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Air temperature changes in Żagań (Poland) in the period from 1781 to 1792

R. Przybylak,* A. Pospieszyńska, P. Wyszyński and M. Nowakowski
Department of Meteorology and Climatology, Nicolaus Copernicus University, Lwowska 1 87-100, Toruń, Poland

ABSTRACT: The temperature measurements in Żagań were made within the Mannheim network of stations established for Europe and North America by the Palatine Meteorological Society in 1780. The meteorological observations made there in the period 1781–1792 were taken according to the rules for observers ('*Monitum ad observatores*') written by Johann Hemmer (Director of the Palatine Meteorological Society), using calibrated instruments sent by the Society. Source raw data from three measurements a day, taken at morning, noon and evening and available in the publication *Ephemerides Societatis Meteorologicae Palatinae* have been used for the analysis. Daily means originally calculated using Mannheim's formula have been corrected to the true daily mean based on statistical analysis using hourly temperature data from modern meteorological station in Wrocław, located near Żagań. The mean annual air temperature for the study period (7.9 °C) was about 0.8 °C lower than its value for the period 1981–2010, calculated from Grabik data (the nearest station to Żagań). The coldest year was 1785 (6.3 °C), while the warmest was 1781 (9.6 °C). The clearly colder sub-period 1784–1788 was probably significantly influenced by the eruption of the Laki volcano in Iceland in 1783/1784. Warmer temperatures than we have today (by +0.4 °C) occurred only in summer. However, the greatest cooling was observed in autumn and winter (temperatures lower than today in both seasons by 1.1 °C). Summer and in particular winter were markedly longer in historical times in comparison to our present-day climate, while other seasons were shorter. Investigations confirm the correctness of the view based on multiproxy data that the continentality of the climate in Poland in the 18th century was greater than today. Both daily and monthly temperature series from Żagań are strongly correlated with other 18th-century temperature series from Poland and Central Europe (with a correlation coefficient mostly higher than 0.90).

KEY WORDS Poland; air temperature; historical climatology; Mannheim network

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1. Introduction

The region of Poland, in both its historical and present boundaries has, in international terms, one of the longest histories of instrumental meteorological observations (*cf* Gorczyński, 1934; Rojecki, 1956, 1968; Marciniak, 1990; Trepińska, 1993; Lorenc, 2000; Przybylak, 2010). The first observations were made in Warsaw in either December 1654 or at the beginning of 1655 (Rojecki, 1956, 1966, 1968). Warsaw was one of 11 European stations which were included in the first network of meteorological stations (the so-called 'Rete medicea') organized by Ferdinand II, Grand Duke of Tuscany, and his brother Prince Leopold de Medici (Camuffo, 2002).

The 18th century saw a great increase of interest in meteorological observations in Poland (Przybylak, 2010). For the period prior to the start of continuous temperature measurements in Warsaw in 1779, isolated series of meteorological data are available for many places (e.g. Wrocław, Warsaw, Gdańsk, Toruń). But up until now, only a small part of these data have been used to describe Poland's climate at this time (Filipiak, 2007a, 2007b; Filipiak and Miętus, 2010; Pospieszyńska and Przybylak, 2010; Przybylak and Pospieszyńska, 2010). In a particularly fruitful period for meteorological observations in the last 20 years of the 18th century; aside from Warsaw, regular observation was also begun in Wrocław (1791) and Kraków (1792). For the period 1781–1792, however, the best and most reliable meteorological observations from the territory of Poland were made in Żagań, located in the south-west near the boundary with Germany (Przybylak *et al.*, 2010b). This statement is based on the fact that meteorological observations here were carried out within the network of meteorological stations called the 'Societas Meteorologica Palatina', established by Charles Theodore, Duke of Bavaria, in 1780 (for more details, as well as list of working stations from that time, see Cassidy, 1985 or Kington, 1988). The station used standardized instruments, and observations were made up to 1792, according to the regulations established by the Society. The results of these observations were published *in extenso* between 1783 and 1795 in Mannheim, in volumes II–XIII of the *Ephemerides Societatis Meteorologicae Palatinae*. The scope and arrangement of the data is shown in Figure 1. It is also thought that between 1783 and 1785, (1783–1789 for the region of

* Correspondence to: R. Przybylak, Department of Meteorology and Climatology, Nicolaus Copernicus University, Lwowska 1, 87-100 Toruń, Poland. E-mail: rp11@umk.pl

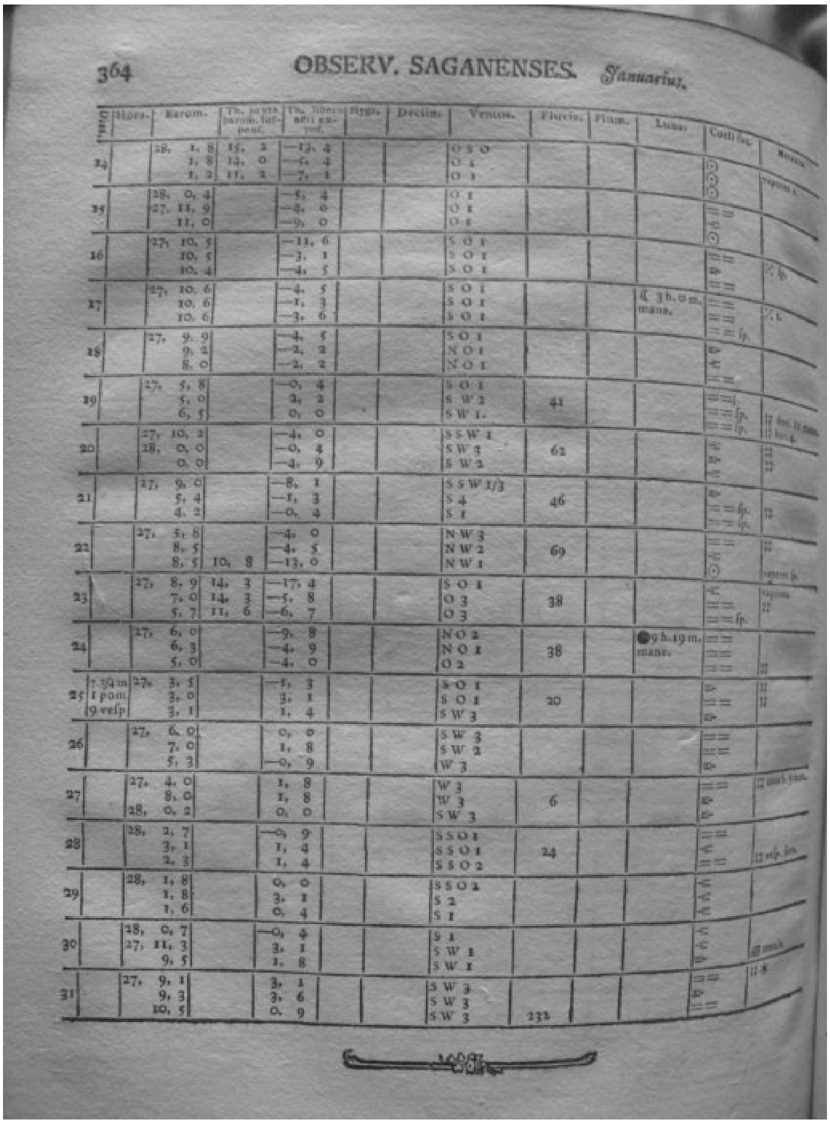

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Figure 1. Example of document presenting source data for the period of 14–31 January 1781 (Preus, 1783).

Oleśnica), instrumental meteorological measurements of atmospheric pressure (in Twardogóra and Oleśnica) and air temperature (in Legnica, Twardogóra and Oleśnica), were also recorded in this part of Poland (Miętus, 1997, Miętus *et al.*, 2000a, 2000b, 2000c; see also Table 2.1.1 in Przybylak, 2010).

The main aim of this article is to describe temperature characteristics (including natural variability) at the end of the 18th century in Poland and to estimate their changes in comparison with the present-day climate.

2. Area, data and methods

Reconstruction of climate conditions in Poland in historical times is very important for improving this kind of knowledge throughout Europe, since Luterbacher *et al.* (2010) showed that winter temperature and precipitation in Poland are highly correlated with those variables in other parts of Europe. This is a result of fact that the main driver of European climate at this time of year is atmospheric circulation. Temperatures in the area of Poland are also very closely correlated (Kożuchowski and Trepińska, 1986) and this allows for generalization of the results from one site (in our case, from Żagań), across the entire area.

Żagań is located in the geographic centre of Europe, in the south-west of Poland on the right bank of the Bóbr river (geographical coordinates: $\varphi = 51°37'$N, $\lambda = 15°19'$E, $h = 102$ a.s.l.) (Figure 2). According to Preus (1783), the observation site was located in the north-west part of the town, in the area of the abbey of the regular canon. Meteorological instruments (a hygrometer and a thermometer) were located outside the building of the abbey at the height of 44 Paris feet (about 14.3 m) above ground, near a north-facing wall (Figure 3). This is in agreement with the recommendations given in the instructions for meteorological observations, as prepared by the organisers of the observer network. (In Preus, 1783, the following is stated: 'A thermometer placed outside a building, not enclosed by buildings or other

Figure 2. Location of Żagań and other sites located in Poland and Central Europe from which temperature data have been used.

obstructions, a little away from the wall, in the open air, is thus exposed to the north that no sunlight, either direct or reflected, can fall upon it. During observation it must not be excited by candle smoke or breath to motion, to which it is very susceptible. When the mercury goes below zero degrees, it is marked with a prefix (−), not using the brackets [. . .]' (Translation from Latin to Polish by Waldemar Chorążyczewski, and from Polish to English by Edyta Grotek)).

As stated in the Introduction to this article, meteorological observations within Mannheim's network began in Żagań in 1781 and were conducted until the end of 1792 (a period of 12 years). Air temperature was measured in Żagań three times a day: in the morning, afternoon and evening. Unfortunately, they were not made at fixed hours (7 am, 2 pm and 9 pm), as was recommended in the instruction. Daily mean was calculated in Żagań using the following formula (Ephemerides . . . , 1783):

$$(t_{\mathrm{morn}} + t_{\mathrm{noon}} + 2 \cdot t_{\mathrm{even}})/4 \quad (1)$$

where t_{morn} is the temperature from the morning obs, t_{noon} is the temperature from the noon obs and t_{even} is the temperature from the evening obs.

The differing observation times oscillated throughout the year too, for example in the morning and evening (ranging usually from 4 to 8 am and 7 to midnight, respectively; for all combinations of measurement times see the last column in Appendix), and this significantly influenced the calculated daily values. Therefore, temperature characteristics calculated based on raw data cannot be used for comparison purposes with today's climate. To eliminate the influence of variable observation times on the daily mean, 48 different variants of Mannheim's formula (1) have been used for calculating it and compared with daily means calculated from 24 hourly measurements a day (method recommended by the World Meteorological Organization). For this purpose, hourly temperature data from Wrocław (the meteorological station located 165 km from Żagań) from the period 1999–2003 has been used. Temperature differences between the daily means calculated using the two aforementioned formulas are presented in Appendix. The values of the differences are presented in Appendix, stratified into months, as corrections were introduced to each mean daily air temperature data for Żagań, calculated independently by us using Mannheim's formula, based on the original measurement data. Corrected daily data shown in Appendix has been used for all calculated statistics. As can be seen from this Appendix, a complete set of daily data is available for all years, except 1787, for which only mean monthly data exist. The reasons why the fixed hours temperature data are not published for this year in the *Ephemerides . . . (1789)* are unknown. Only data about wind, cloudiness and weather are available. Mean monthly temperature data available in the cited volume of *Ephemerides* has been corrected by adding the values of average differences between monthly means, based on daily data calculated using Mannheim's formula (i.e. from original measurements) on one hand, and a series of corrected mean monthly data (see Table 3; method described above) on the other. For this purpose, data from Żagań for all years for which daily data exist have been used.

However, it must be said here that the organisers of Mannheim's network were aware of the possible biases resulting from different times of observations and therefore also introduced some corrections to the daily means. The corrections they introduced were, however, obtained as differences between daily means calculated using formula (1) based on real measurements (different hours of observation), and daily means calculated using the same formula, but for measurements taken regularly at 7 am, 2 pm and 9 pm (Kington, 1988). To calculate these differences (corrections), appropriate hourly temperature data from Berlin was used. Nevertheless, as was written earlier, we decided to introduce more precise corrections (to true daily means from 24 h) using data from the meteorological station in Wrocław, which is located significantly closer to Żagań than Berlin. As Tables 1 and 2 show the temperature series from Wrocław is also better correlated with the series from Żagań ($r = 0.98$) than data from Berlin ($r = 0.86$). The extent of the errors in describing true daily mean temperature using Mannheim's formula for measurement times 7 am, 2 pm and 9 pm is shown in Appendix (variant of mean no. 34). As can be seen, the average monthly errors are generally not very high and oscillate from −0.22 °C in December to 0.16 °C in April.

