Adapting the safe operating space concept for water management at catchment scale under climate change

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STARS 4 Water

EU Grant Agreement 101059372

INRAE

la science pour la vie, l'humain, la terre

NHC2025

Reykjavik, Iceland, 3-5 July 2025

STARS 4 Water

Creates
new generation data services and data-driven models tailored to stakeholders needs and requirements

Enhances
the knowledge base and the scientific underpinning of climate risks and impacts at river basin scale

Improves
decision making by stakeholders through the development of dashboards and a safe operating space framework

Co-design with stakeholders in 7 river basin hubs

info@stars4water.eu

21 partners led by Deltares

stars4water.eu/

EU Grant Agreement 101059372

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STARS 4 Water

1. What is the Safe Operating Space (SOS) framework?
2. How do we implement the SOS concept in river basin management?
3. First assessments in the Seine River basin (France)

Improves decision making by stakeholders through the development of dashboards and a safe operating space framework

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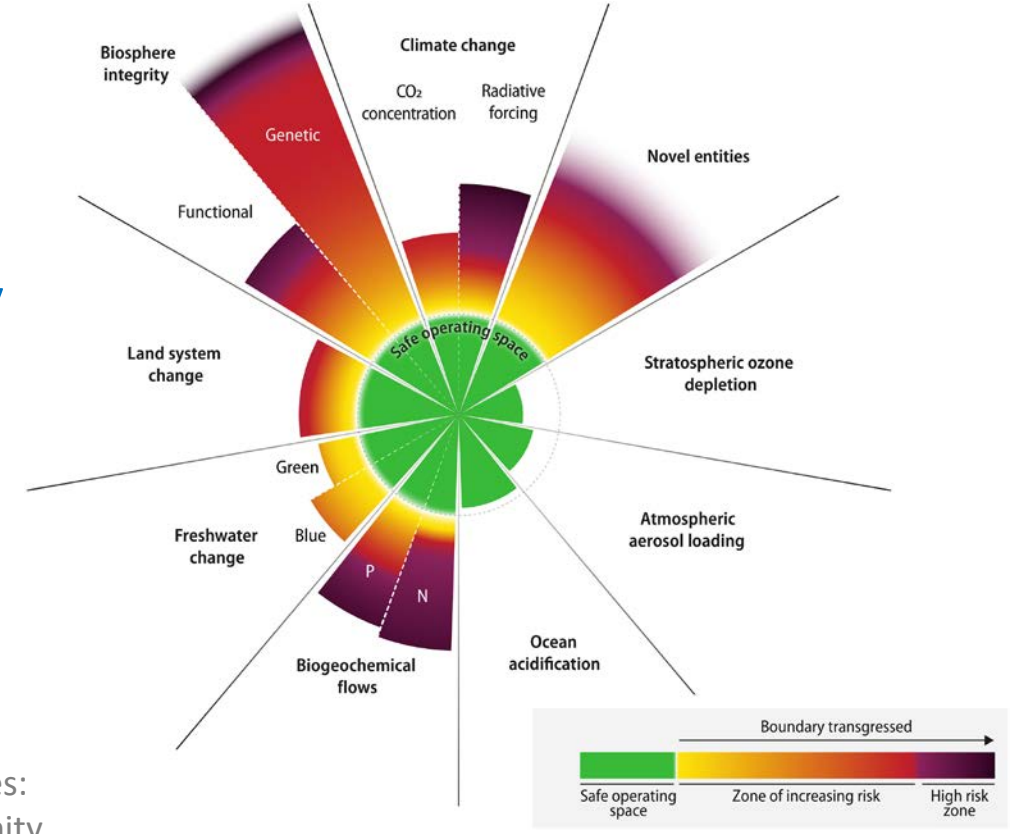
SOS framework

The planetary boundary concept

Stockholm Resilience Centre (2009), and revisions:

- to define the environmental limits within which humanity can safely operate
- to inform policy-making and governance efforts toward global sustainability



Rockström, J. et al (2009) Planetary Boundaries: Exploring the Safe Operating Space for Humanity. *Ecology and Society* 14(2): 32, http://www.ecologyandsociety.org/vol14/iss2/art32/

