Hydrological EXtreme Events in Changing Climate: The HEX Events project

Funded by INQUA: Project 1120

Gerardo BENITO[1], Mark G. MACKLIN[2], Kim M. COHEN[3], Juergen HERGET[4]

[1]*Museo Nacional de Ciencias Naturales, CSIC, Serrano 115 bis, 28006 Madrid, Spain (benito@mncn.csic.es).*
[2]*Institute of Geography and Earth Sciences, Aberystwyth University, Aberystwyth, U.K. (mvm@aber.ac.uk)*
[3]*Faculty of Geosciences, Utrecht University, The Netherlands* (k.m.cohen@uu.nl).
[4]*Department of Geography, University of Bonn, Germany* (herget@giub.uni-bonn.de).

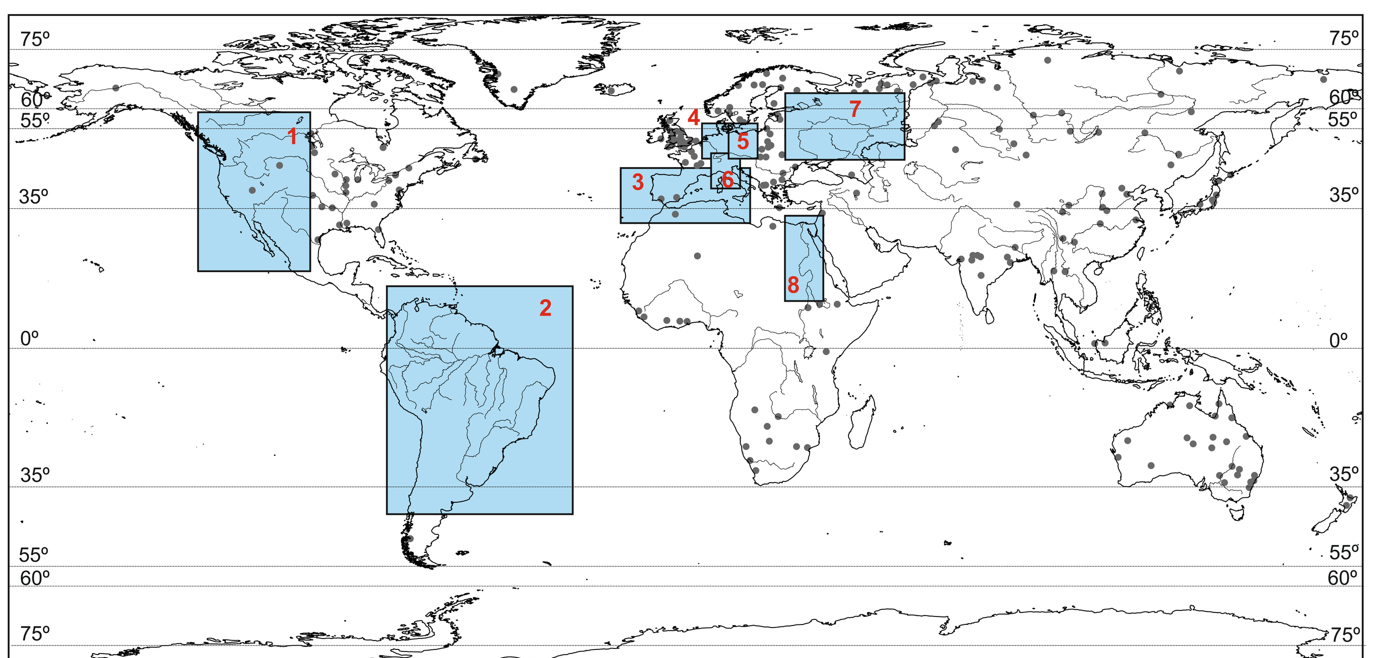
INTRODUCTION

Chronological control of Late Pleistocene and Holocene fluvial archives has much improved during the past decades, and this is renewing their use in order to improve records of extreme hydrological events worldwide. A extreme hydrological event is here defined in the sense given by Gregroy et al., (2006), meaning any past process or phenomena related to the hydrological cycle (e.g. rainfall, runoff, snowmelt, flood, water recharge) with a magnitude higher/lower than the mean and probably above or below a critical threshold. An hydrological event may relate to periods ranging from minutes, up to several years (for the case of droughts); clustering of events with higher or lower frequency is analysed

