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Assessment of catchment-scale evapotranspiration via boundary condition switching versus root water uptake modeling

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Although being one of the fundamental terms of the hydrologic cycle at all scales, evapotranspiration (ET) is also one of the most difficult to model, because of its dependency on many climatic and ecological factors. Therefore, practical applications of hydrological models where ET plays a significant role are subjected to large uncertainties.

Here we compare two methods to compute actual ET in CATHY (CATchment HYdrology), a process-based coupled model of surface and subsurface flow that solves the three-dimensional Richards equation for partially saturated porous media and a one-dimensional diffusion wave approximation of the de Saint-Venant equation for overland and channel routing.

The first method includes a sink term in the Richards equation to account for root water uptake. The potential transpiration is distributed across the root depth as a function of the root distribution and water stress is modeled using the reduction function suggested by Feddes. Accordingly, in well-watered conditions the vegetation transpires at its potential rate, while, when the soil dries below a certain value of soil moisture associated with incipient water stress, transpiration reduces linearly until it reaches zero at the wilting point.

The second method uses a switching procedure for the boundary conditions at the soil surface relying on a pressure head, ψ_{min}. As long as the water potential at the soil surface is larger than ψ_{min}, the boundary condition at the surface is a flux (Neumann condition) that equals the potential evapotranspiration rate; when the water potential reaches ψ_{min}, the boundary condition switches from a flux to a constant pressure head (Dirichlet condition), and the evapotranspiration process becomes soil- and/or vegetation-limited.

These two ET models are implemented in CATHY and applied to a paired catchment experiment in southwestern Victoria, Australia, where two adjacent catchments with different agricultural uses (grazing and blue gum plantation) provide an extensive hydrological data set.

Our results show that the boundary condition-switching algorithm, with a proper choice of ψ_{min} and for limited root depths, yields ET rates very similar to those computed by the well established Feddes' formulation and thus potentially represents a simple and effective way to account for the impacts exerted on the catchment hydrological response by different types of shallow-rooted vegetation.