Christian Rohr

12 Ice Jams and their Impact on Urban Communities from a Long-term Perspective (Middle Ages to the 19th Century)

Abstract: Ice jams and subsequent floods were among the most disastrous events for riverside cities in pre-modern times. An ice jam could cause the water to rise very quickly and in some cases much higher than even the worst summer floods. Urban quarters could be flooded rapidly and with little time for any rescue activities for the afflicted inhabitants. The low water temperature made it nearly impossible to survive in the floods. This paper examines ice floods in a long-term perspective to see how urban communities in Europe perceived and adapted to those dangerous hazards. After an overview of the sparse records from the Middle Ages (still to be researched systematically), three single events from Early Modern Times are highlighted. By looking at the disastrous ice floods of 1573, 1784 and 1830 in the cities of Krems and Vienna, both situated along the Danube River in modern Austria, the development of coping strategies and the emergence of memory cultures in an urban context are outlined.

Introduction

Ice jams and subsequent floods are among the most disastrous events that can occur in riverside cities. Within the field of historical disaster research, however, they have been remarkably neglected. This paper contributes to the field by showing the potential for studies dedicated to ice jams and their consequences in urban contexts. It begins with general considerations on disaster perception and management, followed by basic information on ice jams and ice floods, including a short overview of the state of the art in managing them. The examples consist of an overview of records from the Middle Ages, as well as three examples from the Danube region in Austria: the ice flood of 1573 in Krems (Lower Austria), the central European event of 1784 with a focus on the situation in Vienna, and once again an ice flood in Vienna that took place in 1830.

This research focuses on the reconstruction of the events, the relevant management strategies with an emphasis on the actors involved, and the memory cultures deriving from the events, leading in some cases to long-time prevention and adaptation measures. By concentrating on the ice jams of 1573, 1784 and 1830, different types of sources will be presented: a detailed petition to the Emperor to gain help, instrumental measurements in combination with newspaper reports, and finally pictorial evidence showing details of coping strategies not otherwise documented.

The long-term perspective applied will help to show a) which areas of the city were hit repeatedly due to the topography of the river and the cityscape; b) how adaptation strategies were developed, and what they were; and c) how the actors involved changed or did not change with regard to their vulnerability and responsibility. The period under examination extends to the first half of the 19th century; since then, stratifications and warm effluents from industrial complexes, as well as a general warming after the end of the so-called ‘Little Ice Age’ (1300–1850) have made ice floods in Western and Central Europa less likely.

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From natural hazards to (natural) disasters

The study of natural hazards from a cultural history perspective has become very popular in the last two decades.[1] Such studies tend to focus on the perception, interpretation, (risk) management and commemoration of events by those affected and by human societies in general. In this context, the term 'natural hazard' is taken to mean the physical event itself, which in some instances has an impact on the human environment, whereas 'natural disaster' is used to denote the perception of such an event by those involved.[2] Several factors are necessary for a natural hazard to be considered a natural disaster. Not all are necessarily relevant at the same time, but at least three or four should be applicable:[3]

a) the helplessness of humans when attempting to cope with damage by available means;
b) an inability to explain and understand the event;
c) material and personal suffering;
d) the unexpectedness of the event, which depends on how prepared an (urban) society is for single or recurrent threats;
e) whether a series of natural hazards occurs within a short period of time, thereby raising the vulnerability of those afflicted;
f) symbolic connotations and patterns of interpretation, such as connections to natural disasters described in the Bible;
g) the wider historical context in the form of the economic, religious and climatic crises (e. g. in the 16th and in the early 19th century).

Unexpected and sudden natural hazards, such as earthquakes, storm surges, severe thunderstorms with hail or floods caused by ice jams, are typically perceived as disasters, because people do not have time to install an effective system of prevention, which, in turn, means that the number of victims is higher. In some cases, vulnerability also plays a role, as when, for example, urban settlements are erected carelessly in dangerous places or unsuitable building materials are used.

If a society is prepared to cope with an environmental hazard, people account for it throughout their daily lives and within their socio-economic system. Based on their communal experience, they adapt the design and layout of settlement and their behaviour to minimise risks. Where the level of resilience in such a society is sufficiently heightened, the result may be a 'culture of disaster'[4] or, more correctly, a 'culture of risk management'.[5] For such communities, most natural hazards cease to be disasters, and their inhabitants understand the reasons for and indications of these extreme events. The inhabitants undertake strategies of prevention, which can include building and regularly maintaining dykes, locating settlements on relatively secure ground and adapting building techniques to the risk in question. For example, windows are placed above ground floor level to prevent the ingress of floodwater, or roof constructions are designed to withstand heavy storms. As far as is possible, regional and supra-regional warning systems may be installed as a further preventative measure. As will be demonstrated in this study, precisely this kind of 'culture of risk management' existed among urban communities in pre-modern Central Europe.

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1 See, for instance, Rohr 2007; Gerrard – Petley 2013; Labbé 2017; Schenk 2017.
2 Cf. Quarantelli 1998; Oliver-Smith 2002; Groh et al. 2003; Smith – Petley 2009.
3 Rohr 2007, 55–62; Rohr 2013, 135.
4 Bankoff 2003.
5 Rohr 2007; Schenk 2010 for riverine cultures; see also Jakubowski-Tiessen 1992; Allemeyer 2006; de Kraker 2005 for maritime coasts.

Ice jams and subsequent floods

According to the 1986 definition by the International Association of Hydraulic Research (IAHR) Working Group on River Ice Hydraulics, an ice jam is a 'stationary accumulation of fragmented ice or frazil that restricts flow' on a river or stream.[6] Contributing factors for ice jams include both weather conditions and the course of the river itself. On the one hand, longer cool periods, even in autumn, and several weeks of temperatures below zero in winter are necessary for the river water to cool down sufficiently. During the so-called 'Little Ice Age', as well as due to volcanic forcing, the number of cold autumn and winter seasons was higher than today. In addition, in pre-industrial times, this cooling was also more readily possible because the water was not – or only rarely – warmed by industrial effluents. On the other hand, an ice-cover will be produced on shallow water with a low current flow, and therefore if the riverbed is not straightened, but widely spread, it is more likely to appear. If the thick ice cover breaks up during warm late winter or early spring weather, the ice floes start moving and can become stuck in shallow areas or blocked by bridges or other buildings that constitute an obstacle. If we consider that many towns had been built on places where bridges across the river could be erected easily, ice jams are more likely in an urban context. Furthermore, the vulnerability is normally higher in densely populated areas.

