Long-Term Heat Wave Extremity Related to Human Body Risk

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Abstract

The impact of climate changes has already been observed in Albania facing its economy to many damages and to quantify the future climate-related risks, a better knowledge of the extreme weather phenomena becomes essential. A significant change has been observed in the frequency and severity of heat wave events during the last decades and this study is focused on the long-term analysis of the local scale for this phenomenon. The analyses were performed for Tirana, the Albanian capital with the highest population (one third of the country's population lives here) and also a very high importance as a good part of Albania's industry is concentrated there. The last decades present an increase for the main indicators of the heat waves as a higher frequency and a longer duration of the wave. To improve the urban climate policies and to help the adaptation, a better knowledge of the extreme weather events is needed. For this reason, more research should be conducted regarding one of the most popular extreme weather, the heat wave phenomenon and in a wider urban area.

Keywords: Heatwave • Extreme heat • Heat duration • Heat peak • Human body risk

Introduction

As a consequence of the increased climate risk that produces millions of damages to the Albanian economy there is a need of using better climate change adaption policies to reduce the risk, to mitigate the impact of extreme weather in order to anticipate the future risk [1]. Some of the extreme weather phenomena produce a human related risk that is associated by a high social and economic cost for the country. The heat wave phenomenon is a noiseless dangerous extreme weather that kills thousands of people around the world and its frequency is increased in many regions an increasing trend is also projected to intensify in the future [2-8]. In these conditions, analyses of the heat waves should be performed in order to quantify their frequency, severity and other extreme heat indicators and the results derived will play an important role in the climate change adaptation of the local scale. In general, there are few local based analyses regarding the heat wave phenomenon compared to the regional or larger-scale analyses. Local outputs may serve as inputs of the climate policies in urban areas to help the society adaptation into the future coming local changes.

Data used and methodology

The data used in the study include daily maximum temperatures from ECA&D data series for Tirana (Lat/Lon: 41:20:00/19:47:00 at elevation 89 m) covering the period of 1950–1990; from the synoptic station of Tirana (the former Albanian Institute of Hydrometeorology – IHM) for the period of 1991–2007 and from the Tirana's AWS of Meteoalb Research Center (MRC) from 2008 to 2020. The data used from the ECA&D passed four homogeneity tests (view ecad.eu) while the data from the former IHM and MRC passed Standard Normal Homogeneity test for daily maximum temperature TX ≥ TN (-20°C ≤ TN ≤ 50°C). Regarding the method used, there is no universally accepted definition for the heat wave phenomenon or its thermal extremes, different authors use the "should exceed" criterion [9-12].

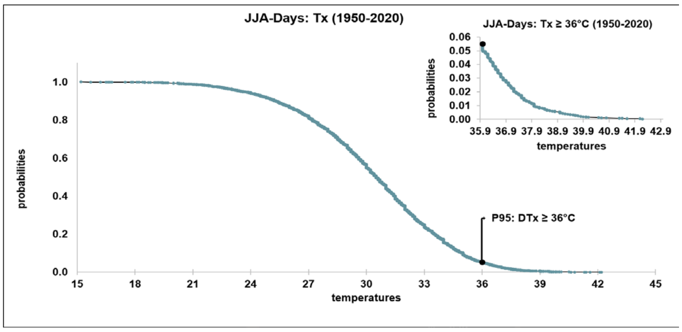
Some authors use the criterion of "should exceed" a thermal threshold or a specific maximum for one or some consecutive days [11-15]. The criterion we adopted in this study is that the daily maximum temperature should exceed the human body temperature of 37°C for at least 3 consecutive days, for it to be considered a heat wave event associated to a human health risk. The rationale behind this choice is based on the discomfort of the human body exposed to the high temperatures, finding the mechanisms to defend core temperature from temperature increases, including sweating and vasodilation of peripheral blood vessels [16]. Using statistical indicators of the type "so many degrees above average" is a moving target in the background of climate changes, and does not take into consideration the human factor, which should be the most important one. Before the filtering of the human body's thermal threshold, long-term analyses were performed regarding the variation of the Hot Days (HoD), Heat Days (HeD) and the Heat Intense Days (HeID) for the whole period. The HoD index counts the number of days with daily maximum Tx ≥ 36°C (estimated by the 95th percentile), the HeD index counts the number of days with daily maximum Tx ≥ 37°C (that also defines the human body threshold) and the index of HeID that counts on the numbers of days with daily maximum temperatures Tx ≥ 40°C. Then, the daily maximum temperatures passed through the double-filtering of human body thermal threshold for at least 3 consecutive days and in the last step, analyses of the main heat wave 3-key indices were performed such as the frequency (HWf), the wave duration (HWd) and the wave peak (HWp).

