Precipitation Threshold Analysis for Floods and Landslides in a data-scarce environment; a Case Study from Buzau, Romania

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April, 2013

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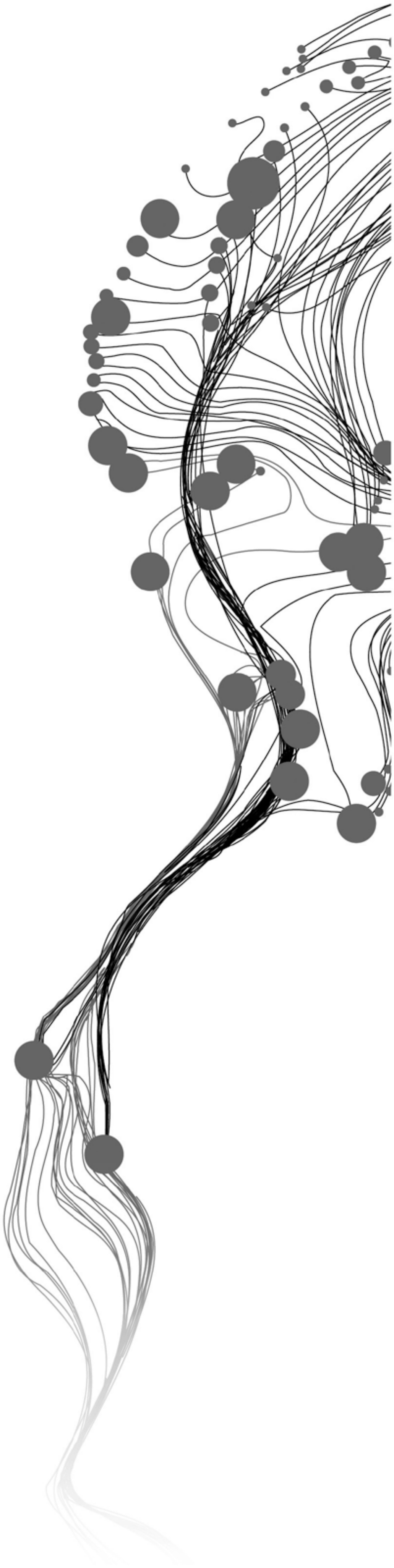

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Enschede, The Netherlands, April, 2013

Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
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ABSTRACT

The development of semi-automatic numerical routine for the deriving of rainfall thresholds for floods and landslides is proposed, based on antecedent rainfall accumulation and historical inventories of landslide and flood events in a case study of Buzau County, Romania. Different point-based precipitation datasets of daily values, from the NOAA-GHCN-Daily, NOAA-GSOD datasets and four stations from the Romanian Meteorological Organization; as well as a grid based point dataset (EOBS), derived from the European Union Framework 6 ENSEMBLES project, of daily rainfall values are obtained (a self-developed script for use in MatLab is presented for handling NetCDF files). As for the historical dataset, a list of dated flood reports available from the Institute of Geography - Romania Academy and Point, a polygon shape file and two point shape files for the location of landslides was delivered. One of the point shape files containing data extracted from diverse local media reports.

Precipitation data are assessed in terms of completeness of records, and compared between those datasets with the same spatial extent, to determine any correlation between precipitation values contained in them. Also recommendations are made for future blending of the Romanian Meteorological Organization precipitation dataset, based on available records of other stations within the dataset that could possibly substitute missing precipitation values. Precipitation datasets (NOAA-GHCN-Daily, NOAA-GSOD and the Romanian Meteorological Organization) are then discriminated based on the suitability of their use to extract daily and antecedent precipitation values for events contained in the available historical inventory of landslides and floods. As for the analysis of the historical inventory, prior to its use in the threshold modelling, quality is assessed in terms of completeness and temporal reliability of the local media derived records. Seasonal classification is done to set aside flood and landslide event records within snow cover and snowmelt periods, to focus on the events that are not possibly related to the snow processes. Temporal data from the USGS earthquake database is used as well to identify landslides that can presumably be triggered by earthquakes.

The resulting datasets from the discrimination processes for precipitation, flood and landslides are then combined to assign a hydrological condition based on antecedent rainfall accumulated values. With the combination of XXday and XX day accumulation of precipitation, the events are plotted to identify constrain parameters for the semi-automatic threshold modelling.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

1.1. Background

Floods and landslides are considered as hydrological hazards which occur in many parts of the world. In fact, together they represent over 50% of disaster events worldwide. According to the World Disaster Report 2012 (www.ifrcmedia.org) floods represent 47% (158) of the total of natural disasters and landslides 5.4% (18), although these figures are still a large underestimation of the actual events, due to the inclusion criteria for the disaster databases(EM-DAT 2013). According to EM-DAT's flood and landslide world statistics for the period of 1980-2008 they affected over 2,800 million people and caused estimated damages well over $13,700 million USD see Table 1.1.

	Floods	Landslides
No. of events	2,887	366
No of people killed	195,843	20,008
Average people killed per year	6,753	690
No of people affected	2,809,481,489	7,031,523
Average people affected per year	96,878,672	242,466
Economic Damage (US$ X 1,000)	397,333,385	6,059,838
Economic Damage per year (US$ X1,000)	13,701,168	208,960

Table 1.1 Flood and Landslide Disaster data 1980-2008 (EM-DAT 2013)

Because of EM-DAT's inclusion criteria these figures still do not represent the total number of occurrences worldwide. In fact events are only accounted for when it meets least one of the following criteria:

- Killed 10 or more people.
- Affected 100 or more people.
- Declaration of a state of emergency.
- Call for international assistance.

In contrast to landslide events mentioned in the previous datasets The International Landslide Centre has recorded between 2004 and 2010 a total of 2640 fatal landslides (Petley 2012). On the other hand, Munich RE has recorder well over 21000 catastrophic events between 1980 and 2012, out of which 35% represent hydrological events (floods and mass movements) (Munich RE 2013).

A disaster occurs when the threat of a hazard materializes into an actual hazardous event which impacts a vulnerable society(Thomas Glade 2005). The study of the hazard, which is defined as the probability of occurrence of a potential damaging phenomenon with certain intensity, requires information both in terms of its frequency and of its intensity, which in turn will allow the analysis of risk and enhance disaster risk management. It is specifically the frequency data that allows quantifying the hazard, and enables the calculating of risk and quantitative cost-benefit analysis for the planning of structural and non-structural disaster risk management measures(Neagu 2012). Since risk management is highly data dependant, the quality of the data will determine the quality of the results, hence the need for reliable, high-quality information (Aleotti and Chowdhury 1999; Glade, Crozier et al. 2000). For example, frequency analysis of hydrological hazards is directly affected by the quality of the data rendering its suitability for the hazard analysis and thus for the interpretation of the results (World Meteorological Organization 2008).

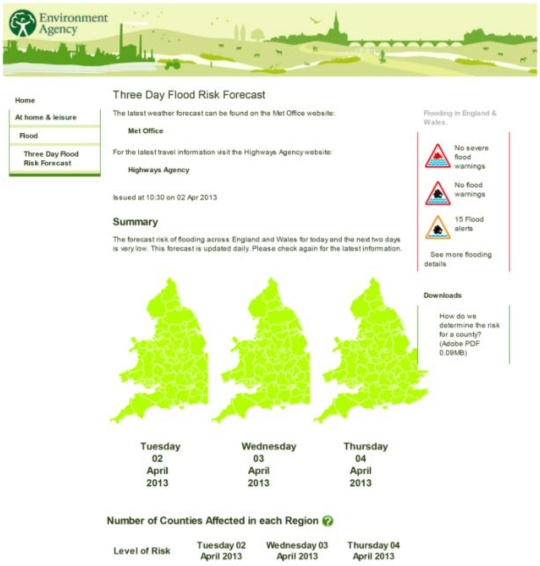

Figure 1.1 UK-Flood warning system
Source: (UK's Envorinment Agency 2012)

As part of the non-structural risk reduction measures are Early Warning Systems, which allow for the identification of a threatening hazardous event beforehand. They can be sophisticated as automated systems which will gather and process information in near-real-time or as participatory measures which includes human communication such as, but not limited to, telephones, wireless radios, sirens (Mercy Corps Nepal 2010). One aspect they have in common is the use of historical information to assess if the current conditions are capable of reaching a point where a disaster may occur, based on similar situation in the past. For example, in the United Kingdom, flood a warning system has been implemented by the Environment Agency through the "Three Day Flood Risk Forecast" Figure 1.1. It can be accessed by the public to obtain flood warnings in their area. Another example is the precipitation threshold implemented by the USGS for anticipating the occurrence of a landslide (see Figure 1.2). These are a few examples of how the understanding of a hazard can lead to take measures to minimize the impact of a disaster.

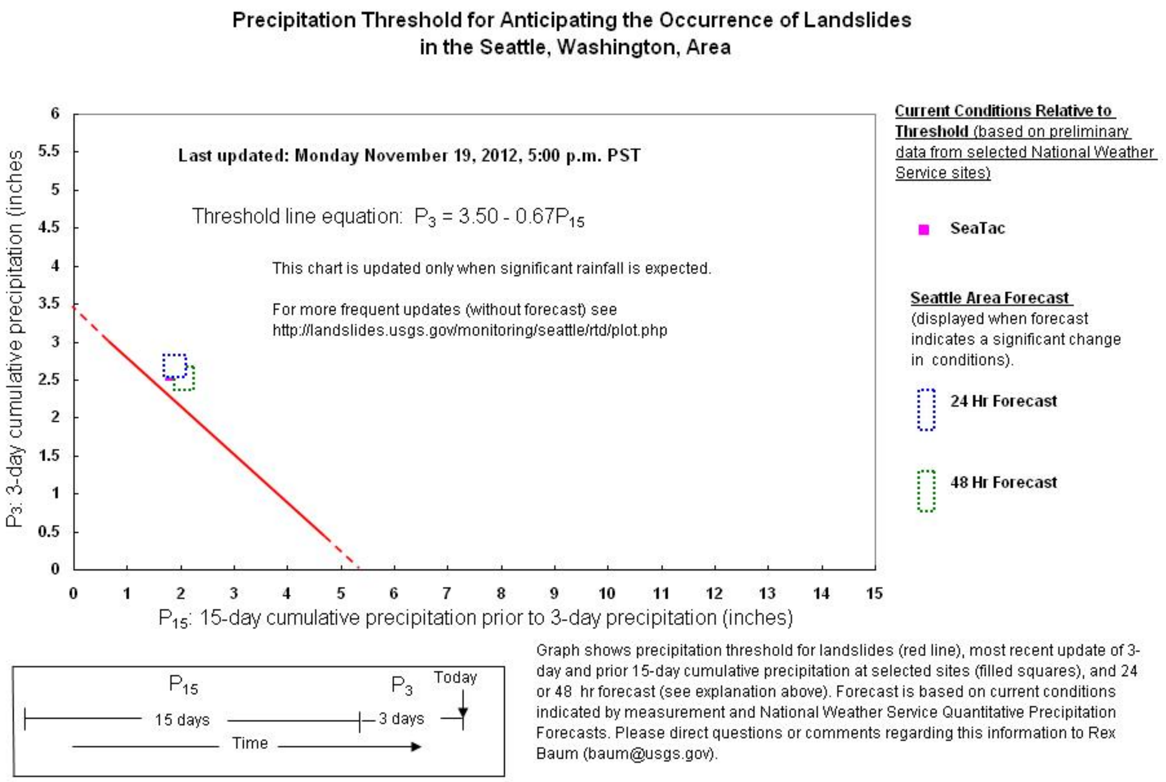

Figure 1.2 USGS Landslide Thresholds for Seattle, Washington
Source: (USGS 2013)

In the case of the threshold used by the USGS, it only illustrates the fact that a landslide may occur, but does not indicate where or the amount of events (Chleborad and Survey 2000). Another issue is the fact that thresholds are bound to the probability of occurrence, meaning that even when the threshold is reached or exceeded, a landslide could still not occur (Jaiswal and van Westen 2009), therefore it only shows that an event can probably occur.

1.2. Problem Statement

In some countries of the world, precipitation data is not readily available to the public or it is sold as a commercial product, at prices beyond the reach of researchers who are bound to budgets. Therefore, the need to obtain accurate precipitation data is a major problem in the analysis of precipitation thresholds. Nowadays there are several international sources of precipitation data through the application of specific satellite missions (e.g. Tropical Rainfall Monitoring Mission), or through agreements with international meteorological agencies in the framework of the World Meteorological Organization (WMO), although there is a probability that the values contained in these datasets are conflicting. In theory the datasets contain the same information, and are measuring the same variables, in fact these could come from the same original source, but still could have different values. On the other hand, completeness of these datasets should be assessed when dealing with hydro meteorological phenomena before using the data for any type of analysis related to hydro meteorological events.

Another major problem, which is sometimes more severe than obtaining precipitation data, is related to the information on the historical hazardous events related to the floods and landslides. Whereas for flooding, it may be possible to use discharge data at gauging stations to make the correlations, for landslides it is important to collect the individual locations of these events with information on the date of occurrence. This has proven to be the main obstacle in the determination of precipitation thresholds for landslides. Data collection on the occurrence of landslides

Precipitation values are useful when describing and understanding hydro meteorological related events, such as floods and landslides. In fact, early warning systems are designed to alert when a critical situation is reached. Monitoring is done through establishing thresholds, which in this case are the minimum required values for the probable occurrence of a landslide or a flood. There are different methods of obtaining the equation for such minimum. Although often thresholds are visually identified or manually fitted in a plot (Reichenbach, Cardinali et al. 1998; Kuthari 2007; Jaiswal and van Westen 2009; Baum and Godt 2010; Jaiswal, van Westen et al. 2010; Diakakis 2012). Extreme precipitation might become hazardous as it potentially triggers flood or landslides. In order to assess the risk and whether risk reduction measures need to be taken we need to understand how the process of water accumulation relates to such hazardous events. Therefore, to be able to know the minimum limit at which this occurs, a threshold must be established. This will allow in the future for early warning systems planning.

1.3. Aim and Objectives

1.3.1. Aim

The aim of this research is to explore the possibility to develop precipitation thresholds for landslides and floods in a data-scarce environment, which has a deficiency in both precipitation data and historical data on flood and landslide occurrences. The study will explore whether precipitation data derived from different sources, including gridded data from internet sources, can be used in combination with historical information derived from local newspaper reports, and records from civil protection. The aim is to develop routines for the (semi) automatic analysis of the precipitation thresholds using combinations of daily and antecedent data, and apply this for a data-poor region in Romania.

1.3.2. Sub-objectives

To be able to establish numerical thresholds several steps must be followed. The use of different datasets makes it a first priority to assess the data quality for the different sources, as well as the suitability to be used in the present research. Once the suitability is assessed, spatial and temporal correlations between occurrence of floods and landslides and precipitation characteristics must be established. The following sub-objectives have been formulated:

1. To evaluate precipitation information from different sources, to identify suitable data based on data quality for its use in a precipitation threshold analysis.
2. To generate a database with as many, and as accurate, dates of occurrence of landslide and flood phenomena, and to use the suitable data for a frequency analysis of reported hazardous events (floods/landslides).
3. To identify precipitation parameters that trigger landslides and floods in the area through spatial and temporal correlation of dates with precipitation values, to be used in a threshold fitting model.
4. To determine a mathematical model to best fit a linear threshold by false positive discrimination with each suitable dataset.
5. To identify the return period of the precipitation parameters defined by the threshold, and to determine whether or not it was an extreme value.
6. To make recommendations based on the different datasets used for threshold modelling.

1.3.3. Research Questions

- Which data sources for precipitation data can be obtained for Buzau County, Romania which are suitable for use in a hazard triggering analysis?
- What is the spatial extent, temporal coverage and completeness of the available precipitation data and is the extent suitable for hazard triggering analysis in the region?
- What is the correlation between precipitation data from different sources?
- Which are the precipitation parameters (based on the different suitable datasets) at specific dates of reported floods and landslides in the area?
- What is the best fitting regional threshold for precipitation-induced floods and precipitation-induced landslides?
- How many different thresholds can be made depending on the season, and on the type of event (e.g. flash floods, river floods, debris flows, shallow landslides, slow moving deep-seated landslides)
- How to make a threshold fitting model and that identifies the threshold in a semi-automated way?
- How different are the values of a threshold between datasets?
- What are the recommendations when using the different datasets?

1.4. Study Area

Buzau County, Romania, is located 110km NE of Bucharest (figure XXX), covering an approximate area of over 6150km^2, which half is mountains and hills. It is considered to be in the middle of the Vrancea Seismic Region, being the most seismic active region in Romania and considered to be the most active province in Europe (Sokolov, Wenzel et al. 2009; Bălteanu, Chendeş et al. 2010)

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According to the Government of Romania, floods have a very large frequency of occurrence. Events with high negative effects have taken place in 1970, 1975, 1985, 2002, 2005, 2006 (Ministry of Environment and Sustainable Development 2007). This is due to snow melts during spring, as well as downpour in the summer, which eventually can cause floods. There has been several studies about floods in the area, like (Mihaela Borcan 2010), (Neagu 2012). Precipitation in the Eastern Carpathians ranges from 600 to

1000mm (spread over 85-125 days), and snow cover that lasts between 100-180 days (Bălteanu, Jurchescu et al. 2012).

Landslides in Romania have been studied as early as 1920 (Bălteanu, Jurchescu et al. 2012). Several geomorphological mapping projects, field surveys and laboratory tests have been done in the Carpathian area (Bălteanu, Jurchescu et al. 2012), this have revealed some patterns in the mass movements. For example, the fact that almost 75% of the active landslides recorded in the mountains develop on deforested slopes. Romania is divided among 11 basic units for river management, river basin which are directly or indirectly sub-basins of the Danube River.

It is one of the most populated regions in Romania, with an average population density of 90 inhabitants/ km^2 and reaching up to 150 inhabitants/km^2 along the main valleys.

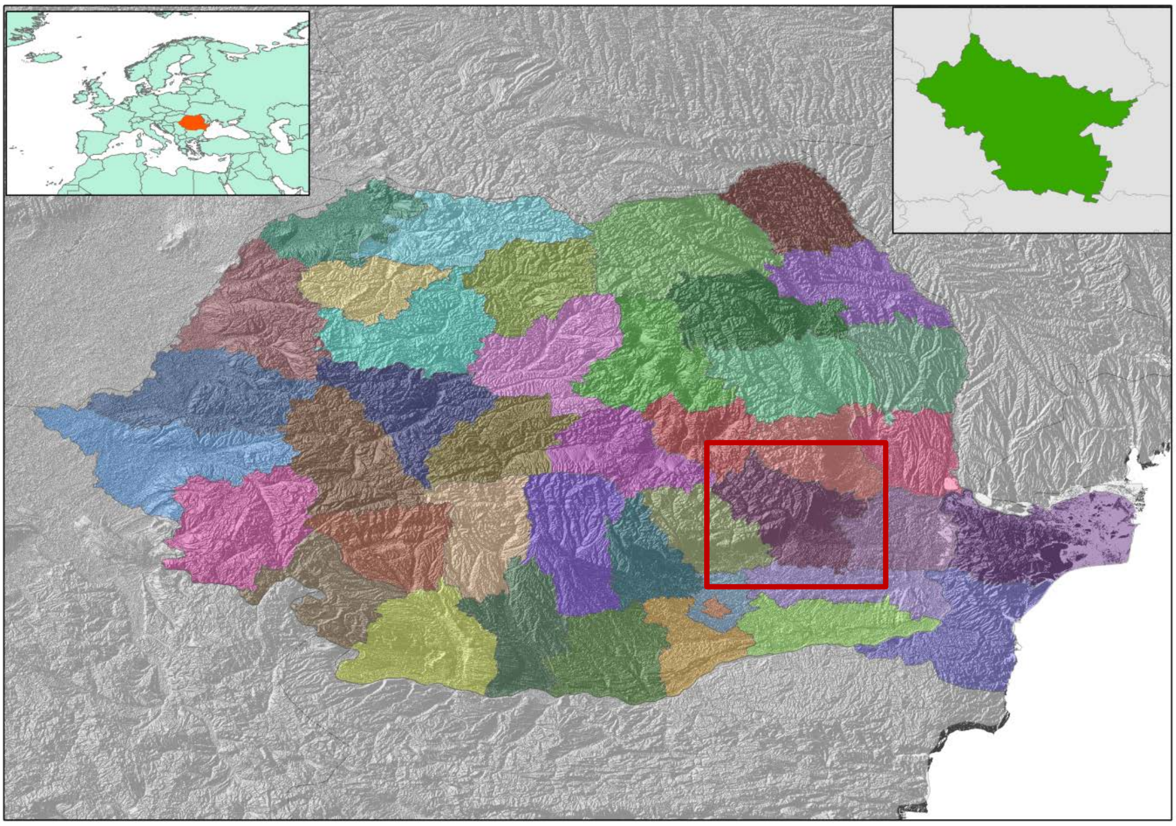


Figure 1.3 Study Area - Buzau County

1.5. Methodology

The study was carried out throughout different phases addressing the different objectives established for the present study. To establish a threshold, empirical data is needed; Section 3.1 describes how data on earthquakes, floods and landslide occurrences (landslide and floods) were acquired. Floods and landslide inventories were made available by CHANGES partner in Romania. Through spatial and temporal analysis of the historical inventories of landslides, delivered in 2 polygon shapefiles and one point shapefile are merged into a single dataset containing only events with a date of occurrence. In the case of the flood historical inventory, based on river gauge reports, the location of river gauges is deducted to establish a point position for every gauge, and events reported at locations that would impact the study area are selected. Section 3.2 addresses the different sources of daily precipitation data that were acquired (four datasets in total). One third of the data is gathered from internet sources in different file formats and one dataset through the CHANGES partner in Romania. Point datasets are made into tables, and a grided dataset is used to extract station specific point values to construct the table to be used when comparing the different precipitation datasets in Section 4.1, where they will be analysed based on the completeness of each point (weather recording station).

To assess the completeness of the datasets (section 4.1) a temporal analysis is done to assess the continuity of the records of every weather recording station in every datasets, based on the dates within the initial and last record. This will establish any date steps (any gaps between dates). Following the temporal analysis, and as part of the completeness analysis data is assessed by quantifying the number of records that contain a value for precipitation, as well as records that report a "missing value". Through the analysis of date steps as well as the "missing values", data will be compared with datasets that are similar. Country wide datasets are compared separately as to regional datasets. From the information derived in Section 4.1, the comparison of datasets in section 4.2 is done through correlation of the available precipitation values. Records with reported "missing value" in one dataset will result in discrimination of the record in both datasets that are being compared. Results from 4.1 and 4.2 are assessed in section 4.3. The suitability of the datasets is established in section 4.3 where precipitation data is selected based on completeness of the records, rendering a dataset suitable or non-suitable to be used in a threshold modelling approach, achieving sub-objective 1. The selected dataset(s) is analysed to determine maximum precipitation values and the return periods associated to them, to be used in section 5.

Hazard frequency analysis in Section 5.1 and 5.2 is done by quantifying the number of events that occurred in the area, per year, as well as by month. This latter classification will allow identifying the season in which evens occur the most, as well as focus on the events that are not subject to snow cover or snowmelt processes'. In the case of flood (section 5.1) precipitation values are assigned to the flood dates by temporal analysis to link weather recording station data to the flood date. In the case of landslides (section 5.2) a spatial and temporal analysis is done to be able to assign the precipitation values from the closest weather recording station. Therefore, distance is calculated from the landslide event to every station to select the closest one that would better represent precipitation characteristics for the date of occurrence. Results from Section 5 address sub objectives 2 and will enable to address sub-objective 3. In the case of floods, only precipitation is analysed as a triggering. On the other hand, landslides are analysed for earthquake induced-events to set aside those events not related directly with precipitation as well as events outside the period of June-September.

Section 6.1 achieves Sub objective 4 by the design of a mathematical model in MatLab to use user defined constrains for running different equations, creating a confusion matrix for every equation that is fitted, allowing the user to determine the number of equations to be tested. With the values from the confusion matrix, the probability of an event becoming a landslide when the threshold is exceeded can be calculated.

Based on the procedures and results, recommendations are done in section 8, discussion and conclusions.

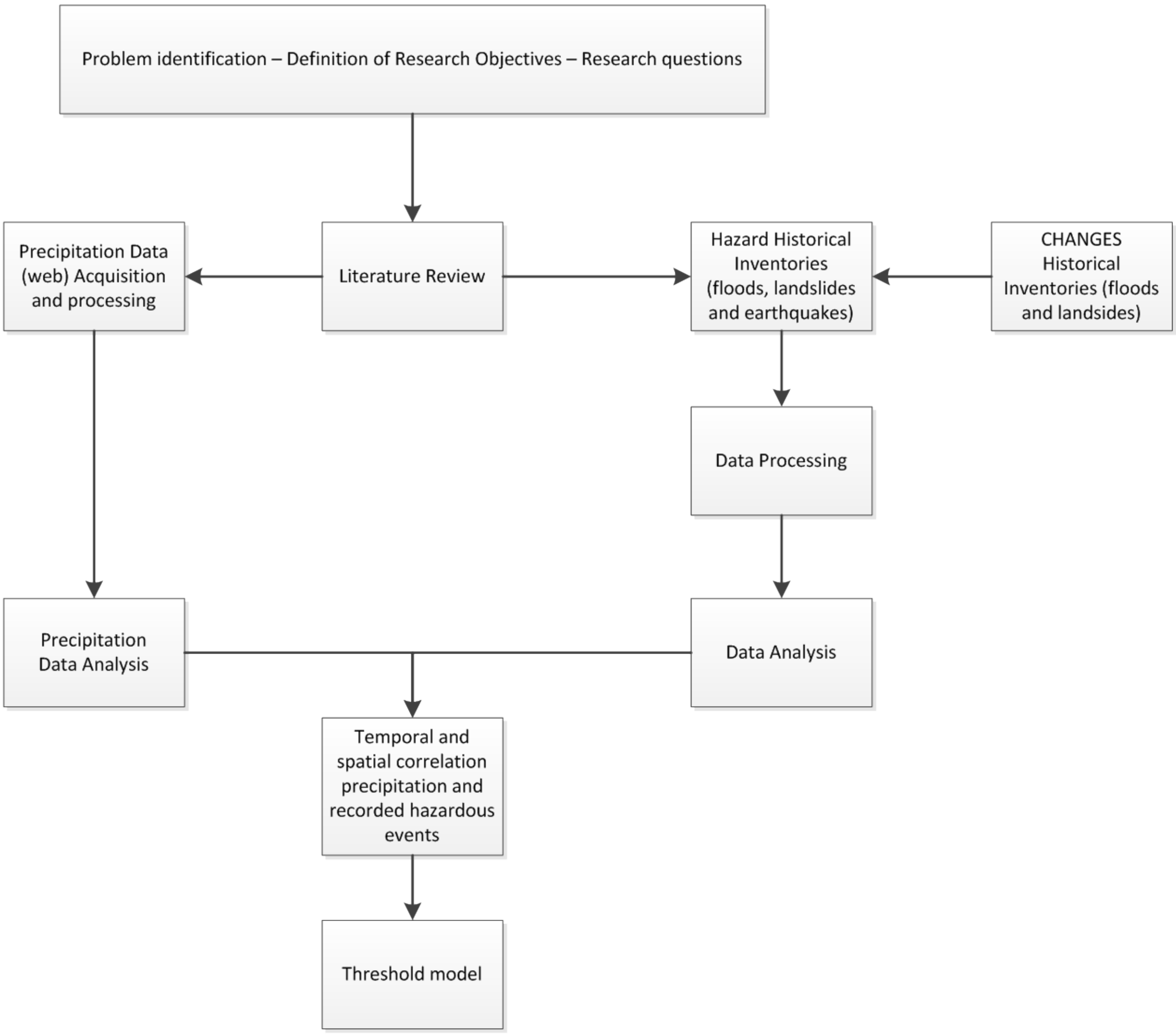


Figure 1.4 Flowchart of proposed framework

1.6. Thesis structure

The research mainly focuses on 3 main aspects. The acquisition of precipitation data other than the CHANGES partner to create a comparable dataset useful for the CHANGES project in regards to data availability for Buzau County, Romania. The second aspect focuses on the quality of the data used in the thesis, such as hazard historical inventories and precipitation data, as well as the results from the inherent quality of the different datasets. As a third aspect, the study presents a semi-automated threshold fitting model based on MatLab, for precipitation induced landslide events, as well as rainfall thresholds for floods.

Chapter 1: Contains specific information about the study area, the problem statement, as well as the objectives and research questions to address the problem.

Chapter 2: Contains the background and the scientific approaches to the use of thresholds as indicators of a probability of a landslide or flood to occur if the threshold is exceeded.

Chapter 3: Contains a general description of the datasets that are to be used during the research, file formats obtained as well as spatial location of the data used.

Chapter 4: Contains the steps that have been followed to assess the quality of the data, such as completeness.

Chapter 5: Contains the frequency analysis of precipitation data, as well as temporal and spatial correlations with precipitation, as well as the data selection for use in threshold modelling.

Chapter 6: Contains an explanation of the procedure to be followed to determine a threshold through the use of the proposed MatLab code.

Chapter 7: Provides the conclusions based on the research questions address throughout the research. Also discussions on the procedures and recommendations.

2. LITERATURE REVIEW

2.1. Threshold Analysis

The occurrence of landslides is widespread, not only in space and time, but also in different physical environments e.g. meteorological and geological (Varnes 1984). Unfortunately, landslides cannot be predicted, and therefore are expressed in terms of frequency, return period, or exceedance probability. Frequency can be assessed by analysing the influence of factors that act as triggers (e.g. earthquakes, precipitation) and is expressed in amount of events in a given time. The return period is the inverse of the annual probability, and refers to the average time period in which an event of certain magnitude is expected to occur. Frequency-Magnitude relationships can be established through historical inventories, although there are issues when doing so, for example it can be the case that the environmental conditions are no longer present in the area (Crozier 2005). As for the exceedance probability, it refers to the probability of an event of magnitude *n* will happen or will be exceeded in a defined period of time.

Frequency may be expressed as absolute, relative or indirect (Corominas and Moya 2008). Each of which is used for different purposes. In the case of absolute, it expresses the number of events given at a specific site or a defined area by number of events per year. In the case of indirect frequency it is used to express frequency in terms of event consequences such as volume displacement. Absolute frequency is often used to describe first-time occurrences or reactivation of previous events. Although the probability of an event being re-activated is different from that of a first-time occurrence, since conditions have been modified (rock falls and debris flow are considered as repetitive events). Then relative frequency is used for quantifying by land units and not necessarily by number of events for example area per year, especially when dealing with Multiple Occurrence Regional Landslide Events (MORLES). In the case of indirect frequency it is used to express frequency in terms of event consequences such as volume displacement.

The approaches to assess the probability of occurrence of landslides are described next.

2.1.1. Heuristic Approach

It is considered as the most basic estimation of landslide frequency, and is based in expert criteria (Corominas and Moya 2008). It is based on the principle that landslides are likely to happen where they have occurred before, and in similar settings (e.g. geological and hydrological). Expert opinion in past events is used to understand what can probably happen (Varnes 1984). A common practice is the use of weights for different criteria, where such weights are assigned by experts, after analysing factors that may lead to landslides (Castellanos Abella and Van Westen 2008; Ruff and Czurda 2008). Although one could argue that different experts would analyse it differently and therefore the weights would result different (Ding, Yang et al. 2006). E.M. Lee (2000) displays the process graphically by showing the different weights of each path, see Figure 2.1. The probability is calculated from the product of the probability for each path.

Given that the method relies on expert opinion, it's the only feasible approach when dealing with numerous landslides caused by different factors (Ruff and Czurda 2008)

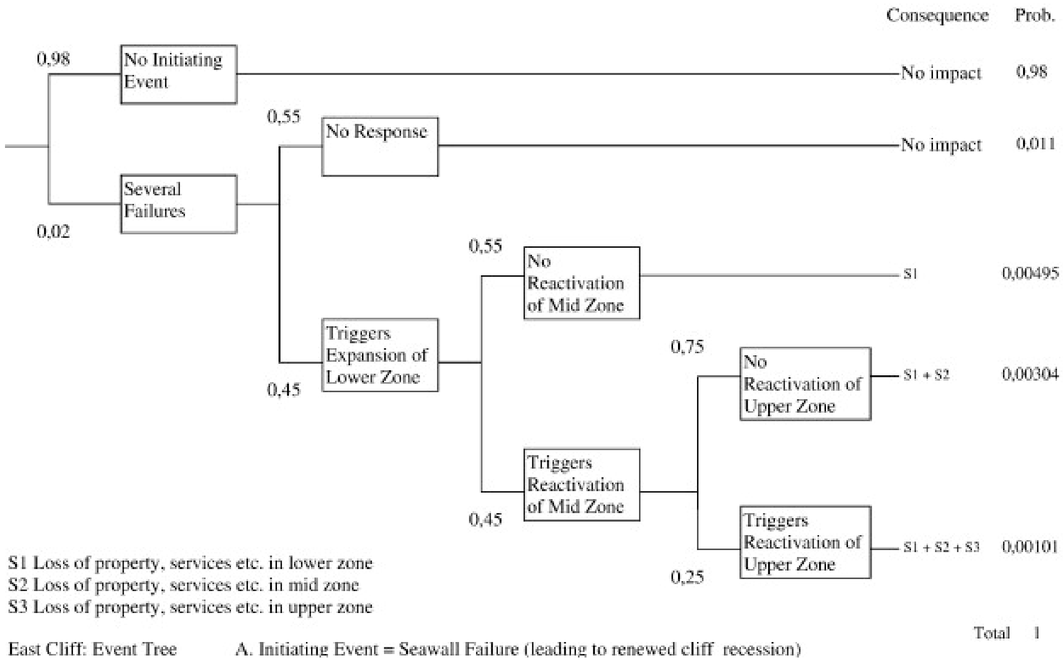


Figure 2.1 Event Tree approach taken from (E.M. Lee 2000)

2.1.2. Rational methods

Rational models considered as geomechanical methods incorporate geological and can incorporate hydrological properties of the site to be analysed. Rational models, such as the infinite slope model determine slope stability through numerical modelling and can be implemented in GIS platforms. It is commonly used to determine landslide hazard analysis, expressing the hazard degree by a *Safety Factor* which is calculated by the ratio of the forces that result in slope failure and those that keep it from failing. Then, the Safety Factor is assumed as the probability of the factor being less than 1 (Corominas and Moya 2008; van Westen 2011). First Order Second Moment, Point Estimate and the Monte Carlo Simulation methods are the most commonly used for calculating the probability of failure (Aleotti and Chowdhury 1999; Haneberg 2005).

