Bulletin of Geography – physical geography series
No 3/2010: 121–171

Krystyna Bryś, Tadeusz Bryś

Department of Agro- and Hydrometeorology,
Wrocław University of Environmental and Life Sciences,
Plac Grunwaldzki 24, 50–363 Wrocław, Poland
krystyna.brys@up.wroc.pl

RECONSTRUCTION OF THE 217-YEAR (1791–2007) WROCŁAW AIR TEMPERATURE AND PRECIPITATION SERIES

Abstract: The authors present the results of a climatologic reconstruction of the 217-year series (1791–2007) of monthly average values of air temperature and monthly totals of precipitation in Wrocław (Breslau). The reconstruction is based on verified measurement (or observation) data from the Breslau-Sternwarte Observatory (1791–1930), which were completed (1931–2007) by reconstructing values calculated from measurement data from other meteorological stations in Wrocław. Only the data for 1945 were estimated from the values of Polish (Cracow, Gniezno, Puławy) and foreign (Berlin, Prague) stations. The problem of restoring the homogeneity of the available initial data was taken into consideration because there were changes in location and observation times. The data were verified by comparing the measured values, among others of temperature, with the data from the nearest as well as other meteorological stations in Warsaw, Berlin, Prague, Vienna, de Bilt. In relation to this, the problem of special and temporal anisotropy of relations between the values of analysed stations was discussed.

Key words: air temperature series, anisotropy, homogeneity, metadata, precipitation series, reconstruction

Introduction

The city of Wrocław (Breslau) boasts one of the earliest histories of permanent measurements of air temperature and other meteorological elements such as precipitation. The first hundred years (1791–1890) of the "Wrocław air temperature series" has been presented in a separate study against an historical background of meteorological measurements in other Silesian stations (Bryś and Bryś 2010). This paper not only continues this reconstruction for the next 117 years up to 2007, but it also presents the reconstruction of the 217-year period (1791–2007) of the "Wrocław precipitation series" conducted on the basis of estimated and measured values of monthly precipitation totals.

Unlike continuous air temperature measurements in Wrocław, which had begun in February 1791, measurements of precipitation at the Breslau-Sternwarte Observatory did not begin until January 1799 (Galle 1857). Earlier, from March 1791, observations of the frequency and types of precipitation were made. Precipitation measurements were conducted on the terrace of the Mathematical Tower of the University of Wrocław and continued until the 1860's. In the second half of the century the measurements were transferred outside the Observatory building. Other important measurement changes frequently occurred in later years. As was the case with measurements of air temperature *Tp*, changes in the location of measurements also had an influence on the nonhomogeneity of values for precipitation *P* in Wrocław. Thus, the problem of restoring the homogeneity of the *Tp* and *P* series is crucial and is closely linked with the methods applied to their credible reconstruction.

Materials and metadata: Historical observations

The analyzed *Tp* and *P* data from the years 1791–2007 were collected from different sources. The data from diurnal measurements of these elements in the Breslau-Sternwarte Observatory (1791–1930) are of major significance for our work. The extant data originate from other meteorological (or precipitation) stations located in different districts of Wrocław (Gądów, Strachowice, Biskupin, Swojec, Psie Pole) and were collected in different years. Only the analyzed values for 1945 were estimated from the values of the other stations in Poland (Cracow, Gniezno, Puławy) and abroad (Berlin, Prague). The more than 200 years of changes in location and other criteria in *Tp* measurements in Wrocław have been presented in separate studies (Pyka 2003; Bryś and Bryś 2010). A similar history of the primary changes in location in Wrocław measurements of *P* requires closer examination in this study as it is linked with a separate history of changes in methods of measurement.

In particular, historical events in the twentieth century were very important for the reconstruction of the *Tp* and *P* (and also the earlier history for *P*) analyzed in this paper. The framework and scale of the available and analyzed materials from different Wrocław stations were connected with the time limits of these changes. The Breslau-Sternwarte Observatory functioned as Wrocław's main station from 1848 to 1920, first within the Prussian and then the German meteorological network. Its operations were taken over from January 1921 to July 1936 by a new station, Breslau-Krietern (in Polish: Wrocław-Krzyki), located in the suburban part of the town, at a distance of about 5.5 km SSW from the previous station. This station, specializing in geophysical measurements, continued meteorological observations until April 1945, at which time it was burned and partly destroyed during World War II.

From August 1936 until 1964, with only 18 months interruption, the basic measurements for Wrocław for the national meteorological network (Polish from 1946) were recorded at the Wrocław-Gądów (in German: Breslau-Gandau)[1] airport station. (Between April 1944 and December 1945 data came from the Breslau-Krietern station.) The Wrocław-Gądów station was located about 6 km WNW from the old university observatory.

Meteorological observations in Breslau-Sternwarte finished at the end of March 1921, but air temperature measurements were probably taken at least until 1930. A new University meteorological station (*Ergebnisse* 1921–1924) began work on 1 April 1921, at the eastern end of Szczytnicki Park (Scheitniger Park), in a grass garden by the new Astronomical Observatory (about 3.5 km east of the current day building) of the University of Wrocław. The station was also given the name Breslau-Sternwarte (sometimes Neue Sternwarte), and the data collected in the form of monthly averages (or totals) from the years 1934–1936 were published in the annals of the German meteorological service (*Deutsches Meteorologisches Jahrbuch* 1934–1936).

[1] The German aerodrome station in 1935–1944 included two autonomous stations: one synoptic and one aerologic (see: next section)

The monthly average values of air temperature from the years 1851–1930 and monthly precipitation totals from 1881–1930 for Breslau-Sternwarte were published in *Klimakunde*…(1939)[2]. The remaining German data of the *Tp* and *P* from the years 1891–1944 used in this paper were published in *Ergebnisse* (1891–1933) and *Deutsches Meteorologisches Jahrbuch* (1934–1944) or in *Atlas Klimatyczny* (1931–1944). Original measurement materials from the German stations mentioned which had been left in various places, probably did not survive either military operations during World War II or subsequent fires and looting in the first post-war months (Pyka 2003; Bryś and Bryś 2010).

From 1887 until 1944, observations were made at: 7.00, 14.00, and 21.00 local time. After World War II, from 1946 until 1965, observation times at Wrocław-Gądów were changed from 14.00 to 13.00 (12.00 UTC). From 1966 meteorological observations, which had continued since 1965 at the Wrocław-Strachowcie airport (about 10 km W of the first Breslau -Sternwarte station), were made at 8 fixed synoptic times: 3.00, 6.00, 9.00, 12.00, 15.00, 18.00, 21.00, 24.00 UTC.[3] The remaining Wrocław meteorological stations (Biskupin, Swojec) used the climatologic times 6.00, 12.00, and 20.00 UTC until 1978 (Swojec) and 1979 (Biskupin) and next: 0.00, 6.00, 12.00, and 18.00 UTC (at 0^h – reading of thermohigrograms; at the remaining times – values of standard measurements).

The Polish *Tp* and *P* data from Gądów (1946–1964) and Strachowice (1960–2007 for *P* and 1963, 1965–2007 for *Tp*), which was used in this paper, originated in several sources (*Atlas Klimatyczny Polski; Biuletyn Agrometeorologiczny; Rocznik Meteorologiczny*). The temperature and precipitation data from about a dozen other Polish stations which used the Wrocław data for estimation or verification, also originated from the above-mentioned sources. The longest Polish homogeneity *Tp* data from Warsaw (1779–1998) and Cracow (1792–1995), used here for comparative purposes,

[2] However, here we are not certain whether the results of the activities of the old Observatory from the years 1921–1930, which were published in *Klimakunde* (1939) in the form of mean monthly air temperature values and monthly precipitation totals, are solely measurement data or are partly estimated data.

[3] A military airport Strachowice was opened at the beginning of 1938. In the period from June 1945 to December 1946 and from 1958 up to the present there has also been a civil airport at Wrocław-Strachowice. Probably the first meteorological measurements were made there in the 1930s, but the earliest temperature data (NOAA data resources) only date from 1963.

originated from works by Lorenc (2000) and Trepińska (1997). These values were supplemented up to the year 2007 on the basis of temperature data from the Polish meteorological sources mentioned earlier. Other historical data (de Bilt, Berlin, Vienna, Prague), used for the same purpose in this paper, were published by Wetterzentrale (*http://www.wetterzentrale.de/klima/*). They were completed by the authors of this paper up to the year 2007 on the basis of *Tp* data from Internet sources of other national meteorological services (KNMI, DWD, CHMU, ZAMG). The data for de Bilt was corrected according to Engelen and Nellestijn, and Errenwijlens (*http://home.casema.nl/errenwijlens/co2/homogen.htm*) and the data for Praha-Ruzyne was enriched and verified by the *Tp* data from Praha-Klementinum (for which we thank Rudolf Brázdil). Additionally, temperature data from the NOAA Internet base of meteorological data (*ftp://ftp.ncdc.noaa.gov/pub/data/gsod/*) was used for verification of the Wrocław series.

Precipitation measurements conducted first at a height of 33.5 m above ground level on the Observatory terrace of the University of Wrocław were transferred to the University courtyard in 1854. Measurements of *P* (at a height of 2.0 m above ground level) were conducted at the new location for only 4 years. In the summer of 1858, measurements were transferred to the nearby Wrocław University Botanical Garden, about 800 m east of the Mathematical Tower (measurements at a height of 1.5 m AGL). Simultaneously, for comparative purposes, measurements were continued until 1868 on the terrace of the Mathematical Tower. The measurements showed a difference of about 30% between the annual totals of *P* at the terrace and in the Botanical Garden. Galle (1879), who was interested in the homogeneity of these data, also precisely described the rain-gauge recorders in use at that time and the history of their changes in the Observatory.

The precipitation measurements taken in the Botanical Garden were not interrupted when meteorological observations were transferred from Breslau-Sternwarte to other stations in Wrocław (Fig. 1). As a precipitation station (or post), precipitation measurements at the Botanical Garden survived until the beginning of the 1960s (with several years of interruption during and just after the war). However, only part of the data was published in the precipitation annals of German or Polish meteorological service. It is worth noting that there were other precipitation stations (or posts) operating in Wrocław apart from this station, but most of them (both German and Polish) functioned for only a few years. Only two – Stabłowice (Breslau-

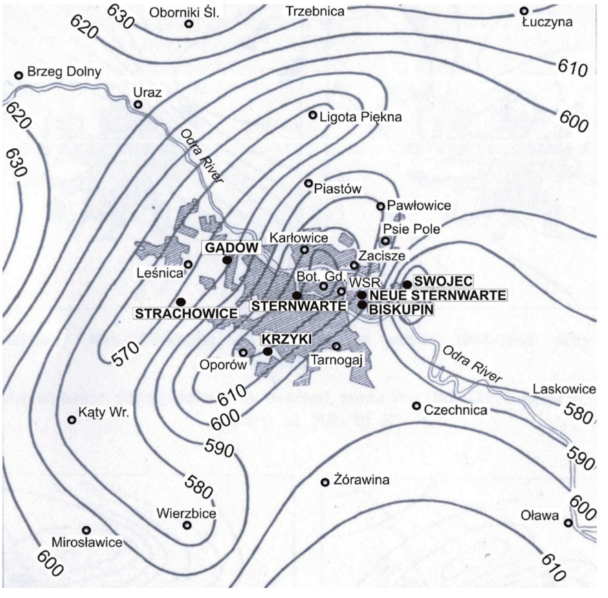


Fig. 1. The location of meteorological and precipitation stations and spatial distribution of average annual totals of precipitation (for the years1957–1966) in Wrocław and its neighbourhood. The isopleths show the effects of urban precipitation shade in relation to the prevailing wind direction from WNW-NW (after Schmuck 1967)

Stablowitz) in the western part of the city (near Leśnica) and Psie Pole (Breslau-Hunzfeld) on its north-eastern outskirts – worked for a longer time (probably starting earlier than 1920, but published data are only available from 1920 to 1940).

The Meteorological Observatory of the University of Wrocław in Wrocław-Biskupin has been operating since February 1946, and is located in Szczytnicki Park about 400 m SE from the previous station (Neue Sternwarte). Basic observation data obtained there from the years 1946–1965 and 1970–1974 were published and elaborated in annual reports (*Biuletyn Meteorologiczny; Prace …*). Together with other data from the years 1881–2000, they were useful for the reconstructions of long-term runs of monthly air temperature averages and precipitation totals (Pyka 1991, 1998a, b), and also for the studies of the climate of Wrocław (Dubicka 1994; Dubicka, Pyka 2001). Thanks to Krzysztof Migała from the University of Wrocław, the authors for the purpose of this paper were able to supplement analyzed data of monthly values of *Tp* and *P* for the years 1946–2007 with unpublished data (1996–2007) from the University Observatory.

The history of agrometeorological measurements began in Wrocław as early as the mid-1930s, including, among others, the measurements of air temperature and precipitation. Measurements were made in the garden of the experimental station of the Agricultural Institute of the University of Wrocław, located in a suburban, agricultural district – Wrocław-Swojec – east of the city. Pre-war results were never published. After an interval during World War II, measurements were not taken until May 1947 at the Agricultural Institute, which was the first part of the University of Wrocław and then at the Higher School of Agriculture (HAS) in Wrocław. A specialized Observatory of Agro- and Hydrometeorological was established in 1962 at the HAS (later known as the Agricultural University of Wrocław and now the Wrocław University of Environmental and Life Sciences). The scale of observations and measurements there has been systematically extended since 1960. However, the data for *Tp* and *P* for the period June 1947 – December 1959 from the station were not complete and revealed numerous missing fragments (about 55% for *Tp* and 15% for *P*). The data for the years 1960–2007, on the other hand, were complete.

Reconstruction difficulties and methodological dilemmas

Previous reconstructions of long-term temperature and precipitation courses in Wrocław (Pyka 1991, 1998a, b; Pyka and Dubicka 2001) did not exceed, or exceeded by just a few years, a 100-year period. The greatest difficulty in the reconstructions was to join together different series of measurements due to location changes of the meteorological stations mentioned above and the difficulty of filling the measurement gap for the year 1945.

The reconstruction of the *Tp* made by Pyka (1991, 1998a), covering the years 1881–1995, made dubious connections between post-war data from the Wrocław-Biskupin Observatory and earlier German measurements. This procedure involved assuming the similarity of meteorological data from the nearby but much older Neue Sternwarte station with university data obtained after World War II from the Biskupin station. While this might seem to be feasible, a more precise examination points to the contrary. This analysis became the basis for the revision of Pyka's thesis, presented later in this study.

Serious doubts about the homogeneity of Pyka's reconstruction of air temperature series arose from local on-site observations made by the authors, who analyzed differences in the location of these two stations. Differentiations in various topoclimatic conditions in both locations are clearly visible. The Neue Sternwarte area represents specific, local climatic conditions, formed by the eastern border, primarily consisting of the orchards of the Szczytnicki Park. The Park covered with tall, old trees that provide not only a very specific precipitation shade but also form a distinct and milder temperature structure within the Park and in the garden of the Astronomical Observatory as well. Topoclimatic conditions differ therefore from those observed in the nearby area of low buildings, where the Wrocław-Biskupin station is located. This difference has a significant influence on the measurements of temperature and precipitation coming from the two stations, though they are not extremely different. One cannot therefore assume, without making the appropriate adaptative corrections, that the results from these stations, as conjoined by Pyka (as a simple compilation), constitute a representative homogeneous series.

The comparison of *Tp* from the Wrocław-Gądów station with temperature values from the Wrocław-Biskupin station also gave rise to doubts undermining Pyka's assumptions. The average temperature in the years 1946–1964 reached 8.4°C for Gądów and 8.1°C for Biskupin. In preparing his series, Pyka (1998a) lowered (on an average of about 0.4 ºC) the pre-war data from Gądów and the previous data from Krzyki and the Astronomical Tower as well. Yet results from a comparison of *Tp* from Gądów (and also Strachowice) with Biskupin indicate a different set of dependencies. Therefore, Pyka's homogeneity trial is based on two false assumptions.

The first assumes that air temperatures at the Neue-Sternwarte station are identical with the *Tp* for the Biskupin station. The second assumes that the location of the post-war airport station in Wrocław-Gądów was exactly the same as that of the pre-war climatology station. The situation in the second case is more complex. All the most important Polish meteorological and climatology sources (for example: *Atlas…*) also identify the post-war station with the pre-war one. However, a precise verification of available data from meteorological annals (*Ergebnisse*, *Rocznik Meteorologiczny*) and the cartographical analysis (Fig. 2) of different archival sources indicate that there were two meteorological stations at the Gądów airfield before the war: 1) the synoptic station (16° 59'E and H=116 m alt.), 2) the aerological-

Fig. 2. The most likely location of the two meteorological stations on the Gądów (Gandau) airfield (Flughafen) before the second World War: C – climatology station, S – synoptic station

climatology station (16°58'E and H=118 m alt.). The first was probably on the future site of the Polish station (1946–1964). The average daily temperatures (recorded at 8 synoptic times) for the Gądów synoptic station in the years 1935–1941, used in this paper, are available from the easily accessible NOAA data resources (*internet sources*). The German meteorological annals (*Ergebnisse* 1936–1938, 1959) published measurement data from Gądów for an 8-year period (August 1936 – March 1944). Most of these data (aside from wind and precipitation) were probably connected with the aerologic-climatology station.[4] The temperature data from these two sources differ about 0.3°C on average, because topoclimatic conditions in various places near the northern border of the airfield were different. The monthly *Tp* values in the years 1935–1936 recorded at the synoptic station were higher on average by about 0.1–0.2°C than the temperatures for Krzyki.

