TeREsA

A Toolbox in R for Environmental Analysis

User Manual v1.1

September 2016

For software version 1.0.1.0

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Chapter 1. Introduction

The *TeREsA* software is an R-based tool that was developed by the CREALP to optimize **environmental data analysis**. Originally conceived for hydro-meteorological data, some of the modules may be also used to process other types of dataset, such as air pollutant distribution or mineral concentration. TeREsA is a free software running on Windows (Windows Vista or later versions required).

The **programming language R** is a powerful tool for statistical computing and graphics (R Development Core Team, 2014). The different modules were developed in the R environment and then implemented in TeREsA to achieve specific tasks.

TeREsA is composed of **13 modules** grouped in **5 thematic classes** whose the first four are devoted to data series analysis, spatial analysis, frequency analysis and drought analysis. A fifth class gathers two independent modules that help for reservoir routing and salt gauging. **Figure 1** presents the TeREsA interface. The classes menu is displayed on the left side of the interface and modules are reachable by the mean of a tab menu.
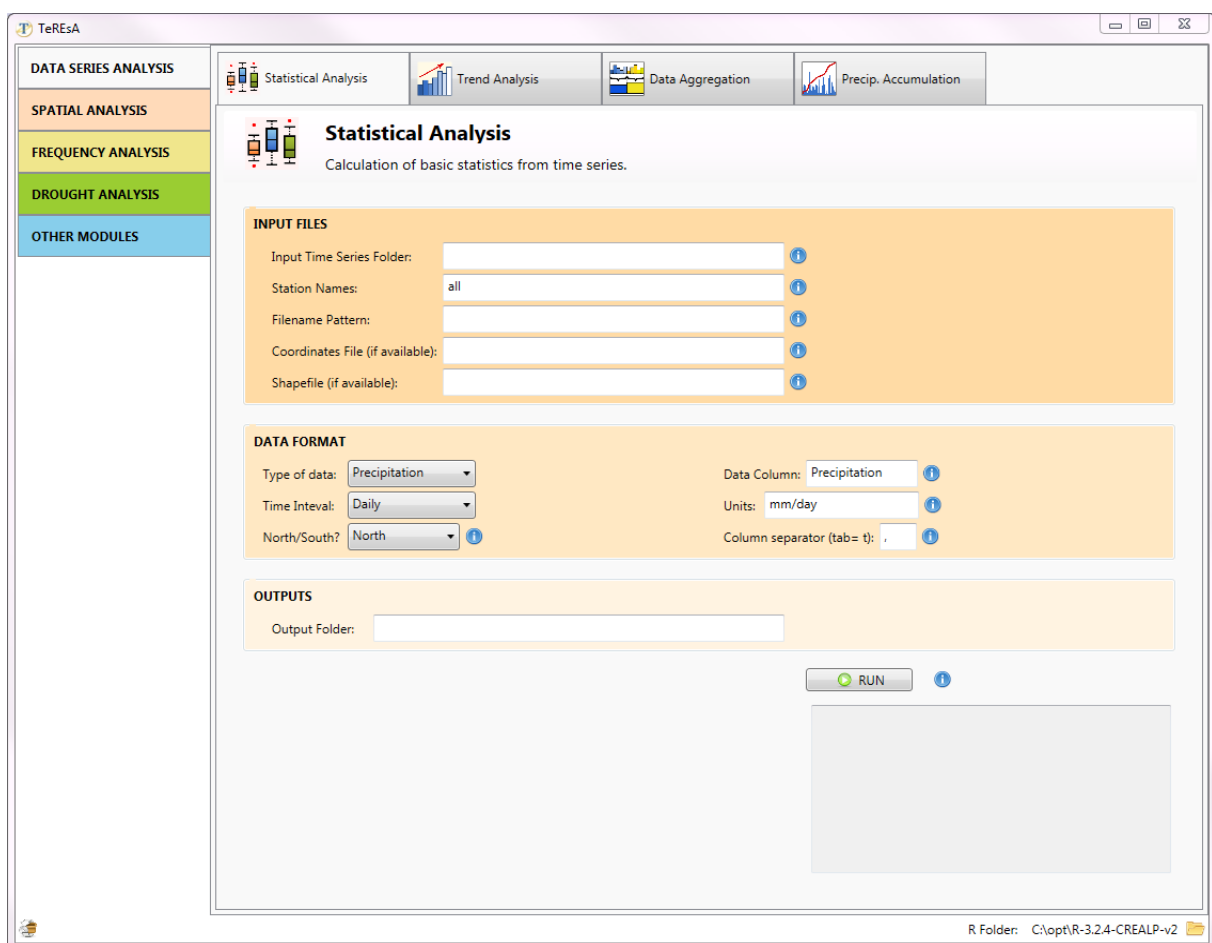

Figure 1. Interface of the TeREsA software

1.1 Document structure

The manual is composed of eight main chapters:

1. Introduction
2. Data files format
3. Data Series Analysis
4. Spatial Analysis
5. Frequency Analysis
6. Drought Analysis
7. Other modules

In each chapter, actions and arguments are presented in blue.

1.2 Installation procedure

Two phases are necessary to complete de installation of TeREsA: **i)** the software TeREsA has to be installed, and **ii)** the R libraries have to be saved in local on your hardware and pointed out by TeREsA.

- Visit the CREALP website : http://www.crealp.ch/fr/accueil/ressources/logiciels-general/teresa.html

- Go to *Resources* -> *Software* -> *TeREsA*

- Download the *TeREsA-install.exe* (link) file and the *RLibrary-TeREsA1.0.zip* (this ZIP file contains all the libraries needed to run the different modules).

Installation of the software

- Execute the file "*TeREsA-install.exe*". The window pop-up (Figure 2) appears.

Figure 2. *Welcome page for the installation of TeREsA 1.0*

- Follow the installation procedure.

Installation of the libraries

In order to use the different tools provided by TeREsA, predefined open-source R libraries are required.

The R Libraries are contained in the ZIP file "**RLibrary-TeREsA1.0.zip"** downloadable from the same page as the TeREsA executable file.

- Put the **RLibrary-TeREsA1.0.zip** file at a defined location on your computer (it is recommended to place it in the same directory as the *TeREsA1.0* executable file).

- Unzip it at (the file contains a folder with the same name: **RLibrary-TeREsA1.0**) and remind its location.

- The ZIP file can be deleted since it is no longer needed.

First use of TeREsA

When *TeREsa* is used for the first time, it is necessary to specify the link that leads to the R libraries (**Figure 3**):

- If the R Libraries are already installed on your computer, click on 'Yes'.

- Select the **RLibrary-TeREsA1.0** folder previously unzipped and confirm

- Validate by clicking 'OK'

- If the action was successful, the following icon ⚠ disappears and the complete path is displayed at the bottom of the window (**Figure 4**).

- The path of the libraries can be modified at any time by clicking on the 📂 icon (bottom of the window)
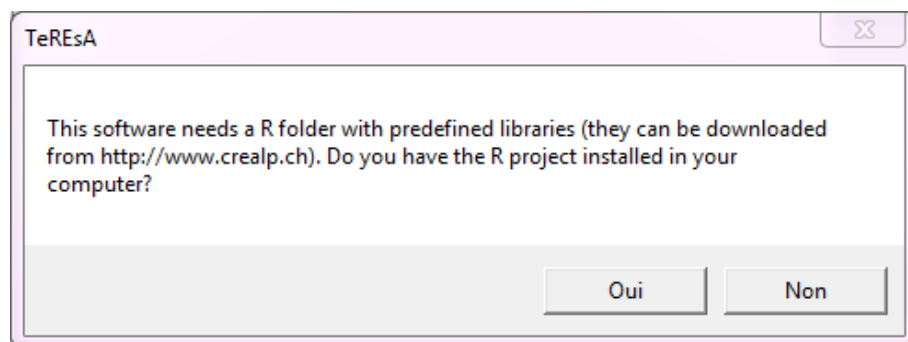

Figure 3. Check whether the R Libraries are already saved on your computer
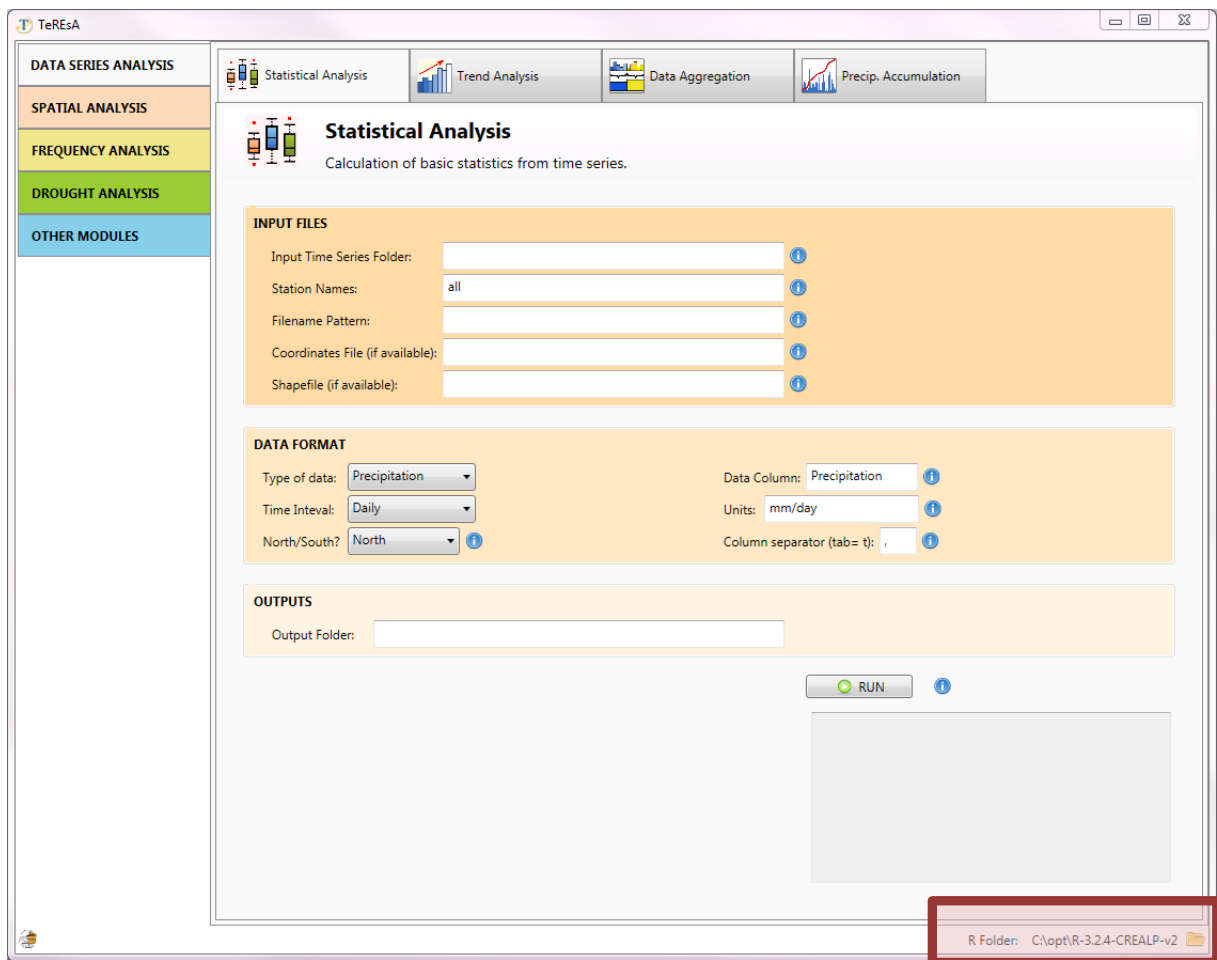
Figure 4. Check if the R Libraries folder is correct
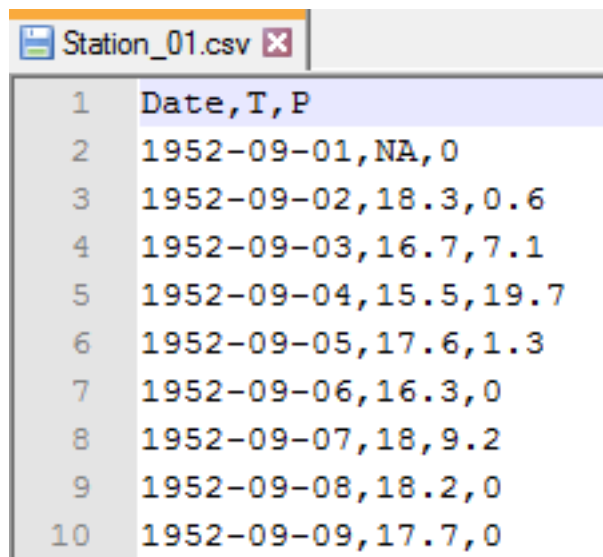
Uninstallation procedure

To uninstall TeREsA, follow the conventional procedure in Windows.