Richardson *et al.*, Sci. Adv. 9, eadh2458 (2023)

SOS framework

The planetary boundary concept

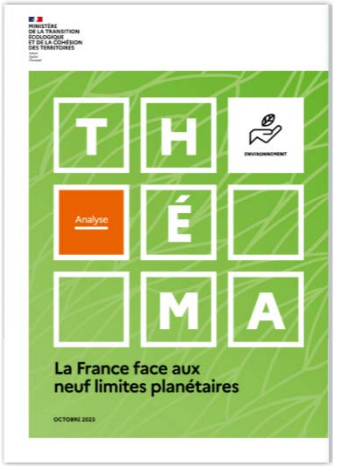
- Areas of increasing risk are associated with critical thresholds (boundaries, limits)
- If thresholds are crossed, shifts into new states could bring potentially disastrous consequences for humans and the environment

Photo: MHR

SOS framework

The planetary boundary concept

- Original focus on "the Earth system“: planet in its entirety
- Since 2015: how to "downscale" the planetary boundaries framework?

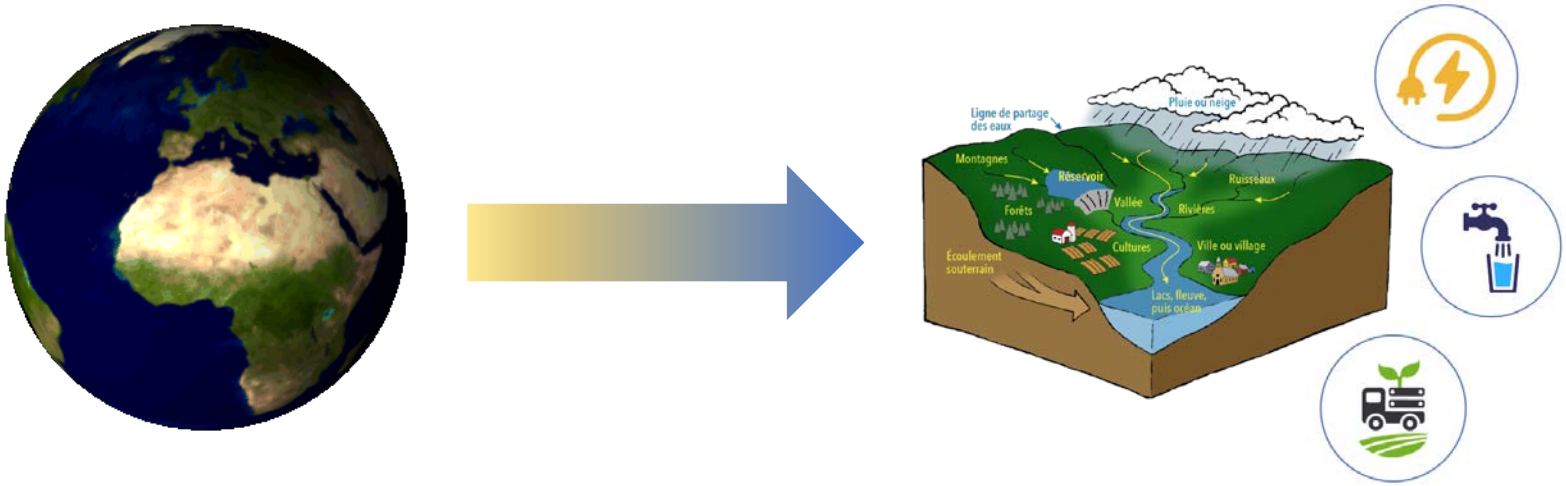


- For each PB: adapt control variable, indicators, limits to the context of a country or territory
- Concerns sometimes already taken into account in local environmental assessments or policies

https://www.statistiques.developpement-durable.gouv.fr/edition-numerique/la-france-face-aux-neuf-limites-planetaires/en/

SOS framework for water management

Assessing the safe operating space at the river basin scale



- Water managers can operate across different water use sectors
- Water managers can implement measures to protect society and adapt operations

SOS framework for water management

But when do operations reach their limits, their effects become uncertain/at risk, or “unsafe”?