The INQUA funded HEX Events project aims to combine extended regional records of hydrological events (above average stream flow and discrete flood events) from multiple proxies and to establish in-phase and out-of-phase periods of hydrological activity in response to climate and atmospheric circulation variability.

The project approach is based on combined meta-analysis of large sets of dates (C-14, OSL, IRSL) from diverse fluvial contexts, allowing series of fluvial activity periods to be more objectively defined, and to better facilitate their characterization in terms of forcing hydrological conditions (climate or human changes).

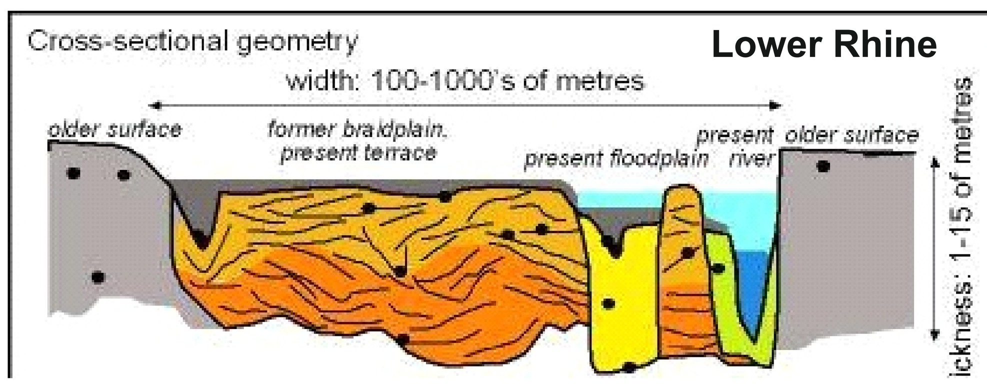
STUDY REGIONS



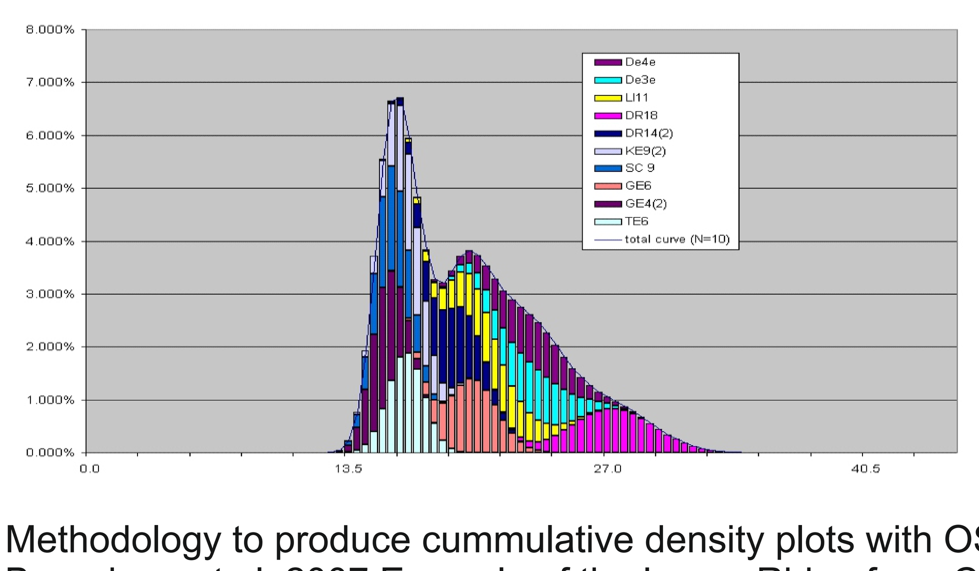
At this stage, the HEX project has established the bases for addressing this standardised methodology on eight target zones. In brackets are named the scientists contributing at each region. Papers will be published in Catena Sp.Issue:
(1) North America, Central and Pacific coast) (Harden, Godaire, Klinger, and Levish)
(2) South America (Latrubesse et al.)
(3) Mediterranean region (Benito, Macklin, and Zielhofer)
(4) Lower Rhine (Toonen and Cohen)
(5) Central Europe (Herget et al)
(6) Northern Italy (Rossato, Fontana, Mozzi)
(7) European Russia (Panin, and Matlakhova)
(8) Nile River basin (Macklin et al)

