Geophysical Research Abstracts
Vol. 21, EGU2019-13695, 2019
EGU General Assembly 2019

Emergent properties of plant hydraulic architecture: from root cells to cavitating stems and land surface models

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Worldwide ecosystems primary production and survival are largely limited by soil water availability, and affected by plant traits that control water uptake, transport, and release in the atmosphere. In order to understand how these complex systems will react to future climates, and optimally adjust their management, the development of experimental and modelling approaches is crucial. In particular, integrating process-based representations plant hydraulics and stomatal closure in land surface models (LSMs) is a major challenge as the limited computational resources necessitate the use of simplified descriptions of these processes.

We present methods used to identify scale consistent emergent principles governing water flow in plants. We show that simplistic mechanistic expressions arise from the cell to the root system scale, and along stems whose geometry, saturated conductivity, sensitivity to cavitation, and leaf area vary continuously with height.

Our results support that cavitation is a whole-stem emergent property; in which compounding effects of gravity and vertical traits variations reported experimentally all substantially contribute to the occurrence of hydraulic failure in tall trees, and need to be accounted for in LSMs. Furthermore, a macroscopic solution of water flow in plant hydraulic architectures was implemented in the Terrestrial Systems Modeling Platform. As compared to the standard approach, this new model of water capture characteristically exhibits a different sensitivity of the onset of water stress to root distribution and soil properties.