DROUGHT AND CLIMATE CHANGE IMPACTS ON THE WATER QUALITY OF THE RIVER THAMES

G. Bussi, P. Whitehead, B. Guillod
School of Geography and the Environment, University of Oxford

The problem: pollution in the Thames

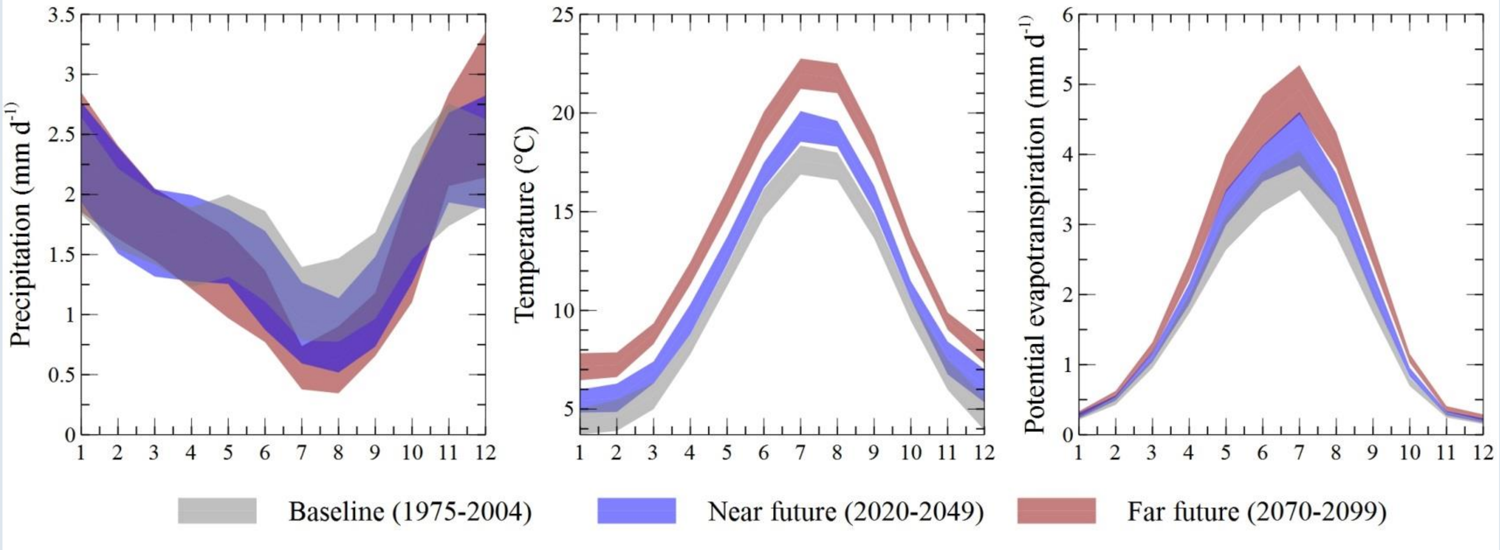
- *Nitrogen*: high nitrate content due to intensive agriculture and fertiliser use
- *Phosphorus*: from effluent (36 STWs, ~ 3M PE) and from fertilisers
- Phytoplankton: algal blooms in summer due to high temperature, radiation and high nutrient availability
- Others: suspended solids, organics, pathogens, microplastics…

The problem: drought & climate change

- Drought:
  - Low flows = low effluent dilution capacity (P), high residence times (phytoplankton)
  - When water availability is low, water quality becomes a concern for water supply
- Climate change:
  - Increase in temperature
  - Dryer summers and wetter winters
  - Low flows likely to decrease

The problem: drought & climate change

- *weather@home (w@h) climate data*: climate model run on volunteers' computers around the world
    - Baseline : 1975-2004 ~ 100 time series
    - Near future: 2020-2049 ~ 100 time series
    - Far future: 2070-2099 ~ 100 time series



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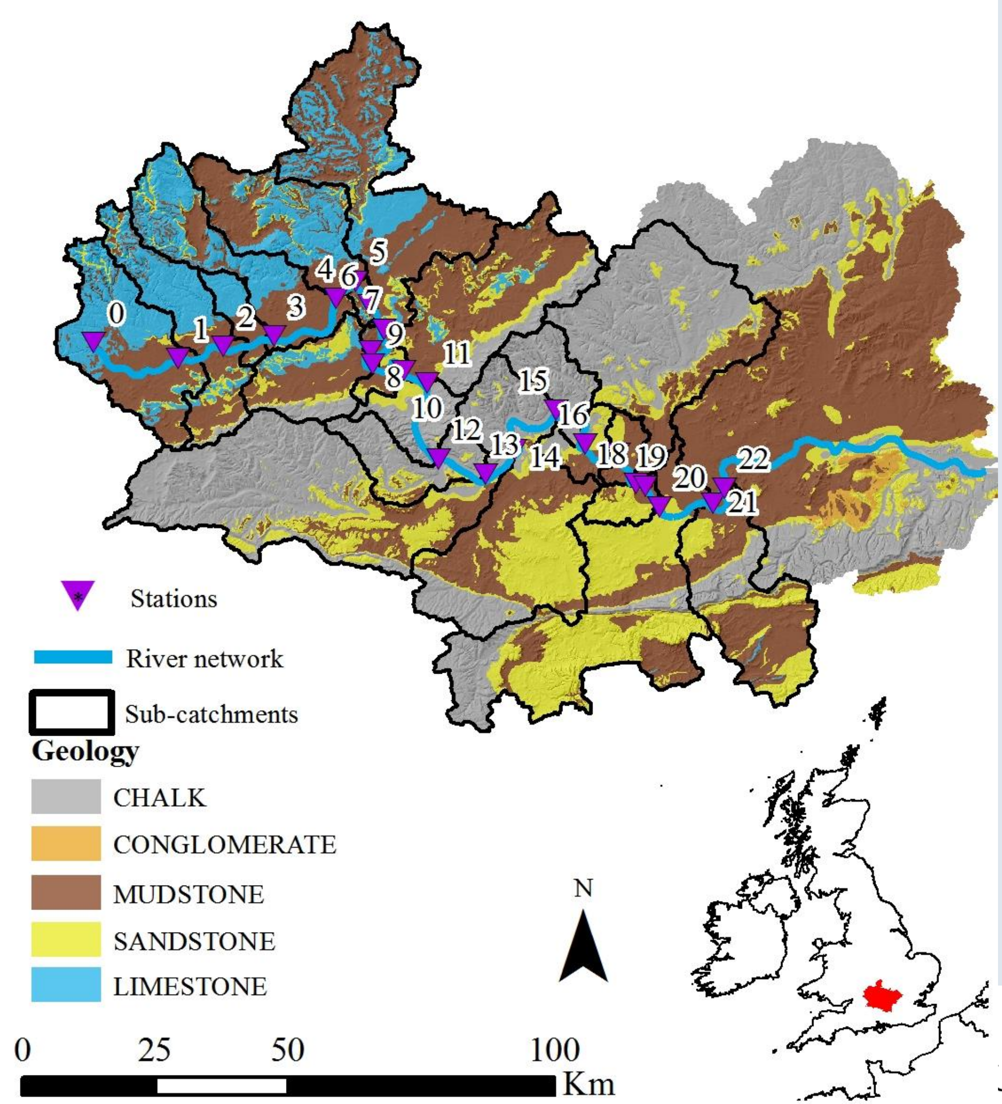
Case-study: the River Thames