Chapter 2. Data files format

In order to execute the modules **Statistical Analysis**, **Trend Analysis**, **Precipitation Accumulation**, **Annual Maximum Frequency** and **Drought Analysis**, the files containing the data to be analyzed have to be homogenized according to a specific format, as follows:

- Each file must contain the data of **only one station** and **at least one variable** (discharge, precipitation, etc.).

- Data must be stored in a ***.csv** or ***.dat** file. If your data is stored in an Excel file, just open it and save it as *.csv* (Coma Separated Values). **IMPORTANT!** For these modules, *TeREsA* will read all the ***.csv** and ***.dat** files located in the same folder; it is important not to have any file with these extensions other than data files stored in the specified folder.

- It is **useful** that the names of each data file contains the name of the station, and maybe a pattern character indicating which type of data we can find in the file. For example, you can name the file **XXXX_Q.csv** when the variable is the discharge (in this case the pattern will be _Q), **XXXX_P.csv** when the variable is the precipitation (in this case the pattern will be _P) or **XXXX_T.csv** when the variable is the temperature (in this case the pattern will be _T), **XXXX** being the name of the station.

- **Avoid using special characters (accents, symbols,…)** in the file paths; the software won't be able to read it.

- Store the files containing the data to be analyzed in **one unique folder** (or at least one folder per type of data and per type of time interval).

- Each file must include, at least:

  - The first column MUST correspond with the date of the observations. The name of this column MUST be "Date". The format of this column MUST be:

    o **YYYY-mm-dd** if the time interval is yearly, monthly or daily (for instance 21-06-2015). For yearly data, just write *YYYY-01-01*, and for monthly data *YYYY-mm-01*.

    o **YYYY-mm-dd HH:MM** if the time interval is hourly (for instance 21-06-2015 23:24).

  - One column with the observed data.

  - The header line must include the names of all the columns separated by commas (,), semicolons (;), spaces or tabs.

  - **IMPORTANT**: none of the column names can contain quotation marks ".

- See example in **Figure 5**. The file is named **Station_01.csv**:

  - The date information is contained in the first column named "Date".

  - It contains the daily average **Temperature** (column T) and the daily **Precipitation** data of the **Station_01** (column P).

- The separator between columns is a comma.

```
Station_01.csv ☒
 1    Date,T,P
 2    1952-09-01,NA,0
 3    1952-09-02,18.3,0.6
 4    1952-09-03,16.7,7.1
 5    1952-09-04,15.5,19.7
 6    1952-09-05,17.6,1.3
 7    1952-09-06,16.3,0
 8    1952-09-07,18,9.2
 9    1952-09-08,18.2,0
10    1952-09-09,17.7,0
```

Figure 5. Example of data file format.

Chapter 3. Data Series Analysis

3.1 Statistical Analysis

This module (**Figure 6**) performs the annual and seasonal calculation of basic statistics tests to the time series contained in a single folder (minimum value, quantiles 25-50-75, maximum value, mean, mode, standard deviation, coefficient of skewness, coefficient of Kurtosis, and data length) and save this results in a CSV file. The statistical analysis module also generates a report containing all results. If spatial information is available (coordinates of the stations and shapefile delimiting the study area), the results are plotted on a map.

Figure 6. Interface of the 'Statistical Analysis' module

Arguments

- Input Time Series Folder: Path of the folder in which data are saved (only files with *.csv* or *.dat* extensions are accepted). Please refer to **Chapter 2. Data files format**.

- Stations Names: List of objects (e.g. stations) to process (names separated by commas). By default (*Stations Names=all*) calculation is performed for all objects contained within the input folder.

- Filename Pattern (optional): Recurrent chain of characters occurring in data filenames.

- Coordinates File (optional): path of the file containing the coordinates of the stations (only files with *.csv* or *.dat* extension will be read). This file must contain a table with the names and coordinates of each station by columns. Each row represents a station: **first** column is the name of the stations (same names as in data!!); **second** column is the **X** coordinate, and **third** column is the **Y** coordinate. If this argument is left empty, the results won't be plotted on the map. See example in Figure 7.

	A	B	C
1	Name	X	Y
2	Station_01	593085	109012
3	Station_02	625308	103113
4	Station_03	589917	92190
5	Station_04	578885	128236
6	Station_05	615477	121791

Figure 7. Example of a Coordinates file

- Shapefile (optional): Path of the shapefile in which spatial information of the studied area is saved (only files with *.shp*, *.shx* or *.dbf* extensions are accepted). If this argument is left empty, the results won't be plotted on the map.

- Type of data: Type of data to analyze: *Discharge*, *Precipitation*, *Temperature* or *Other*.

- Time Interval: Time interval at which data are compiled: *Yearly*, *Monthly*, *Daily* or *Hourly*.

- North/South? : Hemisphere in which the study area is.

- Data Column: Name of the data column which is presented within the input data files.

- Units: Units in which the data are expressed (*m3/s*, *l/s*, *mm/h*, *mm/day* …). Only used for display purposes.

- Column separator: Separator between columns used in data files (only "," or ";" or "t" for tab are accepted).

- Output Folder: Path of the folder in which results are saved.

Results

Once all required arguments are introduced, click on **RUN** to execute calculation. The ⬚ RUN button becomes inactive ⬚ RUN as long as process is ongoing.

Once the calculation process has successively completed, a log file is created within the output folder. This file provides details about the process and may help to identify possible errors.

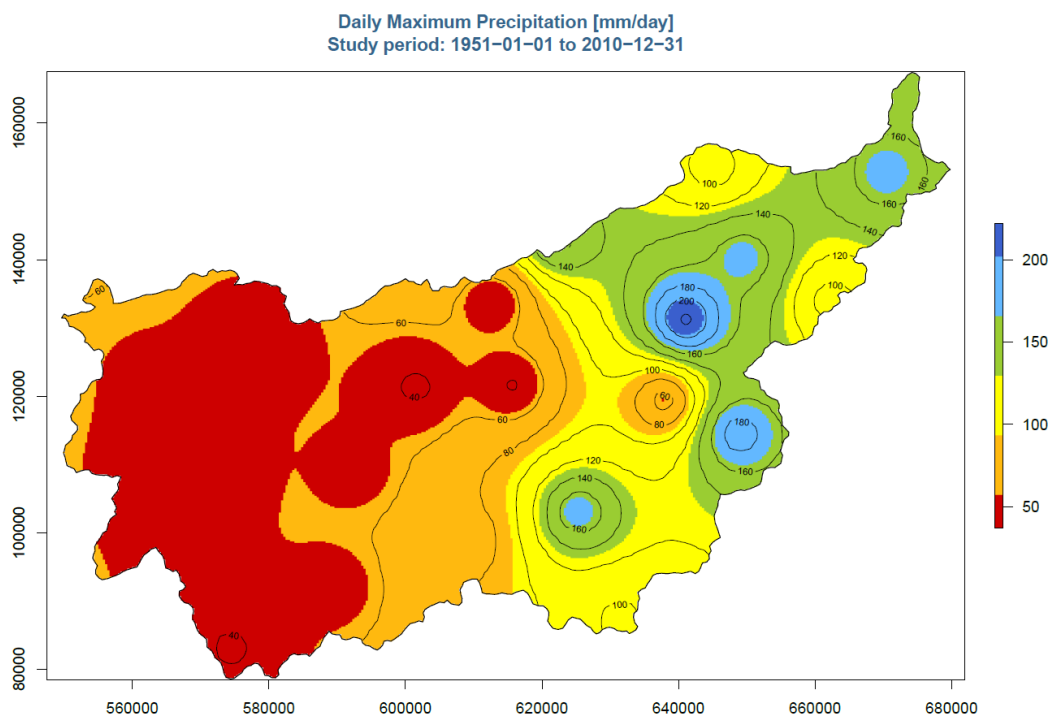**Figure 8** shows an example of results: Daily maximum rainfall intensity distribution within a basin registered over a 50-years period.

Daily Maximum Precipitation [mm/day]
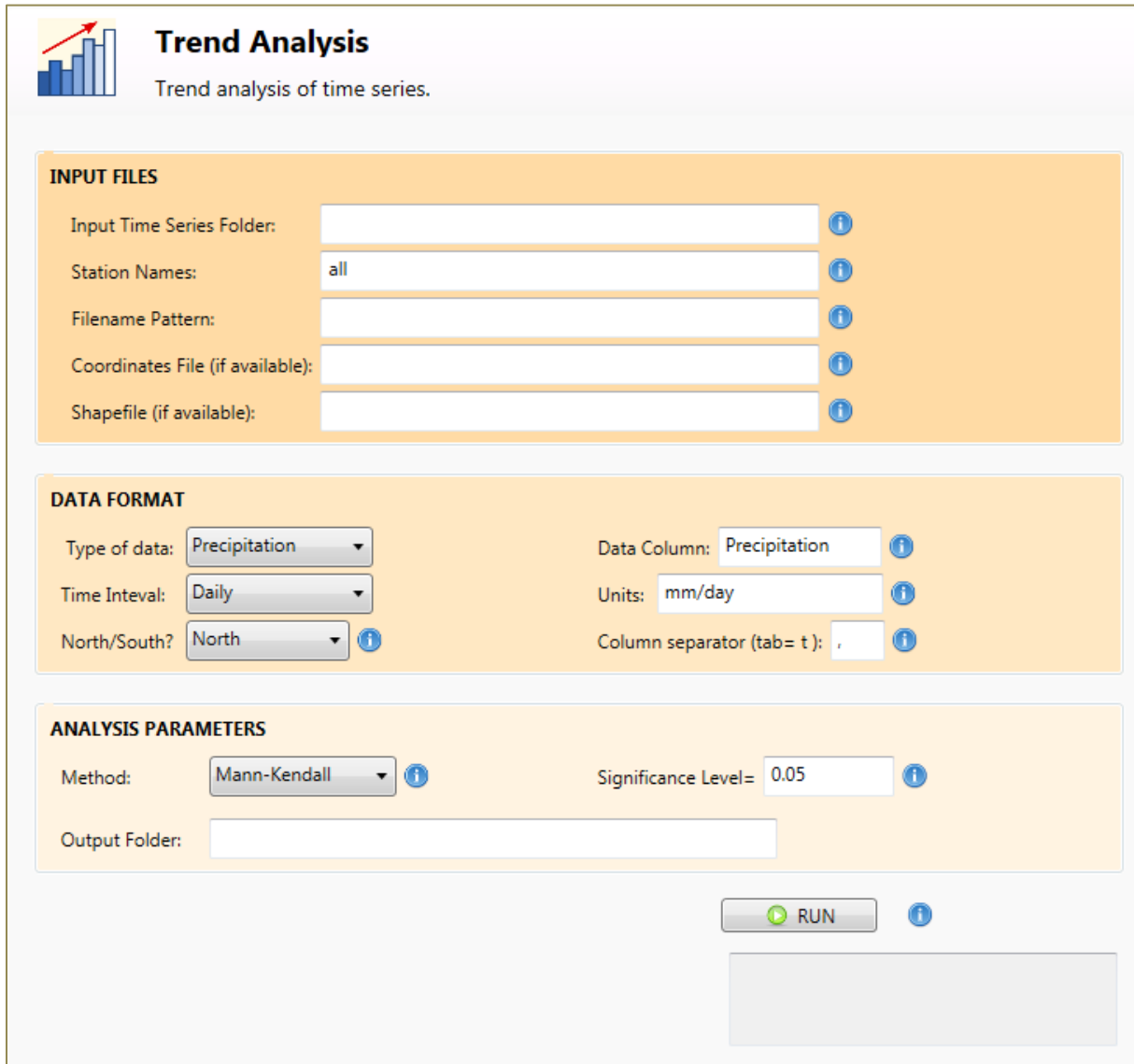**Study period: 1951−01−01 to 2010−12−31**

