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Towards an improved and more flexible representation of water stress in coupled photosynthesis-stomatal conductance models; implications for simulated land surface fluxes and variables at various spatiotemporal scales

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Coupled photosynthesis–stomatal conductance (A–gs) models are commonly used in ecosystem models to represent the exchange rate of CO_2 and H_2O between vegetation and the atmosphere. The ways these models account for water stress differ greatly among modelling schemes. This study provides insight into the impact of contrasting model configurations of water stress on the simulated leaf-level values of net photosynthesis (A), stomatal conductance (gs), the functional relationship among them and their ratio, the intrinsic water use efficiency (A/gs), as soil dries. A simple, yet versatile, normalized soil moisture dependent function was used to account for the effects of water stress on gs, on mesophyll conductance (gm) and on the biochemical capacity (Egea et al., 2011). Model output was compared to leaf-level values obtained from the literature. The sensitivity analyses emphasized the necessity to combine both stomatal and non-stomatal limitations of A in coupled A–gs models to accurately capture the observed functional relationships A vs. gs and A/gs vs. gs in response to drought. Accounting for water stress in coupled A–gs models by imposing either stomatal or biochemical limitations of A, as commonly practiced in most ecosystem models, failed to reproduce the observed functional relationship between key leaf gas exchange attributes. A quantitative limitation analysis revealed that the general pattern of C3 photosynthetic response to water stress can be represented in coupled A–gs models by imposing the highest limitation strength to mesophyll conductance, then to stomatal conductance and finally to the biochemical capacity.

This more realistic representation of soil water stress on the simulated leaf-level values of A and gs was embedded in the JULES (Joint UK Land Environment Simulator; Best et al., 2011), model and tested for a number of vegetation types, for which driving and flux verification data were available. These simulations provide an insight into the effect that the revised parameterization will have on GCM simulations of climate variability and change.

Best, M. J. et al. (2011). The Joint UK Land Environment Simulator (JULES), model description – Part 1: Energy and water fluxes. Geosci. Model Dev., 4, 677-699.

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