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The dilemma of saving water or being cool: What determines the stomatal response under a changing climate?

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Stomata play a critical role in terrestrial water and carbon cycles, regulating the trade-off between photosynthetic carbon gain and water loss in leaves. They adjust their aperture in response to a number of physiological and environmental factors, yet the mechanisms driving this response, particularly under climate extremes, remain poorly understood. Partial or complete stomatal closure reduces plant water stress under water-limited or high atmospheric evaporative demand conditions, but at the cost of reduced productivity, elevated heat, leaf shedding, and mortality. A proper account of such complex stomatal behavior is of particular importance for current ecosystem models that poorly capture observed vegetation responses in the context of climate change which is predicted to cause more frequent and intense temperature extremes along with an increase in the frequency of drought in many regions in the future.

This study seeks to explore stomatal responses to environmental change accounted for by a varying soil-plant resistance under different atmospheric and soil moisture conditions. To this end, we developed a physically based transpiration model that couples stomatal control of leaf gas exchange to the leaf surface energy balance and the entire plant hydraulic system by considering the interdependence of the guard cell water potential (or turgor pressure) and transpiration rates. Model simulations of diurnal variations in transpiration rates were in good agreement with field observations, and facilitated quantitative prediction of stomatal and xylem flow regulation under a wide range of environmental conditions. Preliminary results demonstrate how soil and plant hydraulic conductances regulating stomatal opening and closure can help mitigate climatic water deficit (e.g., at midday) by boosting evaporative cooling. Our results are expected to advance physical understanding of the water cycle in the soil-plant-atmosphere continuum, and shed light on observed differences in vegetation responses to climate extremes.