- ~10,000 km^2
- 158 km (non-tidal)
- Drinking water supply for ~14M
- Prec.: 730 mm/year
- Temp.: 11C (4.6-16.4)
- Arable land: 39%
- Urban land: up to 30% in the lowlands

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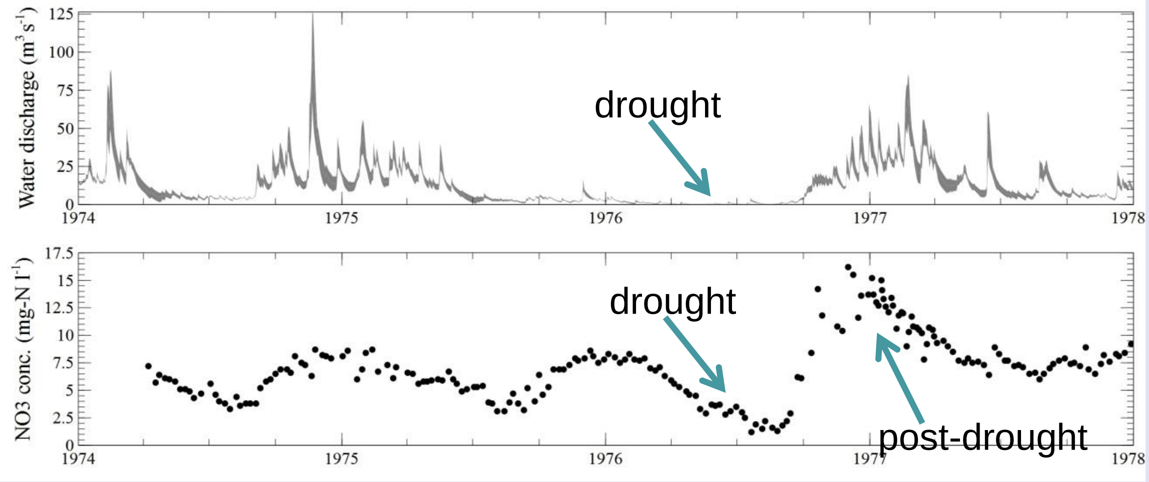
Nitrogen: drought impacts

- During drought:
  - reduced agricultural runoff and drainage
  - increased denitrification due to longer water residence times
- During drought termination (or drought recovery):
  - nitrate flushed from the catchment soils

Thames at Farmoor

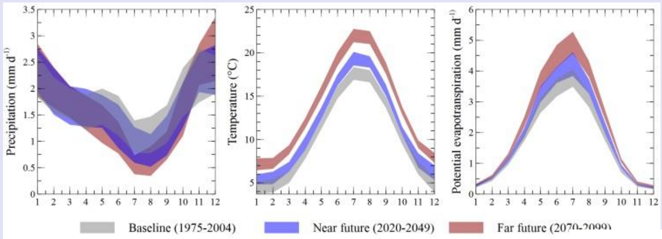


Flow: INCA model
Nitrate: Env. Agency

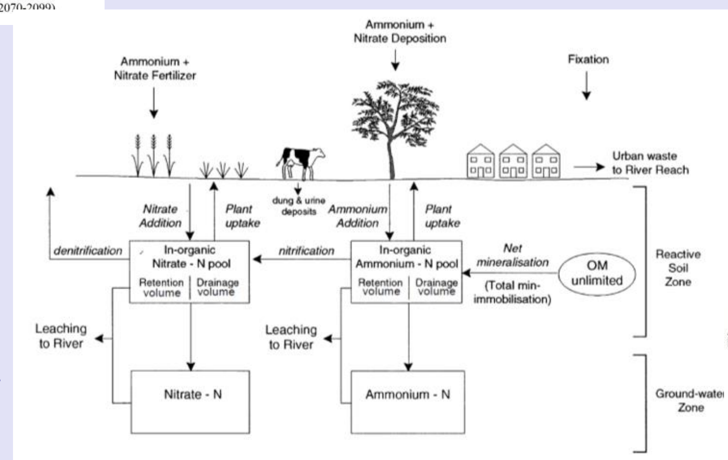
Nitrogen: climate change

- Decrease in nitrate concentration:
  - Less runoff: lower export of nitrogen from soils to the rivers
  - Increased plant uptake (?)
  - Lower flows expected in summer: lower nitrate concentration due to increased denitrification (longer residence times)
- But…increase in drought termination nitrate peaks:
  - Increase in winter precipitation: larger export of nitrogen from soils
  - Increase in torrentiality and floods: more nitrogen “flushed” from soils after droughts

