AIR-TEMPERATURE SINGULARITIES AND DIFFERENCES BETWEEN INTRA- AND EXTRA-URBAN WEATHER STATIONS. CASE STUDY: BUCHAREST-FILARET AND BUCHAREST-BĂNEASA

**IONAC Nicoleta¹, URÎTESCU Bogdan¹, GRIGORE Elena¹,
CONSTANTIN Dana Maria¹ DUMITRESCU Alexandru²**

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Abstract. It is already a well-known fact that air-temperature is the most important climatic factor of differentiation between intra- and extra-urban areas, mainly due to the characteristics of the underlying active surface. Bucharest town-area is no exception to the rule. Ranking as Romania's largest city, its air-temperature singularities and differences account for the most important example expressing the role that the artificial ground layer may play in the creation of specific urban climates. The thermal differences as well as singularities between the Bucharest town-area (Bucharest-Filaret) and its surroundings (Bucharest-Băneasa) are analyzed by means of multiple air-temperature parameters: hourly measurements (01, 07, 13 and 19 hrs.), daily, monthly, yearly values of maximum, average and minimum means, over a 30 year period (1981-2010). Besides, the analysis of some air-temperature singularities or records highlight the clear differences of air heating processes, mostly due to the different interaction patterns between solar radiation and the underlying active layer, at local scales. However, in general, although the intra-urban areas should keep warmer in summer and cooler in winter, the cooling effects seem to still remain lower in the city because of the greater artificial heat input that is being added to the built-in environment.

1. INTRODUCTION

Urbanization, which mainly resulted in an intensive spatial concentration of population, dense built-in areas with impervious pavements, multiplied and vertically-differentiated layers of active surfaces, as well as scarcer green infrastructures, is obviously exacerbating any urban climate environment, by

¹ University of Bucharest- Faculty of Geography, Bucharest, Romania
ionac.nicoleta@geo.unibuc.ro, bogdan_uri@yahoo.com, ela_zigzag@hotmail.com,
danamartines@yahoo.com

² National Administration of Meteorology, Bucharest, Romania: alexandru.dumitrescu@gmail.com

largely altering the proportion between the urban heat island (UHI) effect, specific of the urban artificial landscapes, and the urban cool island (UCI) effect, characteristic of the green, vegetated spaces and bodies of water sparsely distributed inside the city area or in its surroundings (Chen A. et al., 2014). In this respect, most recent studies have shown that the urbanization effect accounts for a large proportion of the overall annual mean surface air-temperature (SAT) increase at intra-urban meteorological stations, as well as for some significant changing trends of local and regional annual mean SAT values (Bian Tao et al., 2014), consequently enhancing the UHI effect that may disturb the frequency and intensity of extreme temperature events, mostly addressing to the increase of both maximum (T_{max}) and minimum (T_{min}) air-temperature values over highly variable patch – patterns, as result of different interactions between the radiation processes and the properties of the underlying active surface. In many studies of urban landscape ecology and designing, land surface temperature (LST) is considered as main climatic tool to reflect the potential and ability of a surface area to radiate and conduct heat transport to the atmosphere, as direct result of the solar heating, upward thermal radiation and convective heat loss processes. Besides, LST, abundantly available from remote sensing products, provides a much higher spatial coverage (Voogt and Oke, 2003; Weng, 2009), being easier to be differentiated at smaller scales (sometimes even at patch levels), depending on the composition and configuration of active surfaces. However, relatively few studies have discussed the overall effect of urbanized areas on their surrounding air-environment, as expressed by their compact UHI effect, based on air-temperature values provided by ground-level meteorological stations, partly because relevant comparative intra- and extra-urban stations were either not available or they did not provide reliable data series under relatively characteristic metadata conditions. After all, the process of urban climatization is not necessarily important at the patch-pattern level of urban spaces, depending on the shape (Sun et al., 2012), composition (Li et al., 2011) and configuration (Zhou et al., 2012) of underlying surfaces, but rather at a more general landscape level, where the mean radiant temperature (T_{mrt}), an important indicator of human comfort and well-being, is directly dependent on the environmental radiative flux (Matzarakis et al., 2010) of urban spaces.

