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URBAN INFLUENCES ON THE DISTRIBUTION OF AIR TEMPERATURE AND RELATIVE HUMIDITY IN BUCHAREST MUNICIPALITY. THE HEAT ISLAND

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Abstract. Bucharest Municipality and its surroundings are situated in the South-Eastern part of the Romanian Plain in a temperate-continental climate, characterized by a continentalization tendency as a result of the climatic influences of transition in the West and excessive in the East. Therewith, one can identify remarkable differentiation between the urban space and the adjacent periurban space related to the manifestation of the *heat island,* which can be identified within the atmospheric space. The paper is based on statistical-climatologic analysis of the data issued from simultaneous microclimatic and topoclimatic measurements (air temperature and relative humidity of moist air) which permitted the identification of the heat island of Bucharest Municipality. The topoclimatic mapping of the horizontal profile of the values of these climatic parameters was achieved within peculiar season and weather types (serene and calm days; serene and windy days; cloudy or overcast sky and calm days; cloudy or overcast sky and windy days). The most significant thermal and hygric differentiation between the urban and suburban areas appear during summer and winter seasons on serene and calm days (without atmospheric dispersion) during morning and noon.The distribution maps of the couple air temperature/relative humidity of moist air within the above mentioned season and weather conditions defines an urban core with higher temperature and lower humidity values comparing to the suburban area. The shape and the scale of the heat island are mainly related to the seasonal variations, being in direct proportion with the spread of the urban area as a result of the high changes of the urban ecosystem.

Keywords: heat island, topoclimatic/microclimatic types, urban and periurban space, Bucharest Municipality

Due to its location in the South-east of the Romanian Plain, Bucharest and its neighbouring area belong to the temperate-continental climate, displaying a continentalization tendency from West to East and from North to South because of the effects induced by the climatic transition influences in the West and excessive influences in the East.

From the thermal point of view, the differences between the urban and the neighbouring area lead to the individualization of a warmer and less dense air volume above the city, the structure, composition and aspect of which depend on

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the dimension of the ***heat island*** developed in the adjacent atmosphere. This is directly proportional with the extension of the urban surface and it superposes the topoclimatic and microclimatic features defined by the variability lapse of its parameters.

The most sensible meteorological elements in defining the urban heat island are *air temperature* and *humidity*, the distribution of which is uneven and in reverse ration from the periphery towards the centre. At the level of each city, there are individualized many nuclei of the heat island, generally centered above the residential flat districts, characterized by high densities of buildings, and above the sectors affected by industrial activities, with higher temperatures and lower air humidity. The lowest temperatures associated with the highest values of humidity are specific to the areas covered by vegetation, such as parks and residential areas with oxygenated surfaces peripherically located etc.

The causes that trigger the individualization of the heat island of Bucharest Municipality are numerous and complex:

- higher values of thermal energy determined by the modification of the Earth-atmosphere balance because of the increase of the CO_2 concentration and of the discharge of a caloric surplus induced by different burning processes (industry, road transportation, dwellings heating etc.);
- increase of the thermal convection above the city, which favours the tendency of wind convergence especially when the atmospheric circulation is reduced (wind $\leq$ 2 meters per second);
- the urban thermal and mechanical effects influences the formation of the clouds and precipitation, determines an increase of the frequency of the days with hail and electric phenomena above the city (6-15 percent higher than the neighbouring areas);
- transformation, in most of the cases, of the potential snowfalls into rainfalls;
- presence of a haze (dust, smoke, powders, different gases, micro-organisms etc.) that determines the modification of the air composition and a series of processes and chemical reactions that induce perturbations in the way climatic parameters manifest, including the radiative regime and the conditions of water vapour condensation;
- increased frequency of the *urban fog* or of *smog* (especially during the cold semester March-October) that reduces the insolation duration within the urban area with negative effects upon the atmospheric visibility, the health and comfort state of the human body;
- development of the *anthropic landforms* due to the increase of the subjacent surface rugosity (presence of multi-level buildings, wide range of materials, especially those used for metallic roofs and pavements made by thermo-conductible materials, predominance of the street network and not of green areas, their different disposal towards the dominant direction of the wind etc.), which determines a different channeling of the air currents (“canyon

boulevards") and a decrease of the wind speed with 20-30 percents compared to the neighbouring areas;