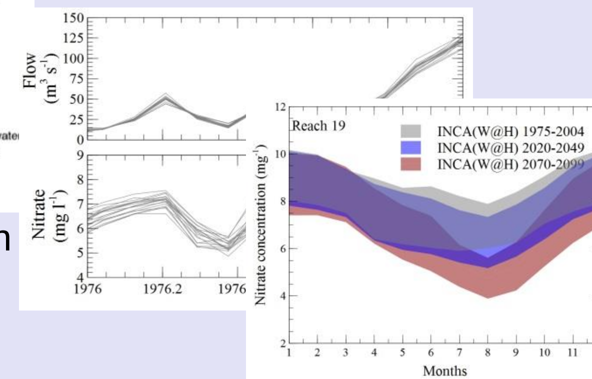
Nitrogen: methodology



Climate model data:
100 x Baseline (1975-2004)
100 x Near future (2020-2049)
100 x Far future (2070-2099)



Calibrated INCA model: flow and nitrogen predictions



Results analysis: drought impact assessment under a changing climate

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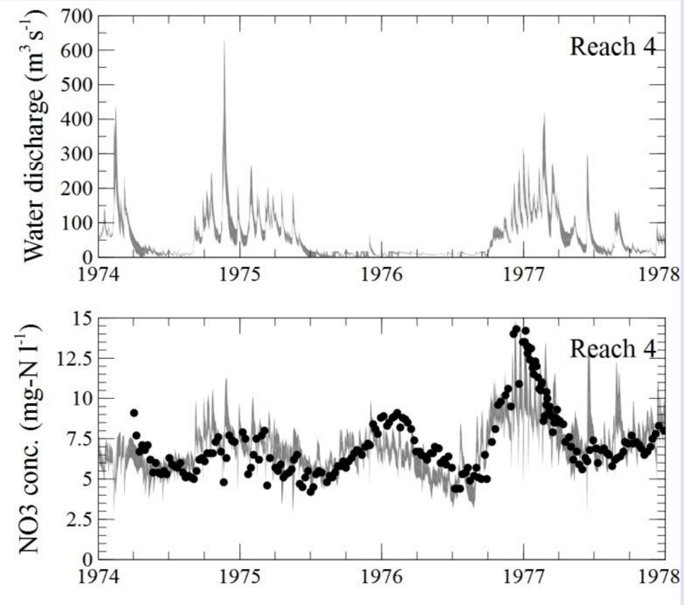
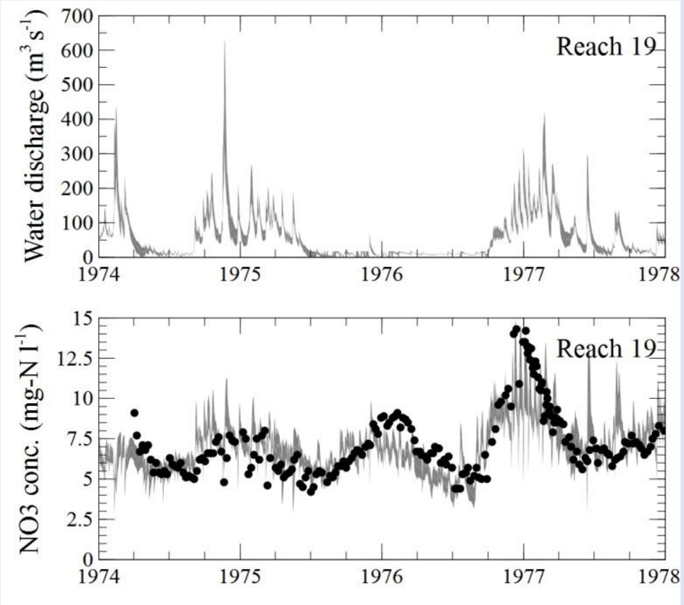
Nitrogen: model calibration

- Monte Carlo-based sensitivity analysis on the model parameters
- 20 "behavioural" model selected (i.e., the best models)





Reach 4

Reach 19

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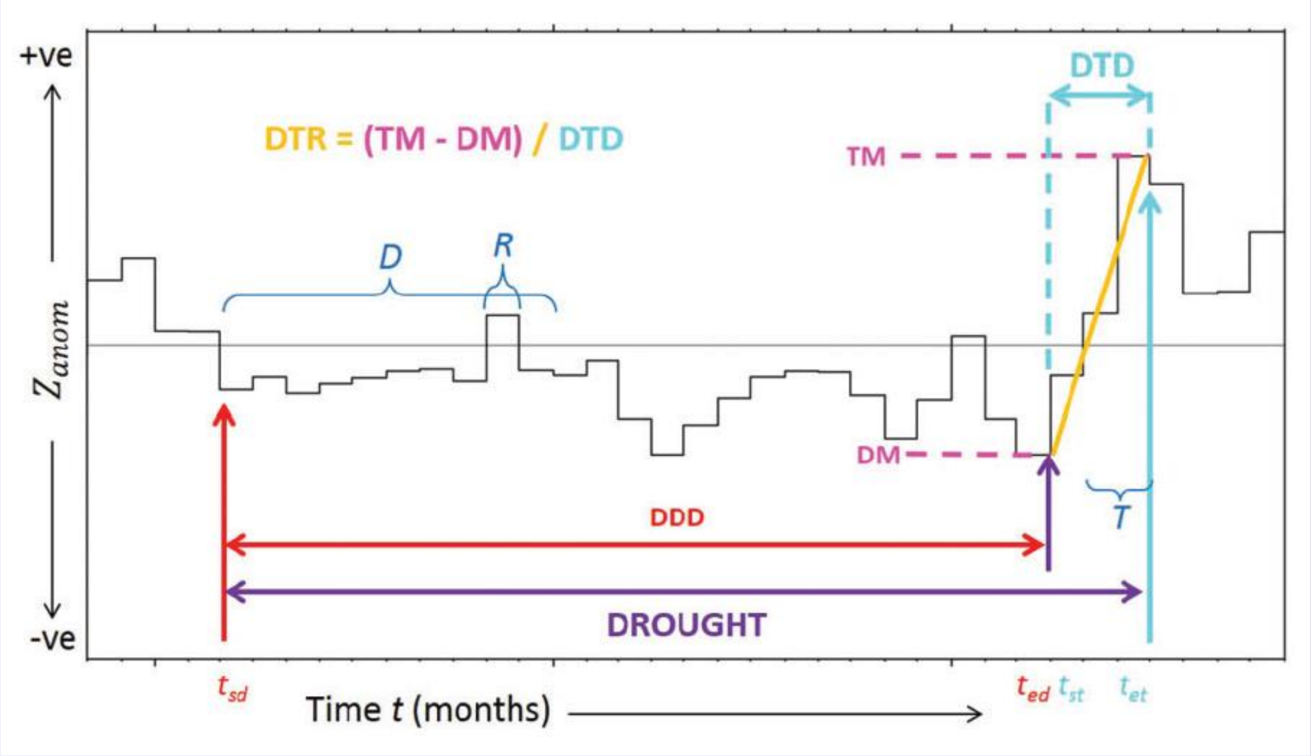
Drought definition

