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The Study of Air Temperature in the Last Decade in the Bucharest Metropolitan Area

Chichirez Cristina-Mihaela
Department of Marketing and Medical Technology - Carol Davila University of Medicine and Pharmacy Bucharest

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Corresponding Author:
Chichirez Cristina-Mihaela
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ABSTRACT

Multiple paleoclimatic studies indicate that the Earth has warmed significantly since the end of the 19th century. The mean temperature of the Earth's surface is rising unnaturally and frighteningly fast, having a large impact and threatening the very near future of human civilization. This paper presents an analysis of the variability of air temperature in the Bucharest metropolitan area in the decade 2011-2020, related to the 1901-2000 period in the context of the global warming. The research includes the study of the mean annual and monthly temperature, the absolute maximum and minimum temperature, the frequency of the thermal character in the cold season and in the hot season and the frequency of days with characteristic temperatures. The 2011-2020 decade was the hottest one since the beginning of meteorological measurements. Related to the 1901-2000-reference period, the air temperature increased by 1.6°C, from 11.1°C to 12.7°C, the mean of the 10 years. The year 2020 was the hottest year, marking the end of the hottest decade since the meteorological measurements were made, the mean annual temperature being 13.5°C, by 2.4°C higher than the mean of the 1901-2010 reference period.

KEYWORDS: Air temperature, Characteristic days, Deviation, Monthly variation, Thermal character frequency

1. INTRODUCTION

The changes observed in the Earth's climate since the early 20th century are mainly due to the human activities, specially fossil burning, which increases levels of greenhouse gases. They capture heat in the Earth's atmosphere, increasing the mean temperature of its surface. Combined with massive population growth and the effects of large-scale deforestation and industrial agriculture, the large-scale burning of fossil fuels has caused an increase of the greenhouse gas concentrations in the atmosphere to levels never seen before in the more than 200,000-year history of the human species (Oskamp, 2000).

Despite political controversy about the climate change, a major report published on 27 September 27, 2013 by the Intergovernmental Panel on Climate Change (IPCC) said that scientists are more sure than ever of the link between human activities and global warming. Multiple paleoclimatic studies indicate that the Earth has warmed significantly since the end of the 19th century (Cronin, 2010). Most climate scientists have concluded that human activity is driving to climate change. There is an overwhelming scientific consensus that global surface temperatures have increased in recent decades and the trend is mainly due to human-made greenhouse gas emissions (Cook et al., 2016).

The consensus further developed that some form of action should be taken to protect people from the impact of climate change and national science academies have called on world leaders to reduce global emissions (Gleick, 2017). In 2017, on the second warning to humanity, 15,364 scientists from 184 countries declared that "the current trajectory of climate change, potentially catastrophic due to the increase greenhouse gases from fossil fuels burning, deforestation and agricultural production - especially from ruminant farms for meat consumption, is especially worrying" (Ripple et al., 2017).

In 2019, a group of more than 11,000 scientists from 153 countries called climate change an "emergency" that would lead to "untold human suffering" if there were no big changes in action. The emergency statement highlighted that "economic growth and population growth are among the most important drivers of CO_2 emissions from the burning of fossil fuels and that we need bold and drastic transformations in economic and population policies". (Ripple et al., 2019).

The mean temperature of the Earth's surface is rising unnaturally and frighteningly fast, having a large impact and threatening the very near future of human civilization. The global annual temperature has increased by about 1°C related to the pre-industrial period, with a mean

rate of 0.07°C per decade since 1880 and it is more than twice the 1981 rate of +0.18°C (NOAA, 2020).

According to the European Climate Change Service Copernicus (C3S), at worldwide level, mean temperatures between June 2019 and May 2020 were about 0.7°C higher than in the same period from 1981 to 2010. In August, the global temperature of the land surface was 1.26°C above the mean. In a warming world, certain types of weather events, such as heat waves and extreme precipitation, will become more intense and frequent as the mean global temperature rises (Hulme, 2014).

