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The excessive heatings in the Romanian Plain

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Abstract: The paper study the extremely hot days, with temperature ≥35°C, on the basis of daily data of the maximum air temperature in the Romanian Plain - one of the territories in Romania with the highest excessive heatings. The excessively hot situations were analyzed in detail by: calculating the total number of extremely hot days gathered year by year and extracting the periods of different durations with such successive days, calculating the frequencies for the analyzed period, identifying the maximum duration intervals of each year and outlining the trends of their evolution. The extreme intensity of the heating is described by the manifestation data both in the air and on the ground. The extraordinary magnitude of the phenomenon was also highlighted by the MODIS satellite data, which indicated maximum temperatures above 50˚C, during the day and 35˚C at night.

Key words: excessive heat, maximum temperatures, evolution trends, satellite data, Romanian Plain.

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1. INTRODUCTION

The global warming trend with its accelerated intensification in the last decade was especially felt during the warm season of the year, the exacerbation of extreme thermal phenomena being one of the main climatic dangers. Studies of these phenomena are of particular importance due to their applicability in a wide range of fields: health, environment, economic activities, etc.

The excessive heating during the hot season of the year is best evidenced in the form of exceeding the temperature threshold specific for extremely hot days - when the maximum temperatures reach and exceed the 35 Celsius degree threshold. Considering the mechanism of heating by the solar radiation of the ground's surface, which, by emitting of long-wave radiation, heats, in turn, the air, the episodes with high air temperatures are revealed by the land surfaces temperature (LST), which can exceed 60°C, depending on the nature of their material. If we focus on the constantly growing urban areas, where majority of the population tends to live and work, we can detect some vulnerable areas that heat up very fast during the day, and remain very hot even during the night, that have a number of negative impacts.

2. LITERATURE REVIEW

Although specific to the summer season, the extremely hot days are a real danger when a longer period persists [1,2], these special situations having a major impact [3] through the different negative effects on the health of the population [4,5], the environment and the socio-economic activities [6].

The rising global temperatures and the increasing number of people living in an urban environment are associated with a phenomenon called the effect of the urban heat island (UHI) [7]. The heat island (UHI) describes the average temperature in an urban environment, compared to the adjacent rural area. This effect is most evident during the night, when the urban environment acts as a battery due to the solar heating, which counteracts the night cooling. Dramatic effect during heat waves, this additional heating

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inhibits the nocturnal recovery of human blood circulation and causes health problems, especially for the elderly [8,9,10,11].

3. METHODS, DATA AND STUDY AREA

The work is based on the meteorological data recorded by the National Meteorological Administration (NMA), available within the European Climate Assessment and Datasets project [12]. The daily recordings of the maximum temperatures (from 1961-2014) were processed from 6 weather stations within the Romanian Plain: Bucharest-Băneasa, Buzău, Călăraşi, Craiova, Galaţi and Roşiorii de Vede.

The data processing allowed a detailed analysis of this parameter relevant for the extreme thermal situations in the Romanian Plain. For a proper interpretation and a more suggestive and synthetic image of their territorial distribution, graphs and maps were made.

The excessively hot situations were analyzed by: calculating the total number of extremely hot days gathered year by year and extracting the periods of different durations with such successive days, calculating the frequencies for the analyzed period, identifying the maximum duration intervals of each year and outlining the trends of their evolution.

Romanian Plain, a vast region with low-altitude relief, extended in the southern part of the romanian teritory (between tableland and hills, in the north, and Danube Valley, in the south), is the most exposed part of the country to advections of the tropical hot air and excessive local warming induced by insolation. The weather stations included in this study are located in different local condition: in the central part of the plain – Bucharest-Băneasa (in the northern limit of the city, at 90 m altitude) and Roşiorii de Vede (on the interfluve, at 102 m), in northern part of the plain, on the rivers valleys – Craiova (192 m) and Buzău (97 m), near the Danube Valley – Călăraşi (19 m) and Galaţi (at 69 m, between 3 major rivers and in proximity of lakes).