There is no doubt nowadays that latest rapid urbanization process has substantially altered local climate records (Wang et al., 2013), although the results obtained by many studies do not seem to converge to a unitary method on how to best quantify its influence on mean, extreme and long-term local temperatures (Gaffin et al., 2008) and on which indices of extremes might be most reliable and relevant. That is why, when assessing the so-called “urbanization-related signals in temperature records” (Wang et al., 2013), one must always take into consideration

that long-term time series of observations from intra- and extra-urban meteorological stations might not be homogenous because the observing sites, the instruments and the measurement protocols have greatly changed over time, or the method of classifying the stations in the two main categories (intra- and extra-urban) may not always be unanimously applied. Nevertheless, the infra-red energetic input from artificial urban surfaces, traffic and indoor heating leads to some important changes in temperatures inside town areas, so that the concept of UHI has been introduced to denote the thermal difference between the urban built-in spaces and the surrounding open-space environments of cities (Cheval & Dumitrescu, 2014). For this reason, air-temperatures measured at intra-urban stations are usually higher than those obtained from surrounding rural stations in any season, but they become more obvious during summer, when the additional heat radiated by buildings amplifies the natural warming process of air inside town-areas. In this respect, the present paper discusses the impact of the urban underlying surface on the time range and distribution of air-temperatures in Bucharest town area, based on the comparative values recorded at two different (intra- and extra-urban) meteorological stations, assessing both the intensity and the time gap of the heating and/or cooling processes inside the city.

2. DATA AND METHODS

The basic data used in this paper include hourly, daily, monthly and yearly mean, maximum and minimum air-temperature values measured at two representative meteorological stations: Bucharest-Filaret and Bucharest-Băneasa, between 1 January 1981 and 31 December 2010. These data were collected from Romania's National Administration of Meteorology and have included the leap years (with 29 days in February) for more accurate results.

The two weather stations on service in Bucharest town-area are (Fig. 1) : **Bucharest-Filaret** (located in the centre of the city, at an 82 m-high altitude, 44° 24' 49" N latitude and 26° 05' 48" E longitude) and **Bucharest-Băneasa** (located at the northern periphery of the town, at an 90 m-high altitude, 44° 30' 38" N latitude and 26° 04' 41" E longitude).

Bucharest municipality is lying in the southern part of the country, in the Vlăsia division of the Romanian Plain, at a distance of about 60 km far off the Danube River, 100 km off the Carpathian Mts. and 250 km off the Black Sea shore. The altitudes of the specific nearly level landforms within the city range from 54 m (Dâmbovița valley) to 95 m (in the north-lying Străulești district); the mean altitudes averaging 80 m-high in most of the town area, which is administratively divided into 6 sectors, extending from the centre to the periphery of the town, that is traversed by the canalized Dâmbovița river (flowing on a 266 km-long distance right through the historical centre of the town) and the Colentina river (peripherally flowing across the

city on a NW-SE direction along 80 km, through 6 regulator lakes which are mainly used for recreational activities). The original wooded-steppe vegetation of the Vlăsia plain is still being preserved only in some north-lying scarce areas that, at present, are used as main recreational places due to their more cooling effects, especially in summer. Unlike these green spots, the built-in area of the city (totalling 238 km²) creates specific climatic conditions which could roughly be characterised as highly artificial, since almost all meteorological elements show visible differences between the values recorded at the two urban weather stations.

Fig. 1 – Location of weather stations on the territory of Bucharest town-area

The mathematical position of the centre of the town is given by the intersection of the 44° 25' 50" N latitude and 26° 4' 50" E longitude lines, meaning that its specific mid-latitude climate of transition may get some continental influences, characterized by higher mean daily and yearly air-temperature ranges (25-26°C), lower rainfall amounts more unevenly distributed in time, a higher frequency of droughts in summer and blizzards in winter, as revealed by the corresponding Péguy climograms, in which most months of the year are climatically moderate, falling inside the triangle area separating the three major climate types (cold and wet; hot and dry; arid), except for the winter months (January and February), with negative air-temperatures and low rainfall amounts, and the peak hot and dry summer month (July).

