Drought and flood risk assessment of the Seine basin reservoir management under climate change

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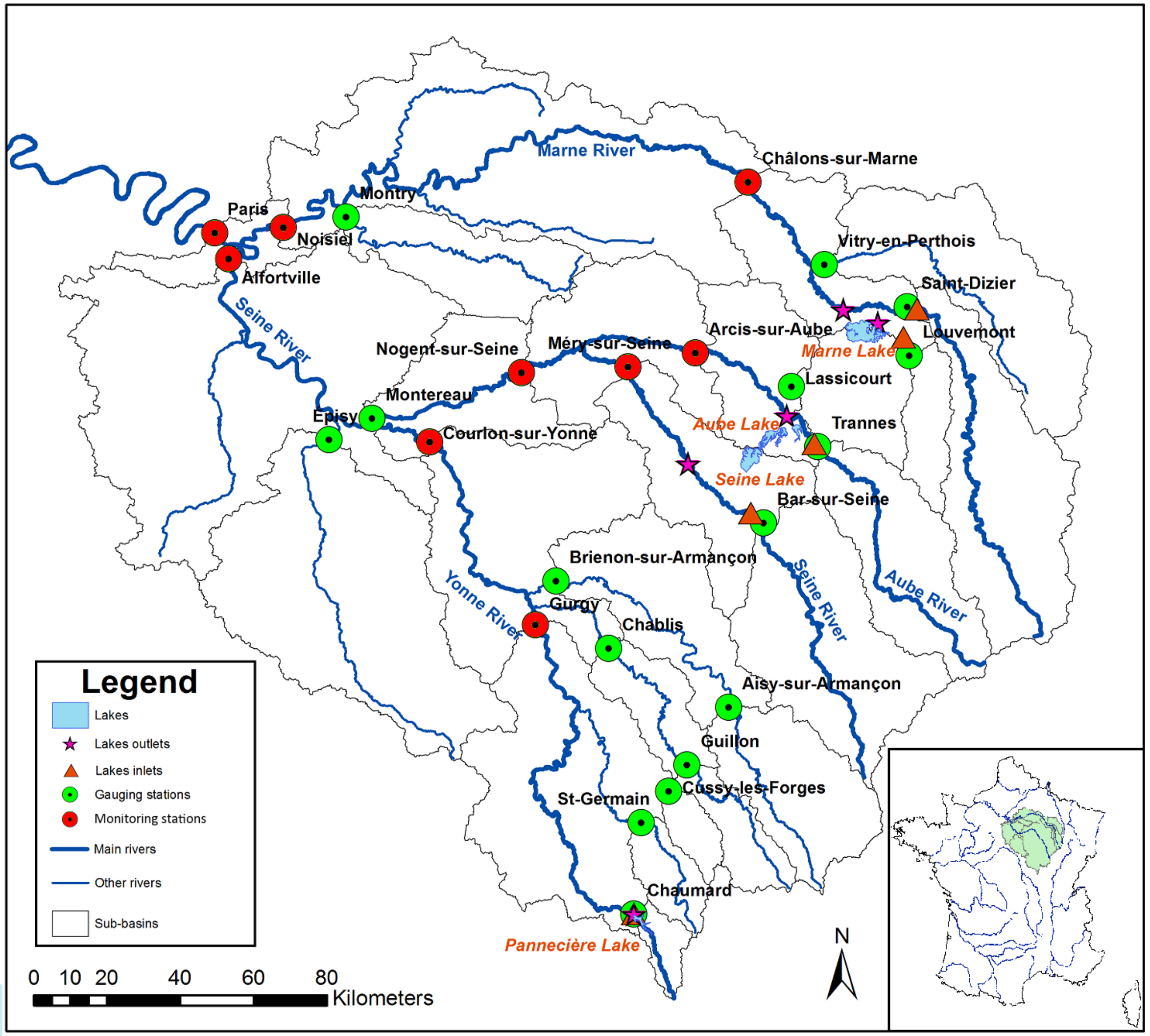
How to provide robust decision guidance to reservoir managers challenging conflicting objectives?

The case of the Seine lakes protecting for both floods and droughts



Manager objectives: maintain the flow at monitoring stations (●) between 2 extremes:

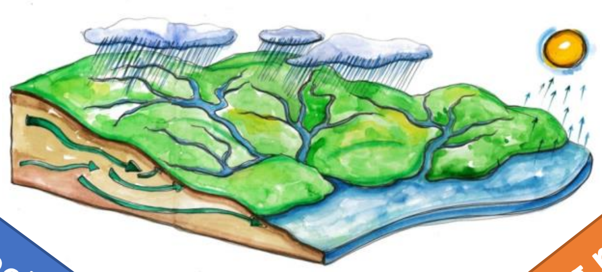
- Thresholds for high flows:
  - 3rd: exceptionally flooded areas
  - 2nd: frequently flooded areas
  - 1st: bankfull discharge
- Thresholds for low flows (based on water use restriction thresholds):
  - 1st: vigilance
  - 2nd: alert
  - 3rd: reinforced alert
  - 4th: crisis

How to provide robust decision guidance to reservoir managers challenging conflicting objectives?

The manager must balance between **Proactive** and **Reactive** Decisions…

Proactive (be ready for a future event) vs **Reactive** (Coping with an event)

