Towards Application of StorAge Selection Functions in Large-Scale Catchments with Heterogeneous Travel Times and Subsurface Reactivity

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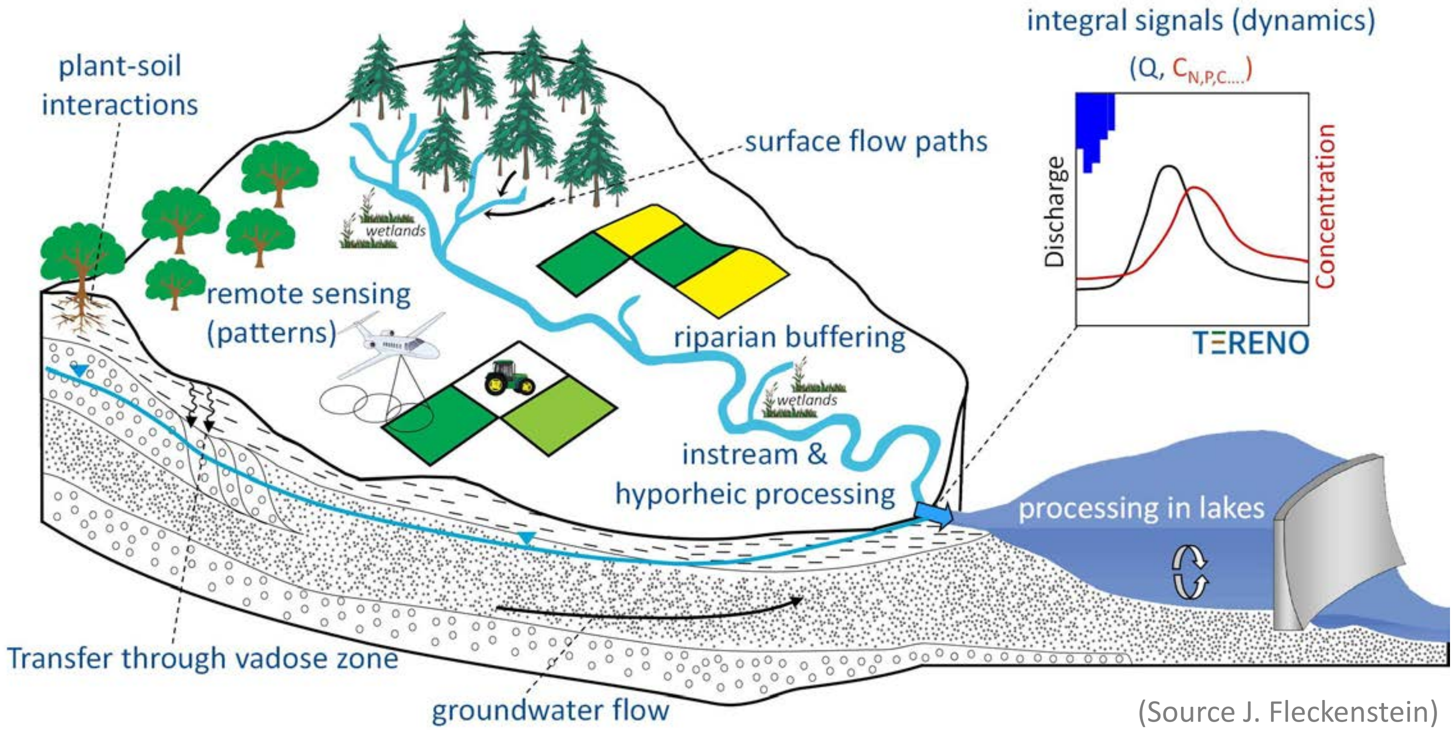
HDG Department Seminar

➢ *Motivation*

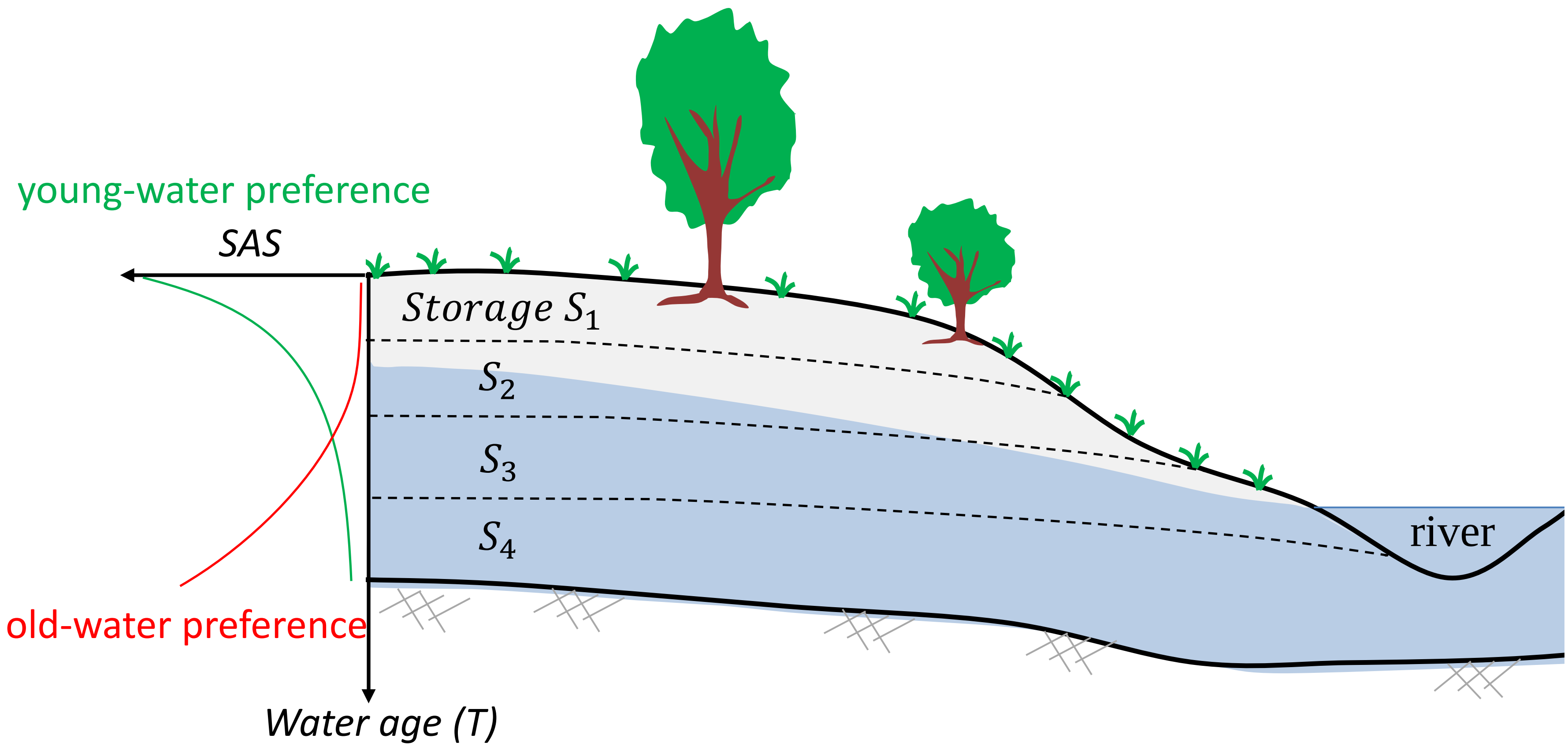
- A mechanistic understanding of nitrate retention and export at a catchment scale (especially meso-scale catchment) to reduce environmental impacts of agricultural practices.



