Designing an expert knowledge based approach for the quantification of historical floods

- the case study of the Kinzig catchment in Southwest Germany

Physical Geography
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HYDROLOGY

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EGU2017-8863 CL1.25 / AS4.26 / HS2.4.5

Why studying historical floods?

Floods represent one of the most destructive natural hazards in Central Europe and worldwide. This highlights the necessity of deepening the understanding of the relationship between climate and flood generation over a longer time period [1].

→ The systematic collection and analysis of **historic *and* recent flood-related data** therefore mean an essential complement [2,3]. The inclusion of historic records can contribute to an **enormous reduction of uncertainties** in flood hazard analysis [4].

→ Methods of historical climatology represent one way of assessing flood occurrences beyond the period of instrumental measurements.

The derivation of quantitative values from vague, descriptive information of historical sources remains, however, a crucial challenge.

Objectives

> designing methods for a **better estimation of past flood events** as a contribution to flood hazard assessment

> **Combining mathematical and statistical methods with hermeneutics to refine the assessment of historical floods**

- validation of the **classification scheme** (Tab. 1) for past flood events
- parametrization of available descriptive, flood related information and estimation of the **dimensions of historic floods**
- assessment of the **additional value in a flood frequency analysis**

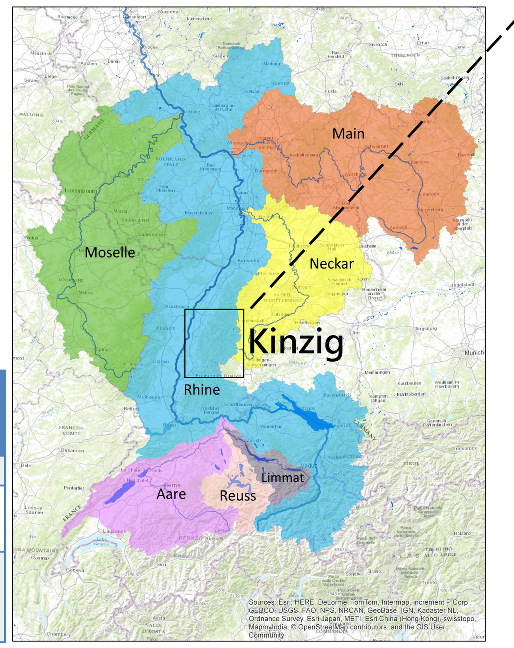
BACKGROUND

The transnational projects TRANSRISK & TRANSRISK^2

- **reconstruction of the flood history** of the last 300 yrs of Upper and Middle Rhine and tributaries [5]
- hermeneutic approach by **critical source analysis** [2], using historical information (chronicles, diaries, newspapers, flood maps, epigraphic marks)
- **index-based classification** of past flood events to derive long time series of floods

Class	Classification (intensity, spatial dimension)	Primary indicators: damages	Secondary indicators: temporal structure	Tertiary indicators: mitigation
1	small flood	little damages (fields, gardens)	short flood	local supporting measures
2	above-average, big or supra-regional flood	strong damages on bridges and bankside buildings; flood protection is affected/damaged	flooding lasts up to few days	coordinated supporting measures with regional organizations
3	extreme or supra-regional flood, catastrophic dimension	severe damages of flood protection systems, on bridges, buildings, bankside fields and gardens; loss of cattle and people	long lasting flooding (up to several weeks)	supra-regional coordinated measures of major extent; the event became part of the long-term memory and resides as a reference

Tab 1: Classification scheme for floods [5, modified]



Study area TRANSRISK

- diachronic studies: **causes and consequences** of floods and the changes over time; analyses of **risk perception and acceptance**
- data publication and storage on **tambora.org**, the climate and environmental history collaborative research environment

