Coupling water quality and quantity models to integrate climate risk to reservoir water quality into water planning

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1. Motivation

- Excess nutrients (N, P) in reservoirs lead to algal blooms (AB). They adversely affect:
  (1) water treatment (2) aquatic ecosystems (3) recreation
- Shallow reservoirs are more vulnerable,
- The risk is amplified by **hotter climates and droughts**.
- Quantifying AB risk is challenging due to uncertainties in:
  (1) climate (2) water demands (3) AB formation equations
- An obstacle for drought resilient planning where water resources investments are generally costly and irreversible

Image credit: https://forthglade.com/blogs/advice/blue-green-algae

Objectives

Build coupled water quantity-quality model → Run model on future scenarios and predict AB risk → Use predictions to influence water supply decision making → Transfer findings to inform regional water planning

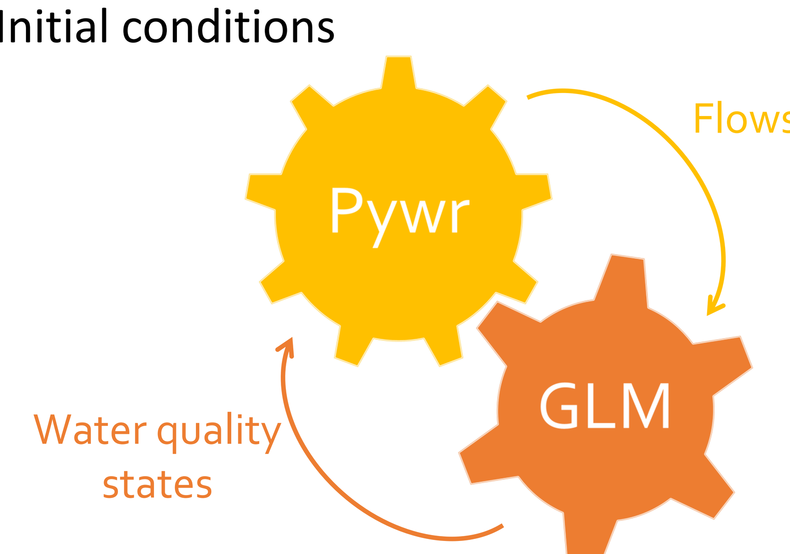
6 CLEAN WATER AND SANITATION

Results will inform billion-pound investment decisions!

2. Models & Coupling Setup

Inputs:

- Candidate water planning strategies
- Forcing variables (flows, meteorology and nutrients)
- Initial conditions



Outputs :

- Risk of algal bloom
- Cost & reliability of water supply

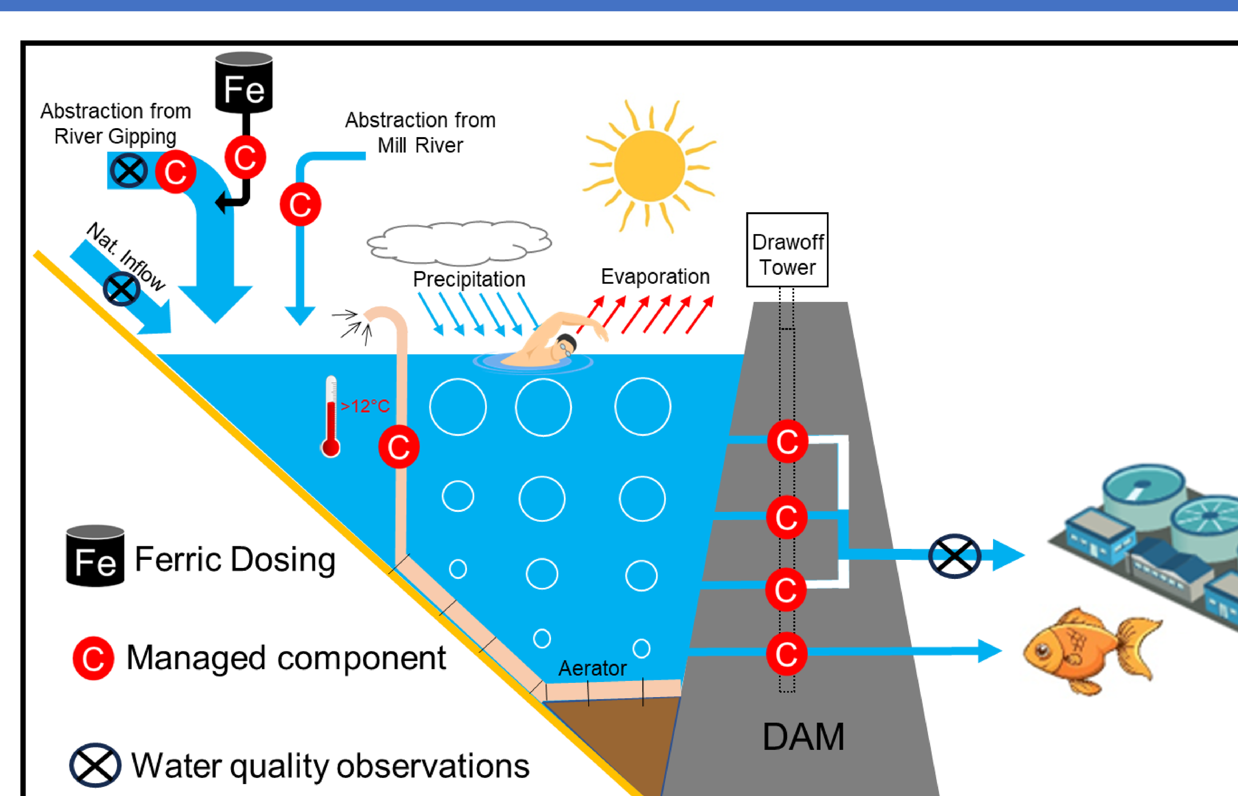
1. Water quantity model: Pywr[1]