Floods



Droughts

Proactive decision: **emptying reservoir**

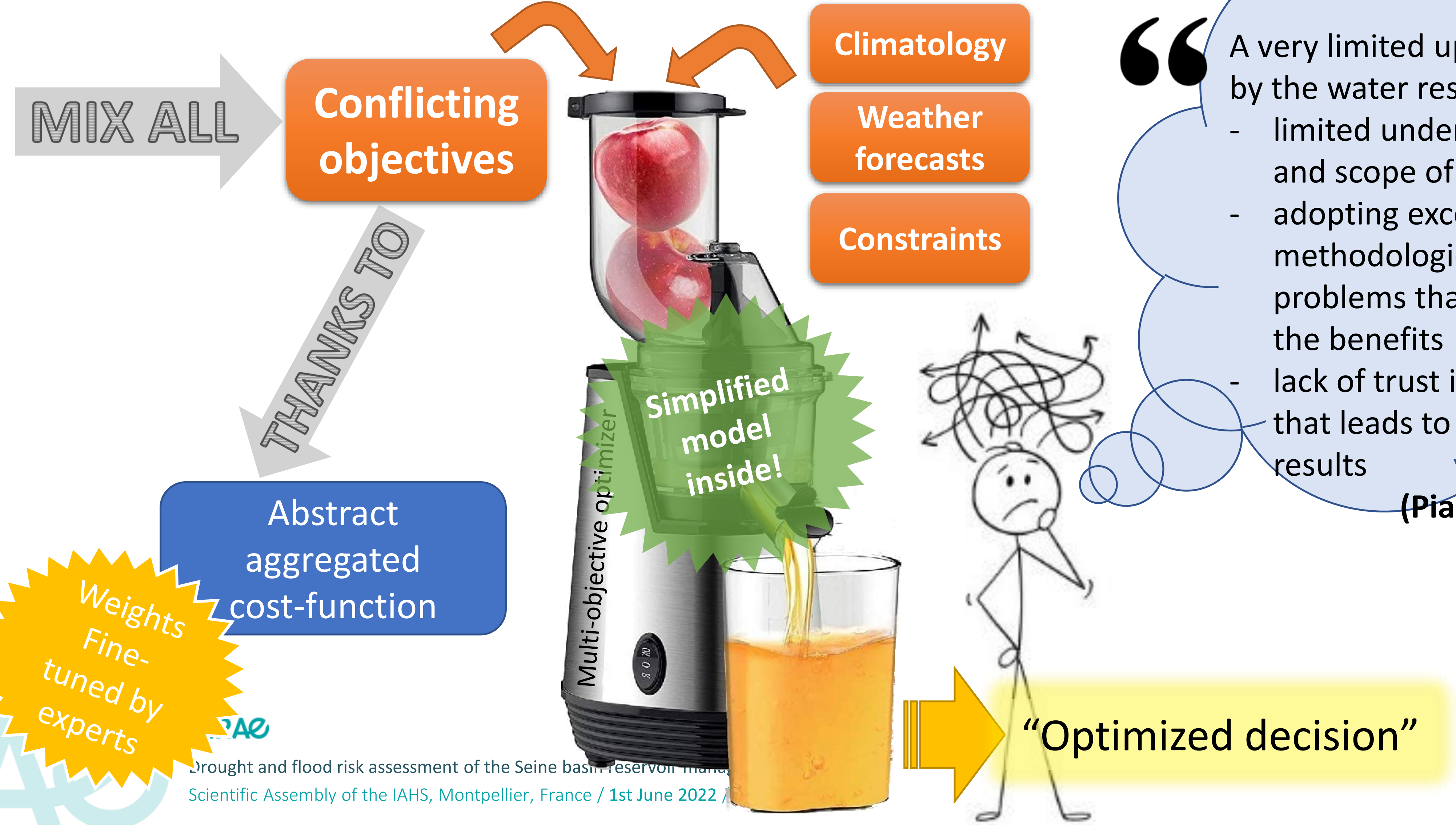
Proactive decision: **filling reservoir**

Reactive decision:
laminating the flood
⇔
filling the reservoir

Reactive decision:
supplying the river
⇔
emptying the reservoir

How to provide robust decision guidance to reservoir managers challenging conflicting objectives?

The usual way (for scientists): **the multi-objective optimiz**



" A very limited uptake of optimization tools by the water resource managers because:
- limited understanding of the benefits and scope of the optimization
- adopting excessively complex methodologies may generate practical problems that do not compensate for the benefits
- lack of trust in the realism of models that leads to discarding optimization results

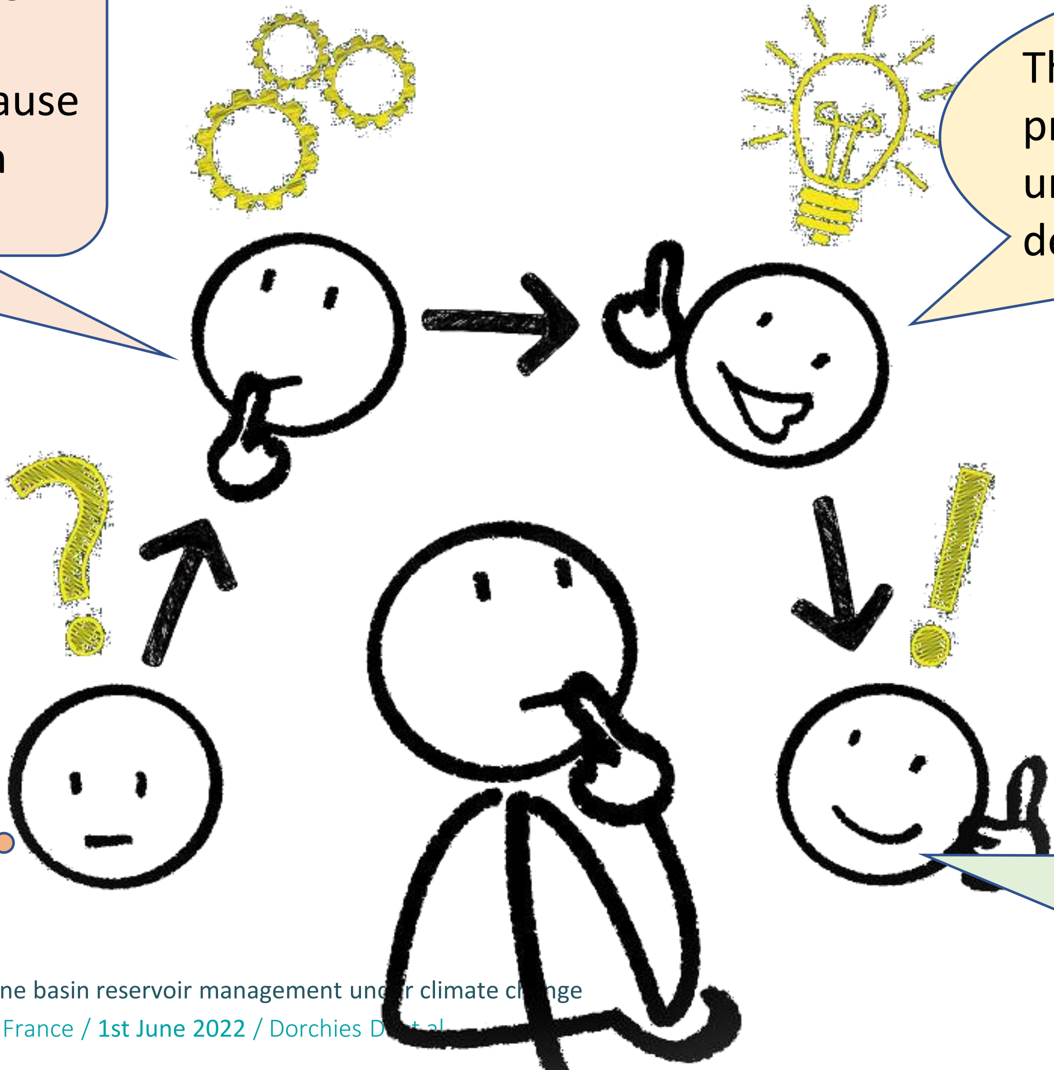
(Pianosi et al. 2020) "

