River water quality modeling using continuous high frequency data allows disentangling whole-stream nitrogen uptake and release pathways

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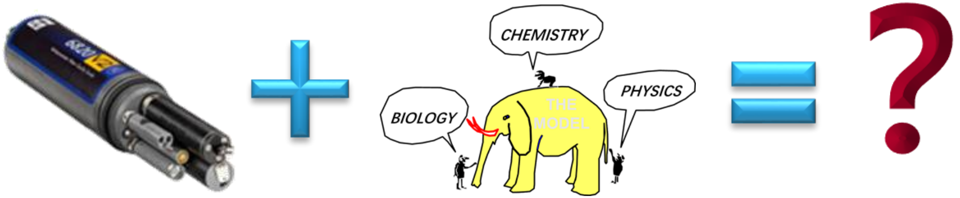
Research Questions

- **Q1**: How can the combination of emerging high frequency monitoring techniques and water quality modeling support continuous quantification of instream N uptake pathways?
- **Q2**: What are instream N uptake efficiency and pathways over the 5 years and their inter-annual comparison?
- **Q3**: What are their seasonal patterns?
- **Q4**: What are their characteristics at the extreme low flow in summer 2018?



Method

- **Model Name**: WASP7.5.2 Advanced Eutrophication Module
- **Model Domain**: 27.4-km 5th river
- **Time Range**: 5 years
- **Time Step**: < 0.01 d
- **Model Setup:**
  - Flow Boundary
    - Upper: 15-min interval Q at GGL
    - Lateral: calculated daily discharge
  - Water Quality Boundary
    - Upper: **15-min** interval data for **DO, NO3, Chl-a** at GGL, monthly data for other variables
    - Lateral: calculated daily NO3, bi-monthly data at routine WQ stations for other variables
- **Model Calibration**:
  - Data: 15-min interval simulations vs measurements at STF
  - Step 1: Q
  - Step 2: Phytoplankton **Chl-a** & periphyton biomass carbon
  - Step 3: **Diurnal DO—>GPP (for assimilatory uptake)**
  - Step 4: **NO3 (for denitrification)**
- **N Uptake Calculation**: At daily, seasonal, annual & 5-y scales.