- Open-source, fast, water resources allocation model
- Simulates the performance of reservoir systems.
- Flexible timestep
- Developed in Python

2. Water quality model: General Lake Model (GLM)[2]

- Open-source, fast, 1-D hydrodynamic model
- Simulates physical, biochemical and environmental lake processes.
- Hourly simulation timestep
- Developed in C

3. Case Study Reservoir: Alton Water

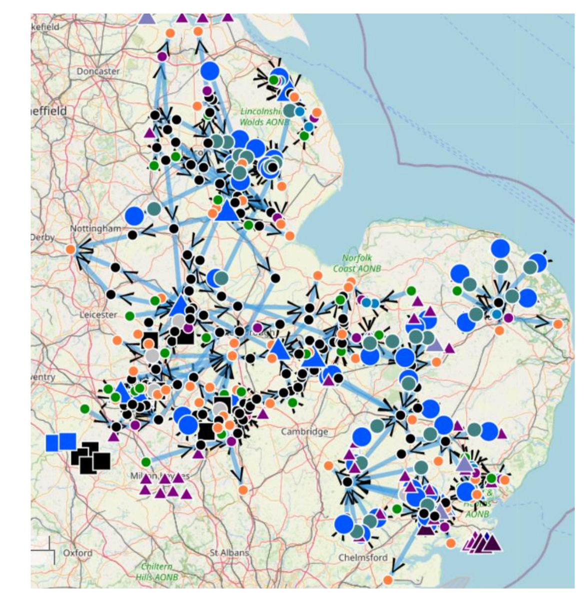


4. Pywr Modeling

Extracting future inflow & demand scenarios from regional model

- Isolate the reservoir for simplicity

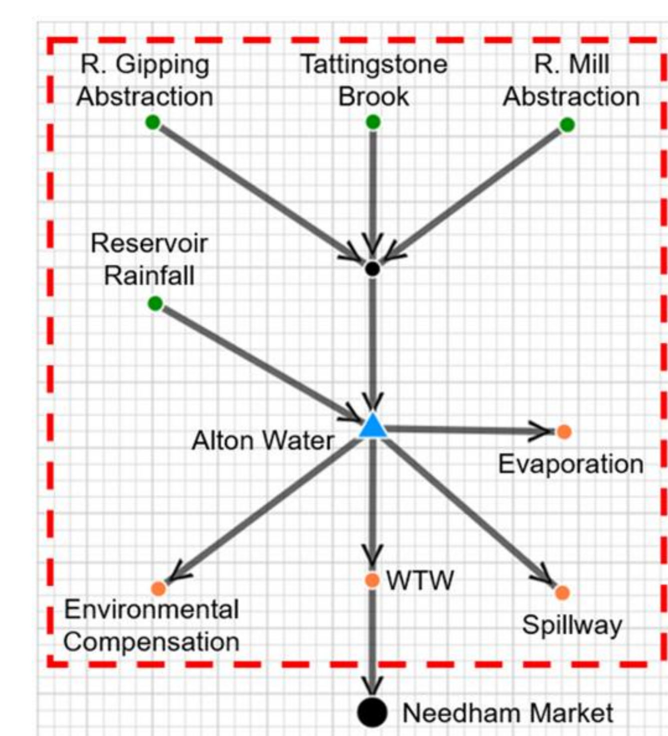
but keep dependency to full water system!