[4] There is a note in *Ergebnisse* (1936) that climatological measurements were made at the northern border of the airfield 100m W from the big plane hangar, but wind and precipitation measurements were made in other places near the new airport building. The cartographical analysis of different German and Polish archival sources points to the fact that the first location was probably near the NW border of the airfield, and the second over 500 m E of the first.

On the basis of this, the authors concluded that by applying various linear and multiple regression equations between the analyzed stations, it is possible to link the pre-war *Tp* data with post-war Polish measurements from the Gądów and Strachowice stations in a logical and statistically correct manner.

The average monthly *Tp* values from Gądów and Strachowice are also not identical. The average differences noted in the period 1960–1965 amounting to about 0.2ºC (values are higher for Gądów), are representative for a longer period of time. This can be proven by comparing *Tp* values for Gądów and Strachowice with the synchronous values for the nearby stations (Swojec, Biskupin) and those further away at a distance of 30–60 km (Legnica, Oborniki, Szprotawa, Wińsko). The resulting estimated temperature differences from these two stations oscillated around 0.2 ºC (in relation to Legnica, Oborniki, Swojec) and 0.4ºC (in relation to Biskupin, Wińsko) and are of a different character. A comparison of monthly values of *Tp* Biskupin and *Tp* Strachowice in the years 1962–2007 reveals a systematic decrease in temperature difference between these stations. The *Tp* differences between Swojec and Strachowice in this same period were stable with insignificant oscillations. This indicates that *Tp* in Biskupin was under the strong influence of UHI, values of which increased in comparison with the stations on the outskirts of the city or located in agricultural areas. Thus, slight irregular differences were often connected with different methods applied to calculate *Tp* averages. For example, a comparison of the average from 8 synoptic fixed times with the average from 3 standard climatological once or the average calculated with the formula (*Tp* 6 UTC + *Tp* max + *Tp* min + *Tp* 18 UTC)/4, which has been in use since 1998 in the the Polish meteorological IMGW net, revealed a difference of about 0.1ºC (occasionally 0.2ºC).

A very characteristic feature of Silesian and Polish meteorological stations (except for Cracow and several mountain stations) is the general lack of homogeneity for longer time series as well as the presence of long interruptions in measurements during the second World War and for some years immediately after the war. For example, most Silesian stations (as was also the case in Wrocław) had two or three location changes in the period between the first and second World Wars. Therefore, it is very difficult to find a homogeneous 20-year temperature series taken in the climatic background surrounding Wrocław (within a maximum radius of 100–150 km) in order to make representative comparisons. Before 1945, only the following mountain stations in Lower Silesia functioned in the same location for an extended period of time: Śnieżka (Schnnegebirge), Miłków (Arnsdorf) and several others in the Sudetes. However, the importance of these stations for the reconstruction of *Tp* in the Wrocław series is limited due to varying and specific mountain topoclimatic conditions and their greater distance from Wrocław than from lowland stations.

In this situation, the fact that the homogeneity of many analyzed series was interrupted greatly complicates the reconstruction of the Wrocław *Tp* series. The most representative series from the other Wrocław station are only partly compatible (sometimes only by a 2-year period), as far as the synchronous period of measurement is concerned, with the analyzed data from Wrocław base station operating at that period. This resulted in the fact that only one linear regression equation could be deduced, as a common statistical tendency for all the estimated monthly values (for example: the correlation of Krzyki with the Gądów synoptic station was possible only for 1935–1936 with $R^2=0.9996$). When possible, we took into consideration multiple regression equations deduced from several analyzed stations instead of a simple correlation with one station.[5] Such reconstructed values were additionally verified by means of a comparison with several other Silesian and Polish stations (including Cracow) against a more distant climatic background. Finally, the reconstructed runs of temperature data (1791–2007) for Wrocław were verified through comparison with the same long-term distance runs of *Tp* from Warsaw, Berlin, Prague, Vienna, De Bilt. The problem of spatial and time anisotrophy in relations between the values from the stations analyzed has been discussed in this context.

Having applied Alexandersson's method (Alexandersson 1986) to reconstruct homogenous series of *Tp* and *P*, the authors nonetheless took a critical approach to the nearly mythical status of the reconstruction capabilities of this method. Complications arise when the data that is compared comes from distant locations in differing climatic backgrounds (see sections below). Reconstruction of precipitation patterns proved to be difficult

[5] The climatic data were often derived from such station measurements where there had been changes of location as well as of observation times. Therefore, they required careful homogenizing which assumes that nonhomogeneity of the series is not possible if it is not obvious, and if the apparent interruption of continuity of measurement values is constituted by physically explicable changes in the station's natural surroundings. As a basic principle, the authors referenced the checked series to the values occurring in the immediate vicinity of the station examined.

because it requires taking into consideration the important influence of the UHI (Urban Heat Island) effect (Landsberg 1981) and of urban precipitation shade (Fig. 1) on spatial variability, even on a fragmentary and small areas of Wrocław. These influences were the subject of many detailed analyses and studies (among others: Zipser-Urbańska 1968; Schmuck 1967; Dubicka 1994; Szymanowski 2004; Bryś 2007). The differentiation of the precipitation pool in a big city has a dynamic character and is connected with the dominating direction of rain-cloud mass advection. In the case of Wrocław, the largest frequency of rain-cloud mass advection from the western sector (W-NW) is counterbalanced by the largest precipitation efficiency (P intensity) from the SE sector (despite the low frequency of rain mass from this direction), connected with the influence of summer Genoese lows. A study by Dubicka (1994) closely analyzed the connection between precipitation in Wrocław and air circulation.

The fact that there were at least several precipitation stations (or posts) in the city or its environs at different times over the twentieth century allowed the authors to establish the fundamental and strongest spatial connections for *P*. Linear and multi-elemental regression equations were deduced to arrive at monthly precipitation values observed in the city center which could credibly be merged with those registered at its borders. Gaps in the observation material, such as the year 1945, were filled in by interpolations based on the quotient method and precipitation totals from neighboring stations further away. The results of estimates made by Wiszniewski's group (*Atlas Klimatyczny Polski* 1979) were incorporated. Similarly, in the years when the references made to other Silesian stations were credible (Bryś and Bryś 2010; Galle 1857, 1879), the authors carried out a general verification of the earlier measuring materials for Wrocław. On the basis of this, they first reconstructed the precipitation series for the years 1799–2007. Only the *P* values for topoclimatic conditions of the central-urban reference station (Botanical Garden) were reconstructed in this paper. Not only had the location of precipitation measurement changes to be taken into account, but so too did the influence of various reception surfaces and the construction of measurement instruments. These latter changes occurred in various years throughout the nineteenth century and were noted by Galle (1879). He also analyzed their influence on the quantity of precipitation measured in Wrocław. This study makes use of the results of Galle's analysis, which in turn were based on corrected precipitation values deduced by him for the years 1851–1876. In making his corrections, Galle used only one quotient coefficient for the entire year, but the authors proceeded differently. Based on his research and relations obtained from previously mentioned, parallel precipitation measurements taken on the terrace of the Mathematical Tower and in the Botanical Garden, the authors deduced statistically substantial relations in the form of linear regression equations. The separate equations were used for each month to correct precipitation totals for the years 1799–1850. The authors converted the erstwhile precipitation notation from Paris lines to millimeters, using the formula: 1 Paris line = 2.256 mm.

This basic measurement series was completed with estimated *P* monthly totals for the years 1791–1798. In this case, the authors used statistically substantial relations of monthly precipitation frequency and types with their monthly efficiency (multiple regression equations were deduced separately for each month) noted for the nearest 30 years. The 217 year Wrocław precipitation series for the years 1791–2007 which they obtained was divided into 4 sub-series: 1791–1842, 1843–1894, 1895–1945, 1946–2007 and verified by the Bartlett test (Twardosz 1996), which did not produce any differences that would have disqualified a homogeneity series deduced by this method. The worst results were obtained for July and May, but the value of X^2 calculated did not exceed the threshold of significant value to the level of p=0.05.

Comparison with long-term precipitation courses noticed for other central European stations (Warsaw, Cracow, Prague, Berlin) showed slight deviations for certain years, most probably connected with local determinants. Their closer analysis requires a longer, separate study. In this article the authors have limited themselves to charts, as in the case of temperature, showing only the pattern of monthly, seasonal, half-year and annual precipitation totals in Wrocław in the years 1791–2007 and to a short discussion of these patterns.

It is worth bearing in mind the unpredictable nature of heavy storm-produced precipitation, the influence of which, in certain summer situations could create a considerabe distance between precipitation results (even those deduced from the most reliable statistical methods) and their real value. Uncertainty about results reconstructed in this manner, considering the fluctuation of the deviation mark (+ or -) from real values and their mutual compensation, which negates their influence over a longer period, should not have a greater significance for the reality of deduced long-term precipitation trends. Being aware of this "uncertainty principle" in the pursuit of the greatest precision in the reconstruction of long-term series of *P* grants us a perspective on the re-occurring practice of replacing precipitation measurement values (even with some errors) with estimated values.

It is worth noting that in the case of small measurement errors and in many controversial situations it is better to leave the data unchanged, neither erasing nor disturbing their whole information value, which is very significant for climatic research. Apart from quantitative information, the qualitative information reflected by this data is also important (for example: fluctuation patterns, relation with neighboring data etc.), which is also a reason for it being preserved in its entirety, in spite of its imperfections. Thus one avoids creating "smoothed over" and artificial meteorological data series that are statistically correct, but discordant with the climatic reality being reconstructed. Research into long-term climatic trends cannot impoverish the available sources on short-term climate dynamics.

On certain aspects of the anisotropy of the temperature and precipitation fields in central Europe

Owing to its location in the range of moderate geographical latitudes, the climate of central Europe is subject to the teleconnectional impact of long-lasting changes of barometric tendencies in the source Atlantic region reflected by NOA and AO indicators. Seasonally variable fluctuations in intensity dependent on complex long-term dynamics and the spatial range of these influences modify, among others, the temperature field in central Europe and determine its variability in different spatial and temporal scales. A specific feature of this variability is the phenomenon of thermal anisotropy and its temporal and territorial differentiation.

Thermal anisotropy is the representation of various thermal features in different directions reflected in geographical space. This study focuses solely on the analysis of air temperature anisotropy of the ground layer (i.e. temperature taken in a meteorological cage at a standard height of 2.0 m). In the case of Poland, anisotropy thus understood and climate continentalism increases as one moves from over Denmark towards the east and advancing inland. Therefore, this evinces a close correspondence (inversely proportional) with the gradual decrease in the impact of thermal oceanism. Additional modification is introduced by local physical and geographical features as well as the nature of the active area surface. Among these factors, vegeta-

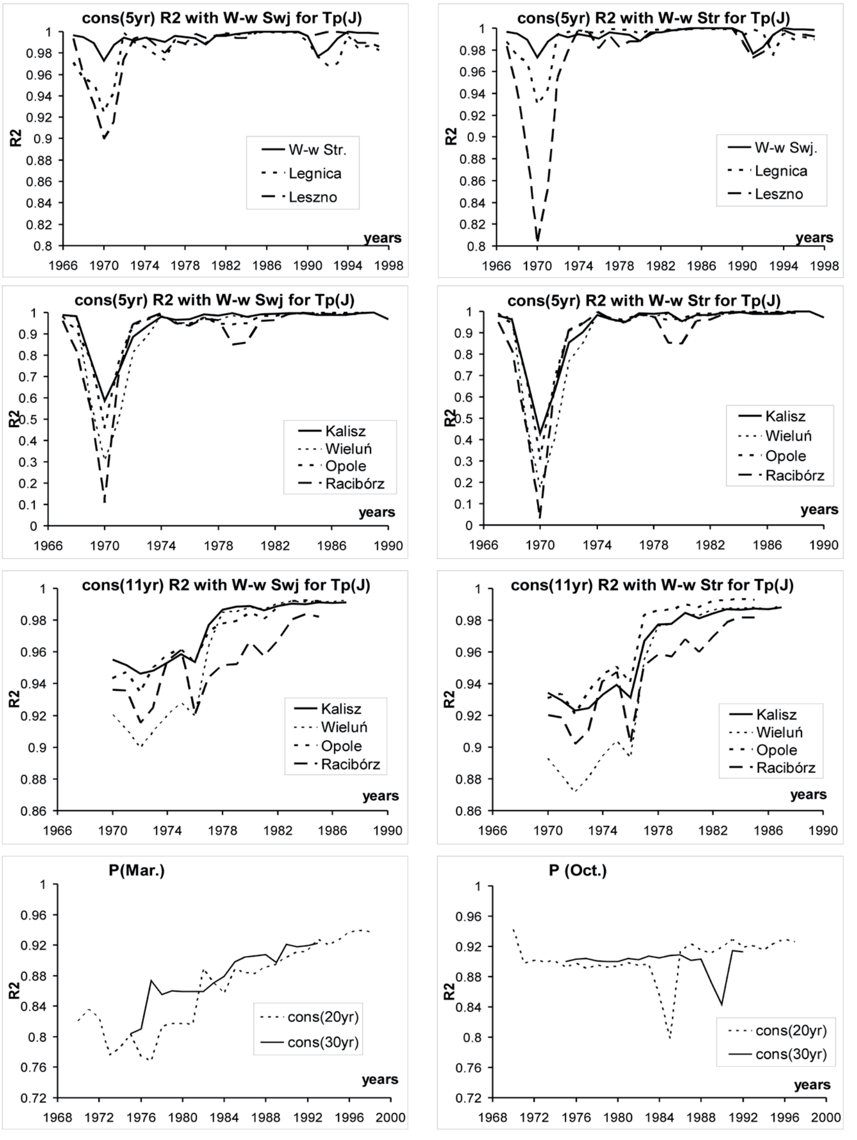


Fig. 3. Temporal anisotropy for monthly values of air temperature (Tp) as exemplified by 5- and 11-year consecutive (cons) correlations (R2 – coefficient of determination) between Wrocław-Swojec (W-w Swj) or Wrocław-Strachowice (W-w Str) and other meteorological stations in January (J). Similar phenomenon for monthly totals of precipitation (P) using the example of 20- and 30-year consecutive correlations between Wrocław-Swojec and Wrocław-Strachowice in March (Mar.) and October (Oct.). Explanation: *Tp* data for the years 1965–1999, *P* for the period January 1961- March 2008

tion cover and areas that are urbanized or have otherwise undergone strong anthropopressure, play a significant and dynamic role. Vegetation cover, differently influencing the effectiveness of area evaporation in each stage of its development (phenophase or agriphenophase), also functions as a thermal buffer. It restricts solar radiation energy inflow into soil and likewise limits explicit heat stream outflow from the ground into the air. Consequently, it affects the redistribution of heat accumulated in soil and is characterized by considerable seasonal and long-term variability. It exerts a disruptive effect on thermal records of the meteorological station as a result of its territorial expansion as well as the growth of perennial plants near the station. This may also lead to an increase in the roughness of the atmospheric substratum. Furthermore, urbanized (or industrialized) areas influence local thermal conditions through the UHI effect, through a rise in radiation extinction as well as alterations in the wind field and the precipitation field (caused, among other things, by accumulated effects and precipitation shadows).

According to Flohn (1981, 1993), horizontal climate variations are both less substantial and significant than temporal ones in medium size areas (such as Poland or its regions). This phenomenon is clearly visible when one looks at modifications of the temperature field. Similar phenomena appear to an even greater degree in variations of the precipitation field (Fig. 3). Its effects are reflected both in seasonal changes of thermal (or precipitation) anisotropy as well as in different aspects of its long-term variability. The primary role of the macrocirculation factor in modifying thermal (or precipitation) features of regions exceptionally "sensitive" to climate variability (i.e., regions of so-called transitory climate) is particularly evident during periods of circulation changes. Records of long-term correlation changes between different stations attest to this fact, and we make use of this in our homogeneity analysis presented below.

The spatial correlation of climate changes, or "teleconnection", provides evidence of a certain spatial order in the variability of different climate elements, including air temperature and precipitation, among others. The analysis carried out in this work on the teleconnectional relations of each of these elements (in a selected part of central Europe) has been rendered by use of the R^2 determination coefficient in its values for different (5- to 35-year) dynamic correlations. Long-term records (1946–2007 or at least a 35 year period within this span) of correlation changes of monthly mean air temperature (or monthly precipitation totals) between stations in Wrocław and its environs were compiled separately for each month. Relations between Gądów, Strachowice, Swojec, Biskupin or Poznań, Opole, Zielona Góra and these background stations have been examined in a manner similar to those between stations in Wrocław (the graphs in Fig. 3, for greater clarity include only 2 such stations: Strachowice and Swojec and 6 stations of the climatic background: Legnica, Leszno, Kalisz, Wieluń, Opole, Racibórz).

Contesting the myth concerning the reliability of certain homogeneity methods

The application of the R^2 coefficient (Fig. 3) reveals not only the statistical significance of these correlations, but also the character of their temporal and spatial variability. It also enables the identification of periods of relative stability and greater fluctuation (which are different for various months) as well as the characteristic, "funnel-shaped" refraction forms of their values. The latter phenomenon can be associated both with a continuity disruption in the measurement methodology (nonhomogeneity) in one of the compared stations, as well as with the occurrence, as time elapses, of different statistical aspects of climate changes (e.g., climate discontinuity, periodicity or climate rhythm) or macrocirculation changes. The occurrence of temporal consistency of these forms in different examined (base) stations in juxtaposition to the same compared background (referential) stations excludes the disruption of measurement homogeneity as a cause of their topographical features. Therefore, the significant role of climate variability in the formation of R^2 discontinuities in *Tp* (or *P*) teleconnections in different spatial mesoscales can be inferred. This, in turn, influences (in some years quite considerably) the accuracy of the reconstructed data. Simultaneously, it undermines the primary assumption of those homogeneity tests that involve weighed mean values, being linear correlation coefficients between temperatures (or *P*) in the base stations and their adjacent stations (or exponential function of their distance), as a measure of a constant long-term influence of the reference station on the examined station (and vice versa).

