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Changes in Air Temperature in Poland at Around Noon in the Years 1951-2018

Abstract: The paper characterises the variability of thermal conditions in Poland at around noon in the years 1951–2018. Based on the data from Kołobrzeg, Poznań and Kraków, the average monthly, seasonal and annual values of air temperature were calculated along with standard deviation, maximum and minimum temperature values, as well as the average values of temperature in the consecutive decades of the studied period. Moreover, values of linear trends were determined along with statistical significance at a level of 0.05, as well as values of the deviations of temperature from a long-term average, which were smoothed by means of 10-year moving averages. The research indicated a statistically significant increase in air temperature, both annual and in individual seasons. Particularly noticeable warming was noted in the winter-spring period, especially in Krakow; the smallest one occurred in autumn. The increase in temperature in the studied years was influenced mostly by the years 2011–2018. Also, higher contrast of thermal conditions compared to other seasons of the year was observed in the winter-spring season.

Keywords: climate warming, air temperature, long-term variance, linear trend, Poland, hours around noon

1. Introduction

Climate changes observed nowadays on Earth manifest themselves primarily by the increasing air temperature. The research indicates that compared to the pre-industrial age, the average global temperature of the planet increased by about 1.0°C, which was caused primarily by the activity of man (IPCC, 2014, 2018). Climate changes in specific parts of Earth proceed at various rates and they have a varying nature. In Central Europe, a clear increase in temperature was noticed starting from the mid-19th century, which is considered the beginning of contemporary warming (Obrębska-Starklowa, 1997). Studies on climatic changes in Poland indicate that since the 1950s there has been a statistically significant increase in the average annual air temperature in the entire country, and the rate of this warming slightly exceeded 0.2°C per 10 years, reaching its maximum between winter and spring (Michalska, 2011; Wójcik and Miętus, 2014).

An increase in temperature is associated with serious consequences both for the functioning of the entire society, as well as for the health and life of individuals. The risks include primarily an increased number of illnesses and deaths related to adverse weather conditions, i.e. excessive mortality caused by heats, increased risk of skin cancer, presence of invasive carriers of infectious diseases, early and increased seasonal production of allergic pollens, or more frequent and rapid occurrences of extreme weather events, such as strong winds, storms, floods or droughts (Kundzewicz, 2012; Błażejczyk et al., 2015; Gawlik, 2015). The recorded increase in air temperature on an annual or monthly basis also means that warming is also to be expected at hours around noon, which is the time of most intense human activity during the day. Therefore, it seems important to investigate whether this time of the day undergoes changes at a larger or smaller scale, and what the nature of these changes is. The objective of research was thus to determine the magnitude and specifics of changes in air temperature during hours around noon, both yearly and in the individual seasons of the year and months.

2. Research area and methods

The research material consisted of data obtained from the Polish Institute of Meteorology and Water Management – National Research Institute (IMGW-PIB), and involved air temperature (°C) from three meteorological stations: in Kołobrzeg, Poznań and Kraków, from 12 p.m. UTC, from each day of the years 1951–2018 (https://dane.imgw.pl/data/dane_pomiarowo_obserwacyjne). These are synoptic stations (Poznań and Kraków – first order, Kołobrzeg – second order), taking measurements continuously using automatic equipment. The station grounds ensure the representativeness of measurements and observations, and the measurements are performed in a meteorological garden. Air temperature is measured in a meteorological cage, and the instruments themselves are located 2 m above the ground level. This data was averaged for individual months, seasons and years. The stations were chosen based on the availability of homogeneous series of data in order to demonstrate variability of air temperature in northern, central and southern Poland (Table 1).

Table 1. Geographic location of stations

Station	φ	λ	Hs [m a.s.l.]
Kołobrzeg	54°11'N	15°35'E	5
Poznań-Ławica	52°25'N	16°50'E	86
Krakow-Observatory	50°03'N	19°49'E	220

Kołobrzeg represents the stretch of the Southern Baltic Coasts. It is located on the Slovincian Coast (the Koszalin Coastland macroregion), at the mouth of the Parsęta river flowing into the Baltic Sea. Here the average annual air temperature is 8.1°C, and the average monthly temperatures – the warmest and the coldest – are 16.9°C (July and August) and -0.4°C (January), respectively (Kozłowska-Szczęsna et al., 2002). The measurement station in Kołobrzeg is located between the town and the health resort, in the vicinity of low but densely distributed single-family buildings.

Poznań is located within the Poznań Lake District, which is a part of the Greater Poland Lakeland featuring not particularly diverse land relief (Kondracki, 2002). The average air temperature in Poznań is 9.0°C. July is the warmest month, with an average temperature of 19.0°C, with January being the coldest, when the monthly average drops to -0.7°C (Grajewski and Pacholczyk, 2012). The meteorological station is placed in the Poznań-Ławica airport, located in the western, peripheral part of the city. The area around the meteorological garden is flat, lacking any natural or artificial obstacles.

Kraków is located at the meeting point of several geographic regions: the Kraków Gate, the Oświęcim Basin, the Sandomierz Basin, the Western Beskidian Foothills, the Kraków-Częstochowa Upland (Kondracki, 2002). Here the average annual air temperature is 8.3°C. July is the warmest month, with an average air temperature of 18.5°C; January is the coldest, when the monthly average is -2.1°C (Kuchcik, 2017). The paper uses data from the Kraków-Observatory meteorological station located approximately 2 km away from the centre of the city, in the area of the left river terrace of the Vistula. The direct surroundings of the station consist of park greenery; slightly further away there are typical city buildings distributed along streets with high intensity of road traffic (Piotrowicz et al., 2011).