Pywr model of regional water supply area

1. Run regional water system under various climate and water use scenarios

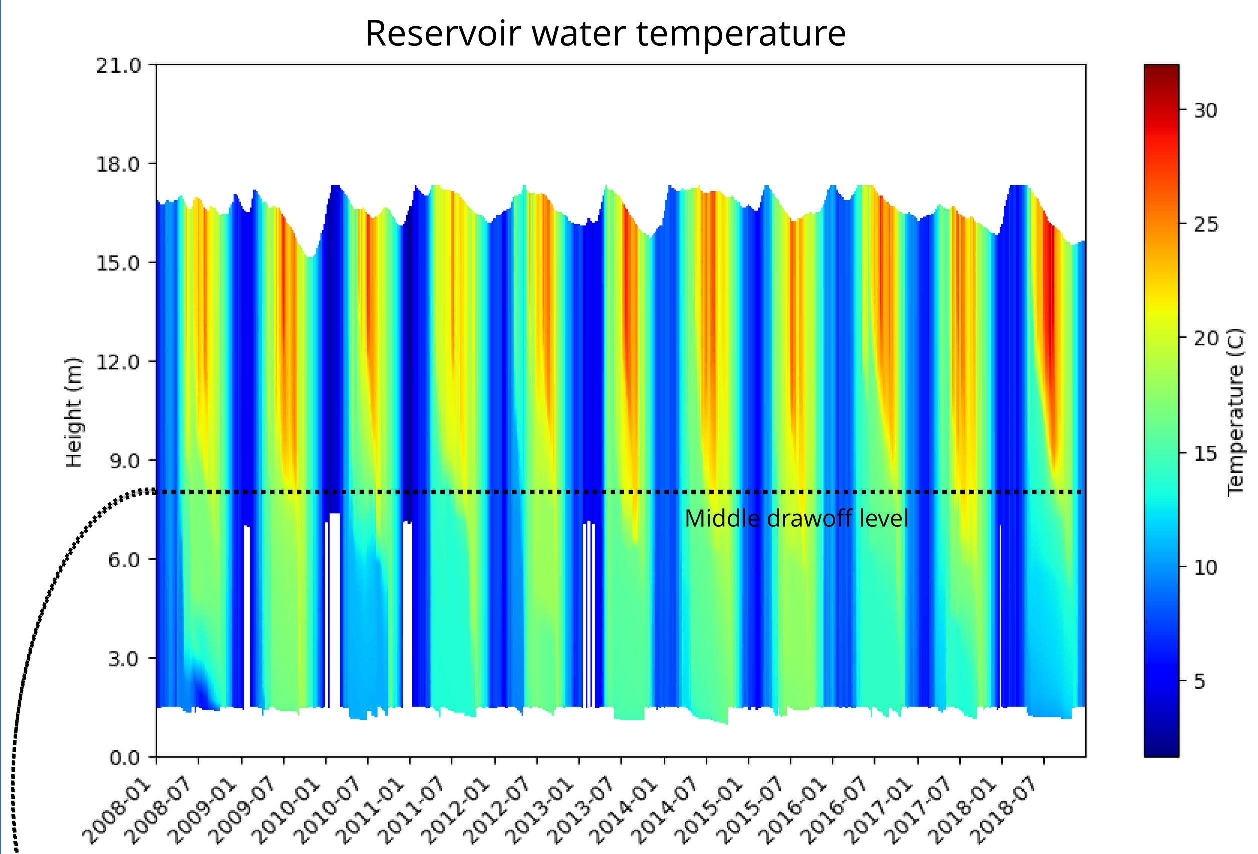
2. Extract inflow and water demand scenarios for Alton Water