(Source J. Fleckenstein)

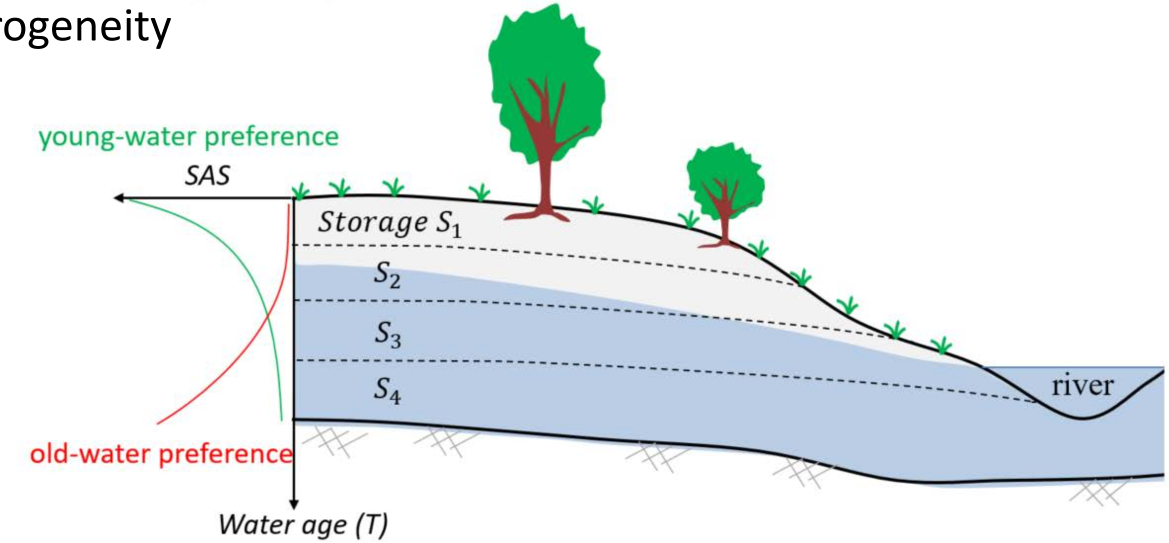
➢ *StorAge Selection (SAS) functions: concept*

- Catchment scale transport model based on water age
- How catchment mixes and releases water (solutes) of different ages via outflows (e.g., discharge)



StorAge Selection (SAS) functions: research gap

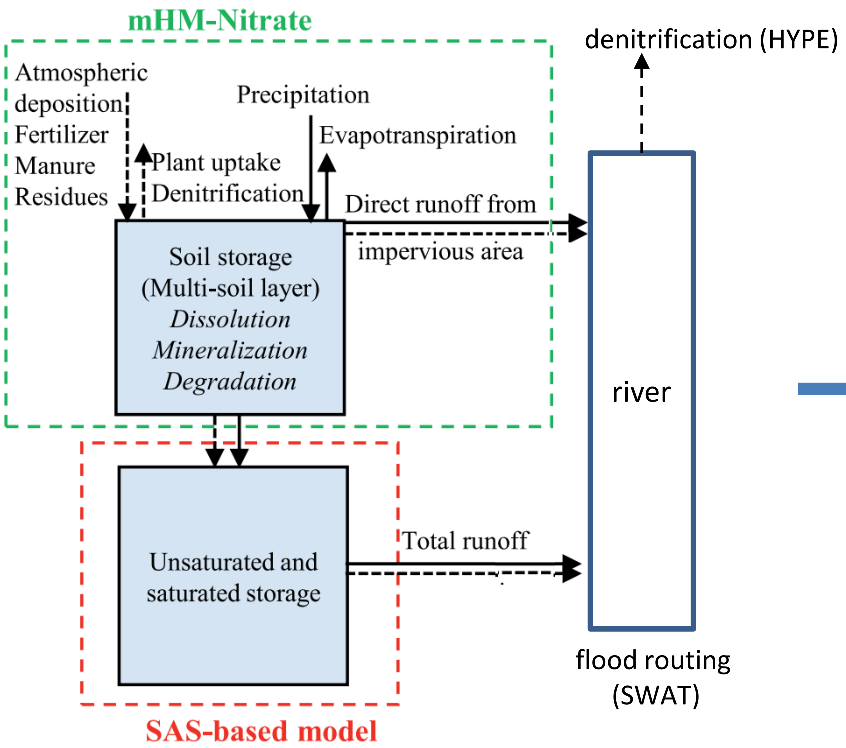
- Small-scale application
- Application in large-scale catchment (10 – 10,000 km^2) is limited
- Application in large catchments with heterogeneous transit times and reactivity rates unknown
- In stream solute transport & removal
- Neglect spatial heterogeneity

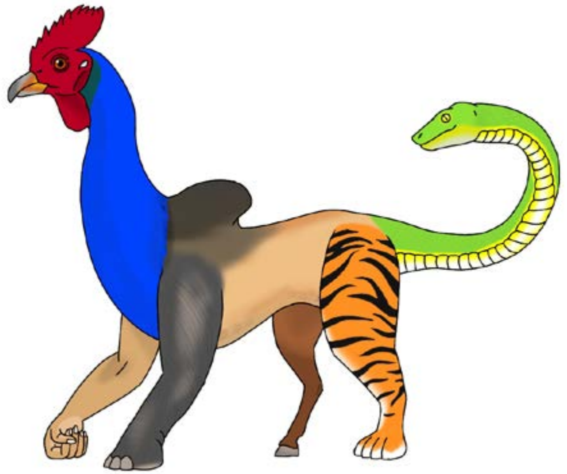


➢ *Research objectives*

- Understand the interplay of transport and reaction times between different sub-catchments in a large-scale catchment with the semi-distributed approach of the SAS concept

