THERMAL SEASONS IN POLAND IN YEAR 2014 IN COMPARISON WITH 1981-2010 PERIOD

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The year 2014 brought a series of heat records in many countries in Europe. The World Meteorological Organization informed that 2014 was set to be the hottest worldwide since the beginning of the observations, in step with a global warming trend. Higher than average mean temperature during summer season was observed also in Poland. The article presents the temporal distribution of thermal seasons during the year 2014 in Poland in comparison with multiannual period 1981-2010. Eight different thermal seasons were distinguished: early spring, spring, early summer, summer, late summer, autumn, early winter and winter. Calculations were based on daily mean temperatures from 12 synoptic stations located in different regions in Poland. The exceptionally early beginning of spring, early beginning and long summer and late beginning of autumn were reflected in a very long vegetation season. The results of temperature analysis were compared with phenological observations of wild plants conducted in synoptic stations in Poland since the year 2007.

Keywords: thermal season, vegetation, phenological observations, Poland

INTRODUCTION

The year 2014 brought a series of heat records in many countries, not only in Europe. National Centers for Environmental Information - NCEI (former National Climatic Data Center - NCDC) informed that the year 2014 was the warmest year across global land and ocean surfaces (combined land and ocean temperature) since observations began in 1880. The average temperature was 0.69 ^{o}C above the 20th century average of 13.9 ^{o}C (the previous records were noted in 2005 and 2010). Nine of the ten warmest years in the 135-year period of record have occurred in the 20th century. The global average land surface temperature in 2014 was 1.00 ^{o}C above the 20th century average of 8.5 ^{o}C and was fourth highest annual value on record. Six months of 2014 (May, June, August, September, October and December) were record warm, while April was second warmest, January, March and July were fourth warmest for their respective months and November was seventh warmest (www.ncdc.noaa.gov).

Europe, as a whole, experienced its warmest year on record. Weather services in Germany, Austria, France, Sweden Belgium and United Kingdom reported that 2014 was the hottest since the beginning of the observations in these countries.

2014 in Poland, the western part of the country was extremely hot (on the average), in the central part was anomalously hot and north-east - warm. Starting in January, in the entire country, the mean monthly temperatures were higher than normal (excluding June). Consequently – an exceptionally early beginning of the thermal spring and summer and late beginning of autumn were observed. These phenomena were reflected in a very long vegetation season and deviations in the beginning of phenological seasons in the whole of Poland.

In the article, the analysis of the differences of the thermal seasons in comparison to the average calculated from the multiannual period and results of phenological observations of wild plants in Poland are described.

MATERIALS AND METHODS

Thermal seasons are determined by air temperature values. In this paper, daily mean air temperatures from 14 synoptic stations operated by the Institute of Meteorology and Water Management – National Research Institute (IMWM-NRI), representative of different climatic conditions in Poland were used. On this base, the eight thermal seasons were distinguished: early spring (0.0 ^{o}C $\leq$ t < 5.0 ^{o}C), spring (5.0 ^{o}C $\leq$ t < 10.0 ^{o}C), early summer (10.0 ^{o}C $\leq$ t < 15.0 ^{o}C), summer (t $\geq$15.0 ^{o}C), late summer (15.0 ^{o}C > t $\geq$ 10.0 ^{o}C), autumn (10.0 ^{o}C > t $\geq$ 5.0 ^{o}C), early winter (5.0 ^{o}C > t $\geq$ 0.0 ^{o}C) and winter (0.0 ^{o}C < t). Beginnings, ends and lengths of all seasons in the year 2014 were compared with multiannual period 1981-2010. In addition, phenological observations of wild plants conducted on 50 synoptic stations in Poland were used. It allowed to distinguish the phenological seasons in 2014 and to compare the results with the average dates of the beginning of these seasons.