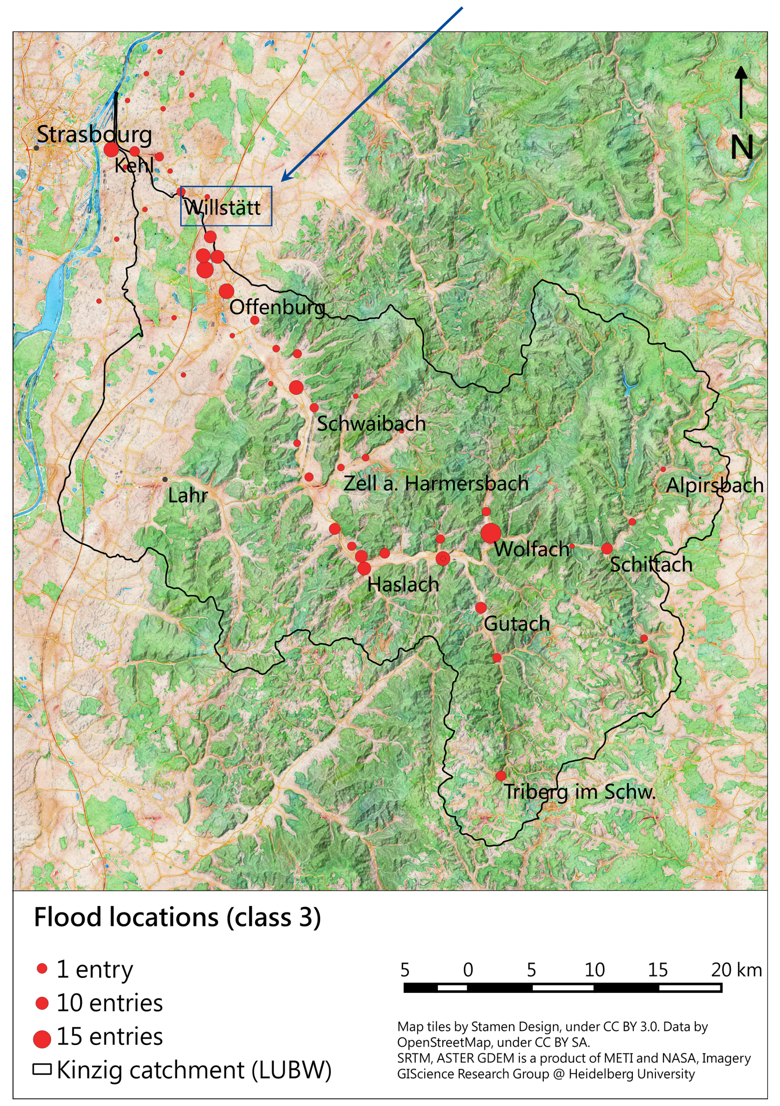
tambora

How can we link historic with modern times ...

(1) Data collection and processing

- available data comprise classified flood record since 1500, based on historic and contemporaneous sources
- enrichment of data base by archives research with:
  - > historical and current river profiles
  - > early-instrumental data on peak flood stages
  - > additional flood mark locations
  - > current official gauge data since 1914 and flood risk maps (LUBW)
- estimation of peak discharges based on available water level data by the empirical Manning´s equation [6]

Flood marks at Willstätt



Locations damaged by extreme (class 3-)flood events in the Kinzig catchment

The Kinzig catchment case study

> largest tributary of the southern Upper Rhine (1406km^2)

> largely undisturbed headwater, rectification of middle and lower course during the 19th century

> sporadic gauge observations since 1822

> more than 300 recorded flood events

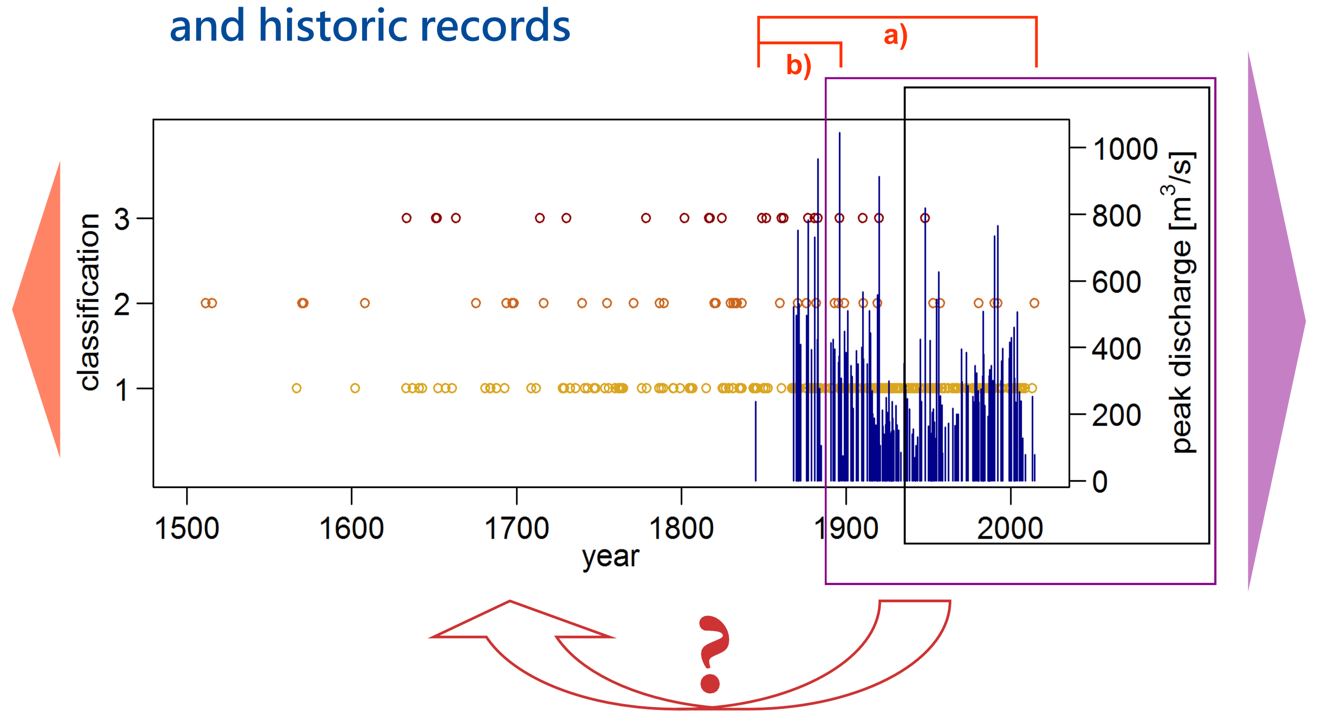
> floods mostly during the winter half-year

