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Modeling Nitrate Export at the Catchment Scale using StorAge Selection Functions

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Catchments store and release water of different ages. The time of a water parcel remaining in contact with the catchment subsurface affects the solute dynamics in the catchment and ultimately in the stream. Catchment storage can be conceptualized as a collection of different water parcels with different ages, the so-called residence time distribution (RTD). Similarly, the distribution of water ages in streamflow at the catchment outlet, which is sampled from the RTD, is called the travel time distribution (TTD). The selection preferences for discharge can be characterized by StorAge selection (SAS) functions. In recent years, numerical experiments have shown that SAS functions are time-variant and can be approximated, for example, by the beta distribution function. SAS functions have been emerging as a promising tool for modeling catchment-scale solute export.

In this study, we aim to integrate the SAS-based description of nitrate transport with the mHM-Nitrate model (Yang et al., 2018) to simulate solute transport and turnover above and below the soil zone including legacy effects. The mHM-Nitrate is a grid based distributed model with the hydrological concept taken from the mesoscale Hydrologic Model (mHM) and the water quality concept taken from the HYdrological Predictions for the Environment (HYPE) model. Here, we replaced the description of nitrate transport in groundwater from the original mHM-Nitrate with time-variant SAS-based modeling, while we kept the detailed description of turnover of organic and inorganic nitrogen in the near-surface (root zone) from mHM-Nitrate. First-order decay was used to represent biogeochemical (denitrification) processes below the root zone and in the stream. The proposed model was tested in a mixed agricultural-forested headwater catchment in the Harz Mountains, Germany. Results show that the proposed SAS augmented nitrate model (with the time-variant beta function) is able to represent streamflow and catchment nitrate export with satisfactory results (NSE for streamflow = 0.83 and for nitrate = 0.5 at the daily time step). Overall, our combined model provides a new approach for a spatially distributed simulation of nitrogen reaction processes in the soil zone and a spatially implicit simulation of transport pathways of nitrate and denitrification in the entire catchment.

Yang, X., Jomaa, S., Zink, M., Fleckenstein, J. H., Borchardt, D., & Rode, M. (2018). A new fully distributed model of nitrate transport and removal at catchment scale. *Water Resources Research*, 54, 5856– 5877.