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Modeling the distribution of water travel time through catchments using the tempered Levy (TOSS) density

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Abstract

In this work we model the advective travel time distribution through a catchment focusing on groundwater. Our hypothesis is that the tempered Levy (or tempered one-sided stable) distribution (Cvetkovic et al., 2012) is suitable for quantifying travel time distributions in catchments; the hypothesis builds on the fact that the tempered Levy density generalizes most of the models that have been used in the literature (from plug flow, exponential and Gamma distributions, to ADE and anomalous models). The hypothesis is tested on thoroughly investigated and simulated Forsmark catchment (Sweden). Our approach is Lagrangian where we follow trajectories and compute first passage (arrival) times of passive tracer particles injected at recharge zones and monitored at different discharge zones. In this study we consider long-term, steady-state conditions. It is shown that asymptotically, the late arrivals are well reproduced by an inverse-Gaussian (ADE) model up to 10%, whereas early arrivals tend to be between the inverse-Gaussian and Gamma distributions. Comparison between the Lagrangian and Eulerian velocities indicates strong preferential flow in the catchment,where less than 5% of the Eulerian velocities contribute to advective transport over the simulated 375 years.