International Conference

HEX 2014

“Hydrological extreme events in historic and prehistoric times”

9th – 15th of June 2014
Bonn, Germany

The Department of Geography
of the
Rheinische Friedrich-Wilhelms-University of Bonn

Programme
and
Abstracts
(Oral and poster presentations)
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Joint conference of

- GLOCOPH – Global Continental Palaeohydrology
- FLAG – Fluvial Archives Group
- LUCIFS – IGBP research activity Land Use and Climate Impacts on Fluvial Systems during the period of agriculture
- IWHA – International Water History Association
- FgHW – Fachgemeinschaft Hydrologische Wissenschaft
- DHG – Deutsche Hydrologische Gesellschaft
- DWhG – Deutsche Wasserhistorische Gesellschaft
- AK Geomorphologie – German working group on geomorphology
- AK Hydrologie – German working group on hydrology
- DEUQUA – German union for Quaternary research
"Hydrological extreme events in historic and prehistoric times HEX 2014"

Monday, 9.6.2014:
15:00 – 18:00 Conference office open
17:00 – 17:45 Introductive general keynote
Gregory, Ken (keynote) The development of palaeohydrological research - the first sixty years
18:00 – (20.00) Icebreaker party Drinks and snacks

Tuesday, 10.6.2014:
8:30 – 16:40 Conference office open
9:00 – 9:30 Opening ceremony
9:30 – 10:15 Sessions: Past hydrological events, periods and their chronologies (1)
9:30 – 10:15 Brazdil, Rudolf (keynote) 500 years climate, floods and droughts in Central Europe based on documentary evidence and instrumental records
10:15 – 10:45 Coffee break
10:45 – 12:05 Session: Past hydrological events, periods and their chronologies (2)
10:45 – 11:05 Kiss, Andrea A preliminary overview on the recent analysis of 500-year flood changes in Europe
11:05 – 11:25 Vietinghoff, Hartwig Historic discharge data for the Elbe – derivation of daily discharges on the Magdeburg gauge 1727 – 1890
11:25 – 11:45 Elleder, Libor Historical changes in frequency and seasonality of extreme floods in Prague
11:45 – 12:05 Böhm, Oliver 700 Years of flood frequencies in the Alpine Foreland of Germany as function of changing climate parameters
12:15 – 14:00 Lunch break
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<td>Toonen, Willem A Holocene palaeoflood chronology of the Lower Rhine</td>
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<td>Trabert, Andreas Trends in flood discharges of Ulster and upper Fulda River from 1961 to 2010</td>
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<td>Fontana, Alessandro Meta-analysis of alluvial 14C database in the Venetian-Friulian Plain (NE Italy)</td>
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16:00 – 16:40 Sessions’ poster presentation & Coffee break

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<td>Hydrological and environmental history of a Mediterranean river recorded in palaeoflood sediments</td>
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<td>The role of extreme flood events to recover gravel-bed streams affected by mining activities</td>
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<tr>
<td>Diez-Herrero, Andres</td>
<td>Frequency analysis (return period) of recent flash-flood events in Caldera de Taburiente National Park (Canary Islands, Spain) from dendrogeomorphological and meteorological data</td>
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<td>Gil Guirado, Salvador</td>
<td>Increasing vulnerability to flooding in the southern Spanish Mediterranean coast (1960-2011)</td>
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<td>Herget, Jürgen</td>
<td>Peak discharges of the July 1342 flood along the Rivers Rhine and Main</td>
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<td>Evidences of extreme paleofloods greater than the 2013 event in the Burnett River, Australia</td>
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<td>Reconstructing a high resolution hydrograph curve based on historical photographs</td>
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<td>Ruiz-Villanueva, Virginia</td>
<td>Inter-decadal variability of hydrological extreme events in the northern foreland of the Tatra Mountains</td>
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<td>Zbinden, Eveline</td>
<td>Flooding of 1342 in Central Europe</td>
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<td>17:00 – 17:20</td>
<td>Agafonov, Leonid</td>
<td>The Ob River (western Siberia) – hydrological events and dendrochronological interpretation for the last three centuries</td>
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<td>Wongsa, Sanit</td>
<td>Reconstruction of historic flood events on the Chao Phraya River, Thailand</td>
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<td>8:50 – 9:10</td>
<td>Kale, Vishwas</td>
<td>Late Holocene Palaeoflood records from monsoon-fed rivers, India: A synthesis</td>
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<td>9:10 – 9:30</td>
<td>Zhang, Yu-zhu</td>
<td>Holocene Palaeoflood events recorded by slackwater deposits on the Beiluohe River, China</td>
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<td>9:30 – 9:50</td>
<td>von Suchodoletz, Hans</td>
<td>Landscape stability – the key to understand Holocene palaeofloods in the Caucasus area</td>
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<td>9:50 – 10:15</td>
<td>Coffee break</td>
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**10:15 – 12:15 Session: Past hydrological events, periods and their chronologies including recent events and human impact (6)**

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<td>Benito, Gerardo Magnitude and timing of Holocene outburst floods of the northern Patagonian icefield</td>
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<td>10:35 – 10:55</td>
<td>Greenbaum, Noam Paleoflood hydrology of Stillwater Canyon, Green River and Cataract Canyon Colorado River – preliminary results</td>
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<td>10:55 – 11:15</td>
<td>Migon, Piotr Recent versus historical fluvial extreme events in the mountainous drainage basins of the Sudetes</td>
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<td>Gebica, Piotr</td>
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<td>11:35 – 11:55</td>
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<td>11:55 – 12:15</td>
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<td>Carling, Paul (keynote)</td>
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<td>14:30 – 14:50</td>
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<td>18:15 – 21:30</td>
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### Thursday, 12.6.2014

#### 9:00 – 10:05  
**Session: Extraterrestrial flow and floods**

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<td>Baker, Vic (keynote)</td>
<td>Extraterrestrial flow - why should we care?</td>
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<td>9:45 – 10:05</td>
<td>Erkeling, Gino</td>
<td>Putative paleoshorelines in Isidis Planitia, Mars: implications for standing bodies of water</td>
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<td>10:05 – 10:30</td>
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#### 10:30 – 12:30  
**Session: New techniques and methods of investigation**

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<td>Problems of the simulation of naturally dammed lakes’ outburst floods</td>
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<td>Jones, Anna</td>
<td>Assessing the potential of XRF core scan analysis of floodplain sediments for reconstructing flood histories</td>
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<td>11:10 – 11:30</td>
<td>Ballesteros Canovas, Juan</td>
<td>Unravelling flash-flood activity in the Spanish Central System</td>
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<td>11:30 – 11:50</td>
<td>Sürmelihindi, Gül</td>
<td>Carbonate deposits in Roman aqueducts as a tool to recognize seasonal layering and extreme weather events</td>
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<td>11:50 – 12:10</td>
<td>Burkow, Markus</td>
<td>The numerical simulation of sediment processes using a three dimensional two-phase flow model</td>
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<td>12:10 – 12:30</td>
<td>Lotsari, Eliisa</td>
<td>Prospects and challenges in simulating future changes in natural river channels</td>
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<td>12:30 – 14:00</td>
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#### 14:00 – 15:20  
**Session: Drought analysis – an underestimated problem and challenge**

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<td>Pfister, Christian</td>
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<td>Macdonald, Neil</td>
<td>Construction of a network of drought series from across the British Isles from early instrumental data series (1697-present)</td>
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<td>14:40 – 15:00</td>
<td>Roggenkamp, Thomas</td>
<td>Low water events on Middle and Lower Rhine in Roman times</td>
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<td>Loczy, Denes</td>
<td>Flood and drought hazards in the floodplains of regulated rivers in SW – Hungary</td>
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<tr>
<td>Time</td>
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<td>Vött, Andreas (keynote) Extreme wave events in the past</td>
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<td>Hadler, Hanna Ancient Greek harbours used as geo-archives for palaeotsunami research</td>
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<td>16:50 – 17:10</td>
<td>Röbke, Björn Roman Evaluating numerical simulation results by means of tsunami field evidence for Cape Katakolo and ancient Epitalio (western Peloponnese, Greece)</td>
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<td>17:10 – 17:30</td>
<td>Böse, Margot An event or a destructive phase documented in Late Holocene fluvial and coastal deposits in NE-Taiwan</td>
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17:30 – (18.30) Farewell drink

Friday - Sunday, 13. – 15.6.2014
Field presentations at selected locations along the Rivers Rhine, Ruhr, Möhne, Weser and Main
Location plan

- Lunch (10.-12.6.)
- Conference Dinner (11.6. - 18.30 hrs)
- Hotel (HEX-listed)
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Abstracts
for oral presentations
THE DEVELOPMENT OF PALAEOHYDROLOGICAL RESEARCH: THE FIRST SIXTY YEARS

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It is sixty years since Leopold and Miller first explicitly used the term palaeohydrology and in the subsequent six decades considerable progress has been made. Milestones have included the utilisation and innovation of palaeohydrological techniques, publications achieved, together with recognition of ways in which palaeohydrological research can be utilised. However the progress of palaeohydrological research can be reviewed against the background of the way in which techniques, embracing pertinent developments in GIS, and concepts have developed over sixty years (e.g. Gregory and Lewin, 2014), facilitating closer linking of timeless and timebound research, assisting assessment of the success of palaeohydrology. In addition to such internal evolution significant external developments have provided a research environment, which includes greater recognition of global change, the impact of IPCC, and the revolution in communication methods (e.g. Gregory et al 2013). Awareness of the impact of more extreme events and alterations in event frequency provide a context in which research results concerning past events are potentially of greater importance. Extreme events in 2013-14, including floods in southern UK which were prompted by the wettest winter since at least 1766, raise public awareness of the impact of such events and of the need to place them in a historical context, prompting review of awareness of palaeohydrology.

Against such internal and external developments, together with the themes for this conference, it is appropriate to ask how further dissemination of research results can be effected. Hitherto communication has included coordinated effort by multidisciplinary research collaboration, such as that by 6 international research groups (Gregory et al 2006a), by strategies such as a provisional protocol (Gregory et al 2006b; Gregory et al 2008), as well as by reviews of implications for management (Gregory, 2003) but further challenges and opportunities that are available should now be proposed as an outcome from this conference.


Central Europe is a region with a long history of systematic meteorological and hydrological observation networks, most of which started in the second half of the 19th century. The pre-instrumental period is covered by the prevailing qualitative descriptive information contained in various types of documentary sources, such as chronicles, memoirs, diaries, letters, financial records, pictures, newspapers, epigraphic records, and other primary historical sources. This information also overlaps with the instrumental period.

In order to avoid bias in measurements that might arise out of, for example, changes in station location and/or surroundings, type and positioning of instruments, and observation timing and procedures, existing series must be checked for relative homogeneity and adjusted as required. Series of monthly temperature and precipitation indices derived from documentary data are created on a seven-degree scale (from -3 as extremely cold/extremely dry to +3 as extremely warm/extremely wet) for climate reconstruction. Applying standard paleoclimatological methodology (using the existing overlap between indices and instrumental records) facilitates the reconstruction of temperature and precipitation patterns. This approach has been used here for reconstruction of Central European temperatures and Czech precipitation totals from AD 1501 onwards.

Seasonal and annual Central European temperature series, combining standard reconstructions based on Germany, Switzerland and Czech indices up to AD 1759, together with mean series calculated from 11 homogenised stations from 1760 onwards, clearly express high inter-annual and decadal variability with a general rising trend since the end of the 19th century. Similarly, precipitation reconstruction for the Czech Lands combines documentary and instrumental data; the best reconstruction is available for summer but, apart from inter-decadal variability, no low-frequency signal is detectable in this series. Czech temperature and precipitation series are available to calculate several drought indices from 1805 onwards (e.g. SPI, Z-index, PDSI) and they disclose an increasing dryness of climate in recent decades. A 500-year drought chronology of the Czech Lands has been compiled using these indices and drought events derived from documentary data. Drought in the pre-instrumental period is here considered as circumstances in which very dry patterns occurred in least in two consecutive months. The number of years with drought was highest in 1951-2000 and lowest in 1651-1700. Documentary evidence has proved rich enough to compile several long-term flood chronologies for Central Europe; the River Vltava at Prague and the Elbe at Děčín provide good examples. Both these series show the highest frequency of floods occurring in the 19th century (mainly of winter synoptic type) and in the second half of the 16th century (summer synoptic type). The most disastrous floods took place (in chronological order) in August 1501, March and August 1598, February 1655, June 1675, February 1784, March 1845, February 1862, September 1890 and August 2002. Documentary evidence also facilitates the description of spatial extent and time of flood culmination, as may be seen on a European scale for the floods in winter 1783/1784 after Laki erupted.

All the results presented, including their uncertainties, are important to our understanding of climate, droughts and floods in Central Europe over the past half-millennium.
Long-term flood series can be gained by combining evidence and systematic hydrological observations. An important aim of the present work is to create a broad European database of long flood chronologies and to use them for detecting changes in flood regimes with respect to common break points. A further aim of investigations is to reveal the main causes (e.g. atmospheric, human) of these changes and study spatial and temporal variability of floods on a European scale.

In the presentation we provide an overview on the current stage of these Europe-wide investigations, including geographical coverage, temporal and spatial distribution of long-term flood series applied in the study. First results concern the information on magnitude, frequency and seasonality of floods, with a special emphasis on detectable changes.
HISTORIC DATA FOR THE ELBE RIVER – DERIVATION OF DAILY DISCHARGE VALUES AT GAUGE MAGDEBURG, PERIOD 1727 - 1890

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The consideration of historic floods is not only interesting in a scientific context. Their consideration within the calculation of return periods of extreme flood events for the dimensioning of hydraulic-engineering facilities is of great practical importance, as the events of the last two decades have shown. For compiling flood statistics normally discharge values are required, while the historic gauge data usually are available as water level records (DWA-M 552, KIRSCH & POHL 2011).

For the Magdeburg gauge at the middle reach of the Elbe river daily water level records are available since 1727 with a gap from 1809 till 1816. Thus, this is presumably the gauge with the longest continious data-record in Germany. Preliminary work on the water level-material for the period 1727-1880 was presented by SIMON (2010). On that basis, FAIST (unpublished) proceeded the work on that material, including the deduction of rating curves for the period 1727-1891, which has to be developed further and presented.

In the considered period there have been multiple, natural and anthropogenic modifications on the Elbe river with influence on the setting of the water levels, alterations at the gauge, morphological changes of the cross section and longitudinal profile, the official datum reference system etc., which were described in a summary by SIMON (2010). Even the ice conditions are of great importance for the water levels and discharge conditions during winter floods of river Elbe river.

Having detailed regard to this alternating conditions and the critical examination of the historic data there were revealed altogether 7 rating curves and 3 modifications for the Elbe courses in Magdeburg on the basis of hydraulic calculations. The results were verified (as far as possible in time) with water level records from other Elbe-gauges up- and downstream of the city of Magdeburg.

In the proposed paper the further evaluation of the historic data will be presented. The stage-discharge curves for the above mentioned historic periods will be verified to find the discharge values for the handed down flood level records. The rating curves enable the derivation of the daily discharge in the considered period, their conversion of the water levels on the recent gauge datum elevation and consequently the inclusion in the long-term discharge statistics. The classification and evaluation of historic and current flood events will be possible with these results.
HISTORICAL CHANGES IN FREQUENCY AND SEASONALITY OF EXTREME FLOODS IN PRAGUE

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Background: Three extreme summer flood events were recorded in the Czech Republic within last 15 years (1997, 2002, and 2013), two of these being classified as 500-years or even 1000-years. Taking into account the entire region of Central Europe, we have to add further extreme summer floods: in the Alps in 2005, and in Slovakia and Poland in 2010. An interesting question thus emerges, if there is an analogy with such a frequency of important or extreme floods in the past. The aim of the contribution is to answer two scientific questions: 1. Had the territory of the present Czech Republic experienced four summer extreme flood events within mere 15 year period earlier in history? 2. Did the region of Central Europe recorded extreme large-scale floods during the last 500 years more often as compared to present? Method: A time-series of peak discharges of historical flood events at the Vltava River in Prague estimated earlier (Elleder, 2010; Elleder et al., 2013) were utilized. Two complementary approaches – hydraulic calculation and exploitation of documentary sources – were used for reconstruction of historical flood peak discharges.

Results: Analogy to the current situation both regarding the frequency and type of the flood events was found in the middle of the 15th and at the turn of the 16th and 19th centuries. Interestingly, the periods of accumulation of the summer floods in Prague in history never exceeded 20–25 years. There is an apparent change in time distribution of summer floods.

Conclusion: Final answer to the questions raised is not possible to give at present, however, as we still do not know if the current period with high frequency of extreme summer flood events is drawing to an end or if the current period will differ significantly from all we have experienced so far.


The flood history of the Alpine Foreland of Germany (AF) could be raised from the 13th century until today. Based on written lore and instrumental data (Early Instrumental Period data starting in 1826) the long-term variability of flood frequencies in a spatial as well as temporal context was of special interest.

Contributing to recent discussion, as to whether anthropogenic-triggered climate change will modify the present state of flood frequencies, a look back into the past is essential to understand the occurrence of floods in general and in particular recent floods. A perceived increase of summer floods in eastern Germany and Bavaria since 1997 requires examination of a long time series to calculate the flood frequencies in a statistical way. Incidentally the dominance of summer floods for the AF in general must be emphasized. In order to understand the role of climatic changes to the development of flood frequencies it is necessary to review long time series to improve our comprehension of variability. Based on 31-year sliding means of flood frequencies 9 flood intense periods for the AF could be assumed. One result revealed is the occurrence of “flood-rich” and “flood-poor” sequences in a nearly rhythmic pattern. Flood-rich periods were recorded between the years 1300 – 1335, 1370 – 1450, 1470 – 1525, 1555 – 1590, 1615 – 1665, 1730 – 1780, 1820 – 1870, 1910 – 1955 as well a ninth period beginning in 1980. The flood-rich-periods are identified by longer flood duration.

