Review of the NCD 47 (2025), 42–52

Nedeljko Todorović
meteorologist, Belgrade, Serbia

SUMMER HEAT IN BELGRADE

Abstract. The main feature of the temperate continental climate in Belgrade is the occurrence of summer heat in the warm part of the year. In meteorology and climatology, the summer months are considered to be June, July, and August, which do not strictly coincide with the period of astronomical summer. Based on climatological criteria, a summer day is considered to be one in which the highest air temperature is equal to or higher than 25 degrees, and a tropical day is one in which the temperature is equal to or higher than 30 degrees. Normally, summer days occur before and after climatological and astronomical summer. Instrumental data on air temperature from the Belgrade Meteorological Observatory at Vračar for the period 1887-2025 were used for the analysis. In order to extend the series and better observe the change trend, corrected and reconstructed data for the period 1848-1887 from the Senjak measuring station in Belgrade were used. An analysis of extreme values of daily, monthly, and annual air temperatures, the average date of the appearance of the first and last temperature with values equal to or greater than 25, 30, and 35 degrees was performed. Trends in these temperature parameters were also examined. The analysis aimed to determine the most significant features of summer heat expressed through air temperature. The results show that extreme values of summer temperatures are a common meteorological phenomenon for the temperate continental climate in Belgrade, that they have a slight increasing trend that is not significant, and that they have multi-decadal variability and periodicity that is mainly in accordance with the Atlantic Multi-decadal Oscillation (AMO). The analyzed data and results are presented in tabular and graphical form.

Keywords: extreme summer temperatures, mean dates, trends.

1. Introduction

The first meteorological instrumental observations and measurements in Belgrade were started on 01.01.1848, by Vladimir Jakšić (1824-1899), a professor at the Lyceum. During his absence, observations were carried out by his friend, Vuk Gavrilović, also a professor at the Lyceum, and in the last year (1899) by members of his immediate family. The measuring site was on Jakšić's private estate at Senjak (44^o 48' N, 20^o 27' E, 90 m asl), then a suburb of Belgrade. The period of Jakšić's observations from 01.08.1887. to 31.12.1899. coincides with the systematic measurements and observations at the Velika škola Observatory that were started by Professor Milan Nedeljković (1857-1951), first in a private house (from 01.08.1887. to 01.05.1891.), in the immediate vicinity of the newly built building in Zapadni Vračar, which is also the current location of the Meteorological Observatory (44^o 48' N, 20^o 28' E, 131.6 m asl). For the analysis in this paper, temperature data from 1887 to 2025 from meteorological diaries and publications [1], [2], and [3] of the Republic Hydrometeorological Institute of Serbia were used. Professor Pavle Vujević interpolated missing data from the period of World War I for average monthly and annual temperatures according to data from meteorological stations in Pančevo, Sremska Mitrovica, and Mala Vojka near Indjija, while data on maximum and minimum temperatures are missing. Also, data from Vladimir Jakšić's observation diary from the Senjak measuring site were used in some analyses which were corrected for the periods 1848-1865 and 1876-1887 according to the measuring site Vračar, and for the missing part of the series in the period 1866-

1875, a reconstruction was performed based on the correlation of data between Budapest, Zagreb, and Belgrade (Vračar) [4], [5].

Previous analyses of extreme temperature values in the period 1888-2023 established their increasing trend. The coefficients of determination (R^2) indicated that the trend of change was not significant for the absolute annual maximum temperature, the number of days with Tmax≥35 °C, the number of days with Tmax≥37 °C, and moderate significance existed for winter minimum temperatures Tmin≤-5 °C and Tmin≤-10 °C [6], [7]. The increasing trends in extreme temperatures indicated that the mean temperature also has a growing trend, with the contribution of the increase in minimum values being more pronounced. The number of days with extremely high temperatures (Tmax≥35 °C) is correlated with the mean summer temperature, and spectral analysis provides the repeatability of the maximum temperature after a period of 60 years. An increase in the number of days with T≥30 °C for eight cases is reflected in an increase in the mean summer temperature by 1 °C [8]. Graphical analysis based on a moving data series of 5 years for the data series from 1888-2012 gives a period of 35 years with a more frequent occurrence of extremely high temperatures (Tmax ≥35 °C) and periods of 34 years with a noticeable change in their frequency. Thus, one entire wave (period) with "warm" and "cold" summers has a duration of 69 years [9]. The current "warm" period is incomplete and may last for several years longer. An analysis of the temperature in the Belgrade region for the period 1988-2014 found that the temperature in the central parts of the city was slightly higher than in the surrounding area. The meteorological observatory in Belgrade was located on the outskirts of the city for the first half of the analyzed period, and then urbanization changed the microclimatic conditions. This change in the microclimate and the creation of "urban heat islands" has been observed in all large cities in the world. The trend can be partly linked to rising global temperatures and partly to changing microclimatic conditions driven by urbanization and the strengthening of the urban heat island [10].