In order to analyse the relationship between the components of the urban environment and the land surface temperature (LST) during the episode of heat wave from the summer of 2007 for the city of Călăraşi two types of data were used: the landuse/cover data from the Urban Atlas (UA) 2006 product of the Copernicus Land Monitoring Services provided by EU Copernicus programme [13] and the LST from MOD11_L2 and MYD11_L2 products of MODIS satellite sensors TERRA and AQUA, which have a moderate spatial resolution (500 m - 1 km), but a daily temporal resolution [14]. The results obtained are meant to highlight the problem areas in the urban environment and may be a possible step to better understand the local urban climate in order for the decision-makers to take the measures necessary to reduce the thermal stress induced for the members of the respective communities.

4. RESULTS

The territorial distribution of the total number of extremely hot days/period show that the highest values are almost triple compared to the smallest ones: Roşiorii de Vede - 290 extremely hot days/period, Călăraşi - 267, Bucharest-Băneasa - 216, Craiova - 193, Buzău 139 and Galaţi - 110 extremely hot days/period (Figure 1). The explanations are very different local conditions. For example, in Galaţi, the proximity of the aquatic surfaces moderates the incidence of these extreme phenomena, while in Roşiorii de Vede the cumulation of the thermal stress with the hydric one induces the exacerbation of the heating.

On the map of the distribution of the total number of intervals with consecutive canicular days from the entire studied period, the following values are distinguished: Bucharest-Băneasa - 52 intervals, Buzău - 36, Călăraşi - 61, Craiova - 47, Galaţi - 28 and Roşiorii de Vede – 68 intervals. Thus we can see clear differences between the stations located in the north of the region and those located in the center of the plain or at more southern latitudes, the highest values, specific for Călăraşi and Roşiorii de Vede, representing more than double the smallest value, specific to Buzău station (Figure 2).

The maximum intervals of consecutive extremely hot days show that almost all the situations were met in 2007, in the conditions of the hottest year of the analyzed period: 9 consecutive days in Bucharest-Băneasa, Craiova and Buzău, 10 in Călăraşi and Galaţi. At Roşiorii de Vede the maximum is represented by the value of 11 consecutive days registered in 1987, but appears the secondary value of 10 consecutive days in 2007.

The analysis of the variability from year to year of the annual amounts of extremely hot days, showed the recording of the increasing values in the last years 2000, 2007 and 2012. The absolute maximums belong to 2012 (34 days / year in Călăraşi), representing double or even values triple against the amounts collected in other excessively hot years - 1987 and 1998.