Ice jam floods are less predictable and potentially more destructive than open-water flooding and can produce much deeper and faster flooding.[7] The immediate increase of the water level due to ice jams can cause much higher flooding levels than any flood caused by melting water or heavy rain. In particular, floods with floating ice floes can be even more destructive than 'normal' open-water floods with driftwood in the water: the damage to bridges, houses, water mills, industrial complexes, harbours, ships and the cultivated environment as a whole is normally much greater. Finally, people and cattle falling into the cold water rarely survive.

Today, ice jam flooding is mostly a problem in regions of the northern hemisphere with long and very cold winters, such as in Canada, the northern part of the United States, Scandinavia and Russia. Most of the literature, both related to historical events and current ones, deals with those regions, but not with central or Western Europe.[8] In the natural sciences, research on river ice and ice jams is quite advanced thanks to the conferences organised by the Committee on River Ice Processes and the Environment (CRIPE) of the Canadian Geophysical Union (CGU) and by the International Association of Hydraulic Research (IAHR) with a specific working group on 'Ice Research and Engineering'.[9] Historical studies focusing on pre-modern ice jam flooding are, however, extremely rare. One exception is Thomas Wozniak's case study of the unique ice jam in Constantinople in the winter of 763/764.[10] A recent state-of-the-art paper by Prabin Rokaya, Sujata Budhathoki and Karl-Erich Lindenschmidt also supports this impression. The authors found, in total, 188 papers published in journals and conference proceedings before October 2017 by creating a word cloud for the keywords in publications. Most of those papers are dedicated to water resources, engineering and geology (each of these three groups constituting approximately a quarter of the overall publications), and the rest is also related to natural and technical sciences. Most of the studies are on Canada and Alaska or on the Russian north, while fewer have considered Europe.[11] Even if we consider a strong bias, because many

6 Beltaos 1995, 71.

7 Cf. Beltaos 1995, 71–75.

8 Cf. Beltaos 1995 on Canada. For an overview of the numerous publications of this author, see the bibliography in Rokaya et al. 2018, 1452. For a recent case study of the Aura River in Turku, Finland, covering the spring ice-breakup from 1749 onwards and the numerous ice jam floods connected to them, see Norrgård – Hellama 2019.

9 <https://www.iahr.org/Portal/About_US/Technical_Division/Ice_Research_and_Engineering_Committee.aspx> (19. 07. 2019, content not available any longer).

10 Wozniak 2017. An enlarged analysis of ice jam flooding in the Early and High Middle Ages is in Wozniak 2020.

11 Rokaya et al. 2018, 1444 f.

historical publications are not published in journal papers with keywords, and although the bibliography to this article contains at least some studies related to historical flood events, it is remarkable that natural scientific research has hardly taken note of studies based on documentary evidence. The above-mentioned study disqualifies them as ‘descriptive’[12] and does not value them as important for understanding past and present-day societies and their coping strategies (e. g. settlement places, infrastructure, annual socio-economic living conditions).

Ice floods in the Middle Ages: an overview

Our knowledge about larger ice jam floods on rivers and in narrow maritime straits in the Early and High Middle Ages (before 1250) is limited to short reports in annals and chronicles of damage and casualties. One exception is the winter of 763/764, which has been recently analysed by Thomas Wozniak. His case study is based on 37 entries in chronicles, of which 16 describe the extreme cold in the year 763 and another 21 deal with the year 764. For contemporary chroniclers, the unusually long duration of snow cover was noteworthy. The Byzantine chronicler Theophanes the Confessor (760–818) provides the longest and most detailed eyewitness description. His report states that the Black Sea was frozen from early October 763 to March 764 for 150 km from the shoreline and to a depth of about 14 m. According to Theophanes, the snow layer covering the ice was about 9.5 m deep. When the ice burst in February, some big ice floes drifting through the Bosporus strait destroyed parts of the town and city walls of Constantinople. Altogether, the hard winter was reported in sources from Ireland, different European monasteries and various Byzantine authors.[13]

Wozniak’s larger research project has documented more than 60 years of extreme winter events during the period between 500 and 1100. Most of the records describe only specific features: either the seasons are mentioned in general terms, such as *hiems magna* (a strong winter), or the sources provide indirect temperature indications related to the frozen water of rivers and lakes, but also about the type and results of precipitation, such as a complete snow cover. In some cases, the chroniclers gave daily data for the onset of snow cover and the melting of the snow. The above-mentioned observations deviate very strongly in extreme years from the determined average values of today’s normal periods, with the winters of 859/860, 875/876, 975/976 or 1067/1068 having a four- to five-month snow cover or the winters of 708/709, 839/840, 993/994 or 1076/1077 having snow cover lasting almost half a year.[14] We may assume that in those years the larger rivers also had an ice cover, causing problems with ice jams in early spring. There are only records for some winters in annals and chronicles that tell us explicitly about completely frozen rivers and subsequent floods, such as the Elbe River in 814/815, the Rhine, Danube, Elbe and Seine rivers in 821/822, the Seine River in 848/849, the Rhine and Main rivers in 880/881, the Thames and Havel rivers in 927/928, numerous not clearly specified rivers in central and western Europe in 1060 and 1068/1069, the Werra River in central Germany and others in 1074/1075, as well as several large river catchments in all of Europe and the Bosporus strait in 1076/1077.[15] In 1093, many rivers in England, the Netherlands and Belgium, as well as the entire Rhine River catchment, were frozen. Even rivers in Ireland were sometimes frozen, such as in the winters of 934/945, 939/940 and 941/942. At least some of those extremely cold winters may be connected with volcanic eruptions that are documented in ice cores, such as in 821/822 and 939/940.[16]

12 Rokaya et al. 2018, 1449.
13 Wozniak 2017.
14 Wozniak 2017, 155 f.; Wozniak 2020.
15 Cf. Alexandre 1987, 339–341; Wozniak 2020 with detailed references.
16 Cf. McCormick et al. 2007, 878–889.

