PROCEEDINGS OF SCIENCE

Long term analyses of extreme daily precipitation in Tirana

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Abstract: Flooding in urban areas is in general, a consequence of suddenly extreme precipitation causing a valuable impact in the financial and social life the urban residents. The extreme daily precipitation plays a notable role in the monthly and seasonal precipitation. Their frequency and severity influences the long term variation of the annual total precipitation. To estimate the variation and trend in a long term period of this phenomenon, some of the main precipitation indices need to be estimated and analysed in a multi-annual bases. There are many methods to classify a daily precipitation event as an intense, extreme or extraordinary phenomenon and objective methods may be the estimation of the daily precipitation that exceed a threshold value; the estimation of the maximum 1-day precipitation; the maximum of 5 consecutive precipitation days, etc. In this study, analyses of the annual total precipitation and annual maximum daily precipitation were performed to have their long term trends. In another step, analyses of the daily extreme precipitation inside the year were done in order to identify any shift of the daily maximum of the precipitation. All the performed analyses cover a 72-years period of daily precipitation data series with daily precipitation amounts > 1 mm for Tirana city, the capital of Albania. The annual maximum daily precipitation stands for the highest value of 24h precipitation of each year and the monthly maximum of daily precipitation accounts on the highest value of 24h precipitation of each month. All the data were used to analyse the long term trend of the annual total precipitation during the period of 1950 – 2021 for Tirana city. Statistical analysis were performed to estimate some of the main indices of the daily precipitation amounts in a multi-annual bases and the results may be used to develop better strategies on flood risk reduction.

Keywords: daily precipitation, flooding, maximum precipitation, variation, precipitation trend

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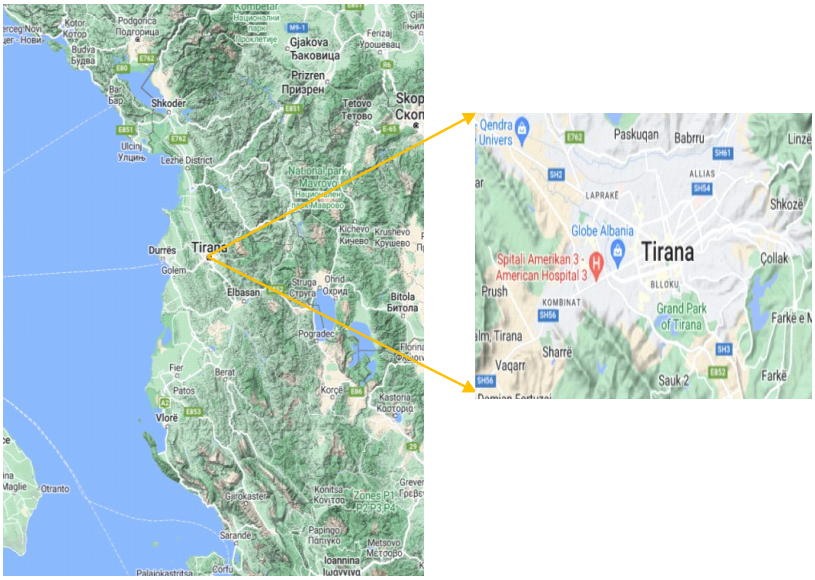
Introduction

The world's climate changed during the last decades causing changes on many climate indicators (Frich et al, 2001). One of the main climate changes was observed in the short life extreme precipitation in the urban areas that often brings flash flood events (Karl et al, 1999; Peterson et al, 2001). The long term trend, their frequency and severity and also many other indicators of the extreme precipitation events present different behavior in different urban areas (Karl et al, 1998 and 1999; WMO, 1999; Manton et al, 2001). Based on the last 30 years, the number of extreme and extraordinary precipitation events have increased and their severity, as well in different urban areas (Frich et al, 2001; Porja and Olli, 2010; Porja and Mustaqi, 2011). In Albanian territory, after the year 1990, the number of intense daily rainfall events result at least doubled and also the 24-hour rainfall amounts have increased (Porja and Nunaj, 2013). In order to have an objective picture of the extreme or extraordinary daily events at monthly, annual or multi-annual bases, a detailed analysis of daily precipitation is required.

