Identification of climatic and anthropogenic drivers for reduced waterflow in coastal Mediterranean rivers of southern France

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/ MOTIVATION

The aim of this work is to investigate the hydrological changes in a set of 6 Mediterranean watersheds and their linkage with both the evolutions of recent climate change and anthropogenic water use. The rivers flow from several mountaineous massives down to the Gulf of Lion. Their downstream part flows through densely populated lowlands where agriculture is an important economic activity and strongly interacts with water resources.

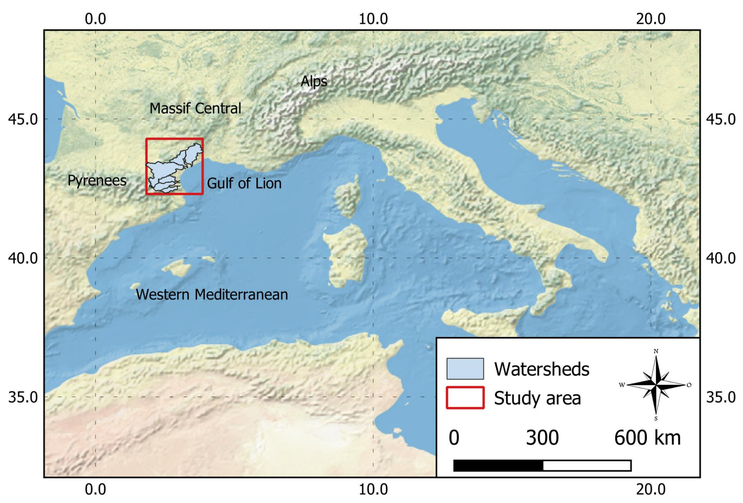


Figure 1: Location of the study area (red square) which covers six coastal watersheds (coloured in blue) flowing into the Gulf of Lion

