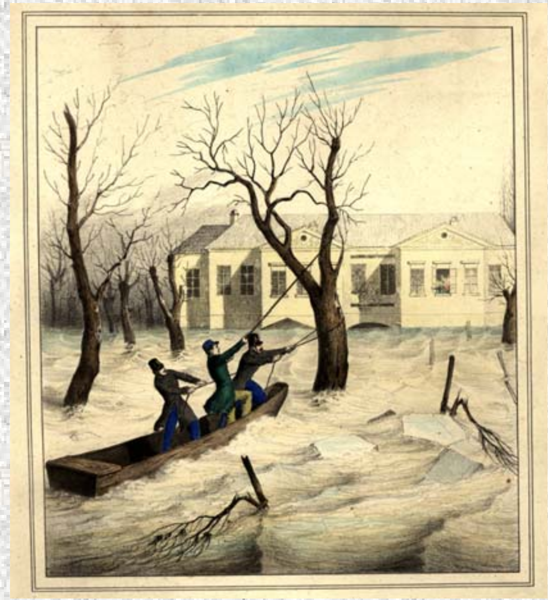
THE AUGUST 2002 FLOOD IN PRAGUE IN THE CONTEXT OF HISTORICAL AND RECENT FLOODS IN THE CZECH REPUBLIC

Rudolf Brázdil

Institute of Geography, Masaryk University, Brno, Czech Republic



Outline

1) The August 2002 flood in Prague
2) Recent disastrous floods in the Czech Republic
3) Types of floods according meteorological reasons
4) Floods in the period of systematic observations
5) Documentary evidence about floods
6) The August 2002 flood in the historical context
7) Conclusions

The August 2002 flood in Prague

The flood in Bohemia in August 2002

19 victims - material damage around 73 billions of Czech crowns

The Vltava in Prague during the flood in August 2002 (photo L. Elleder)

Prague – Kampa with statue of Bruncvík – during (left) and after (right) August 2002 flood (photo L. Elleder)

Watermarks at Kampa in Prague - comparison of the Vltava floods from 2002 (August), 1784 (February) and 1845 (March)

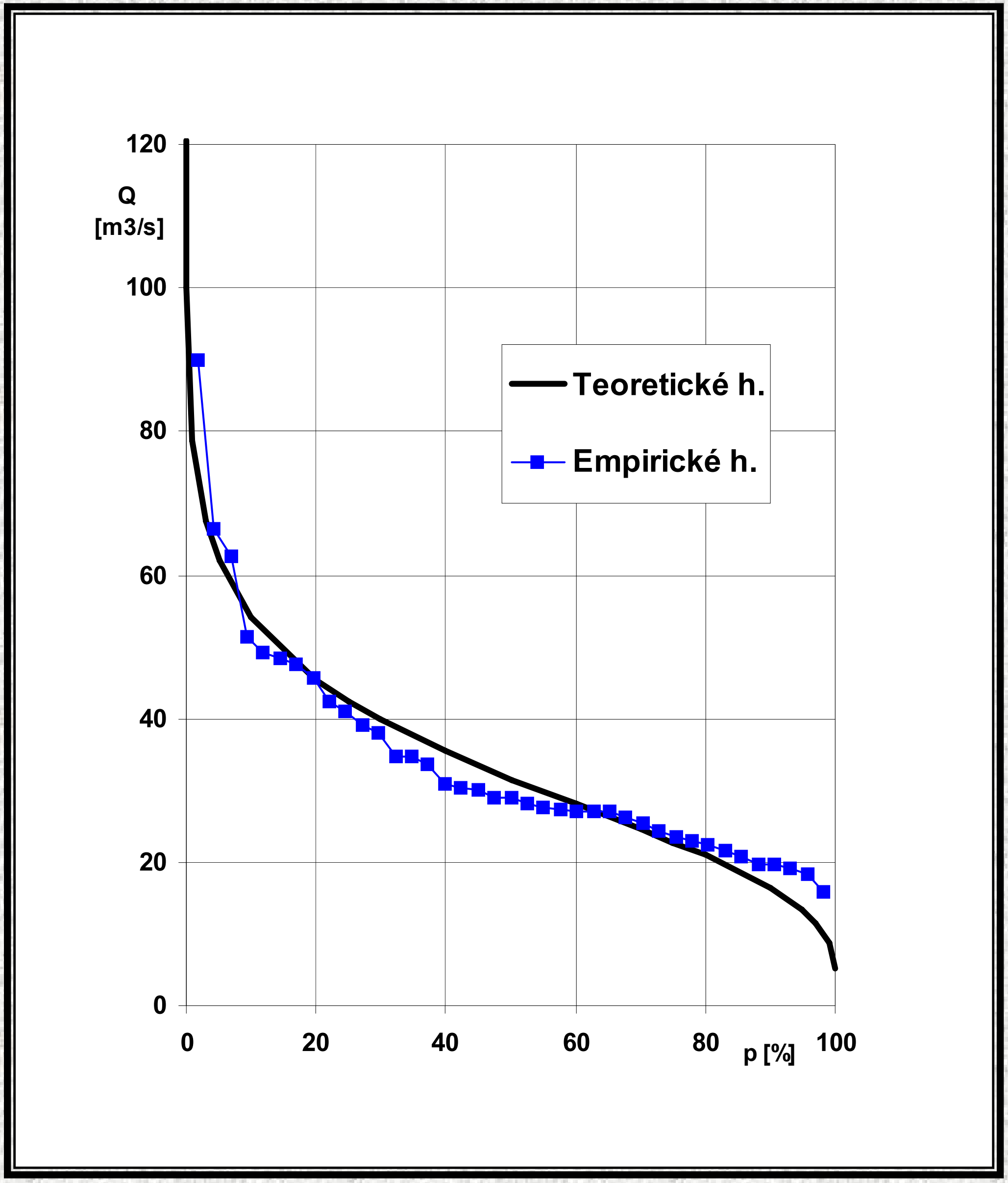
N-year return period of floods

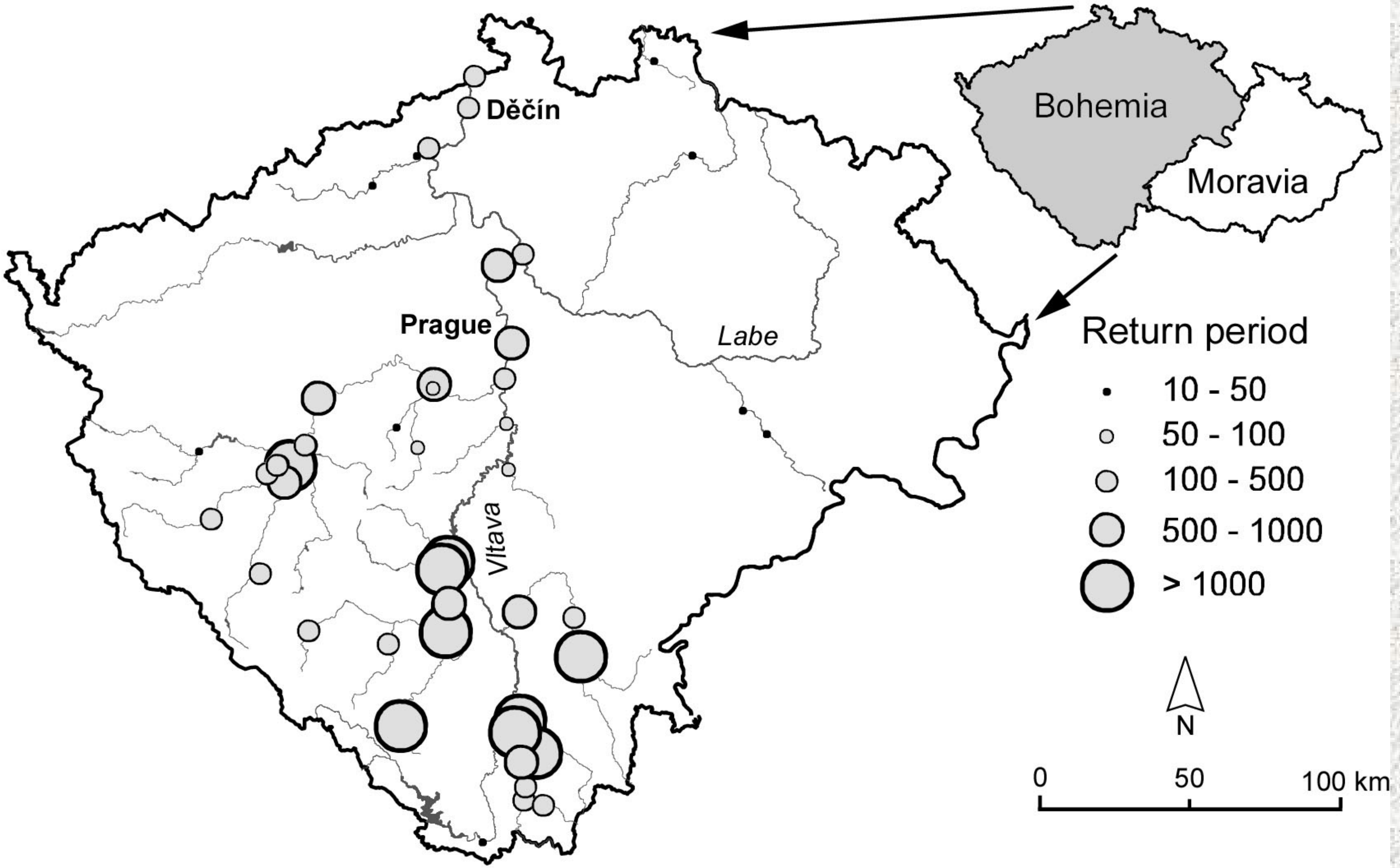
Based on historical measurements the probability of repetition of corresponding value of peak discharge rate is calculated by distribution fitting.

Relation between probability of occurrence and period of repetition (return period N):