Slope stability analysis can be combined with hydrological modelling to assess the effect of water in different lithology (Schmidt and Dikau 2004). For single hazards at a local or regional scale, transient hydrological 2D or 3D finite element models can be applied (Miller and Sias 1998; Shrestha, Yatabe et al. 2008). Shallow landslides can be analysed at a regional scale with simplified hydrological methods using GIS analysis

Dynamic modelling can also be achieved, although the information requirements of such models include rainfall intensity, antecedent hydrological conditions, soil properties, and the conductivities of both saturated and unsaturated conditions (Crozier 2005).

2.1.3. Empirical Probability

Based on the frequency observed from previous landslide events, probabilistic models can be implemented (Guzzetti, Reichenbach et al. 2005). Very similar to the approach used in hydrological analyses, the annual probability of landslide occurrence is obtained based on the assumption that landslides occur randomly and independently as recurrent events. Although these assumptions do not entirely apply to landslides, especially the independency of events, but given a lack of understanding on the physical processes which control landslides, this approach is accepted as a first approach, and quite frequently used as the only viable method for landslide probability analyses (Crovelli 2000; Corominas and Moya 2008).

According to Crovelli (2000) Poisson and Binomial models are most commonly used to obtain the probability of a landslide. Where the binomial model has the restriction of time being discrete, which means time is divided into a series of discrete increments of the same length, and for each increment only one event may or may not occur. The binomial model is commonly used in the estimation of flood occurrence, as well as debris flow. In the case of the Poisson model, the annual probability of a landslide event of a given magnitude which occurs on average one time every T years is:

$$P\{N = 1; t = 1\} = \frac{1}{T} = \lambda \qquad \text{Eq.(2.1)}$$

Where T is the return period of the event, and λ is the expected frequency for future ocurrences (rate of occurrence). The Poisson distribution of *n* landslides during time *t*:

$$P\{N(t) = n\} = e^{-\lambda t}\frac{(\lambda t)^n}{n!} \quad \text{where} \quad n = 0,1,2,\ldots.. \qquad \text{Eq.(2.2)}$$

For the probability of occurrence of one or more landslides in t years the equation is:

$$P\{N \geq 1; t\} = 1 - e^{-\lambda t} \qquad \text{Eq.(2.3)}$$

Equation 2.3 depends on the magnitude of the landslide events. Therefore, Magnitude-Frequency relations should be established in order to carry out the quantitative assessment of the landslide hazard. It must be taken into account that different landslide types occur with different at different time patterns. In case the same location is in theory affected by different landslide types derived from different sources, it will result in an increase of the probabilistic occurrence; therefore the combined frequency must be calculated.

2.1.4. Indirect Approaches

Definition of rainfall or earthquake induced landslides has been a topic of main interest for the past decades. A threshold for rainfall-induced landslides must be defined as the minimum and maximum threshold. Where the minimum threshold is defined as the precipitation value

One of the most predominant early work on a definition of rainfall-induced landslides was carried out by Caine (1980). By plotting Intensity-Duration (ID) curves of rainfall events, from diverse climatic and geologic characteristics in which landslides occurred, he was able to identify that landslide events occurred above a curve defined by the characteristics of rainfall. Although the thresholds were generalized, the curves are still being estimated but for specific areas. (Guzzetti, Cardinali et al. 2004; Hong, Hiura et al. 2005; Chleborad 2006; Corominas and Moya 2008; Papa, Medina et al. 2012; Peruccacci, Brunetti et al. 2012). Along with the ID approach, intensity linked to antecedent rainfall has also been developed.

Thresholds based on ID curves require detailed data which in many cases is not available; therefore a threshold approach by using antecedent and daily rainfall has been developing as well. This method combines the previous hydrological settings, varying from antecedent number of days depending on the area (e.g. 5 days, 15 days, one month, two months or more, as well as periods in between)(Aleotti and Chowdhury 1999; Chleborad 2006; Baum and Godt 2010; Jaiswal, van Westen et al. 2010) to mention a few. For Slovenia, Jemec and Komac (2011) classified landslides in two groups. The first group contains landslides that occurred after a high intensity - short duration rainstorm which surpassed the antecedent rainfall. The second group contains landslide events with a longer antecedent period of 7 days.

2.2. Precipitation Thresholds for Floods

As for floods, the study of precipitation thresholds is less explored and more recent (Reichenbach, Cardinali et al. 1998; Martina, Todini et al. 2006; Montesarchio, Lombardo et al. 2009; Golian, Saghafian et al. 2011). The process to determine a threshold can be summarized by the fitting of an equation in the lower boundaries at which a flood or landslide took place.

2.3. Threshold fitting

In most of the literature reviewed, the mathematical or statistical methodology for the fitting of a threshold is not specified, but three methodologies stand out (7th Framework Programme Cooperation Theme 6 Environment 2010):

- Manually fitted over a linear or logarithmic scale, in an attempt to represent the lowest boundary at which hazardous events occur, and the parameters of the functioned derived from the visual plot.
- The equation describing a threshold is first adopted, and the parameters are adjusted to fit the data.
- A function is fitted to the data and shifted to visually match the lower boundary of the data.

3. DATA COLLECTION

This chapter presents the available data for this research. Initially as this research contributes to the EU FP7 Marie Curie Initial Training Network CHANGES (www.changes-itn.eu) we were convinced that the Romanian counterpart in the project would provide the required data. However, during the course of the MSc research it became clear that this was a false belief. Unfortunately it was impossible to obtain meteorological data from the operational weather stations directly from the Romanian Meteorological Organization (RMO) as commercial prices were asked exceeded the available budget. However data from some stations in the direct region of interest have been made available through the counterpart of the CHANGES project.

Other data sources were consulted in order to maximize the spatial coverage with respect to that of the stations provided through the CHANGES partner. Two datasets from the National Oceanic and Atmospheric Administration (NOAA) were obtained for specific weather stations, as well as point data and a gridded observational dataset for precipitation (called E-OBS from here on) from the European Climate Assessment and Dataset (ECA&D).

The datasets contain time series of daily precipitation in different formats. ASCII and NetCDF (Network Common Data Form), files have been used, depending on the dataset. For the ASCII files, two different formats were used and handled with Excel and MATLAB (NOAA-GSOD & NOAA-GHCN). NetCDF files were analysed using a series of commands within a self-developed script using MATLAB and the NetCDF toolbox allowed for reading and data extraction (See Appendix A for script).

3.1. Hazard Occurrence Events

3.1.1. Landslide data obtained from the CHANGES Partner

Landslide data has been compiled by the Institute of Geography – Romanian Academy (IG-RA), through the Natural Hazards Research Center in Patarlagele, Romania. It was made available in three separate files, see Figure 3.1.

3.1.1.1. Landslide Polygon-Shape file IG-RA Inventory

Through a first inventory file, nearly 1500 polygons of identified landslides were made available. From this dataset, only 74 events contain a date of occurrence and a vague damage description. Recorded dates range from 2006 through 2011. A second file was delivered, based on landslide mapping from an orthophoto with a total of 107 landslide polygons. However, none of the polygons contain recorded date of occurrence. Through simultaneous review of the data, there are a number of polygons that are overlapping so a spatial analysis was carried out to clip and merge polygons, in order to eliminate any duplicate mapped area. As a result, 1603 polygons of landslide areas are used in single polygon-shapefile for this research.

3.1.1.2. Landslide Points with information from Local News Media

A total of 96 events were registered by accessing local news media (Opinia de Buzau http://www.opiniabuzau.ro/, Sansa Buzoiana http://www.sansabuzoiana.ro/, Strada http://www.stradadebuzau.ro/, Viata Buzaului http://viatabuzaului.ro/) and records from the County Council as well as the Civil Protection Agency. Through personal communication with Mihai Micu from the GI-RA the task was quite challenging and encountered the following issues:

- Records range from 1990-2005, since anything before 1990 was not published to readers due to the political regime.
- Newspapers rarely keep digital archives, therefore on-site review was required.
- Landslide reports vary from one publication to another e.g. day variation on reported dates, so time intervals were used to reference the date.
- Reports only log events which caused damages.
- Reference is only by village without an exact location.

For the record, this dataset was put together to enable more records to be used when analysing precipitation data, but by no means should be used for a spatial distribution of landslides, other than weather recording station correlation.

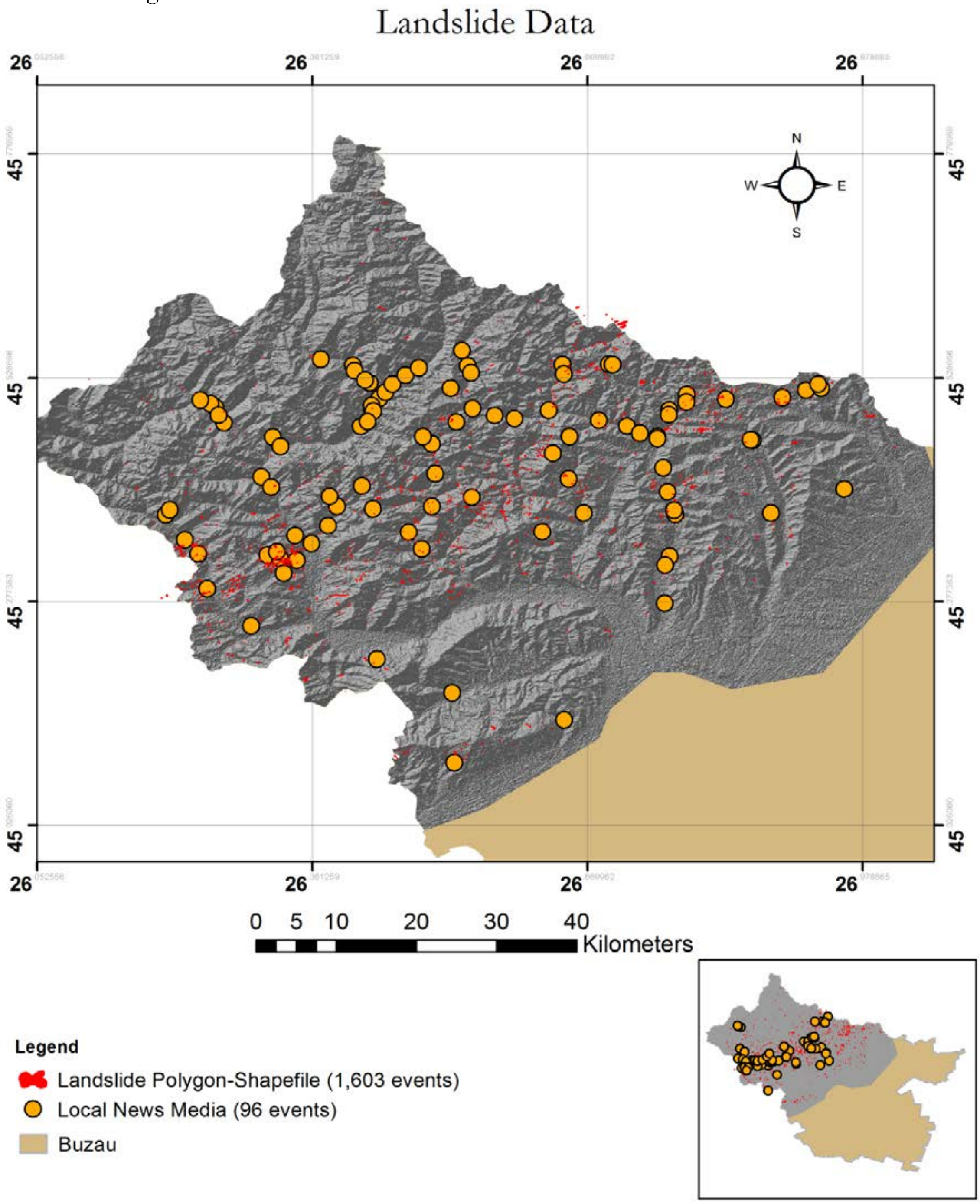


Figure 3.1 Landslide Data

3.1.1.3. Compiled Landslide Dataset

From the polygon and point shape files, data with recorded date is extracted from each dataset to conform a new point file. From here on, the information contained in this dataset will be referred to as Compiled Landslide Dataset (CLD) and contains the events that have been used for this research, see Figure 3.2 for CLD's spatial distribution.

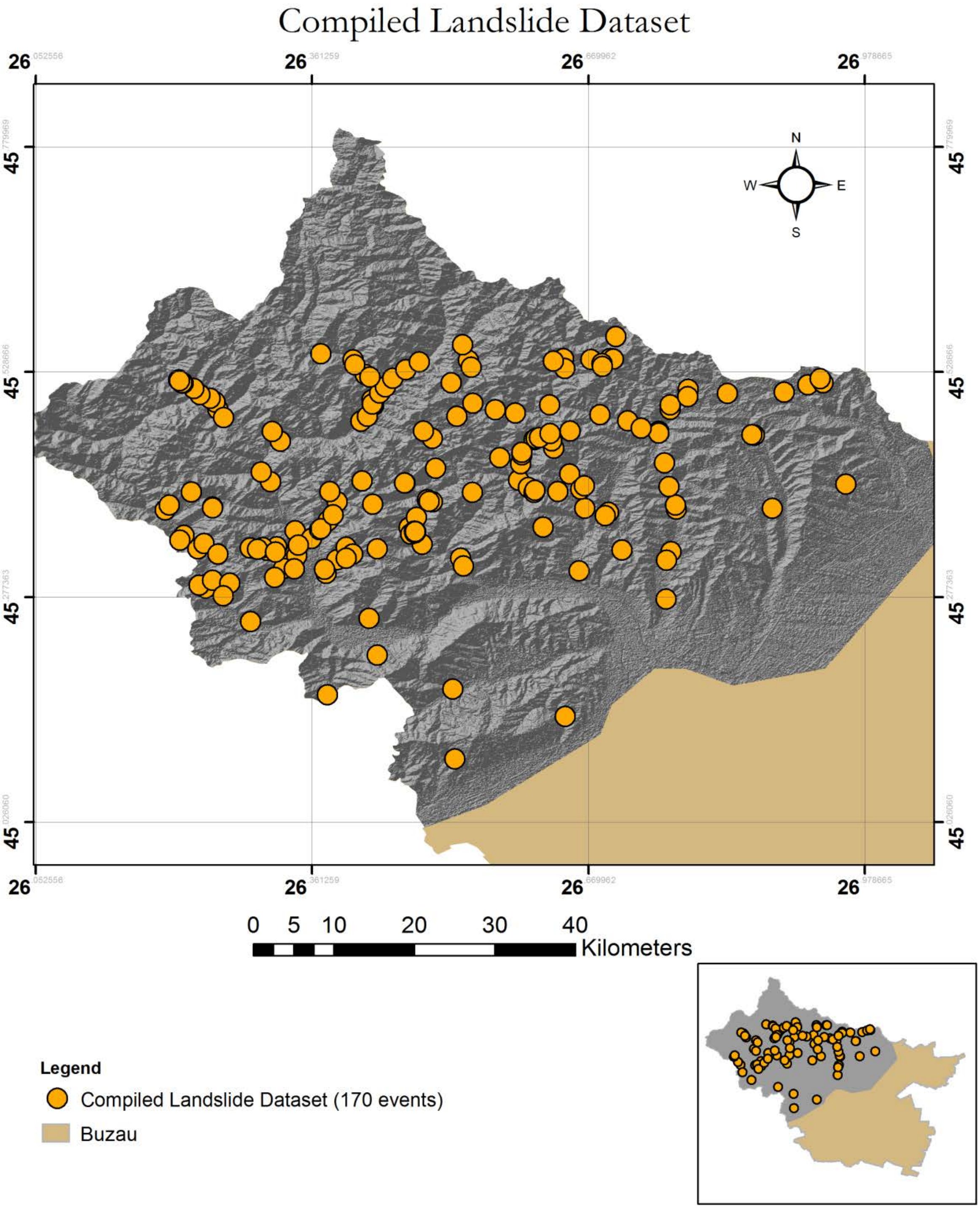


Figure 3.2 Compiled Landslide Dataset

3.1.2. Flood data obtained from the CHANGES partner

A list of flood events was made available by the Institute of Geography – Romanian Academy. The list contains the date of the event and information associated to respective river gauges. A total of 149 events have been registered from 1975 until 2011 through 44 river gauging stations (RGS) in the Buzau-Ialomita basin. However, not all flood events occurred within Buzau County limits. Therefore, a selection of RGS's was done by geographically positioning each gauging station from the list, with respect to the nearest river section related to the town that was used as reference name in the list.

From the 44 river gauging stations, there are a total of 5 within Buzau County and one outside the county limits (see Table 3.1 for flood reports list and Figure 3.3 location of RGS).

Date	River	RGS	Date	River	RGS
7/3/1975	Buzău	Sita Buzăului	6/20/2001	Buzău	Sita Buzăului
7/2/1975	Buzău	Nehoiu	7/27/2002	Buzău	Sita Buzăului
7/2/1975	Buzău	Măgura	2/16/2005	Buzău	Sita Buzăului
7/3/1975	Buzău	Banița	5/7/2005	Buzău	Sita Buzăului
7/2/1975	Bâsca Chiojdului	Chiojdu	5/7/2005	Buzău	Măgura
6/30/1991	Buzău	Măgura	5/8/2005	Buzău	Banița
6/30/1991	Buzău	Banița	7/11/2005	Bâsca Chiojdului	Chiojdu
7/18/1991	Bâsca Roziliei	Bâsca Roziliei	9/21/2005	Buzău	Sita Buzăului
7/29/1991	Bâsca Chiojdului	Chiojdu	12/30/2005	Buzău	Sita Buzăului
3/10/2000	Buzău	Sita Buzăului	8/11/2006	Buzău	Sita Buzăului
6/5/2001	Buzău	Sita Buzăului	3/23/2007	Buzău	Sita Buzăului

Table 3.1 River Gauging Stations – Available flood reports through the CHANGES partner

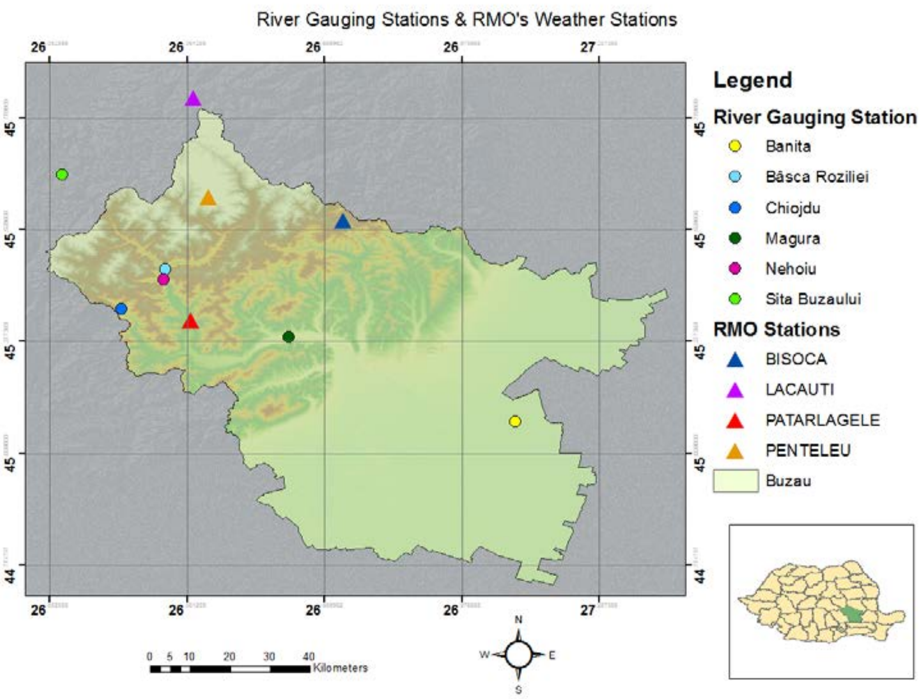


Figure 3.3 River Gauging Stations & RMO's Weather Stations

3.1.3. Earthquake data from the United States Geological Survey (USGS).

Given the active seismic nature of the area, and the possibility that landslides might have been triggered by earthquakes instead of rainfall, an inventory of earthquake events was acquired through the "Global Earthquake Search (BETA)"[1]. By delimiting the search area to the top left corner of 20.0º, 48.5º and a bottom right corner of 30.0º, 43.3º, the resulting query delivers a total of 761 events from 1990 through 2011.

Earthquake occurrence becomes important given the geological nature of the area. As an earthquake prone area, landslides could have been triggered also by an earthquake. As well, a combination of factors beyond the scope of this threshold research, such as earthquake occurrence mixed with temperature changes, and/or precipitation.

Magnitude Min	Magnitude Max	Class	Count	%
1	2.9	A	173	22.73%
3	3.9	B	386	50.72%
4	4.9	C	179	23.52%
5	5.9	D	21	2.76%
6	6.9	E	1	0.13%
7	12	F	1	0.13%
Total Events			761	100.00%

Table 3.2 Earthquake Occurrence by magnitude

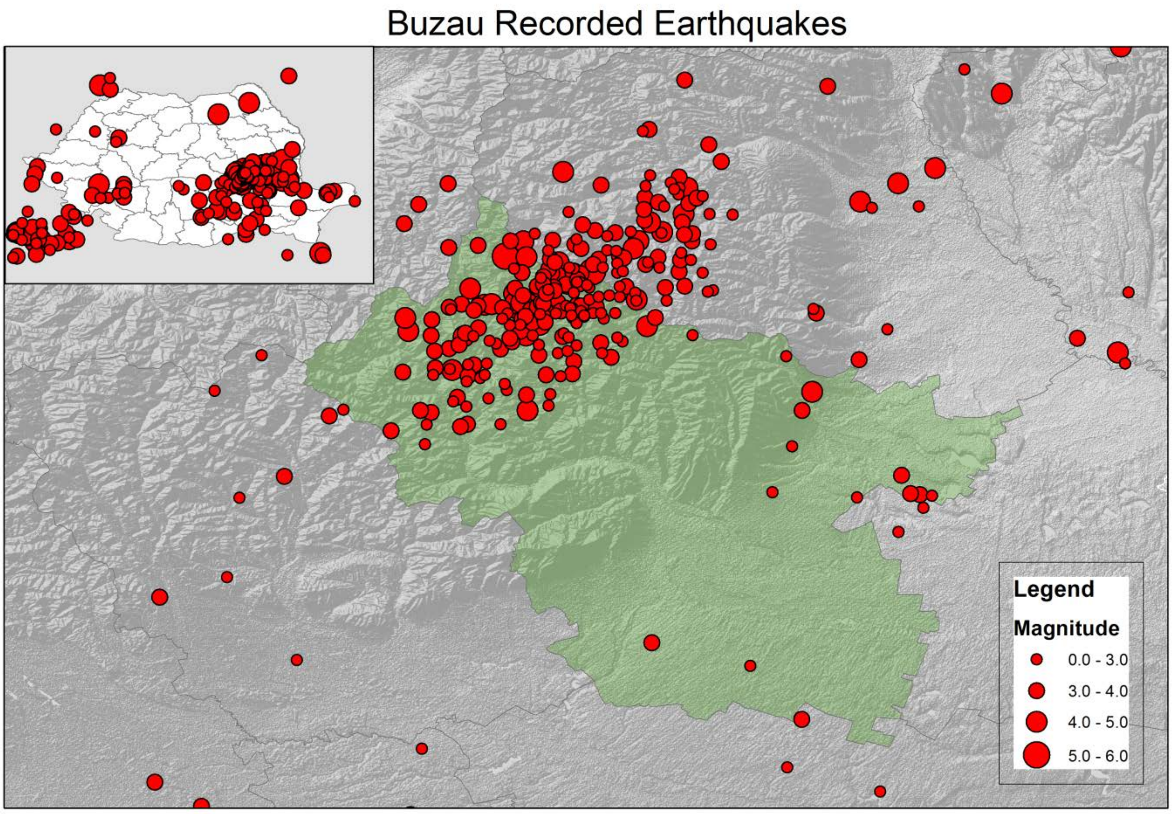


Figure 3.4 Buzau recorded earthquakes

[1] Found at http://earthquake.usgs.gov/earthquakes/eqarchives/epic/

3.2. Precipitation Point Data

3.2.1. Rainfall data obtained from the CHANGES Partner

Records for four of RMO's weather recording stations (WRS) were made available. Data ranges from 1970 to 2010, Located in ranging altitudes between 269m above sea level up to 1772m above sea level. It was made available through the CHANGES project partner in Romania.

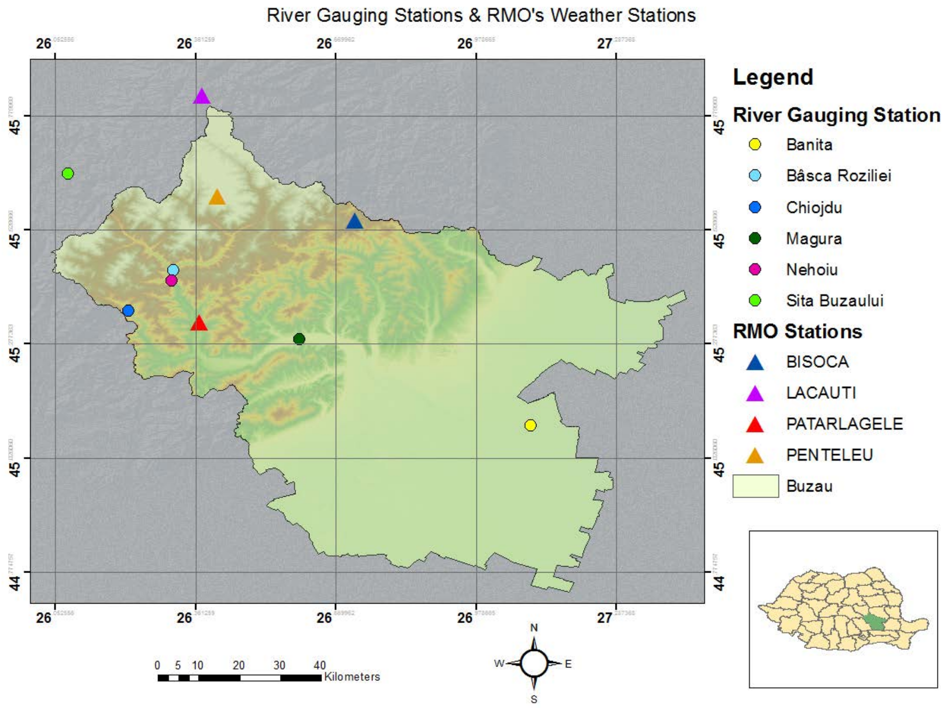


Figure 3.5. River Gauging Stations and RMO's Weather Stations

3.2.2. National Oceanic and Atmospheric Administration (NOAA)

The National Oceanic and Atmospheric Administration is an agency from the United States Department of Commerce. Within its mission is to help understand the impact of climate through science. Being scientifically driven, it develops products to better prepare society and it's response to weather related events.

First, as an overview the information used for this research was focused to acquire precipitation data for the study area, and to better understand how the use of different datasets affect the results. Therefore, two datasets were acquired, the Global Surface Summary of the Day (GSOD), as well as the Global Historical Climatology Network-Daily (GHCN) (both contain daily records), which will be described in more detail in the next section. The resulting datasets comprise a number of stations throughout Romania as shown in Figure 3.6. Each station has a different recording period as presented in Appendix A.

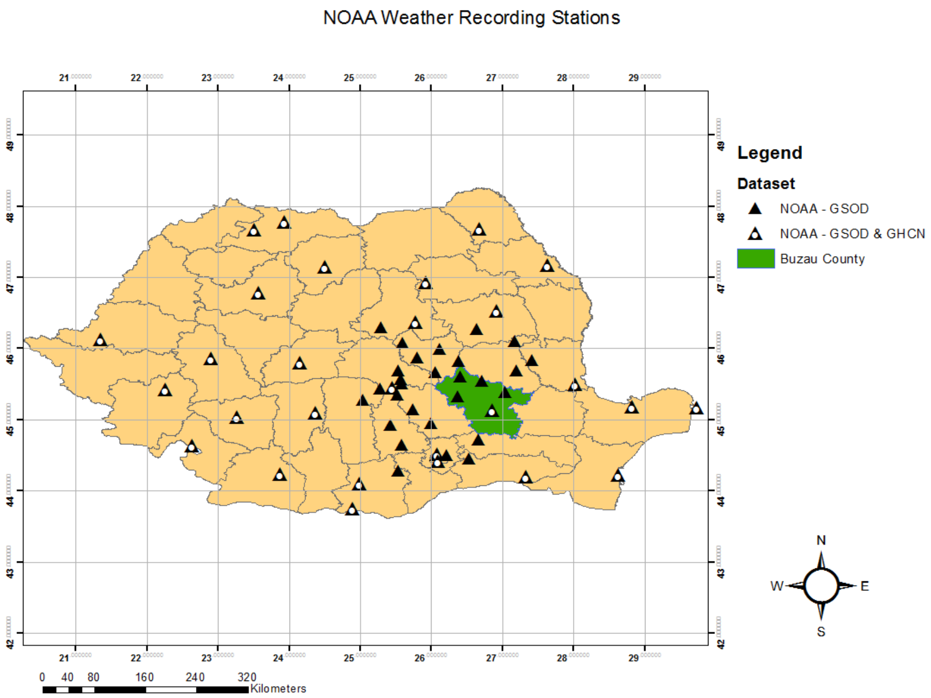


Figure 3.6. NOAA Weather Recording Stations.

3.2.2.1. Global Surface Summary of Day (GSOD)

GSOD dataset is put together by the National Climatic Data Center (NCDC), in Ashville, North Carolina (USA), and is derived from the Integrated Surface Hourly Dataset (ISH)[2] dataset. There are over 9,000 stations available from throughout the world. The data summaries provided by the GSOD are based on data exchange under the World Meteorological Organization (WMO) World Weather Watch Program according to WMO Resolution (Cg-XII).

Stations were selected based on two criteria:

1. Proximity to study area.
2. Matching stations with other datasets for comparison reasons.

The resulting dataset is consisting of data from 56 stations with daily rainfall data. Although the majority of weather recording stations are outside Buzau County limits, a dataset comparison will be possible by matching coinciding stations between datasets.

For quality purposes, data has been flagged to indicate the type of reading that each value reflects (flag descriptions can be found in Table 3.3). In fact, daily extremes and totals are accounted for only when the station reports sufficient data to provide a valid value. Therefore, missing value reports are frequent. Station values are taken from the station reports from the day, which can actually include part of the previous day in the 24 hour period. According to additional information within the database, data undergoes automated Quality Control (QC). The purpose of such QC, according to information from NOAA, is to correctly decode synoptic data, and to eliminate many of the random errors. Even though QC is carried out, a small percentage of errors are still expected to be contained in the data. Records are

[2] According to http://gcmd.nasa.gov/records/GCMD_gov.noaa.ncdc.C00532.html (NASA), the ISH is composed of surface weather observations from more or less 20,000 stations. This data is collected from different sources. Please refer to the website for more information.

stored in inches, and for missing values data is stored as 99.99. As for characteristics of the measurements, a flag for indicating whether precipitation was snow or rain is possibly provided for each existing record.

Flag	Description	Flag	Description
A	1 report of 6-hour precipitation amount.	G	1 report of 24-hour precipitation amount.
B	Summation of 2 reports of 6-hour precipitation amount.	H	Station reported as '0' as the amount for the day (e.g. from 6-hour reports), but also reported at least one occurrence of precipitation in hourly observations - this could indicate a trace occurred, but should be considered as incomplete data for the day.
C	Summation of 3 reports of 6-hour precipitation amount.		
D	Summation of 4 reports of 6-hour precipitation amount.		
E	1 report of 12-hour precipitation amount.	I	Station did not report any precipitation in its hourly observations-it's still possible that precipitation occurred but was not reported.
F	Summation of 2 reports of 12-hour precipitation amount.		

Table 3.3. NOAA-GSOD Flag Description

3.2.2.2. Global Historical Climatology Network (GHCN-Daily)

As an integrated database, the GHCN dataset comprised of daily summaries from various stations across the world. According to additional information, records are subject to a common suite of quality reviews. The dataset contains 27 stations for Romania (see Figure 3.6). Station coverage is less than NOAA-GSOD data. This GHCN data has no unaccounted records (dates), but values are reported as missing. In fact, the GHCN dataset is based on the information provided by the European Climate Assessment and Dataset (ECAD&D)(Menne, Durre et al. 2012).