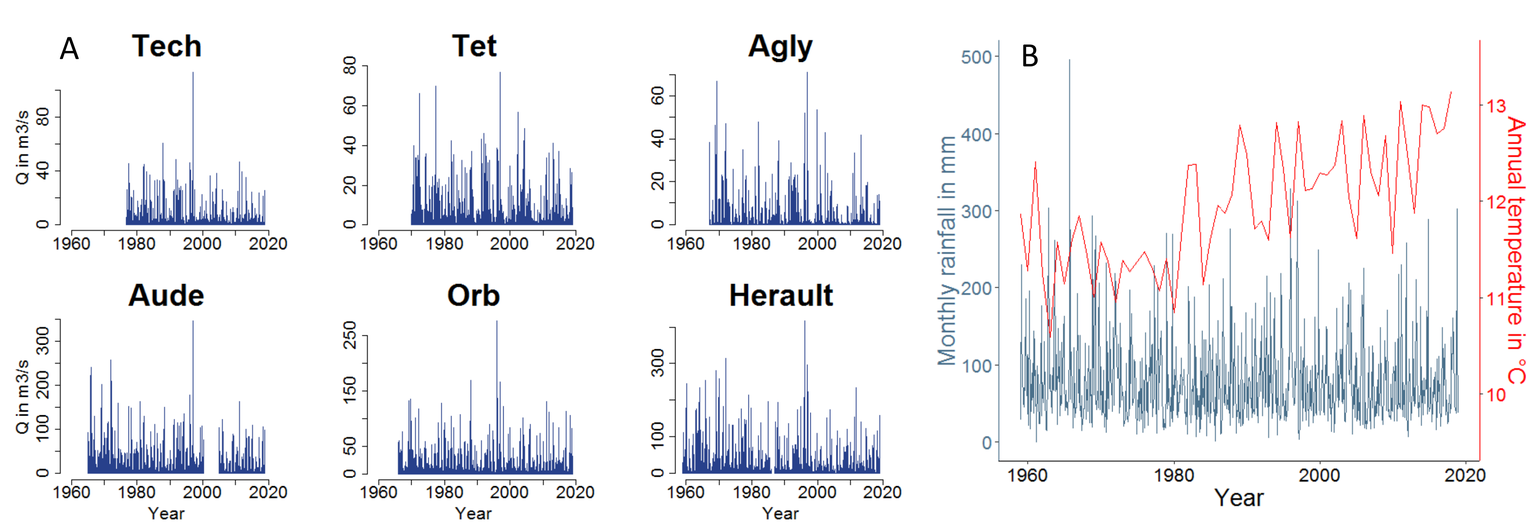


Figure 2: Daily dataset used **A.** Waterdischarge data collected from the HYDRO database hosted at the French Ministry of Environment (shown as a monthly step for each river). From the top-left corner to the bottom-right one are presented the rivers from South to North. **B.** Precipitation (blue) and temperatures (red) from the Safran atmospheric-system, provided by Meteo-France, the French meteorological survey. The data are summarized for the entire study area.

/ METHODS

- Data are provided at a daily scale. Discharge (Q) data were collected from 6 gauging stations located the most downstream on each river. Rainfall (P) and temperatures (T) are 8-km gridded data taken from the French meteorological survey. The data allowed us to reconstruct the hydroclimatic evolution through 60 years, from 1959 and up to 2018.
- At a first step, we asses the caracterization of the recent climatic and hydrologic changes by using the non-parametric Mann-Kendall test to detect linear trends.
- We then compare the evolution of waterdischarge with a drought index, the Standardized Precipitation-Evapotranspiration Index (SPEI). To make the comparison appropriate, we transformed the waterdischarge into an index called the Standardized Runoff Index (SRI).
- Drought indices and climatic variables are fitted to a linear model in order to reproduce the flow's curve and its variability. Variables used are the model of Pike (Q-Pike), the Standardized Precipitation-Evapotranspiration Index (SPEI), and a Fournier index (Four).
- Finally we also investigate anthropogenic water withdrawal through surface water extraction for irrigation. Groundwater mining is negligible compared to this form of water use and farmers are the biggest consumers of water resources.

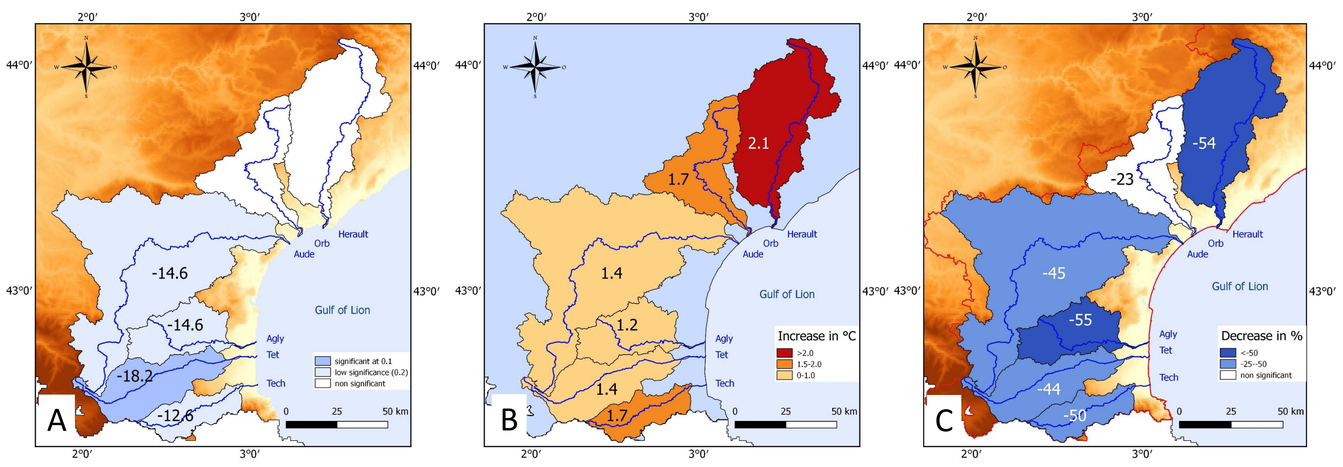


Figure 3: Recent hydroclimatic changes over the period 1959-2018 and for each watershed separately. **A.** Annual evolution of the rainfall amount (in %). **B.** Annual evolution of mean temperatures (in °C). **C.** Annual evolution of the river flow (in %)

