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# Characterisation of flash floods in small ungauged mountain basins of Central Spain using an integrated approach

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ABSTRACT

One of the main problems of flood hazard assessment in ungauged or poorly gauged basins is the lack of run-off data. In an attempt to overcome this problem we have combined archival records, dendrogeomorphic time series and instrumental data (daily rainfall and discharge) from four ungauged and poorly gauged mountain basins in Central Spain with the aim of reconstructing and compiling information on 41 flash flood events since the end of the 19th century. Estimation of historical discharge and the incorporation of uncertainty for the at-site and regional flood frequency analysis were performed with an empirical rainfall–runoff assessment as well as stochastic and Bayesian Markov Chain Monte Carlo (MCMC) approaches. Results for each of the ungauged basins include flood frequency, severity, seasonality and triggers (synoptic meteorological situations). The reconstructed data series clearly demonstrates how uncertainty can be reduced by including historical information, but also points to the considerable influence of different approaches on quantile estimation. This uncertainty should be taken into account when these data are used for flood risk management.



## 1. Introduction

The evaluation of floods occurring in small mountain basins requires an accurate definition of the spatial and temporal distribution of rainfall and discharge, for which an extensive network of precipitation and streamflow gauging stations is needed. However, this type of network is rarely available in mountain areas in general and in Spain in particular (Rico et al., 2001). Hence, much of the instrumental data available is from too short a period to yield reliable and representative information, thus adding considerable uncertainty to the determination of large return periods of catastrophic events (Brázdil et al., 2006). In more general terms, the consequent lack of data largely hampers the analysis of flood magnitude and frequency and calls for the application of alternative or complementary approaches.

Documentary records (such as systematic records by the government, ecclesiastical archives or newspaper reports) have been considered as an alternative source of data with respect to historical floods (Barriendos and Coeur, 2004; Benito et al., 2004). Eyewitness reports on floods in ungauged basins have also been used in the past and constitute yet another source of information in historical hydrology and palaeohydrology (Benito et al., 2003a, 2003b; Brázdil et al., 2006; Thorndycraft et al., 2006). The transformation of these qualitative data into numerical values is standard practise in studies on historical climatology or palaeohydrology (Barriendos and Coeur, 2004; Brázdil et al., 2005, 2010; Martín-Vide and Barriendos, 1995).

The most accurate source of palaeofloods is the identification of palaeostage evidence, such as flood sediments, erosional landforms, driftwood or damage to vegetation (Benito and Thorndycraft, 2005). As mountain rivers are normally characterised by high stream power and high sediment transport rates (Johnson and Warburton, 2002), resulting in a highly variable and changing morphology, flood sediments may not necessarily be either deposited or preserved. At the same time, however, mountain basins are often forested and the coarse-grained sediment and/or woody debris transported by floods may cause damages to trees. This damage will typically cause specific growth reactions in trees (i.e., dendrogeomorphology; Alestalo, 1971; Stoffel and Wilford, 2012), thus enabling past (flash) floods to be dated (Yanosky and Jarrett, 2002). The potential of dendrogeomorphic reconstructions of past events in ungauged basins

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and the value of this data for flash flood research have been demonstrated in various studies over the past few years (Ballesteros et al., 2010a, 2010b; Ballesteros Cánovas et al., 2011a, 2011b; Díez-Herrero et al., in press; Ruiz-Villanueva et al., 2010). In addition to yielding information on the frequency or spatial extent of past events, information conserved in tree-ring records also enables the reconstruction of events with at least annual and sometimes even seasonal precision (Stoffel and Bollschweiler, 2008), and may, moreover, provide information regarding river dynamics (Arbellay et al., 2012).

Based on the above considerations, this study takes into account non-instrumental data sources (tree-ring records and documents) in order to improve at-site and regional FFA in ungauged and poorly gauged mountain basins in Central Spain (Sierra de Gredos), where the lack of instrumental data (flow data) prevents the use of traditional methods for the characterisation of flash floods. In particular, the paper aims to (i) reconstruct the most complete catalogue of past flash floods in the study area, (ii) analyse their frequency, severity, seasonality and synoptic meteorological causes, as well as the human impacts in terms of damage to infrastructures and fatalities, and, in addition, (iii) address the estimation of historical peak discharge, taking into account uncertainties regarding antecedent conditions and land-use changes so that the results of this study can be incorporated into flood risk management.

## 2. Study region

The basins analysed in this study are located in the eastern Sierra de Gredos massif (Province of Avila) of the Spanish Central System and belong to the basin of the River Tiétar, a tributary of the River Tagus (Fig. 1). Geology in the region is mainly composed of granites (Upper Palaeozoic granitoids) covered by a sandy weathering mantle.

