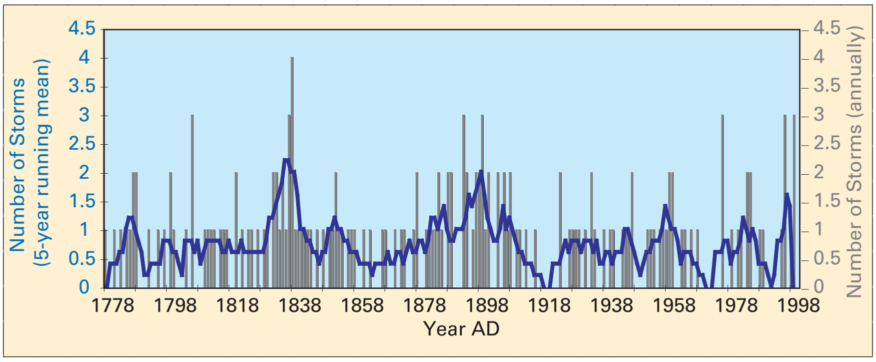

Fig. 2: Time series of tropical cyclone frequencies for South Carolina, centered at Charleston, from 1778-2000. The red vertical bars represent annual frequencies while the blue line represents a 5-year running mean.

year varied from zero to four, but mostly from zero to two. Details of 68 storms were analyzed for the 1778-1870 period, with 25 of them being newly documented storms. A calculated mean recurrence interval for 1778-1870 suggests significant tropical storm impact on Charleston every 1.30 years, clearly lower than the interval of 1.80 years that dominates during most of the late nineteenth and twentieth centuries. The 5-year running mean indicates that much of this greater tropical cyclone activity occurred in the 1830s. This decade is clearly the most active in the entire time series. In particular, 1838 had four storms, the most annually for the entire record, and two of the four storms occurred in June.

Documentary evidence of the Southeastern United States, although not as lengthy as in Europe and Asia, provides valuable information of high resolution climate back into the eighteenth century, well before the modern instrumental record. It contributes to other existing high resolution paleoclimatic and paleohurricane databases for North America, providing further insight on the spatial variations and causes of natural climatic variability. Aside from tree-rings, that are sensitive mostly to late-spring rainfall and drought, these historical data are the only evidence of past climate that can provide seasonal quantitative reconstructions for the region. Historical climate records from the Southeastern United States can also aid in testing and verifying general circulation model simulations of the past several centuries.

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Floods in Europe – A Look into the Past

Rudolf Brázdil[1], Rüdiger Glaser[2], Christian Pfister[3] and Heiko Stangl[2]

[1]Department of Geography, Masaryk University, Brno, The Czech Republic; brazdil@sci.muni.cz
[2]Department of Geography, University of Heidelberg, Germany; ruediger.glaser@urz.uni-hd.de; heiko.stangl@urz.uni-hd.de
[3]National Center of Competence in Research on Climate (NCCR), Institute of History, University of Bern, Switzerland; pfister@hist.unibe.ch

During the 1990s, floods (e.g. 1993 and 1995 on the Rhine and the Meuse, 1997 on the Morava and the Oder and 2002 in Central Europe) have been among the most devastating disasters in Europe resulting in losses of human lives and substantial damage, disrupting community life and generating collective stress and widespread fear. The deluge of August 2002 in Central Europe caused such staggering losses that Germany's large economy has struggled to cope with the costs of recovery. The issue of whether and how such disasters might be related to the greenhouse effect and global warming is repeatedly put on the agenda. However, the number of well-documented cases is too small for conclusions to be drawn. In Europe, early water gauge measurements started during the eighteenth century (e.g. 1708 in Zurich) but for most rivers, instrumental observations are only available for the twentieth century. This is insufficient for an assessment of flood frequency changes in the presence of substantial natural climate variability. Documentary evidence about severe flood events can substantially increase the number of cases available for analysis.

Documentary evidence on floods

Two types of evidence – written reports and flood marks – need to be distinguished.

Reports on severe floods go back to the Middle Ages. They are documented in sources such as annals, chronicles, memoirs, diaries, letters, newspapers or economic records. For example, the first reliable report about a flood in Prague was written by the chronicler Kosmas (Brázdil, 1998): *"In the year of our Lord 1118 in the month of September there was such a flood as, I think, it has not been on the Earth since the Deluge. This river of ours, the Vltava, suddenly broke out of its bed – how many villages, how many houses in the suburbs, huts and churches did it take away! At other times, although it happens rarely, the water reaches only the floor of the bridge, but this flood rose to a height of ten ells [i.e. approximately 6 m] over the bridge."* This chronicler tried to quantify the magnitude of the event by relating the highest water level to the altitude of the bridge (one of the predecessors of the recent well-known Charles bridge).