Historical models and Earth surface temperature values suggest that there is a strong link between anthropogenic warming and the increased persistence of extreme weather (Mann et al., 2017). These approaches allow quantifying the influence of historical global warming on the probability and severity of individual events (Rahmstorf and Coumou, 2011). All extreme climate events are associated with large-scale changes in the thermodynamic environments (Trenberth et al., 2015). For example, the increase of mean temperature leads to heat waves (Meehl and Tebaldi, 2004); decreased soil moisture and higher evaporation trends lead to a higher incidence and severity of drought (Dai, 2011) or changes in soil moisture (Fischer and Seneviratne, 2007); high sea surface temperature and moisture anomalies are related to storms and melting of Arctic ice fields (Petrie, 2015).

Climate-related events are already posing risks to society through impacts on health, food, water security, as well as human security, livelihoods, economies, infrastructure and biodiversity (UNEP, 2019).

Surface temperatures and precipitation in most regions vary greatly from the global mean due to geographical position, especially of the latitude and continental location. Both the mean values of temperature, precipitation and their extremes (which generally have the greatest impact on natural systems and human infrastructure) are also strongly affected by local wind patterns (Lorenz et al., 2019).

Climate change endangers human health, affecting all sectors of society, both domestically and globally. The environmental consequences of climate change, both those already observed and anticipated, such as sea level rise, rainfall changes leading to floods and droughts, heat waves, more intense hurricanes and storms, and the degraded air quality will affect human health both directly and indirectly (Porter et al., 2010).

2. MATERIAL AND METHODS

Bucharest is the capital of Romania and it is located in the southeastern part of the country, in the Vlăsiei Plain. It is the most prosperous city in Romania and it is one of the main industrial centers and transport hubs from the Eastern Europe. The climate in Bucharest is specific to Romania, respectively temperate-continental, with four seasons: winter, spring, summer and autumn. In this study, we have used daily air temperature data for the interval 2011-2020 from the archive of the Bucharest Filaret weather station, and for the period 1901-2000 the data from the Statistical Yearbook of Romania.

The data series were processed in MS Excel, determining the monthly, seasonal, annual variation in air temperature and number of days with characteristic temperatures (winter days, frosty nights, summer days, tropical days, tropical nights and hot days). For the examination of the thermal character, the percentage deviation of the air temperature from the multiannual mean was used, the rating being given according to the Hellmann criterion, as follows: normal, warm, hot and very hot.

3. RESULTS AND DISCUSSIONS

The air temperature is the meteorological parameter that is the most supposed to an annual cycle as a consequence of its dependence on solar radiation. Analysis and interpretation of the climatic data concerning of the temperature presents a great importance, both for the theoretical framing in a climatic zone, especially practice. Monthly and annual mean air temperature values are one of the most commonly used climatic parameters in the study and characterization of the climate (Chichirez et al., 2012). Over the past decade, in the Bucharest metropolitan area, the mean annual air temperature was ranged between 11.5°C in 2011 and 13.5°C in 2020 (fig.1).

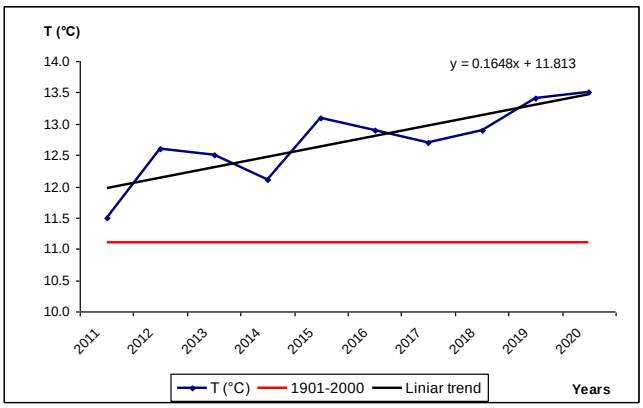

Fig.1. Mean annual air temperature (°C) recorded in Bucharest metropolitan area (2011-2020)

The equation of the regression right, having a positive coefficient, indicates an incresed trend of the temperature over the 10 years. Compared to the 1901-2000 –reference period, the air temperature increased by 1.6°C, from 11.1°C to 12.7°C, the mean of the 10 years.