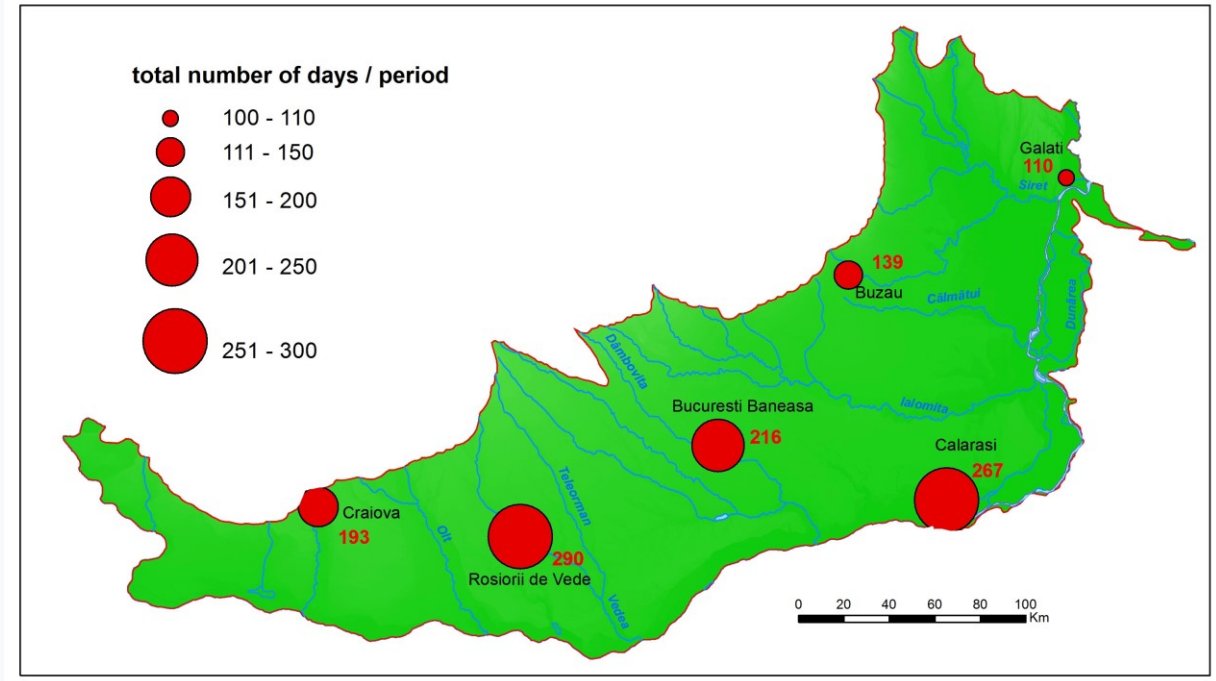


Figure 1. Total number of extremely hot days/period.

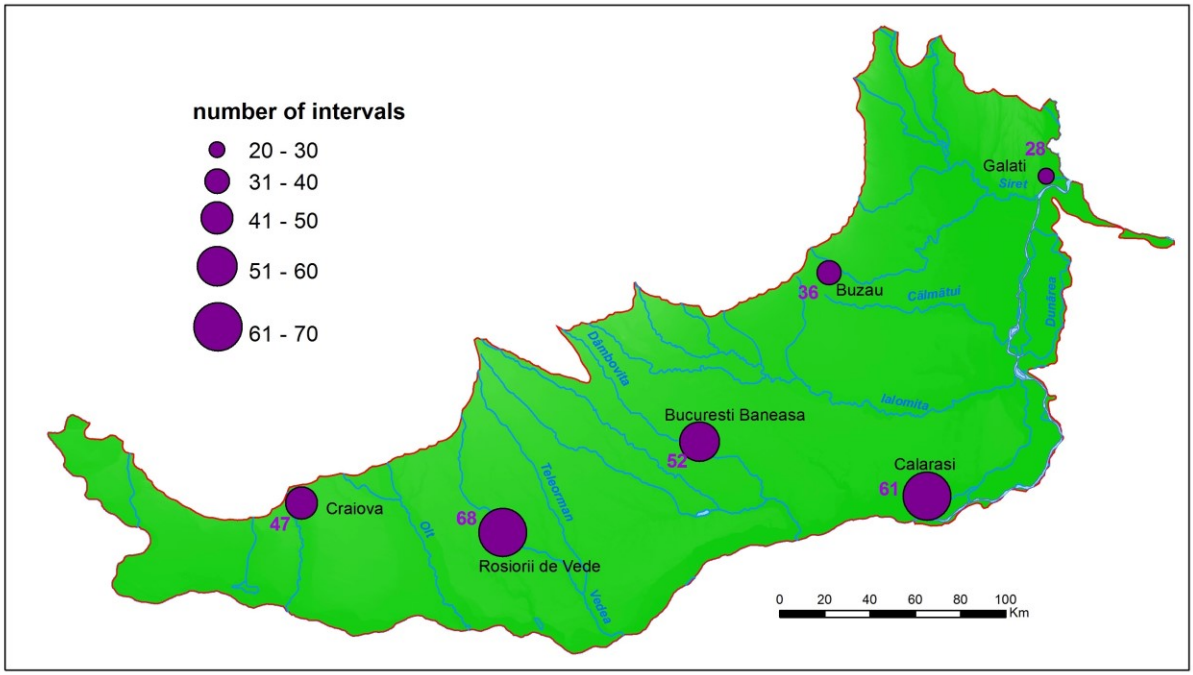


Figure 2. Total number of intervals with consecutive extremely hot days/period.

The absolute frequency by value classes of the duration of consecutive days with heat temperatures, illustrated in the graphs constructed for each of the six stations, shows that in most cases the extremely hot episodes are short, two or three consecutive days, the absolute values indicating clear differences between stations. The record durations of the extremely hot episodes reach 9 or 10 successive days at all the analyzed stations, but the persistent phenomena has a higher frequency in the Roşiorii de Vede and Călăraşi, with high values regardless of the lengts of the intervals (Figure 3).