Results

Analyses of the Hod, HeD and HeID indices

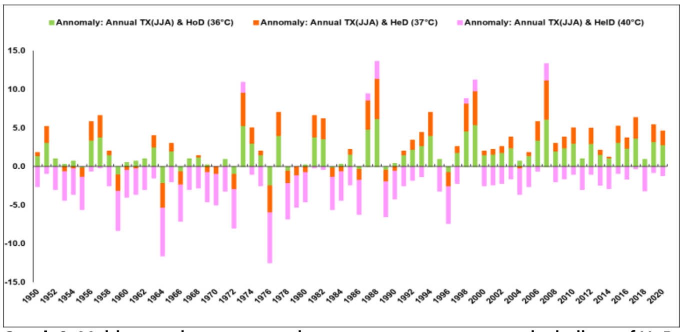
To analyze the heat wave phenomenon, we plotted the Cumulative Probability Distribution Function (CDF) of observed daily maximum temperatures (Tx) recorded during hot months of June, July and August in Tirana city for the period 1950–2020 and analysis of the Hot Days (TX ≥ 36°C; 95th percentile), the Heat Days (Tx ≥ 37°C) and the Heat Intense Days (TX ≥ 40°C) were performed for the whole period and it results that (Graph 1):

1. No. of days with Tx ≥ 36°C (HoD) comprises 5.5% of all analyzed days
2. No. of days with Tx ≥ 37°C (HeD) comprises 2.7% of all analyzed days
3. No. of days with Tx ≥ 40°C (HeID) comprises 0.17% of all analyzed days



Graph 1. Daily maximums temperatures for June, July and August, in Tirana (1950 – 2020)

The maximum summer temperatures (STx) were calculated for each year of the 1950 – 2020 period and were compared to the indices of HoD (Tx ≥ 36°C), HeD (Tx ≥ 37°C) and HeID (Tx ≥ 40°C) in order to analyze the multi-annual variation of thermal anomaly (Graph 2).



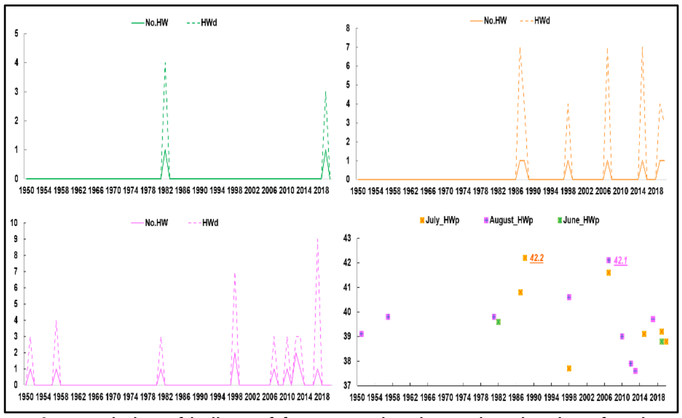
Graph 2. Multi-annual summer maximum temperatures versus the indices of HoD, HeD and HeID

