EARLY INSTRUMENTAL METEOROLOGICAL OBSERVATIONS IN THE CZECH LANDS I: FERDINAND KNITTELMAYER, BRNO, 1799–1812

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In the Czech Lands there exist a number of early meteorological measurements carried out before the introduction of regular meteorological observations. With the intention of obtaining homogeneous climatological series for the city of Brno, meteorological measurements before 1848, i.e. before the beginning of official publication with observations made by Dr. P. Olexik, are systematically investigated. Currently the oldest known records for Brno date from 1799–1812, compiled by Captain Ferdinand Knittelmayer (rtd.), which remain preserved in the form of selected summary data from observations taken five times a day. The motivation for the observations was Knittelmayer's belief that the course of the weather could be forecasted on the basis of the nineteen-year lunar cycle. This paper presents the results of statistical analysis of air pressure and temperature, wind direction and wind force, cloud characteristics and the number of precipitation days in comparison with measurements taken at the Brno-Tuřany meteorological station in the period 1961–1990.

V českých zemích existuje řada časných meteorologických měření, prováděných před začátkem pravidelných meteorologických pozorování. S cílem získat homogenní klimatologické řady Brna jsou systematicky zpracovávána meteorologická měření před rokem 1848, tj. před začátkem oficiálně publikovaných pozorování dr. P. Olexika. Zatím nejstarší známé záznamy z Brna z let 1799–1812 pocházejí od penzionovaného setníka Ferdinanda Knittelmayera, které zůstaly zachovány v podobě vybraných shrnujících údajů z pěti denních pozorování. Motivací pro pozorování byla pro Knittelmayera víra v možnost předvídat průběh počasí na základě 19-letého měsíčního cyklu. Práce prezentuje výsledky statistické analýzy tlaku a teploty vzduchu, směru a síly větru, charakteristik oblaků a počtu srážkových dnů, porovnávaných s měřeními na meteorologické stanici Brno-Tuřany v období 1961–1990.

Key words: early instrumental measurements, pressure, temperature, wind, cloudiness, precipitation days, meteorological singularities, Ferdinand Knittelmayer, Brno

INTRODUCTION

Early instrumental meteorological measurements are important sources of documentary data that can broaden our information base for weather and climate before the establishment of national networks of meteorological stations. Although the beginning of the official network of meteorological stations in the Czech Lands is associated exclusively with the establishment of the Central Institute for Meteorology and Earth Magnetism in Vienna in 1851, which started a long tradition of systematic publishing with the results of observations for the year 1848 (Brázdil et al., 2005), measurements had been made at a number of meteorological stations long before that. Excluding isolated quantitative air temperature data, the first systematic daily measurements in Bohemia come from the physician Johann Carl Rost, in Zákupy, for the period 21 December 1719–31 March 1720. These were published together with measurements from further European stations within what was known as the "Breslau network" organised by Johann Kanold, a physician in Wrocław (Breslau in German) (Brázdil, Valášek, 2002). Measurements survive from 1752, taken by Josef Stepling, the first director of the observatory in Prague's Klementinum, which continued in systematic form from 1 January 1775 thanks to the initiative of the third director, Antonín Strnad (Pejml, 1975). Strnad himself became a significant propagator of meteorological observations, and they spread into further parts of Bohemia, such as Žitenice, Teplá and elsewhere (Seydl, 1952).

Learned and economic societies played an important role in the development of meteorological observations in Bohemia. Convinced that the properties of the atmosphere and weather had an important influence on agriculture, the I. R. (Imperial-Royal) Patriotic-Economic Society established in 1796, thanks to the activities of the member Antonín Strnad, made meteorological observations in the Bohemian regions and had their own tables purpose-printed for recording. The Society also had an appropriate number of barometers and thermometers made and supplied to them for their observers. A landmark event was the publication of the results for 1817–1821 by Alois David, the fourth director of the Klementinum observatory, (Nachricht I–II, 1825–1826), which were to be followed by new papers from the Society, including observations from Bohemia and their analysis for the years 1822–1847 (Neue Schriften I–X, 1828–1847; Verhandlungen, 1849–1850).

As far as is known, the earliest daily meteorological measurements in Moravia originated with the Telč physician František Alois Mag of Magg, beginning in his second observation diary on 7 May 1771 and ending on 9 March 1775 (Valášek et al., 2001; Brázdil et al., 2002a, 2002b). According to data sent to Antonín Strnad, it is evident that Mag was actively observing in the winter of 1788/89, at the very least (Strnadt, 1791, 1793). In Olomouc, meteorological observations were carried out by Josef Gaar, a local lyceum professor, from 1790 onwards, part of his observations being presented in the oldest description of the climate of Moravia, by Kryštof Passy, another professor from Olomouc (Brázdil, Valášek, 2001).

The establishment of the Meteorological Section of the I. R. Moravian-Silesian Economic Society in 1815 lent important and lasting impetus to the development of meteorological observations in Moravia and Silesia. As well as receiving detailed printed instructions as to the techniques of observations, participants could also buy a barometer and a thermometer with a Réaumur scale, made by Prof. Kassián Hallaschka, and they were asked to send their observations to the address of the Meteorological Section in Brno. Parts of the records remain preserved in the Society archives; furthermore, the daily observations for Brno in 1820–1847 were even published regularly in Brünner Zeitung, the local newspaper (for details, see Brázdil et al., 2005).

Brno has a long tradition of meteorological observations. Although it is known that they started in 1797, only those made two years later and onwards survive, coming from Captain Ferdinand Knittelmayer (rtd.) (Brázdil et al., 2005). The present paper deals with a detailed analysis of those observations, from 1799 to 1812.

FERDINAND KNITTELMAYER

Ferdinand Knittelmayer (also spelt Knittlmayer or Knitlmajer) was born on 20 January 1750 in Vienna. After completing grammar school studies at the age of 18, he joined the army as an imperial cadet. During his military service he took part in several campaigns: the Bavarian succession wars in 1778 and 1779 subsequent to the demise of the Bavarian branch of the Wittelsbach family, the war with the Turks in Moldavia in 1790, and the field campaigns in the Rhineland and Alsace, 1792–1794. He was then deemed unfit for further field service and transferred to the peacetime garrison in Brno, where he commanded a reserve division. In 1801, Knittelmayer retired from the army on medical grounds, with the rank of captain. During his time in Brno he had become a member of the I. R. Moravian-Silesian Economic Society, devoting himself to astronomical and meteorological observations. In the winter of 1812/13 he contracted a painful eye disease which eventually blinded him, a crushing blow to his service as an active observer. He died in Brno on 21 November 1814 (Buse, 1816).

METEOROLOGICAL OBSERVATIONS MADE BY FERDINAND KNITTELMAYER

Early instrumental meteorological measurements are, as a rule, partly published in contemporary materials, frequently accessible only with difficulty. The original records are often lost or remain preserved in the form of manuscripts in district, regional or other archives. Typically enough, Knittelmayer's meteorological observations for Brno have unfortunately not been preserved in the form of original measurements from the individual daily terms. The author made only monthly, seasonal, half-yearly and annual overviews of his daily observations for all the meteorological elements and phenomena monitored for the period 1799–1812 (Table 1).

Table 1. The beginning, interruption and end of Knittelmayer's observations in Brno according to individual meteorological elements.

