librería lattice
library("hydroTSM") #llamar librería TSM
pmensual<-read.table(file.choose(), header = F) #lectura de archivo, se abrirá una ventana para
seleccionar el archivo, cual fuese su ruta, header "F" por no contener datos en la cabecera solo
contiene etiquetas
```

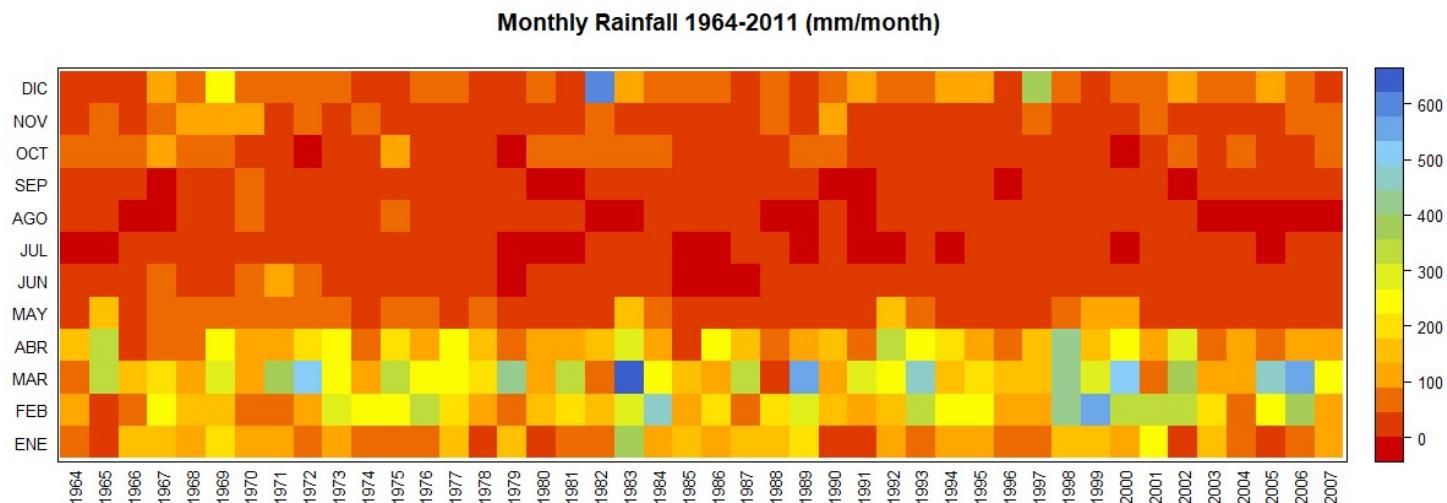
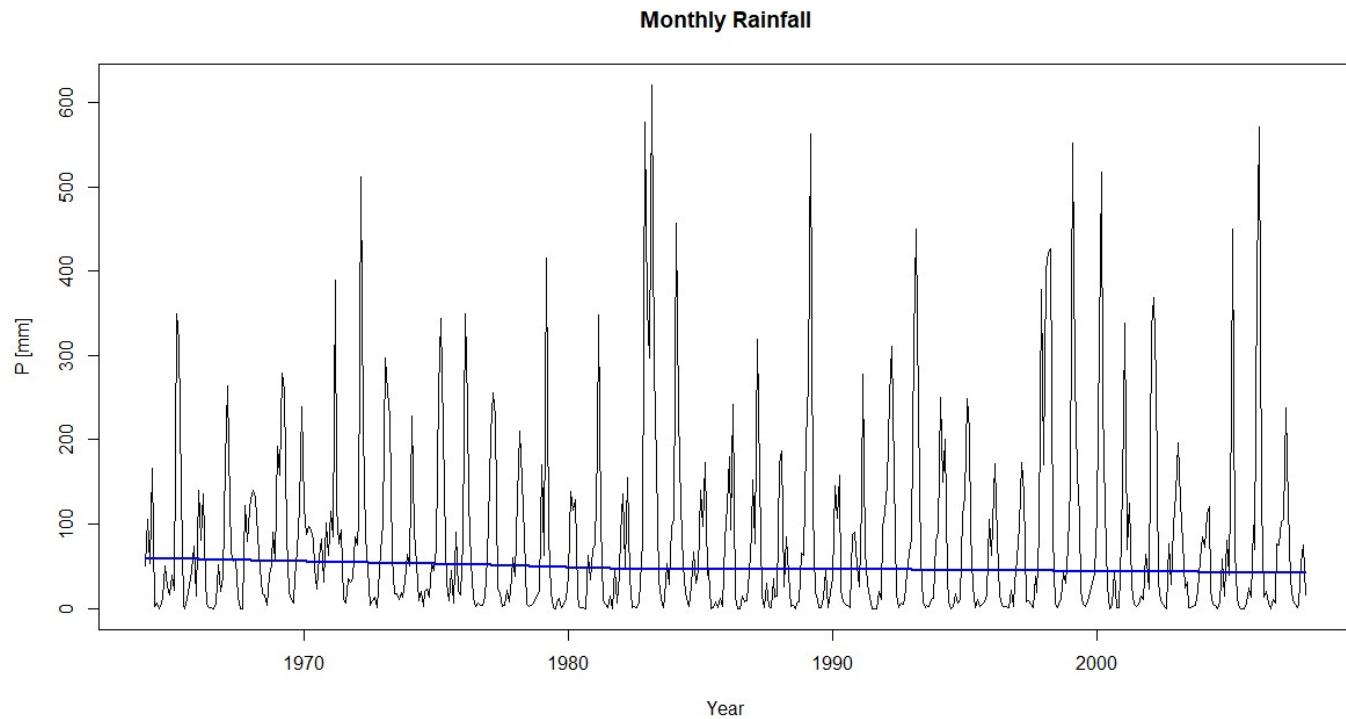
#Visualización de la serie de tiempo:

```
datos<-pmensual[2:45,2:13]
datos_vector<-as.vector(t(datos)) #convirtiendo a vector lineal
datos_ts<-stats::ts(datos_vector, start=c(1964, 1), end=c(2010, 12), frequency=12)
plot.ts(datos_ts, col="black", main="Monthly Rainfall time series", ylab="P [mm]", xlab="Year")
lines(lowess(time(datos_ts), datos_ts), col="blue", lwd=2) #agregar curva de tendencia
```

#Diagrama de calor o HeatMap:

