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Water balance modeling accounting for compensatory root water uptake

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Root water uptake by plants is one of the major components of the terrestrial water balance, and transpiration is a critical process controlling energy exchange between the land surface and the atmosphere. Accurate sub-models of root water uptake are therefore important building blocks in a wider context, for example in global climate change models. One especially important and difficult task is to reflect the dynamic response of plant uptake to water stress in the root zone. In particular, most models designed for practical use (e.g. in land surface schemes or simulation models of crop growth and soil water balance) cannot account for compensatory water uptake, in which uptake increases in sparsely-rooted but still well-watered subsoil layers to compensate for topsoil drying. This is thought to be critical in meeting atmospheric transpiration demand in water-limited environments and may significantly influence land surface energy balances and simulations produced by global climate models. 'Root architecture' models can provide useful insights into water uptake processes, but are too complex for routine use in large-scale modeling applications. An important challenge is to develop root water uptake models which are both relatively parsimonious with respect to data requirements, but which also can capture the complexity of compensatory bio-physical response mechanisms in a realistic way.

In this presentation, a model of root water uptake is described that accounts for compensation. It is physics-based and requires no more parameters than empirical approaches previously proposed. It is shown that the degree of compensation can be expressed as a function of potential transpiration, total root length, and soil hydraulic properties and that 'hydraulic lift' can be simulated if this 'compensation factor' increases above a critical level. The water uptake model is coupled to Richards' equation for water flow in a 1D soil profile and short-term simulations of summer dry-down periods are run to illustrate the significance of compensatory uptake for hydraulic lift from the water table by phreatophytes. The model is linked to soil evaporation and canopy interception sub-routines and the Priestley-Taylor equation for potential evapotranspiration to run predictive long-term water balance simulations with and without compensation for a range of contrasting scenarios with respect to climate, soil type and vegetation. Parameters describing key soil and plant characteristics such as leaf area index, stomatal conductance, and root length and distribution were obtained from the literature. For otherwise identical parameterisations, the model without compensation underestimated evapotranspiration by c. 5% and transpiration by up to 10% for climates of intermediate aridity (around 1 for the Budyko index) and also for more arid environments where the rainfall is strongly seasonal (i.e. Mediterranean climates).