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Three decades of heat waves and extreme precipitation in Tirana

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Abstract: One of the most popular derivatives of the global warming is the increase of the frequency of extreme weather phenomena during the last decades. In the Albanian territory during the last three decades were observed extreme weather phenomena as heat waves during summer and also many events of extreme daily precipitation in different periods of the year. Both the extreme weather phenomena have caused a significant impact in the economy and life of the Albanian society. To better manage the negative impact any time these extreme phenomena happen and to minimize the losses, a better knowledge of each phenomenon is needed. In different Albanian regions, during the last three decades, there are signals of an increasing in the number of the extreme weather events. This study is focused on analysing the extreme weather events in Tirana city, the capital of Albania where live nearly the half of Albanian population. For this reason, to have an objective picture about the behaviour of these phenomena for Tirana, a long-term analysis should be performed for each of the phenomena, observed in the last three decades. Different authors used different determining methods to define a phenomenon as an extreme weather event and a good method could be the estimation of some of the most important indicators of each phenomena. This study covers a 30 years period and some indices were estimated and analysed regarding the heat wave phenomenon as the heat wave frequency (HWF), heat wave duration (HWD), heat wave season (HWS), heat wave intensity (HWI) and heat wave peak (HWP). In a second step, some of the main indices of the extreme daily precipitation were estimated and analysed as the annual total precipitation (PRCPTOT), simple daily intensity index (SDII), consecutive wet days (CWD), annual maximum of one day precipitation (RX1day), number of days of total precipitation over than 100 mm (R100mm) and number of days of total precipitation over than 150 mm (R150mm). Daily data of air temperatures and precipitation were used to calculate the above indices and their analysis aims to reveal any useful information that may be used as a tool to improve both the strategies of risk reduction of the heat waves and flooding firstly in Tirana city and after, in other similar urban areas.

Keywords: Extreme rainfall, flood, temperatures, heat wave, global warming

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Introduction

During the last three decades, an increasing in the extreme weather phenomena was observed in the Albanian territory where the most faced extreme events are long heat waves and daily extreme precipitation that often causes urban flash flooding. Tirana as one of the most populated and urbanized cities presents a high risk of extreme weather regarding both the increased number of events and their severity. On the last decades, the long heat waves and flash floods became a serious issue to the Tirana's citizen's life and property and a better managing of their negative impact is needed any time the events happen.

For this reason, a long term analyses of each of the above phenomenon was performed for the period of 1992 – 2021 where firstly, each of the phenomenon was defined as an extreme event and secondly, it was performed the estimation and analyses of some important indicators of each phenomenon regarding their frequency, duration, peak values and other extreme indices.

Data used and methodology

Records of daily temperature and precipitation for the period of 1990 – 2007 of Tirana city were available from the former Institute of Hydro-meteorology of Albania while the data for the period 2008 up today were available from the AWS Network of Meteoalb Center, a provider of climate and weather data in Albania. There aren't any unique definition criteria to define the heat wave as an extreme phenomenon or to define its extreme threshold values; different authors (Prieto et al, 2004; Diaz et al, 2005; Cony et al, 2010) have used different definition criteria for heat wave phenomenon. Based on a given area's geography and its climate, the heat waves are phenomena of sudden and intense rise of air temperatures caused by the invasion of warm air masses toward that area maintaining it for many days in conditions of high heat. In the Western Balkan, the origin of the warm and dry air masses is in general from the Sahara desert (Maheras et al, 2006; Cony et al, 2010; Porja et al, 2013;) that is the reason that heat wave phenomenon is popularly called "invasion of African heat".

Differently from some authors (Ayala and Olcina, 2002) who show that heat wave duration is short, not longer than 3-5 days, the studies of the last decades in Albania, present a wide interval of values for heat wave duration from 10 to over than 15 consecutive days (Della-Marta et al, 2007; Porja et al, 2013). The "invasion of African heat" may occur at any time of the year causing a notable air temperature anomaly but it is the summer season when the phenomenon is very popular.

From June to August, very hot and dry air masses travel from the Sahara to the Southern East of Europe causing a sudden rise of the daily temperatures where the daily maximums exceed the monthly normal (respectively 27.2°C, 30.1°C and 30.2°C for June, July and August) and even highest historical records values.

In this study, heat wave event was defined as the daily maximal temperature higher 5°C than the multi-annual average of maximum monthly temperatures (MAMMT) of June, July and August for a period of five consecutive days. After the threshold estimation, five key indices of

the heat waves were estimated and analyzed starting with the heat wave frequency (HWF), heat wave duration (HWD in days), heat wave length season (HWS in days), heat wave intensity (HWI in degree Celsius) and the heat wave peak value (HWP).