Data used and methodology

The daily precipitation data was used to build the annual total precipitation data series, the annual maximum of 1-day precipitation data series and the monthly maximum of 1-day precipitation data series. The daily precipitation data were taken from the AWS installed in the center of the Tirana city, the most populated and urbanized city of the Albania (Map 1).



Map 1 – Tirana city is located in 41°19'40" N and 19°49'8" E, with an averaged elevated at 110 m above sea level, an area of 41.8 km^2 and a population of 557 422 citizens

The annual total precipitation (PRCPTOT), the annual maximum 1-day precipitation (Rx1-day) and the monthly maximum 1-day precipitation (Rx1-month), were calculated by the formulas:

The annual total precipitation (PRCPTOT), the annual maximum 1-day precipitation (Rx1-day) and the monthly maximum 1-day precipitation (Rx1-month), were calculated by the three following equations:

(1) $PRCPTOT_j = \sum_{i=1}^{I} RR_{ij}$

where the $PRCPTOT_j$ is the annual total precipitation on wet days, RR_{ij} is the daily precipitation of day (i) of the year (j) and the wet day is considered a day with daily precipitation ≥ 1 mm.

(2) $Rx1day_j = max(RR_{ij})$

where the $Rx1day_j$ is the annual maximum 1-day precipitation and the RR_{ij} is the daily precipitation of day (i) of the year (j).

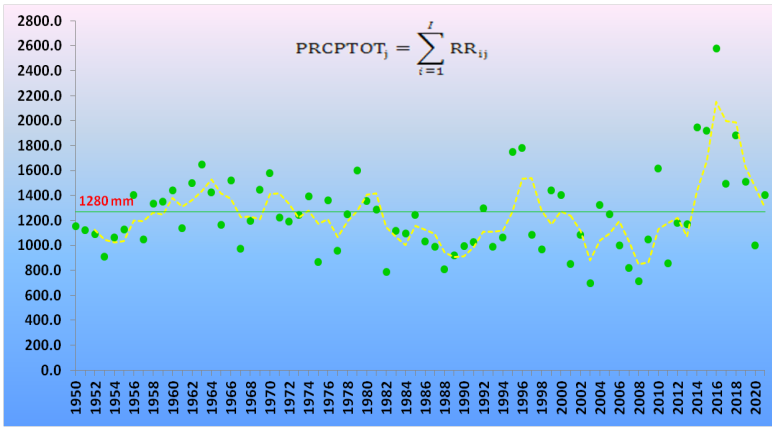
(3) $Rx1month_j = max(Rx1day_{ij})$

where the $Rx1month_j$ is the monthly maximum 1-day precipitation and the $Rx1day_j$ is the maximum daily precipitation of day (i) of the year (j).

The analyzed data, cover a 72-yrs period in order to capture the longest range of rainfall variation with the focus on the extreme daily precipitation and the extreme daily precipitation. This study's interest stands on estimating and analyzing some of the main extreme precipitation indices but in a second step those data will be compared to their respective values of the normal climate period (1961 – 1990). The extreme precipitation indices of the reference period are the averaged multi-annual precipitation total (AMPT).

Results

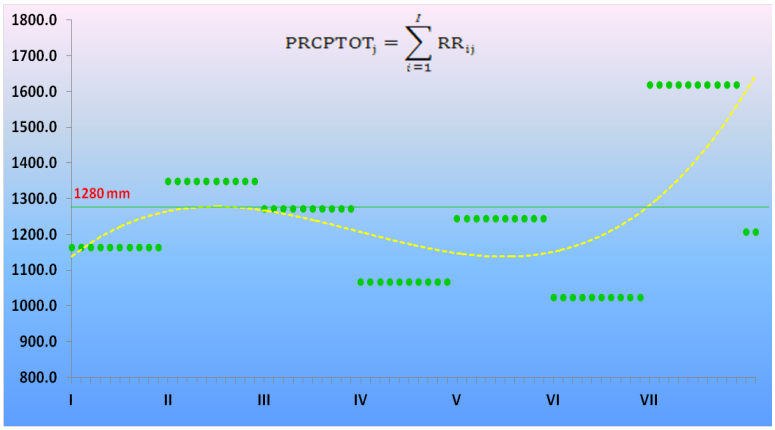
The analysis of the 72-yrs annual total precipitation reveal some interesting results about the long term variation of the Tirana's precipitation. The expression (1) was used to estimate the PRCPTOT values for each year of the 72-yrs period (Graph1).



