PAGES Floods Working Group

For an improvement of our flood knowledge through paleodata

PAGES Floods Working Group

PAGES (Past Global Changes) and Floods Working Group

PAGES (Past Global Changes) was founded in 1991 by the US and Swiss National Science Foundations. Since 2016, PAGES is funded by the US National Science Foundation and the Swiss Academy of Sciences. PAGES is also supported in-kind by the University of Bern (Switzerland).

PAGES is a core project of the global sustainability science program Future Earth, and was previously a core project of the International Geosphere-Biosphere Programme (IGBP) until its closure at the end of 2015. PAGES has also a scientific partnership with the World Climate Research Programme (WCRP).

PAGES supports research which aims to understand the Earth's past environment to obtain better predictions of future climate and environment, and inform strategies for sustainability. International and interdisciplinary collaborations are encouraged. Over 5000 scientists from more than 125 countries currently subscribe to PAGES.

The **PAGES Floods Working Group** (FWG) was founded in 2015 for a period of three years (2015-2018, extendable). FWG aims to bring together all the scientific communities reconstructing past floods (historians, geologists, geographers, etc.) and those studying current and future floods (hydrologists, modelers, statisticians, etc.) to coordinate, synthesize and promote data and results on the natural variability of floods. **The overall goals** of the FWG are:

i) Providing regional to global analyses of the natural flood variability with a particular focus on the most extreme events,
ii) Promoting and disseminating historical and paleoflood science data at different levels, i.e. academic, engineers and stakeholders.

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EXECUTIVE SUMMARY

This document aims to define the Strategy and Research Plan for the **PAGES Floods Working Group** for the coming years. It has been facilitated by the 'Cross community workshop on past flood variability' in Grenoble (2016) and the FWG Annual Meeting in Zaragoza (2017). Throughout this document we refer to **paleofloods** as any past flood events documented by historical or natural archives.

The **PAGES Floods Working Group** (FWG, 2015-2018) aims to coordinate, synthesize and promote data and results on the natural variability of paleofloods with the following **overall goals:**

i) to provide regional to global analyses of the natural flood variability with a particular focus on the most extreme events,

ii) to promote and disseminate historical and paleoflood science and data at different levels, i.e. academic, engineers and stakeholders.

To reach these goals, the Working Group has been structured in three **Work Packages** (WP):

WP1 - Collecting, storing and sharing worldwide paleoflood data

WP2 - Integrating and analyzing paleoflood data

WP3 - Communicating and disseminating paleoflood science and data at different levels, including stakeholders

For each WP, key actions have been identified to enable significant progresses in the field and associated deliverables are expected in the coming year(s). WP coordinators are committed to stimulate and organize activities to fulfil these objectives. In particular, workshops and sessions in conferences will be organized to facilitate progress of WP activities.

Introduction

Floods are among the most destructive natural hazards causing widespread loss of life, damage to infrastructure and economic deprivation. Accurate knowledge about their future trends (hazard) and related impacts on society and ecosystems (risk) is therefore crucial for the sustainable development of societies worldwide through effective adaptation planning. Ongoing climate warming is expected to lead to an intensification of the hydrological cycle and to a modification of the frequency and magnitude of hydro-meteorological extreme events. However, climate projections of the occurrence of precipitation extremes and related floods are still highly uncertain because of i) the complexity in precipitation pattern variations at a regional scale and ii) a limited temporal and spatial coverage of instrumental data capturing floods.

To extend our knowledge of the flood variability (recurrence and magnitude) in time and space, different approaches based on evidences from the field (e.g. historical or natural archives like historical documents, fluvial, lacustrine and marine sediments, tree rings or speleothems) have been intensively developed over the last years to decades (Fig. 1). So far, the different communities (e.g. historians, geologists, geographers, etc.) have worked mostly independently. Because of the growing issue of the flood risk in the contexts of climate change and population growth, it appeared timely to coordinate efforts to collect, store and share existing data (WP1) with the global community as well as developing methods for producing accurate paleoflood series that will enable regional to global analysis (WP2). The FWG also aims to provide an ideal platform to promote collaboration with other key communities like hydrologists, statisticians and modellers to perform analyses of the large and valuable paleoflood dataset with state-of-the-art statistical and modelling tools. This effort ultimately aims to provide a more comprehensive understanding of the natural flood variability and substantially improve the reliability of flood-risk assessments (WP2).