Most of the flood-rich and –poor -periods (respectively beginning and ending of them) can be connected to changes in intrasystem and external natural climate variability. These include changing sunspot numbers, the Little Ice Age and its so-called LIATEs (Little Ice Age Type Events) as well as changes in the North Atlantic Oscillation (NAO) indices. Between the years 1610 and 1930 conspicuous correlations between sunspot activity and the flood frequencies of the AF can be shown. A high variability of coherences between flood activity and climatic parameters can be revealed by means of the correlation of flood frequencies and the NAO. Starting 1830, the beginning of a noticeable climatic period, highly significant correlations between the flood frequencies of meteorological summer and the NAO can be shown. External climate system signals, which could be used to explain the changing flood frequencies in the AF, end in 1930. Intrasytem signals such as the correlation of flood frequencies with the NAO have changed during the transition from the post Little Ice Age period to the Modern Climate Optimum around 1930. It is imaginable that natural variability signals have been overwritten by anthropogenic emissions.
CLUSTERS OF EXTREME FLOODS;
THEIR ROLE IN TRANSFORMATION OF FLUVIAL SYSTEMS

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The higher frequency and clustering of heavy rains and floods play a leading role in the formation and changes of fluvial regime in various climatic zones and morphogenesis of fluvial systems. Let us turn our attention on the effects of clusters of extreme rainfalls and floods in the mountain catchments as well on the depositional depressions of the mountain forelands.

The length and intensity of heavy rains as well of flood wave may vary in time starting from minutes and hours up to days and their clusters from days to years, decades and even centuries. In our research we turn to little attention to shorter time units. Usually we measure the highest value of precipitation and river discharge only once during one day (very rare during every hour). In reality the high rain intensities and discharges may fluctuate from minutes to hours and those flood waves and their various configuration of clusters may play a leading role in the transformation of river channels and construction of alluvial fans.

Similarly the clustering of several flood waves during one rainy season in monsoon climate decide on the trend in evolution of river channels and aggradation in the mountain foreland. But a direct evolitional trend is progressing if the floods are repeating every summer or snowmelt floods are regular during many years.

In longer time units sometime we observe the clusters of years of higher river activity separated by various number of years when follows the stabilization of channels and revegetation of bars and river banks. It proceed the readvance of forests or bogs. The appearance of heavy flood or even their cluster may lead to the avulsion of river channel and progressing aggradation. The analysis of the Holocene alluvial fills help to reconstruct longer phases of clusterings and reconstruct climatic variations.

The distinct acceleration in formation of clusters of heavy floods is connected with human activity. The destruction of natural vegetation cover causes the acceleration in degradation of slopes. Even in the uplifting young mountains we may observe either natural trend to down- cutting of channels or instead of that the progressing aggradation. Also the threshold values for transforming processes are much lower and therefore frequency of channel forming events is higher.

Generally in the reconstructions of fluvial regime of the distant past like the Holocene it is difficult to separate the role of clusters of various time length. The wetter phases are characteristic mainly by more frequent floods of longer duration occupying extensive areas. In the mountain areas the recorded flash floods are created by local downpours of convectional origine.
A HOLOCENE PALAEOFLOOD CHRONOLOGY OF THE LOWER RHINE

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Sedimentary records of the apex of the Rhine Delta in the Netherlands provide an excellent archive for reconstructing the chronology and magnitudes of Lower Rhine palaeofloods. Floods that exceeded bankfull discharge produced well preserved individual layers in local abandoned channels (Toonen et al., 2012). Eight cores were retrieved to construct a 8000-year palaeoflood chronology of the Lower Rhine. Flood magnitudes were reconstructed, based on ~3000 grain-size analyses of cm-scale individual flood layers. End-member statistics were used to characterize the coarsest tail of grain size distributions, which is a proxy for flow velocities and peak discharges (Toonen, 2013).

Age-depth models were constructed, based on $^{14}$C-dating, palynology, and XRF-data (pollution). Historical records of major flooding events (back to AD 1350) were used to refine recent chronologies, exploiting the property of the largest flood events to be recognizable in sedimentary records all over the delta plain (event-chronostratigraphy). Facies characteristics (e.g., mean grain-size and organic content) are consistent with accumulation rates and were used for age-depth interpolation between tie-point ages.

Largest floods, with ‘millennial’ recurrence times and a discharge surpassing any measured discharge of the last century (Toonen et al., 2013), occurred in AD 1374, AD 784, and ca. 4.5, 4.7, and 6.2 ka BP. Each of these floods triggered geomorphological changes of regional importance, such as avulsion and local river cut-offs. Strong variability in recorded flood intensities, and a significant multi-decadal periodicity in flood deposition indicate a non-stationary flooding regime, which has been especially anomalous during the Little Ice Age.

The 8000-yr flood palaeoflood chronology allows comparison with regional trends in flood intensities and regionally reconstructed extreme events, and testing of existing design standards for flood protection. Extended palaeoflood chronologies give important insights in the validity of current flood frequency analysis on modern measurement data series, which probably have a poor representation of extremes, as these usually only cover a single century. Moreover, this flood chronology serves as important input for research on non-stationary behavior of flooding regimes and cycles of intensified flooding that may be related to climate.


Intensifying processes in the hydrologic cycle, induced by global warming, involve the danger of increasing flood discharges. The aim of this work is to analyse the development of floods in eastern Hesse during a period of shifting climate with only minor changes in land use and due to river construction etc.

The study area includes the catchments of Ulster (420 km²; including the gauging stations Günthers and Philippsthal) and upper Fulda River (down to Bad Hersfeld; 2120 km²; including the gauging stations Hettenhausen, Kämmerzell and Bad Hersfeld 1). Bad Hersfeld 1 and Hettenhausen gauges only provide measurements from 1967 respectively 1972 on.

For this purpose, discharge datasets of three gauging stations, covering the period from 1961 to 2010 as well as data from 1972 to 2010 of all five gauging stations mentioned above, were analysed statistically. After preliminary examination of the daily and sub-daily raw data, time series of annual maximum discharges were extracted and for each a linear trend was calculated via the least squares method. The statistical significances of the exposed trends were then verified, using the Mann-Kendall test. Furthermore, potential breakpoints together with their likelihood were computed, applying the Mann-Whitney breakpoint analysis. For detected breakpoints the differences in long-term mean maximum discharges before and after these breakpoints were checked for annual, semi-annual and monthly time series. This part of analysis was realized for the 50 years time series of the Ulster’s gauging stations only.

Results mainly show upward trends with a highest degree of severity (up to 28.7 %) at the Ulster’s gauging stations however, only the 50 years time series of the Philippsthal gauging station (lower Ulster catchment) reaches a significance level over 80 %. The potential breakpoints show a characteristic clustering at the end of the 1970s. The highest likelihoods of 94.8 % (50 years time series) and 87.8 % (39 years time series) were detected in the datasets of the Philippsthal gauging station. The analysis of the development of long-term mean maximum discharges before and after a harmonised breakpoint between 1977 and 1978 shows higher discharges for the time series after 1977 – especially in the winter months, which is this region’s common flood season. This effect is more distinctive in the lower Ulster catchment.

The results coincide with the findings of large-scale studies for western and southern Germany in many ways. Especially long-term flow patterns in contiguous catchments of Lahn (western Hesse) and Main River (northern Bavaria) bear a close resemblance to those of the Ulster and the Fulda River, which suggests that a large-scale cause, e. g. changing precipitation patterns, could be a main reason for our findings.
Mountain regions as the Alps cover sensitive and vulnerable ecosystems exposed to changes of atmospheric circulation, meteorological and hydrological extreme events and perturbation by land-use. The record of 104 severe and catastrophic flood events from 1800 to 2010 shows that the densely populated Swiss Alps is a true "hot spot" of hydrological risk. However, outside the known range of extreme events reconstructed from documentary and instrumental data, the knowledge about frequency and magnitude of flood events is limited. During recent years a number of papers has been published that reconstruct debris flows and floods frequencies from lake sediments. However, most of these works are focused on high elevation small-scale catchments, which are rarely representative regarding flood dynamics in meso-scale catchments or flooding of the alpine main valleys, where settlements are exposed to flooding.

The present work focuses on sedimentary records retrieved from alluvial delta flood plains in the Bernese Alps. These geoarchives provide interdecadal-resolution proxy data for the multidisciplinary study of the potential effects of climatic changes on alpine floods during historical and prehistoric times (last 3200 years). According to the geomorphological survey, historical maps, 2 m-spatial resolution digital terrain model and field work, meso-scale fluvial landforms were identified in the delta flood plain. A total of 16 cores in the Aare delta and 21 cores in the Lütschine delta were operated by percussion coring down to 10 m depth. The chemical element composition of the sedimentary archives was analyzed at 1 cm intervals by XRF-II core scanning, LOI and laser diffraction grain size techniques.

The alluvial delta plain facies are defined by shallow gravel channel beds; coarse and middle sand beds of levees, flood layers and crevasse splay deposits; silt and organic-rich alluvial and palustrine sediments and peat. The best records, in terms of lithological-geochemical and temporal resolution, were retrieved from interdistributary basin. Because of the quasi-cyclic variability of several segments of these records (geochemical ratios, factors, TOC, grain size), spectral analyses of the geochemical and pollen time series and climate proxies ($\delta^{14}$C, $\delta^{18}$O GISP2 record, NAO) were performed, providing evidences for similar periodicities of 60, 85, 105 and 200 yrs. Thus, the mechanisms of the aggradation processes are very likely influenced by solar activity and the North Atlantic dynamics. It is interesting to note that the 105-yr frequency detected in the analyzed alluvial delta plains proxies is also identified in the summer flood index of Switzerland.

In general, the sedimentary flood proxies indicate that cooler climate pulses were an important external driving force of hydrological extreme events. This hypothesis is supported by the reconstructed floods of the Aare and Lütschine rivers (last 500 yrs) from local documentary sources, historical settlement pattern on flood prone landforms, flood levels and river channel shifts. With regard to the last centuries, 21 sedimentary flood layers of the Aare River have been calibrated by historical documents (since 1480 AD) and instrumental data indicating five mayor flood cluster: c. 1420 - 1499, 1551 - 1605, 1703 - 1762, 1831 - 1875 and 1977 - present. Although 33 of 36 reported flood damage events (92%) occurred in the Aare River since 1480 AD during the extended summer period (JJAS), alpine paleofloods are not only controlled by summer climatic conditions, but also by other seasonal, annual and pluri-annual phenomena such as snow cover and glacier dynamics, etc.
In this paper we present a review of a ca. 10-years research effort1 aiming at reconstructing floods dynamics in in French Alps through the last millennium, based on lake sediment records. We will particularly discuss how such geological records can be considered as representative of past climate. This implies a wise interpretation of data in order to really understand “what does the core really says”. Namely, we showed that different lake systems record different types of flood events. Low altitude lakes, fed by large-scale catchment areas are more sensitive to regional heavy rainfall events2–6, whereas high altitude small lakes record local extreme rainfall events7–9. Moreover, human societies’ development must be taken into account as it is susceptible to modulate the climate-geological record relationship8. Altogether our data permit the establishment of a millennium-long perspective upon both regional heavy rainfall and torrential activities in high elevation sites. We hence show that both types of events frequency co-evolve in Northern as well as Southern French Alps where cold spells (e.g. the Little Ice Age) generally present higher flood frequencies7-10. On the other hand, intensities of torrential events present a North-South opposite pattern: during warm spells (e.g. the Medieval Warm Period or nowadays), northern Alps are subject to rare but extremely intense heavy rainfall events, whereas in the southern Alps torrential floods are both rare and weak. During cold spells (e.g. the Little Ice Age), the inverse pattern is observed: torrential floods are more frequent everywhere and above-average intensity in Southern Alps. This point is particularly important for risk management in mountain areas in a context of global warming.

Our results point out how complex can be the response of regional system to global climate changes. We are hence far from completely understanding this complexity which is moreover imperfectly simulated by climate models. As geological records represent the only way to reconstruct long-term trends in flood regimes, more efforts must still be pursued to get a more complete image of this complexity and further improve climate models.

META-ANALYSIS OF ALLUVIAL $^{14}$C DATABASE IN THE VENETIAN-FRIULIAN PLAIN (NE ITALY)

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The Venetian-Friulian Plain is the northern-most alluvial environment facing the Adriatic Sea and it represents the transition from the Mediterranean domain to the Alpine and temperate regions of central and eastern Europe. The investigated area consists of the alluvial systems of Brenta, Piave and Tagliamento rivers, that formed alluvial megafans and are fed by mountain basins of respectively 1787, 3899 and 2580 km$^2$. The database of radiocarbon datings connected to the Holocene alluvial evolution of the Venetian-Friulian Plain consists of 136 samples and 36 are classified as change-after dates. We applied to this catalogue the statistical analyses described in Macklin et al., (2010) with the aim to detect periods of enhanced flooding activity.

The individual probability distribution of each calibrated radiocarbon age was summed, producing a cumulative probability density function (CPDF) plot for each alluvial systems and for the whole database too. Each change-after CPDF have been subtracted to its correspondent CPDF of the entire sub-dataset, obtaining plots of the Relative Cumulative Probability Function (RCPF). The analysis of these curves evidences that significant information is available between about 8.5 and 0.8 ka cal BP, whereas for older and younger periods radiocarbon data are almost absent, due to the geomorphological evolution of the area. Even the interval 8.5-0.8 ka cal BP is not entirely statistically significant, because the available change-after dates are relatively few. Main scarcity of them is recognized between 4.5 and 2.3 ka cal BP but, considering the stratigraphic and geomorphologic record, some important flooding are documented in this period. Meta-analyses demonstrated a fairly well correlation of several flooding period occurred in NE Italy with some Ice Rafted Debris events (IRD) documented in Northern Atlantic Ocean. These results seem to point out that the Holocene intervals of enhanced flooding activity relate with events, or phases, of climatic deterioration occurred at regional and continental scale. The comparison with other European flood sequences, obtained with both statistical and stratigraphic approaches (e.g. Macklin et al., 2006 and Lauterbach et al., 2012), highlights some possible matching intervals around 7.5, 6.9, 6.2, 2.3, 1.9, 1.0, 0.85 ka cal BP.


THE SOUTH AMERICAN TROPICS DURING THE LAST THOUSANDS YEARS: WHAT DO CONTINENTAL GEOMORPHOLOGIC AND SEDIMENTARY RECORDS TELL US ABOUT ENVIRONMENTAL CHANGES?

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Despite the enormous growing in environmental studies and the development of programs to understand the forest/atmosphere/hydrosphere interactions, the studies on paleohydrology to understand the past and to discuss future trends in the South American tropics have been systematically misinterpreted or avoided from the large scale priority environmental programs. Recent archeological results postulated that the Amazon and other tropical areas supported a substantial population at the time the conquerors arrived to America. During the Holocene several climatic episodes had been recorded in South America such as the Medieval Optimum and the Little Ice age. We assessed the chronological record using the methodology applied by the TERPO Commission of INQUA- focus area on hydrological change and climate project. No remarkable but potential signals in the tropical zone are identified. In this presentation we present a general review of geologic-geomorphologic proxies with focus on fluvial deposits and landforms and secondarily some information on lake, soils and palynological record that indicate some potential environmental changes near 8-7ky and close to 1000BP.
Background: Much attention has been paid to research on river runoff in the context of global climate change (IPCC, 2007; SWIPA, 2011). Such attention is deserved because river runoff is an important component of hydrological cycle, a main constituent of the climate system. Terrestrial water-cycle processes regulating evaporation, runoff and changes in the hydrological cycle are directly linked with atmospheric processes (Chahine, 1992; Rawlins, 2010; Shiklomanov et al., 2011). Changes in the terrestrial hydrologic budget of the Northern Hemisphere influence the freshwater inflow to the Arctic Ocean (Peterson et al., 2002, 2006; McClelland et al., 2004; Mauritzen, 2012). Annual river discharge is the dominant part (38%) of freshwater input to the Arctic Ocean (Serreze et al., 2006), and the export of river freshwater to the Arctic Ocean is about 11% of the global river discharge (Shiklomanov, 2000).

The Ob River is one of the world’s greatest rivers. Its basin (2.9x10^6 km^2) is the fourth largest over the world and is about the size of Western Europe. Estimates of annual discharge from the Ob Basin range from 400 km^3 to 429 km^3 and it is to 12% or more of the annual freshwater inflow to the Arctic Ocean. Approximately 70% of annual discharge occurs in the ice-free period from May to October, and 80% of the annual runoff originates southward of 61° N (1152 km from the Ob estuary). Ob River discharge has the highest autocorrelation coefficient (r = 0.38) for discharge in the Northern Hemisphere for a one-year lag and there is a reliable quasi-periodicity of many-year variations in runoff (Simonov, Khristoforov, 2005). The Ob catchment basin can therefore provide great insight into global scale perturbations to the climate system.

Method: We developed tree-ring width chronologies (larch and Siberian stone pine) for the 9 test sites (285 trees in total) along the Lower Ob River valley (N 64° 49'- N 66° 06°). Response of tree-ring chronologies to hydro-climatic conditions were analyzed using program SEASCORR (Meko et al., 2011) to identify the seasonal hydrological and climatic signals in an annual tree-ring time series for 1936-2009. Modern interaction between the Ob discharge and air temperature over the Ob floodplain was used for understanding hydro-climatic conditions as a background.