3.2.3. European Climate Assessment and Dataset (ECA&D)

As a follow up to ECA (European Climate Assessment), the ECA&D project started in 2003, and has obtained the status of Regional Climate Centre (RCC) for high resolution observation data in the World Meteorological Organization Region VI, which covers Europe and the Middle East. Its main objective is to analyse temperature and precipitation within the WMO region, focusing on trends and climatic extremes from meteorological stations (ECA&D 2012).

The information contained in the dataset, is comprised of records of stations around Europe. As each member country supplies different data, but in some cases is restricted, and labelled as non-downloadable. Stations which are restricted can only be used to compute and calculate trends, extremes, and any other procedure within the ECA&D project.

Records are provided by contributing parties, which in most cases are National Meteorological Services. Once received, they are first archived. This means the transformation to standardized format for its storage. Quality control is also part of the process where data is flagged as valid, suspect or missing and put through a homogeneity test. Further on, data is analysed for calculating extremes. As a final step, which is of main interest for this research, is dissemination. Through the ECA&D website, point data (blended and non-blended) are available as ASCII files.

First a brief explanation on what blended and non-blended data series are. In the case of ECA&D, to produce the grid data only blended series are used. Which means that information that is registered as missing in the raw data (non-blended) is “filled in” with information from nearby stations. For example, let’s suppose we have a dataset from Station01 ranging from date D1 to D100, with missing values from

D50-D60 and D90-D100. Now the closest stations to Station01 must be found. Having found the closest station with information available (non-missing value) for period D50 to D60, the difference in elevation is taken into account. Information from SYNOP[3] messages is also used when no data is available from nearby stations. The next step, is to build the blended series as shown in Figure 3.7 (adapted from (ECA&D 2012)).

Figure 3.7. Blended Series build-up adapted from (ECA&D 2012)

For research purposes, point data and gridded values have been acquired. In fact, station availability for Romania corresponds to the same stations for the NOAA-GHCN dataset (27 weather recording stations in total). Since the NOAA-GHCN dataset is built from the ECA&D station information, the locations can be found in Figure 3.6 (see GHCN stations). As for temporal coverage, all records start as of 1/1/1950. Station information is downloadable as ASCII files.

3.3. Gridded Dataset (E-OBS)

The information contained in this dataset has been developed as part of the European Union Framework 6 ENSEMBLES project, with the aim of validating Regional Climate Models as well as for climate change studies. In the case of Romania, stations contained in the ECA&D dataset are used to produce a grid of daily values. Raw data is put through a quality control process, in which suspected values are removed or reviewed manually in regions where suspected amounts can occur. Data is also made homogeneous across regions with the same climate, for it will be used in a Kriging interpolation (Haylock, Hofstra et al. 2008).

The resulting dataset is available in NetCDF and requires specialized software for its handling, for the purpose of this research, as mentioned earlier, a self-developed script using MatLab and the NetCDF toolbox was used to extract the data. First, a grid was extracted for everyday of the time series (example Figure 3.8). As a second step, using the coordinates of the weather recording stations values were extracted into points for everyday of the time series and for every station location available in the area. The grid used to extract data extends from N 46.875, E 24.875 to N 43.875, E 28.125, with a spatial resolution of .25° (see Figure 3.9). The stations that will conform the EOBS Point Extracted Data and their locations are shown in

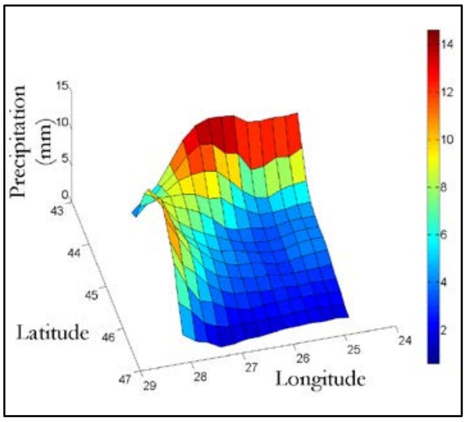


Figure 3.8 Resulting grid from Matlab

[3] According to the World's Meteorological Organization, 1995 Manual on Codes – International Codes – Volume I.1. (WMO No. 306), Geneva, found in http://www.wmo.int/pages/prog/www/WMOCodes/Manual/Volume-I-selection/Sel2.pdf , SYNOP is a code (FM-12 by the WMO) formed by numbers used for reporting weather observations from automated and manned weather stations from a fixed land location.

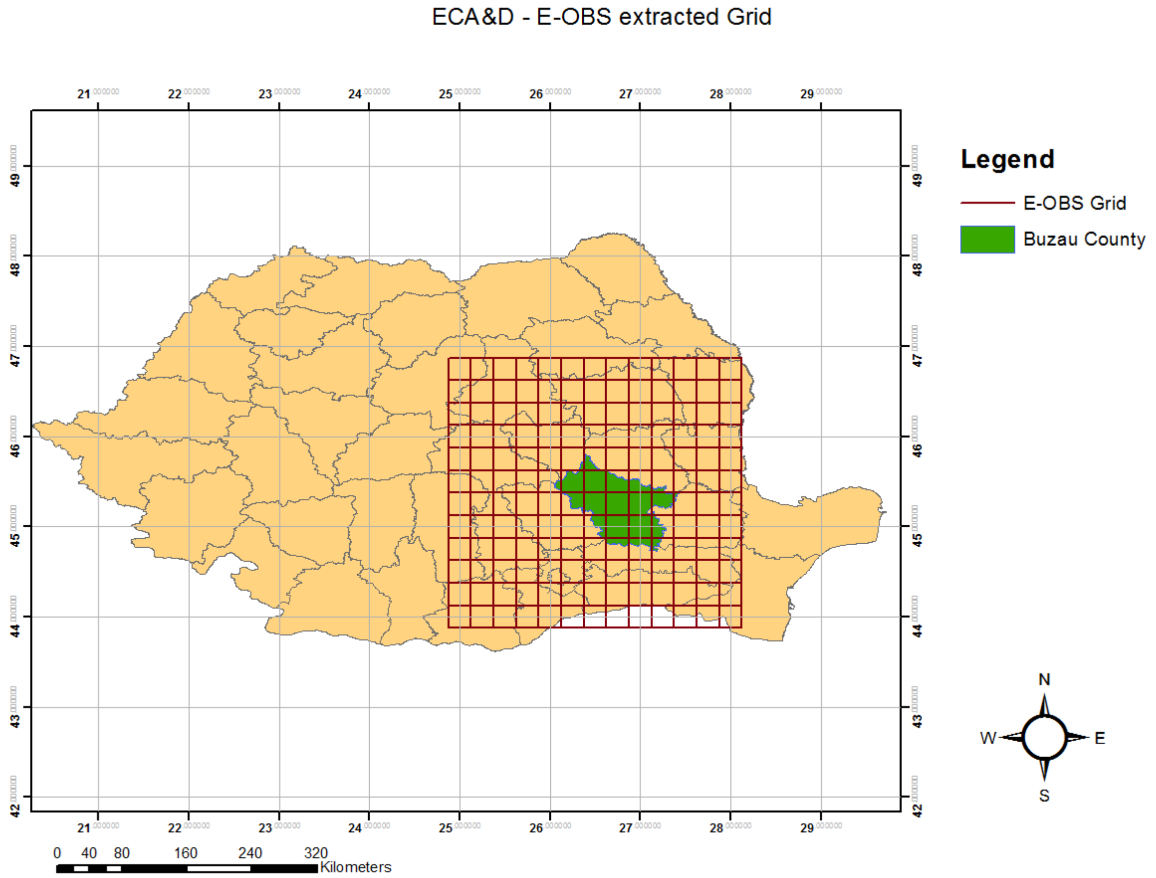


Figure 3.9 Grid extent from EOBS for point extraction at station locations to build the EOBS-PED dataset.

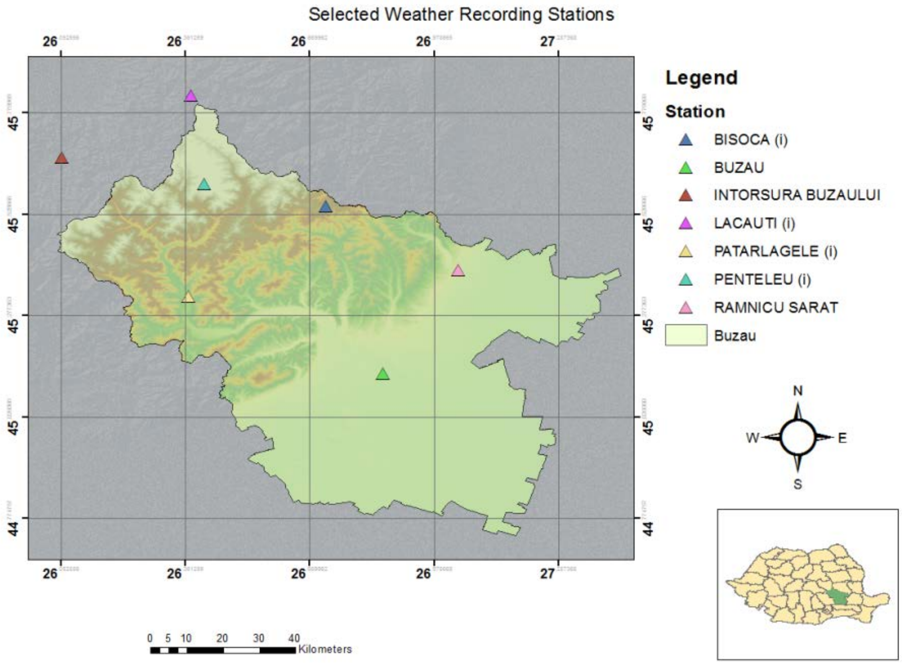


Figure 3.10 Resulting stations from the Point Extracted data from EOBS gridded dataset (EOBS-PED)

4. PRECIPITATION DATA ANALYSIS

Precipitation records (from the different sources mentioned in the previous chapter) have been analysed for two main purposes. The first type of analysis was done to verify the completeness of the individual datasets. The second type of analysis was done to compare the data from the different datasets. For example, Both datasets from NOAA were compared with each other to analyse their differences. This same comparison is carried out among the RMO and EOBS-PED as a reference for future research e.g. CHANGES project. For the purpose of this section and throughout the research the following definitions are used:

- Record: date entry for a specific day, which contains reported rainfall, regardless of the value.
- Missing Record: refers to the absence of a date or dates within the specific dataset.
- Missing Value: refers to a precipitation value within a Record reported as missing.
- Non-Missing Values: refers to an actual numerical value of precipitation for a specific record.
- Date Step: refers to the occurrence of one or multiple consecutive Missing Records.

4.1. Completeness

Completeness analysis is carried out to understand the extent of each dataset to cover a certain period in time. The research deals with specific dates of event occurrence, as well as the probability of the same conditions to be repeated. Therefore, it is important to assess whether such event dates and previous dates are accounted for, as well as how complete a return period analysis can be done.

4.1.1. RMO

Data from the RMO contains 45,286 records, out of which only 16,034 have registered values, which is only 35.41%, although according to the CHANGES partner who provided the data, it contains blended series. The remaining 64.59% are logged as missing values. The distribution of these values per station can be found in Table 4.1. All dates are accounted for from beginning to end. Therefore, there are no reported steps within this data set.

Station	Start	Finish	Non Missing Values	%	Missing Values	%
Bisoca	1/1/1990	12/31/2010	2267	29%	5403	71%
Lacauti	1/1/1970	12/31/2010	6145	41%	8830	59%
Patarlagele	1/1/1970	12/31/2010	4805	32%	10170	68%
Penteleu	1/1/1990	12/31/2010	2817	36%	4853	64%

Table 4.1. Number of records of Non Missing values and Missing Values for each station in the period from Start to Finish.

4.1.2. NOAA – GSOD

In the case of the NOAA – GSOD dataset, within the 57 stations, 882,322 records would be expected if there were no date steps. But in fact, there are 303,495 missing records. That is 34.40% from the total. Within the remaining 66.06% the amount of actual values within the records was analysed. The yielded results show that out of the available records, 96.77% have a recorded value. These values are derived from Appendix C which contains the “Missing and Non-Missing Values” analysis carried out for each station.

4.1.3. NOAA – GHCN

In the case of the GHCN dataset, missing records is not an issue, for all dates are accounted for. Even so, the format of the data even includes non-existent dates, such as 30th and 31st of February. Therefore, data must be prepared and such values eliminated when analysing the data. As for completeness and continuity, missing values account for 3.2% of the total of records. Distribution of values per station can be found in Appendix D.

4.1.4. ECA&D and E-OBS gridded data

E-OBS data acquired contains records from the 1st of January 1950 until 37st of December 2010. There are missing records for the following dates: 01/30/2010, 5/31/2010, 10/31/2010 and 11/30/2010.

4.2. Data Comparison

When comparing datasets, one must ensure the use of same parameters. In the case of the datasets used, only two comparisons can be made since the station density per dataset does not allow a full comparison amongst all of the data. Therefore, as a first instance NOAA datasets are compared with each other (GSOB and GHCN-Daily). Although NOAA-GSOD holds a higher station density than the NOAA – GHCN, there are coinciding stations. On the other hand, RMO stations and E-OBS extracted points are also compared, although RMO's stations are limited to four stations, but coincide with 4 of the points extracted from the E-OBS grid.

4.2.1. NOAA – GSOB vs. NOAA – GHCN

Both NOAA datasets (GHCN and GSOD) have been compared with each other. Not all data contained in the dataset could be used. The criterion for record selection was first the existence of a record for the date, and second that such dates did not report "Missing Value". The reason to do so, is that being from the same source (NOAA), one would expect to find the same records with the same values. However, the results show that there are many differences. Although there is an observable trend for almost all stations, there is also much data that does not hold any relation between datasets. The coefficient of determination for each station can be found in Table 4.2.

Station	R^2	Station	R^2
Arad	0.38	Deva	0.42
Bacau	0.25	Drobeta Turnu Severin	0.32
Baia Mare	0.17	Galati	0.45
Bistrita	1.00	Iasi	0.25
Botosani	0.30	Ocna Sugatag	0.23
Bucaresti Filaret	0.11	Ramnicu Valcea	0.56
Bucaresti Baneasa	0.27	Rosiori De Vede	0.46
Buzau	0.35	Sibiu	0.27
Calarasi	0.28	Sulina	0.11
Caransebes	0.33	TgJiu	0.35
Ceahlau Toaca	0.35	Tulcea	0.29
Cluj Napoca	0.22	Turnu Magurele	0.35
Constanta	0.30	VarfuOmul	0.27

Table 4.2 Correlation coefficient between stations from NOAA-GSOD and NOAA GHCN-Daily. Records with missing values are excluded on both datasets for each specific station

As shown in the previous table, Bistrita (R^2=1.00) has the highest fit for both datasets (see Figure 4.1), but only meets the criteria in 5981 records. In fact, it is only met by 62% of GSOD and 57% of GHCN available records.

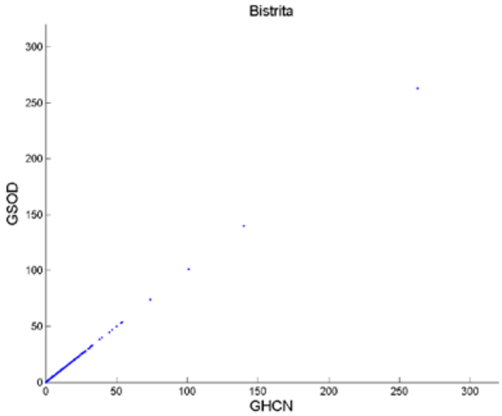


Figure 4.1 Bistrita GHCN vs. GSOB

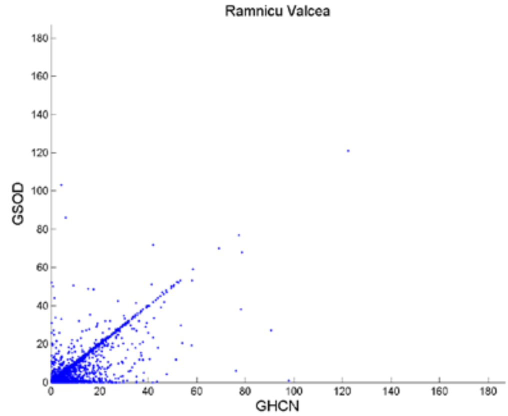


Figure 4.2 Ramnicu Valcea GHCN vs. GSOD

As a second highest value, Ramnicu Valcea holds an R^2=0.56 as shown in Figure 4.2. Although the rest of the stations have lower R^2 values, in most cases a trend can be distinguished, although there are two cases that two trends are noticeable. For the cases of Sulina and Varfu Omul, a 1:1 relationship, as well as a 1:10 can be seen (see Figure 4.2 and Figure 4.4).

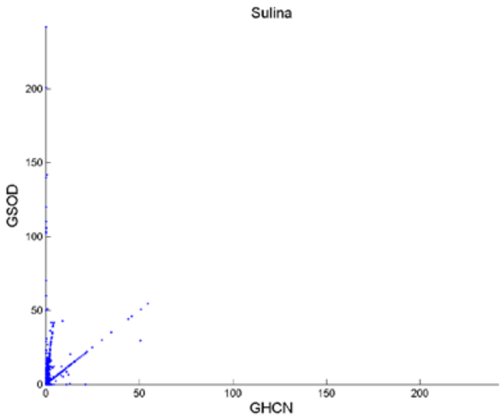


Figure 4.3 Sulina GHCN vs. GSOD

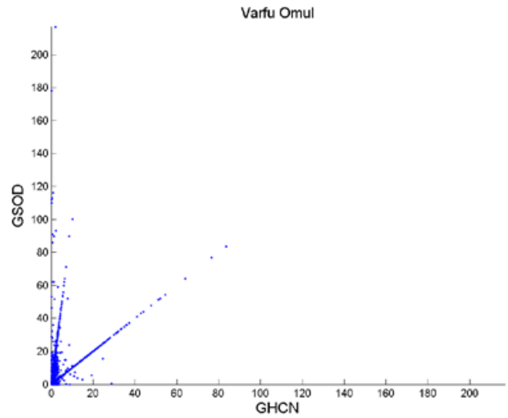


Figure 4.4 Varfu Omul GHCN vs. GSOD

After obtaining the results of the comparison of GHCN dataset with the GSOD dataset, NOAA was contacted to inquire for the reason of such differences and the use of the datasets for this research. Their response was clear, and already suspected, GHCN should be used preferentially over the GSOD. As an argument, it was stated that the GSOD is not a true daily summary and often contains missing data, as already shown in the previous section. See Appendix E for the entire set of plots.

4.2.2. RMO vs ECA&D (E-OBS extracted data)

RMO's stations were compared to the E-OBS point extracted data (EOBS-PED) for the dates in which both datasets were active (see Figure 4.5), and for those records that do not reflect a missing values.

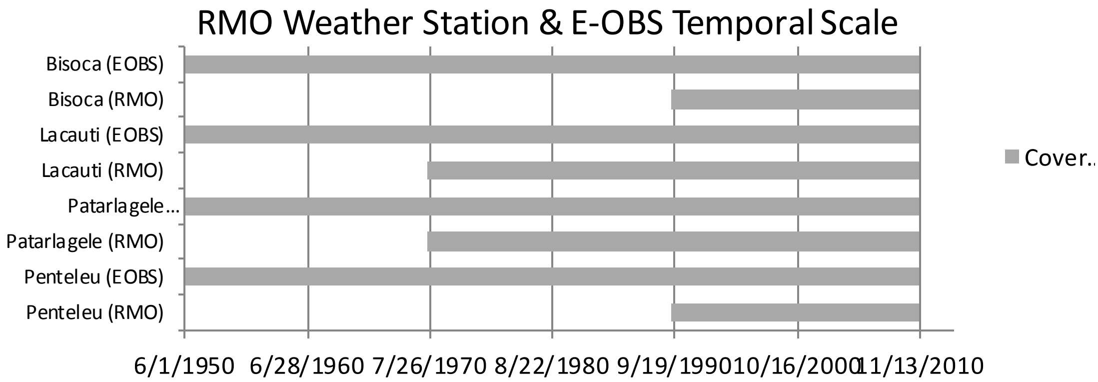
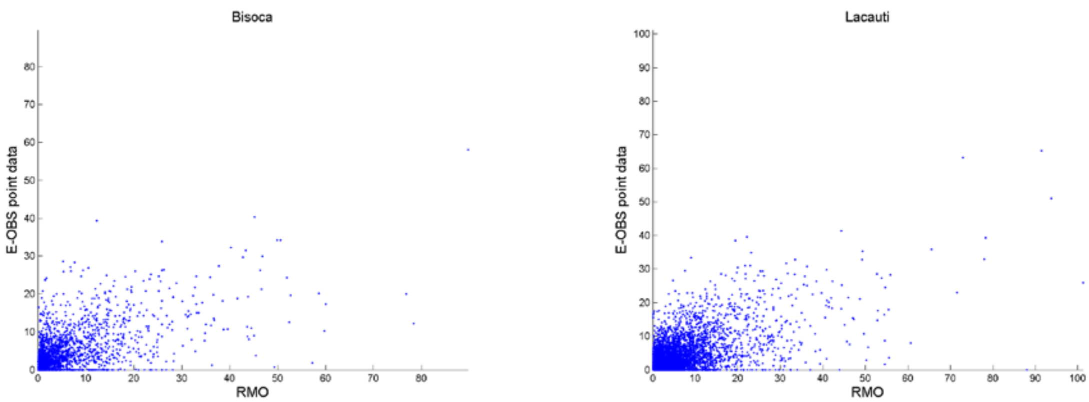


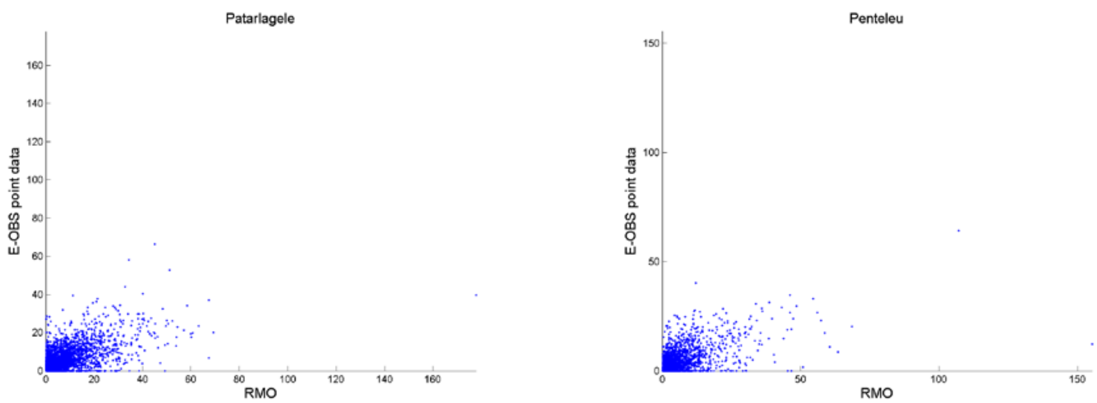
Figure 4.5 Temporal extent of RMO's and EOBS-PED's stations.

Since the values from the E-OBS extracted points are taken by interpolation of a grid, values are expected to be smoother than those taken from the stations directly. Nevertheless, the comparison of values gives R^2 values that range from 0.55 to 0.67. Although there is not a distinctive trend in the plots (see Figure 4.6 and Figure 4.7), this is attributable to the fact that the E-OBS does not represent the range at a specific point, but rather the mean of the area. It should also be kept in mind, that the distribution from the ECA&D stations used to build the E-OBS grid for the Buzau area contains only one station (Buzau).



R^2= 0.57 R^2=0.61

Figure 4.6 Scatter plot from values of RMO's vs. EOBS-PED Bisoca station (right), and Lacauti station (left)



R^2=0.62 R^2=0.55

Figure 4.7 Scatter plot from values of RMO's vs. EOBS-PED Patarlagele station (right), and Penteleu station (left)

4.3. Data Selection

Data completeness becomes essential when analyzing precipitation as a triggering factor for landslides and floods. For instance, missing values from antecedent rainfall could be crucial for assessing the accumulation of precipitation that could have triggered an event. In the case of missing consecutive values when analyzing accumulated precipitation could yield a low accumulated value, when in reality, precipitation could have been so extreme to actually have caused the weather recording station to fail (Tank, Zwiers et al. 2009), and at the same time, precipitation for that day could have been crucial to triggering an event. Therefore, datasets were excluded based on the completeness of their time series, as well as on non-missing values. The aim is to minimize the effect of missing values when evaluating the accumulated precipitation for a given date related to a flood or landslide event, since these are critically dependent on the completeness of the records.

The resulting selection leaves the RMO and EOBS-PED datasets to be the most complete, and therefore, the ones to be used for research. Although the RMO dataset is quite incomplete, it will be used to assess in general terms the quality of the EOBS-PED (daily values), since this last dataset contains gridded extracted values.

From here on, weather recording stations will be referred to as follows:

Station Name	Station Code
Bisoca	E01
Buzau	E02
Introsura Buzaului	E03
Lacauti	E04
Patarlagele	E05
Penteleu	E06
Ramnicu Sarat	E07

Table 4.3 Station Code

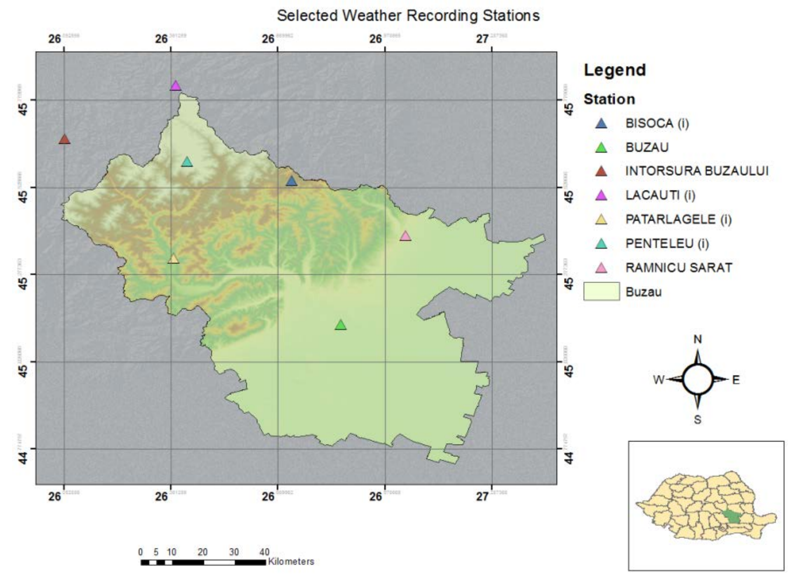


Figure 4.8 Selected weather recording stations

4.4. Precipitation Frequency Analysis

Maximum year precipitation was used in a Gumbell distribution to determine the return period equations for (x) amount of precipitation. Table 4.9 contains the equation per station for each of the datasets (see Appendix F for tables and plots).

Station Name	RMO Return Period Equation	EOBS-PED Return Period Equation
Bisoca	$Tr = 0.1978e^{0.0513x}$	$Tr = 0.2341e^{.0823x}$
Buzau	----	$Tr = 0.1741e^{.0892x}$
Introsura Buzaului	----	$Tr = 0.1703e^{.091x}$
Lacauti	$Tr = 0.3379e^{.0422x}$	$Tr = 0.1848e^{.0886x}$
Patarlagele	$Tr = 0.553e^{.0315x}$	$Tr = 0.1669e^{.0871x}$
Penteleu	$Tr = 0.7476e^{.0248x}$	$Tr = 0.1930e^{.0856x}$
Ramnicu Sarat	----	$Tr = 0.2802e^{.0768x}$

Table 4.4 Equations per station for calculating Return Period (Tr), where x is the precipitation value.

These equations will be used in Section 6.1.1 to determine if the events that occurred prior or on the date of a flood were extreme values.

5. ANALYZING THE HISTORICAL FLOOD AND LANDSLIDE EVENTS

5.1. Floods

The event list contains data ranging from 1975 to 2007, comprised by 143 records. Out of the total, 22 occurred in Buzau (15%). From the 22 events reported in Buzau, 16 (72%) are concentrated in three separate years: 1975 (5 events), 1991 (4 events) and 2005 (7 events). Previous studies (Mihaela Borcan 2010) have identified that precipitation during winter months (January and February) have a major influence on the run-off during March and April (more specifically during early and mid-spring). To account for snow accumulation and its melting process is beyond the scope of this research. Therefore, the focus of the analysis was made for the months from June to September, a period which concentrates 15 events (68%) as shown in Figure 5.1.

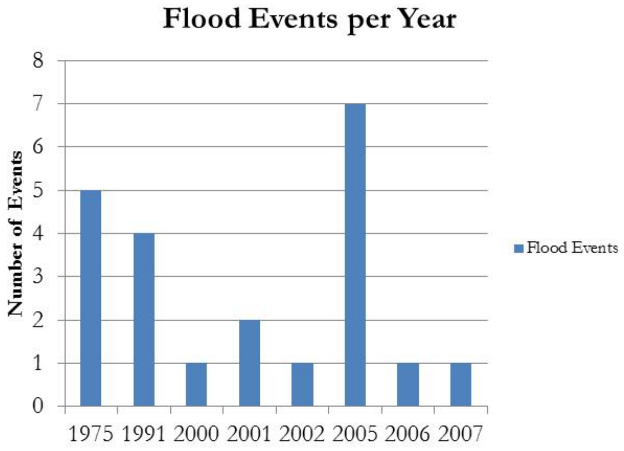


Figure 5.1 Flood Events per Year for Buzau County

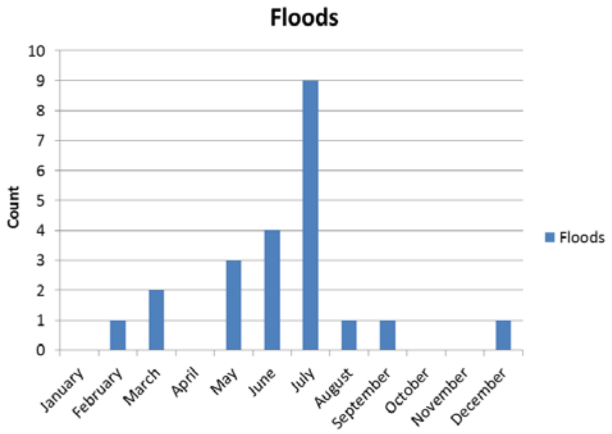


Figure 5.2 Seasonal Flood Events

From the historical inventory and based on events reported for the period of June-September was constructed (see Table 5.1). It can be seen that one event which started on the 2nd of July 1975 according to the reports from Chiodju, Magura, and Nehoiu was also reported the following day by the stations Banita and in the case of the report from Sita Buzaului, even though it is located in the upper catchment, reported a flood event on the second day. Given the location of Sita Buzaului it is assumed that the run-off from precipitation on the 2nd of July 1975 had an effect but there is no information available to assess with certainty. A spatial analysis was done to determine if there was a link between both reports. The analysis showed that the stations that reported the flood on the 2nd of July are located in the upper part of the catchment (Chiodju, Magura, and Nehoiu) and therefore have an effect on Banita. Analysing the historical records, and from information obtained through the GI-RA and as part of a visit to the site, run-off that is recorded by the river gauge Sita Buzaului would not have an effect on those river gauges located downstream, at least not one that can be assessed only by precipitation analysis due to the construction of a dam, which started in 1974. It is unclear when the dam started functioning. The only information that was given besides initial construction is that in 1984 it was commissioned for water supply and hydroelectric purposes, and in 1994 the reservoir started filling up to its capacity. With the information available the effect of this river gauge cannot be assessed, since the reservoir levels are unknown, as well as any opening of the relief gates and the outflow from the hydroelectric plant.

Date	Banita	Bâsca Roziliei	Chiojdu	Magura	Nehoiu	Sita Buzaului	Registered Floods
7/2/1975	0	0	1	1	1	0	3
7/3/1975	1	0	0	0	0	1	2
6/30/1991	1	0	0	1	0	0	2
7/18/1991	0	1	0	0	0	0	1
7/29/1991	0	0	1	0	0	0	1
6/5/2001	0	0	0	0	0	1	1
6/20/2001	0	0	0	0	0	1	1
7/27/2002	0	0	0	0	0	1	1
7/11/2005	0	0	1	0	0	0	1
9/21/2005	0	0	0	0	0	1	1
8/11/2006	0	0	0	0	0	1	1
Registered floods per River Gauge	2	1	3	2	1	6	15

Table 5.1 Flood Report by Date & River Gauge Station (June-September)

Annual mean precipitation in combination with the flood frequency can show if in fact we can assume that flood events recorded during June to September are not the result of snowmelt. Therefore, mean precipitation is displayed along with the flood frequency for both datasets. Both sources seem to have the same behaviour of increased precipitation for the period, although, when comparing each month EOBS-PED shows a shift of one month in respect to RMO stations see Figure 5.2 and Figure 5.3. For the case of comparing the maximum values, both datasets do show the maximum values in July.