Element	Beginning	End	Interruptions
Pressure	1 May 1799	26 Sep 1812 (3 Oct 1812)	21 May 1799 23 Apr–7 May 1804 28–30 June 1809
Temperature	1 May 1799	4(5) Oct 1812	28–30 June 1809
Wind	1 May 1799	20 Mar 1812	19–22 Jan 1801 22–28 Dec 1811 27 Jan–3 Feb 1812
Clouds	1 May 1799	19 Sep 1812	22–31 Dec 1811
Weather phenomena	1 May 1799	22 Dec 1812	-

The surviving extracts of Knittelmayer's observations consist of 15 individual unbound files and one file of introductory text, deposited among the manuscripts of the Archives of the City of Brno (Meteorologische Beobachtungen). They are individual 40×25-cm sheets, folded and not bound; at first sight they give the impression of individual copybooks.

In his seventeen pages of introductory text, Knittelmayer presents, in a neat cursive hand, basic information about his measurements. He gives explanations of the appended tables and outlines instructions for their later utilisation. He measured and observed air pressure and temperature, the force and direction of the wind, the clearness and cover of the sky, the movement and properties of clouds and other meteorological phenomena. The observer also mentions the location of the instruments in his flat, from which he had a pleasant and free view. The Réaumur thermometer was placed in free air in front of the window, facing east, but in such a fashion as to be permanently protected from the rising sun. The barometer, with a scale in Vienna inches was, in contrast, hung up within the room, on the inner side of the window. Knittelmayer determined the direction of the wind by the free-swinging weathercock on the spire of St. James' church, also making use of the direction of the smoke from chimneys. Wind force was determined as he himself felt it. He could observe the clouds in the sky all around, as well as their movement and properties. Other characteristics were observed in the normal way.

Dřímal (1956) located Knittelmayer's Brno observations in what was once a Dominican monastery (around 230 m a.s.l.). In its tower, Knittelmayer may have had a small observatory in which he carried out his astronomical and meteorological observations (Figure 1). The monastery was used by the military garrison in which Knittelmayer was a captain. It is probable that his flat, with the instruments described, was on the second floor of this building with windows facing east and a view of the city centre that included the spire of St. Jacob's church.

Knittelmayer took proper meteorological records five times a day, although he was aware of the fact that at astronomical observatories such observations were made only three times a day. His first term, winter or summer, was at sunrise, *"of which it is known to me from experience that at that moment the thermometer had day-by-day its lowest value, and subsequently the greatest cold times set in"*. The morning term was at 9 o'clock in summer and at 10 o'clock in winter. The third daily observation took place at 14.00 in summer and soon after 12.00 in winter *"when about this time the thermometer will stand highest, i.e. it shows the highest daily temperature"*. The evening observations were bound to the time of sunset. The last daily term for Knittelmayer was at 23.00 and often at exactly midnight.

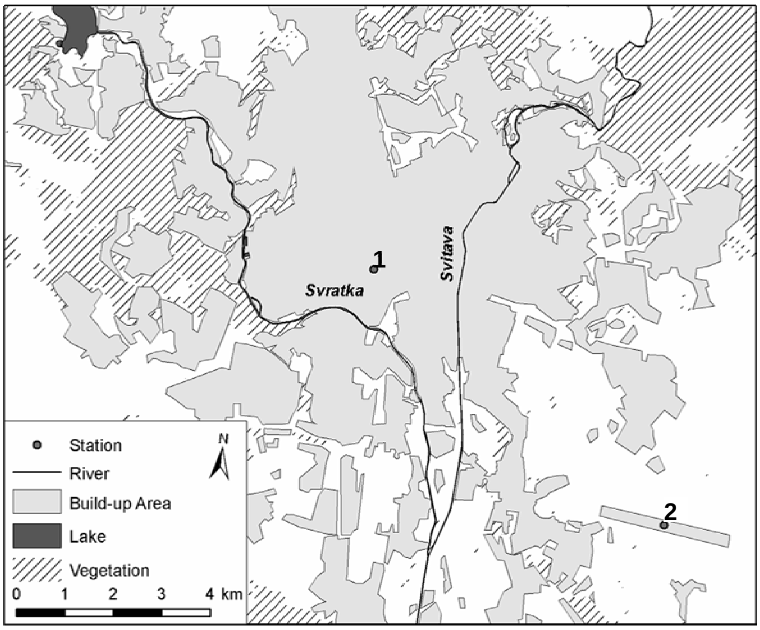


Figure 1.

a) A view of the former Dominican monastery in Brno (see arrow), in the tower of which, from 1802 onwards, Ferdinand Knittelmayer may well have had a small observatory in which to perform his astronomical and meteorological observations (drawing by František Richter from 1827 – Brodesser, 2005),

b) locations of meteorological stations used in Brno:

1 – former Dominican monastery (Knittelmayer),
2 – the Brno-Tuřany meteorological station.

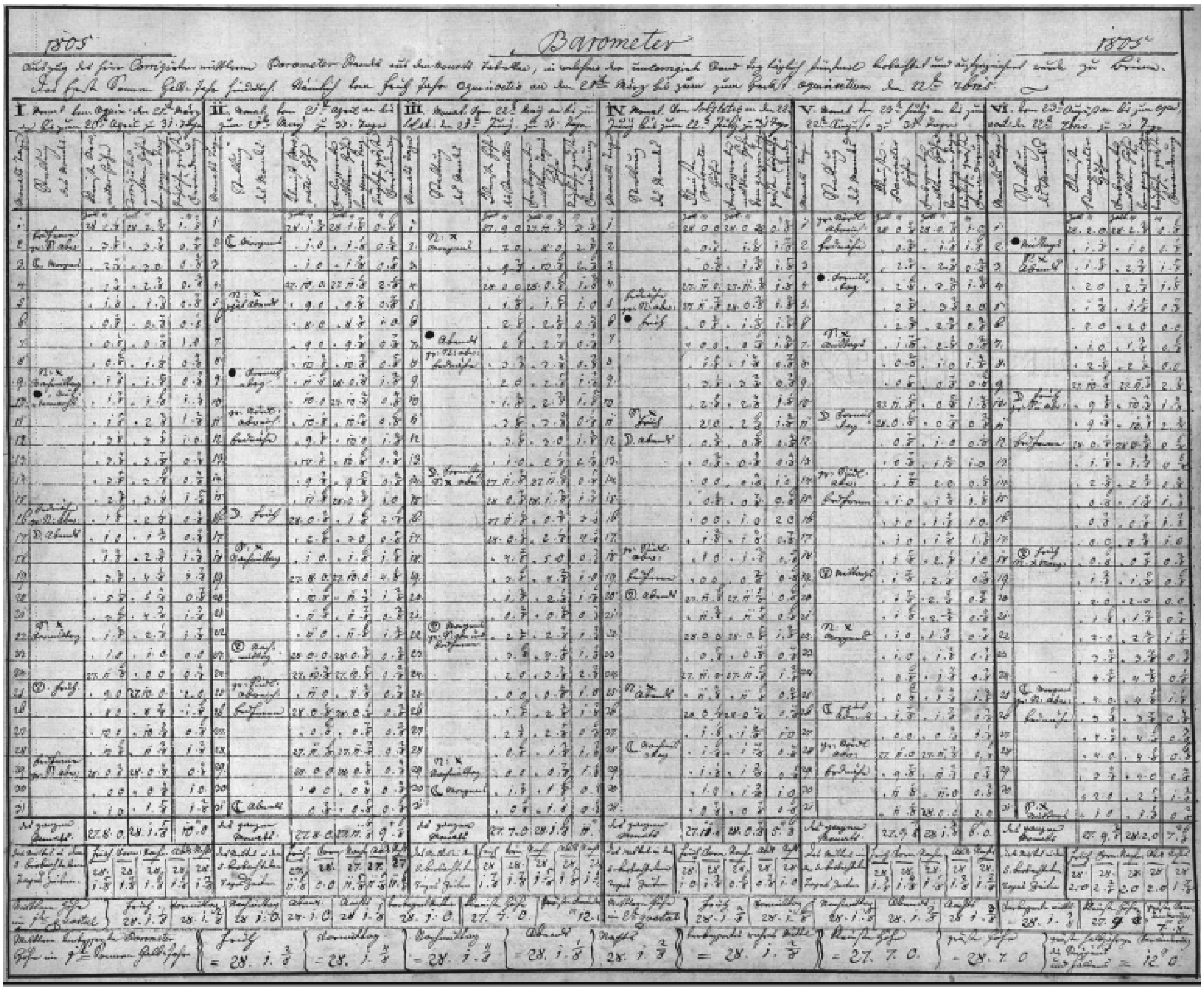
For the presentation of the results of his measurements, Knittelmayer used the astronomical division of the year with respect to the days of summer and autumn equinoxes, which he divided into 6 summer months (all of them of 31 days) and 6 winter months (of 30 days each, and the last one only 29 days):

