Clim. Past Discuss., 7, 4261–4296, 2011
www.clim-past-discuss.net/7/4261/2011/
doi:10.5194/cpd-7-4261-2011

Climate of the Past Discussions

Hydrometeorological extremes and their impacts, as derived from taxation records for south-eastern Moravia, Czech Republic, AD 1751–1900

R. Brázdil[1,2], **K. Chromá**[1], **H. Valášek**[3], **and L. Dolák**[1]

[1]Institute of Geography, Masaryk University, Brno, Czech Republic
[2]Global Change Research Centre AS CR, Brno, Czech Republic
[3]Moravian Land Archives, Brno, Czech Republic

Received: 5 December 2011 – Accepted: 5 December 2011 – Published: 9 December 2011

Correspondence to: R. Brázdil (brazdil@geogr.muni.cz)

Published by Copernicus Publications on behalf of the European Geosciences Union.

Abstract

Historical written records associated with tax relief at ten estates located in south-eastern Moravia (Czech Republic) are used for the study of hydrometeorological extremes and their impacts during the period AD 1751–1900. At the time, the taxation system in Moravia allowed farmers to request tax relief if their crop yields had been negatively affected by hydrological and meteorological extremes. The documentation involved contains information about the type of extreme event and the date of its occurrence, while the impact on crops may often be derived. A total of 175 extreme events resulting in some kind of damage is documented for 1751–1900, with the highest concentration between 1811 and 1860 (74.9 % of all events analysed). The nature of events leading to damage (of a possible 272 types) include hailstorm (25.7 %), torrential rain (21.7 %), and flood (21.0 %), followed by thunderstorm, flash flood, late frost and windstorm. The four most outstanding events, affecting the highest number of settlements, were thunderstorms with hailstorms (25 June 1825, 20 May 1847 and 29 June 1890) and flooding of the River Morava (mid-June 1847). Hydrometeorological extremes in the 1816–1855 period are compared with those occurring during the recent 1961–2000 period. The results obtained are inevitably influenced by uncertainties related to taxation records, such as their temporal and spatial incompleteness, the limits of the period of outside agricultural work (i.e. mainly May–August) and the purpose for which they were originally collected (primarily tax alleviation, i.e. information about hydrometeorological extremes was of secondary importance). Taxation records constitute an important source of data for historical climatology and historical hydrology and have a great potential for use in many European countries.

1 Introduction

Meteorological and hydrological extremes have led, both in the past and in recent times, to loss of human lives and great material damage. Recent global warming, conditioned by anthropogenic enhancement of the greenhouse effect, generates quite reasonable fears that extreme phenomena of increased frequency and severity might accompany it (Mitchell et al., 2006; Beniston et al., 2007; Solomon et al., 2007; Füssel, 2009; Kundzewicz et al., 2010; Sander, 2011). It is essential that the longest possible series of meteorological and hydrological (further as hydrometeorological) extremes be compiled for the study of periods with only natural forcing factors and comparison with those that combine with anthropogenic effects. In terms of systematic observations in the Czech Republic, these are limited by the timing of the establishment of the national networks of meteorological and hydrological stations, which largely began in the latter half of the 19th century. These observation series may, however, be extended into the preceding period by means of documentary evidence that contains direct and indirect information about the weather and related phenomena, including hydrometeorological extremes and their impacts.

Reports of the weather and water damage related to claims for tax relief or similar compensation constitute highly important documentary sources, of an institutional character, for use in historical climatology (Brázdil et al., 2005b, 2010) and hydrology (Brázdil et al., 2006a). If inclement weather (such as hail, flood, torrential rain, windstorm) damaged crops heavily, taxpayers cultivating the land in question were able to apply for a proportional rebate. Written records related to the various stages of this administration process survive in several kinds of archive and may be used as an important source of information about past hydrometeorological extremes and their impacts.

Despite the fact that such data exists in many countries, their use for the study of past climates or hydrometeorological extremes is relatively rare. For example, Grove and Battagel (1983) used data from general tax commissions to characterise climatic impacts on the economy in the 17th and 18th centuries in the region of Sunnfjord (western Norway). An enormous number of petitions for tax relief during AD 1667–1723 showed a deterioration of economic conditions as a result of the onset of glaciers, when farms situated at higher altitudes, in particular, were affected by landslides and

avalanches, and those in lower positions by floods. García et al. (2003), using data on tax payments, compiled series of wheat and barley yields in the Canary Islands in AD 1595–1836 and subsequently used them to reconstruct precipitation.

Several studies exploiting taxation records have been made in the Czech Republic. Matušíková (1996) used such evidence to study responses from landowners (and/or demesne administrators) to requests for help based on the impacts of extreme events (e.g. floods, hailstorms) in the Elbe region in the latter half of the 17th century. Brázdil and Valášek (2003) investigated several weather extremes in the Pernštejn demesne for AD 1694–1718. Rich evidence of hydrometeorological extremes and their impacts was obtained from documents kept by the Liechtenstein holdings of Dolní Kounice and Mikulov, by Brázdil et al. (2003). A summary of knowledge related to records from several estates in southern Moravia has been published by Brázdil et al. (2006b). Zahradníček (2006) dealt with the same topic for the Bítov estate, Dolák (2010) for the Buchlov estate and Chromá (2011) for the Veselí nad Moravou estate. Extremes derived from the above documentation were used for a more general study of historical natural extremes in Moravia (Brázdil and Kirchner, 2007), as well as of floods on the River Morava (Brázdil et al., 2011).

The current paper centres upon early taxation data for the study of hydrometeorological extremes and their impacts in comparison with recent events along a part of the River Morava in south-eastern Moravia, an important agricultural region of the Czech Republic. Section 2 describes the area studied and outlines its historical features. The following section discusses the development of the taxation system in Moravia, including procedures for tax rebate or relief. Section 4 deals with the way in which taxation records may be used to derive information about hydrometeorological extremes. Section 5 provides a spatio-temporal analysis of the hydrometeorological extremes derived from the taxation evidence and describes the most outstanding events. Limitations and uncertainties of the evidence employed, as well as a comparison of historical events with those of recent times, are addressed in Sect. 6. This is followed by some concluding remarks.

2 Area studied

The area in question extends along the middle section of the River Morava, a zone that includes several historical estates, lying approximately between the settlements of Kvasice and Strážnice (Fig. 1). The selection of this area was influenced by existing research into the evolution of the River Morava floodplain and a study of floodplain sediments intended to reconstruct the river's development (see Kadlec et al., 2009; Grygar et al., 2010; Matys Grygar et al., 2011). The area studied was delimited by the extent of ten estates there in the 18th–19th centuries (Table 1). As a part of the Dolnomoravský úval Graben, this territory is one of the most important agriculturally productive regions in Moravia and the Czech Republic, both producing crops (mainly cereals) and raising cattle. Thus arable land was not the only consideration; meadows for hay production or direct pastures were equally important, and extended largely along the River Morava.

The ten estates in the territory studied (Table 1) were owned by various noble families. In the period spanning the early 17th century to 1848, they included a total of five major towns (Bzenec, Strážnice, Uherské Hradiště, Uherský Ostroh, and Veselí nad Moravou), 13 small towns and 106 villages. Their individual areas in the first part of the 19th century covered between 27 606 ha (Uherský Ostroh) and 5277 ha (Kvasice). The periods for which documents survive, deposited in the Moravian Land Archives of Brno since 1954 (for the holdings of Uherské Hradiště town in the Uherské Hradiště State District Archives and for the Strážnice estate partly in the Hodonín State District Archives), vary widely for individual estates and only partly contain tax information that can be used for the study of hydrometeorological extremes. This information may be complemented for the Strážnice estate by other documents, such as the recording "books of memory" kept by several of its farms (see sources S12–S15).

3 Changes in the tax system in Moravia

Since quite early historical times, damage done by meteorological and hydrological events has constituted legitimate grounds for relief of tax duty. However, the actual procedure for tax collection changed over time. For example, in the 16th century the feudal lord handed over fiscal statements ("*přiznávací berní listy*"), in which the landowner himself specified what had been affected by fire or weather and to what extent he was reducing the sum of money due (S1). Lower tax payments arising out of damage were also addressed by meetings of Moravian councillors (diets), at which the Moravian Estate Administration specified the ways in which claimants – farmers – had to state the nature and causes of the damage and provide evidence for it (for the year 1608, see Kameníček, 1905).

In the second part of the 17th century, the "hidage" system of taxation was introduced to Moravia. Centuries before, one "hide" had been the unit of land sufficient to support a family, but in the course of time it became a somewhat arbitrary and subjective unit of land taxation. Only the land of subjects (rustic, or peasant, land) was subject to tax; the land of the lords (dominical, or noble) was exempt from duty. In the First Moravian Land Registry, 1655, it was agreed that "whosoever in the future shall suffer damage due to fire or otherwise, for the purpose of reduction of (taxes due from) hides affected by the damage, report it to the regional administrator who will evaluate it with the neighbours". This also applied to damage done by hydrometeorological events. Just ten years later, this Land Registry was revised and a Second Moravian Land Registry established in 1675, enabling similar tax relief (Novotný, 1934).