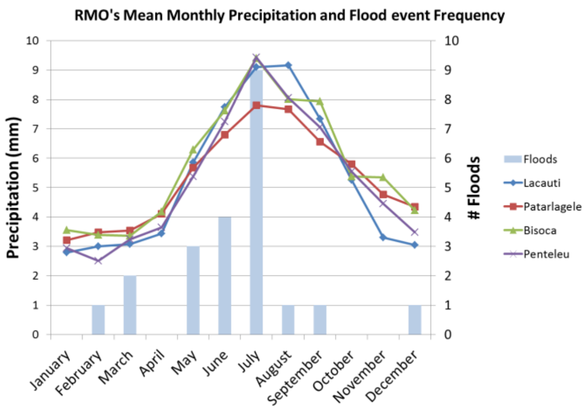


Figure 5.3 RMO's Mean Monthly Precipitation and Flood Frequency

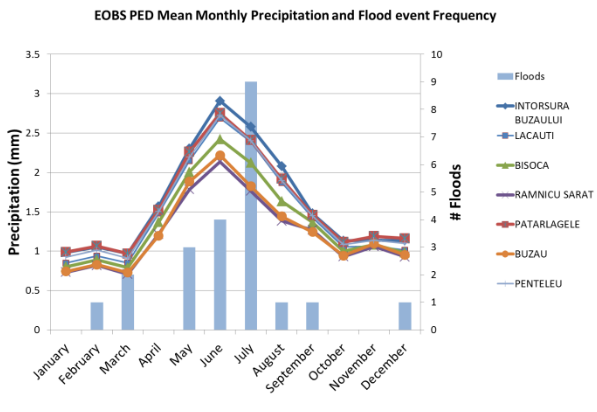


Figure 5.4 EOBS-PED Mean Monthly Precipitation and Flood Frequency

The Romanian Meteorological Organization dataset on precipitation does not contain all stations involved in the process for flood analysis; therefore, it will only be used for assessing precipitation return periods for the available stations.

Using the flood events that occurred during the months of June-September , as well as five days prior to the reports a table of precipitation values is constructed (Appendix G). In most cases, the precipitation involved in the flood event is equal to the maximum precipitation for that year in the period from June-September (see Appendix G, Appendix H, Appendix I). From these tables, we can conclude that the precipitation present at the date or within 5 days prior to the flood was in some cases the maximum daily precipitation recorded for that year, in the period of June-September (see Appendix J). From analysing the data, it can be concluded that although the maximum precipitation for the period of June-September was present, if not on the reported flood date but within five antecedent days, the precipitation was not extreme in the majority of the cases, and in both datasets. Although two cases stand out, from the RMO dataset, Patarlagele in July 2nd 1975 reported a precipitation of 177.8mm which based on the return period equations from Section 5.1 indicate a return period of over 100 years. Another case, although not as extreme, is the case of Penteleu, also in the RMO dataset, in July 18th 1991 recorded a precipitation event with a return period of 35 years.

5.2. Landslides

According to the historical records a total of 170 landslides have been registered with a date of occurrence and location, which represents 10% of the total mapped landslides. In turn, 90% of the mapped landslides, do not have recorded dates, hampering any result from frequency analysis, and its relationship with precipitation values (daily and accumulated). Nevertheless,

In fact, data was delivered in two separate stages. Before the delivery of the second set of events, a frequency analysis was carried out (see Figure 5.4) with 74 records. The first conclusion was that winter landslides prevailed in the area, and that a much detailed research was needed to be able to account for other factors besides precipitation (e.g. temperature changes, the effect of the sun and whether or not there was cloud cover), in order to consider snowmelt as a triggering factor to pore pressure variances that could lead to a landslide. The merger of the two datasets, led to a more complete change in the frequency analysis, as shown in Figure 5.5, with the use of the total events (170 records). In fact, the number of events for the summer period is increased significantly.

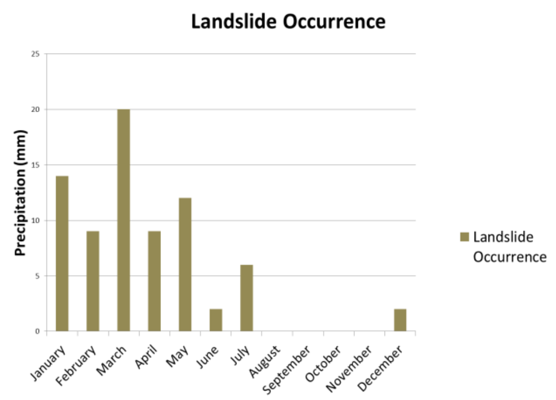


Figure 5.5 Landslide Occurrence 1st data delivery

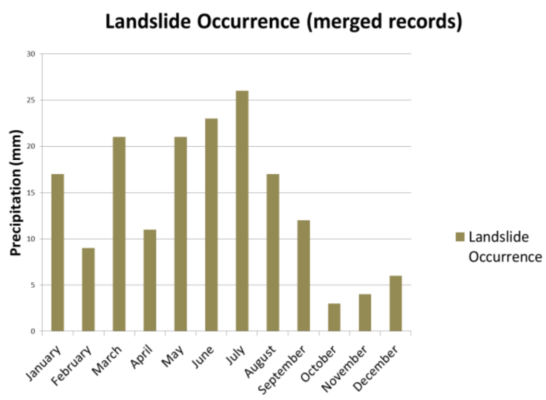


Figure 5.6 Landslide Occurrence (total records)

Using landslide occurrence and mean precipitation are graphed together to assess the relationship that precipitation holds with landslide events. Data from RMO and EOBS-PED datasets are graphed separately (Figure 5.6 and Figure 5.7 respectively).

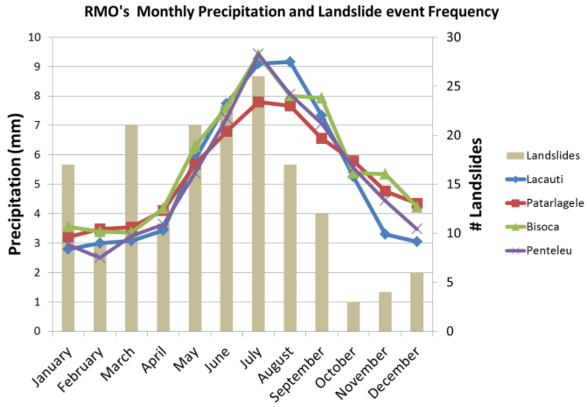


Figure 5.7 RMO's Mean Monthly Precipitation and Landslide Frequency

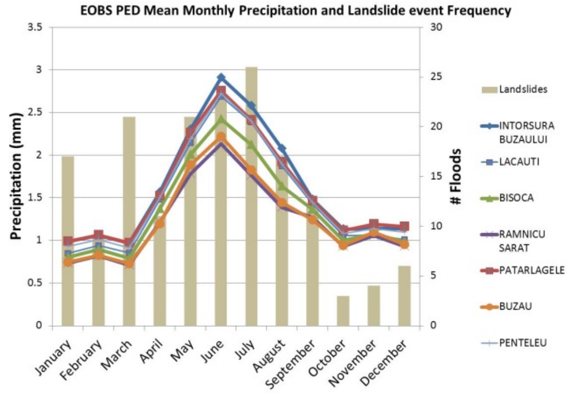


Figure 5.8 EOBS-PED Mean Monthly Precipitation and Landslide Frequency

As in the case of floods, data between RMO's and EOBS-PED shows a shift of one month on the maximum mean value (June for EOBS-PED), although when compared with the maximum values, both datasets coincide with the highest value (within each dataset) in July. The year distribution (see Figure 5.9) shows that 2006 was a peak year of landslide occurrence with 35 events, but then again, this numbers are based on the records that have a date of occurrence, accounting only for 10% of the mapped landslides.

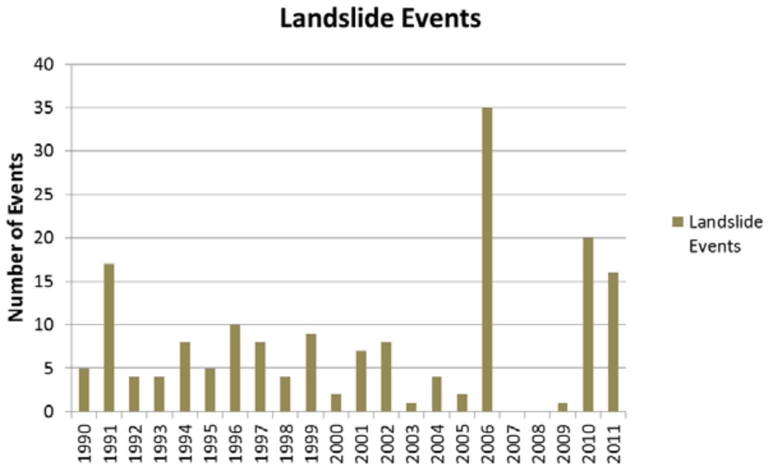


Figure 5.9 Landslide events per Year

Through spatial and temporal analysis the distance from every landslide event to each weather recording station was determined. The shortest event-station distance was used to assign the station assuming it would best represent the precipitation at the landslide location. This enables for spatial temporal analysis of the precipitation, assigning precipitation values for each date of a reported landslide event, as well as the antecedent precipitation (3, 5, 10, 15, 30, 60, 90, 120 and 180 days). Information about earthquake occurrence was also cross-referenced to each landslide event (see Figure 5.10 for an example of the results).

ID	Date	Longitude	Latitude	Station_ID	STATION	EQ_ID	MAGNITUDE	Daily	3-Day	5-Day	10-Day	15-Day	30-Day	60-Day	90-Day	120-Day	180-Day
LS00001	5/30/1990	26.642226	45.543381	E01	BISOCA	1	7	17.165	38.1065	14.6548	16.3889	16.3889	38.52346	81.40681	88.84031	108.6965	116.4688
LS00002	5/30/1990	26.761642	45.486978	E01	BISOCA	1	7	17.165	34.4695	35.5963	16.3889	16.3889	38.52346	81.40681	88.84031	108.6965	116.4688
LS00005	12/14/1990	26.5411	45.493721	E01	BISOCA	N/A	N/A	3.8814	9.2162	25.0352	28.8134	36.12849	36.12849	59.31113	92.25902	102.8036	173.1834
LS00006	4/11/1991	26.714227	45.474218	E01	BISOCA	N/A	N/A	8.3144	11.0129	0.76773	0.76773	4.91683	9.56589	31.07097	38.18358	77.90645	137.2176
LS00010	7/1/1991	26.761759	45.492019	E01	BISOCA	N/A	N/A	2.2052	4.0236	13.9435	43.1661	43.1661	114.7186	280.1933	326.8163	336.2643	368.5189

Figure 5.10 Spatial and Temporal analysis of Landslide events to Precipitation and Earthquake occurrences

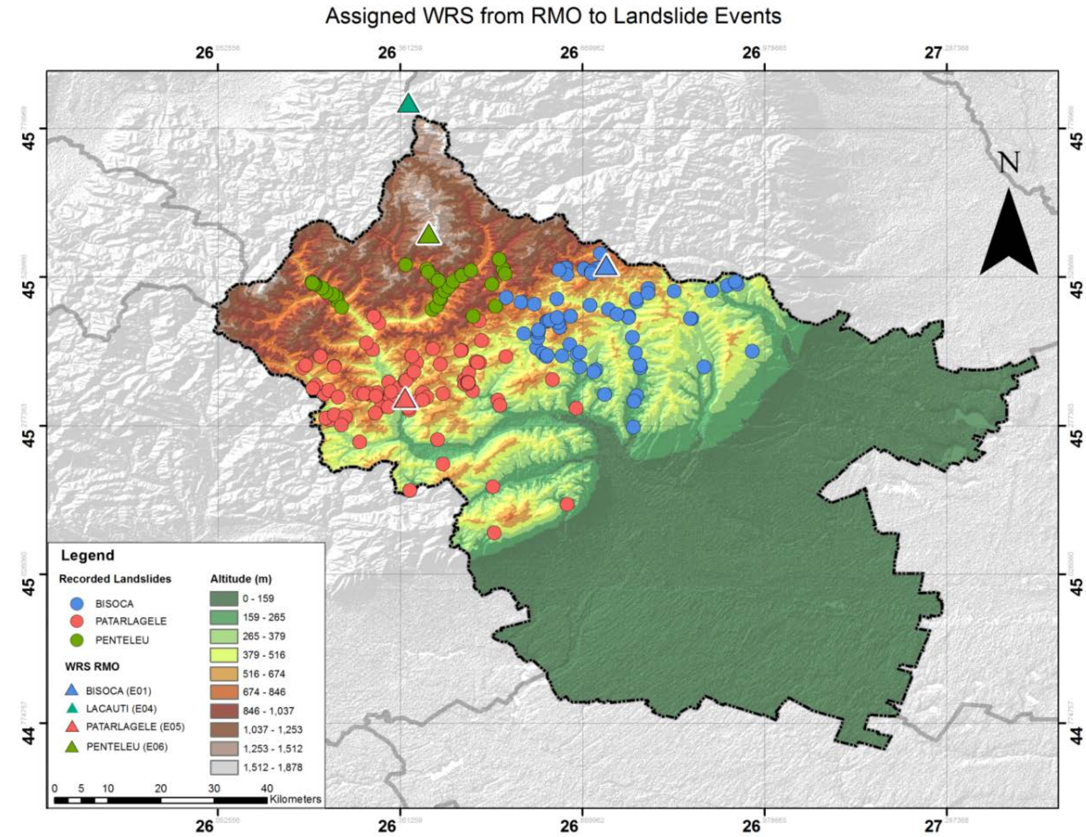


Figure 5.11 Assigned Weather Recording Stations from RMO to Landslide Events

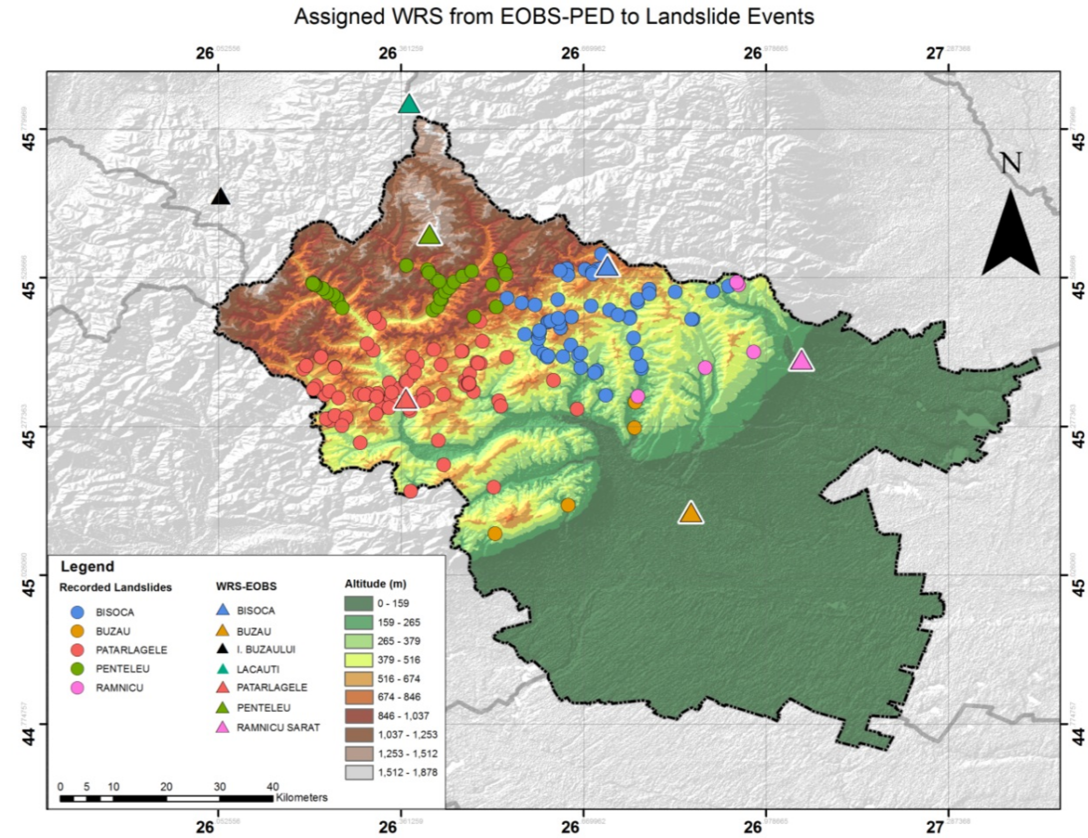


Figure 5.12 Assigned WRS from EOBS-PED to Landslide Events

The spatial analysis shows in both datasets that landslides are more common around the area of Patarlagele Weather Recording Station (see Figure 5.12 and Figure 5.13), regardless of the dataset, although it could also be attributed to the low station density of the RMO dataset, which inherently increases the number of events to Patarlagele's station, although only by 3. Bisoca on the other hand increases the number of landslide occurrences by 9.

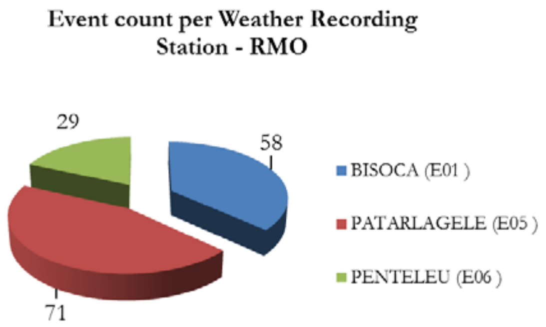


Figure 5.13 Landslide events by Weather Recording Station from RMO

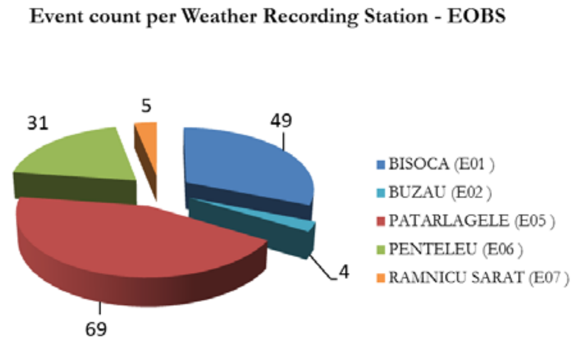


Figure 5.14 Landslide events by Weather Recording Station - EOBS

Based on the magnitude (Richter scale), events are considered to possibly been triggered by an earthquake, if the earthquake magnitude is greater than 4.0, which is the most common minimum magnitude at which mass movements are triggered (Keefer 2002). Also a classification of events that occurred outside the period of June-September across the temporal extent of the historical inventory were set aside, to focus on those events that were most likely triggered by precipitation (see Figure 5.15 for spatial distribution).

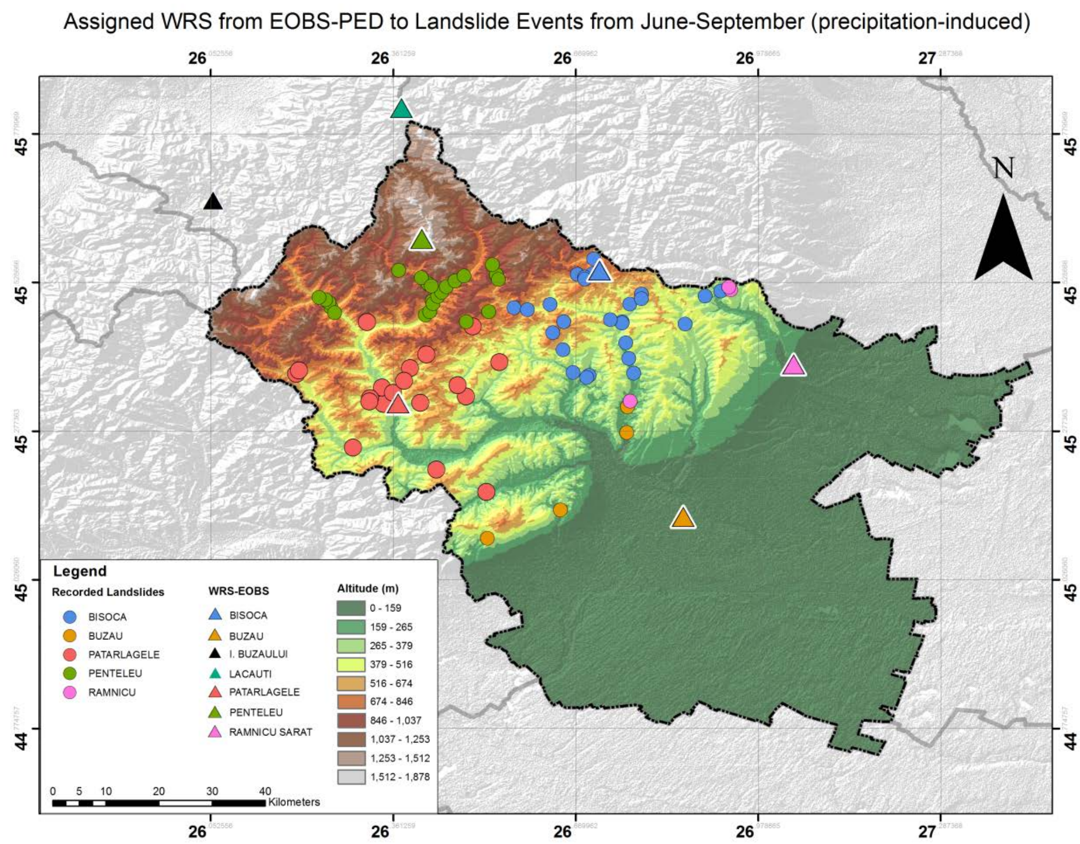


Figure 5.15 Spatial distribution of selected landslides to be used in threshold modelling.

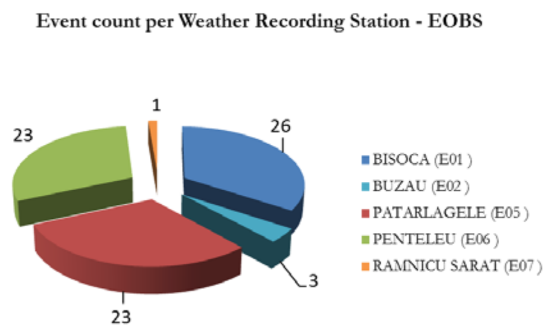


Figure 5.16 Distribution of final dataset to be used in threshold modelling.

A total of 76 events will be used for the threshold modelling (see Figure 5.16). The distribution decreased significantly in the case of Patarlagele, with a frequency decrease of more than 50%, which could indicate that landslides in the area are related more to the snow cover and snowmelt processes'. Although this is just an assumption, for only 10% of the mapped landslide records have a date of occurrence. Another significant decrease is for Bisoca as well shows a decrease in frequency of 50%.

Based on the 76 landslides, different scatter plots are done. Daily and three day precipitation days are used for the (Y) axis, see Appendix K and Appendix L.

6. THRESHOLD ANALYSIS

To determine the minimum required precipitation values at which a hydrological event can occur, in this case a flood or a landslide, an analysis of the values that have triggered such events must be known as well as accumulated values prior to the date of occurrence. As a first step, values for the Y-axis (R_{n-y}) must be established and will define how the X-axis values (R_x) are calculated.
By definition:

$$Date\ of\ Event = n$$

$$R_y = \sum_{i=n-y}^{n} R_i$$

Where y represents the antecedent days used to the event that will be used in the Y-axis. For the X-axis values, accumulated rainfall is calculated as follows:

$$R_x = \sum_{i=n-y-x}^{n-y} R_i$$

Where x represents the antecedent days used prior to (n-y). In Figure 6.1 represents the accumulated periods used by the USGS x=15, and y=3 to illustrate the procedure.

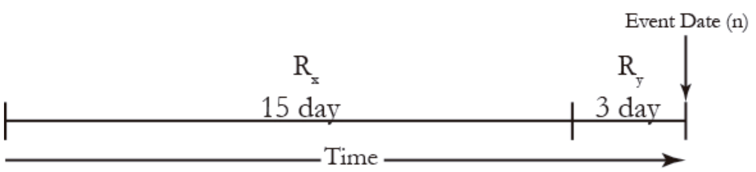


Figure 6.1 Time distribution

6.1. Threshold Modeling Methodology

Precipitation data available is for daily values, therefore the empirical threshold model chosen for the study is based on antecedent rainfall by temporal analysis. Following the criteria in Figure 6.1, the value of R_x and R_y are assigned to each of the events in the historical inventory. In this section, Rx and Ry correspond solely to those of landslide events. Once the values have been assigned three constrain points must be identified as follows:

1. Constrain 1 (Cx_1,Cy_1) should be the point nearest to the origin (0,0), as it will be used as a pivot point. Depending on the density of the data, it can either be visually identified, or can be found calculating it with:

$$\sqrt{{R_x}^2 + R_y^2} = Distance\ to\ (0{,}0)$$

By selecting the (R_x,R_y) that meets the criteria, the values are used as ($Cx1$,Cy_1) which will define a pivot point (the C denotes Constrain, where i in x_i denotes the constrain number). See figure XXX, the red point indicates the point used as (Cx_1,Cy_1).

In case there are more than 2 points with the same minimum distance to (0,0) the methodology is explained in the next section.

2. Point 2 (Cx_2,Cy_2) is identified by the following criteria:

- $Cx_1<R_{x2}$
- $Cy_1>R_{y2}$
- Calculating the slope for every (R_x,R_y) that meets the above criteria, then selecting the (R_x,R_y) that results with the steepest slope (m_{C2}).
- The next step is solve a linear equation in the form of $m_{C2}x+b_{C2}=y$, using the slope we obtained in the previous step, and (C_{x1},C_{y1}) for x and y respectively to obtain b_{C2}. The next step is to solve for when y=0, to know where the equation will intersect the X-axis (using m_{C2} and b_{C2} from the previous calculations). The value of x obtained from solving the linear equation will be used for C_{x2}, and 0 for C_{y2}. Therefore, our Constrain 2 should have the form of (C_{x2},0).
- In the case that there is no point that meets the criteria of $Cx_1<R_{x2}$ and $Cy_1>R_{y2}$, the value of Cy_2 will be that of the max R_x.

3. Constrain 3 (Cx_3,Cy_3) is identified by the following criteria:

- $Cx_1>R_{x2}$
- $Cy_2<R_{y2}$
- Calculating the slope for every (Rx,Ry) that meets the above criteria, then selecting the (Rx,Ry) that results with the least steep slope (m_{C3}).
- The next step is to solve a linear equation in the form of $m_{C3}x+b_{C3}=y$, using the slope we obtained in the previous step, and (C_{x1},C_{y1}) for x and y respectively to obtain b_{C3}.

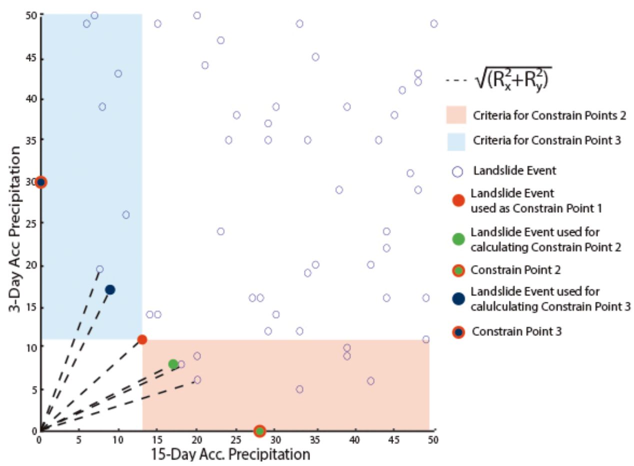


Figure 6.2 Graphic description for assigned Constrain Points

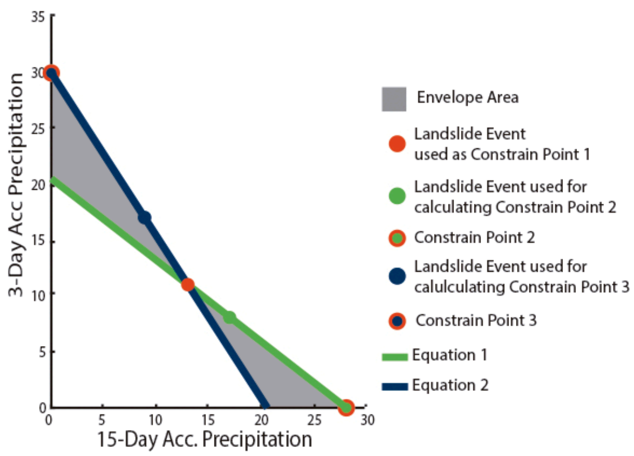


Figure 6.3 Envelope Area between Equation 1 and Equation 2

The next step is to solve for y when x=0 to know where the equation intersects the Y-axis (using m_{C3} and b_{C3} from the previous calculations).. The value of y is then used for C_{y3} to obtain $(0,C_{y3})$. In case there are no points that meet the criteria $Cx_1>R_{x2}$ and $Cy_2<R_{y2}$, the value of Cy_3 will be obtained from the maximum R_y.

The equations will bound the parameters to be used in the threshold modeling (Figure 6.3). The distance along the X-axis as well as the Y-axis between the two equations is calculated to establish the parameters in which the modeling will be able to test different equations taking into account that every equation must pass through Constrain Point 1. By combining this procedure with the total amount of precipitation records, the model will run several equations in order to assess the equation that discriminates the most values underneath each equation. It will allow then, to decide the best fitting parameters of m and b for the threshold equation.

The Matlab Script only requires to determine the pivot point (C1) and the R_{x2},R_{y2} as well as R_{x3},R_{y3}. With this information, a confusion matrix is built for every equation that is to be fitted within the envelope area. The number of equations will vary depending on the user.

6.1.1. Landslide Thresholds

Example plots for deriving constrains can be found in Appendix L and Appendix M.

7. DISCUSSIONS AND CONCLUSIONS

7.1. Suitability of precipitation Data for its use in a precipitation threshold analysis

Precipitation data was available through three different sources and with different file formats, table XX lists them by dataset.

Dataset	Data Source	Data Format
Global Summary Of Day (GSOD)	National Oceanic and Atmospheric Administration	ASCII file
Global Historical Climatology Network (GHCN)	National Oceanic and Atmospheric Administration	ASCII file
ECA&D	European Climate Assessment & Dataset	ASCII file
RMO	Romanian Weather Organization	*.xls (Excel format)
EOBS-Point Extracted Data EOBS-PED	European Union Framework 6 ENSEMBLES	NetCDF

Figure 7.1 Available precipitation datasets for Buzau County

Through data analysis the suitability of each dataset was established. The total temporal extent of each dataset was analysed to allow for previous hazardous events to those included in the historical inventories of floods and landslides. Although correlation values between datasets varied as shown in Section 4.2, this is attributable to the process with which each dataset was constructed.

The Global Summary of Day proved to be the dataset with the most station density in the area; it also gave way to many questions in regards to completeness as well as in precipitation values when available. In fact, the discrepancies in values with other datasets from the same source raised the need to ask for further information to NOAA on the possible reasons of such differences. The answer was clear; this dataset is in fact not to be considered as a daily dataset. This has already been useful to the CHANGES project. The GHCN dataset consisted of continuous records resulting in a complete dataset with no date steps or missing values, but not suitable for the area given its station density. With only one station for the study area, and located in the plain area, far from the location and settings of landslides and floods. The ECA&D was not analysed since station density is equal to that of the GHCN dataset, and this latter is based on the ECA&D dataset, and therefore the analysis of one results on the results for both, yielding another a non-suitable dataset for the purpose of the present study. The Romanian Meteorological Organization dataset, although comprised of the blended precipitation data series contains numerous missing values. In respect to the density in terms of spatial extent, it covers the three main sources of landslide hazards in the area, as well as the main sources of flooding (based on the available information). Distance between stations could be used in attempting a blending process between the stations within the dataset or even perhaps with the EOBS-PED. This possibility was explored, but the limitation on time did not allow for exploring the possibility. In regards to the EOBS-PED dataset, completeness was not an issue, with only 4missing records from the overall temporal scale, meets the requirements of the World Meteorological Organization (Tank, Zwiers et al. 2009). In regards to station density, the gridded format enables it to be used on specific locations e.g. landslide locations, for the assessment of precipitation at any given site. Although precipitation values seem to be smoothed, and probable extreme values considered as outliers in the gridding process (Hubbard, Goddard et al. 2005), its use on the evaluation of climatic models provides assurance of its reliability and if used, the smoothing aspect should be taken into account. Knowledge of NetCDF files is advisable, for the procedures of extraction can be consuming if no prior knowledge is given on its structure (reason for which a brief example of how data was extracted for this study), as well as in the software capable of handling NetCDF formats. As a recommendation for further research identifying storm patterns of hydrological events that have resulted in landslides could also be explored.

In conclusion all of the datasets used for the present study showed advantages and disadvantages, some greater than others, although it is clear that EOBS data is the most complete and with maximized spatial coverage. Its use could be suitable in a hazard triggering analysis. Although another dataset to be considered is the RMO, since it could be blended within itself, or if a relationship is established between EOBS values and RMO stations, perhaps EOBS can serve as a blending dataset. For that reason, a set of tables for consideration to be taken into account if blending is intended. Table 7.1 shows the number of values that can be found on each station when (X) or (Y) stations report a missing value.

Station	(X) Bisoca	(X) Lacauti	(X) Patarlagele	(X) Penteleu
(Y) Bisoca (5403)		1077	668	977
(Y) Lacauti (4886)	560		1156	658
(Y) Patarlagele (5262)	527	2496		963
(Y) Penteleu (4853)	427	625	554	

Table 7.1Missing Value/Records possible to be blended. Low left values indicate the number of records from (Y) missing records that can be found in (X) stations. Right upper cells indicate the number of missing records from (X) stations that can be found in (Y). The number in parenthesis for stations in (Y) show the total number of records reported as “missing value”.