Source of data: ANM, 2016

Fig. 2. Péguy climograms for Bucharest-Băneasa (a) and Bucharest-Filaret (b) weather stations

Essentially, in winter, the most frequent invasions of polar continental air from the north-eastern and eastern parts of Europe, as well as of arctic air-masses from the North, may determine severe cold waves over short periods of time, which may greatly be favorable to the accumulation and stagnation of cold air over the low-lying area of the Romanian Plain, thus producing stable thermal inversion conditions, greatly decreasing air-temperatures to very low values. In summer, under the influence of western oceanic and south-western tropical-maritime air-masses, undergoing a major process of adiabatic cooling while passing over the mountains, the weather is generally cloudless and warm, especially when eastern advections of hot and dry air get more intense. In case of such tropical continental advections, extremely high air-temperatures may occur, especially at the Bucharest-Filaret station, greatly influenced by the urbanization effect (Ionac, 2005). In this respect, it is noteworthy that air-temperatures recorded at Bucharest-Filaret weather station from 1900 to 2018, rank among the top ten high values in the country, as related to the: mean annual air-temperature (13.4°C in 2007 – the third in the country, with the highest value reaching 13.6°C at Drobeta Turnu-Severin, in 2015); annual mean of minimum air-temperatures (8.8°C in 2015 – the fourth in the country, with the highest value reaching 10.8°C at Sulina, in 2007); annual mean of maximum air-temperatures (19.7°C in 2007 – the third in the country, with the highest value reaching 20.0°C at Giurgiu, in 2007) and the annual absolute maximum air-temperature (42.4°C in 05.07.2000 – the fifth in the country, with the highest absolute record of 43.5°C at Giurgiu, in 05.07.2000) (ANM, 2018).

3. AIR-TEMPERATURE DIFFERENCES AND SINGULARITIES IN BUCHAREST

3.1. Mean annual air-temperatures are greatly varying between the two weather stations throughout the time period taken into consideration (1981-

2010), with higher values at Bucharest-Filaret (11.5⁰C) than Bucharest- Băneasa (10.7⁰C), thus demonstrating the heat surplus inside the town area, as compared to its surrounding rural areas, mainly due to the additional input of the central, dense built-in spaces. The positive influence of urban spaces on air-temperatures is also demonstrated by the fact that the mean annual value recorded at Bucharest-Filaret equals to the highest equivalent value over Romania's entire territory (11.5⁰C at Mangalia), showing that specific physical geographical conditions, namely the artificial underlying active surface, covered by densely-built infrastructure, play a very important role in regulating the heat exchanges between land surface and atmosphere.

3.2. Mean monthly air-temperatures show a general increasing evolution from January, when minimum values have been recorded at both weather stations (-1.4⁰C at Bucharest-Băneasa and - 0.7⁰C at Bucharest-Filaret), to July, when the highest value is reached at Bucharest-Băneasa (22.6⁰C), or August, at Bucharest-Băneasa (22.6⁰C), as result of a more intense heating of the built-in

Tab. 1. Annual and monthly mean air-temperatures at the weather stations located in Bucharest town area, 1981-2010

Weather station	J	F	M	A	M	J	J	A	S	O	N	D	Mean annual air-temperature 1981-2010
Bucharest-Băneasa	-1.4	0.2	5.1	11.0	16.8	20.7	22.6	21.8	16.9	10.5	4.5	-0.2	10.7
Bucharest-Filaret	-0.7	1.1	6.1	11.9	17.6	21.4	23.4	24.1	17.7	11.8	5.5	-1.4	11.5