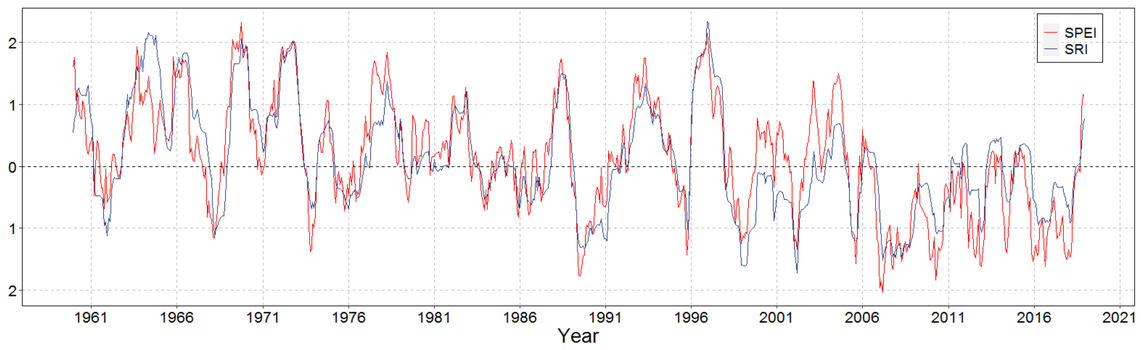


Figure 4: Temporal evolution of 12-months Standardized Precipitation-Evapotranspiration Index (SPEI) and Standardized Runoff Index (SRI) computed from our hydroclimatic dataset. The data in the plot are summarized for the entire study region (sum of all six rivers).

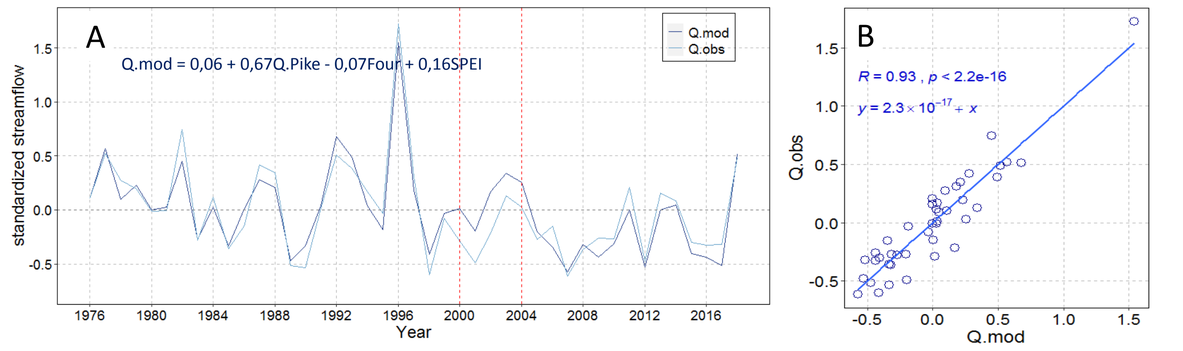
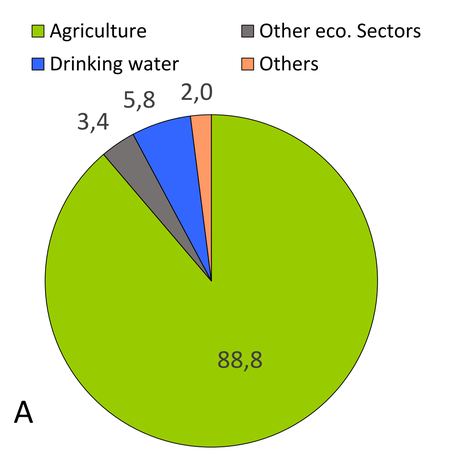


Figure 5: Reconstruction of the observed water flow (called Q.obs) in the entire study region (sum of the six rivers) in comparison with the modelled water flow (called Q.mod) from multi-regression statistics based on climatic parameters. **A.** Comparison of Q.obs and Q.mod on the period 1976-2018 (period of availability of the Q.obs). Note that for the period 2000-2004 the discharge of the Aude river is missing and **B.** Linear relationship between Q.obs and Q.mod. The following variables were retained in the model: the theoretical water discharge of Pike (1964) (Q.Pike) derived from annual values of rainfall and potential evapotranspiration, the intra-annual variability of the monthly maximum rainfall (Fournier 1960), and the Standardized Precipitation-Evapotranspiration Index over a 12-months step period (SPEI-12).



