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Disentangling in-stream nitrate uptake pathways based on two-station high-frequency monitoring in high-order streams

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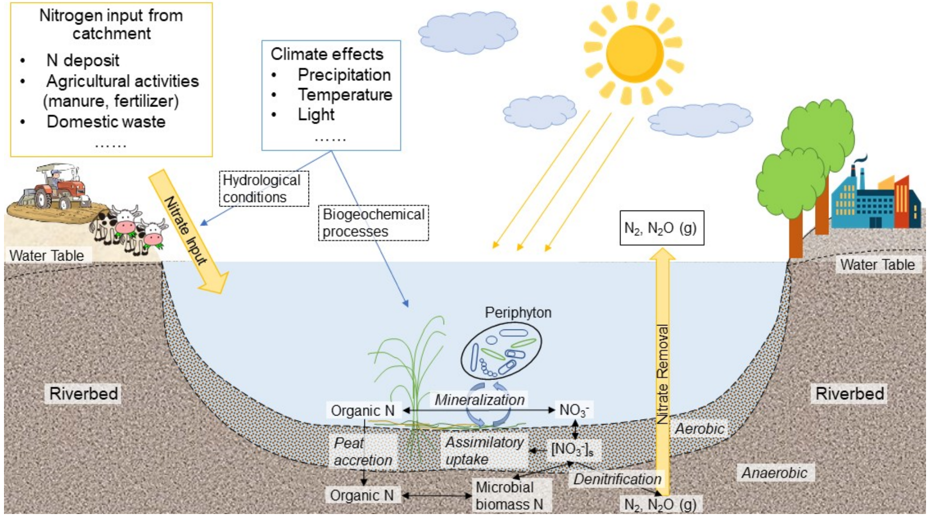
Why and What we want to do?

Motivation

- ➢ In-stream biogeochemical processes can highly influence nutrients load transporting from land surface to the sea.
- ➢ Nitrogen is one of the most concerned nutrients when considering water quality.
- ➢ Researches about N uptake in high order streams are still limited.

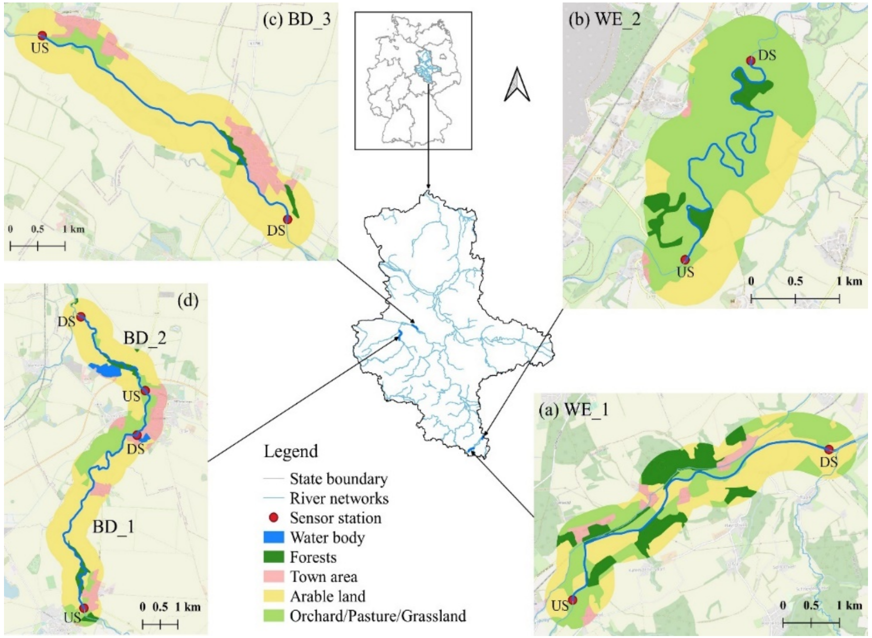
Main research questions

- How does reach-scale N uptake process change under different environment condition and river morphology?
- How does different reach-scale N uptake pathways change?



Methods

Study reaches



Reach	River	Upstream station	Downstream station	L	W	SI	Slope (‰)
WE_1	Weisse Elster	51°00'29"N, 12°01'28"E	51°01'46"N, 12°05'27"E	6280	23	1.20	9.55
WE_2	Weisse Elster	51°05'58"N, 12°12'15"E	51°07'07"N, 12°12'58"E	6100	23	2.65	11.50
BD_1	Middle Bode	51°53'25"N, 11°10'59"E	51°55'57"N, 11°12'26"E	7170	17	1.44	6.97
BD_2	Middle Bode	51°56'36"N, 11°12'40"E	51°57'43"N, 11°11'07"E	3360	17	1.24	5.95
BD_3	Lower Bode	52°00'03"N, 11°21'21"E	51°58'14"N, 11°25'11"E	6150	20	1.12	1.63