Alexanderson's test (Alexandersson 1986; Brázdil and Stepanek 1998; Miętus 1998; Lorenc 2000), which applies the so-called referential series (a temporal sequence of mean values weighted from values of an examined meteorological element recorded in adjacent stations) has gained popularity for the restoration of data homogeneity. It is based on the assumption that there exist, for the purpose of homogeneity, reliable statistical relations between the examined station and its adjacent stations. These, it argues, can be evaluated by the use of linear regression and weighted mean value, which results in a reference sequence (for comparisons with the sequence of values from the examined station). It is only necessary to be certain that in these adjacent stations, the continuity and homogeneity of the observation series are maintained in the period examined. The homogeneity criterion is the most difficult to fulfill due to the fact that, for objective reasons, there is no absolute possibility of retaining the same observation rules in the course of long-term (e.g., decadal) measurements conducted by different observers, using various equipment and not always in the same place and time. Location changes were often considerable (vertical and horizontal relocations of the measurement station), while methods of data compilation underwent substantial alterations (e.g. an alteration in the method of calculating a mean, day value connected with changing the quantity or observation times). Detailed and thorough information (metadata) concerning these alterations is not always available. Consequently, even the stations regarded as homogeneous do not possess fully homogeneous observation sequences. The concept of the referential series diminishes these objective methodological inconveniences as it focuses on the assumption that if one takes into consideration a greater number of reference stations for the creation of the referential series one can thus reduce measurement homogeneity disruptions in any of these stations. The simultaneous occurrence of significant nonhomogeneity in the majority of stations is highly improbable (apart from rare instances when system changes were introduced simultaneously in all of the stations) and therefore ought not to be taken into consideration.

As indicated, however, by the results cited earlier, of the correlation changes in the years 1946–2007 between several examined stations and their reference stations (the same for all), the use of the referential series does not guarantee an increase in the estimation accuracy of the missing data. This series (as well as its relations to the value of the examined station) is subject to previously mentioned climate changes that destabilize weight coefficients, particularly in periods of macrocirculation changes which are not taken into account in the calculation of weights. As is assumed in the criticized method of restoring homogeneity, Alexandersson's average stability of weights or weights in the form of average stable correlation coefficients is at variance with natural reality. The temporal variability of spatial air temperature relations between Wrocław (or other examined stations) and the stations of closer or more outlying surroundings, measured by means of R^2 value, indicates the necessity of considering separately possible periods of greater estimation unreliability and inaccuracy in the homogeneity procedures. This is indispensable and should be applied as a constant regular practice determining the possible reliability limits of the reconstructed series (or its respective parts), and not those stated on the basis of some theoretical, oversimplifying assumptions. The formal and statistical methodological criteria need to be in accordance with the over-arching concrete criteria closely related to the complexity of natural reality and the physical processes that define it.

Ignoring these methodological precepts can result in the creation of fictional segments of the examined temporal sequences that are divorced from natural reality, which only appear to be sequences of numerical values constituting a reliable reconstruction of measurement continuity of the meteorological element examined. They imply an exaggerated and physically inexplicable accuracy of value estimation in the whole study period. This implication can be achieved through high R^2 values acquired by means of standard (and therefore non-shifting, long-term periods) correlation comparisons of longer sequences of the examined data, as well as through the application of adequate linear regression equations. One often must confront the "fetishization" of the applied method (eg., Miętus 1998), an odd result of which is the homogeneity of monthly mean temperature with an accuracy of up to 0.01°C. Equally irrational is the "mythical" conviction that this method is efficient in the detection of nonhomogeneity periods and in the precise estimation of correction quantity. This method is thus unreliable in the process of restoration of an inhomogeneous value to its methodological consistency with former homogeneous values. The occurance of temporal anisotrophy is important phenomenon of climate variability. The research results about anisotrophy presented in this paper by the auhors show unequivocally that application of Γ parameter for examing the inhomogeneity of the temperature series leads to an ambiguous interpretation of the genesis of Γmax rather than to the detection of measurement continuity disruptions by of Alexandersson's test. The correlation connections presented herein, analyzed also in different one hundred year periods for Wrocław and outlying stations, are of a non-stationary nature, depending to a large extent on macrocirculation changes. The role of these changes is generally demonstrated in the regular or quasi-regular effect of temperature variations in the analyzed long-term series, including, among others, the detection of approximately 8 and 12–14-year oscillations in the Czech mean monthly *Tp* series (Pisoft et al. 2004). This paper also took into consideration other aspects of this dependency.

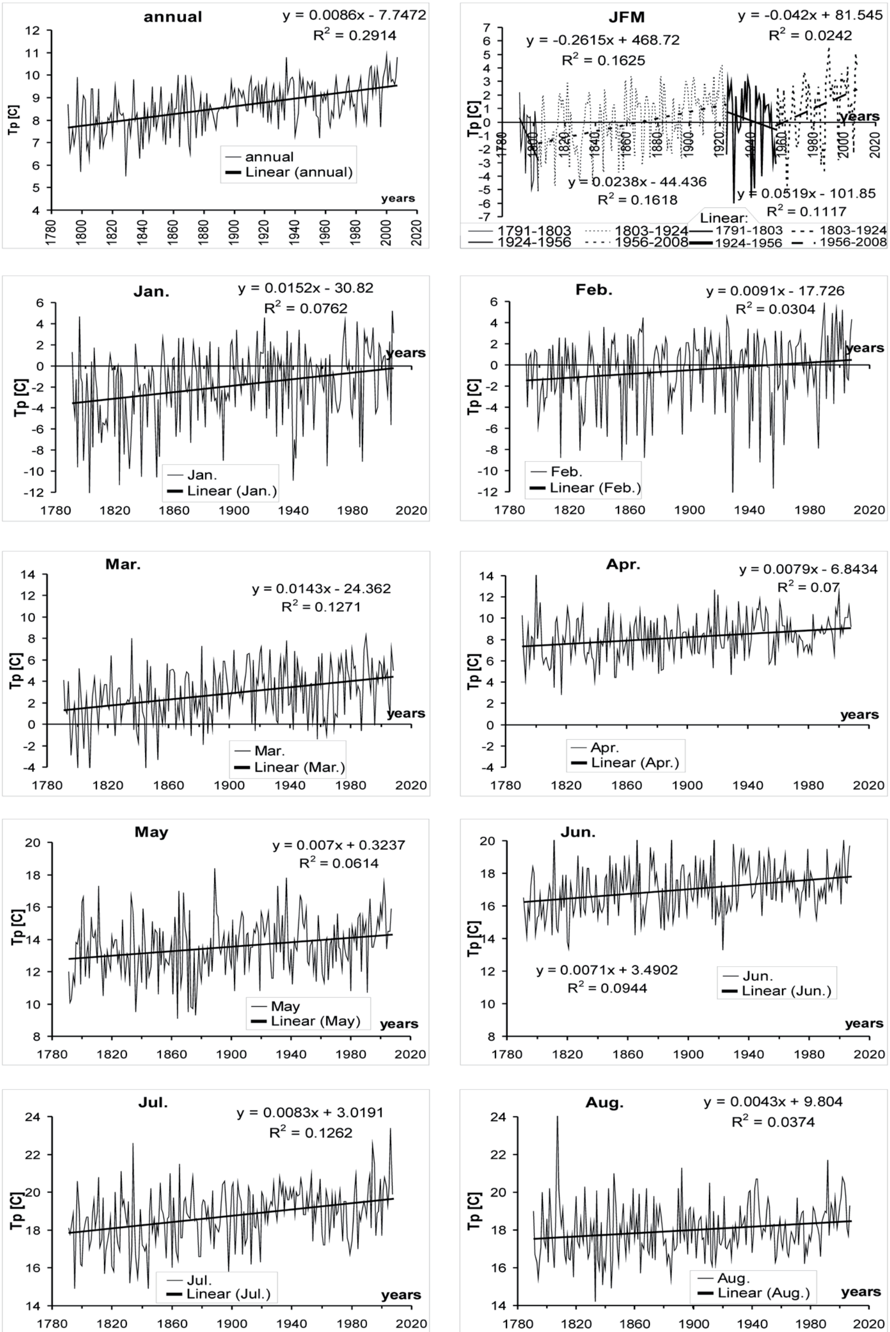
It is probable that the spatial distribution of this nonstationarity is connected with the phenomenon of its migration over time, which in turn is in central Europe a repercussion, with ever-increasing delay (as one moves further away from the source area of teleconnection), of the climate changes underway in the North Atlantic and subtropical zones. In the mesoscale area examined, this is reflected in the spread of certain features of the activization of zonal or meridional circulation along with spatially and temporally diverse effects of their conflicting influences. The previously mentioned phenomena of local character connected in turn with differentiation of the active area as well as its radiation, temperature and evaporation interactions with different air masses are of secondary importance. Among them vegetation cover and anthropopressure play an important yet secondary role compared with the impact of circulation.

Reconstruction results and a short discussion

The reconstruction of the *Tp* values made by the authors, in contrast to that of Pyka (1998a), shows a distinct increase of temperature in Wrocław over the twentieth century as well as over the entire analysed 217-year period. In the years 1791–2007, the warming tendency, for topoclimatic conditions of the former Breslau-Sternwarte Observatory, amounted to 0.85°C/100 years (Fig. 4). The strongest secular trend appeared in the years 1829–1939 and amounted to 1.43°C/100 years. A relatively small increase in temperature occurred during the twentieth century, because its trend only amounted to 0.39°C/100 years. This was the result of a relatively strong decreasing tendency in the years 1934–1956, which for 22 years interrupted the process of climatic warming. A very strong increasing tendency began again after 1956. The increase in warming for the years 1956–2007 amounts to 1.65°C, which is equal to a tendency of 3.2°C/100 years. Of decisive importance here were changes in the winter time. In the period from January to March (JFM) a warming tendency in the years 1791–2007 amounted to 1.24°C/100 years, while in the periods from December to February (DJF) 1.22°C/100 years, and November to January (NDJ) 1,23 °C/100 years. These were the strongest trends from all analysed 3-month periods of the year. The weakest tendency 0.45°C/100 years appeared in the period of August to October (ASO), while in the period of July to September (JAS) it amounted to 0.56°C/100 years, and from September to November (SON) 0.6°C/100 years. The weak tendency (0.66°C/100 years) was visible also in the summer (JJA), and relatively strong (0.99°C/100 years) in the spring (MAM). The result of these tendencies was that the trend in the warm half-year (April-September) amounted to 0.64°C/100 years. The largest increase occured in January (1.50°C/100 years), March (1.43°C/100 years) and December (1.23°C/100 years). The smallest one occurred in August (0.42°C/100 years), September (0.43°C/100 years) and October (0.45°C/100 years). All these trends are statistically significant to a level of α =0.05.

The warming trend in winter (DJF, and also JFM) started in 1803; a cooling tendency was apparent earlier. However, the period 1803–1838 had a particular significance for temperature changes in Wrocław. The first three decades of the twentieth century were the final culmination of the "little ice age" in Wrocław and a period of transition to a new era of progressive warming (Bryś and Bryś 2010). Of crucial importance for this new tendency was the strong secular trend of increase in winter temperature in the years 1803–1924 (2.35°C/100 years), and especially strong in 1838–1921 (2.86°C increase, i.e., 3.42°C/100 years). After 1924, we see the beginning of a dynamic period of greater oscillations of the winter *Tp* from year to year (compared with 1791–1924). This period consists of two different stages: 1) 1924–1956 with a strong decreasing tendency (1.35°C of the drop, i.e. 4.16°C/100 years); and 2) 1956–2007 with a strong increasing trend (2.71°C of the growth, i.e. 5.27°C/100 years).

The reconstructed *Tp* and *P* series for Wrocław represent long-term modifications of natural climate oscillations and tendencies by specific urban conditions, especially UHI and many phenomena connected with it. In addition, these modifications are to a large extent formed by local, anthropogenic specificity (urban and industrial physiography), which overlaps with local natural conditions (location of a city and its natural physiography, such as relief, types and distribution of plant cover, water reservoirs and tides etc.). This results in the strong impact of differentiated topoclimates in large urban areas on the principle climatic features observed in meteorological stations located in various places around the city analyzed. Relations between the base station and measuring stations do not have a stable character but are


annual
y = 0.0086x - 7.7472
R2 = 0.2914
annual
Linear (annual)
Tp [C]
years
JFM
y = -0.042x + 81.545
R2 = 0.0242
y = -0.2615x + 468.72
R2 = 0.1625
y = 0.0238x - 44.436
R2 = 0.1618
y = 0.0519x - 101.85
R2 = 0.1117
1791-1803
1803-1924
1924-1956
1956-2008
Linear:
1791-1803
1803-1924
1924-1956
1956-2008
Jan.
y = 0.0152x - 30.82
R2 = 0.0762
Jan.
Linear (Jan.)
Feb.
y = 0.0091x - 17.726
R2 = 0.0304
Feb.
Linear (Feb.)
Mar.
y = 0.0143x - 24.362
R2 = 0.1271
Mar.
Linear (Mar.)
Apr.
y = 0.0079x - 6.8434
R2 = 0.07
Apr.
Linear (Apr.)
May
y = 0.007x + 0.3237
R2 = 0.0614
May
Linear (May)
Jun.
y = 0.0071x + 3.4902
R2 = 0.0944
Jun.
Linear (Jun.)
Jul.
y = 0.0083x + 3.0191
R2 = 0.1262
Jul.
Linear (Jul.)
Aug.
y = 0.0043x + 9.804
R2 = 0.0374
Aug.
Linear (Aug.)

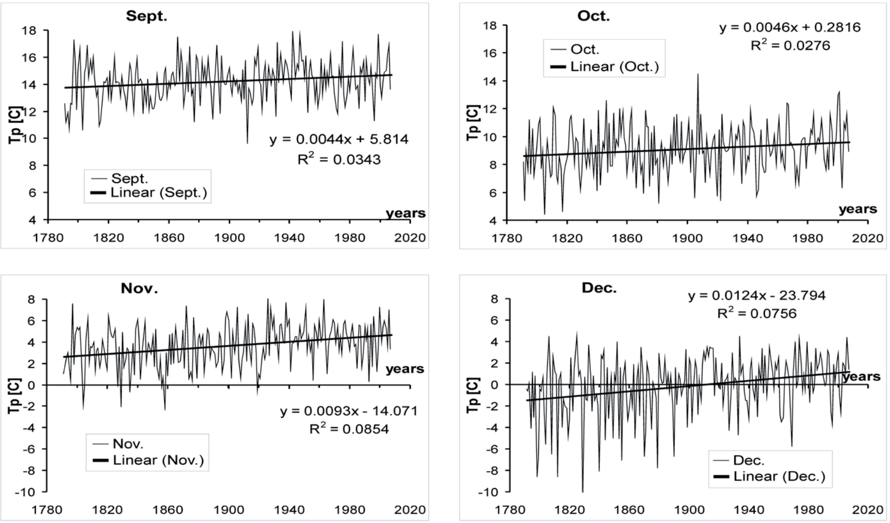


Fig. 4. The course of the mean annual, selected 3-month period (JFM) and monthly (Jan., Feb., Mar., …Dec.) temperature values (Tp) and their linear tendencies for the years 1791–2007 in Wrocław

rather variable due to the dynamics of conditions (sometimes in a specific range of values) from year to year (time anisotrophy). Their directional, progressive variability in time most often reflects the dynamics of anthropopressure on the urban landscape. Greater instability of a macro-circulatory provenance may appear alongside locally conditioned instability. All these factors have an influence on the precision of the reconstructed series *Tp* and *P* in the base station of reference (Breslau-Sternwarte), the estimated values of which originate from the interpolation of data from other measuring stations.

However, the tendencies and the structure of climatic oscillations presented here were shaped primarily by macroscale changes in circulation. In the analyzed 217-year history of thermal changes in Wrocław there are two long-term climatic variations that are especially important. They appear, similar to those presented in winter period (Fig. 4), also in the long-term course of annual *Tp* values. The most important change began during the first three decades of the twentieth century and was connected with the previously mentioned transition to a new era of progressive warming. The second change, which has taken place over the last five decades, following a 22-year (1934–1956) period of cooling, is connected with a new phase of warming and a sub-phase of significant increase of the *Tp* in the years 1987–2007.[6] In the authors' opinion, there is an analogy to be made with past temperature changes in Wrocław. In 1797–1829, there was a period of cooling. The period of warming in the years 1829–1956 had two major phases with two sub-phases. In the first phase one can distinguish two larger sub-phases: 1) a longer one of increased *Tp* (1829–1868); 2) a shorter one of decreased *Tp* (1868–1888). The second phase was similar: 1) a longer sub-phase with *Tp* increase (1888–1934); and 2) a shorter sub-phase with *Tp* decrease (1934–1956). Profound and rapid changes appeared in the years immediately before the culmination of warming began, as was the case in the sub-phases of cooling.

The latest period (phase) of warming has so far been characterized by a longer sub-phase of temperature increase. However, it seems that this sub-phase culminated between July 2006 – June 2007 and we should now probably expect, as was the case previously, a sub-phase of decrease in the average annual temperature. The earlier changes had a characteristic form – their proximal stage was longer than the distal stage. The first stage was a period of about 40–50 years and the distal stage (the years of post-culmination decrease) appeared as a relatively steep and short period (about 22–23 years, sometimes about 30–35 years). Is the present a new transition period and a turning point in climatic change? Possibly, but it may also for some time be a continuation of the increase sub-phase. On the basis of analyses of other long-term *Tp* series (Berlin, de Bilt, Cracow, Warsaw, Prague, Vienna), the authors would argue that the turning point has already occurred or will occur during the next few years.

