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Analyzing impacts of seasonality and landscape gradient on event scale nitrate-discharge dynamics based on nested high-frequency monitoring

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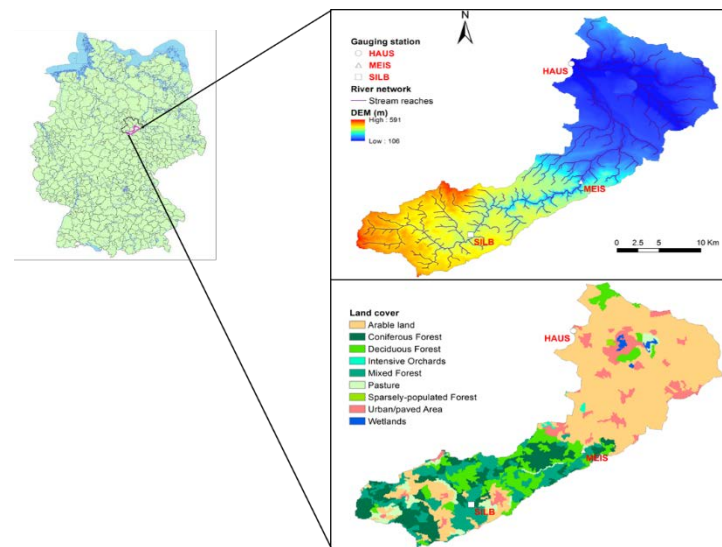Brueckstrasse 3a, 39114, Magdeburg, Germany (xiaolin.zhang@ufz.de)

Figure 1. The Selke catchment (central Germany) with three nested gauging stations: Silberhuette (SILB), Meisdorf (MEIS) and Hausneindorf (HAUS).

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Introduction
Study area and data overview

Motivation

- Land to stream transport was concluded as more important nitrate transport regime than in-stream process and point-source contributions in the Selke catchment

- Complex combination of meteor-hydrological, geographical and pedological characteristics in each subcatchment

- Highly seasonal and spatial heterogeneity of discharge and nitrate concentration

Objectives

- ✓ quantify event-scale C-Q relationships across heterogeneous landscape conditions in the nested Selke catchment

- ✓ analyze impacts of landscape characteristics on hysteresis patterns

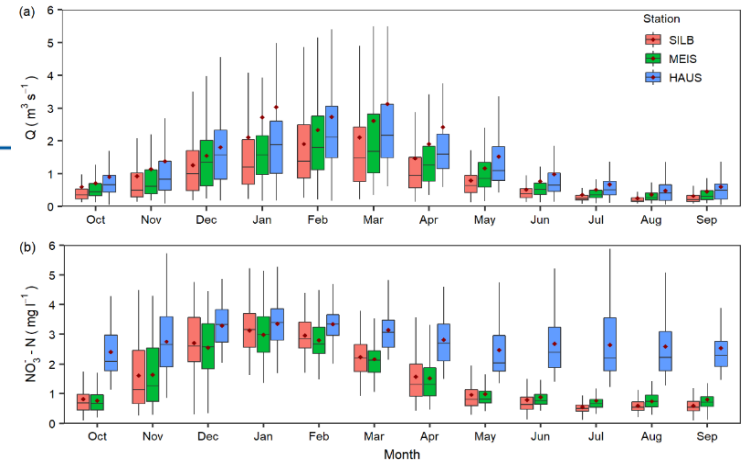- ✓ cohesively investigate the seasonal variability of hysteresis patterns

Figure 2. Boxplot of monthly discharge and nitrate-N concentration at SILB, MEIS and HAUS stations from 1994 to 2017. According to mean discharge variation, from Oct to Dec was defined as wetting period. From Jan to Mar was wet period. From Apr to Jun was drying period. From Jul to Sep was dry period.

Land use of each subcatchment:

- Uppermost: drainage area of SILB station, mixed with forest and arable land (almost 61% and 25%, respectively)

- Middle: area between SILB and MEIS stations, dominated by different kinds of forest (almost 79%)

- Lower: area between MEIS and HAUS stations, dominated by agricultural land and urban area (almost 80%)

Methods
Hysteresis analysis and shared events

Event detection

- Local maximum and minimum method

Quantify hysteresis pattern

- Data during event period was normalized*

- Normalized data were quantified as hysteresis index (*HI*) and concentration-changed index (*CI*)

$$Q_{t,norm} = \frac{Q_t - Q_{min}}{Q_{max} - Q_{min}}$$

$$N_{t,norm} = \frac{N_t - N_{min}}{N_{max} - N_{min}}$$

$$HI = \int N_{t,norm} \cdot dQ_{t,norm}$$

$$CI = N_{tp,norm} - N_{ts,norm}$$

$N_{tp,norm}$ and $N_{ts,norm}$ are the normalized NO_3^--N value at the discharge peak and the start-time of each event, respectively

