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Air temperature anomalies in experimental forests in Rogów in 1924–2015*

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Abstract. Meteorological measurements, that aim to monitor weather and climate conditions to aid research in changing forest ecosystems, have been conducted in the Warsaw University of Life Sciences' experimental forests in Rogów since 1924. Based on the long-term air temperature measurements, it can be demonstrated that in the years 1924–2015, anomalously cold months have occurred less often (ca. 3.2%) than anomalously warm months (ca. 4.5%). During the last 20 years, only two anomalously cold months were recorded (November 1998, December 2010), whereas anomalously warm months occurred frequently (May 2002, July 1999, 2002, 2006, 2010, 2012, 2014, August 2002, 2015, September 1999, 2006, October 2000, 2001). We hypothesised that the more frequent anomalously warm months would constitute a trend in increasing the air temperature for particular months between 1924–2015, but surprisingly, a statistically significant trend was observed for all winter (XII–II) and spring months (III–IV) as well as the end of summer (VIII).

Keywords: anomalously warm months, anomalously cold months, air temperature trend

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1. Introduction

An increase in air temperature is one of the basic manifestations of contemporary climate change. Global warming intensified especially in the second half of the 20th century and at the beginning of the 21st century, the temperature increase in 1981–2005 was 2.4 times higher than in 1906–2005 (Kundzewicz 2011). However, in individual months and locations, the changes in thermal conditions may be significantly below or above the general trend (Kundzewicz 2011). The increase in temperature is accompanied by an increase in the frequency of extreme events. One of the manifestations of climate change is the more frequent occurrence of periods with extremely high air temperature – heat waves, and a decrease in the frequency of periods with low temperature – cold waves (Marosz et al. 2011; Kossowska-Cezak; Twardosz 2017). Similar regularities were also observed in the frequency of the occurrence of hot and cold days (Kundzewicz 2016). The response of forest ecosystems to climate change is delayed due to the longevity of forest stands (Zajączkowski et al. 2013). Climate change can lead to a reduction in forest stability, as well as the reduced availability of environmental resources, ecosystem services and the production and protective functions of forests (WS 2013). The species composition of forest stands will change, that is, species with higher moisture requirements, such as alder, ash and spruce, will give way to others as sites become drier (Brzeziecki et al. 2012). Irrespective of the adopted models of climate change, more diverse stands in terms of initial composition will most likely exhibit an initial decline of biomass, followed by an increase, leading to the reconstruction of the earlier state (Dale et al. 2010). In addition to changing the production characteristics of tree

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stands, specific non-production functions will also change, the value of which may be higher than the economic value of the wood (Kędziora et al. 2014).

In light of the changes taking place in forest ecosystems (Dale et al. 2010; Brzeziecki et al. 2012; Zajączkowski et al. 2013), monitoring the factors that may affect observed forest dynamics is an important research issue. Thermal and humidity conditions are among the basic abiotic factors affecting forest habitats. As part of a study of the climate in the area of Łódź − at the SGGW Experimental Forest in Rogów − thermal and pluvial conditions were found to influence the radial growth of some species of forest trees (Chojnacka-Ożga, Ożga 2012; Bijak 2013). Analysing the long-term course of precipitation, no statistically significant changes were found (Chojnacka-Ożga, Ożga 2015). The lack of clear trends in precipitation with clearly visible positive trends in air temperature (Kożuchowski, Żmudzka 2003; Żmudzka 2009; Kossowska-Cezak 2010) may lead to serious changes in forest ecosystems.

The aim of this study is to determine the anomalous average monthly values of air temperature in the SGGW Experimental Forests in Rogów and their changes in 1924–2015. The application objective is to determine the direction of the change in air temperature for the studied years and its size. The following study hypotheses were formulated:

- The number of anomalously warm months increases, while the anomalously cold ones decrease.
- Thermal anomalies occur in the months with the strongest trends of change in air temperature.

2. Study site and methods

In 1923, the meteorological station was established at the SGGW Experimental Forests in Rogów (51°40'N, 19°55'E, h = 194 m above sea level). Only precipitation measurements were made in 1923, while in 1924, measurements and observations of other meteorological phenomena were gradually introduced. After World War II (until 1993), measurements were also performed at a forest (under the canopy) meteorological station. During the entire measurement and observation period, three climatological measurement periods were in force at the station. The research material consisted of average monthly air temperature values calculated and compiled in climatological logs and monthly record of meteorological observations.