The increasing tendencies are also evident in the reconstructed totals of *P* (Fig. 5). For annual precipitation totals the linear trend amounted to 68.9 mm/100 years, i.e., relatively 12.8% of the growth. For hydrological year (Nov. – Oct.) the trend was a little stronger, because it amounted to 69.5 mm/100 years (12.9% of the growth). In the warmer half-year (Apr.-Sept.), this tendency amounted to 39.8 mm/100 years (11.5%), but for April-June only 13.2 mm/100 years (8.3%) and for July-Sept. 29.4 mm/100 years (12.3%). In the remaining 3-month periods, nearing

---

[6] The highest average annual *Tp* (10.9 °C) in Wrocław appeared in 2000. The value is over 5 °C higher than the smallest average annual *Tp* (5.5 °C) for 1829 (see:Table 1).

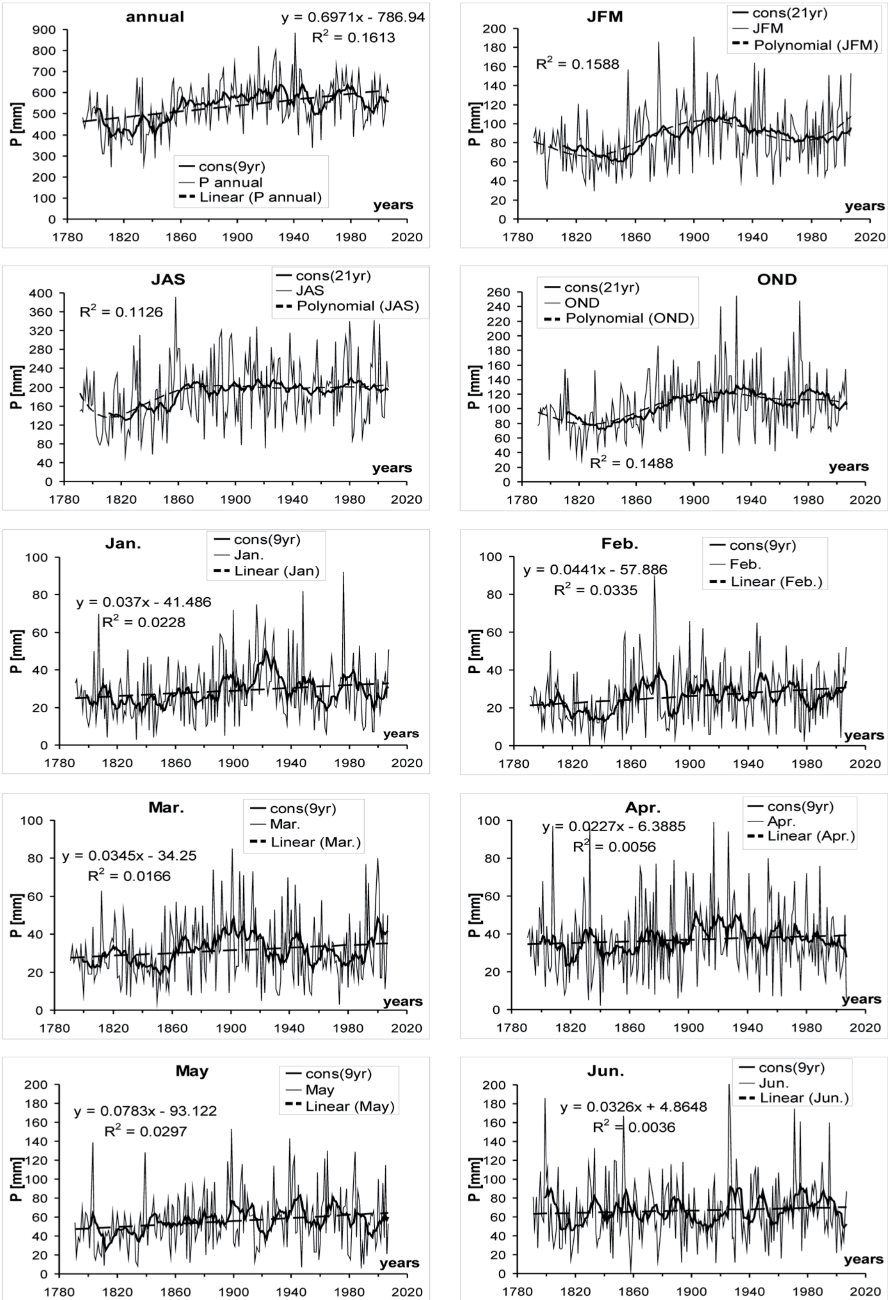
calendar seasons, it amounted to 11.4 mm/100 years (13.3%) for Jan.-Mar. and 17.7 mm/100 years (16.8%) for Oct.-Dec. For comparison, in the climatological seasons it amounted to 13.3 mm/100 years (15.2%) in the winter (DJF), 13.4 mm/100 years (10.8%) in the spring (MAM), 27.8 mm/100 years (13.3%) in the summer (JJA) and 14.9 mm/100 years (12.6%) in the autumn (SON). From the midst of remaining 3-month periods of the year, the weak trend was visible also for Feb.-April (10.0 mm/100 years and 10.7%), and relatively strong for Nov.-Jan. (15.3 mm/100 years and 15.8%). For May-July the values amounted to 25.4 mm/100 years and 12.8%, while for Aug.-Oct. only 18.46 mm/100 years and 12.5%.

The largest monthly increases appeared in July (14.4 mm/100 years and 19.0%) and August (10.1 mm/100 years and 15.3%). The relatively strong ones are also in November (6.5 mm/100 years and 18.5%), October (6.3 mm/100 years and 17.0%) and February (4.4 mm/100 years and 17.0%). The lowest increase appeared in September (2.1 mm/100 years and 4.6%), April (2.2 mm/100 years and 6.0%) and June (3.3 mm/100 years and 4.9%). Except for September, all these trends are statistically significant to a level of $\alpha = 0.05$.

The largest annual totals amounted to more than (or about) 800 mm and appeared in a phase of pluvial maximum between 1880 and 1945 (881 mm in 1941, 822 mm in 1915 and 799 mm in 1927). In addition, a shorter period of high values, sometimes above 700 mm, appeared between 1970 and 1986. The smallest annual totals were under 300 mm and appeared in a phase of pluvial minimum between 1804 and 1852 (247 mm in 1811, 261 mm in 1834 and 289 mm in 1842). The first three decades of the phase saw the transition period mentioned above, leading to the most important climatic reversal in the twentieth century, whose thermal and precipitation increase effects continue to the present.

A period of stagnation or slight decrease in the monthly and seasonal totals of *P* during the warm half-year has been observed over the past two decades. An opposite tendency appears in the period January-March, as a strong increase trend has been noted for March beginning in the 1990's.

The reconstructed values of *Tp* and *P* presented in detail in Table 1 and Table 2 also show their long-term quasi-cycle oscillations. These are related not only to circulation changes but also to solar variability effect. The authors discussed these issues at length in another article (Bryś and Bryś 2007).


annual
y = 0.6971x - 786.94
R2 = 0.1613
cons(9yr)
P annual
Linear (P annual)
P [mm]
years
JFM
cons(21yr)
JFM
Polynomial (JFM)
R2 = 0.1588
P [mm]
years
JAS
cons(21yr)
JAS
Polynomial (JAS)
R2 = 0.1126
P [mm]
years
OND
cons(21yr)
OND
Polynomial (OND)
R2 = 0.1488
P [mm]
years
Jan.
cons(9yr)
Jan.
Linear (Jan)
y = 0.037x - 41.486
R2 = 0.0228
P [mm]
years
Feb.
cons(9yr)
Feb.
Linear (Feb.)
y = 0.0441x - 57.886
R2 = 0.0335
P [mm]
years
Mar.
cons(9yr)
Mar.
Linear (Mar.)
y = 0.0345x - 34.25
R2 = 0.0166
P [mm]
years
Apr.
cons(9yr)
Apr.
Linear (Apr.)
y = 0.0227x - 6.3885
R2 = 0.0056
P [mm]
years
May
cons(9yr)
May
Linear (May)
y = 0.0783x - 93.122
R2 = 0.0297
P [mm]
years
Jun.
cons(9yr)
Jun.
Linear (Jun.)
y = 0.0326x + 4.8648
R2 = 0.0036
P [mm]
years

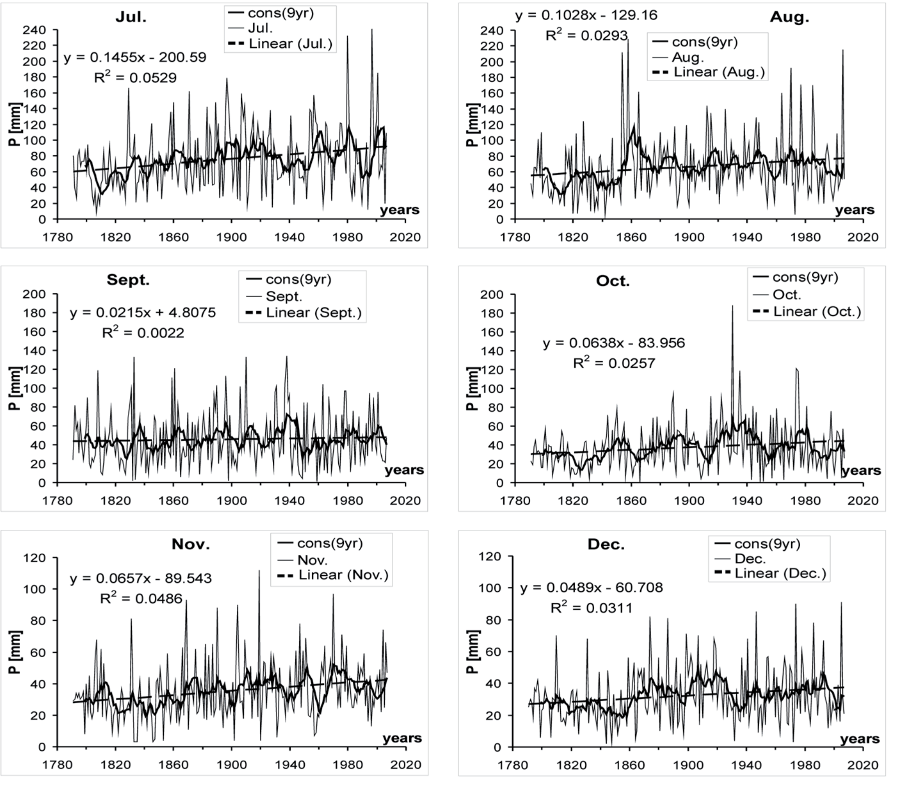


Fig. 5. The course of the annual and selected 3-month periods: January-March (JFM), July-September (JAS), October – December (OND), and also monthly (Jan., Feb., Mar., …Dec.) precipitation totals (P) for the years 1791–2007 in Wrocław and their polynomial of the 6th degree or linear trends. The values also are smoothed over by 9- or 21-year moving (cons) means

Table 1. Monthly (Jan., Feb., Mar.,…Dec.), annual (January-December; ann.), warm half-year (April-September; A-S) and seasonal (DJF, MAM, JJA, SON) mean values [°C] of air temperature in Wrocław in the years 1791–2007. Explanation: bold italics for estimated or interpolated values, bold and colouring for extreme values (max – gold, min – blue)

years	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	ann.	A-S	DJF	MAM	JJA	SON
1791	***1.3***	***1.1***	4.1	10.3	12	16.5	18.1	19	12.6	8.2	1	-0.4	8.7	14.8		8.8	17.9	7.3
1792	-3.4	-4	1.4	6.9	10.1	15.6	17.8	16.7	11.2	5.4	1.6	-0.6	6.6	13.1	-2.6	6.1	16.7	**6.1**
1793	-4.8	0.4	1	4.3	10.3	14.1	18.2	16.3	11.9	9	2.6	0.1	7	**12.5**	-1.7	5.2	16.2	7.8
1794	-1.3	1.1	4	7.7	11.8	16	18.9	15.4	10.7	7.6	3	-4.1	7.6	13.4	0	7.8	16.8	7.1
1795	-9.6	-2.3	0.6	9.3	11.2	15.3	**14.9**	16.4	12.6	11.2	1.7	1.2	6.9	13.3	-5.3	7	15.5	8.5
1796	4.7	-0.4	-2.9	5.7	13.8	17.2	17.7	17.1	12.5	7.3	0.4	-3.1	7.5	14	1.8	5.5	17.3	6.7
1797	-1.1	1.4	0.6	8.3	13.7	18.4	20.6	20	17.3	10.6	7.6	0.8	9.9	16.4	-0.9	7.5	19.7	**11.8**
1798	-1.6	1.1	1.9	8.1	14.5	18	19	17.4	15.7	7.2	1.9	-8.6	7.9	15.5	0.1	8.2	18.1	8.3
1799	-9	-5.8	-0.3	6.1	11.2	14.2	16.2	17.1	12.1	8.1	4.7	-6.8	5.7	12.8	-7.8	5.7	15.8	8.3
1800	-4.3	-4.4	-4.2	**15**	16.3	15.3	16.1	18.6	15	9.1	5.4	-0.4	8.2	16.1	-5.2	9	16.7	9.8
1801	-0.7	-2.5	5.2	8.1	16.6	15.4	17.8	16.3	16.6	10.9	5.1	-0.6	9.1	15.1	-1.2	10	16.5	10.9
1802	-3.5	-1.4	3.3	9.6	11.7	16.7	18.4	20.2	13.6	11.3	5.4	0.7	8.9	15	-1.8	8.2	18.4	10.1
1803	**-12.5**	-4.1	1.4	11.5	13.1	15.3	18.7	18	10.6	7.7	2.8	-2.8	6.7	14.5	-5.3	8.7	17.3	7
1804	0.4	-3.1	-2.3	6.4	13.7	16.1	18.7	17.1	14.9	8.9	-1.8	-5.6	7	14.5	-1.8	5.9	17.3	7.3
1805	-7.7	-3.1	0.8	5.7	11.6	14.6	17	16	15.3	**4.4**	0	0.9	6.3	13.4	-5.5	6	15.9	6.6
1806	1.7	1.5	2.7	6.1	15.4	15.2	17.5	18.2	16.9	8.2	4.2	**4.5**	9.4	14.9	1.4	8.1	17	9.8
1807	-1	1.5	0.2	6.3	14.2	16	18.9	**24.6**	14.5	9.7	6.2	0.9	9.4	15.8	1.7	6.9	19.8	10.1
1808	-2.2	-2.5	**-4.5**	5.5	14.1	17.3	19.6	20.2	15.8	8.6	2.1	-6.5	7.3	15.4	-1.3	5	19	8.8
1809	-6.4	1.9	0.2	5.1	14.5	16.8	18.1	19	14.9	7.1	3.6	2.6	8.1	14.7	-3.7	6.6	18	8.5
1810	-3.7	-2.7	2.6	5.3	12.5	14.2	18.9	18.2	16	7.3	3.5	1.2	7.8	14.2	-1.3	6.8	17.1	8.9

Table 1. cont.

1811	-7.3	-2.2	4.3	8.3	17.3	20.5	20.8	19.1	14.4	12.1	4	0.9	9.4	16.7	-2.8	10	20.1	10.2
1812	-5.4	-1.2	2.5	3.5	13.7	16.5	17.1	16.7	13.1	11.5	1.3	-8.6	6.7	13.4	-1.9	6.6	16.8	8.6
1813	-5.6	2.6	1.2	9.6	13.2	14.6	17.5	16.3	13.6	7.2	3.2	0.4	7.8	14.1	-3.9	8	16.1	8
1814	-5.1	-8.8	-0.5	10.1	10.5	14.4	19.7	17.7	10.9	6.7	3.4	1.1	6.8	13.9	-4.5	6.7	17.3	7
1815	-6	0.8	3.7	7.7	13.1	16.9	15.7	16.5	11.3	8.6	1.6	-4	7.2	13.5	-1.4	8.2	16.4	7.2
1816	-0.4	-2.7	1.7	7.2	11.6	15.7	16.9	16.4	12.9	7.7	2.4	-1.4	7.4	13.5	-2.4	6.8	16.3	7.7
1817	1.1	2.6	2.7	**2.8**	13.3	17.9	17.5	17.7	14.2	4.6	4.2	-2	8.1	13.9	0.8	6.3	17.7	7.7
1818	-0.4	-0.2	3.7	8.3	12.5	15.9	17.9	15.5	14.1	7.2	3.1	-2.2	8	14	-0.9	8.2	16.4	8.1
1819	-0.2	1.5	3.7	7.6	12.1	17.9	18.7	18.2	14.5	7.9	2.1	-4.8	8.3	14.8	-0.3	7.8	18.3	8.2
1820	-6.7	0.1	1.8	9	14.2	13.8	16.1	19.8	13.1	8.5	1.4	-3.2	7.3	14.3	-3.8	8.3	16.6	7.7
1821	-1	-3.3	1.4	11	13.5	13.4	15.8	17.4	15	9.1	6.4	2.5	8.5	14.4	-2.5	8.6	15.5	10.2
1822	0	2.1	6.4	9.6	14	17.4	20	17.1	12.9	11.2	5	-2.5	9.5	15.2	1.5	10	18.2	9.7
1823	-11.3	-1.6	2.8	6	14	16.7	17.9	18.6	14.3	11.5	4.5	1.4	8	14.6	-5.1	7.6	17.7	10.1
1824	-0.4	1.3	1.2	7.3	12.6	15.4	17.3	17.7	16	9.6	4.4	2.9	8.8	14.4	0.8	7	16.8	10
1825	-1.1	-1.8	-1.1	8.2	13.2	15.8	16.9	17.3	14.1	8	5.2	**4.5**	8.3	14.3	0	6.8	16.7	9.1
1826	-8.4	-0.8	3	6.8	11.8	17	21.1	20.3	14.2	9.9	2.4	0.8	8.2	15.2	-1.6	7.2	19.5	8.8
1827	-3.1	-8.1	3.4	9.9	15.2	19.1	19.3	17.5	14.1	9.6	-0.2	1.3	8.3	15.9	-3.5	9.5	18.6	7.8
1828	-5.3	-3.4	3.4	10	12.9	16.6	19.6	16.5	13.1	7.4	3.6	0.2	7.9	14.8	-2.5	8.8	17.6	8
1829	-7.3	-5.7	0.2	7.9	11.6	15.3	18.7	16.8	14.6	6.2	-2.1	**-11.2**	**5.5**	14.2	-4.3	6.6	16.9	6.2
1830	-9.8	-5.3	1.9	9.5	13.1	18.4	18.3	18.4	13.5	7.4	4.9	0.7	7.6	15.2	**-8.8**	8.2	18.4	8.6
1831	-6.2	-1.7	1.8	11	12.8	15.8	19.5	17.5	13.1	11.3	1.6	-1.4	8	15	-2.4	8.5	17.6	8.7
1832	-2.4	-1	1.9	6.8	11.1	15.5	15.2	18.4	12.2	8.6	2.4	-1.5	7.3	13.2	-1.6	6.6	16.4	7.7
1833	-4.6	2.7	2.3	5.8	16.7	18.3	16.9	**14.2**	13.5	7.8	3.4	3.7	8.4	14.2	-1.1	8.3	16.5	8.2

Table 1. cont.