2. Methodology

The summer heat wave was depicted using meteorological temperature data recorded at the Belgrade Meteorological Observatory on Vračar (1887-2025) and corrected and reconstructed data from the Senjak measuring site (about 2 km away) in the period before the Vračar Observatory began operating (1848-1886). The analysis included meteorological and climatological data on the highest daily and the highest annual air temperatures, the number of days with the highest daily temperature T≥25 °C (summer day), T≥30 °C (tropical day), T≥35 °C, T≥37 °C and T≥40 °C, the average, earliest and latest dates of the first and last day, and the duration of the periods with temperatures T ≥ 25 °C, T≥30 °C and T≥35 °C. Their change trends were calculated for the periods 1976-2025, 1887-2025, and 1848-2025. The results are presented in tables and graphs.

3. Analysis and results

Although extremely high summer temperatures have been recorded in Belgrade over the last three and a half decades (record value: 43.6 °C, 24.07.2007), instrumental data in Table 1 show that they were also present in the first half of the twentieth century and in the middle of the nineteenth century.

Table 2 shows the highest air temperature values for June, July, and August, and the strengthening of the urban heat island [10].

Table 1. The highest annual air temperatures in Belgrade, Senjak (1848-1886), and Vračar (1887-2025).

1841	1842	1843	1844	1845	1846	1847	1848	1849	1850
							40.8	**41.4**	**39.4**
1851	1852	1853	1854	1855	1856	1857	1858	1859	1860
37.6	**38.6**	**39.8**	**39.4**	**39.2**	**36.8**	**35.4**	**34.5**	**37.4**	**35.6**
1861	1862	1863	1864	1865	1866	1867	1868	1869	1870
37.6	**39.4**	**37.1**	**34.7**	**36.1**					
1871	1872	1873	1874	1875	1876	1877	1878	1879	1880
					33.1	**36.3**	**32.5**	**35.5**	**35.0**
1881	1882	1883	1884	1885	1886	1887	1888	1889	1890
36.6	**37.8**	**36.5**	**35.3**	**33.5**	**34.7**	**37.3**	**39.0**	**38.0**	**37.9**
1891	1892	1893	1894	1895	1896	1897	1898	1899	1900
37.4	**36.1**	**33.1**	**39.1**	**35.4**	**34.8**	**35.4**	**35.8**	**34.3**	**34.8**
1901	1902	1903	1904	1905	1906	1907	1908	1909	1910
36.5	**37.8**	**37.9**	**37.4**	**38.7**	**34.8**	**37.2**	**37.2**	**36.0**	**33.1**
1911	1912	1913	1914	1915	1916	1917	1918	1919	1920
37.7	**34.6**	**32.0**		**34.5**	**40.2**	**41.6**	**39.0**		**36.5**
1921	1922	1923	1924	1925	1926	1927	1928	1929	1930
41.8	**39.3**	**40.1**	**36.0**	**36.1**	**32.5**	**38.4**	**39.1**	**35.4**	**37.4**
1931	1932	1933	1934	1935	1936	1937	1938	1939	1940
39.2	**34.8**	**35.1**	**35.3**	**38.5**	**39.4**	**35.7**	**36.7**	**38.0**	**32.7**
1941	1942	1943	1944	1945	1946	1947	1948	1949	1950
33.3	**37.2**	**37.1**	**35.5**	**36.1**	**41.8**	**38.2**	**36.7**	**35.7**	**39.2**
1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
39.0	**38.4**	**34.5**	**37.0**	**32.5**	**36.6**	**39.1**	**38.4**	**34.4**	**35.0**
1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
38.7	**35.8**	**38.4**	**33.6**	**37.7**	**32.7**	**35.5**	**37.3**	**33.5**	**34.0**
1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
35.0	**34.9**	**36.1**	**35.3**	**33.4**	**32.5**	**34.4**	**34.1**	**35.1**	**32.8**
1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
38.0	**35.7**	**34.7**	**35.6**	**36.9**	**34.7**	**37.0**	**40.2**	**34.0**	**35.1**
1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
35.0	**37.4**	**39.6**	**38.9**	**34.8**	**34.9**	**35.1**	**38.7**	**37.2**	**40.5**
2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
37.8	**37.4**	**38.4**	**38.5**	**35.9**	**35.9**	**43.6**	**38.3**	**36.3**	**38.4**
2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
39.3	**39.9**	**39.1**	**34.8**	**37.6**	**36.0**	**39.8**	**34.7**	**37.5**	**36.2**
2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
40.0	**39.0**	**37.4**	**39.7**	**38.6**					

Table 2. The highest daily air temperatures by date in June, July, and August in Belgrade (1887-2025).

