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Two-region mass transfer to account for 2D profile scale heterogeneity in a 1D effective plot scale flow model

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In arable soil landscapes, specific spatial heterogeneities related to tillage and trafficking can influence the movement of water and chemicals. The structure in the topsoil is characterized by spatial patterns with locally compacted zones. The contrasting hydraulic properties of more-and-less compacted soil zones can result in heterogeneous flow fields and preferential flow. Two- or three-dimensional models used to account for soil spatial variability are relatively too complex when trying to include local heterogeneities in the description of field scale flow and transport problems. The idea was to reduce the model complexity linked to the explicit description of heterogeneities in 2D or 3D without deteriorating the validity of simulation results. When reducing the spatial dimensionality, the geometry in a 2D, cross-sectional explicit plot description is removed on the expense of an increased complexity of the 1D model with two flow domains and mass exchange between them.
Our objective was to design a simplified 1D model approach that effectively accounts for plot-scale soil structural variability. In this simplified 1D model, effective soil hydraulic parameters can be assigned to each of the two domains separately. Different theoretical scenarios simulating different shape, size and arrangement of compacted clods in the tilled layer were set to estimate their effect on solute behaviour. The mass exchange parameters could be determined from structure quantification and by comparing simplified 1D with reference 2D results accounting for defined soil structural (i.e. here the compacted regions) geometries. The mass exchange is strongly related to the geometry of the compacted zones including their distribution and size within the non-compacted soil. Additionally, the simplified model approach was tested by comparing it with measured results from a field tracer experiment.