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Modeling 3D soil and sediment distributions for assessing catchment structure and hydrological feedbacks

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Structural heterogeneity, namely the spatial distribution of soils and sediments (represented by mineral particles), characterizes catchment hydrological behavior. In natural catchments, local geology and the specific geomorphic processes determine the characteristics and spatial distribution of structures. In constructed catchments, structural features are determined primarily by the construction processes and the geological origin of the parent material. Objectives are scenarios of 3D catchment structures in form of complete 3D description of soil hydraulic properties generated from the knowledge of the formation processes.
The constructed hydrological catchment 'Hühnerwasser' (Lower Lusatia, Brandenburg, Germany) was used for the calibration and validation of model results due to its well-known conditions. For the modelling of structural features, a structure generator was used to model i) quasi-deterministic sediment distributions using input data from a geological model of the parent material excavation site; ii) sediment distributions that are conditioned to measurement data from soil sampling; and iii) stochastic component sediment distributions. All three approaches allow a randomization within definable limits. Furthermore, the spoil cone / spoil ridge orientation, internal layering, surface compaction and internal spoil cone compaction were modified. These generated structural models were incorporated in a gridded 3D volume model constructed with the GOCAD software.
For selected scenarios, the impact of structure variation was assessed by hydrological modelling with HYDRUS 2D/3D software. For that purpose, 3D distributions of soil hydraulic properties were estimated based on generated sediment properties using adapted pedotransfer functions. Results from the hydrological model were compared them to measured discharges from the catchment. The impact of structural feature variation on flow behaviour was analysed by comparing different simulation scenarios.
The established initial sediment distributions provide a basis for the consecutive modelling of feedbacks between surface and subsurface water flow and changes in soil properties, e.g. by using a landscape evolution model. The results should allow conclusions about the effect of different initial structural setups on the further dynamic landscape development at catchment scale.