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ANALYSIS OF DAY-TO-DAY VARIATIONS IN AIR TEMPERATURE IN THE REGION OF SIEDLCE

Elżbieta Radzka[1]✉ 0000-0003-4728-4779, Marlena Radzka[2], Maria Markowska[3]

[1] Faculty of Agrobioengineering and Animal Husbandry, University of Siedlce, Prusa 14, 08-110 Siedlce, Poland
[2] Student of Medical University of Łódź, Kościuszki 4, 90-419 Łódź, Poland
[3] Centre for Foreign Languages, University of Siedlce, 3 Maja 54, 08-110 Siedlce, Poland

ABSTRACT

Aim of the study

As a result of the increase in average air temperature associated with the present-day climate change, heatwaves are forecast to occur with increasing frequency. What is more, they will be longer, more intense, and potentially very dangerous for human health and life. The present work reports the day-to-day variation in air temperature and the variation of thermally characteristic days in Siedlce from 2001 to 2023.

Materials and Methods

Day-to-day values of average and maximum air temperatures were obtained from the Siedlce Meteorological Station of the Institute of Meteorology and Water Management – National Research Institute (IMGW-PIB). The day-to-day variation in air temperature was determined across six ranges, and their frequencies in each month were calculated. Additionally, based on the maximum temperature, the number of thermally characteristic days (from cold to hot) was identified, and sequences of hot and very hot days were determined. The direction of trends in the number of hot and very hot days was also established.

Results and Conclusions

In the Siedlce region, days marked by significant day-to-day temperature changes occurred on average 4.8 days per year, and they were the most frequent in January (5.5 days/year) and least frequent in October (3.7 days/year). Significant strain on the body due to day-to-day variation in temperature, ranging from 6 to 9°C, was recorded on about 0.5 days per year, on average. In 2001–2023, there were 39 hot days and 9 very hot days per year, on average. When comparing the number of hot and very hot days between the periods 2001–2012 and 2013–2023, an increase of about 6 hot days and 3 very hot days was observed. The trend coefficients for these changes were also positive, amounting to 0.43 and 0.24 days, respectively. In each month of the warm season (April to September), sequences of hot days occurred, while very hot days did not occur only in April and May. The most frequent were sequences of hot days that were 4 to 6 days long.

Keywords: day-to-day temperature change, maximum temperature, very hot days, hot days, changing trends, Siedlce

✉e-mail: elzbieta.radzka@uws.edu.pl

INTRODUCTION

According to the World Health Organization (WHO) definition, "Health is a state of complete physical, mental, and social well-being, and not merely the absence of disease or infirmity" (WHO 2005). Climate change has negative health consequences, and poses a significant challenge to public health. Over the past 50 years, there has been observable increase in the frequency of extremely high temperatures and a decrease in the occurrence of frosty cold waves. Due to the rise in average air temperature, present-day climate change and changes in atmospheric circulation over Europe, such phenomena are forecast to occur with increased frequency, resulting in longer, more severe heatwaves that will pose a threat to human health and life (Kyselý, 2008; Kyselý, Huth, 2008). A maximum temperature of over 25°C indicates a hot day; a maximum temperature above 30°C indicates a very hot day; and several consecutive very hot days constitute a heatwave. These are certainly not health-enhancing days. Heatwaves in Poland most frequently occur when a high-pressure system persists over Central and Eastern Europe, causing an influx of very warm tropical air masses from the south, or continental polar air masses from the east (Wibig et al., 2009; Tomczyk, 2014). In Poland, heatwaves occur from May to September (Koźmiński and Michalska, 2011; Krzyżewska and Wereski, 2011). In the past, particularly long and oppressive heatwaves occurred in the years 1963, 1994, 2006, 2010, and 2015 (Kuchcik, 2006; Wibig et al., 2009; Krzyżewska, 2015; Sulikowska et al., 2016).