Results: Using tree-ring chronologies we reconstructed the Ob River discharge for period from previous August to current July (that is nearly the same as hydrological year) for the last 300 years. Developed reconstruction of the Ob River discharge has good correlation (r = 0.67, p<0.05) with records from gage of “Salekhard” for 1936-1996. Our approach and results demonstrate the high potential of tree-ring chronologies to reconstruct river discharge in this region and allow to interpret hydro-climatic interactions over the Ob catchment basin.
EXTREME HYDROLOGICAL EVENTS RECORDED AT ANNUAL RESOLUTION IN NE IBERIAN PENINSULA SINCE THE XIV CENTURY

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Lake Montcortès is a small (0.14 km² surface area), 30 m deep, karstic lake located in the eastern Pre-Pyrenees (NE Spain). The permanent anoxic hypolimnetic conditions in this lake have favored the preservation of finely annually laminated sediments in central-distal areas of the lake basin for the last three millennia. A robust age model has been established through varve counting on petrographic thin sections combined with radiocarbon and $^{210}$Pb dating. The good correlation of the varve counting with the $^{14}$C AMS dates underlines the annual nature of the lamination.

Three main types of detrital microfacies have been distinguished in the varves: i) non-continuous detrital layers; ii) continuous detrital layers; iii) matrix-supported layers. In addition, two types of turbidite layers have been identified. Transport mechanisms have been proposed for those deposits including slope reworking processes as well as interflow and underflow events. Annual number of detrital layers interbedded within this varve record was compared against instrumental records of extreme daily rainfalls (available since 1917) providing minimum rainfall thresholds and return periods associated to the identified types of clastic microfacies. Non-continuous detrital layers are deposited during rainfall events higher than 80 mm (> 2 years in average recurrence interval) while graded detrital layers and turbidites were associated with even higher amplitude rainfall events (> 90mm and > 4 years recurrence interval).

The frequency distribution of extreme hydro-meteorological events during the last centuries is not stationary and its pattern coincides with historical floods from the nearby Segre River. Higher heavy rainfall frequency occurred during AD 1347-1400 and AD 1844-1894, while less rainfall events happened at AD 1441-1508, 1547-1592, 1656-1712, 1765-1822 and 1917-2012. Variations in extreme rainfall frequencies prior to the 20th century show a positive correlation with solar activity, suggesting solar induced-changes in atmospheric circulation patterns. The 20th century stands out as the longest interval of low number of extreme rainfall events within the studied period and contradicts foreseen regional trends of increasing frequency of extreme rainfalls under warmer climate scenarios.
Concerning weather, weather-related extremes and catastrophic consequences, 1342 was an extraordinary year: the July 1342 (known as the most famous ‘Magdalena’) flood event in large parts of Central Europe is known as the millennial flood event. This flood, caused by excessive rainfall, attracted great attention: causes and consequences (e.g. soil erosion, short-term impacts on society) were discussed in a number of studies. Nevertheless, this great flood event was also preceded and followed by extraordinary wet conditions. Due to the overwhelming importance of the most famous ‘Magdalena flood’, the events (partly also responsible for the Magdalena flood) received generally somewhat less attention.

In our presentation we would like to draw the attention to the extraordinary character of the entire year of 1342 with providing an overview of the flood events and flood waves occurred during this extraordinary year in Europe. The database is built by applying standard source critical evaluation procedure: after collecting the references available in published evidence and collecting further contemporary source evidence, sources in each case were checked back from the originals and evaluated concerning contemporaneity and originality, and then the reconstruction of individual flood events and flood waves were settled based on this original evidence.

Results, presented on series of maps (including discussion on causes and some major consequences), show that in some parts of Europe not only 1342, but also the year of 1343 was rather humid and wet with a great number of flood events: in these two years floods were reported from northern Greece through North-Italy, the Carpathian Basin (almost in every season) to the south German territories. 1342 and 1343 were rich in floods even in some of those areas where the July 1342 event could not be detected.
RECONSTRUCTION OF HISTORIC FLOOD EVENTS ON THE CHAO PHRAYA RIVER, THAILAND

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Background: Series of reconstructed historical floods are valuable sources of proxy data that can be utilized for the study of flooding fluctuations in the pre-instrumental period. In this study, the severity and frequency of historical flood events in the Lower Chao Phraya River were analysed using historical documentary evidence of Rattanakosin Kingdom (Bangkok, 1782 to present) period.

Method: The occurrence of floods in the past is analysed with bearing in mind that the basic land used change, topographical and hydrological characteristics of the river investigated, as well as, the climatological causes of their flooding during the instrumental period. A numerical model is developed in this study for simulating the complex flood water flow phenomena of the Lower Chao Phraya river basins.

Results and conclusion: Flood frequency oscillations identified in this study coincide in general terms, of which the worst historic flooding in Lower Chao Phraya River was affected by tropical storms and monsoons passing through. Performance of the numerical model was applied to simulate the Lower Chao Phraya floodplain. Some numerical results compared with historic records data were presented to demonstrate applicability of the analysed and numerical model. Good performances of simulated results were observed in both flow fields and flood propagations, indicating that reconstruction of historic flood events by using the numerical model is reasonably exploitable.
PALAEOHYDROLOGY OF THE EAST EUROPEAN PLAIN (EEP)
IN THE LAST 20 KA BASED ON ALLUVIAL CHRONOLOGY

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We collected a data base containing 983 radiocarbon and optical dates on alluvium with cal ages <20 ka from ca 150 published sources. To extract palaeohydrological signal we used two kinds of proxies: sedimentological – buried biogenic horizons, active sedimentation on floodplains and small valley (balka) bottoms, and geomorphological – channel size (small, large channels), chute cutoffs and avulsions, erosion events, etc. Both types of Local Palaeohydrological Events (LPEs) were classified into activity and stability groups (A-events, S-events). According to stratigraphy, designated were E- (event) dates concurrent to a particular LPE and C- (change) dates carrying signals both on concurrent LPE and on preceding or succeeding LPEs (post-dates, pre-dates). Totally 646 interpretable dates indicated 754 LPEs of which 88% were located in the central EEP.

OxCal v.4.2 package was used to sum probability densities (PDs) of different date. Output from OxCal was in the cal BP timescale. Finally it that was transformed into the b2k scale (calibrated years before 2000 CE), which looks most convenient by different reasons. To exclude the influence both of the form of calibration curve and of time trends, we analyzed relative PDs (RPDs) obtained by dividing particular PDs by the PD of the total massive of 983 dates. The resultant RPD-graphs for HA- and LA-events with separate graphs for C-dates, pre-dates and post-dates were used to establish hydroclimatic chronology.

Three palaeohydrological epochs were designate: low fluvial activity in the end of LGM, extremely high activity in the end of MIS 2 during ca 18 – 11.7 ka, much lower activity in the Holocene. The high late-MIS 2 activity is exhibited in large palaeochannels (macromeanders) and balka incision that demonstrate very high runoff amounts that decreased significantly at the onset of the Holocene and have never returned thereafter.

In the Holocene, two hierarchical levels of hydroclimatic variability were designated according to their duration – regional phases (centuries to few millennia) and regional events (decades to few centuries). The Early Holocene was designated as a transitional phase with contradictory palaeohydrological signals when fluvial systems were rebounding from high Late Glacial runoff. In the Middle – Late Holocene three activity and four stability phases were marked out. A-phases: 150-900, 1900-3500 and 4600-5500 years b2k, S-phases: 0-150, 900-1900, 3500-4600 and 5500-8500 years b2k. Tendency is rather clear of activity decreasing in the first half and increasing in the second half of the Holocene. Events were divided into three types: activity A-events (7), stability S-events (8) and complex C-events (4) that are distinct in both high and low activity signs. We compared the resultant chronology with two types of independent archives: palaeosoils and lake levels over the EEP. Correlation with palaeosol formation – alluviation epochs was found very close. Correlation with the Caspian Sea level changes that integrates changes of water balance in the central EEP is rather close in the second part of the Holocene and is less clear for earlier times, which can to some extent be explained by poorer and less reliable data both in Caspian and in fluvial chronology.
LATE HOLOCENE PALAEOFLOOD RECORDS FROM MONSOON-FED RIVERS, INDIA: A SYNTHESIS

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The monsoon-dominated Indian subcontinent is drained by some of the most flood-prone rivers in the world. For flood hazard assessment long flood series are essential. However, like most other large rivers, there is paucity of long-term hydrological data. Under such circumstances, pre-instrumental (recent, historic or pre-historic) records of large and extreme floods on the monsoon-fed rivers could be reconstructed by using palaeoflood hydrological techniques. In the last two decades palaeohydrological studies have been carried out on eight major rivers in southern and western India. The main aim of these studies was to reconstruct the magnitude and frequency of recent, past, or ancient floods using geological evidence. The major rivers are Narmada, Tapi, Godavari, Krishna, Pennar, Kaveri, Mahi and Luni. In addition, a 1000-yr record of landslide dam outburst floods from upper Ganga is also considered. This paper synthesizes the results of palaeoflood studies from these nine rivers.

Four major conclusions emerge from the synthesis of palaeoflood records in India: (a) the palaeoflood records generally span a time period of 1-2 millennia, (b) some rivers have yielded evidence of discrete flood events during the mid to late Holocene, (c) the period between ~14 and 19 century CE was marked by a sharp decline in the frequency of large and extreme floods on all rivers, suggesting a palaeoclimatologic cause. This distinct period of low monsoon floods approximately coincides with the Little Ice Age, a global climatic phenomenon, and (d) the post-1950 floods were the largest, at least during the last several hundred years, indicating increase in both the magnitude and frequency of large floods in recent decades.

Comparison of the palaeoflood data with other climate proxy and historical records indicates that the century-scale variations in the flood frequency are linked to long-term variations in the monsoon rainfall over the Indian subcontinent.
HOLOCENE PALAEOFLOOD EVENTS RECORDED BY SLACKWATER DEPOSITS ON THE BEILUOHE RIVER, CHINA

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Palaeohydrological investigations were carried out in the Beiluohe River valley in the middle Yellow River basin. Palaeoflood slackwater deposits (SWDs), are the natural record of overbank flooding are often identified in the Holocene aeolian loess–soil profiles along the river valley. Three bedstes of palaeoflood SWD were found within the mid-Holocene Climatic Optimum paleosol (S₀) on the right riverbank. Both the sedimentary and the analytical results including magnetic susceptibility, grain size distribution and concentrations of chemical elements, indicate that these palaeoflood SWDs were deposited from a suspended sediment load of the overbank flooding. Three episodes of extraordinary overbank flooding events recorded by these palaeoflood SWDs were dated to 7600–7400, 5800–5000, and 4200–4000 a BP, respectively, by using the optically stimulated luminescence (OSL) dates and pedostratigraphic correlations. Peak discharges of these flood episodes were estimated to have been between 13,600 to 14,100 m³ s⁻¹ by using the slope—area method. These flood events are considered a regional expression of known climatic events and demonstrate the mid-Holocene climate are far from stable. These results provide an important reference that magnitudes of floods are highly sensitive to climate change in semi-arid and sub-humid regions with a monsoonal climate.
Flooding constitutes a serious hazard for human civilisations. To be able to predict future flooding it is necessary to understand the former dynamics of fluvial systems, i.e. causes and triggers for changes of their dynamics. Generally, fluvial sediments are good archives for studying flood events at centennial and millennial time scales, although due to their discontinuous and complex character these studies have to be comprehensive and to be compared with other palaeoenvironmental archives.

In the Caucasus area, different climatic and ecologic conditions are found very close to each other. Here, floodplains are generally densely populated and regularly hit by strong inundations. This demonstrates the urgent need to understand the fluvial dynamics of this region. Accordingly, during the last years we studied Holocene fluvial sediments along several rivers in eastern Georgia by means of geomorphologic, sedimentologic and chronologic methods. The results of our investigations show that during most of the Holocene the flood dynamics of the rivers followed partly contrasting patterns that were determined by regional climatic and environmental conditions. In difference, during the last millenia the flood dynamics was also influenced by anthropogenic activity. Taken as a whole the critical factor that controlled the flood dynamics in the Caucasus area was landscape stability, either influenced by natural or human factors.
MAGNITUDE AND TIMING OF HOLOCENE OUTBURST FLOODS OF THE NORTHERN PATAGONIAN ICEFIELD

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The Baker River (Southern Chile) drains a catchment of 27,000 km² and has a mean annual discharge of 1100 m³/s. Since last deglaciation, the morpho-sedimentology of the Baker valley has been controlled by Outburst Floods (OFs) of different scales. Repeated OFs (16 events since 2008) drained circa 200 million m³ from glacial-lake Lago Cachet 2 (Colonia River), forced evacuations, caused considerable damages and animal mortality, and put the fjord town at the Baker River mouth at risk. There are a number of uncertainties on the number, timing and magnitude of past glacier outburst floods, and their relation with climate variability. The aim of this study is to reconstruct the frequency, timing and magnitude of Holocene glacial-lake outburst floods in the mid-Baker river whose main sources are from upper Colonia river valley. We apply geomorphic mapping, stratigraphy (including radiocarbon and OSL dating) and palaeoflood hydrology to reconstruct these events. Geomorphic mapping reveals evidence of two Holocene alluvial terraces. The oldest (highest) Holocene alluvial level contains basal gravels capped by a well-developed buried Podzolic Luvisol that was radiocarbon dated to 6160±40 BP. In this alluvial sequence, at least two major floods occurred between then and 5300 BP and at least eight major floods between 5300-2500 BP. Dating of the uppermost sediments revealed that at least three Late Holocene (post 610±30 BP) outburst flood event(s) inundated upper terrace surfaces along the reach. The lowest alluvial floodplain is inserted on the higher plain, and it is composed by fine to medium sand with brown-grey colour deposited by snowmelt floods from the upper Baker catchment. The stratigraphy shows at least fourteen flood units, twelve post-dating a radiocarbon age of 570±30 BP. We report on the implications of this geomorphic data for landscape development and applied hydrology in relation to the proposed HydroAysén hydroelectric scheme.
PALEOFLOOD HYDROLOGY OF STILLWATER CANYON, GREEN RIVER AND CATARACT CANYON COLORADO RIVER: PRELIMINARY RESULTS

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Stillwater Canyon of the Lower Green River in east-central Utah, U.S.A., contains numerous paleoflood slack-water deposits that we identified in a 2010 field reconnaissance. In a more detailed 2012 survey of six of the sites we documented between 7-11 paleofloods, reaching elevations of up to 12 m above water level (a.w.l). One site (the Ledge Site) preserves only two paleoflood deposits, and these occur to an elevation of about 13.5 m a.w.l. The most complete record (30 flood deposits) is exposed at the Rockfall Site, but these only reach to 8 m a.w.l. Except for a tributary mouth site at Dead Horse Canyon, these study sites are all channel-margin vertical accretion deposits. OSL and radiocarbon ages indicate that the preserved paleoflood deposits are younger than 680±250 years.

Using measurements from 1:24,000-scale topographic maps and channel-bed surveys by sonar, we determined approximate channel geometries for hydraulic calculations. The latter indicated peak discharge estimates for the paleofloods up to >8500 m$^3$s$^{-1}$. These results are consistent with other paleoflood data for the Colorado River Basin, including the Upper Colorado River near Moab, Utah, where the largest paleoflood in a 2000-year record, at 15 m a.w.l., reached a discharge of 9880 m$^3$s$^{-1}$, and the Lower Colorado River near Lees Ferry, Arizona, where the peak paleoflood discharge in a 4500-year record is 14,000 m$^3$s$^{-1}$ (O’Connor et al., 1994).

The Lees Ferry site records flows from both the Green River and the Upper Colorado. In 2012 we also surveyed two paleoflood slack-water sites (Tilted Park and Big Cottonwood) in Cataract Canyon, about 10 km downstream of the junction of the Green and Upper Colorado Rivers, but about 200 km upstream of Lees Ferry. Though it was not possible to estimate discharges because of the complex hydraulics of the Cataract Canyon rapids, the surveyed slack-water deposits (dated to < 1000 years) occur up to 13.5 m a.w.l., and the channel cross sections are much larger than for either Stillwater Canyon or the Upper Colorado near Moab, Utah. These study results have important implications for the risk to water-resources infrastructure of the Colorado River system, which is the most important source of water for the arid southwestern U.S.A.
RECENT VERSUS HISTORICAL FLUVIAL EXTREME EVENTS IN THE MOUNTAINOUS DRAINAGE BASINS OF THE SUDETES

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The Sudetes are the highest range in the Central European belt of mountains and uplands (1,603 m asl) and receive annual rainfall from 700 to >1500 mm. Daily sums during summer extreme precipitation events may exceed 150 mm and these cause floods of different types and extent. Mountain rivers often converge in intramontane basins, which are therefore particularly susceptible to flood damage.

In the last two decades major floods occurred in 1997, 1998, 2006, and 2010. The 1997 event was of regional extent, affecting also the lowland valleys, and was nicknamed as the ‘flood of the millennium’. The subsequent floods were restricted to specific drainage basins in the Sudetes, but nevertheless resulted in considerable damage along fluvial tracts. However, flood-induced valley floor and floodplain reorganization were limited or landform changes were erased during engineering works, even if locally significant.

The most recent fluvial extreme events, although unparalleled in the 2nd half of the 20C, can be compared with earlier floods from the 1850–1945 period. Major floods occurred in 1854, 1897, 1903, 1926, and 1938, indicating that extreme fluvial events are an important component of the natural system of the Sudetes, although very difficult to predict.

Research on past extreme fluvial events is based on multiple sources. Archival documents cover the time span back to the early 14C, although their usefulness in reconstructing historical floods is variable. Nevertheless, they show an increasing frequency of floods in the late 15C and the 2nd half of the 16C, as well as around 1800. Fluvial landforms indicative of past floods include mainly abandoned channels. These records are complemented by proxy dendrochronological data whose accuracy is down to one year or season. Trees growing on the riverbanks or on the floodplain are injured due to log or ice impact and may become uprooted. Additionally, reaction wood appears in tilted trees on undercut banks. The results of dendrochronological studies carried out in several river basins in the Sudetes are consistent with the historical record (e.g. 1897, 1903, 1926, 1997 floods), while in small forested headwater basins, where direct observations were limited, they constitute the main source of information.