To check different aspects of temperature change from historical (1781–1792) to present times (1981–2010) daily temperature data from station Grabik ($\varphi = 51°40'$N, $\lambda = 15°07'$E, $h = 165$ m a.s.l.), operated by the Institute of Meteorology and Water Management in Warsaw,

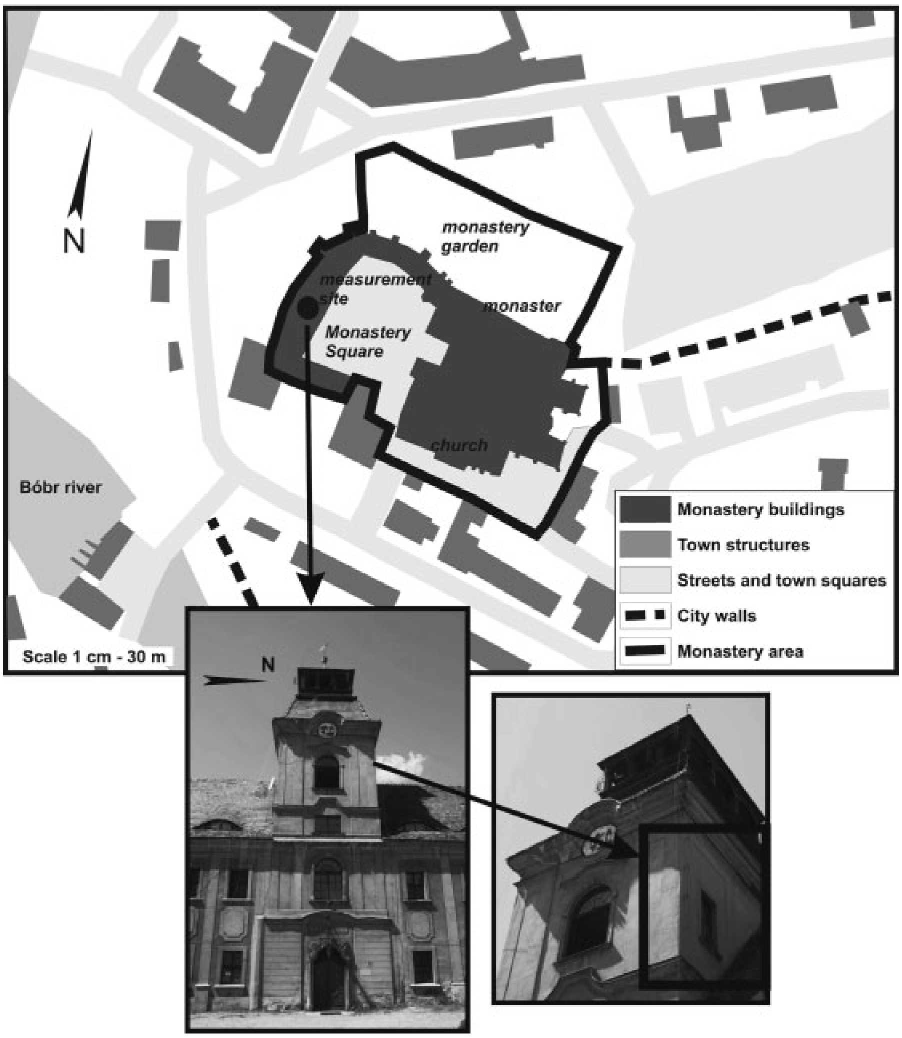

Figure 3. Historical measurement site on the tower of Żagań monastery (modified plan of the centre of Żagań, redrawn based on plan published in the Rozporządzenie . . . , 2011. photos by A. Pospieszyńska, 19 May 2013).

Table 1. Correlation of mean monthly air temperature values from 18th century between data taken from Żagań and selected Central European stations (all correlation coefficients are statistically significant).

Correlation coefficient (r)		
Żagań 1781–1792	0.86	Berlin 1781–1792
	0.96	Stockholm 1781–1792
	0.98	Vilnius 1781–1792
	0.99	Warsaw (homogenised series) 1781–1792
	0.99	Prague 1781–1792

Table 2. Correlation coefficients between mean daily air temperatures from Żagań and temperature series from Wrocław, Warsaw and Vilnius in the period 1781–1792 (all coefficients are statistically significant).

Season	Żagań Wrocław 1791–1792	Żagań Warsaw 1781–1792	Żagań Vilnius 1781–1792
Winter	0.95	0.78	0.63
Spring	0.97	0.93	0.87
Summer	0.91	0.68	0.42
Autumn	0.97	0.92	0.87
Year	0.98	0.94	0.90

located only about 15 km from Żagań have been used. Monthly temperature data from Grabik taken from period 1981–2010 are highly correlated with data from Wrocław ($r = 0.998$ at $p = 0.00$), which in turn in historical time correlate very well with data from Żagań (Table 2). Different heights of temperature measurements in historical (14.3 m a.g.l.) and contemporary (2 m) times have a large influence on the daily cycle (average anomalies reach up to 1 and $-1\,^{\circ}$C in daytime and night-time, respectively), but are not important for calculation of mean daily, and in particular, monthly, seasonal and annual data. Average temperature differences between 2 and 10 m in Koniczynka located near Toruń (central Poland) calculated from measurements on meteorological tower in period 1996–2001 were $\leq 0.05\,^{\circ}$C for 8 months and for all seasons (except winter when difference was $-0.08\,^{\circ}$C). Moreover means of spring and summer were identical.

Table 3. Mean monthly, seasonal and yearly values of air temperature (in °C) in Żagań, 1781–1792.

Year	1781	1782	1783	1784	1785	1786	1787	1788	1789	1790	1791	1792	m	σ
January	−3.2	0.5	0.5	−8.6	−3.3	−1.1	−3.4	−0.3	−5.0	0.2	1.6	−2.5	−2.1	2.9
February	0.3	−4.0	−4.0	−3.9	−4.0	−1.8	−0.2	−2.0	1.3	2.8	1.2	−3.1	−1.4	2.4
March	4.1	1.3	1.1	0.2	−5.5	0.1	4.5	0.4	−3.4	3.1	4.1	2.6	1.1	3.0
April	10.1	6.6	6.7	5.6	4.3	10.0	7.1	7.5	8.4	6.1	9.9	8.7	7.6	1.9
May	15.2	13.8	13.7	14.4	11.6	12.4	12.1	14.1	16.6	16.1	12.5	12.6	13.7	1.6
June	20.0	18.2	18.0	17.8	15.5	16.9	16.8	18.7	17.4	18.2	16.6	17.4	17.6	1.1
July	20.1	20.4	20.4	18.2	17.2	16.2	16.9	20.2	18.5	17.2	18.6	20.0	18.6	1.5
August	22.4	18.4	18.3	18.2	16.6	16.1	16.2	16.7	18.3	17.1	19.5	18.2	18.0	1.7
September	16.7	14.2	14.3	14.5	15.2	12.1	10.6	14.8	13.9	12.3	12.2	12.8	13.6	1.7
October	7.0	6.5	6.7	5.4	7.4	5.0	8.7	6.9	9.2	7.1	8.1	6.3	7.0	1.2
November	3.8	0.5	0.5	4.2	3.5	−2.2	2.0	0.9	3.6	2.1	1.9	2.2	1.9	1.8
December	−0.7	−1.6	−1.6	−1.8	−2.2	−0.5	0.3	−12.3	2.7	1.0	0.5	−0.1	−1.4	3.7
DJF	−1.5	−1.4	−1.7	−4.7	−3.0	−1.7	−1.4	−0.7	−5.3	1.9	1.3	−1.7	−1.7	2.1
MAM	9.8	7.2	7.2	6.7	3.5	7.5	7.9	7.3	7.2	8.4	8.8	8.0	7.5	1.5
JJA	20.8	19.0	18.9	18.1	16.4	16.4	16.6	18.5	18.0	17.5	18.2	18.5	18.1	1.3
SON	9.2	7.1	7.2	8.1	8.7	5.0	7.1	7.5	8.9	7.2	7.4	7.1	7.5	1.1
Year	9.6	7.9	7.9	7.0	6.3	6.9	7.6	7.1	8.4	8.6	8.9	7.9	7.9	0.9

Basic statistical characteristics [coefficient of correlation (r), standard deviation (σ), skewness (γ_1) and kurtosis (γ_2)] of analysed series of temperature data were calculated according to formulas recommended by von Storch and Zwiers (1999).

3. Results and discussion

3.1. Temperature at the end of the 18th century

Mean annual air temperature in Żagań in the period 1781–1792 was equal to 7.9 °C. In 12 years analysed, this temperature parameter oscillated from 9.6 °C in the warmest year (1781), to 6.3 °C in the coldest year (1785) (Table 3). On average, as well as most often, the warmest month was July, similarly as is noted today. The mean temperature of this month in the study period reached 18.6 °C, while the highest noted in 1782 and 1783 exceed 20.0 °C (20.4 °C), and the lowest, 16.2 °C (1786). However, the highest monthly temperature in the entire study period was observed in August 1781 (22.4 °C) (Table 3, Figures 4 and 5). In this month, anticyclonic situations were markedly prevalent (Kington, 1988, p. 42–43). The absolute maximum temperature, taken from only three measurements a day, reached 35.8 °C (on 26 and 27 July 1782), when an anticyclone centre was located over Austria and winds transported warm masses from the Iberian Peninsula, and maybe from the north-western part of Africa (Kington, 1988, p. 65). However, the coldest summer month (only 15.5 °C) occurred in June 1785. In this month, cyclonic situations and winds from the northern sector dominated (Kington, 1988, p. 134–135).

Year-on-year variations in the winter months' temperatures were significantly greater than those of the summer months (Table 3 and Figure 6). Also core of winter temperature, which means the existence of a month with a significantly lower temperature than the neighbouring months (for details see, for example, Wexler, 1958; Van

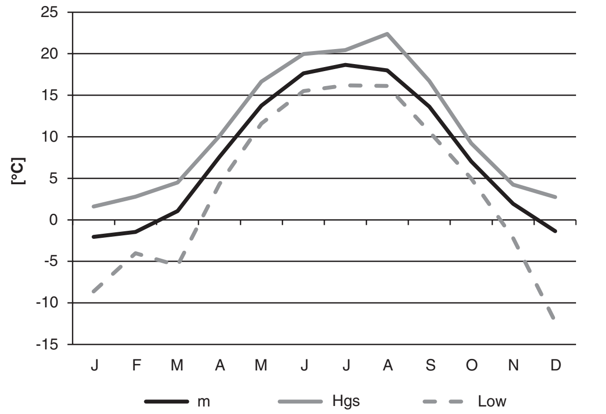

Figure 4. Annual courses of monthly means (black line), highest mean (grey solid line) and lowest mean (grey dashed line) of air temperature in Żagań in the period 1781–1792.

Loon, 1967; King and Turner, 1997; Styszyńska, 2004; Suparta et al., 2012), was markedly less visible than in summer (Figure 5). The coldest month in the cold half of the year occurred most often in January (5 times) and February (3 times), but was also noted in December (two times), November and March. In summer, the warmest month was limited to the three months typically included in 'summer'. On average, the coldest temperature in Żagań occurred in January (−2.1 °C). The temperature in this month oscillated in a wide range, from −8.6 °C (1784) to 1.6 °C (1791) (Table 3). However, evidently the coldest temperatures in single month occurred not in January, but in December in 1788 (−12.3 °C) (Table 3 and Figures 4 and 5). In turn, the warmest winter month occurred in February 1790 (2.8 °C). The lowest temperature (−32.6 °C) was measured on the 17th of December 1788.

Annual air temperatures in the study period show a decreasing trend from the beginning until 1785 (the coldest year), after which a tendency to warming is observed (Figures 6 and 7). Such behaviour is also notable in the

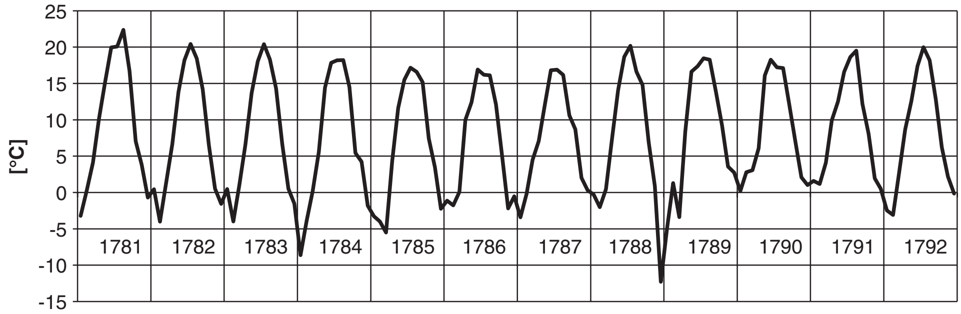

Figure 5. Course of mean monthly air temperatures in Żagań, 1781–1792.