The WHO estimates that temperature changes result in over 140,000 deaths annually (Harris et al., 2017). It is anticipated that by 2030, this number will increase by 250,000 annually (WHO 2017) due to a temperature rise of over 4°C compared to pre-industrial times (Watts et al., 2019). During the heatwave in August 2003, more than 70,000 additional deaths occurred in Western Europe (Robine et al., 2008). It is estimated that mortality increases by 0.2–5.5% for each unit increase in temperature above a certain threshold (Menne and Ebi, 2006). Assuming an average global temperature rise of 3°C (in the period 2071–2100), Europe could potentially record 86,000 additional deaths annually (PESETA, 2009). Particularly vulnerable to high temperatures are the elderly (over 65 years), children, pregnant women, and individuals with cardiovascular and respiratory diseases (Semenza and Menne, 2009). Pregnant women under thermal stress (high temperatures) have an increased risk of pregnancy toxemia, including pre-eclampsia and eclampsia. There is a particular increase in the risk of preterm birth and low birth weight during the second and third trimesters as a result of heatwaves. Pregnant and breastfeeding women are also more susceptible to renal problems due to thermal stress (Watts et al., 2019). Individuals with pre-existing mood and anxiety disorders may experience exacerbated mental health problems caused by extremely high temperatures (Cervellin et al., 2014; Vida et al., 2012). A rapid increase in suicide rates has been observed following a rise in temperatures (Linkowski et al., 1992; Cohn et al., 2004; Lin et al., 2008). Obradovich et al. (2018) claim that an increase in temperature within the range of 25 to 30°C and above raises by 0.5% the probability of mental health issues. Nitschke et al. (2011) report that heatwaves increase hospital admission rates due to mental disorders, with Accident and Emergency visits rising by 5–10%. High temperatures, often referred to as the "silent killer," cause numerous deaths, especially among the elderly (Díaz et al., 2002a and 2002b; Kozłowska-Szczęsna et al., 2004; McMichael et al., 2006). It has been observed that during heatwaves, there is an increase in the number of deaths due to cardiovascular and respiratory failure (Kozłowska-Szczęsna et al., 2004), as well as symptoms related to dehydration and heatstroke (Semenza et al., 1999; Naughton et al., 2002).

In Polish literature, there have been studies on heatwaves, their characteristics, and forecasts (Wibig et al., 2009; Kossowska-Cezak and Skrzypczuk, 2011; Matuszko and Piotrowicz, 2012; Batko and Twardosz, 2013; Kuchcik, 2013; Twardosz and Kossowska-Cezak, 2013), which employed various methods and covered different regions. Significant day-to-day temperature changes also play a marked role, as they lead to poorer well-being and a tendency toward aggressive behaviour or flagging concentration. Due to the increasing frequency of these weather anomalies, a growing number of people are exposed to their effects (Krzeszowiak and Pawlas, 2015).

The aim of this study is to determine the day-to-day variation in air temperature and the number of thermally characteristic days in Siedlce in the years 2001–2023.

Fig. 1. Geographical location of Siedlce (source: Strategia rozwoju…, 2016)

MATERIALS AND METHODS

Siedlce (52°10′03″N, 22°17′24″E, 150 metres above sea level) is located on the Siedlce Plateau, within the South Podlasie Lowland, in the eastern part of the Mazowsze Region (Fig. 1).

In terms of climate, this area is located in the Mazowsze-Podlasie climatic region where continental influences prevail. The region's climate is characterised by a fairly long, early-starting summer and a longer-than-average winter. The average monthly air temperature ranges from about 4.5°C (January) to about 18°C (July). The annual precipitation sum lies within the range of 500–600 mm. As is the case with the entire country, there is a predominance of westerly and north-westerly winds here. The growing season lasts 190 to 200 days, and the number of days with snow cover ranges from 80 to 100 days (Kondracki, 2001).

The meteorological data from the years 2001–2023 was obtained from the Meteorological Station in Siedlce of the Institute of Meteorology and Water Management – National Research Institute in Warsaw. The data pertains to the average daily (24-hour) and maximum air temperatures. To determine the range of day-to-day air temperature changes, the classification proposed by Kostrzewski (1961) was used (Tab. 1).