The anomalously warm or anomalously cold months were determined for the course of many years, assuming as the criterion, according to the Lorenc (1994) classification, a deviation from the mean by ± 2SD (standard deviations). The direction and significance of the trends of changes in air temperature were calculated by determining the linear trend equations (significance of the trend was determined using F statistics) and the Mann-Kendall test.

3. Study results

The average annual air temperature from 1924–2015 was 7.5°C and varied from 5.3°C (1940) to 9.6°C (2015). It was characterised by a statistically significant upward trend of 0.13°C/decade.

In the winter months (XII–II), a positive thermal anomaly occurred only in December 2015. Negative anomalies occurred more frequently: in December 1927, 1933, 1969, 2010, in January 1940, 1942, 1963 and 1987, and in February 1929, 1940, 1947, 1956, 1985 and 1986 (Figure 1). Particularly noteworthy is February 1929, when the minimum temperature dropped below -30.0°C three times, and on February 9, 1929, when the daily amplitude was 23.0°C.

The air temperature in the winter months of 1924–2015 was characterised by a statistically significant positive trend (Figure 1).

In the spring months (III–V) in March, an anomaly occurred only once (negative in 1942), with anomalies occurring more frequently in the remaining months (negative in April 1929 and 1955 and in May 1965 and 1980, whereas positive in April 2000, and in May 1931, 1937, 2002).

The air temperature in March and April in the analysed multi-year period was characterised by a statistically significant positive trend, while in May, the upward trend was not significant (Figure 2).

In the summer (June–August), there were no negative anomalies, while positive anomalies were found 4 times in June (1940, 1954, 1964, 1979), 9 times in July (1932, 1959, 1994, 1999, 2006, 2002, 2010, 2012, 2014) and 7 times in August (1938, 1939, 1942, 1951, 1992, 2002, 2015).

In the summer months of the surveyed years, a statistically significant positive trend in air temperature was found only for August (Figure 3).

In autumn (September–November), positive anomalies occurred less frequently and negative ones more often (Figure 4). In September, there were only positive anomalies (1931, 1942, 1947, 1967, 1999, 2006), October had positive (1967, 2000, 2001) and negative (1936, 1946) anomalies, and in November, there were less positive anomalies (1926, 1946) than negative ones (1941, 1956, 1965, 1993, 1998).

In 1924–2015, air temperature in the autumn months was characterised by trends that were not statistically significant: a decline in September, with increases in October and November (Figure 4).

In particular decades of the analysed period, the number of months with an anomalously low or high average temperature fluctuated (Table 1).

The least number of anomalous months occurred in 1966–1985. The number of months with abnormally low air temperatures in the analysed multi-year period decreased.