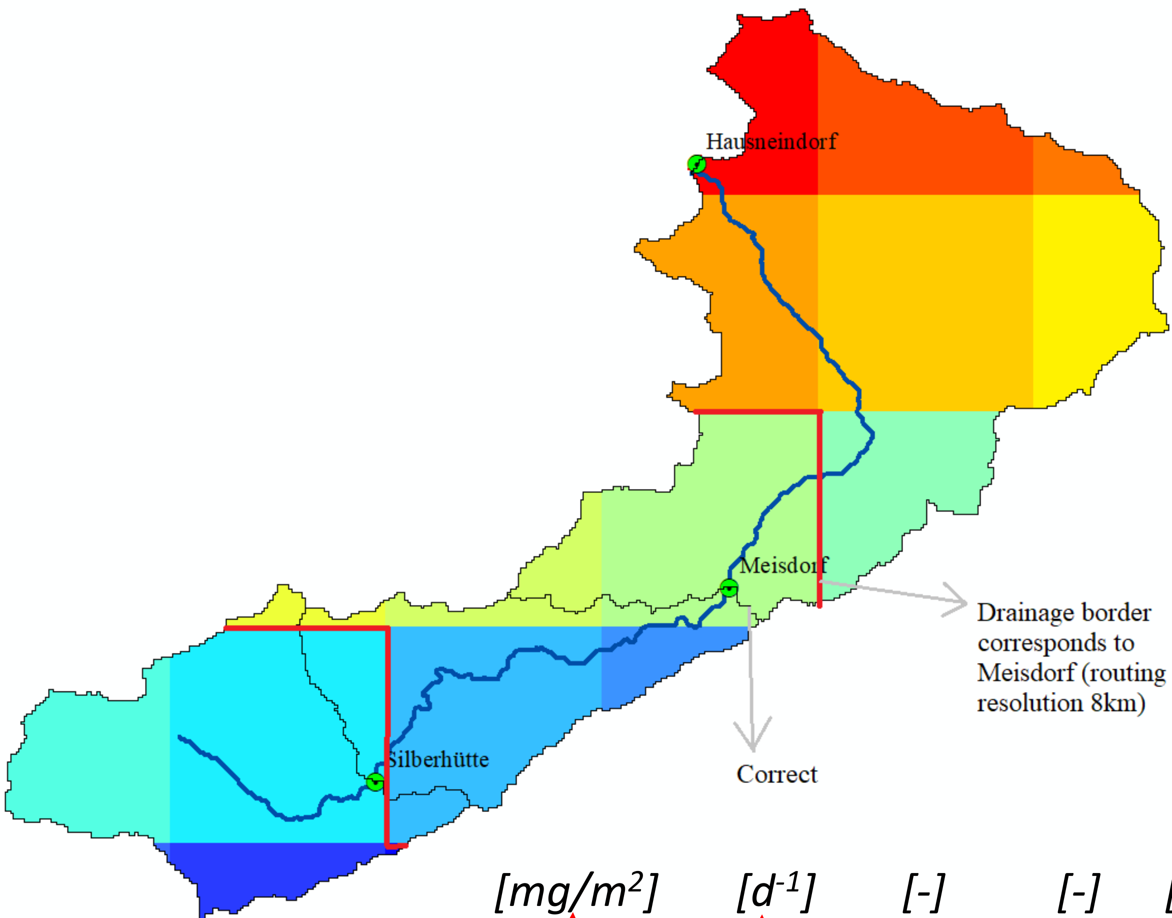
➢ *The modified mHM-SAS*





The mHM-SAS-NITRATE-HYPE-SWAT model

- *The modified mHM-SAS: new routing compared to mHM-Nitrate*

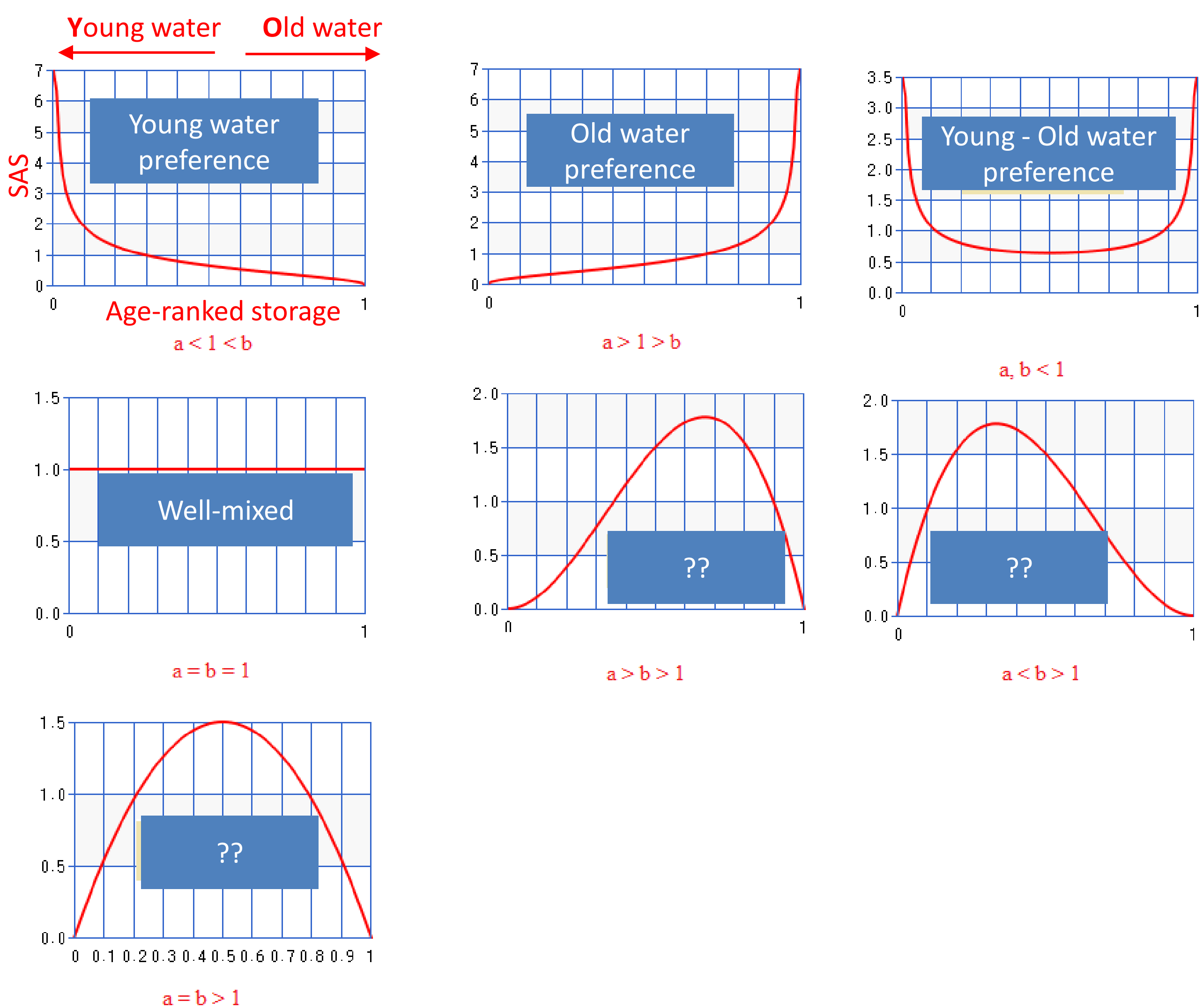


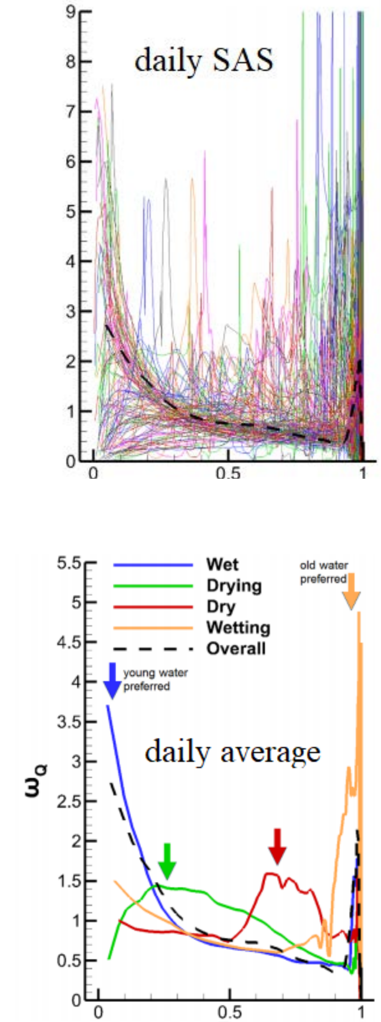
Instream denitrification:

$$\underset{[mg/m^2]}{DENIw} = \underset{[d^{-1}]}{deniw} \cdot \underset{[-]}{f_{tempw}} \cdot \underset{[-]}{f_{concw}} \cdot \underset{[m^2]}{A} \cdot \underset{[d]}{DT}$$

$$DINw = DINw - DENIw$$

➢ *The modified mHM-SAS: SAS function with beta(a,b)*



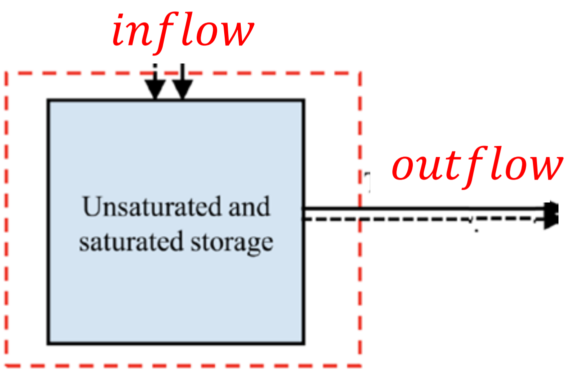


(Yang et al., 2018)