- summer months
  21 March–20 April (“Frühmonat” or “Keimmonat”),
  21 April–21 May (“Blüthenmonat”),
  22 May–21 June (“Rosenmonat”),
  22 June–22 July (“Wärmemonat”),
  23 July–22 August (“Erndtemonat”),
  23 August–22 September (“Obstmonat”),
- winter months
  23 September–22 October (“Weinmonat”),
  23 October–21 November (“Nebelmonat”),
  22 November–21 December (“Schneemonat”),
  22 December–20 January (“Kältemonat”),
  21 January–19 February (“Eismonat”),
  20 February–20 March (“Thaumonat”).

Further folded sheets within Knittelmayer’s set of papers contain the processed results of his observations, always arranged as units. These consist of individual sheets and some hand-made forms with fixed columns into which mean measured values were entered, as well as all notes of importance. The heading of each sheet refers to the year and the kind of measurements taken, together with a brief note about the time-span within which the measurements were carried out. For each observed element there always exist three independent files. The first file includes the tables of the six summer months of the given astronomical year (i.e. from the spring to the autumn equinox of the same year) for the period 1799–1812 (Figure 2). The second file, also constituting an independent unit, contains the results for the winter months, i.e. from the autumn equinox of the given year to the spring equinox of the subsequent year, again for the above period. The third set gives an overview of the results obtained for all years and months of the whole period 1799–1812.

A voluminous extract of Knittelmayer’s meteorological observations was bought by the I. R. Moravian-Silesian Economic Society, who donated it to the Franz Museum, an affiliated organisation. In 1900, Knittelmayer’s set of results was moved to the Moravian Land Archives, and in 1941 it was further transferred to the Brno City Archives.

Figure 2. A specimen of Knittelmayer’s summary records of air pressure.



WHY KNITTELMAYER MADE METEOROLOGICAL OBSERVATIONS

Knittelmayer's motivation for meteorological observations was his astronomical experience. He reasoned that, largely, the same course of weather recurs after fulfilling the nineteen-year lunar cycle, because the light of the moon on the corresponding days is the same as 19 years previously (Buse, 1816). Earlier, Antonín Strnad was also persuaded of the prognostic importance of the nineteen-year lunar cycle for the weather forecast. He published his prognostica for the years 1788–1790, given as parallels to the weather in the given year as observed at Prague-Klementinum in 1769–1771 (see Strnadt, 1788, 1789, 1790). Knittelmayer ascribed the formation of the weather to two unchangeable factors (the sun and moon) and three changeable and iregularly-operating ones (local patterns, chemical processes and the winds). This is why he paid attention to all phenomena that could possibly be connected with the above factors in his observations.

At the end of each lunar quarter and the whole month, in the same way as at each quarter and half year, the daily observations were compared with one another and also with the course and state of the moon. The objective was, on the one hand, to determine the mean characteristics of the weather or similarities and deviations of the course of the weather over several months through all respective combinations. On the other hand, he sought to derive estimates from those observations for the probable course of the weather during the following change of the moon. The results of the meteorological observations thus made it possible for Knittelmayer to determine in advance the course of the weather for the following moon quarter or for the whole month. In essence, it was an attempt at a weather forecast by an analogue method.

For a clearer comparison of his results, Knittelmayer made graphs of the course of air temperature and pressure, a specimen of which, with corresponding text and subsequent tabular expression, may be found in the daily *Patriotisches Tageblatt* (Knittelmayer, 1800a, 1800b, 1800c, 1801). His graphical expression of the course of meteorological elements between 21 March and 21 May 1800 in Brno are among the earliest approaches of this kind in the Czech Lands (Knittelmayer, 1800b, Annex). The following specimen also documents the style of his thinking: *"Both in the first* [Frühmonat] *and in the second month* [Blüthenmonat] *the temperature rose to the New Moon, mainly with the passage of the Moon across the equator; towards the first quarter it dropped a little. Towards the Full Moon soon afterwards the temperature dropped perceptibly, particularly due to the fact that the southern deviation of the Moon increased. Towards the last quarter the temperature slowly rose again, as the Moon approached the equator."* (Knittelmayer, 1800b). He also gave an analogous explanation for the wind directions: *"In consideration of the phases of the Moon it appeared that the first three months* [Frühmonat–Rosenmonat] *from New Moon to the first quarter there blew mainly south-easterly winds, which towards the third* [Rosenmonat] *changed to north-easterly. In the further three months* [Wärmemonat–Obstmonat] *the north-easterly was the most frequent at the beginning, then the north-westerly, and at the end the southerly wind."* (Knittelmayer, 1800c).

THE CHARACTER OF THE WEATHER IN BRNO, 1799–1812

The technique of early instrumental meteorological measurements encounter a number of difficulties when compared with the analysis of modern measurements. As well as problems of accessibility, the place of observation itself within the given community is usually not specified. Detailed information about the instruments employed and their location is also lacking. Observation hours, which were often not stable even within the same set of measurements, as well as the methods of calculating the mean values, differ from current practice. The observations are not always complete, while what is complete coincides with only a limited number of contemporary stations that might be utilised as reference points. There are also problems with visual observations, the use of different terminology or definitions of meteorological phenomena. These facts make the process itself difficult, as well as hindering the statistical analysis of older observations, including their comparison with present-day standards (Brázdil et al., 2005).

This holds true to a considerable extent for Knittelmayer's observations from Brno, for which, in the publication by Brázdil et al. (2005), monthly means of air temperature and pressure were calculated for the period 1800–1812. They were further used for the compilation of Brno temperature and pressure series for 1800–1850. In the following part of the paper are the results of Knittelmayer's meteorological observations arranged by individual meteorological elements and phenomena in the period 1799–1812. This, in comparison with the standard period 1961–1990, appeared conspicuously colder from December to March, partly in April and November as well (Figure 3), according to the data from the secular Prague-Klementinum and Vienna-Hohe Warte stations. On the other hand, higher temperatures were achieved above all in May and August, but also in September and July. In the case of air pressure, higher values as against the standard period were recorded mainly in June and August, but also in February–April, a conspicuously lower pressure occurring in December.