Day	Jun	Year	July	Year	August	Year
1	**34.0**	1923	**38.0**	1950	**40.1**	1923
2	**32.8**	1927	**38.4**	1998	**41.6**	1917
3	**34.6**	1927	**38.0**	1950	**38.7**	1998
4	**33.8**	1921	**40.5**	2000	**39.0**	2017
5	**34.2**	1921	**40.2**	1916	**39.8**	2017
6	**34.4**	1908	**40.2**	1988	**39.6**	2017
7	**34.9**	1908	**38.6**	2025	**39.2**	1931
8	**34.3**	1891, 2025	**38,3**	1931	**38.4**	2013
9	**35.0**	1891	**38.5**	2004	**39.7**	1921
10	**35.5**	2024	**38.2**	2017	**38.5**	1921
11	**36.5**	1928	**37.6**	2017	**40.3**	1921
12	**35.5**	1935	**38.1**	2024	**41.8**	1921
13	**35.5**	2000	**38.0**	2021	**38.7**	2024
14	**37.2**	2000	**38.7**	2021	**39.7**	2024
15	**34.5**	1987	**39.2**	1931	**39.3**	1922
16	**34.7**	2009	**39.6**	2024	**38.5**	2021
17	**36.0**	2016	**38.5**	1928	**37.3**	2024
18	**38.0**	1918	**38.8**	2007	**39.3**	1946
19	**36.3**	1918	**40.2**	2007	**39.2**	1946
20	**37.2**	1908	**40.1**	2007	**38.7**	1946
21	**35.7**	2012	**38.4**	2007	**39.6**	2000
22	**37.5**	2024	**40.7**	2007	**40.0**	2000
23	**36.4**	1993	**39.0**	2022	**39.9**	2007
24	**38.7**	2021	**43.6**	2007	**39.9**	2012
25	**36.9**	2025	**37.3**	2000	**38.9**	2012
26	**38.1**	2025	**38.6**	2025	**37.5**	2012
27	**35.8**	1930	**37.0**	1921	**38.4**	2010
28	**36.7**	1935	**38.5**	2021	**38.4**	1950
29	**36.0**	1938	**39.4**	1936	**38.4**	2003
30	**36.7**	1938	**36.8**	1917	**38.9**	1928
31			**38.6**	1917	**36.6**	2015

The highest annual air temperatures were measured in the three summer months, and there is an exception, because in 1946, a temperature of 41.8 ^{o}C was measured on 09.09. equaling the previous highest value from 12.08.1921. Only after 61 years, on 24.07.2027, was the highest value of 43.6 ^{o}C measured. Tables 1 and 2 show that most of the data record values were recorded in two periods: in the first half of the 20th century, and the second from 1987 to 2025. The record date values between these two periods were lower.

Figure 1 graphically shows a series of data on the highest annual air temperatures in Belgrade for two periods, the first 1887-2025, and the second 1848-2025, which is an extended series based on the reconstruction and correction of data from the Senjak measuring site. The average value of the highest annual air temperature in both series is

practically the same (36.73 and 36.75 ^{o}C), but they differ in the trends of change. In the first series, the trend is 0.57 ^{o}C/ 100 years; in the second, longer series, 0.12 ^{o}C/ 100 years, which shows that the trend of change decreases with the extension of the data series. For both series, the coefficients of determination are small, which indicates that the increase in the highest annual temperature is not significant. Table 3 shows the sequence of years with the highest average summer temperatures in Belgrade (1888-2025, Tavg=21.72 ^{o}C). The list of the 24 hottest summers is dominated by years from the last three and a half decades, and to a lesser extent, years from the first half of the twentieth century.

Table 4 shows the order of the absolute highest air temperatures in Belgrade for the period 1888-2025, with the dates when they were measured. In the given period of 138 years, there were a total of 22 cases with a temperature of 40 degrees, of which 15 cases with a value equal to or greater than 40.0 °C. Three cases with a value of T≥40 °C were recorded in 2007, and in 1921, two cases plus one case with a value of 39.7 °C. From this overview table, it can be seen that the highest temperatures were measured in the first half of the twentieth century and in the last three and a half decades.