Figure 8. Example of results obtained with the 'Statistical Analysis' module

3.2   Trend Analysis

This module (**Figure 9**) performs different annual and seasonal trend tests to the time series contained in a single folder: Mann-Kendall test, Spearman's test, Pettitt test, Cox-Stuart test, Sen's nonparametric estimator of slope or Linear Regression. The Trend Analysis module creates 5 CSV files (1 for the annual test and 4 for each seasonal test), each one containing a table with the test results. When Mann-Kendall, Spearman's or Cox-Stuart test are chosen, and if spatial information is available (coordinates of the stations and shapefile delimiting the study area), the trend results are plotted on a map.

Figure 9. Interface of the 'Trend Analysis' module

Arguments

- Input Time Series Folder: Path of the folder in which data are saved (only files with *.csv* or *.dat* extensions are accepted). Please refer to **Chapter 2. Data files format**.

- Stations Names: List of objects (e.g. stations) to process (names separated by commas). By default (*Stations Names=all*) calculation is performed for all objects contained within the input folder.

- Filename Pattern (optional): Recurrent chain of characters occurring in data filenames.

- Coordinates File (optional): path of the file containing the coordinates of the stations (only files with *.csv* or *.dat* extension will be read). This file must contain a table with the names and coordinates of each station by columns. Each row represents a station: **first** column is the name of the stations (same names as in data!!); **second**

column is the **X** coordinate, and **<u>third</u>** column is the **Y** coordinate. If this argument is left empty, the results won't be plotted on the map. See example file in Figure 7.

- Shapefile (optional): Path of the shapefile in which spatial information of the studied area is saved (only files with *.shp*, *.shx* or *.dbf* extensions are accepted). If this argument is left empty, the results won't be plotted on the map.

- Type of data: Type of data to analyze: *Discharge*, *Precipitation*, *Temperature* or *Other*.

- Time Interval: Time interval at which data are compiled: *Yearly*, *Monthly*, *Daily* or *Hourly*.

- North/South? : Hemisphere in which the study area is.

- Data Column: Name of the data column which is presented within the input data files.

- Units: Units in which the data are expressed (*m3/s*, *l/s*, *mm/h*, *mm/day* …). Only used for display purposes.

- Column separator: Separator between columns used in data files (only "," or ";" or "*t*" for tab are accepted).

- Method: Method to be applied: *Mann-Kendall* test, *Spearman's* test, *Cox-Stuart* test, *Pettitt* test or *Regression*.

- Significance Level (α) for the test: Probability of rejecting the null hypothesis given that is true. Not used if the chosen method is Regression. See the TeREsA-Technical Manual (Fluixá-Sanmartín et al., 2016) for more information.

- Output Folder: Path of the folder in which results are saved.

Results

Once all required arguments are introduced, click on **RUN** to execute calculation. The ⬢ RUN button becomes inactive ⬢ RUN as long as process is ongoing.

Once the calculation process has successively completed, a log file is created within the output folder. This file provides details about the process and may help to identify possible errors.

Figure 10 shows an example of a trend analysis results. Blue triangles represent meteorological stations with increasing rainfalls and red triangles the ones with decreasing rainfalls.
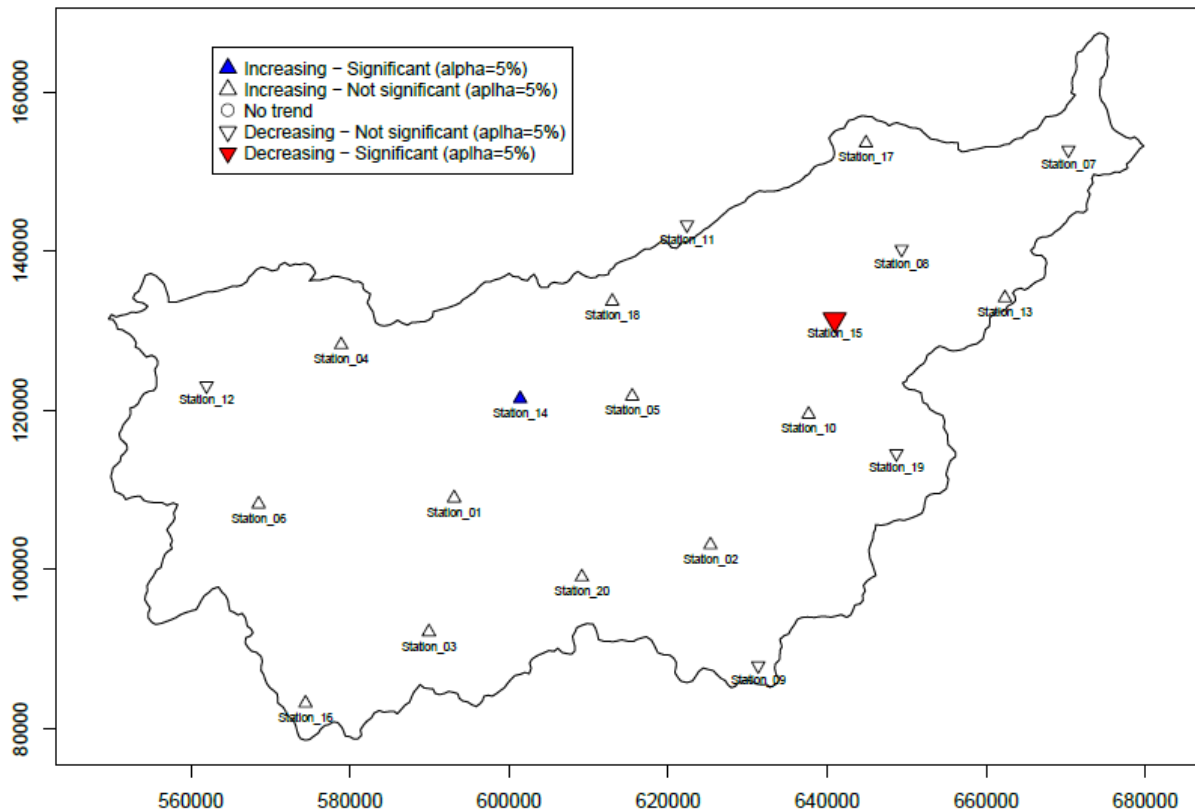
Figure 10. *Example of results obtained with the 'Trend Analysis' module*

3.3 Data Aggregation

This module (**Figure 11**) aggregates one data series for a defined aggregation length. The data does not have to be necessarily expressed in time units.

Figure 11. *Interface of the 'Data Aggregation' module*

Arguments

- Input Time Series File: Path of the CSV file to aggregate.

- Column separator: Separator between columns used in the data file (only "," or ";" or "t" for tab are accepted).

- Aggregation method: Method to apply (mean, max, min, median, standard deviation).

- Number of data to aggregate: The sequential number of data used into the calculation.

- Output Dataset: Path of the file where the module will save the results.

Results

Once all required arguments are introduced, click on **RUN** to execute calculation. The RUN button becomes inactive RUN as long as process is ongoing.

Once the calculation process has successively completed, a log file is created within the output folder. This file provides details about the process and may help to identify possible errors.

The module generates a CSV file where data are aggregate by the defined length. If non-numerical data is found, the result will be "NA".

3.4   Precipitation Accumulation

This module (**Figure 12**) performs the computation of the Cumulated Precipitations over a time period tests to the time series contained in a single folder. The Precipitation Accumulation module creates a CSV file containing accumulated precipitation for all stations, and a PDF file with the resulting accumulation graphs.

Figure 12. Interface of the 'Precipitation Accumulation' module

Arguments

- Input Data Folder: Path of the folder in which data are saved (only files with *.csv* or *.dat* extensions are accepted). Please refer to **Chapter 2. Data files format**.

- Stations Names: List of objects (e.g. stations) to process (names separated by commas). By default (Stations Names=all) calculation is performed for all objects contained within the input folder.

- Filename Pattern (optional): Recurrent chain of characters occurring in data filenames.

- Time Interval: Time interval at which data are compiled: Yearly, Monthly, Daily or Hourly.

- Data Column: Name of the data column which is presented within the input data files.

- Units: Units in which the data are expressed (mm/h, mm/day …). Only used for display purposes.

- Column separator: Separator between columns used in data files (only "," or ";" or "t" for tab are accepted).

- Start date (optional): Starting date of the accumulation period defined by user, in the format YYYY-mm-dd HH:MM (e.g. 2015-06-21 23:24). If left empty, the period starts with the first available data.

- End date (optional): Ending date of the accumulation defined by user, in the format YYYY-mm-dd HH:MM (e.g. 2015-06-21 23:24). If left empty, the period end with the last available data.

- Output Folder: Path of the folder in which results are saved. A result file will be created for each station.

Results

Once all required arguments are introduced, click on **RUN** to execute calculation. The ⬤ RUN button becomes inactive ⬤ RUN as long as process is ongoing.