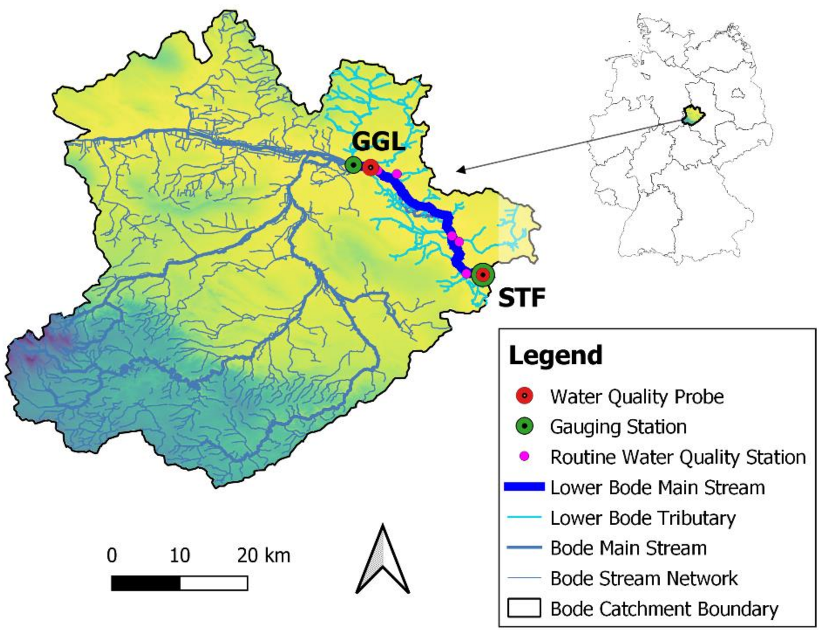


Fig. 1 Site description of Lower Bode

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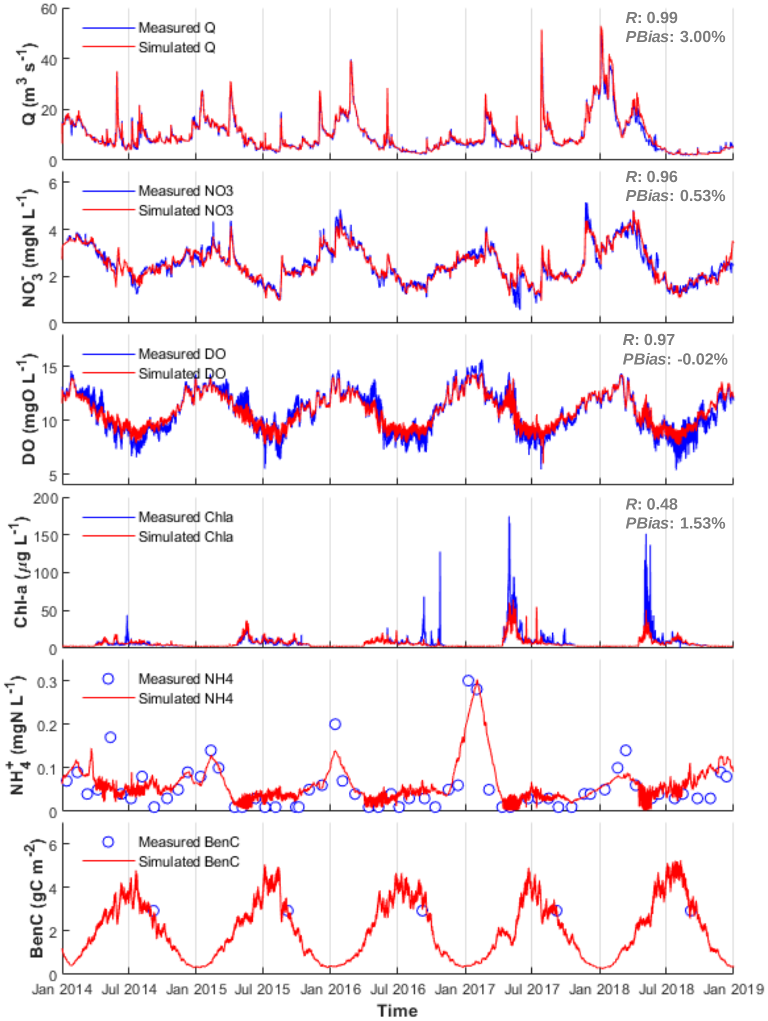
Simulation vs Measurement (Q1)

- ✓ Not only compare **state variables**, but also **process fluxes**!
- ✓ In this case, **GPP** from measurement is the hidden process information in high frequency data to support quantification of **assimilatory N uptake.**
- ✓ In spring, GPP by Phytoplankton is dominant. In summer, GPP by Periphyton is dominant.

Fig. 2 State variable comparison



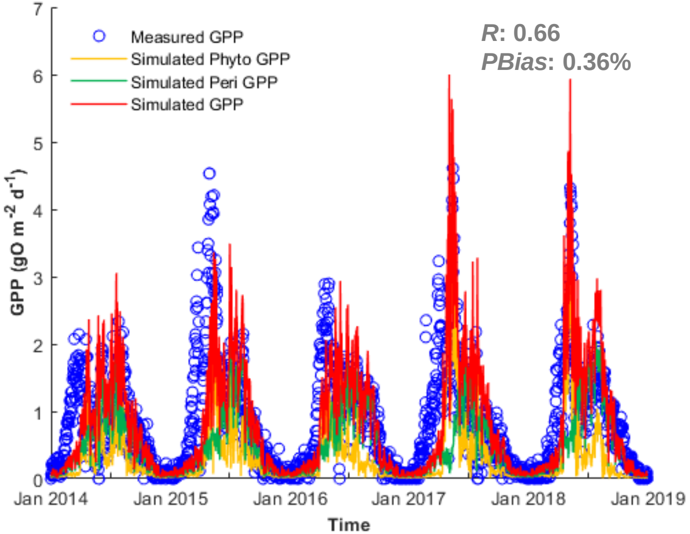


Fig. 3 Simulated and observed GPP comparison

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Instream DIN Uptake on 5-Year and Annual Scales (Q2)