The climate of the study area is Continental Mediterranean, characterised by frequent precipitation in autumn, winter and spring stemming from Atlantic depressions from the SW, and by very dry summers (only 10% of annual precipitation) associated with the presence of the Azores anticyclone. Annual precipitation in the Pelayo basin (800 m asl) is 1913 mm.

Vegetation is abundant in the area and is dominated by *Pinus pinaster* Ait. at the headwaters and deciduous forests (*Quercus pyrenaica* Wahl. and *Quercus ilex* L.) in the lower parts of the study region. European alder (*Alnus glutinosa* L.) and narrow-leaved ash (*Fraxinus angustifolia* Vhal.) predominate in the river corridors. Tree clearance has been practised in the study areas in the past and is still being practised today.

This study focuses on two ungauged basins (those of the River Arenal at Arenas de San Pedro and the River Pelayo) and two poorly gauged basins (the Arenal downstream from Arenas de San Pedro and the River Santa Maria) in the Spanish Central System. The Pelayo

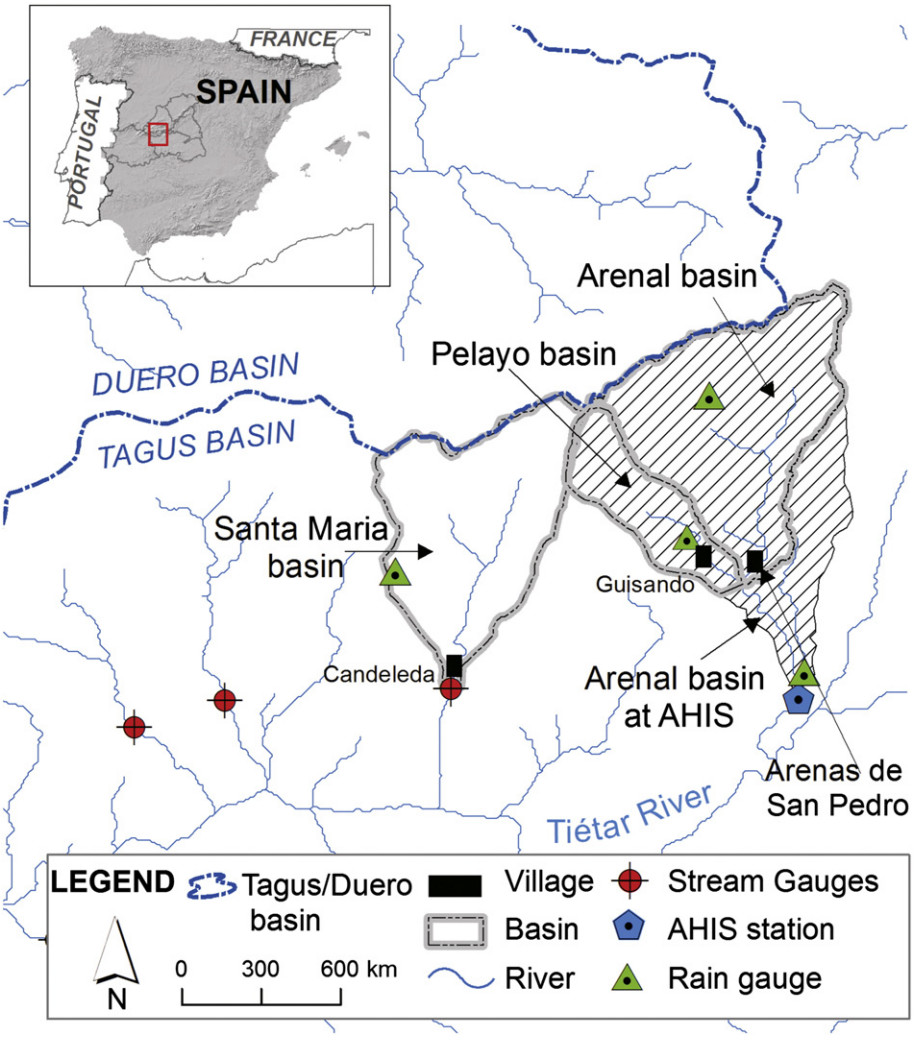


**Fig. 1.** Location of the four basins analysed: The basins of the Santa María River at Candeleda, the Pelayo at Guisando and the Arenal at Arenas de San Pedro are shown by grey dotted lines and the Arenal River basin at the AHIS station in grey stripes.