Photos: MHR & A. Lemoine

SOS framework for water management

When do operations reach their limits?

Effects of
Climate and Operations

Photos: MHR, A. Lemoine

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SOS framework for water management

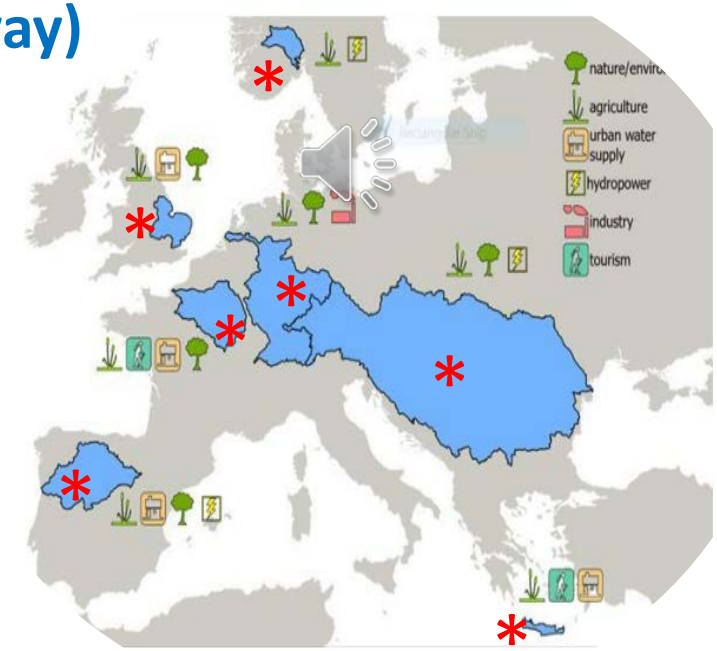
River basin hubs in STARS4Water project

Drammen (Norway)

East Anglia (UK)

Seine (France)

Douro (Spain)



Rhine

Danube

Messara (Crete)

SOS framework for water management

Co-creation process

What models, data and indicators are the most appropriate?

Which level of data aggregation yields meaningful relationships?

How boundaries or thresholds can be set?

How do we represent the current status, and the future scenarios?

What is a safe distance for operations?

Photos: MHR

SOS framework for water management

Typical probabilistic/ensemble approaches

Top-down

Driven by projections of future climate change from GCM/RCM and modelled impacts

Driven by the systematic evaluation of sensitivity to weather and climate

Bottom-up

Future inflows

Water resources management & assessment

Adaptation measures

SOS framework for water management

Storyline approach

- No a priori probability of the storyline is assessed
- Emphasis on understanding driving factors involved, and their plausibility
- Making the predicted future more tangible

Driven by stakeholders: work backward from a particular vulnerability or decision point

Water resources management & assessment

Risk awareness and intervention

Shepherd T. G. et al (2018) Storylines: an alternative approach to representing uncertainty in physical aspects of climate change. *Climatic Change* (2018) 151:555–571 https://doi.org/10.1007/s10584-018-2317-9

STARS 4 Water

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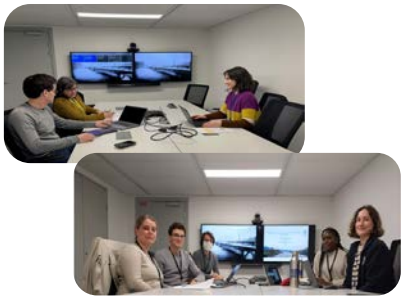
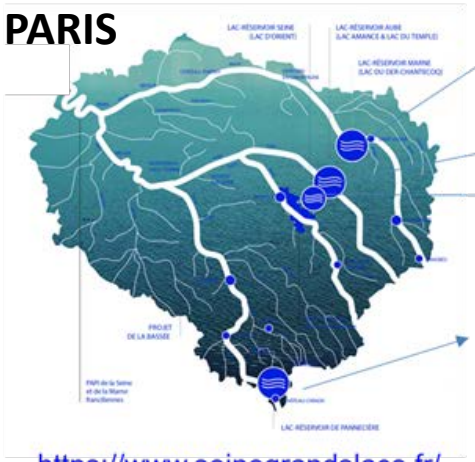
Work by: Julie Collignan (post-doc researcher at INRAE)

