

Transit time distributions of heterogeneous catchments: are current lumped-parameter models applicable ?

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A recent paper by Kirchner (Aggregation of environmental systems- Part 1: Seasonal tracer cycles quantify young water fractions, but not mean transit times, in spatially heterogeneous catchments, HESS, 2016) has shown that spatially variable mean transit time (MTT) of subcatchments are liable to lead to a total transit time distributions (TTD) at the catchment's outlet deviating from the commonly used models such as the exponential or the gamma distribution, and thus to significantly bias the MTT estimates at the catchment scale. In this contribution, we systematically explore the deviation of heterogeneous TTDs from common three theoretical distributions (the exponential, gamma and double exponential models) as a function of the TTD shape of the subcatchments and the degree of heterogeneity defined as the range of MTTs. Further, we study whether models fitted using a combination of tracers yield operationally acceptable estimates of the total TTD. We find that deviations from the exponential model are modest for a range of MTT going from one year to twenty years, whereas the gamma or double exponential models become necessary to reproduce more strongly curved TTDs obtained when MTTs below one year are included in the interval. As the intervals increases even more to cover MTT of a few days to a hundred years, both gamma and double exponential models often fail to mimic the total TTD. We conclude that for permeable aquifers where the degree of heterogeneity is usually modest, simple theoretical TTDs calibrated using environmental tracers seem to be sufficiently robust, while applying these models to catchment studies, where heterogeneities in transit time are potentially very large, could lead to large estimation errors.