Some reports just mention the occurrence of an event. Others may include description on the causes of the flood, its magnitude and duration as well as detailed accounts on the damage caused. Often, a mark is placed on a building (e.g. houses, gateways, bridges – see Fig. 1) or on a rock to document the highest water level during an event. Flood marks may be used to estimate the maximum discharge rate of an event and to assess its spatial dimension using a digital terrain model. However, this requires detailed knowledge of land-use, landforms and the river-bed, which are often not known for the remote past. An evaluation of all evidence from different sources often allows the classification of events according to three (Table 1) or four classes (Pfister 1999) in order to set up semi-quantitative time series.

Table 1. Intensity classification of historical floods (Brázdil et al., 1999; Sturm et al., 2001)

Level	Classification	Primary Indicators	Secondary Indicators
1	smaller, regional flood	little damage, e.g. fields and gardens close to the river, wood supplies that were stored close to the river are moved to another place	short flooding
2	above average or supra-regional flood	damages on buildings and constructions related to the water like dams, weirs, footbridges, bridges and buildings close to the river like mills etc.; water in buildings	flood of average duration, severe damages to fields and gardens close to the river, loss of animals and sometimes people
3	above average or supra-regional flood on a disastrous scale	severe damages on buildings and constructions related to the water i.e. dams, weirs, footbridges, bridges and buildings close to the river like mills etc, water in buildings; in part, buildings are completely destroyed or torn away by the flood	longer flood duration, days or weeks; severe damages on fields and gardens close to the river, extensive loss of animals and people; morphodynamic processes like sand sedimentation cause lasting damages and change the surface structure

In many cases the evidence is sufficient to yield information on seasonality, severity and impacts. Scientific objectives of historical flood analysis include the following points of view: assessing the size of extreme flooding, classification of extreme floods according to season and causes and assessing long-term changes in flood frequency under conditions of a "natural" climate.

Flood Typology in Central Europe

To characterise the severity of a flood, its return period corresponding to culmination discharge rate is calculated (so-called N-year water). Four basic types of events may be distinguished according to their meteorological causes: (i) short but intensive downpours or cloudbursts (flash floods), (ii) long-lasting continuous rainfalls, (iii) snow-melt and (iv) ice damming.

The so-called flash floods occur on a local scale and may have disastrous local impacts as they are connected with heavy precipitation during convectional storms. The other two types of floods affect larger territorial units. They are related to supra-regional synoptic patterns such as cyclones or troughs, causing a continuous precipitation for several consecutive days (type ii) or sudden warming (types iii and iv). Floods from snow melting depend on the water equivalent of the snow cover, the extent of frozen soil and the intensity of warming combined with precipitation to contribute to a cumulative impact. Ice damming results from a sudden warming in the upstream area of a river following a long period of very low temperatures. The water then breaks up the ice. Ice clods may pile up and dam the water or damage bridges (such as occurred in February 1784 in parts of Germany and Bohemia).

The described causes of floods often overlap, and they are related to other physical-geographical factors such as the saturation of the catchment area, vegetation, and with anthropogenic factors such as the building of water structures (dams, reservoirs, weirs), land use, and changes in riverbeds.

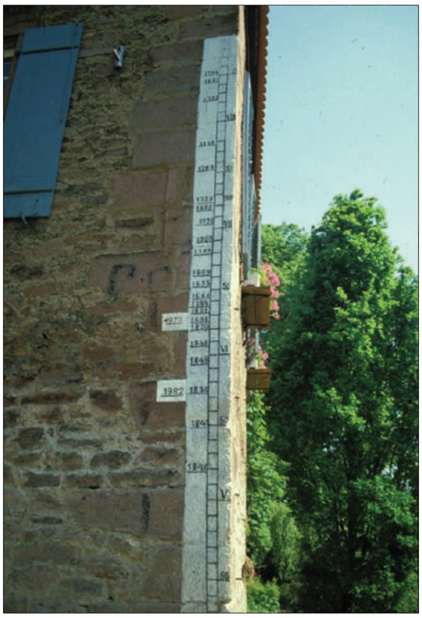

Fig. 1: Flood marks at Wertheim on the tributary of the Tauber river to the Main (Glaser, 2001)

The frequency of floods in a natural climate

The issue of whether clusters of severe floods may occur in a natural climate is crucial for detecting a fingerprint of the greenhouse effect in the records of extreme events.

Progress in historical climatology achieved during the 1990s. Besides the detailed investigations of some catastrophic past floods (e.g. July 1342, February 1784), long flood chronologies were set up for different rivers in Europe (Fig. 2). Recently, the dynamic and socio-economic aspects of historical floods in Central Europe are analyzed in the framework of the European research programme FLOODRISK (Wanner et al., 2002). Historical flood events for Germany based on documentary evidence since AD 1500 were recorded in three severity classes and related to reconstructed air pressure and precipitation data. Decadal scale variability became apparent in the recording of all large river systems, indicating winter periods with higher (e.g., 1630-1700 and 1830-1880) and lower (e.g., 1720-1780 and 1880-1930) flood frequencies. The correlation between the winter season frequencies of the different river systems is non-stationary, and a discernable long-term trend is not evident. The circulation analysis based on a long-term Atlantic-European surface air pressure data showed that the humidity transport from the Atlantic Ocean to the European continent is a key factor conditioning flood situations.