SOS framework for water management

Seine River basin



SEINE GRANDS LACS



https://www.seinegrandslacs.fr/

Total: 805 Mm³

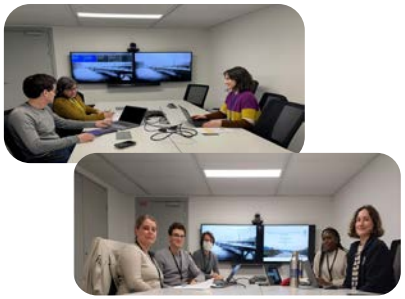
4 reservoirs

Main objectives

- Flood protection
- Regulation of low flows
- Biodiversity & aquatic ecosystems preservation

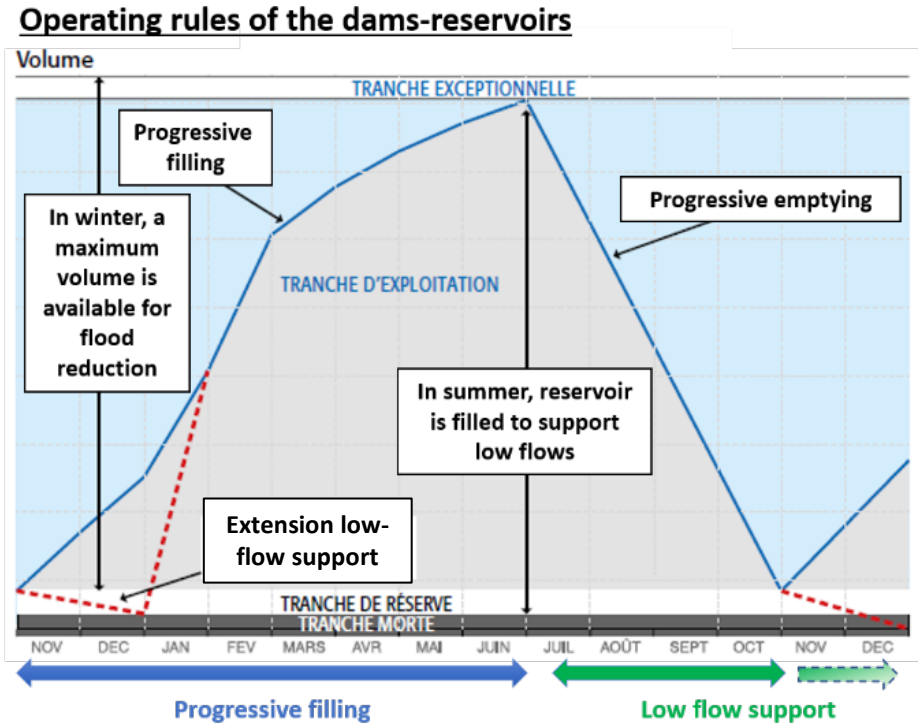
SOS framework for water management

Seine River basin



SEINE GRANDS LACS

- Operating rules
  - Focus on filling (Nov-Jun) and release (Jul-Oct) periods



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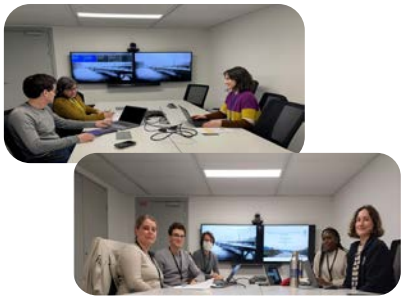
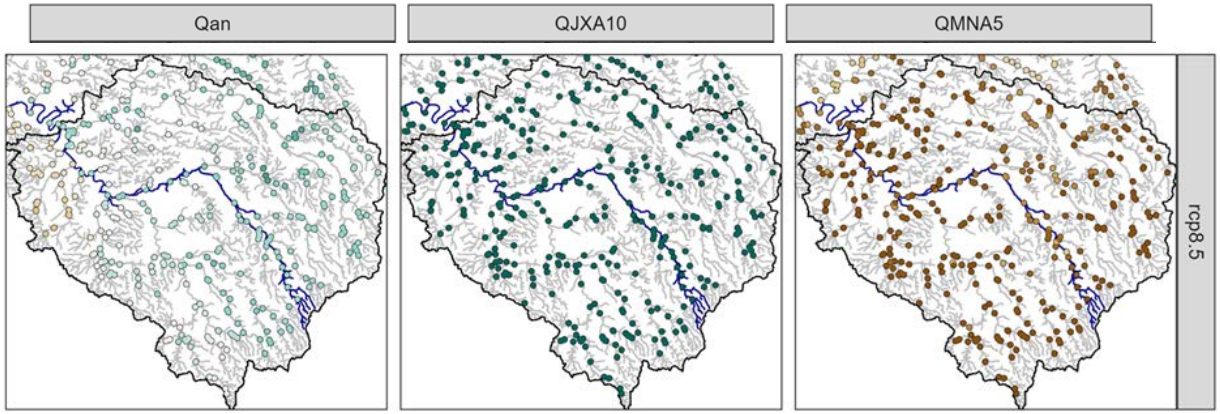
SOS framework for water management

Seine River basin

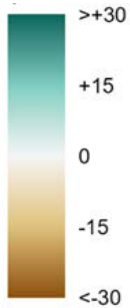


Relative change (2070-2099 to 1976-2005)

Average flows | High flows | Low flows

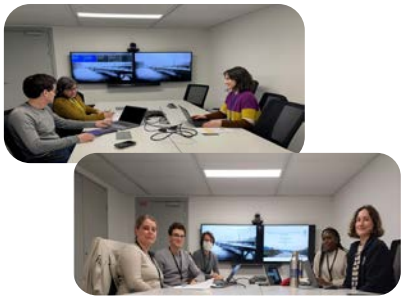


- Operating rules
- Climate projections:
  - Uncertainty in the sign of precipitation changes
