

The representativeness of the Bucharest Băneasa and Bucharest Filaret meteorological stations as expressed through the quality of air temperature data.

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Abstract: This study investigates the quality of air temperature data measured at the Bucharest Băneasa and Bucharest Filaret meteorological stations by analyzing their representativeness. As urbanization and land-use changes increasingly affect the measurement of meteorological parameters, the reliability and spatial relevance of long-term temperature records are essential for both climatological research and applied meteorology. The study assesses the quality of air temperature data from the two stations in relation to their surrounding environmental conditions and the degree of urbanization in their vicinity. Using graphical representations and metadata evaluation, the research identifies differences between the temperature values measured at the two stations and examines how air temperature data have been influenced over the past 20 years by anthropogenic factors around the stations. These influences are interpreted through the lens of representativeness, offering deeper insight into how urban and peri-urban areas can impact the quality of meteorological data. The findings support ongoing efforts to optimize Romania's meteorological network and provide a foundation for improving climate monitoring strategies in complex urban environments.

1. Introduction

In the current context of accelerated urban expanding and continuous changes in land use, the quality and relevance of meteorological data have become increasingly critical for both climate research and operational meteorology.

Air temperature is one of the most important weather and climate parameters, measured by all standard automatic weather stations worldwide. It is also the most significant variable in climate studies related to global warming (Kinoshita, 2014).

The accuracy of these measurements depends on the quality of the measuring instrument or sensor, overall uncertainty and performance, as well as on the calibration procedures and maintenance routines (Estevez, Giráldez, 2011). Additionally, temperature measurements may be influenced by any heat sources located near the meteorological platform. The distance to artificial or natural heat sources, local

topography, vegetation, and shading effects are all factors that can affect the representativeness of air temperature measurements (Raliță, 2005).

In this context, by analyzing the degree of representativeness of meteorological platforms becomes essential to understand to what extent recorded values reflect the actual conditions of the surrounding areas, as well as to define the spatial area a weather station effectively serves.

Therefore, this study analyzes the quality of some parameters of air temperature data measured at two weather stations in Bucharest — Băneasa and Bucharest – Filaret, based on their area representativeness. By selecting these two measurement locations, the study seeks to explore the contrast between a peri-urban area (Băneasa) and a near-central urban area (Filaret), in order to highlight the differing impacts of urbanization on recorded climate parameters.

To conduct this research, graphical representations and metadata analysis for both stations have been made to evaluate the degree of representativeness of each meteorological platform and to see how some specific parameters of measured air-temperatures have been influenced by anthropogenic activity over the past decade.

2. Data and Methods

This study used hourly air temperature data measured from January 1, 2010 until December 31, 2020, at the Bucharest Băneasa and Bucharest Filaret meteorological stations. The meteorological data were extracted from the database of the National Meteorological Administration from Romania (NMA).

The analysis of air temperature data quality and the representativeness of the meteorological platform was structured into three major stages:

- Vectorization of the meteorological platforms and surrounding obstacles using QGIS 3.32 Lima (Figure 1a);
- Preliminary data processing: by using PivotTables in Excel;
- Processing and drawing the corresponding isotherms by using the Python programming language (Figure 1b).

The air temperature hourly data, measured between 2010 and 2020 at the Bucharest-Filaret and Bucharest Baneasa meteorological stations, were initially processed in Microsoft Excel, by using the PivotTable function, to obtain the annual and multiannual air temperature averages. Additionally, the temperature data were organized in Excel as a table consisting of: calendar date, hour and temperature value. The table was then exported to a .csv file format to enable their processing in Python.

The graphical representations were created by using the Python programming language to generate isopleths. The programming code was initially written in Notepad++, and the necessary libraries were installed. In the code, temperature values were stratified and visualized by means of a custom color palette: dark blue, light blue, pale yellow, light red, and dark red — ranging from low to high temperatures (Figure 1b).

To assess the siting conditions of meteorological stations, in order to determine the degree of representativeness of air temperature measurements, a detailed spatial

analysis of each meteorological platform was carried out. This analysis was conducted by using the open-source software QGIS 3.32 Lima following the steps:

- Setting the reference coordinate system: Dealul Piscului 1970 / Stereo 70, EPSG:31700;
- Delimiting the study area by creating a circular buffer with a radius of 100 meters around the meteorological platform;
- Vectorizing the meteorological platform and the surrounding natural and anthropogenic obstacles into polygons, color-coded according to the nature of each obstacle. The color scheme used for polygon delineation was as follows: brown for the meteorological platform, orange for buildings, blue for water bodies, dark green for tall vegetation (trees), light green for low vegetation (grass, agricultural crops), and grey for surfaces covered with concrete or asphalt (fig.1a).
- Counting the vectorized obstacles and measuring the straight-line distance between each obstacle and the center of the meteorological platform. These measurements were recorded in a table attached to the representativeness sheet;
- Exporting the representativeness sheet from QGIS as a high-resolution image file (300 dpi, .png format);
- Creating summary tables based on the representativeness sheets generated through the vectorization process.



Figure 1. (a) Screenshot from QGIS with meteorological platform; (b) Screenshot with programming code for Python.

3. Results and Discussion

3.1. Geographical Position

Located in the south-eastern part of the country, Bucharest is Romania's capital and largest city (Ielenicz, 2005). It is constantly expanding, with human settlements rapidly developing in order to meet high and growing demand. (Posea, 2006). From a hydrological perspective, the municipality is drained by the Dambovița and Colentina rivers, both belonging to the Argeș hydrographic basin (Pișotă, 2005). Bucharest is characterized by a mid-latitude climate of transition, influenced either by the cold and

dry continental air masses from the East and North-East and the humid air masses from the West. (Ciulache and Ionac, 1995; Ionac and Matei, 2014)

The meteorological stations analyzed in this study are located within the administrative territory of Bucharest metropolitan area (fig.2a), at an approximately 11 km distance apart from each other, in a straight line. Geographically, they are situated in the central part of the Romanian Plain, more specifically in the Vlăsia Plain subunit. Both stations are part of the national meteorological observation network and are coordinated by the Regional Meteorological Centre - Muntenia, part of Romania's National Meteorological Administration (Figure 2b).

Both the Baneasa and Filaret meteorological station are equipped with automatic weather stations with synoptic and climatological programs, which include measurements and observations on (A.N.M., 2024):

- air temperature and humidity;
- atmospheric pressure
- direction, speed and wind gusts;
- atmospheric precipitation;
- cloud cover and cloud base height;
- horizontal visibility;
- snow depth, density, and water equivalent;
- sunshine duration;
- past and present weather;
- global and diffuse solar radiation;
- soil temperature (on the ground surface and at depths of 5, 10, 20, 50, and 100 cm).

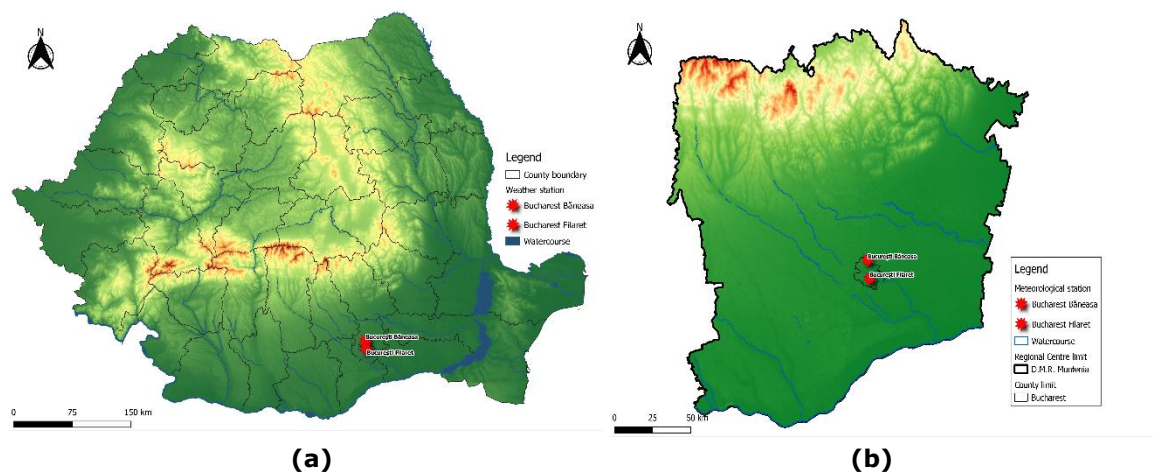


Figure 2. (a) Geographical location of the Bucharest-Băneasa and Bucharest-Filaret meteorological stations (b) Position of the meteorological stations within the Muntenia Regional Center; (Source: data processed in QGis)

The Bucharest-Băneasa meteorological station (table 1) is located in the northern part of Bucharest, in the peri-urban area, approximately 9 kilometers away from the city center. Established in 1929, the meteorological station has operated over time in three different locations, with the current site being in use since 1973.