For the blending process, the distances (distance values can be found in Table 7.2) must be known in order to use the closes station with an available value for the specific date.

Station	Bisoca	Lacauti	Patarlagele	Penteleu
Bisoca		40.14 km	36.46 km	24.14 km
Lacauti	40.14 km		55.52 km	24.75 km
Patarlagele	36.46 km	55.52 km		31.07 km
Penteleu	24.14 km	24.75 km	31.07 km	

Table 7.2 Distance between Weather Recording Stations.

When comparing dataset in respect of correlation which could be useful in the blending process, values of R^2 can be found for Maximum and Average precipitation in Table 7.3 and Table 7.4 respectively.

Station	Bisoca	Lacauti	Patarlagele	Penteleu
Bisoca		0.525	0.383	0.488
Lacauti	0.525		0.353	0.548
Patarlagele	0.383	0.353		0.879
Penteleu	0.488	0.548	0.879	

Table 7.3 R^2 Values between stations of Maximum Monthly Precipitation for available records with a numerical value (when one of the stations being compared reports a “Missing Value” the record of both stations for that date are not considered).

Station	Bisoca	Lacauti	Patarlagele	Penteleu
Bisoca		0.923	0.948	0.970
Lacauti	0.923		0.947	0.950
Patarlagele	0.948	0.947		0.968
Penteleu	0.970	0.950	0.968	

Table 7.4 R^2 Values between stations of Average Monthly Precipitation for available records with a numerical value (when one of the stations being compared reports a “Missing Value” the record of both stations for that date are not considered).

7.2. Suitable Databse of floods and landslides

Historical inventories of past events were provided by the CHANGES partner. The collection of the data was not done within the present study, but rather used the delivered data to construct a suitable dataset. Flood events proved to be few, and when linked to precipitation values, this showed that floods occurred when precipitation of low return periods was present. Aside from precipitation values, the amount of events did not allow for a substantial number of events to be used in a threshold fitting model.

The low number of events could be related to the effect of hydroelectric plants being built (and operational) in the Buzau River Catchment during the temporal extent of the historical inventory.

In the case of landslides, seasonal classification was done with the first delivered file, which in majority (89%) occurred, as shown in Figure 5.5, during the snow cover or snowmelt period. The second dataset was delivered recently and time limited the amount of analysis that could be done to determine the quality of the data. Although exploratory analysis on frequency, yielded that the events contained occurred during the period of June-September. Another issue with the second delivery of the data (99 events) was that dates were given as a range of days. This was based on the dates that each media report recorded the event, hence the reason for the various probable dates attributed to each event. Therefore, the accuracy of the data was compromised.

7.3. Precipitation parameters as triggers for floods and landslides

In the case of the floods, the analysis showed that most of the events were related to the maximum value of precipitation for the summer in which they occurred. Although there are also cases in which the return period of the precipitation that caused floodings was lower than 1yr. In regards to threshold modelling it was not possible to be done since the number of events in the historical inventory was too few to fit the model and validate. Therefore, the approach was taken to use the return period as a base of analysis on whether or not an extreme precipitation was the trigger for the flood events.

.

7.4. Precipitation parameters as triggers for

For the case of landslides, most of the useful events were delivered at a time in which the processing of the information did not allow for the run of the model. Therefore, parameters could not be established

7.5. Determine probability when threshold is exceeded

Given the fact that the objective 4 was not able to be completed, this objective is not met.

7.6. Recommendations on using different datasets

The recommendations have been addressed as the objectives were discussed in this section.

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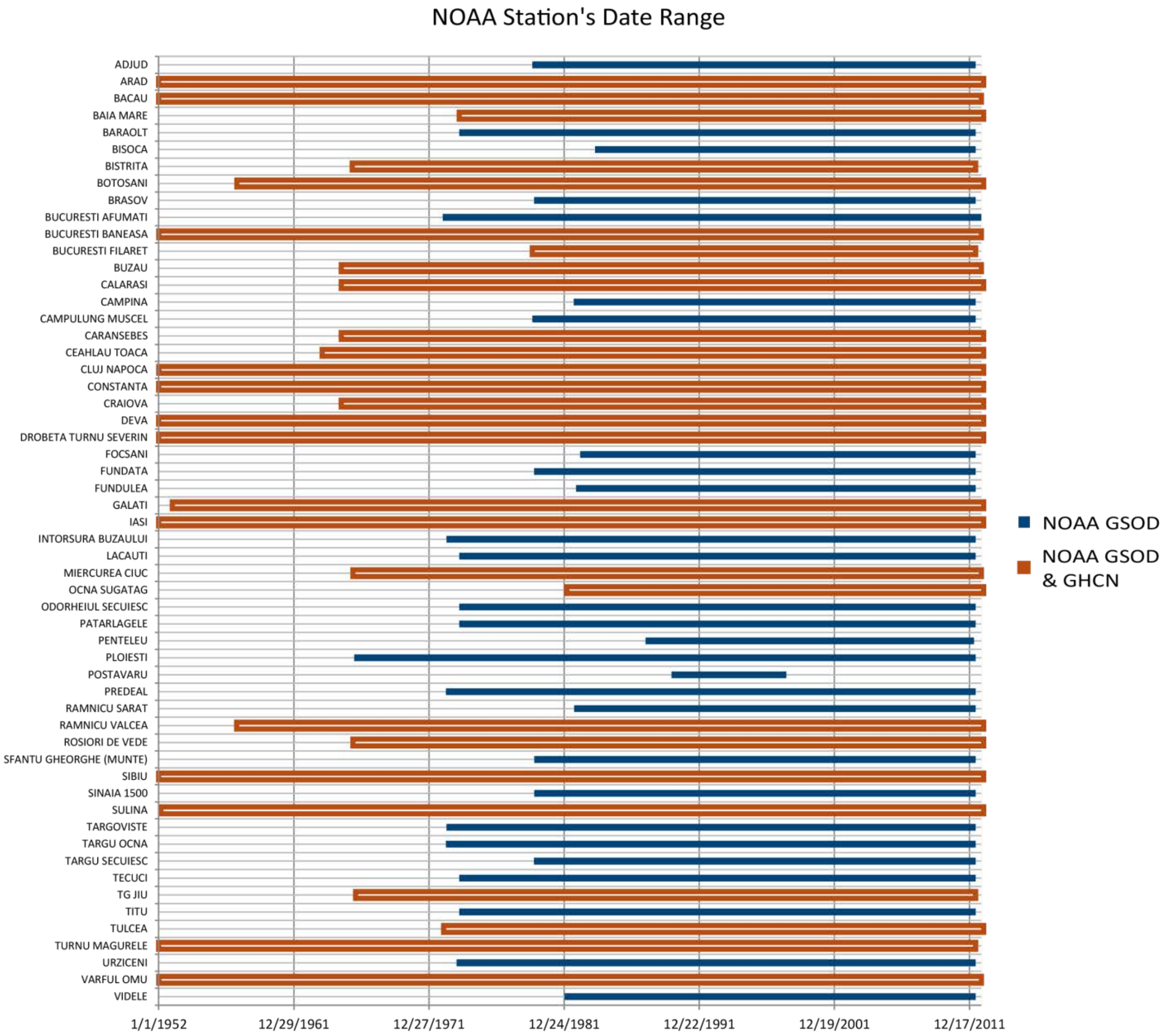
Appendix A - NetCDF data extraction and interpolation script

```
time=nc_varget('C:\ndfd\Data\rr_0.25deg_reg_v7.0.nc','time');
%the following command will allow to identify the coordinates, which will
%enable the user to specify the range of positions to be used that contain
%the values of interest
longx=nc_varget('rr_0.25deg_reg_v7.0.nc','longitude');
laty=nc_varget('rr_0.25deg_reg_v7.0.nc','latitude');

%once identified, a variable file is to be created with such values (the
number indicated refers to the location where the coordinate value is
located)
yss=laty(75:87);
xss=longx(262:275);

%this command allows to extract the information per x,y. What it does, is
%create a row of the grid, extracting values of (x1,x2,xn,...xn+1)
%by y1. As it can be observed, the second value of the first vector is
%static (corresponding to y1), while the third value is changing
%(x1,...xn+1). The first value of the same vector, denotes the position of
%the time variable, which starts at 0. The structure name of the

%tpf75
tp175=nc_varget('rr_0.25deg_reg_v7.0.nc','rr',[0 75 262],[23011 1 1]);
tp275=nc_varget('rr_0.25deg_reg_v7.0.nc','rr',[0 75 263],[23011 1 1]);
tp375=nc_varget('rr_0.25deg_reg_v7.0.nc','rr',[0 75 264],[23011 1 1]);
tp475=nc_varget('rr_0.25deg_reg_v7.0.nc','rr',[0 75 265],[23011 1 1]);
tp575=nc_varget('rr_0.25deg_reg_v7.0.nc','rr',[0 75 266],[23011 1 1]);
tp675=nc_varget('rr_0.25deg_reg_v7.0.nc','rr',[0 75 267],[23011 1 1]);
tp775=nc_varget('rr_0.25deg_reg_v7.0.nc','rr',[0 75 268],[23011 1 1]);
tp875=nc_varget('rr_0.25deg_reg_v7.0.nc','rr',[0 75 269],[23011 1 1]);
tp975=nc_varget('rr_0.25deg_reg_v7.0.nc','rr',[0 75 270],[23011 1 1]);
tp1075=nc_varget('rr_0.25deg_reg_v7.0.nc','rr',[0 75 271],[23011 1 1]);
tp1175=nc_varget('rr_0.25deg_reg_v7.0.nc','rr',[0 75 272],[23011 1 1]);
tp1275=nc_varget('rr_0.25deg_reg_v7.0.nc','rr',[0 75 273],[23011 1 1]);
tp1375=nc_varget('rr_0.25deg_reg_v7.0.nc','rr',[0 75 274],[23011 1 1]);
tp1475=nc_varget('rr_0.25deg_reg_v7.0.nc','rr',[0 75 275],[23011 1 1]);
tp75=[tp175,tp275,tp375,tp475,tp575,tp675,tp775,tp875,tp975,tp1075,tp1175,t
p1275,tp1375,tp1475];
tpf75=tp75(1:22827,1:14);
clear('tp175','tp275','tp375','tp475','tp575','tp675','tp775','tp875','tp97
5','tp1075','tp1175','tp1275','tp1375','tp1475','tp75')

%This step is repeated for every row of the grid to be extracted. The
structure of the row variable name corresponds to tpy1, where y1 is the
location for the first value of y.
%Once each row of the grid has been extracted,the following commands will
generate a grid for each time step of the file, and extract the value for
the points given (In this case, The location of the weather reporting
stations used within the grid area.

EOBS25=zeros(1:22827,34);
for n = 1:22827;
EOBS25(n,1) =
griddata(xss,yss,[tpf75(n,1:14);tpf76(n,1:14);tpf77(n,1:14);tpf78(n,1:14);t
pf79(n,1:14);tpf80(n,1:14);tpf81(n,1:14);tpf82(n,1:14);tpf83(n,1:14);tpf84(
n,1:14);tpf85(n,1:14);tpf86(n,1:14);tpf87(n,1:14)],26.912495,46.531889);
end
dlmwrite('EOBS25.txt' , EOBS25, ' ' );
```

Appendix B


NOAA Station's Date Range
ADJUD
ARAD
BACAU
BAIA MARE
BARAOLT
BISOCA
BISTRITA
BOTOSANI
BRASOV
BUCURESTI AFUMATI
BUCURESTI BANEASA
BUCURESTI FILARET
BUZAU
CALARASI
CAMPINA
CAMPULUNG MUSCEL
CARANSEBES
CEAHLAU TOACA
CLUJ NAPOCA
CONSTANTA
CRAIOVA
DEVA
DROBETA TURNU SEVERIN
FOCSANI
FUNDATA
FUNDULEA
GALATI
IASI
INTORSURA BUZAULUI
LACAUTI
MIERCUREA CIUC
OCNA SUGATAG
ODORHEIUL SECUIESC
PATARLAGELE
PENTELEU
PLOIESTI
POSTAVARU
PREDEAL
RAMNICU SARAT
RAMNICU VALCEA
ROSIORI DE VEDE
SFANTU GHEORGHE (MUNTE)
SIBIU
SINAIA 1500
SULINA
TARGOVISTE
TARGU OCNA
TARGU SECUIESC
TECUCI
TG JIU
TITU
TULCEA
TURNU MAGURELE
URZICENI
VARFUL OMU
VIDELE
1/1/1952
12/29/1961
12/27/1971
12/24/1981
12/22/1991
12/19/2001
12/17/2011
NOAA GSOD
NOAA GSOD & GHCN

Appendix C

GSOD Missing and Non-Missing Values

TER – Total Expected Records.

MR- Missing Records.

%MR - % of Missing Records in respect to the TER.

MV – Missing Values (Record is accounted for, but "missing data" is reported).

%RMV – Relative % of Missing values (from actual available records).

NMV – Non Missing Values.

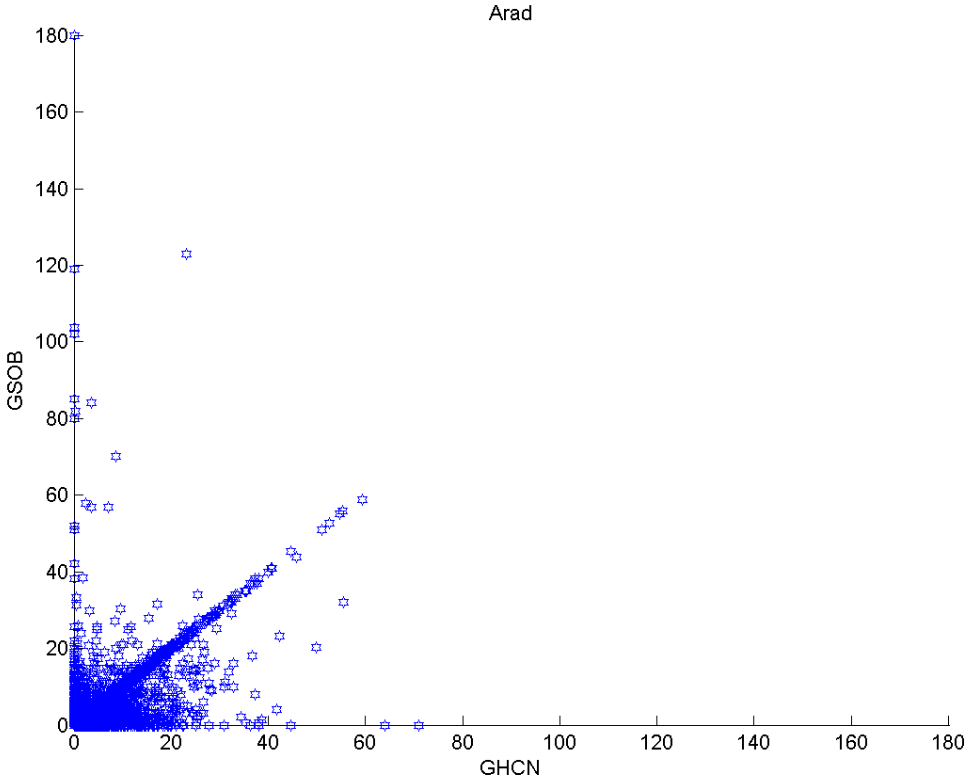
%RNMV – Relative % of Non-Missing values (from actual available records).

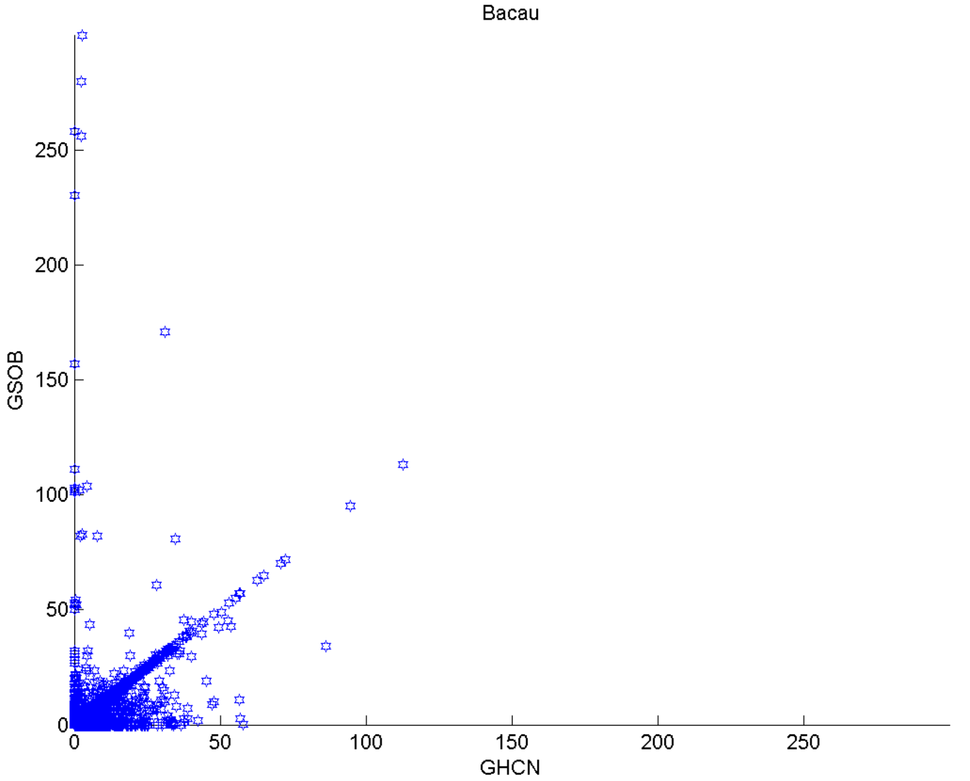
ID	Name	TER	MR	% MR	MV	% RMV	NMV	% RNMV
15219	ADJUD	11976	6292	53%	163	2.9%	5521	97.13%
152000	ARAD	22281	3492	16%	343	1.8%	18446	98.17%
15150	BACAU	22220	3988	18%	363	2.0%	17869	98.01%
150140	BAIA MARE	14165	4382	31%	2163	22.1%	7620	77.89%
15215	BARAOLT	13949	10694	77%	68	2.1%	3187	97.91%
15285	BISOCA	10279	5498	53%	113	2.4%	4668	97.64%
150850	BISTRITA	16840	7249	43%	220	2.3%	9371	97.71%
150200	BOTOSANI	20168	2550	13%	277	1.6%	17341	98.43%
15300	BRASOV	11927	6283	53%	218	3.9%	5426	96.14%
15421	BUCURESTI AFUMATI	14549	36	0%	5611	38.7%	8902	61.34%
15420	BUCURESTI BANEASA	22219	3395	15%	346	1.8%	18478	98.16%
15422	BUCURESTI FILARET	11976	6776	57%	229	4.4%	4971	95.60%
15350	BUZAU	17290	1877	11%	135	0.9%	15278	99.12%
154600	CALARASI	17351	2239	13%	140	0.9%	14972	99.07%
15349	CAMPINA	10854	5521	51%	117	2.2%	5216	97.81%
15324	CAMPULUNG MUSCEL	11976	6372	53%	202	3.6%	5402	96.40%
151080	CEAHLAU TOACA	17867	2146	12%	198	1.3%	15523	98.74%
151200	CLUJ NAPOCA	22280	3310	15%	380	2.0%	18590	98.00%
154800	CONSTANTA	22281	3444	15%	281	1.5%	18556	98.51%
154500	CRAIOVA	17351	2233	13%	187	1.2%	14931	98.76%
152300	DEVA	22281	5704	26%	276	1.7%	16301	98.34%
154100	DROBETA TURNU SEVERIN	22281	3179	14%	252	1.3%	18850	98.68%
15264	FOCSANI	10684	5336	50%	193	3.6%	5155	96.39%
15301	FUNDATA	11927	6294	53%	304	5.4%	5329	94.60%
15424	FUNDULEA	10791	7232	67%	92	2.6%	3467	97.42%
153100	GALATI	21914	3169	14%	259	1.4%	18486	98.62%
150900	IASI	22281	7002	31%	322	2.1%	14957	97.89%
15261	INTORSURA BUZAULUI	14295	6347	44%	184	2.3%	7764	97.68%
15262	LACAUTI	13949	8466	61%	215	3.9%	5268	96.08%
15170	MIERCUREA CIUC	16972	4290	25%	184	1.5%	12498	98.55%
150150	OCNA SUGATAG	11259	3158	28%	144	1.8%	7957	98.22%
15168	ODORHEIUL SECUIESC	13949	8494	61%	206	3.8%	5249	96.22%
15328	PATARLAGELE	13949	8857	63%	104	2.0%	4988	97.96%
15284	PENTELEU	8874	4467	50%	211	4.8%	4196	95.21%
15377	PLOIESTI	16788	7269	43%	160	1.7%	9359	98.32%
15259	POSTAVARU	3099	1571	51%	23	1.5%	1505	98.49%
15302	PREDEAL	14308	6439	45%	235	3.0%	7634	97.01%
15307	RAMNICU SARAT	10848	5170	48%	147	2.6%	5531	97.41%
153460	RAMNICU VALCEA	20177	2978	15%	240	1.4%	16959	98.60%
154700	ROSIORI DE VEDE	17033	3810	22%	116	0.9%	13107	99.12%
15238	SFANTU GHEORGHE (MUNTE)	11922	6224	52%	226	4.0%	5472	96.03%
152600	SIBIU	22281	8016	36%	286	2.0%	13979	98.00%
15325	SINAIA 1500	11922	6313	53%	239	4.3%	5370	95.74%
153600	SULINA	22220	4211	19%	215	1.2%	17794	98.81%
15375	TARGOVISTE	14294	6411	45%	125	1.6%	7758	98.41%
15194	TARGU OCNA	14308	8152	57%	151	2.5%	6005	97.55%
15217	TARGU SECUIESC	11934	6758	57%	119	2.3%	5057	97.70%
15265	TECUCI	13950	8221	59%	197	3.4%	5532	96.56%
153400	TG JIU	16749	7187	43%	154	1.6%	9408	98.39%
15419	TITU	13949	8344	60%	180	3.2%	5425	96.79%
153350	TULCEA	14586	2546	17%	309	2.6%	11731	97.43%
154900	TURNU MAGURELE	22066	12877	58%	148	1.6%	9041	98.39%
15402	URZICENI	14018	8762	63%	86	1.6%	5170	98.36%
15280	VARFUL OMU	22215	4319	19%	304	1.7%	17592	98.30%
15455	VIDELE	11099	6267	56%	118	2.4%	4714	97.56%
152920	CARANSEBES	17351	1878	11%	194	1.3%	15279	98.75%

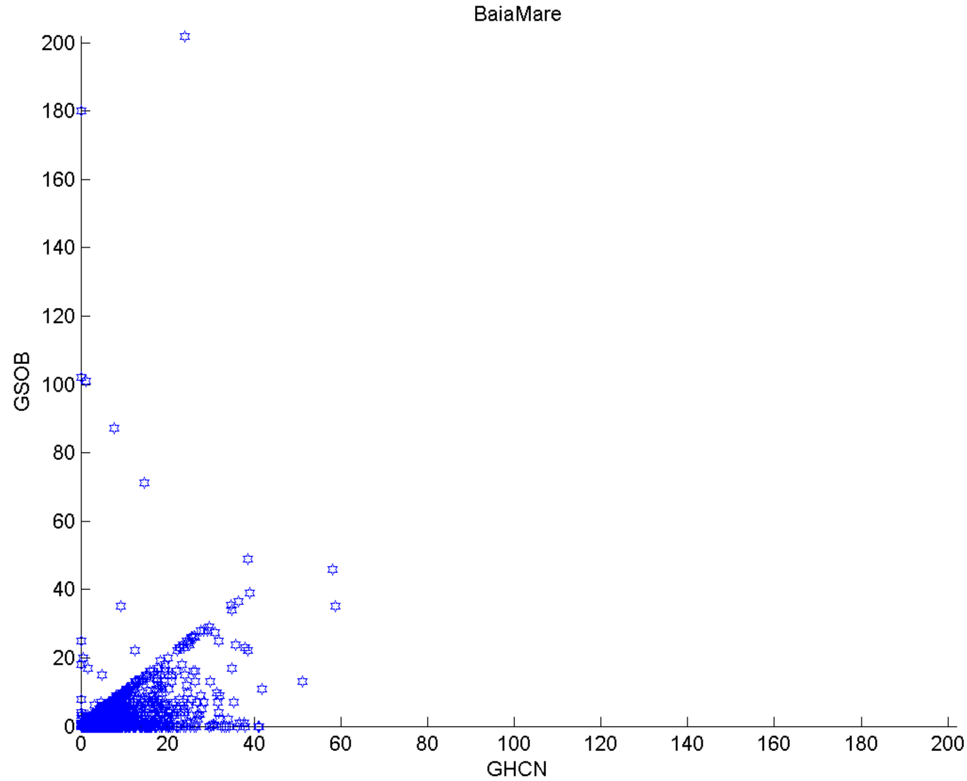
Appendix D

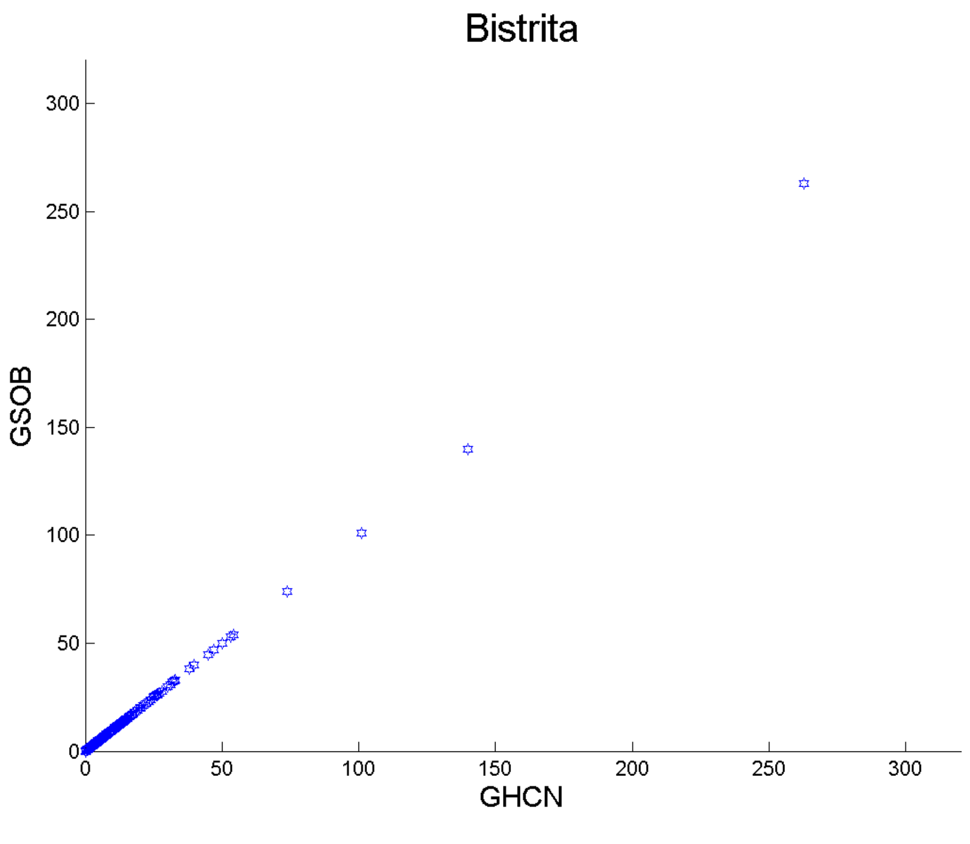
Station	Total Records	Missing Values	% Missing Values	Non-Missing Values
Arad	19716	357	1.8%	98.2%
Bacau	18228	331	1.8%	98.2%
BaiaMare	14880	270	1.8%	98.2%
Bistrita	10385	4391	42.3%	57.7%
Botosani	18228	331	1.8%	98.2%
BucarestiFilaret	39370	713	1.8%	98.2%
BucarestiBaneasa	18228	331	1.8%	98.2%
Buzau	24180	439	1.8%	98.2%
Calarasi	26784	486	1.8%	98.2%
Caransebes	18228	331	1.8%	98.2%
CeahlauToaca	1488	27	1.8%	98.2%
ClujNapoca	32364	587	1.8%	98.2%
Constanta	18228	331	1.8%	98.2%
Craiova	18228	331	1.8%	98.2%
Deva	18228	331	1.8%	98.2%
DrobetaTurnuSeverin	31620	574	1.8%	98.2%
Galati	18228	331	1.8%	98.2%
Iasi	18228	331	1.8%	98.2%
Miercurea Ciuc	18228	331	1.8%	98.2%
OcnaSugatag	17794	324	1.8%	98.2%
RamnicuValcea	18228	331	1.8%	98.2%
RosioriDeVede	18228	331	1.8%	98.2%
Sibiu	18228	331	1.8%	98.2%
Sulina	21049	1905	9.1%	90.9%
TgJiu	30876	560	1.8%	98.2%
Tulcea	18228	331	1.8%	98.2%
TurnuMagurele	23436	425	1.8%	98.2%
VarfuOmul	21700	2402	11.1%	88.9%