  - Marked differences between winter and summer
  - More severe hydrological droughts



SOS framework for water management

Seine River basin



- Local concerns: water resource security & masking real vulnerabilities
- Simulating historic events not enough: absence of failure situations (thanks to the current management actions)

Operating rules + Climate projections

What if the upstream reservoirs cannot fulfill their management objectives in the future (e.g. more severe low flows)?

SOS framework for water management

Seine River basin

Methodology:

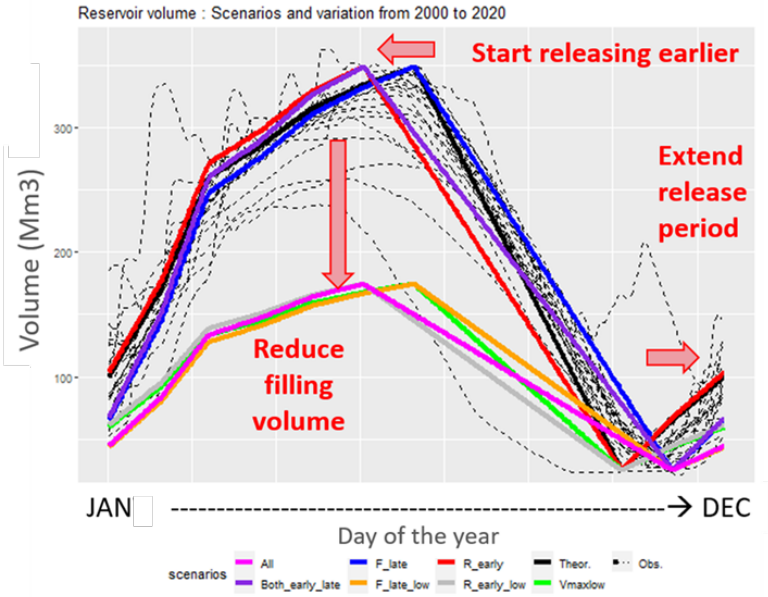
- Calibration of a semi-distributed hydrological model with reservoir management integrated
- Simulations with:
  - 4 contrasted climate scenarios (from the national project Explore2)
  - 10 co-created management scenarios (incl. “no reservoir”, “current theoretical rule curves”)
- Analysis focusing on low-flows

