DOWNSTREAM ACCENTUATION OF HYDROLOGICAL ALTERATIONS BY DAMS IN HEAVILY REGULATED BASINS OF CATALONIA, SPAIN.

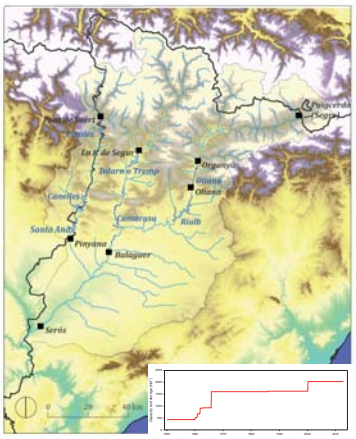
Vicente-Serrano, S.M.[1], Zabalza-Martínez, J.[1], López-Moreno, J.I.[1], Martín-Hernández, N.[1], Borràs, G.[2], Pla, E.[3], Pascual, D.[3], Serrano-Notivoli, R.[4]

[1]Instituto Pirenaico de Ecología, Consejo Superior de Investigaciones Científicas (IPE–CSIC), Zaragoza, Spain; [2]Oficina Catalana del Canvi Climàtic, Generalitat de Catalunya Barcelona, Spain, [3]Centre de Recerca Ecològica i Aplicacions Forestals (CREAF), Barcelona, Spain, [4]Estación Experimental de Aula Dei (EEAD-CSIC), Zaragoza, Spain

1. Introduction. Dams induce deep modifications to the downstream hydrology by altering the natural river regimes and often by the diversion of river flows for different water uses. In this study, we use long-term (1950-2013) river flows and climatic series to analyze the downstream cumulative effect of dams on the alteration of the natural river regimes and the disassociation between climate and runoff evolution in the Segre basin, with a drainage area of 13000 km^2. The basin has its headwaters in the Catalan Pyrenees and is highly regulated by numerous dams built in the second half of the twentieth century. River flows of the Segre basin are mostly used for irrigation.

2. Objective: Analyse changes in the availability of water resources throughout the basin and to know the interaction between climate trends and dam regulation. Long-term monthly averages of upstream and downstream sectors are compared, as well as the relation between climatic and hydrological time series.

3. Study area:



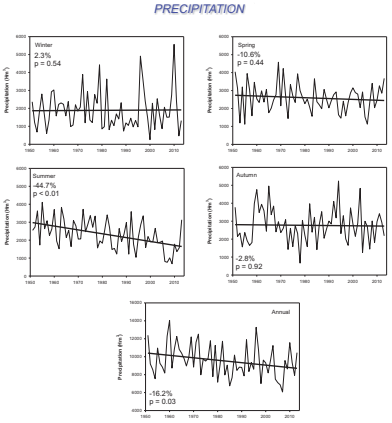
Spatial distribution of gauging stations and reservoirs. Evolution of storage capacity (red) and monthly storages in the reservoirs of the basin (blue)

We have used monthly streamflow data in eight gauging stations from 1950 to 2013 (four upstream and four downstream the main reservoirs).

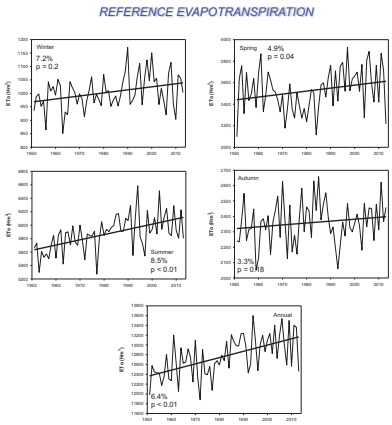
Monthly precipitation and reference evapotranspiration were quantified by means of 500 m. gridded data.

Inflows and outflows from the main reservoirs, and the average water extractions for urban and irrigation uses were also available.

4. Climate trends: General decrease of precipitation and increase of the atmospheric water demand, mainly in summer months

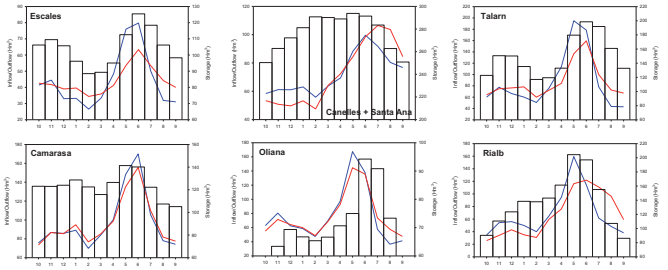


Evolution of seasonal and annual precipitation



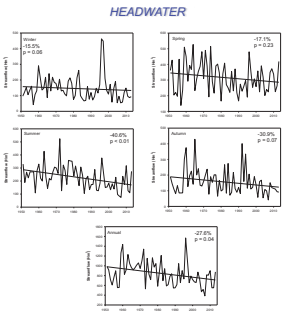
Evolution of seasonal and annual reference evapotranspiration