➢ *The modified mHM-SAS: SAS function with beta(a,b): Temporal variations*

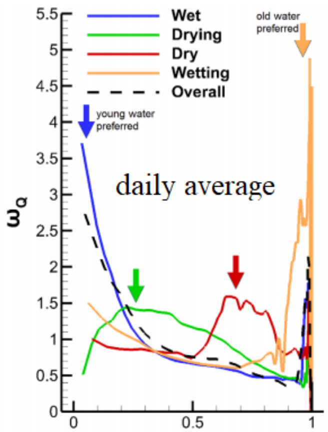
$$r(t) = \frac{Sum(inflow\ during\ last\ n\ days)}{Sum(outflow\ during\ last\ n\ days)}$$

$$beta\big(a(t), b(t)\big) = \begin{cases} a(t) = \dfrac{\alpha}{r(t)} \\ b(t) = \beta \cdot r(t) \end{cases}$$



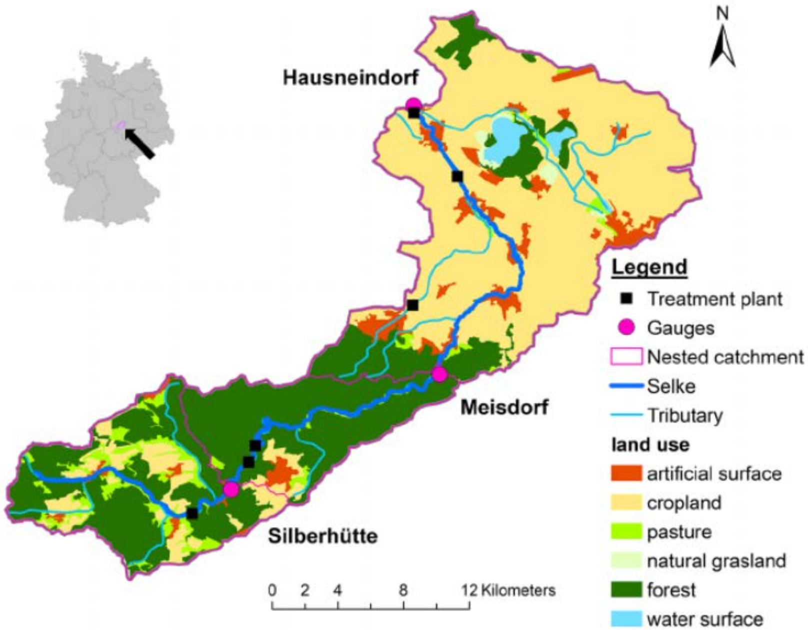
Time-variant beta with 3 parameters: n, α, β

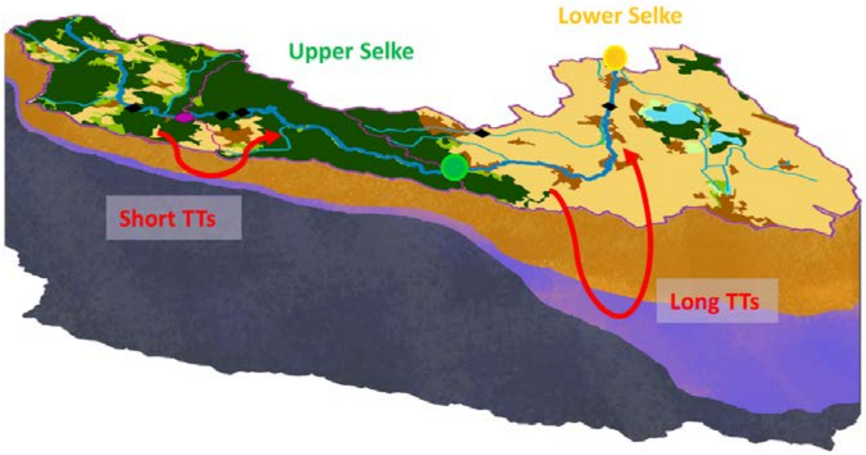
No old-water preference:
if a < 1 < b then b = a



(Yang et al., 2018)

- *Study area: Selke catchments (456 km²)*





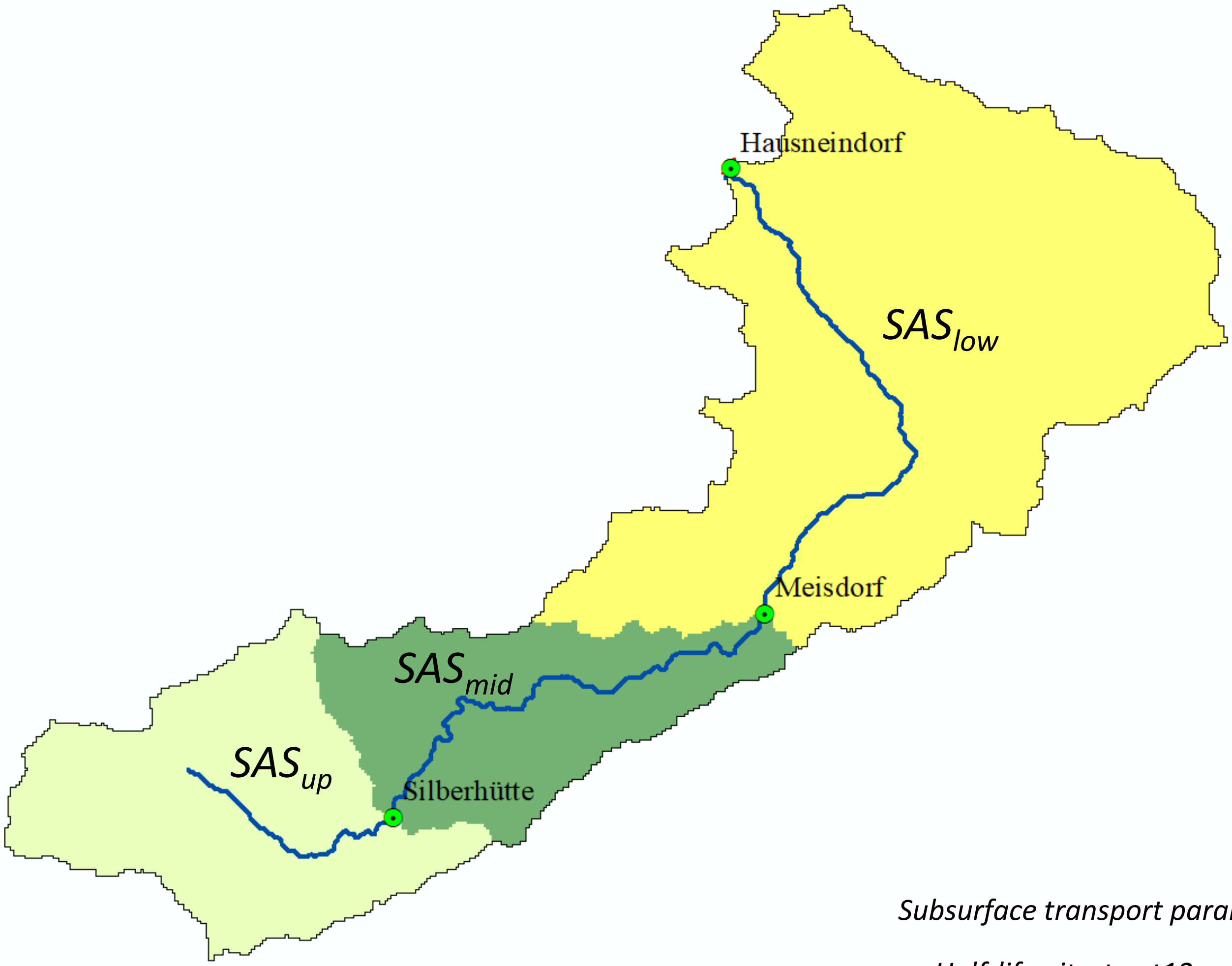
(Winter et al., 2021)