5-Year

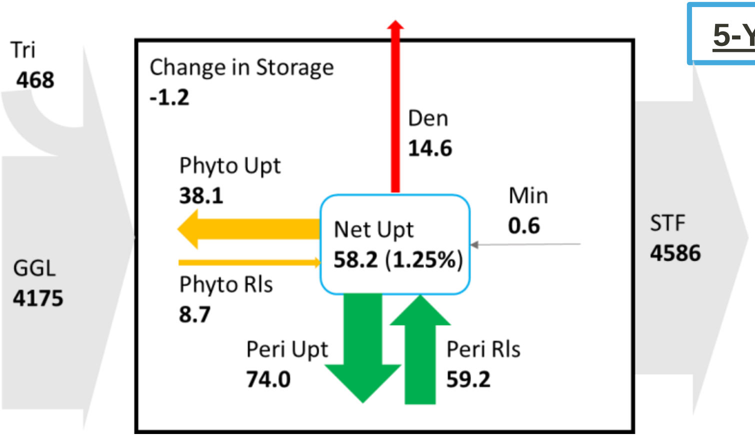

Fig. 4 Total DIN budget in Lower Bode from 2014 to 2018

The black box represents the lower Bode.

The line thickness is proportional to the DIN fluxes in the unit of MgN (=10^6 gN).

- ✓ Net DIN uptake efficiency in the 5th-order agricultural river amounted to **1.25%**.
- ✓ Total uptake amount ranking via pathways: Periphyton Uptake > Phytoplankton Uptake > Denitrification

Annual

- ✓ Annual mean DIN uptake rate varied from **47.37 (2015)** to **67.09 (2018)** mgN $m^{-2}d^{-1}$
- ✓ The DIN uptake efficiency of 2018 was not the highest because of the maximum input load.

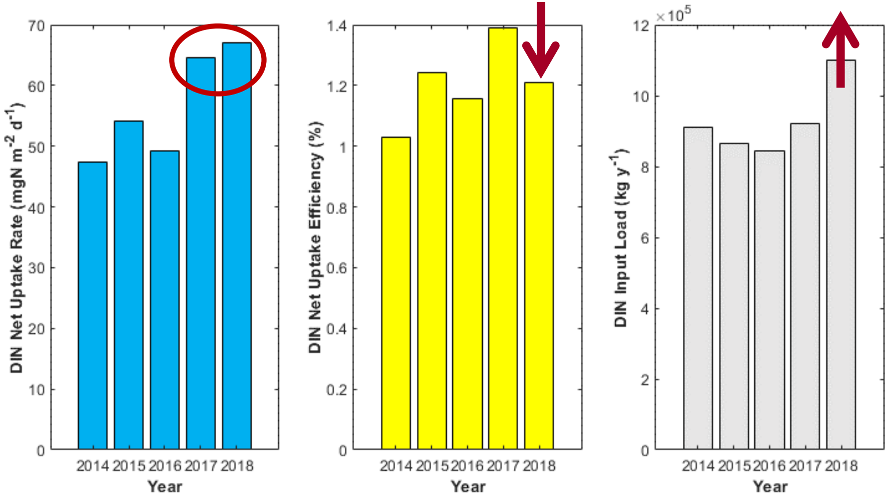

Fig. 5 Annual DIN uptake rate, uptake amount of the total load & total input DIN Load.