1834	2.1	0.3	2.1	6.8	15.7	18.3	22.6	20.1	15.5	9	3.2	0.8	9.8	16.5	2	8.2	20.3	9.2
1835	-0.5	1.7	2.6	6.7	13.2	16.8	18.6	16.4	15	7.9	-0.7	-2.5	8	14.5	0.7	7.5	17.3	7.4
1836	-2.4	0.8	8	8	9.5	16.6	16.6	15.9	13.4	10.5	1.9	0.8	8.3	13.3	-1.4	8.5	16.4	8.6
1837	-1.9	-2.5	-0.5	***6.3***	***11.3***	***15.6***	***15.5***	***18.4***	***12***	***8.6***	3.9	-1.5	7.2	13.2	-1.2	5.7	16.5	8.2
1838	-10.5	-5.9	**2.6**	***6.1***	***13.5***	***15.7***	***16.6***	***15.1***	***14.9***	***7.2***	0.9	-0.9	6.3	13.7	-6	7.4	15.8	7.7
1839	-1.8	-0.1	-0.6	***4.1***	***13***	***17.9***	***19.1***	***16.4***	***15.9***	***9.4***	5.2	-2	8.1	14.4	-0.9	5.5	17.8	10.2
1840	-1.7	-1.3	***-1.7***	***6.8***	***11.3***	***15.3***	***17.2***	***15.9***	***14.1***	***6.1***	6.1	-8.1	6.7	13.4	-1.7	5.5	16.1	8.8
1841	-2.3	-6	***3.6***	***9.1***	***15.9***	***16.3***	***17.1***	***17.6***	***14.4***	***11.9***	4.4	2.7	8.8	15.1	-5.5	9.5	17	10.2
1842	-5.8	-1.5	***3***	***4.7***	***13.8***	***15.8***	***16.9***	**20.2**	***14.2***	***6.5***	0.5	2.4	7.6	14.3	-1.5	7.2	17.6	7.1
1843	-0.7	3.6	1.2	***7.9***	***10.9***	***15.6***	***17.2***	***18***	***11.8***	***8.3***	3.3	3.2	8.4	13.6	1.8	6.7	16.9	7.8
1844	-2.3	-2.3	0.5	***7.4***	***13.1***	***16***	***14.9***	***14.9***	***13.8***	***9.6***	4.6	-5.2	7.1	13.4	-0.5	7	**15.3**	9.3
1845	-0.1	-6.8	***-4.5***	***8.2***	***11.7***	***17.7***	***19***	***16.4***	***12.5***	***9.1***	5.9	1.6	7.6	14.3	-4	5.1	17.7	9.2
1846	-0.6	1.6	6	9.7	12.3	17.9	20.2	21	14.4	12.6	2.1	-3.2	9.5	15.9	0.9	9.3	19.7	9.7
1847	-3.9	-1.3	1.9	5.9	15.1	14.8	17.9	19.3	12.1	7.4	3.9	-0.9	7.7	14.2	-2.8	7.6	17.3	7.8
1848	-10.6	2.3	5.4	11.5	13.4	19.1	18.6	17.2	13.1	11	3.5	0.7	8.8	15.5	-3.1	10.1	18.3	9.2
1849	-3.2	2	1.3	7.5	14.6	16.7	17.3	16.2	12.2	7.9	2.9	-5	7.6	14.1	-0.2	7.8	16.7	7.7
1850	-8.6	2.8	0	8.4	14.4	18.2	18.3	18.2	12.2	7.9	4.5	0.9	8.1	15	-3.6	7.6	18.2	8.2
1851	-0.8	-0.3	3.4	10.3	10.6	16.1	17.8	17.7	12.6	11.8	1.7	0.2	8.5	14.2	-0.1	8.1	17.2	8.7
1852	2.6	0.9	0.3	4.3	14.7	18.6	20.5	19.4	14.7	8.8	5.2	4	9.5	15.4	1.2	6.4	19.5	9.6
1853	1.2	-1.9	-3.3	4.4	12.4	17.2	19.1	17.6	13.6	9.8	1.6	-5.1	7.3	14.1	1.1	**4.5**	18	8.3
1854	-1.5	-1.2	2.3	7	14.5	15.4	18.9	16.6	12.9	9.3	0.6	1.6	8.1	14.2	-2.6	7.9	17	7.6
1855	-3.4	-9	0.9	6	12.1	18.1	18.4	18.2	12.8	12	2.5	-7.1	6.9	14.3	-3.6	6.3	18.2	9.1
1856	-0.3	0.5	0	9.9	12.8	17.3	16.5	17	13.2	10.2	-0.2	0.6	8.1	14.5	-2.3	7.6	16.9	7.7

Table 1. cont.

1857	-2.3	-1.2	2.1	8.3	12.7	16.9	18.6	19	14.9	11.8	0.7	2	8.7	15.1	-1	7.7	18.2	9.1
1858	-4	-7.5	0.3	6.6	12.4	19.1	18.6	18	15.2	9.9	**-2.4**	-1.1	7.2	15	-3.2	6.4	18.6	7.6
1859	0.6	2.9	5.7	7.5	13.2	17.1	21.1	20.2	13	9.4	3	-3.3	9.2	15.4	0.8	8.8	19.5	8.5
1860	0.8	-2.2	1.2	8.1	14	17.5	16	17.5	14.2	7.3	0.8	-2.4	7.8	14.6	-1.6	7.8	17	7.4
1861	-6.7	2.7	5	5.4	10.6	18.8	19.7	18.7	13.7	9.1	4.7	-0.5	8.5	14.5	-2.1	7	19.1	9.2
1862	-3.8	-2.4	5.1	9.3	15.4	16.4	18.3	17.5	14.7	11.1	1.9	-2	8.5	15.3	-2.2	9.9	17.4	9.2
1863	2.6	2.5	5.1	7.9	13.9	17.1	16.9	19.9	14.9	11.9	4.8	1.9	10	15.1	1	9	18	10.5
1864	-6.3	0	4.8	5.1	**9.1**	17.7	16.4	15.7	13.9	7.7	2	-5	6.8	13	-1.5	6.3	16.6	7.9
1865	-0.6	-6.7	-0.5	9.2	17	14.2	21.5	17.3	14.1	8.9	5.4	0.6	8.5	15.6	-4.1	8.6	17.7	9.5
1866	2.7	2.8	1.9	10.1	11.1	20.2	17.6	17	17.5	6.3	4.1	1.7	9.4	15.6	2	7.7	18.3	9.3
1867	-0.7	3.4	0.7	8.2	11.9	16.5	17.6	18.5	14.2	9	2.1	-3	8.2	14.5	1.5	6.9	17.5	8.4
1868	-2.2	3.1	3.6	8	16.9	18.6	19.5	20.2	16.4	9.9	2.2	3.5	10	16.6	-0.7	9.5	19.4	9.5
1869	-2.5	4.5	1.4	10.6	14.8	14.7	19.7	16.9	15.5	7.4	3.2	0.8	8.9	15.4	1.8	8.9	17.1	8.7
1870	-1.3	-8.8	-0.1	7.3	13.9	15.9	18.9	16.7	12.4	8	5.1	-6.7	6.9	14.2	-3.1	7	17.2	8.5
1871	-7.3	-3.5	4.2	6.3	9.5	14.9	18.7	18.1	13.7	6	1.5	-4.4	6.5	13.5	-5.8	6.7	17.2	7.1
1872	-0.5	-0.4	4.9	10.2	15.8	15.9	18.6	16.5	15.3	11.9	7.4	2	9.8	15.4	-1.8	10.3	17	11.5
1873	2.2	-1.2	4.8	6.7	9.9	16.8	20	19.8	13.4	10.7	5	0.9	9.2	14.4	1	7.1	18.9	9.7
1874	0.2	-0.5	2.2	8.8	9.7	16.8	20.8	16.4	16.8	10.7	0.6	-1.5	8.5	14.9	0.2	6.9	18	9.4
1875	-0.6	-6.7	-1.2	6.6	13.4	19.6	18.5	19.2	13.2	6.4	1.2	-4.2	7.2	15.1	-2.9	6.3	19.1	6.9
1876	-5.2	0.3	4	9.8	9.3	18.3	18.6	18.3	13.6	10.3	0.4	0.2	8.2	14.7	-3	7.7	18.4	8.1
1877	1.8	1.3	1.3	5.9	10.7	19.2	18.4	19.3	11.2	7.2	6.3	-0.5	8.5	14.1	1.1	6	19	8.2
1878	-0.9	1.8	2.6	9.6	13.6	17.4	16.6	18.8	16.1	10.8	4.2	-1.3	9.1	15.4	0.1	8.6	17.6	10.4
1879	-3.3	1	0.8	7.1	12	18	16.6	18.1	15.8	8	0.6	-7.8	7.3	14.6	-1.2	6.6	17.6	8.1

Table 1. cont.

1880	-2.2	-0.4	2.3	10	11.4	17	19.3	17.2	14.6	8.4	4.3	2.9	8.8	14.9	-3.5	7.9	17.8	9.1
1881	-5.8	-1	1.5	4.8	13.5	16.1	19.6	17.5	12.4	5.2	4.7	0.6	7.5	14	-1.3	6.6	17.7	7.4
1882	1	1.8	7.3	8.4	12.5	14.6	19.5	16.2	15.7	8.8	3.7	0.1	9.2	14.5	1.1	9.4	16.8	9.4
1883	-1.3	0.7	-1.9	5.1	12.7	17.1	18.6	16.7	14.3	9.6	4.6	0.2	8.1	14.1	-0.2	5.3	17.5	9.5
1884	2.3	2.6	3.9	5.2	13.4	14.5	19.2	16.5	15.2	7.9	1.1	2.4	8.7	14	1.7	7.5	16.7	8.1
1885	-3.4	2	3.3	10.2	11.7	18.6	18.4	15.4	14	9.1	2.7	-0.2	8.5	14.7	0.3	8.4	17.5	8.6
1886	-1.4	-4.1	-0.9	9.8	14.1	15.7	17.5	17.9	15.9	8.6	5.2	1	8.3	15.2	-1.9	7.7	17	9.9
1887	-3.3	-2	1.5	8.2	12	15.2	20.1	16.9	14.6	6.7	4.8	-0.7	7.9	14.5	-1.4	7.2	17.4	8.7
1888	-3.1	-3.4	1	7.1	13.7	17	17	17	13.8	8	2.5	0.8	7.6	14.3	-2.4	7.3	17	8.1
1889	-4.2	-2.2	-0.4	8.8	**18.4**	20.5	18.3	17.2	11.4	9.8	3.4	-2	8.3	15.8	-1.9	8.9	18.7	8.2
1890	1.8	-2.5	5.8	8.9	15.6	15	18.1	20.2	13.8	8	3.1	-6.7	8.5	15.3	-0.9	10.1	17.8	8.3
1891	-4.5	-1.5	3.9	6.1	15.4	15.9	17.9	17.3	15.1	11.4	2.9	1.6	8.5	14.6	-4.2	8.5	17	9.8
1892	-2.3	0.7	1.1	7.9	13.5	17.6	18.3	21.3	16.9	8.6	1.7	-1.9	8.6	15.9	0	7.5	19.1	9.1
1893	-9	1.3	4.1	8.3	13.1	17.6	19.5	17.9	13.9	11.6	2.2	1	8.5	15.1	-3.2	8.5	18.3	9.2
1894	-2.3	1.6	4.7	11	13.8	15.3	20.4	17.5	11.8	9.2	4.8	0.5	9.1	15	0.1	9.8	17.7	8.6
1895	-3.3	-6.6	1.4	9.4	14.4	18.1	20.6	18.8	16.1	8.3	4.3	-1	8.5	16.2	-3.1	8.4	19.2	9.6
1896	-2.6	-0.2	5.9	6.2	11.8	18.5	19.4	16.7	14.3	11.1	1.1	-0.5	8.5	14.5	-1.3	8	18.2	8.8
1897	-3.2	0.2	5.9	8.6	13.1	18.5	18.2	19.1	14	8.2	2.3	0.3	8.8	15.3	-1.2	9.2	18.6	8.2
1898	2	2.1	4.9	8.7	14.3	16.9	15.8	19.2	14	8.7	6.2	3.3	9.7	14.8	1.5	9.3	17.3	9.6
1899	2.4	2.1	3.2	8.7	12.8	15.5	18.8	17.3	14.6	9.1	6.8	-4	9	14.6	2.6	8.2	17.2	10.2
1900	-0.6	1.1	0.9	7.5	12.3	17.8	20.3	19	15.2	9.9	6	2.4	9.4	15.4	-1.2	6.9	19	10.4
1901	-3.9	-4.4	2.5	8.8	15.2	18	20.5	18.2	13.8	11.1	3.4	1.9	8.8	15.8	-2	8.8	18.9	9.4
1902	3.4	-0.4	3.3	7.1	10.8	16.6	16.7	16.5	13.2	7.4	0.6	-3.6	7.7	13.5	1.6	7.1	16.6	7.1

Table 1. cont.

1903	-0.4	3.5	6.9	6.6	14.3	16.3	18.3	17.7	14.6	10.5	4.9	-0.6	9.4	14.6	-0.2	9.3	17.4	10
1904	-0.9	1.6	2.8	9.3	12.9	16.9	20.5	18.5	13.9	8.9	3	2.2	9.2	15.3	0	8.3	18.6	8.6
1905	-2.5	1.3	4.8	6.6	14	19.1	19.9	18.7	14.3	5.6	4.2	1.5	9	15.4	0.3	8.5	19.2	8
1906	0.7	1.5	3.1	10.5	15.1	16.2	19.5	17.5	13.4	9.4	7.3	-2.8	9.3	15.4	1.2	9.6	17.7	10
1907	-1.7	-1.8	2.5	6.8	15.7	17.5	16.7	17.6	14	**14.5**	2.4	0.5	8.8	14.7	-2.1	8.3	17.3	10.3
1908	-1	1.4	3.4	6.7	15.4	18.6	19	16.2	12.8	8.7	0.6	-1.5	8.4	14.8	0.3	8.5	17.9	7.4
1909	-1.7	-3.6	2.1	7.9	11.8	16.5	17.2	18.5	15.1	11.6	2.4	2	8.4	14.5	-2.3	7.3	17.4	9.7
1910	1.4	3.6	3.9	8.5	14.3	18.8	17.6	17.2	12.9	8.8	3	3.1	9.5	14.9	2.3	8.9	17.9	8.2
1911	-0.2	0	4.8	8.6	14.4	16.8	20.3	20.5	15.8	9	5.6	2.3	9.9	16.1	1	9.3	19.2	10.1
1912	-4.3	1.6	6.5	6.9	12.3	17.8	20	16.4	**9.6**	6.7	2.2	3.5	8.3	13.8	-0.1	8.6	18.1	6.2
1913	-1.3	1.1	6.6	9.2	13.5	16.5	16.2	16.1	13.7	10	6.6	2.6	9.3	14.2	1.1	9.8	16.3	10.1
1914	-3.6	3	5	10.6	13.5	17.1	19.9	19	13.4	8.4	3.6	3.5	9.5	15.6	0.7	9.7	18.7	8.5
1915	0.6	1.3	0	8.5	14.6	19.1	18.2	16.2	12.5	7.3	2	3.4	8.7	14.9	1.8	7.7	17.8	7.3
1916	3.3	0.7	6	9.1	14.4	15.2	18.1	17.1	13	8.9	5.7	3.4	9.6	14.5	2.5	9.8	16.8	9.2
1917	-2.4	-4.7	-0.6	5.3	15	**20.6**	19	18.8	15.9	9.8	5.3	-1.1	8.5	15.8	-1.2	6.6	19.5	10.3
1918	1.3	1.3	4.2	12.7	14.4	14.8	17.8	17.3	15.4	10.1	3.2	2.5	9.6	15.4	0.5	10.4	16.6	9.6
1919	1.2	0.2	3.7	7.1	10.8	16.4	16.3	17.2	16.7	7.6	-0.5	0.3	8.1	14.1	1.3	7.2	16.6	7.9
1920	1.2	2.6	6.6	12.2	15.7	15.4	20	17.6	14.2	5.7	1	-0.3	9.3	15.9	1.4	**11.5**	17.7	7
1921	4.6	0.5	7.2	8.8	15.3	15.7	19.8	***19.8***	14	10.5	0.6	-0.4	9.8	15.6	1.6	10.4	18.4	8.4
1922	-5	-2.5	4	7.7	14.2	17.5	18.5	17.1	12.1	5.4	2.6	2	7.9	14.5	-2.6	8.6	17.7	6.7
1923	1.4	-0.2	4.6	7.2	14.5	**13.3**	19.5	17	14.9	11.6	3.5	-2	8.8	14.4	1.1	8.8	16.6	10
1924	-4.1	-4.5	1.2	7.2	15.1	17.3	18.4	17.2	15.6	9.7	2.4	0.4	8	15.1	-3.5	7.8	17.6	9.2
1925	2.3	4.5	2.1	8.9	15.7	15.5	19.1	17.5	12.7	9	2.9	0.5	9.3	14.9	2.4	8.9	17.4	8.2

Table 1. cont.