Graph 1 – The variation of the annual total precipitation of Tirana for a 72-yrs period

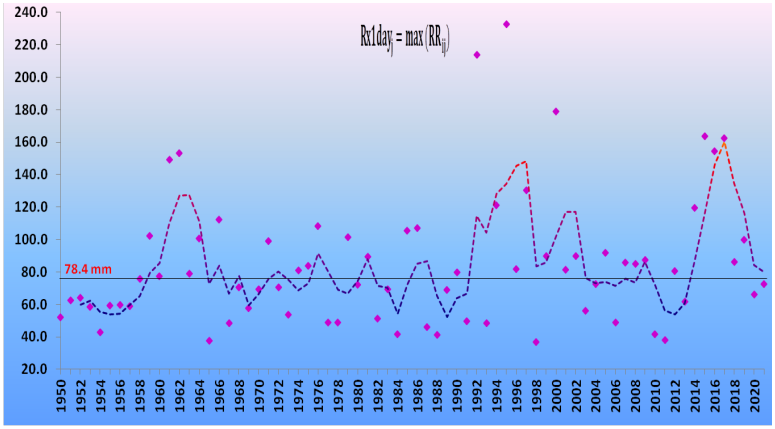
From the Graph 1, the PRCPTOT values in 59.7% of the years result below the AMPT reference value (1280 mm) while in 40.3% of the years, PRCPTOT values stand higher than it. To smooth the PRCPTOT values, the 5-yrs moving average is used to have a more objective pattern of the variation of PRCPTOT values during the period of 1950 - 2021. Following the 5-yrs moving average (yellow line) there is a low variation of the PRCPTOT values during the period 1950 – 1979, followed by a decreasing trend of PRCPTOT values up to the year 1990. In the other side, there are variations in the PRCPTOT values during the 1991 – 2021 with respectively an increasing trend in the PRCPTOT values for the period 1991 – 2000; a low decreasing trend for the period 2001 – 2010; another increasing trend for 2011 – 2019 and a clear decreasing trend of PRCPTOT values, during the last two years 2020, 2021.

As it can be seen from the Graph 1, the PRCPTOT values show a high variation during the last three decades and in order to have as many details as possible about this variation, the 3-decades period was split into 10yrs – intervals. For each 10-yrs interval, the average of PRCPTOT was estimated and compared to the AMPT reference value (Graph 2).



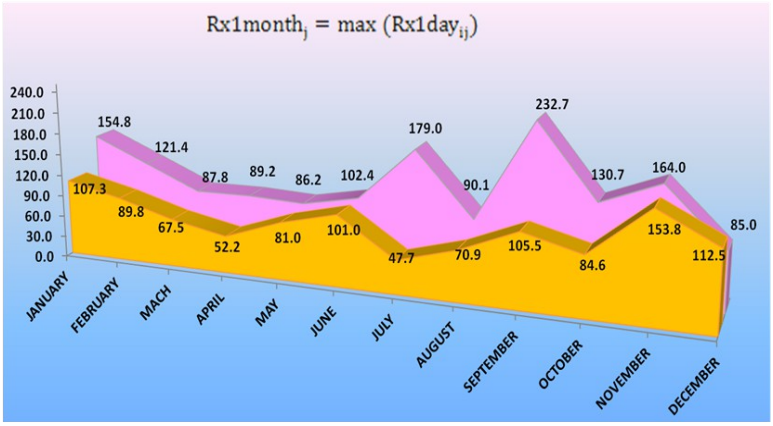
Graph 2 – The decade's mean of PRCPTOT for Tirana during the 72 yrs period

The Graph 2, presents decade's mean of the PRCPTOT of Tirana during seven decades and two last years of the whole analyzed period and it results on four dry decades; two wet decades and one decade (1970 – 1979) with a mean PRCPTOT of 1270.5 mm/yr close to the AMPT reference value (1280.0 mm). It is the last decade that stands on 26.4% over than the reference values, as it counts on 1617.2 mm. This fact presents a clear increasing on the PRCPTOT values, during the decade of 2010 – 2019. Standing to the main interest of this study, analyzes of the annual maximum 1-day precipitation (Rx1day) were performed as one of the most important indices of the extreme day precipitation. The Rx1day index was calculated by the expression (2) for each year of the whole period and results were compared to the Averaged Daily Maximum Precipitation (ADMP) values of the normal climate period to analyze the variance during the 72-yrs period (Graph. 3). Based on the averaged Rx1day values for the normal climate period that counts on 78.4 mm/24h (ADMP value) it results that in 51.4% of the years, the values of Rx1day stand below the ADMP while in the 48.6% of the years, the Rx1day values stand above it.



