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Flash flood frequency assessment from historical data in an ungauged basin: the Ondara River at Tàrrega (NE Spain)

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In the last four centuries, the Ondara River has flash-flooded several times the town of Tàrrega (NE Spain), resulting in a huge amount of deaths and damages to buildings. Indeed, from the early XVIIth Century, a minimum of six major events have occurred, in which the old-town streets have been flooded –in some cases, up to the dwellings' second floor–, commonly during night hours, with an obvious surprise factor which added to the quickness of the events. These six events happened in 1644, 1783, 1842, 1874, 1930 and 1989; the flood marks preserved in Sant Agustí Street at Tàrrega allowed the reconstruction of the peak flows.

The Ondara River catchment at Tàrrega has an area of 150 km2 and an average slope of 1,6%; there are neither gauging records nor hydraulic structures.

In order to find a relationship between magnitude and frequency of the major flash floods, a two-staged methodology was used: in the first stage, the sediment-laden peak flow of each flood was calculated; in the second one, an extreme value distribution function was fitted to those peak flows in order to assess their recurrence likelihood.

More in detail, each flash flood peak flow was reconstructed through the iterative application of a hydraulic model. The input data for each modelling were:
i) a digital terrain model of the river bed; for each flood, the topographic and the land use changes given by contemporary maps and archaeological data were taken into account
ii) the stream, floodplain and urban areas roughness coefficients (0.035, 0.04, and 0.1, respectively)
iii) the channel slope (0.0045)
iv) a tentative peak flow.

As said above, the process was iterative, trying different peak flows until the modelled maximum water level was close enough to the one known through the flood limnimarks. The hydraulic model used was the unidimensional HEC-RAS v. 4.0/2008 (USACE), applied in several cross sections of the Ondara River at Tàrrega, spaced 40-50 m in average.

Thence, the Bayliss & Reed (2001) plotting-position methodology for non-systematic data series was used to estimate the return period of each reconstructed peak flow. Finally, a type I extreme value distribution (Gumbel) was graphically fitted to these coupled values (peak flow-return period).

The reconstructed sediment-laden peak flows of the six floods and their plotting-position-derived return period were: 1600 m3s-1 and 667 years (1644 flood); 1200 m3s-1 and 239 years (1874 flood); 500 m3s-1 and 146 years (1783 flood); 250 m3s-1 and 105 years (1842, 1930 and 1989 floods).

The Gumbel distribution fitted to these coupled values gave the following expected peak flows: Q100years de 275 m3s-1, Q500years de 1500 m3s-1 and Q1000years de 2500 m3s-1. The goodness of fit, calculated with the Kolmogorov-Smirnov test for a four-sized sample (since 1842, 1930 and 1989 floods have the same magnitude) and a type I error of 1%, was accepted.

This relationship between flood magnitude and frequency for the Ondara River at Tàrrega –estimated through historical reconstruction procedures– is very different from the one calculated by the Catalan Hydraulic Authority in the Civil Protection Plan Against Flood Risk (INUNCAT) with a rainfall-discharge global modelling using maximum rainfall data series, which gives the following values: Q100years de 87 m3s-1, Q500years de 164 m3s-1 and Q1000years de 231 m3s-1.

This difference may have three explanations:

1) The type I error for rejecting the null hypothesis, that is, for rejecting the goodness of fit of the Gumbel distribution, was too low (1%)

2) Since the peak flows have been calculated with a rainfall-discharge model, the INUNCAT return periods are those of the rain depths instead of those of the peak flows; and, since the relationship between the magnitude of the rainstorm and that of its resulting flood is not bijective –unlike a rainfall-discharge modelling assumes–, the return periods are not correct.

3) The INUNCAT flows are calculated from daily rainfall data instead of hourly data; This time gap is too great to take account of the quick response of a catchment of this size and land use covers. Besides, the rainfall data series is only thirty year long.

Anyhow, since the 1000-year-return-period flow calculated for the INUNCAT have been exceeded at least six times in the last 400 years, one may positively argue that this value is not correct and suggest a more conservative flow, like the one obtained through historical flood-reconstruction methods.