The average monthly, seasonal and annual values of air temperature were calculated along with standard deviation based on the data from 12 p.m. UTC; the highest and lowest temperature values were determined. The average values of temperature in the consecutive decades of the studied period were also calculated. Using the linear regression analysis, the values of linear trends were calculated and their statistical significance at a level of 0.05 was determined based on the parametric t-Student test. The occurring temperature anomalies were analysed using the deviations of temperature values from the long-term average, which were subsequently smoothed by means of 10-year moving averages.

3. Results

The average yearly values of air temperature at 12 p.m. UTC in the years 1951–2018 ranged from 10.1°C in Kołobrzeg to 12.3°C in Kraków, while the calculated values of deviation indicate that at the time Krakow featured more diverse thermal conditions than the coastal area. Average annual temperature values for the individual seasons indicate that the greatest differences between stations at hours around noon occurred in spring, with the smallest ones in autumn and winter, and Krakow was the warmest station throughout the year (Table 2).

Although Kraków was on average a thermally privileged station, it featured the lowest minimum values in the spring-summer period of all the investigated stations, while the lowest minima in autumn and winter at 12 p.m. UTC were recorded in Poznań. On the other hand, midday maxima in all seasons of the year had their highest values in Kraków, where they exceeded 30.0°C almost the entire year with the exception of winter (Table 2).

August was the month with the highest air temperature at 12 p.m. UTC in Kołobrzeg, with an average value of 19.6°C and a maximum reaching 36.9°C; in Poznań it was July, characterised by an average air temperature of 22.3°C and a maximum of 36.2°C. In Kraków, the same values of average monthly air temperature amounting to 23.0°C were recorded in July and August, while the maxima were 35.4°C in July and 36.9°C in August, respectively. On the other hand, the lowest air temperatures at hours around noon were measured in January, with monthly averages of 0.7°C in Kołobrzeg, -0.1°C in Poznań, 0.1°C in Kraków and min-

Table 2. Monthly, seasonal and annual values of air temperature, standard deviation as well as minimum and maximum air temperature [°C] at 12 p.m. UTC in the years 1951–2018 (Author's own calculation based on IMGW data obtained from https://dane.imgw.pl/data/dane_pomiarowo_obserwacyjne)

	Kołobrzeg				Poznań				Kraków			
	$t_{śr}$	σ	t_{min}	t_{max}	$t_{śr}$	σ	t_{min}	t_{max}	$t_{śr}$	σ	t_{min}	t_{max}
January	0.7	4.3	-17.1	12.7	-0.1	5.1	-22.2	13.4	0.1	5.7	-18.6	17.1
February	1.5	4.1	-16.1	16.8	1.2	5.0	-19.4	16.2	1.8	5.7	-21.8	20.3
March	4.6	4.1	-8.4	22.4	5.8	5.1	-12.2	22.6	6.6	5.9	-11.1	23.8
April	8.6	4.7	-1.0	28.4	11.9	5.4	-1.6	29.7	13.0	5.9	-0.8	30.7
May	13.0	4.6	1.8	30.7	17.3	5.2	0.4	30.6	18.2	5.5	1.6	33.1
June	16.7	3.8	7.3	33.1	20.5	4.7	8.9	35.2	21.2	4.9	7.3	33.9
July	19.3	3.4	10.2	34.7	22.3	4.7	9.5	36.2	23.0	4.8	10.4	35.4
August	19.6	3.4	11.3	36.9	22.1	4.4	11.0	36.2	23.0	4.8	9.8	36.9
September	16.5	3.4	6.5	31.4	17.7	4.4	7.4	33.9	18.5	4.9	6.2	34.7
October	11.8	3.6	0.6	25.7	12.1	4.4	-2.2	27.6	13.2	5.2	-1.1	27.4
November	6.0	3.6	-8.0	19.3	5.6	4.3	-10.1	19.3	6.5	5.1	-8.4	23.1
December	2.2	4.1	-18.1	13.2	1.4	4.6	-19.1	14.6	1.7	5.0	-18.7	18.6
spring	11.5	5.6	-2.4	32.9	15.1	6.6	-5.7	35.0	16.0	6.8	-7.2	33.9
summer	18.7	3.5	7.9	36.9	21.1	4.8	9.1	36.2	22.0	5.1	7.2	36.9
autumn	8.0	5.5	-11.7	25.7	7.8	6.4	-15.7	27.6	8.7	7.1	-14.8	30.2
winter	1.8	4.4	-18.1	19.2	1.5	5.3	-22.2	20.1	1.9	6.0	-21.8	22.8
year	10.1	7.8	-18.1	36.9	11.5	9.4	-22.2	36.2	12.3	9.8	-21.8	36.9

imum values of -17.1°C, -22.2°C and -18.6°C, respectively. The values of standard deviation for the individual months also proved that thermal diversity at noon was higher during the winter-spring period compared to summer (Table 2).