Source: ANM, 2016

town areas, occurring especially under conditions of atmospheric stability, when cloudiness and air-humidity maintain relatively low values. Then, air-temperatures slowly decrease to negative values (-1.4⁰C) until December, at Bucharest-Filaret, or January, at Bucharest- Băneasa, demonstrating that the artificial land cover inside the city not only that gets heated easier and faster than the vegetated green spaces in its surroundings, but it also delays the occurrence of both lowest and highest values by one month. All throughout the year, the mean monthly air-temperature values recorded at Bucharest-Filaret weather station keep constantly higher than those recorded at Bucharest- Băneasa (from 0.7⁰C in June to 2.3⁰C in August), except for December, when intra-urban air-temperature keeps lower than the extra-urban one, as direct result of massive radiative cooling over extensive active-surface layers. Essentially though, the town's thermal superiority is evident all the year round but the greatest air-temperature differences occur mainly during the months with stable atmospheric

conditions, when they get more prominent, either positively ($+2.3^{\circ}\text{C}$ in August) or negatively (-1.2°C in December) (Table 1).

3.3. The monthly means of hourly air-temperature values at four observation hours (01.00, 07.00, 13.00, 19.00 local time) are more expressive of the thermal differences between the central and peripheral town's areas (Table 2):

- at 1.00 o'clock, the greatest air-temperature differences occur in summer (July), as result of the overnight intense radiative cooling of buildings in central and residential areas. The lowest air-temperature values are delayed by one month between the two weather stations, just as the daily values, thus reflecting that radiative cooling processes play an important part in thermal differentiation of the two main landcover types: the built-in and the open-spaced surfaces;
- at 7.00 o'clock, the thermal differences between the two weather stations get lower, except for November – February time period, when air-temperatures at Bucharest-Filaret keep much higher than at Bucharest-Băneasa, mainly as result of the additional heat input inside the city, where domestic heating systems work at full capacity;
- at 13.00 o'clock, the hourly air-temperature values in December, at Bucharest-Filaret keep lower than those in the peripheral rural areas, recorded at Bucharest-Băneasa station, mainly because of the more intense radiative cooling of the artificial surfaces, on one hand, and of the higher frequency of low stratiformis clouds becoming persistent under conditions of thermal inversions;
- at 19.00 o'clock, both the highest and the lowest air-temperature values are no longer synchronous between the two weather stations, as they are delayed by one month from the extra-urban to the intra-urban station, either as effect of a more stable atmosphere in August, favoring excessive heating of the central built-in areas as compared to the peripheral vegetated ones, or as a consequence of the more intense radiative cooling processes occurring over the artificial active surfaces in December, which must intensely be heated by artificial heating systems.

As regards the annual variation of air-temperature values recorded at the four hours of observation (1.00, 7.00, 13.00, 19.00), some other interesting aspects are still to be noted: for instance, the air-temperature values at night are consistently higher at Bucharest-Filaret than at Bucharest-Băneasa, in all months, except for December, when air-temperature values inside the city get lower than in the outskirts, due to the more intense radiative cooling processes of all surrounding horizontal and vertical surfaces. Moreover, the thermal differences between the two weather stations seem to keep very low but they get higher during summertime (July-August), when the infra-red emissions of all surrounding artificial surrounding surfaces increase. In the morning (at 7.00

o'clock), as the radiation budget values get more homogenized, while turning from the outgoing to the incoming radiation transfers, the air-temperatures recorded at the two weather stations are very similar, except for a small positive deviation occurring at Bucharest-Filaret, in summer. At noon (13.00 o'clock), the same rule applies for both weather stations, but air-temperature values start increasing towards winter months, when the additional heating input of the city becomes evident. In the evening (19.00 o'clock), the central built-in areas have constantly higher air-temperature values than the open-air spaces in the outskirts, but in August, the thermal difference between the two weather stations reaches its highest value, probably due to the heavy traffic during towards evening rush hours, when all working people come back home for rest, or to the more intense heat losses of all built-in surfaces inside the city.