Graph 3 – The maximum 1-day precipitation of Tirana during the 72 yrs period

From the Graph 3, it can be seen that the highest value of Rx1day (232.7 mm/24h) belongs to the year 1995 while the lowest value of 36.9 mm/24h belongs to 1998. In order to smooth this huge difference of Rx1day extreme values, the five-years moving average was used to have a more objective variation of Rx1day. Analyzing the line of the 5-yrs moving average in the Graph 3, some periods of low variation in the Rx1day values are shown and two periods of high variation result for the period 1992 – 2017 implying that the highest values of Rx1day belong to the last three decades. Referring to the normal climate period, Tirana's Daily Absolute Historical Precipitation of 153.5 mm/24h (DAHP) was exceeded during the period 1992 - 2021 in six different years (1992, 1995, 2000, 2015, 2016 and 2017). A new Daily Absolute Historical Precipitation of 232.7 mm/24h was recorded in 1995, for Tirana. This record continue to be in force up today presenting in this way a more severe short-life storm that produced an extraordinary daily precipitation. In a last step, the Rx1month values were estimated by expression (3) for the whole 72-yrs period and were analyzed referring to the monthly respective values of the normal climate period (Graph 4).



Graph 4 – The Rx1M values of Tirana during the period of 1960 – 2021

The Graph 4 shows that all the Rx1month values during the last three decades (pink shape) stand above their respective values of the Rx1M of the normal climate period (orange shape). The difference stands on the December month that makes the exception; it shows a lower Rx1month (85.0 mm/24h) compared to its respective value of the normal climate period (112.5 mm/24h). Regarding the Rx1month values of July, September of the last three decades, the respective values stand clearly above their respective normal climate values. The Rx1M values of July and September of respectively 179.0 mm/24h and 232.7 mm/24h result by 3.8 and 2.2 times, higher than their normal climate respective values (47.7 mm/24h and 105.5 mm/24h). Another important detail from the Graph 4 is that, the DAHP value for Tirana city has shifted from November month (normal climate period) toward to September (232.7 mm/24h, 1995).

Summary and conclusions

The analysis of the PRCPTOT for the period of 1950 – 2021 show a superiority of the dry periods versus wet periods, with respectively 59.7% of the years and 40.3% of the total years, referred to the AMPT values. There is a high variation of the PRCPTOT during the end of the last century (1991 – 2021) and in the beginning of this century where the mean of the PRCPTOT accounts to 26.4% over than AMPT reference value for Tirana (1280.0 mm).

Regarding the Rx1day index, in 51.4% of the years its values result below the AMPT while it stands above it, in 48.6% of the years. The highest and the lowest values of Rx1day belong respectively to the years 1995 and 1998 ((232.7 mm/24h, 36.9 mm/24h) presenting a large difference of Rx1day extreme values. Even in this case, the highest variation of the Rx1day values belong to the last three decades of 1992 – 2021 exceeding the Tirana's daily absolute historical precipitation (DAHP) of the period with normal climate (153.5 mm/24h, November 1962). In the last three decades it results that six years (1992, 1995, 2000, 2015, 2016 and 2017) have exceed the DAHP value and the highest Rx1day of 232.7 mm/24h (Sep. 1995) is the new and the recent record of DAHP for Tirana city.

Analyzing the Rx1day in monthly bases, it results that the last three decades have the highest Rx1M values, compared to their respective values of the normal climate period (1961 – 1990). There is an exception with December month, the Rx1M value of the last three decades counts on 85.0 mm/24h, lower than its respective value of the normal climate period (112.5 mm/24h).

There are also the Rx1M values of July and September of the last three decades that stand clearly above their respective values of the normal climate period. The July and September Rx1M values count on 3.8 and 2.2 times higher than normal climate value of 47.7 mm/24h, 105.5 mm/24h respectively. Even the DAHP of Tirana shifted from November (normal climate period) to September month during the last three decades.

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