The Second Moravian Land Registry tax system lasted until what became known as the Land Registry of Maria Theresa in 1760, on which work had begun during the reign of Empress Maria Theresa as early as 1748. Her decree of 26 July 1748 (Fig. 2a) specifically mentions damage by water and weather to houses, barns, fields and yields; depending on the severity of the water damage, tax relief may be granted for up to two or three years, while for simple weather damage a decision must be

Discussion Paper | Discussion Paper | Discussion Paper | Discussion Paper |

made as to whether no damage, or half-damages, will be acceptable (S3). The Maria Theresa Land Registry redefined the list of holdings and all other objects liable for land taxes and dues. On the basis of this list, net profit from peasant homesteads became the basis for the determination of tax. For the first time, a list of dominical (noble) land became liable for taxation to contribute to general state expenses, together with the incomes of feudal lords from industrial undertakings, serf (robot) payments and manorial labour, and including the possessions of the Church and the towns.

Briefly, from 1 November 1789 until 1 May 1790, the Land Registry of Joseph II, son of Maria Theresa, was valid in Moravia. This reform was an attempt to diminish the difference in taxation between the rustic and the dominical. The fundamental tax unit became the community and individual pieces of land were newly assessed for taxation.

The Maria Theresa Land Registry was soon reinstated, under which the tax dues of both overlord and peasant was standardised (Fig. 2b). Taxes were raised with this system until 1 November 1820, when a provisional revision came into force for the whole of Moravia and continued until the introduction of the Stable Land Registry in 1851. For land tax, this provisional arrangement linked up with a slightly adapted version of the Joseph II Land Registry, with respect to changes in landholders, the extent of land and the agricultural crops grown. A new evaluation of yields also became the subject of taxation (Kocman et al., 1954).

Information obtained at the level of estate management may be compared with data based on the plenary processing of taxes for the whole land. The institutions involved were the regional offices, particularly their land book-keeping departments, in which taxes were collated and to which actual sums of money were directed. Unfortunately, much of the material from these institutions has been preserved only by chance in Moravia (regional offices) (Macek and Žáček, 1958); otherwise, much deliberate destruction of documents took place (Kocman et al., 1954), so contemporaneous data can be obtained only sporadically.

4 Hydrometeorological interpretation of taxation documents

The mechanism of tax reductions consisted of three stages. Firstly, the owners of land, representatives of a settlement or individual farmers sent basic information about what had taken place, together with a detailed description of the damage, to the state executive (regional offices). After this, commissioners appointed by the regional administrator were obliged to inspect the places affected personally (in situ) and make records. Finally, the state executive made its decision as to whether to allow or reject the tax relief requested. This whole process is reflected in various surviving documents, largely written in German, and corresponding to the three stages mentioned.

However, the originally reported damage was not always compensated in full. For example, the area-equivalent damaged by torrential rain and flood in the Pernštejn demesne on 2 June 1710 was decreased by commissioners to only two-thirds of the originally estimated damage to sown and worked fields (605 6/8 *měřice* [133.7 ha]) and finally reduced by the administrator of the Brno region to 382 7/8 *měřice* [84.5 ha] (Brázdil and Valášek, 2003).

Information about the hydrometeorological extremes themselves has to be derived from detail more or less supplementary to the description of the damage done, it is often only very limited. The nature of certain extremes sometimes has to be interpreted from the context of reports making general statements such as "*Wetterschaden*" (weather damage) or "*Wasserschaden*" (water damage). While the former was generally used for damage caused by hailstorms, the latter might mean damage related to torrential rain, flash flood or flood. Although the majority of events are exactly dated, the occurrence of some of them is attributable only to certain months, or even more generally to the period before the day upon which the corresponding written document is dated.

Various types of hydrometeorological extremes may be identified from taxation records, such as thunderstorm, hailstorm, windstorm, torrential rain (downpour), flash flood, flood, late frost, cold and wet spells, and drought. They are nearly all associated with the vegetation period, in which damage to agricultural crops and hay occurred (mainly from May to August). In other parts of the year they are very rare. One example may be found in the report of a windstorm, 21–23 November 1868, on the Strážnice estate, which blew dry soil particles from the fields, exposing the rootlets of winter crops and fatally drying them out. The crops had to be sown again (S15). A similar case occurred there between 28 January and 1 February 1848, when windstorms blew soil from the fields and damaged winter crops (S17). A record from 23 November 1868 cites a windstorm that did damage to two buildings and in the forests in and around Město Albrechtice (Heisig, 1929), but the real windstorm catastrophe in the Czech Lands was still to come, on 7 December 1868, when widespread destruction of woodlands took place (Brázdil et al., 2004).

Although damage arising out of late (in spring or early summer) or early (autumn) frosts was not included among the weather events formally entitled to tax relief, widespread damage to field crops and vineyards occasionally forced farmers to apply for it. Their efforts, however, did not appear to meet with success. One example may be a severe frost, mentioned on the Strážnice estate for 18 May 1662, which did significant damage to cereals, fruit trees and vineyards (S35). This event is mentioned by many other documentary sources from the Czech Lands, some of them citing a great deal of snow falling afterwards (CZdb for the year 1662).

Information derived from individual estates is not confined only to their specific localities, their own settlements, and events occurring there. Estate administrations were sometimes asked for financial support for people stricken by disastrous events on other estates or even in other parts of the Austrian empire. Examples may be found in hailstorm damage on 22 July 1840 to several estates in Moravia and on 25 June 1844 in southern Bohemia and Lower Austria (S33), and also in floods in Pravlov on the River Jihlava in March 1839 (S33) and Prague on the River Vltava at the end of March 1845 (S27) (see also Brázdil et al., 2003, 2005a). Rain destroying the harvest in Hungary in 1845 also triggered such responses (S28).

5 Hydrometeorological extremes in south-eastern Moravia in 1751–1900 derived from taxation records

The analyses that follow are based on extreme events and the type of extreme. A single extreme event is understood as a case in which damage caused by inclement weather occurred on a given day to one or more estates concurrently. The second approach classifies extremes by type; one event may be attributed separately to several types of extreme, for example to thunderstorm, hailstorm and windstorm.

5.1 Spatio-temporal analysis

Investigation of the taxation records for ten estates disclosed a total of 175 hydrometeorological extreme events occurring in the 1751–1900 period. However, as becomes obvious in Fig. 3a, their temporal distribution is very variable. Only 12 events (6.9 % of the total) were recorded in the latter half of the 18th century (mainly for the Milotice estate) and 41 events in 1851–1900 (23.4 %; from 1875 onwards recorded largely for the estates of Uherský Ostroh and Strážnice). The highest frequency of events is visible in 1816–1849, with some years outstanding: 1839 (ten events), 1840 and 1848 (eight each), 1845 (seven) and 1828 (six). In terms of annual distribution of events, May (22.9 %) is followed by June (22.3 %), July and August (16.6 % each), totalling 78.3 % of all events in four months. Fifteen events (8.6 %) could not be attributed to a particular month because the dating in the taxation documents was unclear (e.g. some of the floods).

If individual types of extremes are addressed (flood, flash flood, torrential rain (downpour), thunderstorm, hailstorm, windstorm, late frost), the total number increases to 272 (Fig. 3b). The frequency of individual types of extreme is again highest in 1839, 1840, 1845, 1848 and 1828. The annual distribution of particular types also remains parallel to the same months as for total events. Hailstorms were the most frequently-mentioned class (25.7 %), followed by torrential rain (21.7 %), flood (21.0 %), thunderstorm (14.3 %) and flash flood (8.1 %).

The figures for total events and individual types of extreme above do not include anything about those of longer duration, such as droughts (appearing eight times in documents for 1719, 1834, 1856, 1863, 1869, 1889, 1892, and 1894 – S12, S15, S19, S20, S25), destruction of winter crops (in one of three cases this was associated with a wet spring, in 1817 – S25, S34) and a cold spell during the harvest in 1821 (S25). An item referring to a strong wind during a fire (11 April 1839 at Mistřín – S9) was also not included.

Despite the great temporal variability of hydrometeorological extremes, there also exist large spatial differences in the records (Fig. 4). The tax relief documents in the study area show the highest number of events interpreted for the estates of Strážnice (74) and Uherský Ostroh (60), while only six events were attributed to the Bzenec estate (derived from the records of other estates) and none to the Kvasice estate. This is largely a reflection of the availability of existing taxation records (completely missing from some estates), the physical-geographical features of the area (higher frequency of events close to the River Morava), its land-use (with respect to cultivated, grazed and forested areas), anthropogenic activity in the area, and the very spatially limited nature of severe convective phenomena.