Once the calculation process has successively completed, a log file is created within the output folder. This file provides details about the process and may help to identify possible errors.
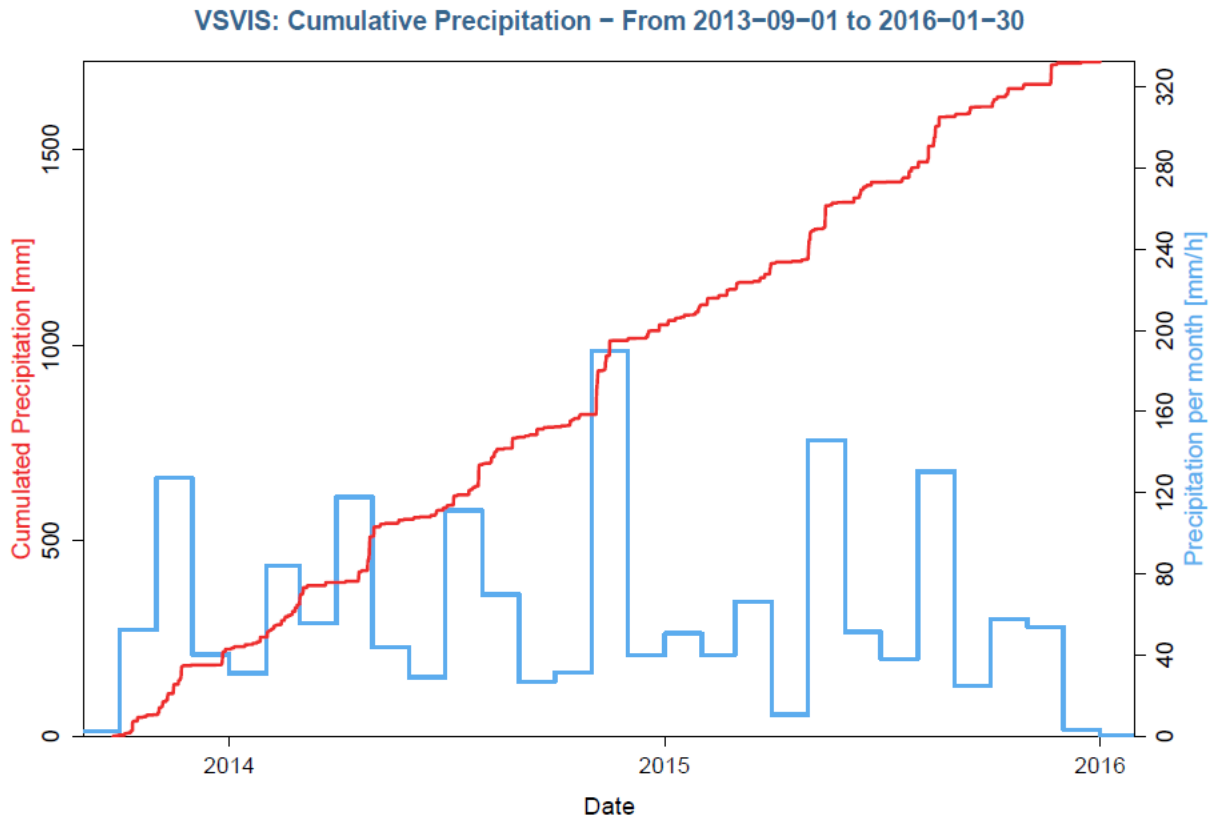
See an example of results in **Figure 13**.

Figure 13. *Example of results obtained with the 'Precipitation Accumulation' module for the station named VSVIS*

Chapter 4. Spatial Analysis

4.1 Polygon Analysis

This module (**Figure 14**) computes the gravity center and the surface area of catchments and subcatchments. The results of the analysis are saved in a shapefile as new attributes. Four attributes are added:

- **X,Y,Z**: the coordinates of gravity center of each polygon.

- **Surface**: the surface area of each polygon according to the projected coordinate reference system of the shapefile.

Figure 14. *Interface of the 'Polygon analysis' module*

Arguments

- Shapefile: Path to the polygon-type shapefile (ESRI). Coordinates must be in distance units (degree unit are not accepted).

- Digital elevation data (optional): Path to the elevation file of the study area, in the same CRS as the shapefile. If no elevation data is provided, the elevation is considered as null and the value "zero" is used as the default value.

- Output file: Path of the shapefile where the module will save the results.

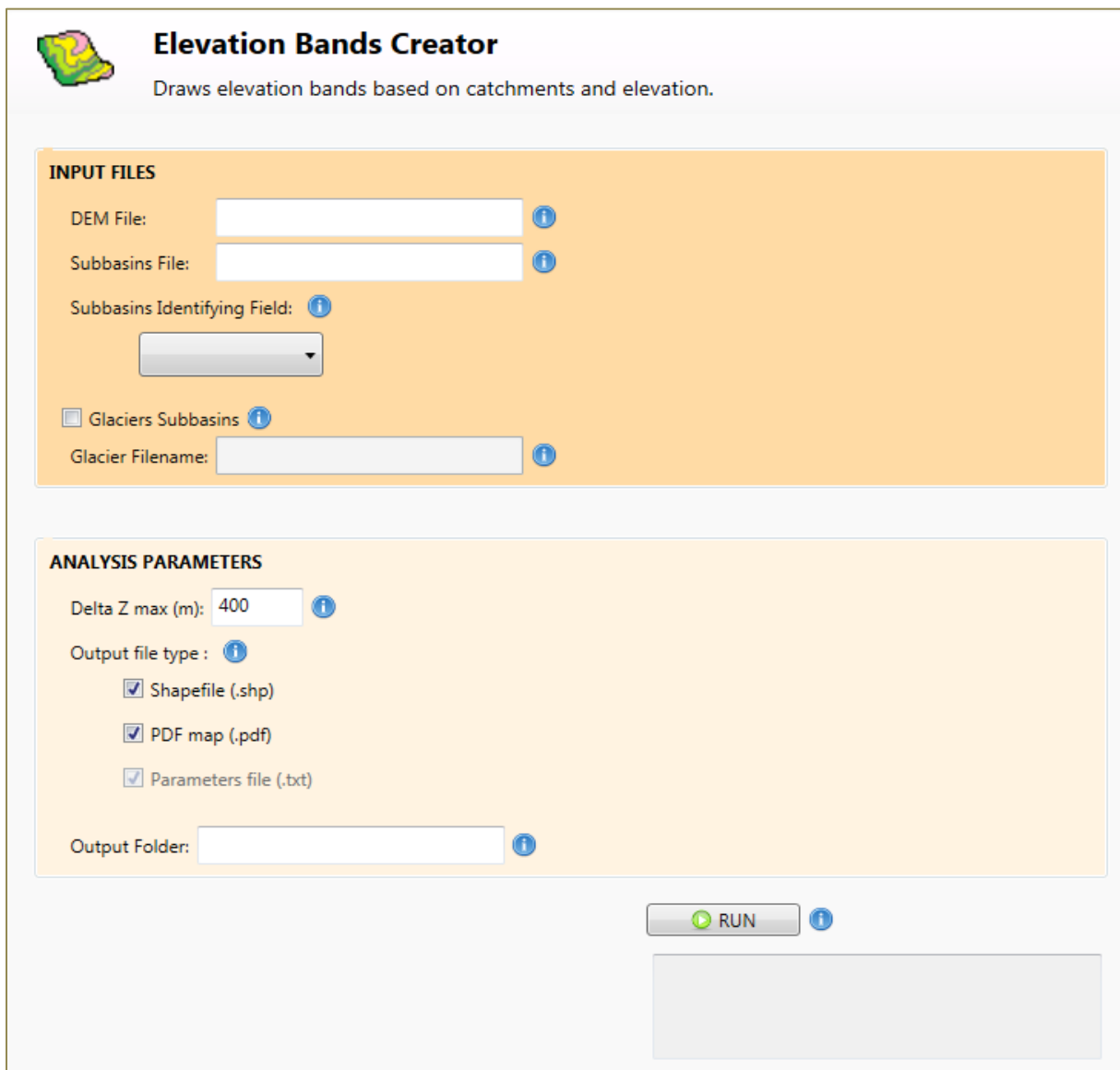**Results**

Once all required arguments are introduced, click on **RUN** to execute calculation. The ⊙ RUN button becomes inactive ⊙ RUN as long as process is ongoing.

Once the calculation process has successively completed, a log file is created within the output folder. This file provides details about the process and may help to identify possible errors.

4.2   Elevation Bands Creator

This module (**Figure 15**) divides a basin polygon into elevation bands. The Elevation Bands Creator (EBC) produces a shapefile with elevation bands as well as a PDF file. It also produces a parameter file that can be used in hydrological modelling, for instance in RS MINERVE software (Foehn et al., 2016; García Hernández et al., 2016).

Figure 15. The interface of the 'Elevation Bands Creator' module

Arguments

- DEM File: Path of the Digital Elevation Model of the basin in a projected Coordinate reference system (CRS). The grid must be regular. Different formats are accepted, such as image files (*.tif, *.bmp, *.gif*), coordinate files (*.csv*,*.txt*,*.asc*) or data files.

- Subbasins File: Path of the basin shapefile (*.shp*) in a projected Coordinate reference system (CRS), optionally divided into subbasins as polygons. Each polygon must contain a unique ID field. Polygon can be a multipart feature (e.g. divided into more than one entity with the same ID). The DEM surface has to entirely cover the analyzed shapefile surface.

- Subbasins Identifying Field: Attribute of each subbasin indicating their names.

- Glacier Subbasins: To be checked if a glacial subbasin exists.

- Glacier Filename: Path of the glacier basin shapefile (*.shp*) in a projected Coordinate reference system (CRS). Each polygon defined in this shapefile will be considered as an independent subbasin.

- Delta Z max (m): Maximum interval of the elevation bands to be created.

- Output Folder: Path of the folder in which results are saved.

If the shapefile is of particularly big size, the module can run out of memory (depending on the memory capacity of the computer).

Results

Once all required arguments are introduced, click on **RUN** to execute calculation. The ⟨RUN⟩ button becomes inactive ⟨RUN⟩ as long as process is ongoing.

Once the calculation process has successively completed, a log file is created within the output folder. This file provides details about the process and may help to identify possible errors.

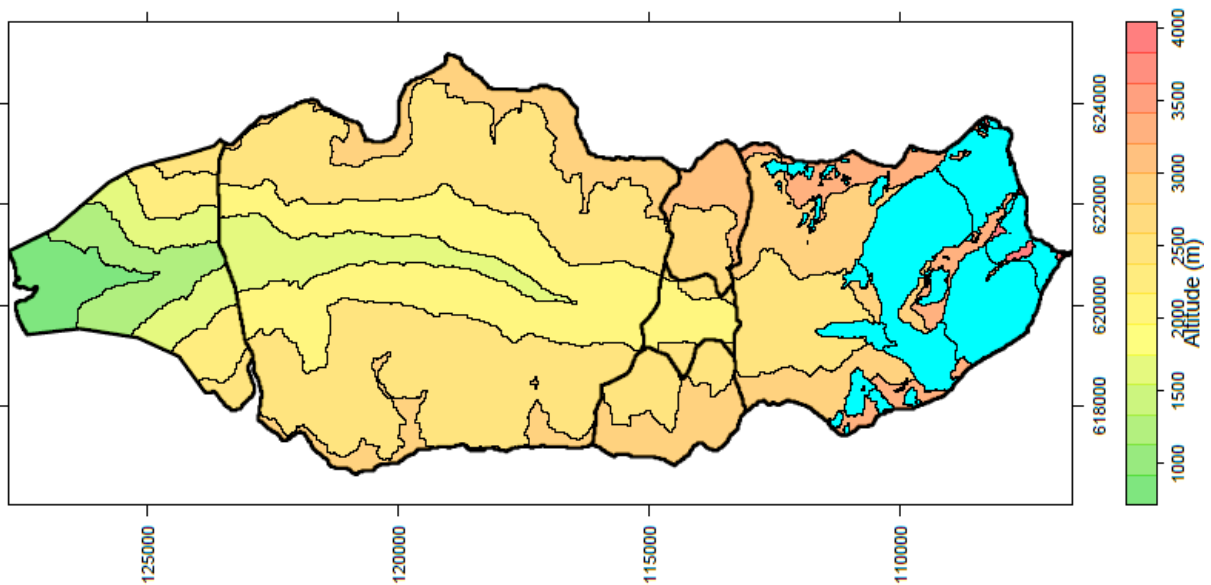**Figure 16** shows an example of an EBC result. Blue area represents the glacier part of the basin.