Tab. 2. Monthly means of hourly air-temperature values at the four hours of observation, at the two weather stations in Bucharest town area, 1981-2010

a. 1.00													
Monthly mean air-temperature 1981-2010	I	F	M	A	M	I	I	A	S	O	N	D	Mean annual air-temperature 1981-2010
Bucharest-Băneasa	-2.7	-1.7	2.5	7.3	12.0	15.7	17.5	17.3	12.8	7.8	2.8	-1.4	7.5
Bucharest-Filaret	-1.7	-0.4	4.0	8.9	13.8	17.6	19.6	19.4	14.8	9.6	4.1	-2.7	8.9
b. 7.00													
Monthly mean air-temperature 1981-2010	I	F	M	A	M	I	I	A	S	O	N	D	Mean annual air-temperature 1981-2010
Bucharest-Băneasa	-3.5	-2.7	1.8	8.1	14.6	18.8	20.5	19.1	13.4	7.3	2.0	-2.0	8.1
Bucharest-Filaret	-2.6	-1.5	2.7	8.4	14.7	19.0	20.6	19.4	14.0	8.5	3.1	-3.5	8.6
c. 13.00													
Monthly mean air-temperature 1981-2010	I	F	M	A	M	I	I	A	S	O	N	D	Mean annual air-temperature 1981-2010
Bucharest-Băneasa	1.6	4.2	9.7	16.2	22.2	25.8	28.0	28.0	23.0	16.5	8.6	2.6	15.5
Bucharest-Filaret	1.7	4.5	10.2	16.8	22.8	26.2	28.4	28.7	23.6	17.1	8.9	1.6	15.9
d. 19.00													
Monthly mean air-temperature 1981-2010	I	F	M	A	M	I	I	A	S	O	N	D	Mean annual air-temperature 1981-2010
Bucharest-Băneasa	-1.1	0.8	6.5	12.6	18.2	22.3	24.4	22.9	18.4	10.3	4.5	-0.2	11.6
Bucharest-Filaret	-0.3	1.9	7.5	13.5	19.1	22.8	24.8	28.7	18.5	12.1	5.8	-1.1	12.8

3.4. The double daily and annual variation of air-temperature values, represented by the corresponding thermo-isopleths, gives the most expressive image on the evolution of air-temperature values over any specific moment of

the day and year. In fact, three-dimensional isopleths provide an accurate image on the state and distribution of air-temperature field, which rise up at noon hours and sink in the morning or in the evening hours. The most prominent positive uprisings of the air-temperature field obviously occur around noon, in summer, but a certain thermal inertia becomes more evident both in the annual distribution of air-temperature values, which concentrate mostly towards the negative values in January and February, that is one or two months later than the winter solstice time, and in their daily distribution as well, when higher air-temperature values persist until later in the after-noon.

Generally, although pretty similar, the thermo-isopleths reconstructed for the two weather stations located in Bucharest town-area also reflect some particular aspects for each one of it. Consequently, in the case of Bucharest-Băneasa weather station (Fig. 3 left), the period of maximum heating (over 25°C) sets in rather abruptly around noon (12.00 hrs.), reaches a peak value at 13.00 hrs. and then, gradually decreases in the after-noon hours (14.00 – 16.00), to minimum values in the evening (20.00 hrs.). A slight migration of the entire thermal field towards right also becomes obvious, mainly because the thermal relief forms during winter are largely attenuated as direct result of a higher thermal inertia that open-space, vegetated areas have in comparison with the built-in ones, as they get heated more slowly during spring, either because they keep open to the free circulation of air for a longer period of time, or because a large proportion of the air heat is consumed to thaw/melt down the snow cover occurring during winter time.

