Anonymous Referee #1

The paper presents a very detailed analysis of weather and climate in south-eastMoravia in the years 1803–1830 based on a newly-discovered daily weather diary from Buchlovice written by Šimon Hausner, a priest in Buchlovice. Although meteorological observations exist for this time period for some stations in the Czech Republic, including the closest station in Brno, the value of such long series of visual observations is very important, not only for improving the climate knowledge of the region, but even more for estimation of the usefulness of that kind of weather excerpts for climate reconstruction, including estimation of its uncertainty.
RESPONSE: We would like to thank the reviewer for many very important comments to which we are trying respond below.

The main weakness of the paper, which necessarily must be supplemented, is a lack of information concerning the way that air temperature and precipitation values are attributed to a specific index in the 7-degree scale. In Section 3.2 there should be information about threshold values used in the process of indexation based on monthly frequencies of warm or cold days in case of temperature and number of days with precipitation in case of precipitation. Do you use data from Brno station for this purpose, e.g. number of days with precipitation?
RESPONSE: The methodology of interpretation of temperature and precipitation indices was described in Section 3.2 (new 4.2) in more detail as follows:
"With respect to the character of Hausner's daily weather records, it became impossible apply some new quantitative approaches to interpret monthly temperature and precipitation indices (see e.g. Fernández-Fernández et al., 2017; Filipiak et al, 2019). From this reason we used a broadly applied approach of Pfister (1992), combining different kinds of sources and their expert evaluation. Information related to temperature patterns was used to interpret monthly temperature indices by expression on a 7-degree scale: –3 extremely cold, –2 very cold, –1 cold, 0 normal, 1 warm, 2 very warm, 3 extremely warm (Pfister, 1992). Interpretation of temperature indices took into account the broad scale of indicators derived from Hausner's records: the monthly frequencies of cold days (severe frost, frost, cold, very cold) and warm days (warm, very warm, hot, very hot, mild), warm and cold winds, monthly summary reports, early and late beginnings of certain phenophases and agricultural work and also, to some extent, cloudiness (e.g. clear and overcast days) and precipitation (state of precipitation, monthly temperature–precipitation relationships). Own interpretation was realised in following iterations:
(i) Pfister (1992) recommended attribution of regularly distributed 7-degre indices to dataset ordered from the lowest to the highest values: index –3 he used for 8.3% lowest values, –2 for 16.6% following values, further with always 16.6% of values for each following indices (–1, 0, 1, 2) up to 8.3% of highest values attributed to index 3. This approach was applied separately to the monthly frequencies of cold days and warm days in 1803–1830, which allowed attribute any index to each of months, when in indexing of the month of winter half-year rather cold days and in the months of summer half-year rather warm days were preferred.
(ii) Monthly indices from point (i) were further evaluated with respect to the structure of cold and warm days looking on their intensity, based on which the corresponding month could be moved to the neighbour category. For example, higher portion of hot or very hot days was a reason for moving to "warmer" category (e.g. from index 1 to index 2), similarly as higher portion of weak frosts or cold days compare to severe frosts and very cold days (e.g. from index –2 to index –1), and opposite. Also indication of warm and cold winds as expression of character of air advection was considered.

(iii) All indices from iteration (ii) were further considered with respect to monthly temperature summaries and earlier/later onset of phenophases, indicating cooler or warmer patterns of preceding months. As additional parameter also information about cloudiness was used (days with higher sunshine duration are warmer compared to cloudy days). Also occurrence of snowfall or snow cover indicated cooler patterns. For months of the summer half-year also relationship warm/dry and cold/wet month was considered. Described facts could again cause moving of some months to another neighbour category. Corresponding indices, fixed after the third iteration, were then used as a final version of weighted monthly temperature indices.

Also precipitation indices were interpreted in similar fashion: –3 extremely dry, –2 very dry, –1 dry, 0 normal, 1 wet, 2 very wet, 3 extremely wet (Pfister, 1992). The interpretation of monthly precipitation indices was based again on several indicators Hausner's records: monthly frequencies of precipitation days, with particular reference to type of precipitation (e.g. snow, drizzle, rain, snow with rain), to precipitation intensity and duration of precipitation spells (as specified in daily records) and to summary monthly reports as well as other indications of wet or dry patterns (e.g. effects on agricultural crops or work in the fields). The own interpretation included three iterations:

(i) The numbers of monthly precipitation days of the given months in 1803–1830 (28 years) was ordered from the lowest to the highest numbers. Following the above percentage distribution by Pfister (1992), corresponding 7-degree indices between –3 and 3 were formally added to individual months.

(ii) Based on additionally reported type, intensity and duration of precipitation, the corresponding months remained in preliminary defined degree from point (i) or it was moved to any neighbour degree. For example, more days with drizzle, short or small precipitation were favourable to adding "more dry" index (e.g. from index 2 to index 1) or days with the whole-day rain or heavy precipitation during thunderstorms could be favourable for opposite attribution of "more wet" index (e.g. from index –1 to index 0).

(iii) All indices from point (ii) were further evaluated from point of view of summary information of precipitation character of the months or any other precipitation-sensitive information. Similar as in the previous iteration (ii), some months could be moved to other degree.

After these three iterations corresponding monthly precipitation indices were considered as final."

It means, that we combined quantitative approach (based on distribution of corresponding data and number of days with some characteristics) with an expert approach based on expert knowledge of climate in the Czech Lands. There is clear that final version of monthly indices is influenced by character of basic data, their interpretation and climatic experience of the researcher. But having no measured data we cannot expect more. Some tests of a quality of indices interpreted can be the high and statistically significant correlation coefficients of our indices with measured temperatures/precipitation series in Brno (Section 5.3, now 6.2). Based on it we believe that our rather subjective interpretation express quite well corresponding temperature and precipitation variability (fluctuations) following from the meteorological measurements of the Brno station.

Replaying to your question on the instrumental data of the Brno station, we did not use them in the interpretation of indices from Hausner's data, i.e. temperature and precipitation measurements in Brno are independent. Brno series were used only for comparison with Hausner's indices in Section 5.3 (now 6.2).

Why did you not make daily indexation using e.g. a 3-degree scale? Does Hausner's weather diary allow for such indexation or not?

RESPONSE: We are really sorry, but Hausner's records did not allow us to do any systematic daily indexation as used, for example, in the paper by Filipiak et al. (2019).

From this reason we could not use also an indexation approach, which was applied in this important reported paper.

When he started weather observations, Hausner was a mature man, thus probably his weather descriptions concerning its extremity were related to his weather experience in the late 18th century, a period which was warmer than 1803–1830. This is probably the reason why your indexation revealed significantly more months described as extremely cold and very cold compared to extremely warm and very warm, in particular in winter months (Table 1). For the entire year the statistic is the following: for -3 and +3 (13 and 4, respectively), and for -2 and +2 (37 and 23).
RESPONSE: Each description of weather, which is not based on instrumental measurements, has a subjective feature and is influenced by many factors, including the observer's experience. We may only speculate how much he was influenced by the experience from the previous period. But why we should primarily expect, that the number of corresponding negative and positive extremes should be more or less the same, i.e. to be in agreement with any "normal" patterns? It would be more or less same, when we would stop creation of corresponding indices after the first iteration (see Section 3.2). But from Fig. 10 clearly follows, that the 1803-1830 period, belonging to the last part of the LIA, was much cooler compared to more recent time, influenced by a global warming. In our opinion, it implies that the number of negative extremes should be higher than the number of positive extremes. It is also confirmed, for example, by the fact that Büntgen et al. (2015) spoken of the 1810s as the coolest decade in central Europe in the past three centuries. Cole-Dai et al. (2009) referred even to this time as probably the coldest decade in the last 500 years or more in the Northern Hemisphere.

The second possibility is that the person who made the indexation compared Hausner's descriptions of weather with the present period, which is also warmer.
RESPONSE: We do not thing that it was particularly this case. On the other hand, each kind of interpretation of "descriptive" daily weather records bears some subjective features. From this reason interpretations of indices based on Hausner's records were compared with measured temperatures/precipitation from Brno (see Section 5.3, now 6.2) which showed quite a good agreement in character of fluctuations in both types of series.

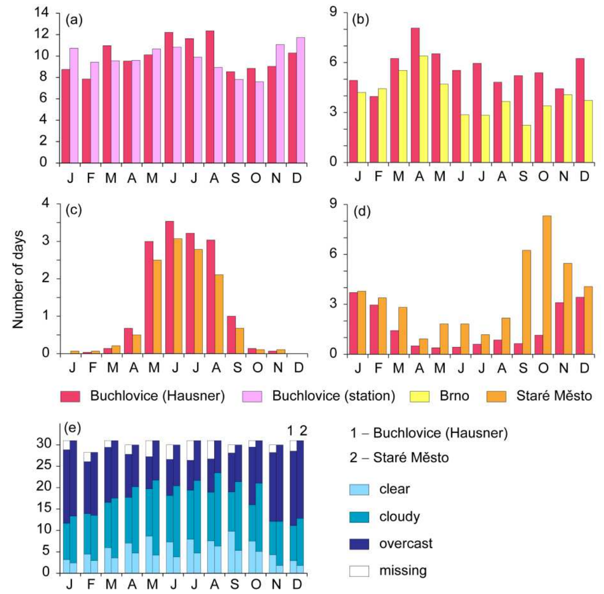
My next doubt concerns the reference period: why did you not use the latest normal period 1981–2010, as recommended by the WMO? Such comparison will give a better estimate of climate change and variability between historical and present periods.
RESPONSE: The reason for the use of the 1961–1990 reference period are following: (i) in the quoted WMO material, the period from 1961 to 1990 has been retained as a standard reference period for long-term climate change assessments; (ii) majority of climatological papers up to now is using the standard reference period 1961–1990, i.e. from point of view of possible comparisons it is better to preserve this period; (iii) the 1961–1990 period is not so strongly influenced by recent global warming as the 1981–2010 period; (iv) according to Czech representative in WMO Dr. R. Tolasz, who participated in preparation of this material, "30-year period out of standard normals should be used rather for evaluation of more recent deviations (e.g. on the monthly level)".

Minor remarks:
1. Page 1, last line – I suggest to add here for the 18th century the recently published paper by Filipiak et al.(2019) presenting results for Gdansk for the period 1721–1786 based on Reyger's weather observations (https://doi.org/10.1002/joc.5845),
RESPONSE: Accepted and included into the manuscript.

2. Quite a lot of shortcomings which exist in the paper should be supplemented, e.g. p. 10, lines 18-19: “With the exception of February and March, all months were also more variable in terms of standard deviation than the reference period”,
RESPONSE: Accepted and corrected as: “With the exception of February and March, all months were also more variable according to standard deviation than in the reference period.”

p. 10, lines 39-40: “Despite generally close agreement between the Hausner series (ref. comm.: there are a lot of variables analysed in the paper: does the statement concern all variables or only temperature and precipitation?) and those for Brno, some instances of greater or smaller disagreement appear”, etc.
RESPONSE: Accepted and corrected as: “Despite generally close agreement between the Hausner temperature and precipitation series and those for Brno, some instances of greater or smaller disagreement appear.”
We are sorry, but other shortcomings in the manuscript are not specified, i.e. there is difficult to respond. The manuscript was corrected for English style by a native speaker.

3. Fig. 13 – I suggest more contrastive colours be used to show data from Brno and Stare Mesto. It is difficult to guess which of the mentioned stations the data in Fig. c represents,
RESPONSE: Accepted and corrected. See the new version of Fig. 13 below:



4. Fig. 13 – in the caption there is information that strong winds were estimated as those with force ï´C¸s 7oB. In Section 3.1 there is no information on how this was estimated based on Hausner’s weather descriptions. I suggest this information be added,
RESPONSE: To specify the interpretation of days with strong winds according to Hausner‘s observations, following sentence was added as the second on the beginning of Section 4.1.4 (now 5.1.4): “As days with strong winds were interpreted those in which

Hausner mentioned strong or very strong wind, very windy weather, “awful” wind, extraordinary wind, windstorm or blizzard (see Section 4.1, point (iv)).”

5. The authors should maybe reconsider the presentation of Section 3.1 (or part of it) in the form of a Table, in particular for temperature and precipitation. It seems to me that the text will then be more clear for readers.
RESPONSE: We have some doubts, that creation of the table would be more simple for readers than presentation of terminology used in descriptive form because the table should be relatively large and complicated. Moreover, it would be inconsistent to do a table only for temperature and precipitation terminology. From this reason we would be more happy to let it in the recent form. We believe that reader interested in topic will be able to go via this well-structured text without any troubles.

I can recommend acceptance of the paper for publication in the Climate of the Past journal only on the condition that the listed remarks and suggestions will be satisfactorily taken into account.
RESPONSE: We tried to respond to every of your important comments in the best possible way with a hope that responses could be taken by you as satisfactorily.

Anonymous Referee #2

This is an interesting paper that provides a new meteorological record for a number of parameters for a region and period where none currently exists. It follows a relatively standard methodology and provides some interesting findings that can be built on in the future to create a more systematic climatological record for the region. I'm happy for it to be published, although I would like the following three points to be addressed:
RESPONSE: We would like to thank the reviewer for many very important comments to which we are trying respond below.

1. The significance of the missing datapoints is not clearly addressed, and figures 5-7 and 13 erroneously use exact numbers of days, despite the missing data. I would like to see a discussion of the distribution of the missing days and - unless the distribution of missing days makes this invalid - the exact days in these figures to be translated into percentages
RESPONSE: Accepted, see our response to Section 3.2 (now 4.2) of your comments. Moreover, the numbers of missing dates were included directly into Figs. 5 and 7 (now 6 and 8). In Fig. 6 (now 7) is already included category 6 - missing days or no information related to cloudiness. As for Fig. 13, please see our detail response to page 11 of your comments.