Meteorological observations and measurements were initially made by means of classical instruments, on a standard methodology, until 1996, when a Thies automatic

weather station was installed and put into operation. This weather station was used until 2011, when it was replaced by an automatic Vaisala weather station.

The Bucharest-Filaret meteorological station (table 1) is located in Bucharest's central area, within a densely built urban area, in the vicinity of Carol Park, the former Filaret Train Station and the Astronomical Institute of the Romanian Academy. The first mention of the Filaret meteorological station dates back to 1892 in the yearbook of the Central Meteorological Institute, led by Ștefan Hepites.

The first complete year of operation for the Bucharest - Filaret station was 1889, and for each month were published tables with: climatological means and extremes, atmospheric pressure, air temperature, relative humidity, wind direction and speed, sunshine duration, soil temperature on the ground surface and at the depths of 60, 90 and 120 centimeters, atmospheric precipitation, water evaporation, ozone layer, nebulosity, actinometry, snow depth. The observation activity was initially made in a classical regime, in accordance with standardized methodology, until 2009, when a Logotronic automatic weather station was installed and put into operation. It was used until 2018, when it was replaced by an automatic Vaisala station, which is currently operational.

Table 1. Location of the Bucharest-Băneasa and Bucharest-Filaret Meteorological Stations (source: A.N.M, metadata base)

Synoptic code	Meteorological station name	Latitude N	Longitude E	Elevation (m)
15420	BUCHAREST BĂNEASA	44°30'38"	26°4'41"	90
15422	BUCHAREST FILARET	44°24'43"	26°5'38"	82

3.2 Meteorological representativeness

The representativeness of meteorological observations represents the degree to which it accurately describes the value of the variable needed for a specific purpose. (WMO, 2024). The concept of meteorological representativeness covers a wide range of elements specific to meteorological activity: technical aspects (related to equipment and methodologies for data collection and processing), as well as factors pertaining to scientific, economic or administrative decision-making. (WMO, 2006, 2007).

The World Meteorological Organization (WMO) provides a set of representativeness requirements for meteorological platforms and outlines, in the „*Guide to Meteorological Instruments and Methods of Observation WMO-No.8*”, „*ANNEX 1. D - Siting classifications for surface observing stations on land*” the exposure standards for sensor measuring: (WMO, 2024):

- air temperature and humidity;
- solar radiation;
- wind and speed direction;
- atmospheric precipitation.

The representativeness class / category of a meteorological platform is determined as the average of the individual classes assigned to each meteorological parameter (air temperature, wind speed and direction, solar radiation and atmospheric precipitation). A Class 1 platform is considered a reference site, as it fully corresponds to the recommendations of the World Meteorological Organization and allows to obtain meteorological data with a high degree of accuracy and regional relevance (Tudorache, 2018). At the opposite pole, a platform classified as class 5 is characterized by the presence of major obstacles (natural or anthropogenic), which compromise the quality of the measured data, and therefore, the relocation of the meteorological platform is highly-recommended in such cases.

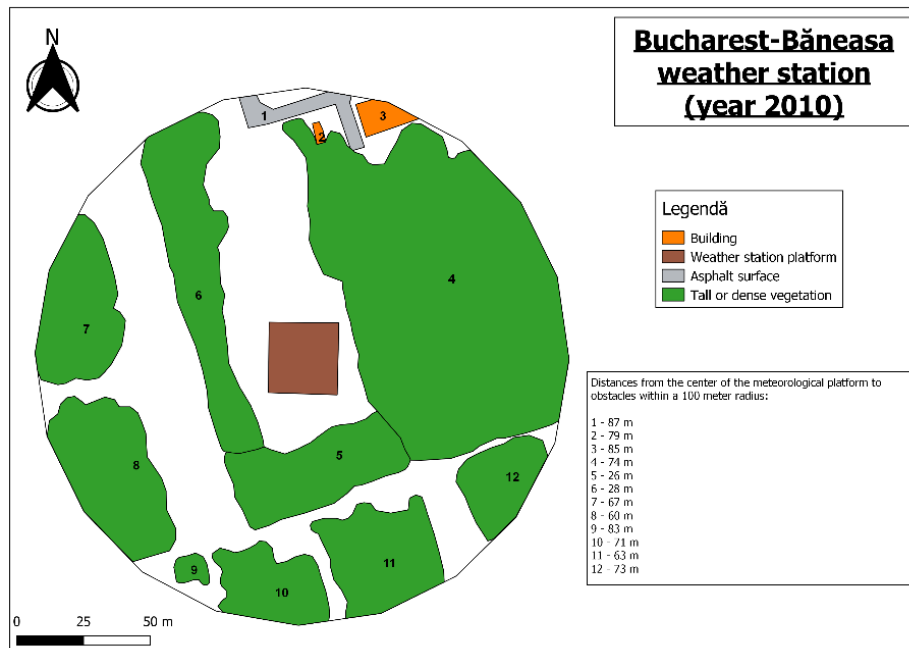
According to the WMO guidelines, the representativeness classes should be updated periodically, since the surrounding environment is subject to continuous changes of both natural and anthropogenic origin. In this respect, a complete review of the assessment sheets and platform reclassification should be conducted every five years or whenever the platform is relocated or undergoes significant contextual changes (WMO, 2024).

The meteorological stations analyzed in this study – Bucharest Băneasa and Bucharest Filaret – although located approximately 11 km apart from each other, in a straight line, show significant differences regarding their representativeness class for air temperature.

The Bucharest-Băneasa meteorological station, located in a peri-urban area of Bucharest, did not undergo any significant anthropogenic interventions or natural changes within the delimited area surrounding the platform all over the analyzed period (2010, 2015, 2020). Within this circular perimeter, there are no anthropogenic obstacles (buildings, surfaces covered with concrete or asphalt) that might influence air temperature measurements. The surrounding vegetation is predominantly natural, consisting of small trees with heights between 1 and 3 meters, elements that do not significantly affect the airflow around the meteorological platform.

In 2010 (Figure 3a and 3b), the representativeness class assigned to the Bucharest-Băneasa meteorological platform for air temperature was Class 1 (Figure 3b). The only heat sources within the 100-meter radius perimeter surrounding the platform were located at distances varying from 79 to 87 meters. The vegetation around the platform consisted of short grass and 2-3 m tall fruit trees.

In 2015 (Figures 4a and 4b), the representativeness class assigned to the Băneasa meteorological platform remained unchanged. The only changes observed in the surrounding area were determined by the spontaneous growth of vegetation and the expansion of tree canopies.



