



## **Analysis of the major floods in the Ebro River basin (Iberian Peninsula) since 1600 AD**

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The magnitude and main characteristics of the major floods of the Ebro River in the last 400 years, one of the most important rivers in the Western Mediterranean, have been reconstructed at several locations along the river system. The reconstruction of each flood peak flow was possible thanks to the previous collection of historical accounts, limnimarks (flood marks) and old maps and sketches with information of flooded sections and areas. Then, for each event, an iterative hydraulic simulation method with a one-dimensional hydraulic model (HEC- RAS) was applied to a DTM of the bed and floodplain morphologies. The roughness coefficients were estimated from present and historical information. To reduce the uncertainty of the hydraulic simulation, models were calibrated with present-day, gauged flows. Nevertheless, the uncertainty of some crucial variables was also evaluated.

The Ebro flows from West to East and can, thus, be divided into two major catchments: the Western sub-basin, which gathers water from the Western Pyrenees and the Iberian Range down to Zaragoza (40,400 km<sup>2</sup>); and the Eastern sub-basin, the Segre-Cinca river system (22,800 km<sup>2</sup>), which drains the Central Pyrenees. Our objective is to reconstruct major floods in both sub-basins in order to assess how they propagated along the river down to Xerta, a village located near the outlet with a very rich flood record.

Results for the studied period (1600-2013 AD) show a total of 9 major floods that exceeded 4000 m<sup>3</sup>·s<sup>-1</sup> at Xerta. From a time point of view, a more intense flooding period is noticeable during the second half of the 19<sup>th</sup> Century, and a clear reduction appears in the second half of the 20<sup>th</sup> century due to the construction of reservoirs. The heaviest flood of this period was in October 1787, with a maximum peak discharge of 13,000 m<sup>3</sup>·s<sup>-1</sup> (0.16 m<sup>3</sup>·s<sup>-1</sup>·km<sup>-2</sup>); this value is of the same order of magnitude than the greatest floods in other Mediterranean and European rivers of similar characteristics and size (Danube at Wien, Roine at Beaulieu, Po at Pontelagoscuro). Besides, among all the analyzed events, only this episode affected the whole Ebro basin. The remaining episodes affect only one of the two sub-basins.

In the Western sub-basin floods were caused by Atlantic cyclones, while in the Eastern catchment flooding waves were related to Mediterranean rains. In the Western catchment, some precipitation events were amplified by snow melting in winter (1871, 1874, 1961). However, most of these Western floods were significantly laminated before they arrived at Xerta due to the long and winding course of the Ebro between Zaragoza and the Eastern sub-basin (more than 100 km).

In the Eastern sub-basin, floods with snowmelt occurred at the end of spring (1853). The highest flows in Xerta were caused by blocking mechanisms of cyclonic fronts on the Pyrenees during several days (1866, 1937, 1982), up to one month in extreme circumstances (1617, 1907), habitually in autumn.