Heterogeneous meteorological conditions, land use, land management practices

Headwater catchments:
short transit times (TTs)
high reaction rates

Lowland catchments:
longer TTs
slow reaction rates

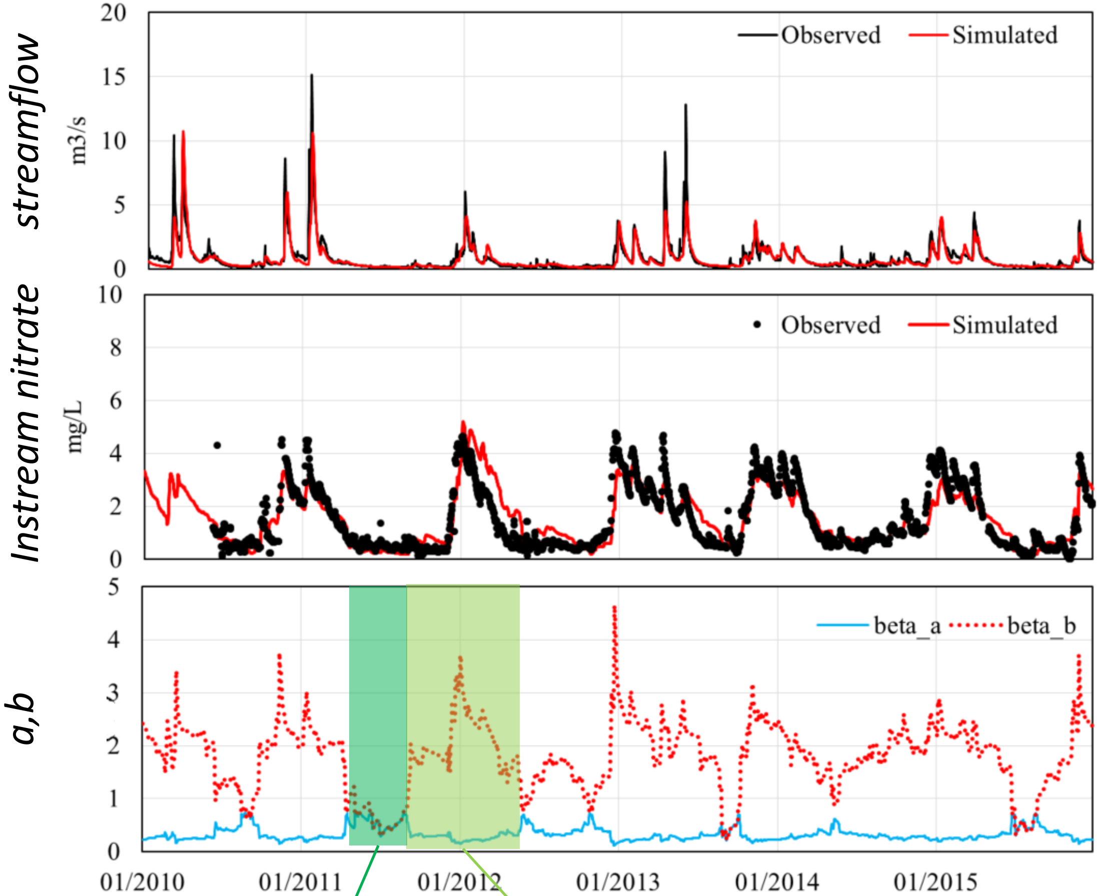
➢ *Study area: Selke catchments*

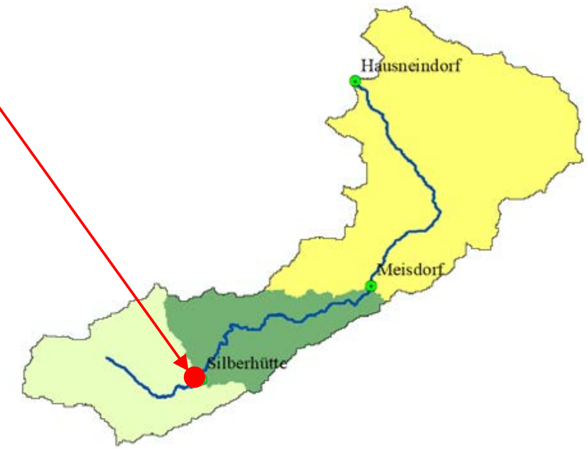


Subsurface transport parameters each sub-catchment

- *Half-life nitrate: t12*
- *Beta function: α, β, n*
- *Subsurface storage: S_0*

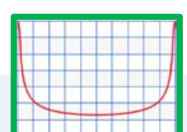
➢ *Simulated Q, instream N-NO_3 at Silberhütte*





a < 1; b > 1: young water preference

a, b < 1: both young & old water preference



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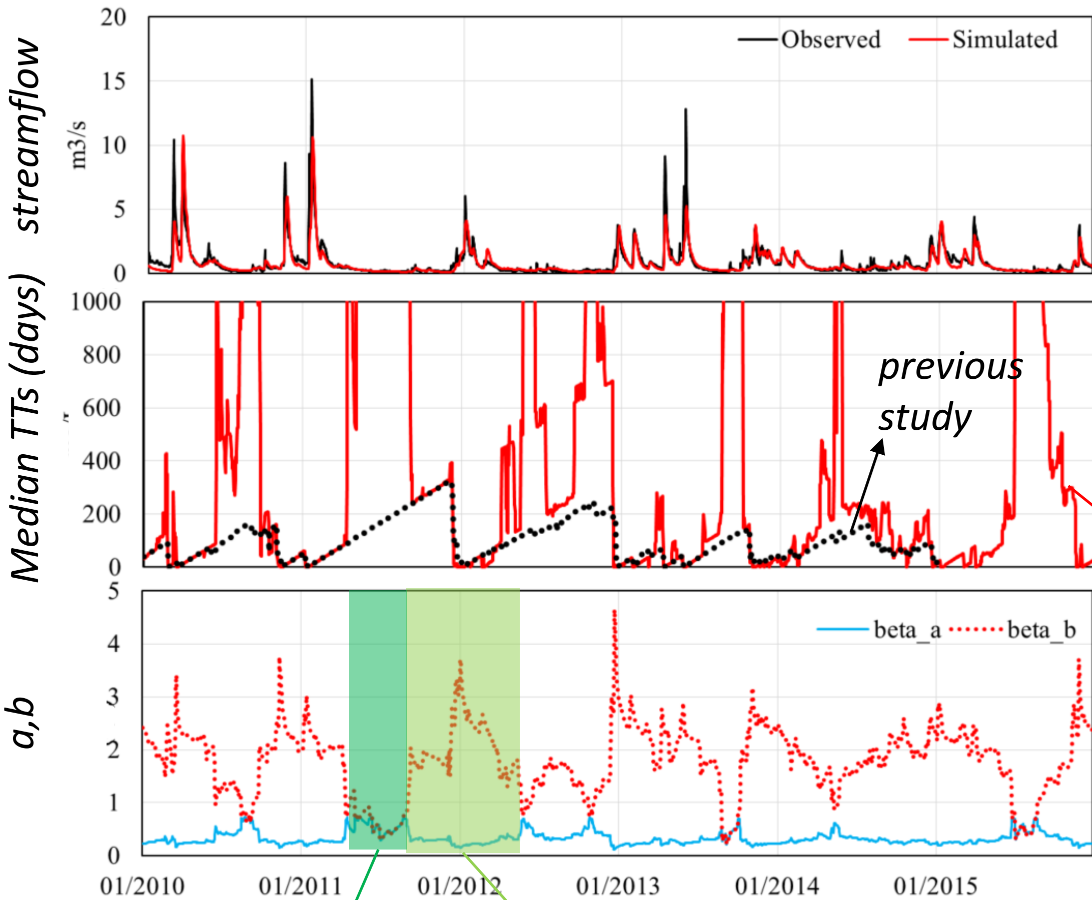
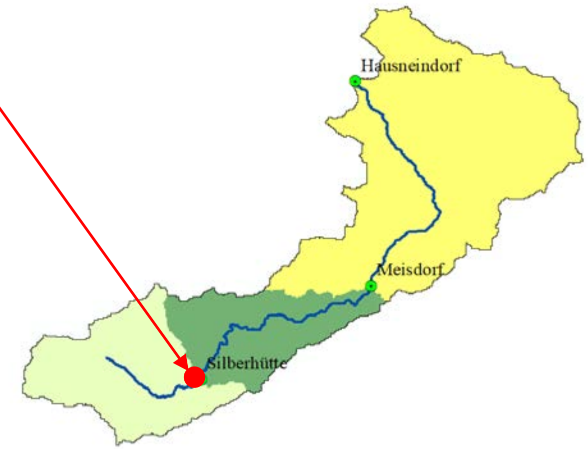