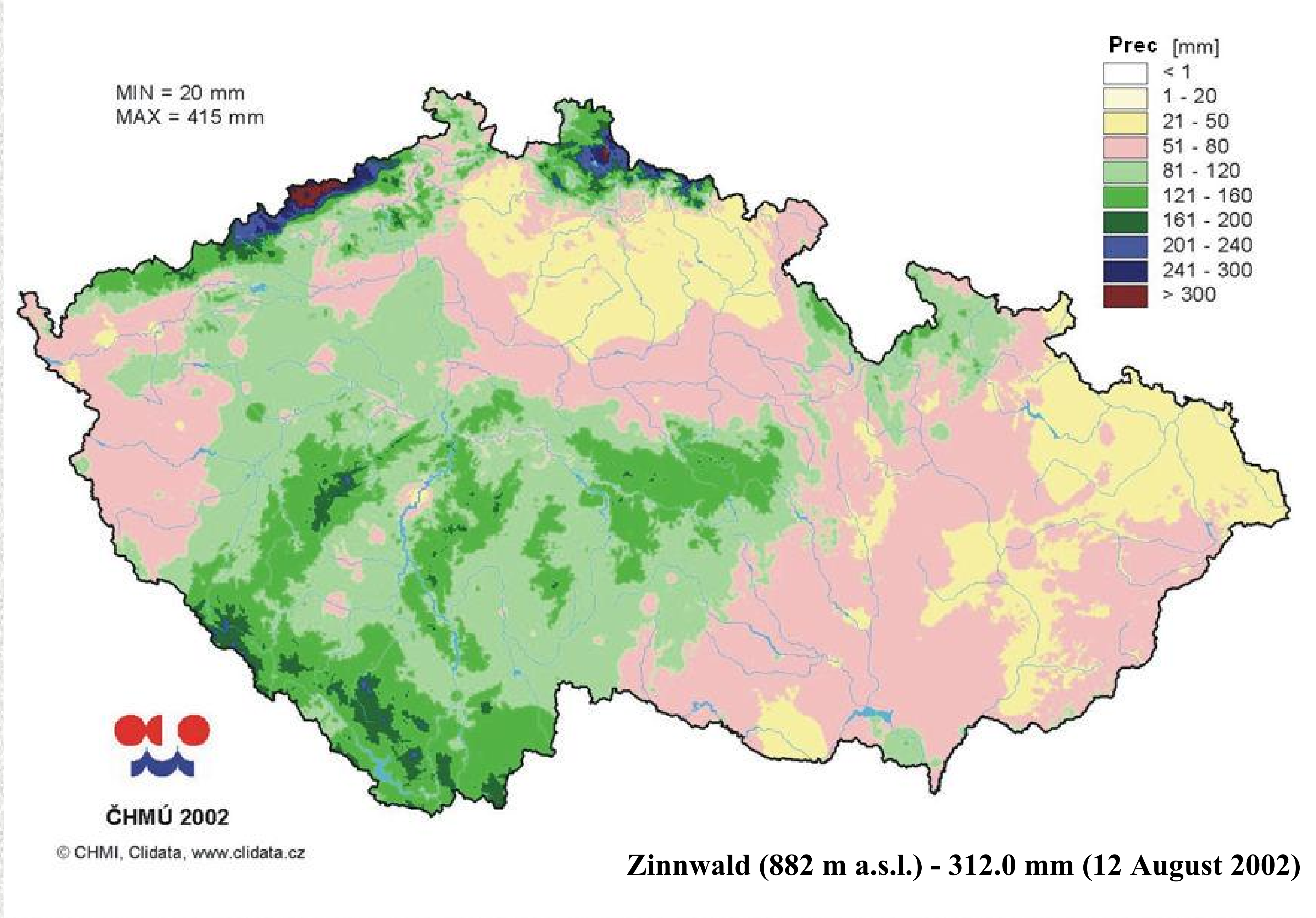
$$P = 1/N$$

P (%)	N (years)
50	2
20	5
1	100



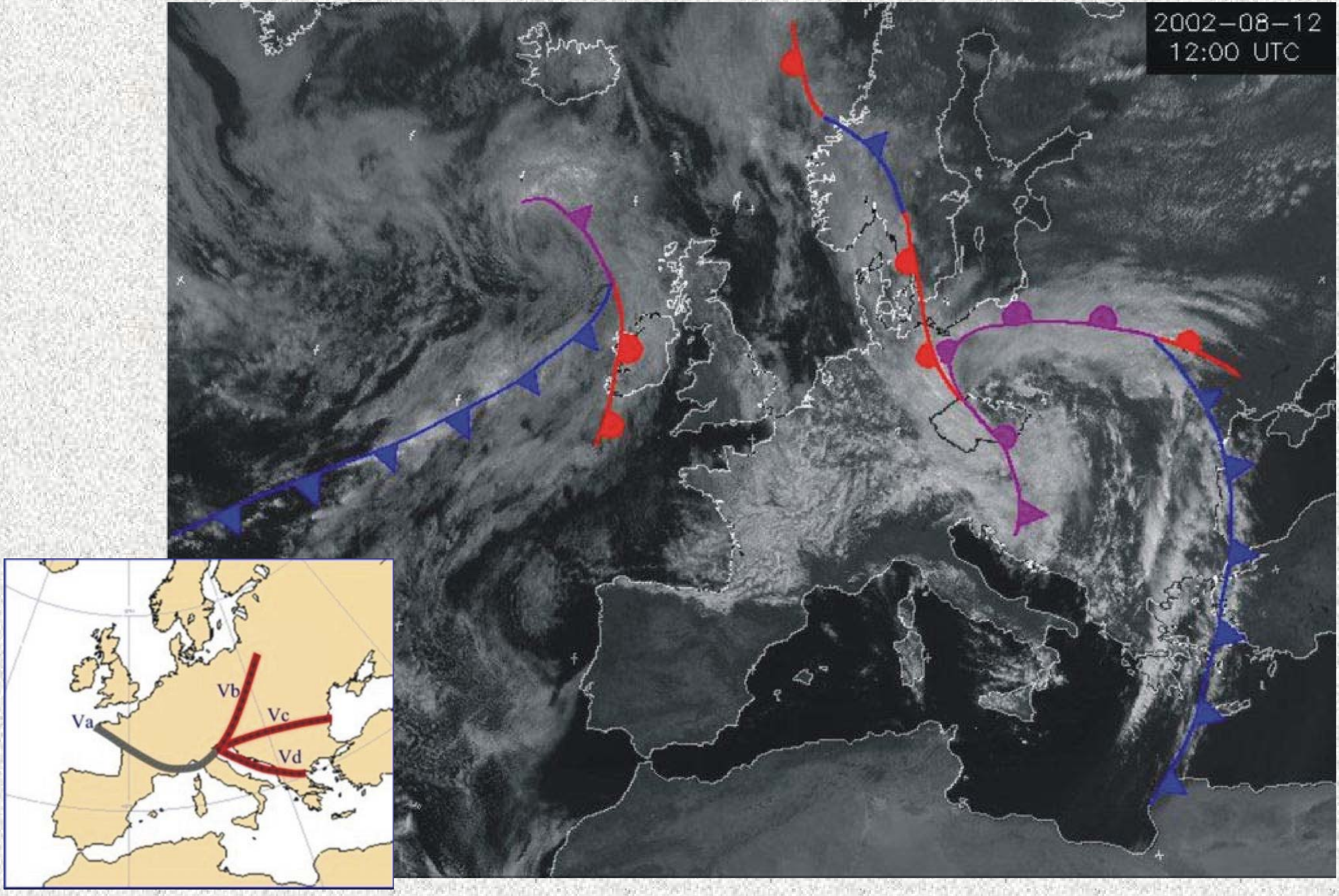


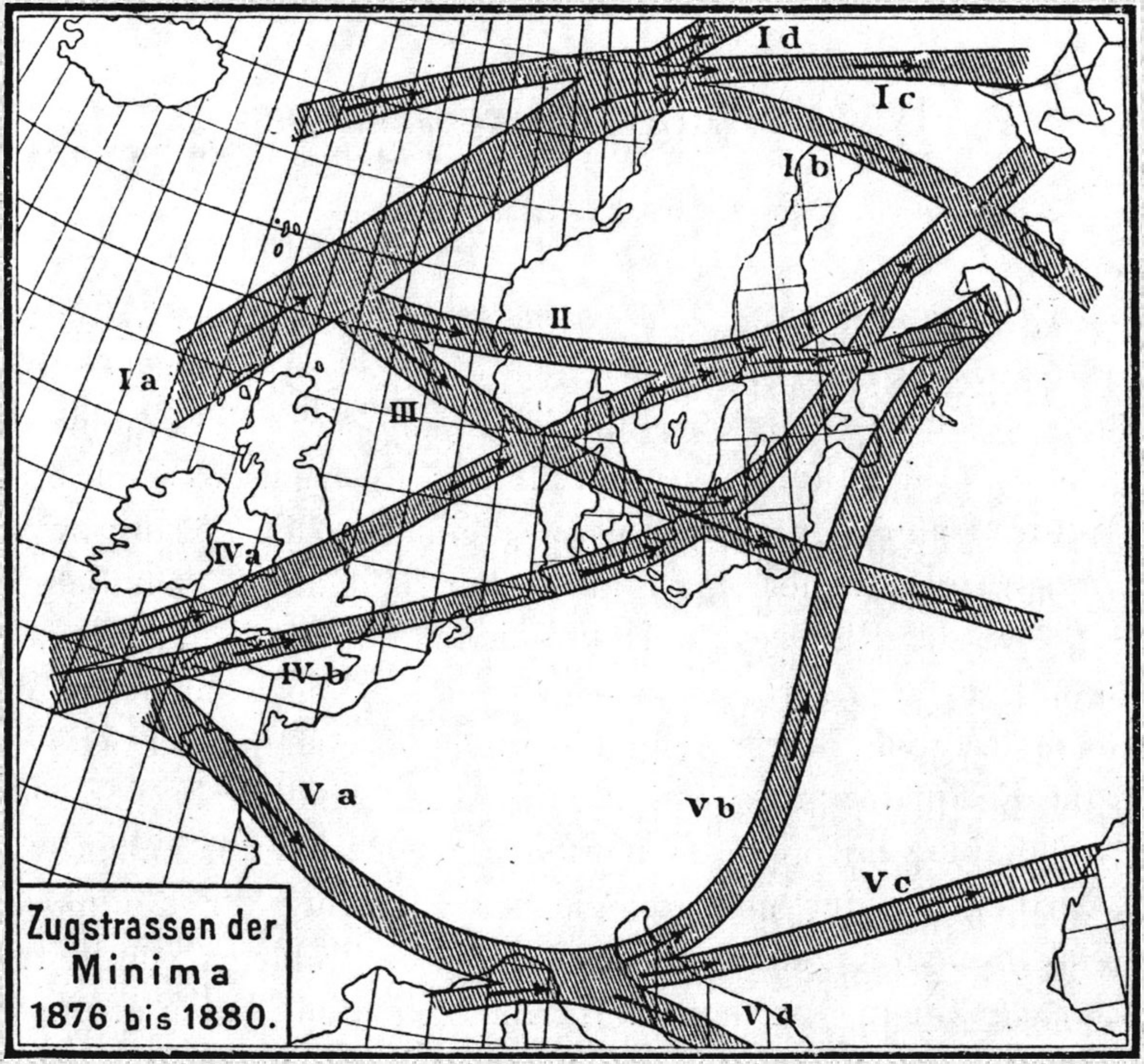
Peak flood discharges according to the return period N (years) on 12-16 August 2002 at hydrological stations in Bohemia (only stations with Qk > Q10)



Precipitation totals on 6-13 August 2002

The meteorological situation



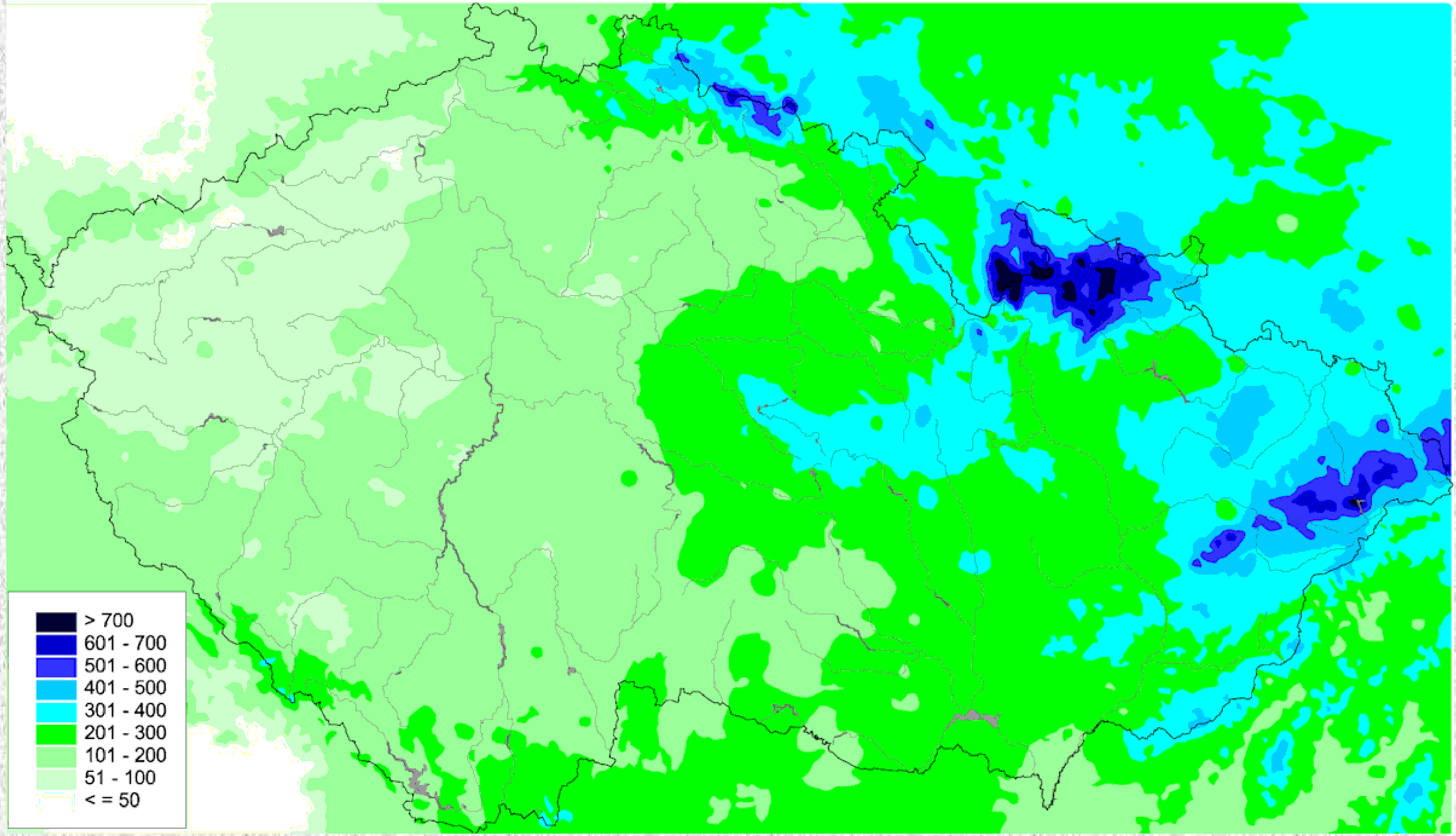


Typical trajectories of cyclones in Europe according to van Bebber – track Vb

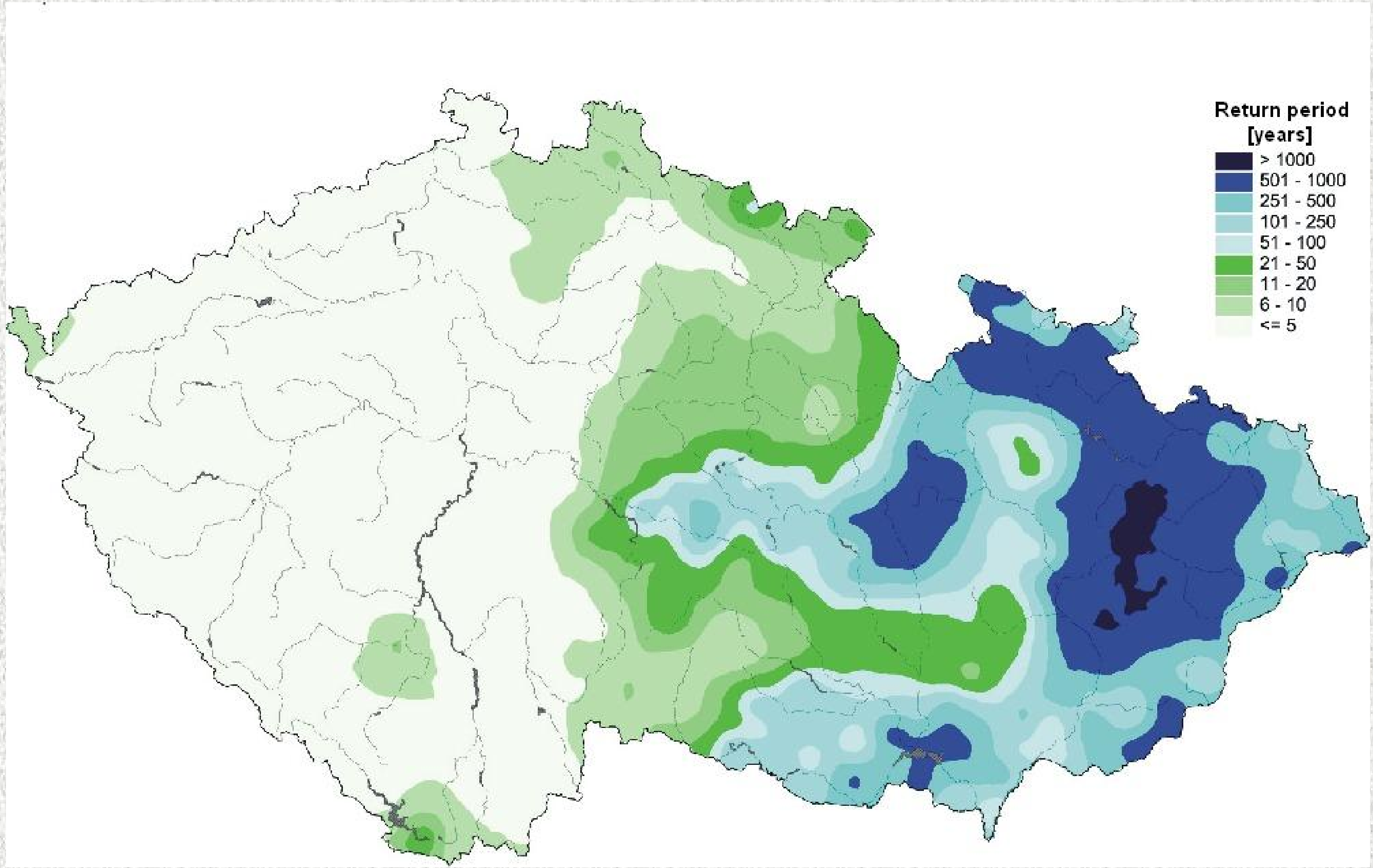
Recent disastrous floods in the Czech Republic