One indicator of summer heat is the number of days with extremely high temperatures with values equal to or greater than 35 degrees.

Table **5** shows the order of the first 28 years with the highest number of days in Belgrade for the period 1888-2025. For the period of 138 years, the average value is 5.3 days. It is noted that the highest number of days was in the years in the first half of the twentieth century and in the last three and a half decades. Based on the data from the overview tables 3, 4, and 5, two periods with more frequent occurrence of summer heat can be distinguished: the first half of the twentieth century and the last three and a half decades. In the sixties, seventies, and the first half of the eighties of the twentieth century, the number of cases was significantly lower. A similar frequency is observed in the data on the number of days with air temperatures equal, or higher than 37 ^{o}C.

In the last three and a half decades, a more frequent occurrence of hot summers was observed compared to the previous period of approximately the same duration. The graphic representation in Figure 2 clearly shows this; the values of the trend increase in the number of days with temperatures equal to or greater than 35 and 37 ^{o}C have an increase of 31.50 ^{o}C/100 years and 13.59 ^{o}C/100 years. The coefficients of determination R^2=0.311 and R^2=0.3006 indicate that the increases are moderately significant. The growth trends for the analyzed period, 1976-2025, indicate a further increase in this parameter. However, if a longer series of data on the number of days with extremely high temperatures equal to and greater than 35 and 37 degrees is analyzed, for the periods 1887-2025 and 1848-2025, significantly smaller growth values are obtained, and the coefficients of determination indicate that the trends of change are losing significance (Figure 3 and Figure 4).

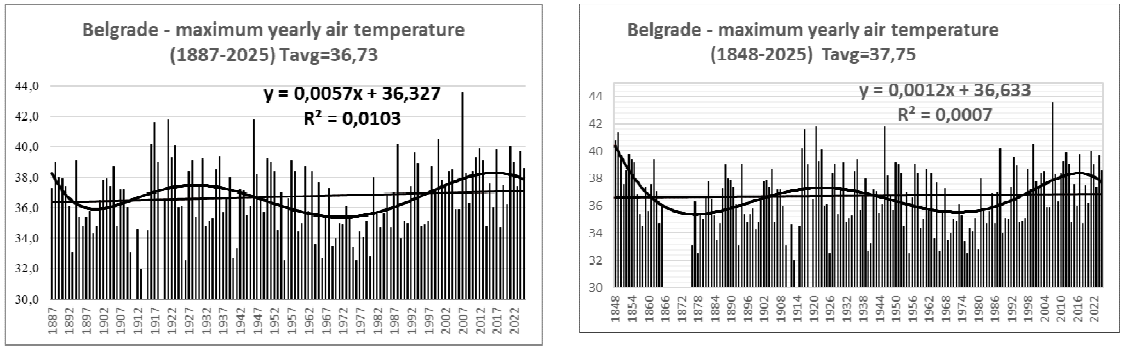

Figure 1. Trends in the highest annual air temperatures in Belgrade (1887-2025, 1848-2025).

Table 3. .Ranking list of the highest average summer air temperatures in Belgrade (1888-2025) (Tavg=21.72 °C)

Rank	Year	Temperature (°C)	Rank	Year	Temperature (°C)
1	2024	26.77	13	1950	23.97
2	2012	25.73	14	1952	23.50
3	2025	25.30	15	2018	23.50
4	2017	25.17	16	2011	23.43
5	2022	24.97	17	2013	23.43
6	2015	24.70	18	1992	23.40
7	2021	24.66	19	1963	23.37
8	2019	24.60	20	2008	23.37
9	2003	24.57	21	1998	23.33
10	1946	24.53	22	1928	23.30
11	2007	24.53	23	1931	23.17
12	2000	24.07	24	1994	23.17

Table 4. Ranking list of the highest daily air temperatures in Belgrade (1888-2025)

Rank	Date	Temperature (°C)	Rank	Date	Temperature (°C)
1	24. 07. 2007.	**43.6**	12	20. 07. 2007.	**40.1**
2	12. 08. 1921.	**41.8**	13	01. 08. 1917.	**40.0**
3	09. 09. 1946.	**41.8**	14	22. 08. 2000.	**40.0**
4	02. 08. 1917.	**41.6**	15	01. 08. 2021.	**40.0**
5	22. 07. 2007.	**40.7**	16	24. 08. 2012.	39.9
6	04. 07. 2000.	**40.5**	17	05. 08. 2017.	39.8
7	11. 08. 1921.	**40.3**	18	09. 08. 1921.	39.7
8	05. 07. 1916.	**40.2**	19	20. 07. 1993	39.6
9	06. 07. 1988.	**40.2**	20	21. 08. 2000.	39.6
10	19. 07.2007.	**40.2**	21	06. 08. 2017.	39.6
11	01. 08. 1923.	**40.1**	22	23. 08. 2012.	39.5