Figure 16. Example of results obtained with the 'Elevation Bands Creator' module

4.3   Data Spatialization

This module (**Figure 17**) generates a dataset of interpolated stations that correspond to the topography of the user's hydrological model. The "Spatialization" process consists of two phases: interpolation and aggregation. Firstly, the time series of precipitation, temperature, and/or evapotranspiration are estimated through the interpolation at each location of a grid of interpolation points. The interpolation points are automatically positioned within the studied area defined by the shapefile. In a second phase, the time series can be aggregated by polygon: based on the interpolation points contained in each polygon, average time series are calculated for each polygon. Each average time series are attributed to a point located at the gravity center of their respective polygons. The module generates an RS dataset that can be directly opened in the RS MINERVE software.

Figure 17. Interface of the 'Data Spatialization' module

Arguments

- Shapefile of catchment polygons: Path of the ESRI polygon-type shapefile that defines the extent of the interpolation grid as well as the boundaries of each polygon (if the results are aggregated).

- Dataset of measured time series: RS Dataset resulting from RS MINERVE (Foehn et al., 2016; García Hernández et al., 2016), containing time series of precipitation, temperature, and/or evapotranspiration (ETP).

- Digital elevation data: Georeferenced digital elevation information in raster or point format. The resolution of the elevation data must be denser than the one of the interpolation grid.

- Start/End date: The time range of series can be reduced by setting a minimum and maximum date. If the range is not modified, the time series remains unchanged.

- Interpolation grid cell size: A regular grid of interpolation points is automatically generated within the extent defined by the shapefile. The grid cell size is the minimum distance between interpolation points. It is recommended to use a value that corresponds to the variations of the terrain. The interpolation computation time is proportional to the square of the inverse of the grid cell size.

- Interpolation method: For each sensor (precipitation, temperature, or ETP), a different interpolation method can be used. The available methods are:

  o Thiessen (nearest neighbour)
  o Inverse distance weighting (exponents 1 or 2 available)

- Aggregation method: In order to reduce the size of the final dataset, the user can choose to export only one interpolation station by polygon of the shapefile. In this case, the interpolation points contained in each polygon are aggregated by averaging the data on each time step.

- Interpolation station name: If wished, a name from a shapefile attribute can be given to the aggregated stations.

- Output File: Path of the dataset where the module will create the results.

Results

The procedure followed by the module is represented in **Figure 18**. More information is available in the TeREsA-Technical Manual (Fluixá-Sanmartín et al., 2016).
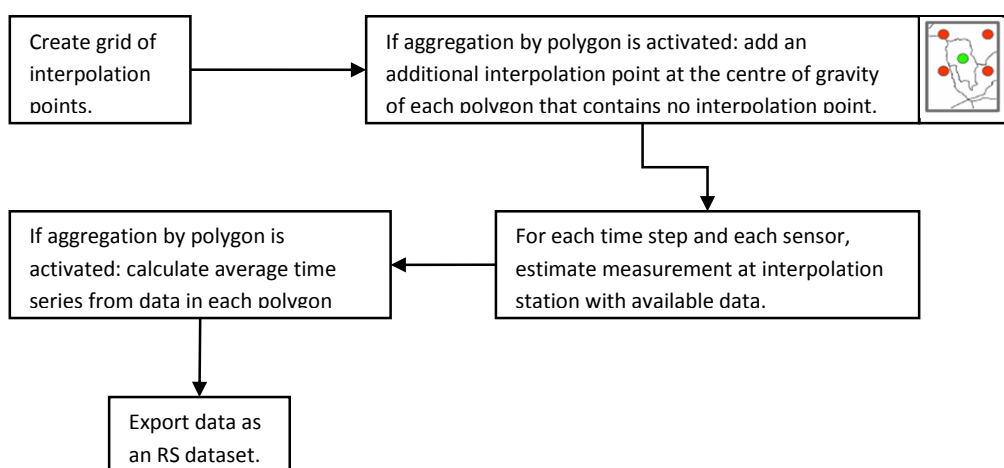

Figure 18. Data spatialization procedure

4.4 Hypso – histo

This module (**Figure 19**) generates a histogram of the basin elevation, and plots its hypsometric curve (empiric cumulative distribution of elevations) indicating the mean elevation of the catchment.

Figure 19. *Interface of the 'Hypso-Histo' module*

Arguments

- DEM file: DEM file of the basin. Missing values of the DEM cells are removed before the calculations. Only the following formats are accepted: CSV file (**.csv*), ADF (**.adf*), ASCII (**.asc*), Bitmap (**.bmp*), DAT (**.dat*), Graphic Interchange Format (**gif*), GRID (**.grd*), Image (**.img*), Portable Network Graphics (**.png*), TIFF (**.tif*) and XYZ (**.xyz*).

- Basin name: Name of the basin (for display purposes only).

- Cell size in X: Interval distance of the DEM cells in the X direction (in meters). Used for defining the cell area.

- Cell size in Y: Interval distance of the DEM cells in the Y direction (in meters). Used for defining the cell area.

- Remove null values: If checked, cells with value = 0 are removed. By default, all NA and negative values are automatically removed.

- Column separator: Separator between columns when the DEM file is in CSV or XYZ format (only "," or ";" or "t" for tab are accepted).

- Elevation Column Name: Name of the column containing the elevation data when the DEM file is in CSV or XYZ format.

- Output Folder: Path of the folder where the results will be saved.

Results

Once all required arguments are introduced, click on **RUN** to execute calculation. The [RUN] button becomes inactive [RUN] as long as process is ongoing.

Once the calculation process has successively completed, a log file is created within the output folder. This file provides details about the process and may help to identify possible errors.

Figure 20 shows an example of results of the Hypso-histo module. Red line indicates the median elevation of the basin (half of the basin area is below this median, and half is above it). A CSV table is also generated with the hypsometric curve of the basin.
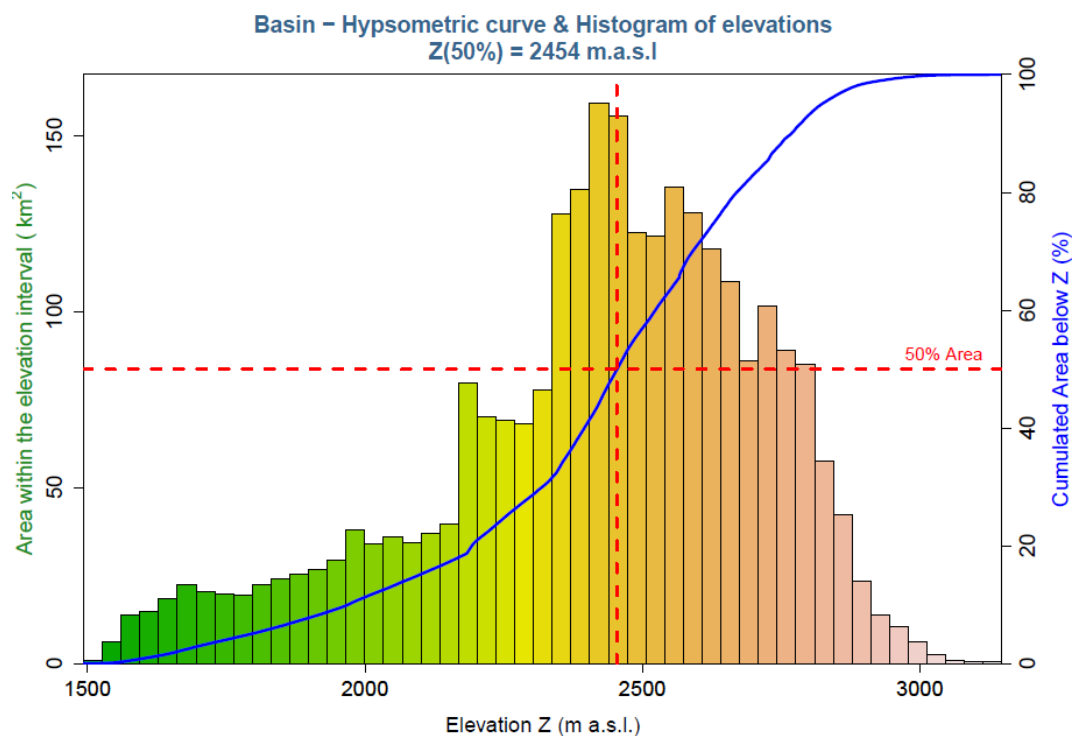

***Figure 20**. Example of results obtained with the 'Hypso-histo' module*

Chapter 5. Frequency Analysis

5.1 Annual Maximum Frequency

This module (**Figure 21**) performs a complete annual maximum frequency analysis to to the time series contained in a single folder. It fits the data to selected EVDs (Extreme Values Distribution). A PDF file is created containing the maximum registered observations and their dates, a table with the parameters for each EVD (and their goodness-of-fit), the *Qp-T* relation and a graphical comparison between them.

Figure 21. *The interface of the 'Annual Maximum Frequency' module*

Arguments

- Input Time Series Folder: Path of the folder in which data are saved (only files with *.csv* or *.dat* extensions are accepted). Please refer to **Chapter 2. Data files format**.

- Stations Names: List of objects (e.g. stations) to process (names separated by commas). By default (*Stations Names=all*) calculation is performed for all objects contained within the input folder.

- Filename Pattern (optional): Recurrent chain of characters occurring in data filenames.

- Type of data: Type of data to analyze: *Discharge*, *Precipitation*, *Temperature* or *Other*.

- Time Interval: Time interval at which data are compiled: *Yearly*, *Monthly*, *Daily* or *Hourly*.

- Units: Units in which the data are expressed (*m3/s*, *l/s*, *mm/h*, *mm/day* …). Only used for display purposes.

- Data Column: Name of the data column which is presented within the input data files.

- Data abbreviation: Abbreviation of the Type of data (e.g. if the type of data to analyze is of "*Precipitation*" type, a proper abbreviation would be *P*).

- Column separator: Separator between columns used in data files (only "*,*" or "*;*" or "*t*" for tab are accepted).

- Distributions: Distributions to which the data must be fitted. Available distributions are: *Normal*, *LogNormal*, *GEV*, *Gumbel*, *Exponential*, *PearsonIII* and *LogPearsonIII*.

- Return period (years): Return periods for which the corresponding quantiles are calculated. User can add more return periods, separated by "-", besides the proposed ones (10 values at the most).

- Output Folder: Path of the folder in which results are saved.

Results

Once all required arguments are introduced, click on **RUN** to execute calculation. The [RUN] button becomes inactive [RUN] as long as process is ongoing.

Once the calculation process has successively completed, a log file is created within the output folder. This file provides details about the process and may help to identify possible errors.