Table 1. Classification of day-to-day air temperature changes (source: Kostrzewski, 1961)

Class (°C)	Change
from 0 to 3.0	mild
from 3.1 to 6.0	fairly notable
from 6.1 to 9.0	notable
from 9.1 to 12.0	large
from 12.1 to 15.0	very large
more than 15.0	violent

The number of days with day-to-day temperature changes was calculated within each range, and their frequency in each month was determined. Additionally, during the warm half-year (April-September), thermally characteristic days were identified based on the maximum daily air temperature using the methodology offered by Koźmiński and Michalska (2011) (Tab. 2).

Table 2. Classification of thermally characteristic days (source: Koźmiński and Michalska, 2011)

Max. temp. classes (°C)	Description (abbrev.)
less than 10.0	cold (C)
from 10.1 to 15.0	cool (CL)
from 18.1 to 23.0	warm (W)
from 25.1 to 30.0	hot (H)
more than 30.0	very hot (VH)

The trend in the number of hot and very hot days was determined based on linear regression equations and changes in the long-term periods of 2001–2012 and 2013–2023. Sequences of hot and very hot days ("hot weather" and "heatwave") were identified. A sequence of hot days was defined as at least three consecutive days with a maximum temperature in the range of 25.1–30.0°C, and a sequence of very hot days as at least three days with a maximum temperature above 30°C. If, during a sequence of hot days, one or two days had a maximum temperature above 30°C, those days were included in the sequence of hot days. If three days with a maximum temperature above 30°C occurred, they initiated a sequence of very hot days.

RESULTS AND DISCUSSIONS

The air temperature is affected by an influx of solar energy, and depends on the time of day, season, and geographical location. Changes in thermal stimuli are particularly important for the functioning of the human body.

The analysis of the discomfort of thermal conditions in terms of changes in day-to-day air temperatures showed that most common (on average 24 days per year) are the days when the day-to-day temperature difference is up to 3°C (Fig. 2 and 3). In the Siedlce region, days with fairly significant burden of day-to-day temperature changes occurred on average 4.8 days per year. Such changes were most frequent in January (5.5 days/year) and least frequent in October (3.7 days/year). Significant strain on the body due to day-to-day temperature variation, ranging from 6 to 9°C, was recorded on about 0.5 days per year, on average. These occurred the most frequently in January (0.9 days/year) and March (0.8 days/year), and the least frequently in June (0.2 days/year). Substantial day-to-day temperature changes (9–12°C) were found to be very rare, occurring only in February (0.1 days/year) and September (0.2 days/year). In turn, very large and abrupt temperature changes were not present in Siedlce in the long-term period studied.

Panfil and Dragańska (2009) found that the average annual number of days with large (≥6°C) changes in day-to-day air temperature in north-eastern Poland exhibited significant spatial variation. Chabowska et al. (2022) argue that the average number of days with day-to-day temperature changes of 3–6°C per year exceeds 18 in most areas of Poland. The analysis also indicated a lesser strain on the human body in western Poland compared to eastern regions. These authors have demonstrated that the analysis of the slope of the linear function for day-to-day temperature changes of over 6°C indicates an absence of a significant trend in this indicator in Poland over the studied period.

Analysis of characteristic days in Siedlce over the studied long-term period revealed that on average, cold days occurred most frequently in April (9.8 days); warm days in May (12 days) and September (9.5 days); and hot days in June (10.1 days), July (12.0 days), and August (9.9 days) (Fig. 4, Tab. 3). The maximum number of very hot days in Siedlce was recorded in August (11 days), and hot days in July (22 days). There were no very hot days in April only, whereas hot days were observed in all months of the warm season (April-September). Cold and cool days were observed most frequently in April, with 7.0 and 9.8 days, respectively. Analysis of the trend in the number of hot and very hot days showed a year-to-year increase. The number of hot days increased by 4.3 days over 10 years, and very hot days by 2.4 days over 10 years, on average. Comparing the long-term period of 2001–2012 with 2013–2023, an increase was observed both in the number of hot days from 36.2 to 41.8, and in the number of very hot days from 7.8 to 10.6 days. Also Cebulak and Limanówka (2007) have pointed to an uptrend in the number of these days in the years 1951–2005 over a significant part of the country, and Michalska and Mąkosza (2007) identified a significant positive trend in the number of very hot days in the Szczecin Lowland. Chabowska et al. (2022) have demonstrated a growing trend in the number of very hot days in subsequent years across almost the entire area of Poland, driven by progressing climate change. An analysis conducted by Błażejczyk et al. (2015) of an occurrence of very hot days in the years 1973–2014 showed a statistically significant increasing trend in the number of days with high air temperatures in Poland.