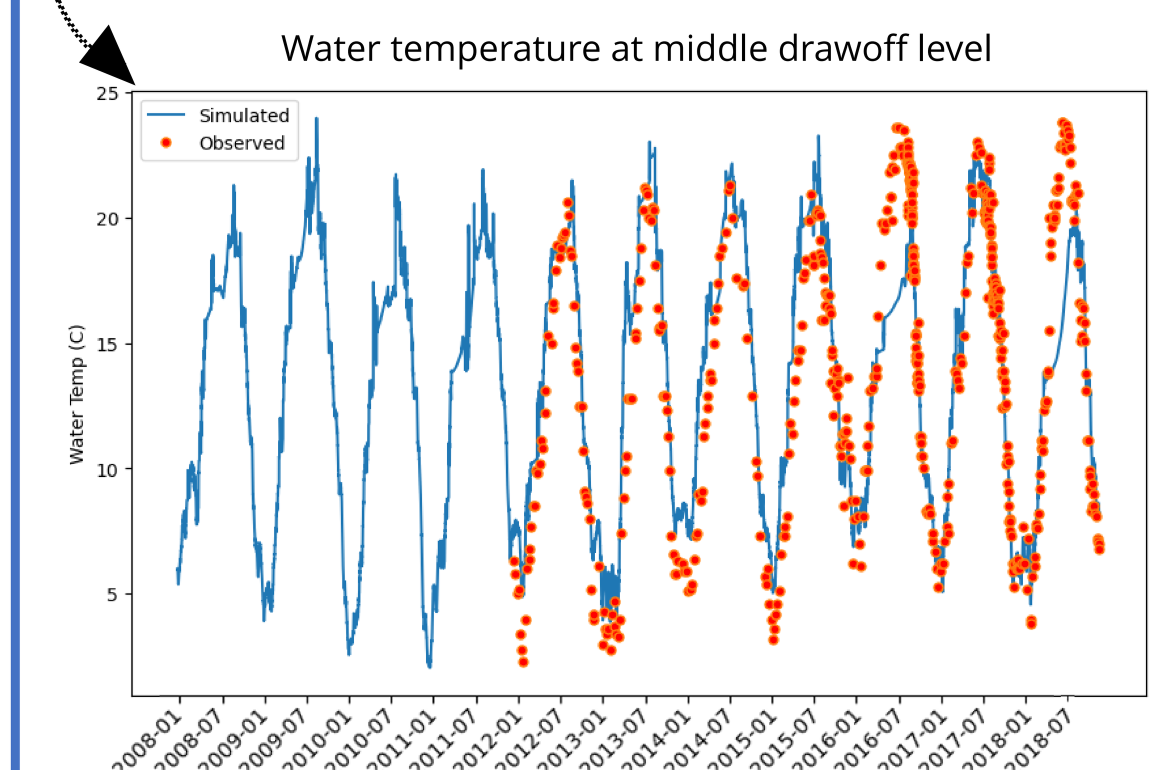


Isolated Network (Alton Water)

5. GLM Modeling

Non-calibrated water temperature simulation





RMSE = 2.46
NSE = 0.82

6. Challenges

GLM validation is challenging due to;

- Water quality measured at one depth,
- Summer artificial mixing facilitated by aerator,
- GLM demanding more water quality variables than water companies usually measure.

GLM is fast but we run thousands of scenarios

- Parametric and input uncertainties necessitate many simulations.

Instabilities in GLM in the coupled setup

- Frequently stopping and restarting GLM results in numerical instabilities

7. Next Steps

Sensitivity analysis

- It will help understand mechanics and key inputs and parameters of AB risk within GLM.

Probabilistic calibration

- Uncertainty ranges of GLM parameters will be estimated to consider them in AB risk assessment.

Double modeling

- A model of simplified water quality dynamics will be created. New model will need less inputs and perform faster than GLM without instability issues.

References

[1] Tomlinson, J.E., Arnott, J.H. and Harou, J.J., 2020. A water resource simulator in Python. *Environmental Modelling & Software*, 126, p.104635.

[2] Hipsey, M.R., Bruce, L.C., Boon, C., Busch, B., Carey, C.C., Hamilton, D.P., Hanson, P.C., Read, J.S., de Sousa, E., Weber, M. and Winslow, L.A., 2019. A General Lake Model (GLM 3.0) for linking with high-frequency sensor data from the Global Lake Ecological Observatory Network (GLEON). *Geoscientific Model Development*, 12(1), pp.473-523.