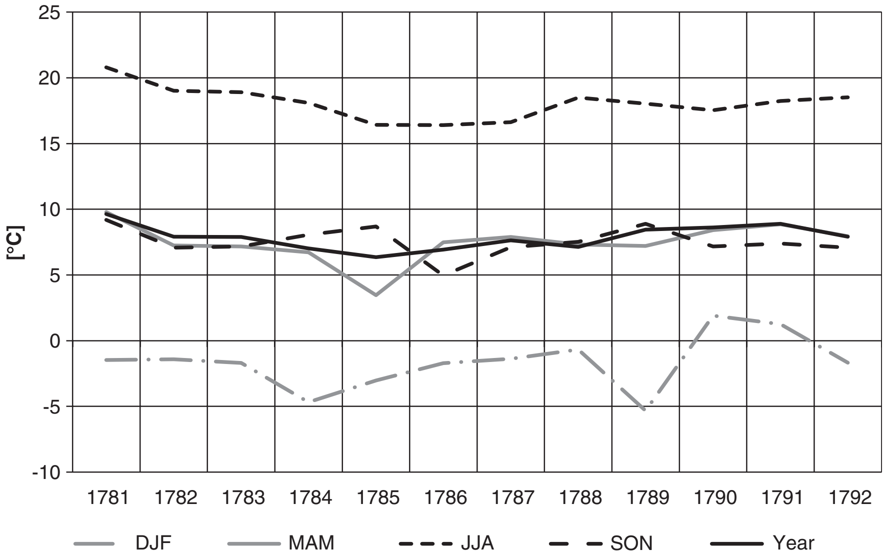

Figure 6. Year-to-year courses of mean seasonal air temperature values in Żagań, 1781–1792.

summer and spring temperatures, while the winter and autumn temperatures instead show fluctuations around a stable level. Three sub-periods can be distinguished based on annual values: two warm (in 1781–1783, and 1789–1792), and one cold (in 1784–1788) (Figure 7). Similar temperature changes were observed in Europe and the north-eastern United States (see, for example, Figure 9 in Thordarson and Self, 2003; Wood, 1992 and references therein or Figure 9 in this article). The cold period occurred just after the long-term Laki eruption (Iceland), which started on the 8 June 1783 and ended on 7 February 1784. In this time, the volcano emitted a large amount of SO_2 (122 Mt) into the atmosphere (Thordarson and Self, 2003). As a consequence, a haze was observed over almost all of Europe (Stothers, 1996; Demarée *et al.*, 1998), including Żagań, where the phenomenon was first noted on 17 June 1783. Its thick lower tropospheric layer was observed there on 23 June, with the last observed occurrence of the Laki haze noted on the 5 November 1783 (Preus, 1783; Thordarson and Self, 2003). As in other parts of Europe (*cf* Ogilvie, 1986, 1992; Wood 1992; Thordarson and Self, 2003; Brázdil *et al.*, 2010), this eruption significantly influenced the climate in Poland (see Figure 46 in Lorenc, 2000). Winter 1783/1784 in Żagań was very cold ($-4.7\,^{\circ}$C), although not the coldest in the entire study period (Table 3, Figures 5, 6 and 8). D'Arrigo *et al.* (2011) questioned the influence of the Laki eruption on the winter in Europe and suggested that the main driver of this cooling was '. . . combined negative phase of the North Atlantic Oscillation (NAO) and El Niño-Southern Oscillation (ENSO) warm event', i.e. the natural variability of climate. Moreover they argue that the Laki eruption did not influence the behaviour of the NAO mode of atmospheric circulation in this time. However, other researchers (Robock, 2003; Schindell and Schmidt, 2004), based on analysis of climate response after major eruptions in historical times, reveal that the temperature anomalies resemble the Arctic Oscillation (AO) or the NAO in the Atlantic-Eurasia Sector. Schmidt *et al.* (2012), using climate model simulation, then found evidence that the Laki radiative effects lasted long enough to also contribute to the winter cooling. Robock (2003) proved that tropical volcanoes produce a warming in winter due to a tendency to a more positive NAO and AO. However, according to his investigation, high latitude volcanoes like Katmai (Alaska in 1912) favour the negative phase of the NAO and AO, i.e. they cause cooling in Europe. Thus, based on this finding we cannot reject the assumption that the Laki eruption had a similar influence

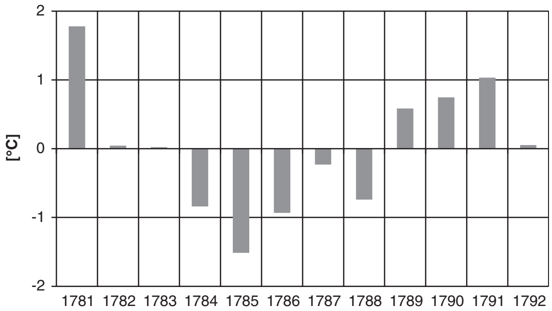

Figure 7. Anomalies of mean annual air temperature in Żagań in the period 1781–1792 (anomalies calculated relative to the mean from 1781 to 1792).

as Katmai on the atmosphere. Nevertheless, further work is needed to definitely describe the causes of the cold 1783/1784 winter in Europe.

Analysis of the data for 1785, however, allows for the conclusion that this year in Poland was mostly influenced by the Laki eruption. It was in this year that both spring and summer were the coldest seasons during the entire study period. The coolness of this period of time cannot be connected with the AO and NAO changes, because these modes of atmospheric circulations are only important in winter. However, significant blocking of solar irradiance by rising aerosol optical thickness after a volcanic eruption is evident (Robock, 2003) and therefore this mechanism could cause a decline of temperature in the spring and summer of 1785 in Poland. Negative temperature anomalies in these seasons, in reference to the mean for the period 1781–1792, were great and were equal to −4.0 and −1.7 °C, respectively. Winter 1784/1785, with its mean temperature of −3.0 °C (and an anomalous −1.3 °C), was not as cold as the previous winter, but still very cold. As a result, 1785 was, as mentioned earlier, the coldest year in the study period (Table 3, Figures 5–6) with an average temperature of 1.6 °C below the long-term mean. The summer of 1786 was equally as cold as summer 1785. Autumn in 1786 was also exceptionally cold (only 5.0 °C, an anomaly of −2.5 °C), while the second coldest autumn was 7.1 °C (1782, 1787 and 1792) (Table 3, Figures 6 and 8). Laki's eruption probably also strongly influenced the climate in Poland in 1786 (all seasons had temperatures equal to or below the long-term mean). Then, from the next year, Laki's mark diminished significantly and temperatures gradually rose until the end of the study period. The described behaviour of temperature in Żagań is in line with the statement by Wood (1992) that 'The period 1784–1786 was unusually cold in many places'.

In-line with expectation, year-to-year changes in mean winter temperature are greatest in comparison to other seasons (see the last column in Table 3 and Figures 6 and 8). These oscillated from −5.3 °C in the coldest winter (1788/1789) (an anomaly of −3.6 °C in comparison with the long-term mean), to 1.9 °C (anomaly 3.6 °C) in the warmest winter, which occurred 1 year later (1789/1790). The majority of winters had temperatures below freezing point. However, the smallest year-to-year changes reveal an autumn temperature, which oscillated from 5.0 °C (1786) to 9.2 °C (1781). The courses and values of the temperature in spring and autumn were very similar, with the exception of 1785 in which, as was mentioned earlier, spring was the coldest during the entire study period, while autumn was the third warmest season (Table 3, Figures 6 and 8). On average, autumn had the same temperature (7.5 °C) as spring.

3.2. Comparison with present-day air temperature

The air temperature series (both daily and monthly data) for Żagań (1781–1792) analysed and corrected by us are actually the most reliable series for Poland now available. For the entire period, only data for Warsaw is also available, but it is based on private observations, conducted three times a day by the Rev. Jowin Fryderyk Bończa-Bystrzycki (Lorenc, 2000; Przybylak, 2010). Thus, the series from Żagań allow for the most reliable estimate of temperature changes in Poland between end of the 18th century and the current values. At present there is no meteorological station in Żagań, and therefore, for comparison purposes data from the period 1981–2010 from the nearest located station in Grabik has been used.

As can be seen in Table 2, the mean daily temperature data from Wrocław are best correlated with those from Żagań. The correlation coefficient (r) between them is extremely very high ($r = 0.98$). Only slightly smaller r (0.94) is with the Warsaw data. Such a close spatial connection between temperatures in the area of Poland (also noted at present, see Kożuchowski and Trepińska, 1986), allows for generalization of the temperature changes presented here between historical and contemporary periods for the entire country (note also the very high correlation with Vilnius). The monthly temperature series reveal even closer relationships (Figure 9). Coefficients of the correlation of the Żagań series with those from Warsaw and Prague reach as much as 0.99 (Table 1). A surprisingly lower correlation (only 0.86) exists with the data from Berlin. Air temperature from this station clearly differs from other stations' data in particular in winters 1784/1785, 1785/1786 and springs 1785–1787.

Very high and statistically significant correlations have also been found for daily data between Żagań and Wrocław, here stratified into seasons (Table 2) – all correlation coefficients are higher than 0.90. Temperature data from Żagań also shows very good correlation with the data from Warsaw and Vilnius, although the correlation coefficients are significantly lower, but are all still statistically significant (Table 2). It is interesting to note, however, that the highest correlation occurs in the transitional seasons. The correlation coefficients for winter temperatures between Żagań, Warsaw and Vilnius are too low, and therefore not in line with expectation. Usually, under current conditions the winter temperatures show the greatest correlation, which is a result of the dominating influence of large scale atmospheric circulation on weather in this season (Kożuchowski and Trepińska, 1986).

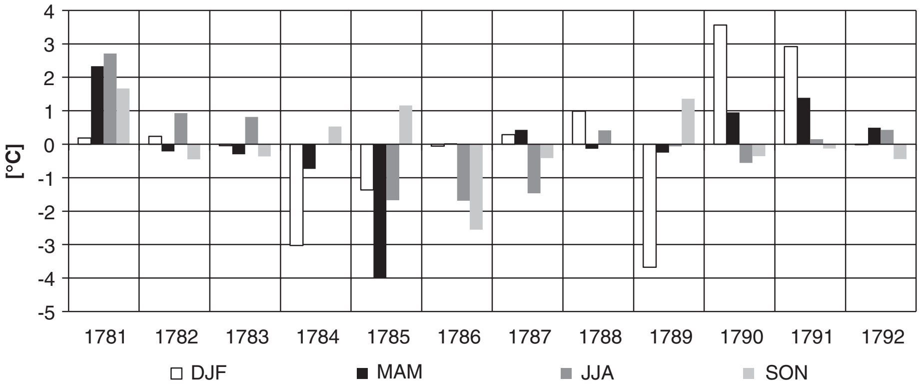

Figure 8. Anomalies of mean seasonal air temperatures in Żagań in the period 1781–1792 (anomalies calculated relative to means from 1781 to 1792).

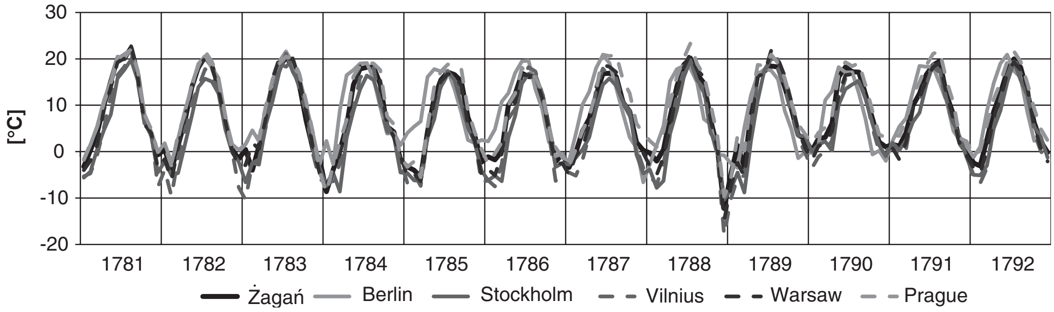

Figure 9. Comparison of mean monthly air temperature series from Żagań with some temperature series from Central European stations in the period 1781–1792.

Mean monthly, seasonal and annual values of air temperature in the historical period in Żagań and the contemporary period in Grabik, as well as their differences, are presented in Table 4 and Figure 10. The majority of monthly temperatures were lower than at present. In particular, March, October, November and December were historically very cold, by about 2–3 °C (Figure 10). July and August show the same temperatures as today, while May, September, and in particular June were warmer. All seasons, except summer, were colder than today. The greatest cooling was observed in winter with temperatures lower by 1.6 °C. In summer, the temperature was warmer by 0.4 °C than it is today. These results fully agree with our reconstruction of temperatures for Poland based on multi-proxy data (see, for example, Przybylak *et al.*, 2004, 2005, 2010a, 2010b; Przybylak, 2011). All of these confirm that the climate of Poland in the 16–18th centuries was more continental than present climate. The mean annual temperature at the end of the 18th century was colder than today by 0.8 °C, and much of this cooling was probably influenced by the Laki eruption. Similar results are presented in many temperature reconstructions available for this period, for both Poland and Europe (Pfister, 1992; Wójcik *et al.*, 2000; Przybylak *et al.*, 2004, 2005, 2010a, 2010b; Brázdil *et al.*, 2005; Przybylak, 2008, 2011).