Figure 10 shows an example of results: the maximum monthly precipitations with the annual maximums in red; the fitting of the different EDVs to the empirical data; the distribution functions; the extreme events registered; the EDV's parameters; and the table with the relation T (return periods) vs P (precipitation quantiles).
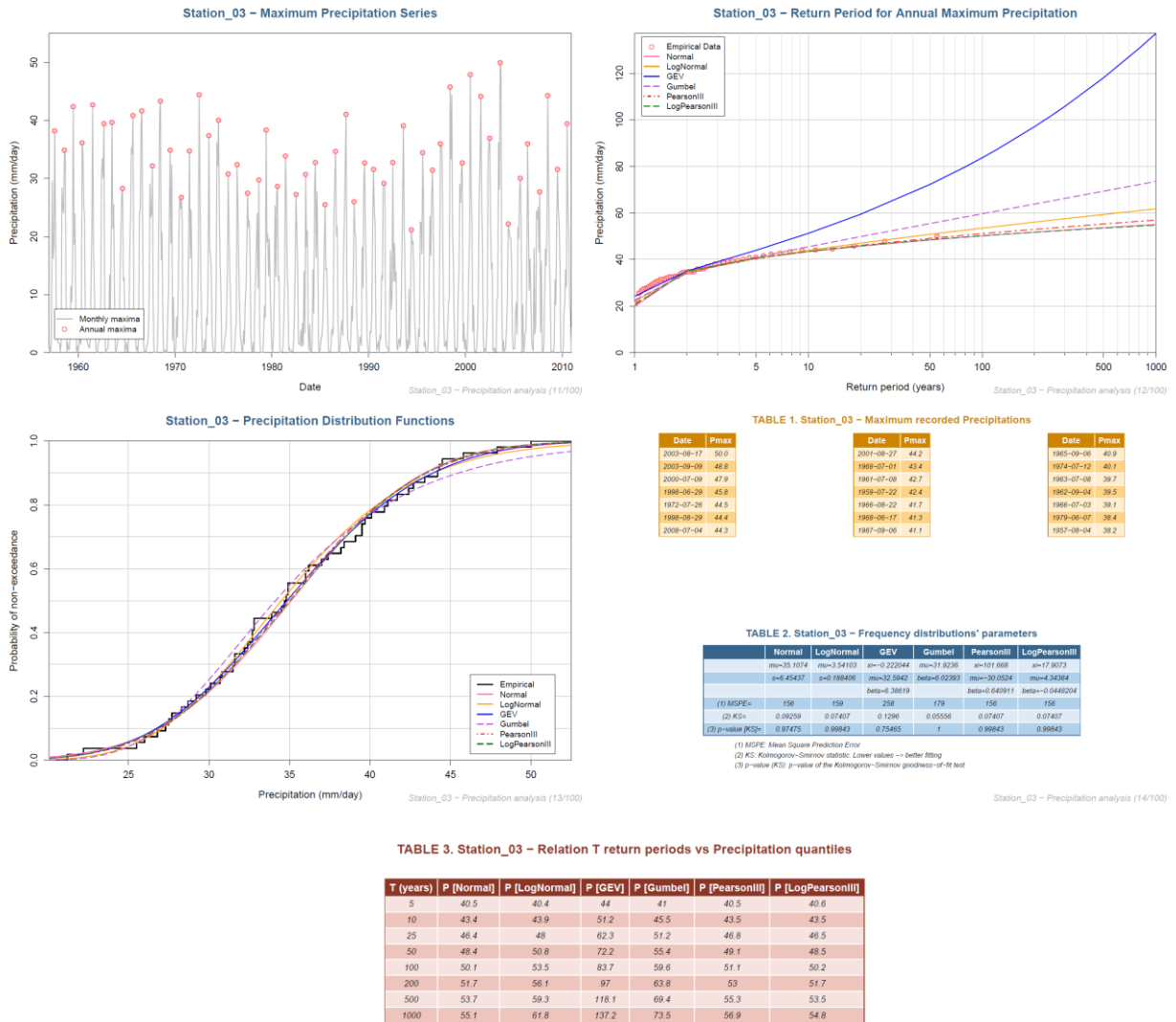
Figure 22. *Example of results obtained with the 'Annual Maximum Frequency' module*

5.2 IDF computing

This module (**Figure 23**) computes the Intensity-Duration-Frequency (IDF) precipitations curves from precipitation time series for one or several stations using the Gumbel reduced model to fit the data. A unique PDF file is created with the IDF curves, as well as a CSV file with the results for each station.

Figure 23. Interface of the 'IDF computing' module

Arguments

- Input Time Series Folder**:** folder where the data files are (as *.csv* format) meeting the criteria (see example in **Figure 24**):
  - CSV file name in form: <station_name>_P.csv.
  - Each CSV file must contain 2 columns: 1st column of dates in hourly timestep with format *YYYY-mm-dd HH:MM* (e.g. 2015-06-21 06:00); 2nd column of precipitation data in mm/h.
  - The Time series has to contain at least the same number of timesteps for each year than the maximum durations (e.g. a maximum duration of 72h implies at least 72 timesteps per year).

```
DATE,P
1993-10-01 22:00,0.3
1993-10-01 23:00,0.1
1993-10-02 00:00,0.8
1993-10-02 01:00,0.2
1993-10-02 02:00,0.2
1993-10-02 03:00,0.1
1993-10-02 04:00,0.5
1993-10-02 05:00,0.2
```

Figure 24. *Example of CSV input data file, with a ',' separator*

- Column separator: separator between columns that are used in data files. Only "," or ";" or "*t*" (for the tabs) are accepted.

- Precip. Durations: duration (in hours) of the precipitation events considered in the calculation of the IDF curves.
- Return Periods: return periods (in years) of the precipitation events considered in the calculation of the IDF curves.

- Output Folder: the path of the folder where results will be saved.

Results

Once all required arguments are introduced, click on **RUN** to execute calculation. The ⊙ RUN button becomes inactive ⊙ RUN as long as process is ongoing.

Once the calculation process has successively completed, a log file is created within the output folder. This file provides details about the process and may help to identify possible errors.

Figure 25 shows an example of results of the IDF Computing module, where each curve represents the relation between the duration (in hours) and the intensity (in mm/h) of a rainfall, for different return periods (in years).
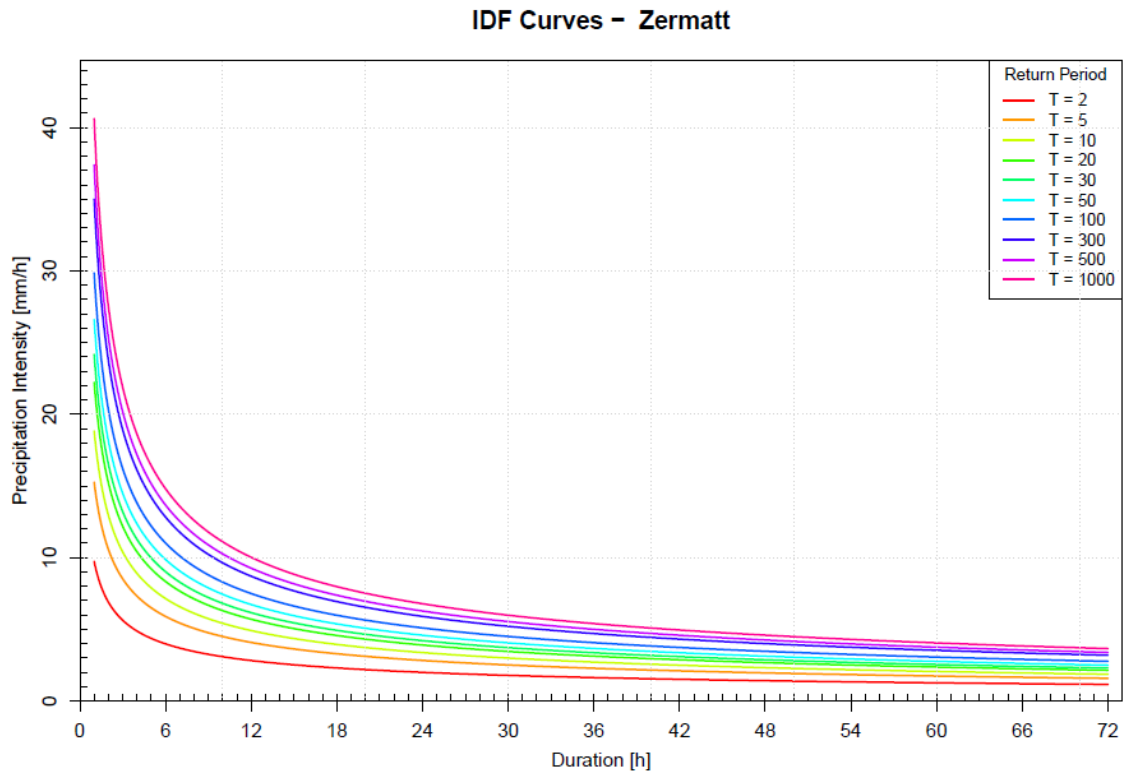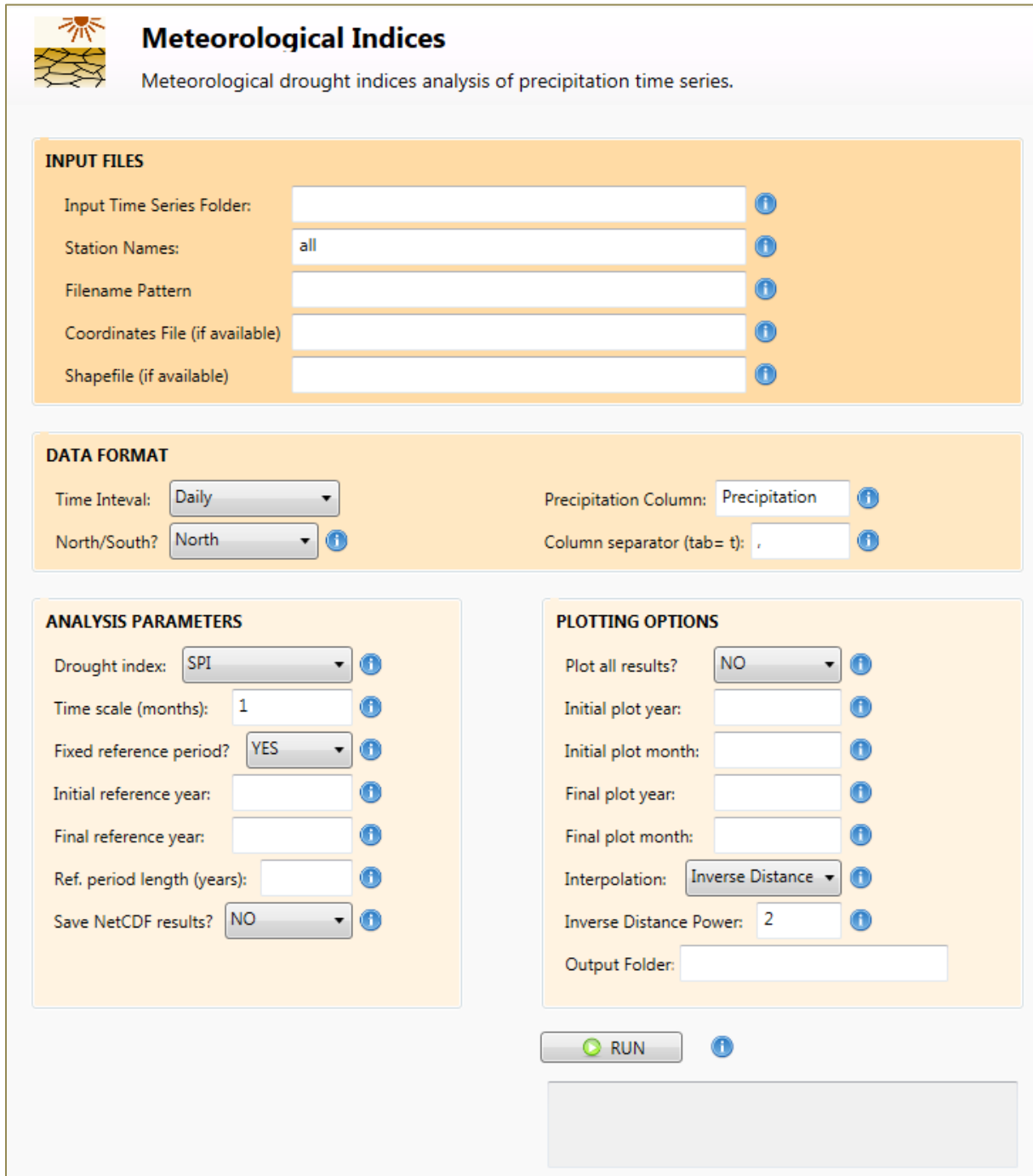
Figure 25. *Example of results obtained with the 'IDF computing' module*

Chapter 6. Drought Analysis

6.1   Meteorological Indices

This module (**Figure 26**) calculates a specified meteorological drought index based on precipitation time series contained in a single folder. The results are saved in several PDF reports. If spatial information is available (coordinates of the stations and shapefile delimiting the study area), it also plots the point and interpolated values of the index.