(a)

Summary of the Site Classification for the Air Temperature and Humidity Sensor

Year: 2010
 Meteorological Station: Bucharest Băneasa
 Synoptic code: 15420
 Geographical coordinates : Latitude: 44° 30' 38"
 : Longitude: 26° 04' 41"

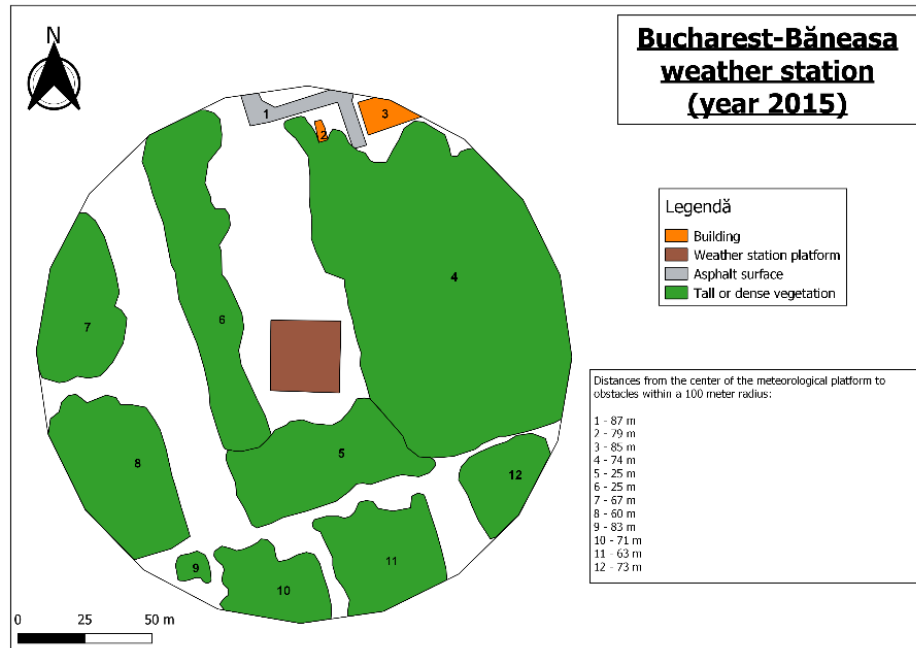
Altitude platforma meteorologica: 91 m

Classification Criteria	Class 1	Class 2	Class 3	Class 4	Class 5	Associated Class
T1) Ground cover	Vegetation <10 cm within 10 m radius	Vegetation <15 cm within 5 m radius	Vegetation <25 cm within <5 m radius	Vegetation <50 cm	Vegetation >50 cm	1
T2) Terrain surface/slope	Flat surface within 10 m radius	Slope <19°	Flat surface within 5 m radius	Slope <19°	Flat surface within <5 m radius Slope >19°	1
T3) Nearby irrigation	More than 30 m away	More than 10 m away	More than 5 m away	Less than 5 m away	Next to sensor	1
T4) Significant heat sources	More than 100 m away (buildings, paved parking lots, etc.)	More than 30 m away (same)	More than 10 m away (same)	Less than 10 m away (same)	-	1
T5) Nearby infrastructure	Subjective determination of heat sources at 2:1 distance from sensor	Same as Class 1	Same sources at 1:1 distance	Same sources, no distance restriction	Density and size of infrastructure significantly affect measurements	2
T6) Aircraft and/or highway proximity	More than 100 m away	More than 50 m away	More than 30 m away	Less than 30 m away	No	1
T7) Radiation shield or housing	Yes	Yes	Yes	Yes	No	1
T8) Sensor installation height from ground	1.2 – 2.0 m	1.2 – 2.5 m	1.2 – 3.0 m	1.0 – 3.5 m	Outside Class 4 limits	1
T9) Maximum expected snow layer thickness	Distance between maximum snow surface and sensor shelter >1.0 m	Distance >0.5 m	Maximum snow surface is below sensor shelter	Ventilation is not obstructed	Ventilation could be obstructed	1
T10) No significant shading	Horizon +50° (shade at <10°)	Horizon +70° (shade at <20°)	Horizon +100° (shade <30°)	Horizon +200° (shade <45°)	Outside Class 4 limits	1

Result of the site classification for the meteorological platform measuring air temperature: 1

(b)

Figure 3. (a) Representativeness sheet for the Bucharest-Băneasa meteorological station, for the year 2010; (b) Representativeness summary for the Bucharest-Băneasa meteorological station, for the year 2010. (Source: data processed in QGis)



(a)

Summary of the Site Classification for the Air Temperature and Humidity Sensor

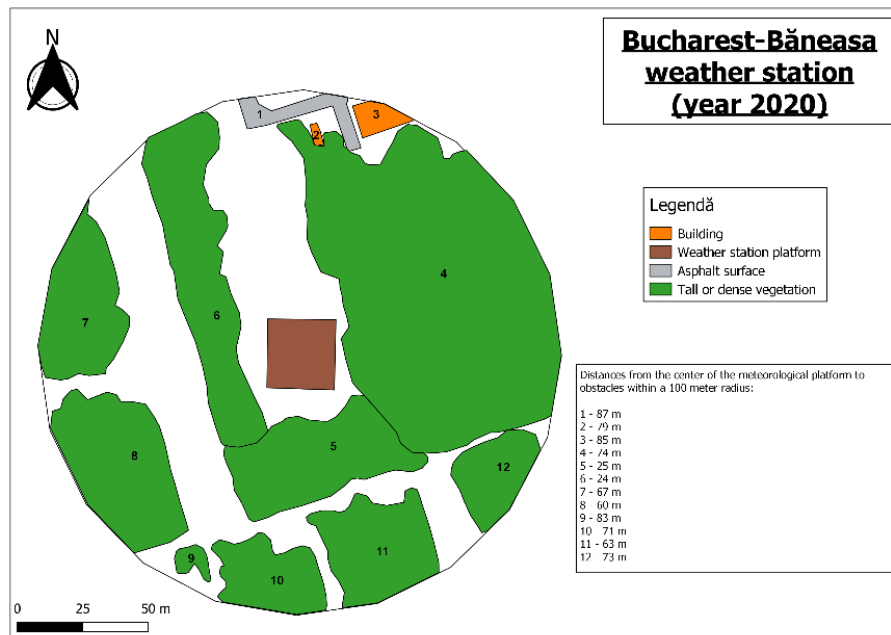
Year: 2015
 Meteorological Station: Bucharest Băneasa
 Synoptic code: 15420
 Geographical coordinates : Latitude: 44° 30' 38"
 : Longitude: 26° 04' 41"
 Altitude platforma meteorologica: 91 m

Classification Criteria	Class 1	Class 2	Class 3	Class 4	Class 5	Associated Class
T1) Ground cover	Vegetation <10 cm within 10 m radius	Vegetation <15 cm within 5 m radius	Vegetation <25 cm within <5 m radius	Vegetation <50 cm	Vegetation >50 cm	1
T2) Terrain surface/slope	Flat surface within 10 m radius	Slope <19°	Flat surface within 5 m radius	Slope <19°	Flat surface within <5 m radius Slope >19°	1
T3) Nearby irrigation	More than 30 m away	More than 10 m away	More than 5 m away	Less than 5 m away	Next to sensor	1
T4) Significant heat sources	More than 100 m away (buildings, paved parking lots, etc.)	More than 30 m away (same)	More than 10 m away (same)	Less than 10 m away (same)	-	1
T5) Nearby infrastructure	Subjective determination of heat sources at 2:1 distance from sensor	Same as Class 1	Same sources at 1:1 distance	Same sources, no distance restriction	Density and size of infrastructure significantly affect measurements	2
T6) Aircraft and/or highway proximity	More than 100 m away	More than 50 m away	More than 30 m away	Less than 30 m away	No	1
T7) Radiation shield or housing	Yes	Yes	Yes	Yes	No	1
T8) Sensor installation height from ground	1.2 – 2.0 m	1.2 – 2.5 m	1.2 – 3.0 m	1.0 – 3.5 m	Outside Class 4 limits	1
T9) Maximum expected snow layer thickness	Distance between maximum snow surface and sensor shelter >1.0 m	Distance >0.5 m	Maximum snow surface is below sensor shelter	Ventilation is not obstructed	Ventilation could be obstructed	1
T10) No significant shading	Horizon +50° (shade at <10°)	Horizon +70° (shade at <20°)	Horizon +100° (shade <30°)	Horizon +200° (shade <45°)	Outside Class 4 limits	1