On the graphs comparing the year-on-year evolution of the total number of extremely hot intervals, regardless of duration, in parallel with that of the maximum durations of consecutive days with such temperatures, it is observed that the values range, although it has different amounts from a station at another, shows similarities in terms of the years of production of the maximum values.

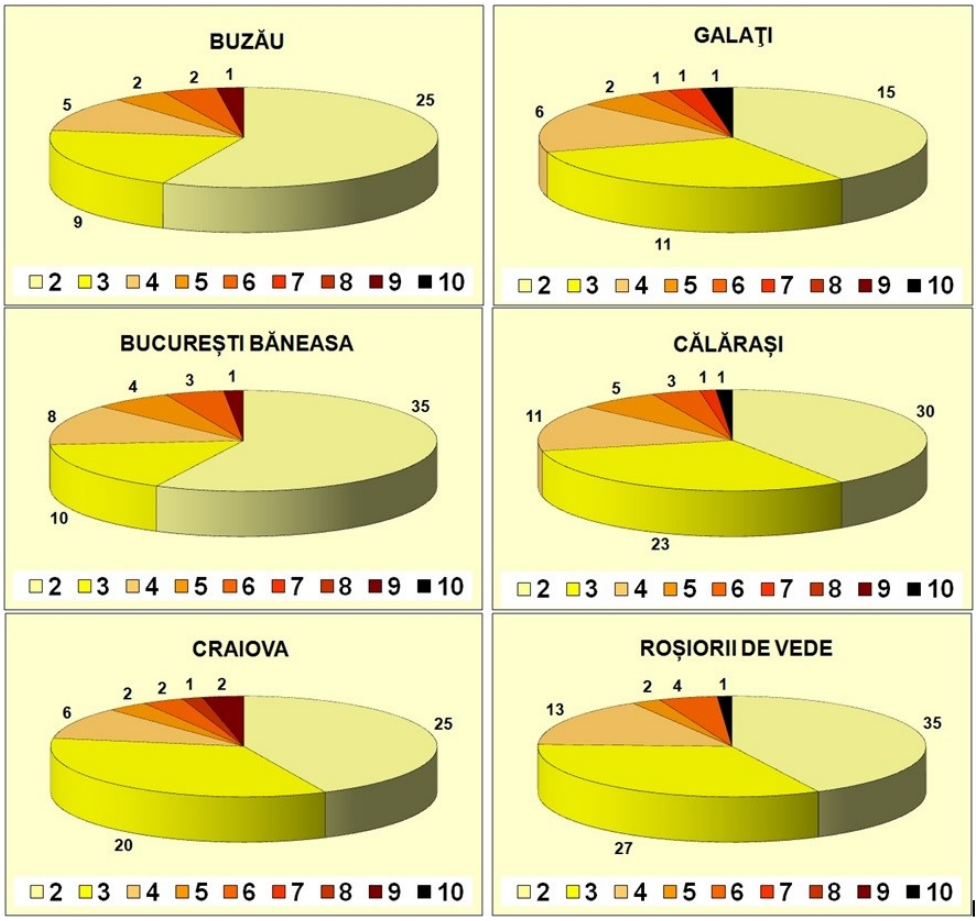
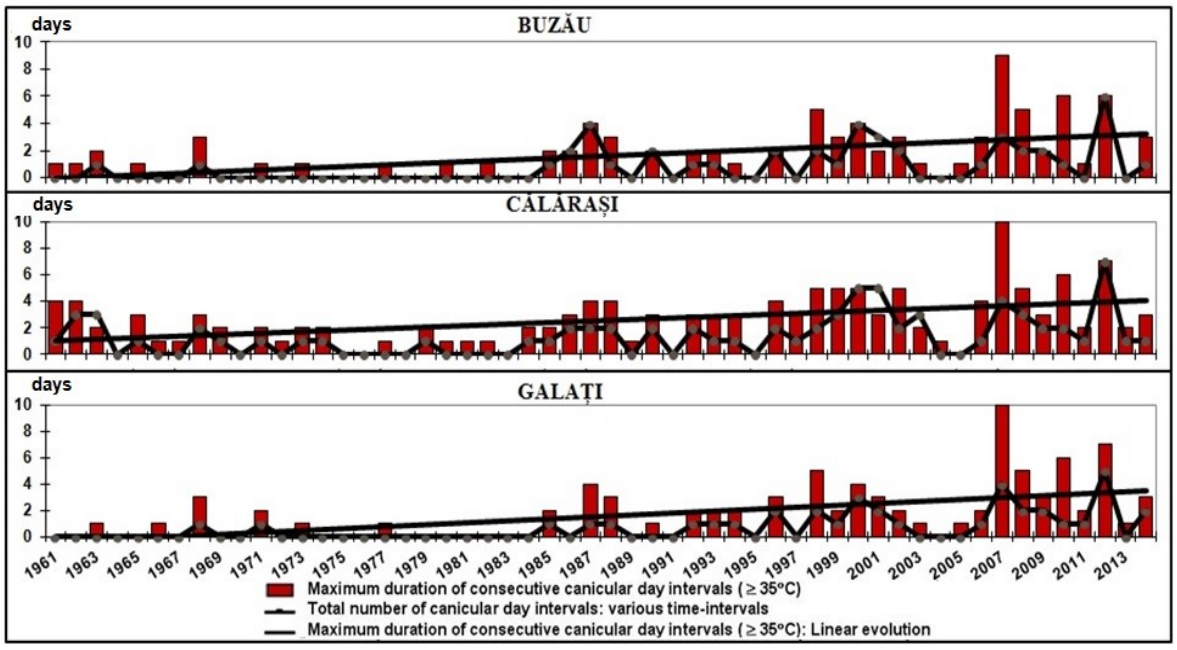
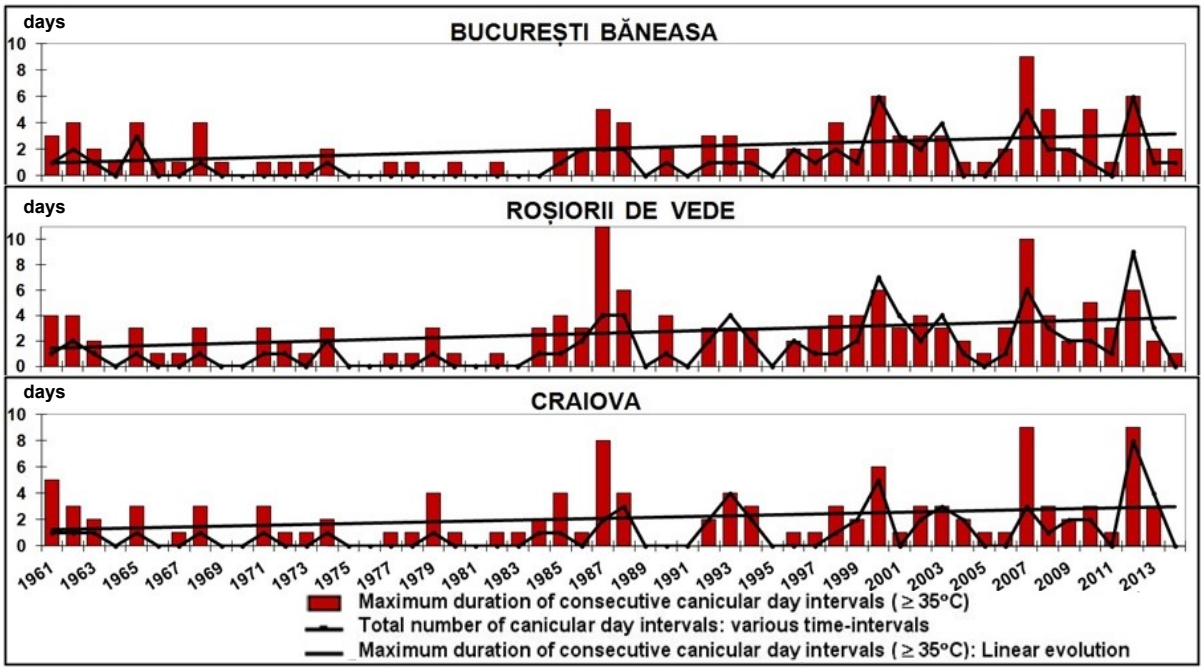


Figure 3. The frequency by values classes of the lenght of extremely hot intervals



(a)



(b)

Figure 4. Variation of extremely hot consecutive days intervals: **(a)** Buzău, Călărași, Galați; **(b)** București Băneasa, Roșiorii de Vede, Craiova.