- Parry et al, 2016, Progress in Physical Geography (CEH and Uni. Loughborough)



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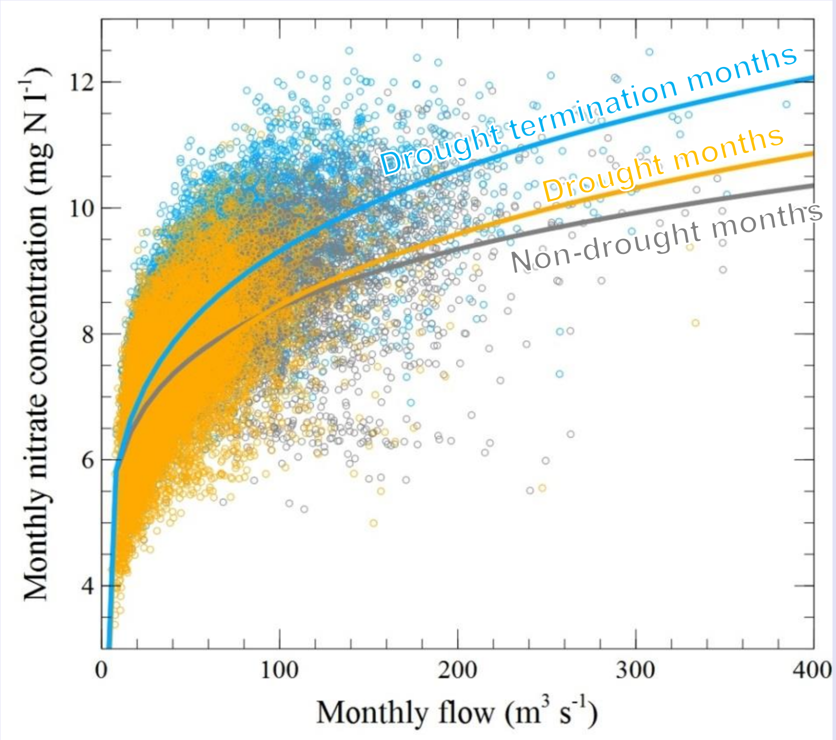
Nitrogen

- INCA model driven by weather@home data
    - Monthly flow vs nitrate concentration relationship



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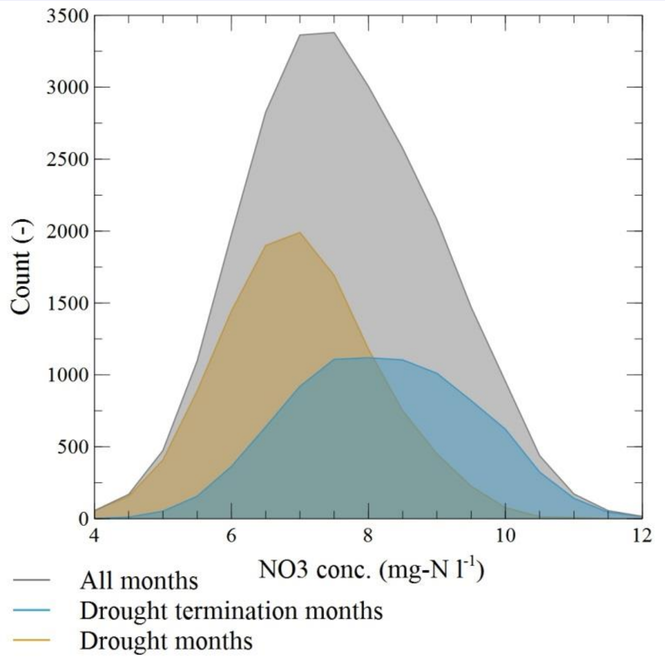
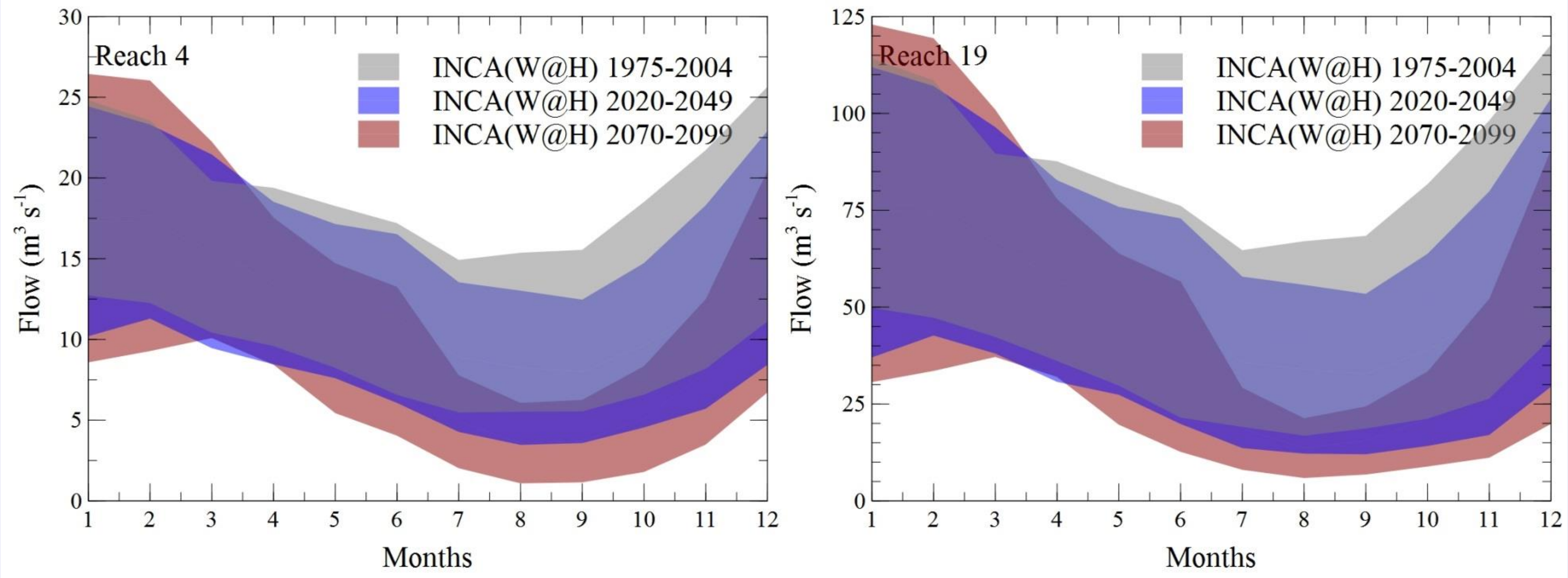
Nitrogen