How to provide robust decision guidance to reservoir managers challenging many conflicting objectives?

From many objective decision… to a decision based on risk prioritization

The manager wants to minimize the risk to fail objectives…
… but not all at the same time because some less important objectives can undermine more important ones

This means that the manager has to prioritize between acceptable and unacceptable risks for each objective depending on the situation



How to get decisions that the manager can justify in the complex context of many conflicting objectives ?

A dashboard of the risks of future failure for each objective, taking into account the state of the system and the climate, would enable the manager to regain control of the decision-making process

From single objective optimization… to many objective risk assessment

How to compute optimal proactive decisions for a given objective?

The problem is solved by dynamic programming:

- Modeling the minimum reservoir release (resp. filling) in reverse time for proactively handling flood (resp. drought) events

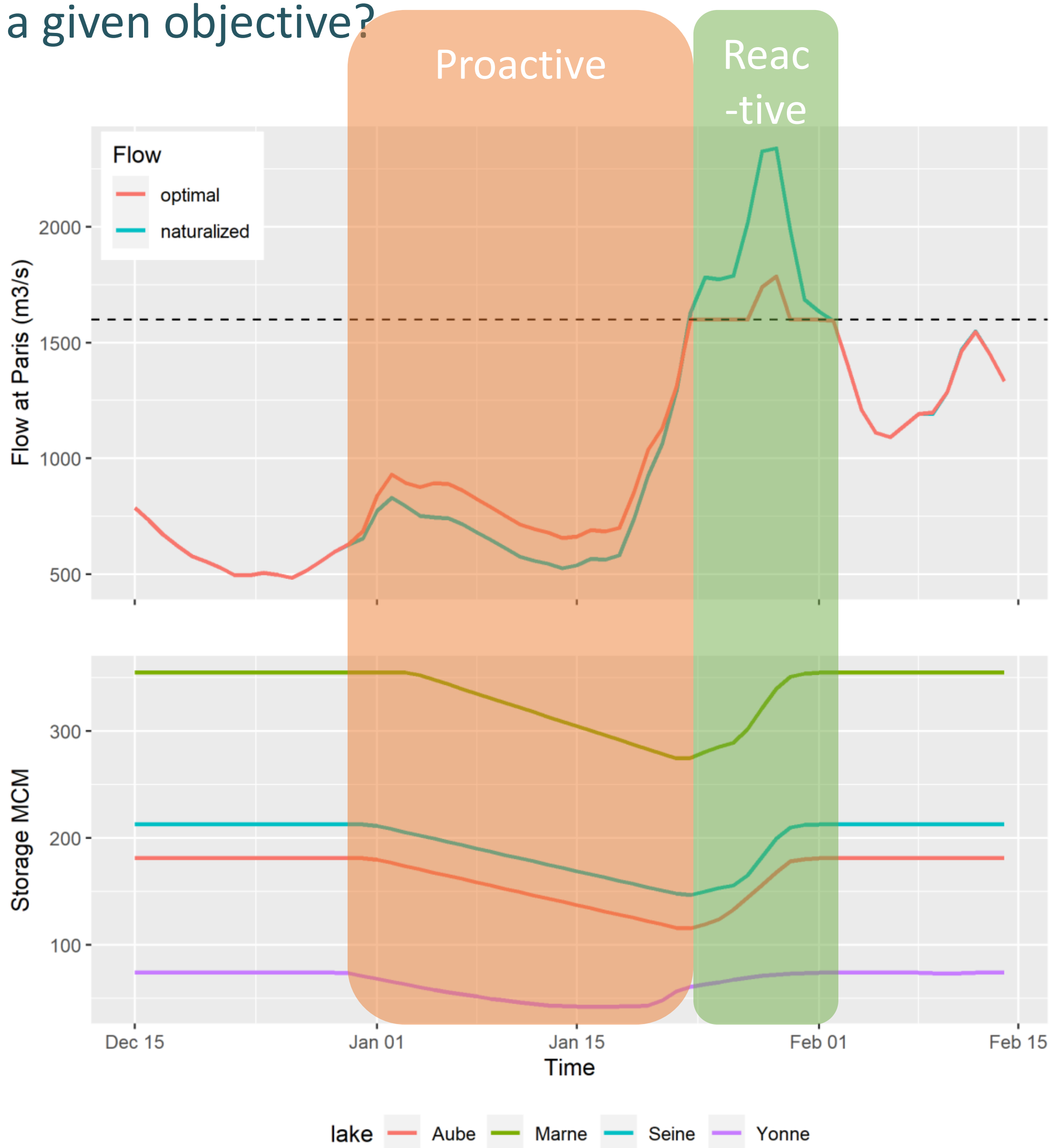
The model uses:

- A daily naturalized flows available at each monitoring station and at the reservoirs,
- a lag hydraulic routing model
- constraint sets (physical constraints and local management rules such as minimum biological flow…)

315 optimizations performed
(9 monitoring stations **x** 7 thresholds **x** 5 constraint sets)

Example:

