Historical hydrology – Editorial

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Hydrology – the science of the water cycle – has a long tradition: the ancient philosophers tried to resolve the mystery of the hydrological cycle. However, even if the general understanding of hydrology has been about right for centuries, typically it was not possible to assess national or global water resources in quantitative terms until the 20th century, when many national hydrological services started systematic water-related observations, collecting data and information.

Now, it is broadly recognized that information on how much water is available in time and space is indispensable for socio-economic development and for securing environmental river flows. Information about the mean, variability, dependability and seasonality of water resources, as well as their utilization and control, is available to decision makers. It provides the potential for water resources development, for managing water in an informed way, and for assessing impacts. Water serves competing uses nowadays and water-related information is needed for planning, design and operation of water resources systems (e.g. multi-purpose reservoirs). However, it is not uncommon that construction projects are launched without adequate water resources assessment. Often, all that is available is a short time series of hydrological records, or even no records at all.

River gauges provide essential information, but the length of record is often limited. Instrumental records can only be extended into the future, when new data are obtained, but not back into the past. Hence, the possibility of extending river records by acquiring information on pre-instrumental events is very welcome. This underpins the importance of historical hydrology or palaeohydrology: providing knowledge of hydrological events outside of the instrumental records. Historical hydrological information is typically limited in location (near to human settlements). Not all large events may have been mentioned in historical information – their inclusion depends on human perception at the time. Events that led to high disruption and damage are quite likely to be remembered. Palaeo-information, encapsulated in geophysical archives, is also available for uninhabited areas. The optimal merging of instrumental, historical and palaeo-information is a difficult task of considerable importance.

An essential part of water management is the pursuit of relative security against hazards associated with water-related extremes: floods and droughts. They are natural events, experienced since the dawn of civilization, sometimes resulting in loss of human life and material damage. Despite the technological progress and better under-
standing of natural processes (and their forecasting), material damage due to hydrological extremes has not been decreasing. Since 1990 there have been many episodes of severe river flooding in many parts of Europe, resulting in large-scale damage.

In order to interpret the most extreme hydrological events, it is necessary to have long records of river flow and other variables. Since existing series of observed data are relatively short, they may not provide information about the largest events that occurred in the past, i.e. beyond the recent experience based on instrumental records, as well as about return periods of extreme floods and their tendency to clustering.

The increased frequency, severity and damage of disastrous floods experienced in recent decades in many areas of Europe, and other parts of the world, leads to intriguing scientific and practical questions. Is this increase related to better information possibilities? Is the main driving factor human encroachment into flood-prone areas? Is there any global warming trend in flood records? Are the recent violent floods really higher than extreme events from the past, pre-instrumental era? What is the role of land-use changes in watersheds and anthropogenic changes in the water courses (e.g. river regulation)? Are there any changes in the generating mechanisms of floods?

Answering these questions needs systematic research which cannot be based just on data from the relatively short period of hydrological measurements starting in the 19th–20th centuries. Significant extension of information about floods from the pre-instrumental period is offered by historical hydrology and palaeohydrology. Although palaeohydrology or palaeoflood hydrology (see e.g. Baker et al., 2002; Benito, 2003) is already recognized as an important part of hydrology, historical hydrology, dealing mainly with documentary evidence about hydrological events, has not been broadly recognized yet. It offers considerable potential for further hydrological investigations. Some progress in historical hydrology has been achieved in recent years in Europe partly as a by-product of the research on weather extremes in historical climatology (see Brázdil et al., 2005b).

However, while recognizing the value of pre-instrumental information, one should remember that the present situation is new. Never in the last thousand years were atmospheric greenhouse gas concentrations and global mean temperatures as high as they are now. Hence, the past can be regarded as a key to the future in a limited way only.

Historical hydrology was selected as the theme of this Special Issue of *Hydrological Sciences Journal* with the aim of defining this new research field and demonstrating its potential in studying hydrological extremes in Europe. It is opening a new interdisciplinary research area linking hydrology and history, which may prove beneficial for further research in both disciplines, overcoming the barriers between the natural and social sciences and inducing a cross-fertilization effect. Although the geographical coverage of the presented articles is limited to only a few European countries (Spain, Germany, Poland, Austria, the Czech Republic, The Netherlands, Belgium and Switzerland), relevant documentary data exist also in other countries.

The Special Issue on Historical Hydrology consists of this Editorial and 14 papers dealing with different research aspects. It starts with an overview paper by Brázdil et al. (2006b), characterizing the state of the art of historical hydrology in Europe with respect to flood risk studies. Historical hydrology is defined as “a field situated at the interface of hydrology and (environmental) history, dealing mainly with documentary sources and using both hydrological and historical methodologies”. Working with documentary evidence created by man distinguishes historical floods from palaeofloods, where
information stems from natural archives. The paper discusses different types of documentary data, historical perception of floods and recent achievements in such areas as: reconstruction of past changes in watersheds and river channels, analysis of long-term frequency patterns of historical floods, estimation of flood discharges associated with historical floods, deciphering meteorological causes of historical floods, synthesis of palaeofloods, historical and instrumental floods, impacts of historical floods and the climate–flood links.