WHY TO COMBINE SPOT AGE DATES FROM FLUVIAL RECORDS?

The alluvial record is the "poor cousin" of the family of proxy records used on palaeoclimate research. Thy are usually criticised by being discontinuous records due to its poor preservation. However, alluvial deposits are good markers of palaeohydrological changes (water/sediment fluxes) in response to basin's intrinsic or external drivers. Chronological control of deposition has been a major drawback in reconstructing these changes. By using combined spotty age datings at regional scale, a "continuous" (conditioned by preservation) long-term palaeohydrological record can be obtained using a standardise methodology.



Sample	age	std.dev
TE6	16.3	0.9
GE4(2)	**15.2**	**0.8**
GE6	**19.7**	**1.3**
SC 9	15.6	0.9
KE9(2)	**16.4**	**1.0**
DR14(2)	18.7	1.2
DR18	27.0	2.2
LI11	**20.7**	**1.9**
De3*	22.9	1.9
De4*	22.8	2.0



PDF of regional unit

Median age	**18.9**
1-s range	**15.5 – 23.9**
2-s range	**14.2 – 28.7**

Methodology to produce cummulative density plots with OSL datings developed for Busschers et al. 2007.Example of the Lower Rhine from Cohen et al., 2009

METHODOLOGY

. The methodology is based on Lewin et al., (2005) and Macklin et al., (2006) approach that combines multiple radiocarbon datings marking stratigraphic changes in different fluvial environments, river drainage basins and countries. The methodology follows these major steps:

1.- Building a database: All published and unpublished dated Holocene fluvial units (C-14, OSL, IRSL, etc) are collected and assembled into a database. Information on drainage basin area, depositional environment and type of material used for dating.

2.- Dates which coincided with an abrupt modification in sedimentation style or rate (change_ dates) were also identified.

3.- Long-term records of extreme hydrological events are reconstructed using the frequency distributions of all change dates. Dates were calibrated and then for each region plotted as cumulative probability density functions (CPDFs) in OxCal (Bronk Ramsey, 2001). A correction to account for plateau and peaks of the radiocarbon calibration curve (INTCAL98; Stuiver et al., 1998) was applied following Macklin et al., 2006; Hoffman et al., (2008) and Cohen et al., 2009.

4.- Changes in the height of the PDCs over the Holocene are interpreted to reflect variations in the occurrence of extreme hydrological events. Multi-centennial deviations above, or below, the zero point on the PDCs represent extended periods during which flood units are more common (indicative of major flooding episodes), or when they are rare or absent (phases when large floods occurred very infrequently or when conditions did not favour the preservation of flood sediments).