On the other hand, a significant decrease in the number and in the severity of floods was observed for the Vltava river at Prague and for the Elbe river at Decín (both the Czech Republic) from the second half of the nineteenth century to the end of the twentieth century, mainly due to significant reduction of floods from February to April (Brázdil, 1998). The recent catastrophic flood in August 2002, estimated for the Vltava at Prague to be a 500-year event, came unexpectedly after a very quiet period of the twentieth century in both catchment areas. Its magnitude was probably comparable to one from the same area in July 1432, which was considered to be a "millennial flood".

For historical and recent floods, their social dimension is important. Consequences caused by historical floods can be divided into two groups (Wanner et al., 2002, see table 1): (i) short-term consequences (e.g. destruction of houses, streets and bridges, breakdown of water supply) (ii) medium-term consequences (e.g. shut down of industrial plants, soaked pastures, animal diseases).

Confronted with the harm caused by catastrophic floods, people are eager to get specific information and rapid support. Examples from Switzerland show that in addition to assistance from political authorities, media fund raising campaigns have been very successful. It becomes apparent that risk management, when consistently utilised by the political authorities, has strengthened the bonds of national unity.

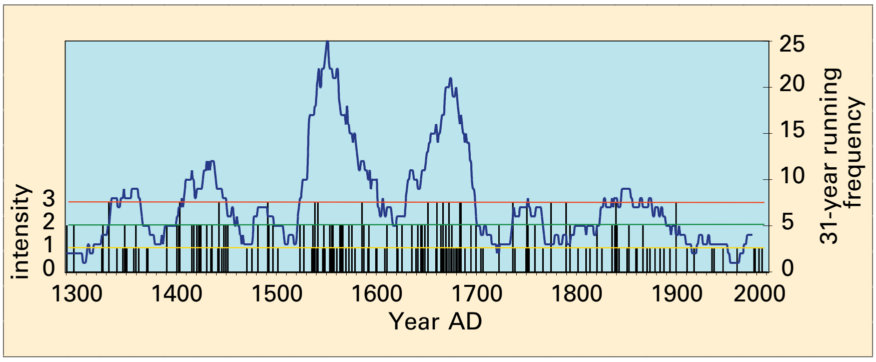

Fig. 2: Flood patterns of the river Pegnitz in Nuremberg (Germany) from 1300 to 2000. The altitude of the bars is proportional to the severity of the events (see Table 1). The curve displays 31-year running averages. Two distinct phases of high flood frequency stand out during the main phase of the Little Ice Age between 1550 and 1700.

Outlook

Historical climatology contributed significantly to the extension of our knowledge about historical floods in Europe for the pre-instrumental period. Flood frequency, seasonality, severity and impacts, as well as trends related to anthropogenic climate change, are all prime subjects for study by historical climatologists. Some historical events serve as analogues for recent floods and well documented recent events are important for understanding similar floods in the past. In these studies, variable anthropogenic effects in the catchment areas such as changes in land use, in riverbeds, in stream regulations and infrastructure (dams, reservoirs, etc.) should be taken into consideration. The value of historical flood evidence lies in its use for flood risk assessments and in helping to prepare flood-prone zones for maximum floods that are documented within the last centuries. These long-term records may reduce uncertainty in hydrological analyses and decrease losses of human lives and property.

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Reconstructions of Minimum Glacier Extensions in the Swiss Alps

Hanspeter Holzhauser[1] **and Heinz J. Zumbühl**[2]

[1]Institut of Geography, University of Zürich, Switzerland; holzi@geo.unizh.ch
[2]Institut of Geography, University of Bern, Switzerland; zumbuehl@giub.unibe.ch

The advance and retreat of alpine glaciers indirectly reflects the natural variability of Holocene climate. Using different methods (analysis of historical sources, dating of trees and soil; Zumbühl and Holzhauser, 1988), we aim to reconstruct glacial fluctuations in order to verify Holocene climate variation.

In order to correctly interpret the current rapid glacier retreat in contrast to the previous maximum extent in 1850/60, it is important to know the Holocene minimum and maximum extent of alpine glaciers. The maximum advance of post- ice age alpine glaciers is well-documented by the high mark of moraines. In contrast, the glacial minimum, that is, the minimal glacial extent between two advances, is not well documented by moraines and is therefore difficult to determine.

The glacial minimum can be demonstrated and dated either by fossil soils and trees that surface at the melting ice edge (Holzhauser, 1984), or by the use of historical documents (Zumbühl, 1980). We provide two examples of how the glacial minimum during the Little Ice Age could be reconstructed using appropriate historical pictorial sources.

The Great Aletsch glacier in 1755

Due to a legal dispute between the Wallis townships of Ried-Mörel, Mörel und Bitsch on one side, and Naters und Rischinen on the other side, we know the extent of the Great Aletsch glacier in the middle of the 18th century. The parties concerned disputed the ownership of some grassland on the western slope of the Riederhorn mountain. An initial court hearing took place in 1684, and a second hearing took place 70 years later from 1754 to 1755. Three generations later, from 1855 to 1856, a third hearing took place.