Shared events -- which propagate from upstream to downstream

- Chosen by similar start-, end- and discharge peak time point of each event at SILB, MEIS and HAUS stations manually

- Adjust start- and end-time points of each shared event to cover the whole event duration at all three stations

- Nitrate load (N_L, unit: kg) and runoff volume (R_V, unit: m^3) of each shared event at each station were calculated

$$N_L = \int (Q_t \cdot N_t) \cdot dt$$

$$R_V = \int Q_t \cdot dt$$

- Contributions from each subcatchment could be calculated by subtracting values between stations

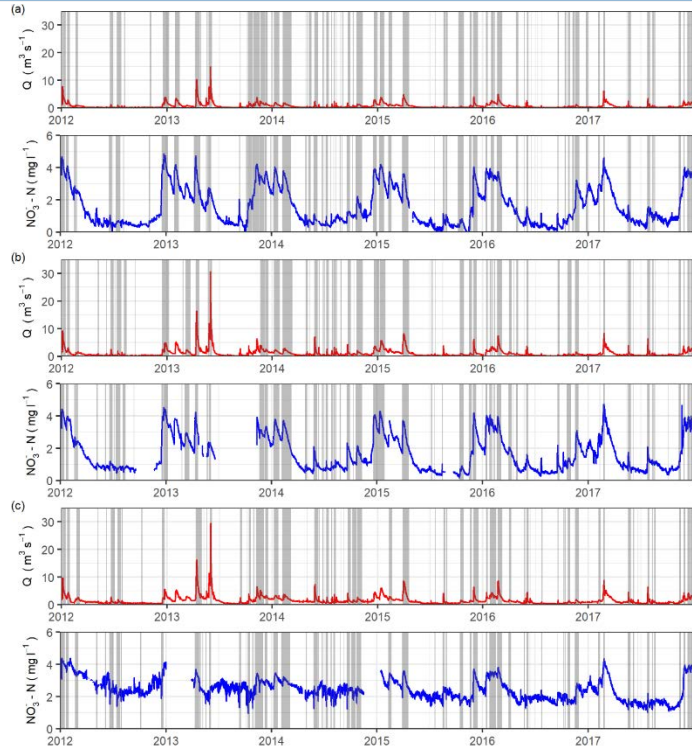# Results
Event detection and hysteresis patterns

Figure 3. Discharge and nitrate concentration given in fifteen-minute frequency from 2012 to 2017 at (a) SILB, (b) MEIS and (c) HAUS station.
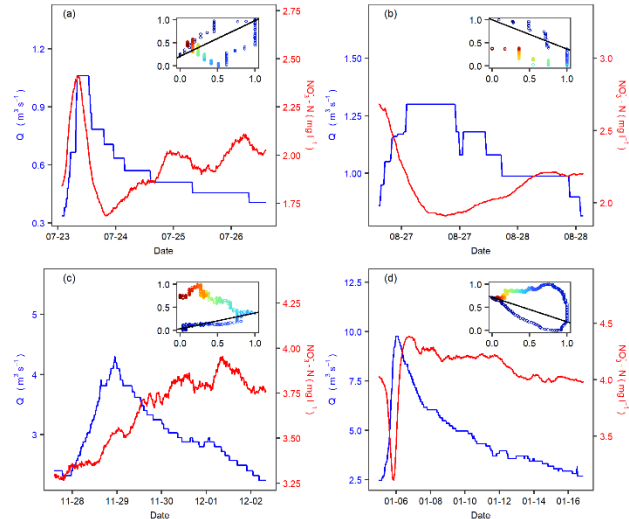

Figure 4. Examples of four hysteresis types detected at HAUS station:
(a)   characterized as positive *HI* and positive *CI*;
(b)   characterized as positive *HI* and negative *CI*;
(c)   characterized as negative *HI* and positive *CI*;
(d)   characterized as negative *HI* and negative *CI*.
The insert plots present the corresponding hysteresis loops, where x-axis and y-axis are the normalized values of discharge and NO_3^--N, respectively.

