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## CHANGES OF THE THERMIC SEASONS IN WARSAW IN THE PERIOD 1933–2004

**Abstract:** The beginning dates and the lengths of thermic seasons in Warsaw (1951-2004) were analysed. These characteristics of seasons are very variable, especially in winter. The changes of winter length influence strongly the dates and length of adjacent seasons, that is, of early winter and early spring. The current warming is best visible exactly during these seasons: winter becomes shorter, while early winter and – to an even longer degree – early spring become longer. The period of spring, summer and autumn is characterised by greater stability. These seasons showed a very weak tendency to change or even its lack, both as regards the length and the beginning date.

**Key words:** thermic seasons, winter, early spring, spring, summer, autumn, early winters, current warming.

The occurrence on the area of Poland of six seasons, separated by specific values of the mean daily temperature, constitutes a paradigm, established by E. Romer (1904, 1912) already about a century ago. The average dates of the beginning and length of the individual seasons, as well as the method of their definition, were the subject of numerous papers (a. o., Romer, 1938; Gumiński, 1948; Wiszniewski, 1960; Paszyński, Niedźwiedź, 1991; Niedźwiedź, Limanówka, 1992; Piotrowicz, 2000). The subject of this paper is the changeability of the characteristics of seasons during the over 70-years-long period when the measurements at the meteorological station Warszawa-Okęcie were being done. The station is located in fairly remote southwest outskirts of the city, and therefore the results can be regarded as being undisturbed by the thermic influence of the urban development (Żmudzka et al., 2003).

As the basis for this paper the mean monthly temperature values from November 1932 through December 2004 were used. The dates of the beginning of seasons have been determined by calculations based on the assumption that the temperature value equal to the monthly mean falls on the middle day of the month and that the temperature changes evenly from one middle day of the month to the next (R. Gumiński's method, 1948).

The seasons are determined by the following temperature ranges:

Winter		t	≤ 0.0 °C
Early spring	0.0 °C <	t	≤ 5.0 °C
Spring	5.0 °C <	t	≤ 15.0 °C
Summer	15.0 °C <	t	
Autumn	5.0 °C <	t	≤ 15.0 °C
Early winter	0.0 °C <	t	≤ 5.0 °C

Table 1 gives the results of the calculations of the dates of the beginning of seasons and their length as well as other characteristics.

Table 1.

Mean and extreme beginning dates and lengths of thermic seasons in Warsaw (1933-2004)

Characteristics of the season		Winter	Early spring	Spring	Summer	Autumn	Early winter
Beginning	Mean	12 December	5 February	31 March	28 May	4 September	4 November
	Standard deviation (in days)	18.9	21.8	9.8	11.4	9.0	8.6
	The earliest date	7 November 1993	29 December* 1997	20 February 1990	8 May 2002	3 August 1966	14 October 1946
	The latest date	9 February* 1975	29 March 1958	19 April 1933	30 June 1984	24 September 1967	22 November 1951
	Range of fluctuations (in days)	95	90	59	54	53	40
Length (in days)	Mean	75	34	58	99	61	38
	Standard deviation (in days)	30.9	16.9	13.8	15.8	11.9	20.0
	Potential	142	111	130	139	111	118
	Shortest	0	10	30	65	37	11
	Longest	1987/88 1988/89 1989/90	1952	1958	1962	1946	1969
	138	91	96	128	95	101	
	1941/42	1998	1990	1937	1966	1974	

\*The dates of the latest beginning of winter and the earliest beginning of early spring refer to years in which thermic winter occurred.

**Winter** is the season exhibiting the greatest variability as regards both the beginning and ending date and length (and also with regard to tem-

perature values in winter, which is however not the subject of this paper). The range of the beginning dates is 95 days (between 7 November and 9 February), thus it is larger than the mean length of this season (75 days; standard deviation of both characteristics is equal to 19 and 31 days, resp., see Table 1). That means that in one year winter may end earlier than it begins in another year. Cool periods without thermic winter are also possible (Fig. 1), as well as winters interrupted by periods with temperature above zero. Particularly long periods of this kind, dividing winter into two parts, occurred in 1943/44 (winter from 6 December through 8 March, including an interruption from 2 through 31 January) and in 1993/94 (winter from 7 November through 26 February, including an interruption from 28 December through 28 January).