The flood in Moravia and Silesia in July 1997

52 victims - material damage 63 billions of Czech crowns



Precipitation totals (mm) - July 1997



Return period of 5-day precipitation totals - July 1997

The flood in the Czech Republic in March 2006


Prague


Chlumec nad Cidlinou

Znojmo


Veselí nad Lužnicí

Types of floods in the Czech Republic according to their meteorological causes

a) short intensive rainfall

local scale (convectional storms) - disastrous local impacts - flash floods

b) long-lasting continuous rainfall

regional or supra-regional scales (cyclones, troughs) - water saturation

c) snow-melting

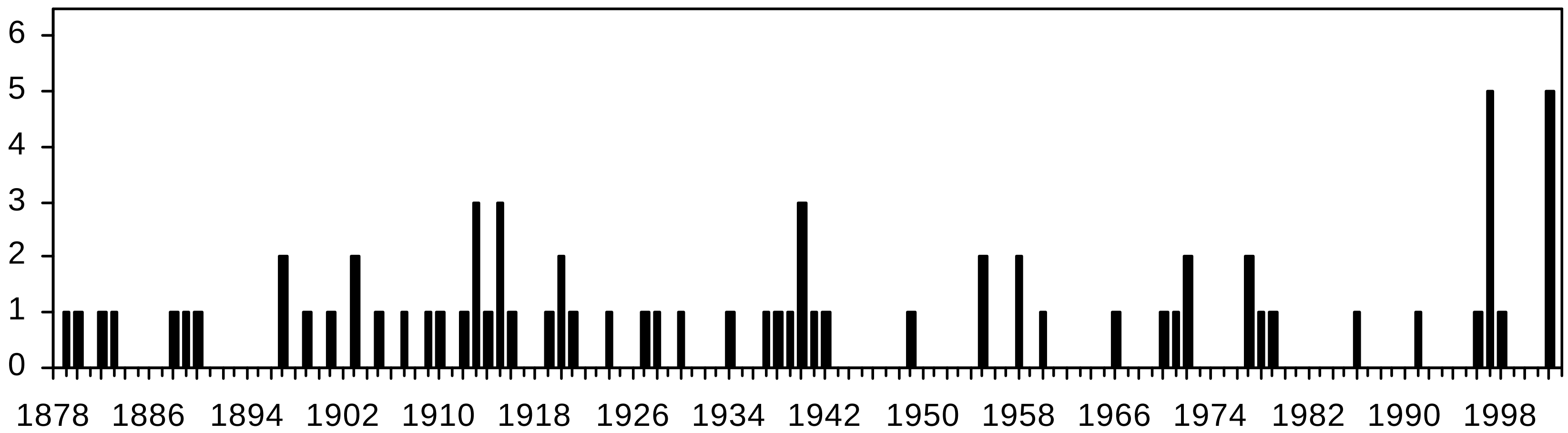
height and water equivalent of the snow cover - freezing soil - intensity of warming (precipitation)

d) ice damming

sudden warming - ice drift - accumulation of ice floes

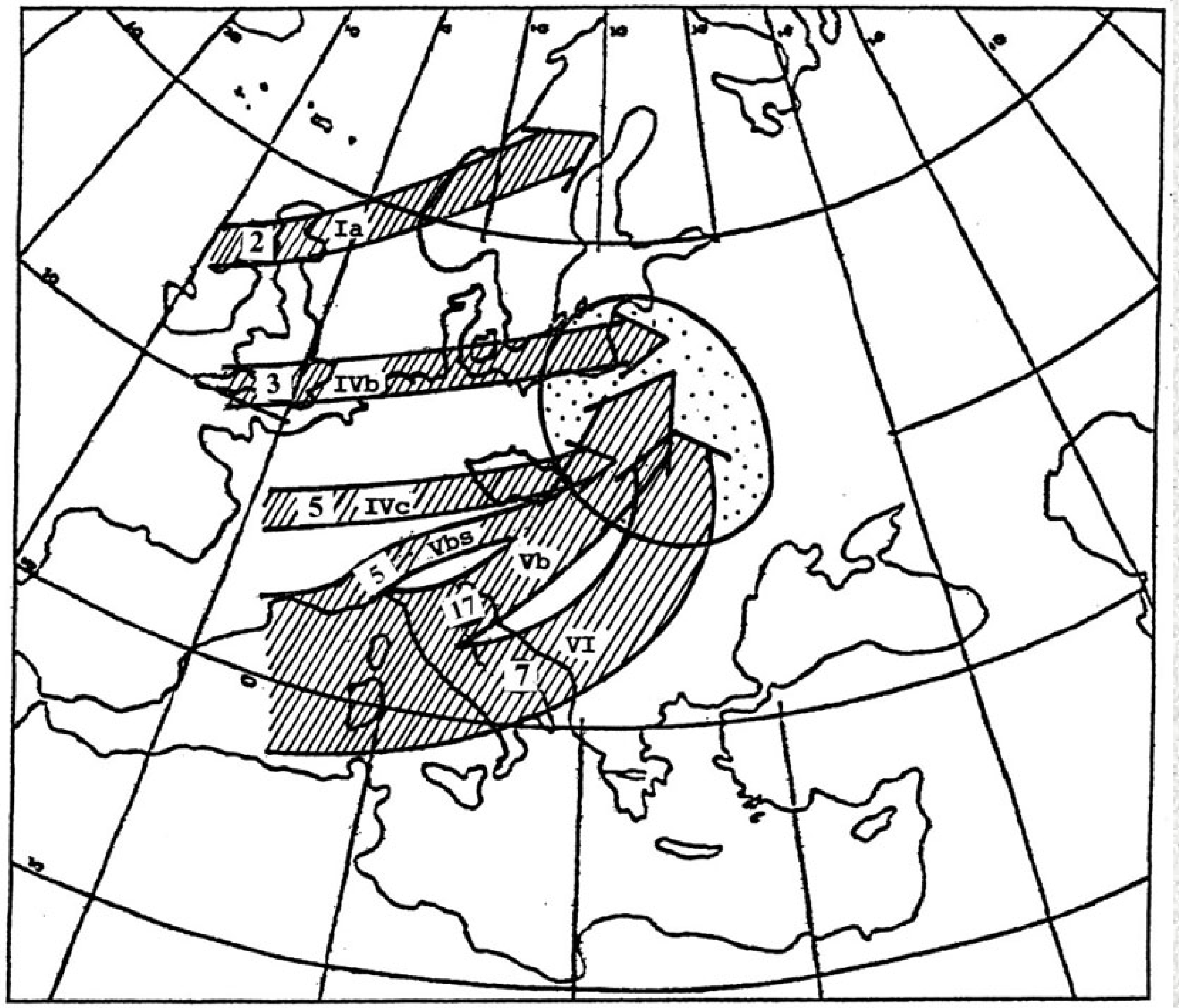
a+b - floods of summer synoptic type, c+d - winter synoptic tape

Extreme daily precipitation totals

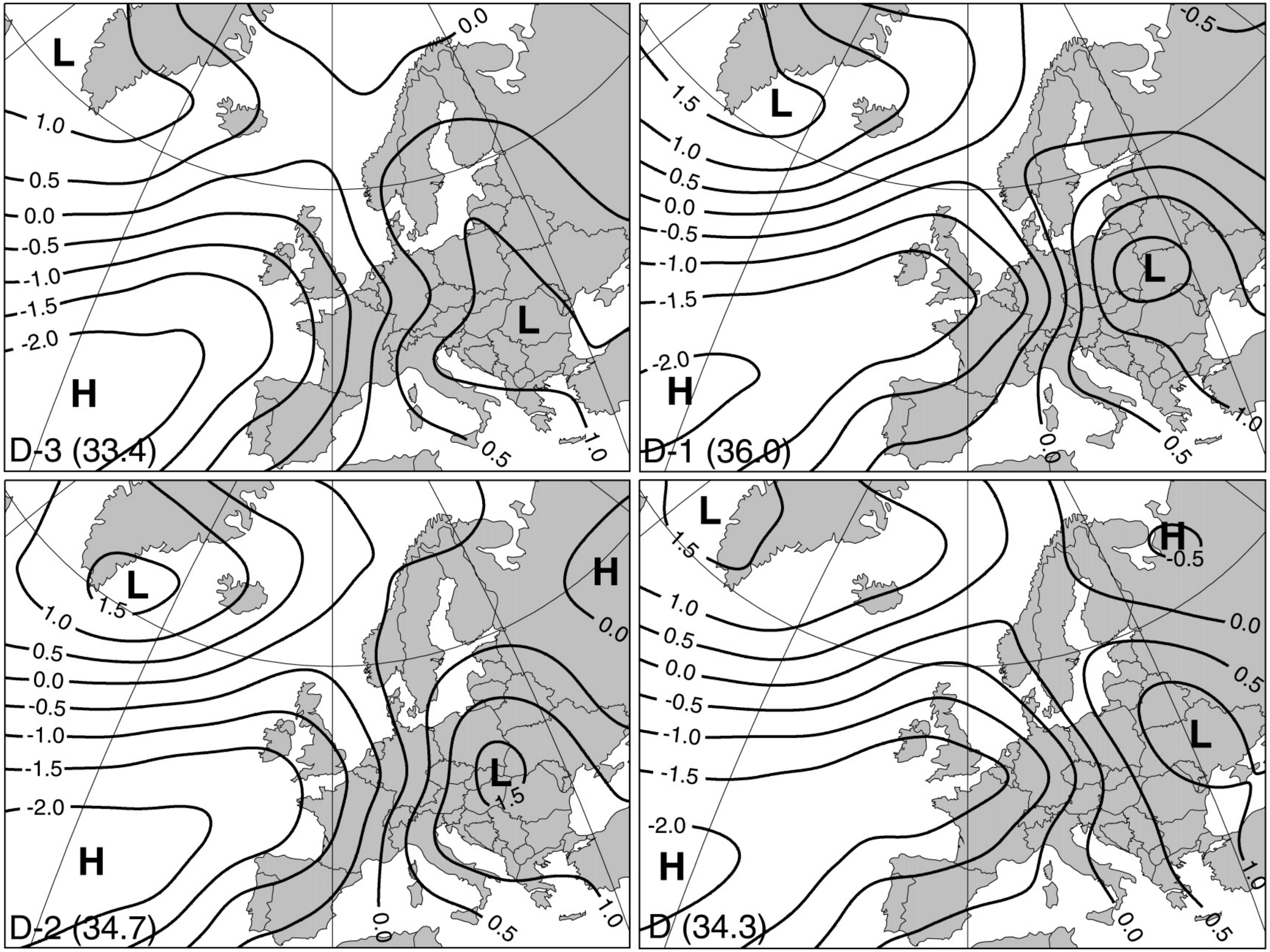


Annual frequencies of days with daily precipitation totals ≥ 150.0 mm in the Czech Republic in 1878-2002

Nová Louka (780 m a.s.l.) - 345.1 mm (29 July 1897)
Lysá hora Mt. (1324 m a.s.l.) - 233.8 mm (6 July 1997)
Zinnwald (882 m a.s.l.) - 312.0 mm (12 August 2002)

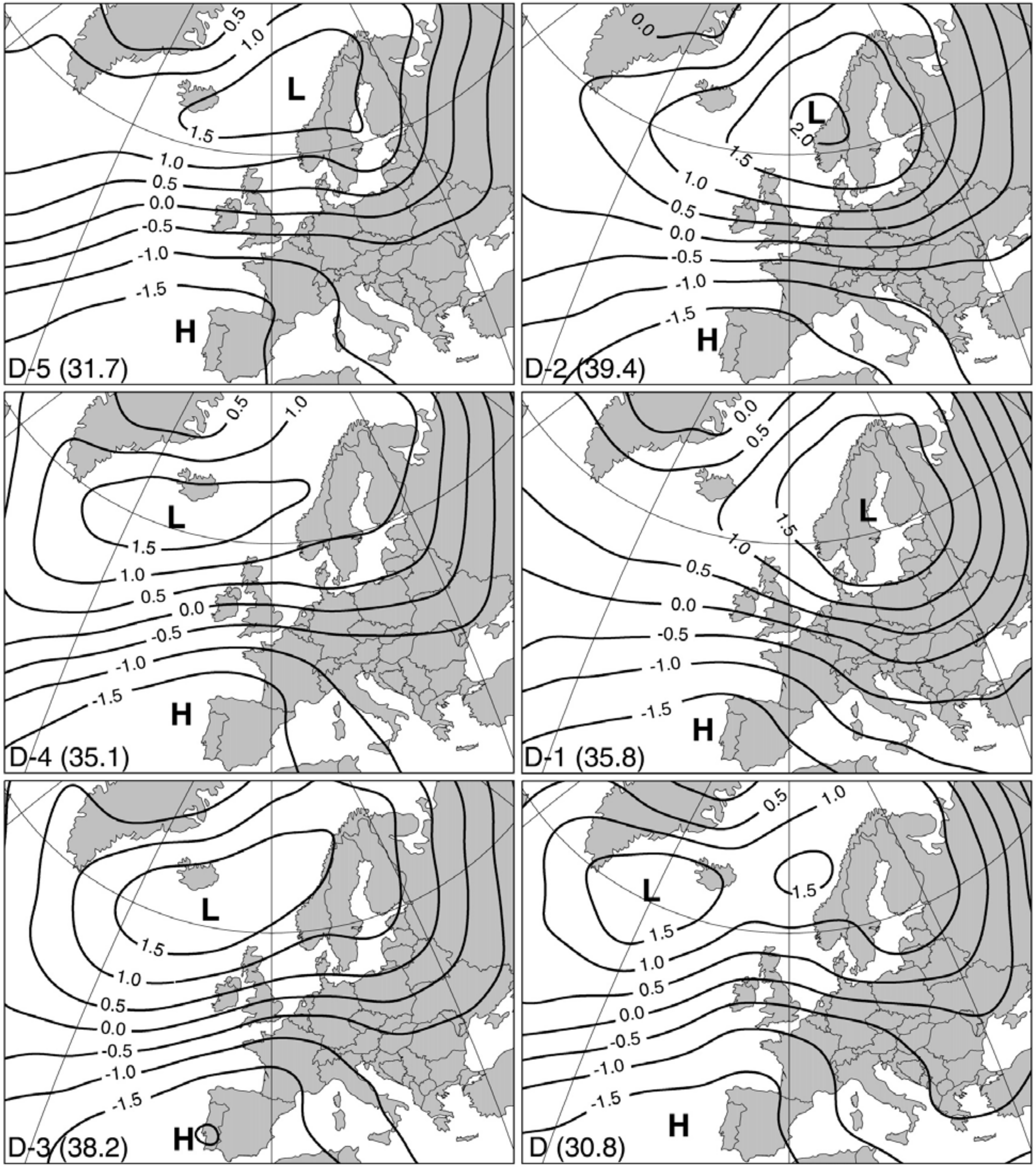


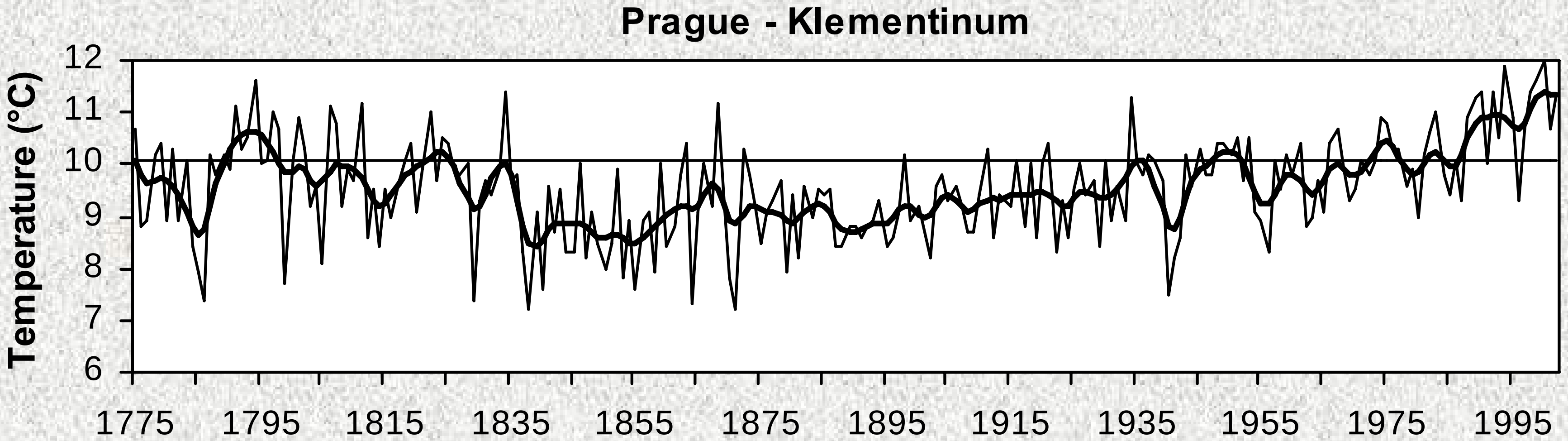
Trajectories of cyclones (hatched) and the area of quasi-stationary cyclones (dotted) connected with the extreme daily precipitation totals ≥ 150 mm in the Czech Republic (1879-2003)