An analysis of air temperature at hours around noon in the consecutive decades indicates a noticeable warming at the beginning of the 21st century (Table 3). In all stations, the years 2011–2018 were the warmest of the whole analysed period, both considering annual values and individual seasons; the greatest increase in average annual air temperature between the 1950s and the years 2011–2018 took place in Kraków, with the smallest one in Poznań. The study indicates that on average almost each subsequent decade of the 1951–2018 period was warmer than the one before. The difference between the second to last decade and the years 2011–2018 was between 0.6 and 0.8°C, which is significantly greater than differences between the preceding decades. An exception occurred in the 1960s, when the average annual values of air temperature in all stations were lower than in the preceding decade. As far as seasons of the year are concerned, the trend of air temperature increase was not that unambiguous. The study reveals that not only the 1960s, but

Table 3. The average monthly, seasonal and annual values of air temperature [°C] at 12 p.m. UTC in the consecutive decades (Author's own calculation based on IMGW data obtained from https://dane.imgw.pl/data/dane_pomiarowo_obserwacyjne)

	January	February	March	April	May	June	July	August	September	October	November	December	spring	summer	autumn	winter	year
Kołobrzeg																	
1951–1960	0.4	-0.2	3.4	7.5	11.6	15.9	18.5	19.0	16.2	11.6	5.6	2.6	10.4	18.1	7.8	0.9	9.4
1961–1970	-0.7	0.3	3.4	8.0	11.8	16.5	18.4	18.3	16.9	12.2	5.8	0.3	10.7	18.1	7.8	0.2	9.3
1971–1980	0.2	1.7	4.5	7.3	12.5	16.5	18.4	19.4	15.8	10.8	5.8	2.6	10.8	18.3	7.5	1.7	9.7
1981–1990	0.7	1.5	5.2	8.4	13.9	16.6	19.2	19.6	15.9	12.4	5.8	2.2	11.8	18.5	8.0	1.9	10.2
1991–2000	1.9	2.6	5.4	9.8	13.1	17.0	19.4	20.1	16.2	11.5	5.2	2.1	12.0	18.8	7.7	2.7	10.4
2001–2010	1.1	2.3	5.1	9.7	13.9	17.2	20.7	20.4	17.1	11.8	6.7	2.1	12.3	19.7	8.3	2.2	10.7
2011–2018	1.5	2.3	5.5	9.9	14.8	17.8	20.2	21.0	17.7	12.5	7.3	4.2	12.8	19.9	9.0	2.9	11.3
Poznań																	
1951–1960	-0.4	-0.4	4.6	10.8	16.6	20.7	22.0	21.6	17.7	12.2	5.3	1.9	14.6	20.9	7.8	0.6	11.1
1961–1970	-1.9	0.1	4.2	11.7	16.0	21.3	21.7	21.0	18.3	12.5	5.6	-0.8	14.6	20.8	7.6	-0.2	10.8
1971–1980	-0.5	1.5	5.9	10.2	16.6	20.0	20.9	21.4	16.6	10.7	5.2	1.8	14.2	20.3	7.1	1.5	10.9
1981–1990	0.0	1.0	6.1	11.3	17.8	19.1	21.7	21.5	16.9	12.6	5.2	1.5	14.9	20.5	7.7	1.6	11.3
1991–2000	1.3	2.5	6.3	12.7	17.4	20.1	22.4	22.5	17.2	11.8	4.8	1.4	15.3	21.0	7.6	2.5	11.7
2001–2010	0.1	2.2	6.3	13.3	18.2	21.1	23.9	23.0	18.3	12.0	6.4	1.0	16.0	22.3	8.1	1.9	12.2
2011–2018	0.9	1.9	7.1	13.6	18.9	21.2	23.4	23.7	19.1	12.9	6.9	3.7	16.6	22.4	9.0	2.8	12.8
Kraków																	
1951–1960	-0.2	0.1	4.9	11.4	16.7	20.7	22.7	22.3	17.9	12.7	5.7	2.6	14.9	21.5	8.3	0.8	11.5
1961–1970	-2.4	0.4	4.6	12.9	17.0	21.2	22.0	21.6	18.9	13.6	6.7	-0.7	15.3	21.5	8.4	-0.2	11.4
1971–1980	-0.1	2.4	7.4	11.5	17.5	20.3	21.6	22.0	17.6	12.1	6.1	2.2	15.2	20.9	8.1	2.3	11.8
1981–1990	0.4	1.6	7.2	12.9	19.0	20.4	228	22.9	18.5	14.2	6.0	2.2	16.3	21.7	8.9	2.1	12.4
1991–2000	1.3	3.1	6.9	13.2	18.6	21.7	23.3	23.5	18.1	12.9	5.8	1.1	16.3	22.0	8.4	2.7	12.5
2001–2010	0.5	2.5	7.3	14.2	19.2	21.8	24.5	23.9	18.7	13.3	7.4	1.3	16.9	22.9	8.9	2.4	12.9
2011–2018	1.4	2.6	8.2	15.1	19.5	22.6	24.4	24.9	19.7	13.7	7.8	4.0	17.7	23.4	9.8	3.4	13.7

also the 1970s – especially in the summer and autumn period – were characterised by a drop in the value of air temperature compared to the decade of 1951–1960 (Table 3).