- 81, 72 and 70 storm events were remained after manual adjust at SILB, MEIS and HAUS stations, respectively

- Mean duration of events was much longer in the wetting and wet periods than in the drying and dry periods

- Mean discharge and NO_3^--N showed the highest mean values in the wet period and the lowest values in the dry period at three stations

Results
Hysteresis analysis

- Mean *HI* was negative from wetting to drying period while positive in dry period at SILB and HAUS stations, but kept negative at MEIS

- Mean *CI* kept positive at SILB and MEIS stations, but was only positive in wet period at HAUS station

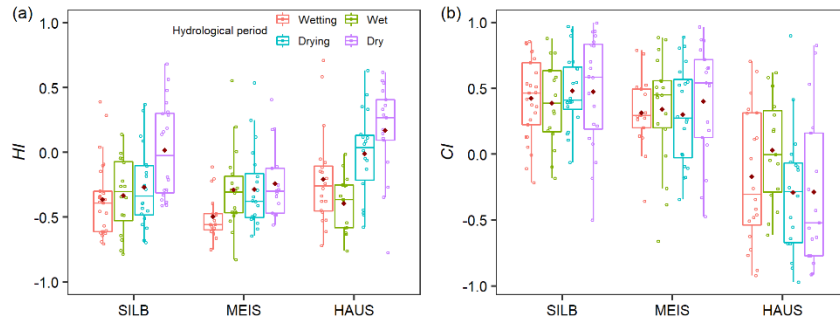- Hysteresis pattern combined *HI* with *CI* showed seasonal and spatial heterogneity

Figure 5. Boxplot of (a) HI and (b) CI of events during four hydrological periods at SILB, MEIS and HAUS stations. The red points represented mean values of HI or CI in each hydrological period at the three stations.
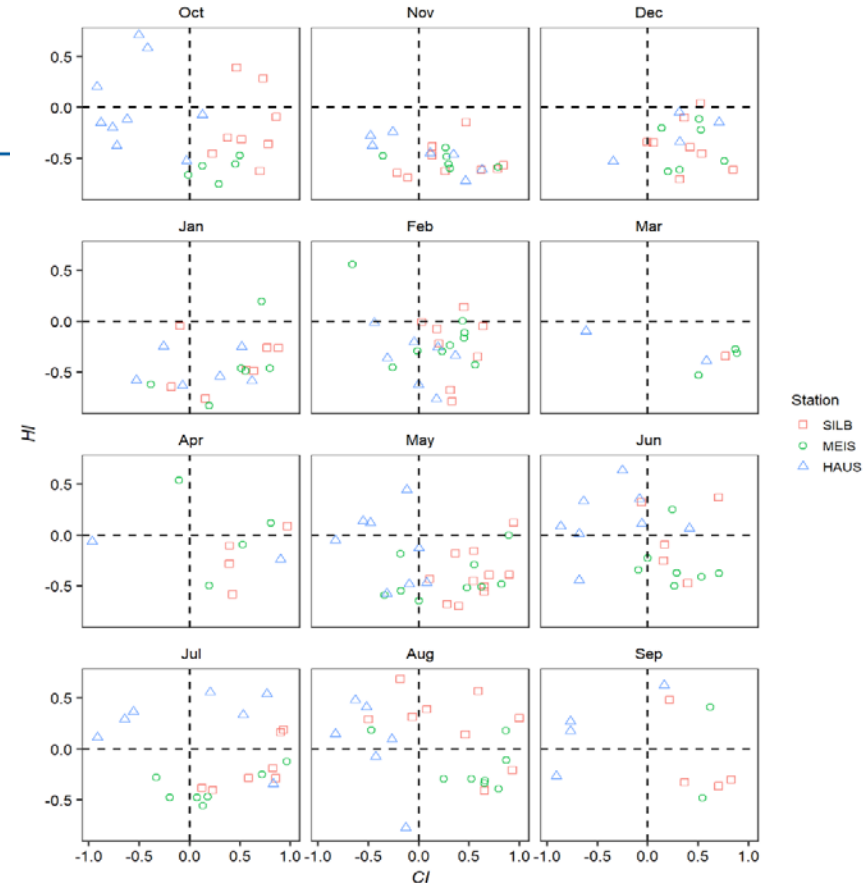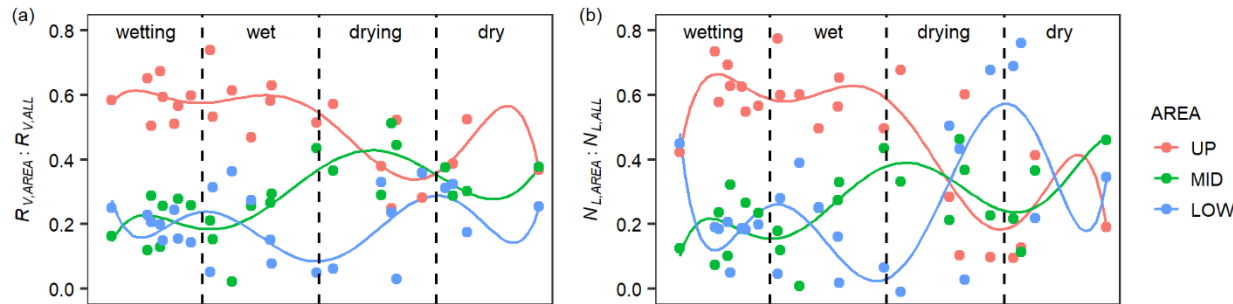