- INCA model driven by weather@home data
  - Monthly flow and nitrate values depending on the drought phase
  - Increase in NO_3 concentration from drought to drought termination ~ +17%



Nitrogen

- INCA model driven by weather@home data
  - Climate change impact on flow



Nitrogen

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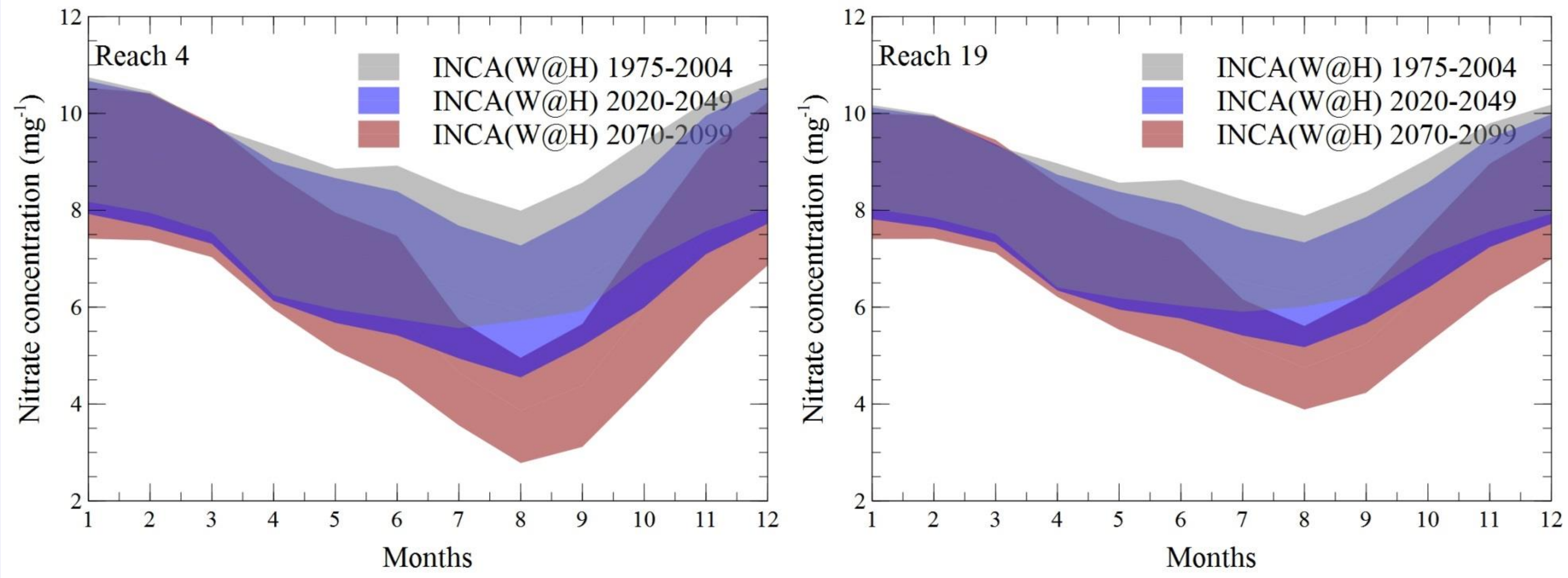
  - Climate change impact on nitrate concentration