Considering the individual seasons, it can be concluded that winter is a season which is particularly susceptible to warming, when differences between average air temperatures at noon in the second decade and the years 2011–2018 ranged from 2.7°C in Kołobrzeg up to even 3.7°C in Kraków. These changes further extended to spring and summer, while the lowest increase in air temperature occurred in the autumn, when differences in air temperature between corresponding periods did not exceed 2°C (Table 3).

In Poznań and Kraków, December was the month in which there was a highest increase in air temperature at noon within the studied period (by 4.5 and 4.7°C); in Kołobrzeg it was February (with a value of 2.8°C). The smallest differences were in turn recorded in Kołobrzeg and Kraków in October (changes of 0.9 and 1.7°C, respectively); in Poznań it was in June, when the temperature increased only by 1.2°C. It should also be pointed out that when analysing the individual months, apart from the fact that the first or second decade of the analysed period was not always the coldest one, the final years were not always the warmest either. This is most noticeable in the case of January and February, when the highest monthly air temperature at noon was recorded in the 1990s (Table 3).

The increase in air temperature recorded based on monthly, seasonal and yearly values of noon temperature in the consecutive decades is confirmed by a trend analysis (Fig. 1, Table 4). In each of the three analysed cities, the trend lines of temperature at

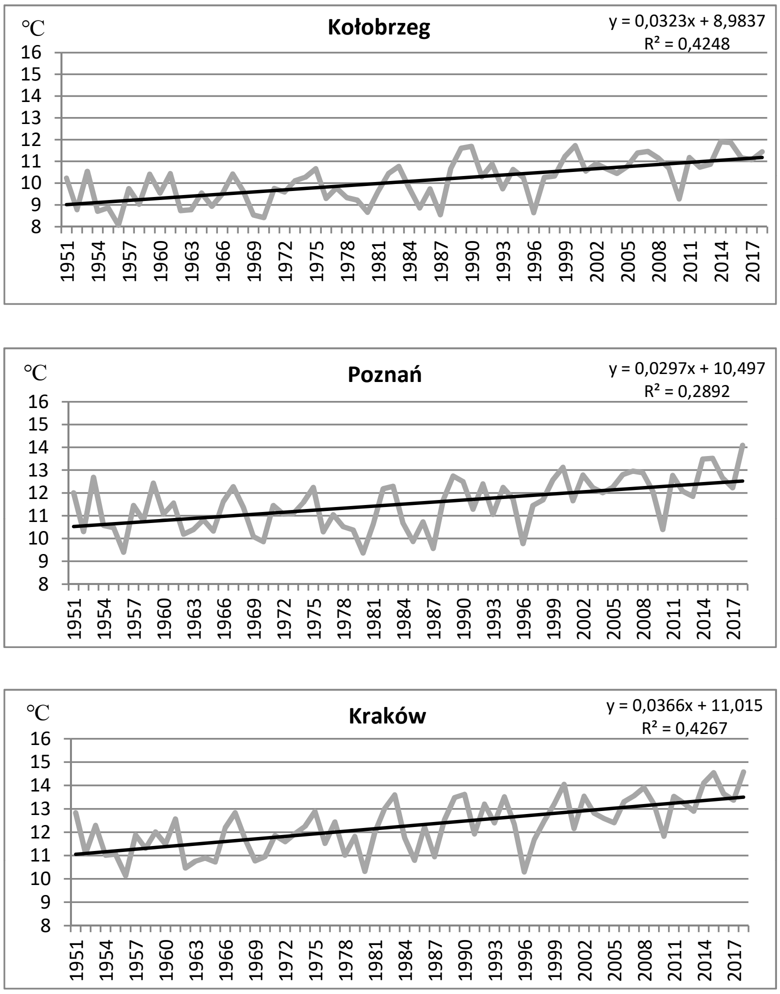

Figure 1. Long-term progress of average yearly air temperature [°C] at 12 p.m. UTC in the years 1951–2018 with a trend line (Author's own study based on IMGW data obtained from https://dane.imgw.pl/data/dane_pomiarowo_obserwacyjne)

12 p.m. UTC are ascending (Fig. 1), and the calculated trend values, including annual, seasonal, as well as in the individual months, are positive (Table 4). The highest average annual trend value in the years 1951–2018 was recorded in Kraków and amounted to 2.45°C, which means an increase in temperature of 0.36°C over the period of 10 years. The lowest value of the trend amounting to 1.99°C and a corresponding increase with a value of 0.29°C per 10 years took place in Poznań. In Kołobrzeg, the greatest warming occurred in spring (a trend value of 2.82°C); in Poznań and Kraków it was winter (trends of 2.87 and 3.27°C, respectively). It should be noted that all trend values, both annual and calculated for individual seasons of the year, were statistically significant at a level of 0.05. The observed considerable increase in temperature in the summer period is also significant, ranging between 1.75 (Poznań) and 2.12°C (Kraków), since previous research did not indicate such a considerable warming at this time of the year (Table 4).

The values of trends for the individual months indicate the greatest temperature increase in Kołobrzeg in May; in Poznań it is April and March in Kraków. In Kraków, March featured the highest temperature increase of the whole period, with a value of 3.54°C, which corresponds to an increase by 0.52°C over ten years. The smallest change in the studied period occurred in October, when the trend value for all three stations did not exceed 1.0°C. It should also be pointed out that the months of late winter, spring and summer were mostly characterised by a statistically significant increase in temperature, while in autumn and early winter the resulting trend values were insignificant at a level of 0.05 (Table 4).