Figure 26*. Interface of the 'Meteorological Indices module*

Arguments

- Input Time Series Folder: Path of the folder in which data are saved (only files with *.csv* or *.dat* extensions are accepted). Please refer to **Chapter 2. Data files format**.

- Stations Names: List of objects (e.g. stations) to process (names separated by commas). By default (*Stations Names=all*) calculation is performed for all objects contained within the input folder.

- Filename Pattern: Recurrent chain of characters occurring in data filenames.

- Coordinates File (optional): path of the file containing the coordinates of the stations (only files with *.csv or *.dat extension will be read). This file must contain a table with the names and coordinates of each station by columns. Each row represents a station: **first** column is the name of the stations (same names as in data!!); **second** column is the **X** coordinate, and **third** column is the **Y** coordinate. If this argument is left empty, the results won't be plotted on the map. See example in Figure 7.

- Shapefile (optional): Path of the shapefile in which spatial information of the studied area is saved (only files with *.shp, *.shx or *.dbf extensions are accepted). If this argument is left empty, the results won't be plotted on the map.

- Time Interval: Time interval at which data are compiled: *Yearly*, *Monthly*, *Daily* or *Hourly*.

- North/South?: Hemisphere in which the study area is.

- Precipitation Column: Name of the precipitation column which is presented within the input data files.

- Column separator: Separator between columns used in data files (only "," or ";" or "t" for tab are accepted).

- Drought index: Index to be calculated: *SPI* (Standardized Precipitation Index), *PN* (Percentage of Normal), *RAI* (Rainfall Anomaly Index), or *Deciles*.

- Time scale (months): Number of months by which the data will be aggregated for the calculation of the index. It must be an integer. Common values are *1, 2, 3, 6, 12, 24, 36* or *48* months.

- Fixed reference period?: Whether the reference period for the calculation of the indices is defined by fixed start and end dates (*YES*), or it is defined as the previous X years (*NO*).

- Initial reference year: Initial year of the reference period (only if Fixed reference period? has been set to *YES*).

- Final reference year: Final year of the reference period (only if Fixed reference period? has been set to *YES*).

- Ref. period length (years): Period length in years, previous to the current date for which the index is calculated (only if Fixed reference period? has been set to *NO*).

- Save NetCDF results?: Whether 2 netCDF files containing the values of the index for the plotting period should be created (*YES*) or not (*NO*). If *YES*, this option may slow down the process and generate large netCDF files. Only used if Coordinates File and Shapefile are specified.

- Plot all results?: Whether the index should be plotted for the entire time series of available results (*YES*) or plotted dates are specified by the user (*NO*). Only used if Coordinates File and Shapefile are specified.

- Initial plot year: Initial year to plot the index. It must be among the time series dates. Only used if Coordinates File and Shapefile are specified.

- Initial plot month: Initial month to plot the index. It must be among the time series dates. Only used if Coordinates File and Shapefile are specified.

- Final plot year: Final year to plot the index. It must be among the time series dates. Only used if Coordinates File and Shapefile are specified.

- Final plot month: Final month to plot the index. It must be among the time series dates. Only used if Coordinates File and Shapefile are specified.

- Interpolation: Type of interpolation that must be carried out when plotting results. (*Inverse Distance Weighting* or *Ordinary Kriging*). Only used if Coordinates File and Shapefile are specified.

- Inverse Distance Power: Value of the inverse distance power for the calculation of interpolated values when Interpolation=*Inverse Distance Weighting*. Only used if Coordinates File and Shapefile are specified.

- Output Folder: Path of the folder in which results are saved.

Results

Once all required arguments are introduced, click on **RUN** to execute calculation. The [RUN] button becomes inactive [RUN] as long as process is ongoing.

Once the calculation process has successively completed, a log file is created within the output folder. This file provides details about the process and may help to identify possible errors.

Figure 10 shows an example of results: the interpolation of the SPI index calculated at different stations for the period April to September 2002.
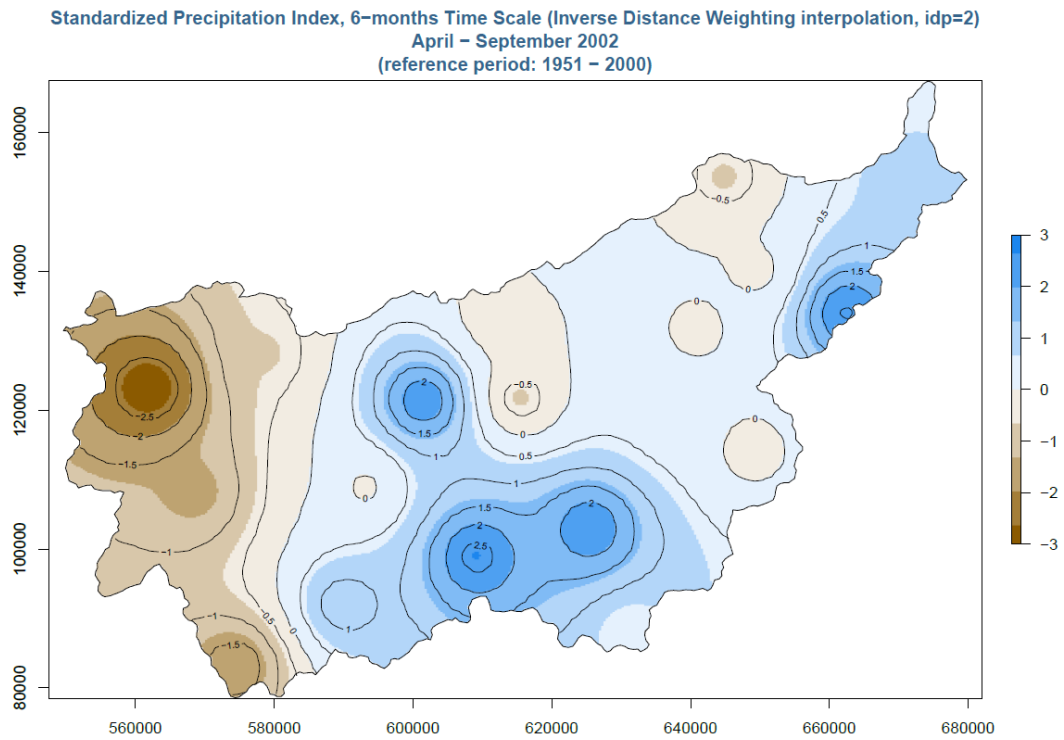
Figure 27. *Example of results obtained with the 'Meteorological Indices' module.*

Chapter 7. Other modules

7.1 Reservoir Routing

This module (**Figure 28**) performs the routing of the different inflow hydrographs entering a reservoir regulated by a dam. It plots and saves in a table the evolution of the inflows, the outflows, the eventual overtopping and the water level in the reservoir.

Figure 28. Interface of the 'Reservoir Routing' module

Arguments

- Name of the dam: Name given to the dam analyzed. Only used for display purposes.

- Height of the crest (H_{crest}): Altitude of the crest of the dam in m a.s.l. (**Figure 32**).

- Initial water level (H_{ini}): Water level in the reservoir at the beginning of the hydrograph in m a.s.l. (**Figure 32**).

- Length of the crest (L_{crest}): Length of the crest of the dam in m (**Figure 32**).

- Water level distribution curve (H-Vol): Path of the CSV file with 2 columns (separated by commas) representing the relation between the water level in m a.s.l. (first column) and the volume stored in the reservoir in m^3 (second column). See example in **Figure 29**.

```
Level,Volume
446,0
447,11600
448,23200
449,34800
450,46400
```

Figure 29. Example of Water level distribution curve

- Hydrographs (Q *vs* time): Path of the CSV file with 2 columns or more (separated by commas) representing the different incoming hydrographs considered in the routing (see example in **Figure 30**):
  - time, in hours (first column)
  - rate of flow, in m^3/s, of the different return periods' hydrographs (second, third,… columns).

```
Time(h),T=10,T=50,T=100
0,520,1300,2757
24,650,1626,3448
48,274,687,1456
72,612,1531,3247
96,443,1107,2348
```

Figure 30. Example of Hydrographs file

- Discharge curve 1 (H-Q): Path of the CSV file with 2 columns (separated by commas) representing the relation between the water level in m a.s.l. (first column) and the discharge capacity of the main outlet in m^3/s (second column). See example in **Figure 31**.

```
Level,Discharge
520.0,0
520.5,730
521.0,1210
521.5,2130
522.0,2850
```

Figure 31. Example of Discharge curve (H-Q)

- Discharge curve 2 (H-Q) (optional): Path of the CSV file with 2 columns (separated by commas) representing the relation between the water level in m a.s.l. (first column) and the discharge capacity of the secondary outlet in m^3/s (second column) if exists. Same format as Discharge curve 1 (H-Q).

- Calculation method: Method used for the calculation of the routing. For the moment, only the 'Modified Puls' method is available.

- Overtopping discharge coef.: Coefficient Cd used in the calculation of the overtopping discharge once the water level has reached the dam crest, according to the equation:

$$Q = Cd \cdot L_{crest} \cdot (H_{water} - H_{crest})^{3/2}$$

  By default, its value is 2.1.

- Output Folder: Path of the folder in which results are saved.

Figure 32. *Dam parameters*

Results

Once all required arguments are introduced, click on **RUN** to execute calculation. The ⦿ RUN button becomes inactive ⦿ RUN as long as process is ongoing.

Once the calculation process has successively completed, a log file is created within the output folder. This file provides details about the process and may help to identify possible errors.