1926	-1.5	3.4	4	10.7	12.9	15.7	19.5	16.5	15.3	8.9	8.2	0.9	9.6	15.1	0.8	9.2	17.2	10.8
1927	1.6	-0.1	7	8	11.6	16.5	19.3	18.1	14.6	9	2.7	-4.3	8.7	14.7	0.8	8.9	18	8.8
1928	0.6	1.4	2	8.6	11.6	15.7	20.5	17.5	14	9.2	7.2	-0.8	9	14.7	-0.8	7.4	17.9	10.1
1929	-6.7	-13	1.1	4.7	15	16.1	19.4	18.3	15.1	10.9	5.3	3	7.6	14.8	-6.8	6.9	17.9	10.4
1930	1.1	-0.1	4.4	9.8	13.2	19.8	18.5	17.1	14.4	9.6	6.3	-0.2	9.5	15.5	1.3	9.1	18.5	10.1
1931	-0.3	-1.1	0.3	6.2	17.3	17.8	19.4	17.5	11.6	7.6	3.9	0.6	8.5	15	-0.5	7.9	18.2	7.7
1932	0.7	-3	0.1	8.8	14.9	15.8	20.8	19.3	17.1	10.1	4.6	0.2	9.2	16.1	-0.6	7.9	18.6	10.6
1933	-5.6	-0.1	4.8	6.6	13.2	16.3	19.9	18.2	14.1	9.8	2.4	-4.7	8	14.7	-1.8	8.2	18.1	8.8
1934	0	1.3	6.2	11.6	15.5	18.5	20.4	18.3	16.3	10.7	5.6	4.5	10.8	16.8	-1.1	11.1	19.1	10.9
1935	-2.2	1.5	1	8.9	12.1	19.4	19	18.7	15.4	9.9	5.7	1	9.2	15.6	1.3	7.3	19	10.3
1936	3.3	-0.5	6	8.1	15	18.1	20.2	17.2	14.2	6.6	4	1.8	9.5	15.5	1.3	9.7	18.5	8.3
1937	-4.1	1.5	4.8	9.2	17.8	19.3	19.6	19.2	15.8	11.1	3.9	-0.6	9.8	16.8	-0.3	10.6	19.4	10.3
1938	0.6	0.9	7.8	6	12.8	18	19.6	20	15.5	10.7	7.7	-1.5	9.9	15.3	0.3	8.9	19.2	11.3
1939	2.2	3.4	1.8	11.2	12	18.5	20.2	20.1	15	7.5	5.5	-1.5	9.7	16.2	1.4	8.3	19.6	9.3
1940	-10.9	-7.9	1.9	9.2	13.4	19	19.7	16.8	14.2	8.6	6.1	-3.2	7.3	15.4	-6.8	8.2	18.5	9.6
1941	-7	-0.3	3.5	6.5	11.2	17.9	20.2	17.8	13	8.3	1.2	1.4	7.9	14.4	-3.5	7.1	18.6	7.5
1942	-8.8	-5.3	-0.5	8	14	16.5	18.8	20.2	17.9	11.9	3.8	2.3	8.3	15.9	-4.2	7.2	18.5	11.2
1943	-1.6	3	6.8	10.6	13.5	16.7	20	20.7	16.3	10.7	4	-0.3	10.1	16.3	1.2	10.3	19.1	10.3
1944	3.4	-0.6	1.1	8.9	13.3	16.8	19.8	20.7	14.5	10.3	4.5	-1.4	9.3	15.7	0.8	7.8	19.1	9.8
1945	-3	3.1	6	9.4	14.8	17.5	19.9	18.9	15.5	9.5	4.5	0.8	9.8	16	-0.4	10.1	18.8	9.8
1946	-2.1	2.1	4.5	10.9	16.7	17.9	20.7	18.2	15.1	5.7	3.4	-3	9.2	16.6	0.3	10.7	18.9	8.1
1947	-6.7	-9.2	3.3	10.8	16.4	19.4	20.2	17.6	17.6	6.2	5.5	1.7	8.7	17	-6.3	10.2	19.1	9.8
1948	2.1	-0.8	4.9	11.8	15	17.4	18.8	18.1	15.7	8.9	4.3	0.2	9.7	16.1	1	10.6	18.1	9.6

Table 1. cont.

1949	0.4	1.5	1	10.1	14.7	15.4	18.8	17.9	15.8	10.5	4.6	3.4	9.6	15.5	0.7	8.6	17.4	10.3
1950	-3.7	2.4	4.9	8.8	15.9	18.8	19.9	19	14.5	8	5	-0.8	9.4	16.2	0.7	9.9	19.2	9.2
1951	0.2	1.7	1.9	8.8	12.6	18.1	19.1	19.7	16.1	7.4	7.2	2.7	9.7	15.7	0.4	7.8	19	10.2
1952	0.7	-0.2	-0.6	11	12.4	16.6	19.7	19.3	11.9	7.5	3.1	-1.1	8.4	15.2	1.1	7.6	18.5	7.5
1953	-0.9	-0.2	3.7	10.4	13.6	19.4	20.9	17.6	14.9	11.3	4.6	0.8	9.7	16.1	-0.7	9.2	19.3	10.3
1954	-6.1	-6.7	3.8	5.7	13.9	18.7	17.4	18.2	15.7	9.8	3.1	3.5	8.2	14.9	-4	7.8	18.1	9.5
1955	-2.7	-2.6	0.2	5.9	12	16.4	19.3	18.3	14.7	8.6	4.1	2.5	8.1	14.4	-0.6	6	18	9.1
1956	0.1	-11.7	1.6	6.3	13.2	16.4	18.5	16.3	14.3	8.8	0.4	1.1	7.2	14.2	-3	7	17.1	7.8
1957	-0.3	3.2	4.9	8.2	11.4	18.9	19.9	16.6	12.8	9.2	5.6	-0.4	9.2	14.6	1.3	8.2	18.5	9.2
1958	-1.4	1.6	-1.4	5.6	15.5	16.3	19.5	17.7	14.2	10.1	4.8	2	8.8	14.8	-0.1	6.6	17.8	9.7
1959	0.3	-2.3	6.3	9.4	13.9	17.7	20.7	18.6	12.3	8	3.7	1.4	9.2	15.4	0	9.9	19	8
1960	-1.8	-1.8	3.7	7.3	13.9	17.7	17.8	17.4	13.4	10.1	6	2.5	8.9	14.6	-0.7	8.3	17.6	9.8
1961	-2.4	3.2	6.6	11.6	11.9	18.1	17.2	17	15.9	11.3	4.1	-2.8	9.3	15.3	1.1	10	17.4	10.4
1962	0.7	-0.6	0	10.8	11.3	16.2	17.2	17.8	13.2	8.3	4.6	-3.5	8	14.4	-0.9	7.4	17.1	8.7
1963	-9.5	-7.6	0.6	9.3	13.8	18	20.1	18.4	15.2	8.9	8	-3.1	7.7	15.8	-6.9	7.9	18.8	10.7
1964	-3.1	-1.4	-1	9.3	14.1	19.2	19.5	16.8	13.7	8	4.8	0.5	8.4	15.4	-2.5	7.5	18.5	8.8
1965	1.1	-3.3	2	7.8	11.5	17.3	17.6	16.6	14.9	7.6	1	2.2	8.1	14.3	-0.6	7.1	17.2	7.8
1966	-4.5	2.1	4	9.8	13.7	18	18.4	17.4	14	12.4	3.7	1.7	9.3	15.2	-0.1	9.2	17.9	10
1967	-0.7	2.3	6.4	8	14	17	19.9	17.9	16.2	12.3	4.6	0.4	9.9	15.5	1.1	9.5	18.3	11
1968	-1.4	1.1	4.6	9.8	12.2	18.1	18.1	17.7	14.6	9.4	5	-2.8	8.9	15.1	0	8.9	18	9.7
1969	-3.3	-1.2	-0.4	7.8	14.9	17.2	19.8	17.3	14.6	9.6	6.1	-5.8	8.1	15.3	-2.4	7.4	18.1	10.1
1970	-4.4	-2	1	7.7	12.6	18	18.8	17.7	13.3	9.2	5.8	1.1	8.3	14.7	-4.1	7.1	18.2	9.4
1971	-4.1	1.7	0.7	8.8	15.6	16.3	19	19.7	12.2	9	3.9	4	8.9	15.3	-0.4	8.4	18.3	8.4

Table 1. cont.

1972	**-3.3**	**1.9**	**5.9**	**8.5**	**13.5**	**17.1**	**20.1**	**17.2**	**11.8**	**6.6**	**5.5**	**-0.2**	8.7	14.7	0.9	9.3	18.1	8
1973	**-0.5**	**2.2**	**4.9**	**6.7**	**13.4**	**16.9**	**18.8**	**18.4**	**15.2**	**7.8**	**3.2**	**0.3**	9	14.9	0.5	8.3	18	8.7
1974	**2.2**	**3.1**	**6.4**	**8.4**	**12.1**	**15.5**	**17.4**	**18.9**	**14**	**6.6**	**4.5**	**4.2**	9.5	14.4	1.9	9	17.3	8.4
1975	**4.2**	**0.4**	**4.8**	**8**	**14.3**	**16.8**	**19.5**	**19**	**17.2**	**8.5**	**2.9**	**2**	9.9	15.8	2.9	9	18.4	9.5
1976	**0.1**	**-0.7**	**0.9**	**7.9**	**13.4**	**17**	**19.5**	**16.2**	**13.3**	**9.7**	**5.7**	**-0.6**	8.6	14.6	0.5	7.4	17.6	9.6
1977	**-0.4**	**2.1**	**7**	**6.9**	**13**	**17.9**	**17.6**	**17.2**	**12.3**	**9.9**	**6**	**0.9**	9.2	14.2	0.4	9	17.6	9.4
1978	**0.4**	**-0.6**	**5.2**	**7.3**	**12.7**	**16.3**	**17.3**	**16.7**	**13.2**	**9.9**	**4.8**	**-0.5**	8.6	13.9	0.2	8.4	16.8	9.3
1979	**-4.1**	**-2.6**	**4.3**	**7.5**	**14.7**	**19.5**	**16.7**	**17.7**	**14.5**	**7.7**	**4.1**	**4**	8.7	15.1	-2.4	8.8	18	8.8
1980	**-4.8**	**0.8**	**2.3**	**6.8**	**10.8**	**16.5**	**17.4**	**17.4**	**13.5**	**9.3**	**3.2**	**1.2**	7.9	13.7	0	6.6	17.1	8.7
1981	**-1.1**	**0.2**	**7**	**7.5**	**14.8**	**18.1**	**18.5**	**17.9**	**14.6**	**9.4**	**4.8**	**-1.7**	9.2	15.2	0.1	9.8	18.2	9.6
1982	**-3.2**	**-0.4**	**5.2**	**6.7**	**13.9**	**17.6**	**20.1**	**19.2**	**16.6**	**10.5**	**5.6**	**2.1**	9.5	15.7	-1.8	8.6	19	10.9
1983	**4.2**	**-1.9**	**5.4**	**10.4**	**14.6**	**17.5**	**20.9**	**19**	**15**	**10.2**	**3.6**	**-0.7**	9.9	16.2	1.5	10.1	19.1	9.6
1984	**1.4**	**0**	**2.8**	**8.2**	**13.3**	**15.8**	**17**	**18.3**	**13.6**	**11.6**	**3.8**	**-0.2**	8.8	14.4	0.2	8.1	17	9.7
1985	**-7.7**	**-5.1**	**3.6**	**8.8**	**15.3**	**15.2**	**18.9**	**18.1**	**13.9**	**8.9**	**1.5**	**3.4**	8	15	-4.3	9.2	17.4	8.1
1986	**-0.2**	**-7.9**	**3**	**9**	**15.6**	**16.9**	**18.5**	**17.7**	**12.2**	**9.6**	**5.6**	**1.4**	8.6	15	-1.6	9.2	17.7	9.1
1987	**-9.1**	**-0.7**	**-0.6**	**8.8**	**12**	**16.4**	**19**	**16.6**	**15.2**	**9.9**	**5.5**	**2**	7.9	14.7	-2.8	6.7	17.3	10.2
1988	**3.2**	**2.5**	**2.7**	**8.6**	**15.3**	**17.1**	**19.5**	**18.4**	**14.8**	**9.6**	**1.6**	**2.9**	9.7	15.6	2.6	8.9	18.3	8.7
1989	**2.2**	**4.2**	**6.9**	**9.3**	**14.4**	**16.5**	**19.2**	**18.8**	**15.7**	**11.2**	**2.6**	**2.3**	10.3	15.7	3.1	10.2	18.2	9.8
1990	**2.7**	**5.9**	**8.3**	**8.5**	**15.1**	**17.3**	**18.7**	**19**	**12.7**	**10**	**5.5**	**0.9**	10.4	15.2	3.6	10.6	18.3	9.4
1991	**1.3**	**-3.2**	**6.6**	**8.6**	**10.7**	**16.1**	**20.4**	**18.9**	**15.8**	**8.4**	**4.2**	**-0.1**	9.1	15.1	-0.3	8.6	18.5	9.5
1992	**0.7**	**2.8**	**4.9**	**9**	**14.9**	**19.5**	**20.9**	**21.7**	**14.7**	**7.6**	**5.3**	**0.2**	10.2	16.8	1.1	9.6	**20.7**	9.2
1993	**1.7**	**-0.3**	**3**	**10.1**	**16.5**	**17**	**18.1**	**17.7**	**14**	**9**	**0.3**	**3.2**	9.3	15.6	0.5	9.9	17.6	7.8
1994	**3.6**	**-0.6**	**6.2**	**9.4**	**13.5**	**17.4**	**22.5**	**19.4**	**15.3**	**7.6**	**5.7**	**2.8**	10.3	16.3	2.1	9.7	19.8	9.5

Table 1. cont.

1995	**-0.1**	**4.9**	**3.9**	**9.1**	**13.5**	**16.9**	**21.5**	**19.1**	**13.9**	**11.6**	**1.7**	**-2.6**	9.5	15.7	2.5	8.8	19.2	9.1
1996	**-4.5**	**-3.7**	**-0.1**	**8.5**	**13.9**	**17.6**	**17.7**	**18.3**	**11.3**	**10.4**	**6.4**	**-3.7**	7.7	14.6	-3.6	7.4	17.9	9.4
1997	**-3.9**	**3.5**	**4.7**	**6.6**	**14.3**	**18.1**	**18.9**	**19.7**	**14.8**	**7.9**	**3.8**	**1.9**	9.2	15.4	-1.4	8.5	18.9	8.8
1998	**2.1**	**5.2**	**3.9**	**10.9**	**15.3**	**18.5**	**19**	**18.1**	**14.5**	**9.4**	**1.2**	**0.2**	9.9	16.1	3.1	10	18.5	8.4
1999	**1.7**	**0.4**	**5.9**	**10.3**	**14.7**	**17.2**	**20.7**	**18.6**	**17.7**	**9.8**	**3.5**	**2.1**	10.3	16.5	0.8	10.3	18.8	10.3
2000	**0**	**4.1**	**5.5**	**12.4**	**16.1**	**18.6**	**17.7**	**19.3**	**13.9**	**13**	**7.3**	**2.9**	**10.9**	16.3	2.1	11.3	18.5	11.4
2001	**0.9**	**1.5**	**3.9**	**8.4**	**15.3**	**16.1**	**20.1**	**19.7**	**13**	**13.2**	**4**	**-1.1**	9.6	15.4	1.8	9.2	18.6	10.1
2002	**1**	**5.2**	**6**	**9.3**	**17.5**	**18.9**	**20.8**	**20.8**	**14.2**	**8.6**	**5.4**	**-2.6**	10.5	16.9	1.7	10.9	20.2	9.4
2003	**-1.3**	**-2.7**	**4.2**	**8.6**	**16.3**	**20**	**20.3**	**20.5**	**14.9**	**6.3**	**6**	**2**	9.7	16.8	-2.2	9.7	20.3	9.1
2004	**-2.8**	**2.3**	**5**	**10.1**	**13.4**	**17.5**	**19.3**	**19.8**	**15**	**11**	**5.2**	**1.8**	9.8	15.9	0.5	9.5	18.9	10.4
2005	**2.3**	**-1.2**	**2**	**10.1**	**14.5**	**17.4**	**20.3**	**18.1**	**16.2**	**10.5**	**3.6**	**1.1**	9.6	16.1	1	8.9	18.6	10.1
2006	**-5.6**	**-1.4**	**1**	**10.1**	**14.5**	**18.9**	**23.4**	**17.7**	**16.9**	**11.6**	**7**	**4.4**	9.9	16.9	-2	8.5	20	11.8
2007	**5.2**	**3**	**7.1**	**11.2**	**15.9**	**19.7**	**19.9**	**19.3**	**13.6**	**8.9**	**3.3**	**1.4**	10.8	16.6	**4.2**	11.4	19.6	8.6