Changes in some other aspects of thermal conditions (besides the characteristics of mean values presented up to now) from historical to present times were investigated. These include analysis of (1) the frequency of occurrence of temperatures in 2 °C intervals, (2) interdiurnal variability and (3) timing (onset, duration and end) of thermic seasons.

Table 4. Basic statistical characteristics [mean (m, °C), standard deviation (σ, °C), skewness (γ_1) and kurtosis (γ_2)] calculated for seasons in Żagań (1781–1792) and Grabik (1981–2010) using mean daily temperature data, and their differences.

Location	Season	m	σ	γ_1	γ_2
Żagań	DJF	−1.7	5.51	−1.19	1.89
	MAM	7.5	6.99	−0.11	−0.51
	JJA	18.1	3.27	0.26	0.00
	SON	7.5	6.13	0.08	−0.39
	Year	7.9	9.03	−0.21	−0.52
Grabik	DJF	−0.1	5.00	−0.60	0.66
	MAM	8.6	5.73	−0.05	−0.45
	JJA	17.7	3.59	0.13	−0.34
	SON	8.6	5.39	−0.25	−0.41
	Year	8.7	8.04	−0.20	−0.54
Difference	DJF	*−1.6*	0.51	−0.59	1.23
	MAM	*−1.1*	1.26	−0.06	−0.06
	JJA	0.4	−0.32	0.13	0.34
	SON	*−1.1*	0.74	0.33	0.02
	Year	*−0.8*	0.99	−0.01	0.02

Statistically significant differences of means at $p \leq 0.05$ level are shown in italic fonts.

The distributions of occurrence of mean daily temperatures, in 2 °C intervals and stratified into seasons, both for historical and present-day periods, are shown in

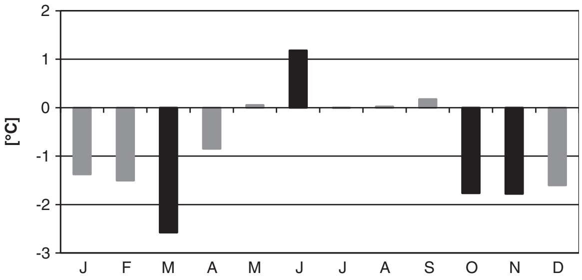

Figure 10. Monthly temperature differences between Żagań (1781–1792) and Grabik (1981–2010). Statistically significant differences at $p \leq 0.05$ level are shown in black.

Figure 11. Their basic statistical characteristics (including values of skewness and kurtosis) are given in Table 4. The greatest differences in temperature distributions between the historical and modern periods are most notable in autumn and spring, where intervals with the greatest frequency of temperature are different. This is not the case for winter and summer, though. In winter the most frequent temperature in both periods oscillated between −2.0 and 3.9 °C, with a maximum interval of 0.0–1.9 °C. Significant differences in frequencies are mainly seen for temperatures higher than 3.9 °C (Figure 11). However, differences in cold temperatures (below −4.0 °C) are not so great. In spring the temperature distributions in both periods are very similar, however in Żagań a greater frequency of occurrence of temperature in intervals can be seen, mainly for values lower than 4 °C and higher than 20.0 °C. Changes in summer temperatures between studied periods were the lowest, and therefore their distributions are the most similar of all the analysed seasons. Even so, some small changes in the frequency of particular temperature intervals can still be noted (Figure 11). In Żagań, extreme warm – and in particular cold – conditions occurred with lesser frequency than today. Autumn definitely saw the greatest differences in temperature distributions between both periods, with a markedly higher frequency in the historical period in comparison to the present, showing temperatures below 10 °C, while the opposite is true for temperatures higher than 10 °C. The greatest changes in the skewness parameter of temperature distributions between historical and present-day periods occurred in winter (−0.59) and autumn (0.33), while the smallest occurred in spring (−0.06) (Table 4). Kurtosis saw the greatest changes in winter (1.23) and the smallest in autumn (only 0.02). However, when we take all the data into account, both skewness and curtosis parameters are almost the same (differences reached only −0.01 and 0.02, respectively; Table 4).

Changes in the weather from day-to-day are also a very important climate characteristic, particularly from the biometeorological point of view. Having a full 11 years of mean daily temperature data from Żagań (without 1787), day-to-day changes have been calculated (using standard deviation, SD) and compared with present-day values from Grabik (1981–2010) (Figure 12). SDs values were calculated separately for each month, season etc, and then averaged for 11 years. Annual courses according to monthly means of standard deviations in both periods show similar shapes, i.e. higher variability was observed in the cold half-years than in the warm half-years. In historical time, however, the day-to-day temperature variability was slightly greater (on average by 0.2 °C) and was not statistically significant. The greatest differences (Grabik – Żagań) in calculated mean seasonal values of standard deviation occurred in winter (−0.5 °C), while the lowest was in autumn (−0.1 °C).

Table 5. Mean dates of the onset and end of each thermal season in Żagań (1781–1792) and Grabik (1981–2010).

Thermal seasons	Żagań		Grabik	
	onset	end	onset	end
Early spring	3.03	2.04	10.02	22.03
Spring	3.04	25.05	23.03	28.05
Summer	26.05	6.09	29.05	5.09
Autumn	7.09	29.10	6.09	8.11
Early winter	30.10	3.12	9.11	23.12
Winter	4.12	2.03	24.12	9.02

Merecki (1914) distinguished six thermal seasons in Poland based on mean daily temperatures (winter, early spring, spring, summer, autumn and early winter). As threshold temperature values he used 0, 5 and 15 °C. The thermal seasons fulfil the following criteria:

$$\begin{array}{ll} \text{winter} & \leq 0^{\circ}\text{C} \\ 0^{\circ}\text{C} < \text{early spring} & \leq 5^{\circ}\text{C} \\ 5^{\circ}\text{C} < \text{spring} & \leq 15^{\circ}\text{C} \\ \text{summer} & > 15^{\circ}\text{C} \\ 5^{\circ}\text{C} < \text{autumn} & \leq 15^{\circ}\text{C} \\ 0^{\circ}\text{C} < \text{early winter} & \leq 5^{\circ}\text{C} \end{array}$$

For the period 1781–1792 (Żagań) and 1981–2010 (Grabik), mean dates of the onset and end of each thermal season as well as their duration have been calculated (Table 5, Figure 13). The greatest changes between both periods are seen for winter. At the end of the 18th century winter started earlier (on 4 December; now it starts on 24 December), and ended later (on 2 March; now 9 February), and its duration was 88 days (now only 49 days). The smallest changes have been noted for summer, although the direction of change was the same as in winter, i.e. the summer was slightly longer in historical times than it is today (Table 5 and Figure 13). Overall, the duration of the other seasons in the last 200 years has increased by 9–13 days.

4. Conclusions

- The mean annual air temperature in Żagań at the end of the 18th century was lower than present-day value by 0.8 °C. The very cold period noted between 1784 and

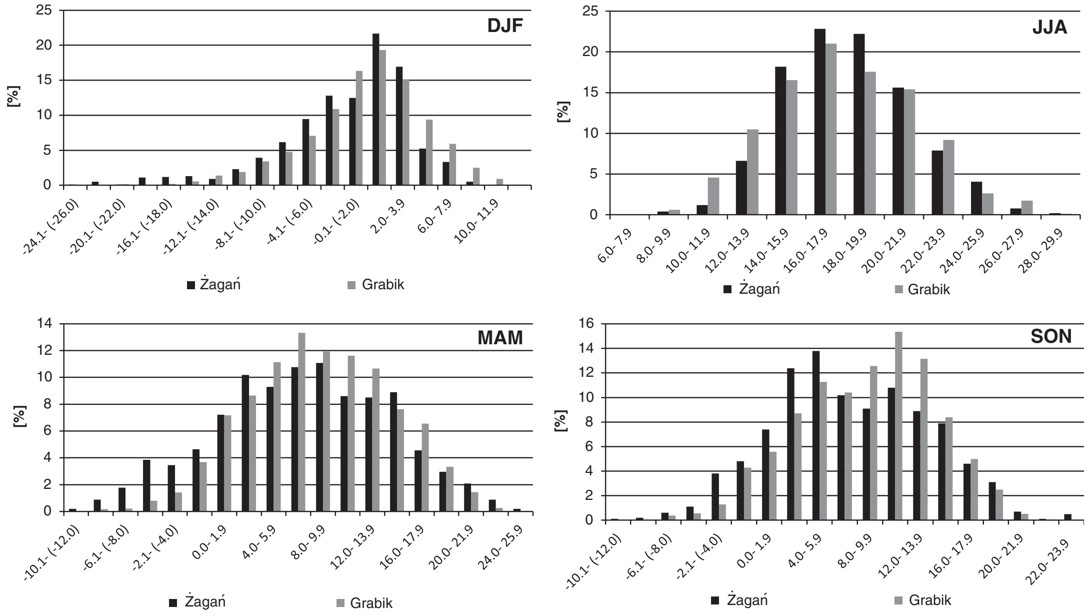

Figure 11. Frequency of air temperature in two-degree intervals for seasons (DJF, MAM, etc.) in Żagań (1781–1792) and Grabik (1981–2010).

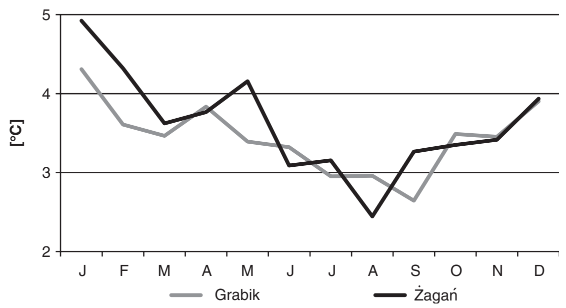

Figure 12. Variability of day-to-day changes (in SDs) of mean daily temperature in periods 1781–1792 (Żagań) and 1981–2010 (Grabik).

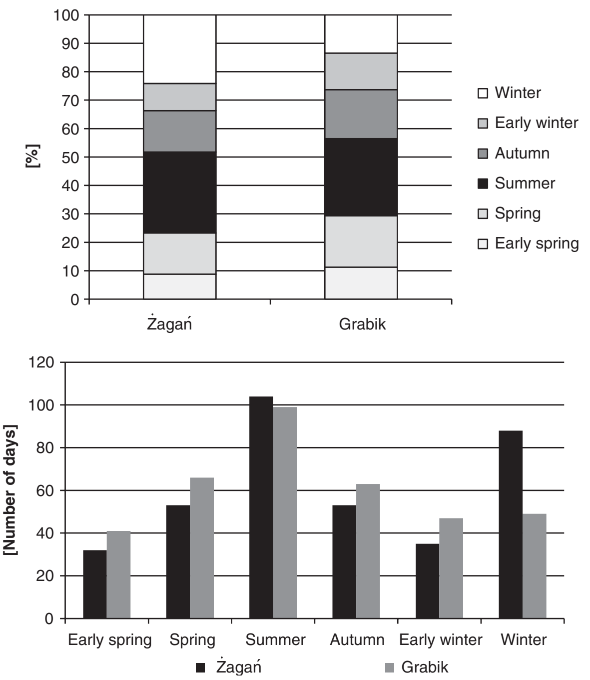

Figure 13. Absolute (in days) and relative (in %) mean duration of thermal seasons in Żagań in the study period 1781–1792, and in Grabik in the contemporary period 1981–2010.

1787 was probably largely influenced by the eruption of the Laki volcano in Iceland in 1783/1784.

- Clearly, the summers were warmer (by 0.4 °C), while winters were colder by 1.6 °C. As a result, summer and in particular winter were markedly longer in historical time in comparison to the present-day climate, while the other seasons were shorter.
- Comparison of the annual range of air temperatures in Żagań in the 18th century and in present times (1981–2010) in Grabik, located near Żagań, reveals that in historical times the continentality of the climate was greater – the annual range of air temperature was higher in the 18th century by 1.3 °C.
- Both mean monthly and mean daily temperatures from Żagań are closely correlated with series of temperature from Central Europe (mostly, the correlation coefficient is higher than 0.9).

Acknowledgements

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APPENDIX

Table A1. Temperature differences (°C) between mean daily values from Wrocław (1999–2003) calculated using Mannheim's formula (48 variants, m2–m49, data from different hours listed in the last column of the table) and calculated from 24 hourly measurements (m1).