Excessive heating with longer durations of the last years (2000, 2007 and 2012 are also highlighted by the outline of accentuated linear trends of increase of the maximum durations of the time intervals, at all the analyzed stations. Thus, we note that 2007 is the warmest by record lengths of consecutive extremely hot days (9-10 days), while 2012 represents the warmest year through record number of such intervals (Figure 4a and b).

The record heat episodes in 2007 and 2012 were the expression of the severest warmings caused by the cumulation of the effect of hot and dry air advection with that of excessive local heating, under conditions of low air humidity and clear sky, specific to the persistence of anticyclonic activity.

4.1. Călăraşi case study

During the record-breaking episode of July 2007, the exacerbation of heating culminated in exceeding the 40˚C threshold in air at many weather stations in Romania. In Călăraşi it lasted 10 days, between July 16-25, and the highest value of air temperature (42.1˚C) was recorded on July 23.

From the MODIS satellite data available for July 23, 2007, the maximum daytime land surface temperature (LST) was over 50˚C, the minimum temperature of 34˚C, with an city-wide average of 44˚C. During the night the maximum temperature reached 35˚C (Figure 5a and b).

The UHI of the city is more visible during the day, having an amplitude of 4˚C compared to the adjacent surfaces (Figure 5c). An exception is represented by the agricultural areas in the north of the city, where the temperatures are even higher (over 50˚C) than inside the city. These agricultural areas are represented by the dark soil from which the crops were harvested. At night the small difference of 1-2˚C between the city and its surroundings makes this UHI not significant in terms of amplitude but is more visible, been more concentrated around the city centre (Figure 5b and c). One explanation could be the small distance to the Danube river and the thermal properties of the bare dark soil from the agricultural areas surrounding the city. However, the temperatures inside the city remain higher than 22˚C, about 54% of the population enduring at night temperatures exceeding 23˚C.

Performing a statistical analysis at the level of land use classes of the Urban Atlas 2006 (2018) database it can be observed that during the day the highest temperatures were recorded at the level of agricultural surfaces, followed by the anthropic surfaces (roads and associated surfaces, industrial areas and residential areas with surfaces sealed in proportion more than 50%) and the lowest temperatures are associated with forests and aquatic surfaces (Figure 6a and b).

During the night the highest temperatures were recorded at the level of the anthropic surfaces (recreational areas, roads and associated surfaces, industrial areas and residential areas with sealed surfaces in proportion more than 50%) and the lowest temperatures are associated with agricultural areas (Figure 6a and c).

According to the National Institute of Statistics data [15] in relation to the number of inhabitants, in 2015, the city of Călăraşi records an important green area (23.8 m^2/inh.) which ensures an increased adaptation capacity of the Călăraşi municipality to the extreme climatic phenomena. However, it is also to be noted that the green areas are located more on the Danube meadow, within the city, these being very small in size. Also, the large surface of the sealed areas causes, during periods with heat waves (as in the case of the period 16 - 25 July 2007), the daytime temperatures to exceed 46°C.

During the day the agricultural areas in the north and northeast of the city, which during this period were harvested, behave like a black soil without vegetation, heating very strongly, thus exerting an important influence on the urban temperature (Figure 5a).