The following papers in this Special Issue contribute to the basic aim of historical hydrology, defined as “reconstructing temporal and spatial patterns of runoff conditions as well as extreme hydrological events (floods, ice phenomena, hydrological droughts) for the period prior to the creation of national hydrological networks” (Brázdil et al., 2006b). The papers can be divided into three groups. The first present long-term flood series derived from documentary evidence and discuss frequency (Barriendos & Rodrigo, 2006; Böhm & Wetzel, 2006; Cyberski et al., 2006; Mudelsee et al., 2006; Rohr, 2006). The second group is devoted to analysis of individual disastrous events (Brázdil et al., 2006a; Bürger et al., 2006; Demarée, 2006; Thorndycraft et al., 2006). Four further papers deal with storm surges (de Kraker, 2006), statistical analysis of long-term flood series (Yiou et al., 2006), atmospheric circulation causes of floods (Jacobeit et al., 2006) and hydrological droughts (Pfister et al., 2006).

Barriendos & Rodrigo (2006) present a comprehensive study of flood series for Spain during the past millennium based on documentary and instrumental data. They discuss frequency, seasonality and severity of floods. They show that Mediterranean basins were affected by floods occurring more commonly in autumn months, while floods in the Atlantic basins occurred mainly in winter. Generally, some climate modulation of flood frequency can be observed. Higher flood frequency was found in the mid- and late 16th century, in the late 18th century and in the second half of the 19th century, while lower flood frequency was detected around the mid-15th century, in the early 16th century, in 1680–1730 and in the early 19th century.

Flood series on the rivers Isar and Lech in the German Alpine foreland have been analysed by Böhm & Wetzel (2006), who combined documentary data and hydrological observations of water stages since 1826. On these rivers, summer floods dominate, being related to heavy rains resulting from cyclones advancing from the Mediterranean. The importance of these cyclones for flood events in Central Europe is mentioned elsewhere in this issue (Brázdil et al., 2006a; Jacobeit et al., 2006), mainly in connection with the Vb path (“Zugstrasse Vb”) defined according to the van Bebber classification (see e.g. Štekl et al., 2001; Mudelsee et al., 2004).

Cyberski et al. (2006) review the history of floods on the River Vistula and its tributaries in Poland over more than a thousand years. Floods on the Vistula are caused by several mechanisms – convective or advective rainfall, snowmelt, ice jam and storm surge. The availability of instrumental data is affected by Poland’s history, including her loss of independence and partitioning among three neighbouring countries. In order to extend the available time series of records, historical hydrology can be used to explain water conditions and water-related hazards in the pre-instrumental era. An interpretation of changes in flooding, caused by land use, river channelling and climate change in sub-basins of the Vistula is offered.

Mudelsee et al. (2006) have assembled a series of floods for the River Werra in Germany for the period 1500–2003. It results from their analysis that the overall risk
of floods in winter (November–April) is approximately 3.5 times higher than the summer flood risk. The winter flood risk peaked around 1760 and 1860 and it has increased again during the past six decades. The summer flood risk peaked at around 1760, but shows a long-term decrease from that time. The authors stress that the different trends of the Werra, compared to the nearby Elbe River, can be explained by the high spatial variability of orographic rainfall. They believe that incomplete documentary evidence for the pre-instrumental period plays only a minor role in the whole synthetic series of the Werra floods.

Documentation of expenses for repairs of the bridge in the town of Wels (Upper Austria) across the Traun River, a tributary of the Danube, was used in the study of floods by Rohr (2006). Records kept in the book of accounts, written by the bridge master and available in the city archive, allowed Rohr to reconstruct flood information for the period 1441–1574 with a classification of flood intensity based on the corresponding damage. Floods in the years 1501, 1567, 1569 and 1572 were evaluated as disastrous.

The August 2002 floods in Central Europe, caused by heavy rains, exceeded the highest known water marks. Brázdil et al. (2006a) compare this flood with another disastrous event from July 1432 in Bohemia (Czech Republic). Based on water marks on Castle Rock on the Elbe at Děčín and levels marked with respect to the relief of the so-called “bearded man” (Bradáč) on the Vltava at Prague, both floods can be rated, probably together with the September 1118 flood, as the most disastrous flood events in Bohemia during the whole millennium. After the period of 1784–1862 (late stage of the Little Ice Age), when four disastrous winter floods occurred, the category of large floods in Bohemia contains only rain-induced events.