Seasonal Patterns (Q3)

Seasonal

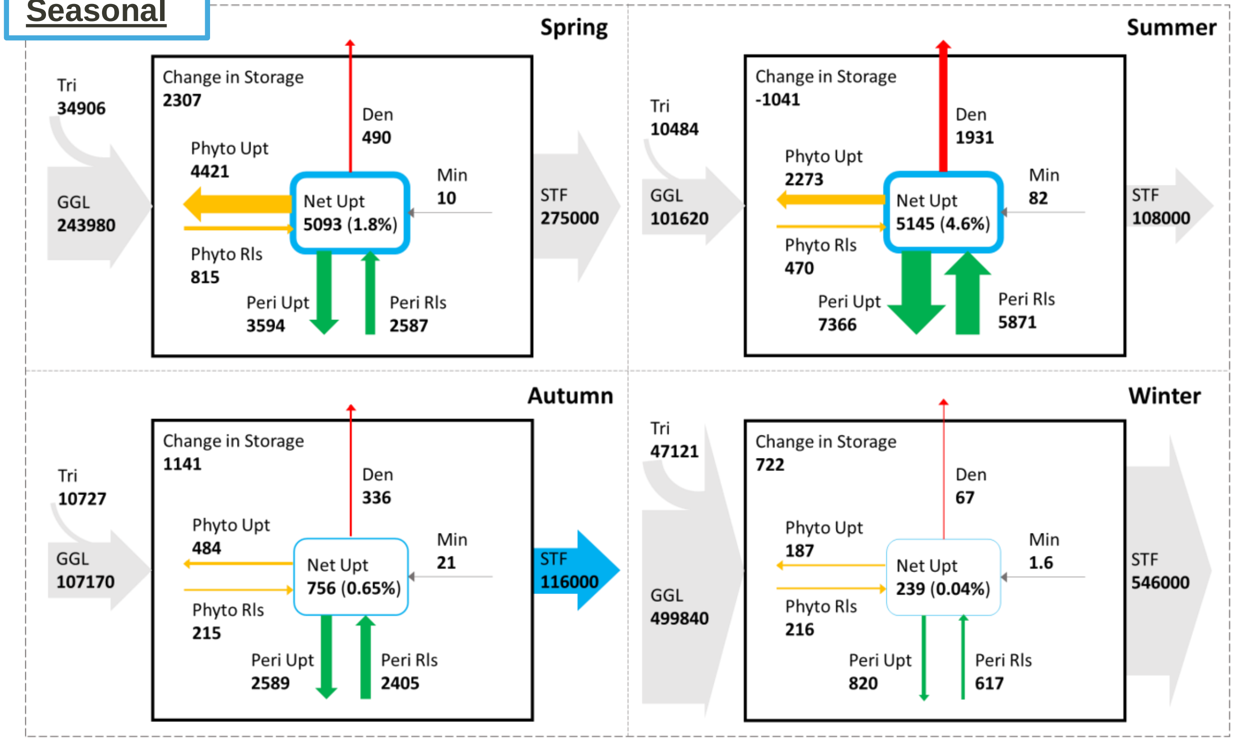

Fig. 6 Seasonal DIN budget in Lower Bode (average results from 2014 to 2018, in kgN)

The beginning of the seasons is set at: Spring - 1 Mar, summer - 1 Jun; autumn - 1 September and winter - 1 December.

- **DIN Uptake Amount Seasonal Ranking**: Summer > Spring > Autumn > Winter
- **Efficiency Seasonal Ranking** : Summer (4.6%) > Spring (1.8%) > Autumn (0.65%) > Winter (0.04%)
- **Spring + Summer**: The sum of net DIN uptake amounts accounted for **91%** of total uptake amount of the year.
- **Spring**: Phytoplankton uptake is dominant (52%).
- **Summer**: Periphyton uptake is dominant (63%).