Air pressure

For air pressure, measured in Vienna inches and lines with an accuracy of one-eighth of a line (1 Vienna inch = 26.34 mm, 1 Vienna line = 2.195 mm), Knittelmayer recorded the lowest air pressure, corrected mean air pressure and the highest daily pressure change. The corrected daily mean pressures transferred to hPa were used in the further processing, although Knittelmayer's description does make the nature of the correction clear. From those values the monthly means of air pressure were further calculated, then tested for relative homogeneity by the Alexandersson test (Alexandersson, 1986) with respect to the mean series of air pressure for the reference stations Prague-Klementinum and Vienna-Hohe Warte. Statistically significant inhomogeneities in 1802 were found in the months of December–February and in August, so these months were subsequently adjusted (both for the monthly and for the daily values). Higher values for air pressure before 1802 in comparison with the subsequent period follow logically from Dřímal's account (1956), according to which Knittelmayer established a small observatory in 1802 in the tower of the former Dominican monastery.

The annual variations of air pressure in Brno in the period 1799–1812 according to Knittelmayer's observations are expressed by monthly means, the means of daily maxima and minima and absolute monthly extremes (Figure 4). In comparison with modern measurements from the Brno-Tuřany station (Figure 1b) in the period 1961–1990, Knittelmayer recorded lower values for air pressure from October to February and higher values from April to June. The annual variations also differ from the point of view of the occurrence of maxima (in Knittelmayer's series the maximum was in September, at Tuřany in October), whereas the minimum was recorded for both places in April.

Air temperature

For the air temperature, given in Réaumur degrees (1°R = 1.25°C), the mean from the highest and the lowest daily temperature, the average of all five daily observations, the mean over the course of the day from the morning to the evening and the mean during the night from the evening to the morning were always given. The object of our further analysis became the mean temperature calculated by the two methods mentioned above. Using the daily maximum and minimum has the disadvantage that the resulting average is based on only two extreme values. In the calculation from five daily readings the mean is loaded with the error following from unequal observation terms in different parts of the year (such as those generated by measurements at the variable times of sunrise and sunset). To judge the differences between the two methods, a box diagram was compiled of the annual variation of differences (Figure 5). Further, the significance of the differences was established by t-test for the paired values. It appears that the means of the five daily observations more frequently exceed the averages from two measurements, at the maximum by more than 3°C. In the opposite case, the maximum differences exceeded by as much as 2°C. The differences found between the means are, however, in all months statistically insignificant at the $\alpha = 0.05$ level of significance.

The daily means calculated from five daily readings were used for the calculation of monthly averages, which were further tested by using the Alexandersson test (Alexandersson, 1986) for relative homogeneity using reference temperature series from the Prague-Klementinum and Vienna-Hohe Warte stations, both for the individual months and for the seasons and the year. The test indicated a possible statistically significant inhomogeneity only in April 1801 as a consequence of a somewhat lower temperature in April 1800, but the correction of only one month was omitted.

Figure 3. Differences in mean air temperature and pressure for the years 1799–1812 and the normal period 1961–1990 for secular Prague-Klementinum (only temperature) and Vienna-Hohe Warte stations.

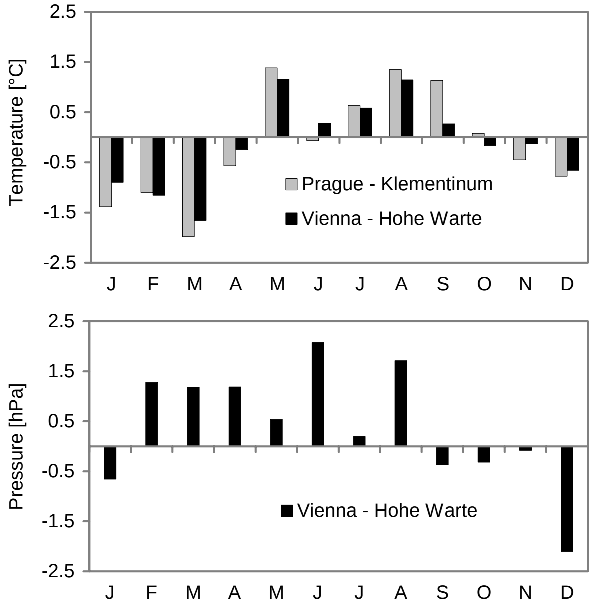


Figure 4. A comparison of the annual variation of mean air pressure in Brno according to measurements made by Knittelmayer (1) in the period 1799–1812 (3 – mean of daily maxima/minima, 4 – absolute daily maximum/minimum) and the Brno-Tuřany meteorological station (2) in the period 1961–1990.

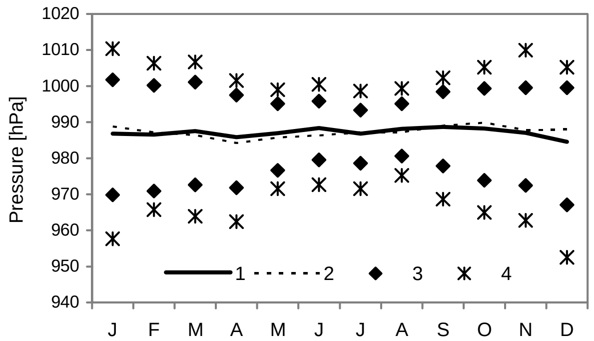


Figure 5. Box plot of the annual variation of differences of daily means of air temperatures calculated from the daily maximum and minimum, and/or five daily readings, in Brno in the period 1799–1812. The graph includes values corresponding to the median, the first and the third quartiles, and absolute positive and negative differences.

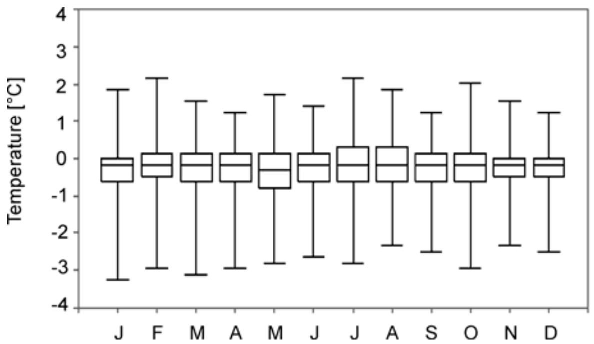


Figure 6. Comparison of the annual variation of mean air temperature in Brno according to Knittelmayer's measurements (1) in the period 1799–1812 (3 – mean of daily maxima/minima, 4 – absolute daily maximum/minimum) and the Brno-Tuřany meteorological station (2) in the period 1961–1990.

