Geophysical Research Abstracts
Vol. 16, EGU2014-11977, 2014
EGU General Assembly 2014

Non-stationarity in experimental travel time measured in a lysimeter: theoretical and modeling lessons from a simplified hydrological system

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Experimental data have been collected over a year-long period in a large weighing lysimeter. Natural climatic forcing occurs, except for rainfall which is artificially generated as a given Poisson process at a daily timescale. A constant water table is maintained and excess infiltrated water is discharged through the outlet at the bottom of the lysimeter. Soil water storage and evapotranspiration fluxes (accentuated by a willow tree planted in the lysimeter) were monitored throughout the experiment, so that accurate time series of all in- and out-fluxes are available. Five rainfall inputs were marked with individually traceable passive solutes (fluorobenzoic acids) at various initial soil moisture conditions during the first month of the experiment. Tracer concentrations were measured in the soil water and in the discharge at high temporal resolution. We aim here at directly measuring solute travel times, a proxy of hydrological transport with the main advantage to blend the bulk effects of water velocity distributions. The drivers of water displacement in this hydrological setting – and in any other realistic case – have intrinsically a non-stationary nature (e.g. random rainfall occurrence, seasonal evapotranspiration cycles and moisture-related soil connectivity), but the integration of these processes over a larger time scale (i.e. typically the time scale of the mean travel time) often lead to the stationary assumption thus considerably simplifying the data interpretation. Results clearly show that even in such a hydrological system with reduced complexity, experimental travel time distributions are non-stationary and are strongly influenced by the states encountered by the system during the transport phase. The measurements help at identifying the relevant key features influencing the experimental bulk transport. Modeling efforts have demonstrated the inability of a plug-flow reactor (old-water first reservoir) to reproduce the solute outfluxes dynamics. On the other hand, the well-mixed reactor performs well at long term, but hardly applies for the period directly following the tracer injection.