From the graph above, it results that STx values stand mainly above the HoD index values (green columns) in 83% of years with a long period of positive-only deviation during (1997–2020) and two deviation maximums of +6.2°C, +6.1°C respectively in the summers of 1988, 2007. While a negative deviation up to -2.5°C results for the summer of 1976, other negative deviations variates from -0.1 up to -1.0°C. In resuming the STx – HoD comparison, it can be said that the maximum summer temperatures show a positive anomaly versus the HoD index (Tx ≥ 36°C) for 83.1% of the years in the period 1950–2020. Regarding the comparison between STx and HeD index (orange columns) it results a decrease in the number of the years with positive anomaly in favor of a doubling number of the years with negative anomaly, up to 35.2%. The deepest negative anomaly of -3.5°C belongs to the summer 1976 while the highest positive anomaly counts on +5.2 and +5.1°C for 1988, 2007. In resuming the comparison, it can be said that the STx values stand clearly above the HeD index value (Tx ≥ 37°C) for more than the half (in 64.8% of the years) of the period 1950–2020. Going to the multi-annual variation of thermal anomaly between the STx and the HeID index values (pink columns) the graph above shows a clear negative anomaly (in the 91.5% of the years) of the STx values from the HeID index (Tx ≥ 40°C) while a positive anomaly of the STx is observed in only 6 years with a maximum positive anomaly of +2.2 and +2.1°C in the summers of 1988 and 2007. In resuming the long-term comparison of the summer daily maximum temperatures STx to the HoD, HeD and HeID indices it results that summer daily maximum temperatures stand mainly above the HoD index in 83.1% of the years with a ratio of 4.92 but the ratio decreases in 1.84, for the HeD index comparison. The opposite ratio results in the number of years with STx values above the HeID index; it decreases in 0.09 that means only eight years record a summer daily maximum temperature ≥ 40°C, the value of the HeID index.

Analyses of the indices of HWf, HWd and HWp

The heat wave index of HWf is the number of heat waves per year, month or season, the HWd index is defined as the number of consecutive days under the heat wave condition and the HWp stands for the highest daily maximum temperature recorded, during any heatwave event.

An event of heat wave is defined by using the human-related thermal threshold of Tx ≥ 37°C, for at least 3 consecutive days. After the 2-criteria filtering process, it results a total number of 20 heat wave events, mainly observed during the last decades (70% of the heat wave events) and analyses of the heat wave indices as frequency, duration, and peak value were performed for the whole period and for each month, in annual bases (Graph 3).



Graph 3. Variation of indices of frequency, duration and peak values for Tirana (1950–2020)

The analyses show not too much regarding the June's heat wave frequency (green line) and heat wave duration (green dashed line) due to the two only events, observed for the whole analyzed period while there is an increased number of the heat wave frequency for July and August, in the last 3-decades.

Regarding the heat wave analyzed indices, it can be said that during the whole period, the highest number of the heat wave events and also the longest waves were observed during the last decades, mainly in the August month, while the heat wave peak values (with a tiny difference of 0.1°C) belong to July and August.

Conclusion

The aim of the study is to better understand the impact of the heat wave phenomenon, especially when it goes to some risk indicators to the human body comfort. For this reason, we adopted the human body temperature of 37°C as a threshold criterion of the daily maximum temperature that should be exceeded for at least 3 consecutive days. The used threshold presents a human risk level for peoples exposed to those temperatures due to the overheating and dehydration. Besides the heat wave phenomenon, there are the hot days, heat days and the heat intense days that also have an impact to the human body comfort and both of three types of summer days present an increasing number in the last decades, especially for heat intense days that in 91.5% of the years, exceeds the summer daily maximum temperatures. While, referring to the heat wave main indices, there is an increasing in both frequency and wave duration in the last decades while there is no a clear pattern regarding the heat wave peaks for whole period; the highest peak counts on 42.2°C (July 1988) and a second similar peak of 42.1°C belongs to August 2007.

Discussion

This study helps to a local objective picture of the heat wave behavior in the urban areas regarding the frequency, duration and the degree of severity. Despite the wide extent of the urban area of Tirana, this study remains a single case; it needs to be applied in several urban areas in order to highlight the impact of heat during the last decades.

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