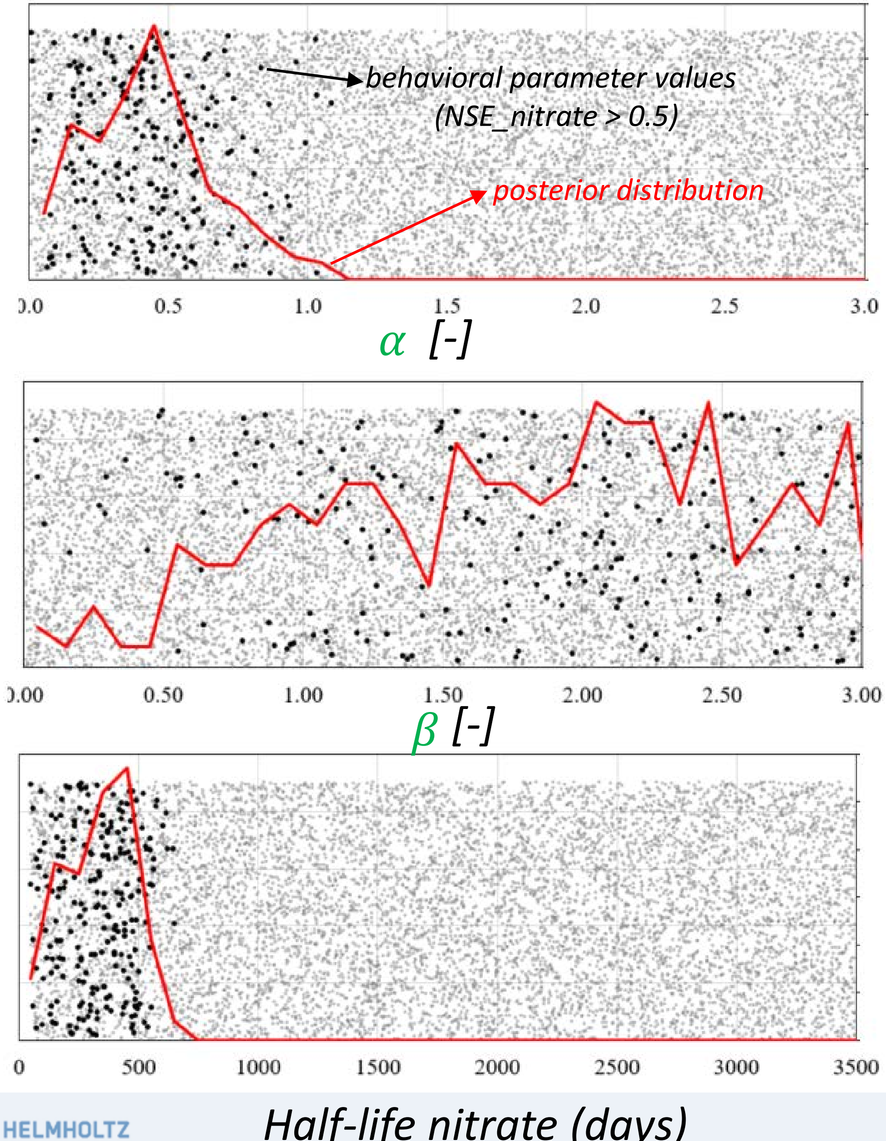


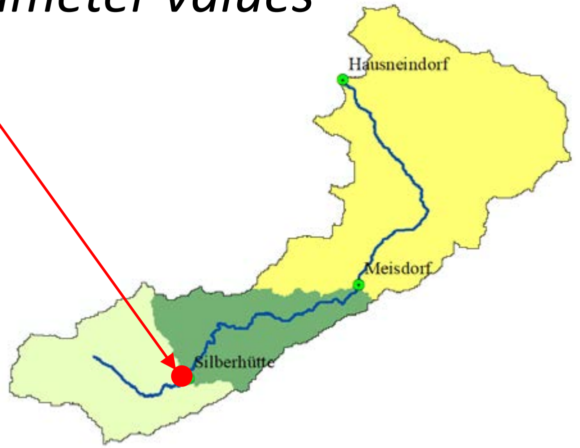
this study

a < 1; b > 1: young water preference

a, b < 1: both young & old water preference

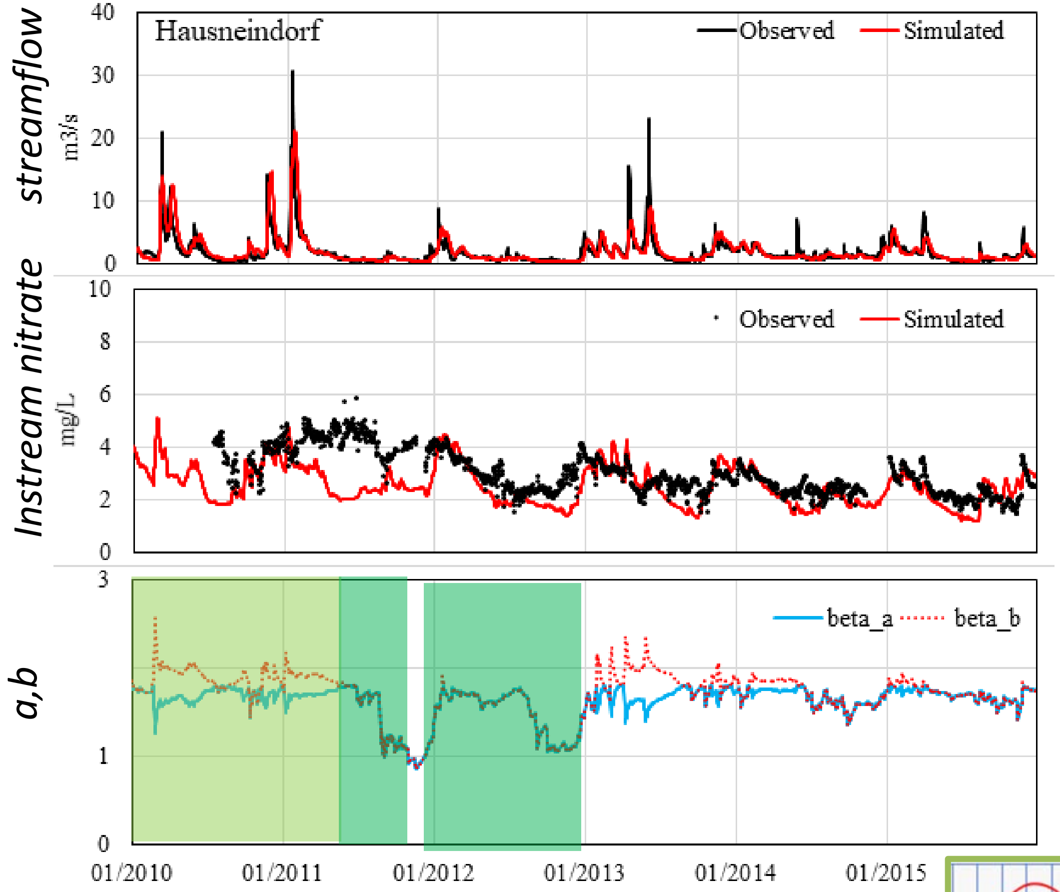
- *Simulated instream N-NO_3 at Silberhütte: Parameter values*