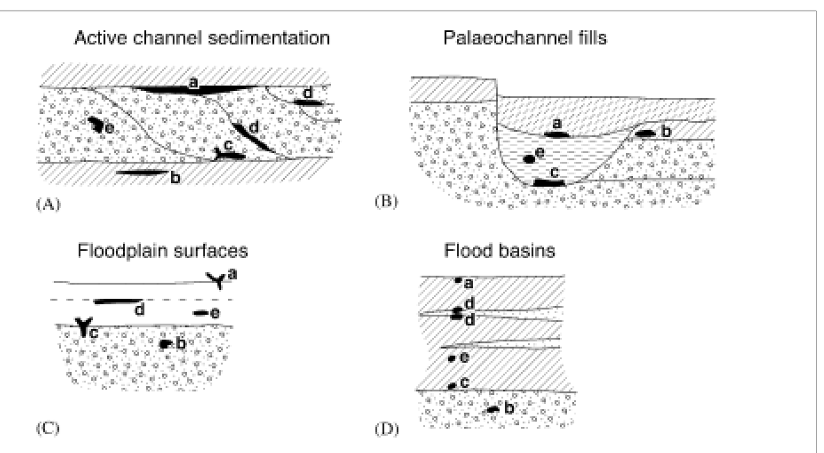
5.- Finally, results of identical PDC-based analyses are evaluate in terms of the degree to which the palaeohydrological records of the different regions record of climate and/or environmental change (global or regional changes), and in-phase and out-of-phase periods of change.

THE SEDIMENTARY CONTEXT OF DATED MATERIAL IN ALLUVIAL UNITS

Depositional Environment	Characteristics
Active channel sedimentation	Gravel facies resulting from migrating rivers (e.g. point bars and river bed aggradation
Palaeochannel deposits	Fine grained sediments or organic deposits infilling abandoned river channels
Alluvial floodplains	Fine-grained alluvial sediments caused by overbank sedimentation during floods
Flood basin sediments	Organic-rich silts and clays formed in paludal-type environments
Slackwater flood deposits	Fine-grained sediments produced by large magnitude floods, preserved in valley side rock shelters in bedrock gorge reaches

Sedimentary context	Characteristics
Change dates	The radiocarbon sample was taken from the base of an alluvial sequence; a sedimentary contact between different sedimentary facies; or an individual slackwater flood deposit
Mid-point dates	The radiocarbon sample was taken from the middle of an alluvial sequence
Bracketing dates	In multiple dated sequences, the oldest and youngest dates bracket the period of fluvial activity e.g. alluviation or a sequence of un-dated slacwater flood deposits

Thorndycraft and Benito, 2006

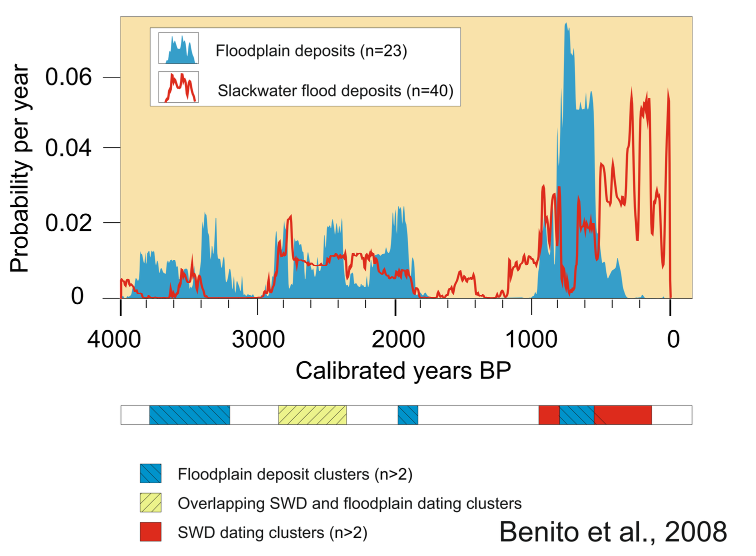


a in unit above, giving min. age (may include in situ growth)
b in unit below, giving max. age
c at base within unit (including in situ growth and floated and re-eroded timbers)
d marking change within unit
e within unit (giving 'floating' date)

Lewin et al., 2005

Dated materials come from a variety of contexts in relation to alluvial units (Lewin et al., 2005).
They may relate to the termination (a) or onset (b)/(c) of unit formation, or mark a change in sedimentation (e.g. in texture) within a unit (d). Whilst it appears from the literature that researchers have in practice tended to attempt dating at hiatuses of one kind or another, many dates nonetheless 'float' within sedimentary bodies which were actively accumulating over long periods of time (e).