Difference	January	February	March	April	May	June	July	August	September	October	November	December	Variant of mean	Observation times
m2–m1	−0.13	−0.22	−0.38	−0.95	1.38	−1.19	−1.19	−1.35	−0.92	−0.50	−0.24	−0.23	m2	4 14 21
m3–m1	−0.19	−0.34	−0.58	−1.19	−1.70	−1.41	−1.37	−1.61	−1.13	−0.67	−0.32	−0.27	m3	4 14 22
m4–m1	−0.31	−0.37	−0.48	−1.03	−1.47	−1.21	−1.22	−1.43	−1.08	−0.79	−0.50	−0.38	m4	4 15 21
m5–m1	−0.38	−0.50	−0.67	−1.27	−1.76	−1.43	−1.40	−1.69	−1.28	−0.96	−0.58	−0.41	m5	4 15 22
m6–m1	0.07	−0.06	−0.18	−0.66	−1.04	−0.88	−0.92	−1.07	−0.61	−0.22	0.00	−0.03	m6	4 13 20
m7–m1	−0.05	−0.10	−0.21	−0.66	−1.06	−0.89	−0.91	−1.06	−0.67	−0.33	−0.16	−0.15	m7	4 14 20
m8–m1	−0.23	−0.25	−0.30	−0.74	−1.12	−0.91	−0.95	−1.15	−0.83	−0.62	−0.42	−0.30	m8	4 15 20
m9–m1	−0.14	−0.25	−0.36	−0.69	−0.93	−0.78	−0.83	−1.01	−0.76	−0.47	−0.26	−0.23	m9	5 14 21
m10–m1	−0.33	−0.40	−0.45	−0.77	−0.99	−0.80	−0.86	−1.09	−0.92	−0.76	−0.52	−0.38	m10	5 15 21
m11–m1	−0.20	−0.37	−0.55	−0.93	−1.22	−1.00	−1.01	−1.26	−0.97	−0.64	−0.34	−0.27	m11	5 14 22
m12–m1	−0.39	−0.52	−0.64	−1.01	−1.28	−1.01	−1.04	−1.35	−1.13	−0.92	−0.60	−0.41	m12	5 15 22
m13–m1	−0.30	−0.44	−0.74	−1.10	−1.49	−1.22	−1.20	−1.49	−1.18	−0.79	−0.45	−0.31	m13	5 14 23
m14–m1	−0.42	−0.46	−0.94	−1.45	−1.74	−1.53	−1.38	−1.62	−1.29	−0.87	−0.50	−0.13	m14	5 14 00
m15–m1	−0.49	−0.59	−0.83	−1.18	−1.55	−1.24	−1.24	−1.57	−1.34	−1.08	−0.71	−0.46	m15	5 15 23
m16–m1	0.06	−0.08	−0.16	−0.39	−0.56	−0.47	−0.56	−0.73	−0.46	−0.18	−0.02	−0.03	m16	5 13 20
m17–m1	−0.08	−0.32	−0.53	−0.93	−1.20	−0.99	−1.01	−1.27	−0.91	−0.52	−0.17	−0.15	m17	5 13 22
m18–m1	−0.02	−0.20	−0.33	−0.69	−0.91	−0.77	−0.83	−1.02	−0.71	−0.35	−0.09	−0.11	m18	5 13 21
m19–m1	−0.53	−0.74	−0.84	−1.20	−1.45	−1.14	−1.17	−1.58	−1.53	−1.25	−0.79	−0.50	m19	5 16 22
m20–m1	−0.25	−0.28	−0.28	−0.47	−0.64	−0.50	−0.58	−0.80	−0.67	−0.59	−0.44	−0.30	m20	5 15 20
m21–m1	−0.43	−0.51	−1.05	−1.66	−1.96	−1.70	−1.54	−1.80	−1.42	−0.97	−0.55	−0.15	m21	5 14 1
m22–m1	−0.06	−0.13	−0.18	−0.39	−0.58	−0.48	−0.55	−0.72	−0.51	−0.30	−0.18	−0.16	m22	5 14 20
m23–m1	−0.16	−0.24	−0.17	−0.26	−0.43	−0.41	−0.45	−0.49	−0.41	−0.29	−0.25	−0.24	m23	6 14 21
m24–m1	−0.34	−0.40	−0.27	−0.34	−0.48	−0.43	−0.48	−0.57	−0.57	−0.58	−0.51	−0.38	m24	6 15 21
m25–m1	−0.22	−0.36	−0.37	−0.50	−0.72	−0.62	−0.63	−0.74	−0.62	−0.46	−0.33	−0.27	m25	6 14 22
m26–m1	−0.40	−0.52	−0.46	−0.58	−0.78	−0.64	−0.66	−0.83	−0.77	−0.75	−0.59	−0.42	m26	6 15 22
m27–m1	−0.50	−0.58	−0.65	−0.75	−1.05	−0.87	−0.86	−1.05	−0.98	−0.90	−0.70	−0.46	m27	6 15 23
m28–m1	−0.26	−0.28	−0.09	−0.04	−0.14	−0.13	−0.21	−0.28	−0.32	−0.41	−0.43	−0.30	m28	6 15 20
m29–m1	−0.32	−0.43	−0.55	−0.67	−0.99	−0.85	−0.82	−0.97	−0.83	−0.62	−0.44	−0.32	m29	6 14 23
m30–m1	−1.07	−1.45	−2.12	−2.98	−3.73	−3.24	−2.98	−3.67	−2.89	−2.09	−1.36	−0.65	m30	6 21 2
m31–m1	−0.54	−0.73	−0.66	−0.77	−0.94	−0.77	−0.79	−1.06	−1.17	−1.07	−0.78	−0.51	m31	6 16 22
m32–m1	−0.08	−0.12	0.00	0.04	−0.08	−0.11	−0.17	−0.20	−0.16	−0.13	−0.17	−0.16	m32	6 14 20
m33–m1	0.01	−0.04	0.16	0.16	0.01	−0.08	−0.15	0.00	0.14	0.16	0.08	−0.10	m33	7 13 21
m34–m1	−0.11	−0.08	0.14	0.16	−0.01	−0.08	−0.15	0.01	0.08	0.04	−0.09	−0.22	m34	7 14 21
m35–m1	−0.68	−0.91	−0.91	−1.28	−1.92	−1.72	−1.71	−2.07	−1.54	−1.07	−0.80	−0.63	m35	7 20 21
m36–m1	−0.35	−0.36	−0.15	−0.16	−0.36	−0.32	−0.36	−0.33	−0.28	−0.41	−0.43	−0.40	m36	7 15 22
m37–m1	−0.17	−0.21	−0.05	−0.08	−0.30	−0.30	−0.33	−0.24	−0.13	−0.13	−0.17	−0.26	m37	7 14 22
m38–m1	−0.27	−0.27	−0.24	−0.25	−0.57	−0.52	−0.52	−0.47	−0.33	−0.28	−0.28	−0.30	m38	7 14 23
m39–m1	−0.57	−0.45	−0.51	−0.68	−0.87	−0.86	−0.73	−0.69	−0.60	−0.63	−0.59	−0.26	m39	7 15 00
m40–m1	−0.45	−0.43	−0.34	−0.33	−0.63	−0.54	−0.56	−0.55	−0.49	−0.57	−0.54	−0.44	m40	7 15 23
m41–m1	−0.03	0.04	0.32	0.46	0.34	0.22	0.13	0.30	0.33	0.21	−0.02	−0.14	m41	7 14 20
m42–m1	0.10	0.20	0.51	0.84	0.85	0.79	0.65	0.68	0.58	0.38	0.06	−0.08	m42	7 14 19
m43–m1	0.20	0.23	0.45	0.51	0.35	0.18	0.13	0.41	0.58	0.55	0.36	0.04	m43	8 13 21
m44–m1	0.08	0.19	0.42	0.51	0.33	0.17	0.14	0.42	0.53	0.43	0.20	−0.09	m44	8 14 21
m45–m1	0.02	0.06	0.23	0.27	0.03	−0.04	−0.05	0.17	0.32	0.26	0.12	−0.12	m45	8 14 22
m46–m1	−0.16	−0.09	0.13	0.19	−0.03	−0.06	−0.08	0.08	0.16	−0.03	−0.14	−0.27	m46	8 15 22
m47–m1	−0.10	0.03	0.33	0.43	0.27	0.15	0.10	0.34	0.37	0.14	−0.06	−0.23	m47	8 15 21
m48–m1	−0.29	−0.24	0.05	0.08	−0.07	−0.10	−0.18	−0.07	−0.07	−0.26	−0.35	−0.36	m48	7 15 21
m49–m1	−0.13	−0.15	−0.30	−0.88	−1.61	−1.49	−1.38	−1.38	−0.84	−0.45	−0.19	−0.22	m49	2 14 21

Table A2. Corrected daily mean air temperature (°C) for Żagań, 1781–1792.

year	month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1781	1	3.1	2.5	0.9	−1.4	−3.9	−1.7	−1.4	−2.5	−2.3	−4.6	−5.9	−6.7	−11.8	−10.5	−8.8	−7.6	−4.3	−3.7	0.4	−4.6	−3.4	−11.0	−11.6	−7.3	1.2	−0.2	0.9	0.8	1.0	1.8	2.5
1781	2	2.2	1.9	−4.0	0.3	−0.2	−6.9	−6.1	−1.1	0.6	3.1	3.4	2.9	7.8	4.9	2.6	1.9	1.7	1.0	1.6	0.4	−1.2	−2.7	−3.5	−4.0	−1.6	1.2	1.0	1.0			
1781	3	1.7	1.0	3.7	5.6	6.4	4.5	8.3	5.5	3.4	4.8	5.5	2.4	0.5	1.6	2.8	2.9	5.2	3.3	8.5	2.7	3.9	6.6	5.6	4.4	8.1	10.0	3.5	2.9	−0.2	0.6	1.9
1781	4	0.6	3.1	3.4	4.8	4.8	6.0	7.4	8.5	12.6	14.3	16.1	14.5	8.3	8.3	10.3	7.6	9.8	11.8	12.4	15.8	13.9	13.9	16.8	15.6	11.0	9.4	9.2	9.7	10.4	12.4	
1781	5	18.9	19.6	19.4	14.7	8.2	8.2	5.4	7.3	13.3	13.6	16.0	17.4	17.7	14.8	16.8	19.6	21.0	17.7	18.6	21.6	19.3	14.8	9.5	6.8	8.8	13.6	15.1	16.2	18.4	18.7	19.1
1781	6	20.2	20.1	16.7	15.1	13.5	15.6	17.0	17.9	20.8	17.3	18.0	19.8	20.8	20.1	21.2	22.4	19.5	21.1	21.9	21.6	21.5	21.5	24.1	24.4	22.5	20.3	21.9	22.6	20.2	19.0	
1781	7	21.3	24.4	26.7	27.9	19.8	19.3	24.5	25.1	21.1	20.9	20.3	20.3	23.2	23.5	20.6	16.9	16.6	16.6	15.9	17.6	17.6	15.3	14.5	14.9	18.8	20.9	19.7	18.8	18.8	20.1	20.0
1781	8	22.3	24.2	20.3	17.8	22.9	24.0	26.1	25.0	23.6	24.4	23.8	24.2	24.9	23.2	23.2	25.9	21.1	21.8	24.0	20.0	18.2	19.8	16.5	20.6	21.5	23.4	19.6	23.3	24.2	21.5	22.2
1781	9	24.9	24.8	25.0	25.0	24.2	21.5	19.8	18.2	19.2	20.8	19.3	16.3	19.1	18.4	17.8	17.5	18.2	15.9	13.3	13.6	15.1	14.0	10.8	9.1	6.8	9.7	9.7	11.3	10.9	10.9	
1781	10	11.4	12.1	12.5	12.3	10.5	11.0	8.6	7.0	7.0	6.2	7.8	8.6	6.5	7.7	6.3	8.0	5.1	7.6	5.4	3.4	7.7	4.4	3.4	0.6	2.7	6.0	5.6	4.5	7.6	5.4	5.3
1781	11	3.6	1.2	2.5	3.4	3.8	10.2	10.8	7.5	4.4	0.9	0.1	2.9	5.8	6.3	8.8	6.3	4.4	4.7	1.5	2.9	1.8	2.9	3.4	1.1	1.0	2.5	3.2	1.9	2.5	2.7	
1781	12	2.5	0.8	0.7	−2.8	−2.1	−4.3	−3.1	−4.7	−7.6	−7.8	−9.2	−11.0	−8.3	−4.4	−2.7	1.1	5.7	1.4	1.6	3.5	3.5	−1.0	1.5	1.0	4.1	3.1	2.8	6.7	7.5	4.9	−5.1
1782	1	−19.8	−8.8	−0.2	6.4	6.9	−0.2	−2.3	1.9	4.0	2.2	−1.5	−4.3	0.7	0.4	−3.8	−1.0	0.3	0.5	0.2	0.0	2.5	0.2	5.9	6.2	5.9	4.3	1.7	2.6	2.4	0.5	0.2
1782	2	−0.3	−1.2	−2.2	−6.2	−7.6	−8.2	−3.5	−5.2	−5.7	−4.4	−7.0	−14.1	−8.8	−8.5	−14.6	−17.2	−8.8	−3.8	−1.6	−2.7	−3.9	−4.1	0.7	2.8	3.5	7.1	7.1	6.2			
1782	3	1.8	1.6	4.3	1.4	5.6	4.8	2.4	3.5	4.6	2.1	4.1	9.1	0.5	−1.9	−6.1	−5.8	−4.3	−4.0	−0.8	1.0	1.1	2.0	2.8	−4.4	−4.7	−4.2	−1.8	3.0	6.8	6.4	9.7
1782	4	9.6	10.6	8.5	6.8	6.5	8.9	11.0	3.6	4.3	4.8	5.2	6.6	8.3	7.7	10.8	9.8	7.2	5.2	4.7	6.8	7.1	9.2	9.9	7.6	2.5	3.7	4.1	4.3	2.1	1.2	
1782	5	3.8	4.6	9.2	12.6	13.3	10.5	10.3	7.7	8.5	12.3	14.0	17.2	15.7	18.1	20.5	15.8	16.8	14.6	14.4	11.7	12.9	14.4	14.5	15.5	13.7	13.0	13.8	18.0	21.3	18.2	21.0
1782	6	16.9	15.4	13.7	12.4	13.8	13.1	11.5	13.4	15.7	19.9	22.0	20.2	18.8	17.8	22.1	23.3	19.5	20.8	17.6	18.3	20.8	20.4	18.4	20.4	22.8	19.0	19.8	17.7	18.9	21.5	
1782	7	20.2	20.9	18.3	17.1	17.9	18.1	22.6	20.8	19.0	16.5	15.6	19.6	22.8	26.0	23.7	22.8	15.9	15.5	15.3	16.0	15.6	20.5	23.6	24.1	26.1	27.5	30.0	25.6	21.7	16.4	17.9
1782	8	18.5	19.9	18.5	19.7	18.9	19.3	23.7	17.9	16.8	17.1	16.5	15.6	16.5	16.7	20.4	22.2	21.6	19.4	16.0	15.8	18.7	23.1	20.3	18.1	21.6	17.6	17.8	16.2	16.7	15.9	14.6
1782	9	13.3	13.2	13.5	13.4	11.9	13.4	13.4	13.0	13.4	15.5	15.2	14.2	13.9	14.2	15.8	17.4	17.7	18.8	15.6	10.5	13.8	16.4	13.7	11.9	12.3	14.8	15.8	13.5	12.3	13.7	
1782	10	10.4	9.4	11.5	10.7	6.4	7.1	7.3	7.4	4.1	5.2	5.6	5.6	5.6	4.5	5.2	5.7	3.8	4.7	9.2	6.5	4.8	10.4	11.2	7.0	2.1	4.9	5.3	3.0	5.8	6.8	5.4
1782	11	6.3	1.9	0.1	4.4	3.5	2.1	0.6	−0.2	3.6	2.7	0.3	2.6	2.9	2.7	3.9	5.5	1.4	−0.5	−2.8	−2.3	0.2	−2.3	−2.4	−3.6	−2.9	−2.5	−2.4	−1.0	−2.0	−4.2	
1782	12	1.0	−2.0	−0.8	−1.3	−2.2	−2.6	−3.5	−11.6	−10.7	−3.8	−4.0	−7.2	−2.9	−3.0	−5.5	−3.4	−1.3	−3.2	1.9	1.6	3.9	1.7	1.2	2.8	−1.2	2.3	5.3	2.9	2.2	−0.6	−5.0
1783	1	−19.8	−8.8	−0.4	6.5	6.9	−0.1	−2.3	1.9	4.1	2.2	−1.2	−4.1	0.9	0.5	−3.5	−1.0	0.6	0.5	0.5	0.2	2.0	0.2	5.9	6.2	5.9	4.2	1.9	2.6	2.4	0.3	0.0
1783	2	−0.3	−1.2	−2.2	−6.2	−7.6	−8.0	−3.5	−5.2	−5.5	−4.4	−7.0	−14.2	−8.9	−8.5	−14.7	−17.2	−8.9	−3.6	−1.7	−2.4	−4.0	−4.3	0.5	2.8	3.6	7.1	7.2	6.4			
1783	3	1.6	1.8	4.0	1.6	5.4	4.8	2.5	3.5	4.6	1.9	4.1	8.5	0.4	−2.4	−6.6	−6.0	−4.4	−4.1	−1.3	0.9	0.8	1.7	2.2	−4.1	−4.9	−4.3	−2.0	3.1	6.2	6.4	9.7