> caused by ice break (until ~ 1870), long-lasting rain or ROS-events

(2) Quantification of past events

... based on the overlapping period of measurements and expert judgement:

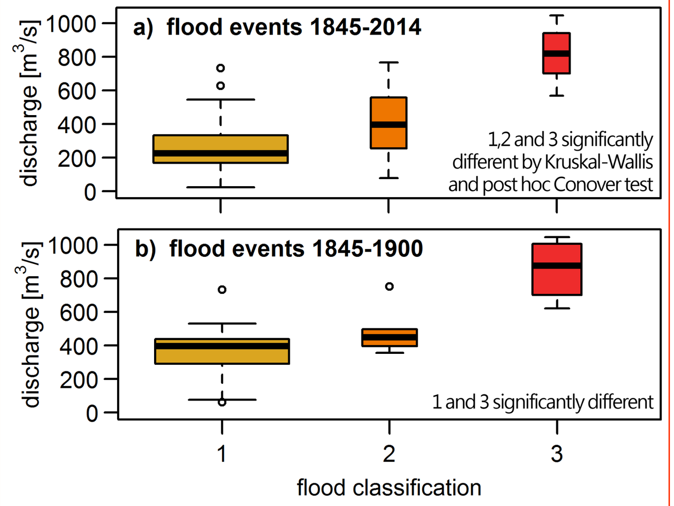
2A. Connecting systematic measurements and historic records



Explore the possibilities of linking unprecise, descriptive data related to historic floods with quantitative information of events within the instrumental period

2B. Validation of the flood classification scheme

...by statistical testing, with the flood peak discharge as measure of the intensity of the flood



2C. Derivation of quantifiable parameters from descriptive, vague or categorical information

Fuzzy rule-based model

PREMISES - *input variables*

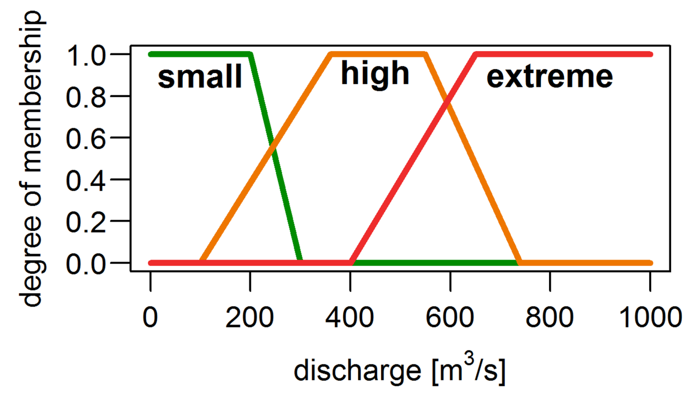
flood index of the event
AND
number of damaged locations
AND
number of available sources
AND
meteorological causes
AND
time period of the event

RESPONSE - *output variable*

flood peak discharge

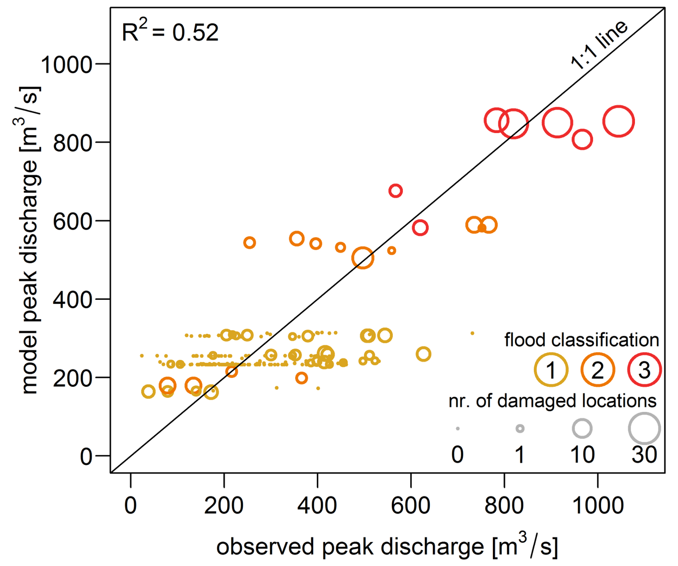
Connection of premises and response by logical rules, trained by data set -> 'expert knowledge'

