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The residence times of surface water-groundwater exchange from 10^{-3} - 10^{3} m and why long tails matter

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The age and residence time of water and their distribution (ADs and RTDs) integrate information about processes that are useful for many hydrologic problems. In this presentation, I will discuss examples of ADs and RTDs associated with a process that is ubiquitous across the hydrosphere – surface water-groundwater exchange.
At the decimeter scale, bedforms induce dynamic pressure gradients which drive exchange between rivers and the hyporheic zone. The RTDs for this exchange follow power-laws which also imply broad ADs. The AD for hyporheic exchange controls redox processes such as denitrification, which is critical for local and watershed-scale nutrient dynamics. Local-scale heterogeneity enhances the power-law RTDs but relative to equivalent homogeneous media, this appears to have minimal impacts on biogeochemical processes.
At the channel-floodplain scale, hyporheic exchange is induced by hydrostatic pressure gradients along sinuous river channels. The ADs/RTDs for this exchange are highly sensitive to planform river morphology but may also exhibit power-law tails. Similarly to decimeter-scale exchange, the ADs/RTDs correspond to cascading redox processes which culminate with denitrification. Thus, the biogeochemical processes are linked to landscape form.
At the basin scale, regional exchange from recharge to discharge zones are driven by regional topography. These Tothian flow systems also have power-law RTDs and broad ADs. The distributions have direct implications on sustainability of regional groundwater resources and can be used as guide for management and exploitation of aquifers.
Thus, ADs and RTDs are useful concepts for myriad hydrologic problems from 10(-3) to 103 meters.