Dates of the beginning of thermal seasons were determined using Makowiec method (used in Poland for growing season determination) based on the following assumptions:

- the beginning of the thermal winter in a given year (or multiannual period) is the earliest date of a series of days with the mean daily air temperature lower than the threshold that is the beginning of such cumulated series of daily mean temperature deviations from the threshold value that do not have positive values during the next 31 days (or more),
- the beginning of the thermal early spring, spring and early summer in a given year (or multiannual period) is the earliest date of a series of days with the mean daily air temperature equal or higher than the threshold that is the beginning of such cumulated series of daily mean temperature deviations from the threshold value that do not have negative values up to the end of the first 6 months of a year,
- the beginning of the thermal summer in a given year (or multiannual period) is the earliest date of a series of days with the mean daily air temperature equal or higher than the threshold that is the beginning of such cumulated series of daily mean temperature deviations from the threshold value that do not have negative values during the next 31 days (or more),
- the beginning of the thermal late summer, autumn and early winter in a given year (or multiannual period) is the earliest date of a series of days with the mean daily air temperature equal or lower than the threshold that is the beginning of such cumulated series of daily mean temperature deviations from the threshold value that do not have positive values up to the end of the last 6 months of a year,
- end of each season is a day before the begining of the next season (Makowiec 1983).

The differences between the dates of the beginning of each thermal season in 2014 and the average date from 30-year

period (1981-2010) were calculated. The obtained results allowed to distinguish the length of all seasons and to compare the results with the multiannual period.

The determination of dates of the beginning of all phenological seasons excluding winter was based on observations (conducted since 2007 by IMWM-NIR) of the following selected wild plants: *Corylus avellana L.* and *Tussilago farfara L.* (earliest spring); *Prunus padus L.*, *Taraxacum officinale F. H. Wigg.* and *Betula pendula Roth* (early spring); *Syringa vulgaris L.and Aesculus hippocastanum L.*(spring); *Robinia pseudoacacia L.* (early summer); *Tilia cordata Mill.* (summer); *Corylus avellana L.*, *Aesculus hippocastanum L.*and *Calluna vulgaris (L.) Hull* (early autumn); *Aesculus hippocastanum L.*, *Tilia cordata Mill.* and *Betula pendula Roth* (autumn).

RESULTS

The dates of the beginning of all thermal seasons in analyzed synoptic stations in the multiannual period and in the year 2014 are shown in Table 1.

Table 1 Dates of the beginning of the thermal seasons

Thermal season	Period	Station													
		Swinoujscie	Leba	Chojnice	Suwalki	Mlawa	Poznan	Zielona Gora	Lodz	Siedlce	Jelenia Gora	Opole	Sandomierz	Lesko	Zakopane
early spring	1981-2010	20.01.	2801	4.03.	16.03.	7.03.	23.02.	20.02.	25.02.	6.03.	25.02.	20.02.	1.03.	1.03.	16.03.
	2014	2.02.	31.01.	6.02.	7.02.	6.02.	1.02.	1.02.	31.01.	6.02.	31.01.	30.01.	5.02.	1.02.	31.01.
spring	1981-2010	29.03.	1.04.	31.03.	11.04.	31.03.	26.03.	26.03.	27.03.	29.03.	30.03.	24.03.	28.03.	29.03.	17.04.
	2014	9.03.	9.03.	9.03.	19.03.	10.03.	2.03.	16.02.	10.03.	13.03.	15.03.	10.03.	9.03.	10.03.	17.03.
early summer	1981-2010	28.04.	10.05.	27.04.	28.04.	25.04.	22.04.	22.04.	24.04.	25.04.	26.04.	22.04.	23.04.	27.04.	10.05.
	2014	6.05.	7.05.	19.04.	19.04.	19.04.	19.04.	19.04.	19.04.	18.04.	19.04.	19.04.	18.04.	18.04.	18.05.
summer	1981-2010	18.06.	26.06.	19.06.	3.06.	2.06.	25.05.	25.05.	26.05.	2.06.	19.06.	25.05.	26.05.	3.06.	11.07.
	2014	21.05.	28.06.	20.05.	17.05.	18.05.	19.05.	20.05.	19.05.	18.05.	7.06.	19.05.	19.05.	6.06.	4.07.
late summer	1981-2010	9.09.	4.09.	30.08.	27.08.	2.09.	5.09.	5.09.	5.09.	1.09.	28.08.	12.09.	5.09.	30.08.	22.08.
	2014	22.09.	20.09.	20.09.	20.08.	22.09.	22.09.	22.09.	22.09.	21.08.	19.08.	22.09.	20.09.	17.09.	14.08.
autumn	1981-2010	16.10.	13.10.	8.10.	30.09.	9.10.	12.10.	13.10.	10.10.	10.10.	9.10.	16.10.	10.10.	9.10.	25.09.
	2014	23.10.	23.10.	23.10.	17.10.	22.10.	22.10.	22.10.	22.10.	22.10.	22.10.	22.10.	23.10.	22.10.	22.09.
early winter	1981-2010	13.11.	10.11.	1.11.	28.10.	2.11.	8.11.	9.11.	9.11.	3.11.	8.11.	10.11.	9.11.	9.11.	18.10.
	2014	26.11.	18.11.	16.11.	22.10.	15.11.	18.11.	19.11.	18.11.	15.11.	19.11.	20.11.	16.11.	18.11.	18.11.
winter	1981-2010	-	16.01.	13.12.	29.11.	30.11.	15.12.	15.12.	13.12.	30.11.	8.12.	21.12.	1.12.	7.12.	18.11.
	2014	29.11.	28.11.	28.11.	19.11.	26.12.	26.12.	26.12.	26.12.	26.12.	26.12.	26.12.	26.12.	26.12.	23.11.
Thermal growing season -beginning	1981-2010	29.03.	1.04.	31.03.	11.04.	31.03.	26.03.	26.03.	27.03.	29.03.	30.03.	24.03.	28.03.	29.03.	17.04.
	2014	9.03.	9.03.	9.03.	19.03.	10.03.	2.03.	16.02.	10.03.	13.03.	15.03.	10.03.	9.03.	10.03.	17.03.
Thermal growing season - end	1981-2010	13.11.	10.11.	1.11.	28.10.	2.11.	8.11.	9.11.	9.11.	3.11.	8.11.	10.11.	9.11.	9.11.	18.10.
	2014	26.11.	18.11.	16.11.	22.10.	15.11.	18.11.	19.11.	18.11.	15.11.	19.11.	20.11.	16.11.	18.11.	18.11.

