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Differential plant type responses to rising atmospheric CO_2 concentrations: The role of mesophyll conductance

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Mesophyll conductance (g_m) is a recognized physiological determinant for plant carbon uptake, which is known to vary widely across leaf types and species. However, the effect of g_m is rarely explicitly considered in terrestrial biosphere models (TBMs) and as a consequence, its effect on ecosystem and large-scale carbon and water cycles under anticipated future conditions is poorly known. In particular, it is unclear whether and how an explicit representation of g_m alters the simulated responses of photosynthesis and water-use efficiency to rising atmospheric CO_2 concentrations across plant functional types.

We developed an empirical model of g_m for use in TBMs that simulates observed responses to environmental drivers (temperature, soil water stress, light, intercellular CO_2 concentration) and that reproduces key relationships with other physiological vegetation traits (e.g. photosynthetic capacity). The model is parameterized by an extensive literature compilation of leaf-level g_m measurements covering all major plant functional types. We present model simulations at ecosystem level for different vegetation types, in which g_m is simulated either implicitly (as in most state-of-the-art TBMs), or explicitly (as in the developed model).

The results reveal that the direct effects of explicitly simulating g_m on carbon and water fluxes are comparably small, but that the explicit representation of g_m changes the temperature-photosynthesis relationship. This change results in higher sensitivities of both photosynthesis and stomatal conductance to elevated atmospheric CO_2 (eCO_2) concentrations. The magnitude of this effect increases with decreasing g_m, such that relative plant physiological responses to eCO_2 are stronger in vegetation types with a low g_m (e.g. needle-leaf forests) compared to those with a high g_m (e.g. herbaceous plants).

We conclude that the explicit representation of g_m in TBMs results in moderate changes to the simulated CO_2 sensitivity of vegetation and further leads to more realistic plant physiological responses to global change with important implications for the terrestrial water-carbon coupling and associated biophysical feedbacks.