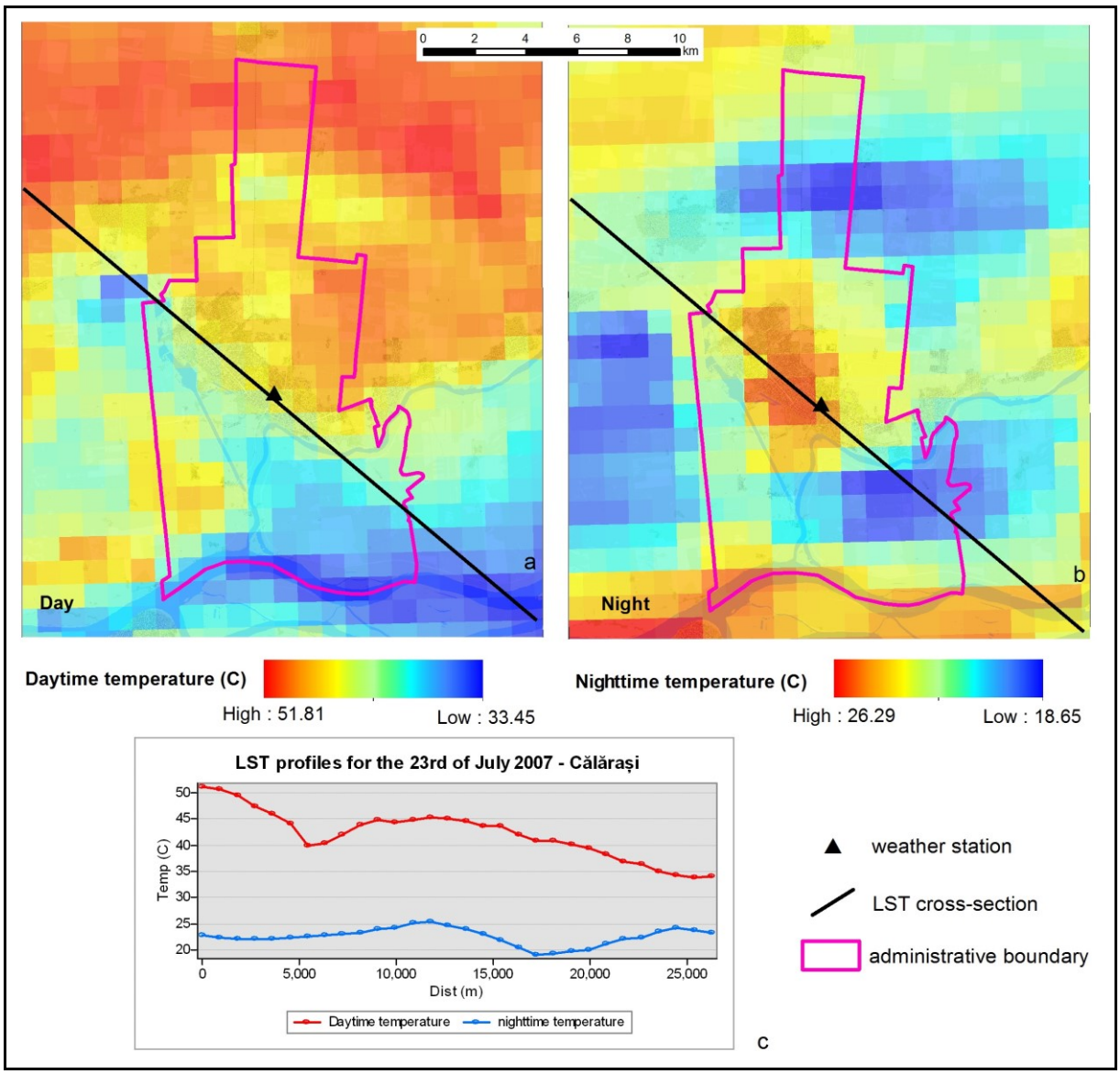


Figure 5. LST data for Călăraşi City: **(a)** spatial variation of the daytime temperature; **(b)** spatial variation of the nighttime temperature; **(c)** daytime and nighttime variation along a NW-SE profile.

5. CONCLUSIONS

From the description of the different parameters chosen for the characterization of the excessive heatings situations, we note that this extreme phenomenon, specific during the summer in the regions of

Romania with low-altitude relief, is felt with greater duration and intensity, but also more frequently in the central parts of the Romanian Plain and in its southern extremity, on the Danube Valley.

The tendency of heating is becoming more and more pronounced in recent years (from 1987) in the studied region, regardless of the local influences and climatic nuances.