Whereas Wozniak's forthcoming book on natural disasters in the Early and High Middle Ages will provide the first comprehensive overview of ice jams and subsequent floods for the period up to the year 1100, a systematic study of extreme ice floods for the following centuries is still a *desideratum* in historical disaster studies. This is, of course, due to the increasing density of sources, which not only report on large ice flood events on a macro-level, but can also give insight into the effect of destructive ice floes and floods on a micro-level, including the impact on water mills and urban infrastructure. In general, the reports on flooding events became more detailed and also referred to casualties and economic consequences.

An example of a well-documented ice flood is the one that took place on the Danube River in Austria in the early spring of 1234. After a very cold winter, the melting of snow and ice led to an extreme flood, whereby the Danube spread far into the surrounding land. Numerous villages and even walled cities were submerged and destroyed. Countless animals died, as well as many people; fields, meadows and vineyards were heavily devastated. Due to the large ice floes drifting down the river – and probably also causing ice jams – an even higher number of people was killed than would be expected in normal flooding; obviously those ice floes crashed into houses and city walls with full force. In addition, it can be assumed that all the people who were seized by the water masses had no chance of survival owing to the low water temperature. The ice floes remained in the landscape for a long time during the year 1234 and melted slowly; agriculture was impossible in the devastated areas. As a result of the ice floods – which had also destroyed the grain stocks – people suffered from famine.[17]

In general, ice on the rivers and subsequent ice floods seem to have been rather the normality compared to years without frozen rivers. In this way, the so-called 'Kleine Klosterneuburger Chronik' (Little Klosterneuburg Chronicle) found it noteworthy that in the very mild winter of 1355/1356 it had been not only very dry and snowless, but also that there had not been any ice jams on the Danube River (*und gestieß die Thainau nie*).[18] On the other hand, the same chronicle tells us about the very harsh winter of 1328, when the Danube River was covered with thick ice for 17 weeks. As a form of gallows humour, a peasant started to plough the snow weeds and hollows on the ice instead of his field during carnival time.[19]

Prevention and adaptation strategies for ice floods in an urban context can be reconstructed in more detail from the 14th century onwards. Urban institutions, such as the bridge masters of Wels (Upper Austria), were responsible for the repairs to bridges after ice jams. Urban accounts have survived from the 15th century, such as the bridge master accounts of Wels, the weekly expenditure books from Basel, or the so-called 'Seckelmeisterrechnungen' (treasurer's accounts) from Fribourg (Switzerland). In combination with narrative sources, they have recently been used for flood reconstruction, including ice floods.[20]

Micro-historical case studies shed light on the impact of ice floods on urban and suburban mills in the Late Middle Ages and in Early Modern Times. Gerhard Fritz has recently examined narrative sources, account books and urban regulations from southern Germany dealing with the risk of natural hazards to watermills. His results show the use of diverse measures to cope with ice floods. In the case of a water mill on the Pleichach River in Würzburg, the landlords were not co-responsible for the repairs after damage by natural forces, but the owner alone had to carry all costs.[21] In 1485, however, the Count of Fürstenberg assisted the miller of Haslach im

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17 Frass 1971, 165 f.; Rohr 2007, based on the contemporary reports in the *Annales sancti Rudberti Salisburgenses*, the *Continuatio Sancrucensis II* and the *Continuatio Lambacensis*.

18 Rohr 2007, 449.

19 Rohr 2007, 449 f., based on the 'Kleine Klosterneuburger Chronik': *Anno 1328 ist die Thonaw gestossen und der stoss ist gestanden 17 wochen, das molten darauf sind worden, das ainer im vaschang, (zu ainem schimpff) darauff geackhert in den molten, die der wind darauff gewaet hat.*

20 Cf. for Wels, Rohr 2006; Rohr 2007, 280–311; Rohr 2013, 139–144; for Basel, cf. Wetter et al. 2011; for Fribourg, cf. Longoni 2019.

21 Fritz 2018, 213, based on a charter of 1336 (Urkundenregesten zur Geschichte der Stadt Würzburg, 1201–1401, ed. W. Engel, Nr. 154).

Kinzigtal (Black Forest) to cope with damage after thunderstorms, floods, ice and other natural forces.[22]

The annual accounts of Hohenberg and narrative sources tell us more details about destruction to the water mills caused by ice. Ice could shut down, damage or destroy the mill through drifting ice floes. People tried to protect the mills with rakes or so-called 'ice trees', which were probably beams mounted across the tributary channels. If that were not enough, staff would have to observe the mill day and night, keeping the ice away from the mill with bars or other equipment. Sometimes that did not help either: in the winter of 1395/1396, the Obermühle in Rottenburg was devastated twice in a row 'by ice and water', as the annual accounts of Hohenberg describe in great detail.[23]

Bridges and water mills seem to have been the most vulnerable places in urban and suburban environments, but adaptive measures obviously were hard to achieve, because these constructions naturally were exposed to the river. In some cases, city walls, too, had been destroyed and at least parts of the city centres were flooded. The responsibility for coping with the damage varied from case to case. However, we do not have enough evidence as to whether frequent ice floods led to a relocation of urban settlements or of single bridges or water mills.