Result of the site classification for the meteorological platform measuring air temperature: 1

(b)

Figure 4. (a) Representativeness sheet for the Bucharest-Băneasa meteorological station, for the year 2015; (b) Representativeness summary for the Bucharest-Băneasa meteorological station, for the year 2015. (Source: data processed in QGis)



(a)

Summary of the Site Classification for the Air Temperature and Humidity Sensor

Year: 2020
 Meteorological Station: Bucharest Băneasa
 Synoptic code: 15420
 Geographical coordinates : Latitude: 44° 30' 38"
 : Longitude: 26° 04' 41"
 Altitudine platforma meteorologica: 91 m

Classification Criteria	Class 1	Class 2	Class 3	Class 4	Class 5	Associated Class
T1) Ground cover	Vegetation <10 cm within 10 m radius	Vegetation <15 cm within 5 m radius	Vegetation <25 cm within <5 m radius	Vegetation <50 cm	Vegetation >50 cm	1
T2) Terrain surface/slope	Flat surface within 10 m radius	Slope <19°	Flat surface within 5 m radius	Slope <19°	Flat surface within <5 m radius Slope >19°	1
T3) Nearby irrigation	More than 30 m away	More than 10 m away	More than 5 m away	Less than 5 m away	Next to sensor	1
T4) Significant heat sources	More than 100 m away (buildings, paved parking lots, etc.)	More than 30 m away (same)	More than 10 m away (same)	Less than 10 m away (same)	-	1
T5) Nearby infrastructure	Subjective determination of heat sources at 2:1 distance from sensor	Same as Class 1	Same sources at 1:1 distance	Same sources, no distance restriction	Density and size of infrastructure significantly affect measurements	2
T6) Aircraft and/or highway proximity	More than 100 m away	More than 50 m away	More than 30 m away	Less than 30 m away	No	1
T7) Radiation shield or housing	Yes	Yes	Yes	Yes	No	1
T8) Sensor installation height from ground	1.2 – 2.0 m	1.2 – 2.5 m	1.2 – 3.0 m	1.0 – 3.5 m	Outside Class 4 limits	1
T9) Maximum expected snow layer thickness	Distance between maximum snow surface and sensor shelter >1.0 m	Distance >0.5 m	Maximum snow surface is below sensor shelter	Ventilation is not obstructed	Ventilation could be obstructed	1
T10) No significant shading	Horizon +50° (shade at <10°)	Horizon +70° (shade at <20°)	Horizon +100° (shade <30°)	Horizon +200° (shade <45°)	Outside Class 4 limits	1

Result of the site classification for the meteorological platform measuring air temperature: 1

(b)

Figure 5. (a) Representativeness sheet for the Bucharest-Băneasa meteorological station, for the year 2020; (b) Representativeness summary for the Bucharest-Băneasa meteorological station, for the year 2020. (Source: data processed in QGis)

In 2020 (Figures 5a and 5b), as in the 2015 assessment, the only changes around the platform were due to vegetation. No major modifications that could influence the measurements were observed and the representativeness class remained the same throughout the analyzed periods.

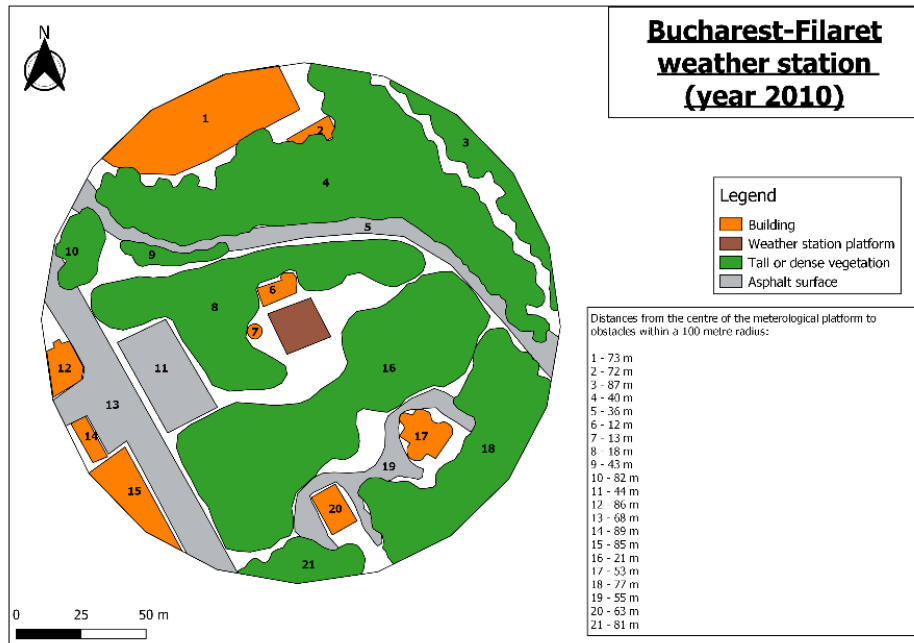
In contrast, the **Bucharest-Filaret meteorological platform** has a poor representativeness class for air temperature, being located in a heavily modified urban environment. Within a 100-meter radius perimeter, there are numerous anthropogenic obstacles, such as buildings and technical structures, access roads covered with asphalt or concrete, and parking areas. The distances between these elements and the air temperature sensor range from 13 to 89 meters, so, these conditions locally influence air temperature measurements.

Thus, according to WMO criteria, the Bucharest-Filaret platform falls into a lower representativeness class than that of the Bucharest-Băneasa station, requiring an adequate correction of the parameters related to air temperature data.

In 2010 (Figure 6a and 6b), the representativeness class assigned to the Bucharest-Filaret meteorological platform for air temperature was Class 3 (fig. b). Heat sources were located relatively close to the 100-meter radius around the platform, with some as near as 13 meters from the automatic weather station. The surrounding vegetation consists of low grass and trees exceeding 4 meters in height. The heat sources lying in the vicinity of the platform are numerous, ranging from technical constructions to buildings, as well as extensive areas covered with asphalt and concrete.

In 2015 (Figures 7a and 7b), during the representativeness assessment process, a new heat source was identified South of the meteorological platform, located approximately 14 meters away from the automatic weather station. The representativeness class for Filaret remained unchanged, staying in Class 3.

In 2020 (Figures 8a and 8b), similarly to the situation in 2015, a new technical construction was identified South of the platform, approximately 15 meters away from the automatic weather station, and classified as a heat source. With the addition of this new heat source, the representativeness class of the meteorological platform remains Class 3, although it is not excluded that, in the future, it might shift to Class 4.