UNDERSTANDING THE FLUVIAL RESPONSE TO CLIMATE & ENVIRONMENTAL CHANGES

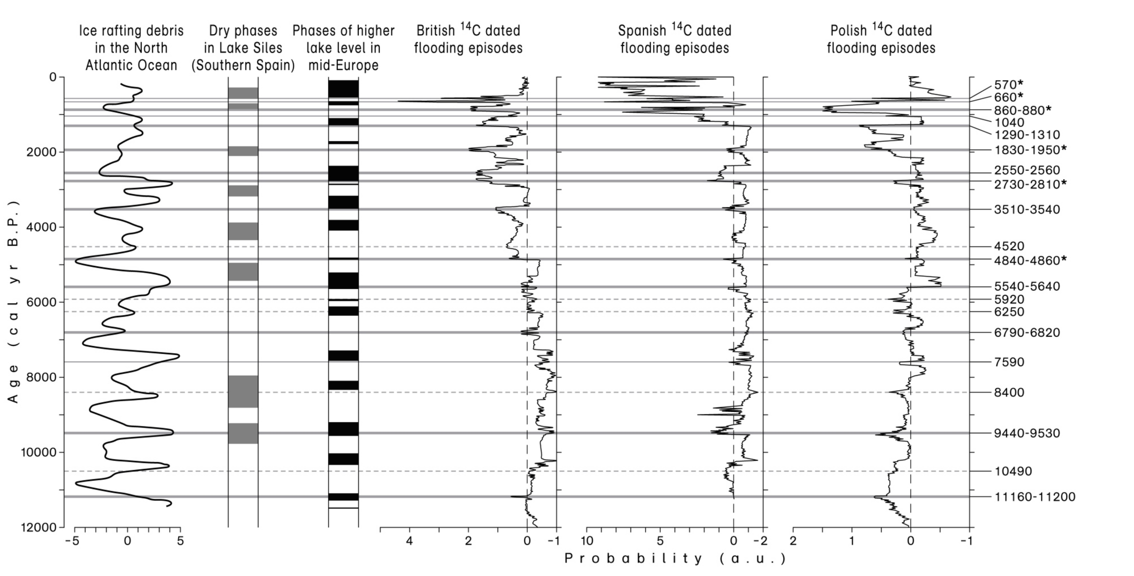


Benito et al., 2008

Increased flood activity in Late Holocene in Spain based on PDCs of C-14 dates: (1) 4820-4440 BP; (4) 2850-2350 BP; (5) 960-790 BP; (6) 520-290 BP.

Floodplain aggradation at 2710-2320 is in phase with timing of SWD indicating a climate driven aggradation phase.

The aggradation phase at 910-500 BP occurred in between SWD clusters, with recognised major role human impact (deforestation, agriculture).



Macklin et al., 2006

PDCs of 14C dates associated with major flooding episodes in Great Britain, Spain and Poland plotted alongside the North Atlantic IRD record (Bond et al., 2001) and hydrological records from lakes in southern Spain and mid-Europe. Episodes of European flooding are listed on the right-hand axis and episodes occurring in all three study regions are denoted with an asterisk (after Macklin et al., 2006).

