Geophysical Research Abstracts
Vol. 15, EGU2013-10958, 2013
EGU General Assembly 2013

A 3D structure and process model for integrative analyses of a constructed catchment

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A structure model is a relatively realistic spatial model that describes the boundary geometries and the 3D solid phase distributions of a catchment. Spatially-distributed sediment mass balances correspond with changes of the system. The objective was to develop a "virtual catchment" model for quantification and visualization of spatial structures as a function of time. A structure generator program was developed imitating sediment dumping, segregation, compaction, and leveling was developed for simulating 3D model scenarios of initial texture and bulk density distributions. Surface structure development was obtained from remotely-sensed digital elevation models for a number of time steps that described initial topography and changes due to erosion and sedimentation processes. The geological 3D software tool GoCad (Paradigm Ltd.) was used for the quantification and visualization. Hydraulic pedotransfer functions were adopted for deriving distributed hydraulic properties for the catchment. Data from the artificially-constructed "Chicken Creek" catchment was used as a test area for the development of such model. Based on the initial 3D model of subsurface structures, the development of hydrological "structures" (e.g., ground water table), newly formed biotic and abiotic structures (e.g., vegetation, initial soil horizons, water table, or extent of plant root zones) can be quantified. The 3D model can identify these regions as "process domains" (e.g., root water uptake, red-ox reactions). The development of the spatially-distributed mosaic of newly formed initial surfaces on deposits of eroded sediments can be obtained by a combination of the 3D model with 2D surface models at certain time steps. Structural changes could be quantified in terms of sediment mass changes. The advantage of a 3D structure model is that distributed parameters of process-models can be derived from a mechanistic reproduction of the system; this is in contrast to spatially interpolated data of properties between sampled data points. The 3D distributed solid phase structure of the catchment can be more directly observed or assessed by minimal-invasive methods than the spatial structure of hydraulic, transport or other secondary properties. The mass balance of the solids in dynamic catchments can be used as additional information for the verification of the geo-system's development. The approach has potential to be transferable to describe the development of other geo-systems starting from initial conditions if basic sediment structures can be reconstructed. For similar anthropogenic geo-systems, transfer can be achieved by adapting the technology of sediment transport and deposition in the descriptions of the generator model. The virtual 3D structure model may help improving the integrative analysis of hydrological catchments especially during rapid development phases.