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Influence of sediment depth and groundwater underflow on residence time distributions in dune-shaped streambeds

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Stream dunes have been widely recognized among the major morphological features driving water exchange between a stream and its sediments, and many modeling studies have been performed to characterize hyporheic exchange induced by this type of bedforms. Despite of these efforts, the high number of factors that affect hyporheic exchange has not been completely addressed yet, mainly because of the simplifying assumptions that are unavoidably required to reduce the complexity of the problem. For instance, the effect of the limited extent of the thickness of the sediment layer on the Residence Time Distribution (RTDs) of hyporheic exchange has not been fully explored. This incomplete knowledge is particularly relevant due to the paramount role of RTDs in controlling biogeochemical reactions in microbiologically active sediments.

In this context, this study presents a modeling analysis of RTDs in dune-shaped streambeds of finite depth in the presence of groundwater flow. Numerical simulations of particle tracking have been performed to determine the combined influence of sediment depth and horizontal underflow on the shape of RTDs. Moreover, different analytical distributions (Exponential, Gamma, LogNormal, Fréchet) have been fitted to the numerical RTDs, and the best distribution for each range of dimensionless sediment depth and underflow velocity have been identified on the basis of Anderson-Darling tests.