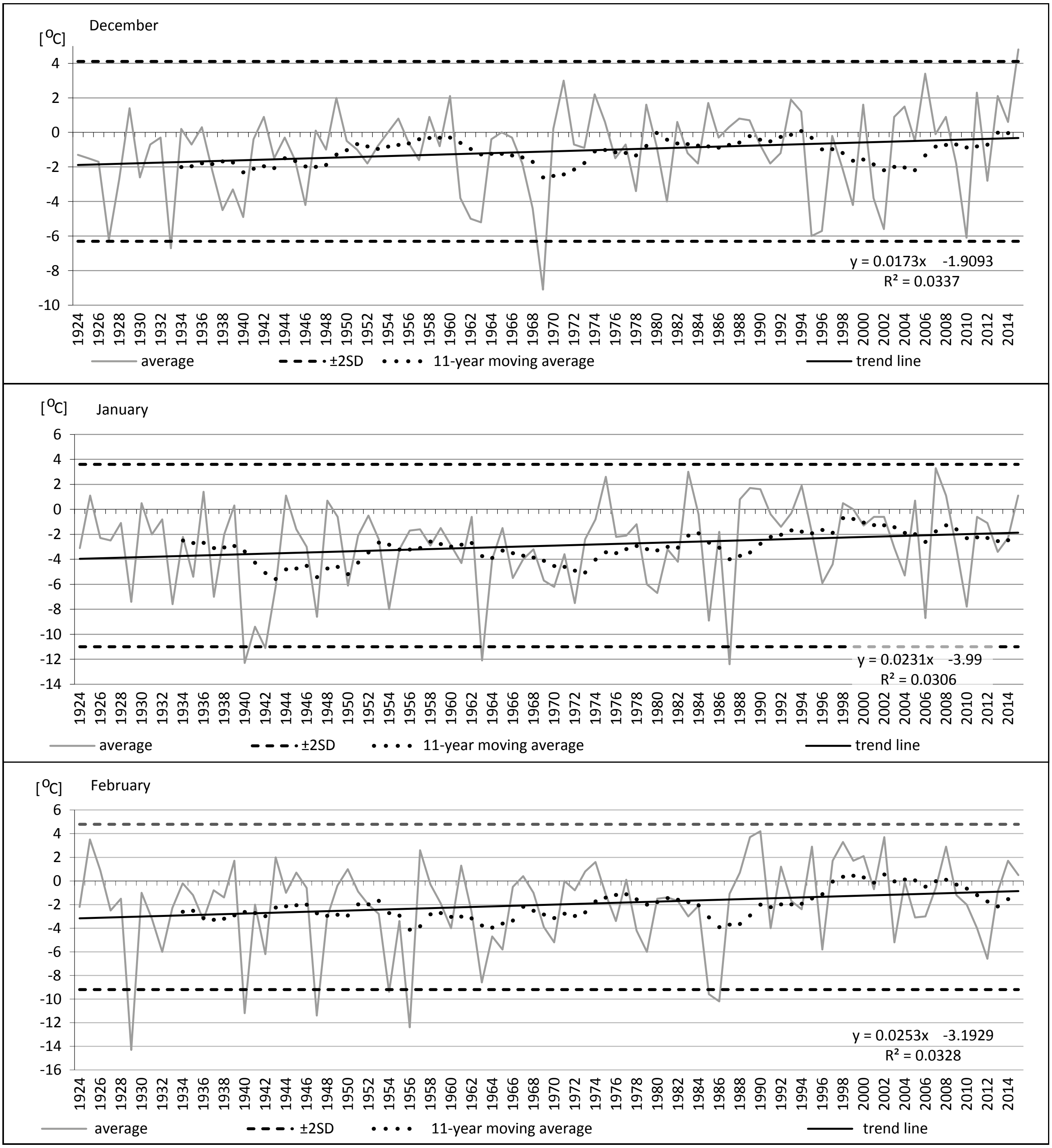

Figure 1. Mean air temperature in Warsaw University of Life Sciences Experimental Forests in Rogów in winter months in 1924–2015

The turn of the 21st century is marked by more frequent occurrences of anomalously warm months (Table 1). Anomalously cold months occurred mainly in winter and anomalously warm months in summer. Anomalous monthly average air temperature values occurred more frequently in autumn than in spring (Table 2).