5. Dam influence on regimes: Alteration of the river regimes downstream the dams

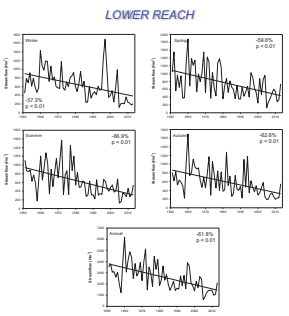


Average inflows (blue), outflows (red) and storages (white columns) in the six main reservoirs of the basin

6. Changes in streamflow: General decrease in streamflow accentuated in the mid and lower reaches of the basin

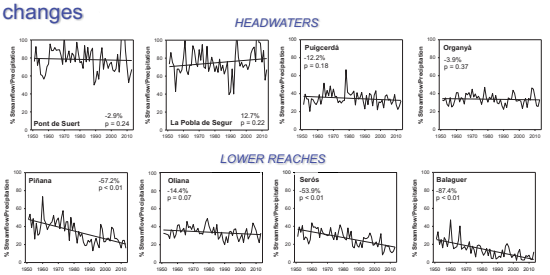


Evolution of seasonal and annual streamflow in Organyà (hedwaters)

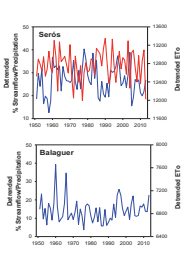


Evolution of seasonal and annual streamflow in Serós (lower reach)

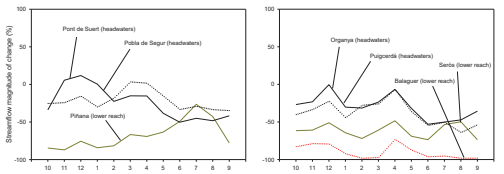
7. Changes in the climate-streamflow relationship: No changes in the headwaters. Strong decrease in the ratio precipitation/streamflow in the lower reaches. The evolution of ETo have some influence, but it can not explain these changes



Evolution of the ration between annual precipitation and annual streamflow in the headwaters and lower reaches

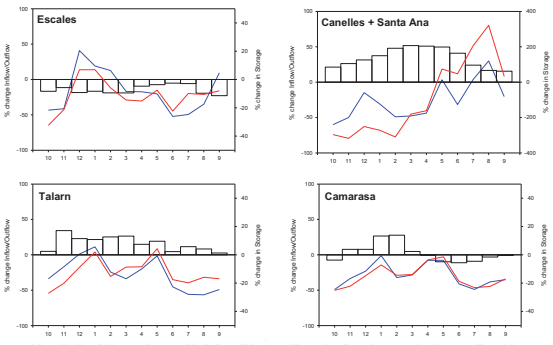


Evolution of detreded ratio stream./precip. (blue) and detreded ETo (red) in the lower reach

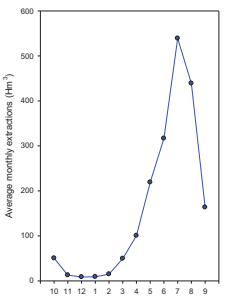


Monthly streamflow changes in different gauging stations in the headwaters and the lower reaches

8. The role of dams on trends: Dams increase reinforce streamflow negative trends in winter and reduce the magnitude of streamflow reduction in summer, but trends by water management in dams do not explain the strong streamflow trends in gauging stations downstream



Magnitude of change in monthly inflow (blue), outflows (red) and reservoir storages (bars) in four reservoirs



Average monthly water extractions for irrigation uses in the basin

9. Conclusions:

- General decrease in precipitation, mainly caused by strong decrease in summer and increase in the reference evapotranspiration.
- Dam management causes a clear alteration of river regimes, reducing and increasing streamflows downstream in winter-spring and summer, respectively.
- Streamflows have decreased in the headwaters and lower reaches, but magnitude of changes has been more important in the lower reaches.
- Streamflow decrease in the headwaters is mostly explained by climate change but climate does not explain itself the strong streamflow reduction observed in the lower reaches.
- Dam operation has affected seasonal distribution of trends in outflows, reducing the magnitude of negative trends in summer months given seasonality in dam operation.
- The magnitude of negative trends in streamflow downstream the dams is higher than that observed by dams outflows. This is explained by high water extraction from river for irrigation uses, mainly in summer months.

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