```
lluvia<-pmensual[2:45,2:13] #lectura de solo datos de lluvia, sin etiquetas de años, ni meses (desde
1964 al 2007)
```

```
meses<-pmensual[1:1,2:13] #lectura de la cabecera de meses en la primera fila
colnames(lluvia)<-unlist(meses) #desagrega los nombres de los meses y se asigna a la matriz
rownames(lluvia)<-pmensual[2:45,1:1] #desagrega los nombres de los meses y se asigna a la matriz
matrixplot(lluvia, ColorRamp="Precipitation",main="Monthly Rainfall 1964-2011 (mm/month)")
```



C. Explorando datos de precipitación diaria de varias estaciones almacenados en una matriz

Uso de las librerías: easypackages, xts, lattice, ggplot2

- Instalar librerías TOOLS - INSTALL PACKAGES: *easypackages*, *xts*, *lattice*, *ggplot2*
- Descargar archivo "p_diarias.csv"
<https://drive.google.com/file/d/1qj6I51SjhNIUfhq56Fw8kK4v3g1ttYq8/view?usp=sharing>
- Revisión de archivo csv (separados por comas con formato de fecha %Y-%M-%D)

Ejercicio C

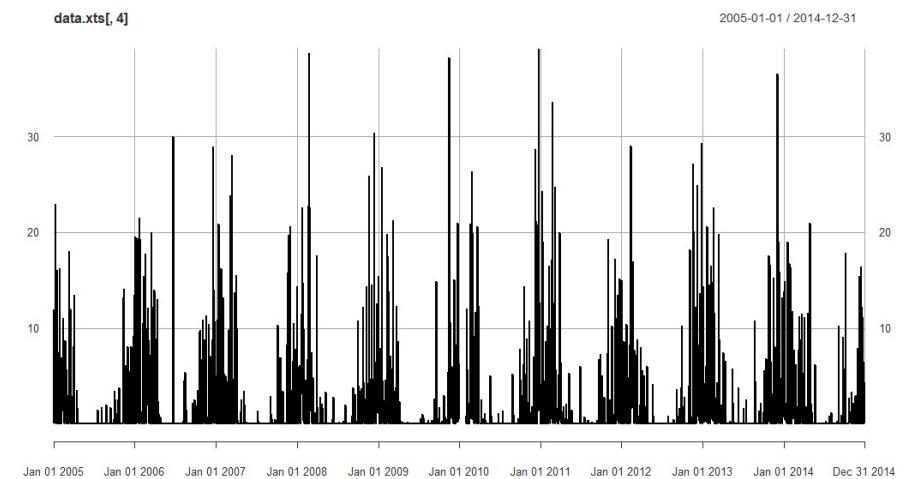
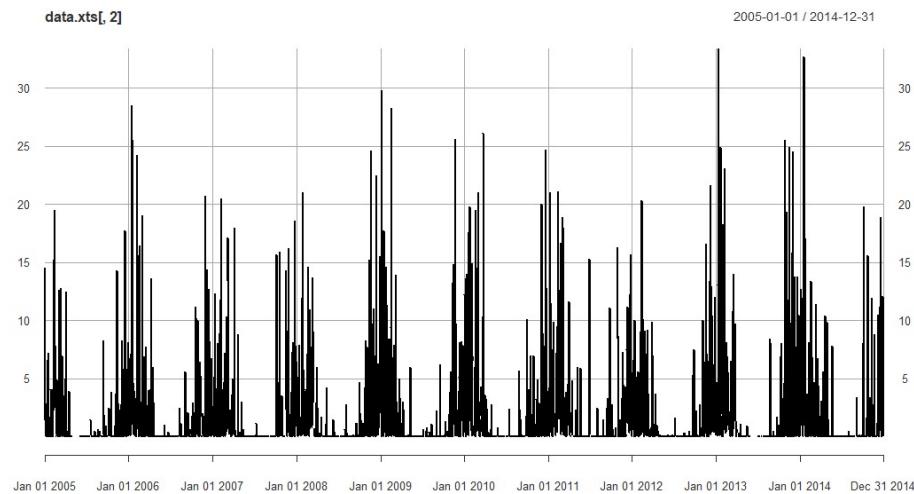
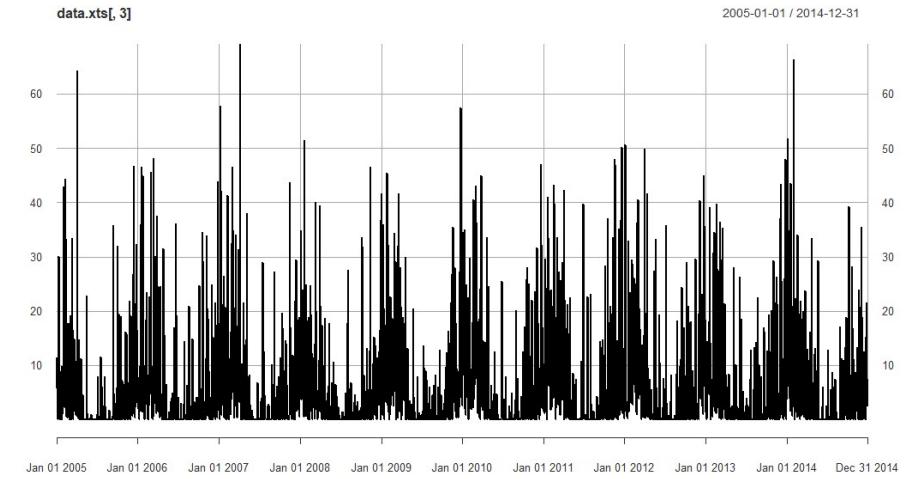
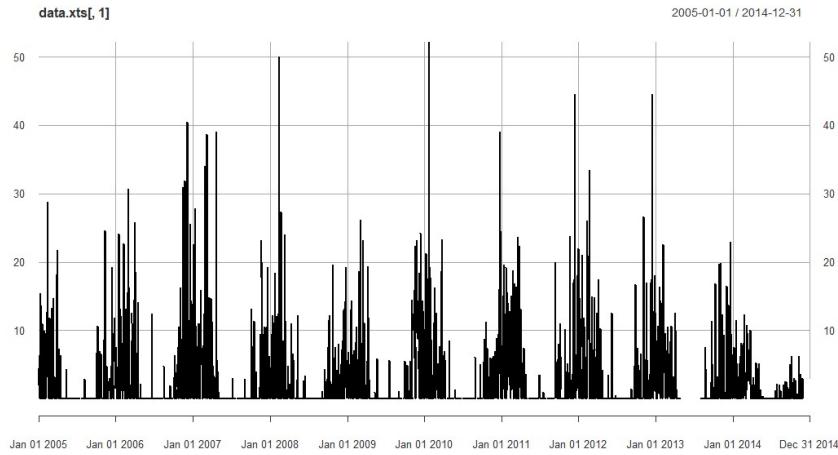
En la consola de scripts, crear un código que realice lo siguiente:

- 1) Leer el archivo de precipitaciones diarias "p_diarias.csv" almacenados en formato matriz con 4 estaciones (identificadores 101, 102, 103, 104) desde el 1Ene2005 al 31Dic2014
- 2) Plotear las series de tiempo para cada estación
- 3) Plotear las series de tiempo en conjunto con la misma escala vertical
- 4) Plotear un boxplot de las estaciones en conjunto
- 5) Plotear 3 histogramas correspondientes a 3 estaciones