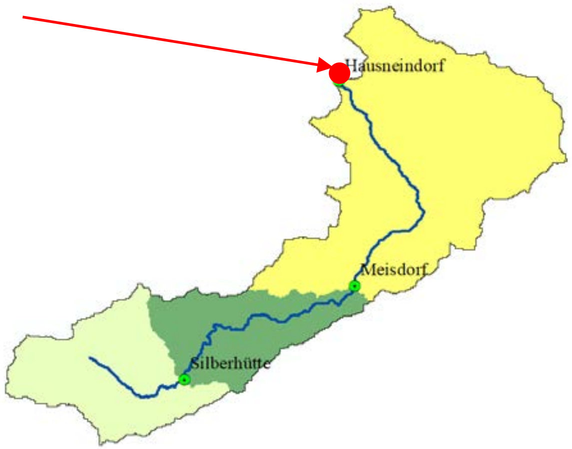


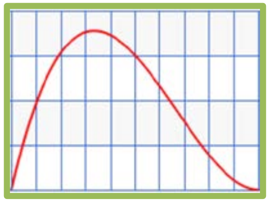


$$beta(a,b) = \begin{cases} a = \dfrac{\alpha}{r(t)} \\ b = \beta \cdot r(t) \end{cases}$$

- *Simulated Q, instream N-NO_3 at Hausneindorf*

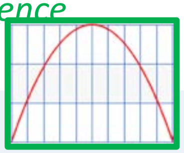




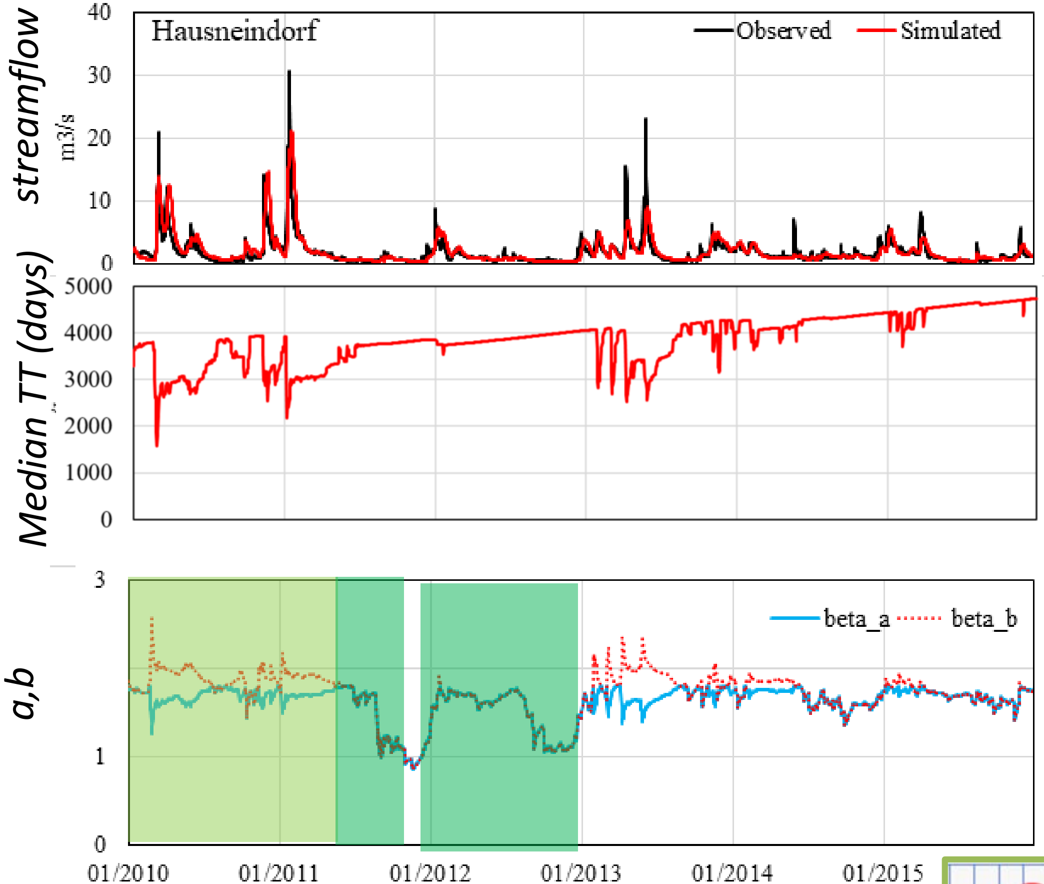


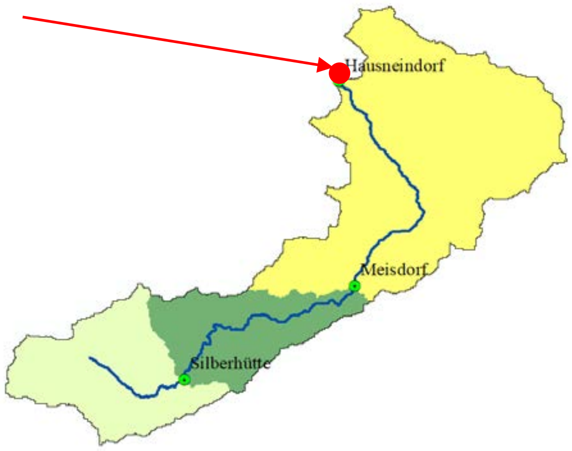
a <b >1: "young" water preference

a, b < 1: "middle age" water preference



➢ *Simulated Q, instream N-NO_3 at Hausneindorf*





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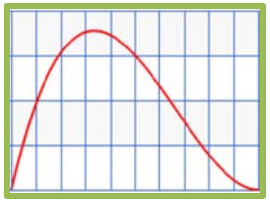
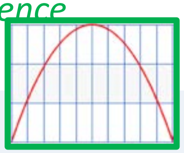