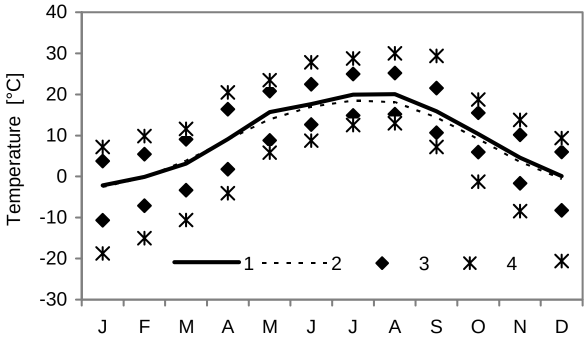
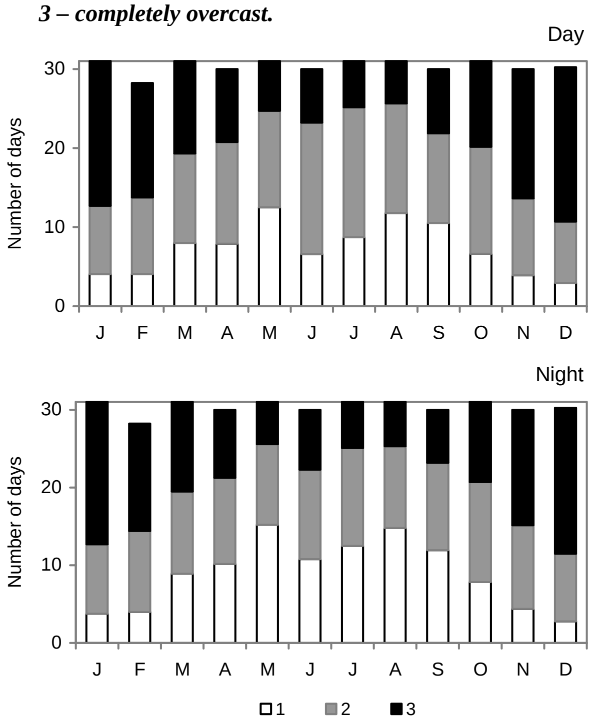


Figure 7. Annual variation of the mean number of days with a certain degree of cloudiness in Brno in the period 1799–1812 according to Knittelmayer's observations:
1 – clear or individual clouds,
2 – more or less overcast,
3 – completely overcast.



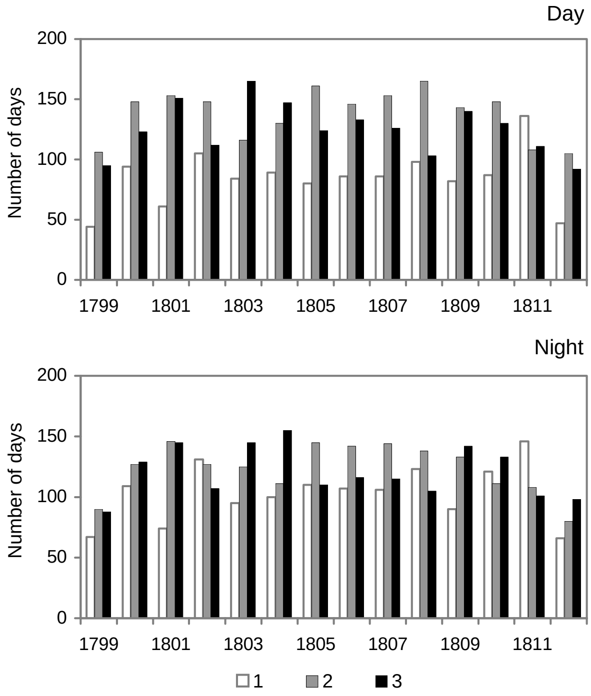
The annual variation of air temperature in Brno in the period 1799–1812 according to Knittelmayer's measurements is characterised on the one hand by the mean temperature, on the other by the mean of the daily maxima and minima and their absolute monthly extremes (Figure 6). In comparison with modern measurements at the Brno-Tuřany station in the period 1961–1990 it follows that in all months, with the exception of March, Knittelmayer recorded higher temperatures. The smallest differences (0.1–0.4°C) correspond to January–February and April, and in the remaining months they were from 0.6°C (June) to 2.0°C (August).

Cloudiness

According to standard climatological observations of cloudiness, it is possible to classify individual days as clear (0–2/10 of cloud cover), as half-covered (2–8/10 of cloud cover) and overcast (8–10/10). This type of information does not quite fall into line with Knittelmayer's observations of the state of the sky, which specify days as divided into those with a clear sky and individual clouds, more or less overcast, quite overcast and cloudy. He used the same system for the night.

The annual variation of the number of days with certain degrees of cloudiness in Brno in the period 1799–1812 is shown in Figure 7. The category "clear and individual clouds" shows its lowest values in the course of the day from November to February, the highest number of these days falling to May and August–September. At night the number of these cases increases. A practically reverse annual variation can be recorded for "quite overcast and cloudy" skies, with the highest frequency of such days from November to February. On the other hand, cases that correspond to half-covered sky according to Knittelmayer are most frequent in June and July. The interannual variability of the number of days with a certain degree of cloudiness in Brno, with the differentiation into day and night, is evident from Figure 8.

Figure 8. The fluctuation of the annual number of days with a certain degree of cloudiness in Brno in the period 1799–1812 according to Knittelmayer's observations:
1 – clear or individual clouds,
2 – more or less overcast,
3 – completely overcast.



Wind

For each day of the month, Knittelmayer recorded the prevailing wind direction, any second direction and the force of the wind, dividing it into strong, mild and weak. Relative frequencies of wind directions for the year and the season in the years 1799–1812 are shown in Figure 9, completed by his observations of the wind force. A dominance of airflow from the west to north quarter is evident (with northerly prevailing except in winter), as is a south-easterly airflow (in winter together with an east-south-east wind). Among the prevailing wind directions in the individual years, the most frequently represented was the south-easterly (1801, 1803, 1804, 1806, 1807, 1810) followed by the northerly (1805, 1808, 1809, 1812) and the north-westerly (1799, 1802, 1804). On one occasion each, the most frequent winds were the north-north-westerly (1800) and the east-south-easterly (1811). The second most frequented direction over three years were the northerly and the south-easterly, over two years the west-north-westerly and the north-north-westerly, and in one year the directions westerly, north-westerly, east-south-easterly and south-south-easterly. The highest percentage representation of strong winds is evident in spring.

On the whole, this information correlates well with the observations of the Brno-Tuřany meteorological station for the period 1961–1990, when the windiest period occurred from February to May with the highest mean wind speed in April. With respect to its position, on the Tuřany terrace outside town, this station is less representative for wind directions in the city itself. In the above thirty years, the prevailing directions were north-westerly (April, June–September), east-north-easterly (February–March, October–December), both together in May and south-easterly in January (Brázdil et al., 2005).

Precipitation days

Within his meteorological phenomena, Knittelmayer used special marks for every day to record the variation and properties of clouds, the rainy or snowy character of the day, rain or snowfall, fog and foggy circumstances, frost, thunderstorms and heat lightning. The number of precipitation days is worthy of attention. It may be divided into days with liquid, mixed or solid precipitation.

A maximum in December and a minimum in September were typical of the annual variation in the mean number of precipitation days in the period 1799–1812 in Brno (Figure 10). Knittelmayer recorded comparable high frequencies of precipitation days in January–April, June–July and November. At Brno-Tuřany station the highest number of precipitation days in 1961–1990 occurred in November–February with the main maximum in December, while the secondary maximum culminated in June. On the other hand, the main minimum occurred in October.