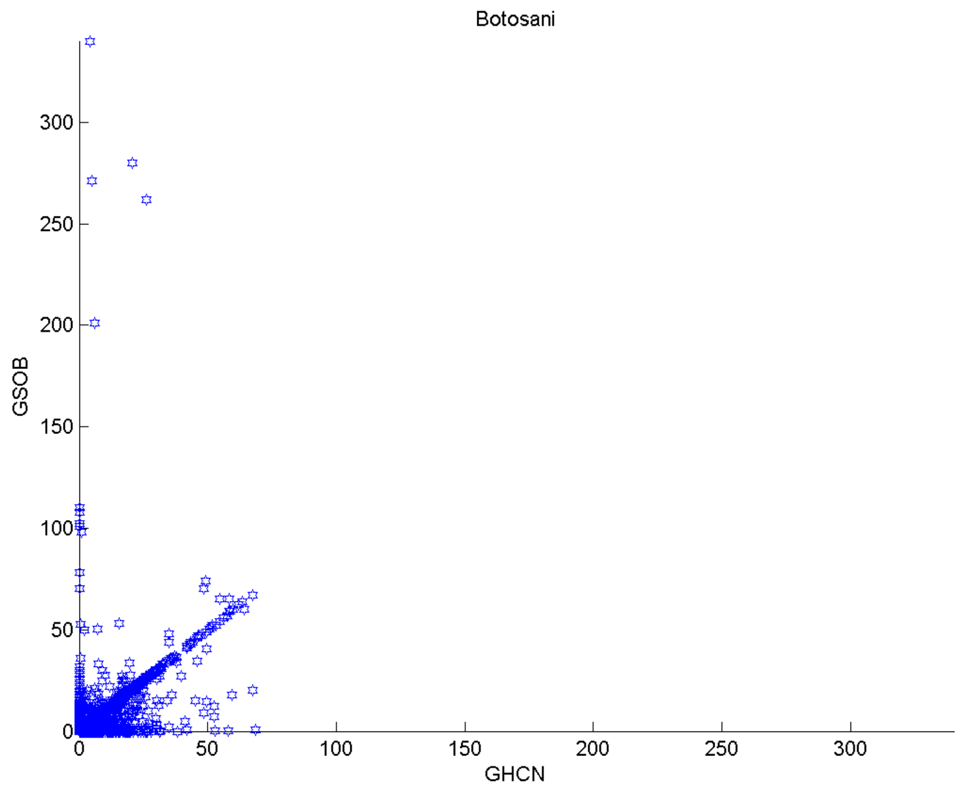
Appendix E GHCN vs GSOB

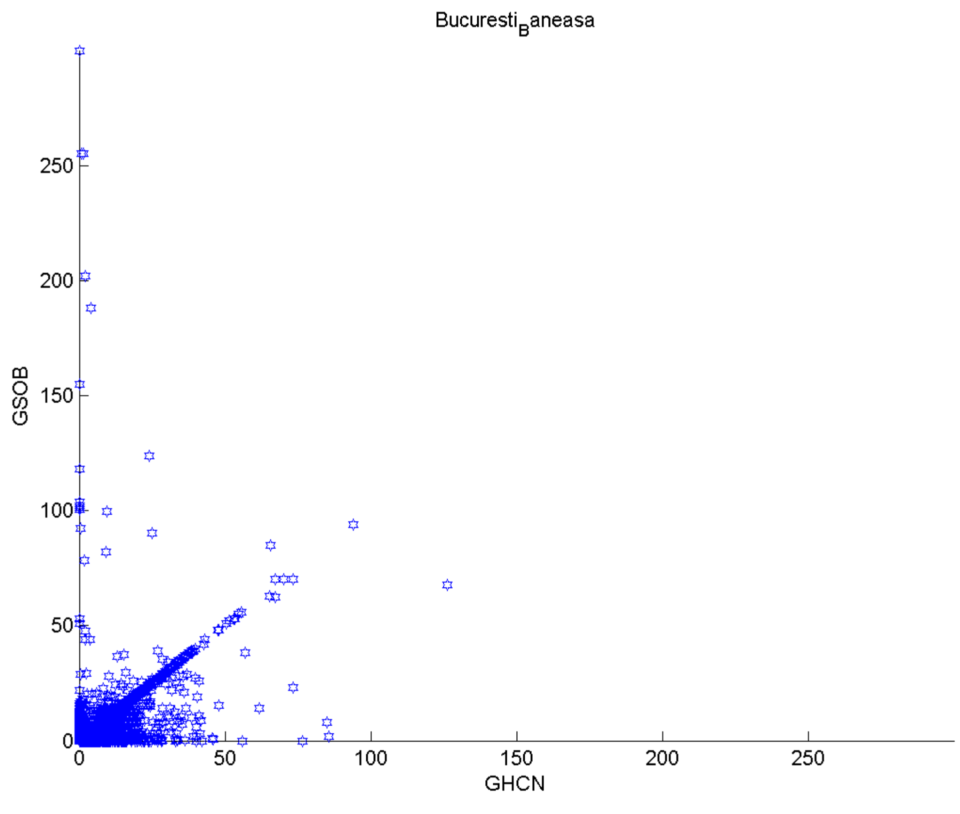





BaiaMare
GSOB
GHCN
0
20
40
60
80
100
120
140
160
180
200


Bistrita
GSOB
GHCN
0
50
100
150
200
250
300


Botosani
GSOB
GHCN
0
50
100
150
200
250
300


Bucuresti_Baneasa
GSOB
GHCN
0
50
100
150
200
250

Appendix F - Gumbel distribution for Return Period Analysis

EOBS –PED Bisoca

Year	Rank	Precipitation	Ordered	Rank	PL	PR	Tr	Y
1950	12	21.243	13.635	1	0.01612903	0.983871	1.016393	-1.41758
1951	27	25.521	14.909	2	0.03225806	0.967742	1.033333	-1.23372
1952	31	26.218	16.168	3	0.0483871	0.951613	1.050847	-1.10807
1953	10	20.789	19.13	4	0.06451613	0.935484	1.068966	-1.00826
1954	3	16.168	19.599	5	0.08064516	0.919355	1.087719	-0.92334
1955	51	35.479	19.696	6	0.09677419	0.903226	1.107143	-0.84817
1956	22	23.977	19.728	7	0.11290323	0.887097	1.127273	-0.77989
1957	38	28.773	20.33	8	0.12903226	0.870968	1.148148	-0.71671
1958	58	52.882	20.772	9	0.14516129	0.854839	1.169811	-0.65747
1959	55	40.901	20.789	10	0.16129032	0.83871	1.192308	-0.60133
1960	14	21.523	20.794	11	0.17741935	0.822581	1.215686	-0.54768
1961	9	20.772	21.243	12	0.19354839	0.806452	1.24	-0.49605
1962	23	24.731	21.281	13	0.20967742	0.790323	1.265306	-0.44609
1963	1	13.635	21.523	14	0.22580645	0.774194	1.291667	-0.39748
1964	34	27.231	22.051	15	0.24193548	0.758065	1.319149	-0.35001
1965	25	24.911	22.697	16	0.25806452	0.741935	1.347826	-0.30347
1966	41	31.027	22.921	17	0.27419355	0.725806	1.377778	-0.25768
1967	4	19.13	22.958	18	0.29032258	0.709677	1.409091	-0.2125
1968	43	31.237	23.502	19	0.30645161	0.693548	1.44186	-0.1678
1969	57	49.094	23.593	20	0.32258065	0.677419	1.47619	-0.12346
1970	46	33.598	23.645	21	0.33870968	0.66129	1.512195	-0.07938
1971	60	63.21	23.977	22	0.35483871	0.645161	1.55	-0.03546
1972	56	43.49	24.731	23	0.37096774	0.629032	1.589744	0.008395
1973	44	31.929	24.766	24	0.38709677	0.612903	1.631579	0.052262
1974	50	35.351	24.911	25	0.40322581	0.596774	1.675676	0.096226
1975	5	19.599	25.069	26	0.41935484	0.580645	1.722222	0.140369
1976	19	23.502	25.521	27	0.43548387	0.564516	1.771429	0.184768
1977	59	55.002	25.79	28	0.4516129	0.548387	1.823529	0.229501
1978	8	20.33	25.791	29	0.46774194	0.532258	1.878788	0.274649
1979	37	28.759	26.115	30	0.48387097	0.516129	1.9375	0.320292
1980	26	25.069	26.218	31	0.5	0.5	2	0.366513
1981	24	24.766	26.916	32	0.51612903	0.483871	2.066667	0.413399
1982	7	19.728	26.949	33	0.53225806	0.467742	2.137931	0.461041
1983	54	38.46	27.231	34	0.5483871	0.451613	2.214286	0.509537
1984	28	25.79	28.192	35	0.56451613	0.435484	2.296296	0.55899
1985	49	35.348	28.402	36	0.58064516	0.419355	2.384615	0.609513
1986	2	14.909	28.759	37	0.59677419	0.403226	2.48	0.661229
1987	40	30.431	28.773	38	0.61290323	0.387097	2.583333	0.714272
1988	29	25.791	29.058	39	0.62903226	0.370968	2.695652	0.768792
1989	30	26.115	30.431	40	0.64516129	0.354839	2.818182	0.824955
1990	15	22.051	31.027	41	0.66129032	0.33871	2.952381	0.882947
1991	45	32.863	31.196	42	0.67741935	0.322581	3.1	0.942982
1992	6	19.696	31.237	43	0.69354839	0.306452	3.263158	1.005302
1993	16	22.697	31.929	44	0.70967742	0.290323	3.444444	1.070186
1994	53	38.262	32.863	45	0.72580645	0.274194	3.647059	1.137961
1995	35	28.192	33.598	46	0.74193548	0.258065	3.875	1.209009
1996	36	28.402	34.384	47	0.75806452	0.241935	4.133333	1.283785
1997	32	26.916	35.026	48	0.77419355	0.225806	4.428571	1.362838
1998	48	35.026	35.348	49	0.79032258	0.209677	4.769231	1.446834
1999	47	34.384	35.351	50	0.80645161	0.193548	5.166667	1.536599
2000	33	26.949	35.479	51	0.82258065	0.177419	5.636364	1.633174
2001	42	31.196	37.384	52	0.83870968	0.16129	6.2	1.737893
2002	52	37.384	38.262	53	0.85483871	0.145161	6.888889	1.852513
2003	11	20.794	38.46	54	0.87096774	0.129032	7.75	1.979413
2004	20	23.593	40.901	55	0.88709677	0.112903	8.857143	2.121922
2005	61	68.83	43.49	56	0.90322581	0.096774	10.33333	2.284915
2006	21	23.645	49.094	57	0.91935484	0.080645	12.4	2.475949
2007	39	29.058	52.882	58	0.93548387	0.064516	15.5	2.70768
2008	17	22.921	55.002	59	0.9516129	0.048387	20.66667	3.003826
2009	13	21.281	63.21	60	0.96774194	0.032258	31	3.417637
2010	18	22.958	68.83	61	0.98387097	0.016129	62	4.119015

EOBS-PED Buzau

Year	Rank	Precipitation	Ordered	Rank	PL	PR	Tr	Y
1950	29	27.158	14.569	1	0.01612903	0.983871	1.016393	-1.41758
1951	33	28.175	15.15	2	0.03225806	0.967742	1.033333	-1.23372
1952	26	25.758	18.096	3	0.0483871	0.951613	1.050847	-1.10807
1953	27	25.914	18.973	4	0.06451613	0.935484	1.068966	-1.00826
1954	7	21.08	19.176	5	0.08064516	0.919355	1.087719	-0.92334
1955	47	36.337	20.603	6	0.09677419	0.903226	1.107143	-0.84817
1956	30	27.159	21.08	7	0.11290323	0.887097	1.127273	-0.77989
1957	35	29.633	21.682	8	0.12903226	0.870968	1.148148	-0.71671
1958	57	47.129	22.009	9	0.14516129	0.854839	1.169811	-0.65747
1959	58	48.28	22.347	10	0.16129032	0.83871	1.192308	-0.60133
1960	22	24.811	22.441	11	0.17741935	0.822581	1.215686	-0.54768
1961	12	22.486	22.486	12	0.19354839	0.806452	1.24	-0.49605
1962	31	27.425	22.638	13	0.20967742	0.790323	1.265306	-0.44609
1963	1	14.569	22.828	14	0.22580645	0.774194	1.291667	-0.39748
1964	43	34.166	23.165	15	0.24193548	0.758065	1.319149	-0.35001
1965	28	26.967	23.564	16	0.25806452	0.741935	1.347826	-0.30347
1966	45	35.379	23.629	17	0.27419355	0.725806	1.377778	-0.25768
1967	21	24.687	23.667	18	0.29032258	0.709677	1.409091	-0.2125
1968	18	23.667	24.016	19	0.30645161	0.693548	1.44186	-0.1678
1969	55	44.817	24.081	20	0.32258065	0.677419	1.47619	-0.12346
1970	38	31.749	24.687	21	0.33870968	0.66129	1.512195	-0.07938
1971	60	58.878	24.811	22	0.35483871	0.645161	1.55	-0.03546
1972	56	45.833	24.935	23	0.37096774	0.629032	1.589744	0.008395
1973	41	33.431	25.173	24	0.38709677	0.612903	1.631579	0.052262
1974	49	36.832	25.461	25	0.40322581	0.596774	1.675676	0.096226
1975	11	22.441	25.758	26	0.41935484	0.580645	1.722222	0.140369
1976	54	41.782	25.914	27	0.43548387	0.564516	1.771429	0.184768
1977	59	50.004	26.967	28	0.4516129	0.548387	1.823529	0.229501
1978	32	27.496	27.158	29	0.46774194	0.532258	1.878788	0.274649
1979	16	23.564	27.159	30	0.48387097	0.516129	1.9375	0.320292
1980	23	24.935	27.425	31	0.5	0.5	2	0.366513
1981	24	25.173	27.496	32	0.51612903	0.483871	2.066667	0.413399
1982	8	21.682	28.175	33	0.53225806	0.467742	2.137931	0.461041
1983	44	34.779	29.495	34	0.5483871	0.451613	2.214286	0.509537
1984	15	23.165	29.633	35	0.56451613	0.435484	2.296296	0.55899
1985	37	30.158	29.804	36	0.58064516	0.419355	2.384615	0.609513
1986	2	15.15	30.158	37	0.59677419	0.403226	2.48	0.661229
1987	42	33.928	31.749	38	0.61290323	0.387097	2.583333	0.714272
1988	20	24.081	32.393	39	0.62903226	0.370968	2.695652	0.768792
1989	13	22.638	32.864	40	0.64516129	0.354839	2.818182	0.824955
1990	4	18.973	33.431	41	0.66129032	0.33871	2.952381	0.882947
1991	51	38.528	33.928	42	0.67741935	0.322581	3.1	0.942982
1992	3	18.096	34.166	43	0.69354839	0.306452	3.263158	1.005302
1993	5	19.176	34.779	44	0.70967742	0.290323	3.444444	1.070186
1994	39	32.393	35.379	45	0.72580645	0.274194	3.647059	1.137961
1995	40	32.864	35.846	46	0.74193548	0.258065	3.875	1.209009
1996	36	29.804	36.337	47	0.75806452	0.241935	4.133333	1.283785
1997	48	36.472	36.472	48	0.77419355	0.225806	4.428571	1.362838
1998	46	35.846	36.832	49	0.79032258	0.209677	4.769231	1.446834
1999	52	39.055	38.141	50	0.80645161	0.193548	5.166667	1.536599
2000	19	24.016	38.528	51	0.82258065	0.177419	5.636364	1.633174
2001	34	29.495	39.055	52	0.83870968	0.16129	6.2	1.737893
2002	50	38.141	40.662	53	0.85483871	0.145161	6.888889	1.852513
2003	10	22.347	41.782	54	0.87096774	0.129032	7.75	1.979413
2004	25	25.461	44.817	55	0.88709677	0.112903	8.857143	2.121922
2005	61	62.973	45.833	56	0.90322581	0.096774	10.33333	2.284915
2006	14	22.828	47.129	57	0.91935484	0.080645	12.4	2.475949
2007	53	40.662	48.28	58	0.93548387	0.064516	15.5	2.70768
2008	17	23.629	50.004	59	0.9516129	0.048387	20.66667	3.003826
2009	6	20.603	58.878	60	0.96774194	0.032258	31	3.417637
2010	9	22.009	62.973	61	0.98387097	0.016129	62	4.119015

EOBS-PED Introsura Buzaului

Year	Rank	Precipitation	Ordered	Rank	PL	PR	Tr	Y
1950	6	19.207	12.7	1	0.01612903	0.983871	1.016393	-1.41758
1951	32	28.981	15.343	2	0.03225806	0.967742	1.033333	-1.23372
1952	39	31.249	17.335	3	0.0483871	0.951613	1.050847	-1.10807
1953	22	25.393	17.767	4	0.06451613	0.935484	1.068966	-1.00826
1954	2	15.343	18.522	5	0.08064516	0.919355	1.087719	-0.92334
1955	48	35.797	19.207	6	0.09677419	0.903226	1.107143	-0.84817
1956	9	22.907	19.414	7	0.11290323	0.887097	1.127273	-0.77989
1957	40	31.366	20.07	8	0.12903226	0.870968	1.148148	-0.71671
1958	59	54.818	22.907	9	0.14516129	0.854839	1.169811	-0.65747
1959	51	38.003	23.119	10	0.16129032	0.83871	1.192308	-0.60133
1960	30	28.692	23.124	11	0.17741935	0.822581	1.215686	-0.54768
1961	27	26.3	23.255	12	0.19354839	0.806452	1.24	-0.49605
1962	46	33.205	23.295	13	0.20967742	0.790323	1.265306	-0.44609
1963	3	17.335	23.454	14	0.22580645	0.774194	1.291667	-0.39748
1964	45	32.828	23.98	15	0.24193548	0.758065	1.319149	-0.35001
1965	14	23.454	24.161	16	0.25806452	0.741935	1.347826	-0.30347
1966	41	31.858	24.187	17	0.27419355	0.725806	1.377778	-0.25768
1967	13	23.295	24.429	18	0.29032258	0.709677	1.409091	-0.2125
1968	54	38.839	24.456	19	0.30645161	0.693548	1.44186	-0.1678
1969	57	43.749	24.964	20	0.32258065	0.677419	1.47619	-0.12346
1970	55	40.943	25.243	21	0.33870968	0.66129	1.512195	-0.07938
1971	61	62.12	25.393	22	0.35483871	0.645161	1.55	-0.03546
1972	38	30.985	25.52	23	0.37096774	0.629032	1.589744	0.008395
1973	47	35.309	25.847	24	0.38709677	0.612903	1.631579	0.052262
1974	31	28.733	25.946	25	0.40322581	0.596774	1.675676	0.096226
1975	56	41.638	25.985	26	0.41935484	0.580645	1.722222	0.140369
1976	24	25.847	26.3	27	0.43548387	0.564516	1.771429	0.184768
1977	58	49.831	26.746	28	0.4516129	0.548387	1.823529	0.229501
1978	34	29.491	28.125	29	0.46774194	0.532258	1.878788	0.274649
1979	53	38.63	28.692	30	0.48387097	0.516129	1.9375	0.320292
1980	17	24.187	28.733	31	0.5	0.5	2	0.366513
1981	23	25.52	28.981	32	0.51612903	0.483871	2.066667	0.413399
1982	10	23.119	28.986	33	0.53225806	0.467742	2.137931	0.461041
1983	52	38.16	29.491	34	0.5483871	0.451613	2.214286	0.509537
1984	12	23.255	30.092	35	0.56451613	0.435484	2.296296	0.55899
1985	42	32.535	30.149	36	0.58064516	0.419355	2.384615	0.609513
1986	1	12.7	30.481	37	0.59677419	0.403226	2.48	0.661229
1987	19	24.456	30.985	38	0.61290323	0.387097	2.583333	0.714272
1988	7	19.414	31.249	39	0.62903226	0.370968	2.695652	0.768792
1989	28	26.746	31.366	40	0.64516129	0.354839	2.818182	0.824955
1990	8	20.07	31.858	41	0.66129032	0.33871	2.952381	0.882947
1991	26	25.985	32.535	42	0.67741935	0.322581	3.1	0.942982
1992	4	17.767	32.617	43	0.69354839	0.306452	3.263158	1.005302
1993	16	24.161	32.647	44	0.70967742	0.290323	3.444444	1.070186
1994	50	37.421	32.828	45	0.72580645	0.274194	3.647059	1.137961
1995	44	32.647	33.205	46	0.74193548	0.258065	3.875	1.209009
1996	33	28.986	35.309	47	0.75806452	0.241935	4.133333	1.283785
1997	11	23.124	35.797	48	0.77419355	0.225806	4.428571	1.362838
1998	25	25.946	36.043	49	0.79032258	0.209677	4.769231	1.446834
1999	43	32.617	37.421	50	0.80645161	0.193548	5.166667	1.536599
2000	36	30.149	38.003	51	0.82258065	0.177419	5.636364	1.633174
2001	15	23.98	38.16	52	0.83870968	0.16129	6.2	1.737893
2002	20	24.964	38.63	53	0.85483871	0.145161	6.888889	1.852513
2003	5	18.522	38.839	54	0.87096774	0.129032	7.75	1.979413
2004	18	24.429	40.943	55	0.88709677	0.112903	8.857143	2.121922
2005	60	58.736	41.638	56	0.90322581	0.096774	10.33333	2.284915
2006	29	28.125	43.749	57	0.91935484	0.080645	12.4	2.475949
2007	37	30.481	49.831	58	0.93548387	0.064516	15.5	2.70768
2008	35	30.092	54.818	59	0.9516129	0.048387	20.66667	3.003826
2009	49	36.043	58.736	60	0.96774194	0.032258	31	3.417637
2010	21	25.243	62.12	61	0.98387097	0.016129	62	4.119015

EOBS-PED Lacauti

Year	Rank	Precipitation	Ordered	Rank	PL	PR	Tr	Y
1950	4	18.491	13.959	1	0.01612903	0.983871	1.016393	-1.41758
1951	27	27.245	15.187	2	0.03225806	0.967742	1.033333	-1.23372
1952	30	28.146	16.018	3	0.0483871	0.951613	1.050847	-1.10807
1953	8	20.663	18.491	4	0.06451613	0.935484	1.068966	-1.00826
1954	2	15.187	18.528	5	0.08064516	0.919355	1.087719	-0.92334
1955	47	34.63	19.028	6	0.09677419	0.903226	1.107143	-0.84817
1956	9	21.148	19.42	7	0.11290323	0.887097	1.127273	-0.77989
1957	38	30.375	20.663	8	0.12903226	0.870968	1.148148	-0.71671
1958	59	51.125	21.148	9	0.14516129	0.854839	1.169811	-0.65747
1959	52	36.584	21.662	10	0.16129032	0.83871	1.192308	-0.60133
1960	23	26.713	21.854	11	0.17741935	0.822581	1.215686	-0.54768
1961	15	23.549	22.423	12	0.19354839	0.806452	1.24	-0.49605
1962	25	26.964	22.647	13	0.20967742	0.790323	1.265306	-0.44609
1963	3	16.018	23.459	14	0.22580645	0.774194	1.291667	-0.39748
1964	42	31.301	23.549	15	0.24193548	0.758065	1.319149	-0.35001
1965	28	27.905	23.93	16	0.25806452	0.741935	1.347826	-0.30347
1966	37	29.967	24.256	17	0.27419355	0.725806	1.377778	-0.25768
1967	5	18.528	24.449	18	0.29032258	0.709677	1.409091	-0.2125
1968	50	35.302	24.998	19	0.30645161	0.693548	1.44186	-0.1678
1969	57	45.536	25.85	20	0.32258065	0.677419	1.47619	-0.12346
1970	55	39.528	26.29	21	0.33870968	0.66129	1.512195	-0.07938
1971	60	63.152	26.373	22	0.35483871	0.645161	1.55	-0.03546
1972	51	35.857	26.713	23	0.37096774	0.629032	1.589744	0.008395
1973	35	29.334	26.871	24	0.38709677	0.612903	1.631579	0.052262
1974	33	28.521	26.964	25	0.40322581	0.596774	1.675676	0.096226
1975	20	25.85	27.135	26	0.41935484	0.580645	1.722222	0.140369
1976	11	21.854	27.245	27	0.43548387	0.564516	1.771429	0.184768
1977	58	51.015	27.905	28	0.4516129	0.548387	1.823529	0.229501
1978	24	26.871	28.045	29	0.46774194	0.532258	1.878788	0.274649
1979	49	35.289	28.146	30	0.48387097	0.516129	1.9375	0.320292
1980	26	27.135	28.212	31	0.5	0.5	2	0.366513
1981	14	23.459	28.427	32	0.51612903	0.483871	2.066667	0.413399
1982	10	21.662	28.521	33	0.53225806	0.467742	2.137931	0.461041
1983	56	41.351	28.714	34	0.5483871	0.451613	2.214286	0.509537
1984	13	22.647	29.334	35	0.56451613	0.435484	2.296296	0.55899
1985	53	38.382	29.737	36	0.58064516	0.419355	2.384615	0.609513
1986	1	13.959	29.967	37	0.59677419	0.403226	2.48	0.661229
1987	39	30.399	30.375	38	0.61290323	0.387097	2.583333	0.714272
1988	12	22.423	30.399	39	0.62903226	0.370968	2.695652	0.768792
1989	36	29.737	30.776	40	0.64516129	0.354839	2.818182	0.824955
1990	16	23.93	31.018	41	0.66129032	0.33871	2.952381	0.882947
1991	21	26.29	31.301	42	0.67741935	0.322581	3.1	0.942982
1992	7	19.42	31.713	43	0.69354839	0.306452	3.263158	1.005302
1993	17	24.256	32.728	44	0.70967742	0.290323	3.444444	1.070186
1994	54	39.343	32.909	45	0.72580645	0.274194	3.647059	1.137961
1995	41	31.018	33.407	46	0.74193548	0.258065	3.875	1.209009
1996	43	31.713	34.63	47	0.75806452	0.241935	4.133333	1.283785
1997	18	24.449	34.83	48	0.77419355	0.225806	4.428571	1.362838
1998	19	24.998	35.289	49	0.79032258	0.209677	4.769231	1.446834
1999	45	32.909	35.302	50	0.80645161	0.193548	5.166667	1.536599
2000	48	34.83	35.857	51	0.82258065	0.177419	5.636364	1.633174
2001	22	26.373	36.584	52	0.83870968	0.16129	6.2	1.737893
2002	40	30.776	38.382	53	0.85483871	0.145161	6.888889	1.852513
2003	6	19.028	39.343	54	0.87096774	0.129032	7.75	1.979413
2004	29	28.045	39.528	55	0.88709677	0.112903	8.857143	2.121922
2005	61	65.183	41.351	56	0.90322581	0.096774	10.33333	2.284915
2006	34	28.714	45.536	57	0.91935484	0.080645	12.4	2.475949
2007	44	32.728	51.015	58	0.93548387	0.064516	15.5	2.70768
2008	32	28.427	51.125	59	0.9516129	0.048387	20.66667	3.003826
2009	31	28.212	63.152	60	0.96774194	0.032258	31	3.417637
2010	46	33.407	65.183	61	0.98387097	0.016129	62	4.119015

EOBS-PED Patarlagele

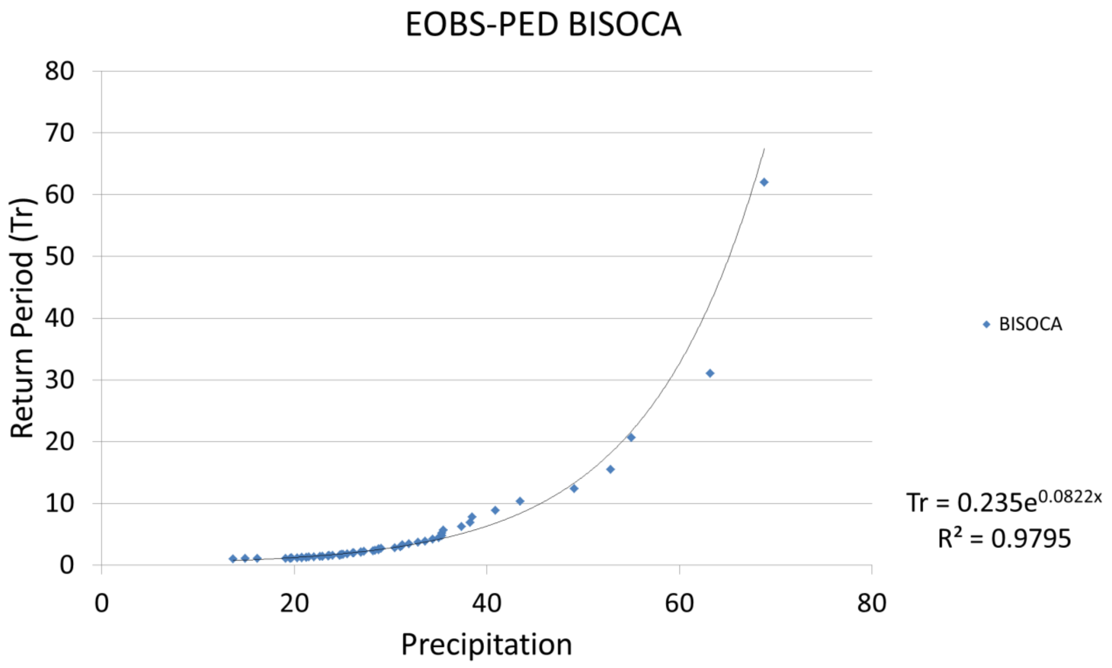
Year	Rank	Precipitation	Ordered	Rank	PL	PR	Tr	Y
1950	11	24.105	16.777	1	0.01612903	0.983871	1.016393	-1.41758
1951	23	26.782	17.084	2	0.03225806	0.967742	1.033333	-1.23372
1952	37	32.638	17.859	3	0.0483871	0.951613	1.050847	-1.10807
1953	16	25.064	18.615	4	0.06451613	0.935484	1.068966	-1.00826
1954	4	18.615	19.503	5	0.08064516	0.919355	1.087719	-0.92334
1955	51	38.395	20.801	6	0.09677419	0.903226	1.107143	-0.84817
1956	17	25.456	21.517	7	0.11290323	0.887097	1.127273	-0.77989
1957	48	36.308	22.043	8	0.12903226	0.870968	1.148148	-0.71671
1958	60	60.557	23.108	9	0.14516129	0.854839	1.169811	-0.65747
1959	56	46.317	23.372	10	0.16129032	0.83871	1.192308	-0.60133
1960	24	26.807	24.105	11	0.17741935	0.822581	1.215686	-0.54768
1961	9	23.108	24.562	12	0.19354839	0.806452	1.24	-0.49605
1962	40	33.244	24.588	13	0.20967742	0.790323	1.265306	-0.44609
1963	2	17.084	24.691	14	0.22580645	0.774194	1.291667	-0.39748
1964	45	34.346	24.764	15	0.24193548	0.758065	1.319149	-0.35001
1965	28	27.857	25.064	16	0.25806452	0.741935	1.347826	-0.30347
1966	42	34.188	25.456	17	0.27419355	0.725806	1.377778	-0.25768
1967	33	31.421	25.789	18	0.29032258	0.709677	1.409091	-0.2125
1968	47	36.268	25.939	19	0.30645161	0.693548	1.44186	-0.1678
1969	57	48.266	25.983	20	0.32258065	0.677419	1.47619	-0.12346
1970	46	35.454	26.19	21	0.33870968	0.66129	1.512195	-0.07938
1971	61	66.406	26.345	22	0.35483871	0.645161	1.55	-0.03546
1972	50	37.752	26.782	23	0.37096774	0.629032	1.589744	0.008395
1973	55	44.113	26.807	24	0.38709677	0.612903	1.631579	0.052262
1974	38	33.044	27.08	25	0.40322581	0.596774	1.675676	0.096226
1975	53	39.703	27.147	26	0.41935484	0.580645	1.722222	0.140369
1976	30	28.602	27.628	27	0.43548387	0.564516	1.771429	0.184768
1977	58	52.837	27.857	28	0.4516129	0.548387	1.823529	0.229501
1978	15	24.764	28.353	29	0.46774194	0.532258	1.878788	0.274649
1979	35	31.887	28.602	30	0.48387097	0.516129	1.9375	0.320292
1980	18	25.789	29.72	31	0.5	0.5	2	0.366513
1981	39	33.19	29.83	32	0.51612903	0.483871	2.066667	0.413399
1982	12	24.562	31.421	33	0.53225806	0.467742	2.137931	0.461041
1983	49	36.973	31.468	34	0.5483871	0.451613	2.214286	0.509537
1984	13	24.588	31.887	35	0.56451613	0.435484	2.296296	0.55899
1985	32	29.83	32.289	36	0.58064516	0.419355	2.384615	0.609513
1986	1	16.777	32.638	37	0.59677419	0.403226	2.48	0.661229
1987	25	27.08	33.044	38	0.61290323	0.387097	2.583333	0.714272
1988	7	21.517	33.19	39	0.62903226	0.370968	2.695652	0.768792
1989	27	27.628	33.244	40	0.64516129	0.354839	2.818182	0.824955
1990	5	19.503	33.847	41	0.66129032	0.33871	2.952381	0.882947
1991	41	33.847	34.188	42	0.67741935	0.322581	3.1	0.942982
1992	3	17.859	34.195	43	0.69354839	0.306452	3.263158	1.005302
1993	10	23.372	34.242	44	0.70967742	0.290323	3.444444	1.070186
1994	52	39.341	34.346	45	0.72580645	0.274194	3.647059	1.137961
1995	31	29.72	35.454	46	0.74193548	0.258065	3.875	1.209009
1996	20	25.983	36.268	47	0.75806452	0.241935	4.133333	1.283785
1997	36	32.289	36.308	48	0.77419355	0.225806	4.428571	1.362838
1998	22	26.345	36.973	49	0.79032258	0.209677	4.769231	1.446834
1999	44	34.242	37.752	50	0.80645161	0.193548	5.166667	1.536599
2000	14	24.691	38.395	51	0.82258065	0.177419	5.636364	1.633174
2001	29	28.353	39.341	52	0.83870968	0.16129	6.2	1.737893
2002	43	34.195	39.703	53	0.85483871	0.145161	6.888889	1.852513
2003	8	22.043	40.289	54	0.87096774	0.129032	7.75	1.979413
2004	6	20.801	44.113	55	0.88709677	0.112903	8.857143	2.121922
2005	59	58.025	46.317	56	0.90322581	0.096774	10.33333	2.284915
2006	26	27.147	48.266	57	0.91935484	0.080645	12.4	2.475949
2007	54	40.289	52.837	58	0.93548387	0.064516	15.5	2.70768
2008	21	26.19	58.025	59	0.9516129	0.048387	20.66667	3.003826
2009	34	31.468	60.557	60	0.96774194	0.032258	31	3.417637
2010	19	25.939	66.406	61	0.98387097	0.016129	62	4.119015

