User Manual Software IT-NHRain V.3.0

Not hurricane rain hazard modelling

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PUBLICATION DATE: 27/08/2018
VERSION: 3

INGENIERIA TECNICA Y CIENTIFICA S.A.S.
Ingenieros Asesores y Consultores
Nit. 860.065.452-5

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Chapter 1

Introduction

1.1. Introduction

IT-NHRain software was created for the analysis of non-hurricane rainfall hazard in a probabilistic approach. *IT-NHRain* considers the intrinsic variability of the problem to generate multiple rain stochastic scenarios, in order to represent the hazard of the zone by means of the historical register in meteorological stations or by image satellites.

This manual is a guide to using *IT-NHRain*. The manual provides an introduction and overview of the software, installation instructions, how to get started, its commands, a step-by-step example, the problems and limitations of the software.

1.2. Problem description

The selection of the hazard model by heavy rains is made taking into account the need to have a detailed model, whose results are based on daily rainfall records, and whose application allows to characterize the rainfall conditions of basins and sub-basins, given its later inclusion as an input to the flood hazard model. As a result, an AME file, compatible with **CAPRA-GIS** platform, is obtained. As well, this can be used directly for flood hazard evaluation in program such as **IT-FLOOD**.

1.3. Theoretical framework

Rain is the direct fall of water in a liquid or solid state over the earth surface. The precipitation term includes rainfall, drizzle, hail, snow, among others; however, intense rainfall phenomena is one of the most significant events in the tropical regions hydrology. This rainfall triggers hydrological processes that eventually become disastrous, such as flooding, landslides and avalanches.

Rain is an atmospheric phenomenon, which begins with the water vapor contained in the clouds. Following the World Meteorological Organization official definition, rain is the precipitation of liquid water particles with a diameter higher than 0.5 mm or of minor drops but very disperse. If does not reach the earth surface is called virga, and if its diameter is very small is called drizzle.

The rain main sources are the clouds, but it never happens unless the tiny particles grows and reach an adequate size to exceed the atmospheric currents ascendant forces. Rainfall likelihood depends on three main factors: pressure, temperature and solar radiation.

Rainfall analysis

Precipitation at a given point is a stochastic process with a variable frequency and intensity depending on the seasons. The basic parameters to be considered are:

- Rainfall duration.
- Mean rainfall intensity.
- Total volume of precipitation.
- Time between successive precipitations.

The most important value is the total precipitation volume P, which can be estimated by $P = I \times t$, where I is the average intensity and t the rainfall total duration. These two parameters are dependent since the higher the intensity lower the duration, and vice versa.

Basin pluviometry estimation

In a large basin, there are data from many whether stations, so the problem of assessing an average basin precipitation has to be addressed. The following methods are proposed:

a. **Precipitation arithmetic mean:** calculated as the arithmetic mean of all precipitations. This method is only acceptable if there are many stations and if the precipitation is similar in all of them. This estimated value does not include any other spatial distribution assessment of the stations.

b. **Thiessen polygon method:** sub-regions or zones of influence around each station divide the studied domain. The stations must be connected two by two and the perpendicular bisector of these segments is drawn, assigning to each station the area A limited by the polygonal enclosed by the perpendicular bisectors. Precipitation measured at each pluviometer is pondered by the total area fraction enclosed in every zone of influence. Once the zones of influence are delimitated and its areas calculated, the mean precipitation P_m is obtained.

$$P_m = \frac{\sum[P_i \times A]}{\sum[A]}$$

c. **Isohyets method:** based in the hypothesis of having enough data to draw the isohyets lines between points with the same mean precipitation. An isohyets map is a fundamental tool for the basin hydrologic analysis. It does not only quantifies the mean value, but also represents graphically the spatial distribution of the precipitation for a given return.

   The mean precipitation between two isohyets is assigned to the area between those two successive isohyets. With this area, which encloses successive pairs of isohyets, the regional precipitation is obtained.

   When drawing isohyets for monthly or yearly rainfall, the topographical effects over the spatial distribution of precipitation are now considered, taking into account factors such as height and exposure of the station.

IDF Curves (intensity, duration, frequency)

The intensity, duration, frequency and spatial distribution of rainfall varies very much, that is why many researchers have been focused in the analyses and weather forecasting.

Rainfall intensity varies significantly from one place to another, even in short distances. Considerable temporary variations along the year are present too. There are many zones where in just one-day falls more rain than it does in others in a whole year.

In the analysis of the precipitation distribution at one point, in addition to the relationship between intensity and storm duration (intensity-duration site specific curves), it is necessary to introduce the likelihood or frequency concept in order to make future assessments, evaluate in a quantitative manner the precipitation associated hazard and estimate the exposed infrastructure risks. These types of curves are commonly named IDF curves and have the general next form:

$$I(t,T) = at^b$$

Where I is the maximum mean intensity (mm/h) , t the duration and T the return period. The inverse of the period of return is the exceedance rate, that is to say, the likelihood of having a storm with intensity t in one year ($1/T$).

The a and b parameters are a function of the meteorological characteristics of the region and should be assessed from experimental data.

PADF Curves (Depth of precipitation-Area-Duration-frequency)

The PADF curves are a particular representation at basin or sub-basin level of the historical storms characteristics. These curves relate the mean precipitation over a certain area with the duration and frequency of a storm. The PADF are built from spatial analysis of the IDF curves from different stations over the basins by fixing the duration of the storms and the occurrence frequency.

Proposed Model

Generalities

The incorporation of a system of stochastic convective rainfall is proposed, this system allows defining specific scenarios for the flood hazard assessment. The proposed model contains two main phases: the making of the precipitation events database and the maximum rainfall spatial analysis.

Precipitation events data base

The goal at this phase is to collect and store the pluviometric and pluviographic information required to perform the following phases. To achieve this, the next criteria must be established:

- Area definition: Necessary for the pluviographic stations within the region, as well as in the surroundings and adjacent areas.
- Identify past historical precipitation events associated to hurricanes and intense rainfall triggered by convective or low pressure systems.
- Historical stations data must have concurrent common periods to strengthen maximum rainfall spatial analysis. The pluviometric and pluviographic information should be taken from the stations data, which belong to the public and private entities that measures rainfall.
- Pluviometric information must correspond to daily precipitation records; while the pluviographic information should permit, identify the mass curve of each precipitation event and its processing to determine maximum intensities for different durations. Pluviometric information must have a temporary resolution frequently than daily.
- The information storage must be done through computational tools, which facilitates an adequate quality control with depuration and eventually complementation purposes, its handling and its analysis in later phases.

Required information for an adequate precipitation database is:

1. Geographic location of pluviometric and pluviographic stations.

2. Location of pluviometric and pluviographic stations in maps with an adequate scale, drainage network, basins and sub-basins.
3. Period of recording at all stations.
4. Daily information for the period of recording at each station.
5. Precipitation depth information for the period of registry for time intervals shorter than one day at each station. If not, information of the historical maximum rainfall for different durations or annual series of maximum precipitations for different durations information. If this information is not available, the Depth-Duration-Frequency (DDF) curves or Intensity- Duration-Frequency (IDF) curves must be used. If this information is not available either, it is possible to estimate it from the daily pluviometric information.

Maximum rainfall spatial analysis

The goal of this model is to establish the relationship between the average maximum depth of precipitation (P), the area (A) over which this precipitation is applied, duration (D) during which the rainfall takes place and the frequency (F) of this event occurrence under these characteristics of depth, spatial coverage and duration. This corresponds to the depth - area - duration - frequency (PADF) curves. The PAD analysis determine the maximum amounts of precipitation over areas of different sizes and for different durations. An additional aspect is the analysis and definition of geometrical patterns (e.g. precipitation spatial distribution) which is made from the analysis of equal rainfall curves maps of the considered storms, identifying center of storms and areas associated to hypocenters, that is to say, areas with much less precipitation. Another consideration to take into account is the temporary distribution of spatially distributed events. Some criteria for the maximum precipitation spatial analysis are described next:

1. Minimum area definition in which rainfall is considered as punctual. Additional definition of the maximum area.
2. Minimum number of pluviometric and pluviographic stations, which record any given rain for the correspondent isohyet map (this number could be around 10 but it depends on the stations density in each case), so they will be reliable enough for the event spatial description.
3. Definition of a threshold value for the selection of an event to be considered as significant, thus, in addition to be recorded in the minimum number of stations as described in step (2), the precipitation at each one of these stations must exceed that threshold value (e.g. larger than 10 mm in 24 hours).
4. For consistency, the same distribution of probability and the same parameter estimation method than the one defined for the site specific analysis of frequency must be used.
5. The precipitation spatial distribution analysis for the considered events should establish the most representative geometrical patterns for its generic characterization (E.g. Elliptical pattern, circular pattern, etc) with preferred locations of hyper or hypocenters, as well as the pattern alignment, and like the functional relations between the pattern parameters (e.g. large to short axis ratio between 2 and 3).
6. The temporary distribution of rainfall with spatial extension must be obtained from the temporary behavior of recorded storms in major areas coupled with the pluviometric and pluviographic stations. In this way, the consistency of the temporary and spatial patterns obtained from the maximum precipitation analysis in major areas is guaranteed.