While it is often claimed that an increasing human impact exacerbates the hazard, the evidence from the Sudetes is equivocal. Certainly the fluvial environment is altered in general but the technical state of man-made constructions is an important factor. Major channel and floodplain alterations have been recently observed in the vicinity of abandoned flood reduction measures. However, in an advanced state of dilapidation a return to more natural fluvial regime is observed and a decrease in frequency of extreme events may be predicted.

In future research we aim to use Unmanned Aerial Vehicles which fill the gap between terrestrial measurements and traditional aerial photogrammetry or satellite data. Due to high spatial resolution of the UAV-based observational material (up to 3 cm/px), the resulting orthophotomaps will help to analyse small fluvial bedforms and fine details of floodplain morphology, providing further data on past and recent extreme fluvial events.
The aim of this work is the identification of geomorphological effects of catastrophic floods caused by rainfalls and ice jams in the Vistula river valley and to use the observations of present-day fluvial processes for palaeogeographical interpretations.

In the Vistula drainage basin rainfalls floods and snowmelt freshets (including ice jams) frequently occur. The floods caused by continuous (3-5 days) and intensive rainfalls cover large areas of the upper Vistula catchment and are characterized by the highest discharges. In mountains rapid water flow creates the flood wave. During the flood wave culmination, in the lower section of the Carpathian tributaries, the highest water level could exceed 10 m. Superimposing of the flood waves of the Vistula river and its tributaries, in particular Dunajec river, results in damming and rise of water between the embankments and their breaking. Such events occurred during the catastrophic floods in 1934, 1960, 1970, 1997, 2001 and 2010. During the catastrophic flood in July 1997 the flooded area in the Vistula valley covered 120 km$^2$. The breaks in the embankments formed erosional troughs (scours) cutting the floodplain up to the depth of 10 m and crevasse splays occupied an area of dozen hectares. The sands and gravels deposited upon the overbank sediments (madas) reached the thickness of 150 cm at the front of splays prograding to the oxbow-lakes.

Different course and conditions are characteristic for ice jam freshets. Formerly, in the natural conditions ice jams formed most often in the meandering and forested valley sections, for example in the Vistula river valley between Kraków town and the Dunajec mouth, as well as in the lower sections of San and Wisłoka rivers. Nowadays, in the valleys of the upper Vistula catchment ice jams are very rare and not dangerous, whereas very dangerous are floods caused by ice jams in partly channelized, braided channel of Vistula river between the Narew mouth (below the town of Warszawa) and Włocławek artificial lake. During the snowmelt and rapid ice float flow from the southern Poland, in this valley section the ice float heaps (up to several meters high) form and significant rises of water level take place. The high energy of flood water combined with the ice erosion destroys bridges, breaks the embankments and leads to the transformation of river channel and floodplain. In many places it results in the channel deepening (up to 3-5 m) or avulsion and lateral erosion. During the winter ice jam floods most water discharges are adopted by lateral channel arms. In the case of blockage of the water flow in main channel and lateral channel arms, the flood wave is switched into the floodplain. The morphological effects of such events are breaks in the embankments and other erosional forms developed in the floodplain. A great amount of bedload sediments is transported by ice jam floods, too. The greatest ice jam flood in the 20. century took place in the lower Vistula river valley in winter 1982 near the towns of Włocławek and Płock.

The observations of fluvial processes during floods indicate, that single bore-hole logs and small outcrops of fluvial sediments are not sufficient material for reliable palaeogeographical conclusions concerning fluctuations of palaeochannel levels, their origin and age. The scours filled with overbank deposits could be erroneously identified in alluvial sequences as a palaeochannels. In turn, the coarse grained sediments of crevasse splays interbedding overbank facies could be incorrectly interpreted as vertical fluctuations of a channel.
FLOODING EVENTS AS MAN-MADE DISASTERS. SPECIAL FLOODING EVENTS IN COASTAL FLANDERS AND THE ESTUARIES OF ZEALAND, 1400-1600

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Flooding is generally considered to be a natural hazard caused by peak water discharge in river areas, storm surges in coastal regions or the combination of both. Usually within days high waters drop, allowing us to assess damage and accordingly repairs to be carried out. In particular for coastal Flanders (Belgium) and Zealand (bordering Dutch province) flooding caused by storm surges have been studied in much detail looking at causes, impact and perception of the phenomena. From this it has become clear that most flooded areas could be largely recovered, except in cases when a second or third flooding event happened very soon afterward undoing much of the repairs of the first flooding event or when repairs could not start at once. However, is this still a valid (flooding) concept for coastal Flanders and Zealand during medieval and early modern times? What about flooding events which did not have a natural cause at all? This paper presents two cases of flooding that were largely caused by man having different consequences on the landscape at different points in time.

These cases were researched by analysing historical documents, historical maps, soil maps, geomorphological maps and the digital elevation model, resulting in a reconstruction of the impact of man-made flooding events in the study area.

The first case presented are the strategic inundations carried out during the Flemish civil war at the end of the 15th century where different parts of the medieval landscape were flooded that could only partly be recovered afterwards. The second case presented are the large scale flooding events that occurred during the Eighty Years' War (1568-1648) in the same areas having such a huge impact on the landscape that over 70% of the late medieval landscape vanished. The differences and similarities between both flooding events will be discussed in terms of causes and consequences, but also looking at the nature of the landscapes being flooded and the duration of flooding before repairs could actually be carried out. Finally a brief comparison between flooding events caused by storm surges and man-made flooding events will be made asking which lessons can be learnt from man-made flooding events in the end.
The study demonstrates how the retrospective geomorphological mapping and the historical approach, applied to meandering river systems in a humid tropical environment, can produce basic knowledge for environmental management and risk assessment at a time of great concern about Global Climate Changes. It is based on Urban and Historical Geomorphology approaches conceived from studies of several authors mainly in Brazil and UK. Preserved and urbanized fluvial systems of the state of São Paulo-Brazil were mapped and analyzed, considering historical timescales and using both hydrological records and historic documents. This approach enabled a comparative analysis between morphological and hydrological indicators of fluvial systems for time intervals of approximately 100 or 50 years. Among others, the storage capacity and the peak flow indicators were utilized to compare fluvial meandering systems located in the Ribeira River Basin and the Upper Tietê River Basin, the latter the main urbanization area of São Paulo metropolitan region. Regarding the storage capacity, it was possible estimate it for different terrace levels of the preserved meandering systems in the Ribeira Valley and from this reference and other data, estimate the original storage capacity and its losses over the urbanization period of the Upper Tietê River Basin. It was estimated that around 70% of the Upper Tietê meandering fluvial systems have currently a high level of morphological disturbance and in this areas the hydrological function of storage capacity of peak discharges was severely lost by impermeabilization or by embankment. In a smaller hierarchical level of this basin, it was revealed that in Tamanduatei basin 83.7% of the original area of its holocenic meandering fluvial systems were eliminated by urban interventions in the last 100 years. In terms of storage capacity losses this rate is comparable to 215 detention reservoirs, considering the average volume of 206,000 m³ of the 17 reservoirs located in this basin. The studies also demonstrated the applicability of this approach in risk analyses, vulnerability and adaptation to the global climate changes and also demonstrated how this approach can be useful as a complementary or alternative perspective to the usual statistical approaches of hydrological models.
There is growing recognition that sedimentary deposits related to high-energy, large-scale, freshwater floods are widespread across the continents and, in the main, can be related to Quaternary outbreak flows from ice-dammed lakes. Such deposits may also occur in the Neogene and earlier. Recognition of these ‘megaflood’ deposits is hindered by the lack of well-conditioned stratigraphic models of depositional successions. However, descriptions of successions from many locations often exhibit commonalities when compared carefully. This presentation examines and condenses the published stratigraphic and sedimentological evidence so as to identify the key signatures of megaflood successions. The deposits often are the only record of a flood and so the secondary purpose is to interpret the sedimentary sequences in order to recreate the behaviour of floods through single and multiple events. Finally, some pointers are provided as to those areas of sedimentological research that might be profitably explored in more depth to improve understanding of megaflood dynamics.
Megaflooding (Q < 1 Sv) is associated to deglaciation. Massive amount of glacial water stored on ice-dammed lake or sub- or supraglacially is released abruptly. Globally, numerous megafloods occurred in last deglaciation including outburst floods from Western N America (Missoula, Bonneville) and Middle N America (Agassiz-Ojibway), Central Asian Mountains (Altai, Tuva) and Central Asian Lowlands (Mansi).

Missoula megaflood(s) was probably the highest discharge of these floods events (Q is ca. 10-20 Sv). Classic and heavily criticised hypothesis of cataclysmic flooding “Spokane Flood” based on description of Potholes Cataract on Scabland by Bretz and Pardee’s work on giant ripple marks on Glacial Lake Missoula started megaflood studies. To date, many fluvial geomorphological studies have been undertaken in order to figure out number of the floods, reconstruct flood magnitudes and estimate megaflood competence for Missoula megaflooding. Our knowledge has remarkably been improved from days of Bretz’s and Pardee’s, but we still have unclear knowledge on effect of glacial dynamics to routing and magnitudes of Missoula floods on NW United States.

Recent studies have emphasised the computational fluid dynamics of downstream megaflood routing and characteristics in the Channeled Scabland and adjacent areas. A one-dimensional numerical model, combined with field evidence and radiocarbon age dating, have been used to study the magnitude, frequency and chronology of late Pleistocene Missoula floods in Columbia River valley between the Pasco Basin, Washington, and Portland, Oregon. Multiple cataclysmic floods have been founded submerged the Columbia River valley and that the largest flood had a peak discharge of ~10 x 10⁶ m³ s⁻¹. The one-dimensional numerical modelling approach is appropriate for a confined valley environment, such as Columbia River valley, where the majority of flood flow path is in one direction along the valley trend. However, flow branching, bifurcation, and reintegration of flood flow paths, as occurred during Missoula flooding, are not adequately resolved by a one-dimensional approach.

We employ two-dimensional hydraulic modelling to understand the paleoflow conditions for different scenarios of Missoula flooding. Our chosen scenarios employ Glacial Lake Missoula outflow hydrographs that were proposed by previous studies. We reconstruct Missoula megaflood routing with multiple computational fluid dynamics including different outflow hydrographs, ice sheet locations and topographical setups. This approach allows us to define megaflood routings and their geomorphic impact to the Channeled Scabland.
UNKNOWN PLEISTOCENE MEGAFLOODS FROM THE WESTERN TUVA MOUNTAINS INTO MONGOLIAN DRAINAGE BASIN

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Our researches were carried out within a broad high mountain plateau located in transitional zone between Russian Altai and western Tuva. This mountainous area is the watershed of two basins: the Arctic Ocean (the southern catchment area of the Ob River) and the inland drainage basin of Central Asia. During Pleistocene glaciations, glaciers extended repeatedly from the high ranges into the major valleys and impounded extensive lakes in the intermountain depressions. Subsequent ice-dam failures led to outburst floods with the huge water discharge. By now, the giant Pleistocene glacier-dammed paleolakes in the Chuya-Kurai system of intermountain depressions (Russian Altai) with their cataclysmic runoff into the Arctic Ocean along the Ob River are the most studied in central Asia (Rudoy and Baker, 1993; Butvilovsky, 1993; Carling et al., 2002). The reconstructed flood parameters allow considering them as the largest known terrestrial cataclysmic flow of fresh water (Baker et al., 1993; Herget 2005). The evolution of the Pleistocene ice-dammed lakes in the Darkhat basin (northern Mongolia) followed a similar scenario with the water runoff into the Arctic Ocean along the Enisey River (Grosswald, 1987).

In this paper for the first time we present evidences of the unknown cataclysmic outbursts of the ice-dammed lakes in the western Tuva. Our geomorphological investigations argue for southward direction of these floods into the Great Lakes Basin (inland Mongolian drainage basin). We describe cataclysmic flood landforms in the Djulukul depression. Many of these geomorphic features were formerly attributed to glaciations. However, they occurred in association with outburst floods from ice-dammed lakes. Indicative landforms of such jökulhlaups are the same as in the neighboring world famous Chuya and Kurai intermountain depressions: 1) flood-scoured channelways; 2) giant bars; and 3) gravel wave terrains. A number of shorelines mark former lake levels. Gravel dunes on the former lake floor and along the path of the flood wave were developed in coarse gravel, indicating the large scale of the water discharge. The slopes of flood-scoured channelways are totally devoid of unconsolidated deposits especially in valleys bends. There are congestions of boulders and rubbles in places of slowing streams. Obtained radiocarbon dates of fossil soils covered young river terraces and alluvial fans as well as the ages of archeological sites presented at the bottom of the Djulukul depression argue for the Pleistocene age of all studied events here.

New data suggests that besides the previously described (Rudoy, 2005) outburst northward at different times there were another flows from the Djulukul depression. One of them was the cataclysmic outburst southward through the Mogun Buren river valley into the Achit-Nur lake basin. Another one was probably a permanent runoff through the Kargy river valley into the Ureg-Nur lake (inland Mongolian drainage basin). Now there is no connection between the Djulukul lake and Kargy river and modern runoff from the Djulukul lake goes northward into the Teletskoe lake (Arctic Ocean basin). The new data on the water supply from reservoirs within mountain framing of the Great Lakes Basin allows explaining significantly higher former lakes levels.
A 420,000 YEAR RECORD OF SPELEOTHEM FORMATION IN A CENTRAL NAMIB CAVE: EVIDENCE FOR COINCIDING INTERGLACIALS AND WET PERIODS

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Most reconstructions of hydrologic conditions of the Namib Desert in the southern hemisphere during the mid-Pleistocene interglacials have been based on terrestrial climate proxies of the organic and inorganic content of marine cores and climate modeling. Usually, the results are ambiguous, mainly due to dating problems and a poor understanding of the fluvial and eolian transport processes of terrestrial material to the oceans. Based on these climate proxies, arid and humid conditions in the desert are assumed to be correlated with interglacial and glacial phases in the moderate climate zone, respectively.

A contrary climate conception follows from a numeric $^{230}$Th/U (TIMS) chronology of a large stalagmite with a thick flowstone layer in a cave in the hyper-arid central Namib Desert (Geyh & Heine 2014). The $^{230}$Th/U dates provide evidence for wet periods during the dominant arid climate of the Middle Pleistocene since 420,000 BP. Speleothem formation requires sufficient drip water supply. Due to this fact, moisture changes were deduced for the Namib Desert or at least the hyper-arid region of the cave site. The evaluated interglacial wet periods of up to 25,000 years duration coincided with interglacials. They lasted with decreasing intensity from about 420,000–385,000, 230,000–207,000 and 120,000–117,000 years ago matching the 100,000-year Milankovitch cycle. The wet periods interrupted the predominantly dry climate of the Namib Desert. Speleothem growth was not recorded for the Holocene. These findings might be valid for a larger region rather than only the vicinity of the cave. Finally, these wet phases coincided with climate variations in deserts of the northern hemisphere, e.g. the Murzuq Basin, Sahara, the Negev, Israel, the Nafud Desert, Saudi Arabia, and the arid northern Oman, Arabian Peninsula.

Reference:
The Atacama Desert of Northern Chile is one of the oldest and driest deserts on Earth. As a result of its hyper-aridity it preserves some of the oldest geomorphology in the world in remarkable detail. Here we will examine the rheology and magnitude of extreme flow events recorded over Pliocene-Quaternary time scales. In this transport limited environment the flows range from hyperconcentrated through to cohesive debris flow and extremely bimodal mudflows capable of transporting extreme outsize clasts over large distances (>20 km) on low slopes (<4 degrees). Within channelized areas the hyperconcentrated flows represent extremely high discharges of water and sediment capable of generating anti-dune bedforms in conglomerates, reminiscent of the characteristics of jökulhlaup events generated in proglacial environments. In the high (2.7 km) relief catchments of the Precordillera, which feed water and sediment into the Central Depression, deposits of megaflood events are preserved. The best example of these is located on the Arcas fan. Here the flows were capable of transporting large (81,000 kg) boulders more than 30 km from their source area. Of this journey the flow would have travelled some 23 km as a confined valley flow on a slope of 5% and then more than 10 km as an unconfined flow across a fan surface with an average slope of 3.2%. The style of deposition suggests a mixture of debris and fluvial flow behaviour. Using Clarke (1996) the suggested flow depths on the fan range from 1 to 5 m at some 10 km from the apex. If we consider the possible range of fluid densities (water with sediment to debris flow) responsible for transport, potential discharges of 17,000 to 215,000 cubic metres per second are calculated, suggesting the generation of 23 to 295 cubic metres of water per square km of catchment. These values would appear to be inconsistent with a runoff generated flood event. Within the Arcas catchment there are a number of large landslides, the largest of which covers an area of 22 km². In this hyperarid region the most likely trigger for such landslide events is earthquake (Mather et al 2014). It is suggested that the location and size of these landslides within the catchment provides potential to generate a temporary dam (some 20 m high) of a significant part (some 100 km²) of the catchment area of the fan system. Due to the ephemeral nature of the hydrological system in this hyperarid region it is unlikely that water would have been stored for any length of time, and there may have been a significant time gap between creating the landslide dam (during an earthquake event) and the temporary impedance of the water generated from a rainstorm event. The age of the flows is uncertain but Cosmogenic radionuclide (CRN) dating is currently being explored.


In a recent paper (Rossato et al., submitted), the holocenic portion of the radiocarbon database of the Venetian-Friulian plain (NE Italy) has been investigated with meta-analyses techniques in order to recognize periods of extreme flooding events. Results confirm a positive correlation with other flood records, both Italian and European, and with independent climate proxies, like the North-Atlantic ice rafted debris (IRD). The area involved in the paper faces the northern Adriatic Sea and is the northernmost Mediterranean alluvial environment, being the most valuable link with the Alps and the continental regions of central-eastern Europe. Given these elements, we pushed the method to the late Pleistocene. In particular, we considered the Brenta megafan, which is the widest alluvial system (2700 km²) in the area and owns the largest ¹⁴C dates sub-dataset (~190 dates).