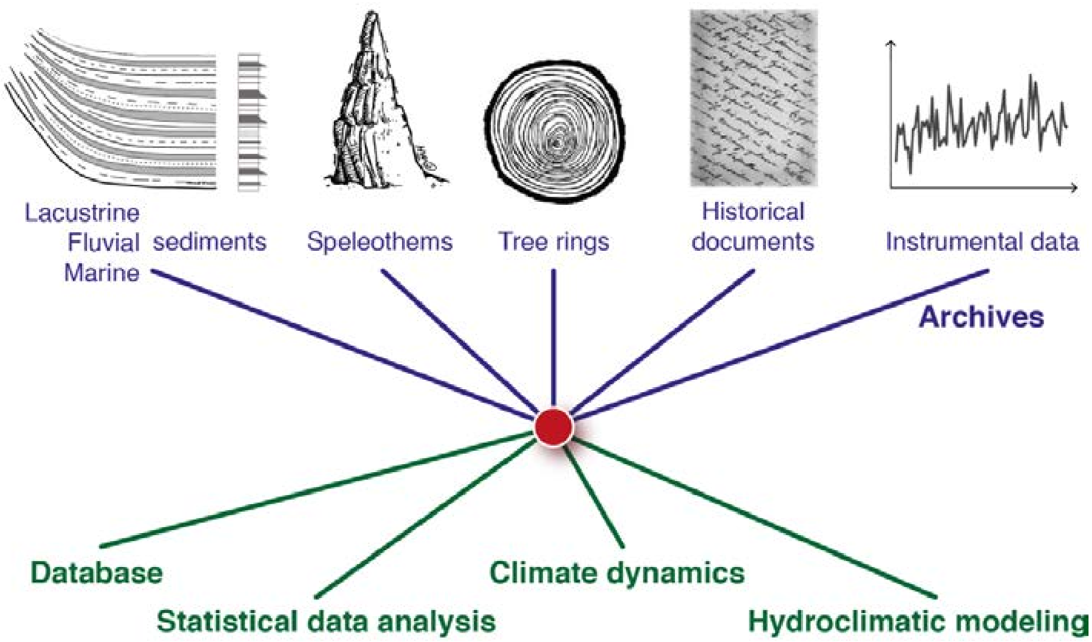

Figure 1: Schematic illustration of the concept and goals of the PAGES Floods Working Group. Data on past floods will be collected from a variety of archive types, integrated into a database, statistically analyzed, and climatically modeled and interpreted.

Over the last 40 years, the number and the quality of paleoflood data sets has substantially increased, especially the number of those concerning low- frequency large-magnitude flood events. The use of paleoflood data as a source of information on discharges associated with long-return-period flooding can provide substantial socio-economic benefits. Nevertheless, palaeoflood data is generally not effectively applied to meet planning and engineering challenges associated with risk assessment and minimisation of hazards on the ground. Therefore, the FWG's major challenge is to advocate the added value of these non-systematic records to improve hazard and risk assessments for the end-users (i.e. academic, engineers and stakeholders). A second major task will be the dissemination of data and results provided by WP1 and WP2 to both the global community and stakeholders. However, improvement to the interconnectivity of paleoflood scientists, researchers, engineers, stakeholders and end-users (WP3) is first required.

Work packages

The overall goals of the FWG are to integrate and analyze existing paleoflood data at the regional and global scales and to promote and disseminate paleoflood science and data at different levels. To reach these overall goals, FWG has been structured in three Work Packages (WP), which are described below.