The methodology for the PAD and PADF relationship determination must be based on procedures proposed in the literature, such as the (World Meteorological Organization, 1969).The range of the area variation must be established from the rainfall maps generated for each available event, from the site-specific equivalent minimum value to the largest extension covered by these events. Eventually, it may be necessary to extrapolate PAD and PADF curves for higher values to this historical maximum in the area. Regarding the duration, it is considered that it could be from one hour to around 10 days, because of the rainstorms associated to hurricanes. Gumbel distribution with MPP for site specific analysis is considered adequate for the spatial analysis.

For the determination of the precipitation data in the PAD and PADF curves analysis, the recorded dates must be established, and afterwards, complete the lack of information with data from other stations. Thus, for each date, the set of precipitation values recorded in all stations within the homogeneous area are obtained, which, displayed through rainfall curves establishes the precipitation spatial distribution in the given date. Additional similar analysis will subtract daily information with shorter duration, if any pluviographic information available, so spatial and temporary distribution for each sub-interval may be established. In the same way, daily information can be aggregated for longer durations to make possible to identify the spatial and temporary distribution of each one. As a consequence of that, for all historical dates with significant events, PAD curves are build (one for each event and for one duration) from which the analysis of frequency for different area values is done. The output is the PADF curve for the homogeneous hydrological zone.

Building a PADF Curves

To build a PAD curve in a homogeneous hydrological zone, the duration is first established; the historical events rainfall map for this duration is then generated, after that, each map is processed with computational geographical tools to determine the high precipitation depth locations, calculating the average precipitation and measuring the covered area. This is repeated successively, extending the rainfall rate coverage (from lower to higher values), computing the mean precipitation over the considered areas. When increasing the isohyets coverage the mean depth decreases progressively and the area increases consistently, so an inverse relationship between the area and maximum mean depth is defined. The algorithm is described next:

1. For each year, select the intense precipitation events with spatial extension. Steps 2 to 16 correspond to the analysis of events for each available year.

2. For each event, draw isohyets maps for duration D using computational tools. Peripheral stations with no precipitation record must be included. For spatial interpolation, the Kriging method is recommended.

3. Identify the isohyets of higher value (p_1), let m_1 be the number of isohyets with p_1 value.

4. Measure the enclosed areas with p_1 values. Denote these areas as a_1, with i from one to m_1.

5. Estimate the mean precipitation at a_1 as:

$$h_1 = \frac{p_1 + (p_{max} - p_1)}{3}$$

Where p_{max} is the maximum punctual value of precipitation within the a_1 area.

6. Sum all a_1 areas as $A_1 = \sum_{i=1}^{m_1} a_1$

7. For the aggregated area A_1, calculate the mean depth as:

$$H_1 = \frac{\sum_{i=1}^{m_1} h_{1i} a_{1i}}{A_1}$$

8. Identify the isohyet(s) with the subsequent inferior value to p_1, and call it p_2. m_2 will be the number of isohyets with a p_2 value.

9. Measure each one of the m_2 internal areas of isohyets with p_2 value. These areas are a_2.

10. Estimate the mean precipitation value in a_2 as:

$$h_{2i} = \frac{h_{1i} a_{1i} + 0.5[p_2 + p_1][a_{2i} - a_{1i}]}{a_{2i}}$$

11. Sum all a_2 areas or$A_2 = \sum_{i=1}^{m_1} a_2$.

12. For the aggregated area A_2, calculate the mean depth as:

$$H_2 = \frac{\sum_{i=1}^{m_2} h_{2i} a_{2i}}{A_2}$$

13. Continue with the subsequent isohyets curves with a similar procedure. For each isohyet n with a precipitation value p_n and with enclosed areas a_n, estimate h_n as:

$$h_{ni} = \frac{h_{1i} a_{1i} + \sum_{j=2}^{n} 0.5\left[p_j + p_{1-j}\right]\left[a_{ji} - a_{ji}\right]}{a_n}$$

14. Sum all a_n areas or $A_n = \sum_{i=1}^{n} a_n$

15. For the aggregate area A_n, calculate the mean depth as:

$$H_n = \frac{\sum_{i=1}^{m_2} h_{ni} a_{ni}}{A_n}$$

16. Draw A_j vs. H_j.

17. Repeat steps 2 to 16 for all precipitation events of duration D available in that year.

18. Overlap graphs A_j vs. H_j of step 16 for all events of that year with D duration.

19. To obtain the maximum of values of step 18, generate an envelope, which covers all the PAD curves generate for each event by selecting the maximum precipitation mean value per area.

20. Repeat steps 2 to 19 for each one of the available years.

21. Build the annual series of maximum precipitation of duration D for each predetermined area defined in step 19. Make a frequency analysis with these series using the same probability distribution and the same estimation method of parameters used in the site-specific analysis.

22. Repeat steps 2 to 21 for other duration D.

23. With the frequency analysis outputs of steps 21 and 22, make the PADF curves.

The result is a graph that contains curves relating precipitation depth, area, duration and frequency. The shows an example of a PADF curves for a duration of 1 day.

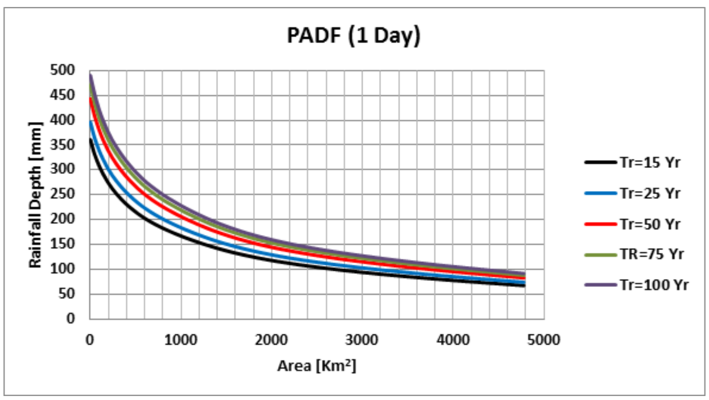

Figure 1. PADF curves example for 1-day duration

Definition of preferential localization of storm centers

The spatial distribution of historical rainfall patterns conditions the generation of stochastic storm events. For this reason, it is necessary to determine the points where the events will be more concentrated. These zones correspond to the locations with greater precipitation intensity and it is possible to use the precipitation multiannual average of in a given month, multiannual mean of the sum of the most critical months or mean annual multiannual

Rain probabilistic hazard definition

In consequence of former analyses, the PADF curves are obtained, representing the homogeneous correspondent zones. The isohyets historical curves analysis allow establishing typical patterns of spatial distribution of precipitation events, which may be differenced according to its origin, either by hurricanes or by intense rainfalls. Complementary to this, preferential locations of this patterns within the zone could be determined. The three previous inputs: PADF curves, typical patterns and preferential location, allow establishing procedures for the synthetic generation of rain events over the zone. For this, in a randomly controlled manner, spatial precipitation events location could be generated, with controlled random characteristics of both form and size, which fulfil the relationships contained in the PADF curves. The procedure is as follows:

1. Select a determined return period, T.
2. Determine randomly a duration D.
3. Select area values, Ai, within the range covered by the PADF curve that corresponds to the previous D duration and return period T.
4. With the PADF curve, determine the values of maximum mean depth P_i.
5. Generate the location randomly, form and size of the precipitation pattern.
6. Generate with the typical pattern the rainfall isohyets curves that preserve for the previous A_i areas the respective precipitations depth P_i.

Table 1 shows the equations to build a spatial circular or elliptical pattern, because an elliptical one is defined by the short and long a and b axis respectively, and it can be expressed with the function$b = Ka$. In the table, the first two columns correspond to the area values and maximum mean precipitations from the PADF curve (steps 3 and 4), with the areas ordered from low to high. The third column shows the equations used to determine the isohyet of the elliptical pattern. Finally, columns 4 and 5 permit to calculate values for each isohyet in both axis.