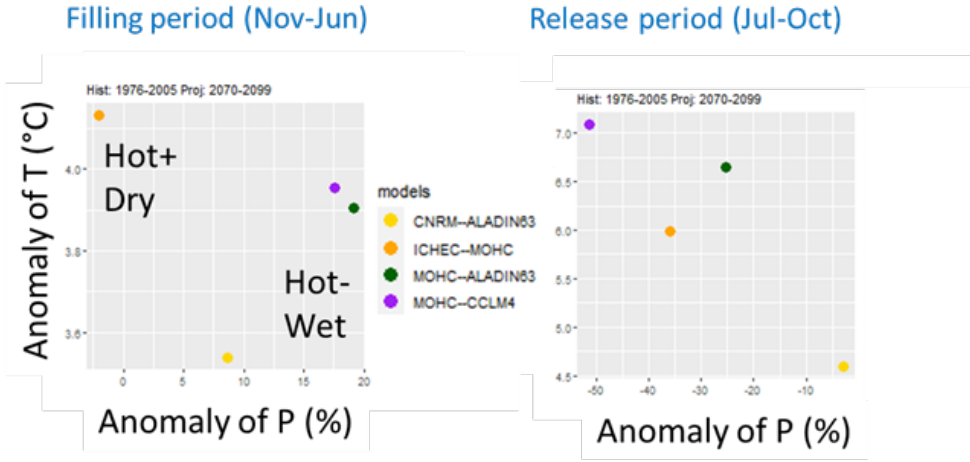
SOS framework for water management

Seine River basin

Operating rules + Climate projections

Marne reservoir





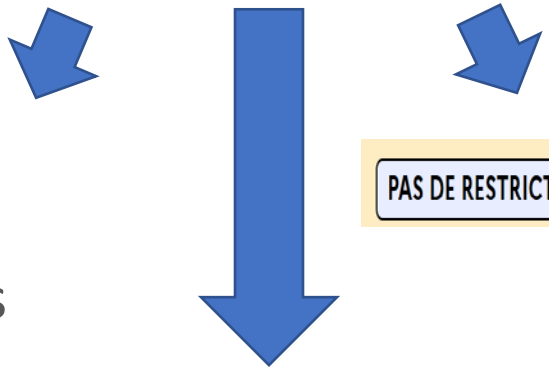
SOS framework for water management

Seine River basin

Operating rules + Climate projections

Indicators and thresholds

VCN10:
Minimum flow over a sliding period of 10 days



GOUVERNEMENT
Liberté
Égalité
Fraternité

VigiEau

PAS DE RESTRICTIONS | VIGILANCE | ALERTE | ALERTE RENFORCÉE | CRISE

Warning levels

Risk awareness and intervention