The ice flood in Krems (1573)

The period around 1570 was characterised by many extreme weather events. Harvests were often destroyed or very poor due to the bad weather. During this time of multiple crises within the Little Ice Age, prices for wheat and rye rose significantly.[24] In addition, people were compelled to pay additional taxes to help fund the wars of the Habsburg emperors against the Ottomans.[25] In Austria, a series of major floods occurred in 1567, 1569 and 1572.[26] Furthermore, the city of Krems in Lower Austria, situated at the end of the Wachau, a narrow passage of the Danube River, was hit by a severe flood caused by an ice jam in January 1573.[27] The accumulation of so many destructive events over such a short time caused this series of events to be viewed as a disaster even within an existing 'culture of flood management'. People could not cope with the damage as they had done in the past. As a consequence, the city council of Krems petitioned the Emperor and landlord Maximilian II (1564–1576) on 17 February 1573.[28] Although the original of this document, formerly preserved in the Vienna Archive of the Imperial Chamber (*Wiener Finanz- und Hofkammerarchiv*), now seems to be lost, its contents are known. In the first section of the document, the councillors described the effects of the 1572 summer flood, which had been severe, but manageable with existing resources. Due to the subsequent ice flood, however, they had been unable to cope and therefore pleaded with the Emperor to commit financial support. Moreover, the city walls and many houses were severely damaged and could not be repaired until the winter. As a result, the city's vulnerability to a second event was much higher than usual.

The winemakers of Krems alleged that their economic loss was even greater: most of the vineyards, fields and meadows near the river were totally ruined and could not be quickly restored.[29] Possibly the inventory in the petition was exaggerated to underline their cause, be-

22 Fritz 2018, 216, based on a charter of 1485 (Fürstenbergisches Urkundenbuch 4, ed. S. Riezler, Nr. 50).
23 Fritz 2018, 217 f., based on the annual accounts of Hohenberg in 1395/1396.
24 Pfister – Brázdil 1999, 41 f.; Behringer 2003.
25 Winkelbauer 2003, 467–469.
26 Rohr 2007, 243–257.
27 For the following section, see Rohr 2013, 136–139; Rohr in print.
28 Kinzl 1869, 150–153; Rohr 2007, 254–256. 332–336.
29 Petition of the city council of Krems (Kinzl 1869, 150).

cause there were, in fact, vineyards also higher up on the slopes above the Danube. However, the houses of the winemakers and at least some of the wine cellars were located near the river bank, and we may assume that they were out of use for months or even years.

Due to the consequences of the summer flood, the ice flood of 9–12 January 1573 became a real disaster. In the petition to the Emperor, this dramatic event is described in great depth. The ice floes on the Danube River built up a large dam within a few hours and the water rose quickly, bringing more and more ice floes into the city. Eventually, the water and the ice brought down parts of the walls, entered the city centre and flooded some streets up to the windows of the houses. The peak level of the ice flood was 1.5 feet higher than the summer flood. Only a third of the twin cities remained dry. The inhabitants could not rescue their cattle, pets and hardware, and they could only escape by climbing onto the roofs of their houses.[30] The clean-up operation only began 12 days after the flood, and even six weeks after the event, blocks of ice were still lying around in the streets.[31]

According to the petition, the loss of wine and grain stored in the houses had been enormous. The future for the winemakers was dark, the petition claimed; the orchards and vineyards would be devastated for years, houses were severely damaged and the wine cellars no longer fit for purpose. The petition concluded that more than 40 houses in Stein and a similar number in Krems would remain empty and deserted. Given that the twin cities of Stein and Krems consisted of 400 houses each in 1565,[32] this means that 10 % of the houses remained uninhabitable. In addition, the winemakers would not be able to sell their products and would therefore fall into poverty.[33] A paragraph of the municipal regulation of 1524 stated that in the case of a flood winemakers are allowed to bring their wine casks to a secure place and to sell wine there. In this way, the winemakers should still be able to provide for their wives and children.[34] Nevertheless, this regulation failed to protect the winemakers in the ice flood of 1573, because it happened so suddenly, as well as occurring at night, so there would have been no time to empty the wine cellars.

The real dimensions of the damage, however, might not have been as dramatic as reported in the petition to the Emperor. It is assumed that ‘only’ the districts of the city situated in the plains near the shore of the river were hit substantially. People obviously managed to escape in time and they were presumably given shelter in the houses of other citizens, because there is no mention of any who drowned, froze to death or became homeless.

It is clear that the damage was far from terminal for some of the inhabitants of Krems, as one set of documents preserved in the Vienna Archive of the Imperial Chamber makes clear. Some of the city’s wealthier residents were able to grant a credit of 5,500 guilders to the Emperor, who had major problems financing his war against the Ottomans in present-day Hungary. In this series of documents, dating from 1572 and 1573, the summer flood of 1572 and the ice flood of 1573 are not mentioned at all. The loan of 5,500 guilders was the last part of a 15,000 guilder credit, granted by the nobleman Michael Freiherr von Eyzing from Krems. Over the following years, the Emperor asked for additional credit amounting to over 10,000 guilders.[35] This indicates that at least some inhabitants of Krems came through the disasters of 1572 and 1573 without remarkable losses.

The mental management and memory of the 1573 catastrophe was achieved by fixing flood inscriptions that recorded the date and water level. Inscription tablets can be found in several public places in Krems, in particular on the town gates. One inscription and flood mark relating to the ice flood of 1573 is still affixed to the Steinertor gate and reads:

30 Petition of the city council of Krems (Kinzl 1869, 150 f.).
31 Petition of the city council of Krems (Kinzl 1869, 151).
32 Kinzl 1869, 137.
33 Petition of the city council of Krems (Kinzl 1869, 151 f.).
34 Municipal regulation for Krems and Stein, 12 March 1524, Article 63; see Rohr 2007, 377 f.
35 Rohr 2013, 138 f.