Table 5. Ranking list of the years with the largest number of days with air temperature T≥35 °C in Belgrade (1888-2025), average value 5.30 days

Rank	Year	Number of days	Rank	Year	Number of days
1	2024	34	15	1917	15
2	2017	27	16	1950	15
3	2015	25	17	2022	14
4	2012	24	18	1992	13
5	1946	22	19	1993	12
6	1931	19	20	1894	11

7	2021	19	21	1922	11
8	2025	19	22	1943	11
9	1918	17	23	1952	11
10	1928	17	24	1988	11
11	2000	17	25	2008	11
12	1921	16	26	1998	10
13	1927	16	27	2011	10
14	2007	16	28	2013	10

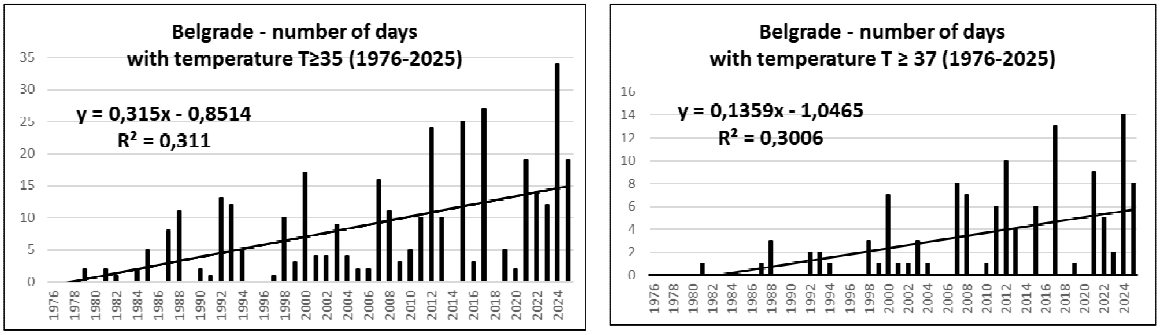

Figure 2. Number of days with air temperatures T≥35 °C and T≥37 °C in Belgrade for the period 1976-2025

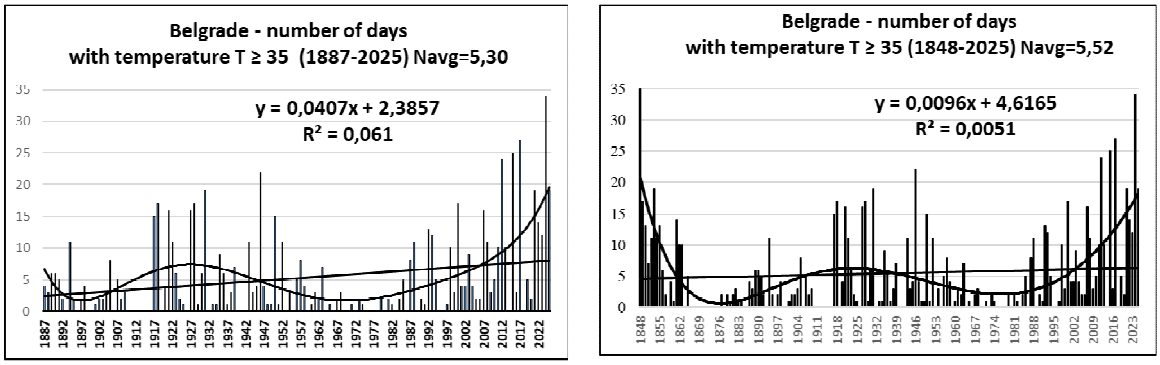

Figure 3. Number of days with air temperature T≥35 °C in Belgrade for the periods 1887-2025 and 1848-2025