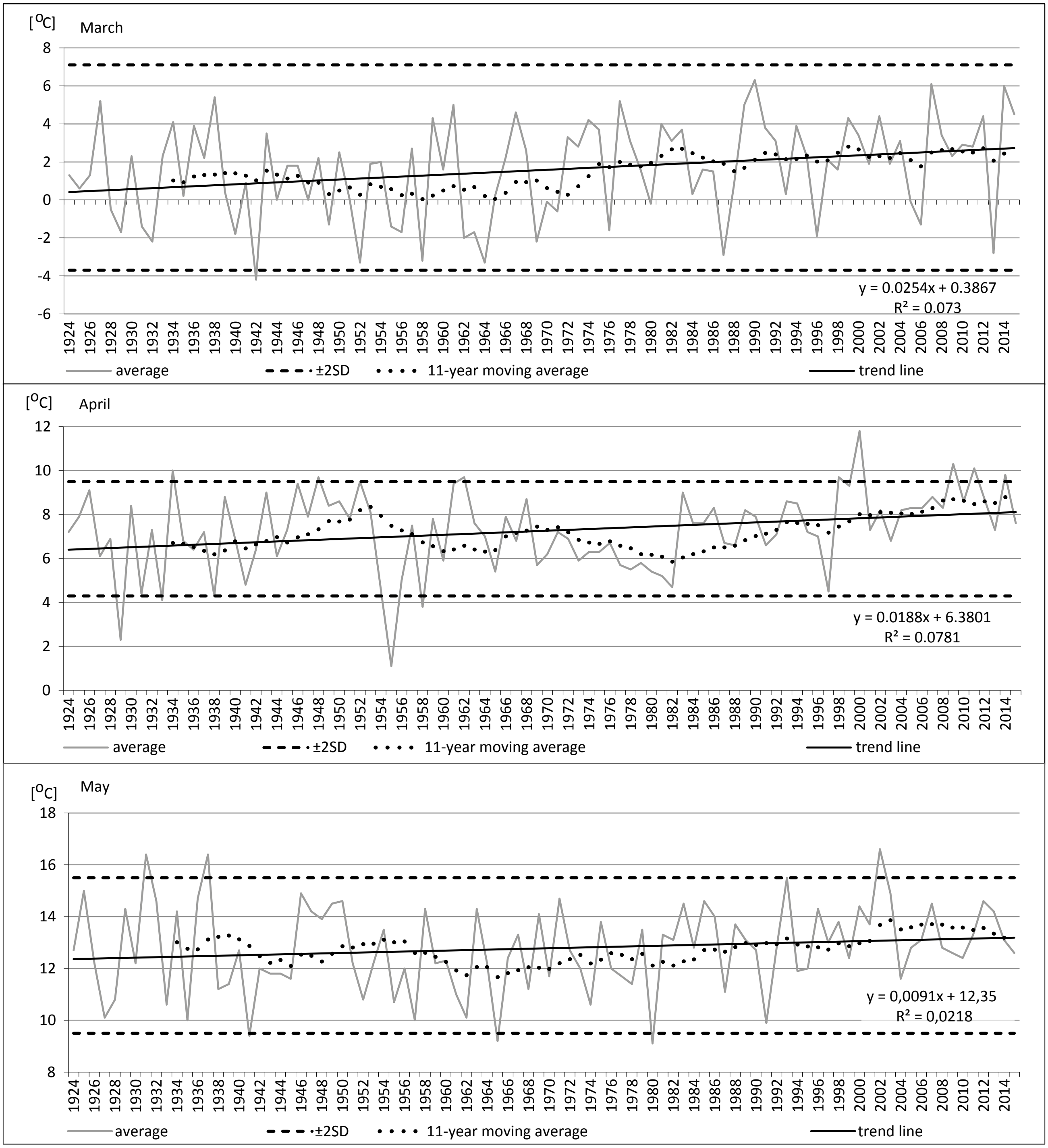

Figure 2. Mean air temperature in Warsaw University of Life Sciences Experimental Forests in Rogów in spring months in 1924–2015

4. Discussion

The upward trend in the mean annual air temperature in Rogów (0.13°C/decade) is slightly higher than the trend for Łódź calculated by Ilnicki et al. (2015). On the other hand, the trends of average monthly values of air temperature in Rogów (a station located in a non-urbanised area) are generally lower than the corresponding values calculated for a shorter