In case of the Bucharest-Filaret weather station (Fig. 3 right), the thermal superiority towards Bucharest-Băneasa is evident; all air-temperature values in the corresponding days and months of the time-period taken into consideration, keeping obviously higher than those at the extra-urban station, mainly due to the heat excess inside the built-in areas, where the walls of the buildings, the asphalted streets and boulevards, the industrial and commercial spaces etc. largely emit heat towards the surrounding environment. Unlike the Bucharest-Băneasa station, the period of most intense heating occurs one hour later though (at 13.00 hrs.) and is better centered on the summer months, as the thermal field forms are somehow more symmetrically distributed around the summer solstice month (June), but they persist longer towards the evening hours, because of the slow outgoing radiative processes or the intra-urban areas. On the contrary, the cooling period during winter, especially in January and February, looks more attenuated than its counterpart at Bucharest-Filaret weather station; the intra-urban air-temperatures obviously keeping much higher than in the peripheral surrounding areas. This is evidently the direct effect of artificial heating systems that increase the heat input inside the city spaces. Moreover, the isopleth lines

getting closer to one another around noon hours, at Bucharest-Băneasa weather station, in the transition seasons, is indicative of a larger air-temperature daily and annual variation, because the more extensive open-air spaces covered by vegetation become dominant in the outskirts areas, allowing more intense heat exchanges between the ground surface and the open atmosphere.

Fig.0. Comparative isotherms for Bucharest-Băneasa (left) and Bucharest-Filaret (right) weather stations

3.5. The means of annual and monthly maximum and minimum air-temperature values display totally different variation patterns than the mean values but generally provide a very good outlook on their extreme variation limits between the two basic types of urban environments.

In this respect, **the mean of the annual and monthly maximum air-temperature values**, broadly represented by the highest air-temperatures from all the four hourly values recorded each day, during the 1981-2010 interval, highlights the continental climate influences mainly affecting the urban territory in summer, when frequent advections of tropical-dry air from the

South and the West determine the rapid and abrupt increase of thermal differences between the central and peripheral urban areas, from only about 0.1°C in January, to more than 0.8°C in August (Table 3). However, the mean

annual difference of daily maximum air-temperature values between the two weather stations keeps pretty low (0.3°C), showing that, in fact, the UHI effect is spatially and temporally restricted to local favorable conditions. On the contrary, the differences between the highest and the lowest daily maximum air-temperature values get much greater at each weather station, reaching up to 0.7°C ; for example, at Bucharest-Băneasa, the difference between the air-temperature values recorded in July or August (28.1°C) and January (1.8°C) is 26.3°C , while the corresponding annual air-temperature amplitude at Bucharest-Filaret is greater (27.1°C), deriving from the temperature difference between July (28.9°C) and December (1.8°C).

Tab. 3. Annual and monthly means of maximum air-temperature values in Bucharest town-area, 1981-2010

Weather station	J	F	M	A	M	J	J	A	S	O	N	D	Annual mean of maximum air-temperature values 1981-2010
Bucharest-Băneasa	1.8	4.3	9.8	16.3	22.3	25.9	28.1	28.1	23.0	16.6	8.8	2.9	15.7
Bucharest-Filaret	1.9	4.7	10.4	16.9	22.9	26.3	28.5	28.9	23.7	17.2	9.1	1.8	16.0

Source: ANM, 2016

As for the mean of the annual and monthly minimum air-temperature values, their variation from one month to another is larger at both weather stations than their maximum counterpart values (Tab. 4). For example, the annual difference of daily minimum air-temperature values between the two weather stations is 1.5°C (that is the difference between 8.1°C at Bucharest-Filaret and 6.6°C at Bucharest-Băneasa), revealing that the intra-urban spaces remain constantly warmer than the peripheral ones, exposed to free air-circulation, partly because minimum air-temperature values increase significantly in summer, when the radiation budget is positive, and because extra heating sources add to the natural ones in winter, accordingly increasing the heat surplus inside the city area. These are the main reasons why in July, for example, the difference of the daily minimum air-temperature values between the two weather stations gets as high as 4.0°C (21.3°C at Bucharest-Filaret and 17.3°C at Bucharest-Băneasa, respectively), while in winter, the corresponding values are the same at both weather stations (-4.1°C) but are delayed by one month from Bucharest-Filaret (with a minimum value in December) to Bucharest-Băneasa (with a minimum values in January). Moreover, it is also important to note that the differences between the mean values of minimum air-temperatures are noticeably higher than the mean values of maximum air-temperatures, indicating that the effect of artificial heating over the

underlying surfaces inside the city is more prominent in increasing the thermal minimum values than in increasing the maximum ones. As for the difference between the highest (17.3°C at Bucharest-Băneasa and 21.3°C at Bucharest-Filaret) and the lowest values (-4.1°C at both weather stations) of minimum air-temperature means, actually representing the annual amplitude of the minimum air-temperature means, it keeps much higher at Bucharest-Filaret (25.4°C) than at Bucharest-Băneasa (21.4°C).