2. There is nothing to show to the reader how the 7-point index figures were arrived at. I'd like to see some kind of calibration table, and/or examples of years under each classification, and/or a comparison of classifications assigned between the different researchers and a discussion of how the final classification was arrived at (assuming this was done)
RESPONSE: Accepted, the methodology of creation of 7-point indices was complemented in Section 3.2 (now 4.2) as follows:
"With respect to the character of Hausner's daily weather records, it became impossible apply some new quantitative approaches to interpret monthly temperature and precipitation indices (see e.g. Fernández-Fernández et al., 2017; Filipiak et al, 2019). From this reason we used a broadly applied approach of Pfister (1992), combining different kinds of sources and their expert evaluation. Information related to temperature patterns was used to interpret monthly temperature indices by expression on a 7-degree scale: –3 extremely cold, –2 very cold, –1 cold, 0 normal, 1 warm, 2 very warm, 3 extremely warm (Pfister, 1992). Interpretation of temperature indices took into account the broad scale of indicators derived from Hausner's records: the monthly frequencies of cold days (severe frost, frost, cold, very cold) and warm days (warm, very warm, hot, very hot, mild), warm and cold winds, monthly summary reports, early and late beginnings of certain phenophases and agricultural work and also, to some extent, cloudiness (e.g. clear and overcast days) and precipitation (state of precipitation, monthly temperature–precipitation relationships). Own interpretation was realised in following iterations:
(i) Pfister (1992) recommended attribution of regularly distributed 7-degree indices to dataset ordered from the lowest to the highest values: index –3 he used for 8.3% lowest values, –2 for 16.6% following values, further with always 16.6% of values for each following indices (–1, 0, 1, 2) up to 8.3% of highest values attributed to index 3. This approach was applied separately to the monthly frequencies of cold days and warm days in 1803–1830, which allowed attribute any index to each of months, when in indexing of the month of winter half-year rather cold days and in the months of summer half-year rather warm days were preferred.
(ii) Monthly indices from point (i) were further evaluated with respect to the structure of cold and warm days looking on their intensity, based on which the corresponding month could be moved to the neighbour category. For example, higher portion of hot or very hot

days was a reason for moving to "warmer" category (e.g. from index 1 to index 2), similarly as higher portion of weak frosts or cold days compare to severe frosts and very cold days (e.g. from index –2 to index –1), and opposite. Also indication of warm and cold winds as expression of character of air advection was considered.
(iii) All indices from iteration (ii) were further considered with respect to monthly temperature summaries and earlier/later onset of phenophases, indicating cooler or warmer patterns of preceding months. As additional parameter also information about cloudiness was used (days with higher sunshine duration are warmer compared to cloudy days). Also occurrence of snowfall or snow cover indicated cooler patterns. For months of the summer half-year also relationship warm/dry and cold/wet month was considered. Described facts could again cause moving of some months to another neighbour category. Corresponding indices, fixed after the third iteration, were then used as a final version of weighted monthly temperature indices.

Also precipitation indices were interpreted in similar fashion: –3 extremely dry, –2 very dry, –1 dry, 0 normal, 1 wet, 2 very wet, 3 extremely wet (Pfister, 1992). The interpretation of monthly precipitation indices was based again on several indicators Hausner's records: monthly frequencies of precipitation days, with particular reference to type of precipitation (e.g. snow, drizzle, rain, snow with rain), to precipitation intensity and duration of precipitation spells (as specified in daily records) and to summary monthly reports as well as other indications of wet or dry patterns (e.g. effects on agricultural crops or work in the fields). The own interpretation included three iterations:
(i) The numbers of monthly precipitation days of the given months in 1803–1830 (28 years) was ordered from the lowest to the highest numbers. Following the above percentage distribution by Pfister (1992), corresponding 7-degree indices between –3 and 3 were formally added to individual months.
(ii) Based on additionally reported type, intensity and duration of precipitation, the corresponding months remained in preliminary defined degree from point (i) or it was moved to any neighbour degree. For example, more days with drizzle, short or small precipitation were favourable to adding "more dry" index (e.g. from index 2 to index 1) or days with the whole-day rain or heavy precipitation during thunderstorms could be favourable for opposite attribution of "more wet" index (e.g. from index –1 to index 0).
(iii) All indices from point (ii) were further evaluated from point of view of summary information of precipitation character of the months or any other precipitation-sensitive information. Similar as in the previous iteration (ii), some months could be moved to other degree.
After these three iterations corresponding monthly precipitation indices were considered as final."
It means, that we combined quantitative approach (based on distribution of corresponding data and number of days with some characteristics) with an expert approach based on expert knowledge of climate in the Czech Lands. There is clear that final version of monthly indices is influenced by character of basic data, their interpretation and climatic experience of the researcher. But having no measured data we cannot expect more. Some tests of a quality of indices interpreted can be the high and statistically significant correlations of our indices with measured temperatures/precipitation series in Brno (Section 5.3, now 6.2). Based on it we believe that our rather subjective interpretation express quite well corresponding temperature and precipitation variability following from the meteorological measurements of the Brno station.

3. It would be good if the authors could provide possible climatological reasons for the difference in values between the reconstruction and contemporary period.
RESPONSE: Accepted. See partly our responses to page 10 of your comments below. Comparison of the reconstruction and contemporary period was motivated by the fact to

put Hausner's period into context of long-term climate variability. We believe that for understanding of this context Fig. 10 and the first paragraph of Section 5.1 (now 6.1) are sufficient. While the 1961–1990 period clearly reflects the first part of intense temperature increase related to recent global warming (caused by increase in GHG gases), the cooler reconstruction period is located in the time of effects of natural climate variability (e.g. volcanic activity) during the last phase of LIA. For example, Büntgen et al. (2015) spoken of the 1810s as the coolest decade in central Europe in the past three centuries. Cole-Dai et al. (2009) referred to this time as probably the coldest decade in the last 500 years or more in the Northern Hemisphere. These papers confirm results of our comparison. To do any real sophisticated climatological analysis of differences in both periods would need to take into account many climatic triggers (solar and volcanic activity, anthropogenic factor) and large scale climate drivers (e.g. different circulation indices like NAOI, SOI, PDO, etc.), But such analysis is going clearly out of the scope of this paper and would need a separate special research.

Detailed comments are below:
Section 3.2. Can you give details of the distribution of missing days? Also this isn't really statistical analysis, instead it's a discussion of the methodology used to generate weather indices, so the title should be changed. I'd also like more detail. What descriptors would produce a rank of -2, as opposed to -3, for instance? Some kind of table that details terms or conditions related to each category are necessary, and/or examples of years falling under each category.
RESPONSE: Accepted. Concerning of the distribution of missing days, it is clearly presented in Fig. 3 (now 4) and for individual years described in the first paragraph of Section 3.2 (now 4.2), where we add also relative expression (the maximum of 11 days in 1810 represents only 3% of days and for other 19 years the number of missing days is less than 1% or even zero). To fulfill your request, we extended corresponding description as follows: "A total of 80 days is missing (i.e. around 3 days per year), tending towards the years 1803–1813 (66 days) with a maximum in 1810 (11 days, i.e. 3.0% of days in this year), followed by 1805 (9 days, i.e. 2,5%) and 1809 (8 days, i.e. 2.2%) (Fig. 4a). Only 14 days of missed observations occurred in 1814–1830 (with 0, 1 or 2 missing days per year, i.e. from 0 to 0.6%). As for annual distribution, the maximum of 10 missing days in February represent only 1.3% of all February days, whole 3 missing days in September correspond to 0.4% of all September days (Fig. 4b). Besides 9 missing days in August and October (1.0%), all remaining months had missing days below 1% of their days. Days with missing observations may in some way decrease presented frequencies of days with different climatic variables."
Concerning of the methodology of creation of indices in 3.2 (now 4.2, based on your comment, the title changed on Methods of analysis), it was changed as follows from point 2 of your comments above. It means, that we combined quantitative approach (based on distribution of corresponding data and number of days with some characteristics) with an expert approach based on expert knowledge of climate in the Czech Lands. There is clear that final version of monthly indices is influenced by character of basic data, their interpretation and climatic expertise of the researcher. But having no measured data we cannot expect more. Creating the indices in three iterations, there is practically impossible to give any "descriptors producing a rank of -2, as opposed to -3" as well as "any kind of table that details terms or conditions related to each category." But we did not resign on any prove of validity of our indices series. Some tests of a quality of indices interpreted can be the high and statistically significant correlation coefficients between our indices series and measured temperatures/precipitation series in Brno (Section 5.3, now 6.2). Based on it we believe that our rather subjective interpretation express quite well basic features of

corresponding temperature and precipitation variability (fluctuations) following from the meteorological measurements of the Brno station.

Page 6 lines 5-6-9. To what extent is this a relic of the reconstruction methodology, rather than a ‘true’ representation of the variability? This seems to be the same for the wetness indicators (lines 33-35)
RESPONSE: Here we just described what followed from our interpretation (for its uncertainties see Section 5.1 and the fourth paragraph of Section 5.3; now Sections 6.1 nad 6.2 respectively). Each interpretation of not exactly measured values of temperatures or precipitation bears some part of subjectivity, which is difficult to quantify. We are not searching here what is a reason of this variability, we are just commenting results we obtained using data and methods of this paper. On the other hand, we believe – in case of temperatures – it is a reflection of the fact described in previous point 3 where we mentioned that the years 1803–1830 were generally cooler. Then we may expect that negative extremes could be probably better expressed than positive.

Sections 4.1.2-4 and Figures 5-7. I'm not sure about the suitability of using absolute counts of days, given that the number of recorded days is so variable. Perhaps percentages would be better? This will depend of course on the distribution of missing days – if they are relatively regularly spaced through the year this would give a stronger justification for using percentages.
RESPONSE: Accepted. Fig. 6 (now 7) already contains information of missing days as mentioned in the figure caption in category “6) missing days or no information related to cloudiness.” Facts of missing days were already taken in account in the text in Section 4.1.3 (now 5.1.3). As for Figs. 5 and 7 (now 6 and 8), they were complemented directly by missing days as in Fig. 6 (now 7) and in related modifications of the text in Sections 4.1.2 (the second paragraph), 4.1.4 (the first paragraph) and 4.1.5 (the first and second paragraphs) if it was necessary (now Sections 5.1.2, 5.1.4 and 5.1.5). The complemented figures 5 and 7 (now 6 and 8) are presented below:

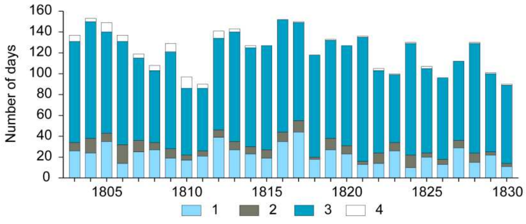


Figure 5 (now 6). Fluctuations in the annual number of precipitation days (1 – solid, 2 – mixed, 3 – liquid) at Buchlovice during 1803–1830 derived from the weather diary kept by Šimon Hausner (4 – missing days).

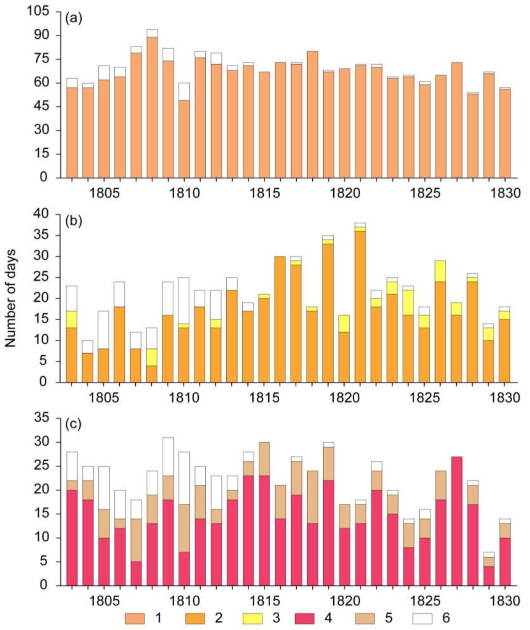
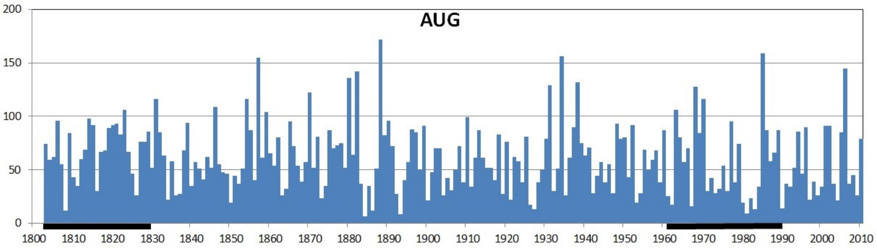


Figure 7 **(now 8).** Fluctuations in the annual number of days with selected phenomena at Buchlovice during 1803–1830 derived from the weather diary kept by Šimon Hausner: (a) strong wind (1); (b) fog (2 – fog, 3 – foggy); (c) thunderstorm (4 – at Buchlovice, 5 – distant thunderstorm) (6 – missing days).

Section 5.2 and figure 9. I think this is in the wrong place in the argument, and should come in the opening sections (before the methodology). This is describing the context of the Hausner diaries, not anything within the diaries themselves.
RESPONSE: Accepted. We thought that this section would be better after presentation of Hausner's observation and their analysis (i.e., the reader knows already anything about this observations), but we followed your request and shifted this section before the methodology.

Page 10 lines 15-24. Can you give any climatological suggestion for the substantially larger temperature increase to the modern period in winter compared to summer? Also, why do we see such a variation in both quantity and stdev of precipitation in August? Can this be explained by one or two years with particularly heavy rainfall during this month?
RESPONSE: Accepted. The winter months are much more variable than the summer months, when particularly negative deviations are going deeper with respect to mean temperature in winter than positive deviations. Moreover, the 1803–1830 period is a part of the last phase of the LIA, characterised generally by cooler winters compared to summer. These facts should be responsible in the substantial larger temperature increase in winter than in summer. By the way, also climate models give larger changes in winter than in summer temperatures.
As for August, differences between both period clearly follow from the figure below, showing long-term August precipitation fluctuations in Brno:



August of the first period 1803–1830 was generally wetter (mean 69.7 mm) and less variable (standard deviation 23.9 mm, variation coefficient 35.3%), while the second period 1961–1990 was drier (mean 56.4 mm) and more variable (standard deviation 38.7 mm, variation coefficient 68.6%).

Page 10 lines 47-49. Needs a reference
RESPONSE: Accepted, the reference Brázdil et al. (2012a) was added.