5.2 Outstanding events

Outstanding hydrometeorological events in the area were selected with respect to their impacts, i.e. the number of settlements affected (Fig. 5). Four cases may be considered the most disastrous:

(i) Thunderstorm with hailstorm, 12 June 1825.

Twenty-four settlements on four estates and further non-specified settlements on the Bzenec estate, all in the studied area, were affected by this event, which consisted of torrential rain and hailstorms followed by flash floods in some places. The spatial distribution of the damage reflects the patchy character of convective

phenomena that arise out of severe storm cells (Fig. 5a). Five dead are mentioned for the Buchlov estate (S4). Residential houses and business premises were partly or totally destroyed and over 1200 cattle perished. Floods carried away bridges and damaged roads. In three villages on the Velehrad estate, the most affected by flash flood, water reached ceiling height in some houses (S27). Meadows and pastures were flooded and covered in transported mud, rendering subsequent haymaking impossible. The harvest, nearly due, including that of vineyards, was significantly damaged. For example, tax relief was set at 10 680 guilders for the 12 settlements on the Velehrad estate (S26, S27), 830 guilders for three villages on the Milotice estate (S9) and 640 guilders for Moravský Písek on the Veselí nad Moravou estate (S25); other estates lack information. Collections to aid the people stricken by this event were organised by the estates of Bzenec, Buchlov and Velehrad (S25, S27, S33), as well as at district level. This tragedy even found fame in a folk-ballad lamenting the terrible flash flood on the three estates, referring also to thunderstorm and windstorm on the following day, 13 June (Hrubý, 1907).

(ii) Thunderstorm with hailstorm and windstorm, 20 May 1847.

A total of 22 settlements on four estates in the area studied were affected by this event. Their spatial distribution reflects the patchy character of convective phenomena, related to severe storm cells accompanied by hailstorms and windstorms (Fig. 5b). Significant damage was done by hailstorms to various crops (mainly winter growth) and, combined with windstorms, to houses and business premises (e.g. broken windows, roofs and even buildings damaged or demolished). For example, two of the most-affected villages on the Uherský Ostroh estate asked for relief of *corvée* duty (manual labour done in lieu of cash tax payments) and three of the inhabitants for the loan of roof tiles from the count's brickyard (S19). Support for those affected also included timber for building repairs. At Uherské Hradiště, a collection was organised to aid the village of Popovice, where the whole harvest had been destroyed (S33). Moreover, the villages of Popovice, Podolí and Mařatice obtained loans from a contributory fund in order to buy seed (S37).

(iii) Flood, mid-June 1847.

This event impacted upon 28 settlements on six estates in the area studied. Very heavy rain over a period of several days brought the River Morava into flood. The land holdings of the afflicted settlements were located along the River Morava (Fig. 5c). Despite all attempts at protective measures, the river flooded and inundated meadows, pastures and orchards. Hay was destroyed, while meadows and pastures were covered in mud, which led to a lack of fodder as well as their being utterly inaccessible to grazing. Moreover, settlements close to the River Velička and Sudoměřický potok Brook were also affected when these two waterways flooded (S4, S17, S19, S25, S27, S36, S37). Heavy rain in Moravia and Silesia was reflected in floods on other rivers dated, for example, to 14 June for the River Bečva (Dobeš, 1947) and the River Opava (Kreuzinger, 1862). The event described was very probably attributable to heavy rain related to the movement of Mediterranean cyclones along the Vb track (van Bebber, 1881, 1883), which often bring high precipitation totals and floods to the eastern part of the Czech Republic (see e.g. Štekl et al., 2001; Brázdil et al., 2005a; Daňhelka and Kubát, 2009).

(iv) Thunderstorm with hailstorm, 29 June 1890.

This event is documented for 34 settlements on seven estates in the area studied. Their spatial distribution reflects the patchy character of severe convective phenomena, represented by thunderstorms, torrential rain and hailstorms (Fig. 5d). Hailstones the size of walnuts fell and three settlements also referred to windstorms. Enormous damage was done to field crops, gardens and vineyards. Although information about this event is mentioned only in the records for the Uherský Ostroh estate (despite being related to seven estates) (S19), its effects were much more far-flung, even to Moravian province level (see CZdb for the

year 1890). A committee established to assist those affected in the city of Brno made a summary two months after the event that mentioned damage to 153 settlements in seven political districts. In financial terms, the damage amounted to a massive 5 721 000 guilders. The district of Uherské Hradiště, in which all of the estates studied were located, reported damage of 2 896 000 guilders and 46 settlements affected (S19). Contribution campaigns to help the afflicted were organised throughout the land. For example, the owner of the Uherský Ostroh estate contributed 2000 guilders in cash and crops to the value of 4000 guilders (S19).

6 Discussion

6.1 Limitations and uncertainties of taxation records

Despite the fact that taxation documents were primarily created for the purpose of tax relief, not to record hydrometeorological extremes, they permit some definition of the types, dates and places of extreme events and to a certain degree of probability the extent of impacts. However, these positive features are counterbalanced by the interpretation of data becoming biased by various types of uncertainty, related to:

(i) Spatial and temporal uncertainty.

This is influenced by the number of written documents to survive. Although spatial differences in phenomena can be partly related to natural patterns (e.g. the occurrence of the River Morava flood that affected only land in the inundation area) and the occurrence of severe convective phenomena, the changeable temporal density of records during the period studied clearly reflects the availability of existing documents. Generally, after a decision on tax relief had been taken, the relevant documents lost importance and were destroyed, or preserved only with the short term in mind. Further reasons for lack of information might be damage to archived documents arising out of inappropriate storage, or their loss by fire or other natural disaster. This holds true not only of documents at the level of particular estates, but also at that of the regional office administration. Another influencing factor may be found in changes in tax systems, largely in the varying proportions of dominical and rustic land.

(ii) Uncertainty in the annual distribution of phenomena.

Because requests for tax relief concerned damage to agricultural crops, the great majority of them were related to the period from May to August. Furthermore, the seriousness of the damage and the likelihood of a consequent request for tax relief also lent disproportionate importance to particular parts or even this restricted period of the year, as defined by stages of crop phenophase. This thoroughly overshadowed events occurring in other parts of the year (e.g. winter floods), leaving them to remain largely un-noted or unnoticed in estate documents. On the other hand, it implies that the extremes that are found are for the greater part related to the convective phenomena that usually accompany the most severe storms.

(iii) Uncertainty as to the type of extreme.

Much depended on observational talent and literacy, not to mention attention to detail, on the part of whoever recorded the information concerning the background, the hydrometeorological extreme and the damage done. For example, one might suppose that the number of violent thunderstorms might have been higher than is mentioned because records often concentrated only upon the heavy hailstorms or torrential rain that actually did the damage.

(iv) Uncertainty about the damage done.

Only events that led to damage that gave entitlement to tax relief were recorded. This means that the hydrometeorological extremes taken down express only some of the events that really occurred during the period and in the area studied.

The full set of events that actually occurred cannot be described with anything like the precision of systematic observation at meteorological and hydrological stations or that derived from regular observation series by any statistical method.

6.2 Comparison of historical and recent hydrometeorological extremes

Any direct comparison between historical hydrometeorological events derived from taxation records with those established statistically from more recent periods is very difficult. While past historical events reflect damage done, more recent data are based on systematic observations (sometimes using a statistical approach such as theoretical distribution for definition of thresholds), but information about damage is added only very seldom and has to be sought in other places, usually also incomplete (e.g. newspapers, chronicles). Moreover, only a small proportion of systematically observed phenomena may be involved in damage. For example, in southern Moravia during the 1957–1995 period, damage resulted from only 6 % of the thunderstorms that occurred and from around 23 % of all the hailstorms (Brázdil et al., 1998). This is close to an analysis by Changnon (1997) for the USA in which only 5 % to 10 % of all thunderstorms and 10 % to 25 % of all hailstorms result in damage.

The highest decadal frequency of hydrometeorological events occurred between 1821 and 1850 (see Fig. 3), leading to the selection of the period 1816–1855 for comparison purposes. In this 40-yr period, the total number of extreme events, as well as of individual types of extremes, was the highest (73.1 % and 72.4 %, respectively, with regard to the whole 1751–1900 period). The selected period was used for comparison with other more recent time intervals, mainly 1961–2000. Based on data arising out of homogeneous temperature and precipitation series for the Brno station in 1816–1855 and 1961–2000 (Fig. 6), it may be concluded that the first period was cooler in all months and wetter, most markedly in January and August. In contrast, not only November and December but also February, March and May were significantly drier.