Figure 6. *HI* and *CI* pattern at (a) SILB, (b) MEIS and (c) HAU stations during four hydrological periods. The first to last row represented the wetting, wet, drying and dry periods, respectively.

Results
Contributions from each subcatchment

Period	Contributions of runoff volume	Contributions of nitrate load
Wetting/wet	The uppermost subcatchment dominated both	
Drying	$R_{V,UP}:R_{V,ALL}$ decreased; $R_{V,MID}:R_{V,ALL}$ increased but was still lowest	$N_{L,LOW}:N_{L,ALL}$ increased to the dominant place
Dry	$R_{V,UP}:R_{V,ALL}$ increased and dominated again	the three subcatchments fluctuated

Totally 24 shared events

Figure 7. Contributions of runoff volume and nitrate-N load from each subcatchment to the catchment outlet of shared events throughout the year. Dashed lines were separations between the four hydrological periods. Solid lines were created with high-order polynomial regression.

Conclusions and discussion

What variable C-Q relationships indicate?

- Spatial heterogneity of nitrate storage

- Variable runoff component generations under variable landscape in different seasons

- For big events, real C-Q relationship can show one or two conceptual interpretations because of complex discharge process

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Important to long-term monitor hydrological and water quality data in (sub)catchment outlet where landscape is different
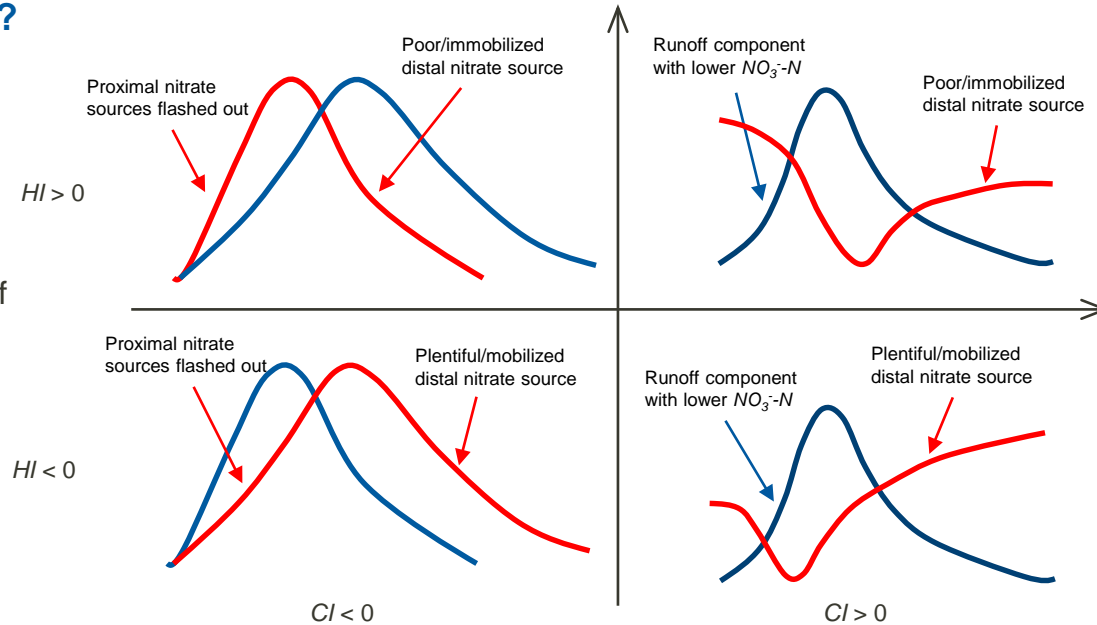

Figure 8. Conceptual interpretation of nitrate-discharge relationships during events corresponding to four hysteresis patterns in Figure 4. Blue lines indicate flow behavior and red lines indicate nitrate behavior. Arrows mean dominant mechanism during rising/falling limbs.