" - " absence of the thermal winter

In Poland, January and February 2014 were warm, March-May warm and extremely warm, July and September-November were warm. In the result, the shift of all seasons is visible, particularly for the early spring, spring, summer and winter (Bulletin 2014).

The differences between the average beginning (calculated from period 1981-2010) of all seasons and the dates in 2014 are shown in Table 2.

For the whole country, the differences (calculated in days) between the period 1981-2010 and year 2014 ranges as follows:

- early spring -44 ÷ +13 days
- spring -38 ÷ -14 days
- early summer -9 ÷ +8 days
- summer -30 ÷ +38 days
- late summer -11 ÷ +21 days
- autumn -3 ÷ +17 days
- early winter -6 ÷ +31 days
- winter -49 ÷ +35 days.

The accelerated beginning of the early spring was noted in the whole country except the coastal areas (Swinoujscie, Leba). As the consequence of warm and extremely warm period from March to May, spring, early summer and summer were significantly accelerated. The long period of high daily temperatures in July and also from Spetember to November, caused very late autumn and early winter. As a result, thermal winter started very late in the whole country (excluding north-east part – Suwalki).

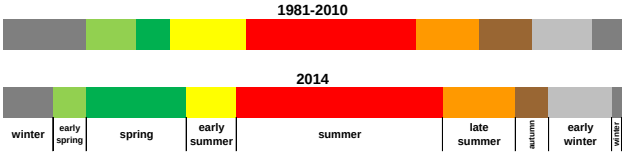
The acceleration of some seasons in the first part of the year and delay of the others in the second half of 2014 is evident in Fig. 1 presenting stations characterizing different parts of the country (Zielona Gora – west; Poznan – central-west; Lodz – central, Suwalki – north-east; Zakopane – mountains; Leba – coast).

Table 2 Differences in the beginning of the thermal seasons in 2014 in comparison with period 1981-2010 [days]