(a)

Summary of the Site Classification for the Air Temperature and Humidity Sensor

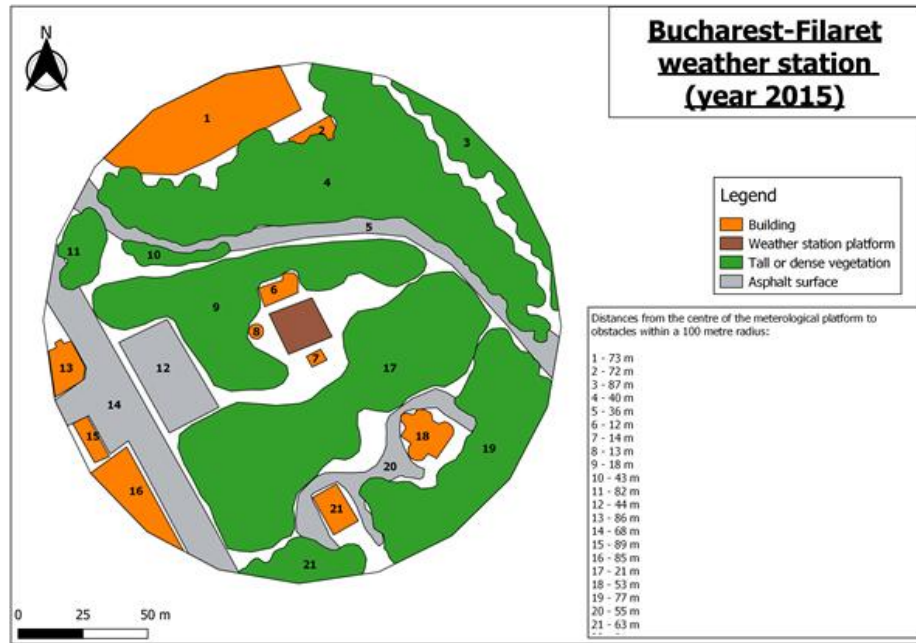
Year: 2010
 Meteorological Station: Bucharest Filaret
 Synoptic code: 15422
 Geographical coordinates : Latitude: 44° 24' 43"
 : Longitude: 26° 05' 38"
 Altitude platforma meteorologica: 82 m

Classification Criteria	Class 1	Class 2	Class 3	Class 4	Class 5	Associated Class
T1) Ground cover	Vegetation <10 cm within 10 m radius	Vegetation <15 cm within 5 m radius	Vegetation <25 cm within <5 m radius	Vegetation <50 cm	Vegetation >50 cm	1
T2) Terrain surface/slope	Flat surface within 10 m radius	Slope <19°	Flat surface within 5 m radius	Slope <19°	Flat surface within <5 m radius Slope >19°	1
T3) Nearby irrigation	More than 30 m away	More than 10 m away	More than 5 m away	Less than 5 m away	Next to sensor	1
T4) Significant heat sources	More than 100 m away (buildings, paved parking lots, etc.)	More than 30 m away (same)	More than 10 m away (same)	Less than 10 m away (same)	-	3
T5) Nearby infrastructure	Subjective determination of heat sources at 2:1 distance from sensor	Same as Class 1	Same sources at 1:1 distance	Same sources, no distance restriction	Density and size of infrastructure significantly affect measurements	3
T6) Aircraft and/or highway proximity	More than 100 m away	More than 50 m away	More than 30 m away	Less than 30 m away	No	1
T7) Radiation shield or housing	Yes	Yes	Yes	Yes	No	1
T8) Sensor installation height from ground	1.2 – 2.0 m	1.2 – 2.5 m	1.2 – 3.0 m	1.0 – 3.5 m	Outside Class 4 limits	1
T9) Maximum expected snow layer thickness	Distance between maximum snow surface and sensor shelter >1.0 m	Distance >0.5 m	Maximum snow surface is below sensor shelter	Ventilation is not obstructed	Ventilation could be obstructed	1
T10) No significant shading	Horizon +50° (shade at <10°)	Horizon +70° (shade at <20°)	Horizon +100° (shade <30°)	Horizon +200° (shade <45°)	Outside Class 4 limits	3

Result of the site classification for the meteorological platform measuring air temperature: 3

(b)

Figure 6. (a) Representativeness sheet for the Bucharest-Filaret meteorological station, for the year 2010; (b) Representativeness summary for the Bucharest-Băneasa meteorological station, for the year 2010 (Source: data processed in QGIS)



(a)

Summary of the Site Classification for the Air Temperature and Humidity Sensor

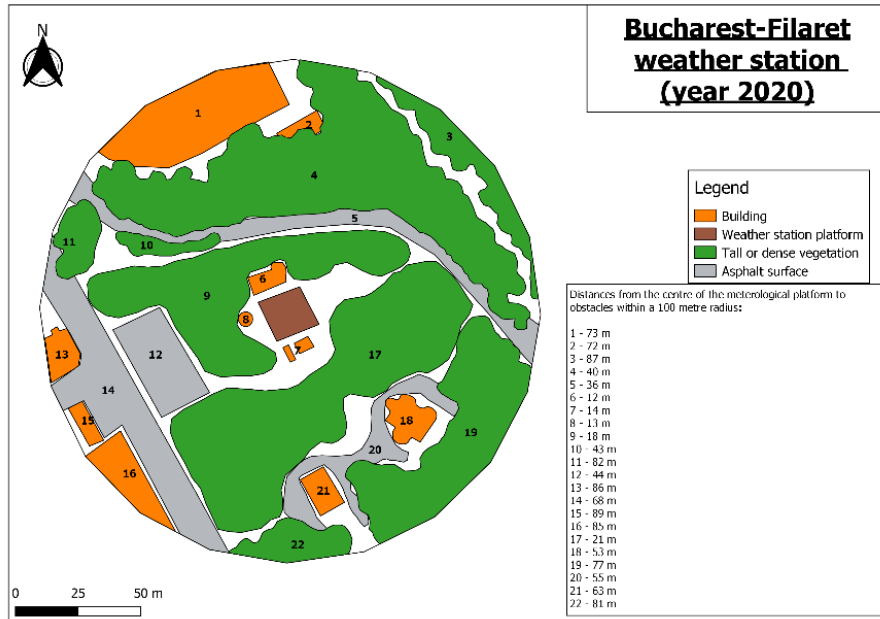
Year: 2015
 Meteorological Station: Bucharest Filaret
 Synoptic code: 15422
 Geographical coordinates : Latitude: 44° 24' 43"
 : Longitude: 26° 05' 38"
 Altitude platforma meteorologica: 82 m

Classification Criteria	Class 1	Class 2	Class 3	Class 4	Class 5	Associated Class
T1) Ground cover	Vegetation <10 cm within 10 m radius	Vegetation <15 cm within 5 m radius	Vegetation <25 cm within <5 m radius	Vegetation <50 cm	Vegetation >50 cm	1
T2) Terrain surface/slope	Flat surface within 10 m radius	Slope <19°	Flat surface within 5 m radius	Slope <19°	Flat surface within <5 m radius Slope >19°	1
T3) Nearby irrigation	More than 30 m away	More than 10 m away	More than 5 m away	Less than 5 m away	Next to sensor	1
T4) Significant heat sources	More than 100 m away (buildings, paved parking lots, etc.)	More than 30 m away (same)	More than 10 m away (same)	Less than 10 m away (same)	-	3
T5) Nearby infrastructure	Subjective determination of heat sources at 2:1 distance from sensor	Same as Class 1	Same sources at 1:1 distance	Same sources, no distance restriction	Density and size of infrastructure significantly affect measurements	3
T6) Aircraft and/or highway proximity	More than 100 m away	More than 50 m away	More than 30 m away	Less than 30 m away	No	1
T7) Radiation shield or housing	Yes	Yes	Yes	Yes	No	1
T8) Sensor installation height from ground	1.2 – 2.0 m	1.2 – 2.5 m	1.2 – 3.0 m	1.0 – 3.5 m	Outside Class 4 limits	1
T9) Maximum expected snow layer thickness	Distance between maximum snow surface and sensor shelter >1.0 m	Distance >0.5 m	Maximum snow surface is below sensor shelter	Ventilation is not obstructed	Ventilation could be obstructed	1
T10) No significant shading	Horizon +50° (shade at <10°)	Horizon +70° (shade at <20°)	Horizon +100° (shade <30°)	Horizon +200° (shade <45°)	Outside Class 4 limits	3

Result of the site classification for the meteorological platform measuring air temperature: 3

(b)

Figure 7. (a) Representativeness sheet for the Bucharest-Filaret meteorological station, for the year 2015; (b) Representativeness summary for the Bucharest-Băneasa meteorological station, for the year 2015 (Source: data processed in QGIS)



(a)

Summary of the Site Classification for the Air Temperature and Humidity Sensor

Year: 2020

Meteorological Station: Bucharest Filaret

Synoptic code: 15422

Geographical coordinates : Latitude: 44° 24' 43"

