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Analysis of catchment behavior using residence time distributions with application to the Thuringian Basin

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Residence time distribution (RTD), as presented e.g. by Botter et al., are a novel mathematical framework for a quantitative characterization of hydrological systems. These distributions contain information about water storage, flow pathways and water sources and therefore improve the classical hydrograph methods by allowing both nonlinear as well as time-dependent dynamics.

In our study we extend this previous works by applying this theoretical framework on real-world heterogeneous catchments. To that end we use a catchment-scale hydrological model (mHM) and apply the approach of Botter et al. to each spatial grid cell of mHM. To facilitate the coupling we amended Botter's approach by introducing additional fluxes (like runoff from unsaturated zone) and specifying the structure of the groundwater zone.

By virtue of this coupling we could then make use of the realistic hydrological fluxes and state variables as provided by mHM. This allowed us to use both observed (precipitation, temperature, soil type etc.) and modeled data sets and asses their impact on the behavior of the resulting RTD's. We extended the aforementioned framework to analyze large catchments by including geomorphic effect due to the actual arrangement of subcatchments around the channel network using the flood routing algorithm of mHM. Additionally we study dependencies of the stochastic characteristics of RTD's on the meteorological and hydrological processes as well as on the morphological structure of the catchment.

As a result we gained mean residence times (MRT) of base flow and groundwater flow on the mesoscale (4km x 4km). We compare the spatial distribution of MRT's with land cover and soil moisture maps as well as driving forces like precipitation and temperature. Results showed that land cover is a major predictor for MRT's whereas its impact on the mean evapotranspiration time was much lower. Additionally we determined the temporal evolution of mean travel times by using time series of all relevant hydrological processes (observed as well as modeled by mHM) from 1960-2010. Our analysis revealed the strong regularity of the catchment dynamics over long time periods. The strong seasonal changes of MRT's, usually modeled by sine-wave approach, could be approximated by sawtooth-wave model.

Our future work will be focused on comparing of our numerical results with realistic data from tracer experiments and isotope measurements.