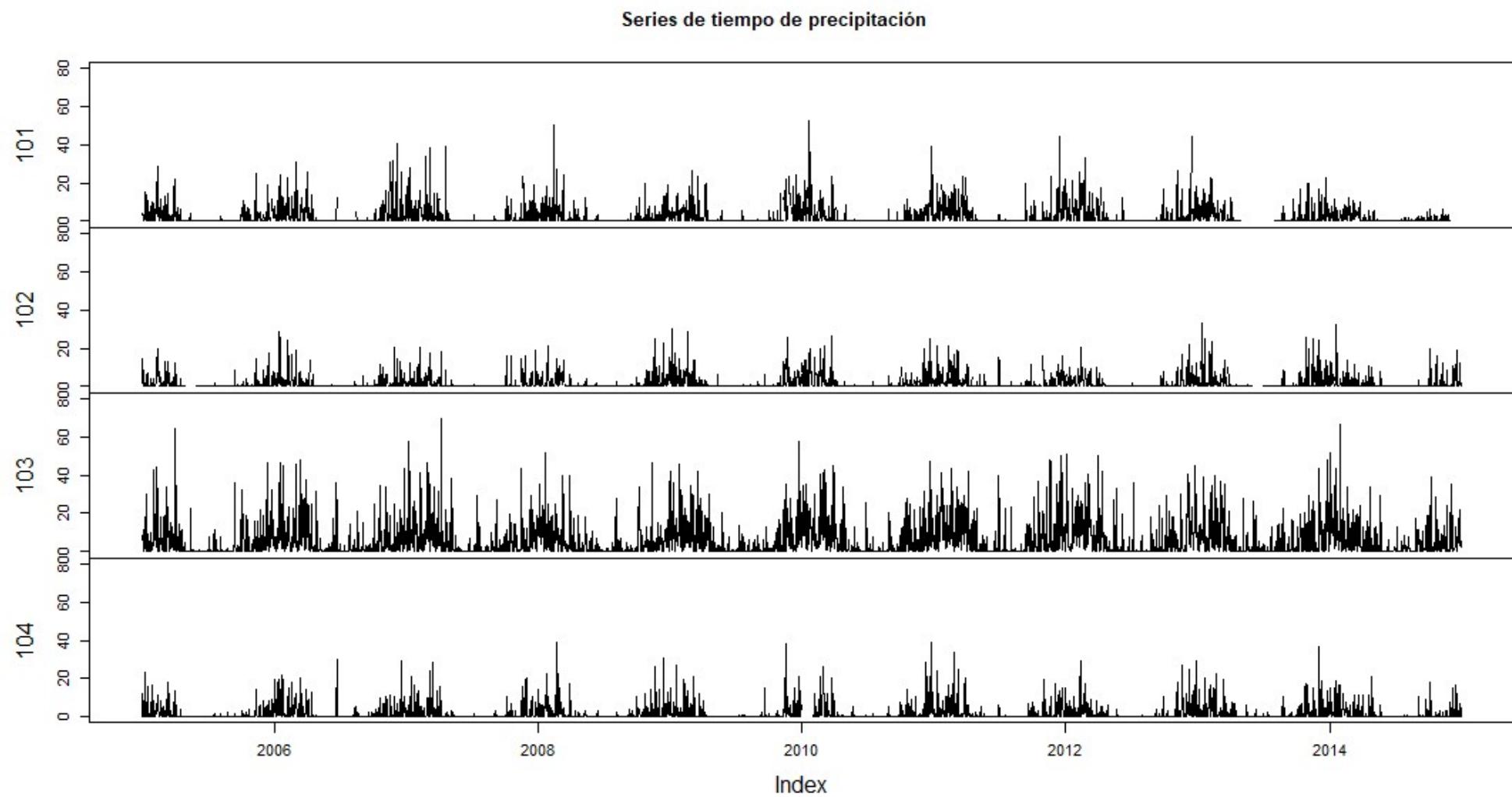
Respuestas C

```
library(easypackages)
library(xts)
library(lattice)
library(ggplot2)
pdiaria <- read.csv(file.choose(), header=TRUE, check.names = F, stringsAsFactors = F)
str(pdiaria) #para verificar la estructura del objeto
idx <- as.Date(pdiaria[,1]) #formato fecha a la 1era columna
data.matrix <- pdiaria[,-1] #formato matriz al resto de columnas a excepcion de la 1era columna
data.xts <- xts(data.matrix, order.by = idx ) #crear un objeto xts (eXtended time series)
str(data.xts)
plot(data.xts)
plot(data.matrix[,1], type="l")
plot(data.xts[,2])

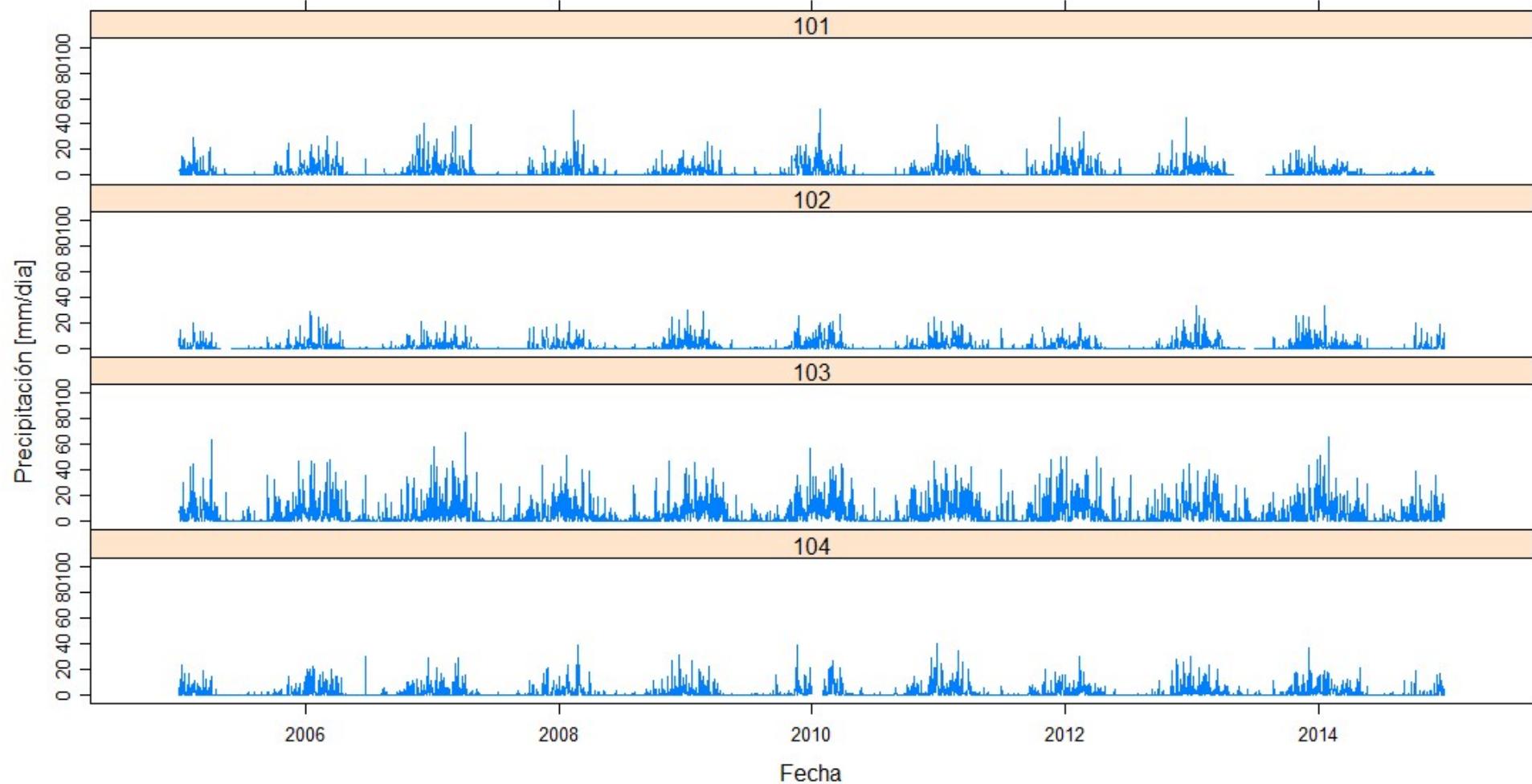
# convertir a un objeto zoo que almacene varias estaciones a la vez
data.zoo <- as.zoo(data.xts)
str(data.zoo)
plot(data.zoo, main = "Series de tiempo de precipitación")