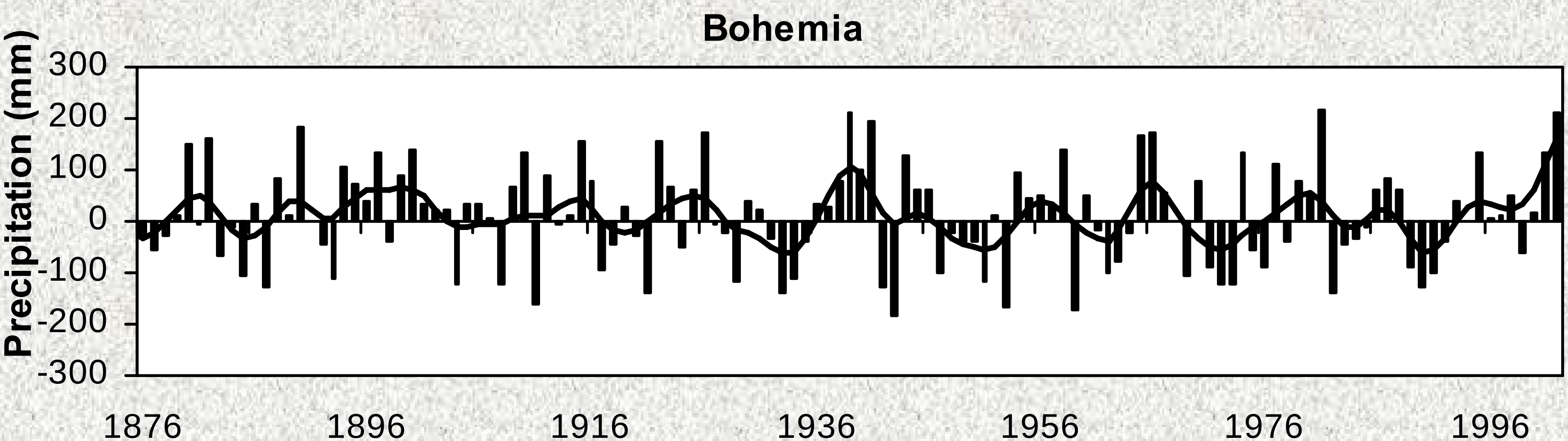


Component scores of the first component of the SLP field on days D-3 to D calculated by the PCA for 40 floods (1896-2000) of the summer synoptic type on the river Odra in Bohumín (brackets - explained variance in %)

Component scores of the first component of the SLP field on days D-5 to D calculated by the Principal Component Analysis Method (PCA) for 37 floods (1881-2000) of the winter synoptic type on the river Vltava in Prague (brackets - explained variance in %)

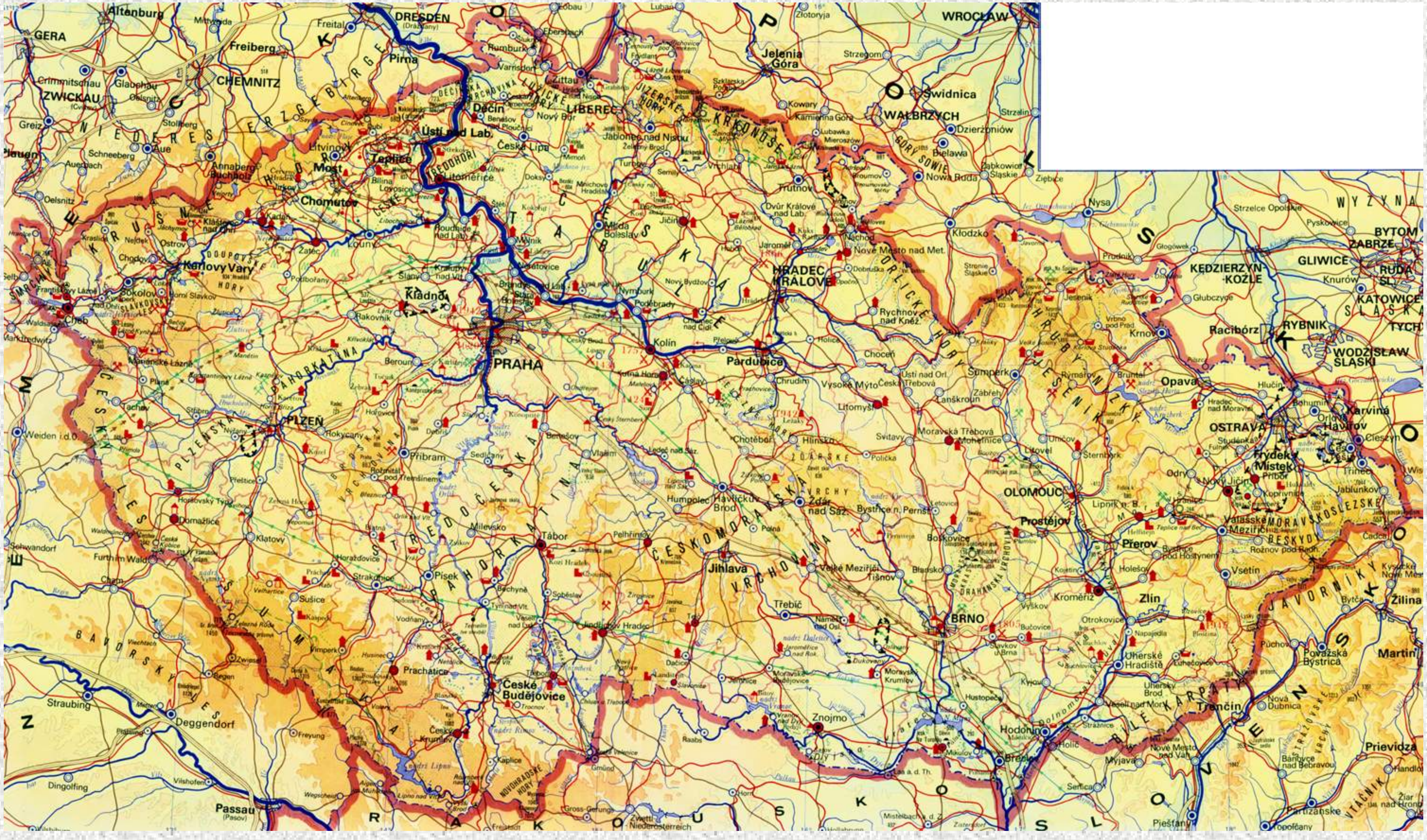




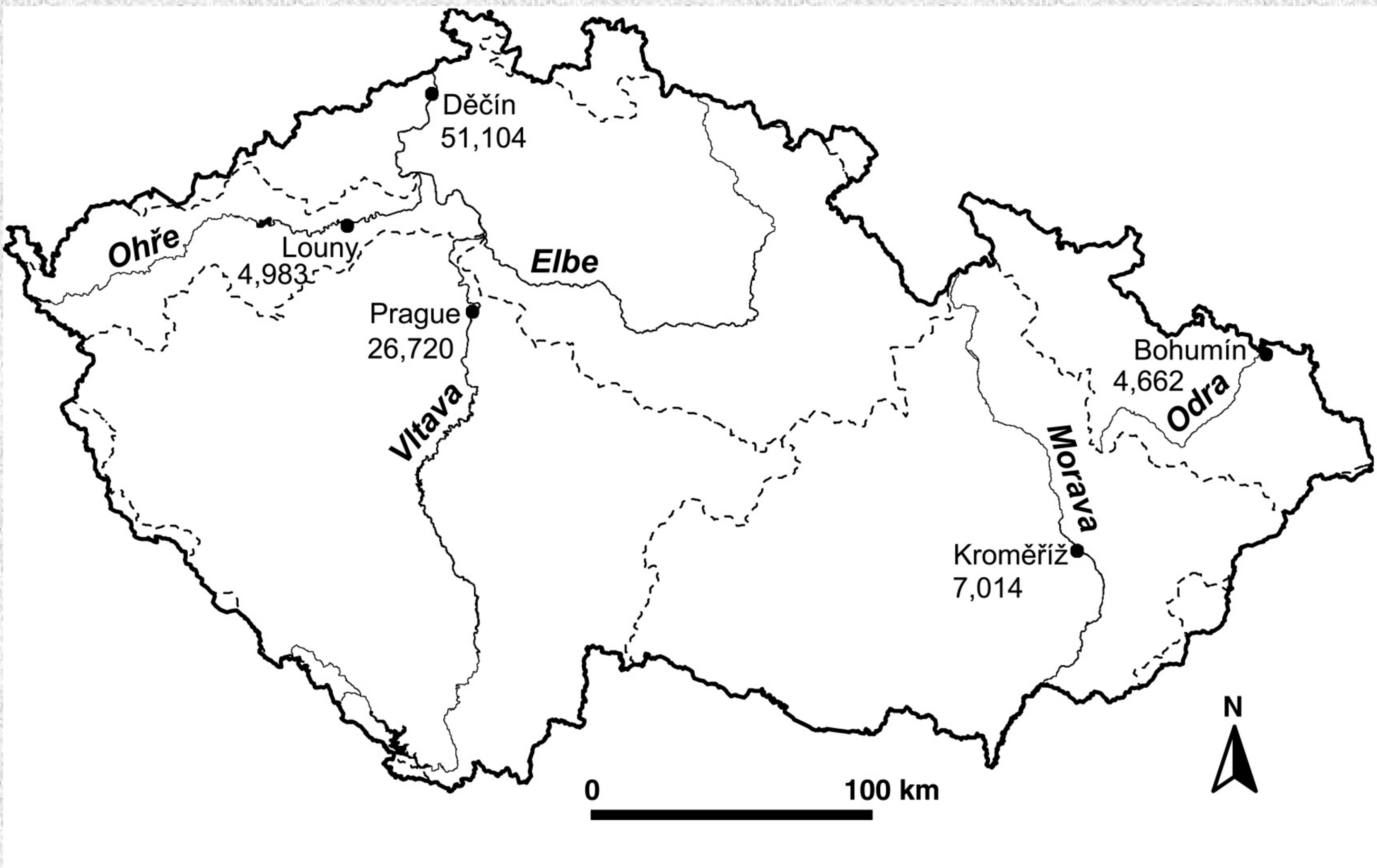


Fluctuations of mean annual air temperatures at Prague-Klementinum (1775-2002) and of anomalies of annual precipitation totals in Bohemia (1876-2002)

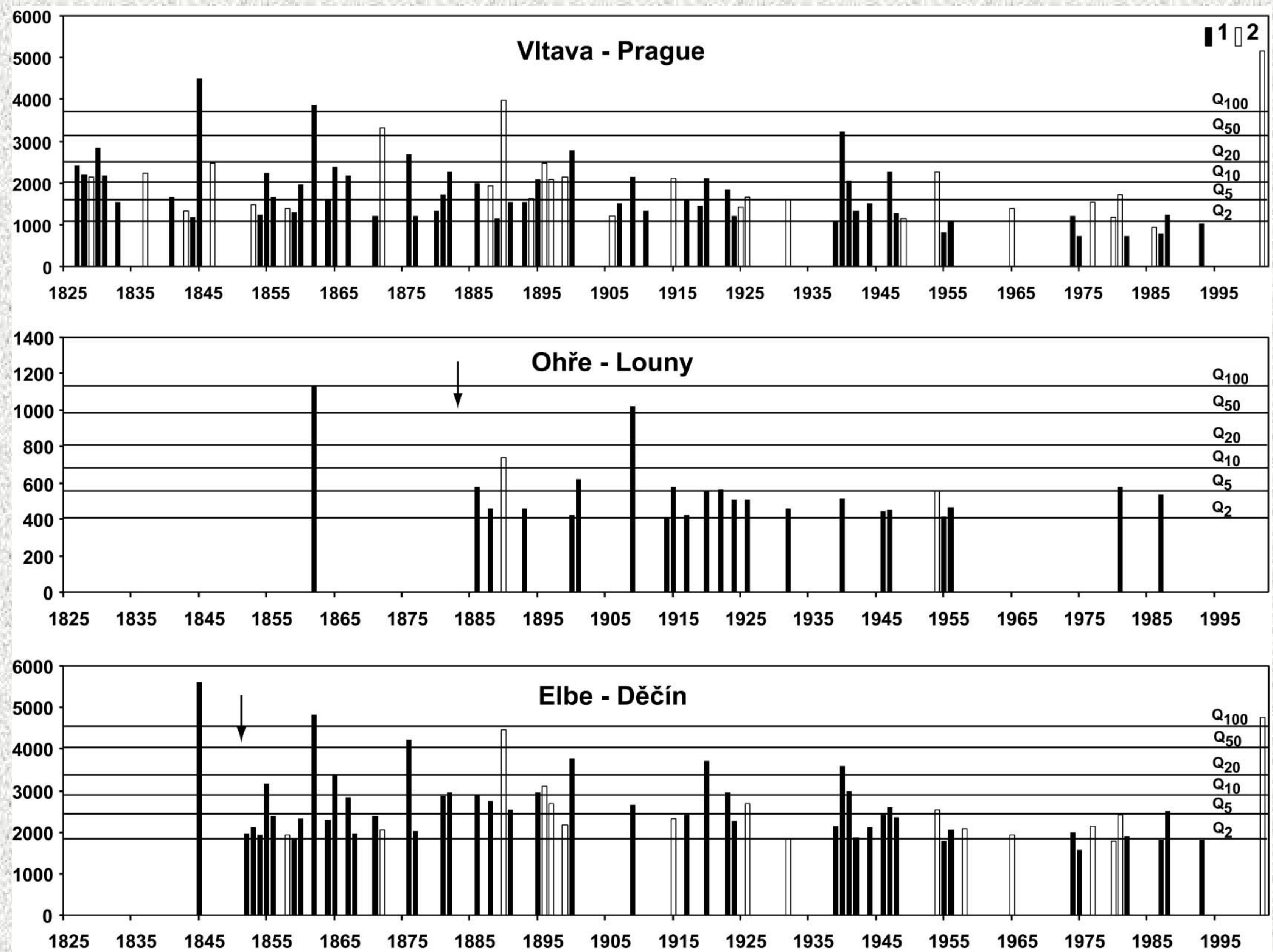
Floods in the period of systematic observations