In addition to the routine methodology applied in meta-analysis research (e.g., Macklin et al., 2010), we investigated the cumulative probability distribution function (CPDF) of the ¹⁴C datings performed on floodplain peat layers, a peculiar feature in the late Pleistocene sedimentary record of the area (Miola et al., 2006). These deposits are interpreted as sedimentation stasis, even few decades-long, being the perfect indicators for detection of short-time hydrological variations or sudden events. Major peaks in the CPDF plot occur in good agreement with Northern hemisphere’s climatic events (e.g., Dansgaard-Oeschger events 2 and 3; Heinrich events 2 and 3) and major perturbations of eastern Alpine glaciers. Considering the age-depth model of the radiocarbon dated ¹⁴C levels, one out of two main changes in the sedimentation rate occurred in correspondence with the highest peak in the CPDF curve.

The analysis of ¹⁴C datings provided interesting insights into the late Pleistocene evolution of the Brenta megafan, both through statistical and stratigraphic approaches. Compared to the Holocene record, the Pleistocene one involves larger error bars in both dating and calibration, introducing bigger uncertainties in the meta-analyses. Hence, we observe that these methodologies applied to Pleistocene ¹⁴C datings datasets may highlight major knickpoints in the Hydrological EVolution (HEV) of alluvial plains, rather than single or closely-clustered Hydrological EXtreme (HEX) events.


EXTRATERRESTRIAL EXTREME FLOOD FLOWS – WHY SHOULD WE CARE?

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Megaflood flows involve very rare, immense outpourings of fluids on planetary surfaces. Because of their rarity Earth’s most extreme flood flows cannot be accessed through modern observations and instrumental measurement. Nevertheless, these phenomena are important both for basic scientific understanding of the role of extreme flooding in shaping the land surface and for the applied scientific assessment of potential hazards posed by the enhanced flood extremes that will be associated with future environmental change. Coping with the new realities of the latter is severely limited by the inadequate scientific knowledge base relied upon by the engineering approaches that still dominate much of the hydrological “science” used to assess extreme flood hazards.

Modern flood science is almost universally based on measuring the properties of relatively common, small-scale flooding and then extrapolating upscale to the inferred properties of very rare, extreme flooding. The scaling relationships for such extrapolations are assumed because the properties of the extreme flood phenomena are taken to be unknown. Reasoning in science requires accessing and making discoveries about the phenomenon of interest---not the making of arbitrary assumptions about things that are presumed to be beyond any ability to access for study. Thus, a truly scientific approach to extreme flooding requires a reverse kind of scaling: extrapolating downward to rare, but potentially hazardous (and/or geologically important) floods by using whatever evidence can be obtained for the most extreme kinds of flooding phenomena to found in nature.

Fortunately there is an immense amount of evidence for the most extreme kinds of flooding. Some of this can be found on Earth, involving records of past flood erosion and deposition. However, Earth’s surface is geologically relatively young, so the available sampling time for extremely rare phenomena is limited. In contrast, the surfaces of other planetary bodies in the solar system are much more ancient, thereby allowing those surfaces to preserve more evidence of the rarest and most extreme past phenomena. The greatest known megafloods of water occurred on the planet Mars, and immense outpourings of water-like flows have also occurred on other planetary surfaces. In some cases, the flows are associated with planetary histories of globally cycling a volatile compound (water for Mars; methane for Saturn’s moon Titan). In other cases (Mercury, Venus, Earth’s moon) the flows were highly fluid lavas. Nevertheless, discoveries of all these phenomena are producing a general science of extreme flood flows on planetary surfaces, as detailed in the following:


PUTATIVE PALEOSHORELINES IN ISIDIS PLANITIA, MARS: IMPLICATIONS FOR STANDING BODIES OF WATER

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Background: Hypotheses on the presence of standing bodies of water in the geological past of Mars have been proposed and tested over the last two decades (e.g., Parker et al., 1989, 1993; Head et al., 1999; Clifford and Parker, 2001; Kreslavsky and Head, 2002; Carr and Head, 2003; Webb, 2004; Ghatan and Zimbelman, 2006; Di Achille and Hynek, 2010; Erkeling et al., 2012; Mouginot et al., 2012). The existence of oceans, seas or lakes is supported by a large variety of morphologic landforms, including ridges, platforms, cliffs and delta deposits. Some of these morphologies appear in the northern lowlands of Mars along two global putative paleoshorelines that represent the two most continuous contacts on Mars and possibly reflect different water levels, i.e., the Arabia contact and the Deuteronilus contact (e.g., Parker et al., 1989, 1993). In terms of morphologic appearance, stratigraphic sequence and geophysical properties, similar landforms are also present in the Isidis impact basin.

Results: The morphologies we identified at three different elevation levels are possibly associated with intense fluvial activity, standing bodies of water, hydrous alteration, wave-cut action, distinct still stands as well as freezing and sublimation of a "cold" ocean. We can distinguish between (1) local occurrences of fluvial and lacustrine landforms of the Libya / Isidis contact between -2500 and -2800 m, (2) a series of putative coastal cliffs (erosional landforms) of the Arabia contact at -3600 and -3700 m, and (3) the Deuteronilus contact that is characterized by an onlap morphology (depositional landform) at -3800 m at the boundary between the Isidis interior plains and the Isidis exterior plains.

Conclusion: The landforms are indicative of aqueous activity and standing bodies of water, that are attributed to a complex hydrologic cycle that may have once existed on Mars in the Noachian (>3.7 Ga) and perhaps also in the Hesperian (>3.1 Ga). The geologic setting and associated mineral assemblages observed in our study area are interpreted to be results of environmental changes over time toward decreasing water availability and can help to reconstruct the climatic evolution of Mars, in particular to characterize the proposed climate change at the Noachian/Hesperian boundary (Erkeling et al., 2012). The morphologies of the observed landforms along the putative paleoshorelines collectively indicate a great potential of the study area for unraveling past environmental conditions that may have been favorable for maintaining life. We propose this site as a new candidate landing site for the European ExoMars mission in 2018/2020 (Erkeling et al., 2014).


Hydrological extreme events in historic and prehistoric times – HEX 2014, Bonn (Germany), June 9-15, 2014
PROBLEMS OF THE SIMULATION OF NATURALLY DAMMED LAKES OUTBURST FLOODS

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Typically, simulation models of flood generated by the outburst of natural landslide or glacier dammed lake consist of three components: the change of water volume and pressure in the lake, the water discharge through a fresh incised channel, and the channel cross-section increase rate. One of the problems arising for the simulation is the choice of a suitable equation for discharge ($Q$) calculation. Frequently, the well known equation by Chezy is applied:

$$Q = F \cdot C \cdot \sqrt{R \cdot I},$$

where $F$ represents the cross-section area of the channel, $R$ its hydraulic radius, which is often substituted by mean depth ($H_m$) and $I$ is slope of the channel.

$C$ depends on the roughness of the riverbed and the mean depth or hydraulic radius of the channel. The dependence was proposed in various forms by several authors (Bazin, Manning, Ganguillet-Kutter, Pavlovskiy, etc.). However problem is not solved completely up to now.

The equation by Chezy was found by its author for natural and artificial channels with gentle slopes and slow flow velocity, hence gradually varied flow conditions. Nevertheless these limitations are not fulfilled in mountain rivers and outburst floods. Recent studies have documented that the Chezy equation cannot be applied for those circumstances in its initial form. It was fond that the Chezy friction factor depends on the stream gradient also even in mountain rivers under regular conditions. It decreases significantly if channel bed sediments are mobilised under life bed conditions and if the depth of flow increases. The conditions become more intricate for mudflows with dominating sediment content.

Taking into consideration that the factor $C$ depends on $R$ and $I$, of which the root is extracted, it was found that the run-off $Q$ depends on the channel shape characteristics in the following form:

$$Q = \frac{F}{m} \cdot I^n \cdot R^p .$$

Here $m$ is a factor of the channel bed roughness, $n$ and $p$ are parameters. Their values for several mountain rivers on average could be quantified in the range of approximately 0.25 to 0.85. However, scatter of the values is rather significant for various rivers. Thus the problem can not be considered as solved so far. But in any case it is clear that the Chezy equation should be used only warily in its standard form for outburst floods calculations.
ASSESSING THE POTENTIAL OF XRF CORE SCAN ANALYSIS OF FLOODPLAIN SEDIMENTS FOR RECONSTRUCTING FLOOD HISTORIES

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Analysis of vertically-accreted floodplain sediment sequences provides a means of obtaining records of major flood events through the late Holocene. This study assesses a technique utilising XRF core scanning of floodplain sediments for reconstructing long flood records in alluvial rivers. Palaeochannel and floodplain sediment sequences were recovered from sites on the Severn and Wye in mid-Wales and on the Boyne in Ireland. Itrax XRF core scanning was used to obtain profiles of the abundance of a range of chemical elements. Grain size was determined using laser granulometry and analysis of back-scattered electron images from sediment thin sections. The suitability of the Zr/Rb and Si/Ti log-ratios for use as grain size proxies was tested by comparison with grain size data. The results indicate that the two grain-size proxies have variable applicability between the different sites. A high-resolution comparison of sediment grain size with the two geochemical grain size proxies illustrates the degree to which they can be used to identify millimetre-scale changes in grain size and the extent to which histories of major floods and relative flood magnitudes can be accurately reconstructed using this method.
The highly dynamic related with high-gradient stream makes that sediment as slack-water deposits are not spatio-temporal stable. As consequence, dating past event based on this paleohydrology evidence may have scientific drawbacks in mountain catchments. In this study, we present a flash-flood reconstruction based on alternative botanical evidence in a mountain forest catchment of the Spanish Central System. Moreover, based on documentary sources and existing precipitation data, we also perform an analysis of the rainfall triggers of past flash-flood events and discuss possible climatic drivers. The analysed mountain stream, called Arroyo de los Puentes, is located in the Valsaín Forest. It has a length of ~3 km and an average gradient of ~15%, featuring a relatively wide alluvial cone covered by a well-preserved pine stand. Along this stream, many disturbed trees are related with torrential geomorphic features, such as alluvial fans, avulsion channels and debris cones, suggesting an intense flash flood activity. A total of 167 disturbed trees were sampled along the stream, with a focus on wounded trees (i.e. scars on stem). Other dendrogeomorphic features included tilted trees, decapitated and uprooted trees. In order to perform a correct dating, two reference chronologies were obtained from undisturbed trees in the upper and lower parts of the catchment. 2D-hydraulic modelling was carried out on stable bedrocks channel segments (DEM 1x1 m) to estimate peak discharges based on the height of scars on trees. As a result, a flood chronology containing 22 events was derived at the study site, defining an average rate of 0.11 events/yr during the last two centuries. Particularly intense events took place during the winters of 1936 and 1956 with estimated peak discharges of 370 and 300 m$^3$/s, respectively. Particularly high flash-flood activity was observed in the 1950s, with events in 1952, 1954, and 1956. The seasonality and precipitation analysis from well-documented events during the last century (based on 9 events) suggests that flood activity took place during late autumn (~46%), winter (22%) and early spring (33%). Events can be related with intense Atlantic fronts (61%), snowmelt (30%) and thunderstorm (9%), respectively. The related daily rainfall data revealed average precipitation totals of 33.3 mm (39-22 mm) for winter events, 56.6 mm for autumn (105-27 mm) and spring (101-27 mm). Results also revealed that for intense events in winter (i.e. 1936 and 1956) precedent precipitation was especially important. Additionally, in 75% of all cases, events fitted with negative monthly phases of the NAO index and related south-west advection of Atlantic storms. The obtained results have clearly shown a high torrential activity in the studied catchment and could help to understand the triggers of mountain floods in Central Spain, as well as to plan futures infrastructure to access at close Guadarrama National Park.
CARBONATE DEPOSITS IN ROMAN AQUEDUCTS AS A TOOL TO RECOGNIZE SEASONAL LAYERING AND EXTREME WEATHER EVENTS

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Roman aqueducts commonly contain carbonate deposits with several types of layering, formed in response to changes in water discharge, temperature, chemistry and biology over the life-time of the water supply system. The layering can record up to 800 years of water flow, commonly with sub-annual details, and can therefore be used as a high-resolution environmental archive. Over 1600 aqueducts have now been described throughout the Roman Empire (www.ROMAQ.org), most of them with carbonate deposits. In most sequences, some special layers or “event horizons” stand out in the stratigraphy since they differ from the regular pattern: these can be layers of a different chemical composition, deviating microstructure or corrosion surfaces. While regular layering is mainly an effect of cyclic seasonal changes in temperature and rainfall, event horizons can be due to extreme weather, earthquakes or human interference. Carbonate deposits are analysed by an integrated method using microstructural- and stable isotope analysis of Roman carbonate deposits, and monitoring of aqueduct springs and channels. First results are presented on regular layering and event horizons in deposits from Roman aqueducts in Israel, Turkey, Greece and southern France. The results are of direct relevance to palaeoclimatology, archaeoseismology and archaeology and are especially suited to recognize extreme weather events. Although Roman aqueducts are the topic of this study, results can be applied to water supply systems of any age.

Carbonate deposits from the Marcia Roman aqueduct, Rome. The sample shows both regular seasonal layering, and “event horizons” (e.g. the white layer near the top), which may represent extreme weather events. Width of the sample 10 cm. Growth direction upwards.
Current driven sediment transport causes the evolution of bedforms like dunes, ripples or scour marks. These bedforms are formed by the interaction of entrainment and deposition of sediment particles. In this study we use a numerical simulation of the three dimensional two-phase flow and the simultaneous transport processes to reproduce these processes. To solve the instationary incompressible two-phase Navier-Stokes equations we use NaSt3D as a parallel fluid solver for incompressible flow problems in three dimensions. High order schemes are applied for spatial as well as for temporal discretization. Domain decomposition is used for parallelization. In this study, we extend NaSt3D by a sediment model for bed load transport. Bed load transport is the main agent responsible for building up bed forms. We use the Exner equation to predict the evolution of the sediment surface. The rearrangement of sediment leads to a new sediment surface which results in new bedforms. This change in the fluid domain is loosely coupled to the Navier-Stokes equations. We test our model by simulating the two-phase flow around an obstacle with a movable underlying sediment surface. The simulation reproduces the scouring in front of the obstacle and the deposition of the eroded material behind the obstacle.
Climatic changes are expected to be important for future fluvial process magnitudes, since climate-related variations in flood frequency and magnitude have been the principal factors governing long- and short-term river sediment discharges in the past. Rivers have been very sensitive to short term, i.e. ~100 years, climate fluctuations. Future environmental changes may not only change the discharges, but also transform river channel types. Simulation approaches and environmental change impacts on natural river channels have earlier been reviewed from present or past perspective, and only preliminary allusions have been related to the future simulation issues.

Due to the highly topical nature of the future climate change impacts on in-channel changes of natural rivers, we first of all present numerical models applied for future in-channel change simulations and review the predicted future in-channel hydro- and morphodynamics, including flood discharges. We also review the prospects and challenges related to these modelling approaches, and particularly how the environmental change signal has been included. It will be concentrated on hydro- and morphodynamic and cellular (i.e. reduced complexity) modeling approaches, since these numerical models are capable of dealing both spatial and temporal dimensions of in-channel changes at natural river reach scale.

Despite the many available models, hydrodynamic, morphodynamic and cellular models have not yet been applied widely in future predictions. Particularly cellular models are under-represented. Predictions vary greatly between areas and scenarios, but increased transportation and flood risk are often predicted. Challenges relate particularly to the representation of external forcing conditions, to the calibration and validation based on past data, to the capabilities to simulate with adequate temporal and spatial scale, and to simulations of channel material, transportation and lateral changes. One-dimensional (1-D) hydro- and morphodynamic models and cellular models have shown prospects, since these have been possible to modify to encounter the needs of future representation. Capabilities to include increasing amounts of external forcing conditions are required. However, some studies showed the need to further develop 2-D models for century scale studies. Since most simulations are from northern latitudes, studies are needed from hydrologically different areas. Wider ranges of scenarios and combined effects of multiple external forcing factors on in-channel processes should be included in simulations.
THE “BLACK SWAN” OF 1540. ASPECTS OF A EUROPEAN MEGADROUGHT

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This is the first paper to provide coherent evidence on what Europe might expect in the case of a worst case heat and drought extreme. The obsession of scientists with summer 2003 being wrongly claimed to be the worst event of this kind since the Middle-Ages, long obscured the view on the devastating potential of the 1540 event. In many respects the record-breaking heat and drought in 1540 was an analogue case to the 2003 event, albeit it was more intense, spatially more extended and longer lasting taking the quality of a genuine “Black Swan”.

The drought was reconstructed from documentary data laid down in 312 chronicles. It lasted from February to December affecting a region of 2 to 3 million km$^2$. Precipitation in spring, summer and autumn was below the minima of the instrumental period. Discharge deficits up to 90% were assessed for major rivers (e.g. Rhine). Temperatures were significantly above those in 2003 due to extreme soil desiccation. The paper addresses the vulnerability of past and present societies to the impact of a recurrent 1540-like event, focussing on the energy, agricultural and transportation sectors.
CONSTRUCTION OF A NETWORK OF DROUGHT SERIES FROM ACROSS THE BRITISH ISLES FROM EARLY INSTRUMENTAL DATA SERIES (1697-PRESENT)

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Drought is one of the major natural hazards experienced; they are complex with both causes and multifaceted impacts poorly understood. Few studies of drought events from a long-term perspective have been undertaken in the UK or Europe, presenting problems in determining important drought characteristics such as; incidence, onset, duration, frequency and severity. In order to undertake robust drought analyses reliable long-term data are required. Historical records have long been recognized as valuable data sources within historical climatology; however, the application of historical records in drought analysis is in its infancy, with few historical studies considering drought. This paper presents a reconstruction of drought events for the British Isles, from AD 1697 to present, drawing upon early instrumental records, though work has already begun to corroborate and extend these series using historical accounts. The drought series are constructed using the Standardized Precipitation Index (SPI) and self calibrating Palmer Drought Severity Index (scPDSI) at monthly and annual resolution. The results identify a number of severe droughts that have been of longer duration and are more severe than the 1976 drought, the most memorable drought in living memory in the UK, an event often used for worst case scenario planning by water resource managers.
LOW WATER EVENTS ON MIDDLE AND LOWER RHINE IN ROMAN TIMES

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Based on historical sources and archaeological features several low water events, occurred on River Rhine in Roman times, are exposed.