Source: Agence de l'eau Rhône-Méditerranée-Corse, version October, 2017

Year	SAU (in ha)
1970	844 812
1979	807 777
1988	762 785
2000	729 503
2010	644 083
2015	638 595
2018	640 138

C

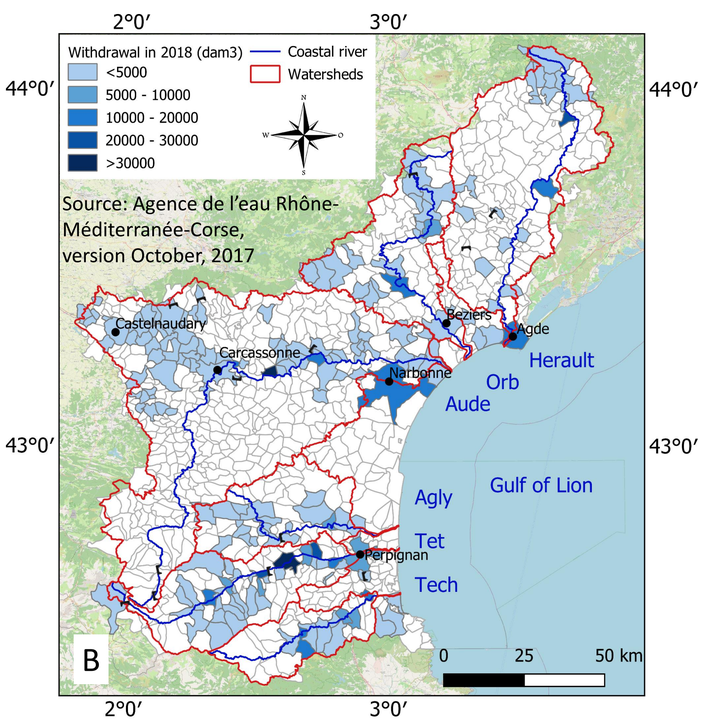


Figure 6: A. Average extraction of sufarce water per sector in % on the period 1997-2018. Note that those data were extracted by administrative area which does not fit the exact study area but a larger extent, including the next watershed situated on the eastern side of the Herault basin. Also the contribution of the hydroelectric plants is not shown. **B.** Extraction of surface water in 2018 by the agricultural sector; data are provided per municipal district. Note that water extraction from other streams than the 6 main rivers, their affluents, and canal they feed are not represented Source **A.** and **B.**: Agence de l'eau Rhône-Méditerranée-Corse, version October, 2017. **C.** Evolution of the Utilised Agricultural Area (SAU). As in **A.** the data are shown for a larger area than the 6 watersheds' extension. Source Agreste-2010 agricultural census and DRAAF Occitanie

/ RESULTS AND DISCUSSION

- Our data reveal an ongoing warming trend during the last 60 years (1959-2018) with a temperatures increase about 1.6 °C on average for the entire study area. Lowering of annual rainfall is also detected, although more located in the southern part of the study region where the Tet river basin shows a decrease about 18% during the same period. Other basins (the Agly, Aude and Tech river basins) are likely to follow this tendency in the near future.
- The strongest trends are detected for water discharge which decreased in the entire study region by about 45% on average. Both climate change and anthropogenic water extraction can be responsible for this. At first sight, climate change is indicated to be the dominant factor since decline in water discharge can be successfully modelled by climatic parameters and indices.
- The evolution of anthropogenic water withdrawal is more difficult to reconstruct. The agricultural sector which is by far the greatest water consumer is suffering from economic crisis and the overall agricultural area significantly decreased in the study region. This also implies reduced water use. On the other hand, because of increasing drought conditions, several areas depict increasing trends for water withdrawal and a general quantification of the evolution of anthropogenic water use still needs further work to be achieved.

/ REFERENCES

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