Geophysical Research Abstracts
Vol. 20, EGU2018-7214, 2018
EGU General Assembly 2018

Expert-knowledge based hydrological landscape models for simulating vertical and lateral flow paths

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The knowledge of vertical and lateral water flow paths in the landscape is essential to understand biogeochemical mass transport. This applies in particular to the input of nutrients and pollutants (for example nitrate, pesticides) into groundwater and surface waters. Common hydrological models are often able to present consistent runoff balances, but fail in the spatial differentiation of flow paths and transport routes as well as in the determination of residence times. To address this issue, this work pursues an expert knowledge-based approach of model process development. Field reconnaissance on catchment dynamics and subsurface process understanding are translated into hypotheses and the set up of a hydrological model. The catchment area is divided into Hydrological Response Units (HRU) and modeled with the Catchment Modeling Framework (CMF). Based on their observed hydrological connectivity the HRUs are combined into temporally high-resolution conceptual process models. The models are tested with runoff measurements, groundwater levels and soil moisture data, with the aim of rejecting such model structures that contradict the spatially distributed measurements of water and solute balances. Model development takes place in the Schwingbach Critical Zone Observatory, a small catchment (AEO 1.28 km^2) in Hesse, Germany. A mix of information from land use mapping, slug and bail tests, driving core sampling, piezometer measurements, runoff measurements and end-member mixing analyses is used to calibrate and validate the model structures. We parameterized CMF according to the multi-objective Generalized Likelihood Uncertainty Estimation (GLUE) method, using the Statistical Parameter Optimization Tool for Python (SPOTPY).
We present to what extent model-based representative structures are able to spatially differentiate measured residence times and flow paths and how unrepresentative model structures can be rejected. In our case a simple structure could not satisfyingly reproduce the seasonal pattern of discharge peaks and got rejected. However, implementing the hypothesis of wetness based shifting subsurface flow path leads to a representative expression of observed discharge data while maintaining observed catchment characteristics.