Nitrogen

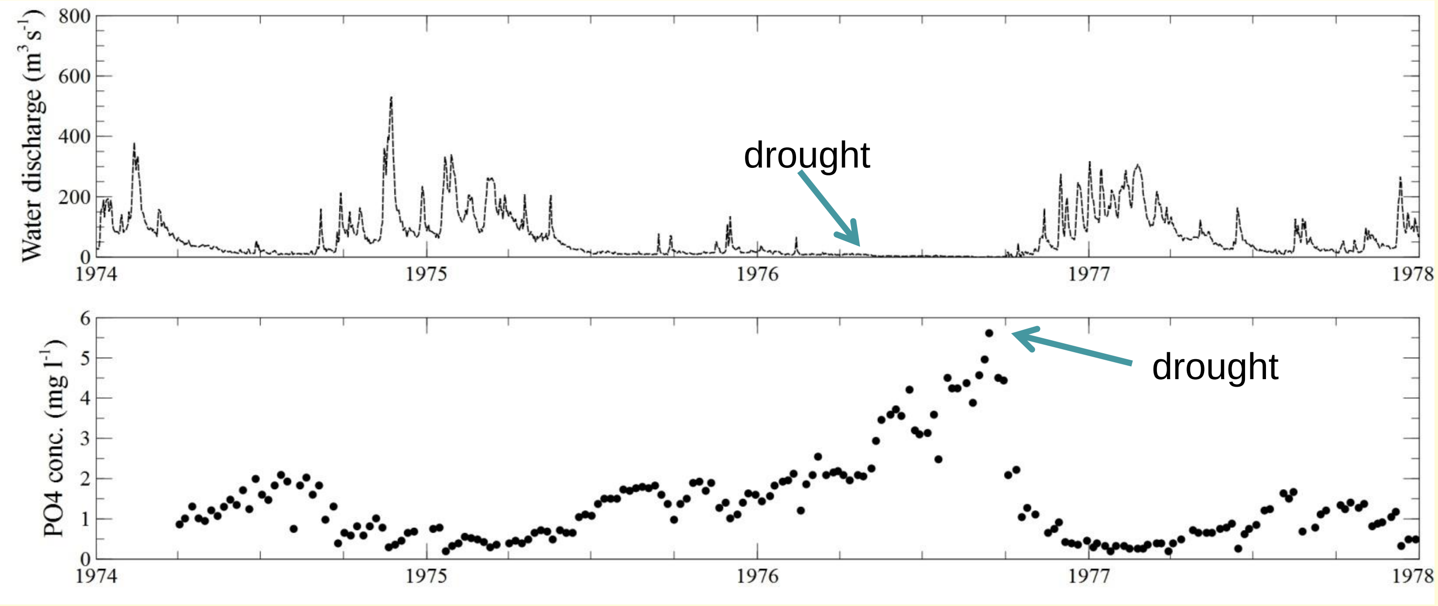
- Climate change impact on drought termination nitrate concentration:
  - 1975-2004: 8.44 ($\pm\sigma$: 7.11-9.76) mg/l
  - 2020-2049: 8.19 ($\pm\sigma$: 6.77-9.61) mg/l
  - 2070-2099: 7.77 ($\pm\sigma$: 6.08-9.47) mg/l

- Climate change impact on drought to drought termination nitrate concentration increase:
  - 1975-2004: +17%
  - 2020-2049: +17%
  - 2070-2099: +21%

Phosphorus: drought and climate change impacts

- Predominantly point sources (STWs)
- Droughts cause lack of dilution and increase in P concentration
- Climate change is expected to cause lower summer flows

Thames at Teddington



Data from the Env. Agency

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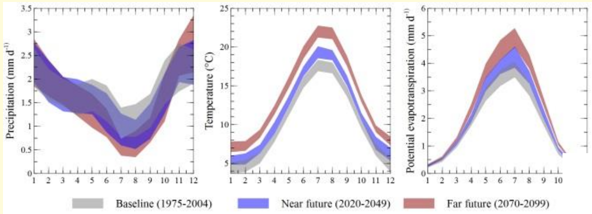

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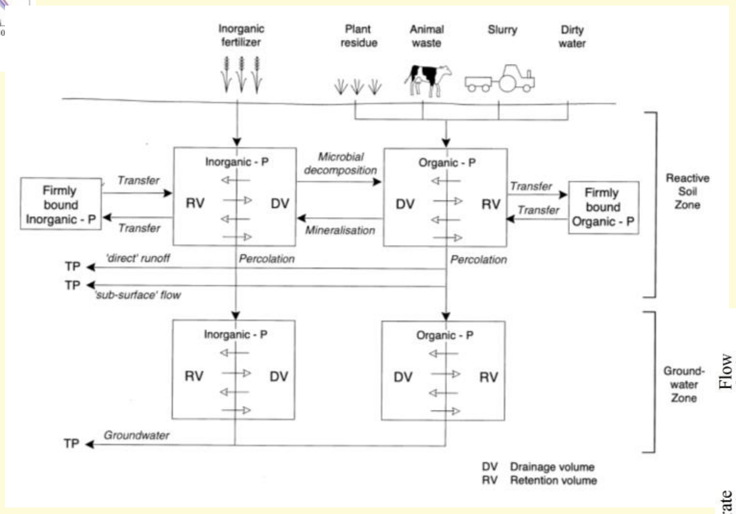
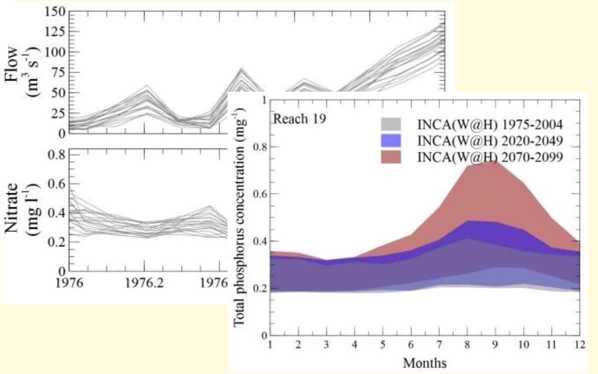


