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The linear reservoir model: conceptual or physically based?

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From a gridded catchment (25 x 25 m), we have investigated the distribution of distances from grid points to the nearest river reach. Based on 130 Norwegian catchments, we find that an exponential distribution fits the empirical distance distributions very well. Such a distribution is very informative regarding how the catchment area is organised with respect to the river network and can be used to easily determine the catchment fractional area as a function of distance from the river network. This is important for runoff dynamics since the travel times of water in the soils is slower than that in the river network by several orders of magnitude. If we consider the fractional areas for each distance interval, the properties of the exponential distance distribution dictate that the ratio between consecutive fractional areas is a constant, κ . Furthermore, if we assume that after a precipitation event, water is propagated through the soils to the river network with a constant celerity/velocity, the ratio between volumes of water drained into the river network at each time step is a constant and equal to κ. A linear reservoir has the same property of consecutive runoff volumes having a constant ratio and if the velocity/celerity is such that the distance interval between the consecutive areas is the distance travelled by water for each time step, Δt, then the rate constant, θ, of the linear reservoir is a straightforward function of the constant κ, θ=(1-κ)/Δt . The fact that exponential distance distributions are found for so many (actually all we have investigated) Norwegian catchments suggests that rainfall-runoff models based on linear reservoirs can no longer be dismissed as purely conceptual, as they clearly reflect the physical dynamics of the runoff generation processes at the catchment scale.