Changes in extreme hydrological events in highly regulated river basins of Catalonia (NE Spain): discerning between climate change processes and water resources management

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1. Introduction. To understand how extreme precipitation events propagate spatially in the river basins is a high priority in the Mediterranean region, where heavy precipitation events and droughts are frequent. Nevertheless, the evolution of extreme hydrological events may be different to that observed by precipitation extremes, given strong land cover changes and/or river regulation, water management practices and water uses. In this study we analyse the evolution of extreme climate and hydrological events in the past five decades in highly regulated basins of Catalonia (NE Spain). The basins have their headwaters in the Catalan Pyrenees and they have been highly regulated by numerous dams in the second half of the twentieth century.

2. Study area

Spatial distribution of gauging stations (black squares), precipitation stations (blue circles) and reservoirs.

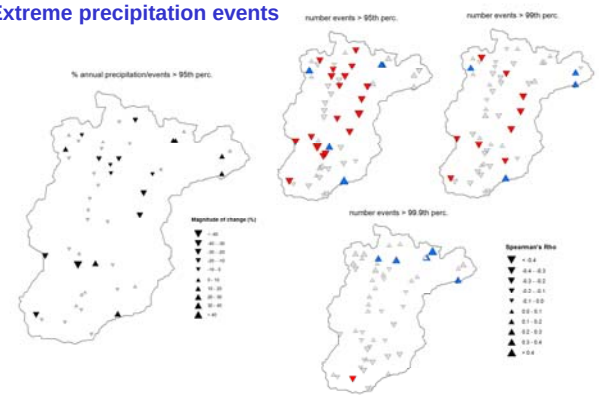
3. Data and methods

We have used daily streamflow data in eleven gauging stations from 1950 to 2013 (seven upstream and four downstream the main reservoirs). Quality controlled and homogenized daily precipitation series were available in 52 meteorological stations. Monthly precipitation and reference evapotranspiration were also available from 500 m. gridded data.

We quantified the trends in the percentage of annual precipitation and streamflow corresponding to events of high and low percentiles. We also analysed the trend in the frequency of extreme events upstream and downstream the main reservoirs.

Hydrological droughts were quantified by means of the Standardized Streamflow Index (SSI) and climatic droughts by the Standardized Precipitation Evapotranspiration Index (SPEI) at time scales from 1- to 48-months. Drought events were identified by means of a threshold approach (SPEI = 0). The annual magnitude and duration of drought events was calculated and temporal evolution and trends in hydrological and climatological droughts were compared.

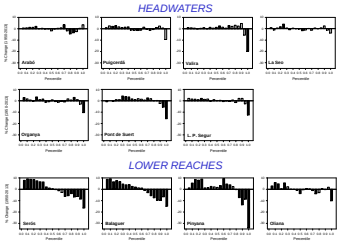
4. Extreme precipitation events



Left: Evolution of the percentage of annual precipitation corresponding to events above the 95th percentile. Right: Evolution of the number of events above 95th, 99th and 99.9th percentiles. Gray color: non-significant trends.

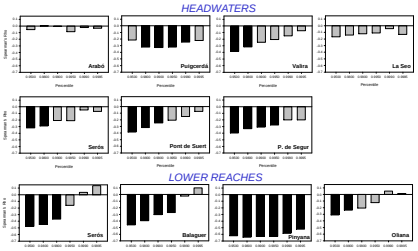
Precipitation shows a general trend toward lower magnitude of total precipitation associated to events above 95th percentile and a decreased frequency of these events. Nevertheless, the frequency of the most severe events (e.g. above 99.9th percentile) show a general increase in the headwaters.

5. High river floods

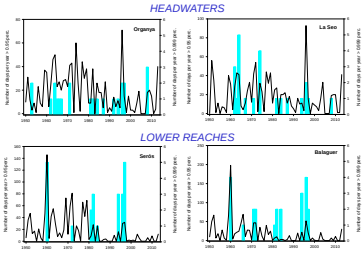


Magnitude of change in the volume of annual streamflow associated to events corresponding to different percentiles. Black columns represent significant trends.

Streamflows show a decrease in the % of annual streamflow associated to the high events (above 90th percentile), but this pattern is much more accentuated in the lower reaches, downstream the dams. Although there is a reduction in the frequency of events above 95th percentile, there are not changes in the frequency of the most extreme events (>99.5th percentile).