The year 2020 was the hottest year, marking the end of the hottest decade since meteorological measurements were made, with a mean annual temperature of 13.5°C, with 2.4°C higher than the 1901-2010 reference period mean. The year 2019 follows it with 13.4°C, 2015 with 13.1°C, 2018 and 2016 with 12.9°C. Globally, the temperature record for 2020 was equal to that recorded in 2016, by 0.6°C hotter than the 1981-2010 climatological

normal and by 1.25°C over the pre-industrial period 1850-1900 (Copernicus Climate Change Service, 2021).

For Europe, 2020 was the hottest year, by 1.6°C above the 1981-2010 climatological normal and by 0.4°C above 2019, the hottest previous year.

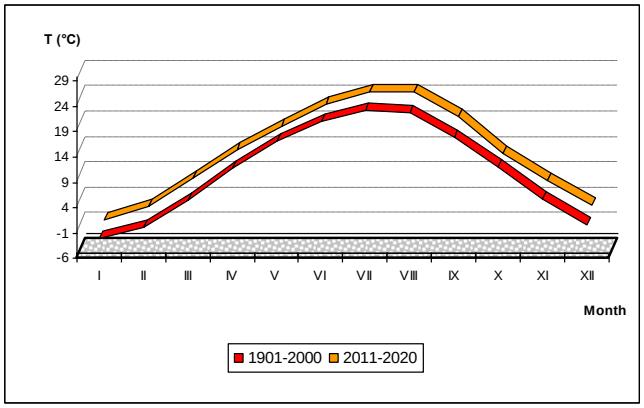

Fig.2. Monthly mean air temperature (°C) recorded in Bucharest at the beginning of the 21st century compared to the 20th century.

During the year, the mean temperature varies greatly from month to month, indicating the continental nature of the climate, with a minimum in winter, in January (-0.7°C), followed by an increase in values until July and August, when the thermal maximum (24.5°C) is recorded, after which temperatures decrease (fig.2). The differences between means of the decade 2011-2020 and the1901-2000 reference period are more evident in February-March (2.3°C) and September (2.0°C).

The curves of the maximum and minimum monthly temperatures follow the same allure as the mean temperature. Thus, in July and August, the mean of the maximum temperatures recorded values above 30°C (31.8 - 32.5°C), and the lowest temperatures were recorded in January, -3.6°C (fig.3).

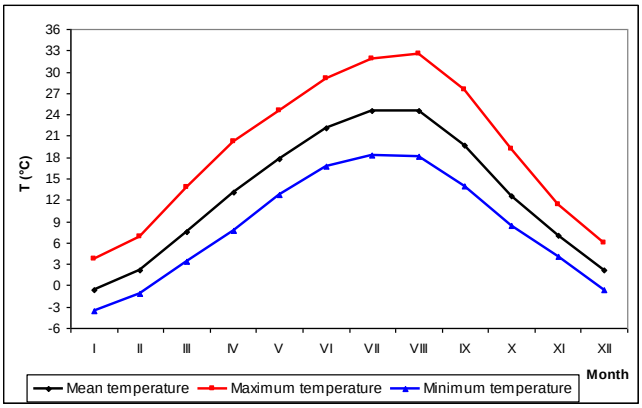

Fig 3. Monthly mean maximum and minimum temperatures (°C) recorded in Bucharest (2011-2020).

The monthly amplitude of air temperature is another climatic parameter, representing the difference between the highest and the lowest thermal value recorded in a given period of time. This parameter is of particular theoretical importance because it expresses the measure which ocean influences make their mark on the climate.

