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Reconciling photosynthesis and hydraulic models to predict stomatal behavior under emerging environmental conditions

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Stomatal regulation of carbon uptake and water loss under a changing environment has major influences on global carbon and water fluxes. This regulation ensures adequate photosynthetic carbon gain to satisfy the mesophyll demand (A) while regulating leaf-water losses through transpiration (T). The evolutionary pathway of this fundamental carbon-for-water trade-off is still largely unknown, but there is growing evidence that plant stomata have evolved physiological controls to maximize photosynthetic performance and provide sufficient water loss to maintain optimal leaf temperature from evaporative cooling, while also avoiding cavitation in the soil-root-xylem hydraulic system and desiccation. Capitalizing on the advantages of process-based models of photosynthesis and hydraulic models, we propose a reconciliation procedure that ensures consistent modeling of water and carbon fluxes in response to emerging environmental controls (i.e. low soil moisture and extreme temperatures). Contrary to previous optimal stomatal models aiming to minimize T while maximizing A, the new model assumes that stomatal regulation aims at maximizing A while being constrained by steady-state flow in the xylem so that at any time sap flow balances T. Using two years of measurements of ecosystem fluxes in a mixed forest in Switzerland, we evaluate the model estimates of optimal stomatal behavior relative to hydraulic failure and will discuss the implications for predicting ecosystem fluxes under emerging conditions of combined water and heat stress.