Den 12 January Anno 1573 ist die gros Eysgüß khu(m)mben vnd in der höch gewesen wie der strich hie vndten verzaichent ist vnd hat gewert zwelff tag lang und grossen [s]chaden gethan

(On 12 January in the year of 1573 there was a huge ice flood, which reached the level shown by the line below. It lasted for 12 days and caused immense damage).[36]

Historical flood marks are useful only up to a point for hydrological research, because we have to consider natural dynamic processes in the watercourse, anthropogenic impact on the river and on the inscriptions themselves (e. g. they are sometimes freshly painted or displaced). However, we may rather use them as signs of memory for 'cultures of flood management', that is, as a 'memento naturae' to keep risk awareness alive.

The ice flood of 1784

The Lakagígar (Laki) volcanic eruption in Iceland during 1783 was followed by a very cool fall and severe winter in 1783/1784, which was characterised by low temperatures, frozen soil, ice-bound watercourses and high rates of snow accumulation across much of Europe. Sudden warming coupled with rainfall led to rapid snowmelt, resulting in a series of flooding phases. The first phase of flooding occurred in late December 1783 and early January 1784 in England, France, the Low Countries and historical Hungary, but the second phase at the turn of February to March 1784 was of greater extent, generated by the melting of an unusually large accumulation of snow and river ice. This phase affected catchments across France and Central Europe, where it is still considered one of the most disastrous known floods throughout the Danube catchment and in southeast Central Europe.[37] Cities like Vienna, Bratislava and Budapest suffered severe damage from the ice floods, as did Paris, Prague and Würzburg. It is remarkable that the German term *Katastrophe* apparently appeared for the first time related to the natural disasters in 1784, used in an article of the *Zürcher Zeitung*.[38]

The sources for this extreme winter and the ice floods are excellent for many places and in particular for Vienna.[39] Narrative sources, including newspapers, are available as well as contemporary images[40] and private documents; gauge and weather stations with sub-daily measurements provided observations on temperature (in Réaumur), air pressure, wind direction and the water level of the Danube River. The *Wiener Zeitung*, which appeared twice a week, included not only numerous reports on heavy rain, floods and cold weather related to Austria, Bohemia, France, Germany, historical Hungary, Italy, Portugal, Russia and Spain, but also instrumental meteorological and demographic data from Vienna. Hydrological measurements at the Vienna-Tabor gauge were made under the direction of the K. K. Wasserbau-Administrator Jean-Baptiste Bréquin (1712–1785) and were published in the *Wiener Zeitung* until his death in January 1785.[41]

The weather situation and the impact of the ice flood can therefore be reconstructed in some detail: after an extremely cold January, in particular around 7 January 1784, daily temperatures rose from below 0 °C to 10 °C on 25 and 26 February, which – coupled with rainfall – caused the rapid (i. e. within hours) breaking of the river ice. During the night of 26–27 February, ice and

36 Rohr 2013, 137.
37 For a European-scale reconstruction of this event, see Brázdil et al. 2010. For a detailed analysis of the situation in Saxony, see Poliwoda 2007, 59–84; for the Rhineland (cities of Bonn and Cologne), see Ennen 1999.
38 Zürcher Zeitung, 15 March 1784. Cf. Poliwoda 2007, 30.
39 For the situation in Vienna and along the Danube River in Lower Austria, see also Strömmer 2003, 209–213.
40 For Vienna see, for instance, a coloured copperplate print by Hieronymus Löschenkohl (1784), showing the flooded Leopoldstadt quarter in Vienna (Vienna, Wien Museum, Inv. No. HMW 13431).
41 See in detail Schönburg-Hartenstein – Zedinger 2004.

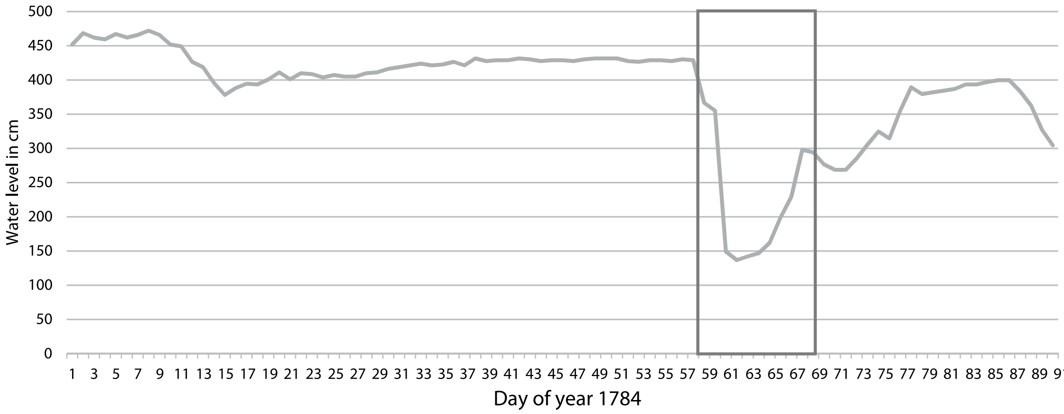

Fig. 1: Vienna, water level of the Danube River, Tabor gauge (1 January to 31 March 1784). The period of the ice flood from 28 February 1784 onwards is marked with a rectangle.

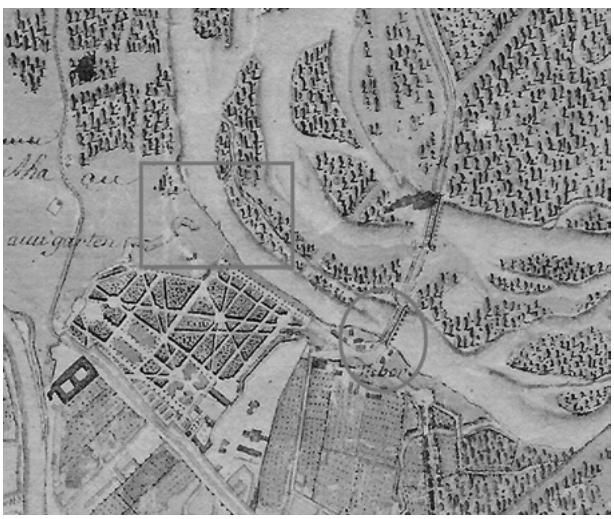

Fig. 2: Vienna, the area of the Vienna-Tabor gauge and the Augarten area according to the Josephinische Landesaufnahme ('Josephinian land survey'), section 71: Vienna and surroundings, detail (1773–1781). The presumable position of the ice jam is marked with the rectangle and the position of the Vienna-Tabor gauge at the Tabor bridge with the circle.

floods destroyed numerous bridges in Vienna and caused severe damage to a large number of properties in the suburbs (now within the outer districts of Vienna), such as Nussdorf to the north of the city centre. The severity of the conditions on the local populace worsened as temperatures again fell below 0 °C on 29 February.