summary(data.zoo)
max(data.zoo, na.rm = T)
plot(data.zoo, main = "Series de tiempo de precipitación", ylim = c(0,80))
xyplot(data.xts,xlab = "Fecha",ylab = "Precipitación [mm/dia]",ylim=c(0,100))
autoplot(data.xts[,1:2]) +theme_bw() +xlab('Fecha') +ylab('Precipitación [mm/dia]')
boxplot(coredata(data.xts))
hist(coredata(data.xts[,1]), freq = T) # cantidad de datos por clase
histogram(coredata(data.xts[,1])) # porcentaje de datos por clase
```



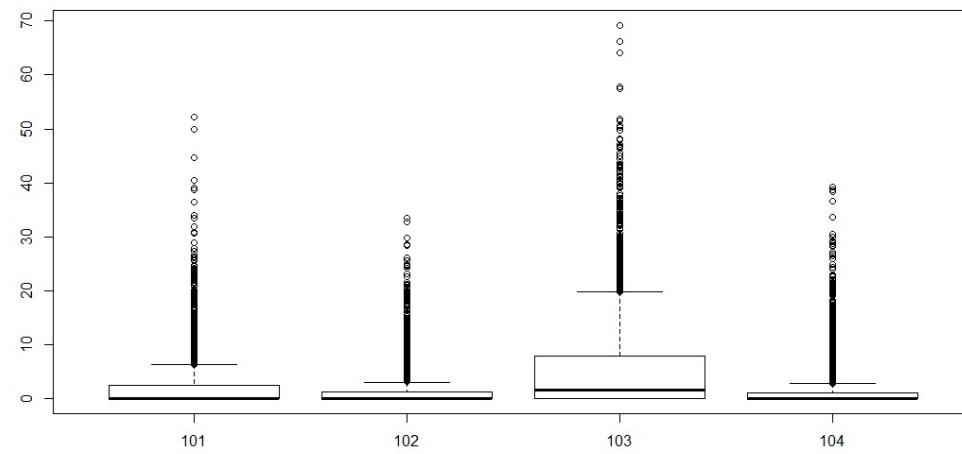
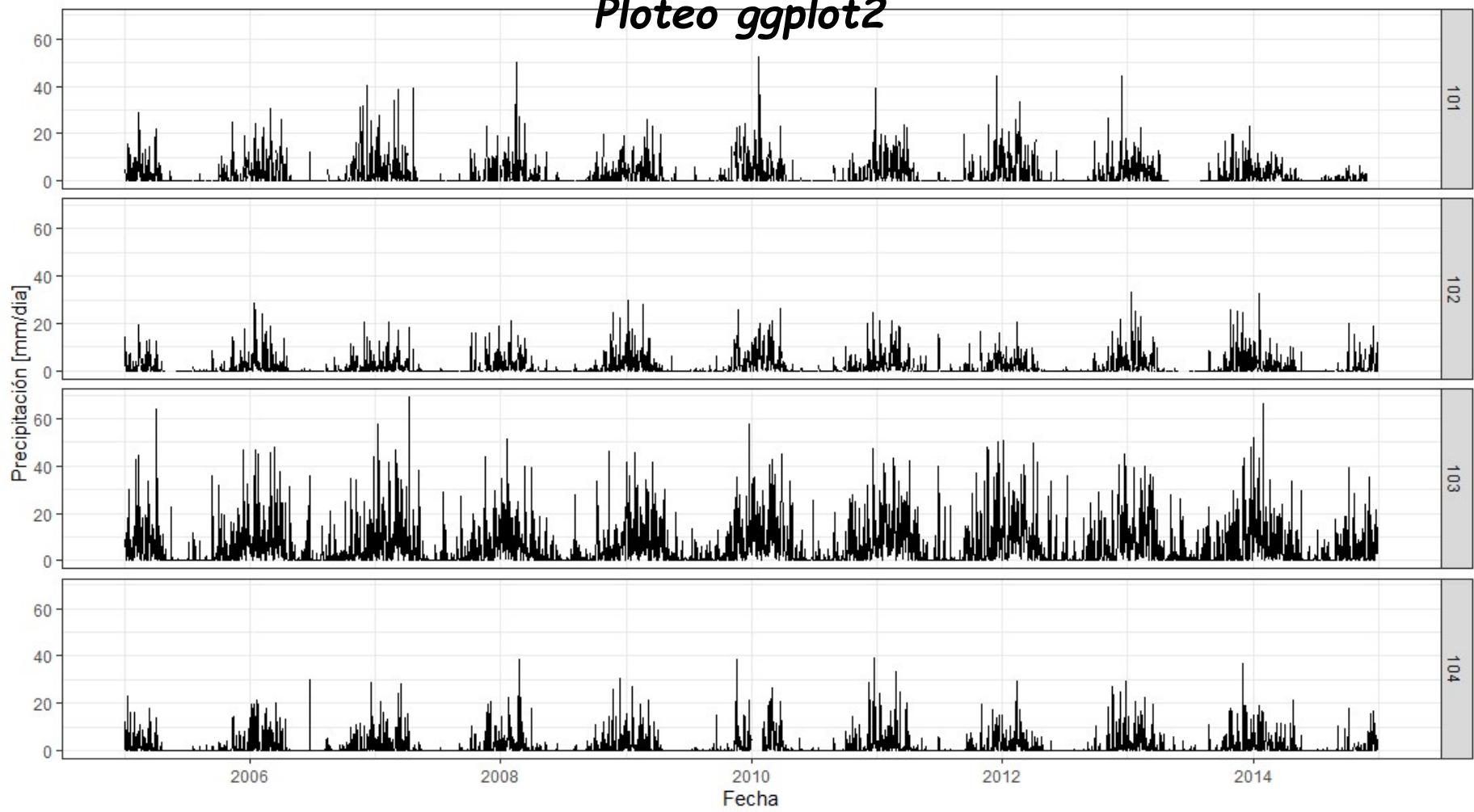
Ploteo simple

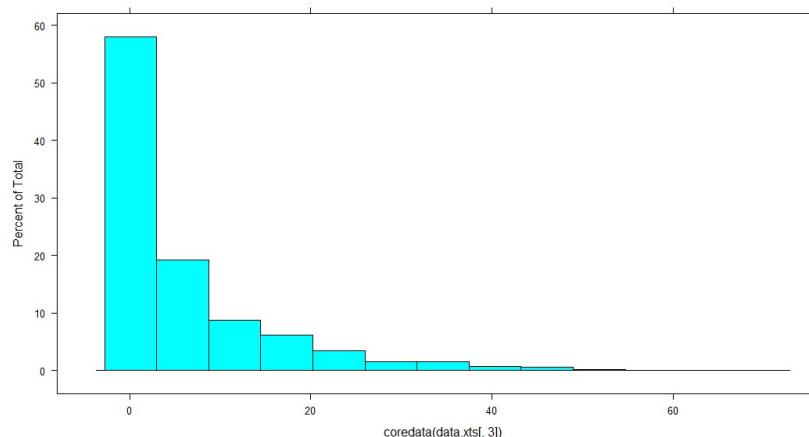
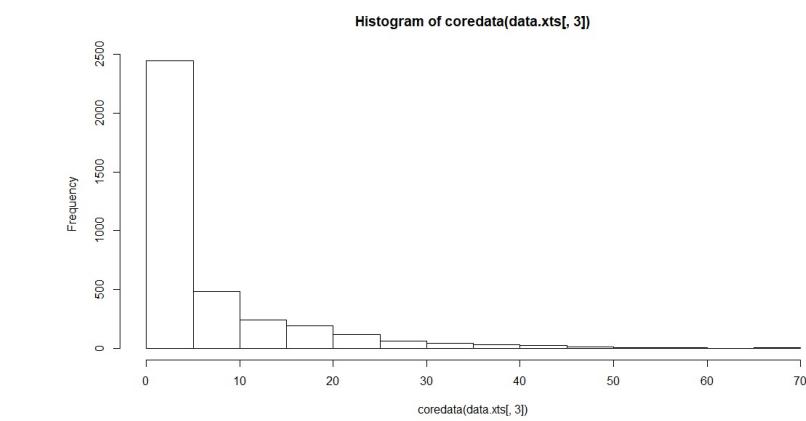
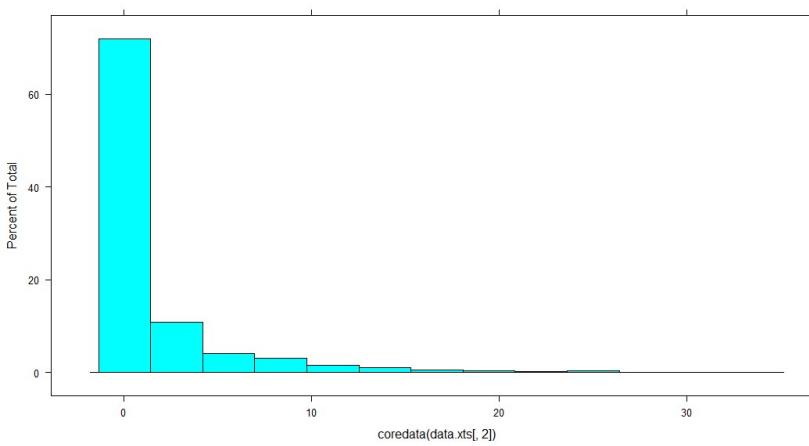
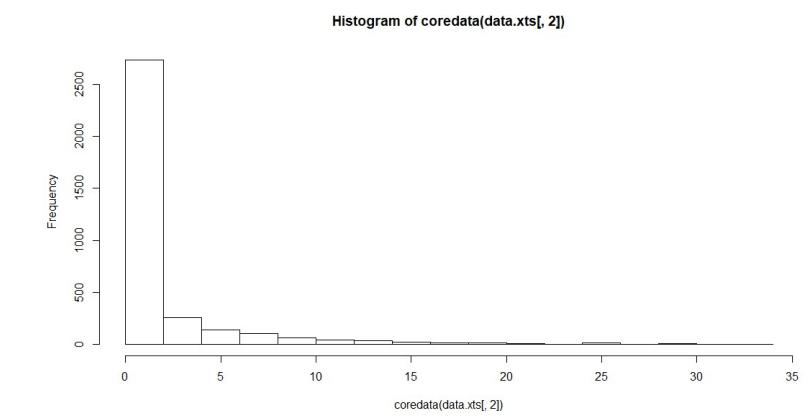
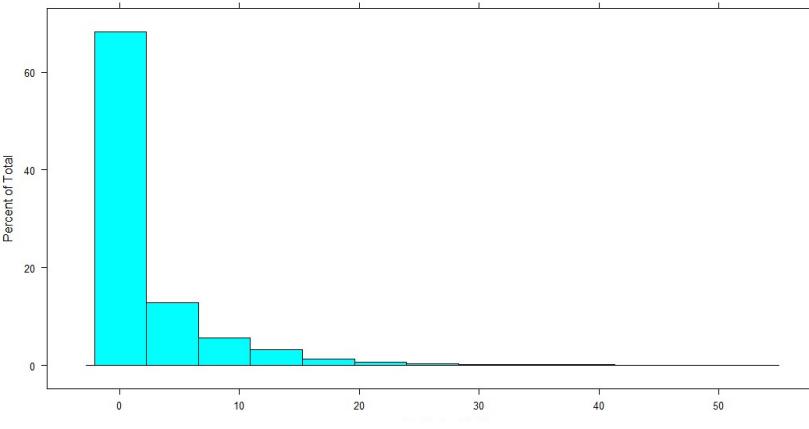