Measurements of precipitation in Brno are available from 1803 onwards, made by Zacharias Melzer (Brázdil et al., 2005), and Knittelmayer's records may prove a suitable supplement to them. Knittelmayer's annual numbers of precipitation days are, however, higher than the numbers stated by Melzer (Figure 11). This is evidently connected with the fact that five observations per day inevitably led to the number of recorded episodes being higher, particularly in the case of weak or short-term precipitation, the daily total of which might not be measurable. The annual numbers of precipitation days recorded by the two authors correlate almost equally in terms of annual sums of precipitation measured (0.83 for Melzer's values and 0.84 for Knittelmayer's).

Figure 9. Relative frequencies [%] of the prevailing wind direction and force for the seasons and the year according to Knittelmayer's observations in Brno for the period 1799–1812.

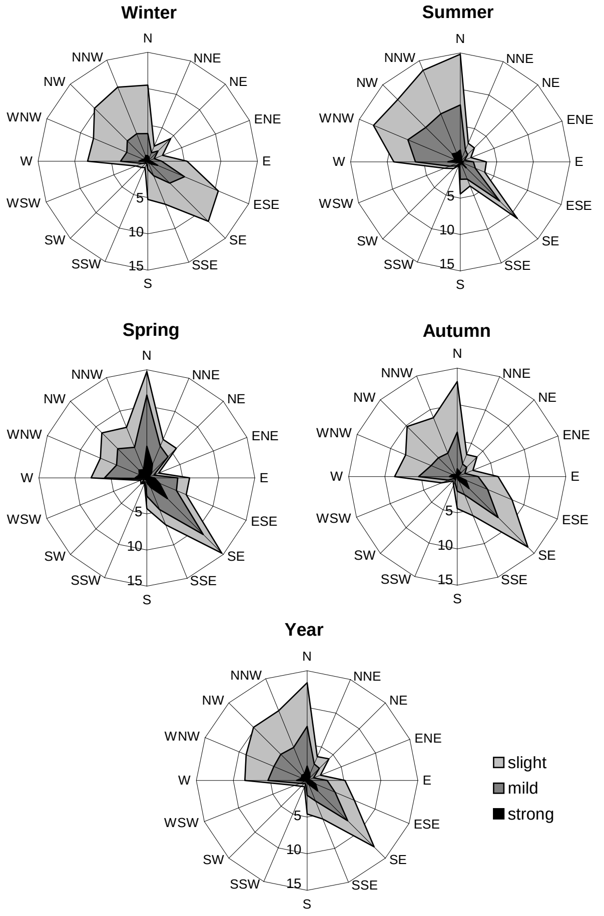


Figure 10. Annual variation in the mean number of precipitation days in Brno in the period 1799–1812 according to Knittelmayer's observations and the Brno-Tuřany meteorological station in the period 1961–1990: 1 – liquid precipitation, 2 – mixed precipitation, 3 – solid precipitation.

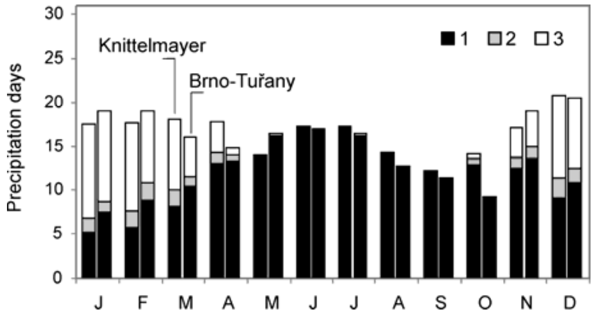
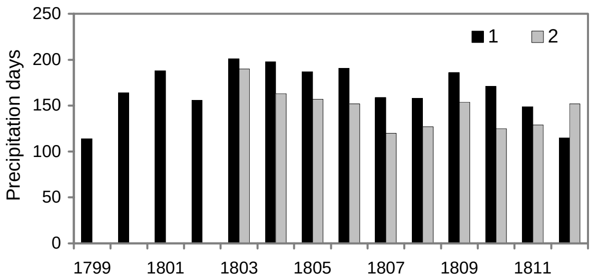


Figure 11. Fluctuation of the annual number of precipitation days in Brno for the period 1799–1812 according to Knittelmayer (1) and Melzer (2). Knittelmayer's data for 1799 and 1812 are incomplete.



Meteorological singularities

The fact that Knittelmayer's legacy includes continuous daily records of meteorological elements also makes it possible to address the study of meteorological singularities, such as calendar-bound deviations of a given meteorological element from its mean long-term variation. Singularities were studied for air pressure, air temperature and numbers of precipitation days using methodology applied by Řezníčková et al. (2006), which makes it possible to evaluate statistically significant deviations in the annual variation of those elements. In Figures 12–14 appear annual variations of three processed elements, both smoothed by three-day running averages and sixty-day low-pass filter, and with values smoothed by three-day running averages with marking intervals of reliability and statistically significant singularities.

In the case of air pressure, in the period 1799–1812 in Brno a total of 32 singularities were found with a mean duration of 2.8 days, among which a significant deviation was recorded on only one day in six cases, with the duration of the longest singularities not exceeding six days (Table 2, Figure 12). The best-known singularity expressed in air pressure, the "Indian summer", is indicated by two peaks of air pressure around mid-September (14–19 September) and the beginning of October (2–6 October). These, however, are overcome in terms of magnitude by several further cases from November to March. The most conspicuous negative singularities corresponding to low air pressure are bound to the period December–February.

For air temperature in the period 1799–1812 in Brno, a total of 35 singularities were found, again with a mean duration of 2.8 days (Table 2, Figure 13). In 10 cases a statistically significant deviation from the average was recorded on only one day and in 16 further cases for only 2–3 days. With the exception of the longest singularity, lasting 7 days from 28 July to 3 August, corresponding to "high summer", further singularities lasting 5–6 days were bound solely to the period from the last days of August to the end of the year, including both positive and negative deviations. Above all worthy of mention is the "Christmas thaw" (24–29 December), which exhibited the highest positive temperature deviation (1.7°C) and which was preceded by the most conspicuous negative singularity (–2.0°C) on 17–22 December.

Table 2. Meteorological singularities in air pressure, temperature and precipitation days in Brno for 1799–1812 according to Knittelmayer's measurements.

Key:
MD – mean deviation
H – higher pressure
L – lower pressure
C – cold
T – warm
W – wet
D – dry