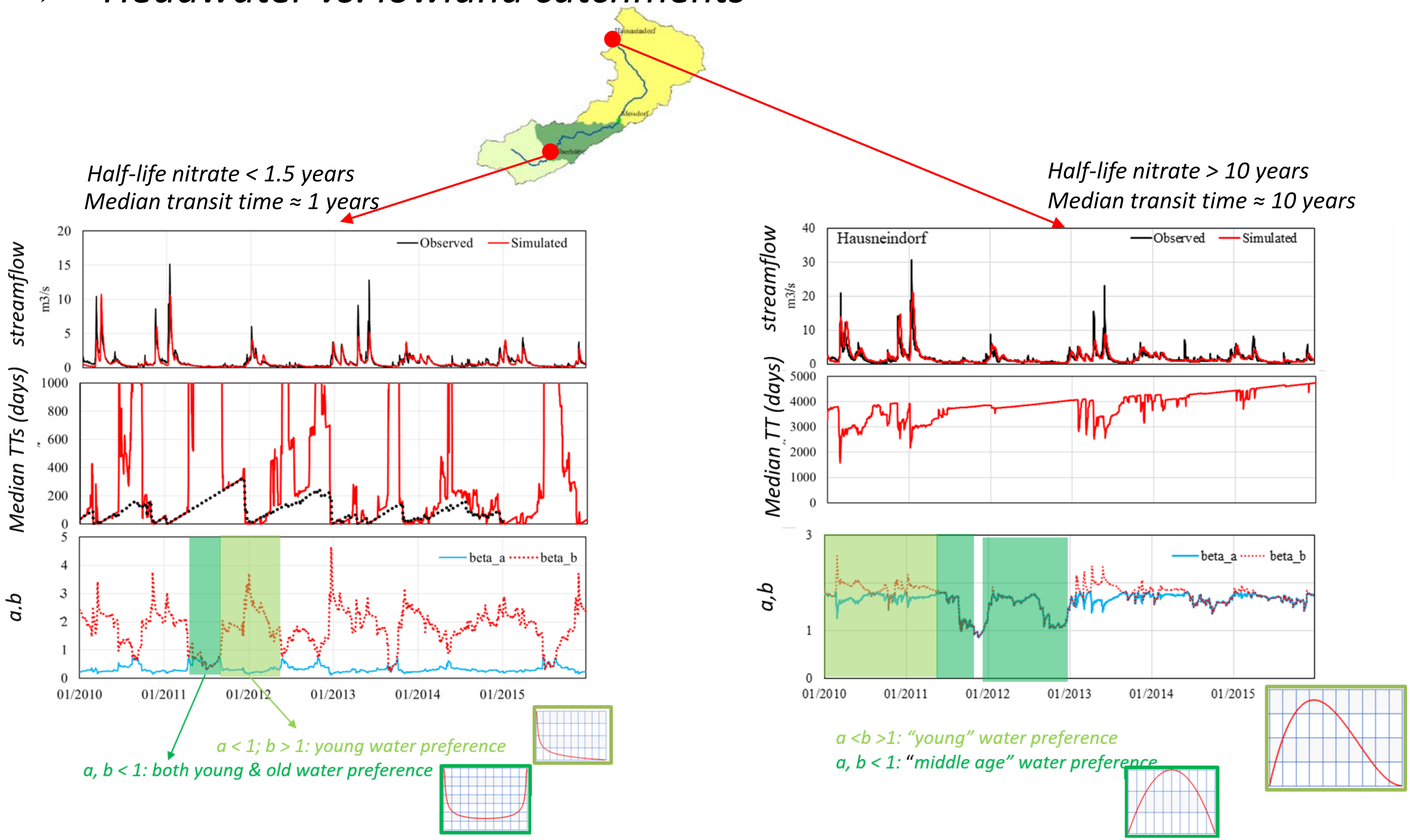




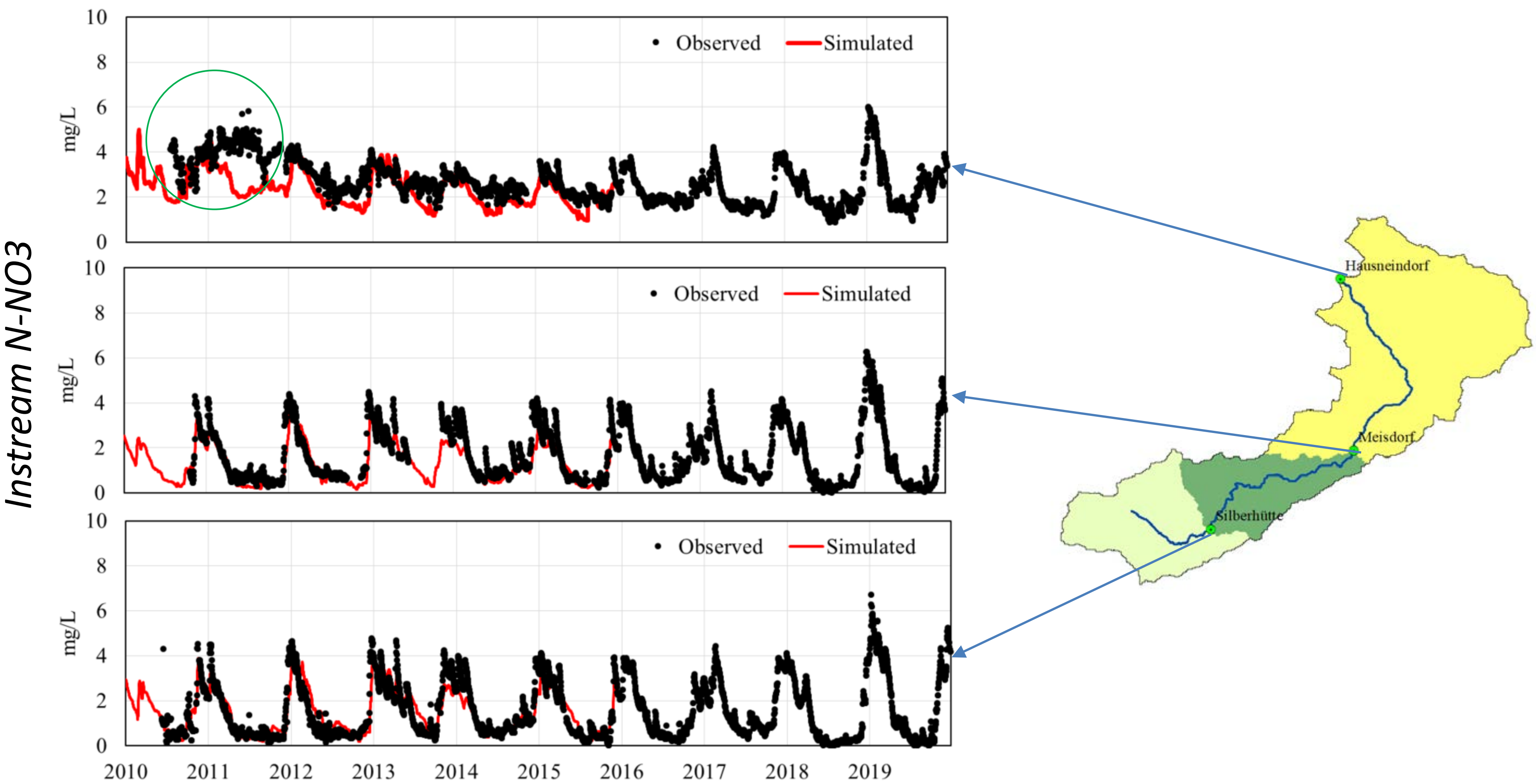
➢ *Headwater vs. lowland catchments*



➢ *Ongoing work…*

- Extend the model to the most recent years as possible
- Test whether lumped SAS approach works <> semi-distributed approach
- Evaluate the simulated young water fraction
- Compare TTDs/RTDs of headwater catchment – Lowland catchment
- Parameter sensitivity/uncertainty analysis
- Check if the model can represent high instream N-NO3 dring extrem dry periods

- *Ongoing work…*



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Thank you for your attention ☺

Questions and Suggestions are welcome