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A coupled model of stomatal conductance, photosynthesis and transpiration

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A model that couples stomatal conductance, photosynthesis, leaf energy balance and transport of water through the soil-plant-atmosphere continuum, has been developed. In this model, stomatal conductance depends on light, temperature and intercellular CO_2 concentration via photosynthesis, and on leaf water potential. Leaf water potential is a function of soil water potential, plant hydraulic resistances and the rate of water flow through the soil and plant. Plant water relations are modelled as an analogue to a simple electrical circuit including plant hydraulic resistances and plant capacitance. Water uptake by roots is controlled by water potential gradient between the absorbing root surface and a cylindrical soil element adjacent to the roots. Absorbing roots are assumed to be uniformly distributed throughout the entire soil volume. Water transport from soil to roots is simulated through solution of the Richards' equation. The net canopy photosynthesis is calculated: (i) for C3 plants, using the detailed biochemical model of photosynthesis proposed by Farquhar et al. (1980) and widely employed in both leaf and canopy-scale gas studies, (ii) for C4 plants, using the model elaborated by Von Caemmerer and Furbank (1999) which describes the C4 photosynthetic pathway as a complex combination of both biochemical and anatomical specialisation.

Model calculations for a soil dry-down cycle of 15 days show the effects of plant water storage in the soil-plant-atmosphere continuum model on the stomatal conductance, leaf water potential and water fluxes (water uptake from the soil, plant water storage and transpiration). The plant water storage delays the onset of stomatal closure in the morning and limits the closure in the afternoon at high evaporative demand. Capacitance is shown to affect plant and soil water potentials, transpiration, and assimilation rates. Test of the model with field data for a period of time shows good simulations

of soil water, xylem water potential, transpiration, and energy balance components. However, to test more specific responses of the model, it would be useful to set up new experiments with different canopies and more specific measurements of plant physiology.