Table 1. Spatial synthetic patterns determination (Circular or elliptical)

A_i	P_i	Valor isoyeta, h_i	Semieje menor a_i	Semieje mayor b_i
A_1	P_1	$h_1 = P_1$	$a_1 = \left(\frac{A_1}{\pi K}\right)^{0.5}$	$b_1 = Ka_1$
A_2	P_2	$h_2 = \frac{2(P_2A_2 - P_1A_1)}{A_2 - A_1} - h_1$	$a_2 = \left(\frac{A_2}{\pi K}\right)^{0.5}$	$b_2 = Ka_2$
A_3	P_3	$h_3 = \frac{2(P_3A_3 - P_2A_2)}{A_3 - A_2} - h_2$	$a_3 = \left(\frac{A_3}{\pi K}\right)^{0.5}$	$b_3 = Ka_3$
…	…	…	…	…
A_n	P_n	$h_n = \frac{2(P_nA_n - P_{n-1}A_{n-1})}{A_n - A_{n-1}} - h_{n-1}$	$a_n = \left(\frac{A_n}{\pi K}\right)^{0.5}$	$b_n = Ka_n$

For the synthetic generation of maximum precipitation events, it is necessary to define three complementary elements:

1. The spatial location of the center of the storm.
2. K value.
3. The longer axis direction.

Regarding the spatial location of the center of the storm, based on the historical isohyets maps, the zones with higher frequency of localization must be identified, which could be represented through polygons. Therefore, within these polygons, random center of storms must be generated. Regarding the *K* value, again from the historical isohyets maps. The limits of K values more representative could be determined, adjusting a uniform distribution or symmetrical triangular, for example. For the longest axis, the isohyets historical maps allow to establish preferential alignments of the storm patterns, from which longer axis azimuth ranges could be defined, from where random values must be generated.

1.4. Analysis flow chart

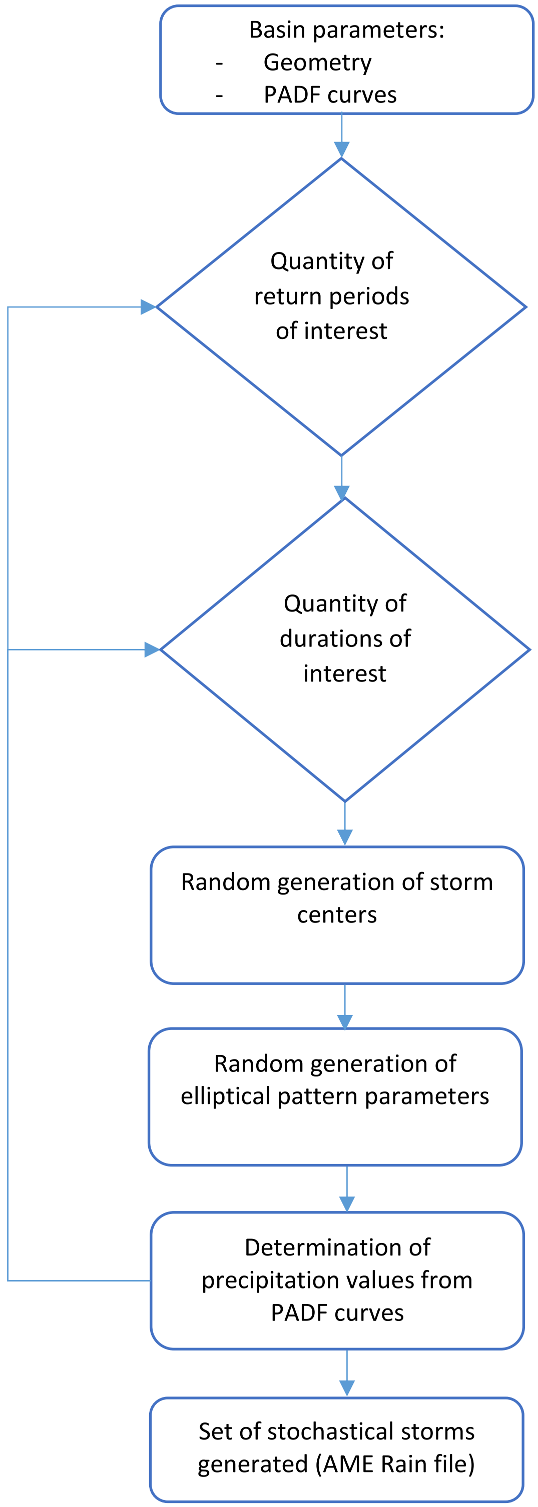

Figure 2. Main flow chart of IT-NHRain

Chapter 2

Software Installation

2.1. Minimum installation requirements

Minimum hardware and software requirements

The following are the minimum hardware requirements for the *It-Flood* installation:

- PC or compatible computer with Pentium III processor (or higher) and processor speed over 1.5 GHz.
- Operating systems: Microsoft XP or Higher
- Free hard drive capacity of 250 Mb or Higher.
- 512 Mb Extended Memory (RAM)
- CD-ROM or diskette unit (Depending on installers set up).
- Microsoft framework V2.0 or higher and the language package

2.2. Recommended hardware requirements

The following are the minimum hardware requirements for the CAPRA-GIS installation:

Processor

- PC or compatible computer with Pentium III processor (or higher) and processor speed over 1.5 GHz.
- Operating systems: Microsoft XP or Higher

RAM Memory

- Free hard drive capacity of 250 Mb or Higher.
- 512 Mb Extended Memory (RAM).

Removable unit

- CD-ROM or diskette unit (Depending on installers set up)

Other software

- Microsoft framework V2.0 or higher and the language package (if CAPRA-GIS is already installed, this is included)

2.3. Installation process

1. Download the installation package from the CAPRA platform (https://ecapra.org/topics/precipitation)

2. Enter in windows explorer and select the file where installers are located.

3. Run the setup.exe program. This command starts the installation program; please follow carefully each step indicated by the installation assistant

Chapter 3

Graphical User Interface

3.1. General Description

IT-NHRain is a software that allows rain hazard modeling, which is made with station or point precipitation recording information in order to perform a maximum rainfall spatial analysis in the basin or zone.

The Figure 3 shows the general interface. The software works in a sequential way, therefore the selection of a tool will let to another window and so on. It is possible to exit in any moment the program by selecting the exit icon in the upper panel. In addition, in any moment the selection of the help button, which corresponds to the question marc icon, will display the main help window of the software.

Figure 3. IT-NHRain general interface

The software has two principal tools: the generation of PADF curves and the creation of the synthetics storms in an AME Rain file. The next sections will explain briefly the associated panel and windows for each one.

3.2. PADF Curves generation

When selecting the **GENERAR button** in the main interface the program will display the tool for creating the PADF curves. The associated windows in the order of appearance are:

1. Input data entry window (see Figure 4): Window for introducing the require files.
2. Curves event identification window (see Figure 5): Window to specify the parameters of the events to consider as extremes.
3. PADF curves generation window (see Figure 6): Window to select the return periods that will composed the PADF curves.

Each figure indicates in orange data input files, in red number inputs and in yellow the buttons.