The instrumental data from the water gauge at Vienna-Tabor is at first glance misleading. The water level reached its peak on the morning of 27 February (13 ft. 9 in.; 419 cm) and stayed higher than 11 ft. (335 cm) until the morning of 29 February. During the day, the water level decreased quickly and remained extremely low at 4 ft. (122 cm) for several days from 1 March onwards (Fig. 1).

The explanation for these data is given in several reports of the *Wiener Zeitung*. Ice floes started moving and got stuck in shallow areas and by bridges. A report from 3 March 1784 testifies to the presence of an ice jam near the Augarten just some hundred metres upstream from the Vienna-Tabor gauge (Fig. 2):

> *Schon am 28. [Februar] des Mittags brach es [das Eis] oberhalb Nußdorf los, und fieng an sich in Bewegung zu setzen. Des Morgens am 29. erhielt das Eis in dem Donauarme nächst Wien ebenfalls einigen Trieb, stemmte sich aber gleich Anfangs an der ersten Donaubrücke nächst dem Augarten. Hier waren Arbeitsleute vorhanden, welche die Eisschollen zerbrachen, um sie in leichteren Gang zu bringen. Sie wurden gegen Mittagszeit plötzlich von der Arbeit weggescheucht, da die Donau mit einem mächtigen Schwalle sich in schnelle Bewegung setzte. In ihrem Laufe wälzte sie an beyden Seiten des Ufers, wo es nicht ganz steil und sehr hoch war, mächtige Eisschollen übereinander hin, und bildete sich ein neues erweitertes Ufer.* […]

(Already on the 28th [February] at noon [ice] broke up above the village of Nussdorf and started to move. On the morning of the 29th, the ice in the Danube arm nearest to Vienna also gained some momentum, but at first it was jammed at the first Danube bridge next to the Augarten. There were workers there who were breaking up the ice floes to make them pass through more easily. At noon, the workers were suddenly shooed away from work, as the Danube set itself in motion with a mighty gush. In its course, it rolled mighty ice floes on top of each other on both sides of the bank, where it was not really steep and very high, and formed a new extended shore […]).[42]

In addition, the reports of the *Wiener Zeitung* provide vivid and detailed insight into the socio-economic consequences of the flooding in Austria, Bohemia, historical Hungary and Germany. The most detailed reports concerned the situation in Vienna on 29 February and the following days, when the ice flood covered large parts of the districts on both the left and right branches of the Danube River, and in particular the suburb of Leopoldstadt (currently district II in Vienna). Inhabitants were trapped in their houses and had to be sustained with food delivered by boat:

Noch ungleich betrübter ward die Lage der Einwohner in der Leopoldstadt, wo alle Häuser längst dem Ufer mit Wasser erfüllet wurden. Die Höhe des Wassers stieg an vielen Orten bis 3 Schuh, so daß man nicht mehr anders als auf Kähnen von einem Orte zum andern gelangen konnte. Es wuchs die hierauf folgende Nacht noch um ein merkliches, und was diesen traurigen Umstand noch weit mehr verschlimmert, ist die anhaltende Kälte, wodurch die Hofnung einer baldigen Oefnung des stemmenden Eises in der Donau entfernet, und durchaus das Elend vergrössert, das unterdessen freylich durch alle in der Gewalt der Regierung stehenden Mittel, welche mit grosser Weisheit und Sorgfalt sind vorgekehret worden, gelindert und erträglicher gemacht wird, aber noch immer hart genug für diejenigen ist, so es betrift.

(Still sadder was the situation of the inhabitants in Leopoldstadt, where all houses along the bank were filled with water. The level of the water increased at many places to three feet [95 cm] so that one could not get [in any] other way from one place to another [except] by boat. It still rose the following night considerably and what made this sad situation far worse was the persistent cold weather, removing the hope of a rapid breaking up of the ice on the Danube River and increasing the misery thoroughly. The misery was meanwhile, of course, made more mild and bearable by all possible means in the power of the government, which were arranged with great wisdom and care, but it still remained difficult enough for the people hit by the flood).[43]

The mighty ice floes caused severe damage to houses, bridges, and the water supply system. In particular, the economic situation of the poor seems to have been disastrous during the hard winter of 1783/1784, both before and after the floods. The *Wiener Zeitung* contains several reports of donations for the poor, presumably money, but in one case also large amounts of firewood. Donations are recorded from members of the Hapsburg family, by aristocrats, by anonymous benefactors and by the church. Individuals also provided support, such as a medical doctor in Vienna who offered to examine and cure the poor for no charge. Similar works of mercy and solidarity were also reported for other towns. The dean of the parish church of Krems was even honoured for his humanitarian efforts by the Emperor.[44] In Malá Strana, a district of Prague, the Order of the English Misses opened their garden and built an additional bridge to enable hundreds of people to escape the ice flood; they also received ill people from the Institute for the Poor and cared for them for over 12 days.[45]

The *Wiener Zeitung* also contains detailed lists of people who died in Vienna during the weeks preceding and following the ice flood. The city centre of Vienna and its suburbs (Vorstädte) were inhabited by 209,121 people in 1783.[46] On an average day, about 15–25 people died; on 7 January 1784, during the peak of the early January frosts in Vienna, 53 people lost their lives. During the ice flood of late February and during the following weeks, the average mortality did not increase much (17–32 people died per day), suggesting that fewer people were killed

42 Wiener Zeitung, 3 March 1784, 438.
43 Wiener Zeitung, 3 March 1784, 438 f.
44 Kinzl 1869, 314.
45 Wiener Zeitung, 20 March 1784, 578.
46 Weigl 2003, 110.