: Longitude: 26° 05' 38"

Altitude platforma meteorologica: 82 m

Classification Criteria	Class 1	Class 2	Class 3	Class 4	Class 5	Associated Class
T1) Ground cover	Vegetation <10 cm within 10 m radius	Vegetation <15 cm within 5 m radius	Vegetation <25 cm within <5 m radius	Vegetation <50 cm	Vegetation >50 cm	1
T2) Terrain surface/slope	Flat surface within 10 m radius	Slope <19°	Flat surface within 5 m radius	Slope <19°	Flat surface within <5 m radius Slope >19°	1
T3) Nearby irrigation	More than 30 m away	More than 10 m away	More than 5 m away	Less than 5 m away	Next to sensor	1
T4) Significant heat sources	More than 100 m away (buildings, paved parking lots, etc.)	More than 30 m away (same)	More than 10 m away (same)	Less than 10 m away (same)	-	3
T5) Nearby infrastructure	Subjective determination of heat sources at 2:1 distance from sensor	Same as Class 1	Same sources at 1:1 distance	Same sources, no distance restriction	Density and size of infrastructure significantly affect measurements	3
T6) Aircraft and/or highway proximity	More than 100 m away	More than 50 m away	More than 30 m away	Less than 30 m away	No	1
T7) Radiation shield or housing	Yes	Yes	Yes	Yes	No	1
T8) Sensor installation height from ground	1.2 – 2.0 m	1.2 – 2.5 m	1.2 – 3.0 m	1.0 – 3.5 m	Outside Class 4 limits	1
T9) Maximum expected snow layer thickness	Distance between maximum snow surface and sensor shelter >1.0 m	Distance >0.5 m	Maximum snow surface is below sensor shelter	Ventilation is not obstructed	Ventilation could be obstructed	1
T10) No significant shading	Horizon +50° (shade at <10°)	Horizon +70° (shade at <20°)	Horizon +100° (shade <30°)	Horizon +200° (shade <45°)	Outside Class 4 limits	3

Result of the site classification for the meteorological platform measuring air temperature: 3

(b)

Figure 8. (a) Representativeness sheet for the Bucharest-Filaret meteorological station, for the year 2020; (b) Representativeness summary for the Bucharest-Băneasa meteorological station, for the year 2020 (Source: data processed in QGIS)

The differences in the representativeness class between the Bucharest-Băneasa and Bucharest-Filaret meteorological stations are directly reflected in the air temperature values recorded at the two measurement platforms. In the context of long-term climatological comparisons, a systematic deviation can be observed in the hourly average temperature values recorded at the Bucharest-Filaret station, which frequently exceed by 1–2°C the corresponding values measured at the Bucharest-Băneasa station.

This thermal difference is mainly due to anthropogenic influences specific to the dense urban environment in which the Bucharest-Filaret meteorological station is located. The presence of buildings, impervious surfaces, and reduced natural ventilation contribute to the formation of a distinct urban climate, associated with the urban heat island effect.

In contrast, the peri-urban location of the Bucharest-Băneasa meteorological station, characterized by better exposure and the absence of significant natural or anthropogenic obstacles, allows for the recording of temperature values more representative of the general atmospheric conditions on the outside areas of the city.

3.3 Climatic characteristics of Bucharest

Bucharest is characterized by a mid-latitude climate of transition, with continental influences, especially during the summer season (Ciulache, 2002). During the warm season, oceanic air masses and tropical-maritime air masses, after crossing the Carpathians, undergo adiabatic warming, so the weather in the areas outside the Carpathian Mts. generally gets clear and hot, particularly when warm and dry air advections from the East intensify. Under the influence of these continental tropical air advections, air temperatures reach significant increase, especially at the Bucharest-Filaret station, which is affected by the built-in environment of central Bucharest.

During the cold season, sharp temperature drops are caused by invasions of polar air from the North-East and East, as well as by Arctic air masses from the North of the continent. These cold air masses tend to stagnate over Romania, particularly in the Romanian Plain, due to its basin-like topography that facilitates the accumulation and retention of cold air, thus creating strong air-temperature inversions.

The climate of the region exhibits a more pronounced continental character than that of the western or south-western parts of the country. This is reflected in larger thermal oscillations, both diurnal and annual, lower amounts of precipitation unevenly distributed over time, and an increased frequency of extreme weather phenomena — prolonged summer droughts, severe winter blizzards, and relatively high cloudiness. (Ciulache, 2002; Ionac)

In order to highlight the thermal differences between the urban and extra-urban areas, hourly air temperature data were processed by using Pivot Table functions to calculate monthly, annual, and multi-annual averages for the period 2010–2020, based on the two meteorological stations under analysis.

The analysis of monthly averages (Table 2) reveals consistently higher air temperature values at the Filaret station as compared to the Băneasa station, thus confirming the influence of the urban heat island. A relevant example is August 2020, when a temperature difference of 1.8 °C was recorded between the two stations, in favor of the urban location.

Looking at the year-to-year variation, 2012 stands out as particularly warm one, with maximum average values of 28.0 °C recorded in July at the Filaret station and 26.4 °C at the Băneasa station. Additionally, February 2017 is notable for a pronounced negative anomaly at Băneasa (−5.2 °C), illustrating the more strongly continental character of the thermal regime in less urbanized areas.

Table 2. Monthly average temperature for the period 2010–2020 for the Bucharest-Băneasa and Bucharest-Filaret Meteorological Stations (source: data processed in Excel)

Monthly average temperature for the period 2010–2020 for the Bucharest Filaret meteorological station												
year/month	January	February	March	April	May	June	July	August	September	October	November	Decembre
2010	- 2,6	0,6	6,0	13,0	17,7	21,7	23,7	26,0	18,8	9,5	11,1	0,3
2011	- 1,6	- 1,2	6,2	11,6	16,8	21,3	24,1	23,6	21,6	11,1	4,1	3,3
2012	- 0,7	- 5,3	7,2	14,7	18,3	23,6	28,0	25,3	20,5	14,7	7,8	- 0,7
2013	- 0,6	3,2	5,8	14,4	19,6	22,1	23,6	24,8	17,8	12,1	8,7	0,3
2014	- 0,0	2,3	9,9	12,2	17,0	19,9	23,2	24,4	18,9	11,9	5,5	1,2
2015	0,2	2,6	7,0	12,3	19,1	21,7	25,7	24,7	20,5	11,7	8,8	4,3
2016	- 2,4	7,4	8,6	15,1	16,7	23,3	25,2	24,3	19,9	10,8	6,3	0,6
2017	- 4,0	1,8	10,1	11,8	17,3	23,1	24,1	25,4	20,0	12,6	7,5	4,1
2018	1,9	2,1	4,5	16,9	20,1	23,2	23,5	24,6	19,5	14,1	5,4	0,1
2019	- 0,9	4,2	10,1	11,6	17,2	23,3	23,3	25,0	20,1	13,6	10,3	4,1
2020	1,8	5,7	9,2	12,9	16,8	21,5	25,0	25,6	21,3	14,4	6,3	4,1