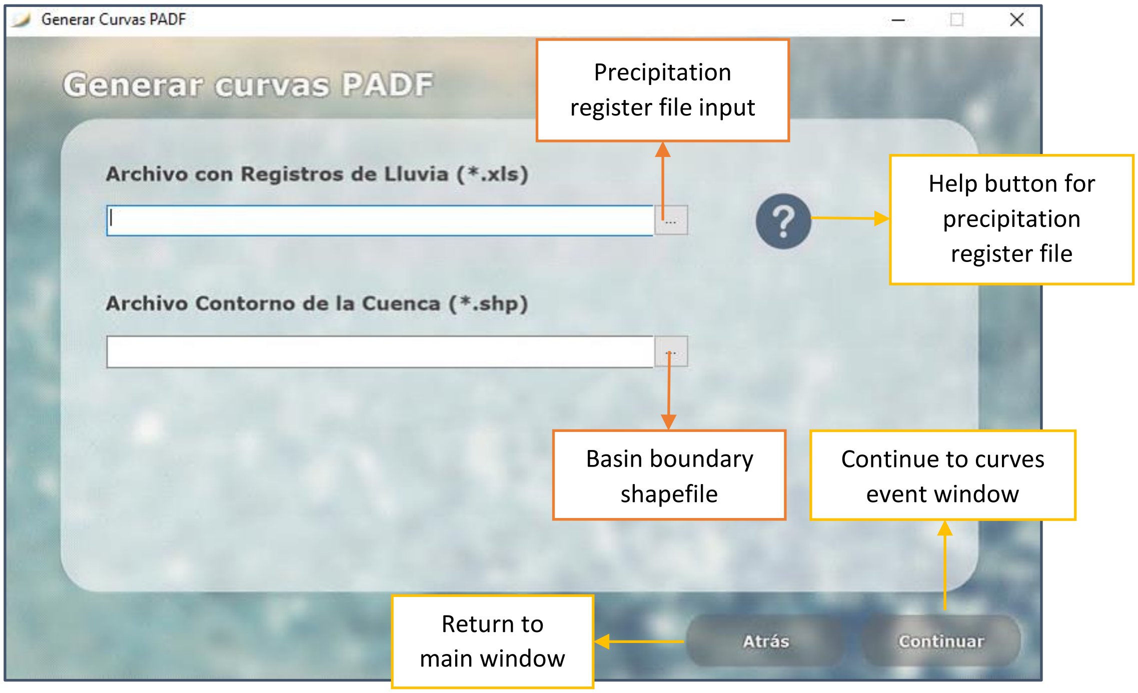

Figure 4. Input data entry window in PADF curves generation

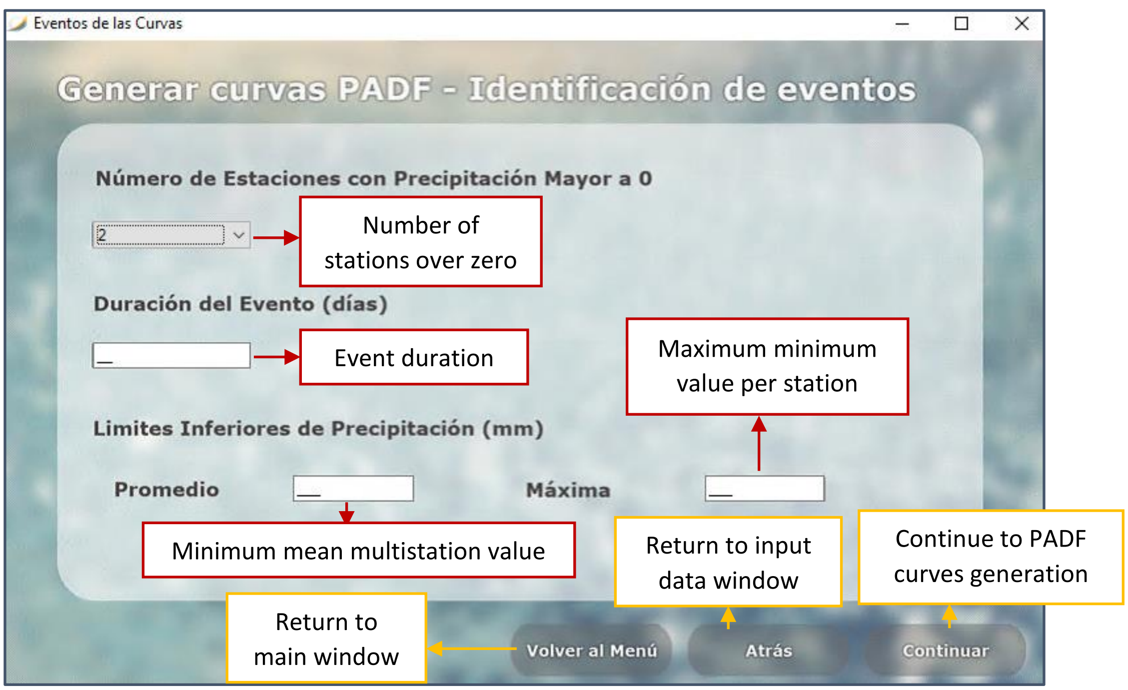

Figure 5. Curves event identification window in PADF curves generation

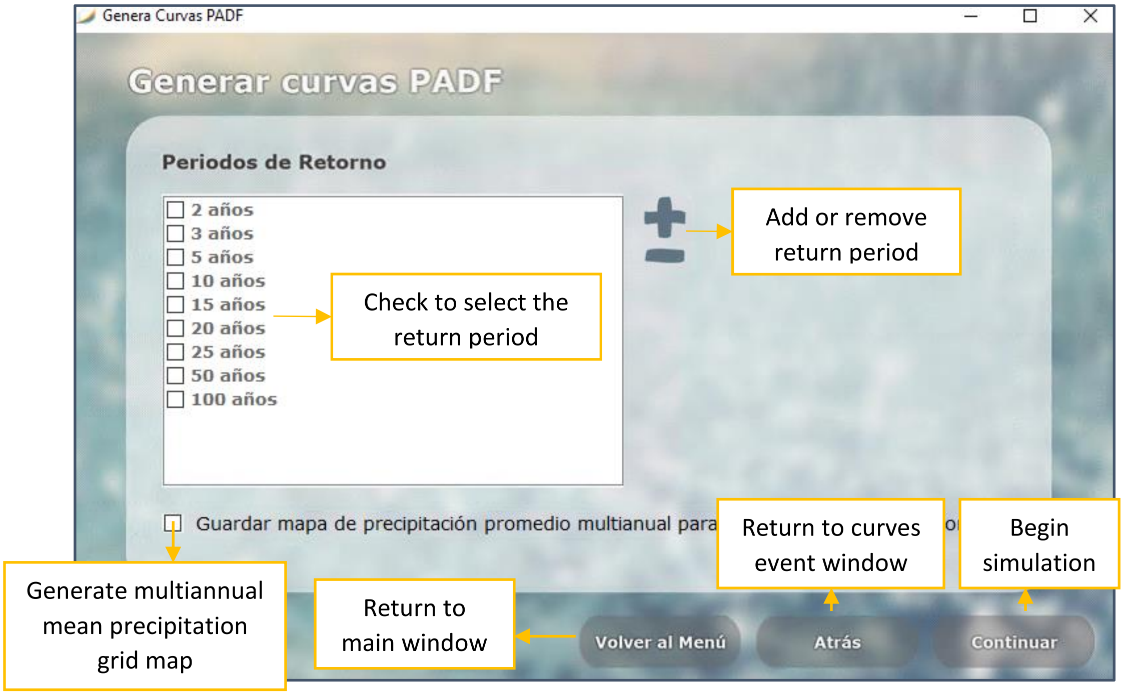

Figure 6. PADF generation curves window in PADF curves generation

3.3. AME Rain file generation

When selecting the **IMPORTAR button** in the main interface the program will display the tool for creating the stochastic storms. The associated windows in the order of appearance are:

1. Input data entry window (see Figure 7): Window for introducing the require files.
2. Stochastic storm generator window (see Figure 8): Window to specify the parameters of the stochastic storms and the final AME Rain file

Each figure indicates in orange data input files, in red number inputs and in yellow the buttons.