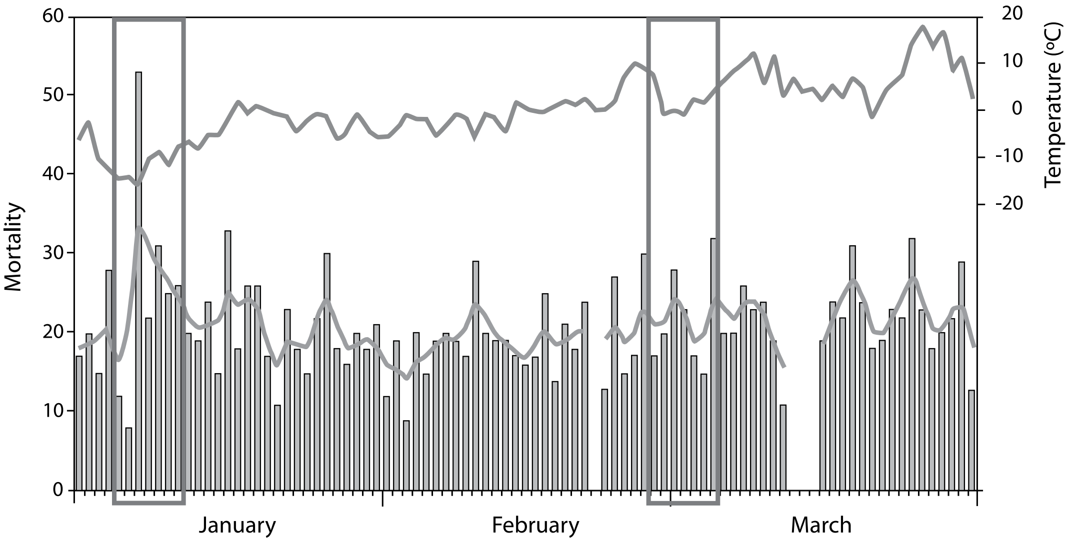

Fig. 3: Vienna, instrumental temperature measurements at 2 p.m. at the Vienna-Tabor water gauge station and mortality rates (people dying per day), January–March 1784 (smoothed by 5-day Gaussian filter). The rectangles mark the coldest days around 7 January 1784 and the time of the ice flood from 28 February 1784 onwards (for data see *Wiener Zeitung*; no mortality data available for 22 February and 13–15 March 1784).

by the ice flood than by the extreme frost in early January (Fig. 3). The warning and evacuation systems in Vienna during the ice flood seem to have been relatively successful in reducing the loss of life.[47]

Nevertheless, the *Wiener Zeitung* also reported that several unidentified people were killed during the ice flood; it is likely that they were homeless individuals or travellers:

> *Im Monat Februar d. J.* [1784] *sind in dem Herrschaft Dürnkrutter freyen Landgerichte im sogenannten Ebersdorferfeld zwey erfrorne unbekannte Mannspersonen gefunden worden, wovon der erste bey 40 Jahre alt, und von grosser Statur ist, ein länglicht runzlichtes Angesicht, schwarz abgeschnittene Haare, schwarze Augen braumen [sic] und Bart, am Leib einen Kopernitz, [...] der zweyte ist bey 18 Jahre alt, hatte ein rundes Gesicht, und keinen Bart, schwarz abgeschnittene Haare, [...] dann schienen beyde dem Ansehen nach aus Mähren zu sein* [...].
>
> *(In February [1784] two male persons were found frozen to death in the area of Dürnkrut in the so-called Ebersdorferfeld (Lower Austria), of whom the first is about 40 years old, large, with a long, narrow wrinkled face, black short-cut hair, black eye-brows and beard, wearing a Kopernitz coat, [...] the second is about 18 years old, large, with a round-shaped face and no beard, black, short-cut hair, [...] They both seem to have come from Moravia [...]).*[48]

The ice flood of 1830

The first third of the 19th century was part of the so-called Dalton Minimum (1790–1835), a period with low solar activity. Severe winters and cool summers were quite common during that time, and for the years following 1808/1809 and 1815, volcanic eruptions brought short-term climatic extremes, such as the 'year without a summer' in 1816 after the Tambora eruption.[49] The ice flood of 1830 in Central Europe was similar to the one in 1784. Again, most of the Central European rivers froze, including the Danube River and its catchment and the rivers in the Czech lands and central Germany.[50] Besides the sources available for 1784 (i. e. newspapers, instrumental measurements), the pictorial evidence is even better for 1830. In addition, the Viennese eyewitness Franz Sartori described the situation in Vienna in a 248-

47 Brázdil et al. 2010, 180 f.
48 Wiener Zeitung, 17 March 1784, 560 f.
49 Cf. Wood 2014; Behringer 2015; Krämer 2015.
50 Cf. Strömmer 2003, 295–301 for Lower Austria, including the city of Vienna; Poliwoda 2007, 194–203 for Saxony.

Fig. 4: Vienna, the flooded quarter of Leopoldstadt (Jägerzeile) on 2 March 1830. Watercolour drawing by Eduard Gurk, 1830.