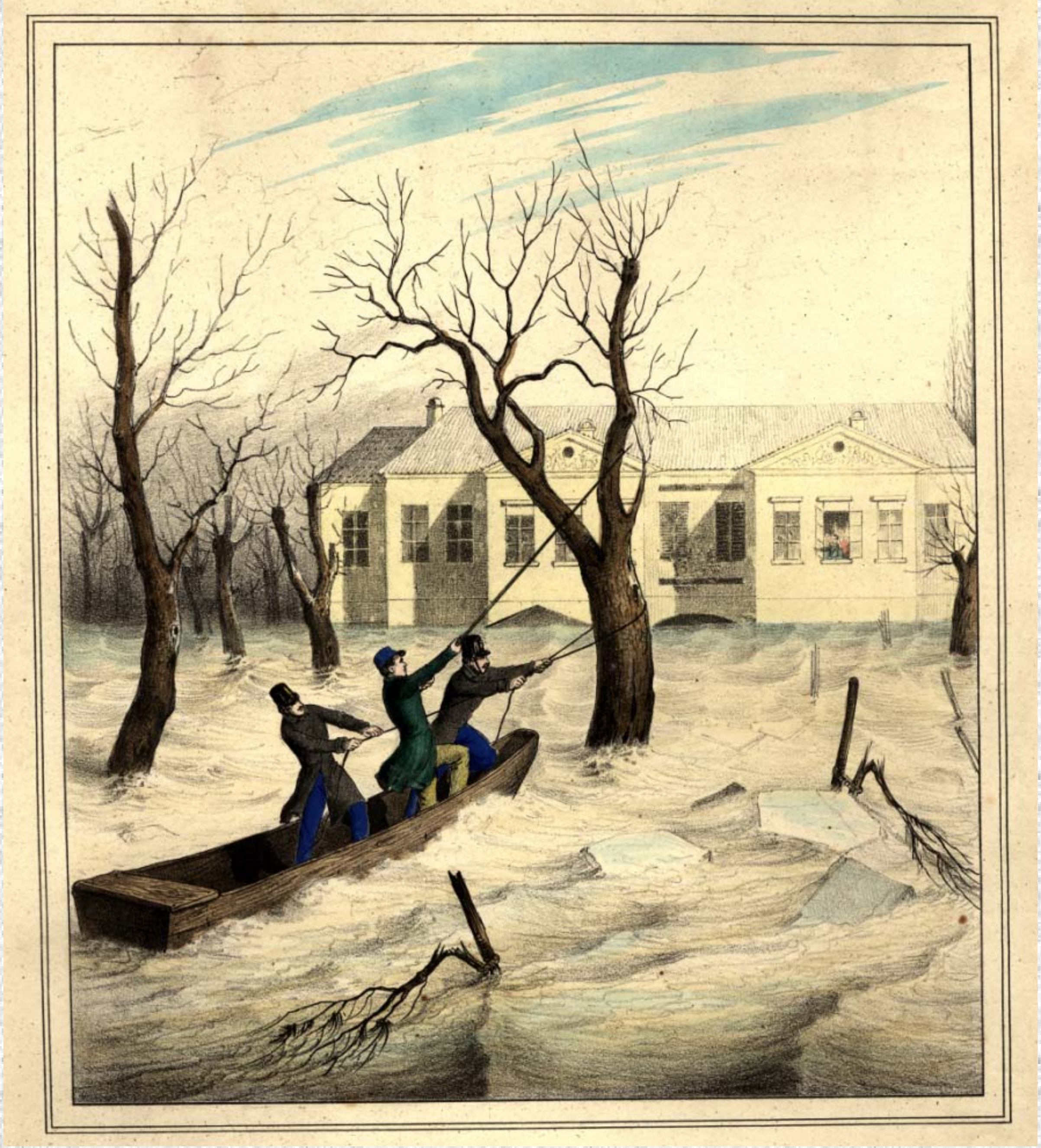
Main catchment areas of the Czech Republic:
Labe (Elbe) - Vltava (Moldau) - Morava - Odra (Oder)



A schematic map of studied river watersheds with hydrological stations and the size of the corresponding part of the catchment area in km^2



The variation of floods with at least two-year peak discharge rates (Q_2, $m^3.s^{-1}$) in 1825-2003: 1 - winter synoptic type, 2 - summer synoptic type



The Vltava flood in Prague (Střelecký ostrov Insel) in March 1845

Damaged Charles Bridge in Prague after flood in September 1890

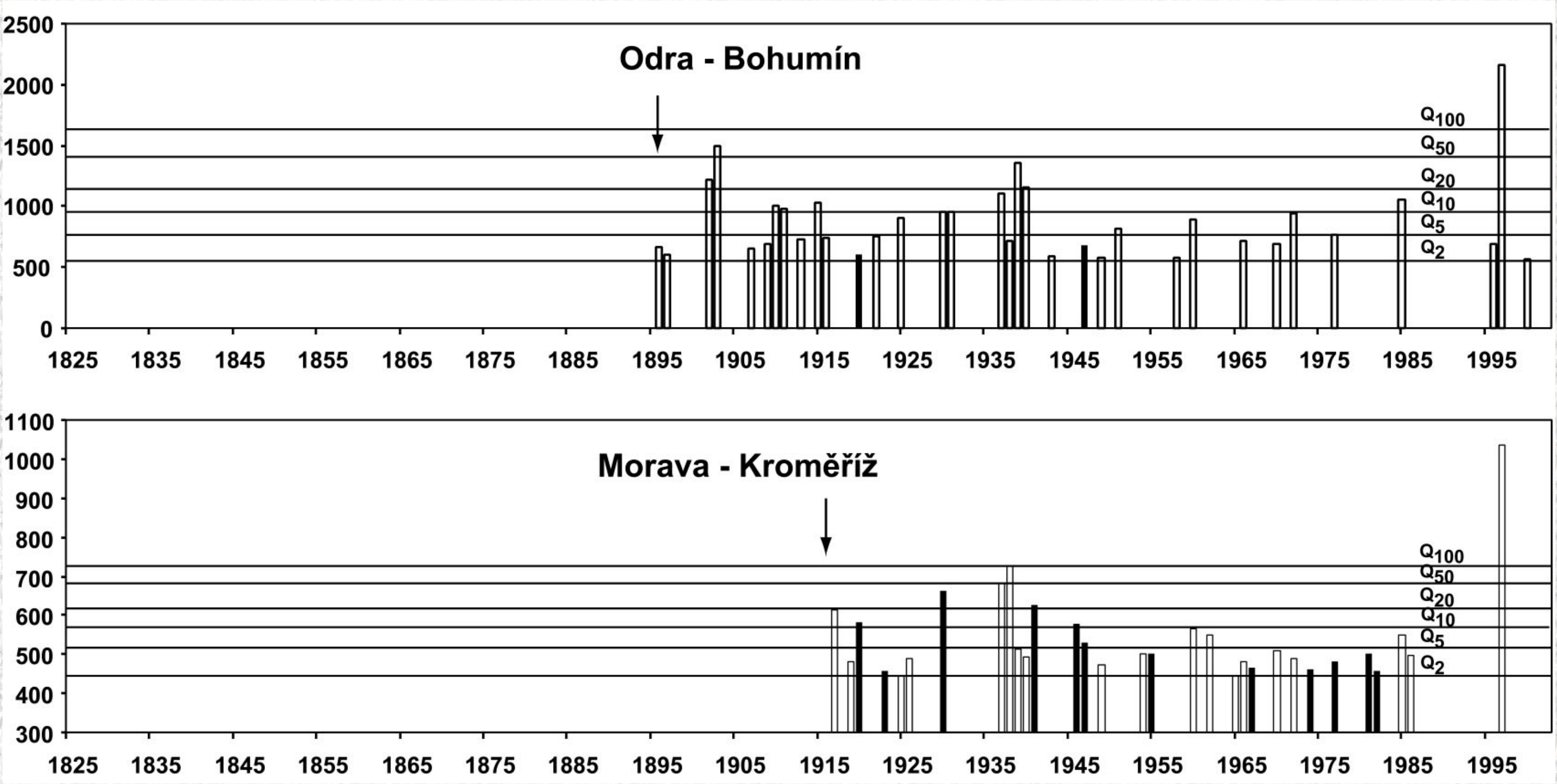
Monthly frequencies of floods with the peak culmination discharge rate ≥ Q_2 for the Vltava (1825-2000) and the Elbe (1851-2000) (completed according to data by Kakos, 2001)

Vltava – Praha (Q_2 = 1090 $m^3.s^{-1}$), period 1825-2000

Period	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Σ
1825-1850	3	4	3	0	1	2	1	0	0	0	0	1	15
1851-1900	5	11	10	4	3	2	1	4	3	1	1	2	47
1901-1950	1	8	6	3	2	1	0	1	1	1	0	2	26
1951-2000	1	0	4	0	0	2	3	1	0	0	0	3	14
1825-2000	10	23	23	7	6	7	5	6	4	2	1	8	102

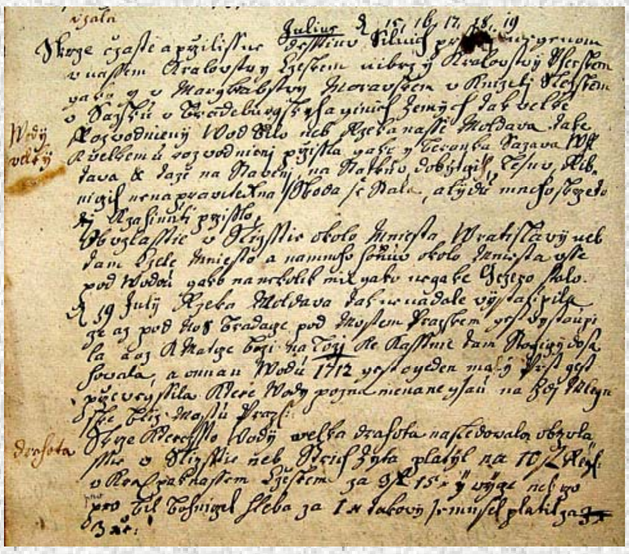
Labe – Děčín (Q_2 = 1830 $m^3.s^{-1}$), period 1851-2000

Period	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Σ
1851-1900	3	8	10	5	2	1	0	2	2	0	2	1	36
1901-1950	3	5	5	3	0	2	0	0	0	1	0	2	21
1951-2000	3	0	5	0	0	1	4	1	0	0	0	2	16
1851-2000	9	13	20	8	2	4	4	3	2	1	2	5	73



The variation of floods with at least two-year peak discharge rates (Q_2, $m^3.s^{-1}$) in 1825-2003: 1 - winter synoptic type, 2 - summer synoptic type

Documentary evidence about floods



Narrative written sources

Popsání
o
strašné povodni
v Praze roku 1890.

Postrach a zděšení vládne každým při vzpomínce o povodni v Čechách. Stříbropěnná Vltava byvši rozvodněna stálými dešti, zatopila nejprve Budějovice a celé okolí, odtud hnala se dravými proudy sesilněna ještě vedlejšími přítoky ku matičce Praze a tu ničí staleté památky české. (...)

Užaslé zástupy lidstva dívají se v ustrnutí a s hrůzou, jak dravé proudy chvátí starobylý **Karlův most**, který znám celému česko-slovanskému národu, jenž od staletí putoval touto cestou na slavnosti a poutě k chrámu sv.-Vítskému.

A tak rozzuřený živel vodní ničí v okamžiku vše, co po staletí ruka lidská vytvořila.

Sřícení Karlova mostu.

Karlův most založen dne 9. července 1357 od Karla IV., dlouhý jest přes 700 kroků a široký 33½ stopy. — Dne 4. září k ránu přihodilo se neštěstí, jakéhož dozajista nikdo neočekával a jakéž nestalo se v Praze již po několik let. **Karlův most**,

