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Plant hydraulics accentuates the effects of atmospheric moisture stress on transpiration

Alexandra Konings[1], Yanlan Liu[1], Mukesh Kumar[2], Xue Feng[3], and Gabriel Katul[4]
[1]Stanford University, Stanford, CA, United States of America (konings@stanford.edu)
[2]University of Alabama, Tuscaloosa, AL, United States of America
[3]University of Minnesota, Twin Cities, Minneapolis, MN, United States of America
[4]Duke University, Durham, NC, United States of America

Transpiration directly links the water, energy and carbon cycles. It is commonly restricted by soil (through soil moisture) and atmospheric (through vapor pressure deficit, VPD) moisture stresses governed by the movement of water through plants, also known as plant hydraulics. These sources of moisture stress are likely to diverge under climate change, with globally enhanced VPD due to increased air temperatures but more variable and uncertain changes in soil moisture. In most Earth system and land surface models, the ET response to each of the two stresses is evaluated through independent empirical relations, while neglecting plant hydraulics. Comparison of these two models is challenged by the difficulty of ensuring any perceived differences are due to the model structure, not an imperfect parametrization. Here, we use a model-data fusion approach applied to long-term ET records collected at 40 sites across a diverse range of biomes to demonstrate that the widely used empirical approach underestimates ET sensitivity to VPD, but compensates by overestimating the sensitivity to soil moisture stress. The bias originates from the joint control of leaf water potential on plant response to soil moisture and VPD stress. To a lesser degree, it also overestimates from increased sensitivity to VPD under dry (low leaf water potential) conditions in the plant hydraulic model. As a result, a hydraulic model captures ET under high-VPD conditions for wide-ranging soil moisture states better than the empirical approach does. Our findings highlight the central role of plant hydraulics in regulating the increasing importance of atmospheric moisture stress on biosphere-atmosphere interactions under elevated temperatures.