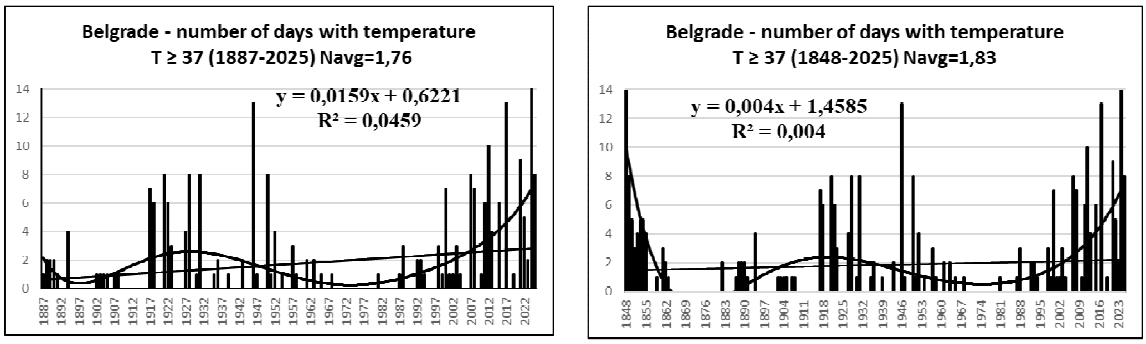

Figure 4. Number of days with air temperature T≥37 °C in Belgrade for the periods 1887-2025 and 1848-2025

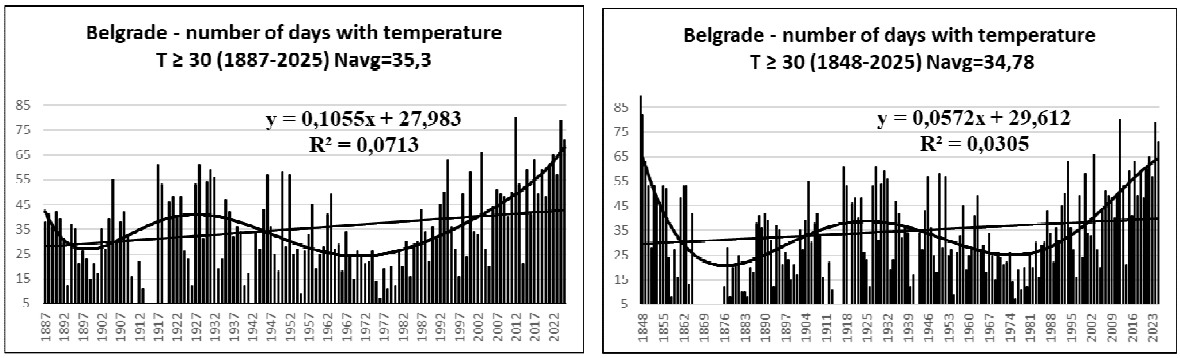

Figure 5. Number of days with air temperature T≥30 °C in Belgrade for the periods 1887-2025 and 1848-2025

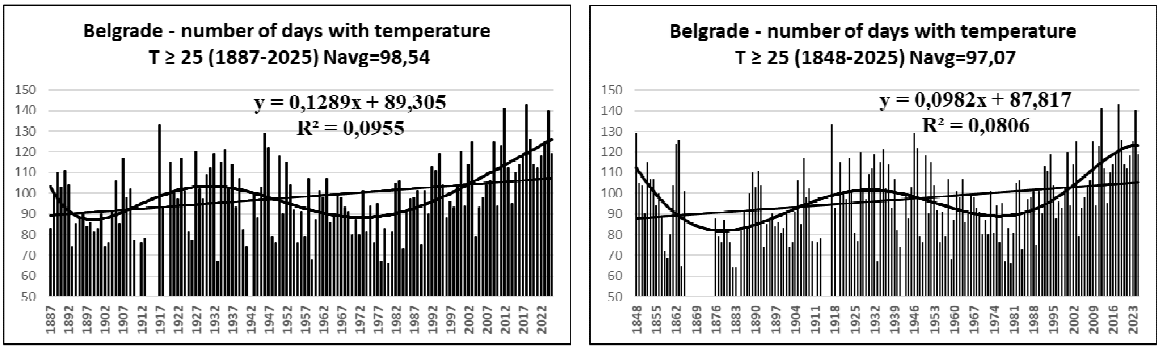

Figure 6. Number of days with air temperature T≥25 °C in Belgrade for the periods 1887-2025 and 1848-2025

A similar pattern is observed in the data series on the number of days with temperatures equal to or greater than 30 and 25 degrees. In Figures 5 and 6, the periodicity of the appearance of these parameters is observed, the decrease in the trend value, and the significance of the change with the extension of the series. In the overview table 6, the trends of changes for the analyzed parameters and different lengths of the series are shown.