Table A2. Continued.

year	month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1783	4	9.8	10.4	8.5	6.4	6.5	9.2	10.8	3.8	4.3	4.6	5.4	6.7	7.8	7.9	10.6	9.4	7.2	5.0	4.4	6.8	7.8	9.5	9.9	8.0	2.7	3.7	4.7	4.8	1.7	1.5	
1783	5	4.6	4.9	9.1	13.0	13.8	10.5	10.6	7.5	8.3	12.0	14.3	17.2	16.1	17.4	21.1	15.8	14.5	15.4	14.7	11.7	10.6	14.9	15.3	15.6	13.4	13.2	11.5	18.8	18.7	18.2	21.3
1783	6	16.7	15.2	12.9	12.4	13.6	12.8	11.3	13.2	15.4	19.7	21.4	20.0	19.0	18.0	21.7	23.3	19.5	20.3	17.6	17.9	21.0	21.0	18.0	19.8	22.6	19.2	19.8	18.0	18.7	21.2	
1783	7	20.3	20.9	18.3	17.1	17.9	17.7	22.2	20.6	18.6	16.1	16.0	19.8	22.9	26.0	23.9	22.6	15.7	15.4	15.2	16.3	16.1	20.7	23.4	23.7	25.9	27.5	29.9	25.4	21.4	16.6	18.0
1783	8	18.6	19.9	19.1	19.9	18.9	19.1	23.7	17.8	17.2	17.2	16.6	16.5	15.9	16.8	20.0	21.6	21.6	18.9	16.3	15.3	18.2	22.8	19.9	17.3	21.3	17.0	17.8	15.7	16.1	15.7	14.1
1783	9	13.3	12.8	13.5	13.4	11.9	13.2	13.6	13.4	13.5	15.3	15.2	14.4	13.9	14.7	16.0	17.4	18.1	18.8	15.9	10.5	13.6	16.3	14.2	11.8	12.6	15.1	15.9	14.2	12.4	14.2	
1783	10	10.9	9.7	12.1	11.0	6.7	7.1	7.3	7.6	4.3	5.7	5.9	6.1	5.6	4.5	5.7	5.7	3.8	4.7	9.4	6.7	4.8	10.4	11.2	7.0	2.3	4.7	5.5	3.0	6.0	6.3	5.4
1783	11	6.3	1.9	0.1	4.5	3.5	1.8	0.6	−0.1	3.6	2.4	0.3	2.7	3.0	2.8	3.6	5.5	1.4	−0.5	−2.7	−2.4	0.1	−2.3	−2.4	−3.3	−2.9	−2.5	−2.0	−1.0	−2.0	−4.5	
1783	12	0.9	−1.8	−0.9	−1.2	−2.2	−2.6	−3.5	−11.5	−10.7	−3.8	−3.8	−7.2	−2.9	−3.0	−5.4	−3.4	−1.2	−3.2	2.1	1.6	3.9	1.7	1.2	3.0	−1.1	2.3	5.3	2.9	2.2	−0.6	−5.0
1784	1	−12.8	−12.6	−15.5	−17.8	−19.4	−19.5	−17.5	−16.4	−14.8	−19.0	−14.1	−8.5	−7.9	−4.0	−4.5	1.5	1.8	−4.0	−2.7	−2.4	−2.3	−10.0	−5.4	−3.0	0.1	−2.8	−2.9	−5.5	−6.7	−8.8	−9.9
1784	2	−8.5	−6.9	−5.9	−2.7	−3.3	−5.1	−3.5	−4.3	−1.7	−8.2	−6.4	−4.5	−4.4	−3.4	−3.3	−5.3	−1.0	−4.7	−4.1	−5.5	−5.5	−7.5	−8.8	−0.6	1.9	3.1	4.6	−1.4	−5.4		
1784	3	−5.1	−2.8	0.0	−0.1	2.0	3.0	4.0	4.4	3.8	2.6	−1.8	0.0	0.6	−0.9	−1.7	−1.8	1.0	1.3	2.3	−3.3	−6.2	−2.1	−2.2	0.0	3.6	6.5	3.3	−0.5	−0.9	−0.8	−3.0
1784	4	−1.8	−2.4	−1.9	−0.3	−1.6	0.2	2.4	3.3	3.6	6.8	6.7	10.0	6.1	5.4	6.7	6.0	5.3	3.8	2.7	7.6	8.6	12.1	13.2	11.1	7.6	6.1	9.0	11.0	11.2	9.1	
1784	5	12.4	8.3	6.1	8.8	5.9	8.6	10.2	16.2	12.2	9.1	15.1	15.3	11.7	13.8	14.7	16.2	16.7	16.8	13.2	16.4	17.7	16.5	19.5	22.1	20.7	21.6	23.4	20.2	14.2	11.6	11.6
1784	6	15.6	17.2	18.1	20.1	20.2	19.2	18.3	16.2	17.2	18.4	18.1	16.3	20.1	16.1	13.0	15.7	20.3	18.6	16.2	19.6	21.5	24.2	18.8	16.9	16.2	15.8	19.5	18.1	15.3	14.9	
1784	7	13.9	13.3	13.5	14.6	17.2	19.7	23.4	24.8	23.1	22.1	19.6	22.5	18.8	19.6	15.5	15.8	16.8	14.1	16.2	16.8	16.2	17.6	15.6	14.8	16.4	18.5	20.5	16.4	19.9	23.6	23.1
1784	8	20.8	20.0	21.7	23.2	23.4	22.3	20.0	15.7	13.9	14.9	12.2	14.9	18.5	19.0	20.3	20.0	19.8	18.2	22.0	20.8	18.6	21.4	18.1	16.4	16.4	15.1	12.2	13.1	17.7	16.5	17.4
1784	9	20.3	17.4	14.7	14.8	17.0	18.6	19.1	18.5	16.2	14.0	16.9	16.8	17.4	13.8	8.4	9.4	10.0	13.3	13.3	14.1	15.4	14.1	14.7	10.9	11.5	15.8	14.6	12.8	11.9	9.3	
1784	10	8.7	6.3	6.6	5.2	3.3	1.1	1.9	4.8	5.3	4.3	7.6	4.1	3.1	3.8	7.4	2.1	4.4	5.9	3.6	8.2	8.1	6.8	7.0	6.9	4.0	4.7	7.1	8.4	8.1	6.3	2.9
1784	11	9.2	5.1	5.5	5.7	4.1	3.8	2.8	3.4	3.1	1.9	4.5	10.3	9.2	6.5	8.9	8.9	5.5	4.5	4.0	2.0	0.4	0.3	0.8	2.9	3.5	4.1	4.1	1.7	0.0	0.6	
1784	12	0.5	0.4	1.1	2.4	1.1	0.6	2.9	1.4	2.3	0.3	0.1	0.3	−2.5	−3.8	−3.2	0.3	0.7	−0.3	−6.7	−1.0	0.3	−1.8	−3.3	−3.7	−3.2	−2.4	−4.4	−10.7	−8.4	−5.2	−10.3
1785	1	−11.9	−7.7	−2.1	1.4	2.8	4.1	0.6	−0.7	−2.7	−4.5	−4.9	−4.0	−3.7	−2.4	−6.0	−2.8	−3.8	−4.3	−1.4	0.7	0.0	−6.6	−6.8	−7.8	−9.5	−7.7	−4.8	−4.6	1.9	−1.5	−0.6
1785	2	−1.3	−0.4	0.3	−0.3	−3.4	−1.0	1.4	0.8	0.5	0.1	−0.7	−3.0	−5.1	−3.9	−2.1	−7.9	−5.6	−3.7	−2.5	−5.1	−4.6	−6.5	−2.6	−2.7	−2.6	−8.6	−15.3	−25.8			
1785	3	−12.0	−8.9	−4.0	−4.7	−9.4	−5.9	−4.3	−6.5	−6.3	−1.2	−4.7	−4.9	−7.5	−7.2	−3.2	−5.2	−1.4	−0.6	−2.7	−2.4	−2.2	−6.8	−8.3	−5.0	−9.7	−7.2	−1.4	−4.8	−6.8	−9.3	−5.9
1785	4	−1.1	1.6	−0.5	−1.3	−1.4	0.5	0.5	1.4	2.0	2.2	2.2	5.0	5.0	3.7	4.7	6.5	7.0	8.7	10.4	10.0	6.3	4.9	5.0	7.8	7.7	7.8	3.9	5.4	6.3	7.0	
1785	5	7.0	7.7	7.3	7.7	9.8	14.8	15.9	15.6	13.0	11.1	7.4	8.0	11.4	13.6	12.0	8.3	8.9	10.5	9.2	15.5	12.4	10.6	13.6	12.0	13.9	14.1	15.3	13.6	13.9	14.0	11.2
1785	6	10.3	9.2	9.2	13.4	16.6	14.8	13.2	16.1	16.6	17.2	18.4	19.7	15.2	15.3	15.0	14.5	15.4	12.0	14.6	16.5	16.5	14.6	14.3	17.1	17.0	17.5	15.0	18.8	20.4	20.6	