In Bucharest, the highest monthly amplitudes of absolute extreme temperatures are recorded in the cold season and they are range from 31.9°C in November to 42.9°C in February (fig.4)

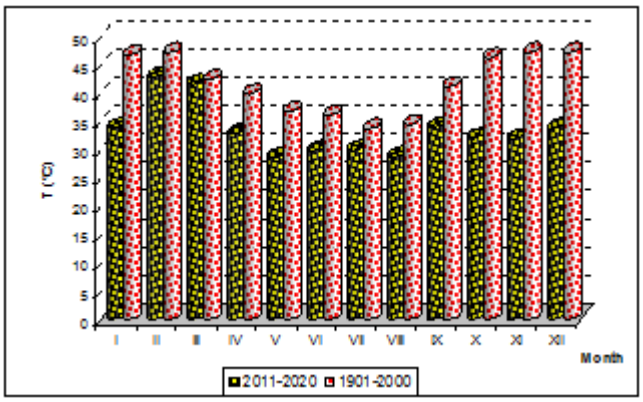

Fig.4. Monthly thermal amplitude (°C) in Bucharest, in 2011-2020 compared to the 1901-2000 reference period.

In the hot season, the amplitude of extreme temperature values are ranged from 28.6°C in May to 34.0°C in September. It is worth that both in the cold season and in the hot season, the thermal amplitude has lower values than 1901-2000 reference period. Thus, in the reference period, in the cold season, the maximum amplitude is ranged between 42.4°C in March and 47.2°C in November, December and February. In the hot season, the thermal amplitude is between 33.8°C in July and 41.2°C in September. This facts highlights a significant increase in temperature in the decade 2011-2020 and especially a reduction in absolute minimum values. The lowest temperature recorded in the decade 2011-2020 was -18.6°C (January 24, 2016), and in the reference period 1901-2000 was -30.0°C (January 25, 1942). Absolute temperature maximum in the decade analyzed was recorded on August 7, 2012 and it was 41.5°C, and the absolute maximum of the reference period was 42,4 °C, recorded on July 5, 2000.

For the cold season (October – March), according to the Hellmann criterion, of the ten years taking into the study, it is estimated that two years (20%) are considered normal, the deviation from the 1901-2000 mean being between -0.5°C and +0.5°C. These are 2011 and 2012 (fig.5). Five of them (50%) are considered hot years, with deviation between +1.1°C and 2.0°C. These are: 2013, 2014, 2016, 2017 and 2018. The years 2015, 2019 and 2020 (30%) are considered very hot, with deviations between +2.1°C and +5.0°C.

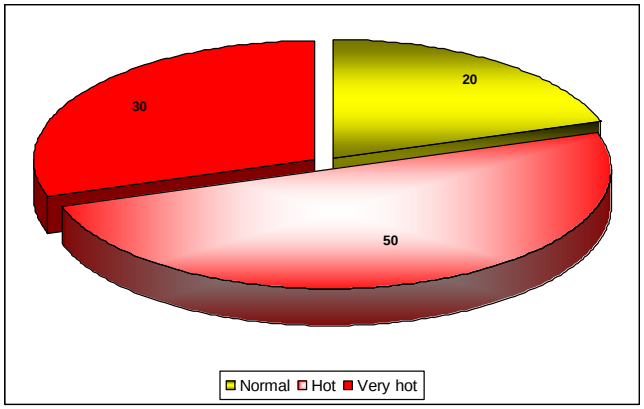

Fig.5. Frequency (%) of the thermal character of the years, in the cold season, according to the Hellmann criterion, in Bucharest (2011-2020).

For the hot season (April – September), according to the Hellmann criterion, of the ten years taking into the study, it is estimated that one year (10 %) is considered normal, the deviation from the 1901-2000 mean being between -0.5°C and +0.5°C. This is 2014 (fig.6). Year 2011 (10 %) is considered warm, with a deviation between +0.6°C and +1.0°C. Six of them (60%) are considered hot years, with deviation between +1.1°C and 2.0°C. These are: 2013, 2015, 2016, 2017, 2019 and 2020. Years 2012 and 2018 (20 %) are considered very hot, with deviations between +2.1°C and +5.0°C.

The influence of the particularities of the underlying surface and atmospheric circulation on the air thermal regime shows also on the frequency of days with different thermal characteristics.