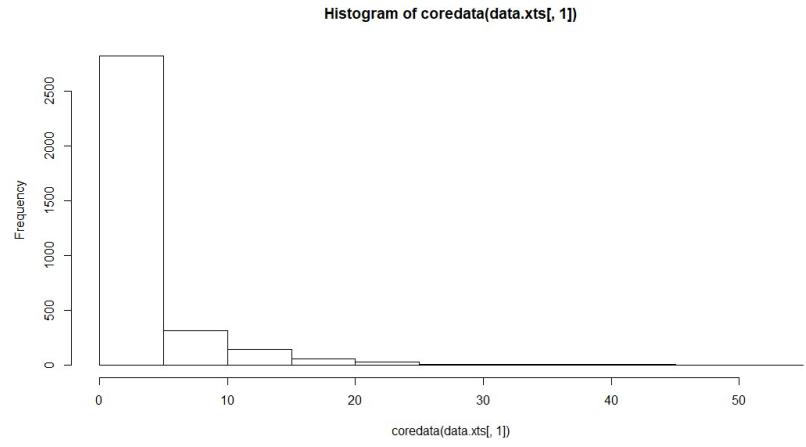


Ploteo lattice



Ploteo ggplot2





D. Convirtiendo datos diarios a mensuales y anuales

Ejercicio D

En la consola de scripts, crear un código que realice lo siguiente:

- 1) Leer el archivo de precipitaciones diarias "p_diarias.csv" almacenados en formato matriz con 4 estaciones (identificadores 101, 102, 103, 104) desde el 1Ene2005 al 31Dic2014
- 2) La estación 103 se encuentra completa, convertir sus datos diarios en mensuales y éstos en anuales. Plotear las series de tiempo, los datos mensuales en formato línea y los anuales en formato barras. Plotear todas las estaciones en conjunto y analizar el vacío de información.
- 3) Plotear un boxplot para los datos mensuales de cada estación
- 4) Plotear un boxplot estacional de la estación 103