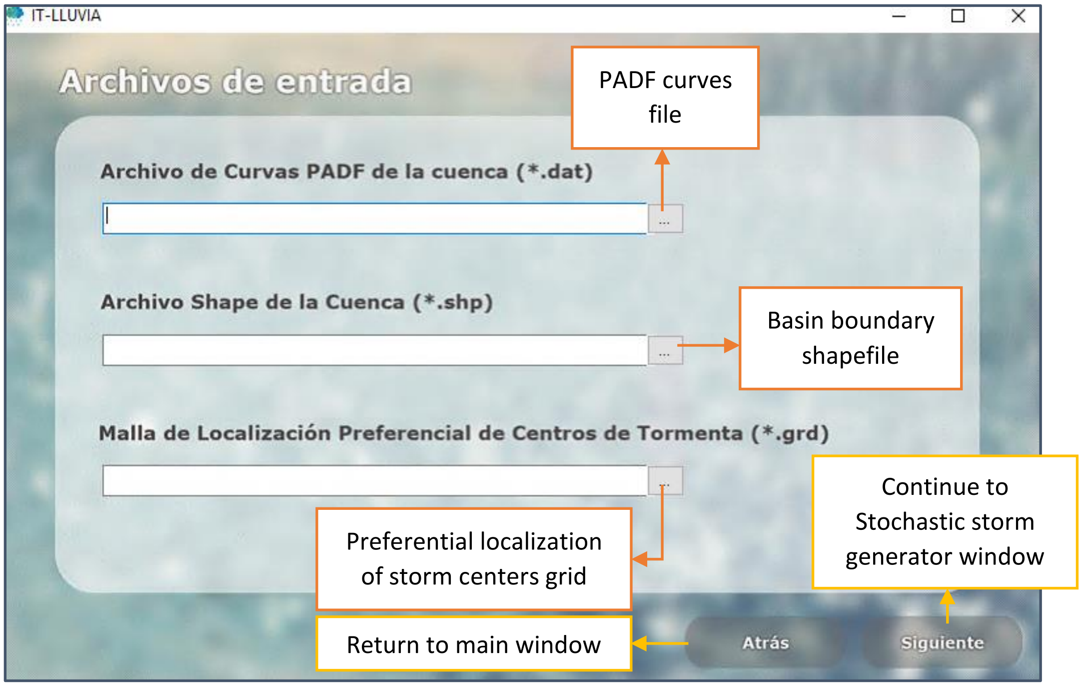

Figure 7. Input data entry window in AME Rain file generation

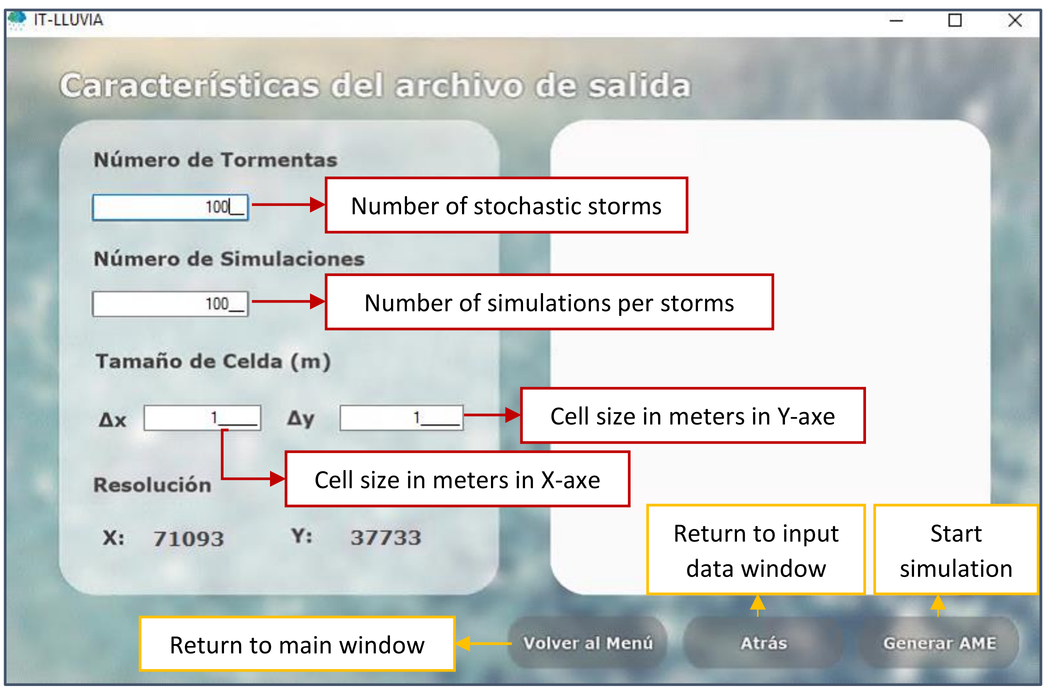

Figure 8. Stochastic storms generation window in AME Rain file generation

Chapter 4

Setting input data and files

4.1. Input parameters setting

The Table 2 explains the input parameters for each tool of the software. The explanation includes the description and the required format.

Table 2. Input parameters description

Parameter	Description	Format
PADF curves generation		
Precipitation register file	2003 Microsoft Excel file containing the precipitation data per station. The next section explains the required format for this file.	*.xls
Basin boundary polygon	The basin boundary in shapefile format. It should be a polygon.	*.shp
Number of stations with precipitation over 0	This number indicates the number of stations in the basin where the register is over 0 to not be considered as a punctual event and to cover in a reliable way the extent of an event.	Positive Integer
Event duration in days	The number of days that lasts the rain event. This depends in the basin size primarily.	Positive Integer
Precipitation lower boundary – Mean multistation value	Limits the minimum mean multistation precipitation value. This is to avoid the use of light rain events.	Positive number
Precipitation lower boundary – Maximum value	Limits the minimum required value in the stations. This is to avoid the use of light rain events.	Positive number
AME Rain file generation		
PADF curves file	File generate by IT-NHRain containing the information of PADF curves (Return period, variation coefficient, area and mean precipitation).	*.dat
Basin boundary polygon	The basin boundary in shapefile format. It should be a polygon.	*.shp
Preferential localization of storm centers grid	Raster that contains information about the way to identify the preferential localization of storms such as precipitation multiannual average of in a given month, multiannual mean of the sum of the most critical months or mean annual multiannual.	*.grd
Number of stochastic storms	It is the number of scenarios generated therefore; the indicated storms for each PADF curve are generated, for each storm: its center, the aspect relation and the inclination are randomly varied.	Positive Integer

Parameter	Description	Format
Number of simulations per storms	The number of simulations permit diminish the uncertainty of the generated values for each storm. The number of simulations is the number of times each storm is analyzed, to finally obtain a precipitation average and an uncertainty at each point of analysis.	Positive Integer
Cell size in meters in both directions	It is the spacing between points of analysis in the X and Y-axis, respectively. This changes automatically the resolution of the resulting AME, which is tied also to the basin boundary polygon size.	Positive number

4.1.1. Precipitation register file

For the generation of the PADF curves files. The file must be a Microsoft Excel 2003 workbook (*.xls) with the next general format:

1. First spreadsheet named “**Estaciones**” that contains all the information about the meteorological stations or points such as:
    - Code: A given code by the user in a positive integer format.
    - Longitude: Longitude coordinate value in a real format.
    - Latitude: Latitude coordinate value in a real format.
    - Name: Name of the station in text format.
    - Country: Country where the station is located in text format.
    - Elevation: Elevation of the station a positive real format.

   A header containing the previous names must precede the spreadsheet in the same order. Then, each row represents a different station. The Figure 9 shows the required format.

2. Remaining spreadsheets named by the year of precipitation record in “YYYY” format. Each spreadsheet is a year that contains the precipitation data of all the stations. The header contains the next information:
    - Date: The date of recording in excel date format. The column should be in ascending order.
    - Code: Each column contains the precipitation information of a different station in positive real number. The way of identification is the code, which must be the same as the one indicated in the **Estaciones** spreadsheet.

   The header order is fixed: first the date and then the codes. The codes number is irrelevant. The Figure 10 shows the specific format of the spreadsheet.