Page 11 – up to line 26. These comparisons are invalid, given the number of missing days in Hausner's records. Again, the use of percentages would be better, if this can be justified due to the distribution of the missing days. Also – as with the section above – can you suggest any climatological reason for the variation observed? It is true that location of the meteorological stations is likely to have an impact, but you are also looking at datasets separated by 130 years of a changing climate.
RESPONSE: Accepted. But we have some doubts, that "these comparisons are invalid", because the missing values can affect corresponding monthly values only in tenths of days. For example, if in February was missing totally 10 days during 1803–1828 (Fig. 4b), it represents in average uncertainty of 0.36 days. It means that monthly values could be theoretically underestimated maximally by values between 0.36 (February) and 0.11 (September) days. These values are not so high that should significantly change shapes of annual distribution of any analysed variables in Fig. 13. But take this comment in account, we included in the corresponding paragraph following sentence: "Because of missing Hausner's observations (see Fig. 4), his mean monthly values in Fig. 13a–d could be maximally underestimated by between 0.36 days (February) and 0.11 days (September) if in all missing days studied variables would be appearing. In case of annual values, possible maximum underestimation could achieve 3.36 days."

Editor

Regarding the possibility, that Hauser was biased by his earlier experiences: It could be worth to add a few words on this matter (either specifically referring to Hauser or more in general) in chapter 5.1.
RESPONSE: Accepted, following sentence was added in Section 5.1 (now 6.1): "But there is difficult to estimate how much was Hausner influenced in his weather observation by experience before their beginning in 1803 and how changed his weather perception during following 28 years of his records."

In regard to the reference period 1961-1990, I agree with the authors, that this is a widely accepted period. In order to avoid irritations, maybe you can add a publication, where this is explained, because also other reference periods are used in this context (e.g. 1901-1960, see Brázdil et al. 2005).
RESPONSE: Accepted, following sentence was added in recent Section 4, the last paragraph: "The selection of the reference 1961–1990 period followed from WMO (2017) guidelines, in which this period "has been retained as a standard reference period for long-term climate change assessments."
Reference:
WMO: WMO Guidelines on the Calculation of Climate Normals, WMO-No. 1203, World Meteorological Organization, Geneva, 2017.

The climate in south-east Moravia, Czech Republic, 1803–1830, based on daily weather records kept by the Reverend Šimon Hausner

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Abstract. Weather diaries constitute an important source of data for historical climatology, employed in the analysis of weather patterns for both the pre-instrumental and the early instrumental periods. Among the many weather diaries that exist in Europe, the daily records kept by the Reverend Šimon Hausner from Buchlovice in south-east Moravia (Czech Republic), covering the 1803–1831 period, are particularly useful. His qualitative daily weather descriptions enable the construction of series for temperature, precipitation, cloudiness, wind and other weather phenomena (particularly thunderstorms and fogs), supplemented by a number of phenological and agricultural work records. His data related to temperature and precipitation patterns were quantified into a series of weighted temperature and precipitation indices on 7-degree scales, which were subsequently compared with standard meteorological observations from the secular meteorological station in Brno. This comparison indicates that Hausner's observations were highly reliable and confirms the importance of his data for a better understanding of the variability of the regional climate in the period of early instrumental measurements in Moravia. At the same time, it reveals the importance of weather-related documentary data in the overlap period with instrumental meteorological observations.

1 Introduction

Recent historical climatology uses a very broad range of documentary evidence, including information about weather and related phenomena, for reconstructions of past climate variability (Brázdil et al., 2005a, 2010; White et al., 2018). Among such sources, visual daily weather observations are of particular importance, often appearing in the form of weather diaries (for the use of private diaries, see the overview paper by Adamson, 2015). Weather diaries usually contain qualitative descriptions of daily weather and, at varying degrees of detail, they also describe certain meteorological, hydrological and phenological events and their impacts.

Although weather diaries occur nearly over the world (see e.g. Glaser et al., 1991; Druckenbrod et al., 2003; Hirano and Mikami, 2008; Mikami, 2008; Zhang et al., 2013; Adamson and Nash, 2014; Lorrey and Chappell, 2016), Europe is a particularly rich region for them, spanning a period of almost eight centuries. The first known daily weather records, for 1269–1270, appeared in England, among a volume of papers by Roger Bacon (Long, 1974), followed by observations made by the Reverend William Merle in Lincolnshire from the years 1337–1344 (Lawrence, 1972). Further European weather diaries were reported in a paper by Pfister et al. (1999), with special reference to the 16th century. Some of these have been analysed in great detail, for example, in the Czech Lands (Brázdil and Kotyza, 1995, 1996) and in Poland (Bokwa et al., 2001; Limanówka, 2001). Other authors continue the story for the late 16th and early 17th centuries (Lenke, 1968; Metzger and Tabeaud, 2017). Still more such diaries then appeared in the 17th century (e.g. Chernavskaya, 1994; Bokwa et al., 2001; Brázdil and Kiss, 2001; Nowosad et al., 2007; Przybylak and Marciniak, 2010; Zwitter, 2013; Domínguez-Castro et al., 2015), as well as in the 18th century (e.g. Chernavskaya, 1994; Brázdil et al., 2008b; Raicich, 2008; Sanderson, 2018; Filipiak et al., 2019), at which point they start to occur concurrently with instrumental observations and take on some of the character of early instrumental meteorological observations; they have even been used to create long-term series of meteorological variables (e.g. Woodworth, 2006). They lose little importance even in the period of instrumental measurements, when they may add important supplementary data to measurements taken at meteorological stations (e.g. Lee and MacKenzie, 2010).

In what has become the Czech Republic in recent years, the earliest daily weather records appeared in south-eastern Moravia, where the Moravian nobleman Jan of Kunovice included daily weather entries into Stoeffler's ephemerides for the years 1533–1545 (Brázdil and Kotyza, 1996). Several other authors followed during the 16th century (for a summary overview, see Brázdil et al., 2013a). Worthy of special mention are the systematic daily weather records kept in the diaries of the Premonstratensian order in the Hradisko monastery (Olomouc) and the Svatý Kopeček priory, spanning the 1693–1783 period with meteorological data covering only 52 years. However, their records for the remaining years have not survived (Brázdil et al., 2008a, 2011). Fortunately, the 1780s are covered by systematic daily weather records kept by Karel Bernard Hein, a priest in Hodonice, south-western Moravia (Brázdil et al., 2003), followed by several others that describe only a few years (e.g. Brázdil et al., 2002a, 2007b). The fact that the later examples overlapped with early instrumental observations means that they made important contributions to knowledge of climate variability at a time when instrumental measurements were running at only a few stations.

Moreover, if such diaries were accompanied by individual instrumental data, they may form a basis for the creation of long-term series, linking them to subsequent standard meteorological observations. This occurred in Brno in South Moravia, where temperature series start in May 1799 and precipitation series in January 1803 (Brázdil et al., 2005b, 2006). Surprisingly, weather diaries supplemented by measurements of certain meteorological variables also appear as very useful sources of meteorological data far later, as is made evident by the example of the meteorological records kept by Alexander Zawadzki in Brno in 1861–1867 (Brázdil et al., 2013b) and Josef Lukotka in Vsetín in 1903–1923 (Brázdil et al., 2014).

The weather diary kept by Šimon Hausner, a priest in Buchlovice, south-east Moravia (Czech Republic), covering the years 1803–1831, is one such newly-discovered weather diary, overlapping with the period of early instrumental meteorological observations. The aim of this study is a comprehensive analysis of these long-term observations, which add to a basic analysis of observed data an emphasis on the importance of weather diaries for the better understanding of regional climatic variability and anomalies, as well as their impacts. Section 2 presents a basic account of Šimon Hausner and his diary, while Section 3 puts Hausner's observations into temporal context. After a description of methods used (Section 4~~3~~), the results of statistical analysis of his observations for individual meteorological elements and phenomena are presented in Section 5~~4~~. Uncertainty in Hausner's records, their temporal context, and comparison of the results obtained with meteorological observations from the secular Brno meteorological station are discussed in Section 6~~5~~. The final section contains some concluding remarks.

2 Šimon Hausner and his weather diary

Šimon Hausner, the author of the weather diary under discussion, was born on 27 October 1756 at Odry in northern Moravia to a German Catholic family (for the locations of places mentioned herein, see Fig. 1). He was called to a priestly career and on 23 September 1780 was ordained as a priest. Until 1784 he was a chaplain, probably in the Buchlovice parish. In that year he left for Žeravice, where he served as a local chaplain [*lokalista*] until 1796. On 6 June 1796, the owner of Buchlov domain, Anežka Eleonora Petřvaldská, elevated him to the position of parish priest in Buchlovice. He also served as a priest for the parishioners of four nearby villages, with whom he communicated in the Czech language. From 1800 onwards, when the Buchlov domain passed into the hands of the Berchtold family, Hausner's relationship with this family deteriorated. He prepared a Latin chronicle called *Memorabilia Hausneriana*, but this was lost at the end of the 19th century. He made records of inscriptions and recorded interior descriptions of the surrounding churches and chapels, most of them no longer standing. He devoted particular attention to the baroque church of Saint Martin and nearby manse in Buchlovice. When the tower of this church was destroyed by a lightning strike on 4 August 1806, he gave financial support to the renovation of the church. A flash flood did heavy damage to the area on 12 June 1825 and, in a similar spirit, he organised financial collections in surrounding villages to help people affected by the disaster. He died of severe pneumonia on 26 January 1831 at Buchlovice (Žižlavský, 1998; Hrdý et al., 2005; archival source AS1; AS2).

Hausner's weather observations, written in German, are part of a hand-made book in the keeping of the Moravian Land Archives in Brno (AS3). The German title appears on the flyleaf, written in a hand other than Hausner's: *Tägliche Witterungs-Beobachtungen des Buchlowitzer Pfarrer Simon Hausner von Jahren 1803 bis 1831 excl*. ["Daily weather observations from the Reverend Šimon Hausner of Buchlovice from 1803 to 1831"]. The first weather record appears for 1 January 1803 and the last for 15 January 1831 (Fig. 2), very shortly before he passed away. The author described the weather day by day. Some of the records are quite short; for example, for 3–5 February 1805 (AS3, p. 34): "*3* [February]. *Overcast all day. 4* [February]. *Same, both days glaze ice. On the 5th* [the night of 4/5 February] *west wind and snowfall. 5* [February]. *Again thawing*." Other entries go into more detail, even describing the weather at various times of the day; for 20 July 1828 (AS3, p. 851) his notes read: "*a pale sunrise, nice sunshine, very hot sunshine from noon to 4 p.m., at 5 p.m. became a little more agreeably cool. In the evening at 10 p.m., heavy rain, soon followed by a very heavy downpour together with a windstorm that continued until the first hour after midnight. S.V.V.* [south-west wind]".

The weather records for the majority of months end with a summarising evaluation of the given month. For example, for March 1808, he wrote (AS3, p. 109): "*Very hard frosts during the whole of March, which were stronger* [as those] *in December and January. The soil was frozen to a depth of two feet* [*c.* 63 cm]*, dust when walking and riding, almost as if it were in summer; no snow at all, fields without cover,* [exposed to] *cold winds, severe frosts at night, nice sunshine during the day*". On other occasions, he repeated the weather for certain days or mentioned events previously not reported for individual days; for example, the entry for May 1825 reads (AS3, p. 736): "*The first four days* [of May] *were cold enough, from 4th to 7th very scorching sunshine, from 7th to 14th gloomy and overcast,* [from 14th] *on 15th heavy frost that damaged vineyards, from 15th to the end* [of May] *variable, weather very cold; it was very pleasant in a well-heated room. Several showers that only damped the dust down, none abundant*."

At the end of every year he prepared a weather summary for the whole year; for example the entry for 1803 reads (AS3, p. 13): "*The winter of this year was very cold, with severe frosts for six weeks* [and] *a large quantity of snow fell; the spring was cold and wet, it rained nearly all summer, making it cold and wet. The autumn was cold and rainy but mid-September was warmer.*" This account of the weather was usually followed by information concerning the growth of crops and harvests, for example the entry for the year 1811 reads (AS3, pp. 210–212): "*All of September was dry for the straw and the vintage came as early as 17th* [September]*, due to periods of great heat. All kinds of cereals, legumes, cabbage and potatoes did not yield*. [...] *Very small* [yield] *of cherries,* [which] *were wormy and rotted. Also only a few apples on the trees* [...] *Very few pears* [...] *Few apricots* [...] *A lot of plums in some places* [...] *This year's wine was very good in quantity and even better in quality.* [...] *Autumn sowing went well. Fields were cultivated in dust* [...]." Hausner's annual summaries are often accompanied by further information, very often reporting prices of grain, fruit and vegetables, etc.

3 The temporal context of Hausner's observations

Part of the unique character of Hausner's observations arises out of their development of meteorological observations in Moravia and Silesia (Silesia here understood as its Moravian section). The earliest surviving instrumental measurements of several meteorological elements, provided by František Alois Mag of Magg, a physician in Telč, appear in his second diary, in entries between 7 May 1771 and 9 March 1775. Although his diary contains references to his first and third diaries, i.e. Mag was observing before 1771 and after 1775, these have not yet come to light (Brázdil et al., 2002b). Further systematic daily weather records, but without instrumental measurements, were provided by Karel Bernard Hein, a priest in Hodonice, covering the period between 1 February 1780 and 5 October 1789 (Brázdil et al., 2003). Some indications of meteorological conditions (pressure, temperature, moisture, evaporation, wind) for the 1790–1794 period, kept by Josef Gaar, a professor at the Olomouc lyceum, follow from tables and figures included in the description of the climate of Moravia entitled *Anleitung zum Kenntnis des Erbmarkgrafthumbs Mähren* ["An Introduction to Knowledge of the Moravia Margraviate"] by Kryštof Passy, 1797 (Brázdil and Valášek, 2001). Continuous meteorological observations began in Brno in May 1799, provided by Ferdinand Knittelmayer, a retired military captain. From 1 January 1803, these records were supplemented by those of Zacharias Melzer, a land accountant who took regular precipitation measurements (Brázdil et al., 2005b, 2006). Both measurements enabled the compilation of secular homogenised Brno temperature and precipitation series, comparable to the already-known Prague-Klementinum measurements in Bohemia (Pejml, 1975; Brázdil et al., 2012a). The creation of "economic societies" in the Austrian empire, intended to support the general economic development of the country, was of key importance to the further development of instrumental meteorological observation in Moravia and Silesia, through the efforts of the I. R. Moravian-Silesian Economic Society, part of this project. This Society organised a network of meteorological stations (Fig. 3), collating the results of their observations (AS5). These are usually, however, relatively short and entries for many months are missing. Meteorological observations from Jihlava, where Andreas Sterly, a town councillor, kept daily observations in the 1816–1840 (1844) period, are an exemplary exception among these stations (Brázdil et al., 2007a). This overview demonstrates the high importance of Hausner's observations, bridging a spatial gap on the one hand and covering very long period with otherwise only few observations for Moravia on the other.

