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Transit times and age distributions for reservoir models represented as nonlinear non-autonomuous systems

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We present theoretical methods to compute dynamic residence and transit time distributions for non-autonomous systems of pools governed by coupled nonlinear differential equations. Although transit time and age distributions have been used to describe reservoir models for a long time, a closer look to their assumptions reveals two major restrictions of generality in previous studies. First, the systems are assumed to be in equilibrium; and second, the equations under consideration are assumed to be linear. While both these assumptions greatly ease the computation and interpretation of transit time and age distributions they are not applicable to a wide range of problems. Moreover, the transfer of previous results learned from linear systems in steady state to the more complex nonlinear non-autonomous systems that do not even need to have equilibria, can be dangerously misleading. Fortunately the topic of time dependent age and transit time distributions has received some attention recently in hydrology, we aim to compute these distributions for systems of multiple reservoirs. We will discuss how storage selection functions can augment the information represented in an ODE system describing a system of reservoirs. We will present analytical and numerical algorithms and a Monte Carlo simulator to compute solutions for system transit time and age distributions for system-wide storage selection functions including the most simple, but important case of well mixed pools.