Table 6. Trends of change in temperature parameters for different periods

Parameter	Trend of change
Highest annual air temperatures, T (1887-2025)	Y=0,0057x + 36,327 R²=0,0103
Highest annual air temperatures, T (1848-2025)	Y=0,0012x + 36,633 R²=0,0007
Number of days T≥25 (1887-2025)	Y=0,1289x + 89,305 R²=0,0955
Number of days T≥25 (1848-2025)	Y=0,0982x + 87,817 R²=0,0806
Number of days T≥30 (1887-2025)	Y=0,1055x + 27983 R²=0,0713
Number of days T≥30 (1848-2025)	Y=0,0572x + 29,612 R²=0,0305
Number of days T≥35 (1976-2025)	Y=0,315x - 0,8514 R²=0,311
Number of days T≥35 (1887-2025)	Y=0,0407x + 2,3857 R²=0,0612
Number of days T≥35 (1848-2025)	Y=0,0096x + 4,6165 R²=0,0051
Number of days T≥37 (1976-2025)	Y=0,1359x - 1,0465 R²=0,3006
Number of days T≥37 (1887-2025)	Y=0,0159x + 0,6221 R²=0,0459
Number of days T≥37 (1848-2025)	Y=0,004x + 1,4585 R²=0,004

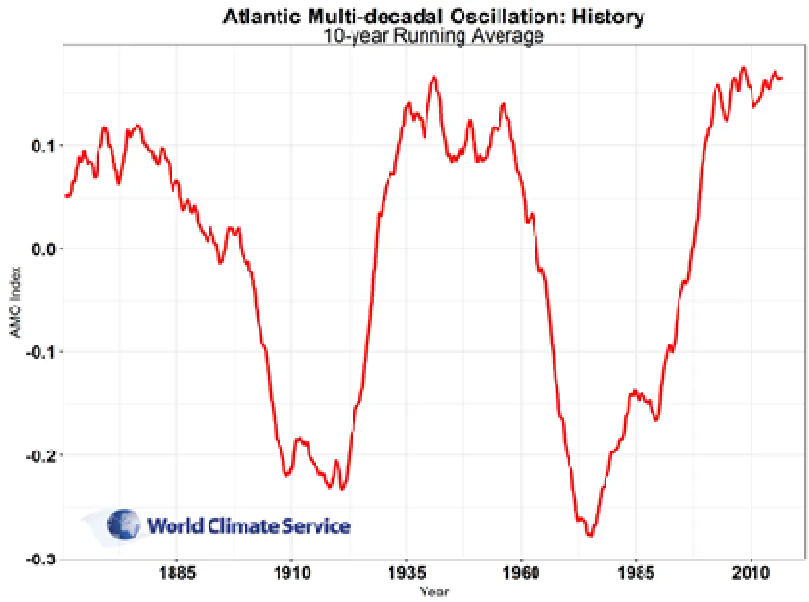

Figure 7. Multidecadal Atlantic Oscillation (AMO).
https://www.worldclimateservice.com/2021/10/11/atlantic-multi-decadal-oscillation/

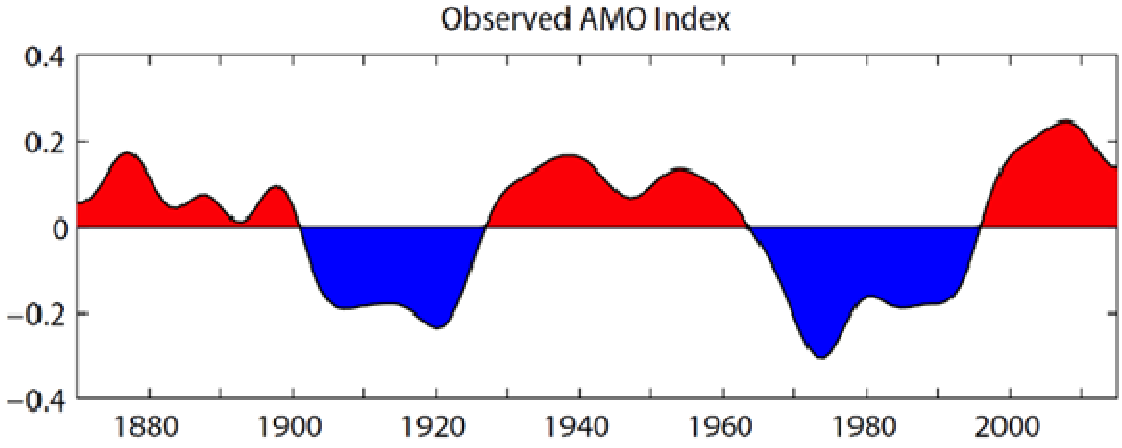

Figure 8. https://climatedataguide.ucar.edu/climate-data/atlantic-multi-decadal-oscillation-amo

The aim of this paper was not to analyze the periodicity of the listed parameters in detail, but to observe a clear graphical similarity with the Atlantic Multidecadal Oscillation (AMO), which has a periodicity of 60 to 80 years. Figure 7 [11] shows the 10-year average values of the moving series of the AMO index. A comparison of the graphs of the data series on the highest annual air temperature and the number of days with temperatures equal to and greater than 25, 30, 35, and 37 degrees in Figures 1, 3, 4, 5, and 6 with the graphical representation of the AMO index shows a great similarity in periodicity (Figure 8).

