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Scaling tree-level hydrodynamics to plot-level hydrology using novel model and measurements

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Hydrodynamic limitations are driven by the water availability to leave of the individual tree crowns, and are known to control transpiration in forest ecosystems under both wet and dry conditions. Current land-surface models do not represent tree-level processes, nor do they represent the above-ground storage in trees. As the intra-daily dynamics of soil moisture are slower and very different than the faster dynamics of water storage in the tree xylem, the current approach that do not incorporate tree-water storage leads to deviations from the observed dynamics of transpiration. We propose a framework to resolve such tree hydrodynamics. The FETCH2 model resolves the water flow, water potential, and water storage in the tree stem and realistically links stomatal conductance to the water potential in the xylem, while water availability in the soil provides a bottom boundary condition for the hydrodynamic system.

We use data from a large scale ecological disturbance experiment at a forest in Michigan to validate this approach. We use a very large array of sap-flow sensors in a plot with eddy-covariance measurements to parameterize the model at both tree-scale and plot scale. We demonstrate novel approaches to continuously measure tree water storage, and to evaluate tree-level hydrodynamic traits that control the ecohydrological response of the plot to water stress and disturbance.