4~~3~~ Methods

4~~3~~.1 Interpretation of Hausner's weather records

Hausner deployed a wide vocabulary to describe the weather and its changes during the day. Although his records often cover an entire day, his mode of specification often enables attribution of the phenomena described to the morning, afternoon, evening and night-time hours. To simplify this for the purposes of analysis, the night and morning hours have generally been taken together, as well as afternoon and evening hours (using noon and midnight as the dividing times). Hausner's terminology permitted analysis of the following weather patterns and phenomena in the fashion described below:

(i) temperature patterns

Hausner used a wide range of words for description of temperature conditions. Warm weather was characterised as warm [*warm*], modified by rather [*ziemlich*] or very [*sehr*], hot [*heiß*, *heißer Tag*] or sultry [*schwül*]. Warming in the winter months with snowmelt was described as *Tauwetter* or *getaut*. Mud [*Koth*] or muddy [*kothig*] often followed. For cold weather he used the terms cold [*kühl*, *kalt, Kälte*], very cold [*sehr kalt*], "piercing" cold [*durchdringend kalt*] or horribly cold [*grimmige Kälte*]. Frost [*Frost, gefroren*] was modified as light [*klein*], negligible [*unbedeutend*], bearable [*leidtlich*], heavy [*stark*] or very heavy [*sehr stark*]. Hoarfrost [*Reif*] was reported separately. Hausner also indicated cold weather indirectly by remarks such as "a fur coat and a heated room were very good" [*der Peltz und geheitzte Zimmer waren sehr gut*]. Particularly in the winter months, the weather was also described as mild [*lind, lindes Witterung*] or very mild [*sehr lindes Witterung*]. An indication of temperature patterns also appeared in wind descriptions, characterised as warm [*warm*] or very warm [*sehr warm*] wind, and cold [*kalt*] or very cold [*sehr kalt/kühl*] wind.

(ii) precipitation patterns

Hausner characterised individual types of precipitation as drizzle [*nieseln*, *wie aus dem Nebel geregnet*]; rain [*Regen*, *regnerisch, geregnet*], modified as "fine" [*klein*], light [*lind*], negligible [*unbedeutend*], weak [*Regen, der den Staub gelöscht*], average [*mittelmäßig*], heavy [*ausgiebig*], very heavy [*sehr stark*], continuous [*beständig*], frequent [*öfters*], showers [*Streifregen*], downpour, cloudburst or torrential rain [*Platzregen*, *Gussregen, Guss, gegossen*]; snow [*Schnee, geschneit*] modified as light [*wenig*] or heavy [*stark*]; and ice pellets [*Graupen*] or hail [*Hagel, Schlossen*], sometimes described as small [*klein*]; black ice was *Glatteis*. Even the depth of snow was specified (e.g., *Schnee auf 2 Zoll* [*c*. 5.3 cm] *gefallen*). Dry weather was indicated by the term dry [*trocken*], modified as very [*sehr*] or extraordinary [*außerordentlich*]. A month without rain was *Monat ohne Regen*.

(iii) sunshine and cloudiness

Hausner often started his daily weather records with the character of the sunrise [*Sonnenaufgang*], modified as gloomy [*trüb*], pale [*blass*], weak [*schwach*], nice [*schön*], nice red sky [*schöne Morgenröthe*]. Sunshine [*Sonnenschein*] was specified as nice [*schön*], beautiful [*prächtig*], very pleasant [*sehr angenehm*], weak [*schwach*], very weak [*sehr schwach*], partial [*teilweise*], broken [*gebrochen*], rare [*selten*], intermittent [*abwechselnd*], warm [*warm*], and very hot [*sehr heiß*]. He often specified the duration of sunshine during a day by the hours at which it began and ended; short, variable sunshine was identified as *Sonnenblicke*. A "nice day" [*schöner Tag*] was opposite to a "sad day" [*trauriger Tag*]. Days without sunshine were described as overcast [*überzogen*, *trüb*].

(iv) wind patterns

Information about the wind [*Wind*] appears in the diary with some degree of regularity. Broadly, wind intensity (force) was characterised as average [*mittelmäßig*], strong [*stark*], very windy [*sehr windig*], very strong [*sehr stark, sehr heftig*], "awful" [*fürchterlich*] and extraordinary [*außerordentlich*]. Windstorm [*Sturmwind*] was worthy of special mention, as were blizzard [*Schneegestöber*] and whirlwind [*Wirbelwind*]. Only seldom did Hausner record calm [*windstill*]. Wind directions were described on an 8-degree scale, usually written in the form of abbreviations.

(v) meteorological phenomena

Hausner recorded thunderstorm phenomena systematically, discriminating between their occurrence as thunderstorm [*Donnerwetter*, *Wetter*] local to Buchlovice and distant thunderstorms [*Wetterlichten*, *geblitzt, gedonnert*] at a greater distance. He also reported on places other than Buchlovice, particularly if some damage had occurred. Bad visibility was characterised as foggy [*neblich*] or directly as fog [*Nebel*], modified as light [*klein*] or dense [*stark*]. For especially dense fog he reported on the number of places at which it was possible to see with respect to dominant objects in the immediate surroundings (e.g. the local chateau, statues of the saints).

(vi) phenological data

As a meticulous observer, Hausner also recorded certain phenophases of crops and fruit trees, including corresponding agricultural work. He gave close attention to the dates of spring and autumn sowing, the beginning and end of blossom on fruit trees, the progress of cereals and grapevines, the beginning of harvest for individual cereals, and the start of the vintage.

~~3~~4.2 Methods of~~Statistical~~ analysis

From a statistical point of view, it is important that only relatively few daily records are absent from Hausner's diary (Fig. 4~~3~~). A total of 80 days is missing (i.e. around 3 days per year), tending towards the years 1803–1813 (66 days) with a maximum in 1810 (11 days, i.e. 3.0% of days in this year), followed by 1805 (9 days, i.e. 2.5%) and 1809 (8 days, i.e. 2.2%) (Fig. 4a). Only 14 days of missed observations occurred in 1814–1830 (with 0, 1 or 2 missing days per year~~)~~, i.e. from 0% to 0.6%). In terms of annual distribution, the maximum of 10 missing days in February make up only 1.3% of all February days, while 3 missing days in September correspond to 0.4% of all September days (Fig. 4b). With the exception of 9 missing days in August and October (1.0%), all the remaining months missed fewer than 1% of their days. The days with missing observations may have a minor effect on the results for frequencies of days with various climatic variables. On the other hand, not all possible meteorological elements or phenomena are covered systematically in the daily records, a factor that may then be reflected in incomplete frequencies of days with these characteristics or phenomena.

With respect to the character of Hausner's daily weather records, it proved impossible to apply some of the newer quantitative approaches to interpretation of monthly temperature and precipitation indices (see e.g. Fernández-Fernández et al., 2017; Filipiak et al, 2019). This led to our using a version of the approach after Pfister (1992), broadly applied, combining different kinds of sources and their expert evaluation. Information related to temperature patterns was used to interpret monthly temperature indices by expression on a 7-degree scale: –3 extremely cold, –2 very cold, –1 cold, 0 normal, 1 warm, 2 very warm, 3 extremely warm (Pfister, 1992). Interpretation of temperature indices took into account the broad scale of indicators derived from Hausner's records: the monthly frequencies of cold days (severe frost, frost, cold, very cold) and warm days (warm, very warm, hot, very hot, mild), warm and cold winds, monthly summary reports, early and late beginnings of certain phenophases and agricultural work and also, to some extent, cloudiness (e.g. clear and overcast days) and precipitation (state of precipitation, monthly temperature–precipitation relationships). The interpretation herein was realised in the following iterations:

(i) Pfister (1992) recommended attribution of regularly-distributed 7-degree indices to a dataset ordered from the lowest to the highest values: index –3 was employed for 8.3% of the total, the lowest values, –2 for 16.6% for the following values, and onwards with values 16.6% for each of the subsequent indices (–1, 0, 1, 2), up to 8.3% for the highest values, attributed to index 3. This approach was applied separately to the monthly frequencies of cold days and warm days in 1803–1830, which enabled the attribution of an index to each of the months. In indexing the months of the winter half-year, rather cold days and in the months of the summer half-year, rather warm days were considered.

(ii) Monthly indices from point (i) were further evaluated in terms of the structure of cold and warm days, with particular respect to their intensity, based on which the corresponding month might be moved to a neighbouring category. For example, a higher proportion of hot or very hot days constituted a reason for movement to a "warmer" category (e.g. from index 1 to index 2), similarly as a higher proportion of weak frosts or cold days compared to severe frosts and very cold days (e.g. from index –2 to index –1). Indications of warm and cold winds as expressions of the character of air advection were also considered.

(iii) All indices from iteration (ii) were further considered with respect to monthly temperature summaries and earlier/later onset of phenophases, indicating cooler or warmer patterns in preceding months. Further, information about cloudiness was used as an additional parameter (days with higher sunshine duration being warmer compared to cloudy days). The occurrence of snowfall or snow cover also indicated cooler patterns. The relationships between warm/dry and cold/wet months were also considered for months of the summer half-year. All these factors could again lead some months being shifted to a neighbouring category.

The indices fixed after the third iteration were then considered the final version of weighted monthly temperature indices.

Also precipitation indices were interpreted in similar fashion: –3 extremely dry, –2 very dry, –1 dry, 0 normal, 1 wet, 2 very wet, 3 extremely wet (Pfister, 1992). The interpretation of monthly precipitation indices was again based on a number of indicators in Hausner's records: ~~made on the basis of~~ monthly frequencies of precipitation days, with particular reference to type of precipitation (e.g. snow, drizzle, rain, snow with rain), to precipitation intensity and duration of precipitation spells (as specified in daily records) and to summary monthly reports as well as other indications of wet or dry patterns (e.g. effects on agricultural crops or work in the fields). This interpretation included three iterations:

(i) The numbers of monthly precipitation days of the given months in 1803–1830 (28 years) were ordered from lowest to the highest. Following the percentage distribution by Pfister (1992) presented above, corresponding 7-degree indices from –3 to 3 were formally added to individual months.

(ii) Based on additionally-reported type, intensity and duration of precipitation, the corresponding months remained at their already-defined degree from point (i) or were moved to a neighbouring degree. For example, more days with drizzle, short or light precipitation were favourable to a shift towards a "drier" index (e.g. from index 2 to index 1), or days with the all-day rain or heavy precipitation during thunderstorms might favour an opposite attribution to a "wetter" index (e.g. from index –1 to index 0).

(iii) All indices from point (ii) were further evaluated from the point of view of summary information concerning the character of precipitation within given months, or in the light of any other precipitation-sensitive information. As in the previous iteration (ii), some months could be moved to an adjacent degree.

After these three iterations, the corresponding monthly precipitation indices were considered as final.

Naformátováno: Odsazení: První řádek: 0 cm

Seasonal temperature and precipitation indices were then calculated as the sums of indices of three consecutive months (e.g. June, July and August for summer). Annual indices were calculated in similar fashion (Fig. 5~~4~~). Hausner's daily weather records also provided interpretations of annual numbers of precipitation days (with division into those with solid, mixed or liquid precipitation), cloudiness, strong winds, periods of fog and thunderstorms (Figs. 6~~5~~–8~~7~~). Further, they enabled the creation of annual series of some phenophases and agricultural work, presented herein as graphs and box-plots (Fig. 9~~8~~).

Temperature and precipitation series for the town of Brno, homogenised at the position of the Brno airport meteorological station – φ = 49º09'11" N, λ = 16º41'20" E, H = 241 m asl (Brázdil et al., 2012a), were used to compare temperature and precipitation patterns in Hausner's 1803–1830 period with a modern reference covering 1961–1990 (Fig. 10). The selection of the reference 1961–1990 period followed from WMO (2017) guidelines, in which this period "has been retained as a standard reference period for long-term climate change assessments." Variability of monthly temperatures was characterised by standard deviation, while variation coefficient was applied to monthly precipitation. Series of seasonal temperature and precipitation indices for Buchlovice (φ = 49º05'06" N, λ = 17º20'04" E, H = 264 m asl) interpreted from Hausner's records were compared with temperature and precipitation series for Brno using Pearson correlation coefficients (evaluated at the 0.05 significance level) and by graphical expression (Figs. 11–12). Finally, the numbers of days with selected climatological characteristics (precipitation days, cloudiness, strong wind, fog, thunderstorm) at Buchlovice in 1803–1830 were used to compare their annual variations with those corresponding to 1961–1990 at the Brno airport station, the Buchlovice rain-gauge station (φ = 49º05'15" N, λ = 17º20'44" E, H = 268 m asl) and the Staré Město meteorological station (φ = 49º05'30" N, λ = 17º25'54" E, H = 221 m asl) (Fig. 13).

5~~4~~ Results

5~~4~~.1 Individual meteorological elements and phenomena

5~~4~~.1.1 Air temperature

Based on the criteria reported in Section 4~~3~~.2, series of weighted temperature indices I_T for Buchlovice in 1803–1830 were created (Table 1). As follows from fluctuations of annual temperature indices (Fig. 5~~4~~a), the year 1822 was interpreted as the warmest ($I_T = 9$) and 1805 as the coldest ($I_T = –16$). The year 1829 was also very cold ($I_T = –13$) and a remarkably cold period occurred in 1812–1816. In terms of individual seasons (winter – DJF, spring – MAM, summer – JJA, autumn – SON), I_T values corresponding to the coldest seasons were higher than those of the warmest seasons (–8 for 1829/1830 and 5 for 1821/1822 for DJF, –5 for 1805 in MAM and SON and 3 for several years in MAM and SON) except JJA, for which the highest index (8) was achieved in 1811 and the lowest (–6) in 1821.