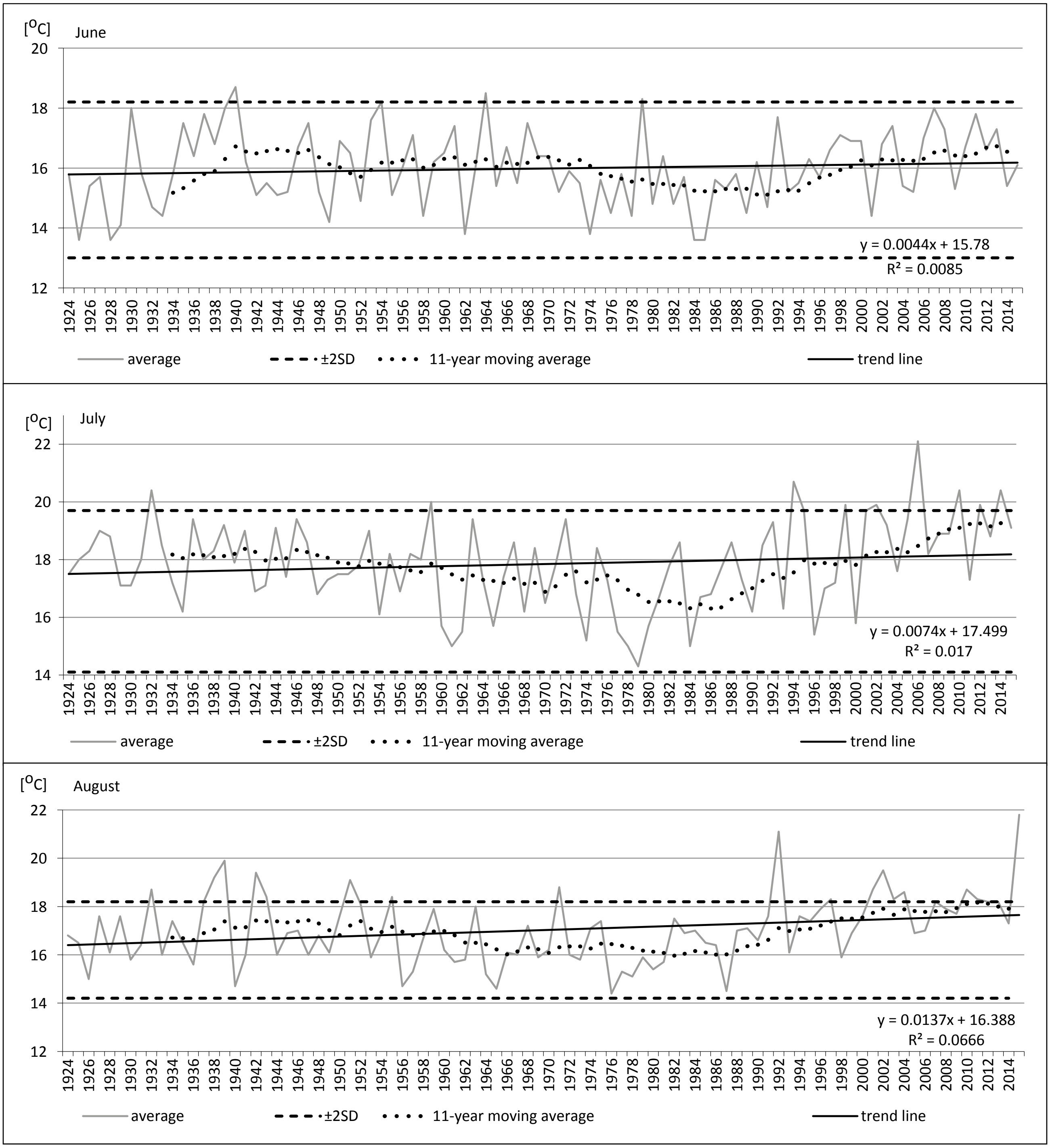

Figure 3. Mean air temperature in Warsaw University of Life Sciences Experimental Forests in Rogów in summer months in 1924–2015

measurement period in Warsaw (Majewski et al. 2012). The regularities indicated by Marosz et al. (2011) on the relatively weak trends of air temperature changes in autumn months were confirmed. Statistically significant trends from 1904–2006 in April, May, June, August, October and November in Łódź (Podstawczyńska 2010) were confirmed in Rogów only for April and August. In the remaining months, it was only a trend in a similar direction as that shown for Łódź.