CONCLUSIONS

1. Meta databases of alluvial dates can identify periods of heightened or changing alluvial activity, likely to reflect phases of increased hydrological events frequency and magnitude.
2. This analysis increases the length of extreme hydrological events at regional scales, that improves our understanding of sediment dynamics and channel behaviour.
3. Temporal changes on extreme hydrological events can be compared to their controls by linking sedimentological and geomorphological records to environmental, hydrological or climatic conditions.
4. The spatial comparation of PDCs is able to establishing links across regions of detectable phases in the palaeohydrology or temporal sediment budget sequence, looking for generalised impacts of climate and/or human impacts in the environment.

REFERENCES

Benito, G., Thorndycraft V.R., Rico M., Sánchez-Moya Y., Sopeña A. (2008). Palaeoflood and floodplain records from Spain: Evidence for long-term climate variability and environmental changes. Geomorphology, 101, 68–77.
Bronk Ramsey, C., 2001. Development of the radiocarbon program OxCal. Radiocarbon 43, 355– 363.eferences
Bond, G. et al., 2001. Persistent solar influence on North Atlantic Holocene and glacial climates. Science 294, 2130-2136.
Busschers, F.S., C. Kasse, R.T. Van Balen, J. Vandenberghe, K.M. Cohen, H.J.T. Weerts, J. Wallinga, C. Johns, P. Cleveringa &, F.P.M. Bunnik (2007). Late Pleistocene evolution of the Rhine in the southern North-Sea Basin: imprints of climate change, sea-level oscillations and glacio-isostacy. Quaternary Science Reviews 26, 3216-3248,
Cohen, K.M.; Wallinga, J.; Busschers, F.S.; Hoek, W.Z.; Kasse, C.; Jones, A.; Rhodes, E.; Macklin, M.G., Benito, G. (2009). Regional database of Lower Rhine OSL dates in sedimentary context: Can we unravel preservation and sampling bias from climatic depositional overprints?. International Association of Sedimentologist meeting, Alghero 2009, Italy.
Gregory, K .J., Benito, G., Dikau, R., Golosov, V., Johnstone, E. C., Jones, J.A.A., Macklin, M. G., Parsons, A.J., Passmore, D. G., Poesen, J., Soja, R., Starkel, L., Thorndycraft, V. R. and Walling, D. E. (2006). Past hydrological events and global change. HPTODAY in Hydrological Processes 20, 199-204.
Hoffmann, T., Lang, A. and Dikau, R. (2008). Holocene river activity: analysing 14C-dated fluvial and colluvial sediments from Germany. In: Quaternary Science Reviews, 27: 2031-2040.
Lewin, J., Macklin, M.G., Johnstone, E., 2005. Interpreting alluvial archives: sedimentological factors in the British Holocene fluvial record. Quaternary Science Reviews, 24, 1873–1889.
Macklin M.G.; Benito G.; Gregory K.J.; Johnstone E.; Lewin J.; Soja, R.; Starkel, L. and Thorndycraft V.R. (2006). Past Hydrological events reflected in the Holocene fluvial history of Europe. Catena, 66 (1-2), 145-154.
Macklin, M. G. and Lewin J. (2008). Alluvial responses to the changing Earth system. Earth Surface Processes and Landforms33, 1374–1395.
Macklin, M.G. and Lewin, J. (2003). River sediments, great floods and centennial-scale climate change. Journal of Quaternary Science 18(2), 101-105.
Starkel, L., Soja, R. and Michczynska, D.J., (2006). Past hydrological events reflected in Holocene history of Polish rivers. Catena 66, 24-33.
Stuiver, M., Reimer, P.J., Bard, E., Beck, J.W., Burr, G.S., Hughen, K.A., Kromer, B., McCormac, G., van der Plicht, J., Spurk, M., 1998. INTCAL98 radiocarbon age calibration, 24000– 0 cal BP. Radiocarbon 40, 1041– 1083.
Thorndycraft V.R. and Benito G. (2006). Late Holocene fluvial chronology of Spain: the role of climatic variability and human impact. Catena 66, 34-41.

8th IAG International Conference on Geomorphology - August 27th to 31st, 2013