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At Extreme Low Flow (Q4)

- The DIN Uptake **rates** at extreme low flow in 2018 was **not especially higher** than those over the same period in the previous years. They were lower than those during the spring of 2017 and 2018 when **phytoplankton bloomed**.
- However, the DIN uptake **efficiency** during this period was **significantly higher** than usual over the 5 years, with the highest value of **~30%**.
- **Denitrification** contributed **half of the net uptake** (~15%) when the uptake efficiency was highest at this stage.

Fig. 7a DIN Net Uptake rate on a daily scale

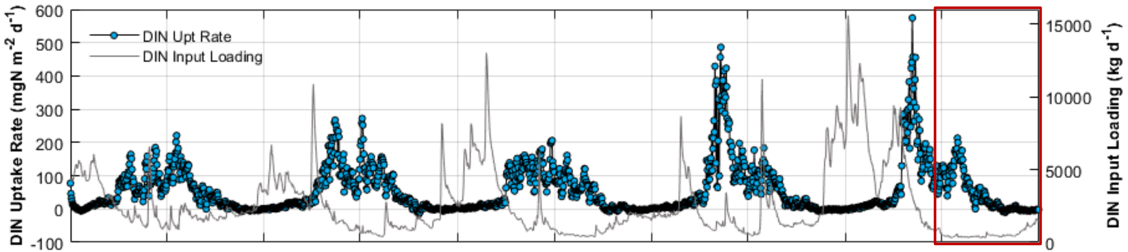


Fig. 7b Net DIN uptake efficiency on a daily scale

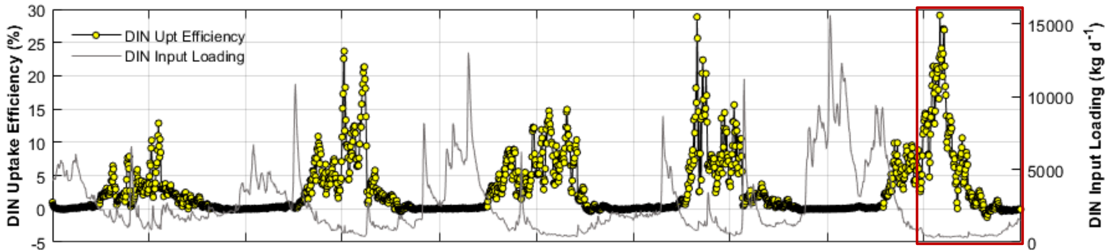
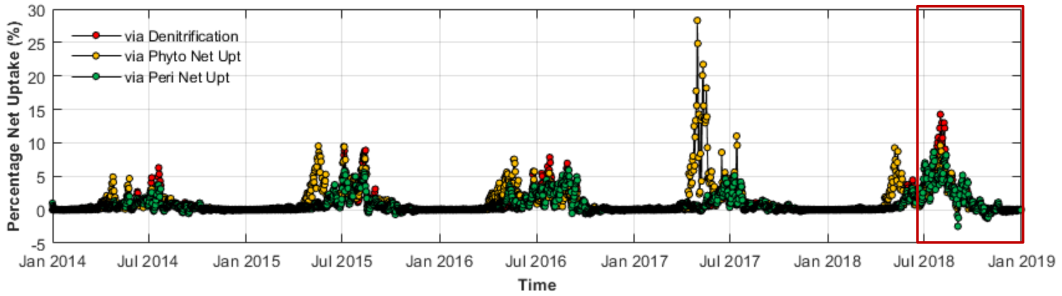


Fig. 7c Net DIN uptake efficiency via different processes



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Take-Home Message

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- Our model performs satisfactorily in mimicking patterns of **NO3, DO, Chl-a, GPP**, etc., one of the few model testing with both simulated and measured state variables at such high temporal resolution **(15-min interval**) with such time span (5-year).

- Our study highlights the value of high frequency data to support river water quality modeling allowing continuous quantification of **instream N uptake pathways** (phytoplankton uptake, periphyton uptake & denitrification).

Thank you!

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