For Romans, River Rhine was an important transportation route as well as a buffer zone to hostile Germanic people. Due to that, low water events where a major challenge for people living near River Rhine.

Romans build several bridges over River Rhine, which was possible only during low water events. Dating the wooden construction material enables developing a chronology of low water events.

One extreme event is documented by Roman historian Tacitus in his fifth book of the Histories. In the year 69 AD a drought caused extreme low water stages at lower Rhine, let a Roman transport ship strand on a river bar.

Objective is the quantitative discharge-reconstruction during this event. The main challenge is the reconstruction of historic river conditions and modifications influencing the cross-section area and the hydraulic roughness. Due to time gap, relevant sources are rare. In order to overcome this problem, a simple approach to estimate historic discharges has been applied to the lower Rhine in Roman times. This approach includes a procedure for reconstructing the hydraulic parameters of the river channel.

The recent mean discharge in investigated area is 2150 m³/s. The reconstructed discharge is between 200 and 300 m³/s, hence minor than smallest known low water event on lower River Rhine, which was 530 m³/s.
FLOOD AND DROUGHT HAZARDS IN THE FLOODPLAINS OF REGULATED RIVERS IN SW-HUNGARY

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Water availability is studied on two rivers in Southwest-Hungary. The Kapos is a medium-size river running across a hilly region, where flood hazard is concentrated on the tributaries draining the Mecsek Mountains. The upper Drava is an Alpine river, while the lower segment (studied within our project) is a border river between Croatia and Hungary, representing one of the last remaining continuous riverine landscapes in Central Europe, where all channel types (straight, meandering, braided, anabranching) are present with a range of natural landforms (large natural islands, gravel and sand banks, distributary channels, meanders, loess cliffs, oxbows etc.). In Hungary the lower Drava is part of the Danube-Drava National Park and extensive areas are included in the Natura 2000 system. In contrast to the Kapos, where the artificial channel is stable and only insignificantly modified by flood events, observations on the Drava indicate dynamic channel and floodplain development. The contrasting behaviours of the two rivers during the 2010 May-June floods are described. Since along the Hungarian segment of the Drava floodplain flood hazard is replaced by drought hazard recently, the research project involves the assessment of floodplain subsections along the Hungarian Drava River from the viewpoints of water availability, soil conditions, vegetation and nature conservation. It is closely linked to the Ancient Drava project, which envisions major transformations in water management and land use of this region, and has numerous implications for regional development.
Palaeotsunami research is crucial for the assessment and mitigation of present and future tsunami risk all over the world. This was dramatically shown by the Tōhoku Japan 2011 tsunami event during the course of which large parts of the Japanese coast were intensely flooded, important economic and transportation infrastructure were destroyed, nuclear power plants were critically damaged and the thousands of casualties shocked the country and public worldwide. In a first reaction, national Japanese and international social communities thought that they were faced with a natural catastrophe of huge and, to date, unknown extent. Only when the initial shock passed, the public learned that the region had experienced palaeotsunami events in the past which had been similar to the 2011 event, if not even greater. Knowledge of these past tsunami events would not have prevented the 2011 disaster as such, but the social, economic and ecological effects would have been much weaker, if the authorities and political institutions, together with leading companies and the population, had been more aware of the risk.

Underestimating modern and future tsunami hazard therefore mainly occurred due to lack of historical data on major tsunami events over the last couple of centuries. Thus, much more attention needs to be paid to geoscientific evidence of past tsunami events. Together with the detailed survey and analysis of recent events, palaeotsunami research needs to be considered as a solid and reliable base for modern tsunami risk assessment and mitigation. The motto ‘using the past as a key to the present and predictor of the future’ remains the most important aspect and motivation for all geoscientists who extend the time of observations far beyond the incomplete historical data (Vött et al. 2013). This simple retrospective approach has, however, a long way to go on the road of acceptance in our complex modern societies. This key note will present case studies from the eastern Mediterranean which show the interdisciplinary character of modern palaeotsunami research.

Reference:
ANCIENT GREEK HARBOURS USED AS GEO-ARCHIVES FOR
PALAEOTSUNAMI RESEARCH

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Since historical times, coastal areas throughout the eastern Mediterranean are exposed to tsunami hazard. For many decades the knowledge about palaeotsunamis was solely based on historical accounts. However, results from timeline analyses reveal different characteristics affecting the quality of the dataset (i.e. distribution of data, temporal thinning backward of events, local periodization phenomena) that emphasize the fragmentary character of these reports. While the compilation of historical data allows a first approach in the identification of areas vulnerable to tsunamis, it must not be regarded as reliable for hazard assessment.

Considering the increasing significance of coastal regions, our knowledge on the tsunami hazard along Mediterranean coasts has to be improved. For setting up a reliable tsunami risk assessment and developing risk mitigation strategies, it is of major importance (i) to identify areas under risk and (ii) to estimate the intensity and frequency of potential events. This approach is most promising when based on the analysis of palaeotsunami research seeking to detect areas of high palaeotsunami hazard, to calculate recurrence intervals and to document palaeotsunami destructiveness in terms of wave run-up, inundation and long term coastal changes. Within the past few years, geo-scientific studies on palaeotsunami events provided convincing evidence that throughout the Mediterranean ancient harbours were subject to strong tsunami-related disturbance or destruction. As harbours provide especially sheltered and quiescent environments they turned out to be valuable geo-archives for tsunamigenic high-energy impacts on coastal areas.

Due extensive local fault systems, coastal areas in the Gulf of Corinth (Greece) hold a considerably high risk for tsunami events. Geo-scientific and geoarchaeological studies carried out in the environs of Lechaion, ancient harbour of Corinth, comprised vibracoring and subsequent sedimentological, geochemical and microfossil analyses of the recovered sediments. Geophysical methods like electrical resistivity tomography (ERT) and ground penetrating radar (GPR) were applied in order to detect subsurface structures and to verify stratigraphical patterns derived from vibracores over long distances. The overall geochronological framework is based on radiocarbon dating of biogenic material and age determination of diagnostic ceramic fragments.

Our results provide distinct evidence of multiple palaeotsunami landfall for the investigated area. Tsunami signatures encountered in the environs of Lechaion include (i) coarse-grained allochthonous marine sediments intersecting silt-dominated quiescent harbour deposits and shallow marine environments, (ii) disturbed microfaunal assemblages and (iii) distinct geochemical fingerprints as well as (iv) geo-archaeological destruction layers and (v) extensive units of beachrock-type calcarenitic tsunamites. Geochronological data for Lechaion suggests that the harbour was hit by strong tsunami impacts in the 8th-6th century BC, the 1st-2nd century AD and in the 6th century AD. The final destruction of the harbour facilities also seems to be strongly related to the youngest tsunami impact. In a summary view, the investigated harbour site proved to be an excellent geo-archive for palaeotsunami research and contributes to the palaeotsunami record for the Gulf of Corinth.
EVALUATING NUMERICAL SIMULATION RESULTS BY MEANS OF TSUNAMI FIELD EVIDENCE FOR CAPE KATAKOLO AND ANCIENT EPITALIO (WESTERN PELOPONNESE, GREECE)

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Due to the high seismicity along the Hellenic Trench and the distinct submarine relief in the Ionian Sea, the west coast of Greece is highly vulnerable to tsunami waves. Besides written records (in particular tsunami and earthquake catalogues), this is especially indicated by a number of geoscientific field traces obtained all along the Greek west coast, suggesting multiple strong tsunami impacts in (pre-)historical times.

In this study, we compare in detail geomorphologic-sedimentological field evidence with high-resolution simulation calculations of different tsunami scenarios for Cape Katakolo and the prominent spur of Epitalio (Gulf of Kyparissia, western Peloponnese). For both sites, a tsunamigenic overflow can be derived from field data. In the numerical model, different wave types and wave heights were chosen to simulate realistic tsunami scenarios in high-resolution for the study area. All in all, the simulation results are in excellent accordance with field traces, corroborating the assumed hydrodynamics of local tsunami inundation. Thus, numerical simulations play an important part in reconstructing (pre-)historical tsunami events and therefore strongly support a local hazard assessment.
Coastal areas are often subject to rapid morphological transformations owing to varying processes such as sea level changes, tectonic uplift, and geomorphological changes by catastrophic storm events or even tsunamis. The study sites in northeast Taiwan at Fulong beach and in the lower Shuangsi give evidence of an aggradational phase, a destructive phase or event and a second aggradational phase during the second half of the Holocene. According to OSL data, a first accumulation of coastal dune sands started on top of marine and peri-marine/fluvial sediments at about 3 ka and lasted about 1500 years, interrupted by one palaeosoil. These data refer to an outcrop at a meander bluff at the southern bank of the Shuangsi (river), not far from its present-day mouth.

This sand accumulation is only the remnant of a former greater dune system that has been eroded in its northern part. The top of the outcrop is represented by two sand layers which are definitely younger than the lower sands as their deposition started about max. 630 years ago. The present-day dune system to the north of the river shows at least four dune ridges and the seaward aggradation is still continuing. The oldest dune ridge was sampled close to its top and dated by OSL to about 600 years ago (Dörschner et al., QI, 263, 2012).

About 3 km upstream, a sedimentary sequence at the river bank has been studied, comprising a lower silty deposit with organic remnants and layered tree trunks at its top. This deposit is considered to be of marine origin, probably a peri-marine situation. This fine-grained sediment is covered by coarse fluvial gravels, indicating at least one catastrophic event. Above the gravels, another fine-grained sediment related to flood events with low energy has been found. Radiocarbon analyses of organic material in both fine-grained sediments yielded ages supporting the results from the coastline.

The sedimentological records and the geomorphological situation give evidence of a short time period with one or several events that destroyed an older dune system at the coast and may be linked to the deposition of the coarse gravels in the river profile with the layered and oriented tree trunks at its base. If the existing age estimates of radiocarbon data are interpreted in this sense, the time window for such an event is about 660 to 600 years ago. The type of event, tropical storm with destructive flood or a tsunami can be discussed.

The coast afterwards entered a phase of resilience: the new dune ridge system came into existence, and since then the process of a prograding coastline has been active and was supported by an uplift of about 2mm/a, which was calculated on the base of marine deposits found in two outcrops. The river deposited fine-grained overbank sediments on top of the gravel.
Abstracts
for poster presentations
Hydrological planning for flood risk presents an initial problem which is unlikely to be solved without using historical floods and paleofloods information. Usually, extreme-value functions are used to estimate the peak flow associated to a given return period. The problem here is that instrumental data of these extreme events are scarce and, in a majority of cases, limited to a few floods of the second half of the 20th century occurred in the major rivers. In other words, there are a lot of cases in which the lack of instrumental data is total, i.e. small ungauged basins.

We present here the methodology we used to reconstruct the peak flows of the greatest floods occurred in several different-sized basins in the NE Iberian Peninsula. The objective of this study is to assess the improvement in the calculation of peak flows with the introduction of historical floods data depending on the size of the basin; we believe that this improvement can be put to good use in future flood risk planning.

The first step in the peak flows reconstruction of the greatest floods occurred in a basin is the collection of peak flow height data from historical information, commonly from epigraphic and documentary sources. From this water height datum, and with additional information on the river reach’s morphology and roughness and on contour conditions, a 1-D hydraulic model (HEC-RAS) calculates the maximum flood discharge. Then, the error of the calculation is obtained. Once the peak flows series is completed, its corresponding return periods are calculated with the statistical software AFINS 2.0, which is able to work with systematic (instrumental) and non-systematic (historical) discharge data simultaneously.

The studied cases are the last four centuries in three different-sized basins: Ondara River at Tàrrega (150 km²), Ebro River at Zaragoza (40.000 km²) and Ebro River at Xerta (80.000 km²). The Ondara River basin is ungauged and the Ebro River at both Zaragoza and Xerta is gauged only since 1913. In these last two sites, the addition of historical information increased by 30% the peak flow associated to any given return period, previously calculated with the 20th century systematic series only. This increase is even greater in the case of the Ondara River basin, where the lack of a peak flow series forced the administration to estimate the flood risk from rainfall data through hydrometeorological models. Thus, the 100-year and the 500-year return period peak flows double and triple, respectively. These results show that the use of historical floods data, besides proving useful in big basins, is essential in small ungauged basins.
CAN TILTED TREES BE USED FOR PALAEOFLOOD DISCHARGE ESTIMATION?

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Botanical evidence are useful paleoindicators of past flood activity in fluvial system. Specifically, tilted trees are one of the most common evidence that can be found in floodplains. Its utility to date past flood event by the identification of reaction wood has been widely recognized. However, despite stem deformation is a mechanical process caused by the hydrodynamic force of the flow, its usefulness for flood discharge estimation has never been studied so far. Here, we present a mechanical root-plate rotational stiffness model to predict tree deformation and its relation with flow energy. This model combines theories from dendrogeomorphology, dendrometric, mechanical structures and hydraulic sciences. We test our approach in three different rivers located at the Spanish Central System with gauged flood events (i.e. Tagus, Cega and Alberche rivers). Input data such as stand forest characteristic (i.e. DBH, height and crown length), tilted tree characteristics, root-plate system size, hydraulic conditions as well as soils characteristics were measured in the field. Other needed input parameters as soil and wood density, expected drag coefficient, roughness parameter as well as soil and wood elastic modulus were taken from literature.

Overall, the comparison between observed deformations and simulated values yielded an underestimated correspondence. Correspondences were higher in Tagus and Cega River ($r^2=0.78$) and lower in Alberche River ($r^2=0.56$), were three outliers corresponded with major floods were found. Despite of the complexity of the process and the assumption made in the approach, the most important finding was to find moderate-highs correlation coefficients between observed and modelled values. This result clearly shows a relationship between the inclination of trees and flood magnitude; although the estimation of the maximum flood peak discharge is subjected to several uncertainties. Therefore, the analysis of uncertainties suggests variability ranged between 112-33%, mainly related with the magnitude of the flood event and tree sizes parameters. Despite more specific studies are needed to reinforce the arisen hypothesis, we think that this study shows futures possibilities to include the deformation of tilted trees as censored data, specifically limited by low bounds, in the flood-frequency analysis of poor or ungauged basins.
EXTREME FLOOD EVENTS IN URBAN AREAS: CLIMATIC PATTERNS AND HUMAN INTERACTIONS IN CATALONIA (NE SPAIN)

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Large collection of flood events into PREDIFLOOD Project database for Catalonia country with 2600 flood events for AD1033-2013 allows different analysis about flood events as a complex phenomena involving natural and human processes in a long-term scale.

First aspect is a comparative analysis between long flood chronologies between urban areas and rural or less populated areas. Flood patterns for moderate and major events show a good relation with climatic patterns in both types of area in historical time. This fact points out the good adaptation of human settlements to flood risk during pre-industrial period. Flood events recorded during 19th century show important increases on frequency, both in urban and rural areas. Economic growth with general industrialization process and important demographic growing can explain this pattern. However, a climatic factor (Little Ice Age) is also playing a role during the second half of 19th century.

First half of 20th century presents a clear reduction of flood frequency. Meteorological records show a relative reduction of torrentiality, with a new climatic scenario after Little Ice Age, but urban areas have also reduced flood exposition with important investment on hydraulic infrastructures, basically drainage networks.

On the contrary, second half of 20th century shows a new interesting pattern. No climatic or meteorological fluctuations are observed, but the frequency of moderate floods increases on urbanized areas. Despite the important infrastructures already operating, as large dams and fluvial dykes, with similar meteorological events and climatic context, floods are more present producing strong damage and victims. Catastrophic major floods have previous frequencies. This fact proofs that natural climatic patterns are unchanged. Consequently, human factors have to be responsible for this variation. Uncontrolled urbanization processes, increasing industry, important demographic growing and new touristic activities can be responsible for this flood increase. Additionally, while severe floods needed more than 60-80 mm of rainfall by day in 19th Century in small coastal basins of Catalonia, during the 20th century this rainfall is reduced for moderate floods to 50 mm and 30 mm in any singular cases. These changing thresholds show an important increase of exposition and vulnerability of urban areas, especially to high torrential events of short duration but intensities around 1 mm/minute.

Taking into account the expected increase of frequency and severity of intense rainfalls due to climate change, the analysis of long time series of floods can help to improve the risk analysis, providing enough information for policy-makers in order to reduce vulnerabilities and increase resilience in the most populated areas.
HYDROLOGICAL AND ENVIRONMENTAL HISTORY OF A MEDITERRANEAN RIVER RECORDED IN PALAEOFLOOD SEDIMENTS

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Rambla de la Viuda (drainage area of 1500 km²) is a Mediterranean ephemeral river with a hydrological regime characterised by large floods. The region has a long history of anthropogenic land-use changes, which contributed to temporal phases of increased rates of sediment yield and changes in flood hydrology. Valley sides revealed important accumulations of slackwater flood deposits. These slackwater flood deposits emplaced by high stage floodwaters show a complete stratigraphy from which we can reconstruct long-term records of floods and environmental changes. Interbeded with these flood units, colluvial units can be observed, and several edaphic horizons developed on colluvial and fluvial deposits were identified.