Bürger et al. (2006) have attempted to integrate an analysis of extreme historical floods with studying contemporary floods. Extreme flooding in 1824 in the Neckar River basin (in the Land Baden-Württemberg, Germany) was reconstructed using historical data (qualitative and quantitative sources). It was possible to reconstruct the regional atmospheric circulation patterns, the weather conditions and the precipitation distribution associated with the event. Results of river flow modelling obtained using the LARSIM model are presented.

Warming of European winters, as well as intense anthropogenic changes in the watersheds, have weakened the ice phenomena on the rivers. This, in combination with less abundant snow cover, has resulted in a significant decrease in the severity and frequency of disastrous winter floods in much of Central Europe (e.g. Mudelsee et al., 2003; Brázdil et al., 2005a, 2006a). Such floods were more typical for winters during the Little Ice Age, as is the case of the February 1784 flood analysed by Demarée (2006). Using very rich documentary evidence and instrumental meteorological records from the Mannheim Ephemerides, he has examined in detail the hard and snowy winter of 1783/84 across much of Europe and the sudden warming after 21 February 1784, which resulted in heavy floods in present-day Belgium, The Netherlands, Luxemburg, northern France, Germany, Austria and the Czech Republic.

Using very detailed documentary data, Thorndycraft et al. (2006) have reconstructed the catastrophic floods of 1617 in Catalonia (northeast Spain), caused by heavy rains on 2–6 November, with severe damage to houses, bridges and water mills. Based on water stage indicators, they were able to estimate the magnitude of these floods on the Llobregat and Ter rivers, which exceeded the largest known events of the instrumental data series. Comparison of the 1617 floods with the longer-term palaeo-
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flood records showed that the largest floods in the region were associated with colder phases of climatic variability.

De Kraker (2006) studied flood events in the estuaries of the rivers Rhine, Meuse and Schelde between 1400 and 1953 using documentary evidence and tried to distinguish between their natural and human causes. The floods analysed were related mainly to storm surges interacting with tidal dynamics. The study examines two or more of the most important storm surges per century, showing close interactions between Man and Nature in the delta area. It was found that flooding occurring during storm surges was most common, while deliberate flooding during periods of warfare had the largest impact on the environment.

The availability of long time series of floods makes it possible to analyse statistical properties of the river flow process. Yiou et al. (2006) applied extreme value theory in a non-stationary context to investigate the amplitude and frequency of floods on the Vltava at Prague (1825–2003) and on the Elbe at Děčín (1851–2003) in the Czech Republic. Although the second half of the 19th century was characterized by the highest frequency and severity of floods, a general decrease during the 20th century can be detected, correlating with an increase in winter temperatures.

Jacobeit et al. (2006) review the links between large river floods and atmospheric circulation dynamics in Central Europe. Circulation studies on historical time scales have, typically, been constrained by the large temporal resolution (monthly or seasonal) of reconstructed atmospheric pressure fields. By investigating daily data, it was found possible to determine sequences of circulation patterns preceding prominent observed river flood events. Based on daily 500-hPa geopotential height fields, major large-scale circulation pattern sequences for such discharge events in Central Europe were determined and put together for an overview, in a seasonal context.

Pfister et al. (2006) have investigated hydrological winter droughts within the Upper Rhine basin using water-stage measurements (since 1808 at Basel, Switzerland) and documentary evidence, namely information on rocks emerging in rivers and lakes during low-water episodes. They documented 30 severe winter droughts since 1540 occurring after periods of low precipitation, mainly due to persistent anticyclones centred over Western Europe. During the 20th century, severe winter droughts were relatively rare, compared to earlier. This can be related to an increase in winter temperature and precipitation.

Brázdíl et al. (2006b) identified the following future research priorities for historical hydrology in Europe.

- Completion of the existing databases of historical floods; verification, cross-referencing and combination of different data for reconstruction of past floods.
- Compilation of further flood information for different countries in Europe and evaluation of floods in terms of severity, seasonality, generating mechanism, and impacts; and studying their behaviour over time, change detection and attribution.
- Improving multi-disciplinary and inter-disciplinary collaboration in reconstruction of the occurrence and severity of the past floods, as well as in study of impacts of past hydrological extremes upon the human society and its adaptation to extremes.

The authors hope that this HSJ Special Issue on Historical Hydrology will not only have a role as a first contribution to these research tasks, but also serve as stimulation for further research activities in the area. It contains much useful material of interest to
a truly multi-disciplinary readership, including experts interested in climate, water, environmental history, natural disaster protection, and possibly also the media.

Acknowledgements The authors acknowledge excellent collaboration with Ms Frances Watkins, Production Editor of Hydrological Sciences Journal on producing this Special Issue. Her assistance and Dr Cate Gardner’s with technical and linguistic editing of submitted papers is gratefully acknowledged. Sincere thanks go to all contributing authors as well as to the broad team of reviewers who significantly helped to improve the papers.

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