Information concerning temperature indices may be supplemented by records of late frosts (April–June) causing damage to agricultural crops, depending on their stages of phenophase. Severe cold snaps in May, expressed by frost and damage, were not explicitly mentioned in 1803–1805, but there are reports of a need of "*fur coats and a heated room*" on 17 and 20 May 1803, 13–14 May 1804 and 24–25 May 1805. On 24 June 1806, frost damaged cucumbers. Grapevines, maize and beans suffered severe frost on 6 June 1810. Despite severe frosts recorded on 26–27 May 1812, Hausner reported no damage to crops. Severe frosts on 28–30 April 1814 ("*ice an inch* [*c*. 2.6 cm] *deep on the water*") damaged grapevines and fruit trees ("*blossoms and the leaves on the trees as if scalded by hot water*") (AS3, p. 301); frosts also returned on 11–13 May. After severe frosts on 16–20 April 1815, Hausner reported lesser frosts on 29–30 May that damaged beans again. After reporting how useful "*a fur coat and a heated room*" were in May 1818, Hausner recorded a severe frost on 1 June that froze cucumbers and beans planted in higher positions. Severe frosts on 21–22 June 1821 damaged cucumbers and beans in lower positions, as well as beans and potatoes in higher locations. A "strong" frost on 15 May 1825 damaged the greater part of the vineyards around Buchlovice, as well as maize and cucumbers. The summary evaluation of a very cold January in 1820 is also interesting, when Hausner noted that "*many people froze through their own fault because they drank a little more*" (AS3, p. 529).

5~~4~~.1.2 Precipitation

Based on the criteria reported in Section 4~~3~~.2, series of weighted precipitation indices I_P for Buchlovice in the 1803–1830 period were created (Table 2). As follows from fluctuations of annual precipitation indices (Fig. 5~~4~~b), the year 1803 was interpreted as the wettest ($I_P = 8$) and the year 1808 as the driest ($I_P = –12$), followed by 1810 and 1825 ($I_P = –11$). A markedly consistent drier period occurred in 1805–1811. Extreme values of I_P for individual seasons were: DJF: 4 for 1826/1827 and –6 for 1812/1813 and 1820/1821; MAM: 4 for 1812 and –5 for 1808 and 1825; JJA: 5 for 1813 and –7 for 1808; SON: 3 for 1813 and –7 for 1815.

The precipitation indices may be supplemented by annual numbers of precipitation days (Fig. 6~~5~~). After a maximum in 1804 (150 days, 3 days of Hausner's observations missing), these numbers decreased to minima in 1810 and~~–~~ 1811 (86 days each, 11 and 4 missing days respectively). Between 1812 and 1821, the frequencies of precipitation days were higher than 120 days per year, with maxima in 1816 and 1817 (152 and 149 days respectively, 1 day missing in 1817). After 1821, frequencies fluctuated around 100 days per year except for two local peaks in 1824 and 1828. Liquid (rain, drizzle) precipitation clearly prevailed in all years recorded. Solid precipitation (snow, ice pellets, hail) reached a maximum in 1817, while mixed precipitation (previous types of precipitation with rain) prevailed in 1806 (6 days missing).

Torrential rain doing damage constitutes an important element of precipitation patterns. A downpour with thunderstorm on 22 May 1805 was the heaviest that Hausner had experienced in Buchlovice up to that time. He reported damaging torrential rain with a very violent thunderstorm on 26 April 1808 for Osvětimany, Stříbrnice and Polešovice; the damage was particularly acute in Polešovice. At the same time, rain mixed with hail fell at Buchlovice. Rain accompanying a thunderstorm on 25 June 1808 was so heavy that it "*did great damage in some places*" (AS3, p. 116). Heavy, torrential rain on 28 May 1810 flooded all the meadows and gave rise to a flash flood that swept away animals as well as wooden laths and beams and other items; even the oldest people in Buchlovice could not recall a comparable event. Torrential rain on 2 June 1814 flooded meadows and spoiled the hay. Only general "*damage*" was reported after a heavy downpour accompanied by small hailstones associated with a thunderstorm on 27 May 1819. A heavy downpour on 19 August 1821 flooded meadows, as did otherwise unspecified heavy rain in June 1827. Extraordinarily torrential rain on 12 June 1825, accompanied by an "awful" thunderstorm, flooded meadows, did heavy damage to field crops (hail), swept away houses (flash flood) and cost three people their lives.

5~~4~~.1.3 Cloudiness

Cloudiness was derived from Hausner's records of sunshine and clouds. Because of interpretation in terms of clear sky, half-covered sky and overcast sky, divided into the whole day, night and morning hours, and afternoon and evening hours, five intervals were defined for cloudiness: 1) clear sky, 2) clear sky in one part of the day and half-covered sky in the other part, 3) half-covered sky, 4) half-covered sky in one part of the day and overcast in the other part, and finally 5) overcast. As is evident from Fig. 7~~6~~, Hausner's records did not permit interpretation of cloudiness patterns in the greater parts of the days in 1803–1812 (maximum 90 days in 1806).This was also reflected in smaller proportions of cloudy days (that is, with cloudiness in categories 2, 3 and 4). Despite 69 days with non-interpreted cloudiness and some missing reports in 1811, the highest number of clear days (103) and a lowest number of overcast days (104) were derived. This correlates well with warmer patterns in MAM–JJA and drier patterns in JJA–SON of this year (Tables 1 and 2). The warmest, also somewhat drier, year of 1822 had the highest number of cloudy days (172) and also an above-mean number of clear days (82) and a below-mean number of overcast days (105); 6 days were without cloudiness interpretation. The lowest number of 59 clear days was derived for 1828 and the highest number of 175 overcast days for 1820.

54.1.4 Wind

Fig. 87a shows fluctuations in the annual frequency of days with strong winds at Buchlovice during 1803–1830. Days upon which Hausner mentioned strong or very strong winds, very windy weather, "awful" wind, extraordinary wind, windstorm or blizzard were interpreted as having strong winds (see Section 4.1, point (iv)). Their frequency generally increased from the beginning of observations until 1808, when the highest frequency of 89 days was achieved (4 days missing from Hausner's observations). After that, a general decreasing tendency in the number of days with strong winds is noticeable. The lowest frequency was recorded only two years later after the absolute maximum in 1808: 49 days with strong winds in 1810; however, a total of 11 days are missing from Hausner's observations.

Information concerning strong winds may be supplemented by the quite natural attention drawn to severe events. Hausner made several records of "awful" or very strong whirlwinds of short duration: on 14 November 1806 people were knocked to the ground, and 14 March 1817, 7 June 1819, 15 and 20 June 1822, and 29 June 1825 were also notable. However, the only "whirlwind", on 14 May 1823, could be considered a probable tornado, accompanied by thunderstorm and downpour, because of the extensive damage recorded, particularly to roofs, barns and houses. But damage done by strong winds is described only very briefly in Hausner's records. Damaging windstorms may be attributed with a high degree of possibility to events on 30 April 1814 (many branches of trees broken), 26 July 1822 (much damage) and 26 May 1830 (broken trees, together with thunderstorm and downpour). During a heavy blizzard on 24 November 1815 it was not possible to walk, or even to ride with wagons (similarly harrowing winds also occurred on 7–9 December). People knocked to the ground (albeit the frailer) by wind were reported for 12 May 1810, 11 February 1821 and 24 August 1828. It was barely possible to walk during very strong winds on 29 March 1811 and 7 December 1812. On 29 August 1818 and 2 September 1826, Hausner reported winds strong enough to knock fruit from the trees. A violent wind on 4 March 1808 "*made the windows noisy*" (AS3, p. 107) and a windstorm on 5 July 1817 was described as "*wanting to tear everything* [down]" (AS3, p. 423).

54.1.5 Fog and thunderstorm

Fluctuations in the annual numbers of days with fog (or foggy weather) appear in Fig. 87b and show quite inconsistent patterns during the 1803–1830 period. Some years, especially around the beginning of observations, appear to be underestimated (e.g. 1804, 1805, 1807 and 1808; Hausner's observations lack 3, 9, 4 and 5 days respectively). On the other hand, some annual numbers of days with fog appear very high (e.g. 36 days in 1821 and 33 in 1819 – 1 day missing from both; partly so in 1816 with 30 and 1817 with 28 such days, 1 day missing).

Annual frequencies of days with thunderstorm, divided into those occurring directly over Buchlovice and those further off (distant thunderstorms), fluctuate over a broad range (Fig. 7c): 30 such days were recorded in 1815 (29 days in 1819, 1 day missing) against only 6 days in 1829. Even though the last-mentioned is significantly below the other lowest frequencies (13 days in 1824 and 1830), the style and density of daily records for 1829 do not give rise to any clear uncertainty (1 day missing in all three years).

Heavy thunderstorms accompanied by damaging torrential rain, strong winds and/or hail, have already been reported. Lightning strikes are another peril of such events. Three consecutive strikes at Buchlovice on 4 August 1806 damaged a house, set the roof of a cellar on fire and damaged the tower and roof of the church. Hausner reported that Mařatice suffered a lightning strike and resultant fire on 2 August 1809. On 21 September 1813, during an intense thunderstorm with heavy downpour, lightning strikes hit Polešovice, Napajedla and Střílky, and started fires everywhere. He further mentions a terrible thunderstorm on 29 May 1826 in Koryčany but supplies no further details. Yet another awful thunderstorm on 10 July 1828 led to flooded meadows and the hail that accompanied it bruised grain, maize, vegetables and fruit trees along a broad belt.

54.2 Phenological data and agricultural work

Hausner's diaries also recorded certain phenophases and aspects of agricultural work directly attributable to the weather. In the course of the year, these entries could include the time at which spring sowing of cereals took place, the first tasks in vineyards, the blossoming of fruit trees and grapevines, the grain harvest, autumn sowing, and wine vintage. Fluctuations in the longest available series of such matters appear in Fig. 98. The start of spring sowing (particularly barley; four years missing in the series) fluctuated between 2 March (1822) and 14 April (1812) (Fig. 98a). The appearance of blossom on fruit trees was noted for several species. The most complete series were those for apricots, cherries and pears. Since series bias could arise out of the mixture of blossoming for early and late species, only the dates for cherries were employed (five years missing): their earliest blossoming was recorded for 15 April 1806, the latest for 10 May 1817 (Fig. 98b). The grapevines (Fig. 98c) blossomed earliest on 29 May 1822 and latest on 3 July 1814 (four years missing). Although Hausner often specified individual species for grain harvests, only series of general grain harvest beginnings (Fig. 98d) were long enough for validity (three years missing), fluctuating between 26 June (1811) and 5 August (1816).

Some remarkably early – or late – beginnings correlated well with extreme temperature patterns (compare Fig. 98 with Table 1). Extremely early sowing in 1822 followed a very warm DJF in 1821/1822 and a considerably late sowing in 1812 a remarkably cold April. The latest blossoming of cherry trees, in 1817, can also be attributed to an exceedingly cold April. A very early blossoming of grapevine and gathering of the grain harvest in 1811 reflected intensely warm patterns in May and June; blossoming of grapevine only a day earlier in 1822 followed a long warm period that had started as early as in November 1821. On the other hand, the latest blossoming, recorded in 1814, was related to an exceedingly cold May and very cold June. The latest grain harvest in 1816 (known as "the year without a summer" after the catastrophic Tambora volcanic eruption – Luterbacher and Pfister, 2015) was related to cold June–July patterns.

65 Discussion

65.1 Uncertainties in Hausner's observations

Hausner's style of keeping daily weather records and its systematic character, featuring a very low number of missing daily observations, leads to the assumption that he was a meticulous observer, and his observations gain a great deal of credibility thereby. Of course, as with other personal daily weather observations, a degree of subjectivity is inherent in his records, but it appears to have been kept to a minimum. But there is difficult to estimate how much was Hausner influenced in his weather observation by experience before their beginning in 1803 and how changed his weather perception during following 28 years of his records. He could not observe the full 24 hours of a day, i.e. he might miss some phenomena; for example those that took place by night if they left no imprint in the morning (perhaps the occurrence of light rain, short-term fog, etc.). These facts may find slight reflections in the frequencies of a few meteorological characteristics presented in Sect. 4. We therefore present some comparisons of Hausner's records with events documented by other sources.

The taxation records kept for the Buchlov domain mention a number of severe events that provided sufficient grounds for tax alleviation for the farmers affected, a bureaucratic process that left a distinct paper trail (see Brázdil et al., 2012b). For example, on 4 June 1820 local torrential rain with hail did damage to agricultural crops in Žeravice (AS4, fol. 5rv, 7rv). Although no such event appears in records for Buchlovice, Hausner wrote in his monthly summary for June of "*heavy downpours during which great* [quantities of] *mud buried meadows*" (AS3, p. 546). On 4 August 1823 hail led to damage in Stříbrnice, Osvětimany and Žeravice (AS4, fol. 18rv); no indication of such an event appears in Hausner's records. An awful thunderstorm, torrential rain, hailstorm and flash flood, with extensive damage, were reported in the broader area of south-eastern Moravia on 12 June 1825 (Brázdil et al., 2012b). Hausner described this outstanding event in great detail (AS3, p. 737): "[...] *faint sunrise, gloomy until 4 p.m., then awful thunderstorm together with* [such an] *exceptional cloudburst that all the meadows flooded, and houses were destroyed*, [while] *at Buchlovice two women and a child died; continuous north wind*." Details of damage at seven villages appear in the taxation records of the Buchlov domain: five people died and 103 cattle perished, while 52 houses, 18 barns, and 63 cowsheds and stables were washed away (AS4, fol. 27rv). Hausner also included this in a monthly summary as a "*terrible, dreadful downpour*" (AS3, p. 739) with a detailed list of corresponding damage in his annual summary (ibid., p. 757): "[...] *on 12 June, between 4 and 5 p.m., an awful thunderstorm occurred, cloudburst with hailstorm*: *young grapevines and grapes were knocked down, leaves and fruits torn from trees, beans, maize, cucumber, lettuce, cabbage, and kale fatally battered by hail. In many places grain totally battered down and tangled; in some places* [only] *less so, rye generally, wheat less, barley, oats* [...] *Due to a cloudburst, all meadows* [so] *clogged by stones and lumber that nobody will have any hay* [...]."