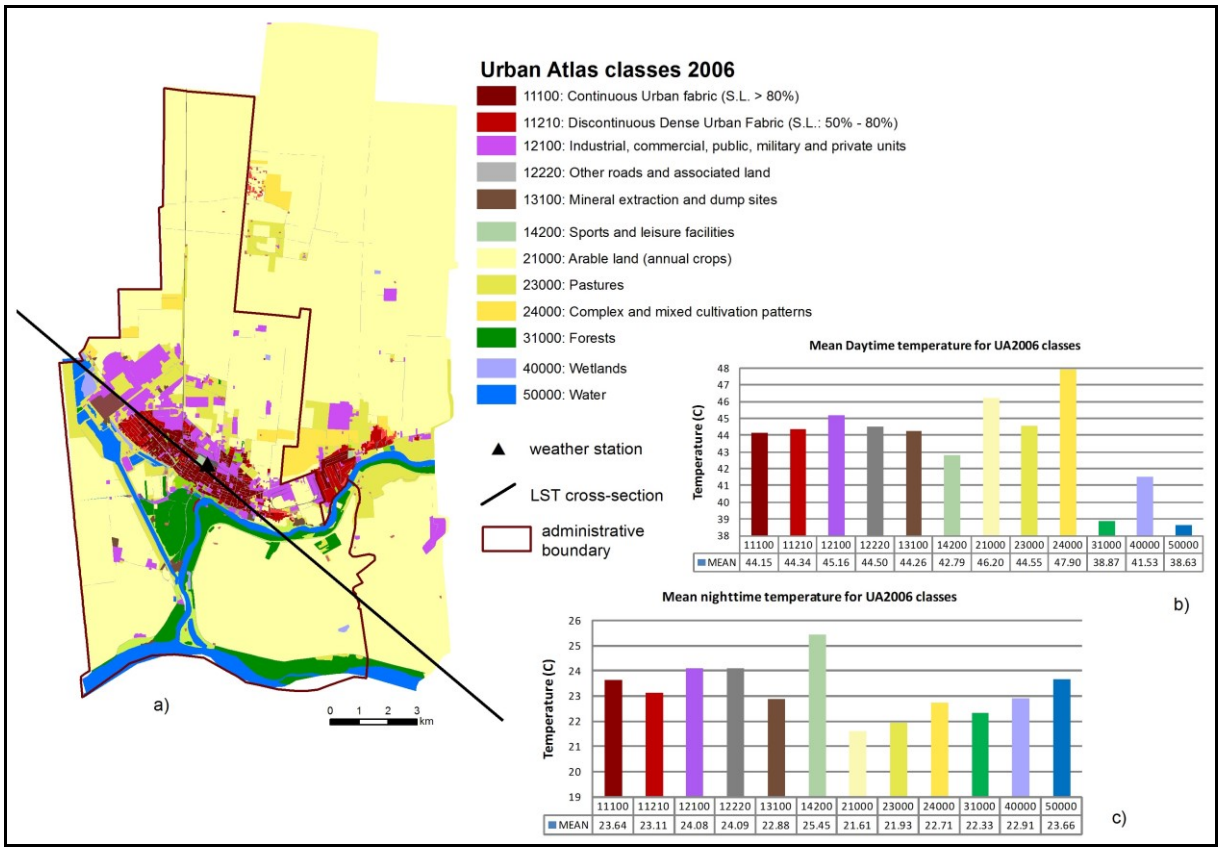


Figure 6. Statistical analysis of the LST at the level of land use classes of the Urban Atlas 2006 for Călăraşi city: **(a)** the land use classes of the UA 2006; **(b)** mean daytime temperature for UA 2006 classes; **(c)** mean nighttime temperature for UA 2006.

The exacerbation and prolongation of the presence of the upper thermal threshold of the heat represents a major thermal stress, and the frequency of these phenomena is considered to continue to increase in the following decades. A major impact is expected especially in urban agglomerations, with negative consequences primarily for the human health, but also with severe consequences on the environment and several economic sectors.

Taking into account the great danger of exacerbation and increase lasting of excessive heatings, is imperative necessary to take preventive measures through education and raise of public awereness, and by developing disaster management system.

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