Processes in the atmosphere are influenced by many factors, and meteorological parameters are one of the indicators. Cyclic, periodic oscillations of air temperature and weather patterns have been observed, in which: North Atlantic Oscillation (NAO), months, years, days, Southern Oscillation (ENSO), several years, Arctic Oscillation (AO, Northern Annular Mode, Northern Hemisphere Annular Mode (NAM)), months, years, days, Pacific Decadal Oscillation (PDO), several decades, Atlantic Multidecadal Oscillation (AMO), 60-80 years, Lunisolar Oscillation (LSO), 9-18 years, and others.

Cycles of Solar Activity and Climate Oscillations: Main Activity Cycle, 11 years, Magnetic Cycle, 22 years, Quasicenturial, 60-130 years, Quasybicenturial, 200-210 years, Quasybimillennial, 2,200-2,500 years, Milankovic cycles, 20,000-40,000 years, Supermillennial, 100,000

Table 7 presents the results of the analysis of the mean dates of the earliest and latest days, as well as the average duration of the period with temperatures equal to or greater than 25, 30, and 35 degrees. Also, the extreme values of these dates and the duration of the periods are given. Table 8 gives the values of the trend changes and their significance. The coefficients of determination indicate that there are no significant changes in the change of the mean dates and the length of the duration periods.

Table 7. Middle, earliest, and latest date of occurrence of the first and last day and duration of the periods with temperatures T≥25, T≥30, and T≥35 ^{o}C in Belgrade (1887-2025)

Air temperature	**T≥25 ^{o}C**	**T≥30 ^{o}C**	**T≥35 ^{o}C**
Middle date of the first day	17.04.	28.05.	15.07.
Middle date of the latest day	13.10.	14.09.	15.08.
Average duration of the period	178,98 days	109,25 days	31,17 days
Duration of the shortest period	118 days, 1902.	29 days, 1976.	0
Duration of the longest period	240 days, 1913.	194 days, 1939.	101 days, 1918.
Earliest date of the first day	03.03.1913.	30.03.1952.	09.06.1891.
The latest date of the last day	21.06.1893.	06.07.1974.	31.08.1944.
Earliest date of the period end	01.09.1971.	22.07.1976.	17.06.1991.
The latest date of the period end	26.11.1963	31.10.1926.	27.09.1918.

Table 8. . Trends in changes in the average, earliest, and latest dates of the first and last day and the duration of the period with air temperatures T≥25, T≥30, T≥35 ^{o}C in Belgrade 1887-2025

Air temperature	**Earliest date**	**Latest date**	**Duration of the period**
T ≥ 25 ^{o}C	y = -0,0936x + 113,43 R² = 0,042	y = 0,071x + 280,78 R² = 0,0474	y = 0,161x + 167,41 R² = 0,0823
T ≥ 30 ^{o}C	y = -0,0229x + 148,99 R² = 0,0023	y = -0,0346x + 259,18 R² = 0,0065	y = -0,0117x + 110,2 R² = 0,0003
T ≥ 35 ^{o}C	y = -0,0955x + 202,76 R² = 0,0358	y = -0,0324x + 229,59 R² = 0,0046	y = 0,0634x + 26,536 R² = 0,0085

4. Conclusion

Summer heat in Belgrade is a feature of Serbia's temperature of continental climate. Instrumental data on air temperature from the Belgrade Meteorological Observatory at Vračar for the period 1887-2025 were used for the analysis. To extend the series and better observe the trend of change, corrected and reconstructed data for the period 1848-1887 from the Senjak measuring station in Belgrade were used. Analysis of extreme values of daily, monthly, and annual air temperatures, as well as the dates of the first and last days with temperatures equal to or higher than 25, 30, 35, and 37 degrees, reveals that extreme summer temperatures are a common meteorological phenomenon in Belgrade. Temperature parameters have a slight upward trend. The trend values are not significant, and their values decrease for higher temperatures. Shorter series have a

greater upward trend, and longer series have a significantly lower one. The duration of periods with appropriate temperatures does not change significantly. Summer temperatures have multi-decadal variability and a periodicity that is largely consistent with the Atlantic Multi-decadal Oscillation (AMO).

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nedeljko52@yahoo.com