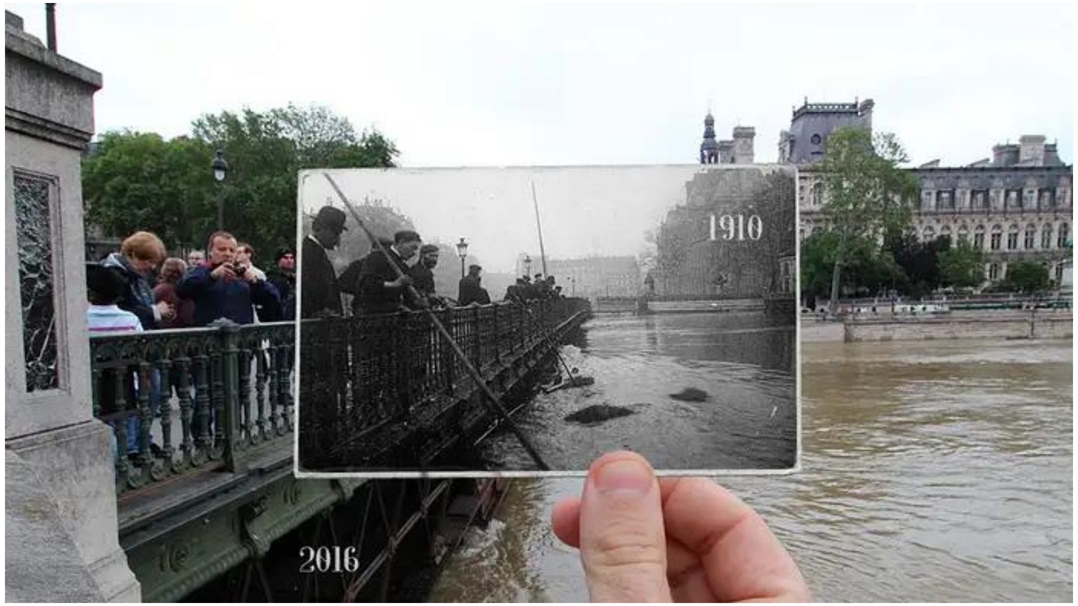
Optimal release of the 4 reservoirs before the 1910 flood in Paris to maintain the flow under the 2nd high flow threshold (1600 m^3/s)



From single objective optimization… to many objective risk assessment

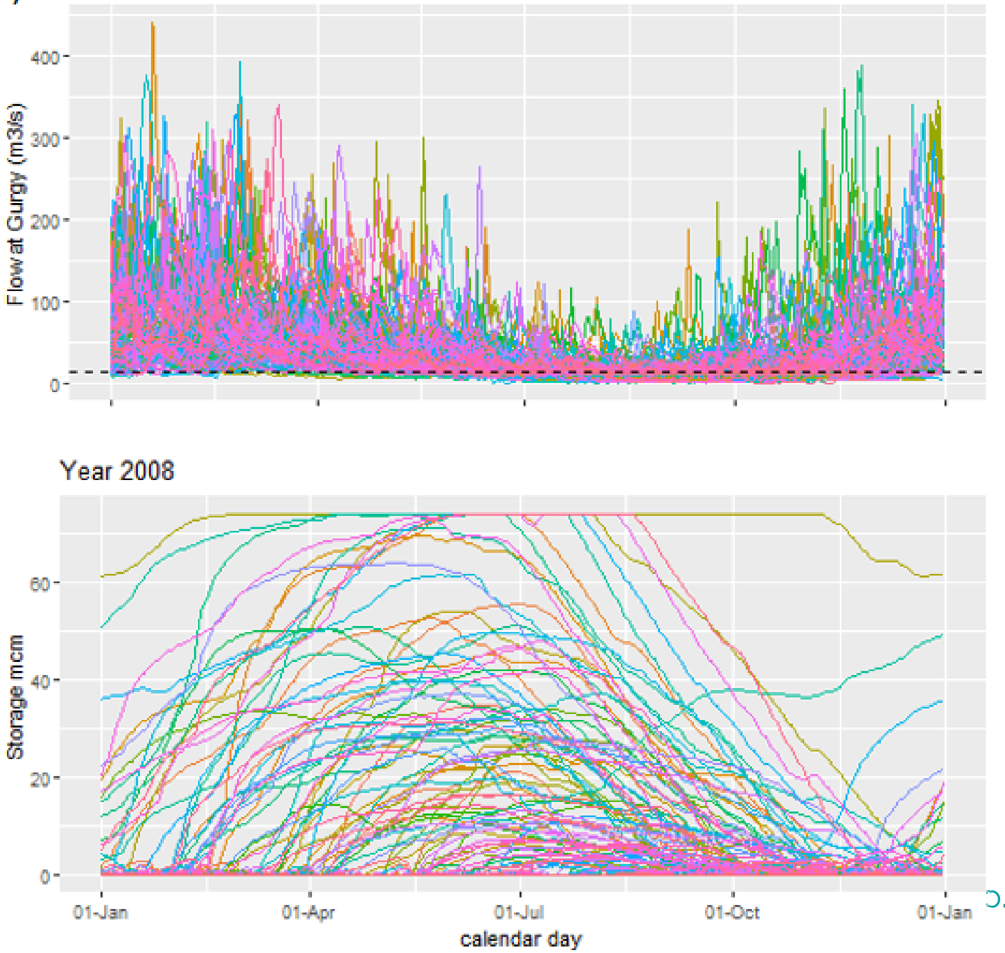
How to convert optimal filling curves into risk assessment curves?