Monthly average temperature for the period 2010–2020 for the Bucharest Băneasa meteorological station												
year/month	January	February	March	April	May	June	July	August	September	October	November	Decembre
2010	-3,4	-0,2	5	11,6	16,5	20,8	22,7	23,8	17,1	8,2	9,7	-0,7
2011	-2,3	-2,3	4,9	10,3	15,7	20,5	23,1	22,2	20	9,7	2,9	2,7
2012	-1,6	-6,3	5,8	13,7	17,4	22,4	26,4	23,7	19,2	13,2	6,9	-1,4
2013	-1,4	2,5	5,1	13,4	18,5	21,3	22,6	23,7	16,4	11	8	-0,4
2014	-0,6	1,7	8,9	11,6	15,9	19,3	22,4	22,9	17,7	11	5	0,7
2015	-0,8	2	6,2	11,1	17,8	20,3	24,3	23	19	10,5	7,4	2,9
2016	-3,5	6	7,5	13,5	15,5	22	23,4	22,7	18,1	9,7	5,2	-0,8
2017	-5,2	0,9	8,8	10,3	16	21,8	22,6	23,2	18,4	10,8	6,5	2,9
2018	0,7	1,1	3,5	15,5	18,8	21,7	22	23,5	18,2	13	4,8	-0,3
2019	-1,3	3,2	8,9	11	16,6	22,6	22	23,3	18,5	12,3	9,5	3,4
2020	0,6	4,8	8,2	11,6	15,7	20,5	23,2	24	19,8	13,7	5,5	3,5

Table 3. Multi-annual average temperature for the Bucharest-Băneasa and Bucharest-Filaret Meteorological Stations (2010–2020) (source: data processed in Excel)

Meteorological station	January	February	March	April	May	June	July	August	September	October	November	Decembre	Multi-annual average temperature (2010–2020)
Bucharest Băneasa	-1,7	1,2	6,6	12,1	16,8	21,2	23,2	23,3	18,4	11,2	6,5	1,1	11,7
Bucharest Filaret	-0,8	2,1	7,7	13,3	17,9	22,2	24,5	24,9	19,9	12,4	7,4	2,0	12,8

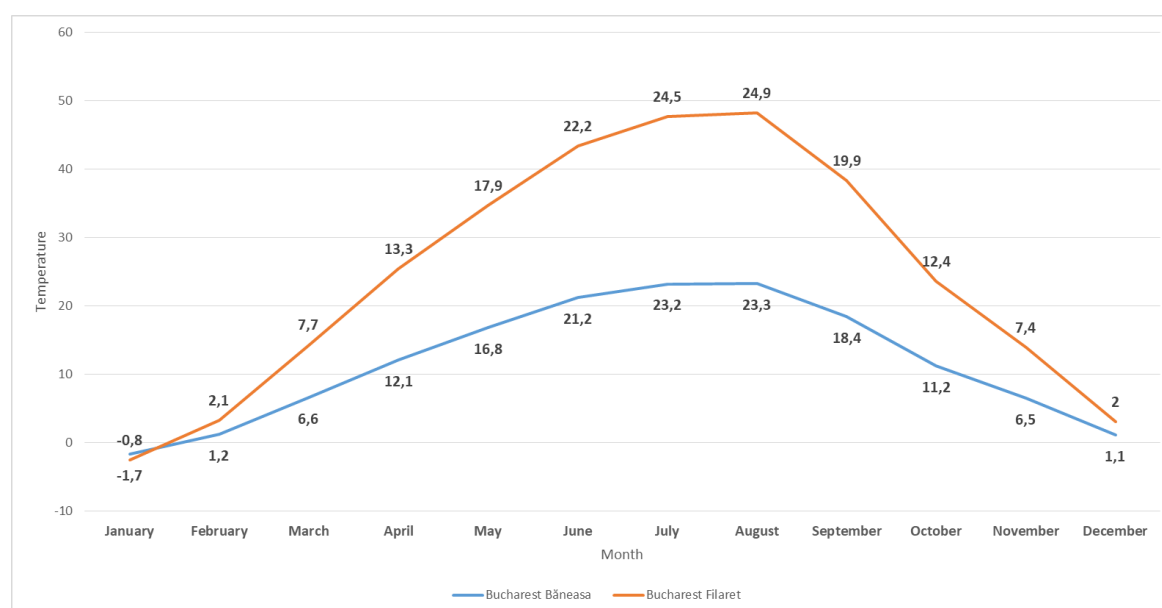


Figure 9. Multi-annual average temperature for the Bucharest Băneasa and Bucharest-Filaret Meteorological Stations (2010–2020) (Source: data processed in Excel)

The graph (Figure 9) and table (Table 3) above show the evolution of multi-year average temperatures recorded at the two meteorological stations, Băneasa (blue line) and Filaret (red line). The Filaret station consistently records higher values as compared to Băneasa, throughout the year. This difference is largely due to urbanization, which is reflected in the representativeness class of the station.

The most significant differences appear during the summer months, when Filaret reaches maximum air-temperatures above 24°C (in July and August), while Băneasa's maximum values keep around 22°C. For example, in August, the average temperature at Filaret is 24.9°C, as compared to 23.3°C at Băneasa. During the cold season, the differences persist but are smaller. In January, Băneasa records an average temperature of -1.7°C, while at Filaret it is -0.8°C. These temperature differences confirm the representativeness class 3 associated with the Filaret station and class 1 for the Băneasa station.

3.4 Isopleths

A complex method for the spatial representation of hourly air temperature values is the use of isopleths. This type of diagram has the advantage of simultaneously illustrating both the diurnal variation of temperature for each month and its annual variation, according to the time of day. The construction of isopleths involves a system of orthogonal axes: the vertical axis (ordinate) indicates the hours of the day, while the horizontal axis (abscissa) corresponds to the months of the year. At the intersection points of these axes, the average hourly air temperature values for each month are plotted. Based on these values and by interpolation—assuming a linear increase in temperature, isotherm lines are drawn, connecting points with equal temperature. Isopleth representation is widely used in climatology, as it lends itself not only to the depiction of thermal parameters (such as average hourly temperatures, deviations from the multiannual mean, thermal amplitudes, and differences), but also to other climatic elements such as humidity, cloudiness, precipitation, and sunshine duration (Dumitrescu, 1972).

The analysis of air-temperature isopleths for the 2010–2015 period, corresponding to the Bucharest-Băneasa (Figure 10a) and Bucharest-Filaret (Figure 10b) meteorological stations, highlights the presence of a well-defined core of average temperatures around 30 °C, particularly in July and August. This thermal core manifests itself between 10:00 AM and 4:00 PM at the Băneasa station, respectively between 09:00 AM and 3:00 PM at the Filaret station. The slight temporal shift of the thermal maximum at Filaret station indicates a faster heating of the air in the dense urban environment, where built-in surfaces dominate.

During the cold season, the differences between the two stations become noticeable at night, when temperatures at the Filaret station are at least 1–2 °C higher than those at Băneasa. This thermal contrast reflects the influence of the urban environment, especially the presence of buildings, asphalt and concrete, which store heat during the day and gradually release it during the night, thus contributing to maintain higher temperatures. The phenomenon is a clear indication of the urban heat island effect, characteristic of densely built-in central areas. In contrast, at the Băneasa station, the

absence of anthropogenic heat sources and the presence of vegetation results in a much faster night time cooling, starting at 7:00 PM, while at Filaret, air-temperatures begin to decrease only after midnight.