Probably the best source of comparisons is information about the flooding from the River Morava, despite the fact that historical cases reflect floodplain inundation while

Discussion Paper | Discussion Paper | Discussion Paper | Discussion Paper |

those based on instrumental data are selected statistically after peak flood discharges Q_k ($Q_k \geq Q_2$, where Q_2 stands for peak discharge with a return period of two years). Depending on river channel capacity, it cannot be excluded that in lower N-year discharges (N-year water stages) the river did not even leave its channel and inundate the floodplain. Moreover, anthropogenic channel modifications in recent times may have increased river channel capacity. In the light of these drawbacks, and the character of floods derived from tax-related records, the only comparison that seems reasonable relates to summer floods associated with heavy rain and occurring from April to September. Of 37 summer floods documented for the River Morava in AD 1751–1900 (based on instrumental data after 1881) by Brázdil et al. (2011), 14 events (37.8 %) were identified by means of tax records from the area studied. In ten of these events (27.0 %), the floods were also known from other sources. Comparing summer floods in the 1816–1855 and 1961–2000 periods, the corresponding frequencies are 27 and 11 respectively.

In analysis of the tax records, flash floods were classified as cases when, after torrential rain, floods occurred on tributaries of the River Morava or upon smaller local stream systems. While in the 1816–1855 period a total of 14 such events occurred (in 11 yr), incomplete (mainly newspaper) evidence for 1961–2000 suggests 13 events (in ten years) affecting some settlement in the area studied. Of particular note is the case of a disastrous flash flood on 9 June 1970 in the Kyjov and Ždánice region (the Ždánice station measured 133.6 mm of precipitation for the day), in the course of which five settlements on what was once the Milotice estate were also affected. Thirty-five people died (34 miners when the lignite mine at Šardice collapsed), 317 houses were damaged as well as many business premises, etc. (Cyroň and Kotrnec, 2000).

The occurrence of flash floods is closely related to relatively brief but very heavy torrential rain. Using 12 rain-gauge stations run by the Czech Hydrometeorological Institute (CHMI) for the area studied in the 1961–2000 period, frequencies of May–August days with precipitation totals ≥30.0 mm, ≥40.0 mm, ≥50.0 mm, ≥60.0 mm and ≥70.0 mm for at least on the one station were calculated (Fig. 7a). Higher totals in these

months were often caused by severe convective storms. Taking into account daily totals of ≥30.0 mm, their frequency varied between one (1973) and ten (1968, 1977) days. However, daily totals of ≥70.0 mm were achieved only four times, in 1962 (flash flood on 22 July), 1965 and 1997 (disastrous flood on the River Morava in July 1997 – see e.g. Brázdil et al., 2005a, 2011), and totals between 60.0 and 69.9 mm in 14 yr (flash floods in five years on 9 June 1970, 5 June 1971, 3 July 1981, 9 August 1981, 26 June 1989, 17 July 1989, 24 May 1990, and 8 June 1990). This means that not every high daily total is necessarily followed by a flash flood, despite the fact that high totals may occur in small areas not covered by any standard CHMI station.

The frequency of May–August days with hailstorms (Fig. 7b) recorded for at least at one of 12 CHMI weather stations in the area studied in the 1961–2000 period fluctuates between one day (1999) and 13 days (1971) with a mean annual frequency of 5.8 days. On the other hand, hailstorm days with damage in 1816–1855 fluctuate between zero (12 yr) and six (1839) with a mean annual frequency of 1.4 days. This corresponds with the 24 % of days with hailstorms recorded in the recent period, also in a good agreement with figures mentioned by Changnon (1997) and Brázdil et al. (1998). This comparison may be also complemented by data related to tax relief in the 1896–1906 period (Koutný, 1908), expressed as frequency of hailstorms doing damage to crops (Fig. 8a) and declared tax relief (Fig. 8b). Spatial distribution is a mixture of various factors, such as physical-geographical features, extension of agriculturally-used land (fields, orchards, vineyards) and stages of crop phenophase in which a given hailstorm occurred (directly influencing degree of damage).

Damage related to the windstorm on the Strážnice estate on 28 January–1 February 1848 (S17) and 21–23 November 1868 (S15) reflects the importance of wind erosion, a perennial problem in south-eastern Moravia (e.g. Švehlík, 1985; Hrádek et al., 1995). This effect is limited to arable land (soils on sandy substrates) in the drier periods of the year (without snow cover in the winter half-year) during south-east winds. For example, soils occurring in the land registers of seven villages in the area studied (five of them on the Milotice estate) have recently been classified as "severely endangered" and Vacenovice (on the Milotice estate) even as “most endangered” in the eastern part of the Czech Republic (degrees 5 and 6 respectively of a six-degree classification) (Brázdil and Kirchner, 2007).

Finally, although the 1816–1855 period, as the interval with the highest number of hydrometeorological extremes in south-eastern Moravia, coincides very closely with the final phase of Little Ice Age in Europe and a significant onset of Alpine glaciers (e.g. Grove, 2004; Holzhauser et al., 2005; Matthews and Briffa, 2005; Wanner et al., 2009), we have to be somewhat cautious in this comparison because of the temporal and spatial incompleteness of data derived from tax relief documents.

7 Conclusions

The paper analyses historical taxation data in terms of the study of hydrometeorological extremes and their impacts for a highly important agricultural-productive region along the River Morava (south-eastern Moravia, Czech Republic). The data obtained are quite new for the region studied (i.e. previously unknown from other sources), complement one another and also add to existing descriptions of extreme events known from other reports (see CZdb). Thus they can also be utilised for cross-checking of excerpted data. Despite certain limitations, the processed reports enable generally reliably statement of the date and place of an extreme event, its type and, with some probability, the extent of its impacts. These sources are thus at least equivalent to other documentary sources in historical climatology and hydrology of an individual or institutional character such as chronicles, memoirs, personal correspondence, etc. (Brázdil et al., 2005b, 2006a, 2010) and in some ways may even prove better.

On the other hand, we have to bear in mind that only extremes that impact heavily on crops are recorded in these administrative documents, i.e. derived frequencies of extremes are much lower than those derived from any statistical method or approach from the period of systematic observations. Taxation data related to hydrometeorological extremes may be also used for the study of associated economic impacts (e.g. Grove

and Battagel, 1983) and the detail included in the information is valuable to the study of the history of everyday life (see e.g. van Dülmen, 1990, 1992, 1994; Novák, 2007; Lenderová et al., 2009; Bůžek et al., 2010). Moreover, this case study, confined to a small area in south-eastern Moravia, demonstrates the high potential of historical taxation data in the study of hydrometeorological extremes in many other European countries or areas, i.e. it can significantly extend our knowledge of natural disasters and their impacts on a broader European scale in the pre-instrumental period as well as the instrumental.

Archival sources

(S1) MZA Brno, fond A 7 Přiznávací berní listy 1528–1623.
(S2) MZA Brno, fond B 1 Gubernium (1048)1613–1785(1790), karton 2097, inv. č. 3962, sign. W1
(S3) MZA Brno, fond B 17 Místodržitelství – patenty 1628–1880, sign. C4.
(S4) MZA Brno, fond F 45 Velkostatek Buchlov (1514)1548–1949, inv. č. 449.
(S5) MZA Brno, fond F 45 Velkostatek Buchlov (1514)1548–1949, inv. č. 456.
(S6) MZA Brno, fond F 45 Velkostatek Buchlov (1514)1548–1949, inv. č. 3180.
(S7) MZA Brno, fond F 73 Velkostatek Milotice (1611)1633–1945, karton 13, inv. č. 317 B-1/1.
(S8) MZA Brno, fond F 73 Velkostatek Milotice (1611)1633–1945, karton 13, inv. č. 317 B-1/2.
(S9) MZA Brno, fond F 73 Velkostatek Milotice (1611)1633–1945, karton 13–16, inv. č. 317 B-1/3.
(S10) MZA Brno, fond F 73 Velkostatek Milotice (1611)1633–1945, karton 16, inv. č. 317 B-1/4.
(S11) MZA Brno, fond F 73 Velkostatek Milotice (1611)1633–1945, karton 16, inv. č. 318 B-2/15.
(S12) MZA Brno, fond F 90 Velkostatek Strážnice 1556–1945, inv. č. 1.
(S13) MZA Brno, fond F 90 Velkostatek Strážnice 1556–1945, inv. č. 2.
(S14) MZA Brno, fond F 90 Velkostatek Strážnice 1556–1945, inv. č. 3.
(S15) MZA Brno, fond F 90 Velkostatek Strážnice 1556–1945, inv. č. 4.
(S16) MZA Brno, fond F 90 Velkostatek Strážnice 1556–1945, karton 114, inv. č. 638.
(S17) MZA Brno, fond F 90 Velkostatek Strážnice 1556–1945, karton 253, inv. č. 831 3.
(S18) MZA Brno, fond F 93 Velkostatek Ostroh (1671)1693–1947, karton 76, inv. č. 154.
(S19) MZA Brno, fond F 93 Velkostatek Ostroh (1671)1693–1947, karton 122, inv. č. 42.
(S20) MZA Brno, fond F 93 Velkostatek Ostroh (1671)1693–1947, karton 124, inv. č. 80.