Table 4. Monthly, seasonal and annual values of long-term trends (1951–2018) and values of trends per 10 years of air temperature [°C] at 12 p.m. UTC (bold text indicates statistically significant trends at a significance level of 0.05) (Author's own calculation based on IMGW data obtained from https://dane.imgw.pl/data/dane_pomiarowo_obserwacyjne)

	Kołobrzeg		Poznań		Kraków	
	1951–2018	per 10 years	1951–2018	per 10 years	1951–2018	per 10 years
January	1.97	0.29	2.18	0.32	2.77	0.41
February	**3.13**	**0.46**	**3.14**	**0.46**	**3.31**	**0.49**
March	**2.63**	**0.39**	**2.91**	**0.43**	**3.54**	**0.52**
April	**3.17**	**0.47**	**3.29**	**0.48**	**3.48**	**0.51**
May	**3.34**	**0.49**	**2.87**	**0.42**	**3.33**	**0.49**
June	**1.82**	**0.27**	0.28	0.04	**1.90**	**0.28**
July	**2.53**	**0.37**	**2.23**	**0.33**	**2.67**	**0.39**
August	**2.55**	**0.37**	**2.43**	**0.36**	**2.99**	**0.44**
September	1.12	0.16	0.86	0.13	1.02	0.15
October	0.60	0.09	0.48	0.07	0.92	0.14
November	**1.47**	**0.22**	1.39	0.20	1.77	0.26
December	1.70	0.25	1.84	0.27	1.60	0.24
spring	**2.82**	**0.41**	**2.28**	**0.34**	**3.03**	**0.45**
summer	**2.07**	**0.30**	**1.75**	**0.26**	**2.12**	**0.31**
autumn	**1.11**	**0.16**	**1.06**	**0.16**	**1.37**	**0.20**
winter	**2.65**	**0.39**	**2.87**	**0.42**	**3.27**	**0.48**
year	**2.16**	**0.32**	**1.99**	**0.29**	**2.45**	**0.36**

The analysis of deviation plots for yearly and seasonal values of air temperature compared to the long-term average also indicated a temperature increase trend at hours around noon in the last several decades (Fig. 2 – Fig. 6).

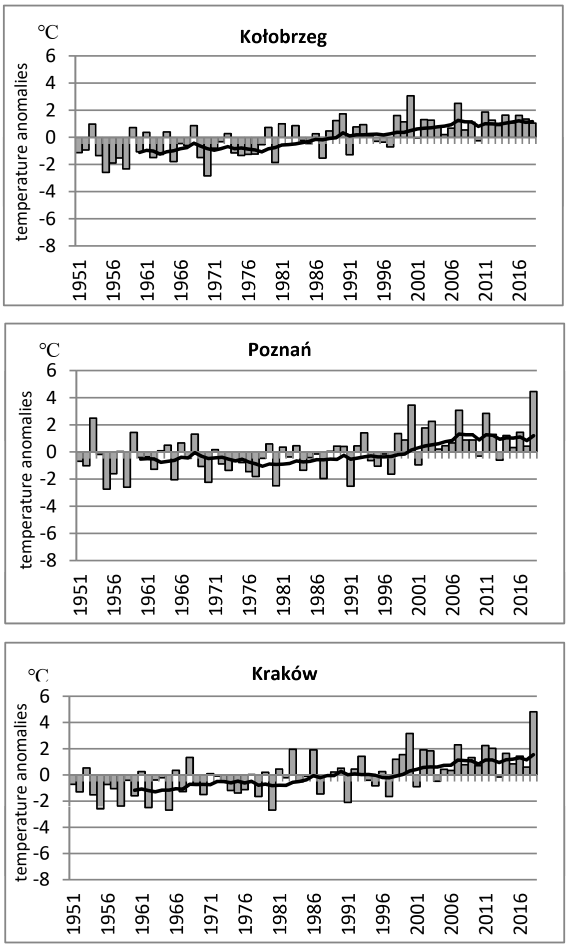

Figure 2. Long-term progress of the deviations of air temperature [°C] from a long-term average during the spring period, along with the progress of a 10-year moving average (Author's own study based on IMGW data obtained from https://dane.imgw.pl/data/dane_pomiarowo_obserwacyjne)