- development of the *urban breeze* induced by the thermal-baric differences between the city and the periurban area characterized by the horizontal movement from the periphery towards the inner city during the day and backward during the night and morning;
- low values of evapotranspiration and air humidity due to reduced green surfaces, to the presence of an underground sewerage network;
- high concentration of solid particles in the urban air that determines the formation of the condensation nuclei in excess thus favouring both the increase of the rainfall torrentiality and of the acid deposits (dry or wet) because of the *wash-out* phenomenon;
- modifications of the solar radiation due to the predominance of glass constructions, windows, swimming pools and lakes, light colours of the buildings etc. characterized by a higher albedo then the neighbouring areas.

All these factors of quasi-permanent influence modify in a specific way the regime of the different climatic components and transmit them to the neighbouring areas as the phenomenon of urban expansion is developing and thus, conditions the presence of the heat island of Bucharest Municipality. The shape and the vertical extension of the heat island is generally ***three-four times higher than the highest buildings in the city***, thus about ***150-200 meters*** and it depends on a multitude of factors, among which we mention: higher concentration of pollutants in the urban atmosphere (which may rise the heat island at higher altitudes, directly proportional with its value), respecting/non-respecting the international norms regarding the green space per capita (which determine the rarifying/concentration of pollutants within the limit atmospheric layer according to the extension of the green surface) etc. The absence of strong air currents able to determine the horizontal and vertical dispersion of heat and pollutants towards the neighbouring areas leads to the vertical extension of the urban heat island, which is associated with the atmospheric pollutants. In the conditions of an active atmospheric dynamics (wind $\geq$3 meters/second), the dimension of the heat island / pollutants tends towards a migration or even dispersion according to the intensity and direction of the modifying wind factor.

The presence and the vertical and horizontal extension of the heat island follow, especially, the distribution of air temperature and of its relative humidity determined on the base of **daily micrometeorological measurements**. They were simultaneously made in a dense network of **37 points** (Fig. no 1) that cover the entire surface of the city; they are representatively placed illustrating all the conditions of the periurban and urban environment: markets, oxygenated surfaces (green spaces, water surfaces), large avenues, crossroads, industrial platforms in different stages of functioning, blocks of flats, agricultural areas, airport etc. There can be also added the three meteorological platforms located both within Bucharest Municipality and its neighbouring areas (Filaret, Băneasa, and Afumați).