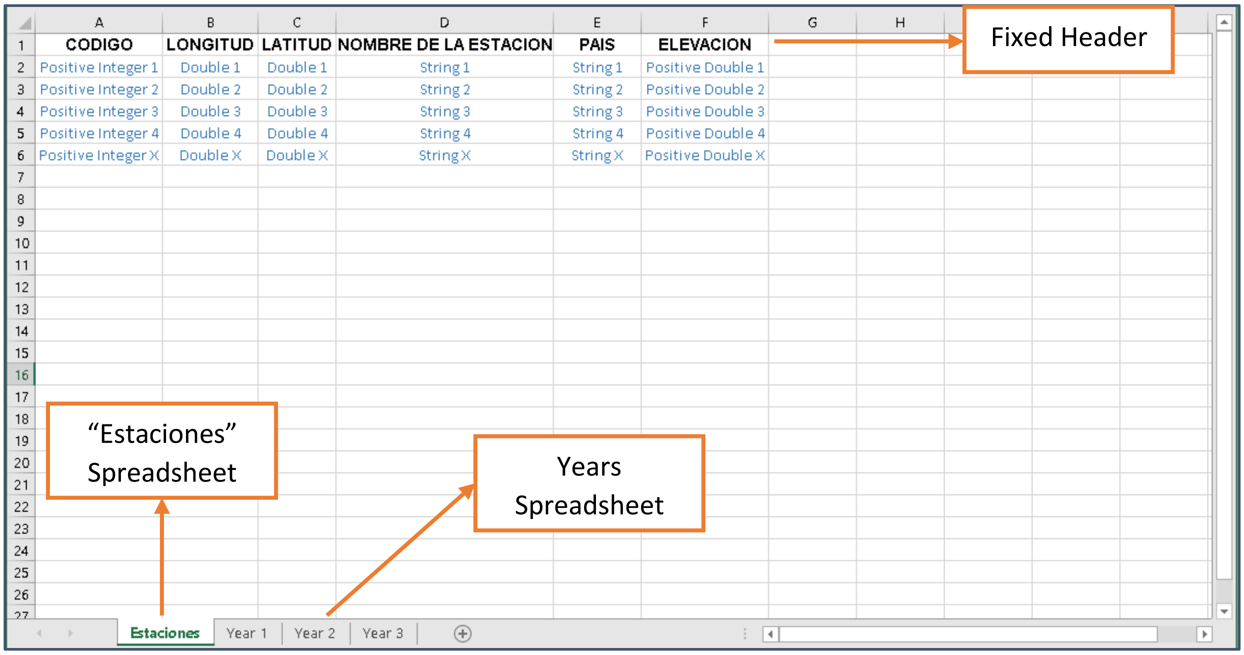

Figure 9. General spreadsheet configuration in the Precipitation register file

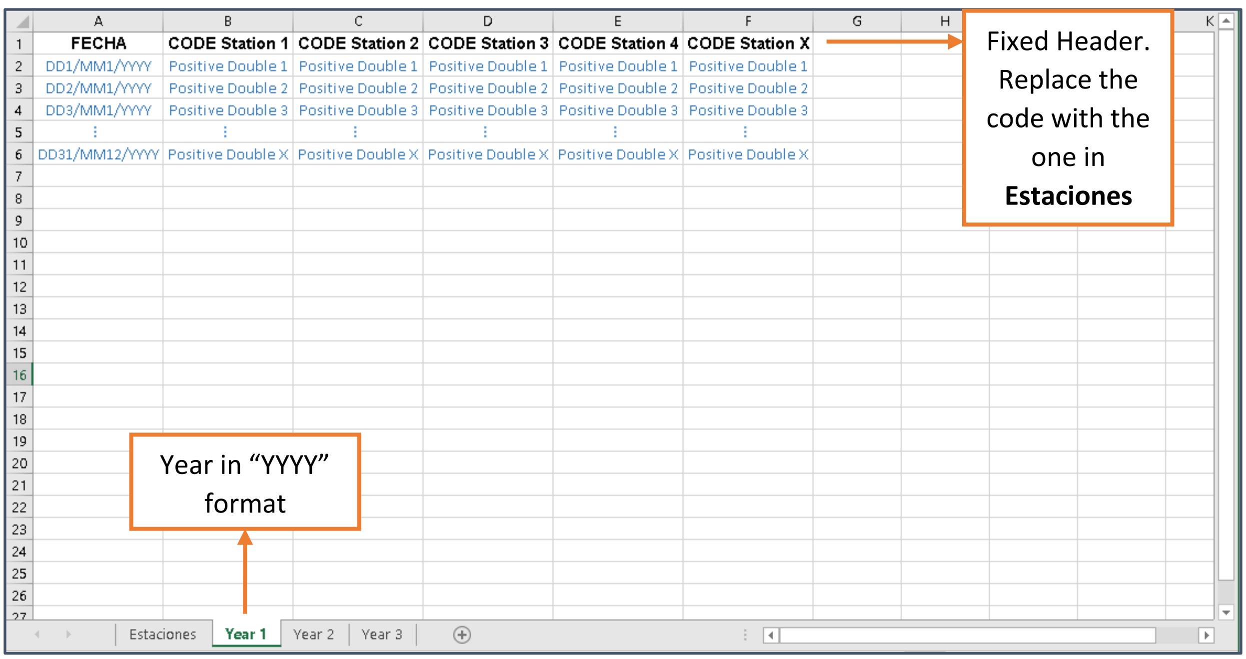

Figure 10. Years spreadsheets configuration in the Precipitation register file

Chapter 5

Visualization output files

5.1. Output files and file format

The two possible output files generated by IT-NHRain are the PADF curves file and the AME Rain file. The next two sections explain briefly the contents and format of each one.

5.1.1. PADF Curves file

The PADF curves file correspond to *.dat file that can read as *.txt file. The present a section of the results file. This will repeat equally to all the selected return periods at the time of the file generation in IT-NHRain.

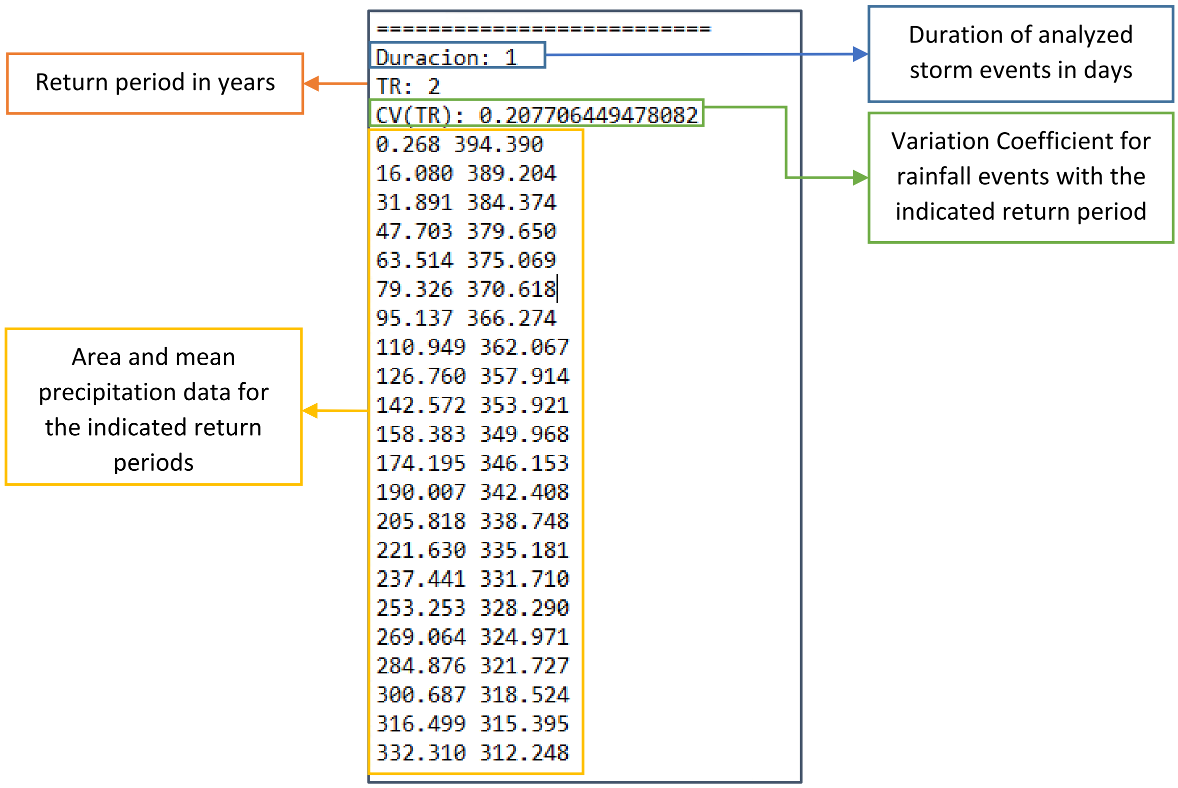

Figure 11. PADF curves file output format

5.1.2. AME Rain file

The result AME rain file (*.AME) contain the information of all the stochastic storms. The principal components are:

- Stochastic storms per return period (this depends in the number of selected storms to generate for each return period by the user).
- For each storm there is one intensity that corresponds to the rain depth in mm. Likewise, the intensity contains two moment information the first is the mean value and the second is the associated standard deviation.

The AME can be visualized in CAPRA-GIS as shown in Figure 12. This AME is compatible for evaluating other hazards such as flood with the use of IT-FLOOD.

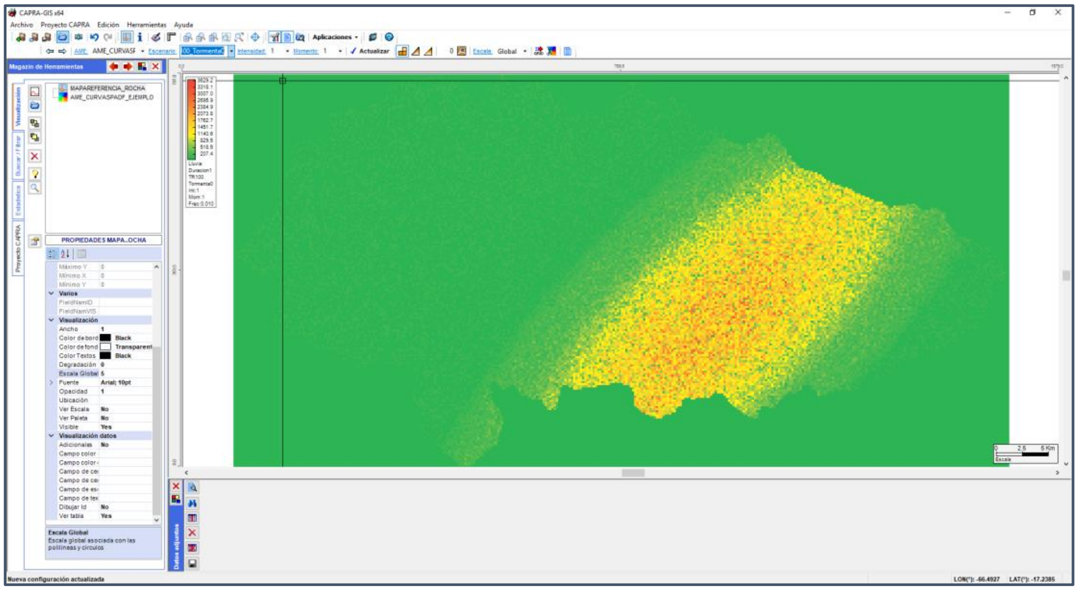

Figure 12. Visualization of AME Rain file in CAPRA-GIS

Chapter 6

Step by step tutorial

6.1. Step-by-step tutorial

This chapter provides an example application of how to use the software, for this tutorial it is used a basin with four stations and precipitation data from 2008 to 2012 (this is just an illustrative example and for real applications it is required a more extensive precipitation register). The example includes the creation of the PADF curves and the *.AME rain file.

Necessary files

- Precipitation register file: Data_PADF_ROCHA.xls
- Basin boundary polygon: MapaReferencia_Rocha
- PADF curves file: CurvasPADF_Ejemplo.dat
- Preferential localization of storm centers grid: CurvasPADF_Ejemplo.dat_Malla.grd
- AME rain result file: AME_CurvasPADF_Ejemplo.Ame

Contents

- Creating PADF curves
- Creating the AME rain file
- Exiting the Program

6.1.1. Creating PADF curves

To begin this example, select the *IT-NHRain* icon in desktop or start bar and the main window of the software should appear as shown in Figure 13. If the program was already open, select the **Volver al Menu button** in any window to return to the main window

Figure 13. IT-NHRain main window

For the generation of the PADF curves select the **GENERAR button** and the input data window will appear. Introduce the necessary files, first the precipitation register file in the format specified in chapter 4 and second the basin boundary shapefile as shown in the new figure.