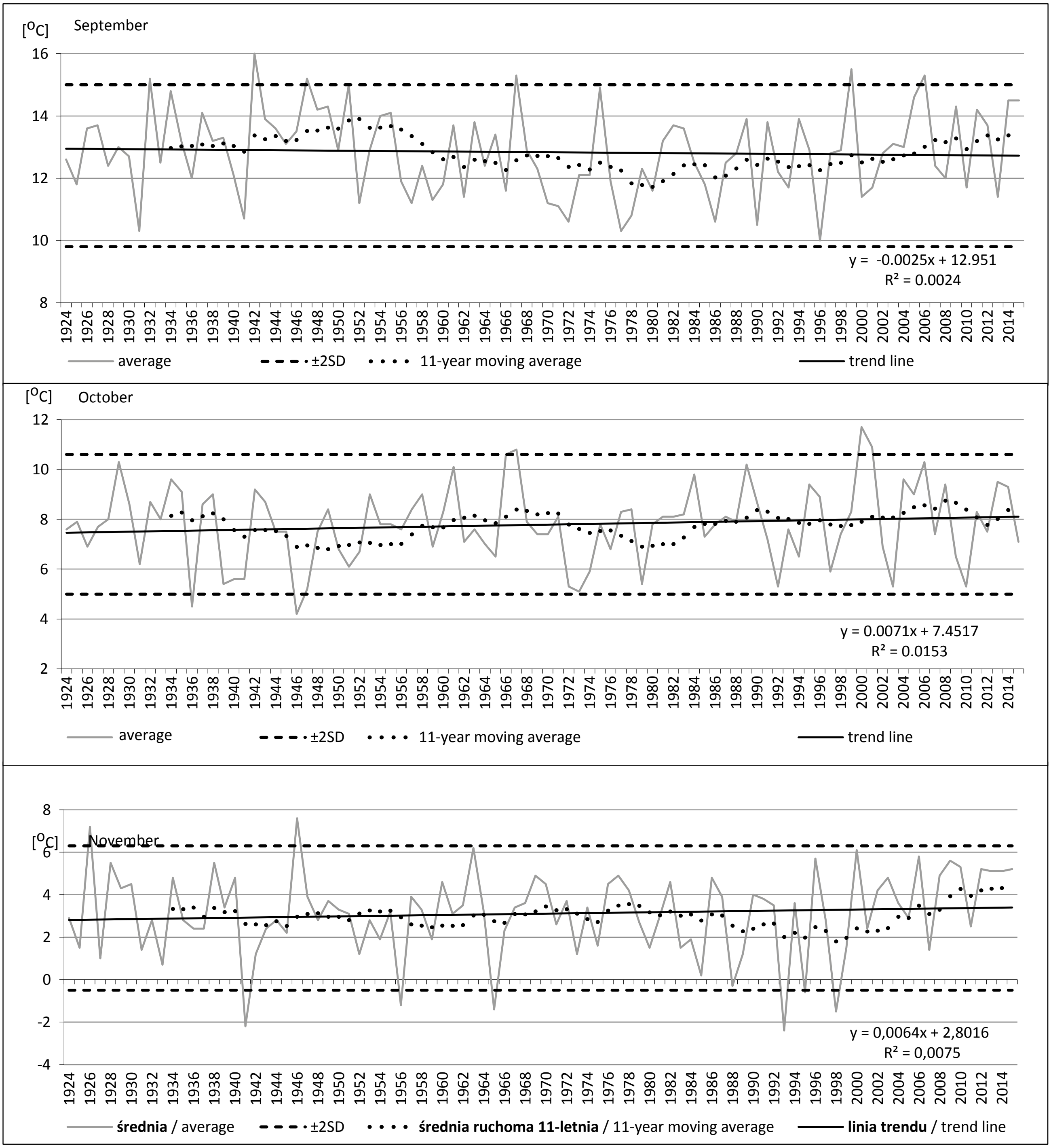

Figure 4. Mean air temperature in Warsaw University of Life Sciences Experimental Forests in Rogów in autumn months in 1924–2015

Based on the same study period, we can conclude that the anomalous air temperature values characterising particular months also occurred at other meteorological stations in Poland (Uscka-Kowalkowska, Kejna 2009; Filipiuk 2011; Lorenc 2016). However, the anomalously high air temperature values of April 2009 and 2011 that occurred in Warsaw were not observed in Rogów. An anomalously warm July 2010 was recorded in Rogów and Warsaw, but not in Lublin.