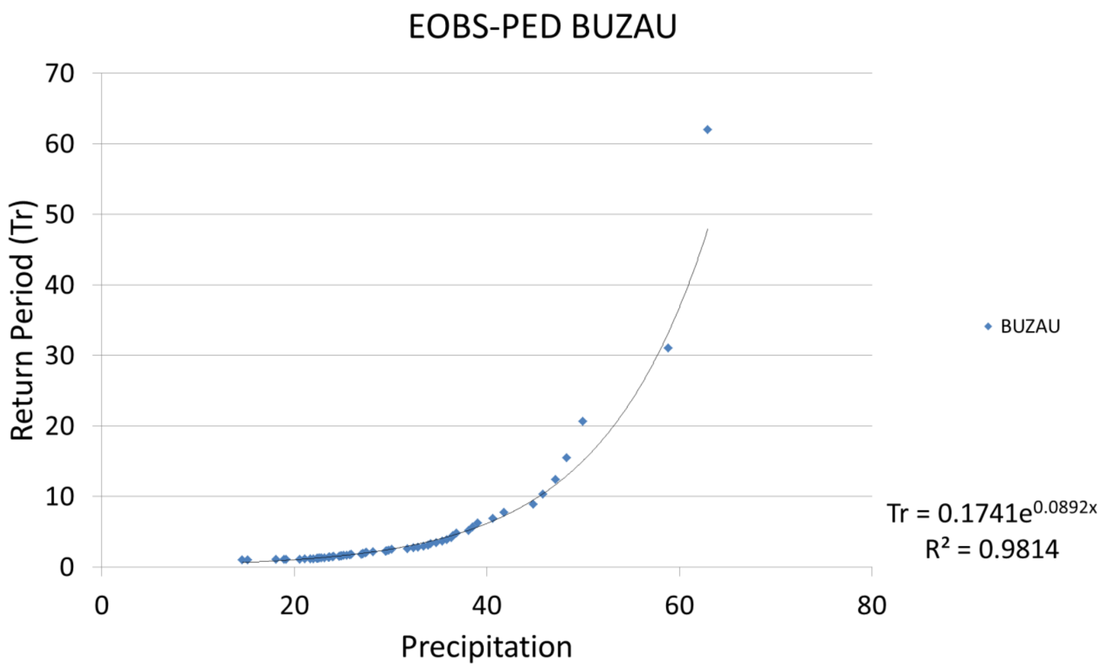
EOBS-PED Penteleu

Year	Rank	Precipitation	Ordered	Rank	PL	PR	Tr	Y
1950	6	20.931	14.611	1	0.01612903	0.983871	1.016393	-1.41758
1951	20	25.488	16.489	2	0.03225806	0.967742	1.033333	-1.23372
1952	38	30.389	16.599	3	0.0483871	0.951613	1.050847	-1.10807
1953	12	22.79	19.118	4	0.06451613	0.935484	1.068966	-1.00826
1954	3	16.599	20.865	5	0.08064516	0.919355	1.087719	-0.92334
1955	50	36.988	20.931	6	0.09677419	0.903226	1.107143	-0.84817
1956	11	22.65	21.392	7	0.11290323	0.887097	1.127273	-0.77989
1957	40	31.205	22.028	8	0.12903226	0.870968	1.148148	-0.71671
1958	59	57.266	22.303	9	0.14516129	0.854839	1.169811	-0.65747
1959	56	41.951	22.61	10	0.16129032	0.83871	1.192308	-0.60133
1960	25	26.384	22.65	11	0.17741935	0.822581	1.215686	-0.54768
1961	9	22.303	22.79	12	0.19354839	0.806452	1.24	-0.49605
1962	37	30.003	23.676	13	0.20967742	0.790323	1.265306	-0.44609
1963	2	16.489	23.885	14	0.22580645	0.774194	1.291667	-0.39748
1964	44	32.823	24.233	15	0.24193548	0.758065	1.319149	-0.35001
1965	18	24.715	24.287	16	0.25806452	0.741935	1.347826	-0.30347
1966	42	31.735	24.664	17	0.27419355	0.725806	1.377778	-0.25768
1967	14	23.885	24.715	18	0.29032258	0.709677	1.409091	-0.2125
1968	49	36.818	25.029	19	0.30645161	0.693548	1.44186	-0.1678
1969	57	48.543	25.488	20	0.32258065	0.677419	1.47619	-0.12346
1970	51	37.868	26.033	21	0.33870968	0.66129	1.512195	-0.07938
1971	61	66.311	26.06	22	0.35483871	0.645161	1.55	-0.03546
1972	52	38.026	26.18	23	0.37096774	0.629032	1.589744	0.008395
1973	53	38.081	26.309	24	0.38709677	0.612903	1.631579	0.052262
1974	43	32.057	26.384	25	0.40322581	0.596774	1.675676	0.096226
1975	39	31.173	26.561	26	0.41935484	0.580645	1.722222	0.140369
1976	16	24.287	26.617	27	0.43548387	0.564516	1.771429	0.184768
1977	58	53.596	26.854	28	0.4516129	0.548387	1.823529	0.229501
1978	23	26.18	27.058	29	0.46774194	0.532258	1.878788	0.274649
1979	46	33.965	27.688	30	0.48387097	0.516129	1.9375	0.320292
1980	22	26.06	27.965	31	0.5	0.5	2	0.366513
1981	33	28.348	28.236	32	0.51612903	0.483871	2.066667	0.413399
1982	10	22.61	28.348	33	0.53225806	0.467742	2.137931	0.461041
1983	54	39.446	28.592	34	0.5483871	0.451613	2.214286	0.509537
1984	15	24.233	28.842	35	0.56451613	0.435484	2.296296	0.55899
1985	47	34.02	29.496	36	0.58064516	0.419355	2.384615	0.609513
1986	1	14.611	30.003	37	0.59677419	0.403226	2.48	0.661229
1987	36	29.496	30.389	38	0.61290323	0.387097	2.583333	0.714272
1988	8	22.028	31.173	39	0.62903226	0.370968	2.695652	0.768792
1989	31	27.965	31.205	40	0.64516129	0.354839	2.818182	0.824955
1990	7	21.392	31.315	41	0.66129032	0.33871	2.952381	0.882947
1991	28	26.854	31.735	42	0.67741935	0.322581	3.1	0.942982
1992	4	19.118	32.057	43	0.69354839	0.306452	3.263158	1.005302
1993	13	23.676	32.823	44	0.70967742	0.290323	3.444444	1.070186
1994	55	40.192	32.859	45	0.72580645	0.274194	3.647059	1.137961
1995	30	27.688	33.965	46	0.74193548	0.258065	3.875	1.209009
1996	29	27.058	34.02	47	0.75806452	0.241935	4.133333	1.283785
1997	24	26.309	34.716	48	0.77419355	0.225806	4.428571	1.362838
1998	21	26.033	36.818	49	0.79032258	0.209677	4.769231	1.446834
1999	48	34.716	36.988	50	0.80645161	0.193548	5.166667	1.536599
2000	34	28.592	37.868	51	0.82258065	0.177419	5.636364	1.633174
2001	32	28.236	38.026	52	0.83870968	0.16129	6.2	1.737893
2002	45	32.859	38.081	53	0.85483871	0.145161	6.888889	1.852513
2003	5	20.865	39.446	54	0.87096774	0.129032	7.75	1.979413
2004	17	24.664	40.192	55	0.88709677	0.112903	8.857143	2.121922
2005	60	64.139	41.951	56	0.90322581	0.096774	10.33333	2.284915
2006	26	26.561	48.543	57	0.91935484	0.080645	12.4	2.475949
2007	41	31.315	53.596	58	0.93548387	0.064516	15.5	2.70768
2008	27	26.617	57.266	59	0.9516129	0.048387	20.66667	3.003826
2009	35	28.842	64.139	60	0.96774194	0.032258	31	3.417637
2010	19	25.029	66.311	61	0.98387097	0.016129	62	4.119015

EOBS-PED Ramnicu Sarat

Year	Rank	Precipitation	Ordered	Rank	PL	PR	Tr	Y
1950	14	20.675	14.012	1	0.01612903	0.983871	1.016393	-1.41758
1951	29	25.229	16.106	2	0.03225806	0.967742	1.033333	-1.23372
1952	21	22.321	16.232	3	0.0483871	0.951613	1.050847	-1.10807
1953	13	20.507	18.202	4	0.06451613	0.935484	1.068966	-1.00826
1954	3	16.232	18.442	5	0.08064516	0.919355	1.087719	-0.92334
1955	46	33.313	19.045	6	0.09677419	0.903226	1.107143	-0.84817
1956	28	25.204	19.069	7	0.11290323	0.887097	1.127273	-0.77989
1957	36	27.762	19.283	8	0.12903226	0.870968	1.148148	-0.71671
1958	55	47.469	19.393	9	0.14516129	0.854839	1.169811	-0.65747
1959	54	40.895	19.409	10	0.16129032	0.83871	1.192308	-0.60133
1960	5	18.442	20.184	11	0.17741935	0.822581	1.215686	-0.54768
1961	18	21.235	20.378	12	0.19354839	0.806452	1.24	-0.49605
1962	33	27.071	20.507	13	0.20967742	0.790323	1.265306	-0.44609
1963	1	14.012	20.675	14	0.22580645	0.774194	1.291667	-0.39748
1964	42	30.701	20.852	15	0.24193548	0.758065	1.319149	-0.35001
1965	11	20.184	21.006	16	0.25806452	0.741935	1.347826	-0.30347
1966	40	30.334	21.222	17	0.27419355	0.725806	1.377778	-0.25768
1967	9	19.393	21.235	18	0.29032258	0.709677	1.409091	-0.2125
1968	30	25.521	21.647	19	0.30645161	0.693548	1.44186	-0.1678
1969	58	49.534	22.284	20	0.32258065	0.677419	1.47619	-0.12346
1970	38	28.855	22.321	21	0.33870968	0.66129	1.512195	-0.07938
1971	60	61.35	22.759	22	0.35483871	0.645161	1.55	-0.03546
1972	57	48.836	22.81	23	0.37096774	0.629032	1.589744	0.008395
1973	39	29.585	23.533	24	0.38709677	0.612903	1.631579	0.052262
1974	53	40.397	23.758	25	0.40322581	0.596774	1.675676	0.096226
1975	16	21.006	23.793	26	0.41935484	0.580645	1.722222	0.140369
1976	26	23.793	24.273	27	0.43548387	0.564516	1.771429	0.184768
1977	59	60.357	25.204	28	0.4516129	0.548387	1.823529	0.229501
1978	25	23.758	25.229	29	0.46774194	0.532258	1.878788	0.274649
1979	27	24.273	25.521	30	0.48387097	0.516129	1.9375	0.320292
1980	12	20.378	26.699	31	0.5	0.5	2	0.366513
1981	20	22.284	26.917	32	0.51612903	0.483871	2.066667	0.413399
1982	8	19.283	27.071	33	0.53225806	0.467742	2.137931	0.461041
1983	49	34.321	27.072	34	0.5483871	0.451613	2.214286	0.509537
1984	31	26.699	27.536	35	0.56451613	0.435484	2.296296	0.55899
1985	44	31.858	27.762	36	0.58064516	0.419355	2.384615	0.609513
1986	2	16.106	28.765	37	0.59677419	0.403226	2.48	0.661229
1987	45	33.009	28.855	38	0.61290323	0.387097	2.583333	0.714272
1988	35	27.536	29.585	39	0.62903226	0.370968	2.695652	0.768792
1989	23	22.81	30.334	40	0.64516129	0.354839	2.818182	0.824955
1990	6	19.045	30.581	41	0.66129032	0.33871	2.952381	0.882947
1991	52	38.294	30.701	42	0.67741935	0.322581	3.1	0.942982
1992	10	19.409	30.878	43	0.69354839	0.306452	3.263158	1.005302
1993	15	20.852	31.858	44	0.70967742	0.290323	3.444444	1.070186
1994	50	34.833	33.009	45	0.72580645	0.274194	3.647059	1.137961
1995	34	27.072	33.313	46	0.74193548	0.258065	3.875	1.209009
1996	43	30.878	33.973	47	0.75806452	0.241935	4.133333	1.283785
1997	41	30.581	34.138	48	0.77419355	0.225806	4.428571	1.362838
1998	56	47.925	34.321	49	0.79032258	0.209677	4.769231	1.446834
1999	48	34.138	34.833	50	0.80645161	0.193548	5.166667	1.536599
2000	32	26.917	36.2	51	0.82258065	0.177419	5.636364	1.633174
2001	47	33.973	38.294	52	0.83870968	0.16129	6.2	1.737893
2002	51	36.2	40.397	53	0.85483871	0.145161	6.888889	1.852513
2003	7	19.069	40.895	54	0.87096774	0.129032	7.75	1.979413
2004	17	21.222	47.469	55	0.88709677	0.112903	8.857143	2.121922
2005	61	72.198	47.925	56	0.90322581	0.096774	10.33333	2.284915
2006	19	21.647	48.836	57	0.91935484	0.080645	12.4	2.475949
2007	37	28.765	49.534	58	0.93548387	0.064516	15.5	2.70768
2008	4	18.202	60.357	59	0.9516129	0.048387	20.66667	3.003826
2009	24	23.533	61.35	60	0.96774194	0.032258	31	3.417637
2010	22	22.759	72.198	61	0.98387097	0.016129	62	4.119015


EOBS-PED BISOCA
Return Period (Tr)
80
70
60
50
40
30
20
10
0
0
20
40
60
80
Precipitation
BISOCA
Tr = 0.235e^0.0822x
R² = 0.9795


EOBS-PED BUZAU
Return Period (Tr)
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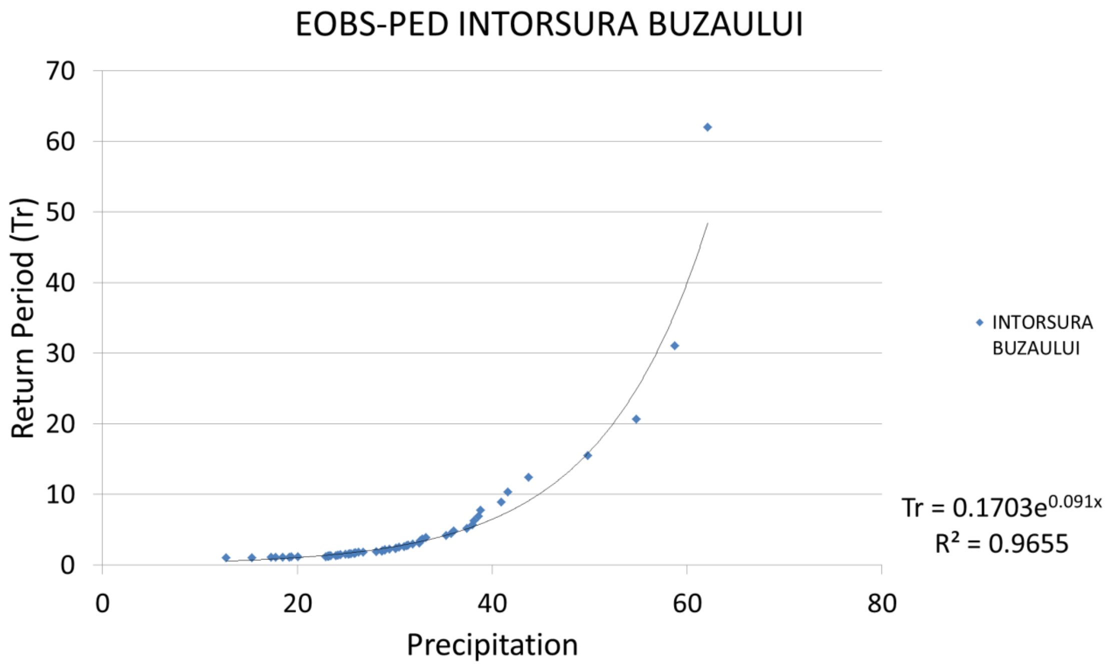
60
50
40
30
20
10
0
0
20
40
60
80
Precipitation
BUZAU
Tr = 0.1741e^0.0892x
R² = 0.9814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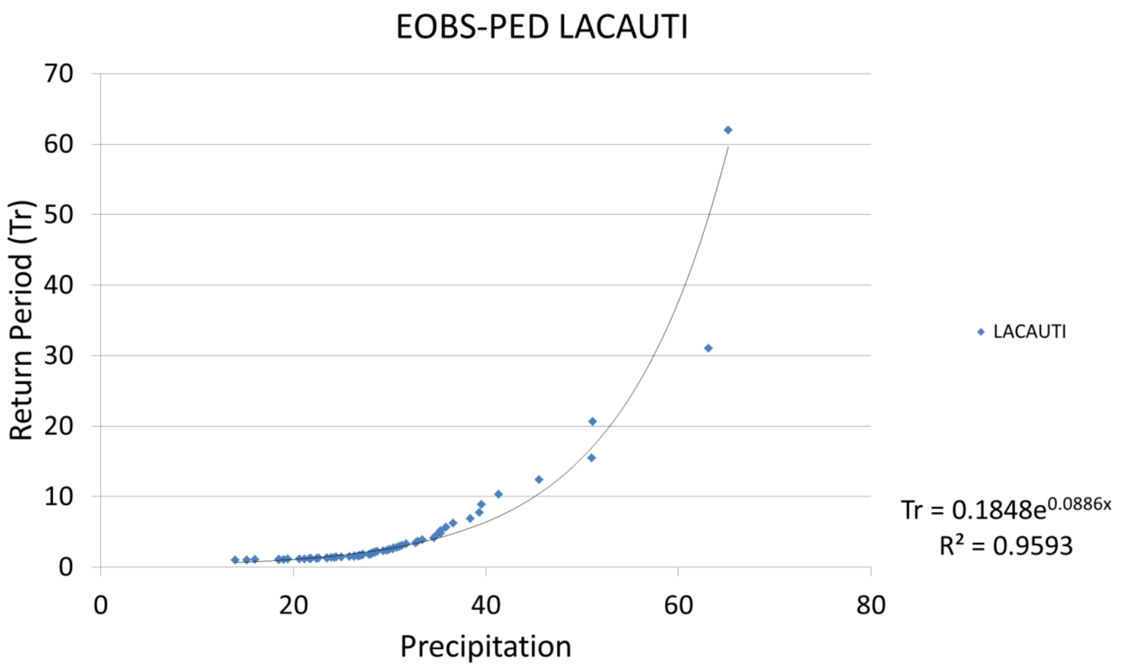
Return Period (Tr)
Precipitation
INTORSURA BUZAULUI
Tr = 0.1703e^0.091x
R² = 0.9655
0
10
20
30
40
50
60
70
0
20
40
60
80


EOBS-PED LACAUTI
Return Period (Tr)
Precipitation
LACAUTI
Tr = 0.1848e^0.0886x
R² = 0.9593
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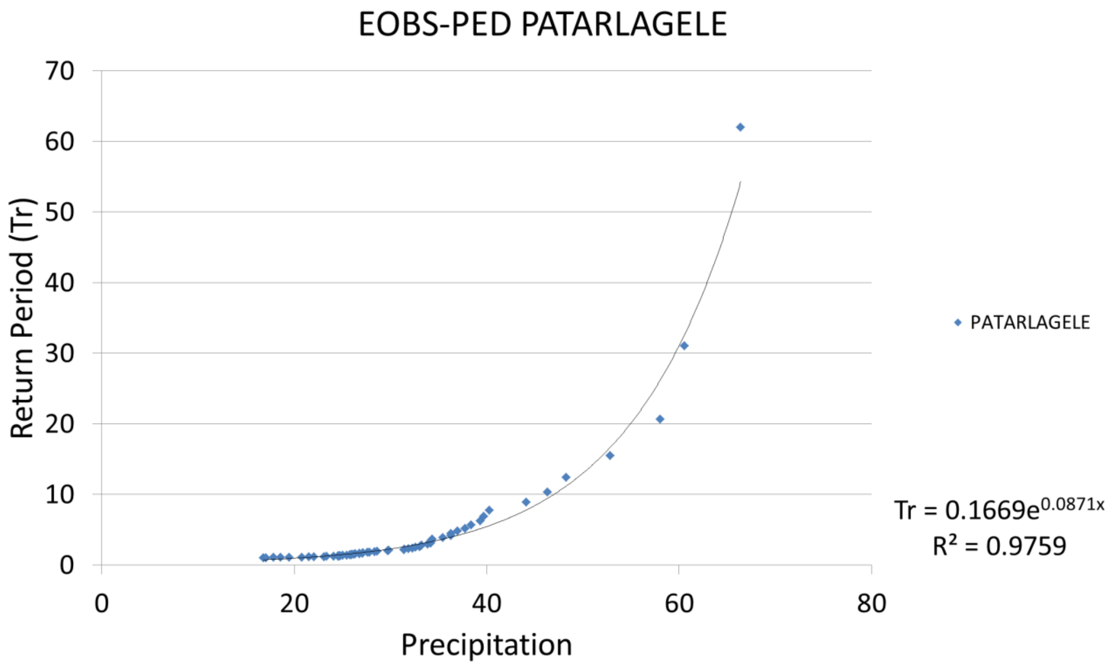
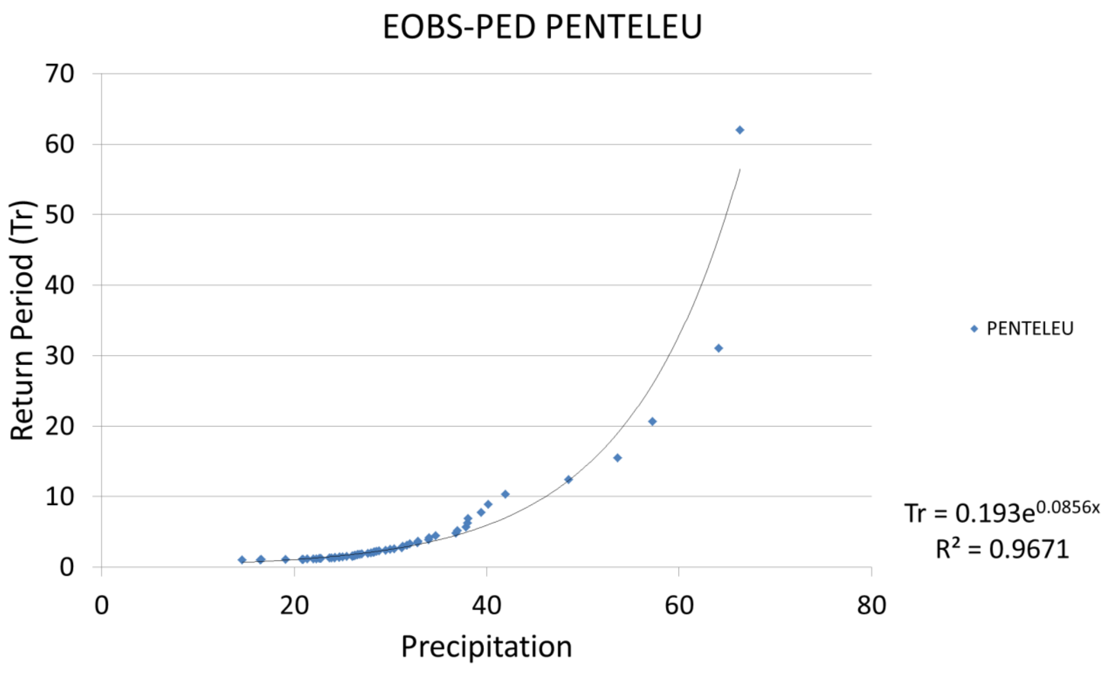
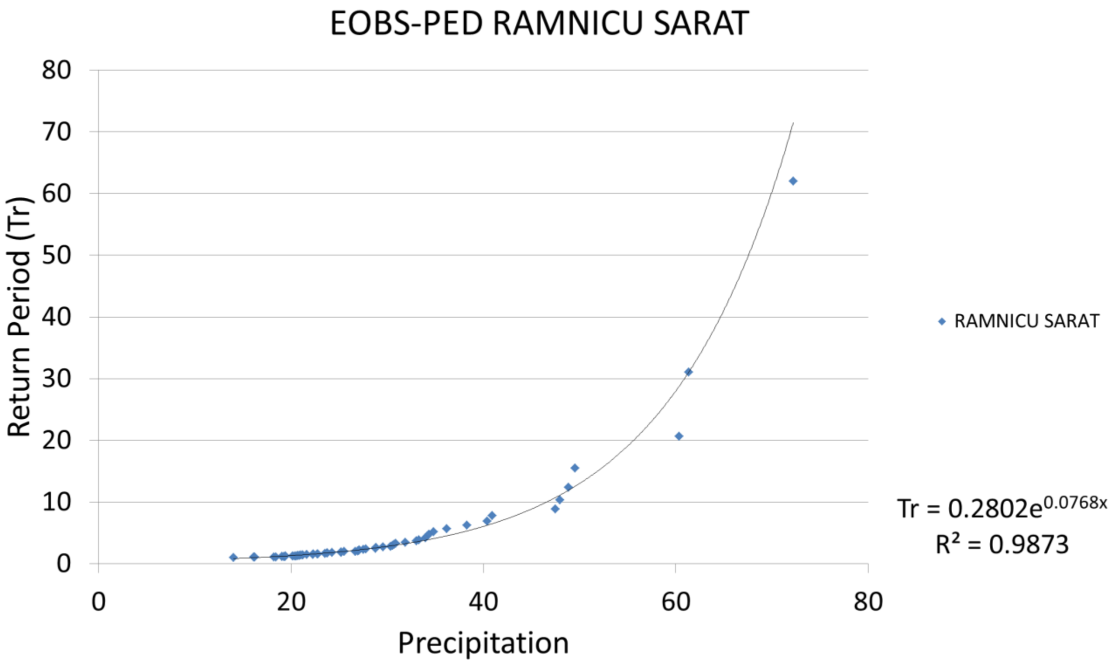
10
20
30
40
50
60
70
0
20
40
60
80

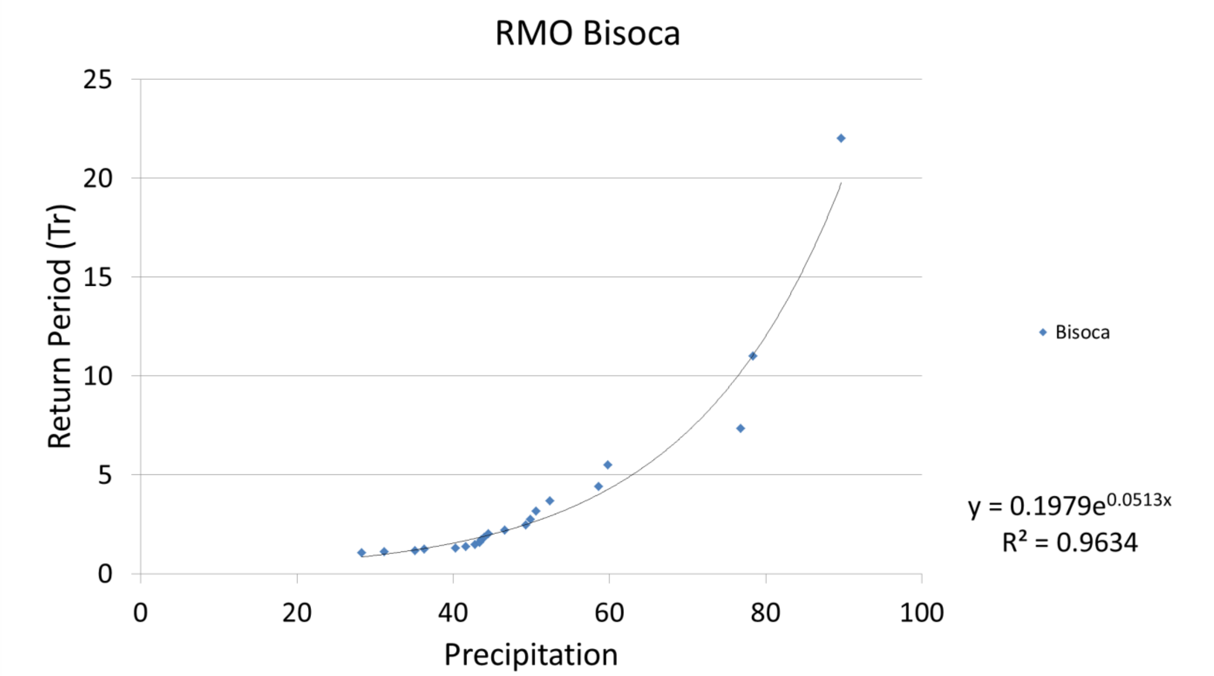

EOBS-PED PATARLAGELE
Return Period (Tr)
Precipitation
PATARLAGELE
Tr = 0.1669e^0.0871x
R² = 0.9759


EOBS-PED PENTELEU
Return Period (Tr)
Precipitation
PENTELEU
Tr = 0.193e^0.0856x
R² = 0.9671


EOBS-PED RAMNICU SARAT
Return Period (Tr)
Precipitation
RAMNICU SARAT
Tr = 0.2802e^0.0768x
R² = 0.9873
0
10
20
30
40
50
60
70
80

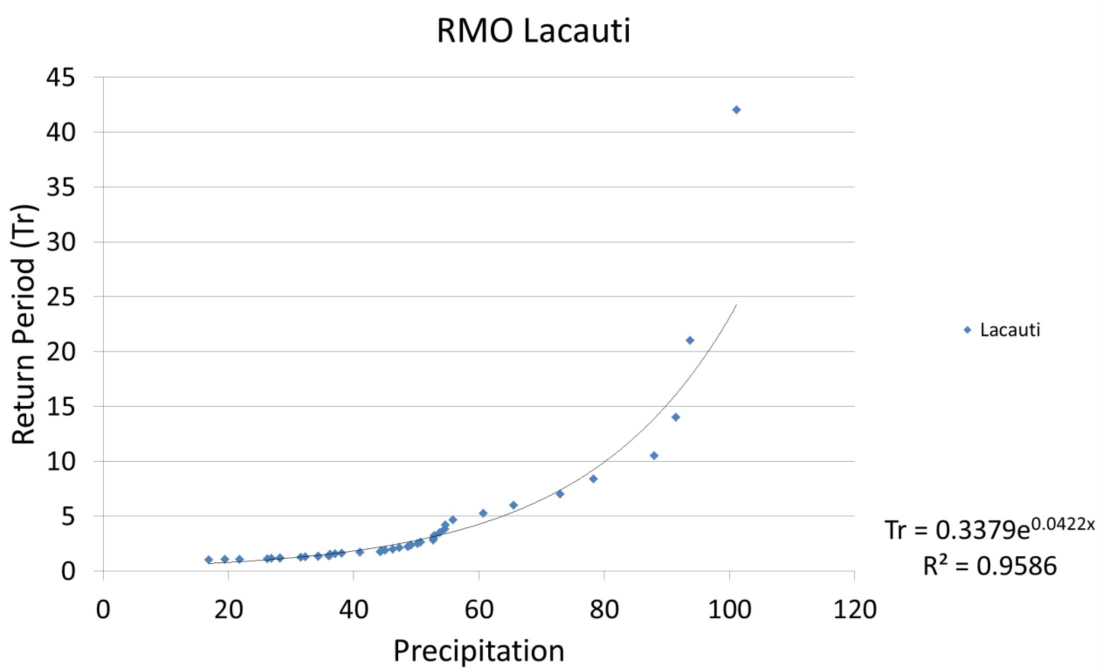
RMO Bisoca

Year	Rank	Precipitation	Ordered	Rank	PL	PR	Tr	Y
1990	18	59.8	28.3	1	0.04545455	0.954545	1.047619	-1.12851
1991	16	52.4	31.2	2	0.09090909	0.909091	1.1	-0.87459
1992	4	36.3	35.1	3	0.13636364	0.863636	1.157895	-0.68936
1993	11	44.5	36.3	4	0.18181818	0.818182	1.222222	-0.53342
1994	13	49.3	40.3	5	0.22727273	0.772727	1.294118	-0.39313
1995	7	42.8	41.6	6	0.27272727	0.727273	1.375	-0.26181
1996	20	78.4	42.8	7	0.31818182	0.681818	1.466667	-0.13552
1997	5	40.3	43.4	8	0.36363636	0.636364	1.571429	-0.01153
1998	12	46.6	43.6	9	0.40909091	0.590909	1.692308	0.112253
1999	15	50.6	44	10	0.45454545	0.545455	1.833333	0.237677
2000	10	44	44.5	11	0.5	0.5	2	0.366513
2001	9	43.6	46.6	12	0.54545455	0.454545	2.2	0.500651
2002	14	49.9	49.3	13	0.59090909	0.409091	2.444444	0.642277
2003	1	28.3	49.9	14	0.63636364	0.363636	2.75	0.794106
2004	2	31.2	50.6	15	0.68181818	0.318182	3.142857	0.959741
2005	21	89.7	52.4	16	0.72727273	0.272727	3.666667	1.144278
2006	19	76.8	58.6	17	0.77272727	0.227273	4.4	1.355458
2007	17	58.6	59.8	18	0.81818182	0.181818	5.5	1.60609
2008	6	41.6	76.8	19	0.86363636	0.136364	7.333333	1.920024
2009	8	43.4	78.4	20	0.90909091	0.090909	11	2.350619
2010	3	35.1	89.7	21	0.95454545	0.045455	22	3.067873