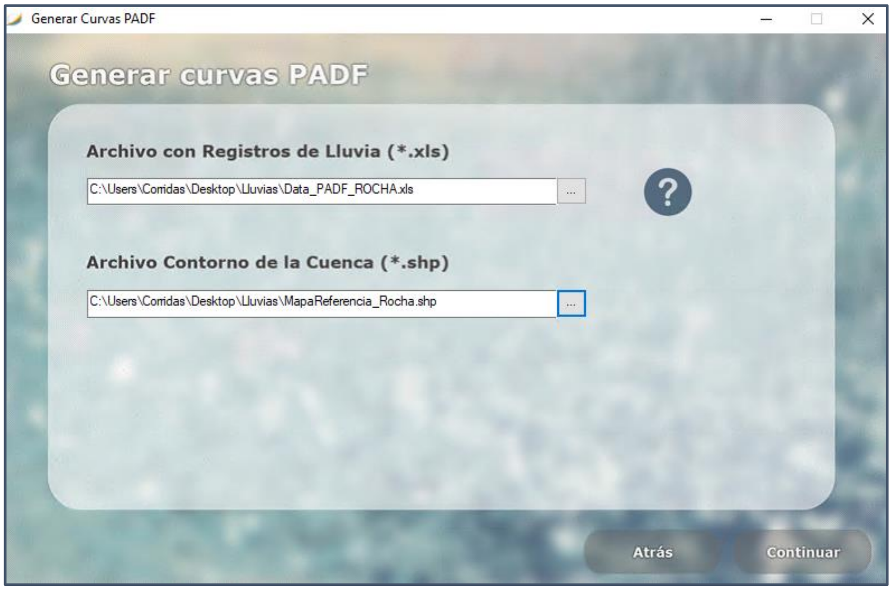

Figure 14. Input data for PADF curves generation window

Select the **Continuar button** and a window will pop up indicating the number of identified stations for processing as seen in Figure 15.

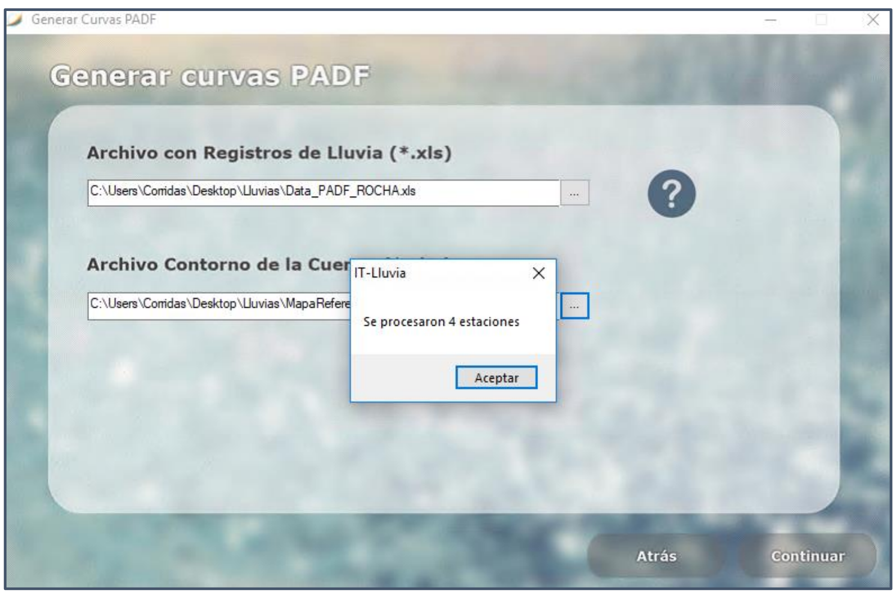

Figure 15. Window indicating the number of stations for processing

Click **Aceptar button** and the window for parameters to select rain events will show. Select the number of stations whose rain value is over zero, the event duration, the lower boundaries of the events such as the mean precipitation value over all the stations and the lower maximum value in one of the stations. These parameters are used by the software to select the events that accomplished the characteristics to be considered and extreme rain event. The Figure 16 presents the selected values for this example.

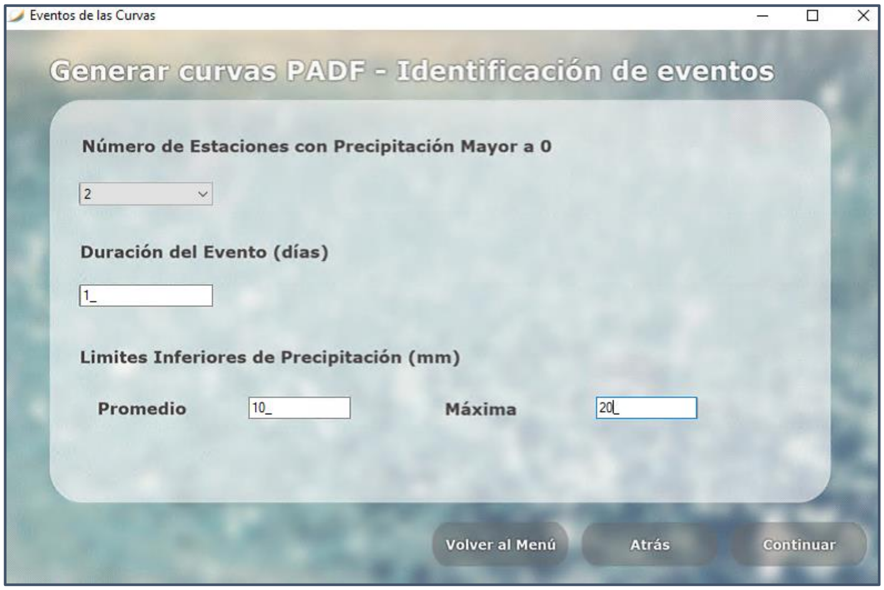

Figure 16. Parameters of rain events to generate PADF curves

Select the **Continuar button** and a window will appear indicating the number of events that accomplished the selected parameters as shown in the next figure.

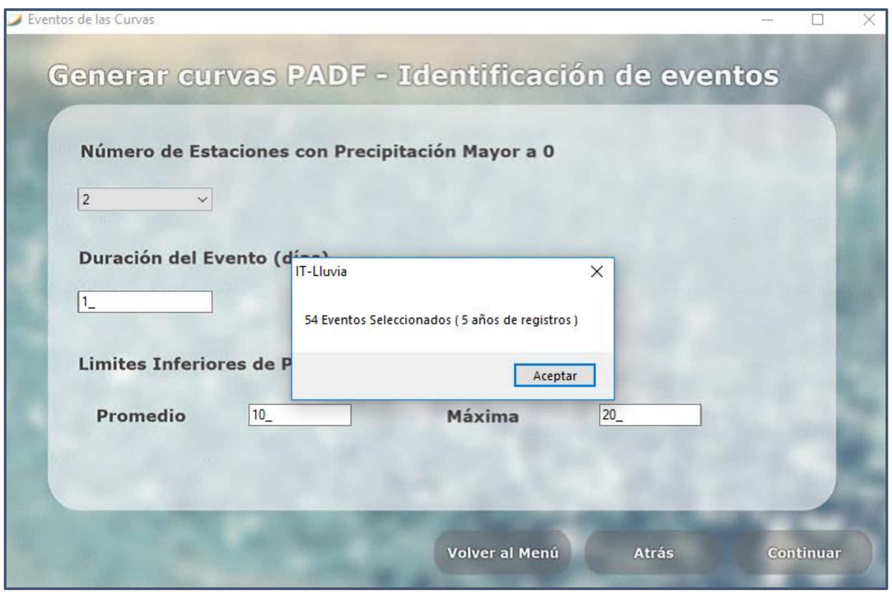

Figure 17. Window indicating the number of identified events

Click in **Aceptar button** and the window for selecting the return period of analysis will appear. Select the return periods that will be included in the PADF curves file. It is possible to add more return period by selecting the plus icon on the right panel. For this example select the 2, 10, 50 and 100 years return period and check the option for saving the map of mean multiannual precipitation for the selected events as shown in Figure 18. These two files will work together for generating the synthetic storms and the associated frequencies.