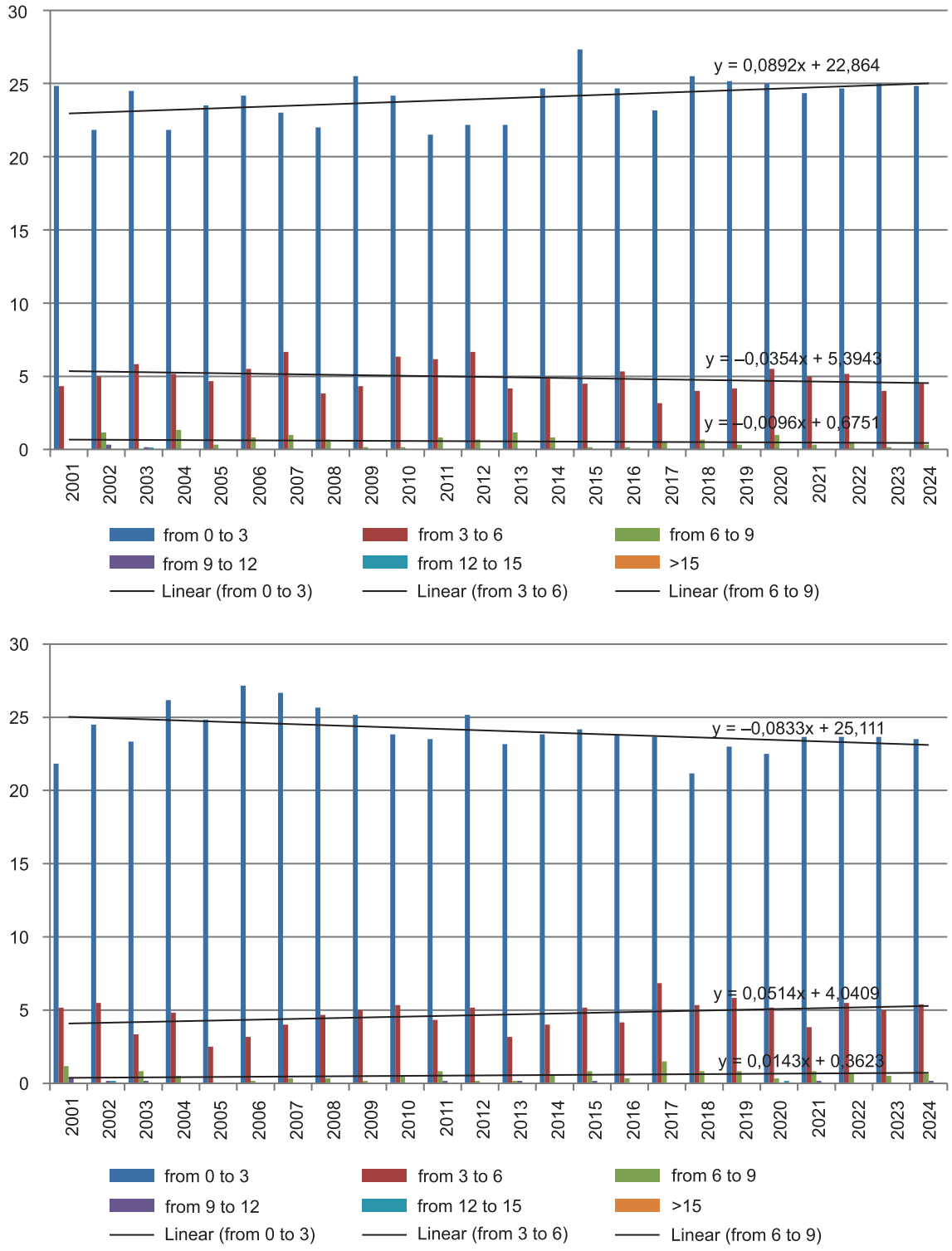

Fig. 2. Number of days with day-to-day air temperature difference (January–June and July–December) in Siedlce in the years 2001–2023 (source: Authors' own elaboration)