(S21) MZA Brno, fond F 93 Velkostatek Ostroh (1671)1693–1947, karton 129, inv. č. 239.
(S22) MZA Brno, fond F 93 Velkostatek Ostroh (1671)1693–1947, karton 129, inv. č. 245.
(S23) MZA Brno, fond F 93 Velkostatek Ostroh (1671)1693–1947, karton 130, inv. č. 296.
(S24) MZA Brno, fond F 93 Velkostatek Ostroh (1671)1693–1947, karton 170, inv. č. 295.
(S25) MZA Brno, fond F 95 Velkostatek Veselí nad Moravou (1621)1652–1945, karton 37–40, inv. č. 153.
(S26) MZA Brno, fond F 207 Velkostatek Velehrad 1649–1952, karton 110–113, inv. č. 112 7/I.
(S27) MZA Brno, fond F 207 Velkostatek Velehrad 1649–1952, karton 120, inv. č. 116 7/A-2.
(S28) MZA Brno, fond F 207 Velkostatek Velehrad 1649–1952, karton 121, inv. č. 117.
(S29) MZA Brno, fond F 287 Velkostatek Bzenec 1604–1943.
(S30) MZA Brno, fond F 300 Velkostatek Napajedla (1248)1603–1928, karton 97, inv. č. 87 30/1-1-3.
(S31) MZA Brno, fond F 301 Velkostatek Kvasice 1729–1946.
(S32) SOkA Hodonín, fond Archiv města Strážnice (magistrát), karton 4, inv. č. 170 F1/52(I).
(S33) SOkA Hodonín, fond Archiv města Strážnice (magistrát), karton 41, inv. č. 595 F1/41.
(S34) SOkA Hodonín, fond Archiv města Strážnice (magistrát), karton 73, inv. č. 842 F1/45.
(S35) SOkA Hodonín, fond Archiv města Strážnice (magistrát), karton 218, inv. č. 1396.
(S36) SOkA Uherské Hradiště, fond Archiv města Uherské Hradiště (správa městských statků a správa hospodářská do poloviny 19. století), karton 254, inv. č. 284.
(S37) SOkA Uherské Hradiště, fond Archiv města Uherské Hradiště (správa městských statků a správa hospodářská do poloviny 19. století), karton 258, inv. č. 307.

Acknowledgements. R. Brázdil and H. Valášek were supported by the Grant Agency of the Academy of Sciences of the Czech Republic for project no. IAAX00130801. K. Chromá was supported by the Grant Agency of the Czech Republic for project no. 205/09/P472. L. Dolák would like to acknowledge the support of project MUNI/A/0966/2009. We would also like to thank Tony Long (Svinošice) for English style corrections, the Czech Hydrometeorological Institute, Brno, for recent meteorological and hydrological data, O. Halásová (Olomouc) for information about recent flash floods and O. Kotyza (Litoměřice) for help with certain references.

References

Beniston, M., Stephenson, D. B., Christensen, O. B., Ferro, C. A. T., Frei, C., Goyette, S., Halsnaes, K., Holt, T., Jylhä, K., Koffi, B., Palutikof, J., Schöll, R., Semmler, T., and Woth, K.: Future extreme events in European climate: an exploration of regional climate model projections, Climatic Change, 81, 71–95, doi:10.1007/s10584-006-9226-z, 2007.

Brázdil, R. and Kirchner, K. (Eds.): Vybrané přírodní extrémy a jejich dopady na Moravě a ve Slezsku (Selected Natural Extremes and Their Impacts in Moravia and Silesia), Masarykova univerzita, Český hydrometeorologický ústav, Ústav Geoniky Akademie věd české republiky, v.v.i., Brno, Praha, Ostrava, 432 pp., 2007.

Brázdil, R. and Valášek, H.: Use of historic data in studying damage due to natural disasters at the domain of Pernštejn in the period 1694–1718 and as a source of information for the study of meteorological and hydrological extremes, Meteorologický časopis, 6, 3–13, 2003.

Brázdil, R., Štěpánek, P., and Vais, T.: Časová a prostorová analýza bouřek, krupobití a extrémních srážek v jižní části Moravy v období 1946–1995 (Temporal and spatial analysis of thunderstorms, hailstorms and extreme precipitation in the southern part of Moravia in 1946–1995), Meteorologické zprávy, 51, 45–52, 1998.

Brázdil, R., Valášek, H., and Sviták, Z.: Meteorological and hydrological extremes in the Dietrichstein domains of Dolní Kounice and Mikulov between 1650 and 1849 according to official economic records of natural disasters, Geografický časopis, 55, 325–353, 2003.

Brázdil, R., Dobrovolný, P., Štekl, J., Kotyza, O., Valášek, H., and Jež, J.: History of Weather and Climate in the Czech Lands VI: Strong Winds, Masaryk University, Brno, 378 pp., 2004.

Brázdil, R., Dobrovolný, P., Elleder, L., Kakos, V., Kotyza, O., Květoň, V., Macková, J., Müller, M., Štekl, J., Tolasz, R., and Valášek, H.: Historické a současné povodně v České republice (Historical and Recent Floods in the Czech Republic), Masarykova univerzita, Český hydrometeorologický ústav, Brno, Praha, 370 pp., 2005a.

Brázdil, R., Pfister, C., Wanner, H., von Storch, H., and Luterbacher, J.: Historical climatology in Europe – the state of the art, Climatic Change, 70, 363–430, doi:10.1007/s10584-005-5924-1, 2005b.

Brázdil, R., Kundzewicz, Z. W., and Benito, G.: Historical hydrology for studying flood risk in Europe, Hydrolog. Sci. J., 51, 739–764, doi:10.1623/hysj.51.5.739, 2006a.

Brázdil, R., Valášek, H., and Chromá, K.: Documentary evidence of an economic character as a source for the study of meteorological and hydrological extremes and their impacts on

human activities, Geogr. Ann. A, 88, 79–86, doi:10.1111/j.0435-3676.2006.00285.x, 2006b.
Brázdil, R., Dobrovolný, P., Luterbacher, J., Moberg, A., Pfister, C., Wheeler, D., and Zorita, E.: European climate of the past 500 years: new challenges for historical climatology, Climatic Change, 101, 7–40, doi:10.1007/s10584-009-9783-z, 2010.
Brázdil, R., Řezníčková, L., Valášek, H., Havlíček, M., Dobrovolný, P., Soukalová, E., Řehánek, T., and Skokanová, H.: Fluctuations of floods of the River Morava (Czech Republic) in the 1691–2009 period: interactions of natural and anthropogenic factors, Hydrolog. Sci. J., 56, 468–485, doi:10.1080/02626667.2011.564175, 2011.
Bůžek, V., Grulich, J., Hrdlička, J., Král, P., Novotný, M., Smíšek, R., Bezecný, Z., Cerman, I., Dibelka, J., Gaži, M., Hlaváček, P., Marek, P., Ryantová, M., Semotanová, E., and Vybíral, Z.: Společnost českých zemí v raném novověku. Struktury, identity, konflikty (The society of the Czech Lands in early Modern Ages. Structures, identities, conflicts), Nakladatelství Lidové noviny, Praha, 1025 pp., 2010.
Changnon, D.: Damaging storms in the United States: selection and quality data and monitoring indices, in: Worskop on Indices and Indicators for Climate Extremes, NCDC, NOAA, Asheville, non-paginated, 1997.
Chromá, K.: Nebezpečné hydrometeorologické jevy v písemnostech panství Veselí nad Moravou v období 1784–1849 (Dangerous hydrometeorological phenomena in documents of the Veselí nad Moravou domain in the period 1784–1849), Meteorologické zprávy, 64, 23–29, 2011.
Cyroň, J. and Kotrnec, J.: Protrhlo se nebe i země ... Šardice 9. 6. 1970 (Both sky and ground burst... Šardice, 9 June 1970), Obec Šardice, 140 pp., 2000.
CZdb: Historical-climatological database of the Czech Lands, Institute of Geography, Masaryk University, Brno.
Daňhelka, J. and Kubát, J. (Eds.): Flash Floods in the Czech Republic in June and July 2009, Ministry of the Environment of the Czech Republic, Czech Hydrometeorological Institute, Prague, 72 pp., 2009.
Dobeš, F.: Kniha o Střítěži (trochu historie, trochu rodopisu). Díl I. (The book about Střítež (somewhat history, somewhat genealogy). Part 1), Nákladem vlastním, Valašské Meziříčí, 367 pp., 1947.
Dolák, L.: Archivní zprávy o škodách způsobených hydrometeorologickými extrémy a jejich dopadech na velkostatku Buchlov (Archival reports about damage caused by hydrometeorological extremes and their impacts for the Buchlov estate), Bc thesis, Faculty of Science,