Pressure				Temperature				Precipitation			
No	Type	Period	MD [hPa]	No	Type	Period	MD [°C]	No	Type	Period	MD of days
1	H	2 Jan	1.7	1	C	6 Jan	–1.3	1	D	4–5 Jan	–2.2
2	H	4–8 Jan	3.2	2	C	12–13 Jan	–1.2	2	D	8 Jan	–1.8
3	L	12–14 Jan	–3.4	3	T	21–22 Jan	1.2	3	W	12–13 Jan	1.9
4	L	20–22 Jan	–3.9	4	C	27 Jan	–1.2	4	W	17 Jan	1.6
5	H	2 Feb	1.7	5	T	27 Feb	0.7	5	D	30 Jan–2 Feb	–2.3
6	H	9 Feb	1.5	6	T	3–4 Mar	0.8	6	W	15–16 Feb	1.6
7	L	12–16 Feb	–3.5	7	T	19–20 Mar	1.4	7	D	19–22 Feb	–2.1
8	H	19–21 Feb	3.0	8	C	23–26 Mar	–1.4	8	W	26–28 Feb	2.7
9	L	26–27 Feb	–1.9	9	C	12 Apr	–0.8	9	W	1 Mar	1.8
10	H	12–13 Mar	2.2	10	T	16 Apr	1.0	10	D	3–4 Mar	–1.5
11	H	23–27 Mar	2.8	11	C	25 Apr	–0.8	11	W	8–10 Mar	2.1
12	L	29–30 Mar	–2.1	12	T	2–4 May	1.3	12	D	18–20 Mar	–3.3
13	H	4–6 Apr	2.2	13	T	9–10 May	0.9	13	W	30 Mar	2.1
14	L	11–12 Apr	–2.4	14	T	22–23 May	0.8	14	W	11 Apr	1.7
15	H	18–19 May	1.0	15	T	28–30 May	0.9	15	W	20–21 Apr	1.7
16	H	8–10 June	1.4	16	C	2 June	–0.8	16	D	2–3 May	–1.7
17	H	25 June	1.2	17	T	6–8 June	1.0	17	D	5–8 May	–1.9
18	L	2–5 July	–1.2	18	C	18–20 June	–0.9	18	W	14–15 May	3.0
19	L	3–4 Aug	–0.8	19	C	23–25 June	–0.9	19	D	27–29 May	–2.4
20	L	9–12 Aug	–1.2	20	T	9–10 July	1.1	20	W	4–5 July	2.1
21	L	20–21 Aug	–1.7	21	C	17–19 July	–0.8	21	D	8–9 July	–1.7
22	L	1 Sep	–1.0	22	T	24 July	0.6	22	W	23–24 July	1.8
23	H	14–19 Sep	2.1	23	T	28 July–3 Aug	1.0	23	W	15–16 Aug	1.8
24	L	23–24 Sep	–1.8	24	C	6 Aug	–0.7	24	D	30 Aug	–2.1
25	H	2–6 Oct	2.5	25	C	16–18 Aug	–0.9	25	W	2 Sep	2.3
26	L	8–11 Oct	–2.6	26	T	28 Aug–1 Sep	1.0	26	D	7–8 Sep	–1.7
27	H	14–15 Nov	2.6	27	T	7 Sep	0.8	27	W	11–12 Sep	2.0
28	H	19 Nov	2.0	28	T	6–9 Oct	0.8	28	D	16 Sep	–1.4
29	L	2–6 Dec	–2.6	29	C	11–15 Oct	–1.0	29	W	9–11 Oct	1.9
30	L	8–9 Dec	–2.4	30	T	24–29 Oct	1.3	30	D	15 Oct	–1.4
31	H	19–21 Dec	3.5	31	C	2–3 Nov	–1.2	31	D	22 Oct	–1.9
32	L	26–29 Dec	–3.2	32	C	13–16 Nov	–1.2	32	D	29 Nov	–1.4
				33	T	7–9 Dec	1.1	33	W	2–5 Dec	2.5
				34	C	17–22 Dec	–2.0	34	D	12–14 Dec	–2.3
				35	T	24–29 Dec	1.7	35	W	26–27 Dec	1.7

Figure 12.
Annual variation of mean daily air pressure in Brno for the period 1799–1812:

a) three-day running means smoothed by 60-day low-pass filter,

b) three-day running deviations with intervals of reliability (80 %) and marking of singularities with a duration of ≥ 2 days (for numbers, see Table 2).

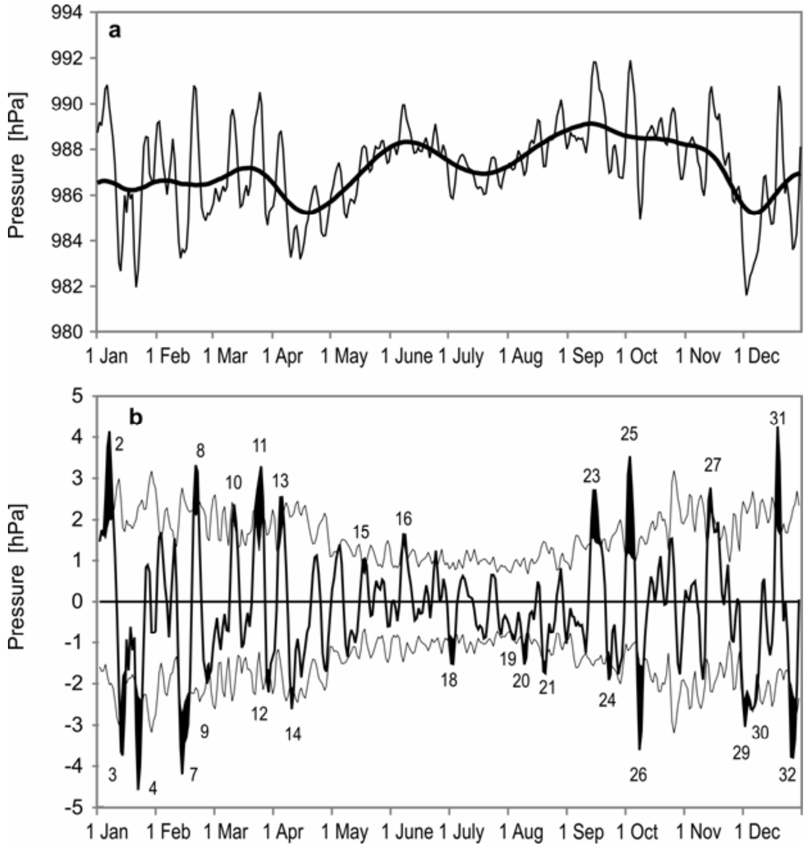


Figure 13.
Annual variation of the mean daily air temperature in Brno for the period 1799–1812:

a) three-day running means smoothed by 60-day low-pass filter,

b) three-day running deviations with intervals of reliability (80 %) and with marking of singularities with a duration of ≥ 2 days (for numbers, see Table 2).