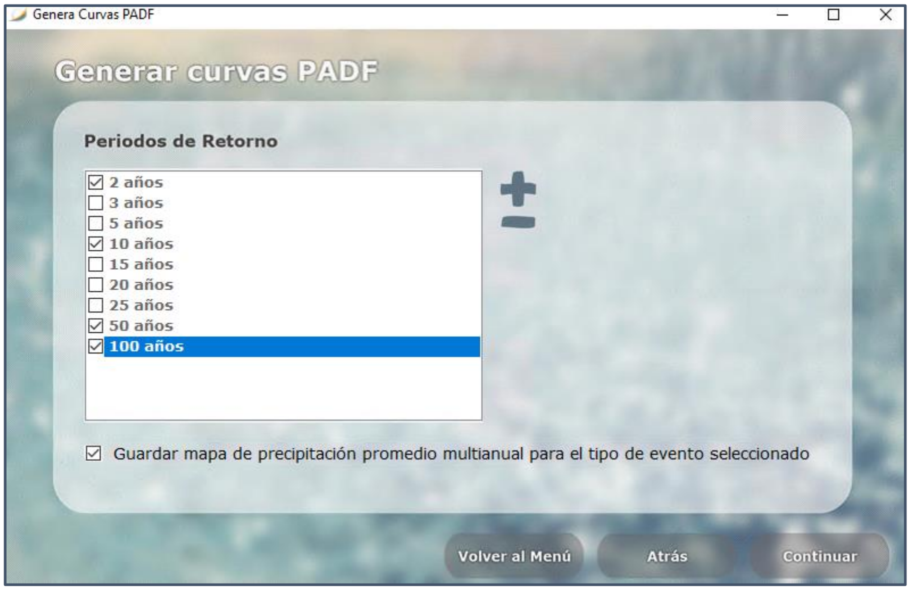

Figure 18. Selected return periods for the generation of PADF curves file

Select the **Continuar button** and the software will ask for a name to save the PADF curves file (*.dat). Type the name and continue this will start the calculation process. Once it ends, a window will pop up indicating the end of the process as shown in the next figure.

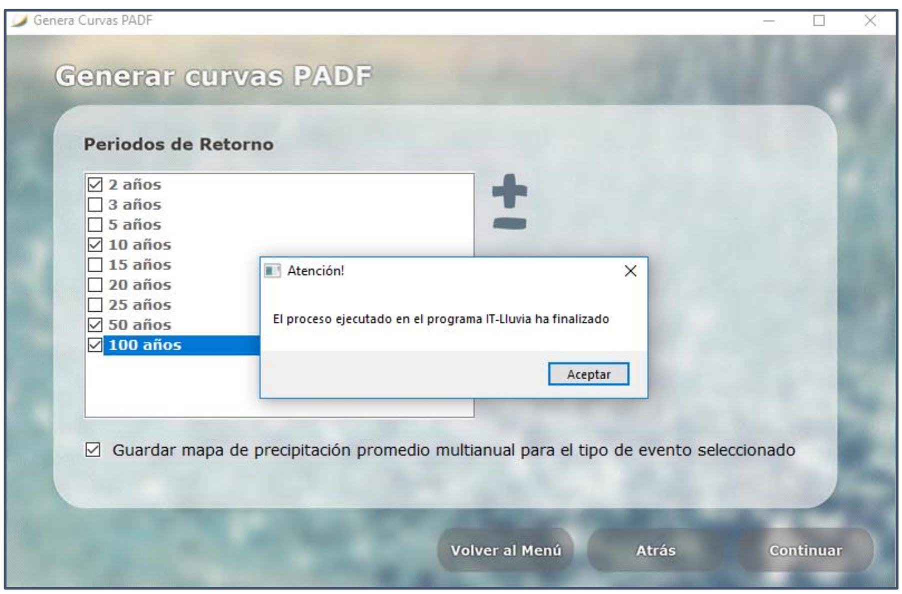

Figure 19. Window indicating the end of the PADF curves generation processing

6.1.2. Creating the AME Rain file

To begin this example if the program is closed, select the *IT-NHRain* icon in desktop or start bar and the main window of the software should appear as shown in Figure 13. If the program was already open, select the **Volver al Menu button** in any window to return to the main window.

Figure 20. IT-NHRain main window

For the generation of the stochastic storms select the **IMPORTAR button** and the input data window will appear. Introduce the necessary files, first the PADF curve *.dat file generated in the past section, then the basin boundary shapefile and finally the preferential localization of storm centers grid generated as well in the past section. This is shown in the next figure.

Figure 21. Input data for stochastic storm generation window

Click **Siguiente button** and the window of AME output parameters will appear. Select the number of stochastics storms to generate per return period, the number of simulations per storms and the cell size in meters according to the desire final resolution (number of cells of the output raster in both directions). The Figure 22 presents the selected values for this example.

Figure 22. Parameters of the AME Rain file window

Select the **Generar AME button** and the software will ask for a name to save the AME rain file (*.AME). Type the name and continue this will show the AME rain metadata window as seen in Figure 23, which contains all the parameters information of the AME.

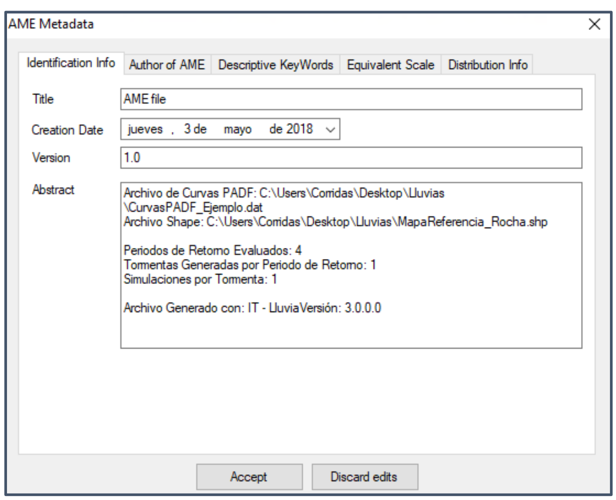

Figure 23. AME Rain file metadata window

Select the **Accept button** and the simulation process will begin. The software will display the progress and the generated storms in the right panel as shown in the Figure 24.

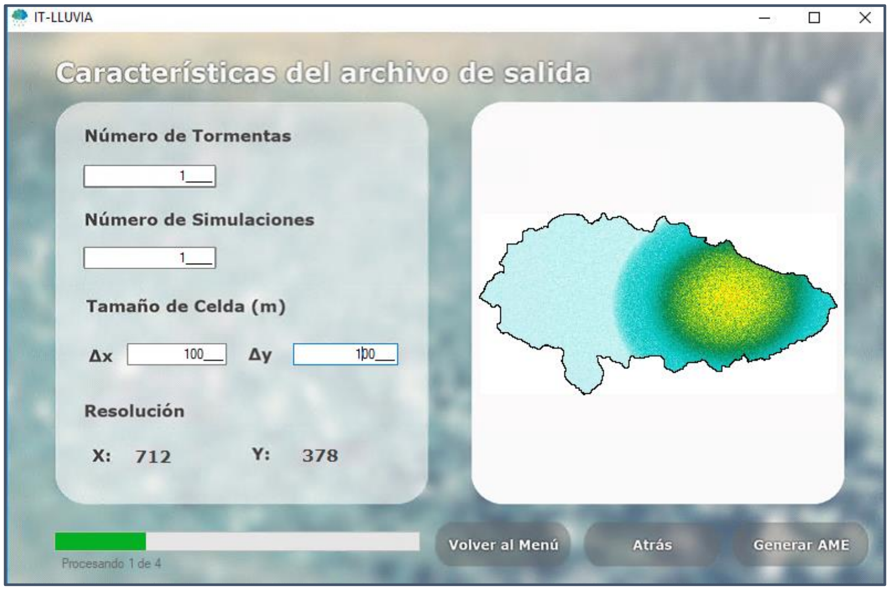

Figure 24. Simulation progress in the generation of stochastic storms

When the simulation ends, a window will pop up indicating that the AME file was created successfully. Otherwise, the software will indicate the generated errors during the process as shown in the next figure.

Figure 25. Window indicating the end of the simulation

The result AME can be open and seen in **CAPRA-GIS.**

6.1.3. Exiting the program

In any moment by pressing the close icon, the program will exit. There is no possibility to save a project file in IT-NHRain.

Chapter 7

Software limitations

7.1. Software limitations

The most important limitations of the software are listed below:

- Currently limited version only generates 20 stochastic storms.
- The proposed model works well in small or medium size basins. In the case of bigger basins, it is possible that the elliptical pattern with one storm center does not represent adequately the spatial distribution of rains.
- The input precipitation data can only be in Microsoft Excel 2003 version. The software is not compatible with newer versions.

Chapter 8

Problems and errors

8.1. Problems and errors

The identified problems at the time of creation of this manual are:

- The software is only available in Spanish. However, this manual can guide a non-Spanish speaker user to use the software in general terms.
- The basin boundary file (*.shp) must not contain additional information besides of the name for the attribute. Otherwise, the software will not read the file and it will return an error.

Chapter 9

References

9.1. References

Chow, V. T., Maidment, D., & Mays, L. (1994). *Applied Hydrology.* McGraw-Hill Science Engineering.

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World Meteorological Organization. (1969). *Manual for Depth-Area-Duration analysis for Storm Precipitation.* Cooperative Studies Technical Paper.