Table A2. Continued.

year	month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1785	7	20.8	21.4	17.0	15.8	17.6	17.2	14.1	16.6	14.6	14.5	11.1	13.1	14.0	14.7	19.5	18.2	17.3	16.5	18.8	20.4	20.5	15.8	15.8	14.3	17.8	18.3	19.4	19.8	19.2	18.7	19.1
1785	8	18.9	18.6	20.9	24.1	22.7	19.8	17.9	18.8	19.3	16.0	15.5	17.0	16.4	15.6	16.2	15.4	16.9	15.9	13.9	12.5	16.4	16.9	16.3	15.9	17.3	13.2	11.4	10.9	11.7	13.3	18.7
1785	9	17.6	15.4	14.2	16.3	18.0	18.3	22.0	25.2	21.5	20.5	18.7	17.6	15.3	14.2	12.6	14.9	15.6	14.1	10.6	15.1	16.3	13.6	10.2	14.5	17.8	15.3	9.5	7.8	6.2	6.3	
1785	10	8.1	7.0	5.1	5.8	8.4	10.1	10.0	11.6	10.2	10.2	10.5	9.1	12.2	14.0	9.8	10.9	11.2	6.9	6.6	3.9	1.7	2.9	7.0	6.8	10.4	4.1	0.5	2.7	4.0	2.9	5.0
1785	11	7.7	8.3	7.3	9.2	10.0	10.4	8.2	4.1	3.6	−1.3	0.5	2.0	3.3	0.6	−0.9	−0.3	3.3	2.1	2.0	2.9	3.0	1.7	3.1	1.0	−1.0	0.5	4.3	2.3	3.9	2.5	
1785	12	3.3	0.1	−0.5	4.2	4.1	3.3	0.0	−1.1	−1.1	−2.0	−0.5	1.9	3.4	1.5	1.3	0.7	−0.6	−6.0	−6.5	−4.1	−3.8	−5.7	−8.7	−7.3	−5.7	−4.1	−4.9	−4.1	−7.8	−8.0	−11.1
1786	1	−11.6	−12.0	−11.3	−13.4	−14.7	−14.8	−9.4	−1.2	0.4	3.1	2.7	2.6	2.0	3.1	2.0	3.4	3.8	0.8	−2.0	−5.1	−2.5	−3.5	−0.4	0.9	1.1	4.0	6.0	7.0	8.5	9.6	6.2
1786	2	7.0	1.5	−0.4	−2.1	0.3	2.7	3.3	1.3	−1.6	−1.6	0.2	1.1	−0.6	−1.8	2.6	0.1	−0.5	2.3	0.8	−1.6	−5.0	−7.8	−12.7	−9.2	−3.9	−6.6	−9.9	−7.4			
1786	3	−7.1	−5.3	−5.3	−5.3	−8.9	−8.4	−4.3	−4.5	−6.1	−5.7	−7.2	−1.6	1.2	−0.6	−0.4	4.5	6.5	4.7	2.1	2.5	3.4	5.5	6.4	8.3	7.1	4.3	2.2	0.4	1.3	7.5	5.0
1786	4	8.1	8.5	7.9	7.8	9.6	10.1	10.9	8.8	5.7	0.9	2.0	4.0	5.4	10.7	12.7	13.0	12.0	9.9	11.9	14.1	13.5	14.3	15.5	13.9	14.1	14.4	13.8	12.0	7.3	6.7	
1786	5	3.0	3.5	4.9	7.0	9.3	8.3	7.7	9.8	13.3	14.8	15.4	16.9	14.7	14.1	12.6	15.6	18.3	14.8	9.9	7.8	9.6	15.5	15.4	16.5	16.1	17.9	18.5	15.6	12.6	13.1	12.4
1786	6	11.0	12.6	12.3	15.2	13.2	14.3	14.8	15.5	14.2	16.1	13.0	14.0	13.0	15.4	14.8	18.0	19.2	17.2	19.4	21.4	21.8	22.1	19.3	22.4	20.7	18.5	18.6	20.1	18.6	20.8	
1786	7	19.4	20.1	19.8	20.6	15.6	11.3	12.5	14.0	15.5	18.2	15.0	14.8	14.8	15.3	14.4	16.4	16.8	13.5	14.4	14.6	13.2	13.6	15.0	16.2	20.4	22.5	18.5	17.0	19.4	17.2	11.9
1786	8	15.8	15.7	12.8	12.7	14.6	21.2	18.7	17.1	16.4	16.9	15.1	15.0	17.3	14.5	16.8	17.2	17.3	16.1	17.4	19.1	21.3	19.2	18.4	14.0	14.2	12.8	13.9	13.9	15.4	14.5	14.5
1786	9	13.3	14.6	16.7	16.2	13.7	11.7	11.3	11.5	16.5	14.8	15.0	13.6	13.9	16.1	17.5	12.7	14.4	14.4	12.2	8.8	7.4	8.7	8.3	8.8	10.1	9.2	9.1	7.5	8.7	6.9	
1786	10	7.0	7.5	7.0	7.2	7.7	7.7	7.8	9.1	8.7	9.1	10.7	11.6	10.4	5.4	4.3	4.2	3.7	4.0	3.9	3.4	4.0	5.4	4.7	0.6	−0.2	2.8	1.0	−1.2	−0.6	−1.5	−0.9
1786	11	1.4	2.3	2.7	1.1	−1.0	−3.6	−5.6	−6.0	−5.1	−3.6	−0.9	−7.5	−10.6	−9.1	−6.7	−3.6	−3.9	−1.8	−2.8	3.0	2.4	0.6	−0.7	−2.2	−2.8	−0.2	−1.5	−3.3	2.1	1.5	
1786	12	1.4	0.1	−0.3	2.4	4.3	3.7	4.5	3.4	4.3	4.0	2.1	0.9	4.5	2.7	2.1	0.4	−2.3	−4.0	−7.3	−7.1	−5.8	−6.0	−6.6	−10.4	−9.3	−5.9	−3.0	3.7	2.2	3.1	2.0
1787	1																															
1787	2																															
1787	3																															
1787	4																															
1787	5																															
1787	6																															
1787	7																															
1787	8																															
1787	9																															
1787	10																															

Table A2. Continued.

year	month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1787	11																															
1787	12																															
1788	1	0.8	1.7	0.5	1.3	3.0	2.4	0.7	2.0	0.7	−1.2	−1.4	0.7	2.7	−0.4	−5.3	−2.6	3.5	1.7	0.6	−6.5	−2.1	−0.8	0.9	2.7	3.0	0.1	−4.0	0.3	−3.2	−4.4	−5.8
1788	2	−7.9	−2.7	0.7	2.1	1.8	1.1	−0.1	−5.0	−5.6	−4.4	−4.5	−5.0	−3.8	−5.3	−8.3	−9.3	−8.5	−10.2	−7.6	−1.9	0.9	2.8	4.0	3.7	4.0	0.1	2.9	3.6	4.0		
1788	3	2.1	0.8	−2.6	−1.6	−3.7	−0.3	−1.3	−2.5	−3.1	−3.5	−4.0	−1.3	−1.3	−1.3	−3.3	−3.4	−3.8	−0.3	0.7	0.7	0.9	1.6	4.2	4.6	3.2	3.6	2.7	4.0	6.5	7.1	8.5
1788	4	9.5	5.3	7.4	5.1	2.4	1.5	3.2	6.0	6.8	7.0	8.3	10.1	6.0	7.0	6.2	2.9	2.1	6.8	10.6	9.9	10.7	12.3	8.1	9.8	9.1	6.9	6.4	9.4	13.0	14.5	
1788	5	13.4	14.2	14.6	7.5	6.3	9.7	14.2	15.8	14.8	12.1	6.2	7.5	7.1	10.1	12.7	12.3	16.0	17.3	15.5	12.4	11.7	13.6	15.4	18.8	20.3	22.1	21.1	22.5	19.6	17.0	14.3
1788	6	14.0	15.2	15.1	18.0	14.1	15.1	17.7	20.2	19.4	17.5	16.0	14.9	15.5	17.1	18.1	19.5	20.1	21.5	24.1	25.1	23.4	19.2	19.1	17.8	18.5	19.5	19.4	23.7	21.7	19.6	
1788	7	17.6	19.8	19.0	20.6	21.1	17.3	18.4	20.0	19.8	21.4	23.8	22.2	24.0	20.7	23.0	25.7	25.6	19.9	21.3	21.5	21.2	20.6	21.8	24.5	15.6	16.2	15.5	15.9	17.6	17.3	16.9
1788	8	17.9	14.2	14.5	14.8	12.4	12.4	15.6	16.4	15.9	15.6	17.1	18.6	19.9	18.8	17.0	16.2	16.9	18.5	16.8	17.1	16.7	17.9	18.6	20.1	20.1	18.7	18.1	13.9	15.4	15.9	14.2
1788	9	14.3	16.4	14.3	17.4	18.4	18.7	19.4	18.8	18.2	18.9	18.2	16.4	17.8	19.5	13.4	11.6	10.9	11.8	9.8	12.2	11.5	13.4	13.9	15.2	14.2	12.3	11.8	11.3	12.0	11.5	
1788	10	10.8	14.1	16.0	15.1	12.3	12.8	11.5	7.3	5.1	5.0	5.3	4.1	5.3	2.0	3.1	5.3	9.3	3.4	2.3	4.5	6.3	6.4	8.5	5.9	3.6	5.4	3.9	6.8	5.3	2.4	5.1
1788	11	7.2	5.1	5.8	8.9	6.8	2.3	0.5	1.7	1.1	1.0	3.5	9.4	9.5	5.1	3.0	−0.2	−0.1	1.7	1.1	−0.1	−0.5	2.3	−1.5	−6.1	−6.8	−9.9	−6.5	−4.8	−5.9	−6.9	
1788	12	−5.9	−5.2	−5.5	−6.9	−4.8	−11.2	−17.5	−16.7	−19.2	−4.8	−2.8	−7.0	−14.0	−18.1	−22.7	−23.9	−22.0	−17.1	−12.6	−9.4	−2.9	−6.9	−13.8	−6.3	−5.8	−19.3	−17.7	−17.0	−18.3	−14.6	−11.0
1789	1	−11.5	−12.9	−23.8	−16.2	−14.8	−20.0	−22.1	−14.2	−6.4	−5.8	−9.2	−19.1	−3.0	−0.5	1.8	0.2	1.9	2.2	1.1	3.1	2.6	1.0	0.5	2.4	3.0	6.5	6.5	0.9	−4.2	−5.3	0.2
1789	2	−1.3	−1.5	2.9	2.2	2.3	0.6	1.4	0.6	0.5	0.8	0.5	−2.4	−2.8	1.4	4.3	1.2	−0.1	1.8	3.9	3.0	0.0	0.6	3.6	2.4	2.0	3.4	4.0	0.9			
1789	3	−1.6	−2.3	−2.9	−5.0	−4.7	−3.9	−5.2	−6.0	−5.7	−6.7	−9.0	−10.8	−7.1	−0.3	1.3	0.2	−4.9	−3.9	−4.5	−4.0	−3.0	0.0	2.8	−1.5	−1.5	0.9	−2.8	−3.1	−3.3	−3.7	−3.0
1789	4	−0.2	3.8	8.3	9.9	3.7	3.2	5.3	9.6	11.0	10.1	12.4	11.0	4.3	3.6	2.8	5.5	7.1	8.2	11.6	9.8	9.9	9.5	8.1	8.7	6.6	9.0	10.9	12.1	16.4	19.3	
1789	5	15.9	16.0	17.8	20.1	23.0	20.3	12.7	12.0	15.8	20.2	20.8	16.5	15.4	18.6	22.3	15.1	15.1	15.8	11.6	8.9	10.8	12.7	13.7	14.1	14.8	17.3	18.3	20.6	20.7	19.7	19.0
1789	6	20.2	23.0	19.1	16.8	16.5	13.6	12.3	13.9	14.0	14.2	15.0	17.0	17.0	16.6	17.4	23.3	20.8	19.1	19.3	22.4	23.9	19.4	17.9	20.3	18.0	17.2	12.9	15.0	13.6	11.4	
1789	7	9.0	12.8	15.8	19.3	21.1	21.2	18.9	19.4	19.0	19.9	20.6	21.6	19.6	20.4	18.4	20.3	22.9	19.4	17.0	14.1	16.5	19.8	18.3	16.7	16.4	18.6	19.9	20.2	20.9	17.0	17.2
1789	8	17.9	16.9	17.0	18.8	19.4	21.7	18.3	15.7	17.5	18.6	18.6	17.2	18.8	19.6	18.7	19.1	18.9	18.6	18.1	20.2	21.1	20.9	18.7	16.8	16.3	18.4	18.1	15.8	16.8	17.1	16.1