Figure 33 shows an example of results: the routing of a 50-years flood through a regulated dam. The green line represents the overtopping discharge, which indicates that after 300 h, a certain overtopping has occurred.
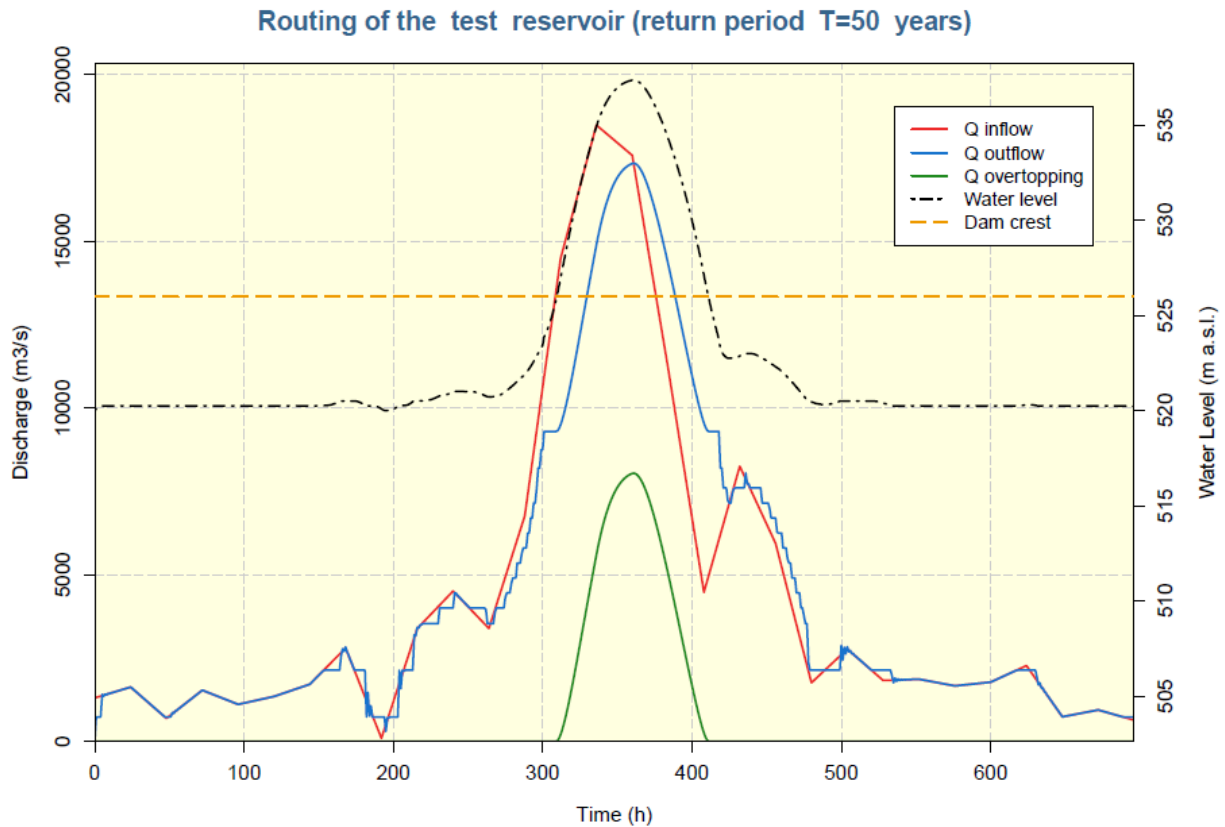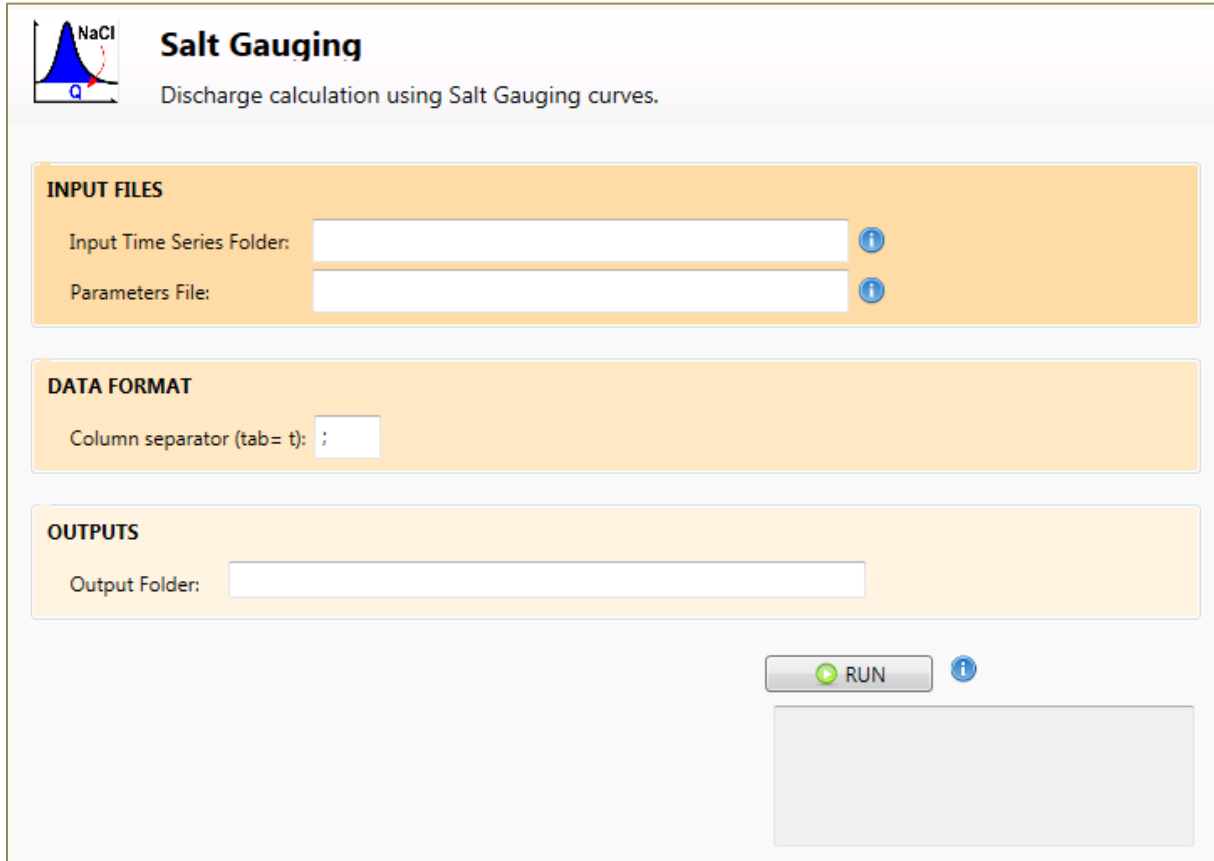
Figure 33. Example of results obtained with the 'Reservoir Routing' module

7.2 Salt Gauging

This module (**Figure 34**) estimates the discharge of a river from a conductivity time Series by analyzing the changes in the water conductivity after injecting some salt upstream the gauging point.

Figure 34. *Interface of the 'Salt Gauging' module*

Arguments

- Input Time Series Folder: Path of the folder in which data files are saved (only files with *.csv* or *.dat* extensions are accepted). Each gauging is identified by an ID that determines the file name (e.g. IdGauging_SG.csv).
- Parameter File: Path of the CSV file containing 7 columns, ordered as follows (see example in **Figure 35**):
  - *Gauging_ID* corresponds to the file name present in Input directory
  - *Station name*
  - *Gauging date* in format dd.mm.YYYY HH:MM (for instance 21.06.2015 23:24)
  - *Mass of salt* poured (g)
  - *Start and End* represents Time boundaries. If not enquired, we use an automatic detection.
  - *Calibration factor* (default is 0.494 [g/l] /[μS/cm]).

Figure 35. *Example of Salt Gauging Parameter File*

- Output Folder: Path of the folder in which results are saved. For each *Gauging_ID*, a results file will be created.

Results

Once all required arguments are introduced, click on **RUN** to execute calculation. The ⊙ RUN button becomes inactive ⊙ RUN as long as process is ongoing.

Once the calculation process has successively completed, a log file is created within the output folder. This file provides details about the process and may help to identify possible errors.

Figure 36 shows an example of results: for each gauging, the software calculates the discharges and summarizes all the information in a plot where the time steps are easily consulted.
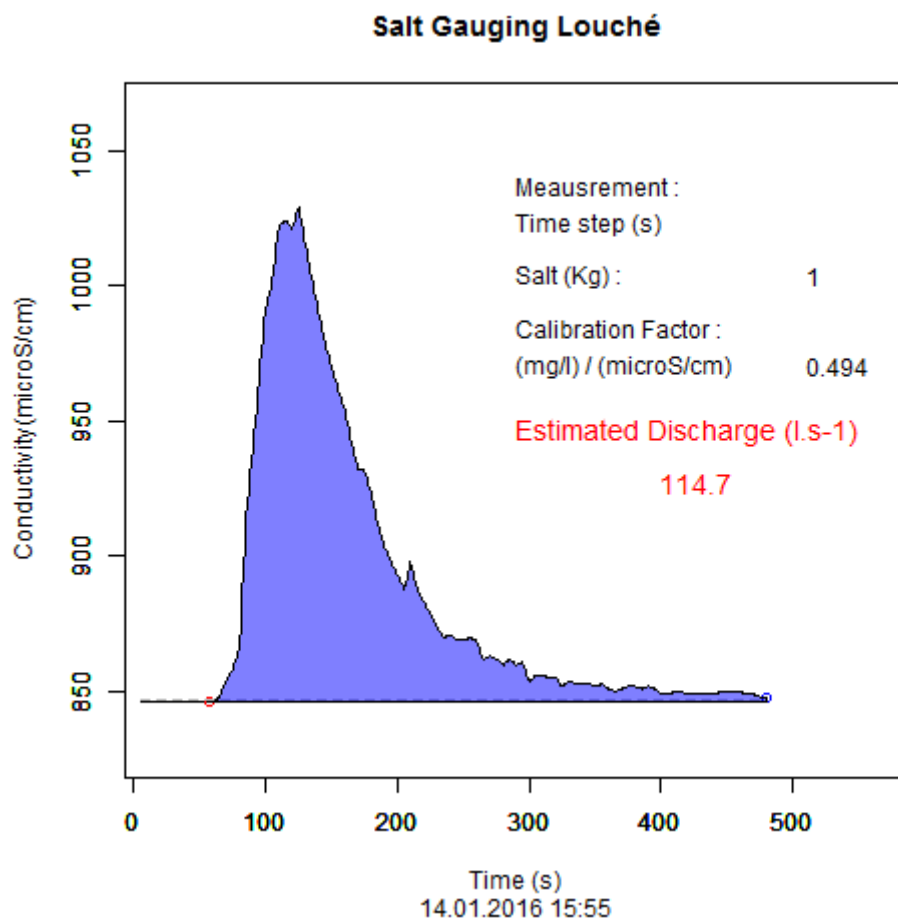
Figure 36. *Example of results obtained with the 'Salt Gauging' module*

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Acknowledgments

- ✓ automap
- ✓ bitops
- ✓ chron
- ✓ class
- ✓ colorspace
- ✓ data.table
- ✓ devtools
- ✓ dichromat
- ✓ digest
- ✓ evaluate
- ✓ e1071
- ✓ fBasics
- ✓ fExtremes
- ✓ fGarch
- ✓ fitdistrplus
- ✓ fTrading
- ✓ FNN
- ✓ formatR
- ✓ geosphere
- ✓ ggmap
- ✓ ggplot2

- ✓ gridBase
- ✓ gridExtra
- ✓ gstat
- ✓ gtable
- ✓ highr
- ✓ hydroTSM
- ✓ intervals
- ✓ jpeg
- ✓ knitr
- ✓ labeling
- ✓ latticeExtra
- ✓ lmomco
- ✓ magrittr
- ✓ manipulate
- ✓ mapproj
- ✓ maps
- ✓ maptools
- ✓ markdown
- ✓ mime
- ✓ munsell
- ✓ ncdf4

- ✓ PearsonDS
- ✓ plyr
- ✓ png
- ✓ pracma
- ✓ proto
- ✓ randtests
- ✓ raster
- ✓ RColorBrewer
- ✓ Rcpp
- ✓ Rcurl
- ✓ reshape
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