WP1: Collecting, storing and sharing paleoflood data (Collaborative Flood Database)

Coordinators: Michael Kahle, Pierre Francus and Rüdiger Glaser

To the best of our knowledge, researchers have produced more than 400 historical and paleoflood records worldwide. However, this large and highly valuable data set is dispersed across different data repositories, databases and personal computers. Collecting, storing and sharing all these existing (published) data through a Collaborative Flood Database requires a collaborative effort, but the payoff will be immense. This first version of the Collaborative Flood Database will offer a single interactive access point to sort the data by record type and will allow comparison, verification and cross correlation among them. Combining data from multiple proxies with mathematical methods (e.g. numerical modelling or statistics) will then lead to an integrated product with better coverage and precision in time, space and intensity level than any single archive type could deliver alone. A single database will enable holistic insights into the causes and effects of floods, including weather conditions leading to floods and impacts on human history. This could serve as input for regional or global climate model studies (see WP2). Such a product will also allow the creation of external tools, to search for and visualize floods across geographic areas and/or time slices with extraordinary flood risk.

The challenge for a Collaborative Flood Database is to standardize the different types of archives and to assess their degrees of accuracy, while maintaining a fundamental data structure common to all archives types. Indeed, the various types of flood archives (Fig. 1) exhibits a different sensitivity to past flood events due to different environmental settings, temporal resolution, and nature of the flood proxy. The flood sensitivity of different archives may also depend on different flood characteristics (such as water height, duration, discharge, etc.). These differences result in distinct types of flood information in terms of their precision in locating an event in space and time, as well as understanding the underlying meteorological causes and impacts on societies. As a result, biases are inherent in each archive. Noise driven by other parameters, such as geomorphological changes in a watershed, can also affect the signal recorded in the archives.

Finally, the unified flood database will serve as a necessary starting point for expanding available metadata for each record. The documentation and storage of very specific metadata for each archive type is indeed fundamental to measured or observed parameters that provide palaeoflood information (width of tree-rings, dating of sediment layers by C14, quotes of historical documents, etc.). The accessibility of complete metadata for all the records in the database is important in achieving the transparency desirable in open science.

To achieve these goals, the database will be organized into five main thematic data clusters documenting the source, location, time, classification and reference of the records. In parallel, the nature of the data will be distinguished between three levels:

i) the essential and common base data required for each and every archive type (e.g. location coordinates, point in time, etc.);
ii) the optional common data available for all proxies (e.g. flood level, discharge, etc.);
iii) the optional data specific to each type of proxy (e.g. tree ring density, sediment grain size, etc.).

Actions:

i) Collect possible contributions to the paleoflood data pool – ONGOING
(Existing Flood DBs could be contacted to inform them about the LiPD enhancement)
ii) Collect parameters used inside paleoflood records across all archive types – DONE
iii) Establish a common file/data-format – PARTIALLY DONE as LiPD format will be enhanced
    - Enhance LiPD format to store inferred flood data in a common way (http://wiki.linked.earth/Category:Floods_Working_Group)
    - Enhance LiPD format to store observations from historical document archives (http://wiki.linked.earth/Category:Historical_Documents_Working_Group)
      All FWG members are invited to join the WG on Linked Earth and add feedback and/or comments there (http://wiki.linked.earth/Category:Floods_Working_Group)
iv) Develop or enhance existing tools to create LiPD files
    - Python LiPD Utilities (http://wiki.linked.earth/LiPD_Utilities)
    - LiPD Online Portal “lipidifier”
    - Export LiPD files from tambora.org
v) Collect LiPD files covering floods, i.e. upload to Linked Earth (http://wiki.linked.earth/Dataset_Tutorial)

Expected deliverables:

i) LiPD format enhanced to standardize flood related parameters as well as parameters of historical climatology/documents (see wiki for details)
ii) LiPD format is enhanced to standardize parameters of historical climatology/documents (see wiki for details)
iii) Provide tools to simplify creation of LiPD files
    - Python LiPD Utilities (http://wiki.linked.earth/LiPD_Utilities) - LiPD team
    - LiPD Online Portal “lipidifier” - LiPD team
    - Export LiPD files from tambora.org - Tambora-Team, Michael Kahle
iv) Generated LiPD files all uploaded to Linked Earth
All members with data available

WP2: Integrating and analyzing paleoflood data

Coordinators: Lothar Schulte, Manfred Mudelsee, Scott St George and Juan Carlos Peña

The integrated study of "real-world data" on past floods derived from historical and natural archives (field data) is challenging, but also provides an excellent opportunity to document the low-frequency, large-magnitude flood events that occurred under different climate regimes (cooler, warmer and transitional climate periods) and/or environmental conditions (changes in land cover, land use, and river management).

