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Exploring nitrate export from small agricultural catchments using StorAge Selection (SAS) functions

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StorAge Selection (SAS) functions describe the selection preference of catchments to release water of a specific age-composition from storage via discharge (Q) and/or evapotranspiration (ET). This information can be used in turn to explore the dynamics of catchment-scale solute export from diffuse sources (e.g. from agricultural nutrients like nitrate), as the age composition of catchment outflow is linked to solute attenuation (e.g. via reactive removal) as well as the configuration of flow paths in the catchment (i.e. flow partitioning). In this study we developed a SAS-function based nitrate export model for a small agricultural catchment in Central Germany to explore the dynamics of nitrate export over a 13-year period. SAS-functions are represented using two parametric Beta-functions, which are inversely calibrated based on the observed nitrate concentration time series in catchment outflow. The obtained SAS-functions generally compared well to non-parametric SAS-functions obtained from a forward model using an explicit numerical flow and particle tracking model (Yang et al. 2018). The calibrated SAS-function based export model was then used to explore various scenarios representing different catchment characteristics in terms of aquifer thickness and reactivity, age selection preferences for catchment Q and ET as well as for constant and seasonally varying solute inputs.
Results show that the concentration levels and the temporal variability of nitrate export from the catchments is strongly controlled by 1) the specific interplay between transport and reactions, described in terms of Damköhler numbers (defining solute attenuation) and 2) the age selection preferences of the catchment (defining dominant flow paths and catchment-scale mixing). For catchments with seasonally shifting selection preference temporal variability of nitrate export is largest and effects of seasonal variability of inputs minor. In contrast, for catchments with constant selection preference for younger water the impact of seasonally varying input on export variability is more pronounced, especially for shallow catchments with low reactivity. Absoulte concentration levels are mainly affected by reactivity and the fraction of old water in catchment outflow. Our results suggest that catchment geometry and the resulting flow paths and associated transit times are dominant controls for the export of reactive solutes such as nitrate from small catchments.

Yang, J., Heidbuechel, I., Musolff, A., Reinstorf, F., Fleckenstein, J.H. (2018) Exploring the Dynamics of Transit Times and Subsurface Mixing in a Small Agricultural Catchment, Water Resources Research, 54(3):2317-2335