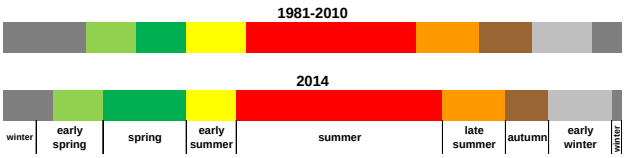
Thermal season	Station												
	Swinoujscie	Leba	Chojnice	Suwalki	Mlawa	Poznan	Zielona Gora	Lodz	Siedlce	Jelenia Gora	Opole	Sandomierz	Lesko	Zakopane
early spring	+13	+3	-26	-37	-29	-22	-19	-25	-28	-25	-21	-24	-28	-44
spring	-20	-23	-22	-23	-21	-24	-38	-17	-16	-15	-14	-19	-19	-31
early summer	+8	-3	-8	-9	-6	-3	-3	-5	-7	-7	-3	-5	-9	+8
summer	-28	+2	-30	-17	-15	-6	-5	-7	-15	-12	-6	-7	+3	-7
early autumn	+13	+16	+21	-7	+20	+17	+17	+17	-11	-9	+10	+15	+18	-8
autumn	+7	+10	+15	+17	+13	+10	+9	+12	+12	+13	+6	+13	+13	-3
early winter	+13	+8	+15	-6	+13	+10	+10	+9	+12	+11	+10	+7	+9	+31
winter	-	-49	-15	-10	+26	+11	+11	+13	+26	+18	+5	+25	+19	+35
growing season - beginning	-20	-23	-22	-23	-21	-24	-38	-17	-16	-15	-14	-19	-19	-31
growing season-end	+13	+8	+15	-6	+13	+10	+10	+9	+12	+11	+10	+7	+9	+31

minus - earlier date of the beginning of the thermal season in 2014 (in comparison to 1981-2010)
plus - later date of the beginning of the thermal season in 2014 (in comparison to 1981-2010)

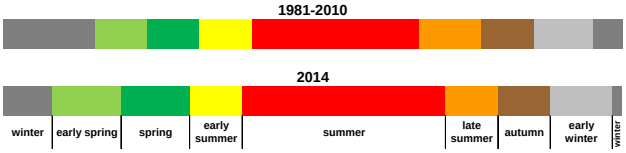
Zielona Gora



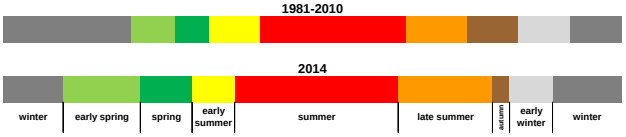
Poznan



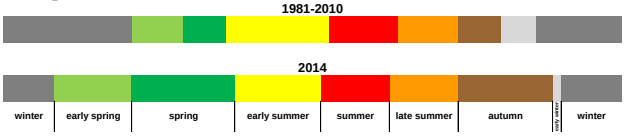
Lodz



Suwalki



Zakopane



Leba

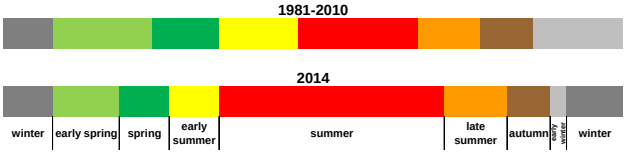


Fig. 1. Beginning and end of the thermal seasons in 2014 in comparison with the period 1981-2010.

In the Polish lowlands, the acceleration of the beginning of the early spring and spring and very long summer are well visible. In mountains (Zakopane) and at the coastal area (Leba), the prolongation of seasons in the first half of the year and longer autumn caused very late and short early winter.

Such a big differences in the beginnings and ends of all thermal seasons in 2014 also caused the changes in their lengths (Table 3).

Table 3 Differences in the length of the thermal seasons in 2014 in comparison with the period 1981-2010 [days]

Thermal season	Station													
	Swinoujscie	Leba	Chojnice	Suwalki	Mlawa	Poznan	Zielona Gora	Lodz	Siedlce	Jelenia Gora	Opole	Sandomierz	Lesko	Zakopane
early spring	-33	-26	+4	+14	+8	-2	-19	+8	+12	+10	+7	+5	+9	+13
spring	+28	+20	+14	+14	+15	+21	+35	+12	+9	+8	+11	+14	+10	+39
early summer	-36	+5	-22	-8	-9	-3	-2	-2	-8	-5	-3	-2	+12	-15
summer	+41	+14	+51	+10	+35	+23	+22	+24	+4	+3	+16	+22	+15	-1
late summer	-6	-6	-6	+24	-7	-7	-8	-5	+23	+22	-4	-2	-5	+5
autumn	+6	-2	0	-23	0	0	+1	-3	0	-2	+4	-6	-4	+34
early winter	-	-	-30	-4	+13	+1	+1	+4	+14	+7	-5	+18	+10	+4
thermal growing season	+33	+31	+37	+17	+34	+34	+48	+26	+28	+26	+24	+26	+28	+62

minus - shorter thermal season in 2014 (in comparison to 1981-2010)
plus - longer thermal season in 2014 (in comparison to 1981-2010)

The analysis of the duration of all seasons showed that spring and summer were longer than the average in the whole country (in some parts of Poland, summer was longer even more than 1 month).