Therefore, the long-term perspective of floods is fundamental for adequate hazard and risk assessment (e.g. flood-frequency analysis). However, the only way to reliably reconstruct robust paleoflood series while accounting for various sources of uncertainty is to analyze, compare, correlate and synthesize paleoflood data. A further reason to use a variety of paleoflood data is to account for limitations in individual records. For example, ungauged catchments lack hydrological information while historical data may be sparse in remote areas with low population densities or that were recently settled, or in headwater catchments. Finally, a multi-archive approach provides the possibility to analyze the three-dimensional spatial distribution (horizontal and vertical) of flood records that best capture the physiographic and environmental diversity of a catchment.

The challenge for an accurate integration of paleoflood data relies on the following key points:

i) Dating uncertainties of the time series are important for statistical analysis of paleoflood data series.

ii) The problem of the comparability of heterogeneous catchments and landscapes, where hydrological and environmental settings are different. According to the controlling factors on processes, the system sensibility (e.g. erosion, aggradation) to climatological and hydrological extreme events is different.

iii) The correct interpretation of records that are directly involved in the physical process of flooding (e.g. sediments deposited directly by a river flood) and records that are indirect flood proxies recording climatic-environmental signals (sediments that are deposited by surface runoff in a small sub-catchment or tree rings).

iv) Due to the heterogeneous natural response of the subsystems to flood drivers, not all flood series can be integrated into a regional synthetic paleoflood master curve.

v) The criteria of selection or rejection of flood series must not only follow statistical protocols, but also consider process-based arguments. To identify "false alarms" and "missed" floods, data series should be tested by known regional hydrological extreme events that are documented by different records.

The objective of the statistical analysis of integrated paleoflood data is to infer the probability of floods across space (geography) and time (non-stationarity). The various sources of uncertainty (dating, measurement and proxy errors) must be fully accounted for in order to achieve a robust flood risk estimation with reliable error bars. Dating uncertainties can be considered by modeling the age–depth curves of the sampled archive (e.g. a lake sediment core). Measurement errors are determined based on repeat measurements of a standard. Proxy errors can be quantified by calibrations on modern, correlated data pairs (proxy and indicated flood variable) if they are clearly identifiable. These uncertainties can be integrated using Monte Carlo simulations to generate error bars for the estimation. The risk estimate and error bars result from fitting a statistical model to the observed and simulated data. The nonparametric Poisson model is suitable for analyzing the time dependence without parametric restrictions. Another parametric analysis option is extreme value distributions: the Generalized Extreme Value distribution for block extremes or the Generalized Pareto distribution for peaks-over-threshold data. Time-dependence can be formulated and estimated for each of the three parameters of the distributions. A further idea is a hybrid statistical model: nonparametric for the occurrence and parametric for the size of an event. Besides estimation, it is also possible to formulate statistical tests of the hypothesis "time-constant occurrence rate". It is helpful to analyze the same data using different methodologies while simultaneously recognizing the strengths and weaknesses of each method (in terms of estimation standard errors, robustness with regard to assumptions and in terms of test power). Parametric spatio-temporal models can be used to study the other dimensions of the problem.

Changes in external forcing and atmospheric variability in the flood variability can also be explored by paleoclimate modeling to understand past climate related to flooding, and obtain rigorous comparisons between the output from numerical simulations e.g. from the Paleoclimate Modelling Intercomparison Project and regional paleo-flood data. Furthermore, these comparisons help to predict future climate change related to flooding.

Actions:

i) Development of methodological approaches to integrate paleoflood datasets through regional pilot studies in different environments,

ii) Assessment of the contribution and improvements of flood frequency analysis using multi-archive analysis,

iii) Development of methodological and statistical approaches to analyze paleoclimate models in relation to the flood variability,

iv) Investigation of changes in external forcing and atmospheric variability of the flood periods by paleoclimate modeling.