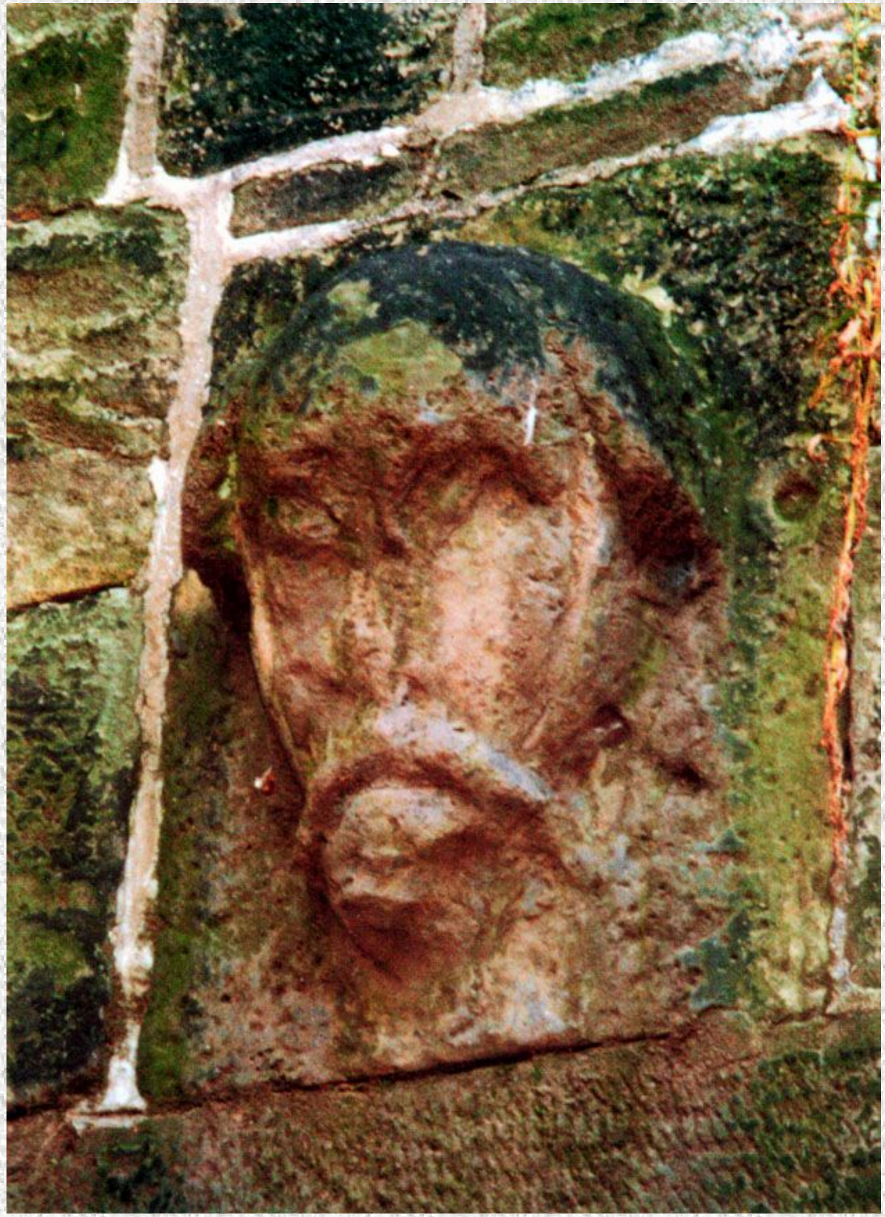
Newspapers and special prints

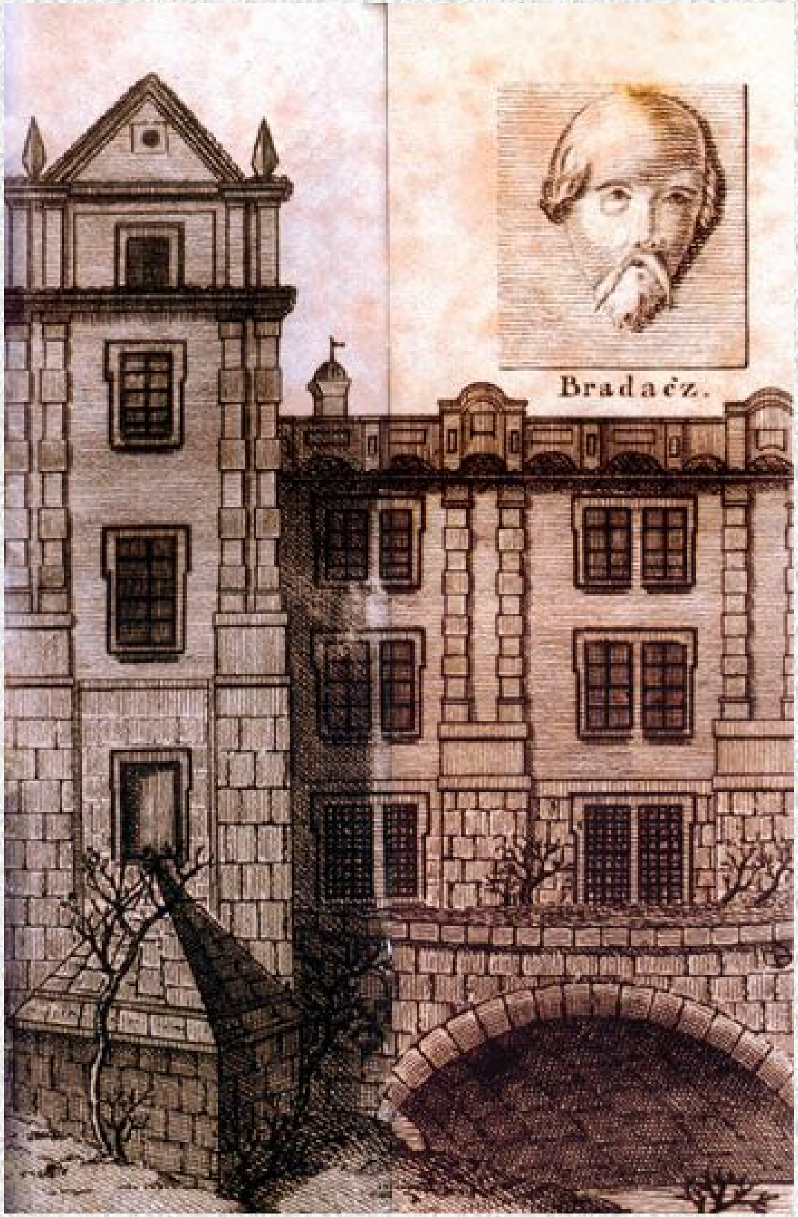
Pictorial evidence

Watermarks

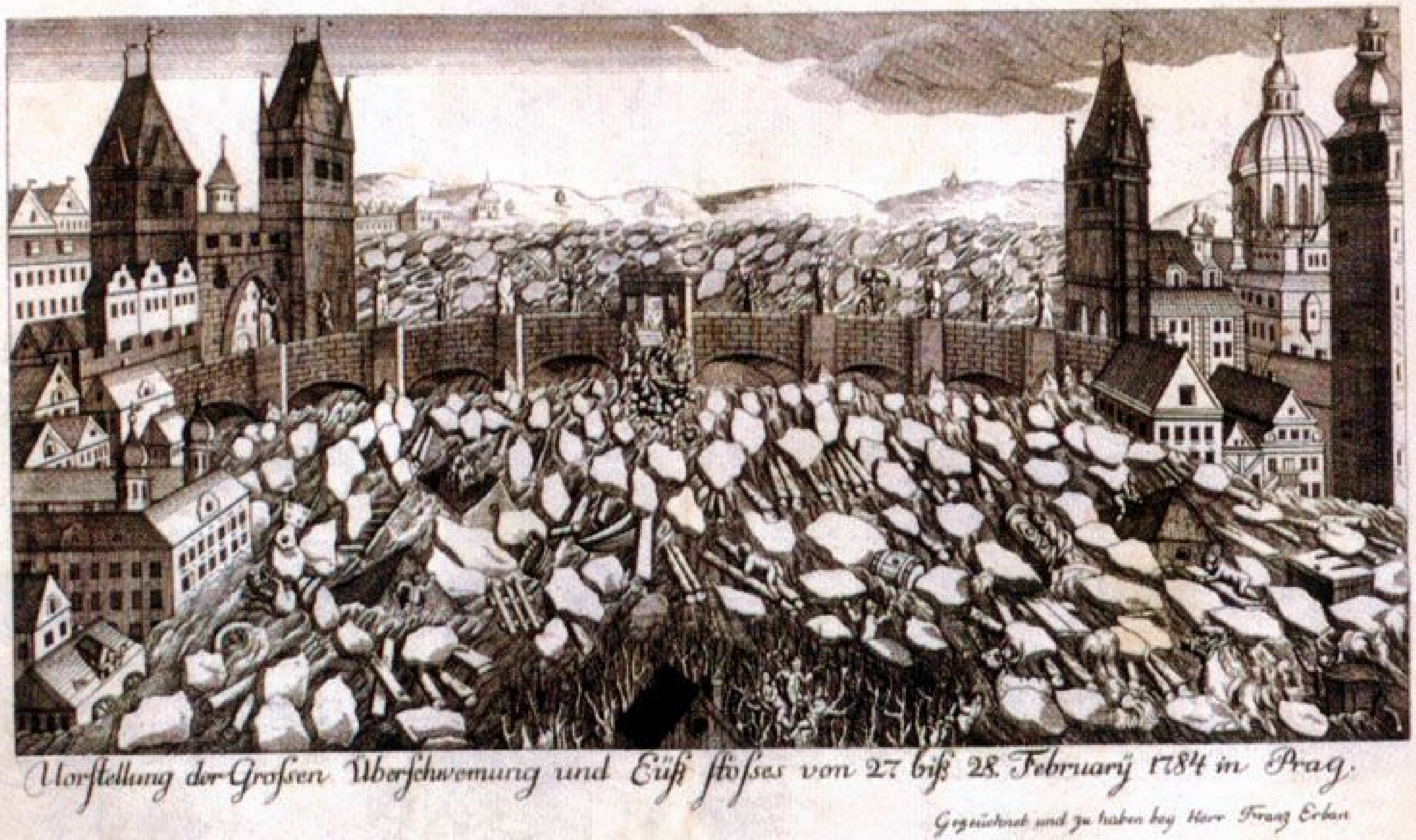
The first reliable report about a flood in the Czech Republic - the Chronicle of Kosmas, Prague, September 1118

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.*

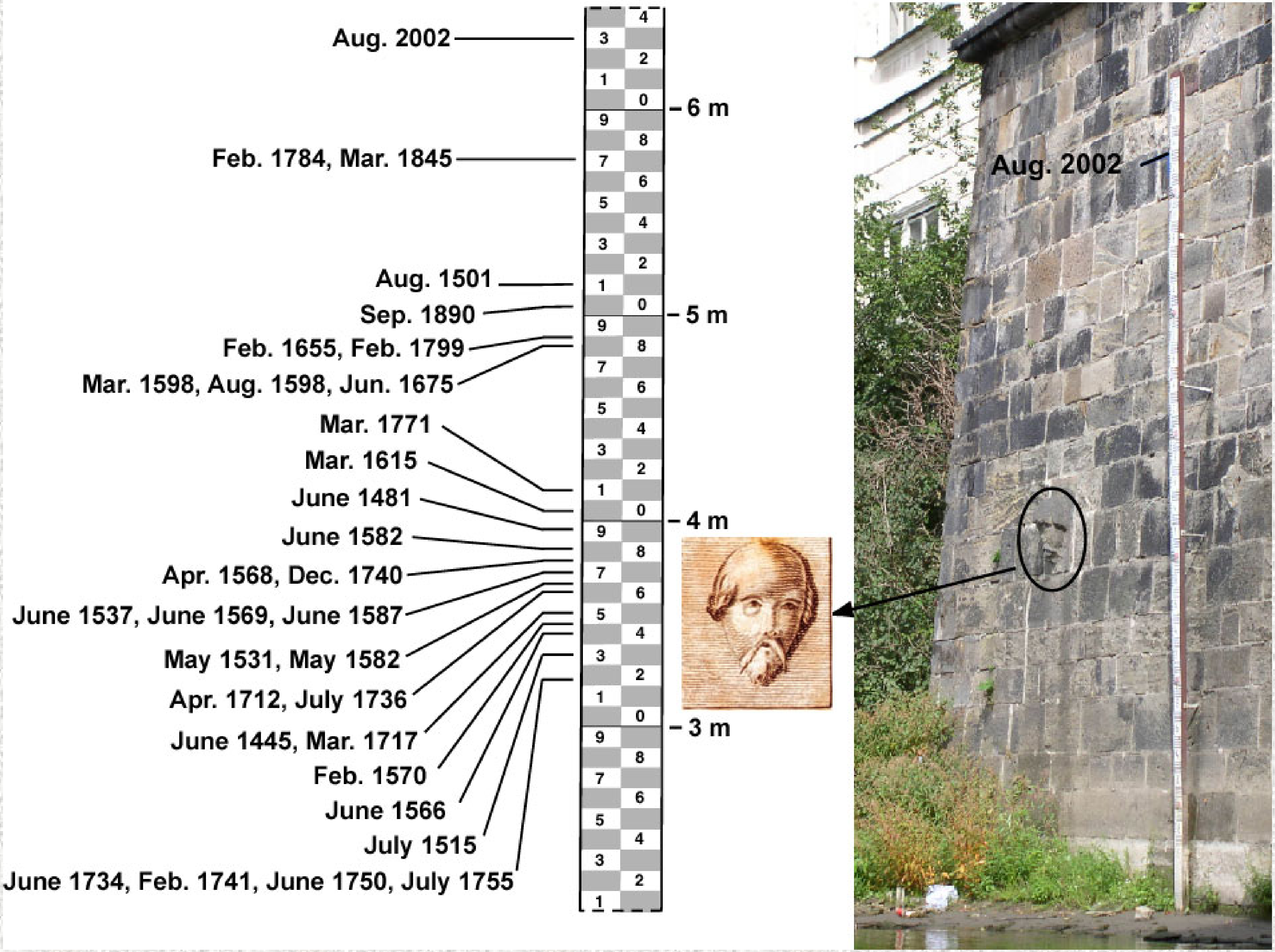




The stone figure of Bradáč, located in the fortification of the right bank of the Vltava River in Prague (close the Charles Bridge)



The flood of the Vltava at Prague on 27-28 February 1784 due to ice damming - the highest known water mark up to August 2002, the Charles bridge damaged (estimated discharge rate 4,560 $m^3.s^{-1}$)



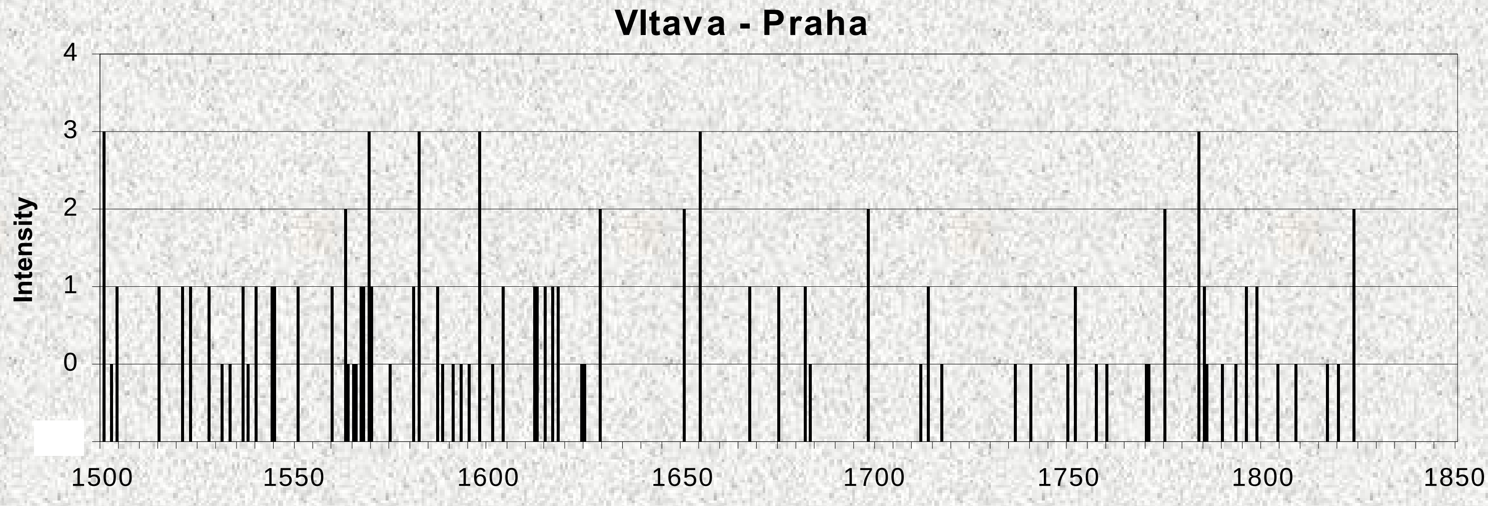
Levels of greatest floods on the Vltava in Prague with the projection to the position of Bradáč (missing watermarks for July 1432 and February 1862)

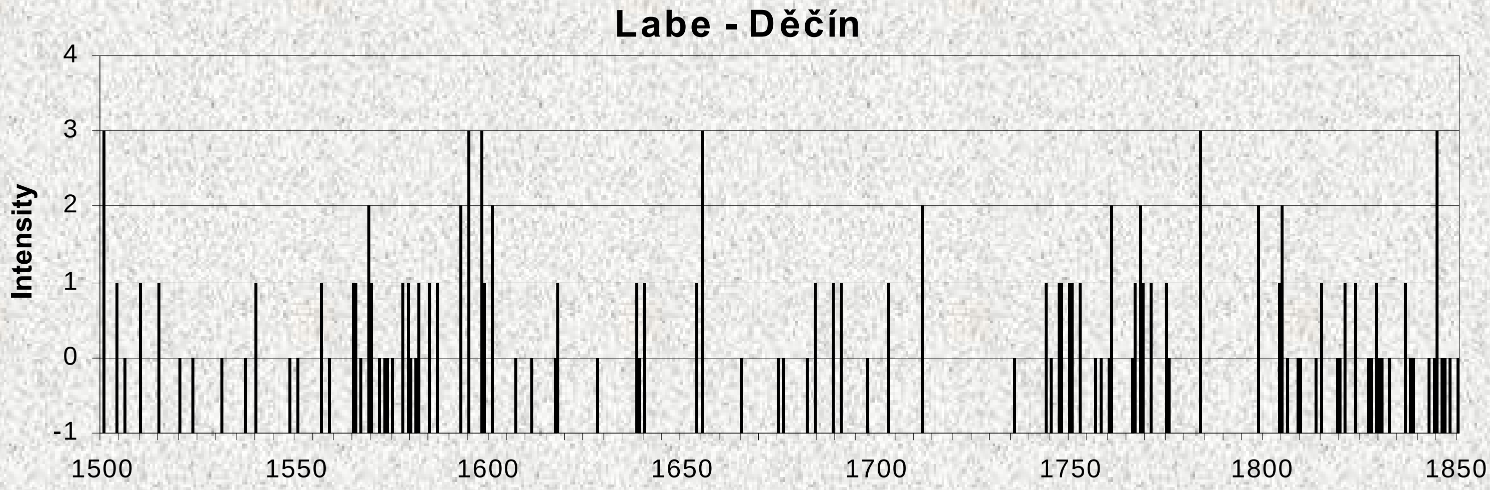
Uncertainties of documentary evidence about floods