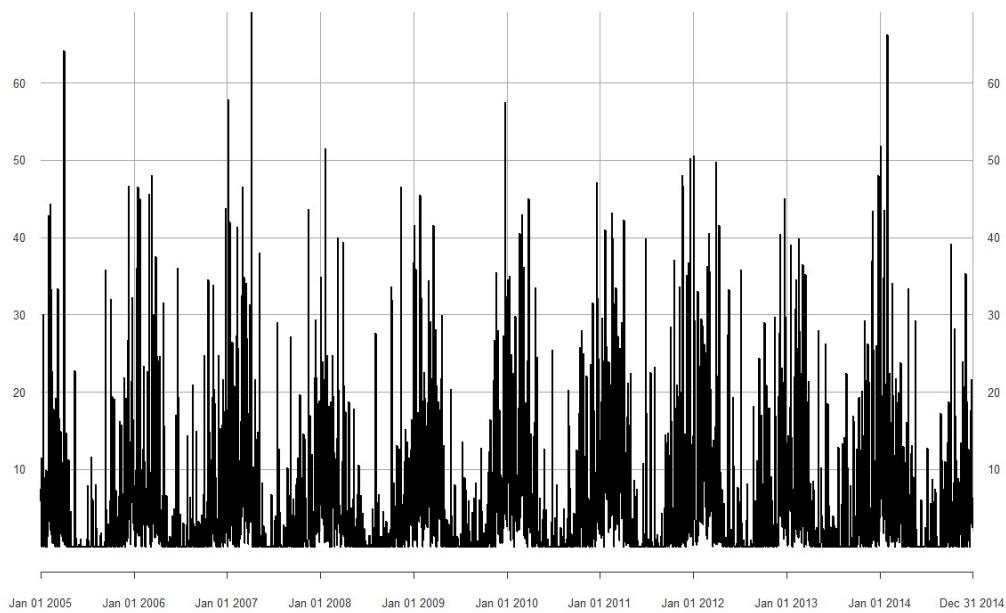
Respuestas D

```
library(easypackages)
library(xts)
library(lattice)
library(ggplot2)
pdiaria <- read.csv(file.choose(), header=TRUE, check.names = F, stringsAsFactors = F)
str(pdiaria)
idx <- as.Date(pdiaria[,1])
data.matrix <- pdiaria[,-1]
data.xts <- xts(data.matrix, order.by = idx )
str(data.xts)
plot(data.xts)
plot(data.matrix[,1], type="l")
plot(data.xts[,3])
#Convirtiendo a mensuales la estacion 103
data.monthly <- apply.monthly(data.xts[,3], FUN = sum)
plot(data.monthly)
#Todas las estaciones a mensuales
data.monthly <- apply.monthly(data.xts, FUN=apply, MARGIN = 2, sum)
xyplot(data.monthly, ylim = c(0,600))
#Convirtiendo a anuales la estacion 103
data.anual <- apply.yearly(data.xts[,3], FUN = sum)
barplot(data.anual)
#Todas las estaciones a anuales