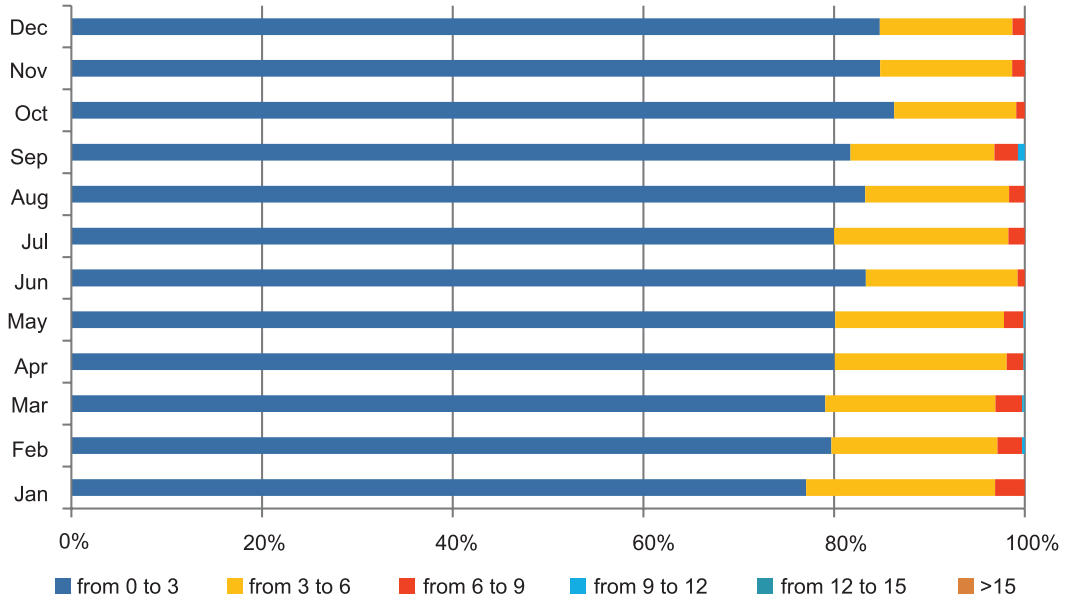

Fig. 3. Structure of day-to-day air temperature variation ranges in Siedlce from 2001 to 2023 (source: Authors' own elaboration)