Analyses of both indices were performed in order to have a full picture of the behavior in the Tirana of the last 30-yrs based on the respective following definitions:

- HWF, the heat wave frequency is the number of the heat waves per year
- HWD, the heat wave duration is the length in days of each individual heat wave
- HWS, the heat wave season is the annual number of days from first to last heat wave
- HWI, the heat wave intensity (°C) is the averaged difference from threshold to record value
- HWP, the heat wave peak (°C) is the maximum daily temperature reached on each wave

Regarding the daily extreme precipitation, the focus of this study stands on estimation and analyses of some of the main extreme precipitation indices defined as:

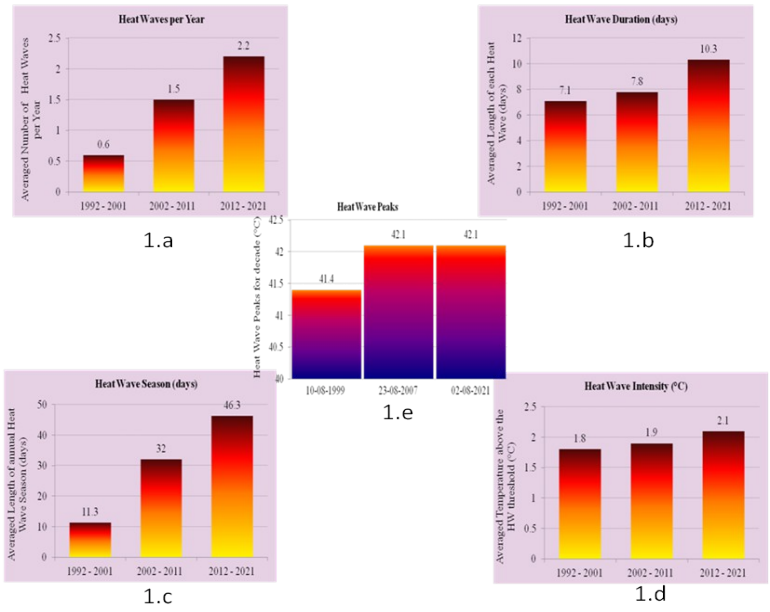
- PRCPTOT, the annual total precipitation during all wet days of daily precipitation >1 mm
- SDII, the Simple daily intensity index is the ratio of PRCPTOT to the number of wet days
- CWD, the maximum number of consecutive wet days with daily precipitation >1 mm
- RX1day, the annual maximum of 1-day precipitation (in mm)
- R100mm, the number of days per year with daily precipitation >100 mm
- R150mm, the number of days per year with daily precipitation >150 mm

The above indices of the both phenomena were analyzed for the same period (the last three decades) in order to capture the fullest possible potential range of the multi-annual heat wave events and daily extreme precipitation with the aim to reveal signals of their future picture.

Results

Heat wave indices

Analyses of the heat wave events during the last three decades (the graph 1) present an increasing in general of both five extreme heat waves indices from one decade to another. The following graph presents a clear change in both the analyzed indices of the HWF, HWD, HWS, HWI and the HWP during the last three decades.



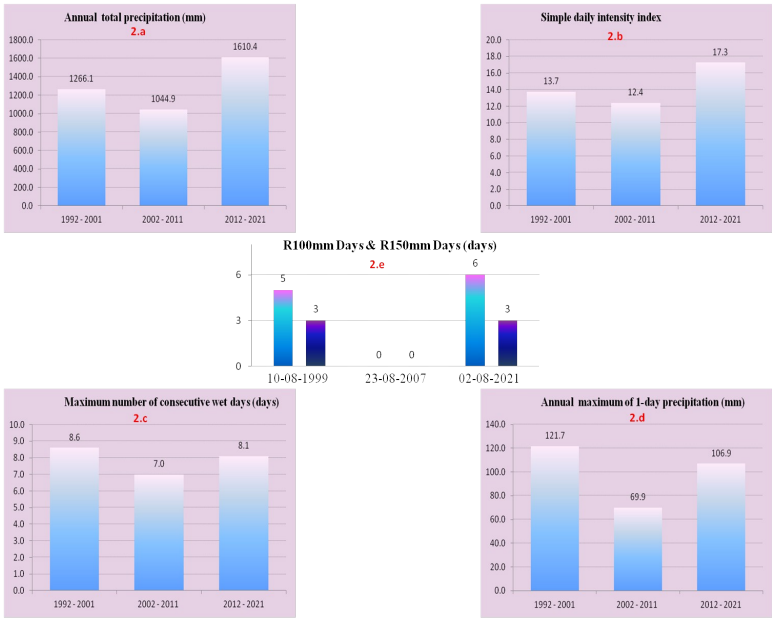
Graph 1 – The five heat wave indices during the last three decades for Tirana

It can be seen from Graph 1.a, from the first to the second decade the number of heat waves per year results 2.5 times higher and also a HWF of 1.46 higher than previous decade results from the second to the last decade (2012 – 2021). Looking at the HWD index (Graph 1.b) there is also an increasing in the number of consecutive heat wave days from the first to the second up to the third decade, from 7.1 days to 7.8 days up to 10.3 days.

