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Model-based prediction of global warming influence on organic carbon and nitrogen fate in a mesoscale catchment

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The terrestrial subsurface functions as a reactor that regulates the fate of various biogeochemically reactive compounds including nutrients as well as harmful species. Knowledge of concentrations of these species in groundwater and surface water as well as their export from the subsurface is highly relevant for the ecology and the water management of a catchment. The turnover and cycles of organic carbon and nitrogen species in the subsurface involve multiple processes and are coupled to hydrological cycles. This makes it challenging to assess their budgets and to predict the changes of these budgets in the context of global warming.

In this study, we use a numerical modeling approach to investigate the response of organic carbon and nitrogen species to climate change effects under different global warming levels in a mesoscale catchment (~850 km²) upstream of the Nägelstedt gauge of the river Unstrut in central Germany. We use a travel-time-based model approach, which couples a spatially distributed catchment model with biogeochemical simulations describing the microbial-driven transformation of carbon and nitrogen species along different flow paths. Results of the simulations indicate that for the considered warming scenarios climate change induced variations of the flow and transport dynamics are minor and have only little impact on concentration levels in the catchment. In contrast, consideration of temperature dependency of biogeochemical reactions can have a stronger impact on species turnover and their export from the subsurface. However, several environmental constraints on degradation processes can dampen intrinsic temperature sensitivity by limiting substrate availability, often causing the reactivity to be lower than expected. Furthermore, changes of species input from the surface into the subsurface due to climate or anthropogenic effects can have more pronounced influences on catchment scale budgets than changes of in situ process dynamics.

With a high fraction of groundwater flow, the Nägelstedt sub-catchment may be less sensitive to climate change compared to catchments dominated by shallow flow contributions. These results suggest that for such type of catchments global warming exhibits limited and delayed impact on catchment export of reactive compounds due to the long residence time of water driven by deep groundwater flow.