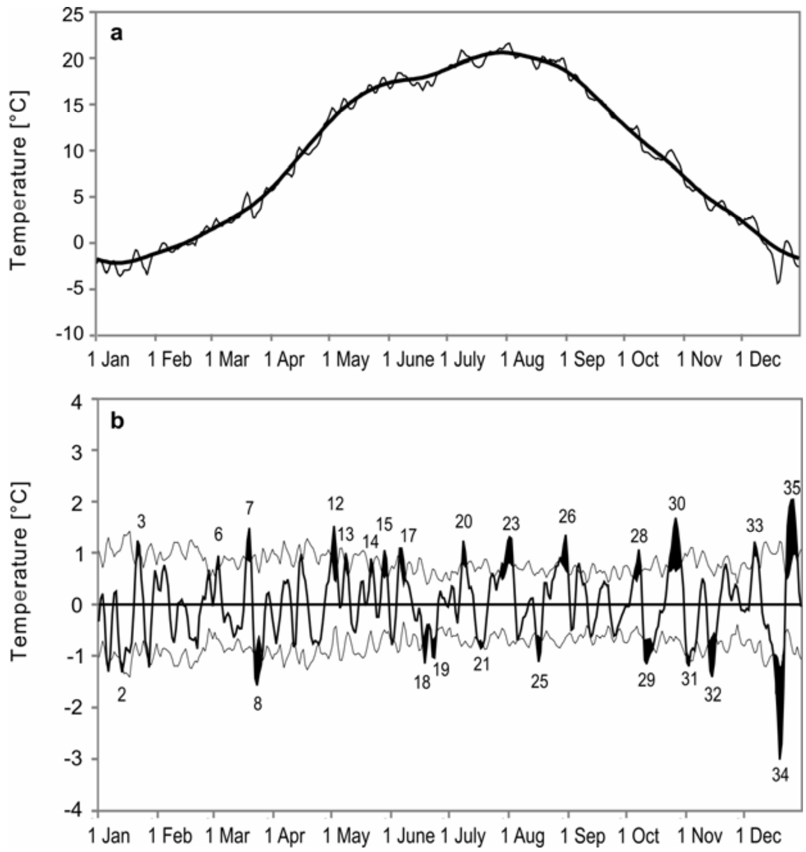
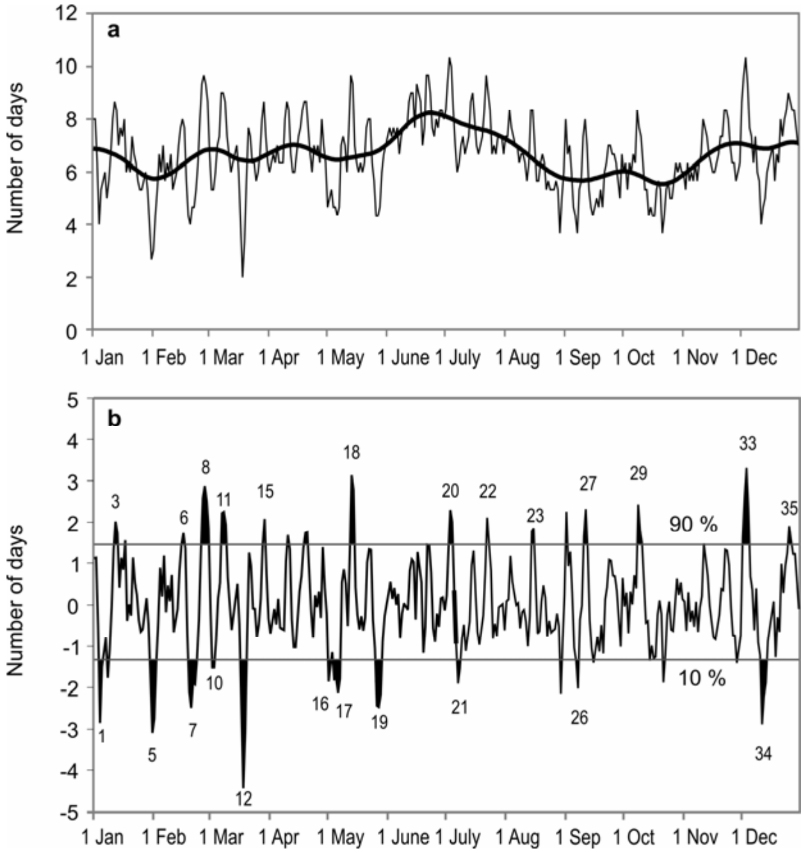


Figure 14.
Annual variation of the number of precipitation days in Brno for the period 1799–1812:

a) three-day running means smoothed by 60-day low-pass filter,

b) three-day running deviations with intervals of reliability and with marking of singularities with a duration of ≥ 2 days (for numbers, see Table 2).



In the case of the number of precipitation days in Brno in the period 1799–1812, a total of 35 singularities were recorded with a mean duration of 2.1 days (Table 2, Figure 14). In 11 cases the significant deviation referred to only one day and only four times did it reach 4 days, three times as a drier episode (30 January–2 February, 19–22 February, 5–8 May) and once as a wetter one (2–5 December). The best-known precipitation singularities, bound to the individual waves of the so-called "European summer monsoon" (e.g. Brázdil, 1982) thus remained limited to only three two-day episodes in July and August in the period studied.

From the preceding analysis it follows that the number of singularities found for air pressure, air temperature and precipitation activity is more or less comparable; the mean duration of a singularity drops from 2.8 days for air pressure and temperature to 2.1 days for precipitation. In terms of the best-known weather singularities traditionally associated with the Czech Republic (see e.g., Souborná studie, 1969; Brázdil et al., 1999; Řezníčková et al., 2006), the situation for Brno in the period 1799–1812 was as follows:

- "deep winter" – was expressed only on the days 12–13 January, bound to a negative anomaly of air pressure, not to the prevalence of an anticyclonic regime of weather
- "May cooling" – usually connected with the "Ice Men" did not appear at all; on the contrary, in four cases there occurred a two- to-three-day positive temperature anomaly
- "European summer monsoon" – from precipitation-expressed waves (see e.g. Brázdil, 1982; Bissolli, 1991), higher precipitation activity in June was altogether absent, with three waves falling to the days 4–5 July, 23–24 July and 15–16 August; a negative anomaly of air pressure on 2–5 July corresponded to the first wave in July
- "high summer" – this was a clearly perceptible singularity in the case of air temperature (28 July–3 August) which, however, did not find expression in a significant rise of air pressure or fall in precipitation activity
- "Indian summer" – was well expressed by two episodes of high air pressure on 14–19 September and 2–6 October, which were, however, not reflected in temperature singularities (positive deviation only for 6–9 October) and in a fall in precipitation activity
- "Christmas thaw" – a conspicuous positive temperature singularity (24–29 December) was supported by a negative anomaly of air pressure (26–29 December) and increase in precipitation activity (26–27 December); this singularity became conspicuous after the preceding significant cooling (17–22 December), connected with a prevailing anticyclonic weather regime (positive anomaly of pressure on 19–21 December).

CONCLUSIONS

Knittelmayer's meteorological records open a history of more than two hundred years of meteorological observations in Brno. They constitute exceptionally valuable data from a period in which meteorological observations were carried out in only a few places. In the Brno environment they were much appreciated, as is evident from an expression of approbation from Karel Josef Jurende, a well-known Moravian pioneer of meteorology, in his description of the climate of Moravia from 1813 ("*The weather and climate of Brno has been observed most accurately and completely for 13 years by the honourable Captain Knittelmayer … Only he, himself, is perhaps able to say anything premeditated and based upon experience about the climate and weather in Brno thanks to his arduous observations. May his precious observations never be lost! – May many follow his example!*" – see Brázdil, Valášek, 2003). Later, Kassián Hallaschka, the professor at Prague university who wrote an expert opinion for the purchase of Knittelmayer's observations for the I. R. Moravian-Silesian Economic Society said: "*With what diligence, with what combination of ability, and finally with what erudition these data are collected, I am unable to describe adequately. With real pleasure, I have gone repeatedly through this paper and admired the investigations and the work of this man, who compiled it according to fixed principles and enlightened ideas in such a way that one cannot wish for more.*" – see Brázdil et al., 2005). Particularly valuable is the fact that, unlike some other Brno observations (such as Kassián Hallaschka, Zacharias Melzer – see Brázdil et al., 2005) the records have remained in the form of daily observations. At the same time, it is necessary to evaluate its importance for compiling pressure and temperature series for Brno since 1799 up to the present. Setting aside the pure facts, the records themselves are of cultural and historical importance, illustrating as they do the contemporary role of meteorology, something that must not be neglected.

Acknowledgements

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