Masaryk University, Brno, 73 pp., 2010.
Füssel, H.-M.: An updated assessment of the risks from climate change based on research published since the IPCC Fourth Assessment Report, Climatic Change, 97, 469–482, doi:10.1007/s10584-009-9648-5, 2009.
García, R., Macias, A., Gallego, D., Hernández, E., Gimeno, L., and Ribera, P.: Reconstruction of the precipitation in the Canary Islands for the period 1595–1836, B. Am. Meteorol. Soc., 84, 1037–1039, doi:10.1175/BAMS-84-8-1037, 2003.
Grove, J. M.: Little Ice Ages: Ancient and Modern, Routledge, London, 718 pp., 2004.
Grove, J. M. and Battagel, A.: Tax records from western Norway, as an index of Little Ice Age environmental and economic deterioration, Climatic Change, 5, 265–282, doi:10.1007/BF00140184, 1983.
Grygar, T., Světlík, I., Lisá, L., Koptíková, L., Bajer, A., Wray, D. S., Ettler, V., Mihaljevič, M., Nováková, T., Koubová, M., Novák, J., Máčka, Z., and Smetana, M.: Geochemical tools for the stratigraphic correlation of floodplain deposits of the Morava River in Strážnické Pomoraví, Czech Republic from the last millennium, Catena, 80, 106–121, doi:10.1016/j.catena.2009.09.005, 2010.
Heisig, F.: Die Denkwürdigkeiten für und von Olbersdorf, Selbstverlag des Herausgebers, Stadt Olbersdorf, 1929.
Holzhauser, H., Magny, M., and Zumbühl, H. J.: Glacier and lake-level variations in west-central Europe over the last 3500 years, Holocene, 15, 789–801, doi:10.1191/0959683605hl853ra, 2005.
Hrádek, M., Kolejka, J., and Švehlík, R.: Natural hazards in the Czech and Slovak Republics, in: Hrádek, M. (Ed.): Natural Hazards in the Czech Republic, Studia Geographica 98, Czech Academy of Sciences, Institute of Geonics, Branch Brno, Brno, 7–56, 1995.
Hrubý, F.: Píseň o hrozné povodni na panství Buchlovském, Velehradském i Bzeneckém dne 12. a 13. června l. 1825 (A song about the terrible flood at the Buchlov, Velehrad and Bzenec domains on 12 and 13 June 1825), Selský archiv, 6, 118, 1907.
Kadlec, J., Grygar, T., Světlík, I., Ettler, V., Mihaljevič, M., Diehl, J. F., Beske-Diehl, S., and Svitavská-Svobodová, H.: Morava River flood plain development during the last millennium, Strážnické Pomoraví, Czech Republic, Holocene, 19, 499–509, doi:10.1177/0959683608101398, 2009.
Kameníček, F.: Zemské sněmy a sjezdy moravské. Díl III (Moravian Land diets and congresses. Part 3), Nákladem Zemského výboru Markrabství moravského, Brno, 912 pp., 1905.

Kocman, A., Musilová, M., Pletka, V., Radimský, J., Švábenský, M., Trantírek, M., Urbánková , L., and Wurmová, M.: Průvodce po Státním archivu v Brně (Guide to State Archives in Brno), Krajské nakladatelství, Brno, 590 pp., 1954.

Koutný, J.: Krupobití na Moravě v letech 1896–1906 (Hailstorm in Moravia in the years 1896–1906), Tiskem Ant. Odehnala, Brno, 117 pp., 1908.

Kreuzinger, E.: Chronik der alten und neuern Zeit Troppau's, oder Troppau und seine Merkwürdigkeiten, Im Selbstverlage des Herausgebers, Troppau, 278 pp., 1862.

Kundzewicz, Z. W., Hirabayashi, Y., and Kanae, S.: River floods in the changing climate – observations and projections, Water Resour. Manag., 24, 2633–2646, doi:10.1007/s11269-009-9571-6, 2010.

Lenderová, M., Jiránek, T., and Macková, M.: Z dějin české každodennosti. Život v 19. století (From the history of Czech everyday life. Life in the 19th century), Karolinum, Praha, 430 pp., 2009.

Macek, J. and Žáček, V.: Krajská správa v českých zemích a její archivní fondy (1605–1868) (Regional Administration in the Czech Lands and its Archival Groups (1605–1868)), Archivní správa ministerstva vnitra, Praha, 352 pp., 1958.

Matthews, J. A. and Briffa, K. R.: The "Little Ice Age": Re-evaluation of an evolving concept, Geogr. Ann. A, 87, 17–36, doi:10.1111/j.0435-3676.2005.00242.x, 2005.

Matušíková, L.: Živelní pohromy na komorních panstvích v Polabí ve druhé polovině 17. století (Natural disasters on the domains in the Polabí region during the second half of the 17th century), Acta Universitatis Carolinae – Philosophica et historica 5, Z pomocných věd historických XIV, 137–141, 1996.

Matys Grygar, T., Nováková, T., Mihaljevič, M., Strnad, L., Světlík, I., Koptíková, L., Lisá, L., Brázdil, R., Máčka, Z., Stachoň, Z., Svitavská-Svobodová, H., and Wray, D. S.: Surprisingly small increase of the sedimentation rate in the floodplain of Morava River in the Strážnice area, Czech Republic, in the last 1300 years, Catena, 86, 3, 192–207, doi:10.1016/j.catena.2011.04.003, 2011.

Mitchell, J. F. B., Lowe, J., Wood, R. A., and Vellinga, M.: Extreme events due to human-induced climate change, Phil. Trans. R. Soc. A, 364, 2117–2133, doi:10.1098/rsta.2006.1816, 2006.

Novák, P.: Dějiny hmotné kultury a každodennosti českého venkova devatenáctého a první poloviny dvacátého století (History of material culture and everyday life of the Czech country during the 19th century and the first half of the 20th century), Národní zemědělské muzeum Praha, Praha, 341 pp., 2007.

Novotný, J.: Moravský berní systém v století XVII. Příspěvek k hospodářským děijinám země (Moravian tax system in the 17th century. Contribution to the economic history of the Land), Časopis Matice moravské, 58, 145–286, 1934.

Sander, J.: Extremwetterereignisse im Klimawandel: Bewertung der derzeitigen und zukünftigen Gefährdung, DLR Deutsches Zentrum für Luft- und Raumfahrt e. V., Forschungsberichte 6, Köln, 125 pp., 2011.

Solomon, S., Qin, D., Manning, M., Marquis, M., Averyt, K., Tignor, M. M. B., LeRoy Miller, H., and Chen, Z. (Eds.): Climate Change 2007: The Physical Science Basis, Cambridge University Press, Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo, Delhi, 996 pp., 2007.

Štekl, J., Brázdil, R., Kakos, V., Jež, J., Tolasz, R., and Sokol, Z.: Extrémní denní srážkové úhrny na území ČR v období 1879–2000 a jejich synoptické příčiny (Extreme Daily Precipitation Totals on the Territory of the Czech Republic in the 1879–2000 Period and Their Synoptic Causes), Národní klimatický program České republiky 31, Český hydrometeorologický ústav, Praha, 140 pp., 2001.

Švehlík, R.: Větrná eroze půdy na jihovýchodní Moravě (Wind erosion of the soil in south-eastern Moravia), Česká státní pojišťovna, Státní zemědělské nakladatelství, Praha, 75 pp., 1985.

van Bebber, W. J.: Die geographische Vertheilung und Bewegung, das Entstehen und Verschwinden der barometrischen Minima in den Jahren 1876 bis 1880, Zeitschrift der Österreichischen Gesellschaft für Meteorologie, 16, 414–419, 1881.

van Bebber, J.: Typische Witterungserscheinungen, Zeitschrift der Österreichischen Gesellschaft für Meteorologie, 18, 447–458, 1883.

van Dülmen, R.: Kultur und Alltag in der Frühen Neuzeit. Band 1: Das Haus und seine Menschen. 16.–18. Jahrhundert, C. H. Beck, München, 316 pp., 1990.

van Dülmen, R.: Kultur und Alltag in der Frühen Neuzeit. Band 2: Dorf und Stadt. 16.–18. Jahrhundert, C. H. Beck, München, 373 pp., 1992.

van Dülmen, R.: Kultur und Alltag in der frühen Neuzeit. Band 3: Religion, Magie und Aufklärung. 16.–18. Jahrhundert, C. H. Beck, München, 343 pp., 1994.

Wanner, H., Grosjean, M., Luterbacher, J., Rutishauser, T., Widmer, R., and Xoplaki, E.: Die Kleine Eiszeit – mögliche Gründe für ihre Entstehung, in: Nachhaltige Geschichte, edited by: Kirchhofer, A., Krämer, D., Merki, C. M., Poliwoda, G., Stuber, M., and Summermatter, S., Festschrift für Christian Pfister, Chronos Verlag, Zürich, 91–108, 2009.

Discussion Paper | Discussion Paper | Discussion Paper | Discussion Paper |

Wolny, G. and Schenkl, K.: Die Markgrafschaft Mähren. Topographisch, statistisch und historisch geschildert. IV. Band. Hradischer Kreis, Karl Winiker, Brünn, 552 pp., 1846.
Zahradníček, P.: Hydrometeorologické extrémy a jejich dopady na panství Bítov v 18.–20. století (Hydrometeorological extremes and their impacts in the domain of Bítov during the 18th–20th centuries), in: Česká geografie v evropském prostoru. XXI. sjezd České geografické společnosti, České Budějovice, 1284–1290, 2006.