possible membership functions for the output variable **flood peak discharge:**



Fuzzy rules confine discharge intervals

The explained variance (training set) is higher than in a comparable glm (0.31).

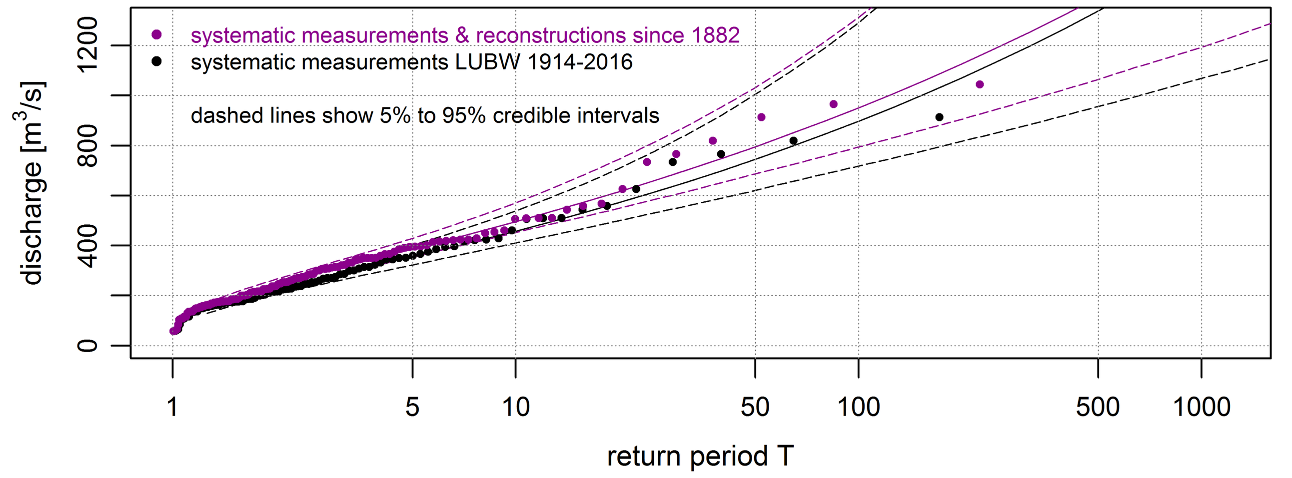


... and the future?

(3) Flood frequency analysis

- integration of the derived quantitative values of historic floods into the time series of systematic measurements, for:
  - > assess the general value of using historic and early-instrumental information
  - > analyze the effect of *incorporation or omission* of single uncertain historic events by a sensitivity analysis
- use of Bayesian MCMC framework [3,7] → allows to include both precise and interval based historic flood data

First results (gauge Schwaibach) by using 'nsRFA' [8]: extension of the continuous series of annual maximum discharges by reconstructions since 1882 lead to a **significant increase of the HQ100 estimate.**



Conclusions

> The comparably long period of early-instrumental and systematic measurements in the Kinzig catchment provides the **opportunity of establishing a mathematical-statistical framework** for connecting qualitative and quantitative data.

> The **flood classification on basis of descriptive historic information** (Tab. 1) can be considered as a **significant indicator** of the dimension of an event and allows a rough estimation.

> A further confinement of uncertainty intervals for historic events can be achieved by including information such as flood marks and **estimations of flood peak discharges by a fuzzy rule-based model**.

> Extending the flood record beyond the systematic measurements leads to a **significant increase of peak discharges** for several return periods and **narrows the confidence interval.**

OUTLOOK

- model uncertainty assessment by **resampling of training and validation data sets**
- estimation of historical peak discharge intervals by **using the derived rules for past events** without measured discharges
- **merging data**: validation of estimations with information of flood marks and the derived intervals for flood classes
- flood frequency analysis including the additional modelled data, sensitivity analysis

References:

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Graphs have been created using R (R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.)

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Acknowledgements:
ANR and DFG funded: TRANSRISK (DFG-Gl 358/5-1, ANR-07-FRAL-025) and TRANSRISK^2 (DFG-GL 358/12-1, ANR-13-FRAL-0012).