Expected deliverables:

i) Determination of regional flood-rich and flood-poor periods of the past,

ii) Geographic characterization and mapping of hydrological extreme events,

iii) Improvements to flood-frequency analysis,

iv) Exploration of past and future changes in forcing of floods.

WP3: Communicating and disseminating paleoflood science and data

Coordinators: Victor Baker, Gerardo Benito, Juan Ballesteros and Tina Swierczynski

Paleoflood hydrology has advanced considerably over the last 40 years to become a highly relevant scientific sub-discipline that is especially effective for the documentation of low-frequency, large-magnitude flood events. The use of paleoflood data as a source of information on the discharges associated with long-return-period flooding can provide substantial socio-economic benefits. Nevertheless, there remains reluctance in the applied sector to make the most effective use of paleoflood data. This reluctance derives from real or perceived sources of error and uncertainty, including the determination of flood ages, the calculation of flood magnitudes, the non-conventional nature of flood-frequency analysis (FFA), and perceived effects of climate change and non-stationarity. The same sources of error and uncertainty characterize conventional hydrology, and these apply in both lesser and greater degrees. For example, conventional stream gauges commonly fail (generating no information) during the same kinds of extreme flood events that leave the best-preserved, long-term geological evidence of their magnitudes. In practice, real-world information on rare, extreme flooding is always preferable to the total lack of information on such phenomena, if only to correct the likely misrepresentation of such events by assumption-based extrapolation from instrumental records that are inadequate to the task.

The **challenge** is to communicate the advantages of using long-term paleoflood data for effective flood hazard analysis, while clarifying appropriate methods for dealing with any associated errors and uncertainties. It is important to communicate the used methods and facts provided by paleoflood analysis, and to make these clear to conventional hydrologists, flood engineers, decision makers, and all the relevant social actors concerned with risk from flooding.

The objectives of the WP are to plan how to:

i) disseminate information on new paleoflood methods and flood data archives, making these available to other scientists and professionals working on flood risk assessment,
ii) communicate findings at the highest levels of national and international policy-makers and,
iii) raise public awareness of paleoflood science, especially in regard to its role in achieving improved understanding of flood risk.

Actions:

i) Who are the stakeholders?
   a) Identification/Mapping of stakeholder groups who are interested in results from paleoflood science (interviewing?)
   b) Indentifying why stakeholder groups are interested in paleoflood data and which data/information is needed from scientists?
ii) What to communicate/disseminate to stakeholders?
   a) Collecting information about cross-community projects and defining appropriate terminology/concepts to communicate palaeoflood results: communication of parameters and concepts that can be understood by stakeholders and the public (e.g. flood magnitude/frequency: low, medium, and high frequency, probable maximum flood).
   b) Defining specific topics for communication to stakeholders and the public (e.g. quantification of extreme flooding for the design of high-risk entities (dams, power plants, and other critical infrastructure), understanding the potential response of flooding to climate change for planning and adaptation, direct communication of information on real floods to engage politicians, decision-makers, and the at-risk public with the motivation to deal with possible flood impacts, as opposed to confusing the same parities with a probabilistic terminology that is only understood by technical experts …)
iii) How to communicate/disseminate to stakeholders and the public (e.g. flood risk communication)?
   a) Developing a communication strategy for science and stakeholders (involve social scientists)
   b) Investigating the interest in certain formats and tools (e.g. forums, specific meetings, workshops, science briefs for stakeholders).

Expected deliverables:

i) Regular short communications about paleoflood data or examples from projects addressing different audiences (scientists, engineers, stakeholders, etc.) by showing key 'lessons learnt' and highlighting the economical 'add value' of considering non-systematic records,

ii) Talks and presentations addressing the general public and stakeholders (list on webpage),
iii) Workshop (in cooperation with social scientists): Communicating results of (paleo-) flood science,
iv) Communication strategy based on workshop results, lesson learnt and publications.

People and Expertise in the PAGES Floods Working Group

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Contributors: The list of ca. 90 contributors showing their respective expertise is regularly updated on the following web page: http://pastglobalchanges.org/ini/wg/floods/people

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