data.anual <- apply.yearly(data.monthly, FUN=apply, 2, sum)
xyplot(data.anual)

boxplot(coredata(data.monthly)) # datos mensuales por estacion
# boxplot con estacionalidad de Lluvia para la estacion 103
boxplot(matrix(coredata(data.monthly[,3])), nrow=nrow(data.monthly)/12, ncol=12, byrow=T),
col="gray", main=c(paste(names(data.monthly[,3])), "Prec mensual [mm]"))
```

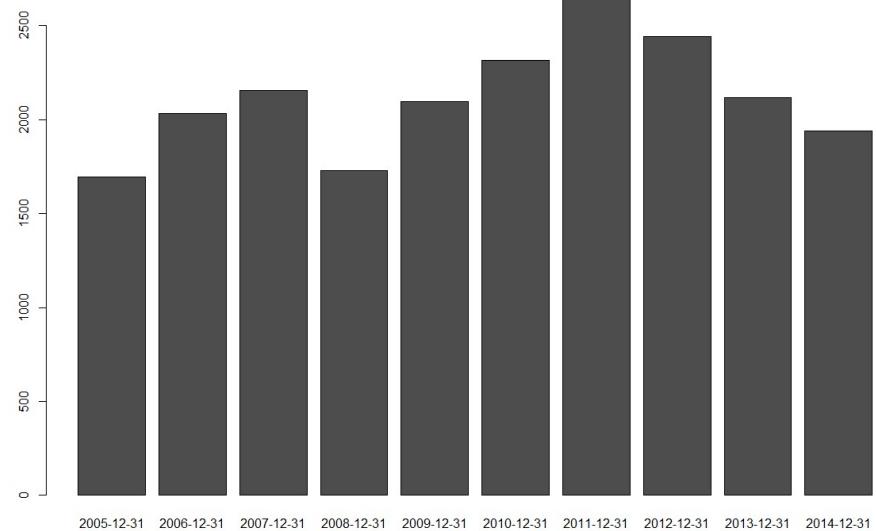
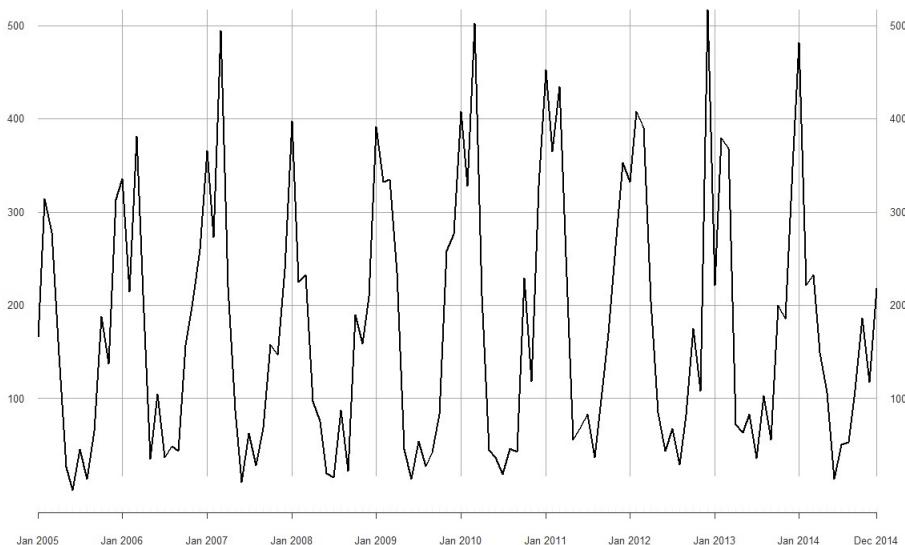
`data.xts[3]`

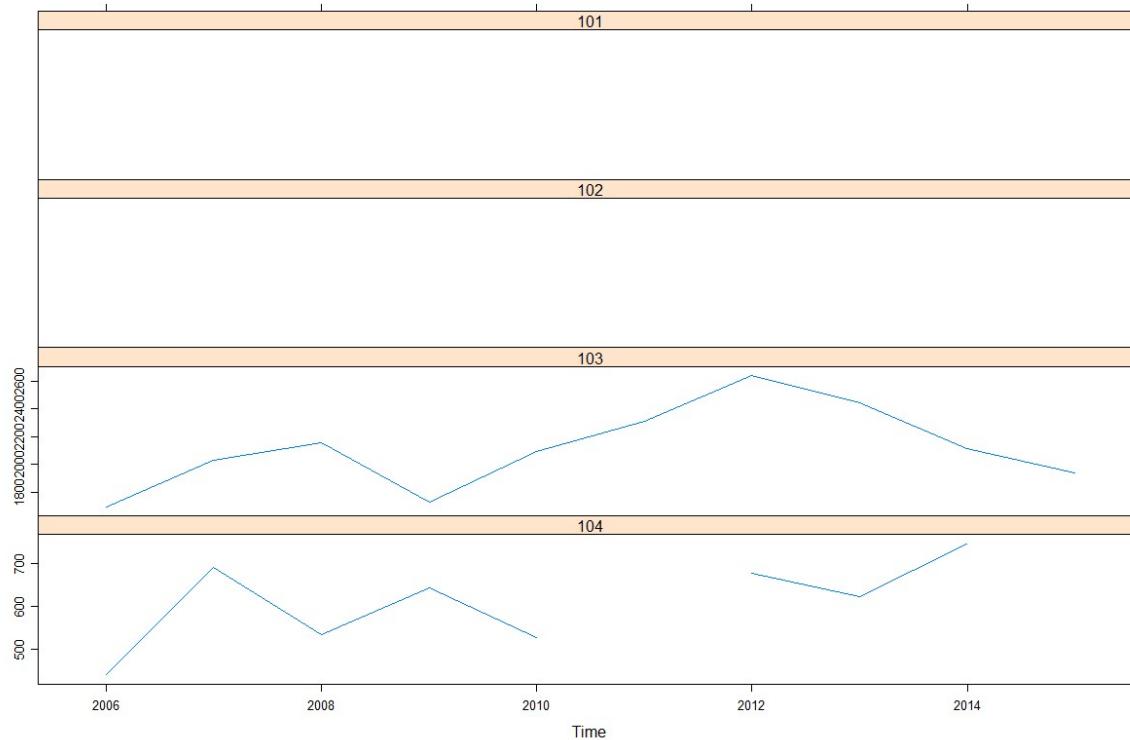
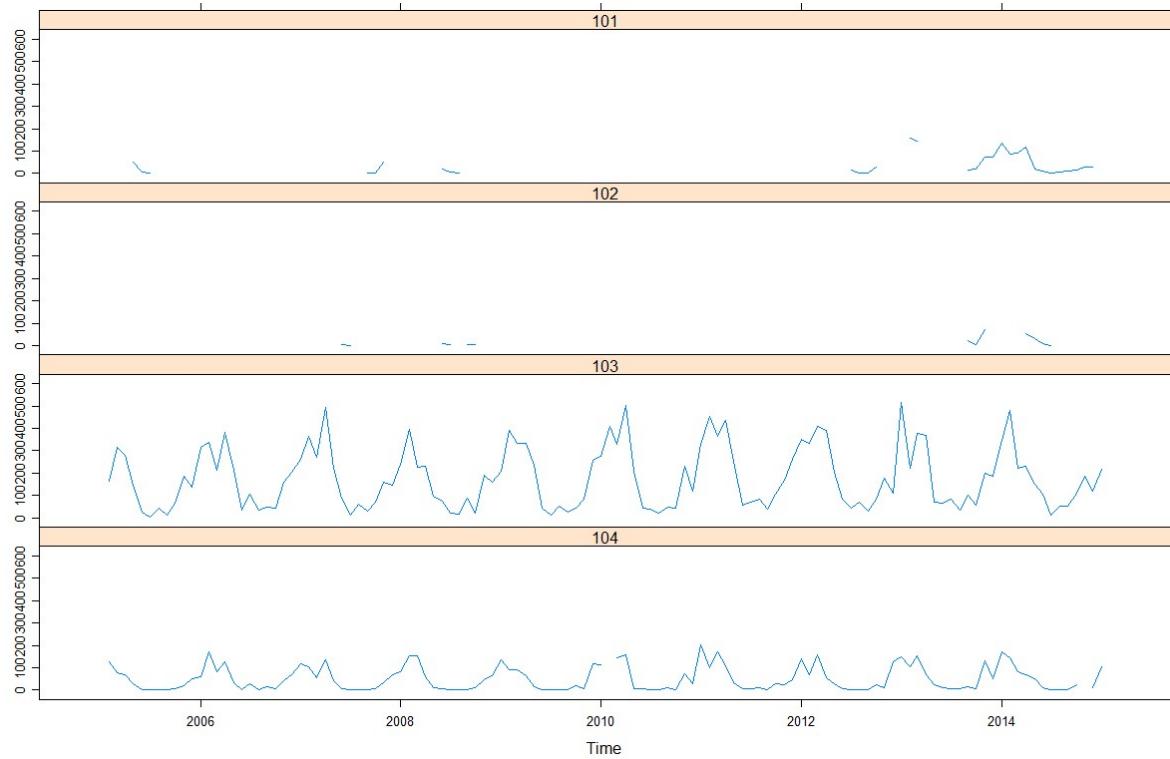
2005-01-01 / 2014-12-31

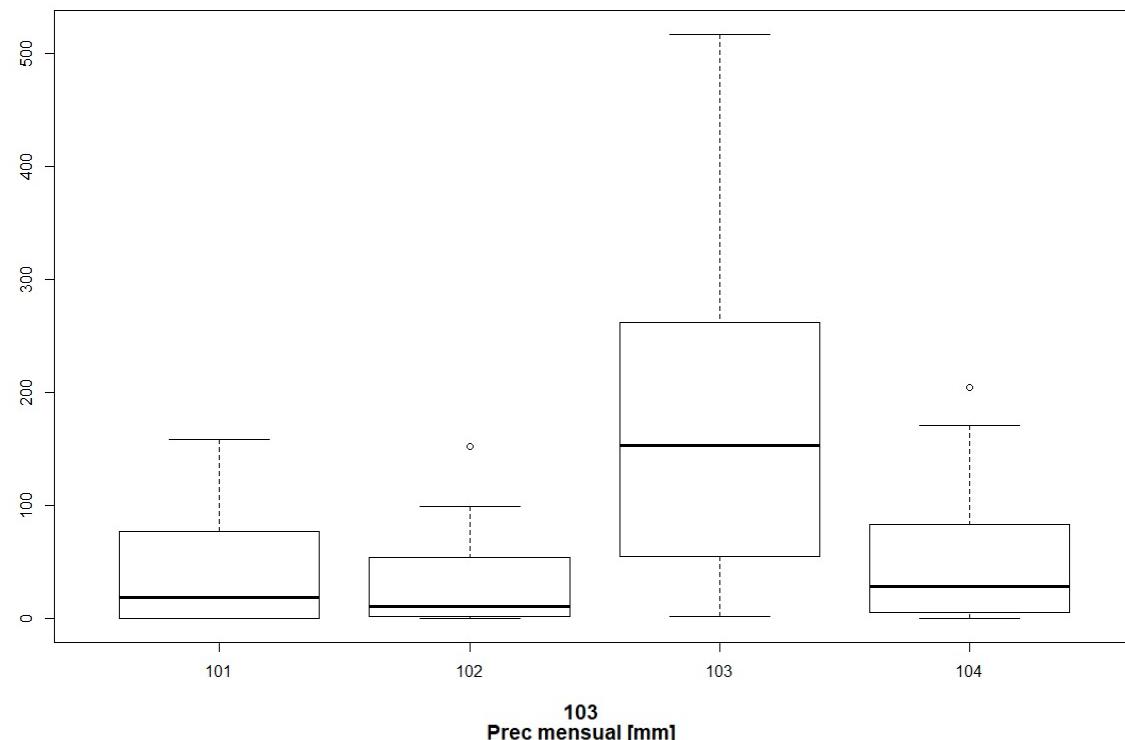


`data.monthly`

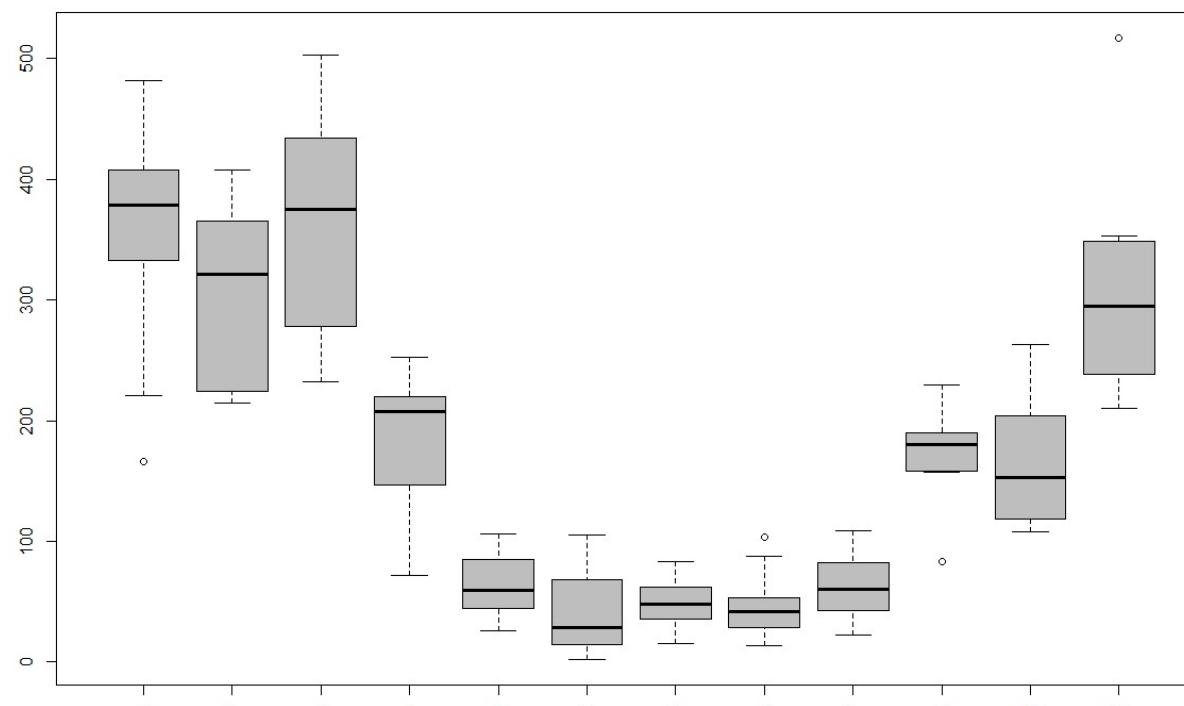
2005-01-31 / 2014-12-31







103
Prec mensual [mm]



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