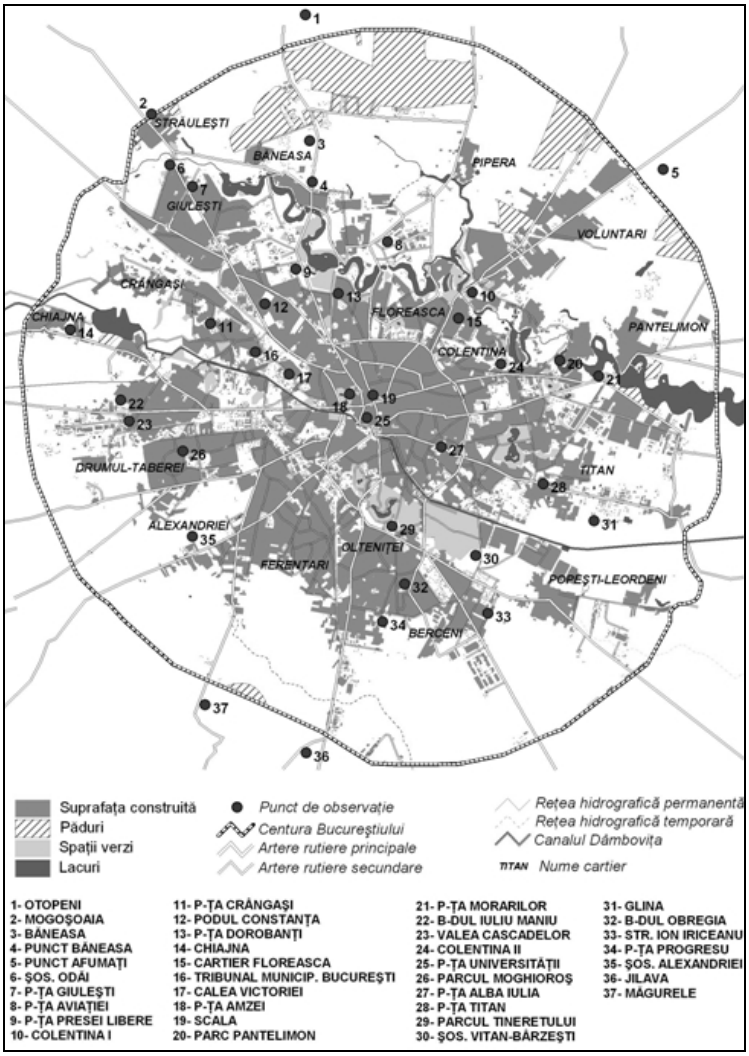

Fig. no 1. Network of topoclimatic observation points of Bucharest Municipality and its neighboring area

The measurements are represented by ten observations in the morning (from 10 to 10 minutes) made at sunrise and nine measurements in the afternoon (from 15 to 15 minutes) between 12.30 and 14.30 p.m. (Romania hour). The instrumental determinations were made in those weather conditions specific to mornings (when minimum temperatures occurred) and to afternoons (when maximum temperature occurred), in each season according to the presence or absence of clouds (clear days, cloudy days, and overcast days), as well as to the presence or absence of atmospheric calm. Based on these measurements and observations, there were calculated the average values of temperature and relative humidity during the two intervals of the day (morning and afternoon) and specific to the following types of

weather: *clear sky and calm; clear sky and wind; cloudy sky and calm; cloudy sky and wind.*

Thus, there were shaped the variation curves of the air temperature and humidity **deviation** for each observation points and their mean value according to the distance (km) to the city center. At the same time, there resulted the **distribution maps** of the mean values of the two meteorological elements for the mentioned diurnal periods and for the four types of weather and seasons. The most significant thermal and hygric differences between the central urban areas and the periurban areas appear when the weather is clear and calm, especially in summer and winter, and characterized by the lack of vertical currents able to generate atmospheric dispersion.

The topoclimatic evaluation of the ***temperature and relative humidity deviations*** between the mean values registered in the centre of Bucharest and those registered at it peripheries reveals the following aspects characteristic to each seasons:

In summer. The urban heat island is better shaped in clear mornings characterized by atmospheric calm, where the 18-21^{o}C isolines concentrically close including the urban space, while the 17^{o}C isotherm appears at the northern and southern extremities of the municipality. The mean values of the relative humidity register 70-80 percents and cover the entire area drained by the Colentina River, while the value of 90 percents is registered only in the northern extremity of the city. Thus, compared to the seasonal multiannual means of 20.4^{o}C, respectively 68 percents, the thermal and hygric deviations of the heat island are of 3.1-3.3^{o}C and -21...-22 percents (Fig. no 2 and 4).

For the afternoons characterized by the same type of weather, due to the intense solar radiation, there can be noticed an homogenization of the temperature and humidity mean values, the thermal deviation decreasing to only about 2^{o}C and the hygric one to about10 percents. Thus, the determined heat island is less developed in isolated temperature and humidity centers (Fig. no 3).