Fig. 5: Vienna, the flooded quarter of Roßau (Schmidgasse) on 2 March 1830. Watercolour drawing by Eduard Gurk, 1830.

page treatise. The focus of the author is on the affected districts of Vienna (casualties, i. e. 74 people killed, damages), on rescue management (single 'local heroes', donations) and on the role of the Hapsburg imperial family.[51]

Eduard Gurk (1801–1841), a Viennese artist and imperial court painter (*Hofkammermaler*), made a series of 'official' watercolour drawings showing Archduke Ferdinand in action (Figs. 4–7). These are not only interesting in the sense of how the imperial family wanted to demonstrate pious solidarity with their subjects in a time of severe political repression, but also in showing details of disaster management not documented elsewhere. Fig. 4 depicts the Archduke on a boat in the centre, whereas other boats supply people with food (on the right). Ice floes and furniture drift in the water. Numerous other boats with well-dressed people in the back-

51 Sartori 1830.

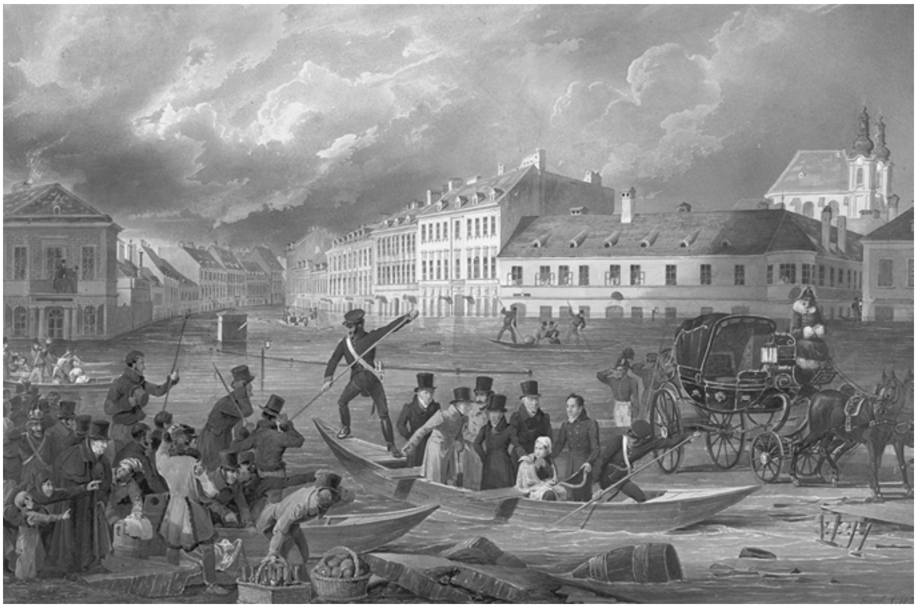

Fig. 6: Vienna, the flooded quarter of Roßau (Schmidgasse) on 2 March 1830 – the disembarkation of the Archduke. Water colour drawing by Eduard Gurk, 1830.

Fig. 7: Leopoldau, the flooded suburban village on 4 March 1830. Watercolour drawing by Eduard Gurk, 1830.

ground show that many houses were obviously equipped with such boats for evacuation, a preventative measure introduced after the ice flood of 1784. In Fig. 5, a child is being rescued, and the bourgeois rescuers are supported by the people in the house. Again, furniture is drifting in the water. Protective fences in the street are to prevent ice floes and other drifting objects from crashing into the houses, a protective measure not documented otherwise and presumably going back to the experiences of 1784. Fig. 6 shows the end of the Archduke's trip through the flooded streets. Horse and carriage are already awaiting him. Finally, Fig. 7 gives an overview of the situation in the suburbs. The village of Leopoldau near Vienna is completely covered with ice floes; they would remain for many weeks and make agriculture and traffic impossible.

Conclusions: Ice floods and their impact on urban societies

In many instances, ice floods were catastrophic events because they gave the affected population hardly any time to prepare. First, the rescue of victims and management of damage had to be undertaken with the available means. Second, these floods were often part of a series of catastrophic events such as in Krems, when the ice flood of January 1573 hit a highly vulnerable society after an extreme summer flood in 1572, or in Vienna in 1784, when the ice flood followed a year of bad harvests in 1783 and an extremely cold January in 1784 after the Laki volcanic eruption. Bridges and water mills were the most vulnerable buildings in urban and sub-urban environments and constituted an obstacle for the ice floes, leading to ice jams.

New protection and coping strategies had to be developed, such as the establishment of 'ice observers' on elevated hills after 1784. After finding that having workers attempt to break up the ice in advance was not very effective, protective fences were erected in the streets as one drawing of the 1830 event testifies. Many houses in the endangered quarters of the cities were equipped with boats for escape. Solidarity through donations as well as the housing of evacuated people was widespread.

Until the 18th century, the urban authorities were mainly responsible for disaster management and future prevention strategies, and in cities with a high risk of flooding, urban legislation provided shelter for the affected inhabitants. Only when the available means were simply not sufficient was further support requested as the petition of 1573 to the Emperor testifies. In some cases from the Late Middle Ages, the mill owner had to cope with the damage alone. From the times of enlightened absolutism, rulers such as Emperor Joseph II, as the sovereign in Austria, took over a 'patriarchal duty' to help their subjects, like a father caring for his children, as shown in 1784. In 1830, during the time of neo-absolutism, the presence of Archduke Ferdinand was even more prominent during the ice flood.

Urban cultural memory is represented through flood marks on prominent buildings such as town gates, but also through drawings and even treatises collecting newspaper reports and documenting the donations and deeds of 'local heroes'. It is remarkable that religious responses to ice floods are missing for all periods examined, beginning from the Middle Ages to the 19th century. Although severe ice floods were unusual, extraordinary events, such floods were in many cases still part of 'normal life' within cultures of risk management.

Illustration Credits

Fig. 1: Christian Rohr, values based on the data published in the *Wiener Zeitung*, 17 January to 3 April 1784.
Fig. 2: Vienna, Österreichisches Staatsarchiv – Kriegsarchiv, BIXa242 sectio 071.
Fig. 3: Brázdil et al. 2010, 181, based on the data published in the *Wiener Zeitung*, 10 January to 3 April 1784.
Fig. 4: Vienna, The Albertina Museum, Inv. No. 22610.
Fig. 5: Vienna, The Albertina Museum, Inv. No. 22609.
Fig. 6: Vienna, The Albertina Museum, Inv. No. 22615.
Fig. 7: Vienna, The Albertina Museum, Inv. No. 22616.

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