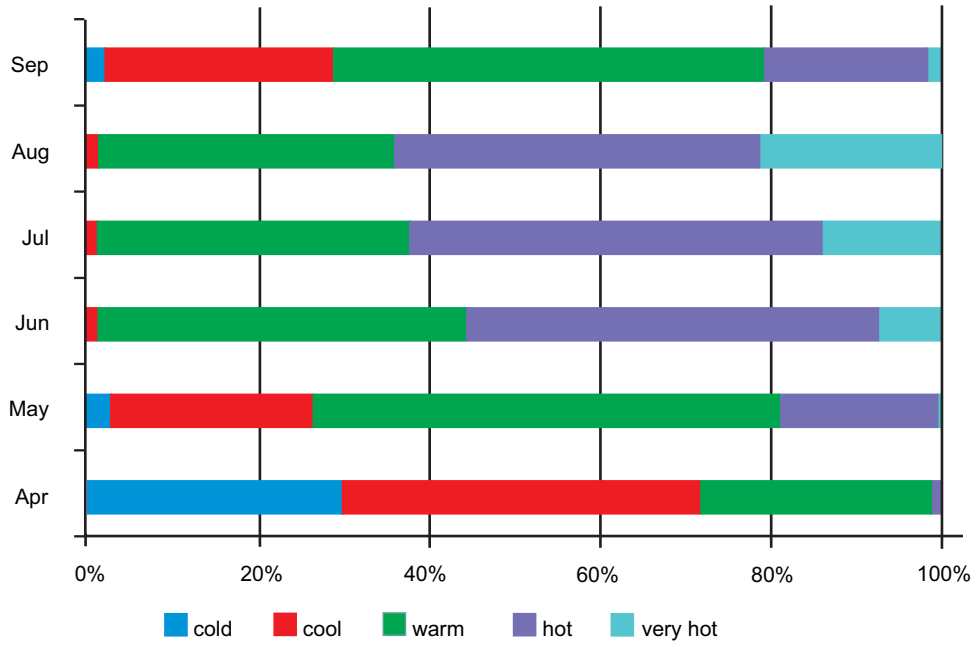

Fig. 4. Structure of the number of cold (C), cool (CL), warm (W), hot (H) and very hot (VH) days in the warm season (April–September) in Siedlce from 2001 to 2023 (source: Authors' own elaboration)

Table 3. The minimum, maximum and average values as well as the standard deviation of cold (C), cool (CL), warm (W), hot (H) and very hot (VH) days in Siedlce in 2001–2023 (source: Authors' own elaboration)

	April	May	June	July	August	September
			Minimum			
C	2.0	0.0	0.0	0.0	0.0	0.0
CL	4.0	1.0	0.0	0.0	0.0	0.0
W	1.0	7.0	1.0	2.0	3.0	6.0
H	0.0	1.0	5.0	8.0	5.0	0.0
VH	0.0	0.0	0.0	0.0	0.0	0.0
			Maximum			
C	13.0	2.0	0.0	0.0	0.0	2.0
CL	20.0	8.0	1.0	2.0	2.0	14.0
W	15.0	16.0	15.0	15.0	14.0	15.0
H	2.0	10.0	18.0	22.0	15.0	15.0
VH	0.0	1.0	7.0	9.0	11.0	1.0
			Average			
C	7.0	0.6	0.0	0.0	0.0	0.4
CL	9.8	5.2	0.2	0.3	0.3	5.1
W	6.3	12.0	9.1	9.1	8.0	9.5
H	0.3	4.1	10.1	12.0	9.9	3.6
VH	0.0	0.1	1.5	3.5	4.9	0.3
			Standard Deviation			
C	4.0	0.8	0.0	0.0	0.0	0.7
CL	4.6	2.4	0.4	0.8	0.6	3.8
W	4.1	2.9	3.7	4.4	3.4	2.6
H	0.7	3.0	4.2	4.6	3.0	4.1
VH	0.0	0.3	2.2	2.7	3.6	0.3

Table 4. Equations representing the trend of changes and averages across the years 2001–2012 and 2013–2023 for the number of hot and very hot days (source: Authors' own elaboration)

	Regression equation	R^2	Average across 2001–2012	Average across 2013–2023
Number of hot days	Y = 0.43 + 33.73	0.08	36.2	41.8
Number of very hot days	Y = 0.24 + 6.20	0.10	7.8	10.6

In each month (April–September), there were sequences of hot days lasting from 4 to 6 days (Fig. 5a), the highest number of such sequences being recorded in July (20 sequences). There were no sequences of hot weather lasting 7-9 days recorded in April or May. The longest sequences of such days, extending for more than ten days, occurred only in July (6 days) and August (2). The longest sequences of hot days lasting 19, 17, and 16 days were recorded in July in the years 2014, 2003, and 2023, respectively. Heatwaves, or sequences of very hot days, occurred in June, July, August, and September. In June, the shortest sequences of very hot days (<3 days and 4–6 days) were observed with an average frequency of one sequence per month. July was the month with the highest occurrence of heatwaves. On average, this month saw as many as 6 sequences of very hot days lasting <3 days, 4 sequences of 4–6 days, and also one sequence of 7–9 days. In August, over the studied long-term period, there were 4 sequences of <3 days, 4 sequences of 4–6 days, and also one sequence extending over 10 days in 2015. Krzyżewska and Wereski (2011), who examined an occurrence of heatwaves in the years 2000–2010 in Poland, pointed out that the most frequent and longest-lasting were heatwaves in the bioclimatic central region, which includes the western and central parts of the country.