Tab. 4. Annual and monthly means of maximum air-temperature values in Bucharest town-area, 1981-2010

Weather station	J	F	M	A	M	J	J	A	S	O	N	D	Annual mean of minimum air-temperature values 1981-2010
Bucharest-Băneasa	-4.1	-3.2	1.2	6.7	11.7	15.5	17.3	17.0	12.2	6.6	1.4	-2.7	6.6
Bucharest-Filaret	-3.0	-1.8	2.5	8.0	13.4	17.2	21.3	19.3	13.7	8.2	2.7	-4.1	8.1

Sursa date: ANM, 2016

3.6. Extreme air-temperatures

Represented by either the absolute highest (absolute maximum) or lowest (absolute minimum) air-temperatures that have ever been recorded in the location of reference, over the entire period of interest, the extreme air-temperatures are mainly resulting from the combined influence of radiative and dynamic factors, producing episodes of severe weather, characterized by either excessive heating, or cooling, respectively. For each weather station, a single extreme air-temperature value (maximum or minimum) can therefore be recorded at every hour, day, month and year of observations; such extreme values representing important indicators of the climatic profile of the region under study.

The annual and monthly maximum air-temperatures / Absolute maximum air-temperatures are mainly occurring when anticyclonic ridges from eastern Europe or northern Africa extend over Romania's territory, thus allowing the advection of tropical-dry air from the South or the South-East, on one hand, or because of the excessive heating of the built-in areas in the central parts of Bucharest city, provided that air humidity and cloudiness are very low, on the other hand.

The annual and monthly variation of the maximum air-temperature values at the two weather stations located in the area of Bucharest municipality clearly reveal once again the thermal superiority of the central built-in spaces over the

vegetated peripheral ones, as all absolute maximum air-temperature values recorded at Bucharest-Filaret weather station are evidently higher than those recorded at Bucharest-Băneasa, in all months of the year, irrespective when they occurred. The maximum air-temperature differences between the two weather stations of reference vary from 0,3°C (in April) to 2,0°C (in January) (Tab. 5). The absolute maximum air-temperature values reached as high as 41,0°C at Bucharest-Băneasa (on 5 July 2000) and 41,7°C at Bucharest-Filaret (on the same day), demonstrating that, in this context, it was the synoptic pattern that produced these record values, supported by excessive heating and radiating processes of the artificial ground surfaces inside the city areas. However, the difference between the highest and the lowest maximum air-temperature values recorded at each weather station, that is: 26,4°C at Bucharest-Băneasa (41,0°C in July minus 14,6°C in January) and 25,2°C at Bucharest-Filaret (41,7°C in July minus 16,5°C in December), clearly expresses the significant heat input inside the city areas, especially in winter, which leads to a consistent attenuation of annual absolute thermal amplitudes in comparison with the open-space surrounding areas.

Tab. 5. Annual and monthly absolute maximum air-temperature values in Bucharest town area, 1981-2010

Weather station	J	F	M	A	M	J	J	A	S	O	N	D
Bucharest- Băneasa	14.6	22.0	25.0	30.2	33.3	37.6	41.0	38.0	35.0	32.0	25.0	17.8
Day / Year of occurrence	22, 2007	27, 1995	26, 1994	6, 1998	3, 2003	26, 2007	5, 2000	5, 1998	15, 1987	6, 1984	10, 2010	18, 1989
Bucharest- Filaret	16.6	22.2	25.6	30.5	34.3	38.2	41.7	37.7	35.4	32.6	25.9	16.5
Day / Year of occurrence	29; 2002	27; 1995	26; 2001	6; 1998	3; 2003	26; 2007	5; 2000	24; 2007	17; 1986	6; 1984	10; 2010	29; 2002

