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Ecohydrology of groundwater-dependent ecosystems: a stochastic framework for plant transpiration

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Groundwater-dependent ecosystems are found in areas with a shallow water table, where the groundwater plays a key role on the ecosystem functions. In these areas, the water table depth, the capillary fluxes, and the soil moisture content exert a major control on most ecohydrologic processes, such as infiltration, surface runoff, aquifer recharge, land-atmosphere feedbacks, vegetation dynamics, nutrient cycling, and pollutant transport. Understanding and modeling the soil water balance and its relationships with climate, soil, and vegetation is therefore a crucial aspect for geosciences such as hydrology and ecology.

The ecohydrology of groundwater-dependent ecosystems can be described with a modeling framework based on a stochastic process-based water balance. The model is driven by a compound marked Poisson noise representing the rainfall events and, under some simplifying, yet realistic, assumptions, it includes rainfall infiltration, root water uptake, capillary flux, and subsurface flow to/from an external water body. The framework provides the long-term probability distribution of water table depth and of soil moisture vertical profiles, enabling a quantitative study of the local hydrology with a limited number of parameters.

We here apply this framework to investigate plant transpiration and root water uptake. The probability distributions of water uptake are derived from those of the soil water content and are investigated for different scenarios of climate, soil, and vegetation. The results of this approach allow for interesting speculations about the groundwater contribution to root uptake, the soil water available for plant transpiration, and the optimal strategies of root growth and plant competition. This information is useful to assess the impact of climate changes, vegetation modification, and water management operations.