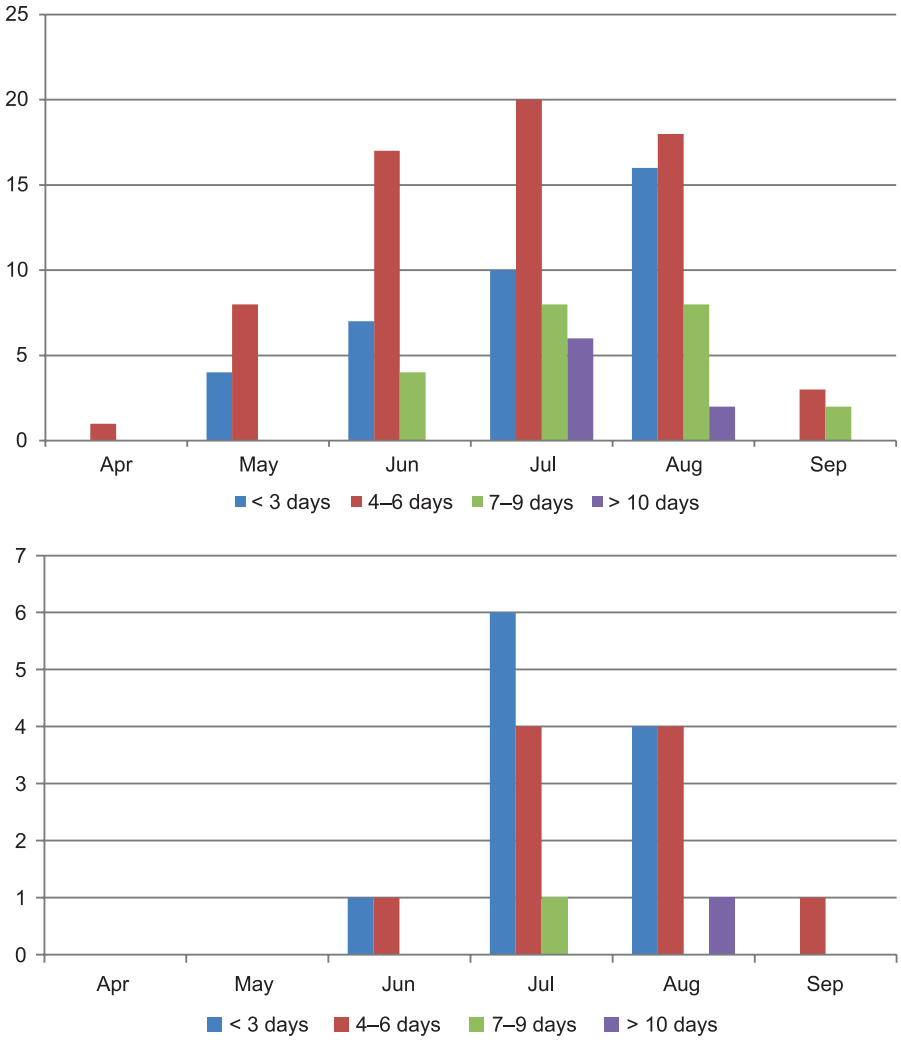

Fig. 5. The number of sequences of hot days (a) and very hot days (b) in the long-term period of 2001–2023 in Siedlce (source: Authors' own elaboration)

CONCLUSIONS

Temperature variability from day to day and heatwaves are significant aspects of climate that affect many areas of life. Climate change contributes to more frequent and intense heatwaves, as confirmed in this study.