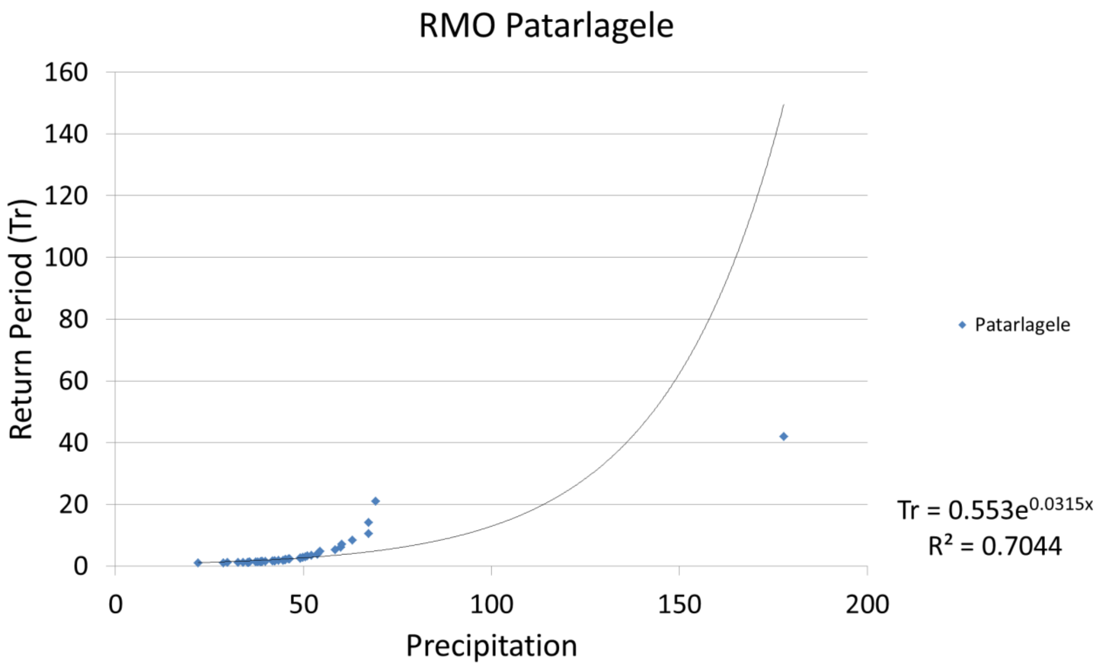
RMO – Lacauti

Year	Rank	Precipitation	Ordered	Rank	PL	PR	Tr	Y
1970	22	47.3	16.9	1	0.02380952	0.97619	1.02439	-1.31846
1971	36	73	19.5	2	0.04761905	0.952381	1.05	-1.11334
1972	35	65.6	21.8	3	0.07142857	0.928571	1.076923	-0.97042
1973	16	38.1	26.3	4	0.0952381	0.904762	1.105263	-0.855
1974	27	52.7	26.9	5	0.11904762	0.880952	1.135135	-0.75529
1975	41	101.2	28.3	6	0.14285714	0.857143	1.166667	-0.66573
1976	4	26.3	28.3	7	0.16666667	0.833333	1.2	-0.5832
1977	40	93.7	31.6	8	0.19047619	0.809524	1.235294	-0.50575
1978	17	41	32.3	9	0.21428571	0.785714	1.272727	-0.43207
1979	28	52.8	34.3	10	0.23809524	0.761905	1.3125	-0.36122
1980	3	21.8	34.4	11	0.26190476	0.738095	1.354839	-0.2925
1981	6	28.3	36	12	0.28571429	0.714286	1.4	-0.22535
1982	8	31.6	36.3	13	0.30952381	0.690476	1.448276	-0.15933
1983	18	44.3	36.3	14	0.33333333	0.666667	1.5	-0.09405
1984	2	19.5	37.1	15	0.35714286	0.642857	1.555556	-0.02919
1985	12	36	38.1	16	0.38095238	0.619048	1.615385	0.035543
1986	21	46.3	41	17	0.4047619	0.595238	1.68	0.100421
1987	15	37.1	44.3	18	0.42857143	0.571429	1.75	0.165703
1988	23	48.7	44.5	19	0.45238095	0.547619	1.826087	0.231641
1989	26	50.7	45.1	20	0.47619048	0.52381	1.909091	0.29849
1990	1	16.9	46.3	21	0.5	0.5	2	0.366513
1991	25	50.2	47.3	22	0.52380952	0.47619	2.1	0.435985
1992	5	26.9	48.7	23	0.54761905	0.452381	2.210526	0.507207
1993	11	34.4	49.2	24	0.57142857	0.428571	2.333333	0.580505
1994	37	78.3	50.2	25	0.5952381	0.404762	2.470588	0.656249
1995	19	44.5	50.7	26	0.61904762	0.380952	2.625	0.734859
1996	31	54.6	52.7	27	0.64285714	0.357143	2.8	0.816824
1997	32	54.7	52.8	28	0.66666667	0.333333	3	0.90272
1998	13	36.3	52.9	29	0.69047619	0.309524	3.230769	0.993243
1999	38	88	53.8	30	0.71428571	0.285714	3.5	1.08924
2000	9	32.3	54.6	31	0.73809524	0.261905	3.818182	1.191773
2001	29	52.9	54.7	32	0.76190476	0.238095	4.2	1.302197
2002	14	36.3	55.9	33	0.78571429	0.214286	4.666667	1.422286
2003	7	28.3	60.7	34	0.80952381	0.190476	5.25	1.554433
2004	20	45.1	65.6	35	0.83333333	0.166667	6	1.701983
2005	39	91.5	73	36	0.85714286	0.142857	7	1.869825
2006	30	53.8	78.3	37	0.88095238	0.119048	8.4	2.065525
2007	24	49.2	88	38	0.9047619	0.095238	10.5	2.301751
2008	10	34.3	91.5	39	0.92857143	0.071429	14	2.602232
2009	33	55.9	93.7	40	0.95238095	0.047619	21	3.020227
2010	34	60.7	101.2	41	0.97619048	0.02381	42	3.725645



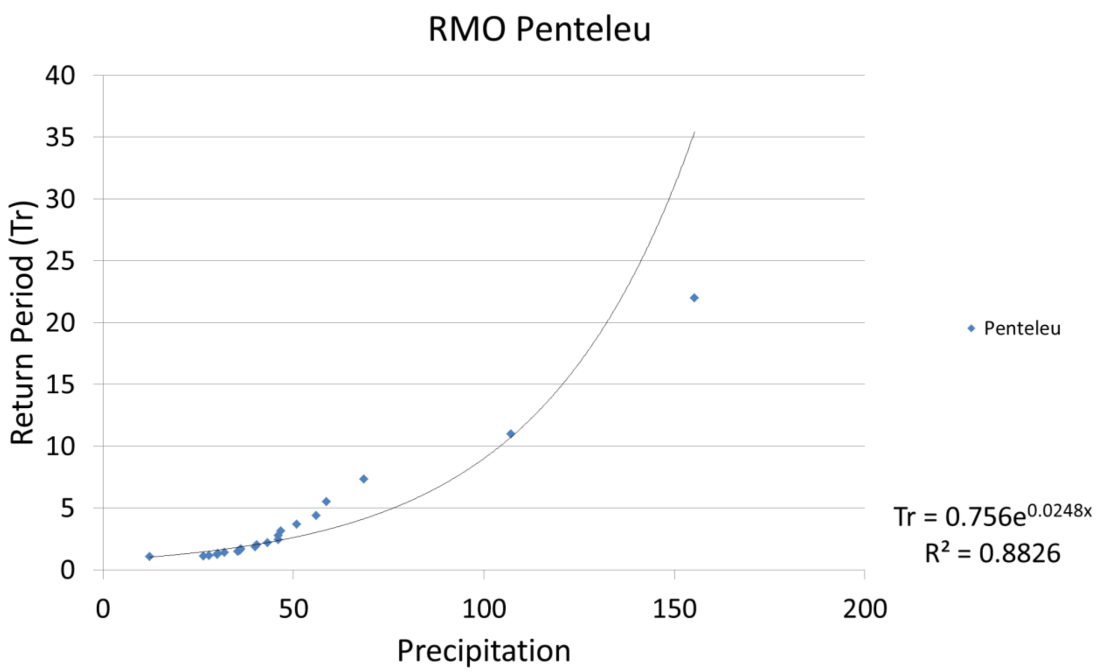
RMO Patarlagele

Year	Rank	Precipitation	Ordered	Rank	PL	PR	Tr	Y
1970	13	39.1	22	1	0.02380952	0.97619	1.02439	-1.31846
1971	20	45.1	28.8	2	0.04761905	0.952381	1.05	-1.11334
1972	5	34	29.8	3	0.07142857	0.928571	1.076923	-0.97042
1973	4	32.7	32.7	4	0.0952381	0.904762	1.105263	-0.855
1974	14	39.9	34	5	0.11904762	0.880952	1.135135	-0.75529
1975	41	177.8	35.2	6	0.14285714	0.857143	1.166667	-0.66573
1976	7	35.5	35.5	7	0.16666667	0.833333	1.2	-0.5832
1977	29	51.1	35.7	8	0.19047619	0.809524	1.235294	-0.50575
1978	9	37.4	37.4	9	0.21428571	0.785714	1.272727	-0.43207
1979	36	60.2	37.9	10	0.23809524	0.761905	1.3125	-0.36122
1980	16	42.3	38.5	11	0.26190476	0.738095	1.354839	-0.2925
1981	3	29.8	38.9	12	0.28571429	0.714286	1.4	-0.22535
1982	31	53.8	39.1	13	0.30952381	0.690476	1.448276	-0.15933
1983	38	67.4	39.9	14	0.33333333	0.666667	1.5	-0.09405
1984	23	46.1	41.8	15	0.35714286	0.642857	1.555556	-0.02919
1985	11	38.5	42.3	16	0.38095238	0.619048	1.615385	0.035543
1986	25	49.2	42.4	17	0.4047619	0.595238	1.68	0.100421
1987	37	63.1	43.4	18	0.42857143	0.571429	1.75	0.165703
1988	39	67.4	44.6	19	0.45238095	0.547619	1.826087	0.231641
1989	18	43.4	45.1	20	0.47619048	0.52381	1.909091	0.29849
1990	21	45.1	45.1	21	0.5	0.5	2	0.366513
1991	28	50.6	45.3	22	0.52380952	0.47619	2.1	0.435985
1992	2	28.8	46.1	23	0.54761905	0.452381	2.210526	0.507207
1993	15	41.8	46.4	24	0.57142857	0.428571	2.333333	0.580505
1994	22	45.3	49.2	25	0.5952381	0.404762	2.470588	0.656249
1995	10	37.9	49.2	26	0.61904762	0.380952	2.625	0.734859
1996	8	35.7	49.9	27	0.64285714	0.357143	2.8	0.816824
1997	27	49.9	50.6	28	0.66666667	0.333333	3	0.90272
1998	35	60	51.1	29	0.69047619	0.309524	3.230769	0.993243
1999	32	54	52.2	30	0.71428571	0.285714	3.5	1.08924
2000	12	38.9	53.8	31	0.73809524	0.261905	3.818182	1.191773
2001	6	35.2	54	32	0.76190476	0.238095	4.2	1.302197
2002	34	58.5	54.4	33	0.78571429	0.214286	4.666667	1.422286
2003	1	22	58.5	34	0.80952381	0.190476	5.25	1.554433
2004	24	46.4	60	35	0.83333333	0.166667	6	1.701983
2005	33	54.4	60.2	36	0.85714286	0.142857	7	1.869825
2006	19	44.6	63.1	37	0.88095238	0.119048	8.4	2.065525
2007	40	69.3	67.4	38	0.9047619	0.095238	10.5	2.301751
2008	30	52.2	67.4	39	0.92857143	0.071429	14	2.602232
2009	17	42.4	69.3	40	0.95238095	0.047619	21	3.020227
2010	26	49.2	177.8	41	0.97619048	0.02381	42	3.725645



RMO Penteleu

Year	Rank	Precipitation	Ordered	Rank	PL	PR	Tr	Y
1990	1	12.3	12.3	1	0.04545455	0.954545	1.047619	-1.12851
1991	21	155.3	26.4	2	0.09090909	0.909091	1.1	-0.87459
1992	16	50.9	27.9	3	0.13636364	0.863636	1.157895	-0.68936
1993	2	26.4	30.1	4	0.18181818	0.818182	1.222222	-0.53342
1994	5	30.2	30.2	5	0.22727273	0.772727	1.294118	-0.39313
1995	9	36.2	32	6	0.27272727	0.727273	1.375	-0.26181
1996	15	46.7	35.5	7	0.31818182	0.681818	1.466667	-0.13552
1997	3	27.9	36	8	0.36363636	0.636364	1.571429	-0.01153
1998	6	32	36.2	9	0.40909091	0.590909	1.692308	0.112253
1999	13	46.1	40	10	0.45454545	0.545455	1.833333	0.237677
2000	8	36	40.4	11	0.5	0.5	2	0.366513
2001	7	35.5	43.2	12	0.54545455	0.454545	2.2	0.500651
2002	19	68.5	46.1	13	0.59090909	0.409091	2.444444	0.642277
2003	4	30.1	46.1	14	0.63636364	0.363636	2.75	0.794106
2004	11	40.4	46.7	15	0.68181818	0.318182	3.142857	0.959741
2005	20	107.1	50.9	16	0.72727273	0.272727	3.666667	1.144278
2006	14	46.1	56	17	0.77272727	0.227273	4.4	1.355458
2007	18	58.7	58.7	18	0.81818182	0.181818	5.5	1.60609
2008	17	56	68.5	19	0.86363636	0.136364	7.333333	1.920024
2009	12	43.2	107.1	20	0.90909091	0.090909	11	2.350619
2010	10	40	155.3	21	0.95454545	0.045455	22	3.067873



Appendix G - Daily Precipitation on flood event and 5 antecedent days

	Lacauti (E04) (EOBS-PED)	Lacauti (E04) (RMO)	Patarlagele (E05) (EOBS-PED)	Patarlagele (E05) (RMO)	Bisoca (E01) (EOBS-PED)	Bisoca (E01) (RMO)	Penteleu (E06) (EOBS-PED)	Penteleu (E06) (RMO)
6/28/1975	0	A	0	A	0	A	0	A
6/29/1975	4.1055	9.6	6.3359	A	5.169	A	5.3197	A
6/30/1975	0	3.6	0	A	0	A	0	A
7/1/1975	8.8198	27.9	11.261	15.1	5.7324	A	9.7517	A
7/2/1975	**25.85**	**101.2**	**39.703**	**177.8**	**19.011**	**A**	**31.173**	**A**
7/3/1975	**22.964**	**71.6**	**17.659**	**10.9**	**15.466**	**A**	**20.677**	**A**
6/26/1991	0	A	0	A	0	A	0	A
6/27/1991	0	A	0	A	0	A	0	A
6/28/1991	0	A	0	A	0	A	0	A
6/29/1991	16.131	19.3	14.111	35.2	11.82	24.3	14.834	25.3
6/30/1991	**13.557**	**15.2**	**13.07**	**28.7**	**11.695**	**36.8**	**12.981**	**6.5**
7/14/1991	0	A	0	A	0	A	0	A
7/15/1991	0	43.9	0	A	0	A	0	A
7/16/1991	0.71607	A	0	0.6	0	8.7	0	24.9
7/17/1991	0	A	0	A	0	A	0	A
7/18/1991	**11.504**	**6.5**	**12.029**	**5.5**	**11.611**	**8.6**	**12.244**	**155.3**
7/25/1991	0	A	0	A	0	A	0	A
7/26/1991	2.033	2.8	0	A	0.35429	A	0.60208	0.7
7/27/1991	16.871	11.6	33.847	27.9	22.601	25.9	24.092	20.6
7/28/1991	11.119	8.1	12.894	10.4	10.133	12.3	11.219	5.1
7/29/1991	**26.29**	**13.6**	**24.711**	**50.6**	**21.522**	**33**	**24.841**	**31.9**
6/1/2001	2.2448	3.1	4.1715	3.2	3.3764	3.4	3.2526	1.6
6/2/2001	0	0.5	0	7.4	0	4.9	0	0.8
6/3/2001	0	3.4	0	10.5	0	1.9	0	1.5
6/4/2001	10.049	9.3	13.257	19	12.255	14.2	11.887	3.2
6/5/2001	**26.373**	**23.9**	**28.353**	**1.4**	**31.196**	**7.7**	**28.236**	**22**
6/16/2001	0	5.7	0	0.6	0.40953	2.3	0	0.6
6/17/2001	0	A	0	A	0	A	0	A
6/18/2001	0	A	0.035315	A	0	A	0	A
6/19/2001	17.633	52.9	18.037	25.7	12.207	30.1	17.319	35.5
6/20/2001	**10.718**	**1.4**	**8.0621**	**12.9**	**10.434**	**2.6**	**9.9952**	**9.7**
7/23/2002	3.9624	5.1	4.9729	A	4.6391	A	4.3143	A
7/24/2002	0	A	0	A	0	A	0	0.4
7/25/2002	3.5641	6.8	0	0.2	0	A	0.84852	2
7/26/2002	30.776	36.3	34.195	58.5	37.384	49.9	32.859	54.5
7/27/2002	**10.395**	**2.7**	**8.3015**	**3.9**	**9.2958**	**11.2**	**9.226**	**11.3**
7/7/2005	0	4.8	0	A	0	A	0	A
7/8/2005	0	A	0	A	0	A	0	A
7/9/2005	0	A	0	A	0	A	0	A
7/10/2005	4.915	A	3.5393	0.9	3.0847	A	4.0768	3.6
7/11/2005	**8.2671**	**A**	**8.1077**	**A**	**11.715**	**2.3**	**9.0831**	**A**
9/17/2005	0	A	0	A	0	A	0	A
9/18/2005	0	4.2	0	A	0	A	0	A
9/19/2005	16.837	8	18.809	15.3	13.471	11.3	17.116	29.8
9/20/2005	17.918	55.4	22.808	54.4	14.039	28.9	18.915	46.7
9/21/2005	**4.7786**	**24.5**	**5.9441**	**23.6**	**2.8418**	**19**	**4.9626**	**32.6**
8/7/2006	4.8611	3.5	5.2356	5.4	4.9391	3.8	5.095	1.9
8/8/2006	8.4409	22.8	8.3659	8.2	8.7596	0.9	8.5911	13.2
8/9/2006	0	A	0	A	0	A	0	A
8/10/2006	1.1594	A	2.0989	0.4	0.17715	A	1.3194	0.7
8/11/2006	**27.263**	**53.8**	**19.965**	**44.6**	**23.645**	**76.8**	**23.555**	**31.4**

A = Missing Value. Date shaded cells indicate a reported flood event. (The events recorded in 1975 (July 2nd and 3rd are treated as one event, as river gauging stations located upstream reported a flood event on July 2nd and river gauges located downstream reported the flood on July 3rd). Shaded precipitation values indicate that the summer maximum for the corresponding station for that year was registered that on that date. See Appendix H and Appendix I.

Appendix H- EOBS-PED Maximum Daily Precipitation per year (June-September)

Maximum precipitation per year for the period of June-September for the EOBS-PED Stations for the years 1975 through 2010.

Year	BISOCA	BUZAU	LACAUTI	INTORSURA B.	RAMNICU S.	PATARLAGELE	PENTELEU
1975	19.588	17.836	25.85	41.638	17.245	39.703	31.173
1976	17.072	16.255	20.183	18.24	16.82	19.644	18.389
1977	55.002	50.004	51.015	49.831	60.357	52.837	53.596
1978	20.191	12.139	26.871	29.491	14.477	24.445	26.18
1979	28.759	19.089	35.289	38.63	24.273	31.887	33.965
1980	25.069	24.935	27.135	24.187	20.378	25.789	26.06
1981	24.766	25.173	23.459	25.52	22.284	33.19	28.348
1982	19.728	16.329	21.662	23.119	14.934	24.562	22.61
1983	38.46	34.779	41.351	38.16	34.321	36.973	39.446
1984	23.133	23.165	22.647	23.255	21.426	24.588	24.233
1985	35.348	30.158	38.382	32.535	31.858	29.83	34.02
1986	13.805	15.15	12.95	12.7	14.282	16.777	14.611
1987	30.431	18.691	30.399	24.456	25.299	27.08	29.496
1988	25.79	24.081	22.423	19.414	27.536	19.603	22.026
1989	26.115	22.638	29.737	26.746	22.81	27.628	27.965
1990	22.051	18.249	23.93	20.07	19.045	18.229	21.392
1991	22.601	30.879	26.29	25.985	19.374	33.847	24.841
1992	19.696	18.096	19.42	17.767	19.409	17.859	19.118
1993	22.697	19.176	24.256	24.161	20.852	23.372	23.676
1994	38.262	32.393	39.343	37.421	34.833	39.341	40.192
1995	28.192	32.864	25.17	23.88	27.072	29.72	27.184
1996	22.791	17.064	31.713	28.986	23.075	24.631	27.058
1997	22.935	24.223	24.449	21.433	29.115	26.204	21.962
1998	22.253	18.206	24.998	25.946	17.22	26.345	25.283
1999	34.384	39.055	32.909	32.617	34.138	34.242	34.716
2000	26.949	24.016	34.83	30.149	26.917	24.691	28.592
2001	31.196	29.495	26.373	23.98	33.973	28.353	28.236
2002	37.384	38.141	30.776	24.964	36.2	34.195	32.859
2003	20.794	22.347	18.81	18.501	19.069	22.043	20.865
2004	17.572	25.461	18.36	19.312	21.222	19.651	18.826
2005	68.83	62.973	65.183	58.736	72.198	58.025	64.139
2006	23.645	19.293	28.714	28.125	21.647	27.147	26.561
2007	29.058	40.662	32.728	30.481	28.099	40.289	31.315
2008	16.947	15.933	18.401	19.159	18.202	19.297	18.564
2009	21.281	20.603	28.212	36.043	23.533	31.468	28.842
2010	22.958	17.816	33.407	25.243	18.931	25.939	25.029

Appendix I - RMO's Maximum Daily Precipitation per year (June-September)

Maximum precipitation per year for the period of June-September for the RMO Stations for the years 1975 through 2010.

Year	Lacauti	Patarlagele	Bisoca	Penteleu
1975	101.2	177.8	Not Active	Not Active
1976	26.3	35.5	Not Active	Not Active
1977	93.7	51.1	Not Active	Not Active
1978	41	37.4	Not Active	Not Active
1979	52.8	60.2	Not Active	Not Active
1980	21.8	42.3	Not Active	Not Active
1981	28.3	29.8	Not Active	Not Active
1982	31.6	53.8	Not Active	Not Active
1983	44.3	67.4	Not Active	Not Active
1984	16.1	40.1	Not Active	Not Active
1985	30.2	38.5	Not Active	Not Active
1986	46.3	49.2	Not Active	Not Active
1987	37.1	16.6	Not Active	Not Active
1988	48.7	42.9	Not Active	Not Active
1989	50.7	43.4	Not Active	Not Active
1990	16.9	16	25.9	10.3
1991	50.2	50.6	36.8	155.3
1992	26.9	28.8	36.3	50.9
1993	34.4	41.8	25.6	19.3
1994	78.3	38.6	49.3	30.2
1995	44.5	37.9	42.8	36.2
1996	54.6	32.2	78.4	46.7
1997	54.7	49.9	33	25.9
1998	36.3	32	26.3	26.2
1999	88	54	50.6	46.1
2000	28.3	38.9	25.2	36
2001	52.9	35.2	43.6	35.5
2002	36.3	58.5	49.9	68.5
2003	28.3	22	28.3	30.1
2004	45.1	35.6	31.2	40.4
2005	91.5	54.4	89.7	107.1
2006	53.8	44.6	76.8	46.1
2007	49.2	60.7	46.8	45.2
2008	34.3	29.4	34.8	38.5
2009	55.9	42.4	43.4	43.2
2010	60.7	49.2	35.1	40

Appendix J - Return period for precipitation values based on maximum yearly precipitation (Jan-Dec)

Return period for the precipitation event at the given date. Shaded date cells are the

	Lacauti (EOBS-PED)	Lacauti (RMO)	Patarlagele (EOBS-PED)	Patarlagele (RMO)	Bisoca (EOBS-PED)	Bisoca (RMO)	Penteleu (EOBS-PED)	Penteleu (RMO)
6/28/1975	0.18	0.34	0.17	A	0.34	A	0.19	A
6/29/1975	0.27	0.40	0.29	A	0.52	A	0.30	A
6/30/1975	0.18	0.34	0.17	A	0.34	A	0.19	A
7/1/1975	0.40	0.49	0.45	0.89	0.55	A	0.44	A
7/2/1975	**1.83**	**1.01**	**5.30**	**149.65**	**1.63**	**A**	**2.78**	**A**
7/3/1975	**1.41**	**0.89**	**0.78**	**0.78**	**1.22**	**A**	**1.13**	**A**
6/26/1991	0.18	0.34	0.17	A	0.34	A	0.19	A
6/27/1991	0.18	0.34	0.17	A	0.34	A	0.19	A
6/28/1991	0.18	0.34	0.17	A	0.34	A	0.19	A
6/29/1991	0.77	0.67	0.57	1.68	0.90	0.69	0.69	1.40
6/30/1991	**0.61**	**0.60**	**0.52**	**1.37**	**0.89**	1.31	**0.59**	**0.88**
7/14/1991	0.18	0.34	0.17	A	0.34	A	0.19	A
7/15/1991	0.18	0.34	0.17	A	0.34	A	0.19	A
7/16/1991	0.20	0.35	0.17	0.56	0.34	0.31	0.19	1.39
7/17/1991	0.18	0.34	0.17	A	0.34	A	0.19	A
7/18/1991	**0.51**	**0.55**	**0.48**	**0.66**	**0.89**	**0.31**	**0.55**	**35.18**
7/25/1991	0.18	0.34	0.17	A	0.34	A	0.19	A
7/26/1991	0.22	0.37	0.17	A	0.35	A	0.20	0.76
7/27/1991	0.82	0.69	3.18	1.33	2.19	0.75	1.52	1.25
7/28/1991	0.49	0.54	0.51	0.77	0.79	0.37	0.50	0.85
7/29/1991	**1.90**	**1.02**	**1.44**	**2.72**	**2.00**	**1.08**	**1.62**	**1.65**
6/1/2001	0.23	0.37	0.24	0.61	0.45	0.24	0.25	0.78
6/2/2001	0.18	0.34	0.17	0.70	0.34	0.25	0.19	0.76
6/3/2001	0.18	0.34	0.17	0.77	0.34	0.22	0.19	0.78
6/4/2001	0.45	0.52	0.53	1.01	0.93	0.41	0.53	0.81
6/5/2001	1.91	**1.03**	1.97	**0.58**	4.44	**0.29**	2.16	**1.29**
6/16/2001	0.18	0.34	0.17	0.56	0.35	0.22	0.19	0.76
6/17/2001	0.18	0.34	0.17	A	0.34	A	0.19	A
6/18/2001	0.18	0.34	0.17	A	0.34	A	0.19	A
6/19/2001	0.88	0.71	0.80	1.24	0.93	0.93	0.85	1.80
6/20/2001	**0.48**	**0.53**	**0.34**	**0.83**	**0.80**	**0.23**	**0.45**	**0.95**
7/23/2002	0.26	0.40	0.26	A	0.50	A	0.28	A
7/24/2002	0.18	0.34	0.17	A	0.34	A	0.19	0.76
7/25/2002	0.25	0.39	0.17	0.56	0.34	A	0.21	0.79
7/26/2002	2.82	1.24	3.28	3.49	7.40	2.56	3.21	2.89
7/27/2002	**0.46**	**0.52**	**0.34**	**0.63**	**0.73**	**0.35**	**0.43**	**0.99**
7/7/2005	0.18	0.34	0.17	A	0.34	A	0.19	A
7/8/2005	0.18	0.34	0.17	A	0.34	A	0.19	A
7/9/2005	0.18	0.34	0.17	A	0.34	A	0.19	A
7/10/2005	0.29	0.42	0.23	0.57	0.44	A	0.27	0.82
7/11/2005	**0.38**	**0.48**	**0.34**	**A**	**0.89**	**0.22**	**0.42**	**A**
9/17/2005	0.18	0.34	0.17	A	0.34	A	0.19	A
9/18/2005	0.18	0.34	0.17	A	0.34	A	0.19	A
9/19/2005	0.82	0.69	0.86	0.90	1.03	0.35	0.84	1.57
9/20/2005	0.90	0.72	1.22	3.07	1.08	0.87	0.97	2.38
9/21/2005	**0.28**	**0.41**	**0.28**	**1.16**	**0.43**	**0.52**	**0.30**	**1.68**
8/7/2006	0.28	0.41	0.26	0.66	0.51	0.24	0.30	0.78
8/8/2006	0.39	0.48	0.35	0.72	0.70	0.21	0.40	1.04
8/9/2006	0.18	0.34	0.17	A	0.34	A	0.19	A
8/10/2006	0.20	0.35	0.20	0.56	0.35	A	0.22	0.76
8/11/2006	**2.07**	**1.07**	**0.95**	**2.25**	**2.39**	**10.17**	**1.45**	**1.63**

A = Missing Value. Date shaded cells indicate a reported flood event. (The events recorded in 1975 (July 2nd and 3rd are treated as one event, as river gauging stations located upstream reported a flood event on July 2nd and river gauges located downstream reported the flood on July 3rd). Shaded return period values indicate that the summer maximum precipitation for the corresponding station for that year was registered that on that date. See Appendix H and Appendix I.

Appendix K Matlab threshold fitting code

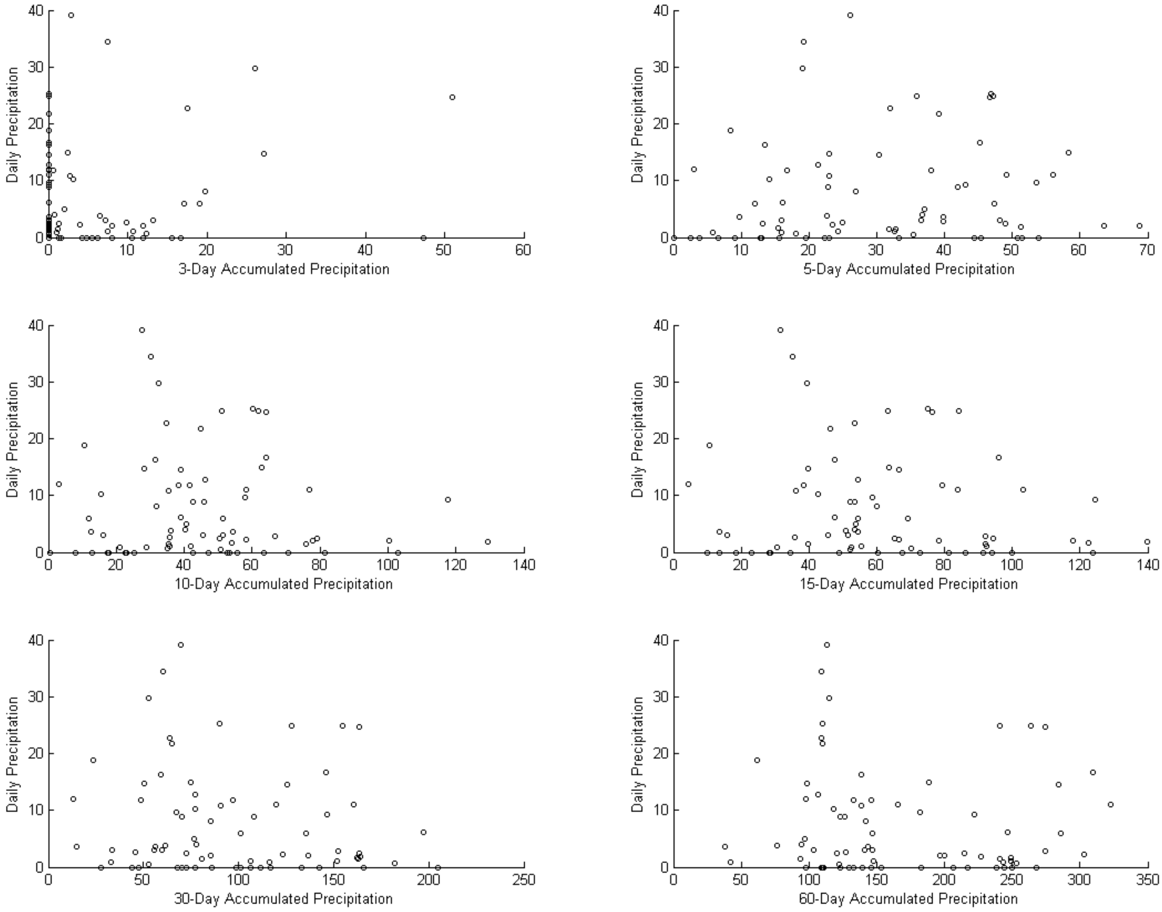
MatLab code for threshold fitting

```
scatter(E05_EOBS(:,3),E05_EOBS(:,1))


Par(1,1)=((Constrains(1,2)-Constrains(3,2))/(Constrains(1,1)-
(Constrains(3,1))));
Par(1,2)=((Constrains(2,2)-Constrains(1,2))/(Constrains(2,1)-
(Constrains(1,1))));
Par(2,1)=Constrains(1,1);
Par(2,2)=Constrains(1,2);

xc1=Constrains(1,1);
yc1=Constrains(1,2);
xc2=Constrains(2,1);
yc2=Constrains(2,2);
xc3=Constrains(3,1);
yc3=Constrains(3,2);


intervalos=100;%2000 en lugar de 100
Bc3=yc3-(((yc3-yc1)/(xc3-xc1))*xc3);
Bc2=yc2-(((yc2-yc1)/(xc2-xc1))*xc2);
steps=(Bc3-Bc2)/intervalos;

Param=zeros(100,4);%2001 rn lugar de 100
for n=0:intervalos
    Param(n+1,1)=Constrains(3,2)-(n*steps);
    Param(n+1,2)=((Param(n+1,1)-yc1)/(0-xc1));
end


for n=1:numel(Param(:,1))
    count_pos=0;
    count_neg=0;
    for m=1:numel(EOBS_05(:,1))
      %m*x-y+b
    if (Param(n,2)*EOBS_05(m,2))-EOBS_05(m,1)+Param(n,1)>=0;
        count_pos=count_pos+1;
        Param(n,3)=count_pos;
    else
        count_neg=count_neg+1;
        Param(n,4)=count_neg;
    end
    end
end

for n=1:numel(Param(:,1))
    count_pos=0;
    count_neg=0;
    for m=1:numel(E05_EOBS(:,1))
      %m*x-y+b
    if (Param(n,2)*E05_EOBS(m,2))-E05_EOBS(m,1)+Param(n,1)>=0;
        count_pos=count_pos+1;
```

```
        Param(n,5)=count_pos;
    else
        count_neg=count_neg+1;
        Param(n,6)=count_neg;
    end
    end
end


%(Y)Day – (X)day
figure('NumberTitle','off','Name','E05_EOBS')
scatter(EOBS_05(:,2),EOBS_05(:,1),'.','blue')
xlabel('30-Day Acc. Precipitation')
ylabel('15-Day Acc Precipitation')
axis ([0 max(max(EOBS_05(:,1),max(EOBS_05(:,2)))) 0
max(max(EOBS_05(:,1),max(EOBS_05(:,2))))])
title E05_EOBS
hold on


scatter(E05_EOBS(:,3),E05_EOBS(:,1),30,'red','filled')
hold on
%mx+b=y

Tr05(:,1)=Param(find(Param(:,4)==max(Param(:,4))),1);
```

Appendix L 1-Day vs. Antecedent rainfall plots

The use of scatter plots is used to determine what parameters to use for threshold modelling, to identify a possible trend at which events are most likely to be triggered.



Appendix M 3-day vs Accumulated Rain

3-Day antecedent rainfall plotted against different combinations of antecedent rainfall to identify a possible trend