The risk assessment is based on evaluation of return period of extreme events by calculating optimal filling curves from daily naturalized flows



Credit: Julien Knez (https://kultt.fr)

Example of optimal minimum volume in Lake Yonne to achieve the objective of a minimum flow of 12,5 m^3/s at Gurgy (1900-2009)

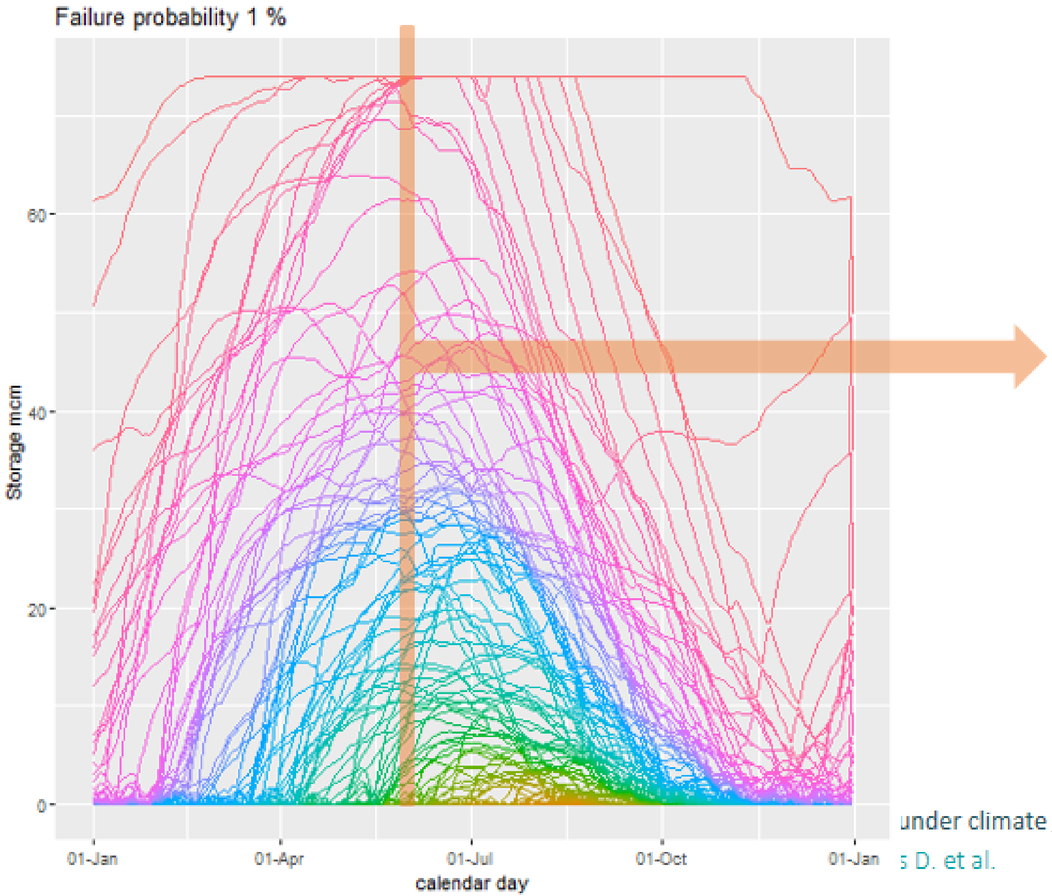


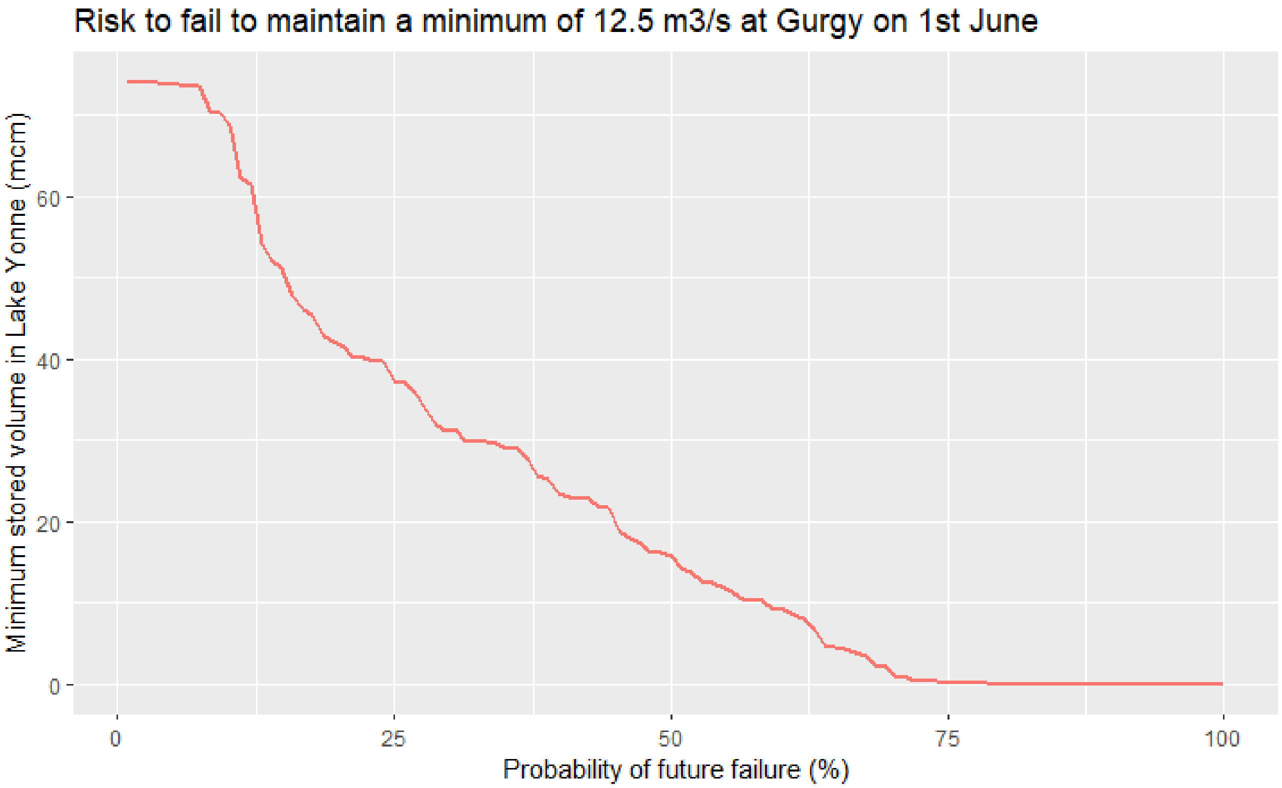
From single objective optimization… to many objective risk assessment

How to convert optimal filling curves into risk assessment curves?