1. The greatest changes in the average daily air temperature of less than 3°C in Siedlce occurred in October, November, and December (on average, 25 days in each month). Moderate variation (from 3.1 to 6.0°C) was most common in January and July (on average, 5.5 days in each month) while substantial variation (from 6.1 to 9.0°C) was observed in January (0.9 days).
2. On average, between 2001 and 2023, there were 39 hot days and 9 very hot days per year. The year 2018 saw the highest number of hot days in the studied period (64 days), whereas in 2010 and 2015 as well as 2019 and 2022 there were the highest numbers of very hot days (respectively, 17 and 16 days). Cold and cool days were most frequent in April (respectively, 7.0 and 9.8 days).
3. Comparing the number of hot and very hot days between 2001–2012 and 2013–2023, there was an increase of approximately 6 hot days and 3 very hot days. Additionally, the slopes of the trend for the changes were positive, with values of 0.43 and 0.24 days, respectively.
4. In each month of the warm season (April–September), sequences of hot days were observed, while very hot days were absent in April and May only. The most frequent sequences were those lasting from 4 to 6 days. The longest sequence of hot days in the studied period was recorded in July 2023, lasting 17 days. For very hot days, the longest sequence occurred in August 2015 and it lasted 11 days.

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ANALIZA DOBOWYCH ZMIAN TEMPERATURY POWIETRZA W REJONIE SIEDLEC

ABSTRAKT

Cel badań
W wyniku wzrostu średniej temperatury powietrza, co jest związane ze współczesnymi zmianami klimatycznymi, prognozuje się coraz częstsze występowanie fal upałów. Co więcej, będą one coraz dłuższe, bardziej intensywne i potencjalnie bardzo niebezpieczne dla zdrowia i życia ludzi. W pracy przedstawiono dobowe zmiany temperatury powietrza oraz charakterystycznych termicznie dni w Siedlcach w latach 2001–2023.

Materiały i metody
Dobowe wartości średnich i maksymalnych temperatur powietrza uzyskano ze Stacji Meteorologicznej w Siedlcach, prowadzonej przez Instytut Meteorologii i Gospodarki Wodnej – Państwowy Instytut Badawczy (IMGW-PIB). Wyznaczono dzienne wahania temperatury powietrza w sześciu zakresach i obliczono ich częstość w poszczególnych miesiącach. Dodatkowo na podstawie temperatury maksymalnej określono liczbę dni charakterystycznych termicznie (od zimnych do gorących) oraz wyznaczono sekwencje dni gorących i bardzo gorących. Ustalono także kierunek tendencji w liczbie dni gorących i bardzo gorących.

Wyniki i wnioski
W regionie siedleckim dni charakteryzujące się dużymi dziennymi zmianami temperatury występowały średnio 4,8 dnia w roku, przy czym najczęściej w styczniu (5,5 dnia/rok), a najrzadziej w październiku (3,7 dnia/rok). Średnio przez około 0,5 dnia w roku występowało znaczne obciążenie organizmu na skutek codziennych wahań temperatury w zakresie od 6 do 9°C. W latach 2001–2023, w ciągu jednego roku odnotowano średnio 39 dni upalnych i 9 dni bardzo upalnych. Porównując liczbę dni upalnych i bardzo upalnych pomiędzy okresami 2001–2012 i 2013–2023, zaobserwowano wzrost o około 6 dni upalnych i o około 3 dni bardzo upalne. Współczynniki trendu dla tych zmian również były dodatnie i wyniosły odpowiednio 0,43 i 0,24 dnia. W każdym miesiącu sezonu ciepłego (od kwietnia do września) występowały sekwencje dni upalnych, przy czym dni bardzo upalne nie pojawiły się tylko w kwietniu i maju. Najczęściej występowały sekwencje dni upalnych trwające od 4 do 6 dni.

Słowa kluczowe: dobowe zmiany temperatury, temperatura maksymalna, dni bardzo upalne, dni upalne, zmiana trendów, Siedlce