- the run-off process is significantly influenced by changes in the character of the landscape
- the intensification of the human influence on nature and its features
- land-use changes connected with agriculture and other sectors of economy
- direct changes in the river bed and water management (e.g. regulation of rivers, building of water structures, using of water for industry)
- the completeness of documentary evidence about floods

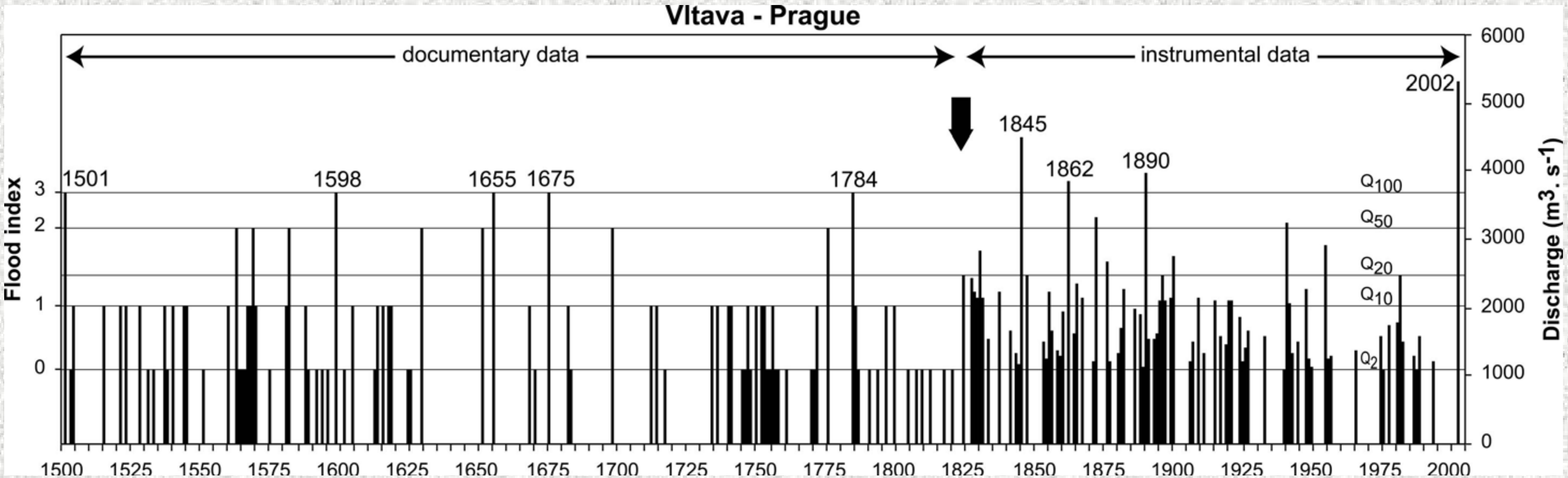
Classification of flood intensity based on documentary evidence (completed according to Sturm et al., 2001)

Level	Classification	Primary Indicators	Secondary Indicators
0	flood	no additional information	no additional information
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	flood of longer duration, several 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

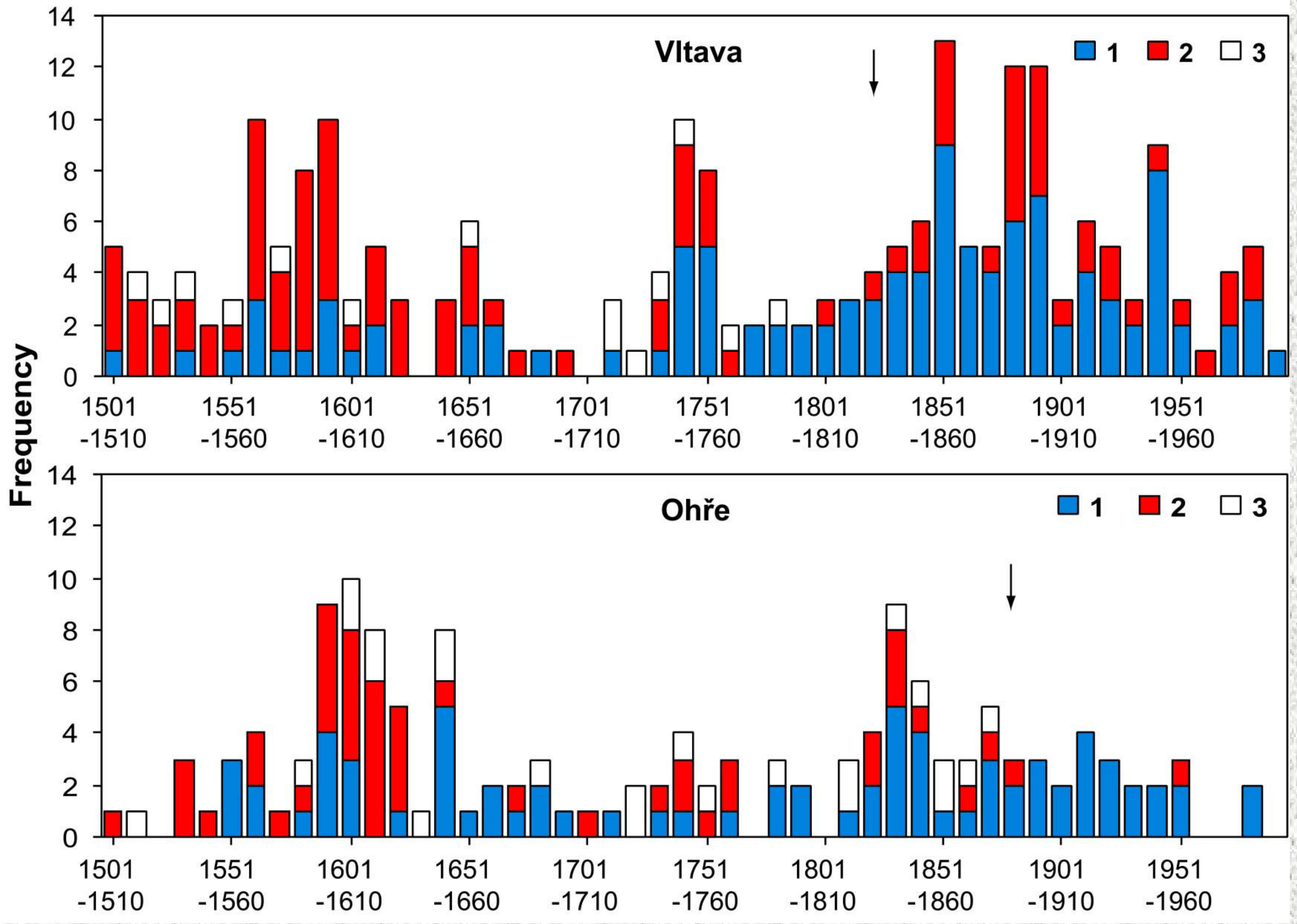




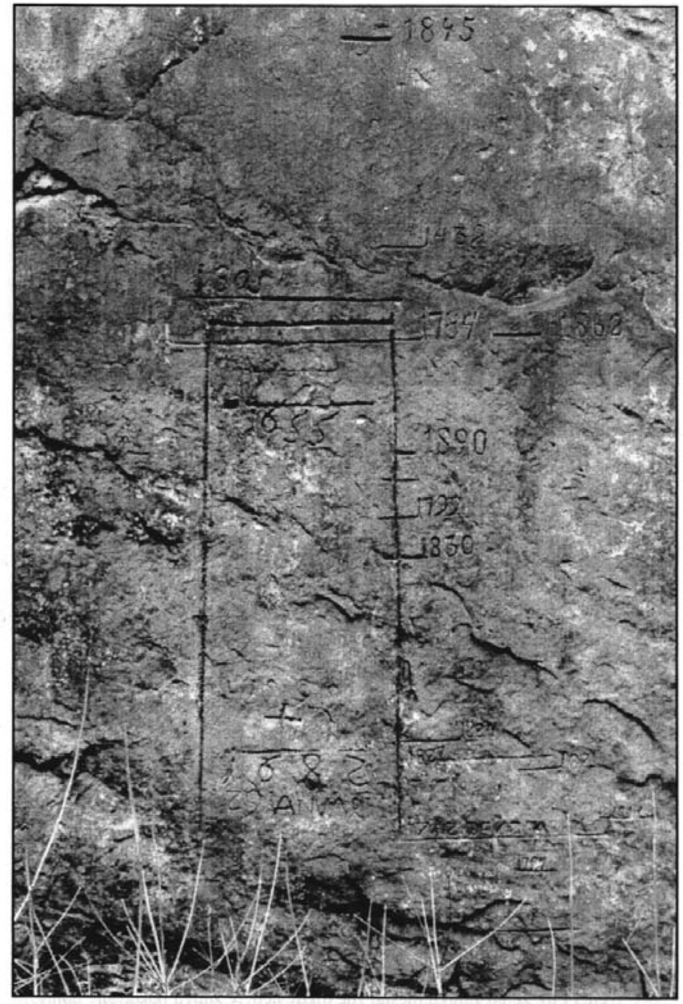
Chronology of floods in the pre-instrumental period based on documentary evidence for the Vltava (1501-1824) and the Elbe (1501-1850)



The synthesis series of flooding derived from documentary evidence and water-gauge measurements - the Vltava river in Prague during 1500-2002

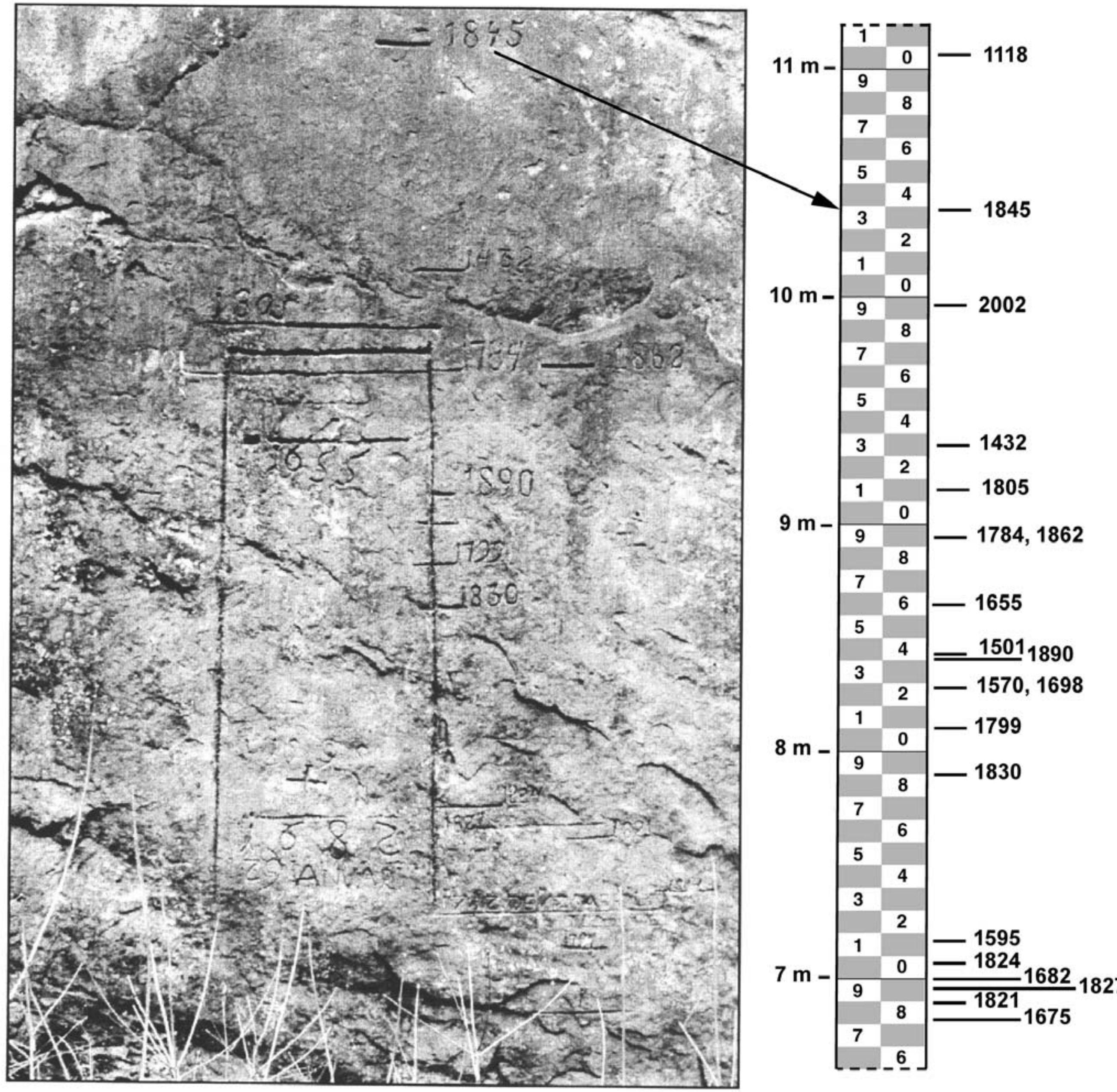


Decadal frequencies of floods 1501-2000: 1 - winter synoptic type, 2 - summer synoptic type, 3 - without specification