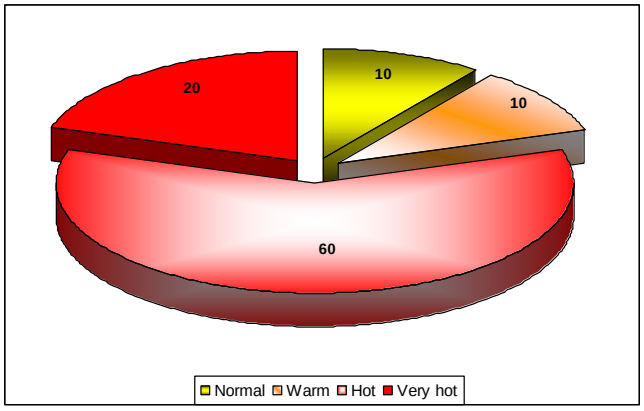

Fig.6. Frequency (%) of the thermal character of the years, in the hot season, according to the Hellmann criterion, in Bucharest (2011-2020).

The decrease in air temperature below 0°C is caused by the installation of the anticyclonic regime, which generates advections of arctic or polar continental cold air masses. The frequency of days when the minimum temperature drops below -10°C (frosty nights) or the maximum temperature drops below 0°C (winter days) is another parameter that highlights the intensity of cooling.

The increase in the maximum air temperature during the day above 25°C, above 30°C and above 35°C (summer days, tropical days and hot days respectively) and the minimum temperature at night above 20°C (tropical nights) is due to invasions of continental hot air and local heating.

In the Bucharest metropolitan area, in the decade 2011-2020, the number of winter days was ranged between two days and 31 days (fig.7). The years with the fewest winter days were: 2020 (two days), 2015 and 2019 (with 6 days every year). Most winter days were recorded in the years: 2012 (31 days), 2011 (21 days) and 2017 (20 days).

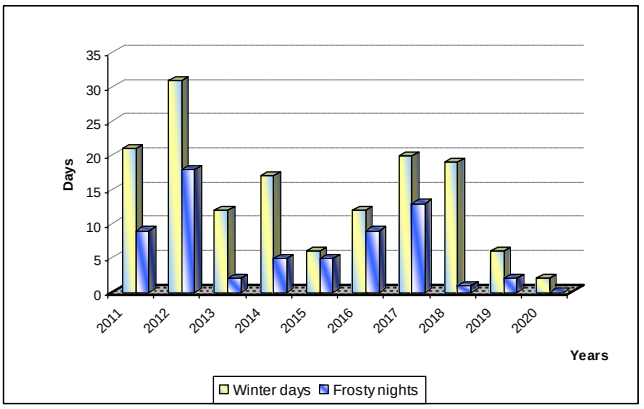

Fig.7. Number of winter days and frosty nights recorded in Bucharest (2011-2020)

The number of frosty nights was ranged between zero and 18 days. The years with the fewest frosty nights were: 2020 (zero days), 2018 (one day) 2013 and 2019 (with two days every year). Most frosty nights were recorded in the years: 2012 (18 days), 2017 (13 days) and 2011 and 2016 (with 9 days every year).

In the Bucharest metropolitan area, in the decade 2011-2020, the number of tropical days was ranged between 44 days and 94 days (fig.8). The years with the fewest tropical days were: 2014 (44 days), 2013 (61 days) and 2011 (65 days). Most tropical days were recorded in the years: 2012 (94 days), 2020 (90 days) and 2018 (83 days). The number of tropical nights was ranged between seven days and 40 days. The years with the fewest tropical nights were: 2013 (7 days), 2011 and 2019 (with 8 days every year). Most tropical nights were recorded in the years: 2012 (40 days), 2016 (32 days) and 2015 (29 days).