Hausner also mentioned an infamous flood that occurred in March 1830, following the extremely severe winter of 1829/1830 (Munzar, 2000; Munzar and Kakos, 2000). He reported it in a monthly summary (AS3, p. 906): "*March very cold month, snow, plenty of ice, it froze heavily* [...] *melting started on 18th* [March] *and such a large amount of water* [rose] *that many bridges over the River Morava were damaged totally or partially.*" Hausner's note for 7 January 1831 is also interesting (AS3, p. 931): "*In the evening, at 0900 and 1000 p.m.,* [the sky] *was very red*." This was caused by the aurora borealis, observed in Brno from 0630 p.m. of this day to 0200 a.m. of 8 January (Brázdil et al., 2005b).

~~5.2 The temporal context of Hausner's observations~~

~~Part of the unique character of Hausner's observations arises out of their development of meteorological observations in Moravia and Silesia (Silesia here understood as its Moravian section). The earliest surviving instrumental measurements of several meteorological elements, provided by František Alois Mag of Magg, a physician in Telč, appear in his second diary, in entries between 7 May 1771 and 9 March 1775. Although his diary contains references to his first and third diaries, i.e. Mag was observing before 1771 and after 1775, these have not yet come to light (Brázdil et al., 2002b). Further systematic daily weather records, but without instrumental measurements, were provided by Karel Bernard Hein, a priest in Hodonice, covering the period between 1 February 1780 and 5 October 1789 (Brázdil et al., 2003). Some indications of meteorological conditions (pressure, temperature, moisture, evaporation, wind) for the 1790–1794 period, kept by Josef Gaar, a professor at the Olomouc lyceum, follow from tables and figures included in the description of the climate of Moravia entitled *Anleitung zum Kenntnis des Erbmarkgrafthumbs Mähren* ["An Introduction to Knowledge of the Moravia Margraviate"] by Kryštof Passy, 1797 (Brázdil and Valášek, 2001). Continuous meteorological observations began in Brno in May 1799, provided by Ferdinand Knittelmayer, a retired military captain. From 1 January 1803, these records were supplemented by those of Zacharias Melzer, a land accountant who took regular precipitation measurements (Brázdil et al., 2005b, 2006). Both measurements enabled the compilation of secular homogenised Brno temperature and precipitation series, comparable to the already-known Prague-Klementinum measurements in Bohemia (Pejml, 1975; Brázdil et al., 2012a). The creation of "economic societies" in the Austrian empire, intended to support the general economic development of the country, was of key importance to the further development of instrumental meteorological observation in Moravia and Silesia, through the efforts of the I. R. Moravian-Silesian Economic Society, part of this project. This Society organised a network of meteorological stations (Fig. 9), collating the results of their observations (AS5). These are usually,~~

~~however, relatively short and entries for many months are missing. Meteorological observations from Jihlava, where Andreas Sterly, a town councillor, kept daily observations in the 1816–1840 (1844) period, are an exemplary exception among these stations (Brázdil et al., 2007a). This overview demonstrates the high importance of Hausner's observations, bridging a spatial gap on the one hand and covering very long period with otherwise only few observations for Moravia on the other.~~

6.2~~5.3~~ Hausner's observations and climate fluctuations

Based on comparison of 1803–1830 with the reference period of 1961–1990 from the long temperature and precipitation series for Brno, the period of Hausner's observations was notably cooler in the winter half-year (October–March) and in June than the reference; of the remaining months, only May and August were slightly warmer (Fig. 10a). With the exception of February and March, all months were also more variable according to ~~in terms of~~ standard deviation than in the reference period (Fig. 10c). Wetter patterns in the Hausner period prevailed particularly in August, when precipitation totals characterised by variation coefficient were significantly less variable (Fig. 10b,d). In contrast, drier patterns prevailed mainly in February, from April to July and in November (Fig. 10b); precipitation totals from May to July and in December were also more variable (Fig. 10d).

Fluctuations in seasonal temperature and precipitation indices, appearing in Tables 1 and 2, may be compared with seasonal temperature means and precipitation totals from observations at the Brno station in the 1803–1830 period (data for Brno are taken from Brázdil et al., 2012a). Seasonal temperatures (Fig. 11) offer the closest accordance between Hausner's Buchlovice series and the Brno series (expressed by Pearson correlation coefficient *r*) for DJF ($r = 0.924$), followed by MAM ($r = 0.904$) and JJA ($r = 0.891$). Consistency becomes lower in SON ($r = 0.829$). However, all correlation coefficients are statistically significant at the 0.05 significance level. The correlation coefficient for annual series ($r = 0.912$) is also statistically significant and very high.

Seasonal precipitation (Fig. 12), exhibits generally lower consistency between precipitation indices interpreted from Hausner's records for Buchlovice and measured totals in Brno. The JJA patterns show the highest similarity ($r = 0.920$); lower correlations pertain to SON ($r = 0.806$), DJF ($r = 0.779$) and MAM ($r = 0.757$) patterns; however, all Pearson correlation coefficients are statistically significant at the 0.05 significance level. The correlation coefficient for annual precipitation series achieves the same value as that for SON.

Despite generally close agreement between the Hausner temperature and precipitation series and those for Brno, some instances of greater or smaller disagreement appear. This is particularly evident in interpretation of temperature/precipitation indices on a 7-degree ordinal scale (Pfister, 1992), an approach that cannot cover both positive and negative extremes well. Moreover, the interpretation of indices depends heavily on the comprehensiveness and degree of representation in Hausner's weather descriptions. These also depend on the intensity of weather manifestations, which is best expressed by DJF, MAM and JJA temperatures and JJA precipitation (these are also expressed in the highest correlation coefficients appearing for these seasons and, with the exception of JJA, in higher values for temperatures compared with precipitation). While the distance between Brno and Buchlovice plays a generally negligible role in temperature patterns, the high spatial variability often associated with precipitation totals contributes to higher differences between the two places (Brázdil et al., 2012a).

Fig. 13 compares annual variations of selected climatological characteristics at Buchlovice, as interpreted from Hausner's records for 1803–1830, with those from meteorological observations at the Brno, Buchlovice and Staré Město stations in 1961–1990. Missing Hausner's observations (see Fig. 4), lead to mean monthly values in Fig. 13a–d being maximally underestimated by between 0.36 days (February) and 0.11 days (September), assuming that the studied variables appeared in all the missing days. For annual values, the possible maximum underestimation might achieve 3.36 days. The annual number of precipitation days according to Hausner's observations and to measurements at the Buchlovice rain-gauge station (Fig. 13a) is nearly the same (120.1 and

117.9 days respectively). Hausner recorded a higher frequency of such days especially in March, the summer months and October, while from November to February their frequencies were lower. The annual number of days with strong winds in Buchlovice (Fig. 13b) is higher than at the Brno airport station (67.4 and 48.1 days respectively); the same holds for the monthly figures (except February), with a maximum in April in both series. The higher numbers of such days at Buchlovice may clearly be attributed to the qualitative evaluation of wind force by Hausner contrasting with the strictly-selected wind-speed thresholds for Brno. The slightly higher annual numbers of days with thunderstorms (Fig. 13c) follow from Hausner's data compared with the Staré Město station (14.9 and 12.2 days respectively). Annual variations are nearly identical in general features for both Buchlovice and Staré Město, with a maximum in June. The number of days with fog (Fig. 13d), consist of a smoothed annual distribution with decreasing monthly frequencies from January to May–June followed by an increase towards December for Buchlovice. The Staré Město station shows a consistently higher numbers of such days, particularly from September to November (42 days with fog annually compared to 19.2 such days at Buchlovice). This may be attributed to the position of the Staré Město station in the valley of the River Morava, a location favouring the frequent occurrence of fog, as well as the use of a strict fog definition related to guidelines for meteorological observations. The horizon was also more-or-less limited in the vicinity of Hausner's dwelling in Buchlovice. A relatively simplified mode of expression was selected for comparison of cloudiness (Fig. 13e), dividing such days into those with clear sky, overcast sky and the remainder (cloudy sky). The comparison of Hausner's records at Buchlovice with the Staré Město station is complicated by the annual absence of 31.8 days or any interpretable records of them. However, it appears that interpretation of Hausner's entries compared to Staré Město overestimates the number of clear days (76.7 to 46.8 days annually) and underestimates the number of cloudy days (117.5 and 172.3 days respectively).

76 Conclusions

The following conclusions may be drawn from this analysis of the weather diary records kept by Šimon Hausner from Buchlovice in south-eastern Moravia, Czech Republic, in the first third of the 19th century:

(i) The Hausner's weather diary is a valuable source of meteorological and weather-related information from south-eastern Moravia in the 1803–1830 period. It enables the creation of a representative series of selected characteristics of temperature, precipitation, cloudiness, wind, other meteorological phenomena, and weather-related phenological events and agricultural work.

(ii) Interpretation of Hausner's weather observations also enables the creation of series of weighted temperature and precipitation indices for south-eastern Moravia, which may then be used in the overlap period with the early instrumental meteorological observations in the Czech Republic for a calibration/verification exercise in temperature and precipitation reconstructions that combine documentary and instrumental data.

(iii) Series of 7-degree weighted temperature and precipitation indices derived from Hausner's weather diary describe highly representative climate fluctuations in south-eastern Moravia during the 1803–1830 period. The cold period in 1812–1816 and the dry period of 1805–1811 are particularly worthy of note.

(iv) Hausner's data have great meteorological, climatological and phenological validity and significantly supplement the Czech database of historical-climatological data and extend knowledge of climatic variability of the first third of the 19th century in central Europe.

Data availability. The original daily weather records of Šimon Hausner are available in Moravian Land Archives, Brno, fund G 138, catalogue no. 851. Data used in graphs are available from the corresponding author.

Competing interests. The authors declare that they have no conflict of interest.

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Table 1. Weighted 7-degree temperature indices reconstructed from the daily weather records kept by Šimon Hausner in Buchlovice, 1803–1830.

Year	J	F	M	A	M	J	J	A	S	O	N	D	DJF	MAM	JJA	SON	Ann
1803	-1	-1	0	1	0	0	0	0	-2	-1	0	-1	-	1	0	-3	-5
1804	2	0	-1	0	0	0	0	-1	0	0	-3	-2	1	-1	-1	-3	-5
1805	-1	-1	-2	-2	-1	-1	-1	-2	0	-3	-2	0	-4	-5	-4	-5	-16
1806	1	1	0	-1	-1	-1	-1	0	1	-1	1	1	2	-2	-2	1	0
1807	1	1	-2	-1	1	0	1	3	1	1	1	1	3	-2	4	3	8
1808	0	-1	-3	-1	1	1	2	2	2	0	-2	-2	0	-3	5	0	-1
1809	-1	-1	-3	-2	1	0	0	2	0	-1	-1	1	-4	-4	2	-2	-5
1810	-1	0	1	0	0	-1	0	1	2	0	1	0	0	1	0	3	3
1811	-1	-1	0	0	3	3	3	2	0	1	-1	-2	-2	3	8	0	7
1812	-1	0	1	-3	0	0	-1	-1	-2	2	-2	-2	-3	-2	-2	-2	-9
1813	-2	0	-2	0	0	-2	-1	0	-1	-1	-1	1	-4	-2	-3	-3	-9
1814	0	-3	0	0	-3	-2	0	0	-2	0	0	0	-2	-3	-2	-2	-10
1815	0	0	1	0	0	0	-2	-1	-1	0	-1	-2	0	1	-3	-2	-6
1816	1	0	-1	0	0	-1	-2	-2	-2	-1	-1	-1	-1	-1	-5	-4	-10
1817	1	1	0	-3	0	2	0	0	1	0	0	0	1	-3	2	1	2
1818	0	0	0	1	0	0	1	1	0	0	-1	-2	0	1	2	-1	0
1819	-1	1	1	2	0	1	1	0	1	0	0	-1	-2	3	2	1	5
1820	-2	0	-1	1	0	-2	-1	2	0	1	0	-1	-3	0	-1	1	-3
1821	1	-2	-1	2	-1	-3	-2	-1	-1	0	1	2	-2	0	-6	0	-5
1822	2	1	1	1	1	1	1	0	0	2	0	-1	5	3	2	2	9
1823	-3	0	0	-1	0	-1	-1	1	1	0	0	0	-4	-1	-1	1	-4
1824	0	1	0	0	-2	-1	-1	0	1	1	1	2	1	-2	-2	3	2
1825	2	-1	-1	0	0	0	0	0	0	0	1	2	3	-1	0	1	3
1826	-2	-1	0	-1	-2	0	2	2	1	1	0	1	-1	-3	4	2	1
1827	0	-2	0	1	2	2	2	1	1	1	-1	0	-1	3	5	1	7
1828	1	-1	1	1	0	0	2	-2	0	-1	0	0	0	2	0	-1	1
1829	-1	-2	-2	0	-1	-1	1	-1	1	-1	-3	-3	-3	-3	-1	-3	-13

1830	-3	-2	0	0	0	1	1	1	-2	-1	0	0	-8	0	3	-3	-5

Table 2. Weighted 7-degree precipitation indices reconstructed from daily weather records kept by Šimon Hausner in Buchlovice, 1803–1830.