Sorted curves gives minimum (resp. maximum) stored volume associated with the probability of failing to achieve a future drought (resp. flood) event

For each calendar day, we obtain the probability of future failure of the objective associated to the current stored volume (1900-2009)



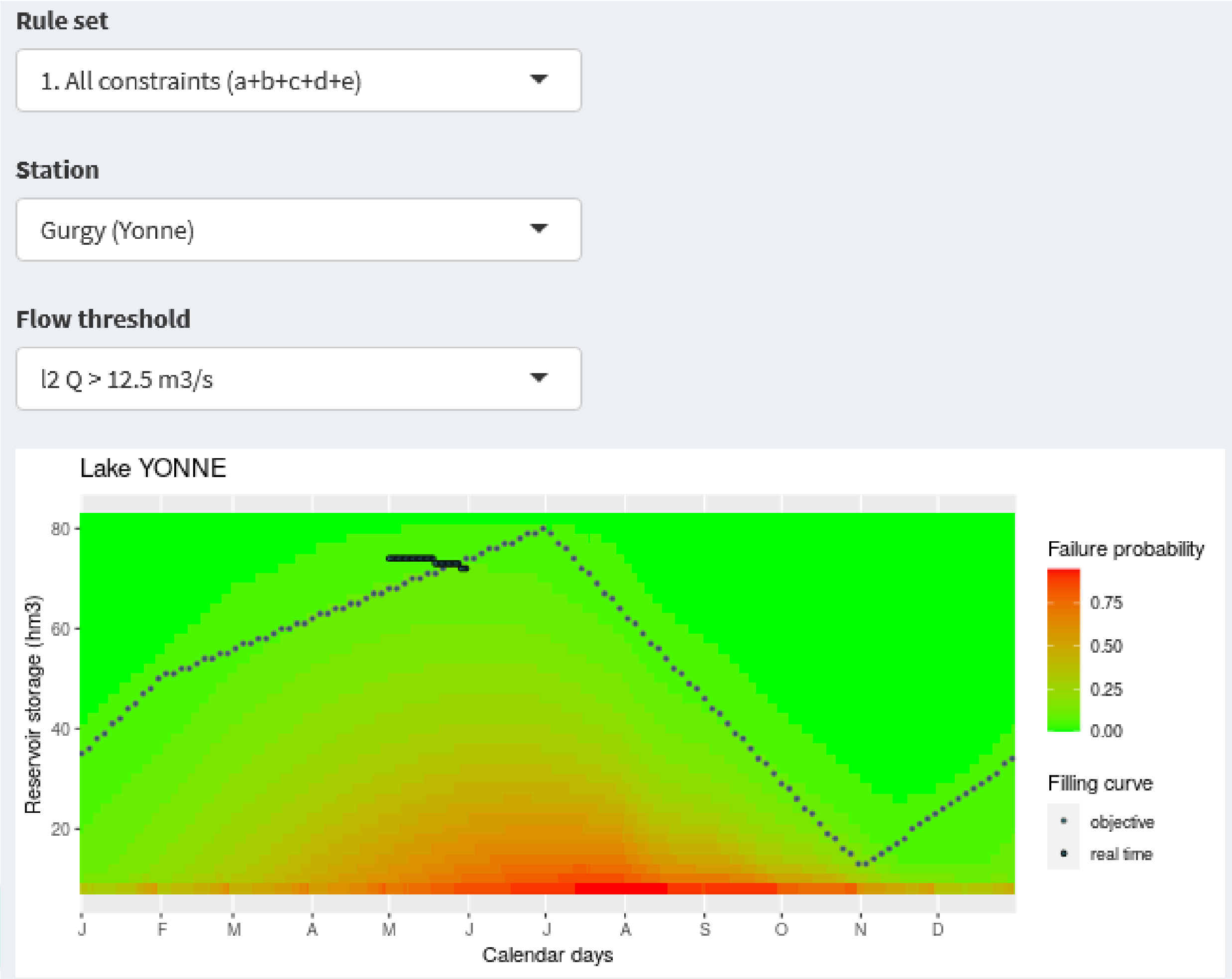


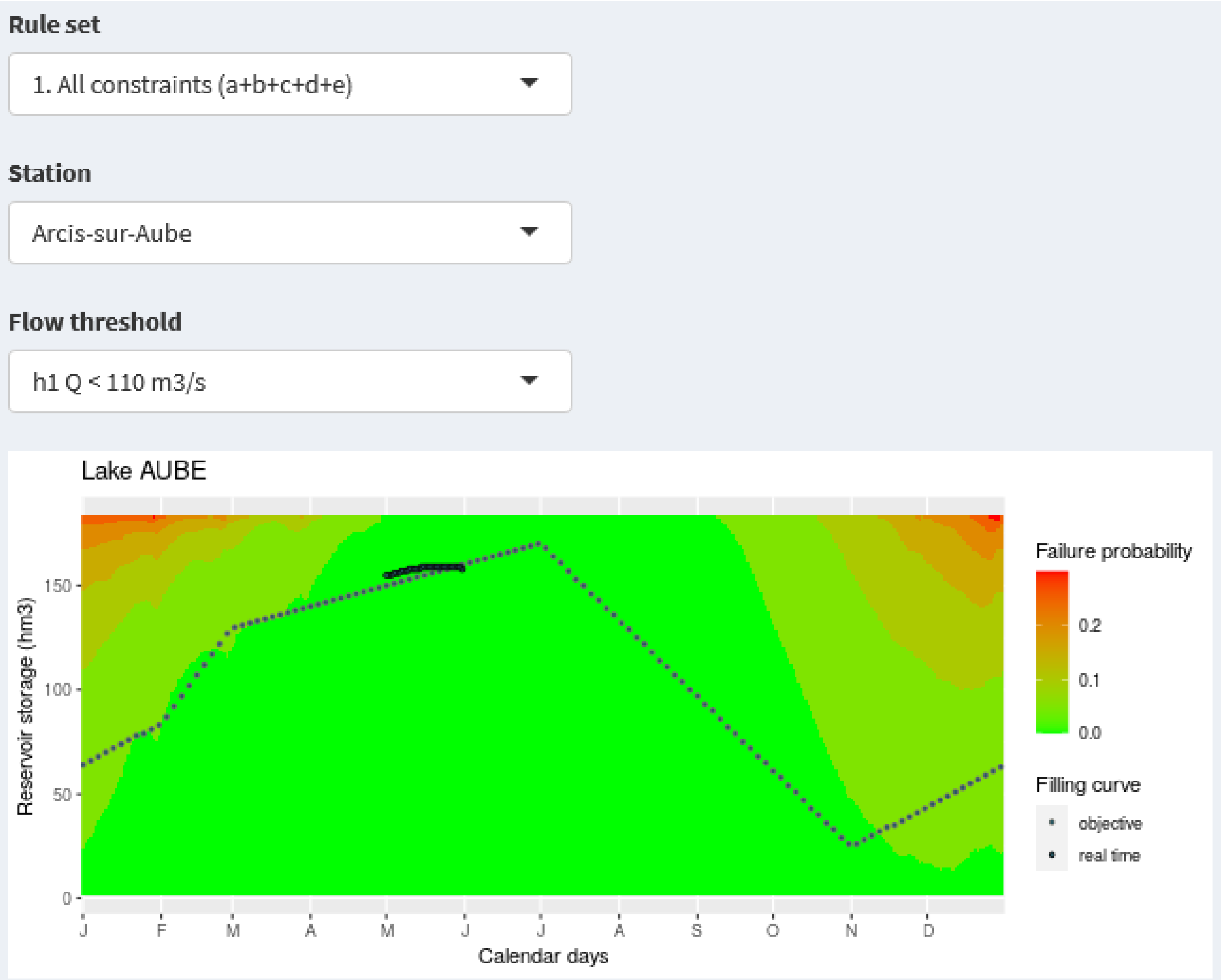
under climate
s D. et al.