The phenomenon is also represented by the slow motion of the distribution curves of the negative, respectively positive deviations of air temperature and relative humidity. It can be noticed that the temperature and relative humidity deviations substantially diminish from the city center (kilometer 0) to the peripheries (Fig. no 4).

In winter. In the clear and calm mornings, there appear the most favourable conditions for the development of the urban "heat island". The differences between the seasonal mean values of temperature and relative humidity between the city center and its peripheries are extremely high and these mean values maintain when the weather is calm. In the morning, there appear two nuclei of the heat island with thermal values of -3…-2^{o}C in the central-eastern part (Pantelimon), respectively the south-eastern part (Balta Albă). Toward the periphery, the values decrease up to -9 or even -11^{o}C (Fig. no 5).

The relative humidity displays values higher than 90 percents in the central-eastern and south-western parts decreasing toward the northern and western

periphery to less than 80 percents. At noon, in the same weather conditions, the heat island is well shaped with positive differences of about 6°C for temperature and of about 20 percents for relative humidity between the center and the periphery. The 2, 3, and 4°C isolines indicate a large central nucleus with ramifications north-eastwards, north-westwards, and south-westwards (Colentina-Pantelimon, Gara de Nord, Progresu). In the case of relative humidity, the 70 and 60 percent isolines concentrically close the entire urban area (Fig. no 6).

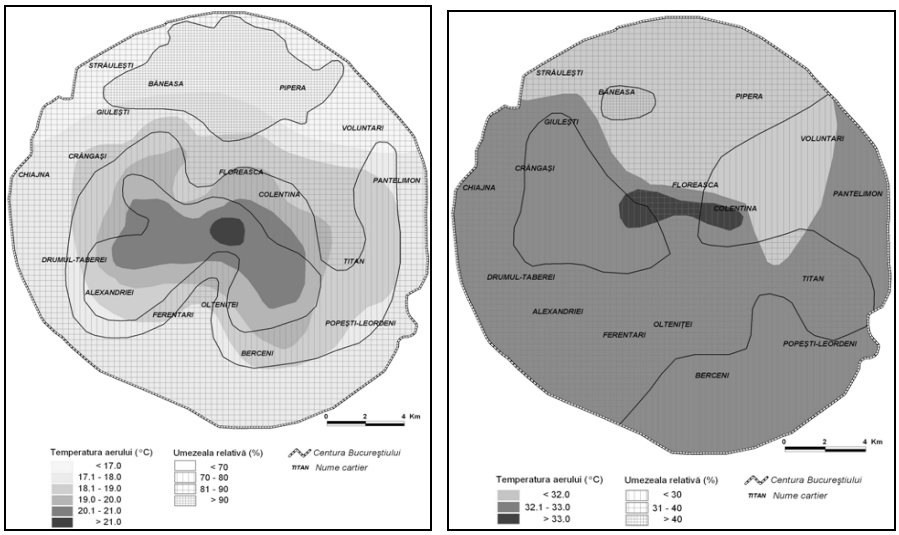

Fig. no 2 and 3. Manifestation of the heat island of Bucharest Municipality in summer with clear and calm weather, in the morning, respectively in the afternoon

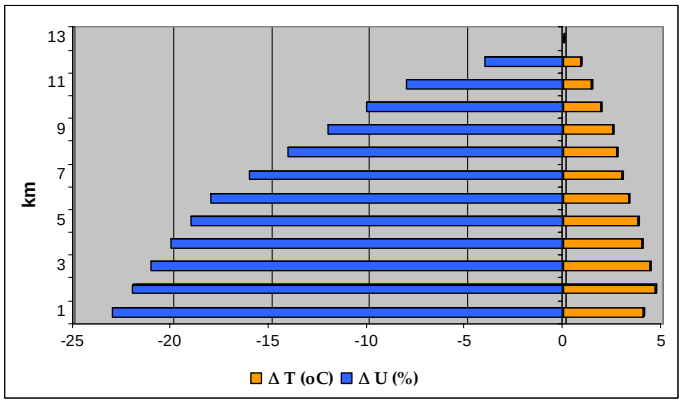

Fig.no 4. Differentiations between the mean temperature values (ΔT) and the mean relative humidity values (ΔU) noticed in the mornings with clear and calm weather according to the distance to the city center (in summer)