Year	J	F	M	A	M	J	J	A	S	O	N	D	DJF	MAM	JJA	SON	Ann
1803	2	0	0	0	2	1	0	0	0	1	0	2	-	2	1	1	8
1804	1	0	0	3	-1	1	1	0	0	0	1	0	3	2	2	1	6
1805	-2	1	0	0	2	0	-2	0	0	0	-2	0	-1	2	-2	-2	-3
1806	1	1	1	-1	-2	-3	0	2	2	-2	0	-1	2	-2	-1	0	-2
1807	0	1	-1	-1	-1	-1	0	-2	-2	-1	2	1	0	-3	-3	-1	-5
1808	-1	-1	-3	0	-2	-2	-3	-2	2	-1	0	1	-1	-5	-7	1	-12
1809	0	0	-2	0	-2	-2	-2	0	1	0	0	2	1	-4	-4	1	-5
1810	-3	0	0	0	0	-3	-1	-1	-1	-2	-1	1	-1	0	-5	-4	-11
1811	0	-1	0	1	0	-1	-1	-2	-1	-2	-2	1	0	1	-4	-5	-8
1812	0	0	3	0	1	0	1	0	-1	1	2	0	1	4	1	2	7
1813	-3	-3	0	0	1	2	2	1	1	2	0	1	-6	1	5	3	4
1814	1	-1	-1	-1	-1	3	-1	1	1	0	-1	2	1	-3	3	0	2
1815	1	-1	1	0	-1	2	1	1	-3	-2	-2	-1	2	0	4	-7	-4
1816	0	0	0	0	2	1	2	0	0	0	0	-1	-1	2	3	0	4
1817	-1	1	1	1	0	0	0	0	-2	1	-3	0	-1	2	0	-4	-2
1818	-2	-1	0	-1	1	-1	1	0	0	0	-1	-2	-3	0	0	-1	-6
1819	-1	1	0	0	0	0	0	1	-2	0	0	0	-2	0	1	-2	-1
1820	1	0	0	-1	2	1	-1	-1	0	0	0	-2	1	1	-1	0	-1
1821	-2	-2	0	0	0	1	2	1	1	-1	0	-1	-6	0	4	0	-1
1822	1	-3	1	-1	-1	-1	0	0	0	-3	-1	-2	-3	-1	-1	-4	-10
1823	-1	2	-2	-2	0	0	1	1	-1	0	-1	0	-1	-4	2	-2	-3
1824	-1	-1	-1	1	1	1	1	0	-1	1	1	0	-2	1	2	1	2
1825	0	-2	-1	-2	-2	0	-1	-1	-1	0	0	-1	-2	-5	-2	-1	-11
1826	-1	0	0	-1	0	0	-1	-2	-2	1	1	0	-2	-1	-3	0	-5
1827	2	2	2	0	0	1	-3	0	-1	0	2	0	4	2	-2	1	5
1828	1	1	0	0	1	1	0	0	-1	0	-1	0	2	1	1	-2	2
1829	1	-1	0	2	0	0	0	0	0	0	-1	1	0	2	0	-1	2

1830	-1	1	-1	2	0	-1	-1	-1	2	0	-2	0	1	1	-3	0	-2

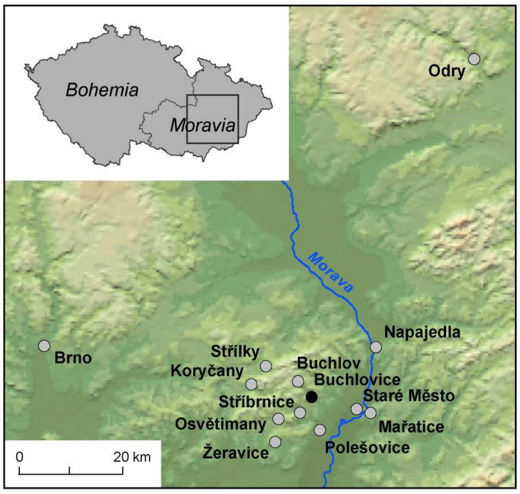


Figure 1. Locations of places within the Czech Republic referred to in this article.

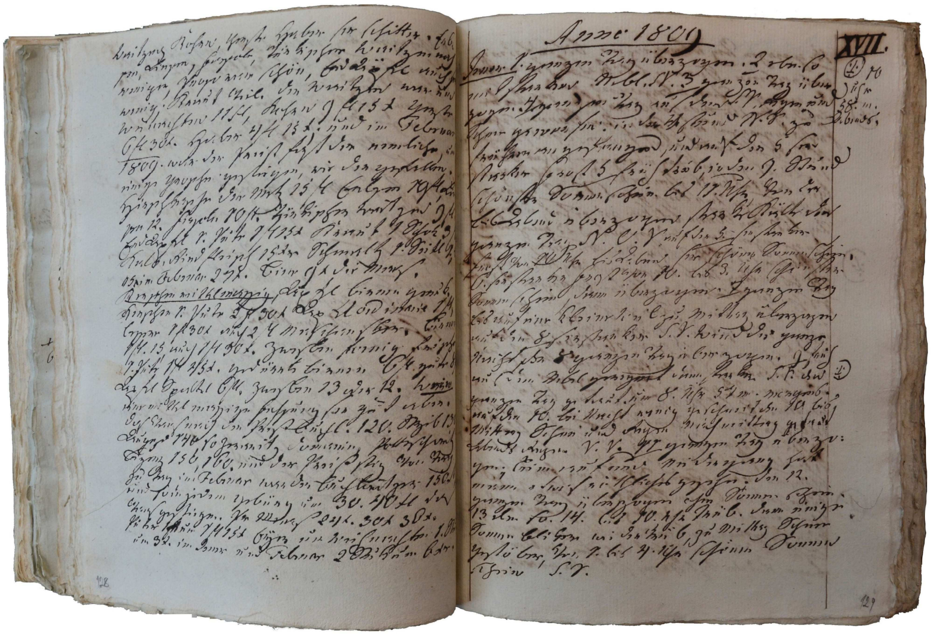


Figure 2. Example of pages from Hausner's weather diary, with records from the end of 1808 (left) and the beginning of 1809 (right) (AS3).

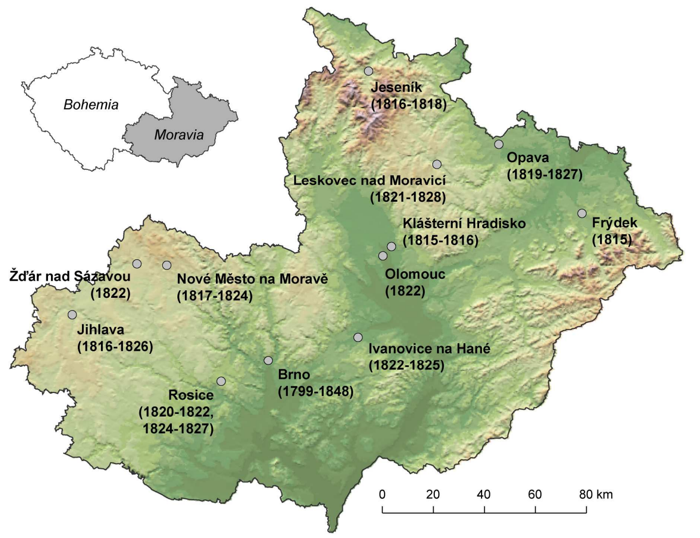


Figure 3. Network of meteorological stations in Moravia and Silesia as organised by the I. R. Moravian-Silesian Economic Society (years indicate available meteorological observations preserved in AS5).

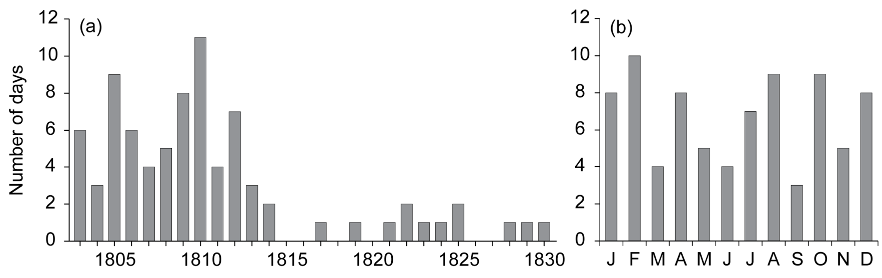


Figure 43. Days missing from daily weather records kept by Šimon Hausner at Buchlovice during 1803–1830 (a) and their annual variation (b).

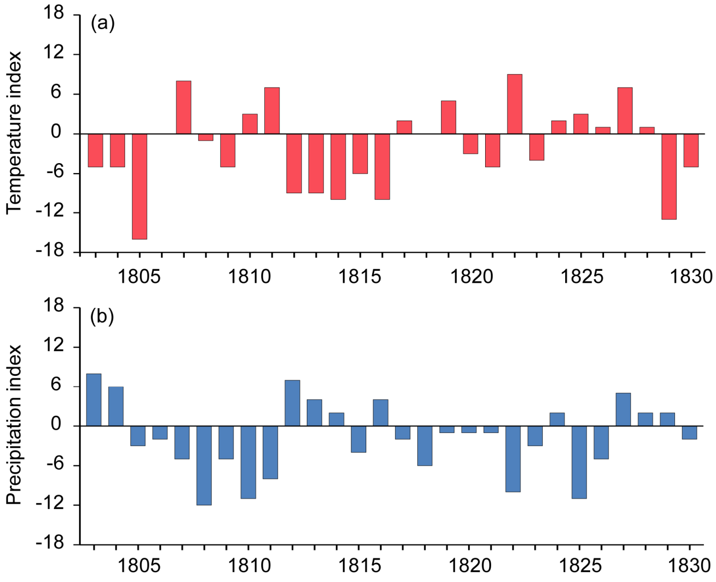
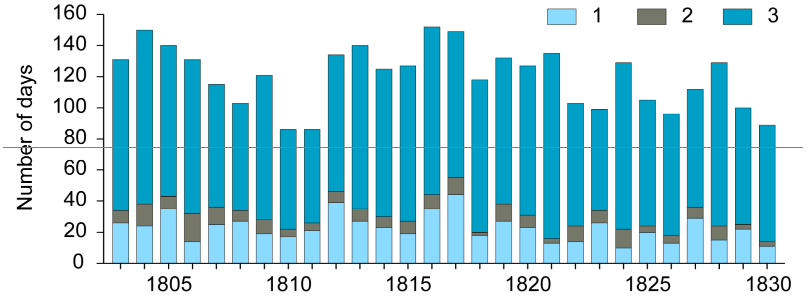


Figure 54. Fluctuations in annual temperature (a) and precipitation (b) indices at Buchlovice during 1803–1830, as derived from the weather diary kept by Šimon Hausner.



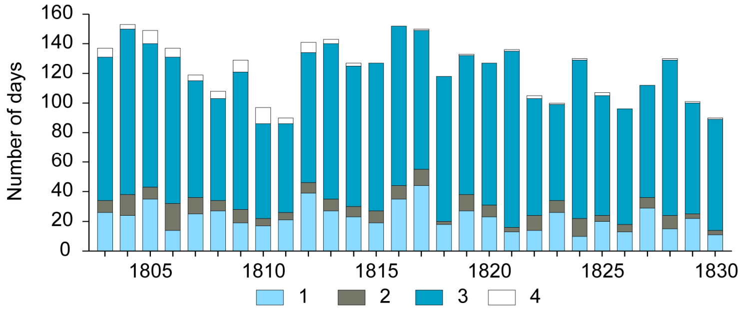


Figure 65. Fluctuations in the annual number of precipitation days (1 – solid, 2 – mixed, 3 – liquid) at Buchlovice during 1803–1830 derived from the weather diary kept by Šimon Hausner (4 – missing days).

Naformátováno: zarovnání na střed

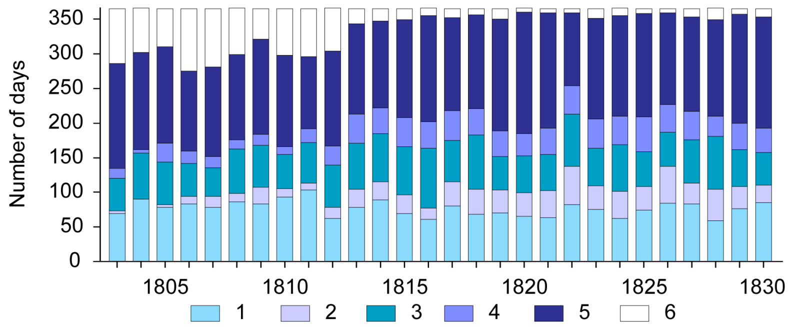
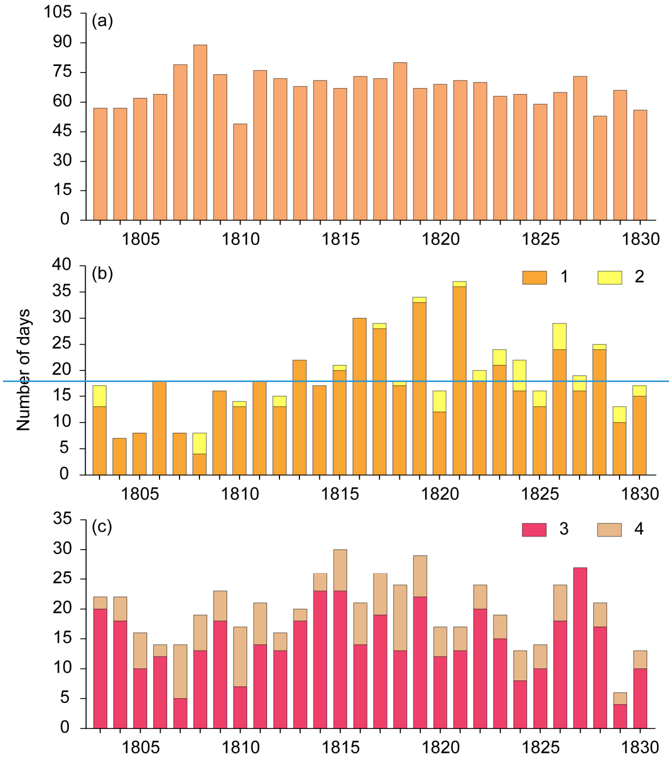


Figure 76. Fluctuations in annual cloudiness at Buchlovice during 1803–1830, derived from the weather diary kept by Šimon Hausner: 1) clear sky, 2) clear sky in one part of the day and half-covered sky in the other part, 3) half-covered sky, 4) half-covered sky in one part of the day and overcast in the other part, 5) overcast, 6) missing days or no information related to cloudiness.