The alluvial and colluvial chronostratigraphical, sedimentological and palaeobotanical (phytoliths) analysis of these units, together with the hydraulic flood modelling approach, made possible to determine: a) the way in which hydrological extreme events may be changing both in frequency and intensity as a result of climate variability, b) the weight of human influence (land-use) on soil hydrology, c) geomorphic channel changes, and c) the grade of resilience of landcover during this temporal scale (last 500 yrs).
Gravel mining in river beds has increased during the decades due to the need of material for constructions, floods mitigation and dam silting. These human activities are usually affecting the sediment dynamics and fluvial geomorphology of river courses. These changes are even more evident in semiarid ephemeral streams owing to the higher sensitivity to human activities. Therefore, on these fragile environments, the human impact on river geomorphology and resilience of these ecosystems should be assessed. For this reason, we have selected the Rambla de la Viuda, an ephemeral gravel-bed stream located in Western Mediterranean (Valencia region, Spain) that has been severely affected by gravel extraction over the last decades. To assess the fluvial geomorphological changes, 13 sets of aerial photographs –from 1946 to 2012 and LiDAR topography –from 2009 to 2013- have been studied using overlay analyses of aerial photographs and LiDAR data, providing a means for assessing planform and vertical changes along a river reach of 10 km in length.

Three different periods have been recognized according to changes in geomorphology and vegetation cover types: i) prior to 1970 the riverbed remained unaltered (almost 80% of the total riverbed area were active elements); ii) from 1970 to 2000 gravel mining in the riverbed significantly altered the river bed geomorphology until the bedrock was reached (up to 40% of total floodplain area was extracted); iii) from 2000 to the present, with a major recovery of gravel bars during the flood in the year of 2000 with an active shapes covering 70% of the total riverbed area. After this flood, further gravel mining and erosion processes started to modify the fluvial course again. Geomorphological changes of last 60 years were used to evaluate the hydrological influence (extreme vs low-moderate events) on the sediment dynamics and resilience of the riverbed to the past and on-going mining impacts. Major extreme events, such as the flood in 2000, the biggest event within the last 50 years, have demonstrated effective to recover the gravel bed morphology to quasi-natural state, demonstrating a long-term geomorphical memory if other factors such as sediment connectivity are not altered. Despite the partial recovering of the flood events, in 2012 the 35% of the initial area (1946) have been exposed, indicating major river bed incision with permanent sediment volume losses.

Our study highlights that river channel recover of the quasi-natural state depends on two main external controls: i) severity of human activities on riverbeds and ii) frequency and magnitude of extreme hydrological events. Those two factors must be considered for the future management policies and river restoration in Mediterranean ephemeral streams.
Deep-water marine channels are highly dynamic environments due to the erosive power of sediment-laden currents. These underflows reshape the morphology of the subaquatic conduits during episodic events such as large floods, major earthquakes and/or landslides. Gravity flows, which can be associated with scarp failures in proximal levees or major floods, can be transported thousands of kilometres to distal areas of canyons. Nevertheless, the evolution of these underflows is still poorly understood because of their complex rheology, their large spatial scale and the difficult monitoring of these energetic events. For this reason, Lake Geneva’s sub-aquatic canyon in the Rhone Delta, with its smaller size, well-known boundary conditions and detailed bathymetric data, makes an excellent analogue to understand these types of hydro-sedimentary processes that usually occur in deep-water channels in the marine realm.

A multidisciplinary research strategy including innovative coring via MIR submersibles, \textit{in situ} geotechnical tests, geophysical and sedimentological analyses, as well as acquisition of repeated multibeam bathymetric data sets, were applied to understand the triggering processes, transport mechanisms and deposition features of gravity flows throughout the active canyon of the Rhone Delta. The difference between two bathymetric surveys in 1986 and 2000 revealed an inversion in the topography of the distal active canyon, as the former distal channel was transformed into a mound-like structure. A 12 m-thick layer was deposited in the canyon. Sediment cores from this deposit were retrieved in 2002 and 2011 via the “F.-A. Forel” and Russian MIR submersibles, respectively. These cores contained a homogeneous, sandy material. Its sediment texture, grain-size, high density and shear strength, and low water content suggest that it corresponds to a debris-flow deposit that possibly took place after the initiation of a mass movement due to a scarp failure in proximal areas of the canyon. In addition, \textit{in situ} geotechnical tests on the modern canyon floor have shown a soft top layer above a stiffer substratum. This soft layer, which increases in thickness towards distal areas, may act as a basal surface for hydroplaning, and might have allowed the debrite to be transported ~9 km away from the source of the scarp failure. This study highlights how large mass movements in proximal sites influence the morphology of distal areas by damming the channel and, eventually, forming new conduits, as revealed by multibeam bathymetries acquired in AD 2012 in this subaquatic canyon.
PLEISTOCENE FLOOD DEPOSITS AT THE ABRIGO DEL MOLINO
ARCHAEOLOGICAL SITE (SEGOVIA, CENTRAL SPAIN)


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Abrigo del Molino archaeological site is placed in the Eresma river valley, in the surroundings of the city of Segovia (Central Spain). It consists in a shallowness cave, with a fluvial-karstical origin, which has been totally filled by detrital deposits. The techno-typological characteristics of the lithic industry and the OSL date (59.7 ± 2.7 ky) confirm the existence of Mousterian levels in the site, showing for the first time the presence of Neanderthal groups in karstic deposits in the northern Iberian Plateau, in the South of the Duero Basin.

Geoarchaeological interpretation of the genesis of the deposits differentiates three groups: a lower group with sandy-loams and fine sands inter-bedded with layers of pebbles and gravels deposited respectively during palaeofloods and by slope contributions; a middle group with massive silts and grain-supported boulders, formed by alternating contributions from the overlying slope and karstic mudflows and rockfalls from the shelter roof; an upper group with silt cemented by carbonates, final backfill alteration and degradation of the host rock.

The sandy-loam levels of the lower group were analysed to characterize the number, frequency and magnitude of the Pleistocene palaeoflood events. They contain interesting sedimentological structures such as several sets of climbing ripples (2-3 cm wide).

The palaeocurrent direction is the inverse of the present day flow direction in the nearby Eresma river. This allowed us to interpret these sediments as eddy bars deposited on the left margin of the Eresma river during past flood events, when the waterflow came into the cave or rock-shelter with the cave mouth facing upstream. The estimation of palaeoflood discharges was very complex because of the important changes in the configuration of the valley bottom, mainly by river incision, lateral migration and the unknown past alluvial fill depth. Nevertheless, the palaeofloods must have been of considerable magnitude and may even have influenced the settlement and seasonal permanence of human groups in this location. This could therefore be a primitive case study of human/flood interference.
DENDROGEOMORPHOLOGICAL RESEARCH APPLIED TO THE CHARACTERIZATION OF FLOOD EXTREME EVENTS IN SPAIN

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Over the last forty years, applying dendrogeomorphology to palaeoflood analysis has improved estimates of the frequency and magnitude of past floods worldwide. This communication reviews the main results obtained by applying dendrogeomorphology to flood hazard research over the last ten years in several case studies in Spain.

These dendrogeomorphological recent advances focused on the following topics: (1) anatomical analysis to understand the physiological response of trees to flood damage and improve sampling efficiency; (2) compiling robust flood chronologies in ungauged mountain streams; (3) determining flow depth and estimating flood discharge using two-dimensional hydraulic modelling, and comparing them with other palaeostage indicators; (4) calibrating hydraulic model parameters (i.e. Manning roughness); and (5) implementing stochastic-based, cost–benefit analysis to select optimal mitigation measures.

Further developments will include new methods for better identification of the causes of specific types of flood damage to trees (e.g. tilted trees) or stable isotope analysis of tree rings to identify the climatic conditions associated with periods of increasing flood magnitude or frequency.

Innovative results have been obtained from the application of these methodologies in different study sites in Spain, including ungauged basins in the Gredos Mountain Range and Segovia (Central Spain), and the Taburiente National Park (Canary Islands).

The research projects Dendro-Avenidas (2008-2010) and MAS Dendro-Avenidas (2011-2014), both funded by the Spanish Ministry of Science and Innovation (now Ministry of Economy and Competitiveness), and the project IDEA-GesPPNN (2011-2013, Spanish Bureau of National Parks; Ministry of Agriculture, Food and Environment) are exploring these novel research areas.
LOOKING FOR PAST FLOOD EXTREME EVENTS IN ARTWORKS AND HISTORIC BUILDINGS

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Classic data sources and methods for the characterization of past flood events suffer from serious scientific problems and technical limitations: the instrumental records (streamflow, rainfall...) are limited to the recent time period (last century) and its spatio-temporal extrapolation is difficult; and palaeohydrological, historical, documentary classic records are limited by the availability and validity of documents and natural evidence.

However, there is another more unorthodox and innovative data source for past floods which remains unexplored: the dendrochronological record in artworks and historic buildings. This involves applying advanced dendrochronological cross-dating techniques to locate and date evidence in the tree-ring sequence that allows us to reconstruct catastrophic past floods occurring centuries ago, and which are only recorded, for example, on the neck of a Stradivarius violin, or the panelling of a Romanesque church. This can extend the historical flood record by centuries or even millennia, allowing us to incorporate these data into the statistical analysis of extreme values to improve estimates of high return periods.

This communication presents the methodological proposal of this research area, and the first results of the application of those techniques to some case studies cases in historic buildings (Segovia Mint, San Millan Romanesque church) and artworks (Stradivarius violin, 17th century paintings).
FREQUENCY ANALYSIS (RETURN PERIOD) OF RECENT FLASH-FLOOD EVENTS IN CALDERA DE TABURIENTE NATIONAL PARK (CANARY ISLANDS, SPAIN) FROM DENDROGEOMORPHOLOGICAL AND METEOROLOGICAL DATA

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The Caldera de Taburiente National Park (Canary Islands, Spain) is mainly formed by the Barranco de Las Angustias basin, a volcanic caldera in origin, an ungauged fluvial basin where flash-flood events drive the main geomorphological process. These processes include erosive and depositional events of high magnitude (various metres thick).

As there is no flood record of the basin available, frequency analysis for return period estimation is not possible from the usual Q_{ci} statistical analysis (GEV, TCEV, LPIII,...) and other techniques for estimating the event recurrence must be used. In this paper a methodology (Figure 1) based on collecting dendrogeomorphological data and the use of the existing basin rainfall record is presented. The meteorological data has been used in two ways: first, to characterize the form and duration of rainfall events in the watershed and second, to estimate precipitation quantiles (using GPD-POT technique). These data together with the basin characteristics have allowed us to develop a hydro-meteorological model (HEC-HMS) for the basin; thus, rainfall can be linked to the generation of liquid flow in the basin.

Figure 1: Methodological flow chart for recurrence interval estimation from dendro- and meteorological data.

Furthermore, dendrogeomorphological data has allowed us to establish a theoretical water surface level for concrete flooding events, which can be easily related to the water depth results of the 2D hydraulic modelling (IBER model) of previously obtained hydrograph data from the hydro-meteorological model. Minimizing topographic differences (RMSE_{MIN}) between these two information sources allows us to infer the possible peak flow responsible for timberline disturbance around the creek channel, and therefore to estimate the magnitude and frequency of the event, or its recurrence interval.
Numerous and diversified are the landslides that occur in Amazonia especially along the rivers of the Amazon System. They are called “Terras Caídas” in Portuguese (river bed collapse) and extend from a few to hundreds meters. We had the opportunity to follow in the field the development from the formation of cracks and fractures to the complete collapse of large river banks occurred in areas close to Manaus during the last ten years. The occurrence of other spectacular landslides are reported in annals or referred to in oral reports. The objective of this paper is to discuss and to analyze the causes of the formations of these landslides and their effects. The most important parameters that contribute to the formation of these landslides are: the effects of the tropical climate during the rainy and dry season, the textural characteristics of the local sedimentary deposits, the slope of the levees with their vegetation covering, the power of the current in the channels and the weak seismic activity of the region. In fact, all the channels in Amazonia are related to neotectonic features (Igreja, 1998), therefore the influence of the neotectonic is also an important factor in the formation of landslides in this region. Landslides generally occur along the rivers where the levees are constituted of modern sediments transported and deposited by the rivers or made from ancient rocks that also form the bed and the floor of the floodplain. Modern sediments of the levees are silty and friable fine sands, intercalated with thin clayey beds. Ancient deposits are compact, more clayey and weathered. In most cases the levees are steep, almost vertical. Rain water infiltrating the pores of the friable sediments increases their masses, contributing to lack of equilibrium and provoking the slides. The power of erosive currents against the levees allied with the precedent factors cause instability resulting in landslides. During the long dry seasons the water of the texture in the clays of the ancient deposits can be lost causing cracks and fractures preceding the landslides. When this occurs the grasses or shrubs or tall trees of the levees are dragged into the water along with the soil and sediments. These phenomena generally occur in a relatively short time, sometimes suddenly. But in other cases can occur during longer periods, being forecast by cracks and fractures. In this paper we relate some events of large landslides and their effects involving climatic factors and neotectonics in the Amazon region during the last 35 years.

References:

INCREASING VULNERABILITY TO FLOODING IN THE SOUTHERN SPANISH MEDITERRANEAN COAST (1960-2011)

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The southern Mediterranean coast of Spain, consist of 41 Andalucía municipalities that cover an area of 5,000 km². This area host a population around 2,000,000 people, laid out through nearly 370,000 buildings and 1,185,000 homes (INE, 2014). A space that, between 1960 and 2011, has experienced major changes in the development model, what have resulted in a huge population and economic growth.

These changes have led to a vulnerability increase in flooding, since, the territory policies approved throughout time, have been too indulgent towards land cover under natural hazard influence. All of that aiming the promoting of "sun and beach" tourism model, based on the massive use of land and the construction of vacation homes (Gaja I Díaz, 2008).

This work uses the information available in newspaper libraries in order to reconstruct flood series since 1960 to 2011. That, let us to identify the number of natural events, classifying them according to their level of intensity (Barriendos, Peña & Martín Vide, 1998) and distinguishing the type of damage that human systems have experienced.

In the study period, the number of floods show an increasing trend, however, the socioeconomic impact of each event decreases just as the affected surface. With regard to buildings and communications, the trend remains stable, while a growing impact on the tourism industry has been registered.

In this sense, we can assume that a delay between adaptation and danger has taken place, which has negative consequences depending on the population size of the municipality. In this way, in populations less than 10,000 people, the frequency of floods increases, and worse, the intensity of them. Thus, new spaces at risk are created where the population has experienced an increase in vulnerability.

This situation gets moderated as the size of populations grows up. However, in cities over 100,000 inhabitants, the lack of updating in defense systems, along with the raise in floor area, has led to an increase in damage to homes and roads.

This risk tendency has happened in two different phases: first, the second half of the eighties which coincides with the entry of Spain into the EU and the assumption of competence in spatial planning by municipalities, and second, year 2000, when process of building housing as a second residences really took off.

This process coincides with other European areas (Barredo, 2009), and apart from considering the climate hazardousness evolution, it evidences that the more exposure and the lack of regulation in the urban planning, have led to an increased flood risk in the Andalusian Mediterranean coast, aspect inversely proportional to population size.

Bibliography:
PEAK DISCHARGES OF THE JULY 1342 FLOOD ALONG THE RIVERS RHINE AND MAIN

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The precipitation event in July 1342 exceeded any other observed event in historic and recent times in Central Europe. According to historic sources, the event lasted several days resulting in extended soil erosion with gullies up to 10 m deep which devastated landscapes and ruined farmers. In several regional records the resulting flood level of the rivers was highest in the entire record. Remarkable is the observation of extreme flood levels also in regions without significant rainfall. The historic flood records are revisited on the background of contradictory reports of their distribution. While occasionally a distribution of the related flooding from the coast of the North Sea down to northern Italy is reported, several studies highlight missing flood reports in catchments in-between.

Based on confirmed reports on floods respectively rainfall, the millennium flood was generated by convective rainfall on the catchment of the River Main and adjacent headwaters of tributaries of the Rivers Danube, Elbe, Weser and Lahn. The intensity of the rainfall was sufficient to cause devastating soil erosion and extreme flood magnitudes along the river catchments even far downstream the precipitation area. Based on recent circulation pattern for extreme summer precipitation in the catchment area of the River Main a “Central European trough TRM” configuration was the origin rather than the frequently postulated “Vb-track cyclone” (Genoa Low). Peak discharge estimations along the Rivers Main (Würzburg, Frankfurt) and Rhine (Mainz, Cologne) revealed values up of typically twice the largest flood ever measured at a gage and mostly are the largest in the entire historic record. Several findings previously related to this flood event fit to the new explanation by considering that during 1342 four additional significant floods took place in Central Europe but were less critical analysed for plausibility by source validation.

Reference:
Herget et al. (submitted): The millennium flood of 1342 revisited. Catena (in review).
CHANGE POINT ANALYSIS
WITH PAST AND FUTURE RAINFALL DATA IN SOUTH KOREA

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Background: Change point analysis can provide important key to understand the fundamental characteristics in hydro-meteorological data. Especially, the results through change point analysis can affect the prediction of flood or drought. However, relatively few studies have addressed the performance between the various change point methods through comparative study. Therefore, in this study, 3 change point detection skills were assessed using the synthetic rainfall data and the selected change point detection skill was performed to find real change point in the past and future rainfall data in South Korea.

Method: The 3 change point methods, CUSUM (CUmulative SUM), BCP (Bayesian Change Point), and DP (Dynamic Programming) are performed to the 3 types of the synthetic rainfall data (homogeneous, single shifted, multi shifted). Also, the exact number of change points, position error, and the 3 indicators suggested by Beaulieu et al. (2009) were used to assess the performance of each detection skill. After assessment of the proposed detection skills, 2 reasonable methods were applied to the past rainfall data and future rainfall data generated from GCM and RCM.

