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Review papers

Documentary evidence of past floods in Europe and their utility in flood frequency estimation

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SUMMARY

This review outlines the use of documentary evidence of historical flood events in contemporary flood frequency estimation in European countries. The study shows that despite widespread consensus in the scientific literature on the utility of documentary evidence, the actual migration from academic to practical application has been limited. A detailed review of flood frequency estimation guidelines from different countries showed that the value of historical data is generally recognised, but practical methods for systematic and routine inclusion of this type of data into risk analysis are in most cases not available. Studies of historical events were identified in most countries, and good examples of national databases attempting to collate the available information were identified. The conclusion is that there is considerable potential for improving the reliability of the current flood risk assessments by harvesting the valuable information on past extreme events contained in the historical data sets.

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1. Introduction

The reliable estimation of extreme flood events is challenging, but necessary for the design and operation of vital infrastructure such as flood defences, bridges, culverts and dams, and for more general flood risk management and planning, e.g. emergency planning, flood risk mapping, and for defining flood insurance premiums. In practice, this information is obtained using flood frequency estimation techniques. Through statistical analysis of observed events, a probabilistic behaviour of flood events is inferred which is then extrapolated to provide estimates of the likely magnitude of future extreme events (e.g. the magnitude of the flood expected to be exceeded on average once every 100-year is estimated from a 40-year record). By nature, extreme flood events are rare and seldom observed locally and as a result hydrologists have little chance of gathering an adequate sample of recorded events to make confident predictions. This naturally raises the question of how best to extrapolate to extreme events, when no or only short series of recent events are available. As floods occur in almost all regions of the world, reliable flood estimation is a generic and shared problem. In Europe, the last couple of decades have witnessed a number of high-magnitude low-frequency flood events (Kundzewicz et al., 2013), causing widespread damage and destruction. But flooding in Europe is not a recent phenomenon, and there are multiple accounts of damaging flood events across the continent going back centuries (e.g., Glaser et al., 2004, 2010; Baptista et al., 2011). While the occurrence of extreme floods is a shared problem across Europe (and beyond), the lack of cross-boundary cooperation (national and regional) has lead to individual countries investing in research programmes to develop national procedures for flood frequency estimation. As a result, no standardised European approach or guidelines to flood frequency estimation exist. Where methods do exist they are often relatively simple and their ability to accurately predict the effect of environmental change (e.g. urbanisation, land-use change, river training and climate change) is unknown (Castellarin et al., 2012; Madsen et al., 2012). Also, the problem of consistent estimates of extreme floods for trans-boundary rivers is rarely considered (Pappenberger et al., 2012). The COST Action ES0901 *European procedures for flood frequency estimation* represents a novel opportunity to develop closer understanding of the methods of flood frequency employed across Europe. The Action is undertaking a pan-European comparison and evaluation of different methods available for flood frequency estimation under the various climatologic and geographic conditions found across Europe, and different levels of data availability. The availability of such procedures is crucial for the formulation of robust flood risk management strategies as required by the Directive of the European Parliament and of the Council on the Assessment and Management of Flood Risks (2007/60/EC).

Currently, flood frequency is most commonly based on systematic instrumental data, collected from established networks of gauging stations operated and maintained by a variety of station authorities/bodies across Europe. These gauging stations are of various forms and complexity depending on the level of data accuracy required. A more detailed discussion of availability, length and types of flood data records as well as procedures for flood frequency estimation procedures used across Europe is provided by Castellarin et al. (2012).

A well-known consequence of the extrapolation from short series is the high level of uncertainty associated with estimates of design floods with large return periods. For example, estimating the 100-year design flood peak from a 24-year record Stedinger and Griffis (2011) reported a factor of 4-to-1 between the upper and lower bounds of the 90% confidence interval. Given that the average record length is typically in the range 20–40 years, hydrologists have attempted to reduce the uncertainty levels by either: (i) bringing additional gauged data from nearby and comparable catchments into the analysis (e.g., Hosking and Wallis, 1997), or (ii) extending the available records by bringing flood data from before the beginning of systematic flow recording into the analysis in the form of historical and palaeoflood data (Guo and Cunnane, 1991), or (iii) using rainfall stochastic generators and rainfall–runoff models to constrain extreme flood assessment by rainfall information (e.g., Paquet et al., 2013). The three methods all have merit, but only the second is the focus of this review.

Realising the importance and utility of long-term datasets, flood hydrologists have increasingly turned their attention to historical flood information (Brázdil et al., 1999, 2006, 2012; Glaser et al., 2004, 2010; Böhm and Wetzel, 2006; Macdonald, 2006; McEwen and Werritty, 2007; Herget and Meurs, 2010; Kobold, 2011; Santos et al., 2011), and how best to incorporate documentary evidence of such historical floods into flood frequency estimation (e.g., Stedinger and Cohn, 1986; Williams and Archer, 2002; Benito et al., 2004; Gaume et al., 2010; Macdonald and Black, 2010; Gaál et al., 2010). However, the application of non-instrumental data into flood risk analysis is not new, as is evident from already existing guidance documents such as the Flood Studies Report (FSR) (NERC, 1975) in the UK, a French handbook for flood risk assessment with historical data (Miquel, 1984), the guidelines for flood frequency estimation in Germany (DVWK, 1999), and the methodological guide to implement the Floods Directive in Spain (MARM, 2011). For the purpose of this study we propose three def-