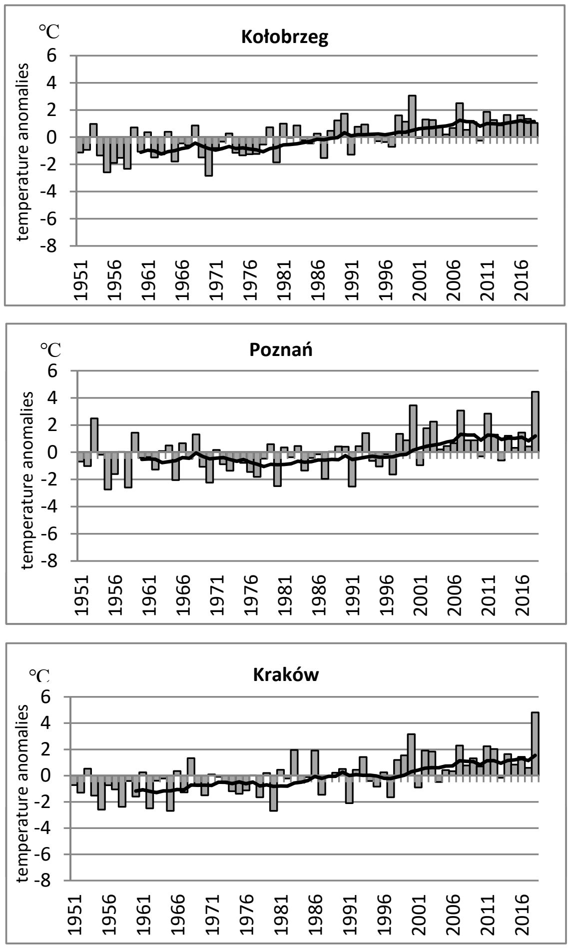

Figure 3. Long-term progress of the deviations of air temperature [°C] from a long-term average during the summer period, along with the progress of a 10-year moving average (Author's own study based on IMGW data obtained from https://dane.imgw.pl/data/dane_pomiarowo_obserwacyjne)

Deviations of annual temperature from the 1990s up until the year 2018 were positive (with a minor exception in 2010), reaching almost 2.0°C, having slightly exceeded this value in Poznań in 2018 and in Kraków in 2015 and 2018. The period between the 1950s and the end of the 1980s was in turn usually characterised by negative temperature anomalies, with values also reaching 2.0°C (Fig. 6).

Among all seasons, the greatest temperature deviations at noon were recorded in winter, when their negative values in individual years reached even 6.0°C, and positive deviations exceeded 4.0°C, while this season, similar to autumn, was characterised by variability of air temperature anomalies which was slightly higher compared to the other seasons of the year. This is because since the 1990s there have been four years with negative deviations (in two cases exceeding 2.0°C), and until the 1990s there were several winters with a positive air temperature anomaly (Fig. 4, Fig. 5). Positive deviations of temperature in the last several decades were much more pronounced in the spring-summer period. Although they were slightly lower than in winter, since they exceeded 2.0°C only slightly (except for the spring season in Poznań and Kraków in 2018), they were not characterised by as high a variability as the autumn-winter deviations, and the individual occurrences of negative deviations during that time had low values, not exceeding 0.5°C (Fig. 2, Fig. 3).

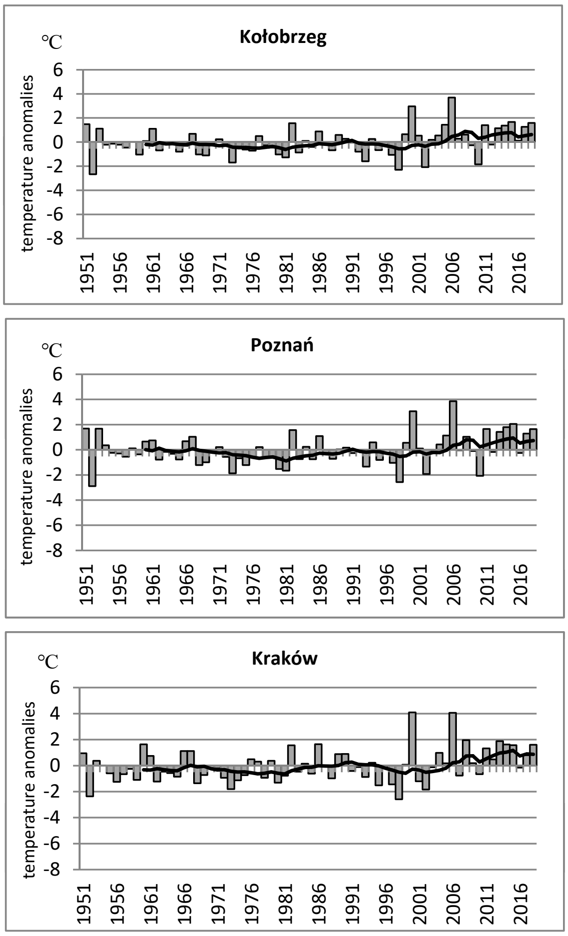

Figure 4. Long-term progress of the deviations of air temperature [°C] from a long-term average during the autumn period, along with the progress of a 10-year moving average (Author's own study based on IMGW data obtained from https://dane.imgw.pl/data/dane_pomiarowo_obserwacyjne)