* L, length (m); W, width (m); SI, sinuosity ; Slope was calculated based on each reach

- ❑ 2 rivers (the Weisse Elster (4^{th}) and Bode (6^{th}) river)
- ❑ 5 reaches
- ❑ 2-3 campaigns in each reach, 11 campaigns in total
- ❑ 3-14 days each campaign, accompanied with water samples

Results

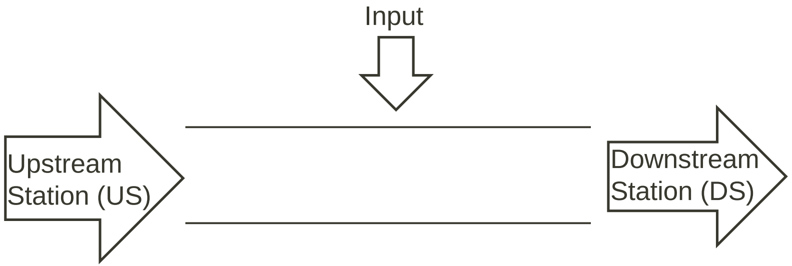
Summary of high frequency measurements for all campaigns

Parameter	WE_1		WE_2		BD_1		BD_2			BD_3	
	2019-05	2019-09	2019-05	2019-09	2019-06	2020-08	2019-06	2020-08	2021-07	2019-08	2020-08
Q (m^3 s^{-1})	9.06±0.38	4.55±0.18	8.58±0.44	4.75±0.26	2.5±0.11	1.57±0.08	2.34±0.17	1.65±0.31	1.93±0.17	1.98±0.11	2.2±0.06
T (℃)	11.84±0.97	13.09±0.5	13.29±2.1	15.17±0.41	19.52±0.7	19.3±1.39	19.35±0.47	20.65±0.64	18.54±1.11	18.56±0.78	16.74±0.24
N (mg l^{-1})	3.84±0.05	3.85±0.13	3.62±0.11	3.51±0.05	1.76±0.03	1.23±0.05	1.65±0.05	1.22±0.08	1.73±0.09	1.23±0.06	1.01±0.06
DO (mg l^{-1})	10.86±0.54	10.33±0.3	10.84±0.82	9.99±0.73	8.68±0.45	8.59±0.37	8.77±0.35	8.16±0.37	8.82±0.41	9.32±1.18	9.45±0.54
Turb (FNU)	1.91±0.23	1.53±0.16	1.78±0.11	1.52±0.17	3.84±0.17	1.8±0.22	4.21±0.44	2.11±0.58	4.05±0.61	1.2±0.14	1.2±0.11
pH	8.13±0.08	8.44±0.05	8.26±0.1	8.65±0.06	8.25±0.07	7.97±0.04	8.23±0.05	7.88±0.05	8.01±0.05	8.15±0.11	8.03±0.06
SpCond (µS cm^{-1})	850.5±52.5	1224.4±39.0	1051.9±32.1	1337.6±16.1	727.5±6.5	733.0±23.5	822.6±21.6	789.0±48.6	768.6±32.9	1094.1±12.5	1169.9±31.6
Chl-a (µg l^{-1})	4.19±0.57	2.72±0.47	2.63±0.45	3.2±0.26	2.12±0.15	2.84±0.58	2.19±0.13	2.8±0.6	1.35±0.13	4.46±0.85	2.57±0.13
τ (h)	5	7	4.5	6	8	14	3.5	4.5	4	14	15.5
v (m s^{-1})	0.35	0.25	0.38	0.28	0.25	0.14	0.27	0.21	0.23	0.12	0.11

Methods

Two station mass balance

Conceptual model of two station mass balance method:



Multiple parameter sensors:

- ✓ Dissolved Oxygen (DO)
- ✓ Nitrate-N concentration
- ✓ Water temperature
- ✓ Specific conductivity

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Stream metabolism

- $NEP_t = \frac{Q_{DSt+\tau/2}[DO]_{DSt+\tau/2} - Q_{USt-\frac{\tau}{2}}[DO]_{USt-\frac{\tau}{2}} - Q_I[DO]_I - kQ_t[DO]_{deft}}{w \times L}$
- $ER_t = NEP_{nighttime,t}$
- $GPP_t = NEP_t + ER_{mean}$

Nitrate uptake

- $U_{NETt} = \frac{Q_{USt-\tau/2}[NO_3^- - N]_{USt-\tau/2} - Q_{DSt+\frac{\tau}{2}}[NO_3^- - N]_{DSt+\frac{\tau}{2}}}{w \times L}$
- $U_{At} = \frac{GPP_t}{2 \times C:N}$
- $U_{Dt} = U_{den} + U_{het} = U_{NETt} - U_{At}$