Table 1. Basic facts about the estates in the area studied (the administrative centre of each estate is the same as its name, except for the Buchlov estate, where it was Buchlovice).

Estate	Owners	Area (ha)*	Number of settlements	Period of estate documents	Archival sources studied
Buchlov	Berchtold	12 407	11	(1514)1548–1949	S4–S6
Bzenec	Dietrichstein, Hesenský	7 770	5	1604–1923	S29
Kvasice	Lamberk, Thun-Hohenstein	5 277	10	1729–1946	S31
Milotice	Seiler	7 339	10	(1611)1633–1945	S7–S11
Napajedla	Rotal, Stockay	12 131	15	(1248)1603–1928	S2, S30
Strážnice	Magnis	21 854	14	1556–1945, 1562–1850 (1881)	S12–S17, S32–S35
Uherské Hradiště	the Uherské Hradiště town	5 600	10	(1257)1297–1945(1949)	S36–S37
Uherský Ostroh	Liechtenstein	27 606	27	(1671)1693–1947	S18–S24
Velehrad	Šimon, catholic fond	10 299	17	1649–1952	S26–S28
Veselí nad Moravou	Chorynsky (from Ledec)	5 360	5	(1621)1652–1945	S25

* is the area related to 1834 (Wolny and Schenkl, 1846).

Discussion Paper | Discussion Paper | Discussion Paper | Discussion Paper |

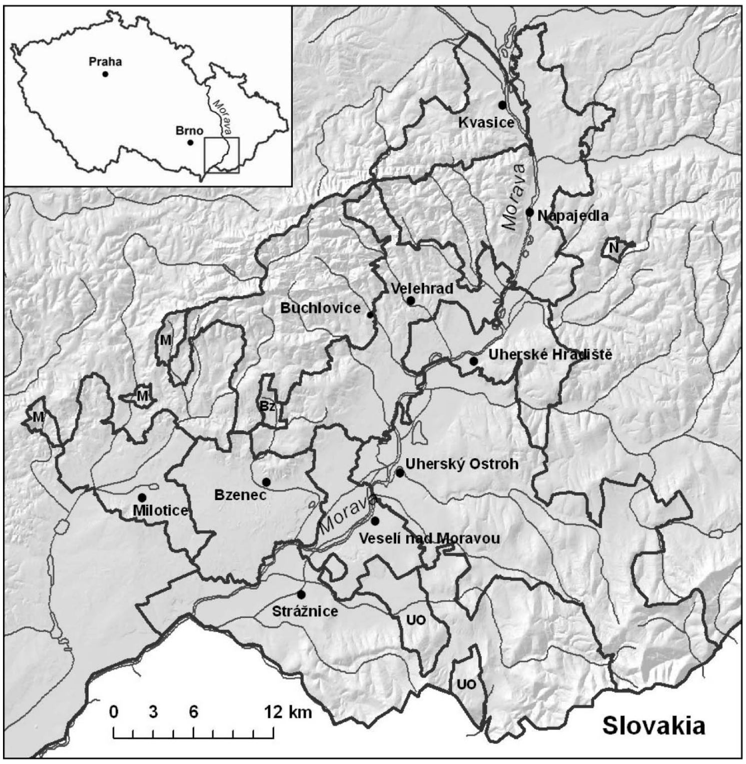
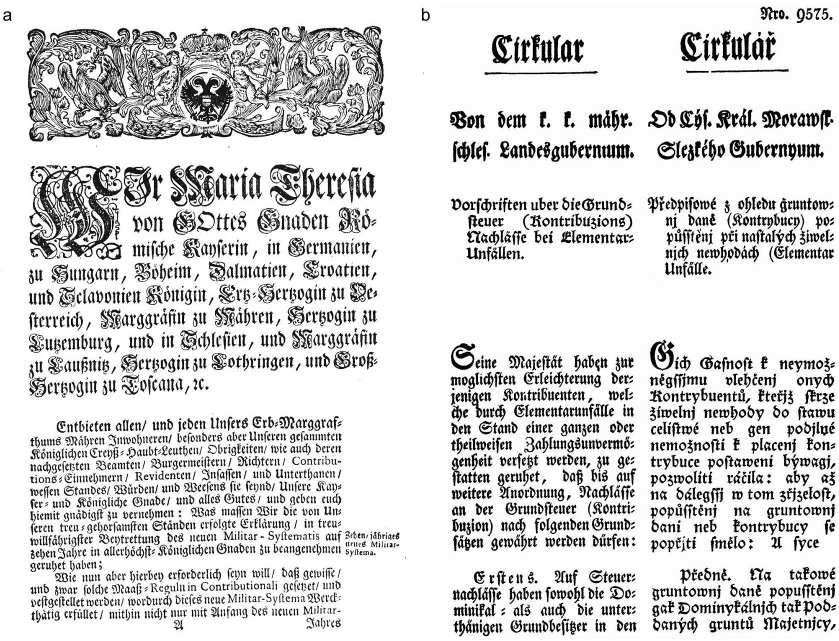


Fig. 1. The area studied, with borders of the individual estates and their administrative centres (smaller areas belonging to a particular estate are marked as Bz – Bzenec, M – Milotice, N – Napajedla, UO – Uherský Ostroh).


a

Wir Maria Theresia von GOttes Gnaden Römische Kayserin, in Germanien, zu Hungarn, Böheim, Dalmatien, Croatien, und Sclavonien Königin, Ertz-Hertzogin zu Oesterreich, Marggräfin zu Mähren, Hertzogin zu Lutzemburg, und in Schlesien, und Marggräfin zu Laußnitz, Hertzogin zu Lothringen, und Groß-Hertzogin zu Toscana, &c.

Entbieten allen/ und jeden Unsers Erb-Marggrafthums Mähren Inwohneren/ besonders aber Unseren gesammten Königlichen Creyß-Haubt-Leuthen/ Obrigkeiten/ wie auch deren nachgesetzten Beamten/ Burgermeistern/ Richtern/ Contributions-Einnehmern/ Revidenten/ Insassen/ und Unterthanen/ wessen Standes/ Würden/ und Weesens sie seynd/ Unsere Kayser- und Königliche Gnade/ und alles Gutes/ und geben euch hiemit gnädigst zu vernehmen: Was massen Wir die von Unseren treu-gehorsamsten Ständen erfolgte Erklärung/ in treuwillfährigster Beytrettung des neuen Militar-Systematis auf zehen Jahre in allerhöchst-Königlichen Gnaden zu beangenehmen geruhet haben;

Zehen-jähriges neues Militar-Systema.

Wie nun aber hierbey erforderlich seyn will/ daß gewisse/ und zwar solche Maaß-Reguln in Contributionali gesetzet/ und vestgestellet werden/ wordurch dieses neue Militar-Systema Werckthätig erfüllet/ mithin nicht nur mit Anfang des neuen Militar-

A Jahres

b

Nro. 9575.

Cirkular	Cirkulář
Von dem k. k. mähr. schles. Landesgubernium.	Od Cýs. Král. Morawsk. Slezkého Gubernyum.
Vorschriften uber die Grundsteuer (Kontribuzions) Nachlässe bei Elementar-Unfällen.	Předpisowé z ohledu gruntowní daně (Kontrybucy) popůsstění při nastalých žiwelních newhodách (Elementar Unfälle.
Seine Majestät haben zur moglichsten Erleichterung derjenigen Kontribuenten, welche durch Elementarunfälle in den Stand einer ganzen oder theilweisen Zahlungsunvermögenheit versetzt werden, zu gestatten geruhet, daß bis auf weitere Anordnung, Nachlässe an der Grundsteuer (Kontribuzion) nach folgenden Grundsätzen gewährt werden dürfen:	Gich Gasnost k neymožnégssjmu vlehčenj onych Kontrybuentů, kteřjž skrze žiwelnj newhody do stawu celistwé neb gen podjlné nemožnosti k placenj kontrybuce postaweni býwagj, pozwoliti ráčila: aby až na dálegssj w tom zřjzelost, popůsstěnj na gruntownj dani neb kontrybucy se popřjti smělo: A syce
Erstens. Auf Steuernachlässe haben sowohl die Dominikal- als auch die unterthänigen Grundbesitzer in den	Předně. Na takowé gruntownj daně popusstěnj gak Dominykálnjch tak Poddaných gruntů Majetnjcy,

Fig. 2. Title pages of documents relating to tax payments in the event of damage to crops caused by hydrometeorological phenomena: **(a)** decree of Empress Maria Theresa, 26 July 1748; **(b)** circular No. 9575 of the Moravian-Silesian Gubernium, 23 April 1819.