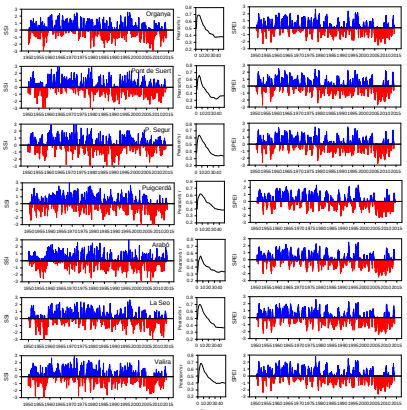


Correlation between the frequency of events above different percentiles (> 95th, >98th, > 99th, >99.5th, >99.9th and >99.95th) and the series of time. Black bars represent significant correlations.

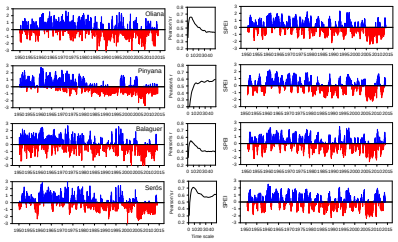


Evolution of the number of events per year above 95th (black line) and 99.9th percentile (blue bars) in two gauging stations located in the headwaters and the lower reaches.

6. Droughts



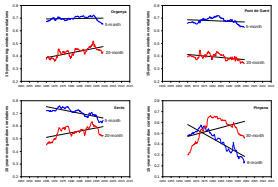
Left: temporal evolution of the SSI in the gauging stations of the headwaters. Central: Correlation between the SSI and the 1- to 48-SPEI time scales. Right: Evolution of the SPEI at time-scale with higher correlation.



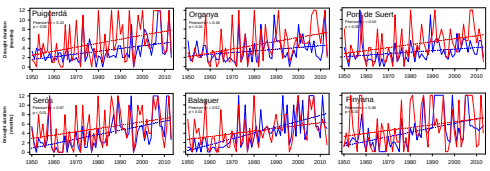
Left: temporal evolution of the SSI in the gauging stations of the lower reaches. Central: Correlation between the SSI and the 1- to 48-SPEI time scales. Right: Evolution of the SPEI at time-scale with higher correlation.

There are changes in the response of hydrological droughts to time-scales of climate droughts, although the magnitude of the changes is more important in the lower reaches than in the headwaters. The lower reaches show a trend toward a lower response to short SPEI time-scales and a higher response to long SPEI time-scales.

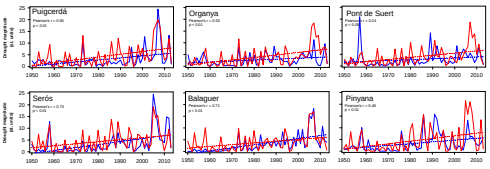
Hydrological droughts are correlated with climatic droughts at time scales between 5-8 months in the headwaters. In lower reaches the magnitude of correlations decrease and it is observed at longer SPEI time-scales. Severe drought events have been recorded in the last two decades.



Evolution of 30-year moving correlations between the SSI and short (blue) and long SPEI time scales in two observatories of the headwaters (above) and the lower reaches (below)



Evolution of annual drought duration (blue: hydrological droughts, red: climatic droughts) in three gauging stations in the headwaters and three in the lower reaches.



Evolution of annual magnitude (blue: hydrological droughts, red: climatic droughts) in three gauging stations in the headwaters and three in the lower reaches.

	Duration		Magnitude	
	SSI	SPEI	SSI	SPEI
Puigcerdà	3.3	4.0	4.8	6.1
Organya	2.1	4.0	2.2	5.5
Arabó	0.7	3.4	1.3	5.4
La Seo	0.9	3.9	0.9	5.6
Valira	3.0	3.4	3.4	5.1
Pont Suert	1.4	2.9	1.7	4.6
P. Segur	-0.5	3.0	0.2	4.4
Oliana	3.0	2.8	4.4	4.7
Serós	4.5	2.7	6.7	3.9
Pinyana	4.3	2.1	3.4	5.6
Balaguer	6.1	2.3	7.1	3.5

Magnitude of trends in drought duration and magnitude in the headwaters (blue) and lower reaches (orange). Bold: significant trends

There is a trend to higher drought duration and magnitude. Nevertheless the trend is stronger for climatic than hydrological droughts in the headwaters. The opposite is found in the lower reaches.

7. Conclusions

- There is a general decrease in the contribution of high precipitation events to total annual rainfall. This pattern is accentuated in the streamflow series, mainly in the lower reaches, which show a clear increase in the contribution of the low flows and a decrease in the contribution of high flows.
- The most extreme floods do not show a significant decrease both in the headwaters and the lower reaches.
- There is an accentuation of hydrological droughts associated to the observed evolution of climate droughts. Nevertheless, drought accentuation is much more important in the lower reaches than in the headwaters.

More information: http://medacc-life.eu/es