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Spatiotemporally distributed sensitivity analysis for catchment water quality models

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Spatially distributed catchment water quality models are recommended to represent heterogeneous catchment characteristics and their influences on surface water quality. However, the associated complexity of parameterization (e.g., equifinality and over-parameterization) prevents the identification of optimal parameter values, and subsequently, the applicability of the model. Therefore, we conducted a spatiotemporally distributed sensitivity analysis, as a foundational diagnostic approach, to explore high-dimensional parameter spaces and assess significances of biogeochemical parameters and corresponding processes. This study was carried out in the Selke catchment (456 km2), a highly heterogeneous nested catchment in central Germany for the period 2011-2015. Based on the grid-based catchment hydrological water quality model (mHM-Nitrate), sensitivity of nitrate submodel parameters (representing processes of soil denitrification, soil mineralization, soil dissolution, soil degradation, in-stream denitrification and in-stream assimilatory uptake) was analyzed at a full spatial and temporal perspective. The Morris method was chosen due to its efficiency. The total number of parameter included were 3,196 and total model runs were 63,940.

Parameter values in each grid cell were sampled independently using the Latin Hypercube method. Temporal sensitivity indices were calculated based on the Root Mean Square Error (RMSE) within the period of a determined moving window. Results showed that the most influential nitrate process was soil denitrification, followed by in-stream denitrification and in-stream assimilatory uptake. Moreover, they all showed high spatial and temporal variabilities. The parameter of soil denitrifications was mostly sensitive in areas where sufficient soil nitrate availability encounters with higher soil moisture. The in-stream parameters were more sensitive in higher order stream reaches, mainly due to the increased benthic area. Sensitivity of all nitrate submodel parameters was also seasonally varying, with considerable differences between years. This study provides spatiotemporal insights into nitrate dynamics throughout the catchment, and therefore, can be informative for process understanding and further model parameter identification.