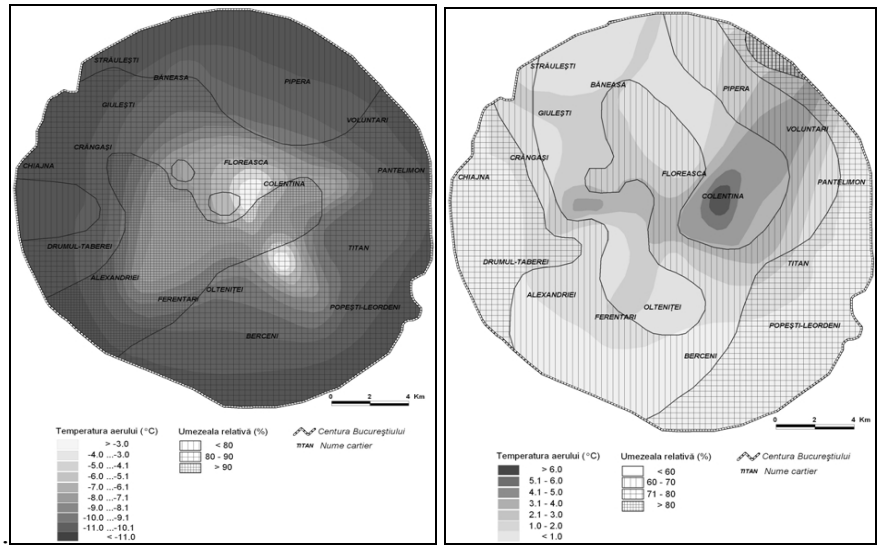

Fig. no 5 and 6. Manifestation of the heat island of Bucharest Municipality in winter, on clear and clam weather, in the morning, respectively in the afternoon

The detailed knowledge of the modifications the city imposes to the climatic elements requires instrumental observations for longer periods; these observations should be made simultaneously in the city and within its periurban area in different climatic conditions. Each territorial extension of the analyzed urban and periurban space imposes modifications of the topoclimatic regionalization.

The importance of the research of the *heat island* phenomenon in Bucharest Municipality, of the thermal and hygric deviation, even it refers to the reference level of 1.5-2 meters above the surface (microclimatic space), as the built space extends, becomes a present necessity if we want to prevent and control the negative aspects that considerably influence the urban population's life quality.

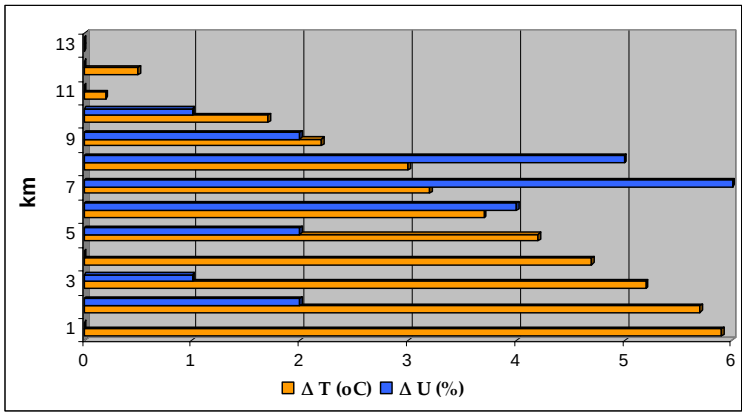

Fig. no 7. Differentiations between the mean temperature values (ΔT) and the mean relative humidity values (ΔU) noticed in the mornings with clear and calm weather according to the distance to the city center (in winter)

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