Calibrated INCA model: flow, sediment and phosphorus predictions



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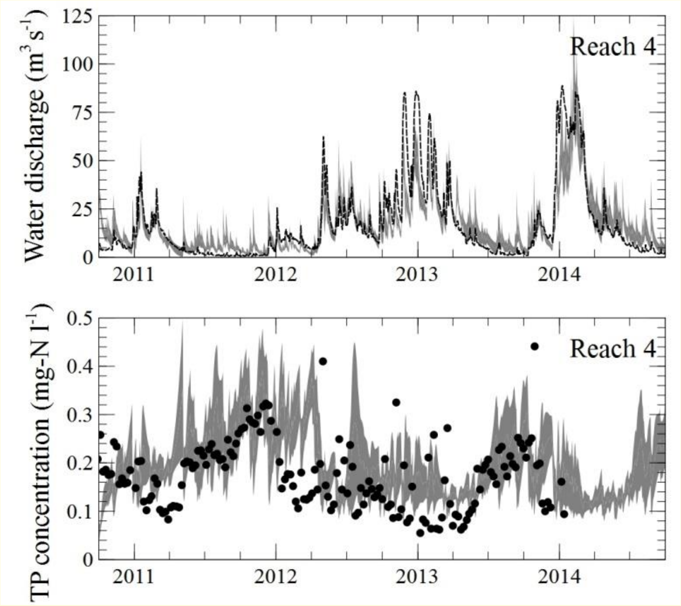
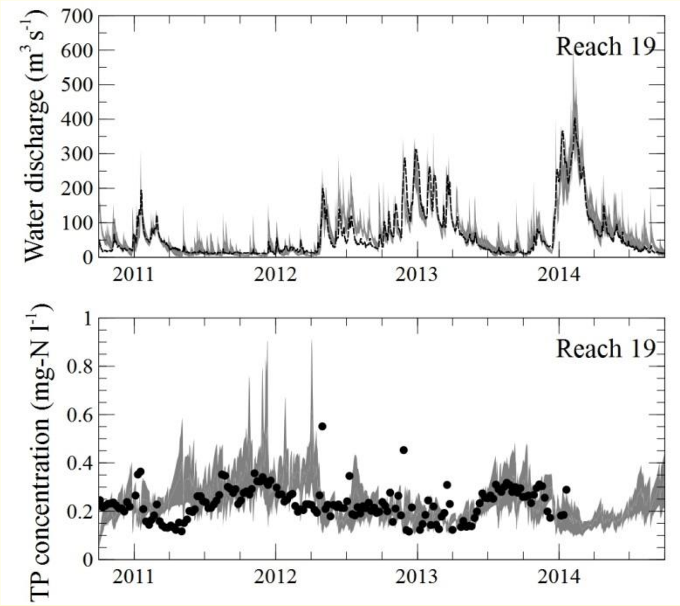
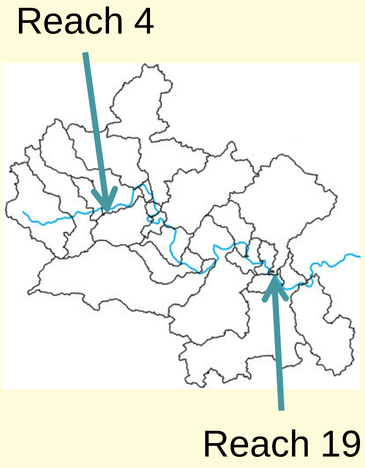
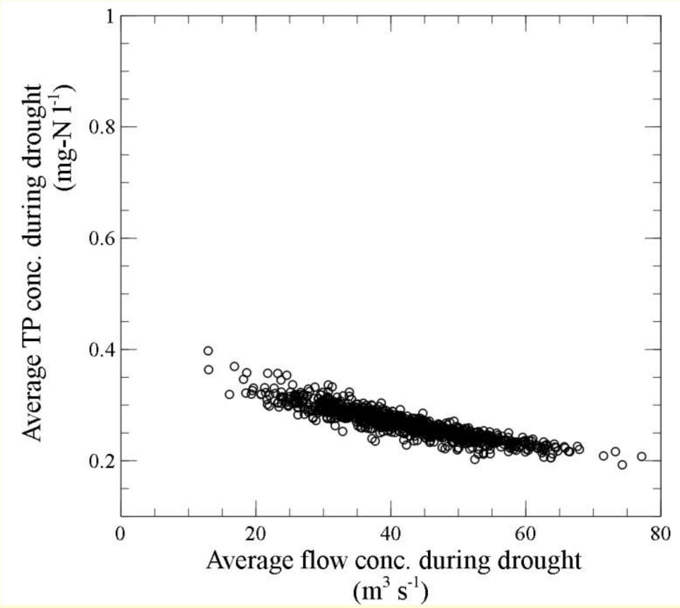


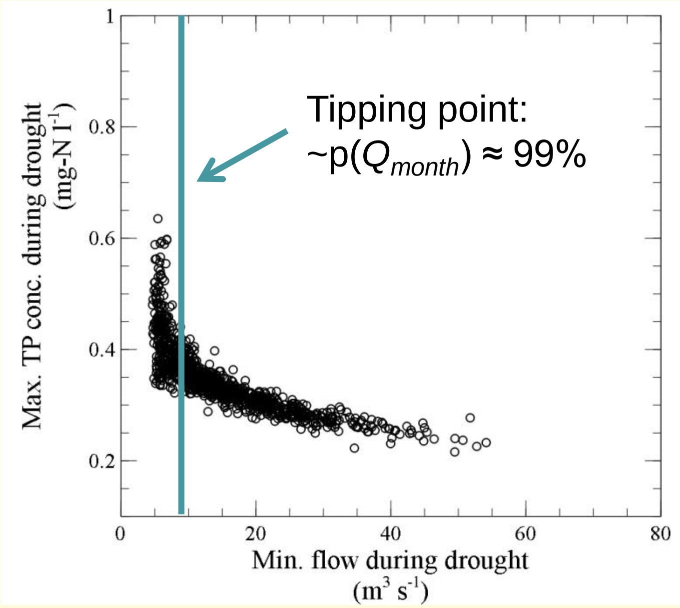




Phosphorus: results

- INCA model driven by weather@home data
  - Phosphorus control during droughts: flow





