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Exploring the effects of geological realism on groundwater flow and solute transport

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The spatial configuration of hydrogeological properties in the subsurface strongly affects groundwater flow and solute transport behaviour and is controlled by subsurface geology. However, many studies of subsurface heterogeneity are implemented in parameter fields which do not resemble sedimentary features observed in nature. We are interested in what effect the anisotropy of such features (i.e. scour-pool fills, sheets and channels) has on the movement of water and solutes in the subsurface at scales that are relevant for groundwater studies at contaminated sites.

We have simulated two confined aquifer systems that mimic the MADE site (Columbus, Mississippi) and the Herten site (Upper Rhine Valley, Germany) using the HyVR simulation package (https://github.com/driftingtides/hyvr/). This package creates 'virtual realities' that are based on geological concepts and aquifer-analog information, and that have small-scale heterogeneity of hydraulic parameters, including porosity and full hydraulic-conductivity tensors. We compare fully heterogeneous and anisotropic virtual realities with parameter fields where the internal configuration of geological features has been upscaled or is locally isotropic.

We conducted groundwater flow and conservative solute transport simulations to explore how these geologically plausible hydraulic parameter fields differ from fields simulated using more traditional methods for characterising subsurface heterogeneity (i.e. two-point geostatistics). Metrics for characterising groundwater flow and quantifying solute mixing include: kinematic descriptors of the plume deformation (stretching and folding), macrodispersion derived from spatial moments, and volumetric dilution indices. Preliminary results indicate that sedimentary anisotropy is relevant for transverse mixing processes in solute plumes in groundwater, and that further investigation of complex features is warranted.