Source: ANM, 2016

The annual and monthly minimum air-temperatures / Absolute minimum air-temperatures may usually occur in the region of analysis only if certain dynamic and physical geographic factors combine their influence, so that a favourable synoptic pattern for excessive cooling could be produced. The main processes that may accordingly determine significant air-temperature decrease, especially in winter, generally refer to the following conditions:

- Advections of cold arctic or polar air along the eastern peripheries of Scandinavian or eastern European anticyclones, correlated with the formation, over the Aegean or the Mediterranean Seas, of powerful low-pressure areas, altogether determining the occurrence of strong blizzards, accompanied by heavy snowfalls;
- Nocturnal radiative cooling processes, which get intensified on

conditions of a high-pressure field maintaining a stable atmosphere, with cloudless skies and persistent cold and dry air, that may accumulate and stagnate in the low-lying areas of the Romanian Plain, thus creating extreme air-temperature inversions. Moreover, a longer persistence of snow cover may also intensify the radiative cooling processes of the land surfaces which, on conditions of calm weather, get very intense, especially in winter, thus significantly reducing the turbulent exchange quotients of the air and preventing their heating, by seriously reducing convection mechanisms;

- In urban areas, the inter-twinned radiations among the walls and the paved streets or concrete surfaces of the town play an important role in the excessive cooling of built-in areas, especially in winter.

Due to the above-mentioned causes, the annual and monthly minimum air-temperatures recorded at the two weather stations in Bucharest town area (Table 6), over the 1981-2010 period, clearly show that most of the time, the in-town areas constantly keep higher than the cooresponding values in the outskirts regions, except for January, when the intense radiative cooling losses inside the city become more prominent. Under these conditions, at Bucharest- Băneasa weather station, the highest minimum air-temperature value was 8.4°C in 15 July 1993 and the lowest one was -25.2°C in 26 December 2002, while at Bucharest-Filaret, the highest minimum air-temperature value was 10.4°C in 10 July 1998 and the lowest one was -23.8°C in 26 December 2010, meaning that the air-temperature difference between the two extreme values reaches 33.6°C at Bucharest- Băneasa and 34.2°C at Bucharest-Filaret. To conclude, this means

Tab. 6. Annual and monthly absolute minimum air-temperature values in Bucharest town area, 1981-2010

Weather station	J	F	M	A	M	J	J	A	S	O	N	D
Bucharest- Băneasa	-21.4	-23.7	-18.2	-3.8	0.8	6.2	8.4	7.6	2.2	-7.0	-19.0	-25.2
Day / Year of occurence	13, 1985; 31, 1987	14, 1985	2, 2005	4, 2004	3, 2007	3, 2008	15, 1993	29, 1981	11,2	30, 1997	26, 1993	26, 2002
Bucharest- Filaret	-22.0	-18.6	-12.4	-1.5	4.7	9.6	10.4	9.6	5.5	-4.3	-11.8	-23.8
Day / Year of occurence	13;1985	14; 1985	4, 6; 1987	7; 2003	6; 1999	1; 1997	10; 1998	29; 1981	27; 1992	30; 1997	26; 1993	26; 2010

that although the thermal minimum values inside de city are generally higher than those recorded in extra-urban environments, the annual difference between them keeps higher due to many local influences determining large variations on small spaces.

Conclusions

The impact of the urban underlying surface on the time range and distribution of air-temperatures in Bucharest town area has been assessed on basis of comparative values recorded at two different (intra- and extra-urban) meteorological stations (Bucharest-Filaret and Bucharest-Băneasa respectively), revealing the thermal superiority of in-town spaces; all air-temperature values in the corresponding days and months of the time-period taken into consideration, keeping obviously higher at Bucharest-Filaret than those at the extra-urban station (Bucharest- Băneasa), mainly due to the heat excess inside the built-in areas.

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