(a)
(b)
(c)
Number of days
1
2
3
4
105
90
75
60
45
30
15
0
40
35
30
25
20
15
10
5
1805
1810
1815
1820
1825
1830

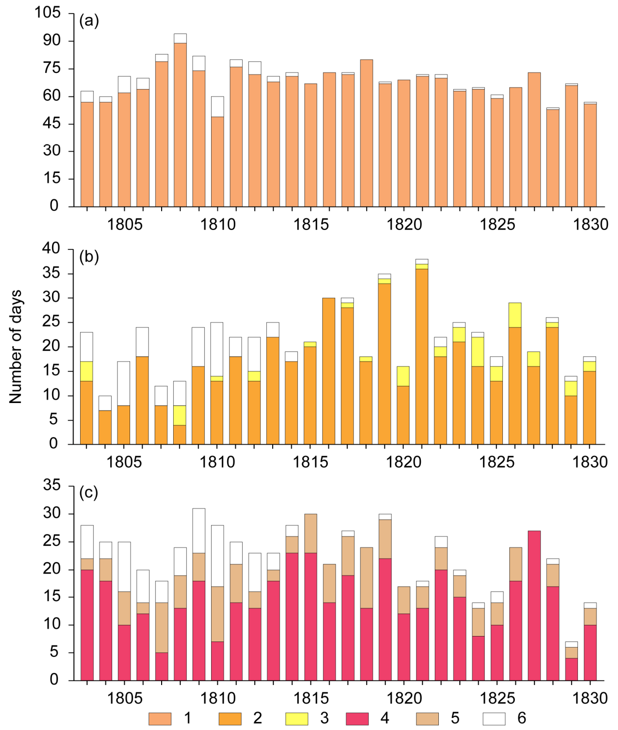


Figure 8~~7~~. Fluctuations in the annual number of days with selected phenomena at Buchlovice during 1803–1830 derived from the weather diary kept by Šimon Hausner: (a) strong wind (1); (b) fog (2~~1~~ – fog, 3~~2~~ – foggy); (c) thunderstorm (4~~3~~ – at Buchlovice, 5~~4~~ – distant thunderstorm) (6 – missing days).

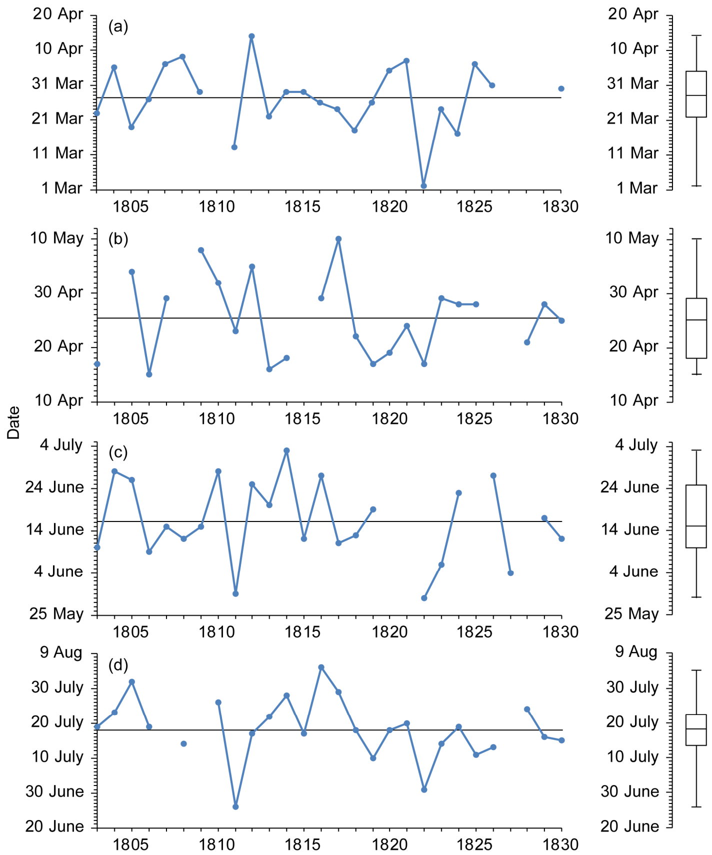


Figure 98. Fluctuations (left) and box-plots (right) of the beginnings of selected phenophases and agricultural work at Buchlovice during 1803–1830 derived from the weather diary kept by Šimon Hausner: (a) spring sowing of cereals; (b) blossoming of cherry trees; (c) blossoming of grapevine; (d) grain harvest.

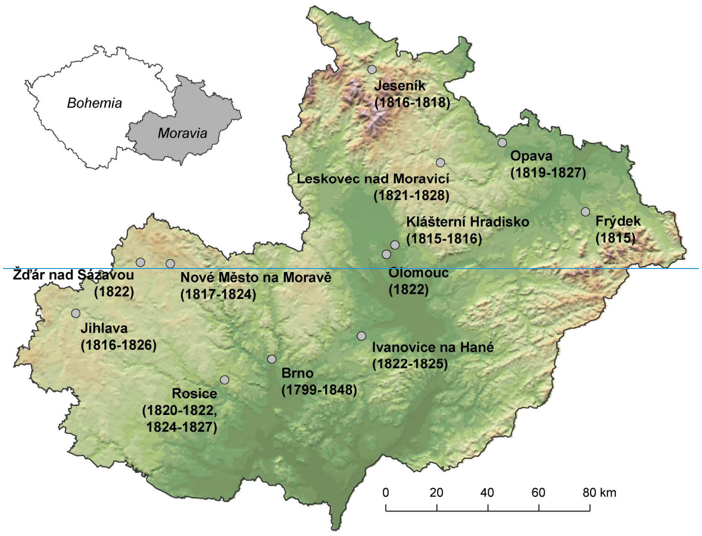


Figure 9. Network of meteorological stations in Moravia and Silesia as organised by the I. R. Moravian-Silesian Economic Society (years indicate available meteorological observations preserved in AS5).

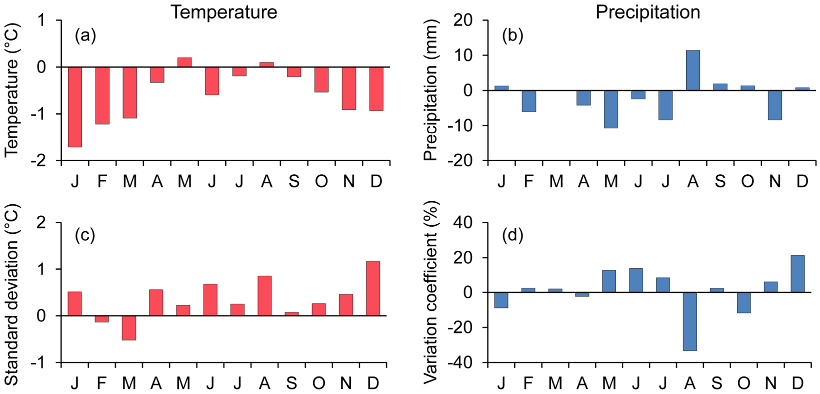


Figure 10. Comparison of monthly mean temperatures, precipitation totals and their variability between the periods 1803–1830 and 1961–1990 in Brno: differences in temperatures (a) and standard deviations (c), precipitation (b) and variation coefficients (d). Positive differences express higher values in 1803–1830 and negative differences in 1961–1990.

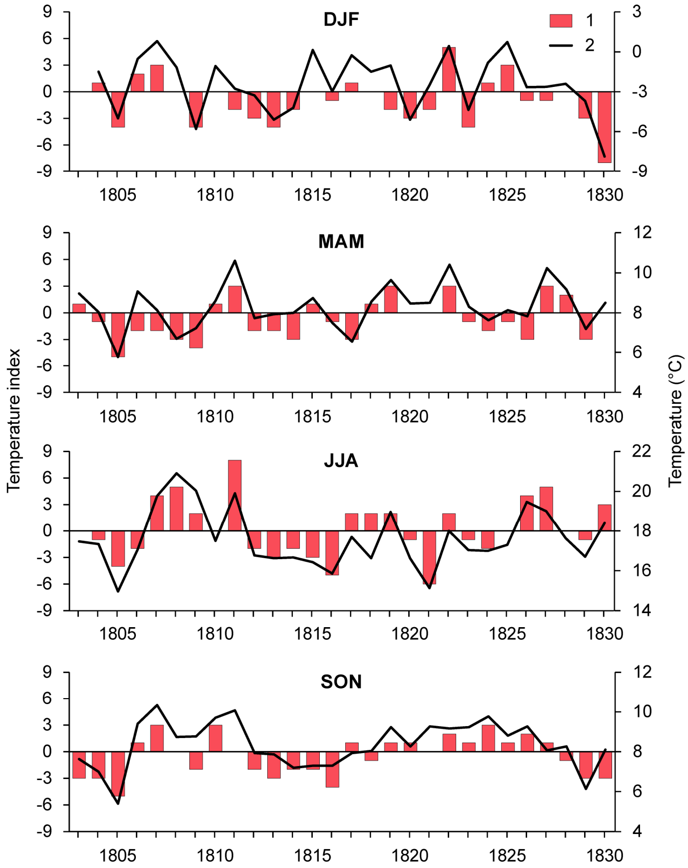


Figure 11. Fluctuations in weighted seasonal temperature indices in Buchlovice (1) and in mean seasonal temperatures in Brno (2) during the 1803–1830 period.

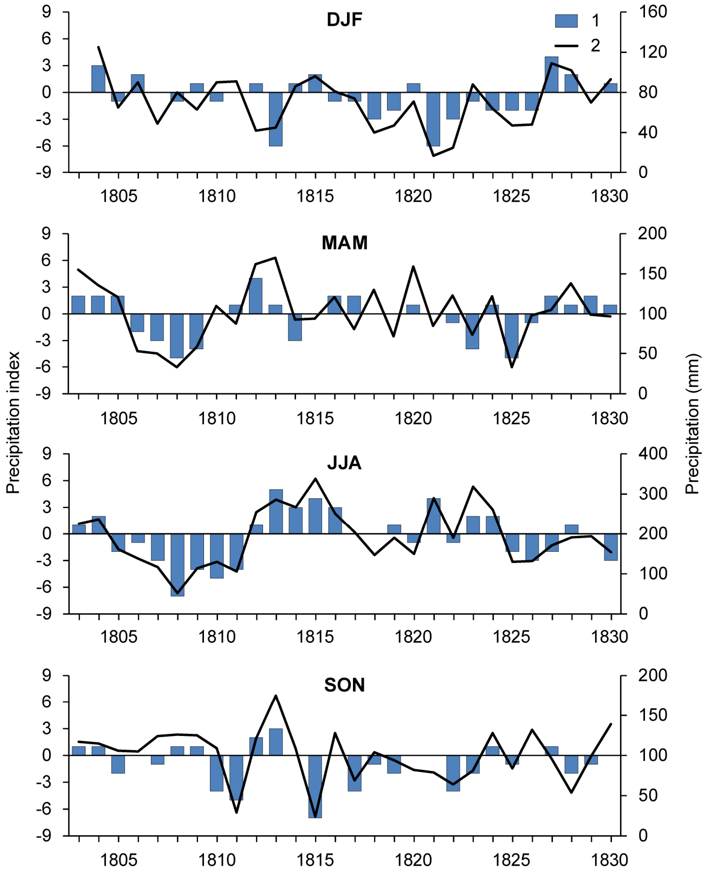


Figure 12. Fluctuations in weighted seasonal precipitation indices in Buchlovice (1) and in seasonal precipitation totals in Brno (2) during the 1803–1830 period.

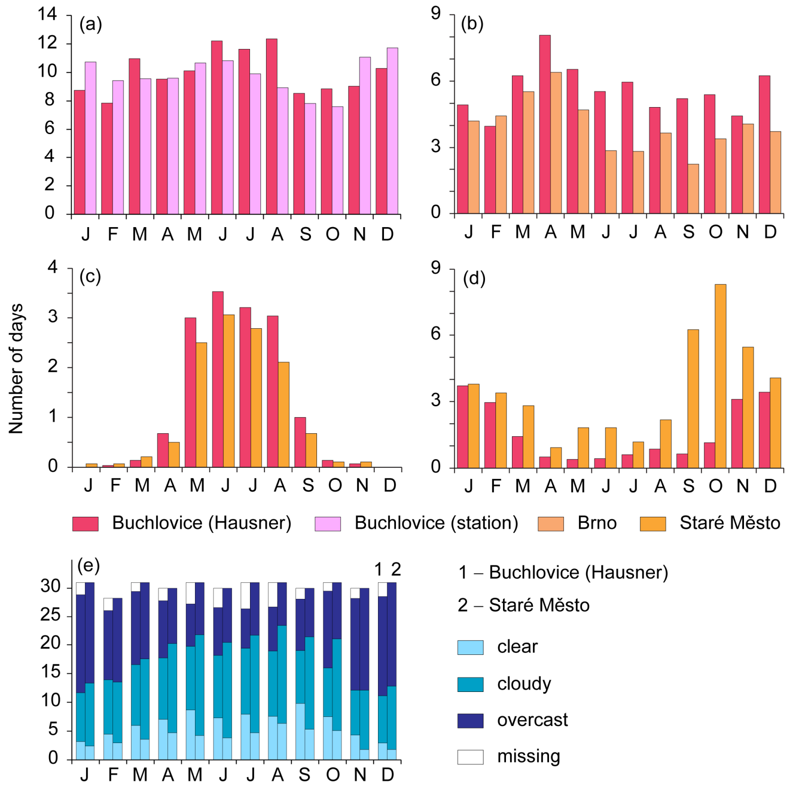


Figure 13. Comparison of annual variation of selected climatological characteristics at Buchlovice interpreted from Hausner's records for 1803–1830 and at three selected meteorological stations in 1961–1990: (a) number of precipitation days (with totals ≥0.1 mm for the Buchlovice rain-gauge station); (b) number of days with strong winds (with wind force ≥7ºB, i.e. wind speed ≥10.8 m s^{-1} for Brno); (c) number of days with thunderstorm; (d) number of days with fog; (e) number of days with various degrees of cloudiness: clear days (0–2/10 of cloud cover at Staré Město), cloudy days (2.1–7.9/10 of cloud cover at Staré Město, sum of categories 2, 3 and 4 at Buchlovice – see Fig. 6) and overcast days (8–10/10 of cloud cover at Staré Město).