Table 2. Monthly (Jan., Feb., Mar.,…Dec.) values [mm] of precipitation totals for Wrocław for the years 1791–2007. Annual values are for the normal year (Jan. – Dec.; ann.) and for the hydrological one (Nov. – Oct.; hydro); warm half-year values (Apr.-Sep.; A-S) and seasonal values (DJF, MAM, JJA, SON) are also presented. Explanation: bold italics for estimated or interpolated values, bold and colouring for extreme values (max – gold, min – blue)

years	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	ann.	hydro	A-S	DJF	MAM	JJA	SON
1791	***33***	***26***	***26***	***38***	***54***	***81***	***80***	***45***	***24***	***23***	***29***	***25***	484		322		118	206	76
1792	***35***	***26***	***34***	***42***	***18***	***48***	***40***	***30***	***82***	***19***	***30***	***30***	434	428	260	86	94	118	131
1793	***25***	***21***	***25***	***28***	***39***	***81***	***26***	***66***	***56***	***38***	***34***	***28***	467	465	296	76	92	173	128
1794	***26***	***31***	***27***	***42***	***34***	***27***	***80***	***66***	***63***	***45***	***31***	***18***	490	503	312	85	103	173	139
1795	***31***	***29***	***32***	***33***	***49***	***75***	***87***	***59***	***31***	***31***	***34***	***37***	528	506	334	78	114	221	96
1796	***18***	***23***	***27***	***18***	***70***	***108***	***67***	***102***	***63***	***34***	***30***	***35***	595	601	428	78	115	277	127
1797	***29***	***18***	***22***	***42***	***39***	***61***	***73***	***52***	***37***	***31***	***32***	***42***	478	469	304	82	103	186	100
1798	***29***	***27***	***35***	***23***	***65***	***55***	***73***	***110***	***24***	***16***	***35***	***33***	525	531	350	98	123	238	75
1799	15	9	18	54	62	186	86	35	40	16	8	6	535	589	463	57	134	307	64
1800	10	16	8	40	53	99	60	45	59	43	40	23	496	447	356	32	101	204	142
1801	14	10	35	68	27	112	94	51	90	57	22	24	604	621	442	47	130	257	169
1802	25	27	26	27	67	34	56	55	20	18	45	37	437	401	259	76	120	145	83
1803	19	37	19	12	139	74	50	30	16	40	22	32	490	518	321	93	170	154	78
1804	50	24	19	44	20	41	29	27	26	38	18	30	366	372	187	106	83	97	82
1805	12	50	19	22	15	27	19	36	22	38	22	27	309	308	141	92	56	82	82
1806	20	13	44	20	22	35	35	22	29	7	56	6	309	296	163	60	86	92	92
1807	70	8	15	23	33	46	**8**	46	49	22	68	31	419	382	205	84	71	100	139
1808	35	33	18	97	23	113	30	41	119	29	22	30	590	637	423	99	138	184	170
1809	19	30	19	34	18	27	19	35	57	26	33	29	346	336	190	79	71	81	116
1810	41	38	29	20	41	26	44	31	12	22	62	70	436	366	174	108	90	101	96

Table 2. cont.

1811	14	14	22	14	9	27	49	20	8	29	19	22	**247**	338	**127**	98	45	96	56
1812	23	14	63	22	44	89	85	31	22	55	53	34	535	489	293	59	129	205	130
1813	4	8	38	37	40	31	45	44	53	48	33	16	397	435	250	46	115	120	134
1814	26	27	25	46	46	68	44	16	31	15	19	16	379	393	251	69	117	128	65
1815	33	14	25	16	35	52	63	90	41	23	33	18	443	427	297	63	76	205	97
1816	20	16	22	8	41	76	93	67	55	41	27	14	480	490	340	54	71	236	123
1817	14	14	22	11	66	14	67	85	78	28	25	22	446	440	321	42	99	166	131
1818	20	13	34	40	40	28	38	50	47	6	9	21	346	363	243	55	114	116	62
1819	21	13	38	14	48	39	54	93	41	16	20	24	421	407	289	55	100	186	77
1820	13	9	36	27	64	63	74	7	29	15	25	35	397	381	264	46	127	144	69
1821	32	38	51	41	51	92	44	40	51	9	25	36	510	509	319	105	143	176	85
1822	35	5	43	23	28	21	57	109	32	9	9	13	384	423	270	76	94	187	50
1823	29	39	17	51	47	73	33	7	15	11	21	30	373	344	226	81	115	113	47
1824	13	20	18	43	38	52	47	29	26	21	37	35	379	358	235	63	99	128	84
1825	18	16	10	16	64	69	38	49	23	8	33	8	352	383	259	69	90	156	64
1826	16	7	13	43	54	56	48	34	14	28	15	25	353	354	249	**31**	110	138	57
1827	51	11	53	34	29	59	24	124	9	33	22	22	471	467	279	87	116	207	64
1828	27	22	41	42	16	51	92	75	28	43	24	27	488	481	304	71	99	218	95
1829	16	17	8	70	60	117	166	55	68	44	28	24	673	672	536	60	138	338	140
1830	14	22	26	56	42	102	80	28	85	27	23	24	529	534	393	60	124	210	135
1831	15	9	38	25	41	90	79	80	98	4	81	68	628	526	413	48	104	249	183
1832	22	**0**	7	5	50	59	75	10	2	20	46	15	311	399	201	90	62	144	68
1833	**3**	27	43	96	13	133	108	70	133	12	**3**	30	671	699	553	45	152	311	148

Table 2. cont.

1834	34	5	20	11	8	44	21	50	3	31	**3**	31	261	**260**	137	69	**39**	115	37
1835	17	15	19	15	51	29	46	11	39	43	**3**	21	309	319	191	63	85	86	85
1836	22	22	15	26	63	37	47	27	57	30	31	26	403	370	257	65	104	111	118
1837	13	12	27	43	41	37	62	15	70	19	42	17	398	396	268	51	111	114	131
1838	44	12	32	29	49	60	55	78	20	19	16	12	426	457	291	73	110	193	55
1839	17	26	24	38	128	48	40	81	34	19	27	47	529	483	369	55	190	169	80
1840	24	6	20	**2**	61	68	71	39	60	43	24	18	436	468	301	77	83	178	127
1841	47	16	15	50	30	114	78	51	10	33	23	21	488	486	333	81	95	243	66
1842	8	3	33	9	55	47	21	**6**	30	41	13	23	289	297	168	32	97	**74**	84
1843	43	13	20	42	57	109	76	26	9	49	44	19	507	480	319	79	119	211	102
1844	21	17	21	32	66	22	97	62	35	72	26	**2**	473	508	314	57	119	181	133
1845	4	35	18	24	80	60	121	32	43	12	19	48	496	457	360	41	122	213	74
1846	23	19	32	30	45	16	60	45	24	21	**3**	34	352	382	220	90	107	121	48
1847	7	18	12	39	39	120	76	103	70	56	5	13	558	577	447	59	90	299	131
1848	14	24	24	42	57	119	67	27	65	30	41	3	513	487	377	51	123	213	136
1849	31	32	27	21	63	54	35	50	14	58	43	33	461	429	237	66	111	139	115
1850	25	30	4	35	36	85	84	50	28	79	33	14	503	532	318	88	75	219	140
1851	18	8	18	40	40	42	77	54	58	45	49	22	471	447	311	40	98	173	152
1852	23	30	12	40	55	50	25	38	18	17	32	8	348	379	226	75	107	113	67
1853	23	19	41	24	68	167	68	23	64	31	4	15	547	568	414	50	133	258	99
1854	36	3	14	26	51	105	57	212	15	49	33	36	637	587	466	54	91	374	97
1855	47	55	55	31	78	49	80	100	61	62	25	22	665	687	399	138	164	229	148
1856	21	59	11	14	32	77	67	55	45	5	59	19	464	433	290	102	57	199	109

Table 2. cont.

1857	21	7	16	47	17	40	101	88	33	22	24	28	444	470	326	47	80	229	79
1858	28	11	10	8	73	**4**	136	**229**	27	46	16	13	601	624	477	67	91	369	89
1859	17	22	50	51	70	33	50	99	111	41	27	56	627	573	414	52	171	182	179
1860	24	46	41	46	26	80	148	106	29	19	28	31	624	648	435	126	113	334	76
1861	32	12	38	18	40	99	76	84	121	7	41	30	598	586	438	75	96	259	169
1862	44	52	15	20	83	87	68	73	12	17	15	36	522	542	343	126	118	228	44
1863	38	22	57	29	76	61	44	26	82	18	29	53	535	504	318	96	162	131	129
1864	13	28	31	60	41	36	69	67	63	31	15	5	459	521	336	94	132	172	109
1865	39	17	38	16	44	67	73	162	6	35	22	10	529	517	368	61	98	302	63
1866	10	59	45	22	70	32	85	88	30	**0**	63	48	552	473	327	79	137	205	93
1867	42	50	31	75	96	51	95	36	37	60	20	44	637	684	390	140	202	182	117
1868	31	39	39	71	16	78	40	89	27	41	65	49	585	535	321	114	126	207	133
1869	28	19	55	13	82	59	33	80	28	25	93	37	552	536	295	96	150	172	146
1870	11	4	24	21	12	53	85	91	74	38	11	50	474	543	336	52	57	229	123
1871	33	36	10	64	32	108	162	34	11	24	38	25	577	575	411	119	106	304	73
1872	15	33	28	43	92	97	61	65	34	20	40	21	549	551	392	73	163	223	94
1873	9	28	8	11	76	85	36	30	64	47	35	27	456	455	302	58	95	151	146
1874	8	27	45	57	35	74	57	46	22	29	28	82	510	462	291	62	137	177	79
1875	32	29	36	21	44	46	100	68	61	69	62	55	623	616	340	143	101	214	192
1876	42	**90**	54	62	66	54	52	94	39	18	21	33	625	688	367	187	182	200	78
1877	35	69	36	8	70	13	103	69	64	25	22	22	536	546	327	137	114	185	111
1878	30	13	45	77	45	34	35	45	9	70	26	29	458	447	245	65	167	114	105
1879	19	44	31	28	75	52	78	78	33	32	42	23	535	525	344	92	134	208	107

Table 2. cont.

1880	39	16	9	39	97	111	71	110	53	57	34	56	692	667	481	78	145	292	144
1881	10	14	55	16	20	51	43	65	73	45	18	10	420	482	268	80	91	159	136
1882	11	15	21	42	90	83	42	81	47	16	65	43	556	476	385	36	153	206	128
1883	25	18	16	16	34	93	142	92	50	26	17	39	568	620	427	86	66	327	93
1884	35	8	46	40	41	96	44	71	24	55	58	33	551	516	316	82	127	211	137
1885	13	9	35	34	87	48	116	96	80	37	32	28	615	646	461	55	156	260	149
1886	53	8	26	18	26	116	104	75	14	66	20	81	607	566	353	89	70	295	100
1887	12	18	34	15	97	63	43	46	27	22	65	24	466	478	291	111	146	152	114
1888	34	29	74	66	57	71	44	70	92	85	20	14	656	711	400	87	197	185	197
1889	15	48	49	28	33	37	148	79	77	94	25	39	672	642	402	77	110	264	196
1890	33	4	10	79	45	101	99	118	103	24	88	8	712	680	545	76	134	318	215
1891	59	10	45	33	38	85	121	45	20	10	43	39	548	562	342	77	116	251	73
1892	57	28	30	38	62	74	27	17	48	56	23	56	516	519	266	124	130	118	127
1893	53	50	32	6	58	12	85	34	27	54	37	13	461	490	222	159	96	131	118
1894	5	38	68	40	52	118	29	69	38	51	12	16	536	558	346	56	160	216	101
1895	51	23	46	9	47	29	53	70	46	48	39	46	507	450	254	90	102	152	133
1896	24	11	39	18	119	64	135	52	113	22	24	19	640	682	501	81	176	251	159
1897	21	30	50	31	92	23	179	64	70	15	19	8	602	618	459	70	173	266	104
1898	30	39	40	73	70	85	138	119	2	78	30	33	737	701	487	77	183	342	110
1899	25	14	9	62	**153**	53	104	27	71	19	22	71	630	600	470	72	224	184	112
1900	72	66	53	35	33	48	91	17	19	47	30	45	556	574	243	209	121	156	96
1901	10	18	**85**	65	29	48	40	96	32	44	41	50	558	542	310	73	179	184	117
1902	43	10	44	31	44	91	61	47	19	45	4	58	497	526	293	103	119	199	68

Table 2. cont.

1903	32	37	17	72	47	52	108	89	24	53	59	52	642	593	392	127	136	249	136
1904	10	36	23	44	29	20	25	38	14	44	90	31	404	394	170	98	96	83	148
1905	35	37	23	44	88	55	82	53	52	43	52	26	590	633	374	103	155	190	147
1906	24	13	73	12	116	43	23	69	102	17	28	41	561	570	365	63	201	135	147
1907	43	25	46	45	43	55	159	74	34	20	29	70	643	613	410	109	134	288	83
1908	21	47	25	55	95	45	127	61	50	4	18	14	562	629	433	138	175	233	72
1909	21	62	71	46	55	63	143	50	36	8	68	52	675	587	393	97	172	256	112
1910	32	10	23	31	83	43	98	76	133	19	51	18	617	668	464	94	137	217	203
1911	56	47	30	27	61	30	17	47	48	24	44	42	473	456	230	121	118	94	116
1912	36	35	22	52	61	90	36	144	53	50	35	47	661	665	436	113	135	270	138
1913	18	6	33	41	62	40	103	116	32	7	51	53	562	540	394	71	136	259	90
1914	43	6	52	23	63	35	114	37	54	38	18	43	526	569	326	102	138	186	110
1915	45	28	73	72	13	89	131	135	62	92	39	43	822	801	502	116	158	355	193
1916	75	40	36	38	29	102	77	102	30	26	31	38	624	637	378	158	103	281	87
1917	59	15	54	**99**	25	11	85	66	11	48	44	31	548	542	297	112	178	162	103
1918	27	23	12	21	23	71	121	76	38	62	19	68	561	549	350	81	56	268	119
1919	37	17	38	44	60	51	101	32	48	66	**112**	62	668	581	336	122	142	184	226
1920	48	35	38	57	70	77	102	62	37	8	4	27	565	708	405	145	165	241	49
1921	57	44	5	44	41	76	23	19	28	39	32	37	445	407	231	128	90	118	99
1922	65	9	38	29	30	50	112	87	46	90	54	48	658	625	354	111	97	249	190
1923	34	44	9	29	43	60	57	46	35	71	53	39	520	530	270	126	81	163	159
1924	27	50	29	32	77	69	28	58	69	37	24	21	521	568	333	116	138	155	130
1925	34	29	35	37	48	73	103	140	42	60	42	43	686	646	443	84	120	316	144

Table 2. cont.

1926	34	30	32	28	45	**206**	107	89	37	64	40	41	753	757	512	107	105	**402**	141
1927	53	18	48	94	59	162	138	52	66	33	57	19	799	804	**571**	112	201	352	156
1928	60	42	29	53	114	37	15	59	39	21	42	32	543	545	317	121	196	111	102
1929	33	13	18	39	52	38	98	97	15	32	57	27	519	509	339	78	109	233	104
1930	21	14	53	58	78	12	85	79	96	**188**	44	23	751	768	408	62	189	176	**328**
1931	***38***	***29***	***11***	***62***	***69***	***122***	***75***	***86***	***102***	***33***	***6***	***25***	658	694	516	90	142	283	141
1932	***24***	***9***	***8***	***46***	***60***	***89***	***50***	***62***	***56***	***31***	***18***	***4***	457	466	363	58	114	201	105
1933	***29***	***32***	***8***	***27***	***63***	***77***	***52***	***36***	***28***	***30***	***50***	***34***	466	404	283	65	98	165	108
1934	***24***	***28***	***15***	***21***	***52***	***64***	***53***	***75***	***35***	***66***	***38***	***24***	495	517	300	86	88	192	139
1935	***17***	***40***	***60***	***44***	***33***	***36***	***59***	***47***	***64***	***119***	***31***	***17***	567	581	283	81	137	142	214
1936	***16***	***29***	***21***	***38***	***71***	***55***	***60***	***62***	***30***	***50***	***32***	***16***	480	480	316	62	130	177	112
1937	***11***	***24***	***41***	***44***	***28***	***44***	***62***	***43***	***104***	***22***	***19***	***56***	498	471	325	51	113	149	145
1938	***62***	***10***	***25***	***30***	***79***	***25***	***59***	***122***	***134***	***47***	***35***	***19***	647	668	449	128	134	206	216
1939	***26***	***20***	***70***	***24***	***143***	***61***	***93***	***66***	***86***	***73***	***25***	***48***	735	716	473	65	237	220	184
1940	***22***	***22***	***35***	***18***	***62***	***31***	***42***	***77***	***93***	***35***	***48***	***21***	506	510	323	92	115	150	176
1941	***61***	***50***	***53***	***72***	***115***	***106***	***131***	***97***	***29***	***69***	***32***	***68***	**883**	**852**	550	132	**240**	334	130
1942	***20***	***24***	***21***	***43***	***123***	***71***	***87***	***55***	***11***	***35***	***25***	***15***	530	590	390	112	187	213	71
1943	***20***	***10***	***14***	***29***	***43***	***104***	***18***	***69***	***40***	***3***	***22***	***27***	399	390	303	45	86	191	65
1944	***54***	***35***	***66***	***50***	***44***	***112***	***80***	***59***	***36***	***81***	***61***	***35***	713	666	381	116	160	251	178
1945	***25***	***40***	***44***	***53***	***94***	***79***	***94***	***90***	***74***	***39***	***37***	***40***	709	728	484	100	191	263	150
1946	***13***	***65***	***13***	***21***	***41***	***113***	***82***	***129***	***19***	***75***	***37***	***23***	631	648	405	118	75	324	131
1947	***30***	***41***	***56***	***30***	***7***	***62***	***52***	***80***	***9***	***21***	***78***	***85***	551	448	240	94	93	194	108
1948	***82***	***58***	***18***	***9***	***73***	***48***	***52***	***123***	***6***	***48***	***25***	***9***	551	680	311	**225**	100	223	79

Table 2. cont.