As the result of the earlier beginning of spring seasons, the growing season started very early in the whole country and ended much later than on the average (Table 2). Spatial distribution of the differences of the beginning and end of the growing season in 2014 in Poland is presented in Fig. 2 and Fig. 3.

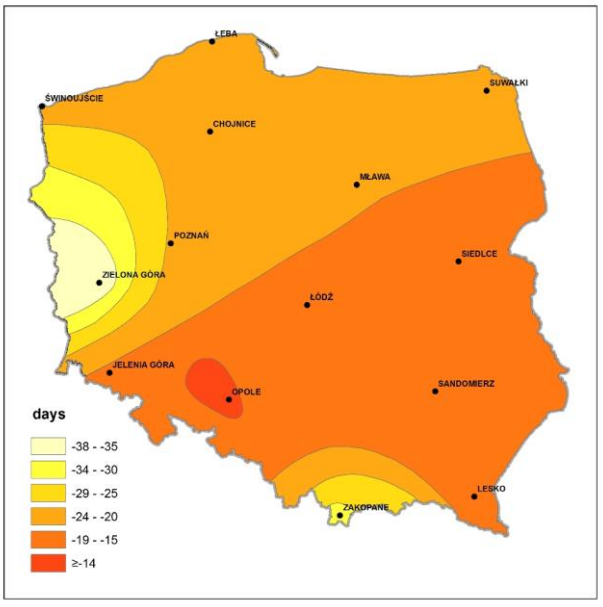


Fig. 2 The differences (in days) of the beginning of growing season in 2014 in comparison with the period 1981-2010.

The biggest differences in the growing season beginning were noted in the west part of the country (more than 1 month earlier than normal). Also in the north, central-north and east-north parts of Poland, a very early beginning of this season was observed. The abnormal situation was noted in mountains area, where an extremly early beginning of the growing season was observed. The end of the growing season was 1-2 weeks later than normal in most areas of the country. The only exception was farthest north-east (Suwalki) where this season ended a few days earlier than the average. The situation described above was very favorable for plants growth because the "warm" period was very long, but the daily extreme temperatures were not very high. Also, the moisture conditions were favorable for plant cultivation because the whole year was classified as "normal" in terms of amount of rain (with the spring a little bit more wet than average).

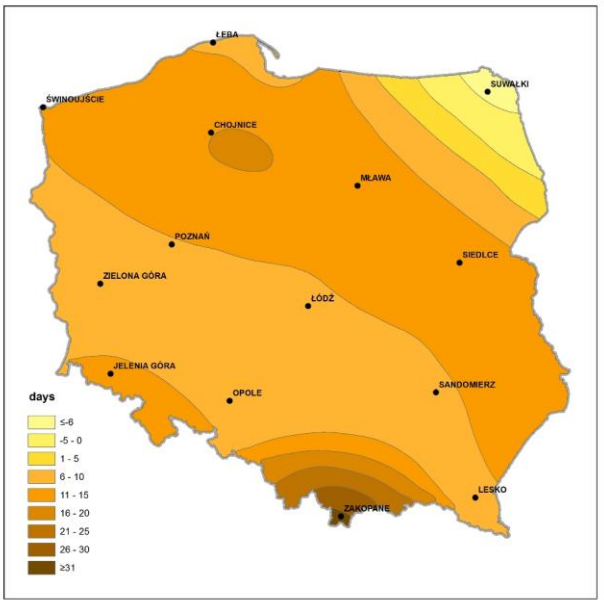


Fig. 3 The differences (in days) of the end of growing season in 2014 in comparison with the period 1981-2010.

