Estimating severe low flows on human-influenced catchments by combining weather generator, analogue spatial disaggregation, and hydrological modelling under historical climate

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I. Introduction

Understanding and quantifying severe low flows is crucial for the management of hydropower or thermal power plants. Moreover, low flows are strongly related to the climatic regime and will be affected by climate change. Recently, a study has shown the interest of using a weather generator combined with hydrological modelling to assess low flow values (Parey et al., 2022) on a single catchment. Therefore, we propose a modelling chain to estimate severe low flow values for several anthropogenically influenced catchments in France, under current climate.

II. Method : principle

- Daily precipitation and temperature
- Mean over France of 28 catchments
- 30 years
- 1981-2010

Bivariate weather generator based on hidden markov chain (HMM Fr)

- Daily precipitation and temperature
- Mean over France of 28 catchments
- 1000 x 30 years
- 1981-2010

Analogue disagregation and empirical copula coupling

- Daily precipitation and temperature
- 28 catchments
- 1000 x 30 years
- 1981-2010

Hydrological model (HM), propagation upstream-downstream and water management modules (WMM)

- Daily discharge and reservoir levels
- 13 power plants
- 1000 x 30 years
- 1981-2010

Comparison to discharge observations
Empirical analysis of low-flows and reservoir levels

II. Method : application

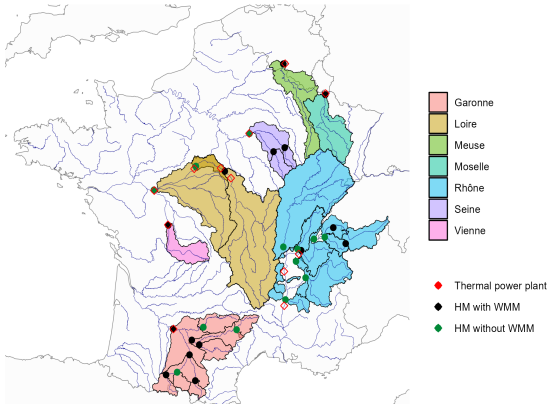

Figure 1: Map of the 28 catchments, outlets, water management modules and 13 thermal power plants.

Modeling chain forced by HMM Fr (Touron et al., 2019) trained on :
- Historical observations (P and T, 1981-2010)

Hydrological model (HS, Garavaglia et al. 2017):
- MORDOR-SD, a lumped conceptual rainfall-runoff model

Water management modules (WMM):
- Quantile-Quantile correction based on historical comparison of natural / influenced discharge
- Simulation of reservoir management based on seasonal level constraints

III. Results : Validation over historical period

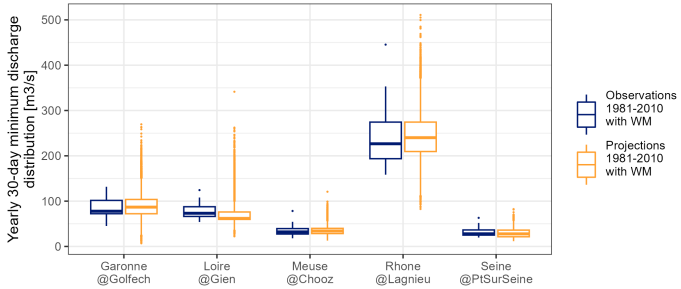

Figure 2: Distribution of yearly 30-day minimum discharge for observed and simulated discharge over the historical period for 5 out of 13 sites of interest.

- Relative agreement between observations and projections over the historical period
- The use of the HMM Fr allows some variability to be added (i.e. some events not seen in the real 1981-2010 period).

III. Results : Example over the Loire@Gien catchment

Two large reservoirs:
- Villerest, 130 millions of m³ and Naussac, 190 millions of m³
- Used for flood control, irrigation, etc.
- Low flow support : 60 m³ /s, reduced to 50 m³ /s when the reservoirs are 50% empty ➔ implemented in the WM, in reality the management is complexe

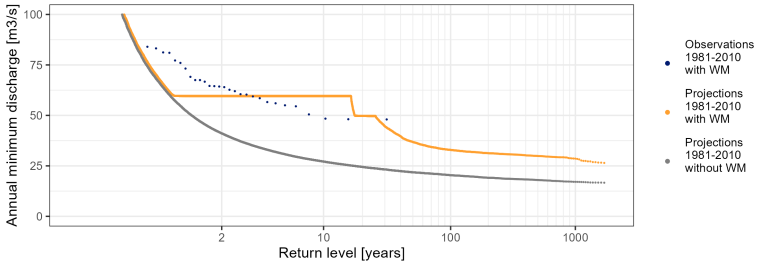

Figure 3: Return levels of annual minimum discharge for observed and simulated discharge over the historical period for the Loire@Gien

- Relatively good agreement with observations
- The impact of reservoirs on low-flows is clear and major
- The water module management produces a certain "flatline" in contrast to the real management

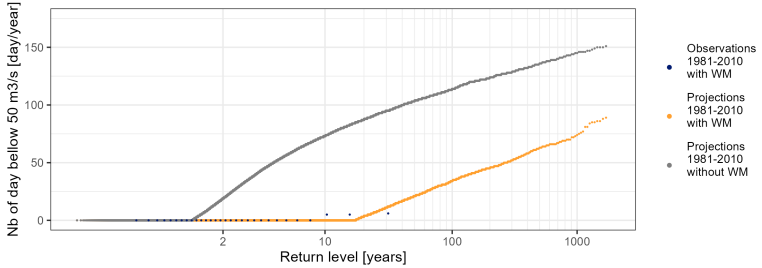

Figure 4: Return levels for number of days below 50 m3/s for observed and simulated discharge over the historical period for the Loire@Gien

- The historical observations showed no discharge below 50 m³ /s
- Projections over the 1981-2010 period indicate that even in the current climate there is a probability of falling below 50 m³ /s

IV. Conclusions

- Relative agreement between simulated and observed severe low-flows
- Applied to 7 anthropogenically influenced large catchments in France
- Work still in progress to improve both the weather generator and the implementation of the water management modules, to be more realistic
- The approach could be applied to future period using downscaled projections to train the HMM Fr model (CMIP5, CMIP6 ?)

V. References

- Parey , S et al., 2022, Extreme Low Flow Estimation under Climate Change, Atmosphere.
- Garavaglia , F et al., 2017, Impact of model structure on flow simulation and hydrological realism : from a lumped to a semi-distributed approach , Hydrol. Earth Syst. Sci.
- Touron, A. 2019, Multivariate modeling of meteorological variables . University Paris-Saclay, PhD Thesis.