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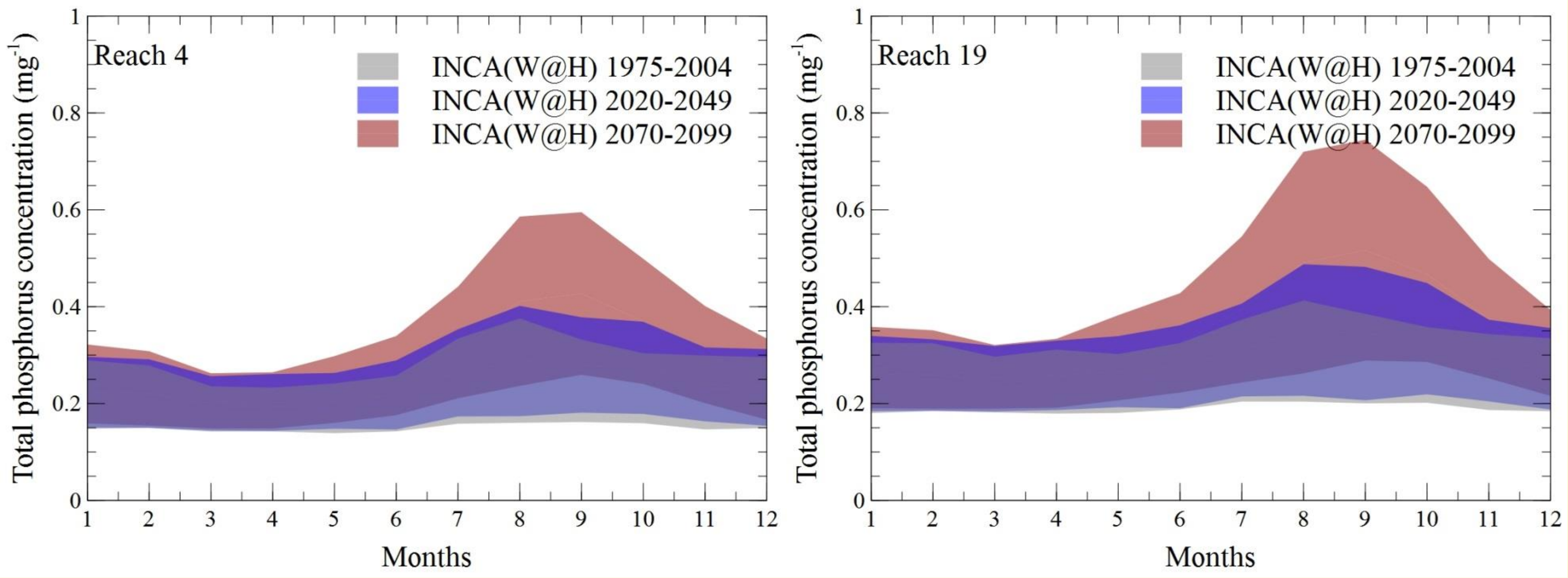
Phosphorus: results

- INCA model driven by weather@home data
  - Climate change impact



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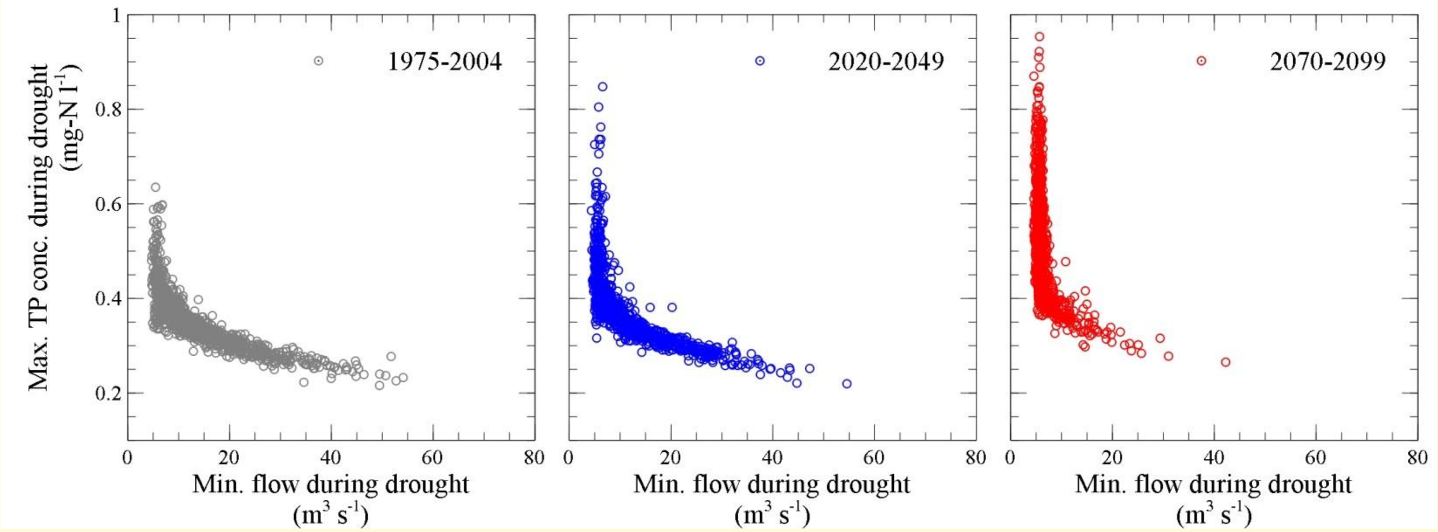
Phosphorus: results

- Tipping point flow:



  - 1975-2004: p(Q_{month}) ≈ 99%
  - 2020-2049: p(Q_{month}) ≈ 98%
  - 2070-2099: p(Q_{month}) ≈ 90%

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Conclusions

- Primary control for droughts & water quality: <u>flow</u>

- Increase of ~17% in nitrate concentration during drought recovery
- Nitrate concentration expected to decrease due to CC (especially in summer)

- Phosphorus concentration controlled by flow (dilution)
- Phosphorus concentration expected to increase in summer due to CC, up to 0.5 mg/l in average (WFD limit: 0.1 mg/l)

THANK YOU!

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