Table 1. Number (n) and percentage (%) of months with anomalously low (AC) and anomalously high (AW) average air temperature in Rogów in 1926–2015

		1926-35	1936-45	1946-55	1956-65	1966-75	1976-85	1986-95	1996-05	2006-15
AC	n	4	6	3	5	1	2	3	1	1
	%	3.3	5.0	2.5	4.2	0.8	1.7	2.5	0.8	0.8
AW	N	4	5	4	2	2	1	2	8	7
	%	3.3	4.2	3.3	1.7	1.7	0.8	1.7	6.7	5.8

Table 2. Number of months anomaly cold (AC) and anomaly warm (AW) in Rogów in 1924–2015

Season	Winter			Spring			Summer			Autumn		
Months	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
AC	4	4	6	1	2	2	0	0	0	0	2	5
		14 (53.8%)			5 (19.2%)			0			7 (26.9%)	
AW	1	0	0	0	1	3	4	9	7	6	3	2
		1 (2.8%)			4 (11.1%)			20 (55.5%)			11 (30.6%)	

Similarly, an anomalously warm August 2002 was not found in Lublin, but occurred in Rogów, Warsaw and Koniczynka near Toruń. These discrepancies can be confirmed by the spatial distribution of thermal anomalies presented by Kossowska-Cezak and Twardosz (2017).

The increase in anomalously warm months shown in recent years in the growing season affects a change in the water regime of forest habitats, and thus, gradual structural changes in forest stands (Zajączkowski et al. 2013). At the same time, the occurrence of months with anomalous air temperature values converges in many cases with the periods that are decisive for the annual growth of particular tree species (Chojnacka-Ożga, Ożga 2012; Bijak 2013). Thus, the frequency of occurrence of months with anomalous average values of air temperature, as one of the manifestations of climate change, can affect the functioning of forest ecosystems.

5. Conclusions

In 1924–2015, anomalously cold months in the Experimental Forests in Rogów occurred less frequently (about 3.2%) than the anomalously warm ones (about 4.5%).

In 1924–1955, the number of anomalously warm and cool months was similar and gradually decreased. Since the 1990s, the number of anomalously warm months has increased significantly.

Anomalously cold months have been rare in the last 20 years (only in December 2010), while anomalously warm ones have occurred much more often during this period (May 2002; July 1999, 2002, 2006, 2010, 2012, 2014; August 2002, 2015; September 1999, 2006, October 2000, 2001, December 2015).

In individual months of 1924–2015 (except for September), the air temperature was observed to have an increasing trend or increasing tendency. A statistically significant air temperature trend occurred in the winter months (XII–II), spring (III–IV) and at the end of summer (VIII).

Based on the conducted analyses, we cannot confirm the more frequent occurrence of thermal anomalies in the months with the strongest trends of changes in air temperature.

Conflict of interest

The authors declare no potential conflicts of interest.

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References

Bijak S. 2013. Sygnał klimatyczny w przyroście radialnym wybranych iglastych gatunków drzew w Leśnym Zakładzie Doświadczalnym Rogów. *Leśne Prace Badawcze* 74(2): 101–110. DOI 10.2478/frp-2013-0010.

Brzeziecki B., Keczyński A., Zajączkowski J., Drozdowski S., Gawron L., Buraczyk W., Bielak K., Szeligowski H., Dzwonkowski M. 2012. Zagrożone gatunki drzew Białowieskiego Parku Narodowego (Rezerwat Ścisły). *Sylwan* 156(4): 252–261.

Chojnacka-Ożga L., Ożga W. 2012. Wpływ warunków termiczno-pluwialnych na przyrost radialny buka zwyczajnego (*Fagus sylvatica* L.) rosnącego na terenie LZD w Rogowie. *Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej w Rogowie* 1(30): 136–144.

Chojnacka-Ożga L., Ożga W. 2015. Zmiany opadów atmosferycznych w Lasach Doświadczalnych SGGW w Rogowie w latach 1923–2014, w: Klimat a społeczeństwo (red. H. Lorenc, Z. Ustrnul). Monografie IMGW-PIB: 71–82. ISBN 978-83-64979-12-5.

Dale V.H., Tharp M.L., Lannom K.O., Hodges D. 2010. Modeling transient response of forests to climate change. *Science of the Total Environment* 408: 1888–1901. DOI 10.1016/j.scitotenv.2009.11.050.

Filipiuk E. 2011. Klasyfikacja termiczna miesięcy, sezonów i lat w Lublinie w latach 1951–2010. *Prace i Studia Geograficzne* 47: 129–138.

Ilnicki P., Farat R., Górecki K., Lewandowski P. 2015. Long-term air temperature and precipitation variability in the Warta River catchment area. *Journal of Water and Land Development* 27: 3–13. DOI 10.1515/jwld-2015-0019.