Regarding the length of the heat wave season from the first to the third decade, there is a clear increase of the HWS index by 2.8 times from the first to the second decade and by 1.5 times higher, from the second to the last one. While the variation of the heat wave intensity along the last three decades presents an increasing of 0.1°C from the first to the second decade and an increasing of 0.2°C from the second to the last decade. There is also the index of heat wave peak value for each decade that defines the highest daily maximum temperature recorded for each heat wave of each year, for each of the three decades. The variation of the HWP values shows an increasing by 0.7°C from the first to the second decade but no change results, for this heat wave index during the last decade.

Daily extreme precipitation indices

The daily extreme precipitation during the last three decades presents a variation of all the six extreme precipitation indices from one to another decade (Graph 2).



Graph 2 – The six extreme precipitation indices during the last three decades for Tirana

The graph above presents a similar change during the last three decades for the couples indices PRCPTOT and SDII; CWD and RX1day; R100mm and R150mm. Concretely, the PRCPTOT index has decreased by - 221.2 mm/yr from the first to the second decade (1992 – 2001, 2002 – 2011) and has increased by + 565.5 mm/yr from the second to the third decade (2012 – 2021). In the the graph 2.b shows a decreasing rate of 1.3 mm/24h (a decade mean) for the SDII index from the first to the second decade while the opposite change results from the second to the last decade where the decade's mean of SDII values increased by 4.9 mm/24h. Regarding the index of CWD, the change in the decade's mean from the first to the second decade has decreased by 1.6 days while the CWD has increased by 1.1 days, toward the third decade. The same decade's change results for the RX1day but it presents a wide range of change from one to another decade. There is a decreasing by 51.8 mm/24 in the RX1da from the first to the second decade followed by an increasing rate of 37.0 mm/24h from the second to the third decade. There are also two other extreme precipitation indices analyzed in this study, the daily extreme precipitation R100mm and the daily very extreme precipitation R150mm.

The respective Graph (2.e, f) presents a mean of 5 days of R100mm in the first decade while it falls to zero during the second decade (2002 – 2011). The R100mm rises again during the third decade to a six number of R100mm. A similar change results for the R150mm index during the last three decades; the R150mm index falls from 3 (the first decade) to 0 in the second decade but it rises again to 3, in the last decade (2012 – 2021).

Summary and conclusions

The analysis of extreme weather phenomena, respectively the heat wave and daily extreme precipitation, present a notably change in their main indices during the last three decades. Regarding the heat wave indices, there is a clear change in the indices of HWF, HWD, HWS, HWI and the HWP during the three decades with a mean decade's increase of 1.43 events for HWF index and an increasing by averagely 1 day, in the HWD index from one decade to another. The index of HWS after the year 2001 has increased by nearly 21 days and also another increase by 14.3 days results for the last decade (2012 – 2021). Even the HWI index during the last three decades presents a a mean decade's increasing of 0.15°C while the index of HWP presents an increasing by 0.7°C from the first to the second decade but it presents no change along the last two decades.

The above facts about the heat wave phenomenon reveal an increasing in the frequency, duration, season length, intensity and in the peak value of the phenomenon during the last three decades, a period that corresponds to the end of the last century (1992 – 2001) to the beginning of our century (2002 – 2011).

The analyses of the daily extreme precipitation during the last three decades present a maximum of both indices of PRCPTOT and SDII in the last decade (2012 – 2021) while the maximum number of CWD and RX1day indices belong to the first analyzed decade (1992 – 2001). Regarding the indices of the R100mm and R150mm, they fall to 0 in the second decade (2002 – 2011) while they rise again, during the third analyzed decade.

The above results reveal an increase in the PRCPTOT and SDII indices from the end of the last century to the first decades of our century while the indices of CWD and RX1day present a decrease during the same analyzed period. Regarding the variation of the indices R100mm and R150mm, the beginning of our century (decade 2002 – 2011) results without events of extreme/very extreme daily precipitation but there is a rise by 1 day of R100mm in the last decade and no change, for the R150mm index.

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