Results: BCP with 0.9 posterior probability and DP were slightly superior to BCP 0.7 and CUSUM in homogeneous synthetic series. In single shifted synthetic series, BCP 0.9 & 0.7 were best detection skills and DP was second best. Also, in multiple shifted synthetic series, BCP 0.9 and DP are reasonable (Fig. 1). In application with the past rainfall data from 5 rainfall gauges and the future rainfall data from RCP 4.5 & 8.5, it is known that BCP 0.9 would tend to find another one change point in the future rainfall data at 3 rainfall gauges. Also, the results by BCP 0.9 and DP were almost same at 2 rainfall gauges.

Conclusion: It can be suggested that BCP 0.9 and DP detection skills be reasonable in South Korea. These results can be efficiently used to resolve non-stationary problems such as calibration process of hydrological model to predict future flood and drought.

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EVIDENCES OF EXTREME PALEOFLOODS GREATER THAN GAUGING RECORDS IN THE BURNETT RIVER, AUSTRALIA

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Background: The lack of long term frequency and magnitude records of flood events exposes the weakness of extrapolating existing short term gauging records for flood prediction and mitigation modelling. In Queensland Australia, on average, the continuous flow and/or discharge gauging records of all historical and existing gauging stations in Queensland is only 27 years. Without a better and more extensive database, existing flood mitigation approaches will not suffice in handling potentially extreme flood hazards.

On Jan 27 2013, Ex-Tropical Cyclone Oswald dropped 291 mm of rain on Barambah Creek catchment, one of the subcatchment of the Burnett River system (33195 km$^2$). The peak discharge of 7594 cm$^3$/s (contributing catchment size of 5553 km$^2$) was the highest ever recorded since the station became operational in 1966. This event contributed to the massive flooding in the city of Bundaberg, at the mouth of the Burnett River which eventually affected over 2000 properties and many thousands more people. The 1% Annual Exceedance Probability (AEP) or 1-in-100 year flood is the typical design flood that is used for flood planning and mitigation works in Australia. Preliminary statistical analysis demonstrates that the amount of rainfall recorded on 27 Jan 2013 is about one-third more than what will produce the 1% AEP design flood for this area.

Method: This research seeks to find slackwater deposits (SWDs) of paleoflood extreme magnitude event greater than observed records. With a huge extent of the river system draining through bedrock, the Burnett catchment provides suitable stable boundary conditions to understand extent of extreme events discharge. Field reconnaissance was conducted in November 2013 to find suitable bedrock settings with SWDs in the Burnett. Dating (through OSL and radiocarbon) and discharge estimation (through 1-dimension models) will be done to ascertain the accuracy of these paleoflood units. Fieldwork will be conducted before May 2014 to collect and map the SWDs units in this reach.

Results: Preliminary field reconnaissance and local knowledge has provided indications that floodwater in 2013 did not inundate a slackwater terrace bench about 5km downstream of the gauging station. It is hypothesized that there is more than 1 extreme flood event at least 100 years ago that is larger than the 2013 event.

Conclusion: This pilot project will provide insights to the suitability of this and adjacent catchments in terms of geology, geomorphology settings and varying climatic conditions for the identifying and understanding of extreme flood events in South East Queensland. It is also an exercise to understand and improve methodologies in the field and lab. It will form the foundation of my PhD work in deriving, 1) a systematic approach to look for evidence of extreme paleoflood events; 2) a better understanding of their links with millennium scale climatic variability and; 3) the implications to improving existing data sets.

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HYDROLOGICAL REGIME CHANGES IN THE CENTRAL RUSSIAN PLAIN IN MIS-3 – MIS-1: THE SEIM RIVER CASE STUDY

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Low terraces of Seim River low terraces (the middle Dnieper catchment; 51º40’N, 35º47’E) were studied by hand and mechanical coring, examination of natural exposures, DGPS topographic profiling, 14C and OSL dating, grain size and spore-pollen analysis, microscopic study of quartz grains. The results were used to establish conditions and chronology of river downcutting – aggradation stages and magnitude of river floods.

Time interval >77–<50 ka BP (here and further ages are in calendar years) was characterized by river aggradation and accumulation of 12-16 m Terrace 1 (T1), river runoff was probably low. River incision by >10 m was detected within the interval <50–~27 ka BP. In the end of this time around 33-27 ka BP the so-called intermediate (or “zero”) 5-7 m terrace (T0) was formed. Incision was most probably caused by considerable increase of water discharges, which is evident from widening of valley floor due to active channel migrations.

By the LGM the river had been incised to the level at or below the present-day channel. The time period >27–~17-18 ka BP was characterized by low floods, river stability/aggradation, wide occurrence of aeolian sands interplaying with deluvial loams (climate aridity, scarce vegetation). Stationary human settlement Avdeevo existed on the T0 terrace, i.e. at low topographic positions which are subject to seasonal flooding now.

Between ~17-18 and ~12-13 ka BP Seim river incised 3-5 m below the present-day channel. High runoff as the cause of this incision is evidenced by formation of “big meanders” (macromeanders) that remained in some downstream reaches of the valley. At the studied section, designated from overbank silts over the T0 terrace OSL dated between 13-16 ka BP. Due to recommencement of the T0 terrace seasonal inundation, human occupation on this terrace ceased and cultural layers were overlaid by overbank alluvium.

In the beginning of the Holocene about ~12-13–~10 ka BP runoff decreased, and longprofile rebound after high discharges in the Lateglacial led to river aggradation to the present-day levels. From >10 ka BP till now, River Seim is characterized by relative stability with rare epochs of high floods. Two such epochs around 4.5 and 2-2.5 ka BP are exhibited by geomorphic and sedimentological features such as channel avulsions, high undercut marks, overbank sedimentation containing ceramics from the Early Iron Age at levels >1 m above the highest modern floods.

Study of the Seim River demonstrates that the Valdai (Weichselian) cold epoch (MIS 5d – MIS 2) was characterized by high amplitudes of river runoff changes. In very general, direct relations between major temperature and runoff changes can be deduced: considerable runoff increase and corresponding river incision occurred within the relatively warm phases – late MIS-3, the Late Glacial time, while the coldest phase (LGM) was characterized by lowest runoff and vertical accretion of valley floor. In the Holocene, amplitude of runoff changes was much lower and runoff-temperature relation is rather opposite: higher floods are characteristic for colder phases.

This study is supported by the Russian Foundation for Basic Research (RFBR), Project No. 14-05-00146.
GEOPHYSICAL INVESTIGATION OF THE FRESH-SALINE WATER INTERFACE IN THE COASTAL AREA OF ABERGWYNGREGYN

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Key Words: Fresh-Saline Water

The importance of the study of saline/fresh water incursion cannot be over-emphasized. Borehole sampling has been extensively used, but it is intrusive, quite expensive and time consuming. Electrical resistivity and electromagnetic techniques have proved successful in groundwater studies since geologic formation properties like porosity and permeability can be correlated with electrical conductivity signatures. Non-intrusive surface geophysical mapping comprising electrical resistivity and electromagnetic methods has been employed to investigate freshwater intrusion and delineate the fresh-saline water interface at the inter-tidal area of Abergwygregyn, North Wales, United Kingdom. Frequency Domain Electromagnetic Profiling and Constant Separation Traversing were used to produce 2-D images and contour plots enabling the identification of freshwater plumes onshore and in the central parts of the study area. Ground truth methods comprised chemical analyses and detailed, point specific information on the stratigraphy. The freshwater intruding from the coastal area appears to be pushing the saline-water further offshore due to the high piezometric head caused by the mountains and hills of Snowdonia adjacent to the study area. The fresh/saline water interface correlates quite well with previous studies carried out in the area. On the basis of the results of the resistivity and conductivity geophysical investigations the freshwater plumes and fresh/saline water interface in the study area were effectively identified and delineated.
RECONSTRUCTING A HIGH RESOLUTION HYDROGRAPH CURVE BASED ON HISTORICAL PHOTOGRAPHS

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Peak discharges of historic floods in urbanized areas of different cities on the River Ahr in western Germany are reconstructed based on documentary sources from pre instrumental and the early instrumental period (1804–1937).

Maximum water levels of five floods are denoted by flood-marks, with one of these events additionally documented by old photographs. The main challenge is the reconstruction of historic floodplain conditions and modifications influencing the cross-section area and the hydraulic roughness. In order to overcome this problem, a simple approach to estimate peak discharges of historic floods has been applied to the River Ahr. This approach includes a procedure for reconstructing the hydraulic parameters of the river channel and overflooded areas, coupled with an approach for the verification of estimated peak discharge reliability. Five reconstructed discharge maxima are presented.

One of these events is well documented by numerous photographs, taken at different times of day. Reconstructing discharges at different stages, compared to exact information on time, allow the reconstruction of a hydrograph curve. The validation of the technique by comparison with recent gauged floods reveals results of adequate accuracy. The results show that reconstructed historic floods were partially larger than any gauged flood of the River Ahr.

Publication:

The question whether the magnitude and frequency of hydrological extreme events have changed due to climate change and other drivers of change is of high interest, particularly in mountain basins which have been found to be extremely sensitive to change. Most of the flood damage in Poland (41 significant floods during the 20th century) occurred in the basin of the Upper Vistula River, especially on its tributaries in the northern foreland of the Tatra Mountains. Therefore, one of the aims of this study is to analyse the inter-decadal variability of magnitude, frequency and seasonality of hydrological extreme events in this region since the mid-20th century. To achieve this, we accomplished the analysis in a multi-temporal approach whereby trends are fitted to every possible combination of start and end years in a record, with a minimum of 30 years length. We compared the results of this multi-temporal analysis with trends in three fixed periods (1951-2011, 1961-2011 and 1971-2011) in order to identify representative short-term trends of longer periods.

We tried to explain the detected trends by correlation between the investigated hydrological parameters and different large-scale climate indices for the Northern Hemisphere, and we looked at other essential climate variables, such as intense precipitation indices, number of days with snow cover and cyclonic circulation types. In addition, catchment and channel changes that occurred in the region over the past decades were considered as potential drivers of flood changes.

Results showed that rivers in the northern foreland of the Tatra Mountains exhibit considerable inter-decadal variability of flood flows. The magnitude and direction of the identified short-term trends are heavily influenced by this inter-decadal variability; however, certain patterns were apparent. Upward trends of annual maximum discharges and flood magnitudes were identified, together with changes in flood seasonality. The magnitudes of autumn and spring floods increased over the last 60 years, whereas those of winter floods exhibited a downward trend. Trends in flood frequency differed depending on the length of record period; significant upward trends were found for the last 60 years, while downward ones for the last 40 years. We thus conclude that more extreme although perhaps less frequent floods are now likely to occur, with a shift in the seasonality, decreasing flood magnitudes in winter and increasing during autumn and spring. This study has gone further, attempting to elucidate how inter-decadal flood variability manifests and how this influences short-term trends. The identification of the factors contributing to the occurrence of flood events and their potential changes is valuable to enhance the flood management in the region and to improve the resilience of the population in this mountainous area.
MODELLING OF OUTBURST FLOOD HYDROGRAPHS

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Lake outburst floods (LOFs) are a global threat in areas of high altitude and along riversides. Hence the reliable and applicable prediction of future outburst floods is a valuable tool in the field of hazard estimation. The forecast of dam failures is possible through a variety of models today. However, their use for hazard estimation in remote mountain areas in case of an impending LOF is strongly limited due to the time intensive collection of numerous modelling parameters and a high dependency on boundary conditions that cannot be validated. This situation limits the application of dam failure modelling. Approaches of peak discharge estimation by \( Q = f(V) \) based on lake volume \( V \) are frequently developed on different data bases. Regarding this, the rise and recession of the flood wave i.e. the hydrograph is not considered. In conclusion some kind of reliable and easy applicable rule of thumb is needed for the LOF hazard estimation.

Here we present hydrographs itself based on historic observations. 561 publications were reviewed for the collection of 68 outburst flood events from naturally dammed lakes that had been quantitatively observed in mountain areas worldwide. These events were either described by a flood hydrograph or at least by the peak discharge and duration of the event. LOFs that were only modelled (even based on an actual outburst) were not taken into account. Begin and ending of the particular flood events were set and the baseflow was removed to emphasize the flood alone. The flood hydrographs were then normalised by converting the maximum discharge and total time of the flood event to one hundred percent and the remaining values were set in relation to that. An array of curves could now be compiled from the normalized hydrographs.

The aim of this investigation was to detect general patterns in LOF hydrographs for the prediction of future outburst floods. Potential or typical flood hydrographs are described in literature e.g. TWEED & RUSSEL (1999) or BJORNSON (2002). Our findings suggest that there are no distinct patterns for the investigated 68 outburst flood events. However, the normalized hydrographs were only considered qualitatively so far. Some regularity could be found after sorting the events by the type of dam and/or type of dam breaching mechanism. Five classes were build which consist of three types of dams and two breaching mechanisms: earthen landslide or moraine dams, ice dams and volcanic activity under ice (regarded as ‘dam’), respectively overtopping or subglacial flow and seeping. The different hydrograph patterns are found to be less significant than characterised in previous publications.

References:


HISTORICAL WATER-QUALITY MEASUREMENTS DURING LOW-FLOW EVENTS
– EXAMPLES FROM THE RIVERS ELBE AND RHINE

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For the information system Undine (http://undine.bafg.de) hydro-meteorological, hydrological and water quality data about low-flow events in large German rivers were collected. First records of quantitative physico-chemical river-water analyses date back to the 18th century. Early regular institutional examinations of waters began in the 1870s and continued for years or even for decades. We concentrate on extreme low-flow events in the rivers Elbe and Rhine in the first quarter of the 20th century, especially during the dry year 1921. To contrast these events, the variations of streamflow and of selected water-quality parameters at different sites along the rivers are shown. The water quality during the events is compared with the historical pollution levels and with the situation in the dry year 2003.

In the considered time period, the only coincidental extreme low-flow event in both the rivers Rhine and Elbe occurred in the year 1921. Low-flow events usually go along with extraordinary conditions of water quality. In the beginning of the 20th century monitoring by municipal waterworks was an important source of water-quality data, providing information for instance about oxidability, hardness, chloride, and sulphate. Oxygen content, degradation processes and concentrations of salt and pollutants are closely related to anthropogenic uses of waters.
THE SCALE AND RANGE OF PLEISTOCENE GLACIAL FLOODS IN POMERANIA (NW POLAND)

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Background: A glacial surge is one of the phenomena that generate extreme runoff of glacial water. They result from rapid recanalization of the subglacial drainage system manifesting in the outburst flood in the forefield. The increased dynamics of the surging glacier and flood water lead to creation of the relief with landform complexes characteristic of the marginal zone, specific both for the active and quiescent phase of the surge. Analogous complexes were also recognized in Pomerania (Szafraniec, 2013). Therefore an attempt was made to determine the scale of the maximum discharges of outburst floods during the glacial-interglacial transition period, and to determine the zones influenced by the extreme flows on the basis of geomorphological evidences. Method: The range of the areas subjected to flooding has been outlined on the basis of the relief intensity coefficient of sandar (Szafraniec, 2013). In turn, discharges have been estimated basing on the morphometric parameters and calculated hydraulic parameters for cross sections of gorges within terminal moraines. They have been presumed as the subglacial tunnels outlets. The presence of tunnel valleys deep-rooted in the proximal slopes of the terminal moraines ridge, and the presence of extensive sandur fans in the forefield – on the extension of the gorges outlets, have been additional assumptions.

Results: The calculations have been made for 168 gorges within the terminal moraines of the maximum range of the Pomeranian phase of the Weichselian glaciation and subsequent oscillations. The scale of the maximum possible discharges has been estimated to be $5 \times 10^3$ to $10^5$ m$^3$ s$^{-1}$. There have been also considered variants related to the phase of the gorge development – for initial phase when the glacier margin was in contact with the terminal moraines (close to the estimated values), and for the phase of recession, when the ice sheet margin might be in some distance from the terminal moraine ($10-15\%$ of the estimated value). The areas subjected to extreme discharges have been determined on the basis of the low-value of the relief intensity factor (below 6) for sandur areas, characteristic of the landforms shaped by flowing water (e.g. river valleys). The Gwda sandur in the central part of Pomerania is an example of such an area. Conclusion: The morphometry of the marginal zone landforms and their spatial relationships provides valuable information on the state of the ice sheet dynamics at the end of the Weichselian glaciation. It also confirms the presence of huge amounts of meltwater during the Pleistocene-Holocene transition period. They induced an increase in the dynamics of outlet lobes, as evidenced by the geomorphological conditions. The model of deglaciation processes in the conditions of present-day climate changes is an important analogy allowing better understanding of the mechanisms of the ice cover evolution regardless of the geological epoch.


Hydrological extreme events in historic and prehistoric times – HEX 2014, Bonn (Germany), June 9-15, 2014
THE FLOODINGS OF 1342 IN CENTRAL EUROPE

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Background: The knowledge about historical flood extremes provides useful information for the reconstruction of flood occurrences and for the climate of the past. The study takes aim at the compilation of detailed information about two historical flood extremes in 1342 in order to provide a better basis for further studies. One of the biggest known floods in Central Europe happened in the summer of the year 1342 and has been chosen as the main object of investigation in this study.

Results: Widespread rainfalls in July 1342 were producing an extraordinary flood in several Central European river catchments - this event became generally known as the Maria-Magdalena-flooding of 1342. Its intensity, damages and further impacts were discussed by different scientists. In the archives, information on a second, less known flooding in Central Europe can be found. It occurred in February of the same year and in different regions than the summer flood. A clear distinction among those two disastrous floods must and can be made. The main problem of reconstructing historical flood events is the often limited disposability of data sets. Data are collected and analysed from different archives on the basis of written and epigraphic sources. The applied methods are source criticism and flood estimation, which are combined within an interdisciplinary research.