Kędziora A., Kępińska-Kasprzak M., Kowalczak P., Kundzewicz Z., Miler A., Pierzgalski E., Tokarczyk T. 2014. Zagrożenia związane z niedoborem wody. *Nauka* 1: 149–172.

Kossowska-Cezak U. 2010. Zmiany warunków termicznych i opadowych w Warszawie określone na podstawie powojennej serii obserwacyjnej z Okęcia (1947-2009), w: Atlas współzależności parametrów meteorologicznych i geograficznych w Polsce 25, Wydawnictwo Uniwersytetu Warszawskiego, 363–386. ISBN 978-83-89502-29-2.

Kossowska-Cezak U., Twardosz R. 2017. Anomalie termiczne w Europie (1951–2010). Wyd. IGiGP UJ Kraków. ISBN 978-83-64089-34-3.

Kożuchowski K., Żmudzka E. 2003. 100-year series of areally averaged temperatures and precipitation totals in Poland. Acta Univ. Wratislaviensis 2542, *Studia Geograficzne* 75: 116–122.

Kundzewicz Z. 2011. Zmiany klimatu, ich przyczyny i skutki – obserwacje i projekcje. *Landform Analysis* 15: 39–49.

Kundzewicz Z. 2016. Ekstremalne stany pogody, a zmiany klimatyczne – stan i perspektywy; Ocena zagrożeń abiotycznych i możliwości ich ograniczania w związku ze zmianami klimatycznymi; stan i perspektywy (szkody klimatyczne): huragany, śniegołomy, powodzie, susze, niskie i wysokie temperatury.

http://www.npl.ibles.pl/sites/default/files/referat/ekstremalne-stany-pogody-a-zmiany-klimatyczne_0.pdf [30.12.2017].

Lorenc H. 1994. Ocena zmienności temperatury powietrza i opadów atmosferycznych w okresie 1901–1993 na podstawie obserwacji z wybranych stacji meteorologicznych w Polsce. *Wiadomości IMGW* 38: 43–59.

Lorenc H. 2016. Wpływ ekstremalnych zjawisk meteorologicznych na stan lasów w Polsce. https://www.ibles.pl/-/viii-sesja-zimowej-szkoly-lesnej-poswiecona-zagrozeniom-lasu-i-jego-funkcji [30.12.2017].

Majewski G., Odorowaska M., Rozbicka K. 2012. Analiza warunków termicznych na stacji Ursynów SGGW w Warszawie w latach 1970-2009. *Woda-Środowisko-Obszary Wiejskie* 2(38): 171–184.

Marosz M., Wójcik R., Biernacik D., Jakusik E., Pilarski M., Owczarek M., Miętus M. 2011. Zmienność klimatu Polski od połowy XX wieku. Rezultaty projektu Klimat. *Prace i Studia Geograficzne* 47: 51–66.

MŚ. 2013. Strategiczny plan adaptacji dla sektorów i obszarów wrażliwych na zmiany klimatu do roku 2020. Ministerstwo Środowiska, Warszawa.

Podstawczyńska A. 2010. Temperatura powietrza i opady atmosferyczne w regionie łódzkim w ostatnim stuleciu, w: Torfowisko Żabieniec: warunki naturalne, rozwój i zapis zmian paleoekologicznych w jego osadach (red. J. Twardy, S. Żurek, J. Forysiak). Bogucki Wydawnictwo Naukowe, Poznań, 63–73. ISBN 9788362662456.

Uscka-Kowalkowska J., Kejna M. 2009. Zmienność warunków termiczno-opadowych w Koniczynce (Pojezierze Chełmińskie) w latach 1994-2007. *Acta Agrophysica* 14(1): 203–209.

Zajączkowski J., Brzeziecki B., Perzanowski K., Kozak I. 2013. Wpływ potencjalnych zmian klimatycznych na zdolność konkurencyjną głównych gatunków drzew w Polsce. *Sylwan* 157(4): 253–261.

Żmudzka E. 2009. Współczesne zmiany klimatu Polski. *Acta Agrophisica* 13(2): 555–568.

Authors' contribution

L.Ch-O – concept, literature review, writing and corrections; W.O. – compilation and calculation of source data and methods, writing and corrections.

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