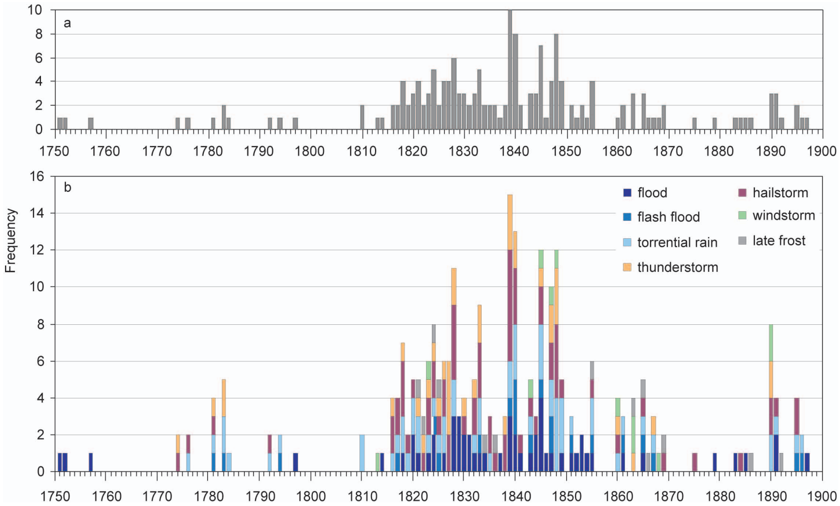


Fig. 3. Annual frequency of **(a)** total hydrometeorological extreme events and **(b)** individually classified types of extremes in south-eastern Moravia during the 1751–1900 period.

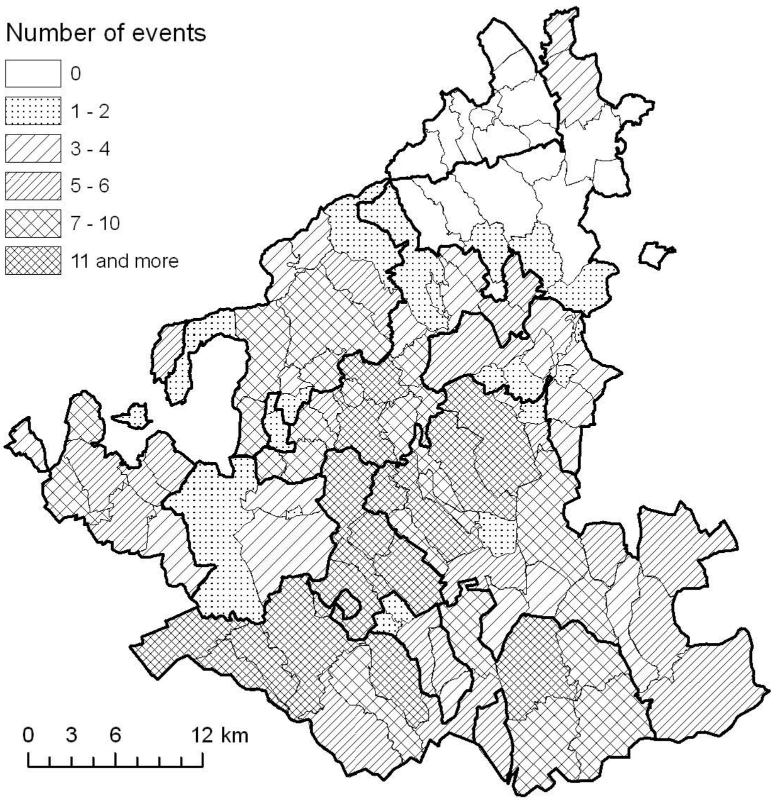


Fig. 4. Numbers of hydrometeorological extreme events recorded in south-eastern Moravia in the 1751–1900 period (numbers are related to the land registers of individual settlements).

Discussion Paper | Discussion Paper | Discussion Paper | Discussion Paper |

Fig. 5. Spatial extent of damage during four outstanding extreme events, expressed for the land registers of individual settlements (in grey): **(a)** 25 June 1825, **(b)** 20 May 1847, **(c)** mid-June 1847, **(d)** 29 June 1890.

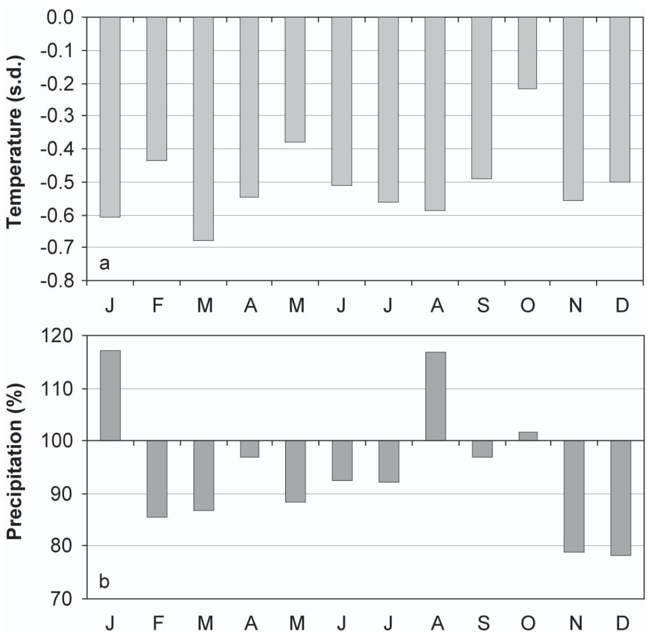


Fig. 6. Differences in mean air temperature (**(a)** – in multiples of standard deviation (s.d.) of the 1961–2000 period) and in precipitation totals (**(b)** – in % of totals in the 1961–2000 period) for the homogeneous Brno series in the 1816–1855 period with respect to the 1961–2000 reference period.

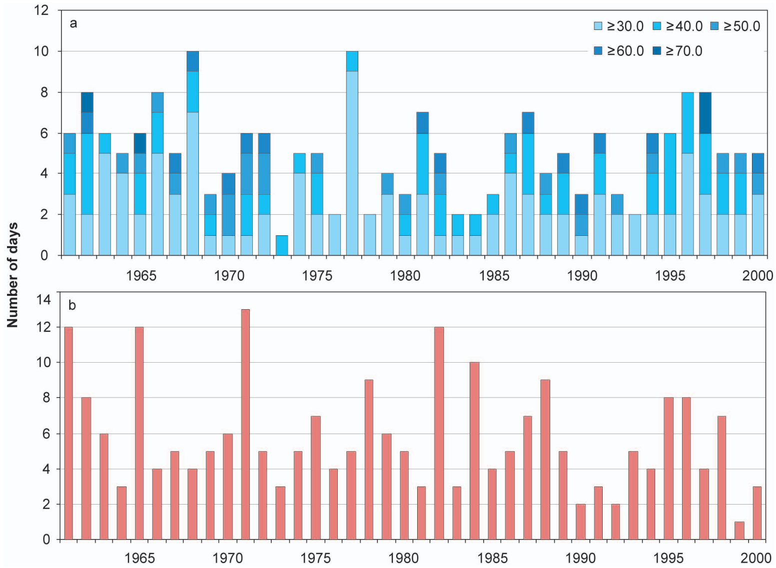


Fig. 7. Frequency of May–August days with daily precipitation totals above limit value **(a)** and days with hailstorm **(b)** recorded for at least at one CHMI weather station in the area studied during the 1961–2000 period.

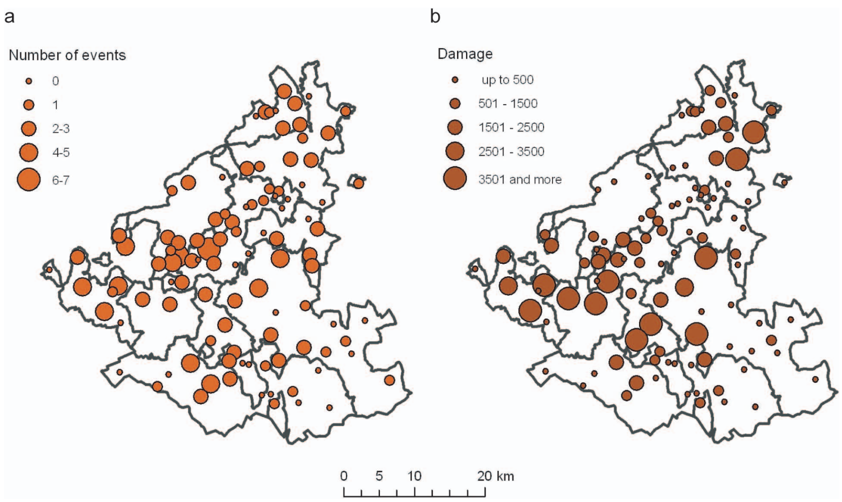


Fig. 8. Frequency of hailstorms doing damage to crops **(a)** and declared tax relief in crowns **(b)** during the 1896–1906 period expressed for individual settlements in the area studied.