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Detailed spatial information of nitrate concentrations and fluxes provided by the fully distributed mHM-Nitrate model

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Higher spatiotemporal accuracy of catchment models is increasingly required for better understanding the functional heterogeneity of catchments and improving management decisions at different governance levels. However, the model complexity correspondingly increases, which limits the application of such models in meso- and large-scale catchments. To balance spatial representation and model complexity in catchment water quality modeling, the fully distributed mHM-Nitrate model was developed based on the grid-based mesoscale hydrological model (mHM) and the hydrological predictions for the environment (HYPE) model. The model was validated in the Selke catchment, central Germany using long-term grab sampling and high-frequency sensor data (at station Meisdorf, NSE values were 0.81 and 0.59 for discharge and nitrate concentration simulations, respectively; at the outlet station, 0.68 and 0.37, respectively). Uncertainty analysis confirmed the model robustness in the testing catchment.

The validated mHM-Nitrate model is a suitable tool to explicitly present spatial distributions of catchment nitrate concentrations and fluxes, benefiting from its flexible multi-resolution structure. We firstly presented 1 km $\times$ 1 km spatial distributions of mean interflow and baseflow nitrate concentrations, representing soil moisture and groundwater nitrate statues respectively. Results showed that interflow concentrations of agricultural land were much higher than those in forested areas, which reflects the strong environmental impacts of agricultural practices (e.g., fertilizer and manure applications). Also, variability for agricultural land was high and critical source areas can be easily identified. Regarding terrestrial nitrate budgets, we presented spatial distributions of input (i.e. nitrate external supply, mineralization and atmospheric wet deposition) and output (i.e. crop/plant uptake, denitrification and terrestrial export) of soil nitrate pool. Results showed that the overall nitrate pool was balanced (around 105 kg ha-1 yr-1), while the spatial variability of each input/output was significant. Finally, we presented the in-stream information of nitrate removal (i.e. net removal by primary production and denitrification processes). In-stream processes show high variability both temporally and spatially.

The new mHM-Nitrate model is capable of providing detailed spatial information on nitrate concentrations and fluxes, which can motivate more specific catchment investigations on nitrate transport processes and provide guidance on spatially differentiated agricultural practices and management.