Collaborative research: Restricted plasticity of canopy stomatal conductance: Conceptual basis for simplified models of canopy transpiration

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Implications of findings and products for our field, other fields, and beyond science and engineering

Our results provide strong evidence for a general theory of spatial evapotranspiration. The general theory is that spatial variability is regulated by plant hydraulic responses to environmental stress. Variability is minimal when environmental drivers of ET are either unstressful or extremely stressful, and maximal when environmental drivers are moderately stressful. The implication of this is of widespread importance to ecohydrology, which seeks to develop conceptually simple models to explain spatially complex feedbacks between hydrologic and ecological processes. Our results show that this complexity is highly bounded and can be mechanistically explained in terms of plant hydraulics in response to relatively easily measured and estimated environmental variables. Our results are important also for hydrology in general since an understanding of spatial heterogeneity of watersheds is fundamental to hydrologic science. Simplifications as identified in this project (based on plant hydraulic mechanisms in space) are needed to make predictions in areas of intensive study and most importantly in the vast majority of watersheds where data is sparse. Our results are important for physiological and ecosystem ecology field as they have broad implications for understanding evolutionary and behavioral aspects of vegetative systems. Our results extend to atmospheric sciences and climate change research because of the importance of the land-surface as a heterogeneous set of boundary conditions for atmospheric processes, directly via water and energy, and indirectly via carbon exchange since transpiration is a bi-product of photosynthesis. Moreover, this project has lead to a Boreal study of the same processes (Ewers) and a carbon cycling study in northern Wisconsin (Mackay). Finally, our work suggests a framework through which any environmental flux could be spatially measured and then explained using temporal drivers.

Our findings are also relevant to other sciences that rely on time-sensitive spatially distributed observations. For example, phenological observation networks have been using eddy covariance towers as focal points for continuous measurements of leaf phenology. However, the potential for using sap flux measurements in phenology monitoring has yet to be tapped. During our project, Mackay presented findings from our study to the inaugural workshop for Northeast Regional Phenology Network (http://www.nerpn.org/). The lack of spatial structure in sap flux per unit xylem area, and the ability to scale transpiration using sapwood area was of particular interest as potentially showing a way to conduct low-cost monitoring of tree physiological activity over large areas with relatively few sap flux sensors.

Going beyond science and engineering the results of this research are significant for policy because of its direct implications for making predictions of spatially driven climate change, water resources, and potentially extreme events associated with the hydrologic cycle. Using the mechanistically constrained parameterizations offered by our results will lead to more robust modeling results that serve policy decisions. Moreover, our results point to a general theory on spatial evapotranspiration that can make regional to global predictions of water cycling simpler to conduct without loss of mechanistic rigor. Thus, future policy on water resources can be better informed, especially in regions lacking detailed observations.