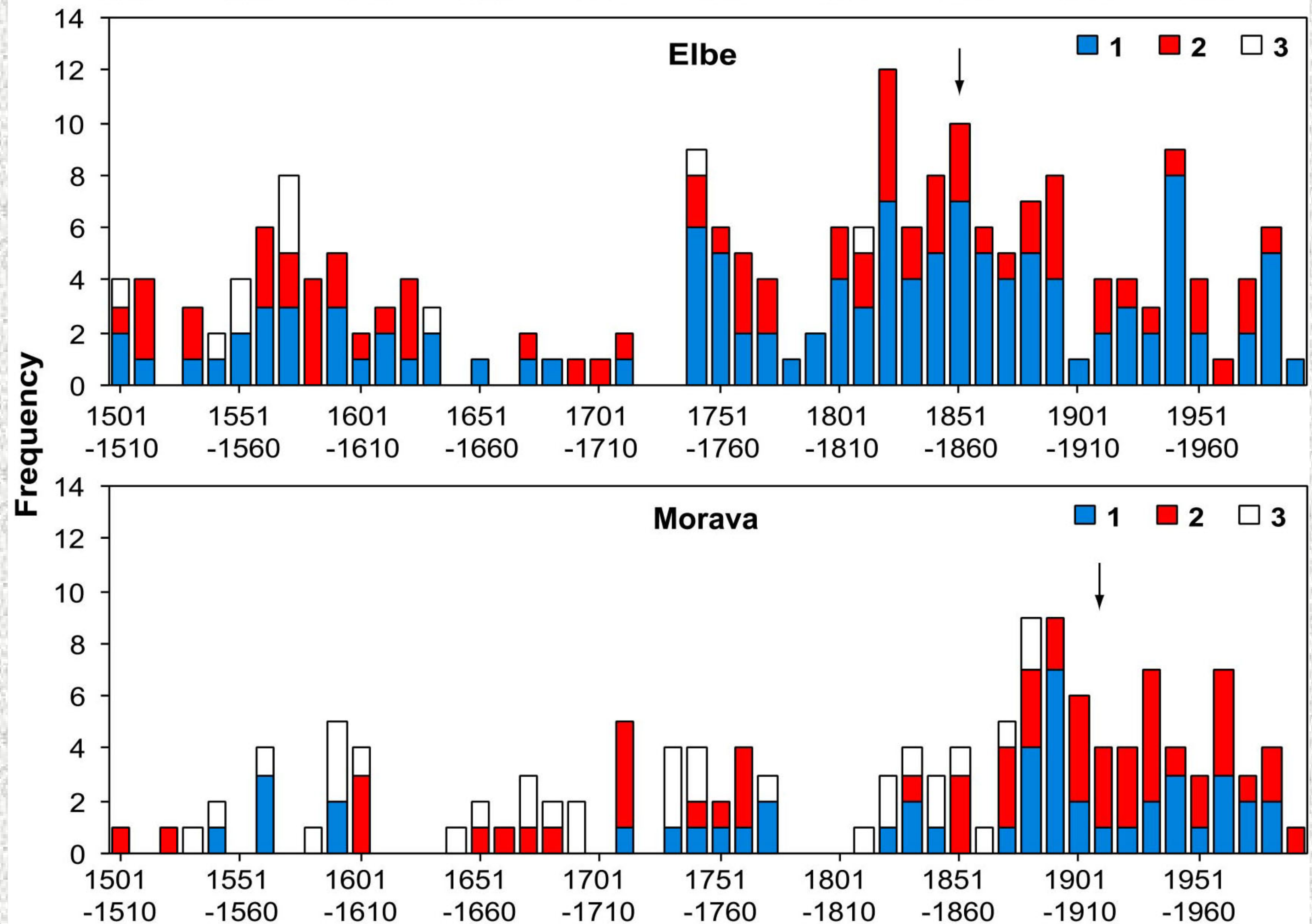


The August 2002 flood in the historical context

The Elbe - Děčín - watermarks on the Castle Rock



Floodmarks of the Elbe on Castle Rock at Děčín

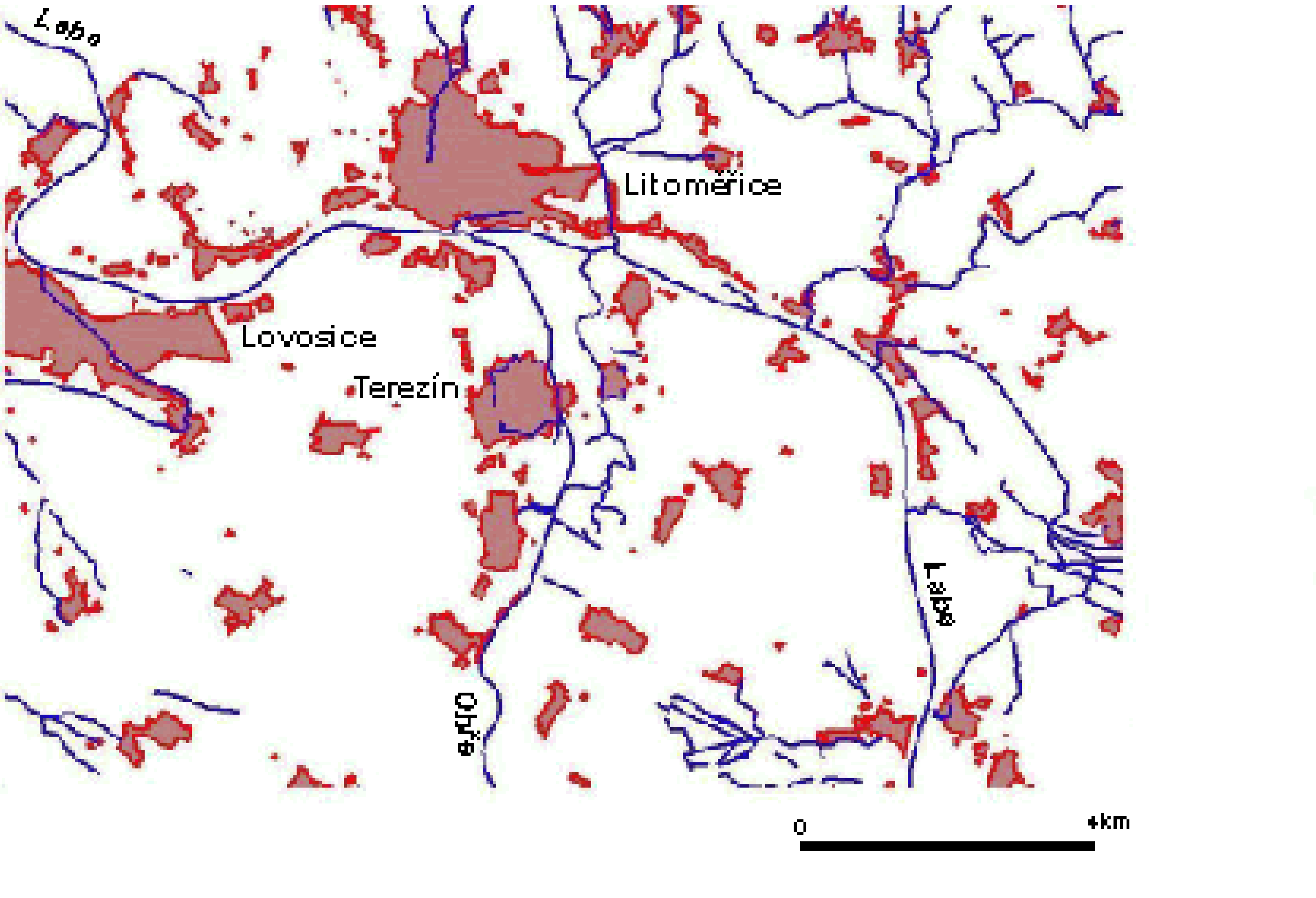


Decadal frequencies of floods 1501-2000: 1 - winter synoptic type, 2 - summer synoptic type, 3 - without specification

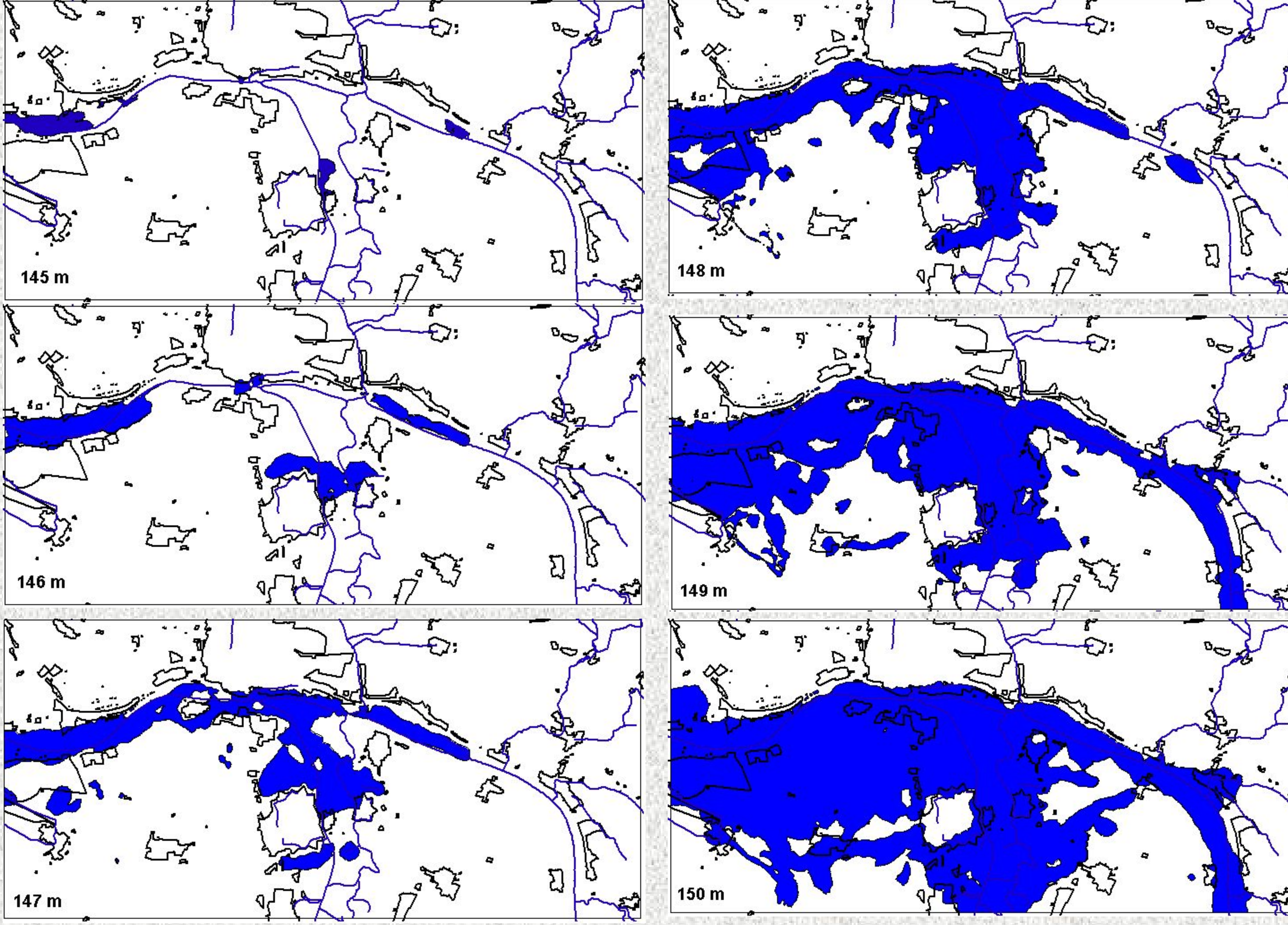
Learning from the past – historical memory

Litoměřice - Želetice, pátek 16. 8. 2002, kulminace

The area of Litoměřice-Želetice on the Elbe River on 16 August 2002 during the culmination discharge rate. This flooded area corresponds with experience known from documentary evidence for similar catastrophic floods as it was in March 1845



Flood marks as a source of data for modelling of potential flooded area during the historical flood events - settlements in the Litoměřice region



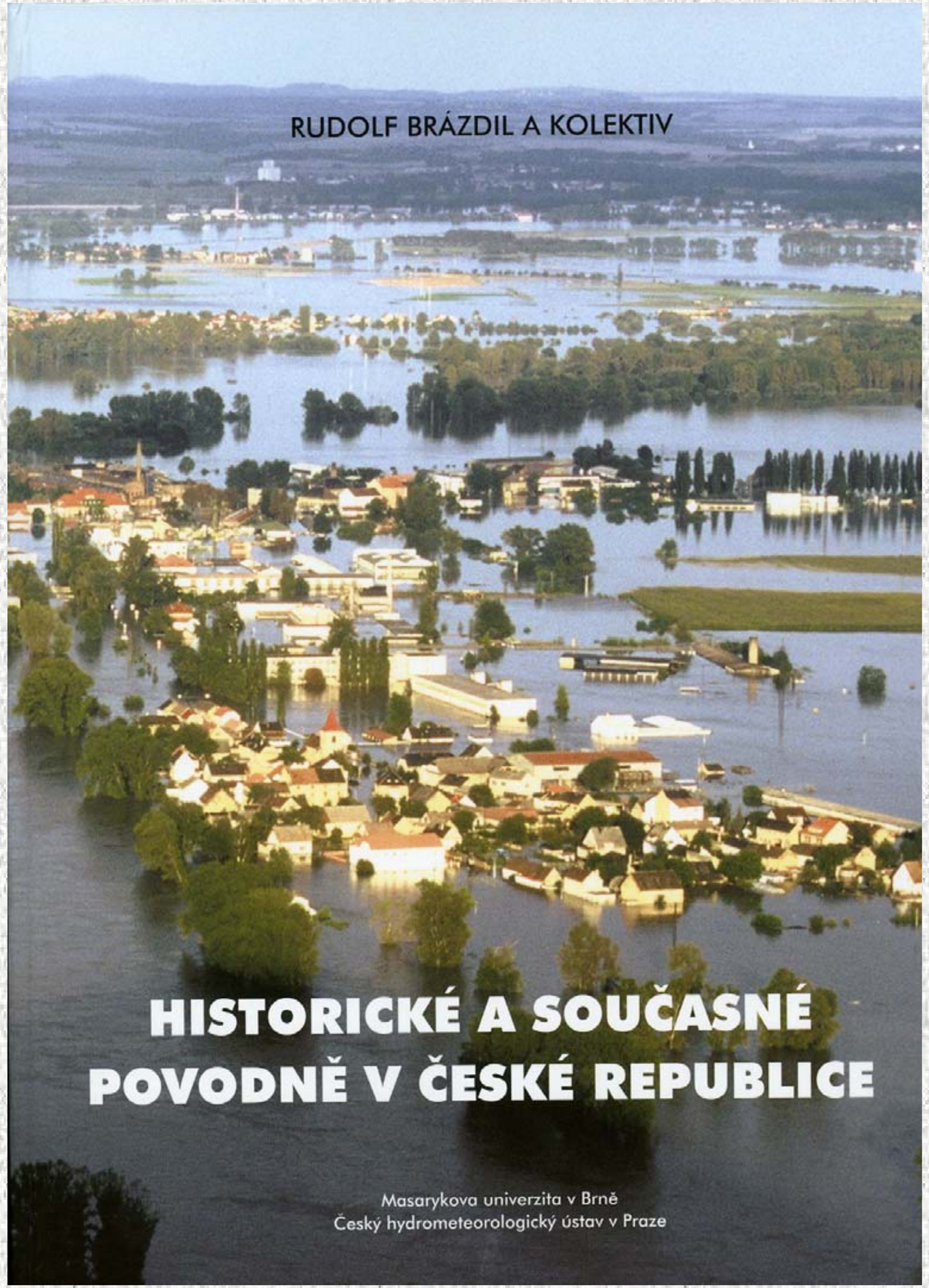
Flood marks as a source of data for modelling of potential flooded area during the historical flood events - the Litoměřice region

Conclusions

- in the period of systematic observations (from the mid-19th century) the drop in the number and intensity of floods in the Czech Republic has been observed - mainly due to decrease of floods in February to April, conditioned by global warming due to a later onset of winters and a lower accumulation of snow cover
- the impacts of floods are the result of the interaction of their meteorological causes, the character of the natural environment and the human society - more catastrophic consequences (more complex infrastructure of society)
- documentary data enhances understanding about flooding to centuries prior to the onset of systematic water-gauge observations - frequency, seasonality, causes, impacts

- documentary evidence is an important source of high-resolution data about floods in the pre-instrumental period
- some historical cases may be used as analogues of the recent floods
- very well documented recent events are important for complex understanding of similar past floods
- the most disastrous well documented floods in the Czech Republic: September 1118, March 1272, February 1342, July 1432, August 1501, March and August 1598, February 1655, June 1675, February 1784, March 1845, February 1862, May 1872, September 1890, July 1897, July 1903, September 1938, July 1997, August 2002
- since May 1872 - floods of the summer synoptic type (from rainfall) prevailed

- floods of February 1784, March 1845, February 1862 (all winter synoptic type) - the end phase of the Little Ice Age?
- long-term flood records may reduce uncertainty in hydrological analyses and contribute to reducing losses of human lives and property



Brázdil, R., Dobrovolný, P., Elleder, L., Kakos, V., Kotyza, O., Květoň, V., Macková, J., Müller, M., Štekl, J., Tolasz, R., Valášek, H. (2005): Historical and Recent Floods in the Czech Republic. Masaryk University and Czech Hydrometeorogical Institute, Brno, Prague, 370 pp. (English summary pp. 287–369).