Results

Hourly results of whole-stream metabolism and in-stream N uptake processes

Processes	WE_1		WE_2		BD_1		BD_2			BD_3	
	2019-05	2019-09	2019-05	2019-09	2019-06	2020-08	2019-06	2020-08	2021-07	2019-08	2020-08
GPP	0.13±0.13	0.09±0.1	0.16±0.16	0.1±0.12	0.03±0.03	0.03±0.03	0.06±0.07	0.04±0.05	0.07±0.07	0.15±0.16	0.19±0.17
ER	-0.09±0.03	-0.14±0.01	-0.06±0.04	-0.17±0.03	-0.14±0.01	-0.07±0.02	-0.15±0.01	-0.08±0.02	-0.1±0.01	-0.11±0.03	-0.13±0.04
U_{NET}	-8.3±4.83	-2.21±3.97	13.8±3.85	1.35±0.77	-5.02±0.8	-3.11±0.54	11.38±1.13	-0.4±1.18	3.96±1.04	5.19±1.99	2.05±0.83
U_A	1.93±1.92	1.24±1.45	2.36±2.31	1.45±1.73	0.35±0.37	0.39±0.39	0.84±0.89	0.56±0.68	0.95±0.92	1.98±2.12	2.42±2.27
U_D	-10.23±5.54	-3.46±3.87	11.44±4.9	-0.1±1.62	-5.37±0.98	-3.5±0.52	10.54±1.64	-0.96±1.29	3.01±1.21	3.21±1.63	-0.37±1.99
m:n:T	3:3:64	24:29:108	90:91:91	32:50:53	0:0:60	0:0:151	91:91:91	32:60:162	334:334:334	112:112:112	70:140:140

Note: units of GPP and ER are g O_2 m^{-2} h^{-1}; units of U_{NET}, U_A and U_D are mg N m^{-2} h^{-1}; m, n and T represent the number of hours of U_D, net NO_3^--N uptake (i.e., positive U_{NET}) and the entire campaign, respectively.

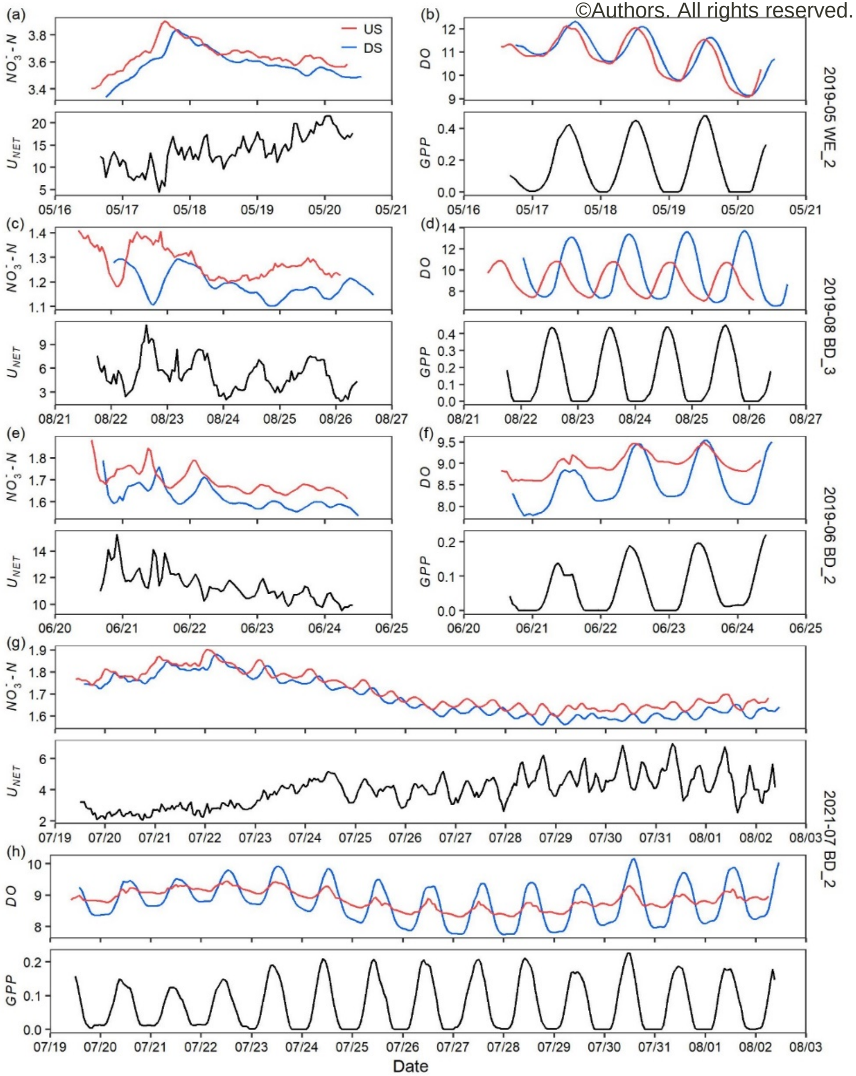
Results

Stream metabolism and nitrate uptake process

✓ The four campaigns had continuously positive values for two pathways (U_A and U_D)