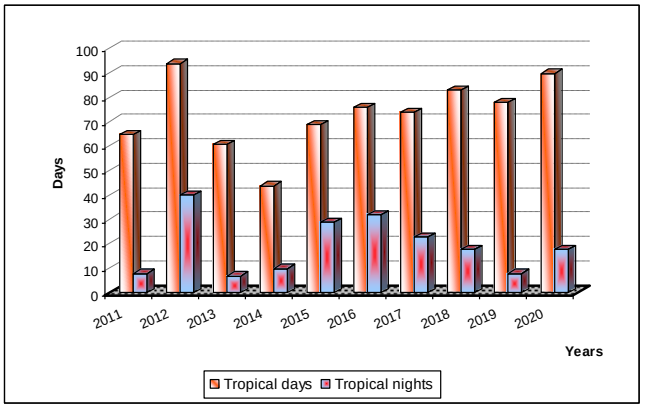

Fig.8. Number of tropical days and tropical nights recorded in Bucharest (2011-2020)

In the Bucharest metropolitan area, in the last decade, the number of summer days was ranged between 113 days and 164 days (fig.9).

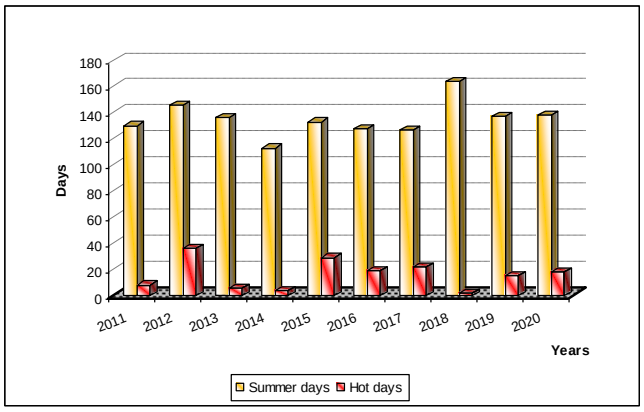

Fig.9. Number of summer days and hot days recorded in Bucharest (2011-2020)

The years with the fewest summer days were: 2014 (113 days), 2017 (127 days) and 2016 (128 days). Most summer days were recorded in the years: 2018 (164 days), 2012 (146 days), 2020 (138 days), 2019 (137 days), 2013 (136 days) and 2015 (133 days). The number of hot days was ranged between two days and 36 days. The years with the fewest hot days were: 2018 (two days), 2014 (4 days), 2013 (6 days) and 2011 (by 8 days). Most hot days were recorded in the years: 2012 (36 days), 2015 (29 days) and 2017 (22 days).

4. CONCLUSIONS

In the Bucharest metropolitan area, the decade 2011-2020 was the hottest since the beginning of meteorological measurements. Compared to the reference period 1901-2000, the air temperature increased by 1.6°C, from 11.1°C to 12.7°C, the mean of the 10 years. The year 2020 was the hottest year, marking the end of the hottest decade since meteorological measurements were made, with a mean annual temperature of 13.5°C, by 2.4°C higher than the 1901-2010 reference period mean. The differences between the means of the decade 2011-2020 and the reference period 1901-2000 are more evident in February-March (2.3°C) and September (2.0°C). In both the cold and hot season, the thermal amplitude is lower than the 1901-2000 reference period. This highlights a significant increase in temperature in the decade 2011-2020 and especially a reduction in absolute minimum values.

The lowest temperature recorded in the decade 2011-2020 was -18.6°C (January 24, 2016). The absolute temperature maximum in the decade analysed was recorded on August 7, 2012 and it was 41.5°C. In the decade 2011-2020, the number of winter days was ranged between two days (2020) and 31 days (2012), and the number of frosty nights was ranged between zero (2020) and 18 days (2012). The number of summer days was ranges between 113 days (2014) and 164 days (2018), and hot days between two days (2018) and 36 days (2012). The number of tropical days was ranged between 44 days (2014) and 94 days (2012), and tropical nights between 8 days (2011 and 2019) and 40 days (2012).

The new information, especially quantitative historical weather data and climate projection data, leads to an improved understanding of the science of variability and climate change. Understanding, anticipating and adapting to potential climate impacts is essential for creating a fixed and more resilient base for sustainable development.

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