Water resources management & assessment

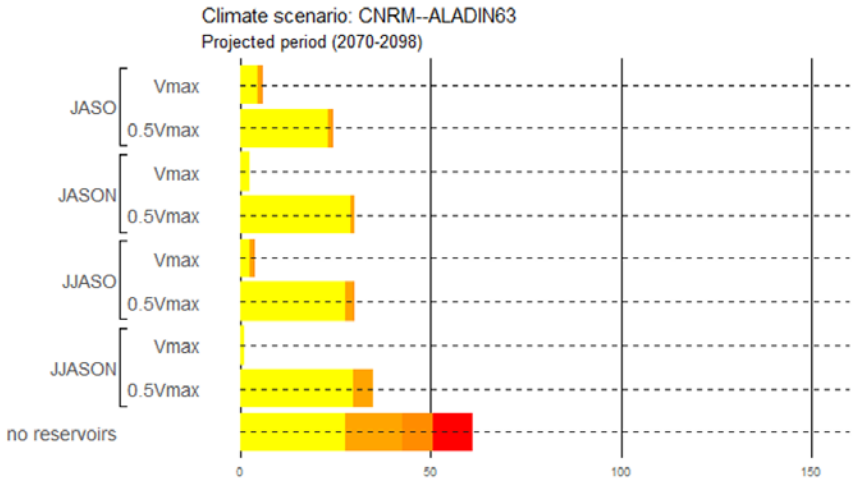
SOS framework for water management

Seine River basin

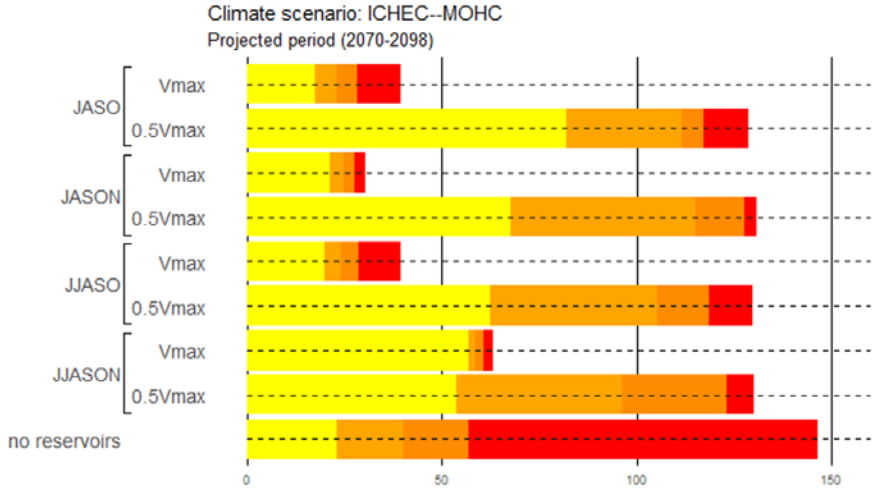
Operating rules + Climate projections

Indicators and thresholds

Wetter to normal scenario



Drier and hotter scenario



Average number of days in a year below threshold (location: Paris)

Threshold | Crisis | Reinforced alert | Alert | Vigilance

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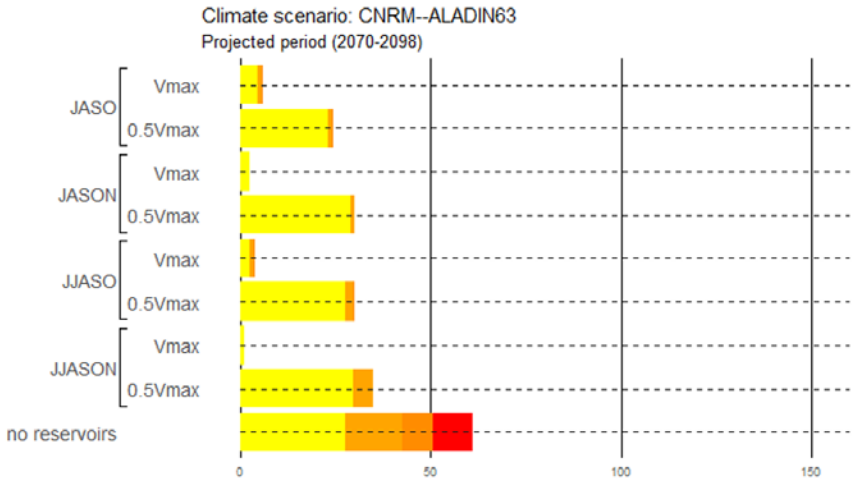
J. Collignan et al. (2025)