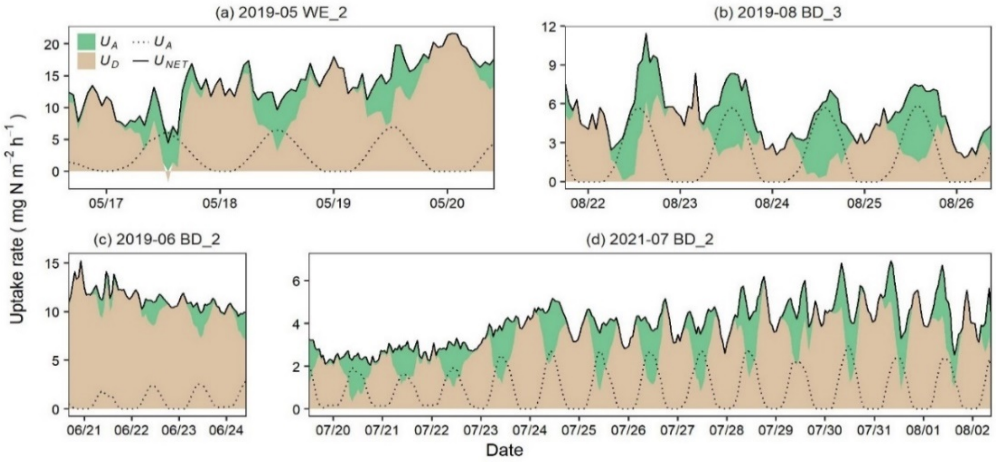
✓ GPP and U_{NET} showed various diel pattern:

- strong diel signals of GPP at all stations
- lack of diel signals of U_{NET} at most stations

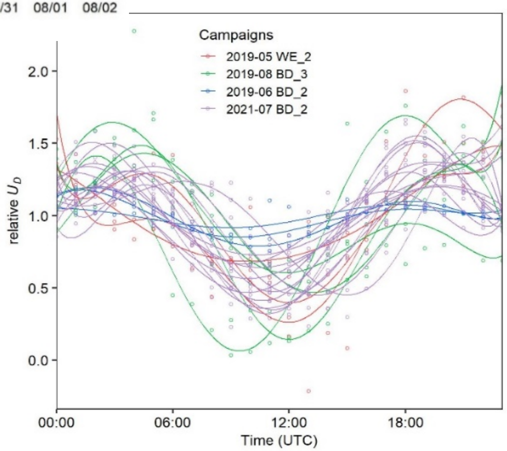


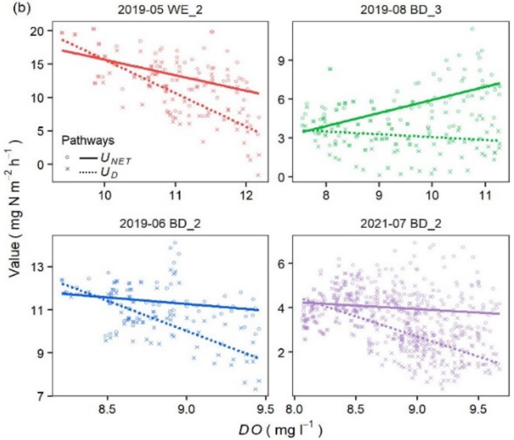
Results and discussion

Diel patterns of NO_3^--N uptake pathways



- Heterotrophic uptake varied during the day and minimize close to midday
- Heterotrophic uptake had a negative relationship with DO but net uptake varied





Implications and future work

Take home message…

- Two-station monitoring disentangles nitrate uptake pathways and their temporal dynamics in heterogeneous high-order streams
- GPP-related autotrophic N uptake can be consistently estimated and is influenced by seasonal radiation and riparian shading
- Inferred heterotrophic uptake follows a diel pattern and is significantly higher in more natural reaches and during post-wet seasons

Future work…

- Upscale to long term high frequency measurements
- Dig more into potential factors influencing various nitrate-N uptake pathways

Zhang, X., et al. (2022) Disentangling in-stream nitrate uptake pathways based on two-station high-frequency monitoring in high-order streams, Water Resources Research (Under review)

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