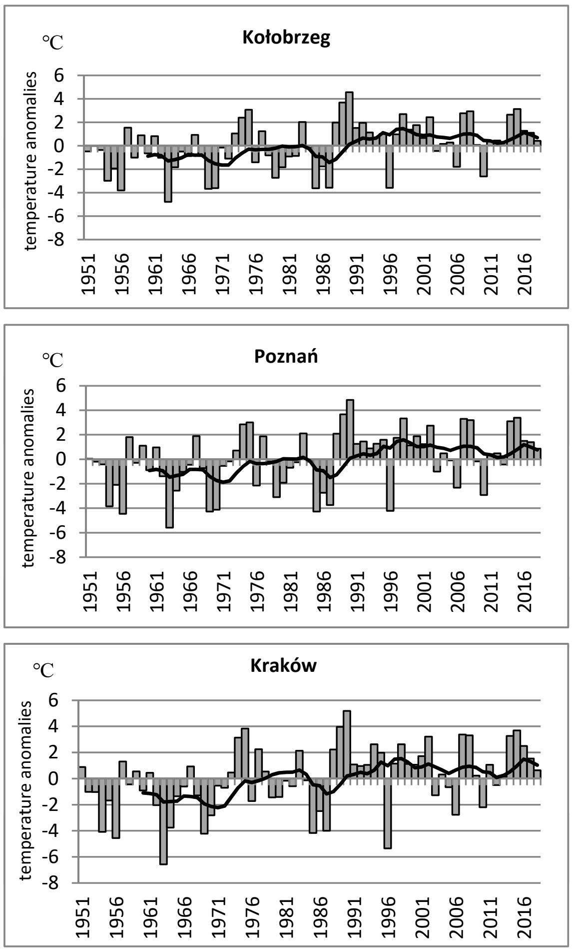

Figure 5. Long-term progress of the deviations of air temperature [°C] from a long-term average during the winter period, along with the progress of a 10-year moving average (Author's own study based on IMGW data obtained from https://dane.imgw.pl/data/dane_pomiarowo_obserwacyjne)

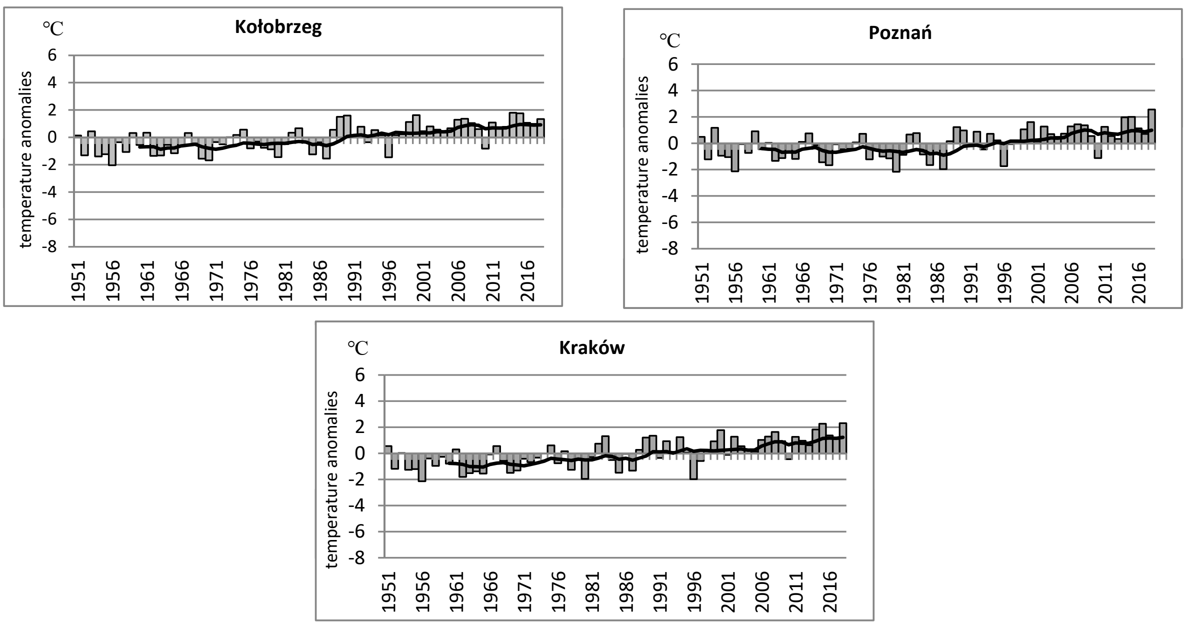

Figure 6. Long-term progress of the deviations of annual air temperature [°C] from a long-term average, along with the progress of a 10-year moving average (Author's own study based on IMGW data obtained from https://dane.imgw.pl/data/dane_pomiarowo_obserwacyjne)

4. Discussion and conclusions

Depending on the station, average annual air temperature in the years 1951–2018 at 12 p.m. UTC ranged between about 10.0 and 12.0°C, with Kraków being the warmest city during that time and Kołobrzeg being the coldest. The recorded values ranged from a January minimum in Poznań amounting to -22.2°C to a maximum in Kołobrzeg and Kraków, with a value of 36.9°C. Moreover, it was noted that of all the analysed stations, Kraków was distinguished by the highest temperature variation at noon. Based on the calculated values of standard deviation, higher contrast of thermal conditions was observed in the winter-spring season, while the summer period was characterised by their higher stability. The resulting annual, seasonal and monthly values of air temperature deviation at 12 p.m. UTC indicate that compared to average thermal variation in Poland (determined based on the data from 213 synoptic stations and climate stations from the whole Poland and neighbouring countries near the border for the 1951–2003 period) (Ustrnul and Czekierda, 2005), hours around noon seem to be less stable.