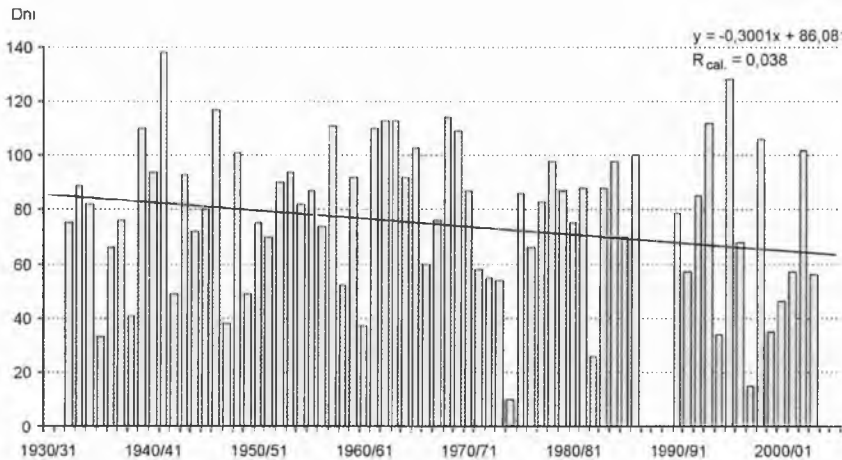


Fig. 1. The duration of winters in Warsaw in the period 1932/33 – 2003/04

The period from the earliest beginning date through the latest ending date of a season can be called its potential length. Due to a great variability of the beginning and ending dates and of its length, the potential length of winter is larger than that of any other season: 142 days. During the whole period in question the longest winter was shorter by only four days: from 9 November 1941 through 26 March 1942 (138 days). During the period of the potential winter three periods of particular thermic instability can be distinguished: 1) from 7 through 21 November (15 days) when in individual years autumn, early winter or winter may occur; 2) from 29 December through 8 February (42 days) when early winter, winter or early spring may occur; 3) from 26 February through 28 March (31 days) when winter, early spring or spring may occur.

The length of winter varied sometimes drastically from year to year (Fig. 1), one can however show periods of generally shorter or longer winters. The series of three years, from 1987/88 through 1989/90 without any thermic

winter at all, was an unusual phenomenon; short (around 53 days) winters occurred in the first half of 1970s. The years 1960s, in particular 1961/62 through 1965/66 were characterised by particularly long winters, with mean length equal to 106 days. It is worth noting that the first half of 1960s was the only period during the 72-years-long period under investigation when the mean length of winter was equal to the length of summer. Generally, winters in the first half of the period under investigation were longer than in its second half; the length of the winter decreased by about three days for each ten years. On the other hand, no discernible tendency for the change of the beginning date of winter occurred.

**Early spring** is, on the average, the shortest season (34 days) and, similarly to winter, it is characterised by a variability of the occurrence dates (standard deviation of the beginning date is 22 days, while the length of this season, 17 days; see Table 1). If in cool seasons without thermic winter we divide the period with temperature  $\leq 5.0^{\circ}\text{C}$  into halves and regard them as early winter followed directly by early spring, then the beginning of the early spring understood this way may fall already at the end of the previous year (e. g., 27 December 1989). An early spring starting so early is also possible after a very short winter (29 December 1997 after a 15-day-long winter). Due to a large variability of the occurrence dates the potential length of the early spring is equal to as much as 111 days; it is therefore more than three times as large as its mean length. That means that just as winter, early spring may end earlier in one year than begin in another year. In reality, the longest early spring lasted 91 days and was therefore not much shorter than the longest spring.