All these meteorological conditions were reflected in the acceleration of phenological seasons during the first part of the year and both - acceleration of the beginning and delay of the end of seasons in the second part of 2014. The smallest differences were noted for summer season (see below):

earliest spring (based on flowering of *Corylus avellana L.* and *Tussilago farfara L.*) -40 ÷ +9 days

early spring (based on flowering of *Prunus padus L.* and *Taraxacum officinale F. H. Wigg.* and leaf unfolding of *Betula pendula Roth*) -20 ÷ +9 days

spring (based on flowering of *Syringa vulgaris L.* and *Aesculus hippocastanum L.*) -14 ÷ +1 days

early summer (based on flowering of *Robinia pseudoacacia L.*) -8 ÷ +5 days

summer (based on flowering of *Tilia cordata Mill.*) -14 ÷ +19 days

early autumn (based on fruit ripening of *Corylus avellana L.* and *Aesculus hippocastanum L.* and flowering of *Calluna vulgaris (L.) Hull*) -23 ÷ +17 days

autumn (based on leaf colouring of *Aesculus hippocastanum L.*, *Tilia cordata Mill.*and *Betula pendula Roth* -22 ÷ +23 days.

The differences between the beginning of the phenological early spring and autumn in 2014 and the average calculated from the multiannual period are showed in Fig. 4 and Fig. 5. Sspatial distribution of differences of phenological seasons is a little bit differnt than thermal seasons distribution because a different period is calculated as an average and many more stations were accounted (50 synoptic stations). The IMWM-NIR is providing the phenological observations since 2007, therefore the mean date of phenological phases were calculated for the period 2007-2013.

Fig. 4 Differences (in days) between average dates (2007-2013) and year 2014 of the early spring.

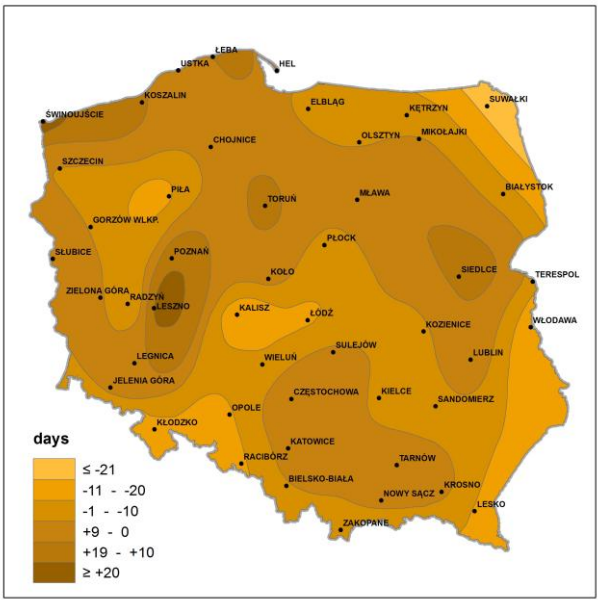


Fig. 5 Differences (in days) between average dates (2007-2013) and year 2014 of the autumn.

CONCLUSION

In Poland, similiarly as in many other countries in Europe, year 2014 was exceptionally hot. The yearly mean temperature was 1,7 ^{o}C above the average. In many places in western Poland, 2014 was the hottest since the beginning of the observations. After very short winter, the beginning of the thermal early spring and spring were observed much earlier than usualy (early spring - 27 days on the average; spring - 22 on the average). The "warm" weather was observed also during the second part of the year. The thermal autumn was delayed 6-17 days and the early winter was delayed 7-13 days depending on the station. In the whole country, spring and summer were longer than the average (respectively 8 and 22 days).

Acceleration of the thermal seasons during the first part of the year and delay in the second part influenced the duration of vegetation season. The biggest differences in the growing season beginning were noted in the western part of the country. In Poznan, vegetation season lasted 260 days. Its mean temperature was 14.2 ^{o}C and it was the highest one since the beginning of the observation in 1860 (the previous records were noted in 1934 and 2006 - 14.0 ^{o}C; 2002 and 2007 - 13.9 ^{o}C).

All these meteorological conditions were reflected in the acceleration of the phenological seasons during the first part of the year and both - acceleration of the beginning and delay of the end of seasons in the second part. The smallest differences were noted for summer.

The anomalous course of the meteorological conditions in the temperate climate results in the shift and changes in duration of the thermal seasons. These shifts are reflected very well in plant world where the reaction to meteorological factors is quick and realtively obvious.

LITERATURE

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