The performed analyses unambiguously indicated an increase in air temperature at noon during the period of 1951–2018. The resulting trends of average annual air temperature ranged from 1.99 to 2.45°C, indicating the greatest warming in Kraków. When comparing trend values for 12 p.m. UTC, calculated for 10 years, to ten-year values of average yearly and seasonal trends produced by other authors (Michalska, 2011; Marosz et al., 2011; Wójcik and Miętus, 2014), it can be concluded that during hours around noon it gets warmer slightly faster compared to the average temperature increase for the given season or year. Among all seasons of the year, the highest increase in air temperature was recorded in winter, when trend values ranged from 2.65 to 3.27°C. A slightly lower one occurred in spring (except Kołobrzeg, in which it was the spring period that featured the highest trend value). Warming of the winter-spring season is confirmed by the calculated trend values for individual months, which featured the highest increase in temperature from February to May. It was also concluded that the trends of average annual air temperature, average for the individual seasons and in particular for the February-May period, are statistically significant at a level of 0.05 across all three stations. The particularly considerable increase in air temperature in spring is also confirmed by other authors (e.g. Bielec-Bąkowska and Piotrowicz, 2013; Fortuniak et. al., 2001; Kożuchowski and Żmudzka, 2001; Żmudzka, 2009; Michalska, 2011; Wójcik and Miętus, 2014), while for winter, as stated by Wójcik and Miętus (2014), the pace and direction of changes in air temperature are heavily dependent on the analysed period. Air temperature at 12 p.m. UTC also exhibited an increase in summer (statistically significant in July and August), albeit slightly lower than in winter and spring, which may indicate an intensified rate of warming and a change in the thermal trend of the warm half of the year, since previous studies rather indicated the lack of changes or even cooling of this season of the year (Trepińska and Kowanetz, 1997; Trepińska, 2001; Okoniewska, 2013). The smallest changes in air temperature, although still positive, were recorded in autumn, which confirms the results of previous analyses, pointing out this season of the year as the least prone to changes (Fortuniak et al., 2001; Kożuchowski and Żmudzka, 2001, Marosz et al., 2011; Wójcik and Miętus, 2014).

The calculated deviations of air temperature from its long-term value also confirmed an increase in temperature at noon during the last several decades. In most cases, both the annual and seasonal values of deviations since the 1990s until 2018 were positive, while during the initial 40 years of the studied period, negative deviations prevailed. A similar trend was obtained by Wójcik and Miętus (2014) while studying the course of anomalies of average annual air temperature in Poland and in the individual physical-geographical regions in the years 1951–2010. The studies also proved that the highest diversity of temperature at hours around noon in the years 1951–2018 occurred in winter. The winter period was already indicated as featuring the widest range of temperature changes in 2011 by the authors who summarised the results of project CLIMATE, who among other things analysed the anomalies of average areal air temperature in the individual seasons of the year relative to the 1971–1990 period (Marosz et al., 2011).

The resulting increase in air temperature at hours around noon in the years 1951–2018 was influenced mostly by an increase in its values in the years 2011–2018, which were the warmest of the whole investigated period. It was also concluded, in particular based on average annual values of air temperature, that each subsequent decade (except for the 1960s) was warmer than the one before, and the difference between the years 2011–2018 and the preceding decade was exceptionally large. A review of literature on climate changes leads to a clear conclusion that each subsequent decade is increasingly warmer. In their 2001 paper, Kożuchowski and Żmudzka noted that the last 20 years (i.e. 1980–1990) were characterised by temperatures higher than the 50-year standard. In their 2014 paper, Wójcik and Miętus pointed out that the decade of 2001–2010 was the warmest of the analysed period (1951–2010), and Żmudzka (2009) concluded that in the early 21st century the pace of warming increased. An increase in warming in the second decade of the 21st century is also confirmed by maps published in the Monthly Climate Monitoring Bulletin, indicating that starting from 2014, each subsequent year was anomalously or extremely warm, with positive deviations compared to the years 1971–2000. Moreover, analyses of the average annual values of air temperature in the consecutive decades of the years 1951–2018 confirmed that the winter and spring period is the most susceptible to an increase in air temperature at noon.

Progressive climate change will affect a number of aspects of human life, including tourism. The rise in temperature in Poland will entail both positive changes and many more negative ones. The anticipated benefits consist in an increase of tourist attractiveness of Polish resorts, including Kołobrzeg, located on the coast, which, due to high temperatures in summer, will be able to compete with the Mediterranean coast. Moreover, the period during which weather conditions in Poland will be conducive to tourist trips and the use of climatotherapy, in particular heliotherapy, may be extended. Unfortunately, at the same time, an increase in temperature will likely involve the occurrence of heat waves dangerous to health – especially burdensome at noon – and an increase in the number of extreme climatic phenomena (drought, floods, strong winds), which will result in a decrease in attractiveness, and thus tourist traffic in some regions of the country. In addition, as a result of the increase in temperature, many naturally valuable and attractive wetlands may disappear. Higher energy demand related to, for example, the use of air conditioning, can significantly increase prices for tourist offers (Czoch and Kulesza, 2014). In the winter season, on the other hand, the range of occurrence and duration of snow cover should be considerably reduced, which will result in transformation or even closing of certain ski resorts. In connection with the forecasted climate change, it will be necessary to implement a number of protective measures for valuable natural areas and to support all ecological initiatives, including the development of ecotourism (Czoch and Kulesza, 2014; Koźmiński at al., 2015). As a result, it will become necessary to limit the time spent in the open area around noon, i.e. during the highest intensity of outdoor recreation. This will entail the need to adapt the tourism industry by means of altering the tourist offer to catter for new ways of spending time by tourists, especially in summer.

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