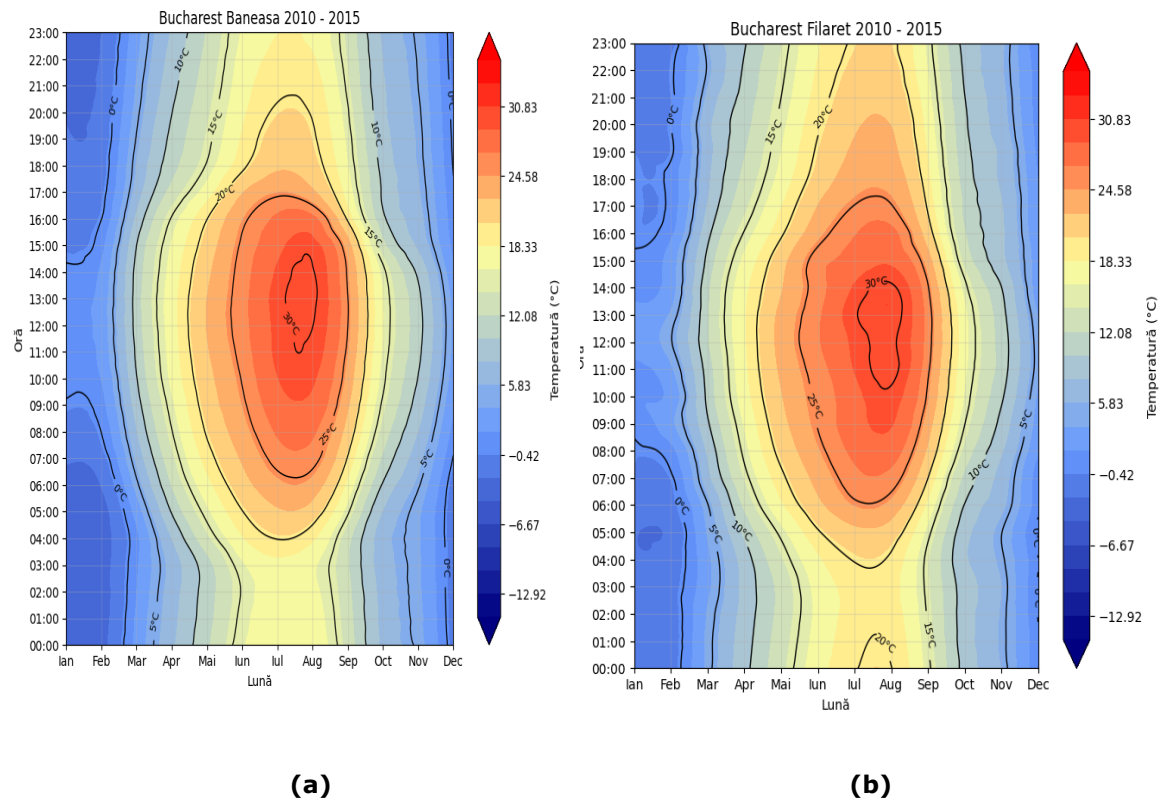


Figure 10. (a) Isopleths for the Bucharest-Băneasa meteorological station for the 2010–2015 period; (b) Isopleths for the Bucharest-Filaret meteorological station for the 2010–2015 period. (Source: data processed programming language Python)

By analyzing the air-temperature isopleths for the 2015–2020 (Figures 11a and 11b) period, one can notice the presence of a well-defined thermal core at the Bucharest-Filaret meteorological station, with temperature values exceeding 30 °C. This core begins to form around 10:00 AM and reaches its peak around 12:00 PM, indicating an early and rapid intensification of air heating. The presence of this thermal peak is associated with the influence of anthropogenic heat sources in the vicinity of the meteorological platform.

In comparison to the previous period (2010–2015), there is a general increase in temperature values at both analyzed meteorological stations, which may reflect the level of representativeness of the two platforms.

Another aspect highlighted by the isopleth analysis is the 20 °C isotherm, which clearly delineates the difference between the urban and peri-urban areas. At the Băneasa station, a temperature drop starts around 7:00 PM, due to the surrounding vegetation and the very low density of anthropogenic heat sources. In contrast, at the Filaret station, the 20 °C isotherm persists until midnight, as a result of the urban heat island effect, where heat sources such as asphalt, concrete, and buildings absorb solar energy during the day and release it in the evening and overnight.

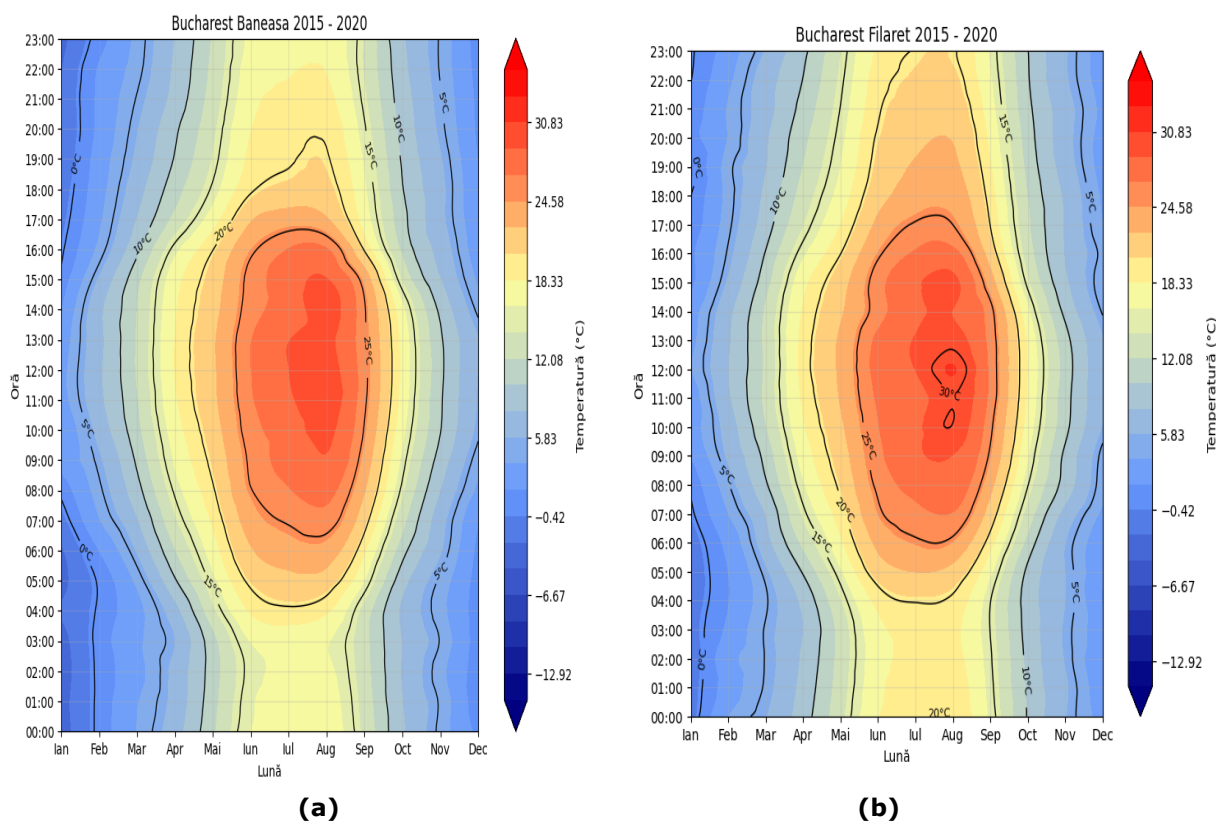


Figure 11. (a) Isopleths for the Bucharest-Băneasa meteorological station for the 2010–2015 period; (b) Isopleths for the Bucharest-Filaret meteorological station for the 2010–2015 period. (Source: data processed programming language Python)

5. Conclusions

Following the assessment of the representativeness of the two meteorological platforms located in the Bucharest area, and the analysis of hourly air temperature data, a significant anthropogenic influence on thermal recordings becomes evident—particularly at the Bucharest-Filaret station. This station consistently records air-temperatures that are 1 to 2 °C higher than those recorded at the Bucharest-Băneasa station, despite the relatively short distance between the two sites. The observed differences confirm the impact of urbanization on the measured values and highlight the importance of carefully selecting the location of meteorological stations in climate studies.

The Bucharest-Filaret station records higher air temperatures, which becomes characteristic of the urban climate, with extended and frequent daytime maxima. Classified as Class 3 in terms of representativeness, the station consequently requires air-temperature data corrections due to nearby anthropogenic obstacles and the urban heat island effect—both caused by the surrounding buildings and infrastructure. In contrast, the Bucharest-Băneasa station, located in a peripheral area with more vegetation, records lower thermal values, with more pronounced nocturnal minima. Due to its favorable location and minimal anthropogenic influence, the Băneasa meteorological station is therefore classified as Class 1 in terms of representativeness. This classification indicates that Băneasa station meets the World Meteorological Organization’s standards for meteorological siting.

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