SOS framework for water management

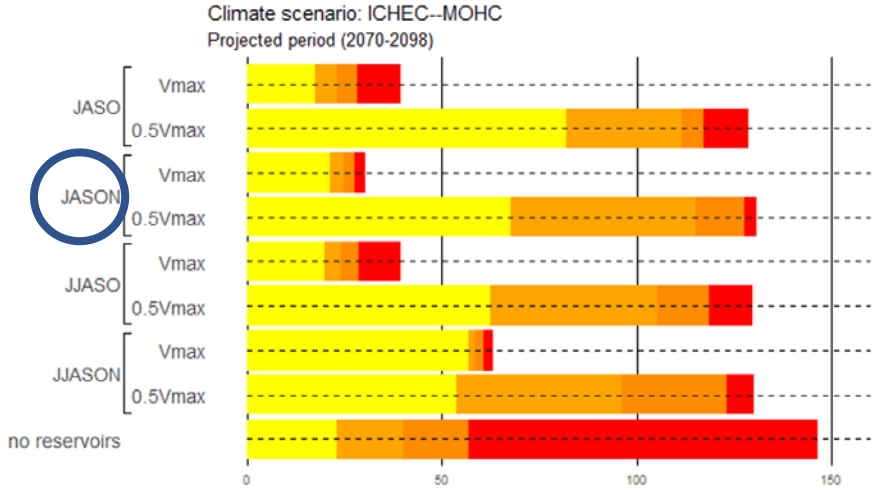
Seine River basin

Relevance of extending low-flow support towards November

Wetter to normal scenario



Drier and hotter scenario



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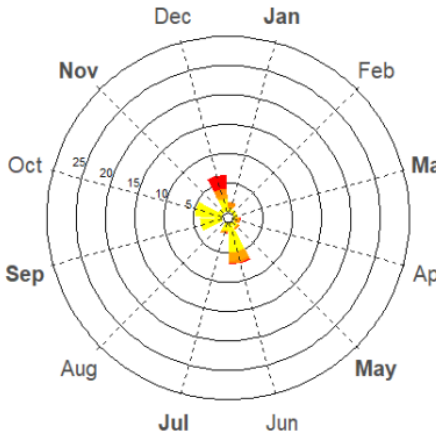
SOS framework for water management

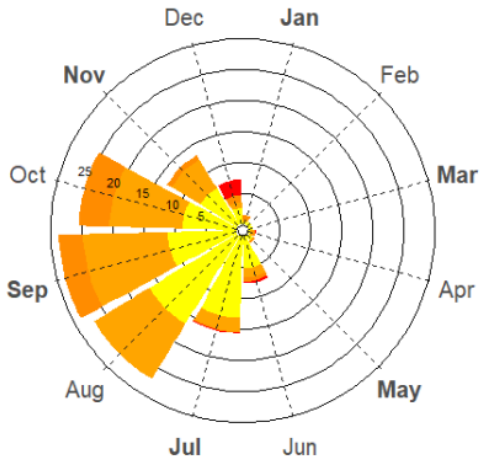
Seine River basin

Relevance of extending low-flow support towards November and of having enough storage when release starts

A. Vmax



B. 50% Vmax



Drier and hotter scenario
Extended release period (JASON)

A. Starting low-flow support with reservoir full

B. Starting low-flow support with reservoir half-full

Average number of days in a month below threshold (location: Paris)

Threshold | Crisis | Reinforced alert | Alert | Vigilance

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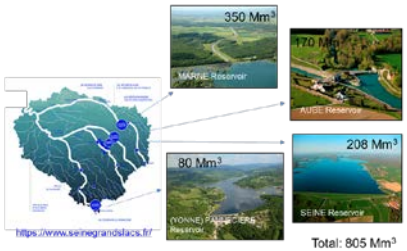
SOS framework for water management

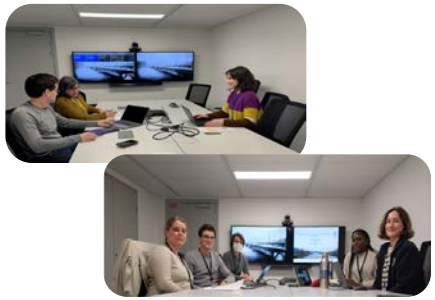
Summary



- **For stakeholders:** relating risks to operations, with focus shift from quantifying all sources of uncertainty to addressing 'what-if' scenarios
  - Seine: under drier climate scenarios, need to extend low-flow support in time, and to ensure reservoir filling
- **For society:** driver of change and adaptation (making collective decisions that can actually translate into actions)

SOS framework for water management

Summary



- **For researchers:** storylines offer a more tangible research-to-operations approach
  - exploring extremes (“stress test”) and interactions with human (management) actions
  - intensive co-creation with stakeholders (recognizing the value of continuity in the engagement process)

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THANK YOU

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