Table A2. Continued.

year	month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1789	9	14.2	16.6	15.3	14.9	16.7	16.5	14.9	15.6	16.9	16.1	18.8	15.8	13.5	15.1	16.1	14.5	15.5	12.3	9.2	9.9	12.1	11.7	10.8	11.4	11.3	12.5	11.3	11.4	11.8	13.6	
1789	10	15.2	12.2	11.8	10.6	9.8	10.1	8.4	8.6	12.9	15.3	11.9	13.0	11.6	12.6	14.6	13.4	10.9	6.1	10.8	9.6	8.9	4.9	5.5	4.9	3.5	2.8	3.8	3.3	5.1	7.3	6.0
1789	11	2.5	8.6	9.7	5.9	4.9	7.6	6.9	4.9	4.9	3.9	2.4	1.2	−0.6	3.7	8.6	8.4	4.8	5.5	5.2	4.7	4.7	3.3	0.4	−3.5	−3.7	−4.5	0.1	1.0	3.2	2.2	
1789	12	−1.4	−2.6	−3.5	−2.4	−0.6	−0.1	2.5	2.5	−0.2	1.2	1.6	2.2	3.0	1.2	2.7	3.6	1.5	1.8	2.5	3.0	5.2	6.9	8.7	8.1	5.4	4.0	2.4	4.6	6.4	9.4	5.2
1790	1	3.7	1.3	1.1	1.6	1.2	0.0	−0.1	2.7	2.5	−0.2	1.4	4.7	7.1	6.6	4.6	2.4	−2.5	−3.2	−0.6	−0.5	−0.8	−1.9	−1.9	−0.5	−1.6	−8.5	−7.7	−4.0	−0.5	0.3	−0.6
1790	2	−2.7	0.5	2.5	5.5	4.6	3.1	5.8	4.3	0.1	−4.2	−4.5	1.3	5.1	3.0	3.6	1.5	2.5	2.3	4.4	2.5	2.7	2.8	3.0	5.0	6.6	7.8	6.5	2.3			
1790	3	0.3	−1.2	0.1	2.6	−2.3	−2.0	1.1	0.2	0.6	5.3	4.4	2.3	2.0	1.9	2.0	0.3	2.2	4.8	2.8	2.9	3.4	5.2	8.3	9.5	7.2	8.5	9.8	8.1	3.8	2.5	−1.6
1790	4	−3.4	0.4	2.0	1.0	−1.7	0.1	1.3	4.0	4.5	4.6	8.0	8.0	11.5	12.8	8.0	12.6	6.9	3.6	0.6	0.0	2.6	4.7	8.3	10.3	12.1	11.0	11.3	12.6	13.7	10.9	
1790	5	13.5	15.2	17.6	18.1	19.8	16.5	18.6	13.6	15.0	13.3	12.4	13.5	11.9	11.8	14.0	10.7	11.5	14.3	15.6	17.8	14.4	12.6	15.8	18.6	23.0	24.0	24.2	22.4	17.5	17.1	14.3
1790	6	14.6	16.0	18.6	19.4	14.9	12.9	14.3	16.2	20.0	23.5	22.9	18.7	15.5	14.3	15.3	17.4	16.3	18.6	21.1	23.3	21.4	23.8	25.4	22.8	22.4	17.0	15.4	12.4	14.1	19.0	
1790	7	19.1	19.2	16.0	16.2	16.5	16.8	14.5	14.2	15.4	16.3	15.0	14.5	14.4	14.4	14.2	13.0	15.3	15.1	18.7	21.4	19.8	15.0	16.5	20.0	17.4	18.0	21.4	22.6	24.4	21.9	16.5
1790	8	20.1	15.7	17.5	17.4	15.9	18.3	18.2	17.7	17.5	17.6	18.0	16.0	16.2	14.7	16.6	19.3	17.7	19.0	17.1	16.0	16.3	16.1	15.4	18.1	16.0	21.4	21.1	14.8	14.9	15.6	14.6
1790	9	15.6	14.2	13.5	12.8	12.4	12.2	11.4	12.0	13.0	13.1	13.2	12.9	15.3	16.8	18.5	16.7	11.9	12.6	14.6	17.3	12.1	11.3	10.6	11.3	9.1	6.8	5.4	5.9	8.5	7.0	
1790	10	9.5	9.6	10.0	10.2	10.8	11.3	12.1	13.7	11.8	9.4	6.3	6.4	7.2	8.7	12.3	8.6	4.3	6.8	8.2	5.4	5.9	1.8	1.5	3.3	4.9	6.9	4.4	2.3	2.4	2.8	2.2
1790	11	1.6	2.0	5.5	5.7	5.9	2.7	0.9	2.0	1.7	2.0	1.6	0.1	1.1	0.7	1.2	−0.8	−3.3	−2.5	−0.6	0.3	5.4	4.8	3.8	4.5	6.5	7.7	2.7	−0.3	−0.1	0.1	
1790	12	0.4	3.7	3.9	3.2	1.9	−0.1	−1.5	−1.7	−2.1	1.8	4.4	3.3	4.2	3.9	2.8	1.8	0.7	3.2	0.1	−0.4	−0.9	1.9	2.1	1.4	1.9	0.8	0.1	−1.1	−1.6	−3.7	−2.5
1791	1	−0.2	−5.4	−2.8	−0.6	−0.8	−0.7	−1.2	3.6	3.3	3.0	2.8	3.8	2.7	3.3	2.9	5.3	7.8	2.6	1.7	2.7	2.6	1.8	0.6	1.5	1.2	1.5	0.8	1.9	0.2	0.6	2.8
1791	2	2.9	0.4	−2.0	−4.4	−3.5	−6.0	−3.4	0.7	0.5	0.8	0.7	1.2	2.1	4.0	6.1	4.6	2.1	1.0	2.2	3.6	4.0	0.6	1.8	2.7	2.2	2.0	3.7	1.8			
1791	3	1.6	2.7	1.3	5.3	7.4	7.0	3.0	−0.1	0.1	4.9	2.8	2.1	4.9	6.3	9.1	10.9	7.0	0.7	3.7	5.0	7.8	4.3	4.5	2.8	2.9	1.7	4.0	4.0	3.4	4.2	1.5
1791	4	2.0	2.6	5.1	8.3	8.5	7.5	8.7	6.6	10.7	12.1	8.2	8.9	6.4	6.3	9.4	11.5	10.1	10.6	11.4	14.6	15.1	15.2	13.1	12.4	10.9	9.7	8.8	11.9	14.5	16.7	
1791	5	15.4	14.8	9.8	4.7	3.3	3.3	4.4	6.0	8.3	11.4	13.3	14.2	14.3	14.9	12.5	11.8	12.2	10.3	10.3	11.6	13.3	17.0	15.8	22.1	18.1	15.3	16.7	16.7	17.5	14.0	14.6
1791	6	16.8	20.5	16.2	15.6	15.4	20.1	19.2	18.6	18.2	15.1	13.1	8.8	10.5	12.7	12.9	14.2	13.6	14.9	18.5	18.1	13.8	15.4	15.9	15.3	17.2	18.5	22.7	19.7	21.1	25.5	
1791	7	20.3	18.6	18.1	17.1	17.7	15.5	16.8	17.7	15.6	15.2	18.2	19.9	14.2	13.5	14.5	18.5	17.6	17.9	20.1	21.4	19.0	17.0	19.3	20.7	20.8	21.0	22.1	21.1	20.0	24.2	23.8
1791	8	26.7	24.4	17.9	15.5	17.9	19.0	22.1	24.8	16.4	18.8	24.5	25.3	22.0	24.6	22.8	22.0	21.0	24.0	15.9	14.4	19.2	19.6	19.1	20.5	20.1	16.9	16.1	13.8	14.1	12.4	13.0
1791	9	15.7	12.3	15.5	18.2	15.9	16.1	17.4	17.3	18.0	16.2	14.4	13.1	13.7	15.7	11.0	11.2	11.1	11.1	8.3	9.3	11.2	8.9	9.4	10.3	10.1	8.3	8.2	6.3	6.5	5.3	
1791	10	6.0	4.7	7.0	6.5	7.3	9.7	13.8	10.9	9.4	13.3	14.6	15.4	16.4	14.1	11.8	9.0	4.2	7.0	10.3	12.1	12.5	10.7	8.6	5.2	3.3	4.3	3.0	3.0	1.5	−2.4	−3.2

Table A2. Continued.

year	month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1791	11	−1.8	−1.2	−1.0	−0.7	−0.1	−5.9	−3.3	−4.3	−5.4	−0.3	0.2	−2.9	−0.8	−0.9	2.9	3.4	2.8	7.2	5.4	6.1	5.1	6.8	6.2	4.9	4.4	5.9	5.5	8.2	8.0	3.5	
1791	12	3.4	5.2	3.7	5.9	3.0	3.9	2.6	2.3	0.0	−1.4	−2.8	−3.3	0.2	1.3	1.2	−0.6	0.8	0.1	0.6	−0.3	−1.6	−5.2	−1.0	1.2	−3.0	−2.5	0.5	0.1	1.3	0.9	0.0
1792	1	−1.4	0.5	−0.4	−2.7	−5.0	−1.3	0.0	−7.7	−11.5	−7.0	−2.9	−3.8	−10.5	−11.3	−4.0	−2.3	−2.6	−0.5	−1.1	−4.4	−4.7	−9.8	−6.4	−1.1	1.8	4.0	5.3	3.2	3.8	3.4	4.1
1792	2	5.2	6.9	5.3	2.6	1.5	1.1	3.1	6.0	−0.5	0.3	3.3	4.1	−7.2	−6.1	−6.1	−18.4	−16.0	−9.3	−8.8	−4.9	−7.9	−4.7	−6.2	−2.4	−3.3	−3.8	−6.6	−7.7	−8.7		
1792	3	−7.9	−8.2	−2.8	2.3	5.0	0.9	2.7	1.3	−0.5	−6.4	−6.7	−4.5	−2.4	0.7	5.1	3.9	4.9	7.6	6.1	2.3	3.1	6.4	6.2	6.8	8.9	10.7	8.0	7.7	6.9	8.3	5.6
1792	4	8.8	12.0	8.9	8.8	6.0	6.8	5.1	7.1	9.2	9.9	10.3	12.1	11.5	3.8	2.6	4.7	9.3	9.0	4.2	0.3	−0.2	5.6	11.2	12.7	11.6	10.5	11.9	14.9	15.2	15.9	
1792	5	14.3	9.0	6.4	7.7	10.9	8.7	11.8	15.0	12.1	9.7	6.1	6.5	7.7	11.3	7.5	9.8	13.4	15.3	13.8	18.9	21.8	16.7	11.9	9.5	11.9	12.4	13.2	16.6	20.0	21.5	17.7
1792	6	17.5	20.7	22.1	19.5	13.2	15.6	21.8	20.4	17.1	18.7	19.1	16.6	15.3	16.3	13.3	15.2	15.4	17.6	20.1	15.4	13.6	15.2	17.0	21.2	16.8	14.1	14.2	17.4	20.6	20.7	
1792	7	16.0	13.3	15.6	17.9	17.7	17.0	18.4	19.9	22.8	23.4	23.0	25.7	21.4	20.9	21.9	20.7	22.6	25.5	25.4	23.4	23.8	20.7	16.3	17.5	18.0	18.4	20.3	20.8	15.8	16.5	18.6
1792	8	21.1	21.0	18.9	18.1	17.6	18.5	16.8	16.9	18.9	19.7	20.3	19.4	19.4	17.9	17.4	16.0	18.6	18.7	17.2	13.9	16.0	18.4	17.3	15.2	17.8	19.5	22.6	21.1	17.9	15.9	16.1
1792	9	19.4	16.2	18.4	19.4	21.5	15.7	13.6	14.9	16.2	17.5	12.3	10.5	11.6	11.9	13.6	10.0	9.6	9.5	10.6	11.5	11.3	11.3	10.5	9.0	9.5	9.4	10.2	7.6	10.4	11.0	
1792	10	12.2	8.9	4.3	4.9	4.3	6.2	5.3	6.3	4.4	3.2	3.3	4.8	7.5	11.5	13.4	10.5	10.4	10.1	7.0	5.0	5.5	7.4	9.6	8.1	5.7	1.9	0.8	2.2	−0.7	2.7	7.3
1792	11	8.5	8.4	5.5	3.7	1.4	2.2	4.5	4.4	2.4	3.5	6.0	3.1	0.9	5.4	8.5	4.1	3.2	4.0	5.1	−2.0	−1.8	−0.1	−2.4	−3.5	−1.9	−1.8	−0.9	−2.5	−1.7	−0.4	
1792	12	−0.6	−6.0	−9.4	−4.7	2.8	2.8	3.9	0.3	1.5	6.5	3.9	0.8	−2.7	−3.4	0.5	−2.9	−2.9	1.7	5.6	4.8	3.8	2.1	1.5	0.1	−1.1	−1.1	−0.8	0.1	−1.6	−5.6	−4.7

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