1949	21	20	29	41	61	88	54	58	4	0	61	24	461	410	306	50	131	200	65
1950	31	26	8	35	50	54	47	46	85	54	38	26	500	521	317	81	93	147	177
1951	23	16	30	29	78	23	80	75	11	1	69	10	445	430	296	65	137	178	81
1952	36	30	34	41	41	58	25	64	85	29	48	31	522	522	314	76	116	147	162
1953	39	12	18	18	47	19	75	36	23	17	20	14	338	383	218	82	83	130	60
1954	19	7	10	80	63	70	139	18	35	20	19	56	536	495	405	40	153	227	74
1955	33	24	8	58	71	33	135	59	33	20	24	57	555	549	389	113	137	227	77
1956	8	31	35	64	23	93	89	70	50	72	36	35	606	616	389	96	122	252	158
1957	20	43	49	7	23	35	157	74	70	5	7	30	520	554	366	98	79	266	82
1958	24	31	26	41	107	101	123	36	42	69	9	31	640	637	450	85	174	260	120
1959	13	6	25	46	15	44	120	21	1	13	21	50	375	344	247	50	86	185	35
1960	30	31	41	33	31	107	72	104	49	79	19	19	615	648	396	111	105	283	147
1961	25	38	28	62	70	76	92	77	14	40	39	44	605	560	391	82	160	245	93
1962	33	35	58	28	78	16	76	72	39	32	53	18	538	550	309	112	164	164	124
1963	9	30	22	7	122	74	17	59	104	22	46	9	521	537	383	57	151	150	172
1964	6	32	27	42	43	80	39	160	13	58	64	29	593	555	377	47	112	279	135
1965	19	21	22	60	130	64	122	45	36	3	28	42	592	615	457	69	212	231	67
1966	27	53	30	25	60	79	117	85	10	69	40	56	651	625	376	122	115	281	119
1967	35	34	38	41	63	57	74	43	91	48	48	50	622	620	369	125	142	174	187
1968	47	30	22	44	83	87	96	80	68	29	55	15	656	684	458	127	149	263	152
1969	34	24	36	22	72	68	23	82	12	18	37	14	442	461	279	73	130	173	67
1970	21	33	35	50	43	47	79	192	26	57	97	51	731	634	437	68	128	318	180
1971	20	43	25	53	74	175	49	43	47	44	48	46	667	721	441	114	152	267	139

Table 2. cont.

1972	**24**	**9**	**26**	**68**	**68**	**103**	**98**	**46**	**72**	**13**	**43**	**3**	573	621	455	79	162	247	128
1973	**28**	**39**	**18**	**36**	**45**	**72**	**100**	**6**	**41**	**41**	**27**	**20**	473	472	300	70	99	178	109
1974	**36**	**31**	**3**	**26**	**92**	**67**	**84**	**90**	**20**	**121**	**37**	**90**	697	617	379	87	121	241	178
1975	**35**	**8**	**31**	**30**	**26**	**161**	**122**	**40**	**13**	**118**	**25**	**24**	633	711	392	133	87	323	156
1976	**92**	**7**	**14**	**10**	**70**	**24**	**121**	**61**	**72**	**55**	**71**	**38**	635	575	358	123	94	206	198
1977	**40**	**46**	**36**	**34**	**72**	**91**	**96**	**171**	**43**	**16**	**51**	**21**	717	754	507	124	142	358	110
1978	**19**	**2**	**26**	**28**	**90**	**37**	**80**	**109**	**97**	**37**	**35**	**60**	620	597	441	42	144	226	169
1979	**34**	**14**	**41**	**48**	**20**	**68**	**58**	**48**	**97**	**19**	**64**	**51**	562	542	339	108	109	174	180
1980	**19**	**31**	**12**	**72**	**18**	**51**	**232**	**69**	**39**	**39**	**31**	**22**	635	697	481	101	102	352	109
1981	**33**	**21**	**51**	**43**	**15**	**73**	**155**	**73**	**62**	**81**	**43**	**40**	690	660	421	76	109	301	186
1982	**38**	**7**	**20**	**29**	**74**	**67**	**48**	**28**	**11**	**10**	**31**	**28**	391	415	257	85	123	143	52
1983	**49**	**38**	**26**	**35**	**103**	**93**	**26**	**42**	**32**	**29**	**25**	**22**	520	532	331	115	164	161	86
1984	**13**	**14**	**17**	**25**	**129**	**84**	**54**	**34**	**76**	**34**	**25**	**15**	520	527	402	49	171	172	135
1985	**27**	**30**	**41**	**51**	**39**	**97**	**35**	**170**	**19**	**19**	**33**	**45**	606	568	411	72	131	302	71
1986	**34**	**11**	**23**	**23**	**88**	**88**	**102**	**131**	**53**	**44**	**28**	**78**	703	675	485	90	134	321	125
1987	**53**	**41**	**15**	**45**	**73**	**59**	**70**	**64**	**47**	**33**	**51**	**31**	582	606	358	172	133	193	131
1988	**30**	**44**	**47**	**18**	**6**	**72**	**72**	**68**	**70**	**14**	**43**	**44**	528	523	306	105	71	212	127
1989	**12**	**16**	**17**	**76**	**31**	**87**	**45**	**26**	**23**	**25**	**50**	**20**	428	445	288	72	124	158	98
1990	**8**	**27**	**16**	**28**	**10**	**118**	**21**	**62**	**48**	**28**	**45**	**41**	452	436	287	55	54	201	121
1991	**10**	**14**	**27**	**33**	**56**	**90**	**47**	**45**	**31**	**14**	**59**	**47**	473	453	302	65	116	182	104
1992	**36**	**38**	**77**	**19**	**19**	**44**	**55**	**61**	**21**	**29**	**26**	**43**	468	505	219	121	115	160	76
1993	**26**	**30**	**35**	**15**	**54**	**56**	**97**	**20**	**63**	**49**	**39**	**67**	551	514	305	99	104	173	151
1994	**34**	**17**	**67**	**54**	**52**	**43**	**12**	**82**	**28**	**25**	**16**	**32**	462	520	271	118	173	137	69

Table 2. cont.

1995	28	26	32	27	63	160	61	94	95	4	45	27	662	638	500	86	122	315	144
1996	7	24	23	35	61	56	100	81	62	45	13	12	519	566	395	58	119	237	120
1997	7	31	19	48	67	49	246	64	33	46	31	36	677	635	507	50	134	359	110
1998	49	24	40	49	26	73	88	40	90	76	26	16	597	622	366	109	115	201	192
1999	20	39	60	40	35	62	106	24	40	21	33	28	508	489	307	75	135	192	94
2000	35	36	80	20	100	22	124	36	32	10	44	23	562	556	334	99	200	182	86
2001	17	20	66	36	46	66	185	53	96	25	35	24	669	677	482	60	148	304	156
2002	24	49	17	31	34	58	54	109	48	55	49	18	546	538	334	97	82	221	152
2003	34	4	17	17	96	28	68	38	32	53	22	39	448	454	279	56	130	134	107
2004	33	29	51	21	38	46	63	49	23	45	74	16	488	459	240	101	110	158	142
2005	38	41	11	27	115	35	108	62	23	5	25	91	581	555	370	95	153	205	53
2006	25	38	25	50	21	66	20	215	21	57	66	31	635	654	393	154	96	301	144
2007	51	52	50	6	53	87	109	51	47	26	47	21	592	629	340	134	109	247	120

Summary – More on the Influence of UHI

The biggest difficulty for the reconstruction of an homogenous 217-year Wrocław series, taking into consideration changes of location and missing data for 1945, was to reach a credible reconstruction of the *Tp* and *P* values for the years 1931–2007. The reconstructed values after 1930 mainly on the basis of other Wrocław stations, were referenced to and incorporated into the earlier Breslau-Sternwarte series as their most probable continuation. However, these series represent the specific and variable environment in the center of the city. Consequently, the influence of UHI on the values of basic meteorological elements in Wrocław must be taken into consideration and requires a more detailed discussion.

UHI most likely began to exert a greater impact in the 1980s, at which time Wrocław began to undergo dynamic industrial and urban development. Earlier, temperature differences between the city and its peripheries were not very great. Galle (1879) noted similarities in temperature data from the western border of Wrocław and data coming from the Breslau-Sternwarte station. He had access to results from 5-year simultaneous measurements in Goldschmieden (now Złotniki in the western district of Wrocław) in the years 1868–1873. Comparing the results of monthly average *Tp*, calculated on the basis of extreme temperatures, he was able to deduce their convergence due to the fact that the difference did not exceed 0.2ºC (in spite of the stations being 10 km apart).

In the early 1920s, Wrocław reached a maximum population density, particularly in the Old City, in the area adjacent to the Breslau-Sternwarte Observatory. After 1925, a long-term process of population and industrial deconcentration began as people moved from the central part of the growing city towards its suburbs. The influence of UHI on the meteorological values from Sternwarte probably stabilized at the beginning of this process. In this situation, a credible estimation of the *Tp* and *P* values before 1925 for existing meteorological stations (Strachowice, Swojec) located at the peripheries of Wrocław is very complicated and is still open to discussion. However, such a reconstruction would be invaluable in order to separate the influence of UHI on tendencies of values measured in the city.

Acknowledgments

This work has been in partly supported by the grant N 30507332/2594 for 2007–2009 financed by the Ministry of Science and Higher Education – MNiSW (Poland).

The Authors would like also to thank: Rudolf Brázdil (Institute of Geography, Masaryk University, Brno) for temperature data (1771–2005) from Prague (Praha-Klementinum) and discussions about homogeneity of Wrocławian temperature data; Krzysztof Migała (Department of Meteorology and Climatology, Wrocław University) for the use in this study of the *Tp* and *P* data from measurements made in the years 1996–2007 at the University Meteorological Observatory Wrocław-Biskupin.

References

Alexandersson H., 1986, A homogeneity test applied to precipitation data, J. Climatol., 6, 661–675.

Atlas Klimatyczny Polski. Temperatura Powietrza. Część tabelaryczna 2a, 1979, IMGW, WKiŁ, Warszawa, 78 pp.

Biuletyn Agrometeorologiczny, 1965…(1966, 1967…2007). IMGW, Warszawa, 1965–2007.

Biuletyn Meteorologiczny, 1971…(1972, 1973, 1974), Pyka J.L. (ed.), Acta Univ. Wratislav., No. 287, 305, 569, 768, Wrocław 1984–1988.

Bràzdil R., Stepanek P., 1998, Kolisani teploty v Brne v obdobi 1891–1995, Geografie – Sbornik Ceske Geograficke Spolecnosti, 103, 13–30.

Bryś K., Bryś T., 2007, Zmienność warunków solarnych klimatu Wrocławia w latach 1875–2004, Pamiętnik Puławski, 144, 13–33.

Bryś K., Bryś T., 2010, The first one hundred years (1791–1890) of the "Wrocław temperature series", [in:] Przybylak R., Majorowicz J., Brázdil R., Kejna M. (eds.). The Polish Climate in the European context: An Historical Overview. Springer, Dordrecht, 485–524.

Bryś T., 2007, Badanie reprezentatywności Obserwatorium Wrocław-Swojec jako stacji agrometeorologicznej i klimatologicznej, [in:] Kostrzewski A. & Andrzejewska A. (eds.) Zintegrowany monitoring środowiska przyrodniczego, KPN, Warszawa, 255–268.

Deutsches Meteorologisches Jahrbuch, 1934 … (1935, 1936 …1944), Deutsches Reich, Reichsamt für Wetterdienst, Julius Springer, Berlin 1936…(1937, 1938, 1939): Wetterdienst, Offenbach/Main 1950.

Dubicka M., 1994, Wpływ cyrkulacji atmosfery na kształtowanie warunków klimatu (na przykładzie Wrocławia), Studia Geograficzne, LX, Acta Univ. Wratisl., 1881, 296 pp.

Dubicka M., Pyka J.L., 2001, Klimat Wrocławia w XX wieku, Prace i Studia Geogr., 29, 101–112.

Ergebnisse Der Beobachtungen And Den Stationen ii. und iii, Ordnung in den Jahren 1914–1918…(1919–1923): im Jahre 1924…(1925, 1926…1933), Veröffentlichungen des Preussischen Meteorologischen Instituts, Julius Springer (Behrend & Co.), Berlin 1925…(1926, 1927…1934).

Ergebnisse Der Meteorologischen Beobachtungen im Jahre 1891… (1892, 1893…1913), Königlich Preussischen Meteorologischen Instituts, Behrend & Co., Berlin 1892 … (1893, 1894…1914).

Flohn H., 1981, Life on a Warmer Earth – Possible Climatic Consequences of Man-Made Global Warming. IIASA Executive Report ER-81–003, Laxenburg, Austria, 75 pp.

Flohn H., 1993, Climatic evolution during the last millennium; what can we learn from it? [in:] Eddy J. A., Oeschger H. (eds.), Global Changes in the Perspective of the Past, John Wiley & Sons Ltd., 295–316.

Galle J.G., 1857, Grundzüge der Schlesischen Klimatologie, Josef Max & Komp., Breslau, XXIII+128 pp.

Galle J.G., 1879: Mittheilungen der Königlichen Universitäts-Sternwarte zu Breslau, Maruschke und Berendt (print), Breslau, 128 pp.

Klimakunde Des Deutschen Reiches, Bd. II, Tabellen, 1939, Verlag von Dietrich Reimert /Andrews & Steiner/, Berlin, 560 pp.

Landsberg H. E., 1981, The Urban Climate, Academic Press, New York, x + 275 pp.

Lorenc H., 2000, Studia nad 220-letnią (1779–1998) serią temperatury powietrza w Warszawie oraz ocena jej wiekowych tendencji, Mat. Badaw. IMGW, Meteorologia, 31, Warszawa, 104 pp.

Miętus M., 1998, O rekonstrukcji i homogenizacji wieloletnich serii średniej miesięcznej temperatury ze stacji w Gdańsku-Wrzeszczu, 1851–1995, Wiad. IMGW, XXI (XLII), 2, 41–63.

Pisoft P., Kalvowa J., Bràzdil R., 2004, Cycles and trends in the Czech Temperature Series using wavelet transforms, Int. J. Climat., 24: 1661–1670.

Prace Obserwatorium Meteorologii I Klimatologii Uniwersytetu Wrocławskiego nr 1 (1946) – nr 14 (1958), WTN, nr 15 (1959) – nr 20

(1965), Kosiba A. (ed.), Acta Univ. Wratisl., No. 105, 115, 130, 159, 187, 206, 255, Wrocław 1947–1976.

Pyka J.L., 1991, Temperatura i opady atmosferyczne we Wrocławiu w latach 1881–1980, Acta Univ. Wratisl., No. 1237, Prace Inst. Geogr., Wrocław, Seria A, VI, 19–54.

Pyka J.L., 1998a, Temperatura powietrza we Wrocławiu w latach 1881–1995, Acta Univ. Wratisl., 2022, Prace Inst. Geogr., Wrocław, Seria C, Met. i Klimat.,V, 25–40.

Pyka J.L., 1998b, Opady atmosferyczne we Wrocławiu w latach 1881–1995, Acta Univ. Wratisl., 2022, Prace Inst. Geogr., Wrocław, Seria C, Met. i Klimat.,V, 41–54.

Pyka J.L., 2003, Meteorological observations and measurements in Wrocław, [in:] Pyka J. L., Dubicka M., Szczepankiewicz-Szmyrka A., Sobik M., Błaś M. (eds), Man and climate in the 20th century, St. Geogr., 75, 11–22.

Schmuck A., 1967, Wpływ miasta na opady atmosferyczne (na przykładzie Wrocławia). Przegl. Geof., 12 (20), 3–4, 293–310.

Szymanowski M., 2005: Miejska wyspa ciepła we Wrocławiu, Acta Univ. Wratisl., 2690, Studia Geogr., 77, 228 pp.

Trepińska J., Kowanetz L., 1997, Wieloletni przebieg średnich miesięcznych wartości temperatury powietrza w Krakowie (1792–1995), [in:] Trepińska J. (ed.), Wahania klimatu w Krakowie (1792–1995), UJ, Kraków, 99–130.

Twardosz R., 1997, Homogenizacja serii pomiarów opadów atmosferycznych na Stacji Meteorologicznej w Krakowie, [in:] Janina Trepińska (ed.), Wahania klimatu w Krakowie (1792–1995), UJ, Kraków, 89–95.

Rocznik Meteorologiczny 1954…(1955, 1956…1965), IMGW, WKiŁ, Warszawa 1959…(1960–1966, 1968, 1970, 1974).

Zipser-Urbańska A., 1968, Wpływ kierunku wiatru na rozkład opadów atmosferycznych w mieście na przykładzie Wrocławia, Czasopismo Geogr., 39, 429–437

Internet Sources:

ftp://ftp.ncdc.noaa.gov/pub/data/gsod/

http://home.casema.nl/errenwijlens/co2/homogen.htm

http://old.chmi.cz/meteo/

http://www.dwd.de/

http:// www. kni.nl/klimatologie

http://www.wetterzentrale.de/klima/

http:// www.zmag.ac.at/klima/