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Extreme values of fluvial discharges to the Guadalquivir estuary as affected by precipitation and regulation upstream

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Freshwater input to the Guadalquivir Estuary (Southern Spain) has been affected since 1930 by a strong regulation due to the dense network of reservoirs in the catchment, ending in the Alcalá del Río dam, which closes a contributing area of 47900 km^2 and blocks the propagation of the tidal wave upstream. The Guadalquivir catchment, in a Mediterranean area, with strong annual and seasonal variability in the precipitation regime, has a large storage capacity in order to face the cyclic droughts. The result is a continuous freshwater inflow to the estuary, with a daily average value of around 10 m^3s^{-1}, and higher discharges as pulse inputs during one or some days associated with the occurrence of precipitation with higher values ($\sim$O(100 m^3s^{-1}) which, exceptionally, rise up to extreme values two orders of magnitude higher ($\sim$O(1000 m^3s^{-1}).

This work focuses on the extreme values (maximum and minimum) analyses of the fluvial discharges to the estuary since the 1930s, and quantifies the influence of the since then increasing regulation upstream on the extreme value regime. It differentiates between the atmospheric and human-induced variations from the relationship between rainfall and discharges from the dam during this 80 yr-period obtained for the different regulation stages reached since the reservoir network was begun upstream. Data available included daily average discharge from the Alcalá del Río dam, since 1931, and daily precipitation since 1945 in 14 selected weather stations along the whole catchment.

The analysis of the daily fluvial discharge from the dam for the study period, with an average value of 50 m^3s^{-1} for the 50% of the data, established three discharge regimes from the contributing area: low, with an average discharge lower than 30 m^3s^{-1}; high (flood), when the daily average discharge exceeds 50 m^3s^{-1}(10% of the data), caused by intense precipitation or discharges from other dams upstream, which may be over 2100 m^3s^{-1}(1% of the data), and, medium, between both of them. The regulation evolution can be divided into different periods: 1931-1937, almost zero; 1937-1969, with a storage capacity half the current value; 1969-1990, with storage up to 75% of the current value; and, finally, 1990-2010, where storage increases up to 8900 hm^3. The results show the expected decrease in floods as regulation was increased, with 62, 54, 33, and 19% of reduction, respectively, for the periods mentioned before, and a 99-percentile in the distribution function which falls from the initial 2800 m^3s^{-1} to a final value of 1440 m^3s^{-1}. As an example, only 30% of floods have taken place during the last twenty years when compared to the second period. Moreover, regulation increases the correlation between flood and precipitation events, since the large number of reservoirs greatly diminish peakflow values due to human operation of the dams. Thus, during 1937-1969, 49% of floods were associated with precipitation events, whereas this figure increased to 60% during the last period, 1990-2010. The extreme regulation in the catchment upstream of the estuary has led to the currently seldom high regime (flood), occurring only on 20% of the days associated with very extreme intensity/duration of rainfall. The consequences on riverine, estuarine, and littoral morphology evolution, and on ecosystems can be easily figured out and pose a threat to the sustainability of the whole estuary and area of influence.