From single objective optimization… to many objective risk assessment

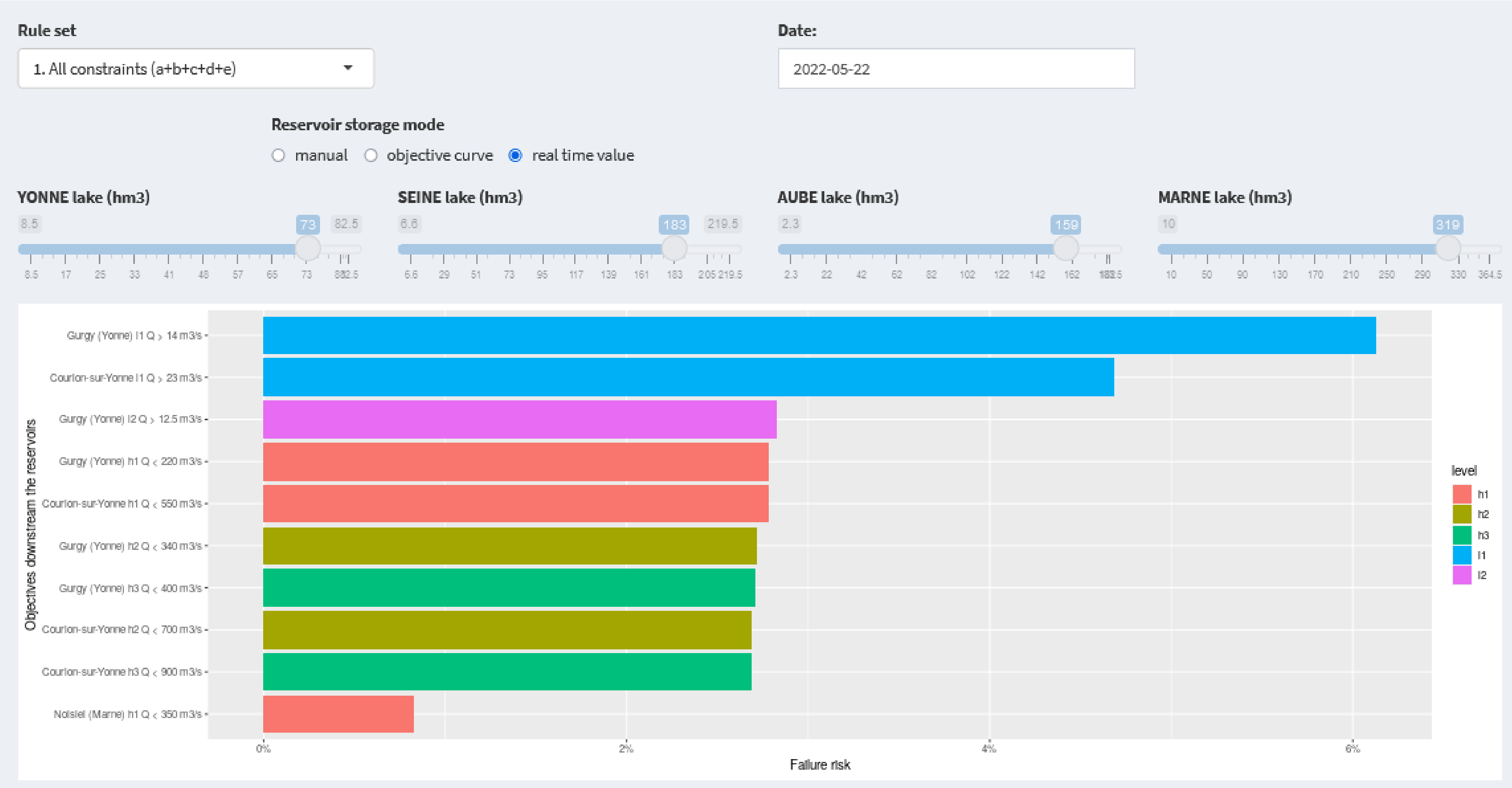
Towards an interactive risk assessment dashboard: http://irmara.g-eau.fr

All results of single objective optimizations are stored in a database where failure risk probabilities are available for all objectives:





From single objective optimization... to many objective risk assessment

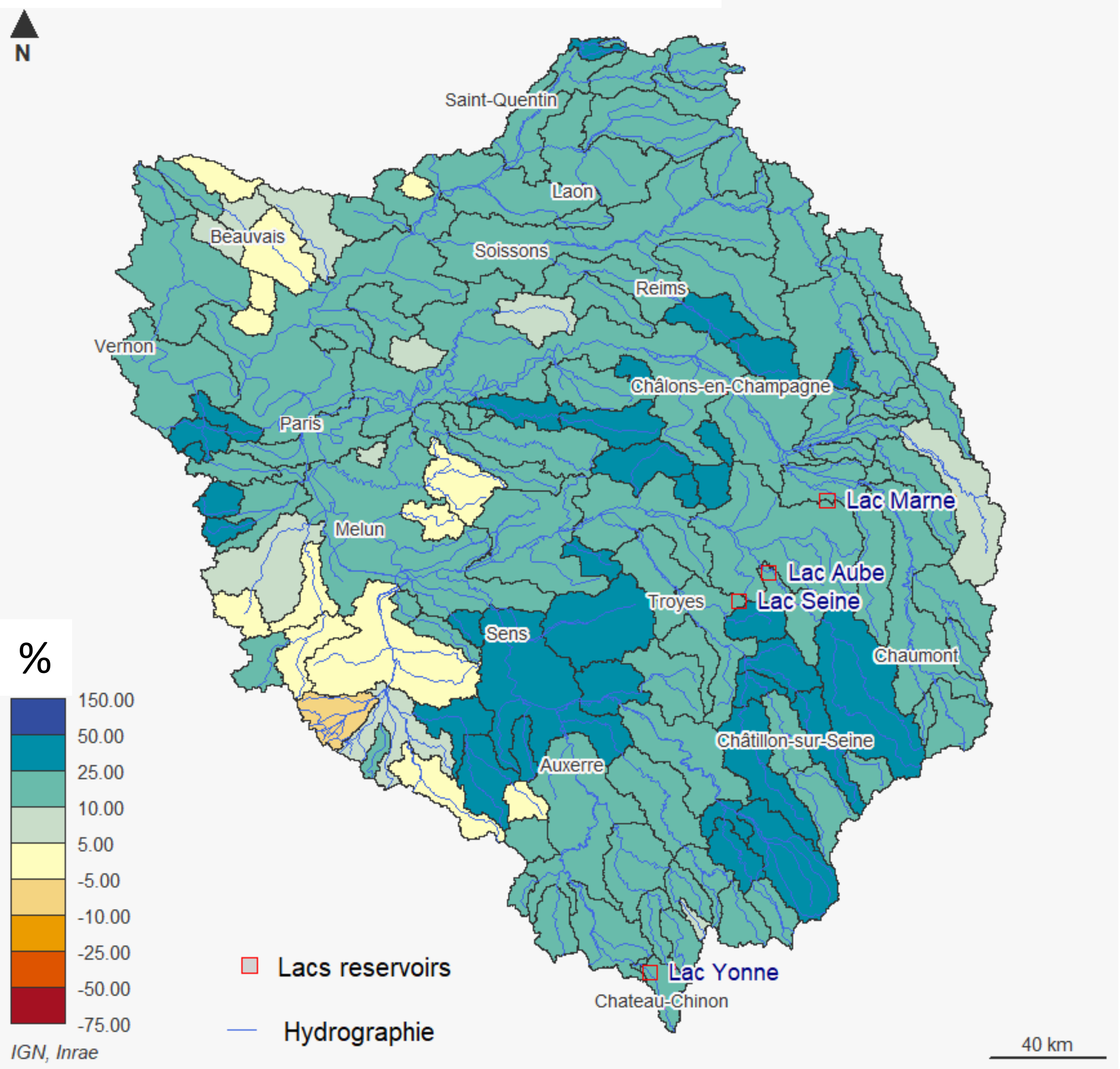


How to deal with climatology unstationarity?

By doing the same exercise with naturalized flows modelled from climate projections

We set up a daily time-step semi-distributed hydrological model of the Seine River basin thanks to the airGRiwrm R package:

- 144 gauging stations used for calibration/simulation
- 1958-2019 SAFRAN reanalysis for historical meteorology
- Direct calibration of the model with influenced flows
- Flow naturalization by removing the reservoirs from the model
- Simulation with 1950-2100 DRIAS2020 climate change projections (5 GCM/RCM pairs for both RCP4.5 and RCP8.5)

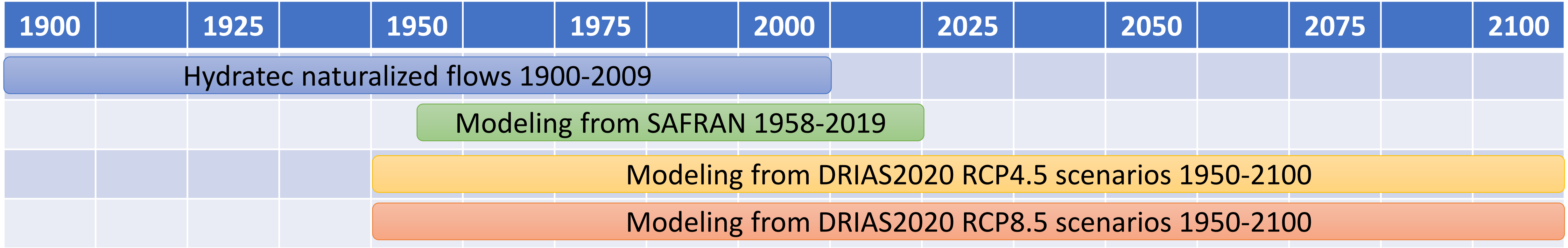


Map of evolution of the maximum annual daily flow with a 10-year return period between 1976-2005 and 2021-2050 (median value over 5 RCP8.5 scenarios)

How to deal with climatology unstationarity?

A work in progress…

- Run single objective optimizations with naturalized flows from climate scenarios
- Integration of the results in the interactive tool https://irmara.g-eau.fr
- Compute the risk assessment from a free choice of naturalized flow sources and periods:



Conclusion and perspectives

Current key points:

We are going to provide a decision risk assessment dashboard to the water resources managers:

- for multi-reservoir based on climatology statistics (historical or projections)
- this allows the manager to evaluate the risk of undermining proactive management when reactive decisions are taken

Future works:

- Derive real-time management rules from failure risk aversion defined by the water resources manager
- Test the robustness of the method in uncertain future
- Compare simulations of these management rules with current rules and other multi-objective optimizations