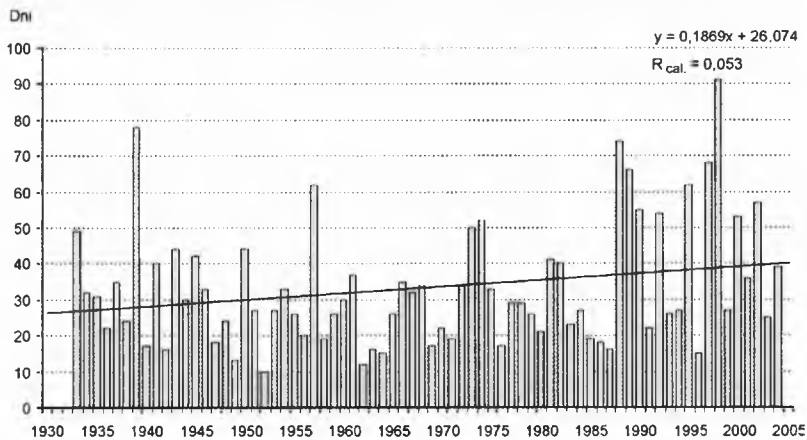


Fig. 2. The duration of early springs in Warsaw in the period 1933-2004

In the period under investigation the shortest early springs occurred after the longest winters, that is, in 1960s, and in particular in the first half of that decade (not much over 20 days, see Fig. 2). The longest early springs,

on the other hand, occurred in the late 20<sup>th</sup> century and at the beginning of the 21<sup>st</sup> century. For that reason early spring demonstrated a statistically significant ( $\alpha = 0.05$ ) tendency to increase in length (almost two days for each ten years) and to the gradually earlier beginning (almost three days for each ten years; a tendency verging on statistical significance).

**Spring** is a more “stable” season than early spring: the standard deviation of the beginning date is equal to 10 days only (Table 1), and the range of fluctuations to 59 days. The earliest beginning of spring was on 20 February 1990; after a cool period without a thermic winter — this was, however, an exceptional date. The second-earliest spring began much later, on 7 March. The potential length of spring is equal to 130 days, and the longest spring lasted 96 days. During the potential spring one can distinguish a 19-day-long period (from 19 April through 7 May), which in every year belonged to spring; this period can be called “absolute spring”.

The length of spring in individual years is less changeable than that of winter and early spring (standard deviation equal to 14 days), and therefore is it more difficult to single out periods of particularly short or particularly long springs. To the former belongs undoubtedly the second half of 1940s (slightly more than 45 days); to the latter, the late 1980s and the early 1990s (over 80 days). In general, in the period in question the length of spring became insignificantly longer, while the beginning date, insignificantly earlier.

**Summer** is the longest season (99 days) and relatively little changeable as regards both the beginning and ending dates and the length. The range of the beginning date was 54 days (standard deviation 11 days — Table 1), and the length, from 65 through 128 days (standard deviation 16 days). The longest summer was therefore only twice as long as the shortest one, while the longest autumn and spring were 2.5 to 3 times as long as the shortest ones, resp.; the longest early spring and early winter were as much as nine

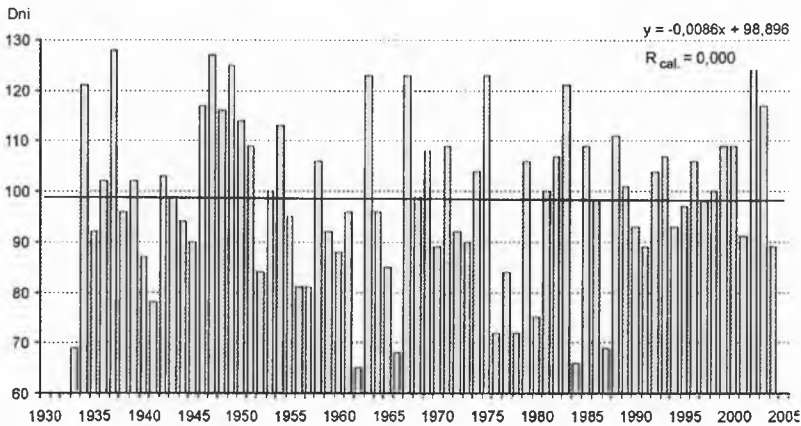


Fig. 3. The duration of summers in Warsaw in the period 1933-2004

times as long as the shortest ones. The potential length of summer is equal to 139 days; it is thus slightly shorter than that of winter, and during the period from 30 June through 2 August the "absolute summer", lasting 34 days, occurs. Summer is also the period in which the mean temperature is maintained at over 15.0°C; in the 72-years-long period under investigation, only one example of summer with an interruption was observed: in 1958 summer began on 15 May, but in June an 18-days long return of temperature below 15°C occurred.

The middle part of the period under investigation was characterised by generally shorter summers (Fig. 3); in particular, such summers occurred in the second half of 1970s (around 80 days). Longer summers, on the other hand, occurred at the beginning of the period under investigation, in particular in the second half of 1940s (around 120 days) and also in recent years (around 105 days). Because of such oscillations, the length of summer does not show tendency to change in length. Neither does a tendency to change the beginning date occur.

**Autumn** is also a relatively stable season, especially as regards the dates of its beginning and end; standard deviation of the beginning date is equal to 9 days only, and the range of its fluctuations, 53 days (Table 1). The earliest autumn began on 3 August (1966), but it was the only example of such an early autumn, after one of the shortest summer periods (68 days); the next-earliest autumn began as late as over two weeks later (18 August 1987). The potential length of autumn is equal to 111 days; it is thus shorter than that of spring, even though spring is on the average slightly shorter than autumn (58 and 61 days, resp.). The period of "absolute autumn" lasts from 24 September through 13 October; that is, in each of the year of the period under investigation this period belonged to autumn. The longest autumn was almost as long as the longest spring (95 and 96 days, resp.), but the shortest autumn was shorter than the shortest spring by a week (30 and 37 days, resp.).

During the period under investigation, the shortest autumn, just as the shortest spring, occurred in 1940s, in particularly in mid-1940s (around 50 days); it was at the same time a period of longest summers. The longest autumns occurred in the second half of 1970s (almost 75 days), that is, in the period when the shortest summers occurred (on the average, shorter than winters). In general, however, autumn shows an insignificant tendency both to increase in length and to the earlier beginning date.

**Early winter** is the second-shortest, after early spring, season (38 days), with the least variable beginning date: the standard deviation is equal to almost 9 days, and the range, only 40 days. The transition from autumn to early winter is therefore least differentiated in time among all "border" dates between the consecutive seasons (from 14 October through 21 November). This does not mean, however, that the length of this season varies only little. On the contrary, its length changes very much: from 11 to 101 days (standard deviation equal to 20 days: Table 1), and the potential length is

as much as 118 days, thus even more than of the much longer (on the average) autumn. This is an obvious result of the very variable beginning date of winter. Thus, similarly to winter and early spring, early winter may end at an earlier date in one year than it begins in another year. This also means that there is a period (7 through 21 November) during which three different seasons can occur in various years: autumn, early winter (most of the time), but also already winter. Similarly, at the end of early winter (29 December through 8 February) a similar alternation of seasons can occur: early winter, winter and early spring. One should however add that the latest ending date of an early winter (8 February 1975) is completely exceptional: it ended the longest early winter, lasting 101 days, after each a very short, 10-days-long winter occurred.

In the 72-years-long period under investigation definitely shortest early winters occurred in 1960s (around 25 days), that is, in the years of longest winters and shortest early springs. Relatively longer early winters occurred in the late 1940s and early 1950s, as well as in 1980s. In general, early winter showed a very weak, insignificant tendency to lengthen and to a slightly later beginning.

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